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ИНСТИТУТ ЯЗЫКА

Кафедра английского языка для естественнонаучных специальностей

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GEODESY

Учебное пособие для студентов,

обучающихся по специальности

«Геодезия и дистанционное зондирование - 120100.62»

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Данное пособие предназначено для студентов, обучающихся по специальности «Геодезия и дистанционное зондирование», и содержит материалы по специальности, дополняющие основной курс английского языка. Материалы пособия могут быть использованы как для аудиторной, так и для самостоятельной работы студентов.

Предисловие

Настоящее пособие предназначено для занятий со студентами 3 курса физического факультета Казанского (Приволжского) федерального университета, по специальности *«Геодезия и дистанционное зондирование - 120100.62»*. Пособие разработано с учетом требований государственного стандарта высшего профессионального образования и предназначено для студентов, продолжающих изучение английского языка на базе программы средней школы.

Целью настоящего пособия является углубление и расширение словарного запаса, приобретение учащимися навыков правильного понимания и перевода оригинального текста (научной неадаптированной литературы) по специальности.

Учебно-методическое пособие состоит из 10 уроков, блока научных текстов для самостоятельной работы, приложений, включающих в себя набор фраз и устойчивых выражений, применяемых при реферировании научных статей, источниковедческой базы.

В учебно-методическое пособие включены оригинальные тексты, опубликованные в ведущих зарубежных научных изданиях, сокращенные по мере необходимости. При отборе статей учитывалась их познавательная ценность. Все статьи связаны со специальностью студентов. Тексты снабжены упражнениями по изучению и закреплению лексики.

Все уроки по своей структуре идентичны, даны ясные формулировки заданий, что позволяет достичь искомой цели.

При работе над пособием, мы старались обеспечить участников учебного процесса объемом текстового и лексического материала, набором упражнений, предоставляющим возможность полноценно, эффективно использовать время, отведенное на изучение профессиональных аспектов иностранного языка.

Content

UNIT1 HISTORY OF GEODESY

1.1 Practise reading the following words.

a) [ð] – **th**e, **th**is, **th**at, **th**erefore, **th**eir, logari**th**m,

[ɜ:] – c**ir**cle, **ear**ly, **ear**th, conc**er**n, w**ere**, det**er**mine

[i:] - Gr**ee**k, **ea**st, incr**ea**se, r**ea**son, bel**ie**ve

[ʌ] – m**u**ch, res**u**lt, an**o**ther, s**u**ch, red**u**ction, s**u**n

b) Alexandria [ˌalɪgˈzɑːndrɪə], Anaximenes [ˌanakˈsɪmɪniːz], Archimedes [ˌɑːkɪˈmiːdiːz], Aristotle [ˈarɪstɒt(ə)l], Cassini [kaˈsiːni], Dunkirk [dʌnˈkəːk], Eratosthenes [ˌɛrəˈtɒsθəniːz], geodesy [dʒɪˈɒdɪsi], Picard [ˈpɪkɑːd, pikaʀ], Plato [ˈpleɪtəʊ], Ptolemy [ˈtɒlɪmi], Pythagoras [pʌɪˈθagərəs], Rhodes [rəʊdz].

1.2 Translate words of the same root into Russian.

To determine – determined – determination – determining – determinant – determinate – determiner.

To observe – observed – observer – observable – observant – observation – observatory.

To defend – defense – defendant – defensive – defender – defenseless – defensible – defensor.

1.3 Fill in the sentences with words from exercise 1.2.

1. Determinate vapour pressure corresponds to … temperature.
2. "That's a new dress, isn't it?" "Yes, you are … !"
3. If you go alone into the forest, you'd better … yourself with a knife.
4. Her reasons for acting are morally … .
5. She is … to finish law school.
6. I was invited to attend their conference as an … .

Active Vocabulary

Word	Pronunciation	Translation
accomplish, *v.*	[ə'kɔmplɪʃ]	совершать, выполнять
accuracy, *n.*	['ækjərəsɪ]	правильность, соответствие, точность; ***syn.*** exactness, precision
angle, *n.*	['æŋgl]	угол
arc, *n.*	[ɑːk]	дуга
cast, *v.*	[kɑːst]	бросать, кидать; ***syn.*** throw
circle, *n.*	['sɜːkl]	круг, окружность
circumference *n.*	[sə'kʌmf(ə)r(ə)ns]	окружность
contribute, *v.*	[kən'trɪbjuːt], ['kɔntrɪbjuːt]	вносить вклад, содействовать, способствовать
controversy, *n.*	['kɔntrəvɜːsɪ], [kən'trɔvəsɪ]	дебаты, дискуссия, полемика, спор; ***syn.*** discussion, argument, debate, dispute
derived, *adj.*	[dɪ'raɪvd]	производный, вторичный, полученный, извлечённый
elevation, *n.*	[ˌelɪ'veɪʃ(ə)n]	высота небесного тела над горизонтом, возвышение, возвышенность, высота
estimate, *v.*	['estɪmeɪt]	оценивать; ***syn***. value
explicit, *adj.*	[ɪk'splɪsɪt]	подробный, определённый, точный; ***syn***. definite
flatten, *v.*	['flæt(ə)n]	выравнивать, разглаживать
graze, *v.*	[greɪz]	слегка касаться, задевать
promulgate, *v.*	['prɔm(ə)lgeɪt]	объявлять, провозглашать, опубликовывать; обнародовать; ***syn.*** publish, proclaim
rectangular, *adj*	[rek'tæŋgjələ]	прямоугольный, ***syn.*** right-angled
reduction, *n.*	[rɪ'dʌkʃ(ə)n]	снижение, понижение, сокращение, уменьшение, спад

solstice, *n.*	['sɔlstɪs]	солнцестояние
speculation, *n.*	[ˌspekjə'leɪʃ(ə)n]	размышление, предположение, теория, догадка; ***syn.*** reflection, contemplation
vicinity, *n.*	[vɪ'sɪnətɪ]	близость, соседство, окрестности; ***syn.*** neighbourhood

1.4 Read the text and answer the following questions.

1. What interested man about the earth for many centuries?
2. What did Pythagoras and Anaximenes consider the earth to be in shape?
3. What measurements did Eratosthenes make and what did he observe?
4. What unit of measurements did Eratosthenes use in his calculations?
5. Whose maps influenced the cartographers of the middle ages?
6. What measurements did Picard and his followers perform?
7. What controversy was between French and English scientists?
8. What conclusion was made during geodetic expedition to Peru?

HISTORY OF GEODESY

Man has been concerned about the earth on which he lives for many centuries. During very early times this concern was limited, naturally, to the immediate vicinity of his home; later it expanded to the distance of markets or exchange places; and finally, with the development of means of transportation man became interested in his whole world. Much of this early "world interest" was evidenced by speculation concerning the size, shape, and composition of the earth.

The early Greeks, in their speculation and theorizing, ranged from the flat disc advocated by Homer to Pythagoras' spherical figure-an idea supported one hundred years later by Aristotle. Pythagoras was a mathematician and to him the most perfect figure was a sphere. He reasoned that the gods would create a perfect figure and therefore the earth was created to be spherical in shape. Anaximenes, an early Greek scientist, believed strongly that the earth was rectangular in shape.

Since the spherical shape was the most widely supported during the Greek Era, efforts to determine its size followed. Plato determined the circumference of the earth to be 40,000 miles while Archimedes estimated 30,000 miles. Plato's figure was a guess and Archimedes' a more conservative approximation. Meanwhile, in Egypt, a Greek scholar and philosopher, Eratosthenes, set out to make more explicit measurements. He had observed that on the day of the summer solstice, the midday sun shone to the bottom of a well in the town of Syene (Aswan). At the same time, he observed the sun was not directly overhead at Alexandria; instead, it cast a shadow with the vertical equal to 1/50th of a circle (7° 12'). The actual unit of measure used by Eratosthenes was called the "stadia." No one knows for sure what the stadia that he used is in today's units. The measurements given above in miles were derived using one stadia equal to one-tenth statute mile. It is remarkable that such accuracy was obtained in view of the fact that most of the "known" facts and his observations were incorrect.

Another ancient measurement of the size of the earth was made by the Greek, Posidonius. He noted that a certain star was hidden from view in most parts of Greece but that it just grazed the horizon at Rhodes. Posidonius measured the elevation of the same star at Alexandria and determined that the angle was 1/48th of circle. Assuming the distance from Alexandria to Rhodes to be 500 miles, he computed the circumference of the earth as 24,000 miles. While both his measurements were approximations when combined, one error compensated for another and he achieved a fairly accurate result.

Revising the figures of Posidonius, another Greek philosopher determined 18,000 miles as the earth's circumference. This last figure was promulgated by Ptolemy through his world maps. The maps of Ptolemy strongly influenced the cartographers of the middle ages. It is probable that Columbus, using such maps, was led to believe that Asia was only 3 or 4 thousand miles west of Europe. It was not until the 15th century that his concept of the earth's size was revised. During that period the Flemish cartographer, Mercator, made successive reductions in the size of the Mediterranean Sea and all of Europe which had the effect of increasing the size of the earth.

The telescope, logarithmic tables, and the method of triangulation were contributed to the science of geodesy during the 17th century. In the course of the century, the Frenchman, Picard, performed an arc measurement that is modern in some respects. He measured a base line by the aid of wooden rods, used a telescope in his angle measurements, and computed with logarithms. Cassini later continued Picard's arc northward to Dunkirk and southward to the Spanish boundary. Cassini divided the measured arc into two parts, one northward from Paris, another southward. When he computed the length of a degree from both chains, he found that the length of one degree in the northern part of the chain was shorter than that in the southern part. This unexpected result could have been caused only by an egg-shaped earth or by observational errors.

The results started an intense controversy between French and English scientists. The English claimed that the earth must be flattened, as Newton and Huygens had shown theoretically, while the Frenchmen defended their own measurement and were inclined to keep the earth egg-shaped.

To settle the controversy, once and for all, the French Academy of Sciences sent a geodetic expedition to Peru in 1735 to measure the length of a meridian degree close to the Equator and another to Lapland to make a similar measurement near the Arctic Circle. The measurements conclusively proved the earth to be flattened, as Newton had forecast. Since all the computations involved in a geodetic survey are accomplished in terms of a mathematical surface (reference ellipsoid) resembling the shape of the earth, the findings were very important.

(http://www.ngs.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003A.HTM#ZZ4)

1.5 Mark the following sentences True or False.

1. Pythagoras believed that the earth was created to be rectangular in shape.
2. Archimedes determined the circumference of the earth to be 30000miles.

3. Measuring the distance from Alexandria to Rhodes and computing the circumference of the earth Posidonius achieved a fairly accurate result.
4. Columbus was led to believe that Asia was 3 or 4 thousand miles east of Europe.
5. Having computed the length of a degree from both chains Cassini found that the length of one degree in the southern part of the chain was longer than that in the northern part.
6. In 1737 a geodetic expedition was sent to Peru to measure the length of a meridian degree close to the Equator.

1.6 Match words similar in meaning.

1. boundary	a. estimate
2. method	b. combine
3. backing	c. limit
4. consequently	d. compute
5. value	e. means
6. outstanding	f. accuracy
7. precision	g. therefore
8. unite	h. reduction
9. calculate	i. support
10. lessening	j. remarkable

1.7 Match words opposite in meaning.

1. correct	a. similar
2. separate	b. increase
3. imprecise	c. unexpected
4. decrease	d. incorrect
5. outdated	e. create
6. expected	f. combine
7. sharpen	g. modern
8. different	h. perfect

9. destroy	i. accurate
10. imperfect	j. flatten

1.8 Match two halves of the statements and translate them into Russian.

1. development	a. error
2. spherical	b. controversy
3. conservative	c. table
4. to measure	d. of means of transportation
5. logarithmic	e. solstice
6. to perform	f. shape
7. observational	g. an arc measurement
8. summer	h. the elevation of the star
9. the bottom	i. of a well
10. intense	j. approximation

1.9 Complete the text with one word.

French Academy of Sciences

The Academy of Sciences owes its origin to Colbert's plan to create a general academy. He chose a small … of scholars who met on 22 December 1666 in the King's library, and thereafter held twice-weekly working … there. The first 30 years of the Academy's existence … relatively informal, since no statutes had as yet been laid down for the institution.

On 20 January 1699, Louis XIV gave the Company … first rules. The Academy received the name of Royal Academy of Sciences and … installed in the Louvre in Paris. In 1816, the Royal Academy of Sciences became autonomous, while forming part of … Institute of France; the head of State became its patron.

For three centuries women were … allowed as members of the Academy, excluding two-time … Prize winner Marie Curie, Nobel winner Irène Joliot-Curie, mathematician Sophie Germain, and many other deserving female scientists.

Today the Academy is one of five … comprising the Institut de France. Its members are elected … life. Currently there are 150 full members, 300 corresponding …, and 120 foreign associates. They are divided into two scientific groups: the Mathematical and Physical … and their applications and the Chemical, Biological, Geological and Medical sciences and their applications.

(http://www.absoluteastronomy.com/topics/French_Academy_of_Sciences)

1.10 Translate the following sentences into English.

1.Геодезия — наука об измерениях, проводимых в целях изучения формы, размеров и внешнего гравитационного поля Земли, изображения отдельных частей ее поверхности в виде планов, карт и профилей, а также решения инженерных задач на местности.

2. Геодезические измерения для разделения поверхности Земли на участки производились в Египте, Китае и других странах за много столетий до нашей эры.

3. Развитию и совершенствованию методов геодезических работ способствовали научные достижения в области математики, физики, инструментальной техники.

4. Первые указания на выполнение геодезических измерений в России относятся к XI в., когда между Керчью и Таманью по льду была измерена ширина Керченского пролива.

5. Работы по составлению карт получили большое развитие при Петре I.

6. После Отечественной войны 1812 г., выявившей плохое обеспечение России картами, последовала организация топографических съемок, которые предназначались в первую очередь для военных целей.

7. Российские геодезисты под руководством Ф. Н. Красовского получили новые параметры фигуры Земли.

8. Ученым М. С. Молоденским была разработана новая теория изучения фигуры Земли и ее внешнего гравитационного поля, поставившая советскую

геодезию в области теории решения ее основной научной проблемы на первое место в мире.

UNIT 2 GEODETIC SURVEYING TECHNIQUES (part I)

2.1 Practise reading the following words.

a) [**u:**] – thr**ough**, evol**u**tion, incl**u**de, concl**u**de

[**aɪ**] – def**i**ne, l**i**ne, comb**i**ne, h**i**ghway, satell**i**te, w**i**de

[**æ**] – l**a**titude, **a**ngular, m**a**nner, tr**a**ct, c**a**talogue, **a**zimuth

[**k**] – tra**c**t, fun**c**tion, exa**c**t, **c**losely, te**ch**nological

[**s**] – surfa**c**e, **sc**ience, pre**c**ise, referen**c**e, distan**c**e, accura**c**y

b) catalogue ['kæt(ə)lɔg], chronometer [krɔ'nɔmɪtə], equator [ɪ'kweɪtə], geoid [ˈdʒiːɔɪd], geodetic [ˌʤiːəu'detɪk], geometry [ʤ(ɪ)'ɔmɪtrɪ], hydrographic [hʌɪdrəˈgrafɪk], perpendicular [ˌpɜːp(ə)n'dɪkjulə], triangulation [trʌɪaŋgjuˈleɪʃn], trigonometry [ˌtrɪgə'nɔmɪtrɪ], trigonometric [ˌtrɪgənə'metrɪk], zenith ['zenɪθ].

Active Vocabulary

Word	**Pronunciation**	**Translation**
adjust, *v.*	[ə'ʤʌst]	подгонять, приспосабливать, регулировать; выверять, настраивать; ***syn***. fit, adapt
anticipate, *v.*	[æn'tɪsɪpeɪt]	ожидать, предвидеть, предчувствовать, предвкушать; ***syn.*** expect, hope, foresee
astrolabe, *n.*	['æstrə(u)leɪb]	астролябия
compile, *v.*	[kəm'paɪl]	собирать, накапливать, составлять; ***syn.*** pile up
contribute, *v.*	[kən'trɪbjuːt], ['kɔntrɪbjuːt]	содействовать, способствовать, вносить вклад
establish, *v.*	[ɪs'tæblɪʃ]	учреждать, устанавливать; ***syn.*** set up

framework, *n.*	['freɪmwɜːk]	основа, структура, строение
justify, *v.*	['ʤʌstɪfaɪ]	подтверждать, доказывать; ***syn.*** confirm, prove, verify
latitude, *n.*	['lætɪt(j)uːd]	широта
longitude, *n.*	['lɔngɪt(j)uːd]	долгота
measure, v.	['meʒə]	измерять, мерить, отмерять, отсчитывать
plumb line	[plʌm]	отвес (прибор для определения перпендикулярности чего-л.)
positioning, *n.*	[pə'zɪʃ(ə)nɪŋ]	ориентация, определение положения, позиционирование
precise, *adj.*	[prɪ'saɪs]	точный, определённый; ***syn.*** exact, punctual
rigorous, *adj.*	['rɪg(ə)rəs]	точный, доскональный, тщательный; ***syn.*** careful, thorough, precise, accurate
survey, *n.*	['sɜːveɪ]	обозрение, осмотр, обзор, обследование, инспектирование, съемка
traverse, *n.*	[trə'vɜːs]	полигонометрия
triangle, *n.*	['traɪæŋgl]	треугольник

2.2 Read the text and answer the following questions.

1. What are traditional surveying techniques? What are they used for?
2. How are astronomic positions obtained?
3. How is astronomic latitude defined?
4. What is astronomic longitude? How is it measured?
5. How do optical instruments astronomic observations made by work (function)?
6. What are the differences between the plane survey and triangulation?
7. What is the principle of triangulation based on?
8. What are four general orders of triangulation?
9. When is each triangulation order used?
10. Which accuracy should four orders of triangulation indicate?

GEODETIC SURVEYING TECHNIQUES (part I)

Four traditional surveying techniques (1) astronomic positioning, (2) triangulation, (3) trilateration, and (4) traverse are in general use for determining the exact positions of points on the earth's surface.

Horizontal positioning. Astronomic Position Determination

Astronomic positioning is the oldest positioning method. It has been used for many years by mariners and, more recently, by airmen for navigational purposes. Geodesists must use astronomic positions along with other types of survey data such as triangulation and trilateration to establish precise positions.

As the name implies, astronomic positions are obtained by measuring the angles between the plumb line at the point and a star or series of stars and recording the precise time at which the measurements are made. After combining the data with information obtained from star catalogues, the direction of the plumb line (zenith direction) is computed.

While geodesists use elaborate and very precise techniques for determining astronomic latitude, the simplest method, in the northern hemisphere, is to measure the elevation of Polaris above the horizon of the observer. Astronomic latitude is defined as the angle between the perpendicular to the geoid and the plane of the equator.

Astronomic longitude is the angle between the plane of the meridian at Greenwich (Prime Meridian) and the astronomic meridian of the point. Actually, it is measured by determining the difference in time-the difference in hours, minutes, and seconds between the time a specific star is directly over the Greenwich meridian and the time the same star is directly over the meridian plane of the point.

Astronomic observations are made by optical instruments-theodolite, zenith camera, prismatic astrolabe-which all contain leveling devices. When properly adjusted, the vertical axis of the instrument coincides with the direction of gravity and is, therefore, perpendicular to the geoid. Thus, astronomic positions are referenced to the geoid.

Triangulation

The most common type of geodetic survey is known as triangulation. It differs from the plane survey in that more accurate instruments are used, instrumental errors are either removed or predetermined. Another very important difference is that all of the positions established by triangulation are mathematically related to each other.

Basically, triangulation consists of the measurement of the angles of a series of triangles. The principle of triangulation is based on simple trigonometric procedures. If the distance along one side of a triangle and the angles at each end of the side are accurately measured, the other two sides and the remaining angle can be computed. Normally, all of the angles of every triangle are measured for the minimization of error and to furnish data for use in computing the precision of the measurements. Also, the latitude and longitude of one end of the measured side along with the length and direction (azimuth) of the side provide sufficient data to compute the latitude and longitude of the other end of the side.

There are four general orders of triangulation. <u>First-Order</u> (Primary Horizontal Control) is the most accurate triangulation. It is costly and time-consuming using the best instruments and rigorous computation methods. First-Order triangulation is usually used to provide the basic framework of horizontal control for a large area such as for a national network. It has also been used in preparation for metropolitan expansion and for scientific studies requiring exact geodetic data. Its accuracy should be at least one part in 100,000. <u>Second-Order</u>, Class I (Secondary Horizontal Control) includes the area networks between the First-Order arcs and detailed surveys in very high value land areas. It should indicate an accuracy of at least one part in 50,000. The demands for reliable horizontal control surveys in areas which are not in a high state of development or where no such development is anticipated in the near future justifies the need for a triangulation classified as Second-Order, Class II (Supplemental Horizontal Control). This class is used to establish control along the coastline, inland waterways and interstate highways. The control data contributes to the National Network and is published as part of the network. The minimum accuracy allowable in Class II of Second-Order is one part in 20,000. <u>Third-Order</u>, Class I and

Class II (Local Horizontal Control) is used to establish control for local improvements and developments, topographic and hydrographic surveys, or for such other projects for which they provide sufficient accuracy. Its accuracy should be at least one part in 10,000 for Class I and one part in 5,000 for Class II. The sole accuracy requirement for Fourth-Order triangulation is that the positions be located without any appreciable errors on maps compiled on the basis of the control. Normally, triangulation is carried out by parties of surveyors occupying preplanned locations (stations) along the arc and accomplishing all the measurements as they proceed.

(adopted from http://www.ngs.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003B.HTM)

2.3 Match words similar in meaning.

1. purpose	a. method
2. data	b. surveyor
3. along with	c. aim
4. imply	d. establish
5. observer	e. information
6. technique	f. mistake
7. compute	g. together
8. accurate	h. measure
9. error	i. precise
10. determine	j. mean

2.4 Form words opposite in meaning using the following prefixes: un-, im-, ir-, il- .

Definite, sufficient, regular, known, different, important, accurate, relative, measured, logical, perfect, possible.

2.5 Give English equivalents for the following word combinations.

1. определять точное положение
2. измерение углов
3. широта
4. долгота
5. правильно установленный
6. исключать ошибки
7. требовать точные сведения
8. подтверждать необходимость
9. обеспечивать точность
10. группа исследователей

2.6 Give Russian equivalents for the following word combinations.

1. surveying techniques
2. to measure the elevation
3. the Greenwich meridian
4. a leveling device
5. to be related to each other
6. to be costly and time-consuming
7. to provide the basic framework
8. the area networks
9. to establish control
10. to accomplish all the measurements

2.7 Match sentence halves.

1. The position of a point can be obtained	**a**. to compute the astronomic longitude of the point.
2. The difference between the time at the point and the time at Greenwich is	**b**. when distances between two points are too long.

used	
3. Astronomic positions are	**c.** measure much longer distances without losing accuracy.
4. The laser equipped geodimeter can	**d.** directly by observing the stars.
5. Flare triangulation is a method which is used	**e.** wholly independent of each other.

2.8 Ask all possible questions to the sentences from exercise 2.7.

2.9 Read the text and give a short summary.

Snel (Snellius or Snel van Royen), Willebrord

(b. Leiden, Netherlands, 1580; d. Leiden, 30 October 1626), mathematics, optics, astronomy.

Snel was the son of Rudolph Snellius, or Snel van Royen, professor of mathematics at the new University of Leiden, and of Machteld Cornelisdochter. He studied law at the university but became interested in mathematics at an early age. Through the influence of Van Ceulen, Stevin, and his father, he received permission in 1600 to teach mathematics at the university. Soon afterward he left for Würzburg, where he met Van Roomen. He then went to Prague to conduct observations under Tycho. He also met Kepler, and traveled to Altdorf and Tübingen, where he saw Mästlin, Kepler's teacher. In 1602 Snel studied law in Paris. He returned home in 1604, after having traveled to Switzerland with his father, who was then in Kassel at the court of the learned Prince Maurice of Hesse.

After his father's death in March 1613, Snel succeeded him at the university, and two years later he became professor. He taught mathematics, astronomy, and optics, using some instruments in his instruction.

Sharing the admiration of his father and of Maurice of Hesse for Ramus, Snel published Ramus' Arithmetica, with commentary, in 1613. During this period Snel prepared the Latin translation of two books by Van Ceulen. Snel's lack of attention to this translation may have been due to preoccupation with geodetic work. In 1615 he became deeply involved in the determination of the length of the meridian, selecting for this work the method of triangulation, first proposed by Gemma Frisius in 1533 and also used by Tycho. Snel developed it to such an extent that he may rightfully be called the father of triangulation. Starting with his house (marked by a memorial plaque in 1960), he used the spires of town churches as points of reference. Thus, through net of triangles, he computed the distance from Alkmaar to Bergen-op-Zoom (around 130 kilometers). The two towns lie on approximately the same meridian. Snel used the distance from Leiden to Zoeterwoude (about 5 kilometers) as a baseline. His instruments were made by Blaeu; and the huge, 210-centimeter quadrant used for his triangulations is suspended in the hall of the Leiden astronomical observatory. The unit of measure was the Rhineland rod (1 rod = 3.767 meters), recommended by Stevin to the States General in 1604 (Stevin, Principal Works, IV [1964], 24); and, following Stevin, the rod was divided into tenths and hundredths. The results were presented In Eratosthenes batavus (1617).

Dissatisfied with his geodetic work Snel began to correct it, aided by his pupils, and extended his measurements to include the distance from Bergen-op-Zoom to Mechelen. Unaided by logarithms, he continued this work throughout his life. His early death in 1626 prevented him from publishing his computations, which are preserved his own copy of Eratosthenes batavus at the Royal Library in Brussels. They were recently checked by N. D. Haasbroek and were found to be conscientious and remarkably accurate. Haasbroek could not say as much for the way in which Musschenbroek handled these notes in his “De magnitudine terrae,” in Physicae experimentales ... (1729).

Snel published some observations by Biürgi and Tycho in 1618, and his descriptions of the comets of 1585 and 1618. Although he demonstrated from the parallax that the comet was beyond the moon and therefore could not consist of terrestrial vapors, he still believed in the character of comets as omina.

In 1624 Snel published his lessons on navigation in Tiphys batavus (Tiphys was the pilot of the Argo). The last works published by Snel himself were Canon triangulorum (1626) and Doctrina triangulorum (1627), the latter completed by his pupil Hortensius.

Snel's best-known discovery, the law of refraction of light rays, which was named after him, was formulated probably in or after 1621, and was the result of many years of experimentation and of the study of such books as Kepler's Ad Vitellionem paralipomena (1604) and Risner's Optica (1606. Snel's manuscript, which contained his results, has disappeared, but it was examined by Issac Vossius (1662) and by Huygens, who commented on it in his Dioptrica (1703, 1728).

The priority of the publication of the law remains with Descartes in his Dioptrique (1637), stated without experimental verification. Descartes has been accused of plagiarism (for example, by Huygens), a fact made plausible by his visits to Leiden during and after Snel's days, but there seems to be no evidence for it.

Snel was buried in the Pieterskerk in Leiden. The monument erected to him and his wife, who died in 1627, is still there.

(adopted from the Internet)

2.10 Ask questions to the underlined words and phrases.

1. At Leiden, Snel prepared a Latin translation of Stevin's Wisconstighe Ghedachtenissen, which was then being published.

2. He also busied himself with the restoration of the two books of Apollonius on plane loci, preserved only in abstract by Pappus.

3. In 1608 Snel married Maria De Lange, daughter of a burgomaster of Schoonhoven; only three of their eighteen children survived.

4. The Doctrina, which comprise a plane and spherical trigonometry, includes the recession problem for two points, often named after P. A. Hansen (1841).

5. Descartes has been accused of plagiarism (for example, by Huygens), a fact made plausible by his visits to Leiden during and after Snel's days, but there seems to be no evidence for it.

UNIT3 GEODETIC SURVEYING TECHNIQUES (part 2)

3.1 Practise reading the following words.

a) **[aɪ] – i**sland, h**ei**ght, upr**i**ght, beh**i**nd, impl**y**, l**i**ne

[əʊ] – old, locate, closure, c**oa**stline, p**o**le

[**eɪ] –** navig**a**tion, calibr**a**te, obt**ai**n, w**a**ve, rem**ai**n

[dʒ] – a**g**ency, ad**j**oin, chan**g**e, **g**eodetic, ad**j**ust

b) barometer [bə'rɔmɪtə], barometric [ˌbɑːrəu'metrɪk], bubble ['bʌbl], interior [ɪn'tɪərɪə], mountainous ['mauntɪnəs],) radar ['reɪdɑː], technique [tek'niːk], telescope ['telɪskəup], thermometer [θə'mɔmɪtə], surface ['sɜːfɪs].

3.2 Translate words of the same root into Russian.

To measure – measured – measureless – measurement – measuring – measurable - measurer

To extend – extended – extending – extensive – extension – extensible

To compute – computer – computation – computable – computing – computerize(d)

3.3 Fill in the sentences with words from exercise 3.2.

1. We … the fence to the edge of our property.
2. Final results had not yet been … .
3. An odometer … the number of miles your car travels.
4. Have you ever done any … for your research?
5. The exhibition has received … coverage in the national press.
6. The assistant took my ... and showed me what was available in my size.

Active Vocabulary

Word	**Pronunciation**	**Translation**
aneroid, *n.*	['ænərɔɪd]	барометр-анероид
calibrate, *v.*	['kælɪbreɪt]	градуировать, калибровать

conterminous, *adj*.	[kɔn'tɜːmɪnəs]	смежный, примыкающий, пограничный, соседний; ***syn.*** adjacent, adjoining
correspond, *v*.	[ˌkɔrɪ'spɔnd]	соответствовать, согласовываться, соотноситься
differential, *adj*.	[ˌdɪf(ə)'ren(t)ʃ(ə)l]	дифференциальный
execute, *v*.	['eksɪkjuːt]	осуществлять, выполнять, делать; ***syn***. perform, fulfil
gauge, *n*.	[geɪʤ]	измерительный прибор
leveling, *n*.	['lev(ə)lɪŋ]	нивелирование
loop, *n*.	[luːp]	петля
mercurial, *adj*.	[mɜː'kjuərɪəl]	ртутный
missile, *n*.	['mɪsaɪl]	реактивный снаряд, ракета
reckoning, *n*.	['rek(ə)nɪŋ]	вычисление, расчёт, определение местонахождения; ***syn.*** calculation, computation
reconnaissance, *n*.	[rɪ'kɔnɪs(ə)ns]	разведка, расследование, зондирование
sparsely, *adj*.	['spɑːslɪ]	редко
supplementary, *adj*.	[ˌsʌplɪ'ment(ə)rɪ]	добавочный, дополнительный; ***syn.*** additional, extra
tidal, *adj*.	['taɪd(ə)l]	связанный с приливом и отливом, периодический, чередующийся, перемежающийся
undulation, *n*.	[ˌʌndjə'leɪʃ(ə)n]	волнообразное движение
upright, *adj*.	['ʌpraɪt]	вертикальный, прямой
yield, *v*.	[jiːld]	давать, выдавать, вырабатывать

3.4 Read the text and match paragraphs A-D with gaps 1-5.

GEODETIC SURVEYING TECHNIQUES (part 2)

Trilateration

Another surveying method involves the use of radar and aircraft. The SHORAN, HIRAN and SHIRAN electronic distance measuring systems have been applied to performing geodetic surveys by a technique known as trilateration. Since very long lines (to 500 miles) could be measured by these systems, geodetic triangulation networks have been extended over vast areas in comparatively short periods of time. In addition, the surveys of islands and even continents separated by extensive water barriers have been connected by the techniques.

1.	

Traverse

The simplest method of extending control is called traverse. The system is similar to dead reckoning navigation where distances and directions are measured. In performing a traverse, the surveyor starts at a known position with a known azimuth (direction) to another point and measures angles and distances between a series of survey points.

2.	

If the traverse returns to the starting point or some other known position, it is a closed traverse, otherwise the traverse is said to be open. The traverse consists of a series of high-precision length, angle and astronomic azimuth determinations running approximately east-west and north-south through the conterminous states, forming somewhat rectangular loops.

Vertical positioning

Vertical surveying is the process of determining heights-elevations above the mean sea level surface. The geoid corresponds to the mean level of the open sea. In geodetic surveys executed primarily for mapping purposes, there is no problem in the fact that geodetic positions are referred to an ellipsoid and the elevations of the positions are referred to the geoid.

3.	

Precise geodetic leveling is used to establish a basic network of vertical control points. From these, the height of other positions in the survey can be determined by supplementary methods. The mean sea level surface used as a reference (vertical datum) is determined by obtaining an average of the hourly water heights for a period of several years at tidal gauges.

There are three leveling techniques-differential, trigonometric, and barometric-which yield information of varying accuracy. Differential leveling is the most accurate of the three methods. With the instrument locked in position, readings are made on two calibrated staffs held in an upright position ahead of and behind the instrument. The difference between readings is the difference in elevation between the points.

4.	

The exact elevation of at least one point in a leveling line must be known and the rest computed from it. Trigonometric leveling involves measuring a vertical angle from a known distance with a theodolite and computing the elevation of the point.

5.	

It is, therefore, a somewhat more economical method but less accurate than differential leveling. It is often the only practical method of establishing accurate elevation control in mountainous areas. In barometric leveling, differences in height are determined by measuring the difference in atmospheric pressure at various elevations. Air pressure is measured by mercurial or aneroid barometers, or a boiling point thermometer. Although the degree of accuracy possible with this method is not as great as either of the other two, it is a method which obtains relative heights very rapidly at points which are fairly far apart. It is widely used in the reconnaissance and exploratory surveys where more exacting measurements will be made later or are not required.

A With the angular measurements, the direction of each line of the traverse can be computed; and with the measurements of the length of the lines, the position of each control point computed.

B The optical instrument used for leveling contains a bubble tube to adjust it in a position parallel to the geoid. When properly "set up" at a point, the telescope is locked in a perfectly horizontal (level) position so that it will rotate through a 360 arc.

C However, geodetic data for missiles requires an adjustment in the elevation information to compensate for the undulations of the geoid above and below the regular mathematical surface of the ellipsoid. The adjustment uses complex advanced geodetic techniques.

D The Canadian SHORAN network connecting the sparsely populated northern coastal and island areas with the central part of the country and the North Atlantic HIRAN Network tying North America to Europe are examples of the application of the trilateration technique. SHIRAN has been used in the interior of Brazil.

E With this method, vertical measurements can be made at the same time horizontal angles are measured for triangulation.

(adopted from http://www.ngs.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003B.HTM)

3.5 Match words with their definitions.

barrier	**azimuth**	**technique**	**loop**	**level**	**ellipsoid**	**elevation**

1. ………. - a way of carrying out a particular task, especially the execution or performance of an artistic work or a scientific procedure;

2. ………. - the direction of a celestial object from the observer, expressed as the angular distance from the north or south point of the horizon to the point at which a vertical circle passing through the object intersects the horizon;

3. ………. - a three-dimensional figure symmetrical about each of three perpendicular axes, whose plane sections normal to one axis are circles and all the other plane sections are ellipses;

4. ………. - a height or distance from the ground or another stated or understood base;

5. ………. - the action or fact of raising or being raised to a higher or more important level, state, or position;

6. ………. - a circumstance or obstacle that keeps people or things apart or prevents communication or progress;

7. ………. - a length of thread, rope, or similar material, doubled or crossing itself, used as a fastening or handle

3.6 Mark the following sentences True or False.

1. Only distances are measured in trilateration.

2. If the traverse returns to the starting point or some other known position, it is an open traverse.

3. Reckoning navigation methods in geodesy involve the determination of an observer's position from observations of the moon, stars and satellites.

4. Vertical surveying is the process of determining heights-elevations above the mean sea level surface.

5. Trigonometric, differential and barometric leveling techniques turn in information of varying accuracy.

6. Differential leveling measures a vertical angle from a known distance with a theodolite and computing the elevation of the point.

7. In barometric leveling, differences in angles are determined by measuring the difference in atmospheric pressure at various elevations.

3.7 Find words in the text similar in meaning.

1. fulfill
2. spacious
3. space
4. use
5. dot
6. apparatus
7. precision
8. right-angled
9. vertical
10. compression

3.8 Match adjectives with suitable nouns.

1. extending	a. technique
2. surveying	b. length
3. rectangular	c. control
4. trilateration	d. instruments
5. high-precision	e. method
6. vertical	f. traverse
7. angular	g. pressure
8. air	h. loops
9. closed	i. angle
10. optical	j. measurements

3.9 Complete the text using the words in CAPITALS in the correct form.

The dictionary defines the verb survey as "To determine and delineate the form, extent, position, etc., of, as a tract of land, by 1) TAKE linear and angular 2) MEASURE, and by applying the principles of geometry and trigonometry". One of the functions of the science of geodesy is defined as the 3) DETERMINE of the exact positions of points on the earth's surface. Astronomic positions are 4) REFER to the geoid that is a surface along which the gravity potential is everywhere equal and to which the 5) DIRECT of gravity is always perpendicular. Another astronomic observation related to 6) HORISONT positioning is the astronomic azimuth. Very 7) ACCURACY azimuths are used in the controlling of the orientation of 8) ONE-order triangulation. Triangulation is extended over large areas by connecting and 9) EXTEND series of arcs and forming a network or triangulation system. The network is adjusted in a manner which reduces the effect of observational errors to a minimum. A denser distribution of geodetic control 10) ACHIEVE in a system by subdividing or filling in with other surveys.

3.10 Translate the following sentences into English.

1.Конечной целью построения геодезической сети (ГС) является определение координат геодезических пунктов.

2. Существуют методы построения ГС, выбор которых определяется условиями местности, требуемой точностью и экономической эффективностью.

3. Триангуляция - метод построения на местности ГС в виде треугольников, у которых измерены все углы и базисные выходные стороны. Длины остальных сторон вычисляют по тригонометрическим формулам, затем находят дирекционные углы (азимуты) сторон и определяют координаты.

4. Трилатерация - метод построения ГС в виде треугольников, у которых измерены длины сторон (расстояния между геодезическими пунктами), а углы между сторонами вычисляют.

5. Полигонометрия - метод построения ГС на местности в виде ломаных линий, называемых ходами, вершины которых закреплены геодезическими пунктами. Измеряются длины сторон хода и горизонтальные углы между ними.

6. Линейно-угловые построения, в которых сочетаются линейные и угловые измерения наиболее надежные.

7. Форма сети может быть различная, например четырехугольник, у которого измеряют все горизонтальные углы и две смежные стороны, а две другие стороны вычисляют.

8. Методы с использованием спутниковых технологий, в которых координаты пунктов определяются с помощью спутниковых систем - это российский Глонасс и американский GPS.

9. Эти методы имеет революционное научно-техническое значение по достигнутым результатам в точности, оперативности получения результатов, всепогодности и относительно невысокой стоимости работ по сравнению с традиционными методами восстановления и поддержания государственной геодезической основы на должном уровне.

UNIT 4 GEODETIC SYSTEMS

4.1 Practise reading the following words.

a) **[eɪ] –** elev**a**tion, m**ay**, n**a**tion, m**a**jor, surv**ey**, b**a**se

[**aʊ] – hour**, h**ow**ever, **our**, f**ou**nd, **ou**t

[ʃ] – condi**t**ion, accompli**sh**, expan**s**ion, establi**sh**, ini**t**ial, offi**c**ial

[ɔ:] – f**o**r, **o**rder, l**au**nch, theref**o**re, m**o**re

b) ellipsoid [ɪ'lɪpsɔɪd], numerical [njuː'merɪkl], geometric(al) [ˌʤɪə'metrɪk((ə)l)], basis ['beɪsɪs], coordinate [kəu'ɔːdɪnət], error ['erə], gravimetric [ˌgrævɪ'metrɪk], system ['sɪstəm], geocentric [ˌʤiːəu'sentrɪk].

4.2 Complete the chart below with the common noun suffixes and mark the stress. There are some spelling changes.

nouns	- ation - ion - ness - ity - ence/ance - sion - ment
noun	**verb/ adjective**
	1. quantify
	2. adjust
	3. capable
	4. refer

	5. rotate
	6. commit
	7. require
	8. separate
	9. differ
	10. expand

4.3 Fill in the sentences with words from exercise 4.2.

1. I'm not sure how he'll make the emotional ….. to retirement.
2. The book is an ….. of a lecture series.
3. She made no ..... to her opponents.
4. He is considering the offer but he has not yet ….. himself.
5. It ….. careful consideration.
6. She ….. from her sister in the colour of her eyes.

Active vocabulary

Word	**Pronunciation**	**Translation**
adjustment, *n.*	[ə'ʤʌstmənt]	улаживание, урегулирование, наладка, настройка
axis, *n.*, *pl.* axes	['æksɪs]	ось
coincident, *adj.*	[kəu'ɪnsɪd(ə)nt]	совпадающий, соответствующий
concurrent, *adj.*	[kən'kʌr(ə)nt]	совпадающий; согласованный
conterminous, *adj.*	[kɔn'tɜːmɪnəs]	смежный, примыкающий, пограничный, соседний; **syn.** adjacent, adjoining
curvature, *n.*	['kɜːvəʧə]	изгиб, искривление, кривизна
datum, *n.*	['deɪtəm]	база, базовая точка (линия, плоскость), начало отсчёта, точка (линия, плоскость) приведения

deflection, *n.*	[dɪ'flekʃ(ə)n]	отклонение; **syn.** deviation
discrepancy, *n.*	[dɪs'krep(ə)nsɪ]	разница; различие, разногласие, противоречие; **syn.** difference, disagreement
extend, *v.*	[ɪk'stend]	простираться, тянуться, длиться
flattening, *n.*	['flæt(ə)nɪŋ]	выравнивание, сплюснутость, сглаженность
involve, *v.*	[ɪn'vɔlv]	привлекать, вовлекать, втягивать
leveling, *n.*	['lev(ə)lɪŋ]	нивелирование
overlap, *v.*	[ˌəuvə'læp]	частично покрывать; перекрывать
particular, *adj.*	[pə'tɪkjələ]	особенный, специфический, особый, исключительный
scope, *n.*	[skəup]	масштаб, предел, размах, сфера, область действия
stretch, *n.*	[streʧ]	вытягивание, растягивание, удлинение, напряжение; пространство, участок, отрезок
survey, *n.*	['sɜːveɪ]	землемерная, геодезическая, топографическая съёмка местности

4.4 Read the text and answer the following questions.

1. What is datum?
2. How many types of datums are there in geodesy?
3. What does a horizontal datum consist of?
4. Why do discrepancies between datums occur?
5. What are three methods of datum connection?
6. Why are elevations in vertical datums referred to the geoid?
7. What are discrepancies among vertical datums?
8. What are vertical datum problems in Europe and in Asia?

GEODETIC SYSTEMS

A datum is defined as any numerical or geometrical quantity or set of such quantities which serve as a reference or base for other quantities. In geodesy two types of datums must be considered: a horizontal datum which forms the basis for the computations of horizontal control surveys in which the curvature of the earth is considered, and a vertical datum to which elevations are referred. In other words, the coordinates for points in specific geodetic surveys and triangulation networks are computed from certain initial quantities (datums).

Horizontal Geodetic Datums

A horizontal geodetic datum may consist of the longitude and latitude of an initial point (origin); an azimuth of a line (direction) to some other triangulation station; the parameters (radius and flattening) of the ellipsoid selected for the computations; and the geoid separation at the origin. A change in any of these quantities affects every point on the datum.

In areas of overlapping geodetic triangulation networks, each computed on a different datum, the coordinates of the points given with respect to one datum will differ from those given with respect to the other. The differences occur because of the different ellipsoids used and the probability that the centers of each datum's ellipsoid is oriented differently with respect to the earth's center. In addition, deflection errors in azimuth cause a relative rotation between the systems. Finally, a difference in the scale of horizontal control may result in a stretch in the corresponding lines of the geodetic nets.

Datum Connection

There are three general methods by which horizontal datums can be connected. The first method is restricted to surveys of a limited scope and consists of systematic elimination of discrepancies between adjoining or overlapping triangulation networks. The second one is the gravimetric method of Physical Geodesy and the third – the methods of Satellite Geodesy. These methods are used to relate large geodetic systems to each other and/or to a world system. Both the gravimetric and satellite methods produce necessary "connecting" parameters from reduction of their particular observational data.

Vertical Datums

Just as horizontal surveys are referred to specific original conditions (datums), vertical surveys are also related to an initial quantity or datum. Elevations are referred to the geoid because the instruments used either for differential or trigonometric leveling are adjusted with the vertical axis coincident to the local vertical. As with horizontal datums, there are many discrepancies among vertical datums. There is never more than 2 meters variance between leveling nets based on different mean sea level datums; however, elevations in some areas are related to surfaces other than the geoid; and barometrically determined heights are usually relative.

In the European area, there are fewer vertical datum problems than in Asia and Africa. Extensive leveling work has been done in Europe and practically all of it has been referred to the same mean sea level surface. However, in Asia and Africa the situation has been different. In places there is precise leveling information available based on mean sea level. In other areas the zero elevation is an assumed elevation which sometimes has no connection to any sea level surface. China has been an extreme example of this situation where nearly all of the provinces have had an independent zero reference. There is very little reliable, recent, vertical data available for much of the area of Africa and Asia including China.

The mean sea level surface in the United States was determined using 21 tidal stations in this country and five in Canada. This vertical datum has been extended over most of the continent by first-order differential leveling. Concurrent with the new adjustment of the horizontal network, mentioned previously, is the readjustment of the vertical network. Countries of North and Central America are involved. In the conterminous United States 110,000 kilometers of the basic network are being releveled.

(adpted from http://www.ngs.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003B.HTM)

4.5 Mark the following sentences True or False.

1. A horizontal datum is a datum to which elevations are referred and vertical one is a datum in which the curvature of the earth is considered.
2. There are some quantities which may affect every point on the datum.
3. The survey of the limited scope, the gravimetric method of Physical Geodesy and the methods of Satellite Geodesy are methods of horizontal datum.
4. There are no differences among vertical datums.
5. There are more vertical datum problems in Europe than in Asia.
6. China is an example of zero elevation which has no connection to the sea level surface.
7. The mean sea level surface in Canada was determined by 31 tidal stations.

4.6. Match words similar in meaning.

1. kind	a. error
2. suppose	b. initial
3. primary	c. restrict
4. chose	d. deflection
5. deviation	e. type
6. adjust	f. determine
7. mistake	g. consider
8. limit	h. instrument
9. tool	i. orient
10. resolve	j. select

4.7 Match words opposite in meaning.

1. ruin	a. differ
2. lower	b. connect
3. be alike	c. unify
4. shrink	d. form
5. enlarge	e. reduce

6. separate	f. accurate
7. unreliable	g. stretch
8. following	h. previous
9. inaccurate	i. elevate
10. diversify	j. reliable

4.8 Match two halves of the statements and translate them into Russian.

1. neighboring	a. advanced nation
2. military interests of	b. existing local surveys
3. different surveys	c. countries
4. various weapon	d. requirement
5. technically	e. each country
6. economic	f. international nature
7. surveys of	g. varying size
8. military	h. distance requirements
9. the size and	i. systems
10. the expansion and unification of	j. shape of the earth

4.9 Fill in the sentences with the statements from exercise 4.8.

Major Datums Before World War II

By 1940, every 1) ….. had developed its own geodetic system to an extent governed by its economic and military requirements. Some systems were developed by 2) ….. and others by new nationwide surveys replacing outdated local ones. Normally, 3) ….. did not use the same geodetic datum. There was no 4) ….. for common geodetic information and the use of common datums was contrary to the 5) ….. . The only 6) ….. based on one datum were the few measurements of long arcs accomplished for the purpose of determining 7) ….. . The net result was that there were many 8) ….. which differed from each other remarkably.

As 9) ….. increased, positioning information of local or even national scope became unsatisfactory. The capabilities of the 10) ….. increased until datums of at least continental limits were required.

4.10 Translate the following text into English.

1. Благодаря многочисленным измерениям и изучению статистики результатов, был обоснован постулат о форме Земли, как геоида – шара, сплюснутого в направлении полюсов. Учет этого обстоятельства позволил сделать картографию более точной, учесть изменения кривизны земной поверхности в зависимости от широты и долготы местности.

2. Для определения положения любой точки земной поверхности используют три координаты: широту, долготу и высоту над нулевым уровнем - уровнем моря.

3. В масштабе какой-либо одной страны нулевой уровень высот определяется на основании осредненных показателей многолетних замеров на нескольких водомерных постах.

4. Традиционно горизонтальные и вертикальная координаты рассматриваются порознь и исходные пункты устанавливаются для них отдельно.

5. Широко распространена, как метод съемки, геодезическая съемка, с помощью которой получают съемочный материал для геодезических карт или планов.

6. Геодезическая сеть любого вида представляет систему базисных точек или опорных пунктов земной поверхности, положение которых определено и зафиксировано в общей для них всех системе геодезических координат.

7. Любая сеть высотных опорных пунктов при выполнении геодезии земли строится методами геометрического или тригонометрического нивелирования.

UNIT5 PHYSICAL GEODESY (part 1)

5.1 Practise reading the following words.

a) [ɔɪ] – sp**oi**lt, enj**oy**, p**oi**nt, empl**oy**, j**oi**nt

[ɪə] –n**ear**, cl**ear**, p**e**r**io**d, conven**ie**nt, h**ere**

[w] – with, bet**w**een, **w**hich, net**w**ork, s**w**ing, **w**ere

[**tʃ**] – **ch**ange, struc**t**ure, su**ch**, ea**ch**, a**ch**ieve, mu**t**ual

b) underline the stressed syllable

acceleration, airplane, although, characteristic, consequently, gravimeter, interval, successive, technique.

5.2 Translate words of the same root into Russian.

To compare – comparison – comparative – comparable – comparatively – comparability

To distribute – distributed – distributor – distributing – distributive – distribution

To occupy – occupied – occupational – occupancy – occupant – occupier – occupation.

5.3 Fill in the sentences with words from exercise 5.2

1. A steady stream of clients kept her … until the middle of the afternoon.
2. The remake was OK but it cannot … with the original.
3. It is clear that a reorganization is necessary on the … side of this industry.
4. The new homes will be ready for … in August.
5. I sat out in the open air in … comfort.
6. The books will be … free to local schools.

Active vocabulary

Word	Pronunciation	Translation
approximately, *adv.*	[ə'prɔksɪmətlɪ]	приблизительно, близко, около, почти

associate, *v.*	[ə'səusɪeɪt], [-ʃieɪt]	ассоциировать, связывать с (кем-л. / чем-л.)
attraction, *n.*	[ə'trækʃ(ə)n]	притяжение, тяготение; **syn.** gravitation, gravity
consideration, *n.*	[kənˌsɪd(ə)'reɪʃ(ə)n]	размышление, обсуждение, рассмотрение
deduce, *v.*	[dɪ'djuːs]	приходить к заключению, делать вывод
drift, *n.*	[drɪft]	сдвиг, направление, тенденция
flip, *v.*	[flɪp]	переворачивать; перекидывать
instability, *n.*	[ˌɪnstə'bɪlətɪ]	неустойчивость, непостоянство
invar, *n.*	[ɪn'vɑː]	инвар (сплав железа с никелем)
pendulum, *n.*	['pendj(ə)ləm]	маятник
pivot, *n.*	['pɪvət]	штырь, болт, штифт
relative, *adj.*	['relətɪv]	относительный, сравнительный,релятивный
reversible, *adj.*	[rɪ'vɜːsəbl]	с передним и задним ходом, реверсивный
solution, *n.*	[sə'luːʃ(ə)n]	решение, разрешение, разъяснение
sufficient, *adj.*	[sə'fɪʃ(ə)nt]	достаточный; обоснованный
supersede, *v.*	[ˌs(j)uːpə'siːd]	заменять, замещать, смещать; **syn.** displace, dislocate
swing (swung, swung), *v.*	[swɪŋ]	качаться, колебаться, подвешивать
tie, *v.*	[taɪ]	соединять, скреплять, связывать; **syn.** connect, join
value, *n.*	['væljuː]	величина, значение
virtually, *adv.*	['vɜːʧuəlɪ]	фактически, практически, в сущности; поистине

5.4 Read the text and answer the following questions.

1. What does Physical Geodesy study?
2. What types of gravity measurements exist?
3. What did scientists use to measure the gravity until the middle of the 20^{th} century?
4. Why was the pendulum method superseded by the ballistic method?
5. What instruments were used for relative gravity measurements?
6. When was the first gravimeter developed?
7. What is drift?
8. What points are called base stations?

PHYSICAL GEODESY (part 1)

Physical geodesy utilizes measurements and characteristics of the earth's gravity field as well as theories regarding this field to deduce the shape of the geoid and in combination with arc measurements, the earth's size. With sufficient information regarding the earth's gravity field, it is possible to determine geoid undulations, gravimetric deflections, and the earth's flattening.

In using the earth's gravity field to determine the shape of the geoid, the acceleration of gravity is measured at or near the surface of the earth. It might be interesting to compare the acceleration measured by the gravimetrist and the acceleration experienced in an airplane. In an airplane, the acceleration is simply called a G force and is measured by a G meter. A G factor of one is used to indicate the acceleration due to the attraction of the earth and is considered a neutral condition. The gravity unit used and measured in geodesy is much smaller. A G factor of one is approximately equal to one thousand gals, a unit named after Galileo. The still smaller unit used in geodesy is the milligal (mgal) or one-thousandth part of a gal. Thus, in geodesy we are dealing with variations in acceleration equal to one millionth of one G aircraft acceleration. The most accurate modern instruments permit measurement of acceleration changes of one hundred millionth part of the well known G factor or better.

Gravity Measurements

Two distinctly different types of gravity measurements are made: absolute gravity measurements and relative gravity measurements. If the value of acceleration of gravity can be determined at the point of measurement directly from the data observed at that point, the gravity measurement is absolute. If only the differences in the value of the acceleration of gravity are measured between two or more points, the measurements are relative.

Absolute measurement of gravity

Until the middle of the 20th century, virtually all absolute measurements of gravity were made using some type of pendulum apparatus. The most usual type of apparatus contained <u>a number of pendulums</u> that were swung in a vacuum. By measuring the peroid of the pendulums, the acceleration of gravity could be computed. In 1818, Kater developed the so-called reversible pendulum that had knife edge pivots at both ends. These pendulums were flipped over (reversed) during the measurements and, using this procedure, a number of important error sources were eliminated. Still, there were numerous other problems and error sources associated with pendulum measurements of absolute gravity, and the results obtained were not sufficiently accurate to meet the needs of geodetic gravimetry. Consequently, <u>in recent years</u>, the pendulum method has been superseded by the ballistic method which is based on timing freely falling bodies. The acceleration of gravity can be determined by measuring the time taken by a body to fall over a known distance.

Relative measurement of gravity

Solution of some of the problems of gravimetric geodesy requires <u>knowledge of the acceleration of gravity at very many points</u> distributed uniformly over the entire surface of the earth. Since absolute gravity measurements have been too complicated and time consuming and, until recently, could not be obtained with sufficient accuracy, relative gravity measurements have been used to establish the dense network of gravity measurements needed. The earliest relative gravity measurements were made <u>with reversible pendulums</u>. The most accurate relative pendulums to be developed were the Gulf quartz pendulum and the Cambridge invar pendulum. These two instruments were used as late as 1969.

Modern relative gravity measurements are made with small, very portable, and easily used instruments known as gravimeters (gravity meters). Using gravimeters, highly accurate relative measurements can be made at a given site, known as a gravity station, in half-an-hour or less. Modern gravimeter-type instruments were first developed in the 1930's. There are two other important considerations when relative gravity measurements are made: drift and base station connections. Gravimeter drift is a phenomenon related to certain instrumental instabilities that cause the dial reading to change slowly with time even when the acceleration of gravity remains constant. Since relative gravity surveys can determine only differences in gravity from point to point, every relative gravity survey must include measurements at one or more reoccupiable points where acceleration of gravity is known. Such points are called base stations. Then all gravity difference measurements are computed with respect to the known gravity value at the base station. Hence, tying a relative gravity survey to a base station establishes the "gravity datum" of that survey. The earliest "gravity datum" was the so-called Potsdam System. The Potsdam system, however, was found to be in error and, in 1971, was replaced by the International Gravity Standardization Net 1971 (IGSN71).

(adopted from http://www.ngs.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003C.HTM)

5.5 Mark the following sentences True or False.

1. Having information about the earth's gravity field, you can determine geoid undulations, gravimetric deflections and the earth's flattening.

2. In geodesy it is dealt with variations in acceleration equal to one thousandth of one G aircraft acceleration.

3. Kater developed a pendulum but measurements and results were not rather accurate.

4. Absolute gravity measurements were simple but time consuming.

5. Reversible pendulums are small, portable and easily used instruments.

6. Gravimeter-type instruments were first developed at the beginning of the 20th century.

7. Base stations are reoccupiable points where acceleration of gravity is known.

8. The Potsdam System was replaced by the IGSN in 1977.

5.6 Ask questions to the underlined words and phrases.

5.7 Match words with their definitions.

point geoid instability gravity apparatus pivot instrument acceleration

1. ………. - a hypothetical solid figure whose surface corresponds to mean sea level and its imagined extension under (or over) land areas;
2. ………. - the force that attracts a body towards the centre of the earth, or towards any other physical body having mass;
3. ………. - the rate of change of velocity per unit of time;
4. ………. - a tool or implement, especially one for precision work;
5. ………. - tendency to unpredictable behaviour or erratic changes of mood;
6. ………. - the technical equipment or machinery needed for a particular activity or purpose;
7. ………. - the central point, pin, or shaft on which a mechanism turns or oscillates;
8. ………. - a particular spot, place, or position in an area or on a map, object, or surface.

5.8 Complete the text with one word.

In the United States, the basic falling body apparatus was … in the early 1970's jointly by J.A. Hammond of the Air Force Geophysics Laboratory and J.E. Faller of the Joint Institute for … Astrophysics. In the so-called Hammond-Faller apparatus, a corner cube reflector falls in a vacuum … distance and time are measured continuously … a laser beam in conjunction with a photo multiplier tube. This … weighed about 800 kilograms and considerably … accurate than the best absolute pendulum apparatus. Hammond recently … completed fabrication of a somewhat … and more accurate version of the original Hammond-Faller apparatus. The new instrument … about 700 kilograms when packed for shipment in nine units. Hammond's apparatus has … used to establish very accurate … for absolute gravity at a number of sites within the United States. Faller is also developing a more refined falling … apparatus.

5.9 Reorder the words to make a sentence.

1. stations - contains - The - 1854 - distributed - reoccupiable - worldwide - IGSN.
2. basic - The - for - established - "gravity datum" - gravity - IGSN71 - today's - surveys - the - relative.
3. For - US - contains - example - stations - the - gravity – network – 50 - base - approximately.
4. measurements - are - national - by - networks - The - usually - established - precise - base - gravimeter.
5. at - Drift - considered - constant - occur - to - a - often - rate - is.
6. at - Consequently - time - measurement - which - is - with - is - each - recorded - the - along - dial - the - made - reading.
7. at - 28 - types - least - different - extensively - kinds - developed – gravimeters - have - of - been - only - two - have - used - been - Although.

5.10 Translate the following sentences into English.

1. Относительные определения силы тяжести производятся маятниковыми приборами с точностью до нескольких сотых долей мгл.
2. Наиболее распространенный прибор для измерения силы тяжести – гравиметр, используемый для относительных измерений, т.е. разности значений силы тяжести в двух пунктах.
3. Существует специальная гравиметрическая аппаратура для измерений силы тяжести с движущихся объектов (подводных и надводных кораблей, самолётов).

4. Для проведения абсолютных измерений силы тяжести требуется большое количество вспомогательного оборудования, поэтому их нецелесообразно проводить при обычных геодезических съемках.

5. Международная гравиметрическая стандартная сеть по состоянию на 1971 включала 10 гравиметрических станций для абсолютных измерений и 1854 пункта для относительных измерений силы тяжести.

6. Хотя статические гравиметры позволяют получить наиболее точные значения, их использование в полевых условиях требует значительных затрат труда и времени.

7. Определения силы тяжести производятся относительным методом, путем измерения при помощи гравиметров и маятниковых приборов разности силы тяжести в изучаемых и опорных пунктах.

8. Сеть опорных гравиметрических пунктов на всей Земле связана в конечном итоге с пунктом в Потсдаме, где оборотными маятниками в начале 20 века было определено абсолютное значение ускорения силы тяжести (981 274 мгл).

9. Новые абсолютные измерения, производимые более чем в 10 пунктах Земли, показывают, что приведенное значение ускорения силы тяжести в Потсдаме превышено, по-видимому, на 13–14 мгл.

10. Наиболее точно абсолютное значение силы тяжести определяется из опытов со свободным падением тел в вакуумной камере.

UNIT 6 PHYSICAL GEODESY (part 2)

6.1 Practise reading the following words.

a) [θ] – ear**th**, bo**th**, me**th**od, mon**th**, **th**ought, **th**eory

[ŋ] – bei**ng**, alo**ng**, emerging, wi**ng**, si**n**gle, le**n**gth

[e] – d**e**nse, n**e**t, l**e**vel, d**e**nsity, r**e**gular, eff**e**ct

b) submarine [ˌsʌbm(ə)'riːn], compensate ['kɔmpenseɪt], anomaly [ə'nɔməlɪ], uniform ['juːnɪfɔːm], satellite ['sæt(ə)laɪt], apparatus [ˌæp(ə)'reɪtəs], inertial [ɪˈnəːʃ(ə)l], equivalent [ɪ'kwɪv(ə)lənt], ellipsoidal [ˌelɪp'sɔɪd(ə)l], topography [tɔ'pɔgrəfɪ], Vening Meinesz [ˌvɛnɪŋ ˈmʌɪnɛs].

6.2 Cross out the word with a different sound.

ʌ	red**u**ction cr**u**st ass**u**me p**u**blish str**u**cture
æ	**a**verage v**a**lue gr**a**vity **a**fter v**a**rious
k	air**c**raft surfa**c**e su**cc**ess **c**onsider a**cc**uracy
əʊ	m**o**tion comp**o**nent pr**o**minent **o**cean kn**o**w
w	**w**ave **w**hole for**w**ard **w**ould **w**here

Active vocabulary

Word	**Pronunciation**	**Translation**
airborne, *adj.*	['eəbɔːn]	переносимый или перевозимый по воздуху
altitude, *n.*	['æltɪt(j)uːd]	высота
application, *n.*	[ˌæplɪ'keɪʃ(ə)n]	применение, приложение
correlation, *n.*	[ˌkɔrə'leɪʃ(ə)n]	взаимосвязь, соотношение
crust, *n.*	[krʌst]	земная кора
data, *n.*	['deɪtə]	данные, факты, сведения
eliminate, *v.*	[ɪ'lɪmɪneɪt]	устранять, исключать, аннулировать; **syn**. remove, expel

encounter, *v.*	[ɪn'kauntə]	наталкиваться на (трудности), столкнуться с
justify	['ʤʌstɪfaɪ]	подтверждать, доказывать, объяснять, обосновывать; **syn.** confirm, prove, verify
lack, *n.*	[læk]	недостаток, нужда, отсутствие
magnitude, *n.*	['mægnɪt(j)uːd]	величина, важность, значение, магнитуда
mantle, *n.*	['mæntl]	(земная) мантия
oscillatory, *adj.*	['ɔsɪlət(ə)rɪ]	колебательный
purpose, *n.*	['pɜːpəs]	цель, намерение; замысел, стремление; **syn.** aim, goal, objective
shore, *n.*	[ʃɔː]	берег, побережье; **syn**. bank, beach, coast
sparse, *adj.*	[spɑːs]	разбросанный, редкий
spurious, *adj.*	['spjuərɪəs]	поддельный, ложный, фальшивый; **syn.** faked, counterfeit
velocity, *n.*	[vɪ'lɔsətɪ]	скорость, быстрота

6.3 Read the text and answer the following questions.

1. When did first gravimeters on ships appear?
2. What instruments were used on surface ships?
3. What is a problem with ocean surface measurements?
4. What systems are used near the shore and in the deep ocean?
5. What problems are there with gravity measurements in the air?
6. What is gravity anomaly?
7. What is the most common type of gravity anomaly?
8. Who developed formulas for computing the gravimetric deflection of the vertical?
9. What does the effectiveness of the gravimetric method depend on?
10. What geophysical data are correlated with each othe

PHYSICAL GEODESY (part 2)

Gravity measurement at sea

The earliest measurements at sea were made by F.A. Vening Meinesz who, in 1927, installed a pendulum apparatus in a submarine. The submarine pendulum gravity measurements of Vening Meinesz are mainly of historical interest today. The first gravimeters installed in surface ships appeared during the 1950's. These early ocean surface gravity measurements were only of modest accuracy and, again, now are mainly of historical value. Reasonably accurate measurements from gravimeters on surface ships date only from the late 1960's. Instruments used include LaCoste-Romberg S Meter, Askania Meter, Bell Meter, and the Vibrating String Gravimeter. All of these meters are compensated to minimize the effects of oscillatory motion of the ship due to ocean surface waves. The effects are also eliminated or averaged out by computational techniques. A big problem with ocean surface measurements is that the forward motion of the ship adds a centrifugal reaction component to measured gravity which must be eliminated by the so-called Eotvos correction. Therefore, the ship's velocity and heading, as well as the ship's position, must be known accurately. Near shore, shore based electronic positioning/navigation systems (such as LORAN) are used. In the deep ocean, satellite navigation and inertial systems must be used.

Gravity measurement in the air

Problems in airborne gravity measurements are similar to those encountered for surface ships. The position, velocity, and heading of the aircraft must be known accurately. Because of the higher aircraft speeds, the Eotvos correction is much larger for airborne measurements than for surface ship measurements. It also is very difficult to compensate for spurious aircraft accelerations. In addition, reduction of the gravity value from aircraft altitude to an equivalent surface value is a problem that has not yet been solved satisfactorily.

Gravity Anomalies

Gravity measurements provide values for the acceleration of gravity at points located on the physical surface of the earth. Before these measurements can be used for most geodetic purposes, they must be converted into gravity anomalies.

A gravity anomaly is the difference between a gravity measurement that has been reduced to sea level and normal gravity. Normal gravity, used to compute gravity anomalies, is a theoretical value representing the acceleration of gravity that would be generated by a uniform ellipsoidal earth. By assuming the earth to be a regular surface without mountains or oceans, having no variations in rock densities or in the thickness of the crust, a theoretical value of gravity can be computed for any point by a simple mathematical formula. The most common type of gravity anomaly used for geodetic applications is the so-called free-air gravity anomaly.

Undulation and Deflections by the Gravimetric Method

The method providing the basis from which the undulations of the geoid may be determined from gravity data was published in 1849 by a British scientist, Sir George Gabriel Stokes. However, the lack of observed gravity data prevented its application until recent years. In 1928, the Dutch scientist, Vening Meinesz, developed the formulas by which the gravimetric deflection of the vertical can be computed. The computation of the undulations of the geoid and the deflections of the vertical require extensive gravity observations. The areas immediately surrounding the computation point require a dense coverage of gravity observations and detailed data must be obtained out to distances of about 500 miles. A less dense network is required for the remaining portion of the earth. While the observational requirements for these computations appear enormous, the results well justify the necessary survey work. Effective use of the gravimetric method is dependent only on the availability of anomalies in sufficient quantity to achieve the accuracy desired. Successful use of Stoke's integral and Vening-Meinesz formulas depends on a good knowledge of gravity anomalies in the immediate vicinity of the point under consideration and a general knowledge of anomalies for the entire earth.

There are many large regions on the continents where gravity measurements are lacking or available only in small quantities. Gravity data for ocean areas has always been sparse, however, Satellite Altimetry has overcome this deficiency. In regions where an insufficient number of gravity measurements exists, some other approach must be used to obtain or predict the mean gravity anomalies for the areas.

Correlations exist between variations in the gravity anomaly field and corresponding variations in geological, crustal, and upper mantle structure, regional and local topography and various other types of related geophysical data. In many areas where gravity information is sparse or missing, geological and geophysical data is available. Therefore, the various prediction methods take into account the actual geological and geophysical cause of gravity anomalies to predict the magnitude of the anomalies.

(adopted from http://www.ngs.noaa.gov/PUBS_LIB/Geodesy4Layman/TR80003C.HTM)

6.4 Mark the following sentences True or False.

1. V. Meinesz used submarines for marine gravity surveys.
2. Early ocean surface gravity measurements were of precise accuracy.
3. Problems with gravity measurements in the air and in the sea are different.
4. The problem of reduction of gravity value from aircraft altitude to an equivalent surface is not solved.
5. Before being used for geodetic purposes, gravity measurements are converted into gravity anomalies.
6. In 1939 a British scientist published his method of determining the undulations of the geoid from gravity data.
7. Extensive gravity observations are necessary for computing the undulations of the geoid and the deflection of the vertical.
8. Geological and geophysical data is not available in areas where gravity information is sparse or missing.

6.5 Match words similar in meaning.

1. precise	a. recent
2. expel	b. heading
3. speed	c. accurate
4. route	d. dense
5. resolve	e. eliminate

6. normal	f. variation
7. variety	g. velocity
8. modern	h. extensive
9. vast	i. regular
10. thick	j. solve

6.6 Give English equivalents for the following word combinations.

1. колебательное движение
2. вычислительная техника
3. скорость и курс корабля
4. система навигации
5. толщина/ мощность земной коры
6. недостаточное количество данных
7. в достаточном количестве
8. принимать во внимание

6.7 Give Russian equivalents for the following word combinations.

1. gravity measurements
2. forward motion of the ship
3. the acceleration of gravity
4. to compute gravity anomaly
5. undulation of the geoid
6. to require extensive observations
7. to justify the necessary survey work
8. other types of related geophysical data

6.8 Match sentence halves.

1. The word, anomaly, as used in geodesy refers to a	**a.** suitable for use aboard a fixed wing KC-135 aircraft.

deviation from the normal	
2. To make use of the anomalies,	**b.** and a Del Norte transponder electronic navigation system to establish aircraft position,
3. The axis of rotation for the ellipsoid passes	**c.** geoid undulations cannot be computed directly but must be determined point by point.
4. The theoretical value of gravity at a point on the ellipsoid's surface depends both	**d.** and can be used either for a single point or to describe a regional or area effect.
5. The distance between the mathematical ellipsoid and the actual geoid	**e.** the observed gravity must be reduced to a common frame of reference, the geoid-mean sea level.
6. In 1959, the US Air Force was instrumental in developing a gravimeter	**f.** through the earth's center of gravity.
7. The gravity measurement system aboard the helicopter uses a LaCoste-Romberg S Meter to sense gravity	**g.** on the size and shape of the ellipsoid and on a value, computed from observational data.
8. Since the geoid is so irregular,	**h.** is called the undulation of the geoid.

6.9. Ask all possible questions to the sentences from exercise 6.8.

6.10 Make a brief report on one of the following topics:

a. Vening Meinesz;

b. Loran – A, Loran – C and eLoran navigation systems

UNIT 7 GEODESY AND SATELLITE NAVIGATION

7.1 Practise reading the following words.

a) **[eə] –** th**ere**, wh**ere**, c**are**ful, th**eir**, p**air**, b**are**

[ɒ] **-** electr**o**nic, c**o**ncept, l**o**ng, horiz**o**ntal, ad**o**ption

[i] – l**i**m**i**t, **i**n**i**tial, s**i**gnal, pos**i**tion, cr**i**t**i**cal, cont**i**nuous

[f] – enou**gh**, **ph**ase, octanogra**ph**er, o**ff**, **f**ield, lau**gh**

b) astronomer [ə'strɔnəmə], dynamics [daɪ'næmɪks], interferometry [ˌɪntəfəˈrɒmɪtri] methodology [ˌmeθə'dɔləʤɪ], reservoir ['rezəvwɑː], technical ['teknɪk(ə)l], technology [tek'nɔləʤɪ], tectonics [tek'tɔnɪks]

7.2 Put the words in the correct column.

<table>
<tr><td colspan="4">Thought heavy ask set couple awful theft half law blood
horse some arm son head heart</td></tr>
<tr><th>ɑ:</th><th>ʌ</th><th>e</th><th>ɔ:</th></tr>
</table>

Active vocabulary

Word	Pronunciation	Translation
advance, *n.*	[əd'vɑːns]	успех, прогресс, достижение; ***syn.*** improvement, progress
baseline, *n.*	['beɪslaɪn]	стандарт, критерий, база
carrier, n.	['kærɪə]	носитель, держатель, кронштейн
cumbersome, *adj.*	['kʌmbəsəm]	громоздкий, объёмный; ***syn.*** bulky
curvature, *n.*	['kɜːvəʧə]	искривление, кривизна
drawback, *n.*	['drɔːbæk]	препятствие, недостаток; ***syn.*** obstacle, disadvantage
frequency, *n.*	['friːkwənsɪ]	частота
ingenuity, *n.*	[ˌɪnʤɪ'njuːətɪ]	изобретательность, находчивость
instantaneous, *adj.*	[ˌɪn(t)stən'teɪnɪəs]	мгновенный; немедленный; ***syn.***

		momentary, immediate
obscure, *v.*	[əb'skjuə]	загораживать, мешать, затмевать
offshore, *adj.*	[ˌɔf'ʃɔː]	находящийся на некотором расстоянии от берега, в открытом море
pipeline, *n.*	['paɪplaɪn]	трубопровод, нефтепровод, канал
plate, *n.*	[pleɪt]	плита, лист, полоса
receiver, *n.*	[rɪ'siːvə]	радиоприёмник
scaling, *n.*	[skeɪlɪŋ]	масштабирование, шкалирование
strengthen, *v.*	['streŋθ(ə)n]	усиливать, укреплять
substantial, *adj.*	[səb'stænʃ(ə)l]	значительный, существенный, важный; ***syn***. essential, important
supplement, *v.*	['sʌplɪment]	добавлять, дополнять, пополнять, ***syn.*** add
suspension	[sə'spenʃ(ə)n]	подвешивание, зависание
terrestrial, *adj.*	[tə'restrɪəl]	земной
tool, *n.*	[tuːl]	инструмент, оборудование

7.3 Read the text and fill it with sentences A-F.

GEODESY AND SATELLITE NAVIGATION

There has always been a love-hate relationship between geodesy and satellite navigation. **1** …….. . When the first satellite, Sputnik 1, started orbiting the Earth in 1957, geodesists in several countries realised that satellites offered substantial potential as a geodetic positioning and navigation tool.

The basic technologies of terrestrial geodesy of the day, notably triangulation, traversing, and precise leveling, were slow and cumbersome, mainly because of the effect of the curvature of the surface of the Earth, which limited the range of measurements to theodolite observations between points situated on hilltops, observation towers, and triangulation masts. The advent of EDM (electronic distance measurement) in the 1960s helped terrestrial geodesy, but it, too, was affected by the same limitation, namely the shortness of observable EDM ranges due to the Earth's curvature.

Earth orbiting satellites did not suffer from this drawback. They could be viewed simultaneously from several points on Earth, and therefore direction and range measurements made, provided that the space vehicles were not obscured by high natural features or tall man-made structures. **2** …….. .

The first of these was satellite triangulation, which was used initially to supplement and strengthen terrestrial triangulation networks. This situation changed significantly when geodesists realized that they could use the Doppler shift on the signal broadcast from a satellite to obtain differential range measurements that, together with the known Keplerian orbit of the satellite, could lead to a relatively fast positioning, or navigation, method. **3**…….. . Transit-Doppler was used in the late 1970s and early 1980s not only for the positioning of naval ships and of submarines surfacing in the polar regions, but also for the strengthening and scaling of national and continental terrestrial triangulation networks.

Enter GPS

These were the early days of a new global satellite positioning, navigation, and timing system, first called the NAVSTAR Global Positioning System, a name later shortened to just GPS. The close relationship between the early GPS and geodesy was further demonstrated by the adoption of WGS84, the World Geodetic System 1984, as the basis of the 3-D coordinate system of GPS.

As always, human ingenuity did not disappoint, and two new differential techniques were developed. The first was the differential GPS (DGPS) technique, which improved relative positioning accuracies of GPS by at one order of magnitude, down to a few meters. **4** …….. . The next advance in improving the accuracy of satellite positioning was made on the advice of radio-astronomers, who proposed replacing the standard GPS pseudo-range measurements, which are based on timing the modulated signal from satellite to receiver.

Instead, they suggested making measurements on the basic carrier frequencies of these signals, just as they did with extra-galactic signals arriving at, say, two widely spaced radio telescopes in so-called very long baseline interferometry (VLBI), leading as a by-product to the Cartesian coordinate differences between the two telescopes. **5** …….. .

GPS had now become the universal high precision quasi-instantaneous positioning and navigation tool, creating the basis for hundreds of new applications. **6** …….. . These included surveying and mapping, positioning in offshore engineering, the monitoring of local crustal dynamics and plate tectonics, the relative vertical movements of tide gauges, and the continuous 3-D movements of critical engineering structures, such as tall buildings, dams, reservoirs, and long suspension bridges.

A. As a result, DGPS soon became the standard methodology for the offshore positioning of oil platforms, pipelines, etc.

B. Indeed, satellite positioning started life as an extension of terrestrial geodesy.

C. Again, geodesists led the way, concentrating on high precision scientific and engineering applications.

D. This technical advance gave birth to Transit-Doppler, the first satellite navigation technology.

E. This was the beginning of centimetric positioning by the carrier phase GPS method, which was later developed further by geodesists into kinematic GPS and centimetric navigation.

F. This led to several new satellite geodesy positioning methodologies.

(adopted from http://www.insidegnss.com/node/885)

7.4 Read the text again and answer the following questions.

1. What limited the range of measurements to theodolite observations?

2. What was the advantage of satellite observations?

3. What was satellite triangulation used for?

4. What technology was used for strengthening and scaling of national and continental terrestrial triangulation networks?

5. What was the basis of the 3D coordinate system of GPS?

6. What is the difference between DGPS and VLBI?

7. What applications did GPS serve for?

7.5 Mark the following sentences True or False.

1. Geodesy and satellite navigation has always got a good relationship.

2. The curvature of the surface of the Earth was the main obstacle to theodolite observations.

3. Transit-Doppler was the first satellite navigation technology.

4. Transit-Doppler technology was used to supplement and strengthen terrestrial triangulation networks.

5. The adoption of WGS84 was the result of the close relationship between GPS and geodesy.

6. VLBI technique is used for the offshore positioning of oil platform, pipelines, etc.

7. The monitoring of local crustal dynamics and plate tectonics was one of the applications based on GPS.

7.6 Match words with their definitions.

receiver	**navigation**	**network**	**vehicle**	**broadcast**	**tectonics**	**magnitude**

1 ………. - a thing used for transporting people or goods, especially on land, such as a car, lorry, or cart;

2………. - a group or system of interconnected people or things;

3………. - transmit (a programme or some information) by radio or television;

4 ………. - the process or activity of accurately ascertaining one's position and planning and following a route;

5. ………. - the degree of brightness of a star, as represented by a number on a logarithmic scale;

6. ………. - a piece of radio or television apparatus that detects broadcast signals and converts them into visible or audible;

7. ………. - large-scale processes affecting the structure of the earth's crust.

7.7 Match adjectives with suitable nouns.

1. substantial	a. leveling
2. precise	b. signal
3. terrestrial	c. engineering structures
4. global	d. potential
5. human	e. movement
6. modulated	f. geodesy
7. local	g. crustal dynamics
8. differential	h. satellite positioning
9. critical	i. range measurements
10. vertical	j. ingenuity

7.8 Complete the text with one word.

Initially, GPS was considered ….. a standard navigation tool for military vehicles on land, ….. and air, but not ….. safety-critical civilian transportation. This was because, ….. military positioning and navigation, safety-critical civilian ….. not only requires quasi-instantaneous and ….. positioning, but also so-called "high integrity….. good coverage." Geodesists will immediately realize that "integrity" stands ….. the geodetic concept of "reliability," whereas "coverage" refers ….. the availability of a sufficient ….. of satellites that can be sighted ….. a receiver continuously and are not obscured by ….. or man-made obstructions.

On ….. own, GPS cannot ….. these requirements to the level required in safety-critical civilian transportation. Military transportation, on the ….. hand, has relatively modest requirements, which can be met ….. GPS.

7.9 Reorder the words to make a sentence.

1. horizontal - The - on - coordinates - aviation - were - and - based – existing - latitudes - longitudes - civil.
2. and - Heights - still - barometric - aviation - were - are - civil - based - in - on - altimetry.
3. The - change - ground - of - barometric - natural - on - do - the - features - not - changing - heights - with - pressure.
4. The - coordinates - challenge - required - civil - was - first - to - the - community - their - aviation - that - horizontal - international - geodetic - a - proper - convince - datum.
5. led - adoption - the - WGS84 - to - aids - of - resurveying - runways, - of - most - airports, - and - en route - and - The - landing - navigation - various.
6. adoption - first - The - GPS - receivers - did - market - mass - not - lend - themselves - to.
7. receivers - four - satellites - Early - by - measuring - operated - pseudo-ranges - sequentially - to - four - different.
8. One - all - satellite - available - signals - these - track - and - could - measurements - process.

7.10 Make a brief report on one of the following satellite navigation systems:

a. GALILEO;

b. GLONASS;

c. BEIDOU.

UNIT8 CREATION OF GEODETIC SATELLITE NETWORK (part 1)

8.1Practise reading the following words.

a) **[aɪ] –** w**i**dely, satell**i**te, p**i**pel**i**ne, prov**i**de, h**i**gh

[u:] –pr**o**ve, sol**u**tion, incl**u**de, m**o**ve, tr**u**e

[ɑ:] – ap**a**rt, adv**a**ntage, tr**a**nsport, l**a**rge, rad**a**r

[dʒ] – ima**g**ery, **g**eodetic, ob**j**ect, ran**g**e, volta**g**e

b) agriculture ['ægrɪkʌlʧə], automobile ['ɔːtəmə(u)biːl], cadastre [kə'dæstə], exploitation [ˌeksplɔɪ'teɪʃ(ə)n], laser ['leɪzə], marine [mə'riːn], mechanical [mɪ'kænɪk(ə)l], reservoir ['rezəvwɑː].

8.2Translate words of the same root into Russian.

To manage – management – manager – managing – manageable.

To apply – application – applicable – applied – applicant – appliance.

To recognize – recognition – recognized – recognizable – recognizing – recognizer.

8.3Fill in the sentences with words from exercise 8.2.

1. The shareholders demanded a change in ….. .
2. There’s plenty of space for all the usual kitchen ….. .
3. He was ….. for having saved many lives.
4. How do you ….. to stay so slim?
5. He has achieved ….. and respect as a scientist.
6. He was one of 30 ….. for the manager’s job.

Active vocabulary

Word	**Pronunciation**	**Translation**
ability, *n.*	[ə'bɪlətɪ]	способность, возможность
acquire, *v.*	[ə'kwaɪə]	получать, приобретать, овладевать
aerial, *adj.*	['eərɪəl]	надземный, воздушный

asset, *n.*	['æset]	имущество
canopy, *n.*	['kænəpɪ]	укрытие, прикрытие, убежище, прибежище
comprise, *v.*	[kəm'praɪz]	включать,заключать в себе, содержать
emergency, *n.*	[ɪ'mɜːʤ(ə)nsɪ]	непредвиденный случай, крайняя необходимость, чрезвычайное положение
emission, *n.*	[ɪ'mɪʃ(ə)n]	выделение, распространение, излучение
exterior, *adj.*	[ɪk'stɪərɪə]	наружный, поверхностный, внешний
feature, *n.*	['fiːʧə]	особенность, характерная черта, деталь, признак, свойство; ***syn***. characteristic, quality, form, shape
image, *n.*	['ɪmɪʤ]	образ, изображение
imagery, *n.*	['ɪmɪʤ(ə)rɪ]	ряд, группа изображений, изображение, проекция
imply, *v.*	[ɪm'plaɪ]	предполагать, подразумевать, заключать в себе, значить; ***syn.*** suggest, involve
inventory, *n.*	['ɪnv(ə)nt(ə)rɪ]	опись, инвентаризация
mapping, *n.*	['mæpɪŋ]	картография, картирование
oblique, *adj.*	[ə'bliːk]	наклонный, покатый, скошенный; ***syn.*** inclined
resolution, *n.*	[ˌrez(ə)'luːʃ(ə)n]	разрешение
spatial, *adj.*	['speɪʃ(ə)l]	пространственный
spotting, *n.*	[spɒtɪŋ]	постановка
terrain, *n.*	[tə'reɪn]	местность, территория, район

8.4 Read the text and answer the following questions.

1. What are methods and technologies of geodetic satellite survey used for?
2. What is the most efficient method in the modern geodetic base network?
3. What tasks does satellite geodetic network solve?
4. What systems are used to perform digital aerial survey?
5. What can be used for creation of spectrozonal colour-infrared images?
6. What does oblique aerial survey allow to do?
7. What are the tasks of digital aerial survey?
8. What does aerial laser scanning imply?
9. What allows acquiring a high-density cloud of laser reflection points?
10. What is aerial laser scanning used for?

CREATION OF GEODETIC SATELLITE NETWORK (part 1)

Methods and technologies of geodetic satellite survey based on GNSS methods are widely used for creation of reference geodetic networks, field aerial survey control point referencing , on-board positioning of aerial imagery photos perspective centres, field topographic survey, land management and cadastre works, monitoring of critical objects.

In the modern world geodetic base network is usually created with the use of global navigation satellite systems (GNSS) GLONASS/GPS principally by application of a differential method. The differential method is the most efficient where there is a network of reference (base) stations with specified geodetic coordinates. Application of the differential method provides for spatial objects' coordinate setting of +/-2 cm accuracy in real time and +/-5 cm in post-processing.

Satellite geodetic network consisting of reference stations can be used for solution of the following tasks: geodesy, cartography, cadastre; planning, construction, exploitation of automobile and railroads; navigation and security control of automobile, railway, air, river and marine transport; planning, construction and exploitation of buildings and engineering constructions, complex engineering objects: bridges, tunnels, oil and gas pipelines, etc.; real-time monitoring of critical objects.

Digital aerial survey

Digital aerial survey is performed with the use of modern topographic mapping aerial survey systems of high productivity, geometric accuracy, spatial resolution and photometric radiometric image quality.

Aerial survey data obtained with the use of full large-format digital aerial cameras is presented in a set of colour and multispectral images in four spectral ranges (red, green, blue, near infrared). Imagery in spectral channels can be used for creation of spectrozonal color-infrared images which possess high decoding interpretation features ability.

Digital aerial survey is performed with the use of on-board positioning and orientation systems which allow direct in-flight determination of imagery horizontalization exterior orientation parameters and thus cutting of expenses on field aerial ground control points referencing survey and the timing of work performance.

Apart from field aerial survey performed at the vertical position of a visual optical axis, oblique aerial survey (tilted visual optical axis) can be performed as well, which allows more efficient spotting recognition of objects and analyzing of their relative spatial position.

Digital aerial survey is efficiently applied for solution of the following tasks: creation and updating of topographic and special plans maps; creation of the mapping base for real estate cadastre; ecology and nature management (agriculture and forestry); monitoring of various objects; creation of 3D models of objects and territories; reaction to emergencies; creation of visual information systems.

Aerial laser scanning

Aerial laser scanning (lidar aerial survey) implies optic-mechanical scanning of an area by high-frequency pulse laser emission (for instance, 150 kHz), receiving and registration of a signal (pulse) reflected from the object's surface, determination of the distance from the reflection point and coordinates setting computation of the reflection point laser scanning points.

In order to ensure compute coordinates of laser scanning points (LSP) the aerial laser scanning system (aerial survey lidar) comprises equipped with a positioning and orientation system providing on the base of GNSS and inertial measurements for location position and orientation of a laser scanning system at the moment of pulse emission. This allows acquiring a high-density cloud of laser reflection points with set spatial coordinates.

Aerial laser scanning data is used for: topographic terrain survey and creation of high-accuracy detailed 3D terrain models; lidar survey has unquestionable advantages in solution of this task as this technology provides for high-accuracy survey and point density and allows coordinate setting to get laser reflection scanning points even in forest areas under the canopy; creation of 3D network models of territories and objects (surface models); 3D modelling of buildings and constructions, built-up territories; inspection of electric-technical objects (high-voltage power transmission lines, electric substations, etc.); inspection of transport infrastructure objects; bathymetry of inland water-storage bodies reservoirs and the shelf (with use special kind of laser scanning system); inventory and monitoring of forests; inventory of the land and asset complex; monitoring of big engineering objects, for instance, open mines of natural resources.

Laser scanning data processing is performed by a software complex Terra Scan H and TerraModeler based on MicroStation.

(Adopted from: http://www.agpmeridian.com/technology/creating_a_network_geodzicheskoy/)

8.5 Mark the following sentences True or False.

1. Methods and technologies based on GNSS methods are used for many geodetic works.
2. GLONASS and GPS were used to create geodetic base network.
3. Planning, construction and exploitation of building and engineering constructions are the tasks that satellite geodetic network solve.
4. Aerial survey data is presented in a set of colour and multispectral images in six spectral ranges.

5. The use of on-board positioning and orientation systems rise the expenses on field aerial ground control points referencing survey.
6. Aerial laser scanning can be used for creation of 3D network models territories and objects.

8.6 According to the text find words opposite in meaning.

1. destroy
2. inaccuracy
3. out of date
4. give away
5. coding
6. interior
7. inefficient
8. absorption
9. questionable
10. forbid

8.7 Match adjectives with suitable nouns.

1. modern	a. applications
2. unencrypted civil	b. incentives
3. intentional	c. signals
4. essential	d. broadcast
5. spoofing	e. element
6. strong	f. businesses
7. myriad	g. advantage
8. illegitimate	h. attacks

8.8 Fill in the text with the statements from exercise 8.7.

During the past two decades, the Global Positioning System, together with other GNSSes, has become an **1** … of the global information infrastructure, with **2** … in almost every facets of **3** ... and lifestyles, including communication, energy distribution, finance and insurance, and transportation. Ever-growing dependence on GNSS creates **4** … to attack civil GNSS, for either an **5** … or a terrorism purpose. Unfortunately, security is not a built-in feature of GNSS open service. It has been known that low-received-power, **6** … are vulnerable to jamming and **7** … . Jamming is the **8** … of a high-power "blocking" signal at the GNSS frequency. Hence, jamming is disruptive but usually detected by the receiver whenever it stops tracking satellites.

8.9 Complete the text using the words in CAPITALS in the correct form.

So far, a variety of methods have been proposed to 1) HARD civil GNSS receivers against spoofing attacks. These defensive methods can be 2) GENERAL categorized into three groups: external 3) ASSIST, signal statistics, and cryptographic authentication. The first group performs consistency checks against metrics external to the GNSS 4) SYSTEM, such as the information from inertial sensors, odometers, cellular networks, and high-stability clocks. The second group performs statistical tests on features inherent in GNSS signals, 5) INCLUDE angle of arrival, signal quality, signal power, and multipath. The third group relies on cryptographic, 6) PREDICT information carried by GNSS signals. Unlike the first group of methods, cryptographic methods need no 7) ADDITION hardware. In comparison to the second group, cryptographic methods enable users to 8) DIFFERENT authentic signals from counterfeit signals with higher 9) CONFIDENT, especially in a complex environment where the statistics of authentic signals can be highly 10) STABLE.

8.10 Make a brief report on one of the following topics:

a. A Reference station;

b. On-board positioning and orientation systems;

c. Lidar survey.

UNIT 9 CREATION OF GEODETIC SATELLITE NETWORK (part 2)

9.1 Practise reading the following words.

a) **[i:] –** h**ea**t, **e**ven, f**ea**ture, fr**ee**ze, b**ea**m l**ea**d

[əʊ] – rem**o**te, l**o**cation, pr**o**cess, z**o**ne, l**o**cator, **o**ver

[aʊ] – all**ow**, with**ou**t, am**ou**nt, h**ow**ever, b**ou**ndary, d**ow**n

[ʌ] – res**u**lt, fl**u**ctuation, destr**u**ct, constr**u**ction, p**u**lse, **u**nderground

c) analysis [ə'næləsɪs], anthropogenic [ˌanθrəpəˈdʒɛnɪk], characteristic [ˌkærəktə'rɪstɪk], hydrology [haɪ'drɔləʤɪ], instrument ['ɪnstrəmənt], localization [ˌləuk(ə)laɪ'zeɪʃ(ə)n], micrometer [maɪ'krɔmɪtə], thermal ['θɜːm(ə)l], thermogram [ˈθəːməgram].

9.2 Cross out the word with a different sound.

i	v**i**s**i**ble for**e**st fr**ee**ze d**e**tect w**i**ndow
aɪ	t**y**pe dev**i**ce sl**i**de ver**y** appl**y**
ð	wi**th** **th**eir **th**ough wi**th**out **th**ermal
h	**h**eat **h**our **h**igh **h**umidity **h**ydrographic
ɪə	cr**ea**tion ar**ea** engin**ee**r aer**ial** th**eo**ry

Active vocabulary

Word	Pronunciation	Translation
acquisition, *n.*	[ˌækwɪ'zɪʃ(ə)n]	приобретение
anthropogenic, *adj.*	[ˌænθrə(u)pə(u)'ʤenɪk]	антропогенный, вызванный деятельностью человека
ballast, *n.*	['bæləst]	балласт
bed, *n.*	[bed]	пласт, слой
boundary, *n.*	['baund(ə)rɪ]	граница, межа; ***syn.*** border, frontier
cavity, *n.*	['kævətɪ]	полость, впадина
contour, *n.*	['kɔntuə]	очертание, контур, форма
detect, *v.*	[dɪ'tekt]	открывать, обнаруживать,

		раскрывать; ***syn.*** find
display, *n.*	[dɪs'pleɪ]	показ, демонстрация, дисплей, изображение
distinctive, *adj.*	[dɪ'stɪŋktɪv]	отличительный, характерный; ***syn.*** distinguishing
distortion, *n.*	[dɪ'stɔːʃ(ə)n]	искажение, искривление
flooring, *n.*	['flɔːrɪŋ]	настил, пол
infiltration, *n.*	[ˌɪnfɪl'treɪʃ(ə)n]	просачивание, проникновение
infringement, n.	[ɪn'frɪnʤmənt]	нарушение
layer, *n.*	['leɪə]	слой, пласт, уровень
moisturize, *v.*	['mɔɪsʧ(ə)raɪz]	мочить, смачивать, увлажнять
pillar, *n.*	['pɪlə]	столб, колонна, опора, стойка; ***syn.*** pole, column, post
reduction, *n.*	[rɪ'dʌkʃ(ə)n]	снижение, понижение, сокращение, уменьшение
reveal, *v.*	[rɪ'viːl]	открывать, обнаруживать, показывать
soil, *n.*	[sɔɪl]	грунт, земля, почва
volumetric, *adj.*	[ˌvɔlju'metrɪk]	объёмный

9.3 Read the text and answer the following questions.

1. What is thermal aerial survey?
2. What devices are used to detect thermal emission?
3. What is a peculiarity of the thermal observation device?
4. What areas is thermal aerial survey used?
5. What does georadiolocation imply?
6. What geophysical instruments are used to get large amounts of data during a short period of time?
7. Where is georadar survey used?

8. What does exploitation of a shelf zone require?
9. What method analyses pulses reflected from boundaries of spheres with different electrophysical characteristics?
10. How is georadiolocation survey performed?

CREATION OF GEODETIC SATELLITE NETWORK (part 2)

Thermal aerial survey

Thermal aerial survey is registration of electromagnetic objects' emission in thermal infrared spectrum range and its reflection in an image and representation of its result like an image.

Thermal emission, whose intensity depends on temperature, can be detected by thermal detectors and transformed into a visible image showing differences in objects' temperature. Thermal survey can be performed both in day and at night time. At thermal-range Earth remote sensing transmission windows are used with a 3-5, 8-14 micrometer wave length. This range shows own emission of earth surface objects.

Thermal vision observation is a type of thermal control for which a thermal observation device is used as measuring equipment. The thermal observation device allows "seeing the heat" and detecting a thermal image on the display. The main distinctive feature of this method is that the thermal observation device allows seeing what cannot be seen with an unaided eye. Man's eye cannot detect objects' temperature, but the thermal observation device is capable of showing its display a +/-1 °C accuracy thermogram of an object.

Thermal survey application areas are engineering applications, ecology, forest resources management, agriculture, engineering geology and hydrology.

Georadar sensing

Georadar sensing is performed with the use of georadars operating at depths up to 5 m and a 20 cm resolution and providing for detection of density fluctuations of the surveyed surface at creation of georadiolocation profile, thus enabling this method to reveal underground communications including those without a temperature contrast.

Georadiolocation or georadar survey is a modern non-destructing method of soil and construction base inspection which implies analysis of pulses reflected from boundaries of spheres with different electrophysical characteristics.

Modern georadars are a powerful geophysical instrument whose application provides for acquisition of large amounts of detailed data during a relatively short time period. Application of a georadar for survey allows creation of a high-reliability volumetric picture during analysis of different spheres at varied depths.

Georadar survey is used for inspection of: soil, which allows detecting the composition and width of layers, presence of frozen or over-moisturized areas, land slide processes and tectonic distortions, cavities, deconsolidation areas, underground communications, boundaries of soil and anthropogenic waters, etc.; automobile roads, which allows assessing the width of road surface construction layers, types, humidity and density of soil and under-surface base; location of soil water levels, location of a sliding curve at land slide areas, spatial contour of geologic horizon base under a back of ballast bed, locations of deconsolidated soil, cavities and infiltration of underground waters; bases and industrial floorings; constructions of buildings (beams, floors, pillars, etc.), which allows detection of inner cracks, uneven settlement, presence of iron reinforcement and its deformation, infringement of construction regulations and project requirements, assess the density and toughness of materials; ice situation, which allows performing control of the width and condition of ice both during freeze-up and flood water periods.

In automobile roads planning the economic effect of application of 3D models acquired with the use of georadars is reached due to reduction of drilling operations with a several-times' enhancement of reliability of the engineering-geologic data, choosing of efficient reconstruction and overhaul types differentiated by automobile road areas.

Exploitation of a shelf zone requires acquisition of data on sea bottom condition, underwater and on-surface constructions. A modern method of sea bottom, underwater and on-surface construction inspection implies analysis of pulses reflected from boundaries of spheres with different electrophysical characteristics.

The georadiolocation method allows observation of ice for assessment of its width, monitoring in the areas of automobile ice passages, winter trails, detection and localization of uneven areas inside ice massives.

Georadiolocation survey can be performed by contact - shifting a georadar antenna on the ice surface, and non-contact - placing a georadar on board an aerial survey aircraft with the use of a side-looking locator.

9.4 Mark the following sentences True or False.

1. Thermal survey can be performed only in day time.
2. Thermal observation device is used to detect a thermal image on the display.
3. Georadar sensing reveals underground communication including those with a temperature contrast.
4. It is possible to get a high-reliability volumetric picture with a help of georadars.
5. Using georadar survey one can detect the inner cracks of the building, composition and width of soil layers.
6. The economic effect of application of 3D models is reached due to increasing of drilling operations.
7. The georadiolocation method allows detection and localization of even areas inside ice massives.

9.5According to the text find words similar in meaning.

1. evident
2. to discover
3. to convert
4. a machine
5. to work
6. to supply
7. an instability
8. to contain
9. a border

10. a distortion

9.6 Match words with their definitions.

application data survey transmission radar equipment layer emission

1………. - examine and record the area and features of (an area of land) so as to construct a map, plan, or description;

2………. - a programme or signal that is broadcast or sent out;

3………. - the production and discharge of something, especially gas or radiation;

4………. - the necessary items for a particular purpose;

5………. - the action of putting something into operation;

6………. - a system for detecting the presence, direction, distance, and speed of aircraft, ships, and other objects, by sending out pulses of radio waves which are reflected off the object back to the source;

7………. - a sheet, quantity, or thickness of material, typically one of several, covering a surface or body;

8………. - facts and statistics collected together for reference or analysis.

9.7Match sentence halves.

1.GPR (ground penetrating radar) can search for objects	**a.** to locate buried objects.
2. GPR can be detected both metal and non-metallic objects,	**b.** GPR is used to define landfills, contaminant plumes.
3. GPR uses the principle of scattering of electromagnetic waves	**c.** through the thickness of the ice and water, sand, earth and stone**.**
4. The fundamental principle of operation is the same as that used to detect aircraft overhead,	**d.** and buried evidence.
5. The depth range of GPR is limited by	**e.** as well as empty under a layer of

the electrical conductivity of the ground,	Earth, masonry walls, and foundations.
6.Optimal depth penetration is achieved in ice where the depth of penetration	**f.** can achieve several hundred metres.
7.In environmental remediation,	**g.** but with GPR that antennas are moved over the surface rather than rotating about a fixed point.
8. GPR is used in law enforcement for locating clandestine graves	**h.** the transmitted center frequency and the radiated power.

9.8 Ask all possible questions to the sentences from exercise 9.7.

9.9 Reorder the words to make a sentence.

1. into GPR been the near developed a sophisticated detailed that can provide technique images of has surface.
2. the research on for has GPR been environmental conducted and of engineering Most applications.
3. depths GPR few provides a pseudo-image three that can that converted easily be to are to accurate down dimensional a centimeters.
4. GPR responds to both metallic and non-metallic objects.
5. is an tool in homogenity for mapping any in the that subsurface is excellent GPR characterized by a density nearly small porosity difference in or.
6. Thermal monochrome is data in to full retain resolution recorded.
7. Conversion purposes analysis to useful for presentation is colour specific and.

9.10 Make a brief report on the following topic:

a. Ground penetrating radar (GPR)

UNIT 10 CREATION OF GEODETIC SATELLITE NETWORK (part 3)

10.1 Practise reading the following words.

a) **[æ] –** an**a**lysis, pl**a**n, overl**a**p, c**a**vity, cr**a**ck, f**a**ct

[ɜ:] – res**ear**ch, s**ur**vey, p**ur**pose, determine, s**ur**face, w**or**k

[ʃ] – spe**c**ial, **sh**all, portion, i**ss**ue, emi**ss**ion, loca**t**ion

[θ] – bo**th**, me**th**od, dep**th**, wid**th**, ear**th,** leng**th**

b) characteristic [ˌkærəktə'rɪstɪk], consequently ['kɔnsɪkwəntlɪ], hydrography [haɪ'drɔgrəfɪ], hydrologic [hʌɪdrəˈlɒdʒɪk], hydrosphere ['haɪdrəusfɪə], percentage [pə'sentɪʤ], oceanographic [ˌəʊʃənəˈgrafɪk], visualize ['vɪʒuəlaɪz].

10.2 Translate words of the same root into Russian.

To change – changing – changed – changer – changeover

To create – creative – creation – creature – creativity – creator

To represent – representative – representation – represented – representing – representational – representable

10.3 Fill in the sentences with words from exercise 10.2

1. All organisations need to adapt to … circumstances.
2. Minority groups need more effective parliamentary … .
3. This job is so boring. I wish I could do something more … .
4. The pollsters asked a … sample of New York residents for their opinions.
5. The question is, will the president … his tune on taxes?
6. The software makes it easy to … colourful graphs.

Active vocabulary

Word	**Pronunciation**	**Translation**
anchor, *n.*	['æŋkə]	ставить на якорь
assessment, *n.*	[ə'sesmənt]	оценка, определение
attribution, *n.*	[ˌætrɪ'bjuːʃ(ə)n]	определение
bottom, *n.*	['bɔtəm]	дно

capture, *n.*	['kæpʧə]	сбор
carrier, *n.*	['kærɪə]	носитель, держатель, кронштейн, поддерживающее или несущее приспособление
duly, *adv.*	['djuːlɪ]	надлежащим образом, должным образом, правильно
entail, *v.*	[ɪn'teɪl]	влечь за собой, вызывать (что-л.)
implementation, *n.*	[ˌɪmplɪmen'teɪʃ(ə)n]	выполнение, исполнение, осуществление, реализация; ***syn.*** realization, accomplishment
monitor, *n.*	['mɔnɪtə]	наставлять, рекомендовать, советовать, отслеживать, контролировать; ***syn***. observe, supervise
mounted, *adj.*	['mauntɪd]	смонтированный, установленный; ***syn.*** established, fixed
overlap, *n.*	['əuvəlæp]	частичное наложение, перекрытие, совмещение
specify, *v.*	['spesɪfaɪ]	точно определять, устанавливать
submersible, *adj.*	[səb'mɜːsəbl]	способный погружаться в воду, способный работать под водой
substantiation, *n.*	[səbˌstænʃɪ'eɪʃ(ə)n]	доказательство; ***syn.*** proof, evidence
vessel, *n.*	['ves(ə)l]	корабль, судно
viable, *adj.*	['vaɪəbl]	жизнеспособный

10.4 Read the text and answer the following questions.

1. What is hydrographic research?
2. How is hydrographic work considered regarding topographic and geodetic works?
3. What devices are used for hydrographic operations?
4. How is the hydrographic survey performed?
5. What is the purpose of the hydrographic survey and how to achieve it?
6. What are the main elements of the modern hydrographic survey?
7. What is a digital orthophoto?
8. What files are necessary to create a digital orthophoto?
9. What are digital orthophotos used for?

CREATION OF GEODETIC SATELLITE NETWORK (part 3)

Hydrographic research

Hydrographic research is a survey process of separate hydrosphere areas which includes scientific design, performance of hydrographic works, processing and analysis of their results. The contents of a hydrographic survey are determined by the composition and amount of the data the Orderer Customer requires.

Similar to assessment of altitude determination of large numbers of points in an area during topographic earth terrain survey, in hydrography for survey of underwater terrain depths are measured in all surveyed area. In fact, hydrographic works are a continuation of topographic and geodetic works in the areas of the World Ocean and inland waters.

But qualities of every geographic sphere and specific purposes lead to important features both in operational methods and applied means. What are these features? First of all, the necessity of special carriers for measuring equipment. When in shore survey geodetic and topographic devices can be placed directly in any point of the surveyed area, for performance of underwater terrain survey as well as other types of hydrographic operations special platforms shall be used and duly equipped to be kept on water surface or under water. Surface vessels and deep-sea submersibles are used as such platforms. Only at complete freezing of a water zone survey can be performed directly from the ice surface.

Further, the platform with the mounted equipment will move in order to perform survey of all water zone of the surveyed area. Consequently, its position is changing non-stop. Even if the vessel is anchored, its shift must be taken into consideration. It is evident that for attribution of measurement results to any fixed point the measurements will be performed very fast. The said circumstance entails the following important feature of hydrographic works: they will be accompanied with frequent and precise coordinate setting of a point in which the measurements were carried out. Ideally, it should be determined non-stop so that measurements at any moment would be linked with the real place.

The purpose of the survey is not only to reliably determine mutual location of different objects at sea, but also to specify the precise location of surveyed objects on the Earth surface. To achieve this, their planned fixing shall be made to a uniform coordinate system of the earth ellipsoid. In on-surface survey planned fixing is made with the use of geodetic networks. At sea there are no such networks, which lead to significant features of plan substantiation of hydrographic works.

The modern hydrographic survey complex includes survey of the following main elements: underwater terrain; sea shores; sea bottom soil; geophysical fields; oceanographic and hydrologic characteristics.

Measurements and observations carried out in water zones and in the process of hydrographic survey are called hydrographic works.

TrueOrtho

A digital orthophoto is simply a photographic map that can be used to measure true distances. It is an accurate representation of the earth's surface. To create a digital orthophoto, several key input files are necessary: aerial photos with a high-percentage overlap, scanned imagery, aerotriangulation (A.T.) results, and a digital elevation model (DEM). Scanned imagery can be obtained from scanning aerial photo diapositives or negatives on an image-quality scanner. The A.T. results include a camera calibration report and the ground control. At a minimum, the DEM can be a regularly spaced grid of masspoints, each containing an x, y, and z value. A more robust digital terrain model (DTM) can also be used because it includes strategically placed masspoints, dense breaklines, and ridgelines.

Digital orthophotography is a resource being utilized by a significant portion of GIS users. It has become a popular base layer in modern GIS. With the price of disk space dropping and the speed of computers increasing, digital orthophotos are a viable option for building a fully developed GIS. Digital orthophotos can be used for technically specific needs such as planimetric or cadastral mapping; utility data capture and quality control; and accurate project analysis and design implementations.

Digital orthophotos can also be used to explain projects and issues to the general public because real-world pictures are easier for the untrained eye to understand. They contain landmarks and recognizable places. For example, digital imagery can help an audience visualize the new light rail corridor by showing existing conditions. Proposed changes can be overlaid as vector information. The world is constantly changing, and digital orthophotography can help monitor change.

(http://www.esri.com/news/arcuser/1001/standup.html)

10.5 Mark the following sentences True or False.

1. Composition and amount of the data is the basis of hydrographic survey.
2. Geodetic and topographic devices should be placed in special point of the surveyed area.
3. Geodetic networks are used for underwater survey.
4. Hydrographic works are measurements and observations carried out in water zones.
5. Aerial photo diapositives or negatives are necessary to obtain a scanned imagery.
6. The DEM includes a camera calibration report and the ground control.
7. Digital orthophotography is an option for building a fully developed GIS.

10.6 According to the text find words similar in meaning.

1. gist
2. region
3. particular
4. coast
5. ship
6. connect
7. site
8. constant

10.7 According to the text find words opposite in meaning.

1. exclude
2. foreign
3. strip
4. shallow
5. individual
6. trivial
7. false
8. die

10.8 Match two halves of the statements and translate them into Russian.

1. the assignment of	a. methods
2. standardization of	b. photograph
3. ground	c. X & Y coordinate values
4. optical	d. improvements
5. came into	e. features
6. the radiometric or	f. displacement
7. removing the relief	g. use
8. vertical aerial	h. software algorithms
9. sophisticated computer	i. tonal adjustments
10. technological	j. scale

10.9 Fill in the sentences with the statements from exercise 10.8.

1. Orthophotography first … in the 1960's.
2. By the early 1970's, … brought this data source into affordable commercial applications and its use has continued to expand.
3. The first orthophotography was produced by computer driven … and equipment.
4. Today, these pieces of equipment have been replaced by the computer workstation and … .

5. The orthophoto is able to display actual … , not cartographic representations of those features.

6. Regardless of the method of construction, four basic operations or corrections must be applied to the standard … to produce the orthophoto.

7. The first correction is the … across the image.

8. The second correction involves … to position the terrain in its true location.

9. The third operation entails … to the image.

10. The final task involves … to allow the image to blend with neighboring images.

10.10 Make a brief report on the following topic:

a. Geodetic satellite network

SUPPLEMENTARY READING

Particle Swarm Optimization in Comparison with Classical Optimization for GPS Network Design

In recent years, satellite methods such as the Global Positioning System (GPS) have gradually been replacing traditional procedures for conducting precise horizontal control surveys. In fact, GPS not only yields horizontal positions, but it gives ellipsoidal heights as well. Thus, GPS provides three-dimensional surveys.

Upon development of the Global Positioning System (GPS), it became very attractive for surveyors due to its fast, accurate and economical results. GPS also can be operated in all weather and 24 hours a day, while still giving precise surveying measurements.

Nowadays, with increasing technological developments, GPS networks have taken place of terrestrial networks.

Optimal design of geodetic GPS networks is an essential part of most geodesy related projects. Whether or not the datum and point locations of a network are known, the process of determining the optimal baseline configuration and their optimal weights—the "second order design problem" (SOD)—with respect to the selected design criteria can be achieved by optimizing the observational plan. The scalar design criteria can only satisfy limited demands for a network, however. Thus, criterion matrices are mostly used; these can be defined as the computed variance-covariance matrix in the design stage that meets many of the accuracy demands. Analytical approximations of the criterion matrices are an effective method of reaching objective functions formulated with criterion matrices.

Theoretically, the best precision and reliability of the relative positions of a GPS network can be obtained if all visible satellites are tracked as long as possible and all possible baselines in the network are measured. Due to the limitations of time and expense, however, that will rarely happen in practice, and therefore an optimum survey design has to be made in order to achieve some prescribed design criteria while minimizing effort.

In the present study, the optimization procedure gives the optimal observational weights, which can be grouped into significant and zero or insignificant weights. The significant weights, some of which may be smaller than the initial weights, are then replaced by their corresponding initial weights. Baselines that obtain a zero or insignificant weight represent those that should be deleted from the final observing plan.

There are two methods for design of a GPS network, classical methods and intelligent optimization techniques. Classical methods include the trial and error method and the analytical method, while intelligent optimization techniques include global optimization techniques and local optimization techniques. Recently, some global optimization methods such as the Particle Swarm Optimization (PSO) algorithm or genetic algorithms have begun to be used in geodetic science.

The PSO method was originally intended for simulating the social behavior of flocks of birds, but the algorithm was simplified and the realization was made that the agents, here typically called particles, were actually performing black-box optimization. In PSO the population of particles is typically called a swarm. In the PSO method, particles are initially placed at random positions in the search-space, moving in randomly defined directions. The direction of a particle is then gradually changed so it will start to move in the direction of the best previous positions of itself and its peers, searching in their vicinity and potentially discovering even better positions.

In the present study, our aim was to carry out observational plan optimization of GPS networks with respect to the accuracy criteria, based on the PSO technique.

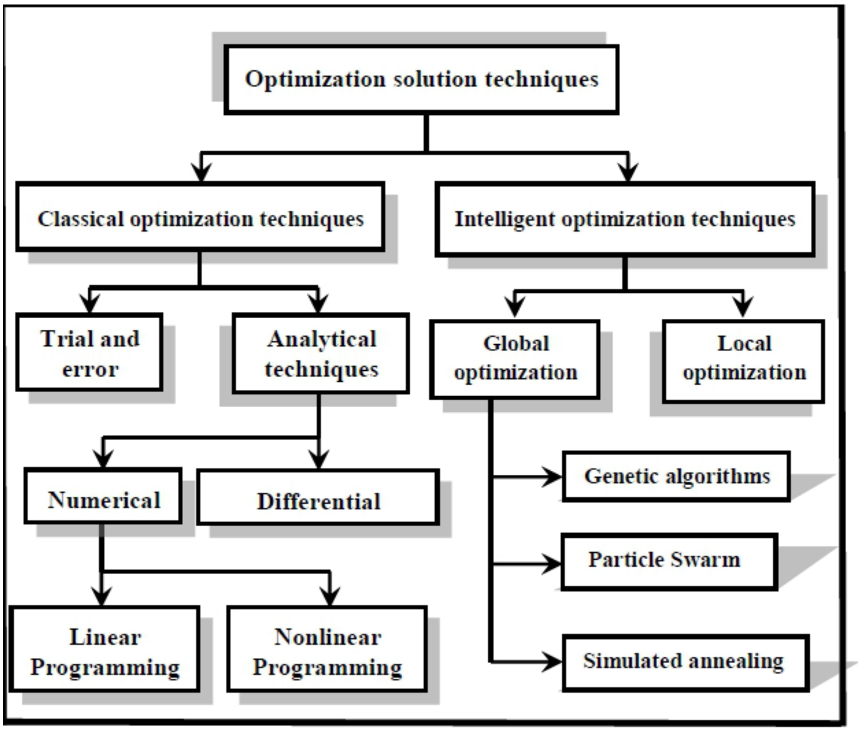

Figure 1. Optimization solution techniques

In general, there are several techniques that can be applied for solving the problem of determining the maximum or minimum value of a function. The main kinds of these techniques are (see Fig. 1) classical optimization techniques and intelligent optimization techniques.

The classical optimization techniques are useful for finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions.

Classical techniques are not exempt from problems. For instance, there may be either no consistent solution, or a solution wherein the proposed network contains many observations which are assigned a weight of zero, which makes these sites disappear from the observation plan and drastically diminishes network redundancy. Many new attempts and applications have been derived for network design problems such as intelligent optimization techniques. The successful performance of these intelligent optimization techniques has also led to their application in many other problems in geodesy and geodynamics. Intelligent optimization techniques represent a new approach to addressing complex problems with uncertainties. Intelligent systems are defined by such attributes as having a high degree of autonomy, being capable of reasoning under uncertainty, having higher performance in a goal seeking manner, working at a high level of abstraction, being able to fuse data from a multitude of sensors, learning and adapting to a heterogeneous environment, and so on. Intelligent optimization techniques can be divided into two categories: local and global optimization.

A local maximum is a candidate solution that has a higher value from the objective function than any candidate solution in a particular region of the search space. Many optimization algorithms are only designed to find the local maximum, ignoring both other local maxima and the global maximum.

Recently, new solutions for optimization problems for geodetic networks have emerged which are intelligent (global) optimization techniques. These include Genetic Algorithms (GAs), Particle Swarm Optimization (PSO) and Simulated Annealing (SA).

Medium to high-frequency static DGPS error reduction using multi-resolution de-noising vs.de-trending procedures

Multipath mitigation in the final measurements domain (carrier/ code observables) is a result of the large amount of residuals from mitigation in the antenna/receiver domain. (Raquet and Lachapelle 1996) used a multi-antenna array to mitigate the multipat error at the GPS reference station. (Han and Rizos 1997) were the first to propose the use of finite impulse response (FIR) filters to extract or eliminate multipath. However, this technique has certain limitations because signals (i.e.: crustal deformation) that fall into the same frequency band will be removed. A more effective technique, based on the use of an adaptive filter to extract and eliminate multipath, was suggested by (Linlin et al. 2000, Lee 2008). Since GPS observation noise tends to change with time, it was determined to be more appropriate to use an adaptive filter rather than a fixed filter for the purpose of multipath mitigation. The implementation of such a technique is dependent on the selection of an appropriate value for the step-size parameter and the filter length. (Zhang and Bartone, 2004) developed a multipath mitigation technique based on the multipath frequency spectrum analysis. They used code minus carrier to model multipath errors and identify window size before the error was transformed into the frequency domain using the Fast Fourier Transform (FFT). In the Fourier coefficients domain, the authors mitigated the multipath error based on the estimated multipath frequency. The reconstruction stage uses the Inverse Fast Fourier Transform (IFFT) to compute the multipath error-reduced code-phase measurements. This technique effectively reduces code multipath error, particularly in the static mode, where the multipath fading frequency is well predicted and the fading frequency ranges from zero to 1 Hz.

However, more investigation is required to apply this correction in kinematic mode given the rapid change in multipath frequency. Wavelets are used extensively as an alternative to FFT analysis because their elements are essentially waveforms indexed by three parameters: position, scale and frequency. This is what produces such strong localized time–frequency properties, which gives the wavelets the ability to provide an accurate location of the transient component in the signal while retaining information about the fundamental frequency. Therefore, wavelet transforms offer advantages over the frequency domain analysis (Fourier analysis) and the time domain analysis (Kalman filter). Most of the research conducted on wavelet multipath mitigation uses wavelet transform on its own or combined with other techniques to mitigate high-frequency multipath error. (Dammalage et al. 2010) used biorthogonal wavelets to de-noise code measurements for DGPS applications and reached a 60% error reduction. (Ogaja and Satirapod 2007) applied the Symlet base function at the fourth scale decomposition level to detect and separate high-frequency multipath errors from receiver noise when using high-rate (1-Hz) GPS data. (Souza and Monico, 2004) investigated the use of both Symlet and Daubechies base functions to reduce the high-frequency multipath in GPS relative positioning. They tested both the hard and soft threshold along with the median threshold estimator and concluded that Symlet12 along with the hard threshold performed the best and achieved a 30% error reduction. (Satirapod and Rizos 2005) used wavelets to mitigate multipath at permanent stations.

The use of wavelets as a de-noising tool for processing and mitigating multipath error proved to be an effective tool for high-frequency multipath mitigation. In contrast, de-noising techniques cannot remove this type of error in medium to low-frequency multipath components. As a result, wavelets should be used differently according the type of errors being mitigated, for high frequency errors wavelet de-noising should be used to mitigate that error while in low frequency error wavelet de-trending should be the method of mitigation. Many of the techniques discussed above already used wavelets as a de-noising tool but it is still not clear which wavelet parameters should be used with GPS double difference data to mitigate the medium to high-frequency errors (mainly multipath and uncorrelated ionospheric error). Moreover, there is no comparative analysis made using different wavelet thresholding estimators or techniques to mitigate the medium to high-frequency errors or the best wavelets de-noising technique for GPS error mitigation.

This research paper will introduce two different multi-resolution techniques that can be used separately or combined to remove the low to high-frequency GPS errors. The first technique is applied using the wavelets as a de-noising tool to tackle the high-frequency errors in the double difference domain and to obtain a de-noised double difference signal that can be used in a positioning calculation. The second technique discussed in this paper uses the wavelets technique as a de-trending tool to tackle the low-frequency portion of the double differenced measurements. The de-trended and the de-noised double differenced measurements will be used to compute accurate positions for the baselines length from a few hundred meters to 50 km.

Wavelets De-Noising

Double difference errors may have low (coarse-gain) and/or high frequency (fine-gain) fluctuations. Fortunately, the high-frequency aspect is relatively easy to remove if the proper de-noising threshold is applied. Multi-resolution analysis has been proven to be an important tool for eliminating noise in signals. The strong localization properties of the wavelets in the time and frequency domain allow the wavelets to detect fine and coarse variations in the signal. A basic wavelet de-noising algorithm consists of three steps:

1. Decompose the noisy signal (double difference GPS signal) using a wavelets multi-resolution analysis of its details and approximations.
2. De-noise the details' wavelets coefficients, which contain the high-frequency portion of the signal.
3. Reconstruct the de-noised signal by applying the inverse wavelet transform to de-noised coefficients.

One of the main advantages of wavelets is the presence of various parameters that can be controlled to help in the classification and separation of different types of signals with different frequencies. The concept of wavelet analysis is based on finding the similarities between the candidate base function and the signal, therefore the wavelet parameters must be selected to match the properties of the GPS double difference error. Four different parameters are used in this research to create several combinations to detect the optimum combination in reducing the high-frequency GPS errors. These parameters are:

1. Wavelet base function and vanishing moment

2. Level of decomposition
3. Threshold type
4. Threshold estimator

All the possible combinations among the parameters are investigated to ensure that the use of the wavelet transform technique is efficient for GPS error mitigation.

Wavelet De-Trending

The low-frequency portion of multipath is what creates the largest error, which in carrier phase measurements can reach up to 5 cm. Wavelets are used to remove the high-frequency oscillation from the investigated signal by changing the detail coefficient values of the wavelet decomposition to zero and reconstructing the signal using the modified wavelet coefficients. If the details associated with noise cannot be determined properly, either useful signals will be missed or a reconstructed signal may contain severe noise. In the case of a double difference signal, multipath is distributed at varying levels of decomposition. In order to reach the low-frequency multipath error, a higher level of decomposition is required. Thresholding the details at a level where the largest low-frequency multipath error is suspected will reduce the overall error. But to reach that error, other unwanted frequencies are induced in the reconstructed signal at the lower levels of decomposition.

Anew approach based on a wavelet de-trending technique is introduced to remove the long wavelength carrier phase multipath error in the measurements domain. In order to mitigate multipath, GPS double difference observables are introduced to an adaptive wavelets analysis procedure based on high and low pass filter decomposition with varying levels of resolution. The procedure is applied after cycle slips detection and repair. Based on the previous knowledge and facts that the largest errors are caused by the low-frequency multipath, the wavelet transform approach is used to separate the multipath error at high levels of decomposition. The separated wavelet coefficients (approximation or high-level decomposition coefficients) are truncated using wavelets thresholding techniques before the reconstruction of the signal to acquire the true double difference carrier phase residuals out of the low-frequency multipath.

The experiment showed that the de-noising technique gives consistent results for both short and long baselines. The average bias reduction that can be achieved from the de-noising technique is around 20-30% and the average RMS reduction is around 30-40%. Moreover, the de-trending technique outperforms the de-noising technique for RMS improvement in short and long baselines. The performance in the de-trending technique is almost three times better than the traditional de-noising technique for bias and RMS reduction. Although the de-trending technique out-performs the de-noising technique in the RMS reduction, it does produce inconsistent result for the bias reduction. The de-trending methodology performed impressively for short baselines in RMS and bias reduction as the average RMS and bias reduction were around 80%. However, for longer baselines the bias reduction is minimal although the RMS reduction is still in the range of 70 – 80%. It can be concluded that the de-trending technique can reduce the double difference errors dramatically for short baselines. Conversely, the de-trending technique can cause a biased solution for long baselines depending on the low frequency part of the error (ionosphere, low multipath), as it will enhance the RMS value and indicate good statistics for the solution but not enhance the bias to the same level. Therefore, it is important to isolate ionospheric error by modeling (and not spectrum filtering) before dealing with multipath, as it is hard to separate between both errors in the spectral domain.

Geodetic use of global digital terrain and crustal databases in gravity field modeling and interpretation

Current terrestrial and satellite observation methods and the corresponding data analysis procedures lead to the construction of global digital databases for the description of the earth's crust and topography with an increasing resolution and accuracy. Today global digital terrain models are available, which can reach a spatial resolution of up to 30×30 meters. However, such a resolution is neither global nor homogeneous and can only be achieved over continents. The question of mapping the ocean topography still remains mainly a methodological task with the major contribution being the inversion of altimetric data and altimetry-derived surface gravity data to produce the corresponding interface, i.e. the relief of the oceanic bottom separating water from oceanic crust. The production of global crustal models on the other hand is based on the exploitation of active seismic data, the compilation of available geological information and the generalization that physical properties of certain tectonic types have global character and can be assigned to similar tectonic settings. Using this methodological approach the model CRUST 5.1 and its follow-up CRUST 2.0 provide a global representation of the geometry and consistency of six (seven, if one includes ice thickness) distinct crustal layers starting from the visible topographic relief and expanding down to the crust-mantle boundary with a unified resolution of 5×5 and 2×2 respectively. The geometry of the last layer of a global crustal model provides directly a global estimate of the Mohorovicic discontinuity, information that can be opposed either regionally or globally to other independent sources of Moho data. A further example of exploiting the global crustal data is for local or regional applications of gravity field modeling, where the shape and density data emerging from the database can be used in the frame of some forward or inverse modeling procedure. However, the main asset of global digital databases with direct relation to gravity field analysis is the spatial resolution of the respective datasets.

The exploitation of this information is linked to the spectral analysis of the global geographical grids and leads to the computation of a particular class of gravity field coefficients, the so-called topographic/isostatic (t/i) spherical harmonic coefficients. The highest degree and order up to which these coefficients can be evaluated depends in this case solely on the spatial analysis of the input information, i.e. the global terrain or crustal data. The denser these global grids are, the higher the maximum degree and order of the corresponding t/i spherical harmonic sets. Thus, the incorporation of dense global digital terrain and crustal data in the appropriate spherical harmonic analysis scheme enables the retrieval and therefore interpretation of the high and very high frequencies of the observed gravity field.

The analysis of global digital terrain and crustal databases leads to the recovery of the medium to high frequencies of the observed gravity field signal. The continuous release of databases with very high resolution enables furthermore the retrieval of the very high frequency part. The significance of the obtained topographic/isostatic models is twofold. On the one hand they provide a direct insight to the corresponding bandwidth of the observed gravity field in terms of their dimensionless potential harmonic coefficients. At the same time they act complementary to other gravity field information, especially when it does not contain information on the small wavelength features of the gravity field, e.g. the currently available satellite-only gravity field models. In this way the geometrical and physical data of the databases can assist the challenging task of gravity field analysis and interpretation. With the resolution of the available global databases steadily increasing the t/i approach presents an efficient tool for an advanced band-limited analysis for capturing, interrelating and interpreting the medium, high and very high frequency part of the observed gravity field of the available, and especially forthcoming satellite only and combined Earth gravity models at all computational scales (global, regional and local). Apart from the resolution of the input data the features of a t/i approach in terms of gravity field recovery are determined by the type of compensation that is applied to the crustal masses. The different compensation mechanisms affect the mathematical formulation of the t/i model and thus the actual computed t/i spectrum. The two standard approaches are the Airy/Heiskanen and the Pratt/Hayford isostatic hypotheses. These two models appear also in the related literature of t/i models, either for the computation of purely isostatic Earth gravity models, or in the frame of the development of synthetic Earth gravity model. The spectral representation of the t/i models that are produced from these two compensation mechanisms reveals a complementary aspect of the two isostatic hypotheses in the spectral domain. One of the main features of t/i models is their smoothing effect on the observed field, without any loss of physical information that any low-pass filtering would cause. This smoothing feature can be seen spectrally by the decrease in power of a t/i model when compared to an uncompensated topography spectrum or some observed reference gravity field. The displayed computations showed that the A/H based t/i model acts in a compensating manner for the long wavelength and most of the medium to short wavelength part of the gravity spectrum. Up to degree 400 it reduces significantly the power of the observed field, and starts to converge to the uncompensated topography spectrum for the high and very high frequencies, the part of the spectrum where the uncompensated topography coincides spectrally with the EGM2008 reference field. The P/H model on the other hand performs in a reversed manner, and thus complementary to A/H as far as its compensation effect is concerned. It shows no compensating effect for the long wavelengths, but starts to act as one would expect a t/i model to perform, only for the high and very high frequencies, where it reduces the power of the uncompensated topography and EGM2008 spectra in almost the same order of magnitude as the A/H model does in the lower degrees. This complementary feature is important and can be utilized in current gravity field analysis, as the incorporation of databases with increasing resolution permits the retrieval of even higher frequencies of the observed gravity field.

Examination of two major approximations used in the scalar airborne gravimetric system — a case study based on the LCR system

As a physical variable that is closely related to the mass distribution of the Earth, gravity is very helpful to geodesists and geophysicists in determining the figure of the Earth and understanding its subsurface structure. For instance, in geodesy, gravity is needed almost everywhere, because only this quantity offers the spatial orientation of the local horizon plane. Many methods such as SST (satellite-to-satellite tracking), SGG (satellite gravity gradiometry), INS/GPS vector gravimetry, and airborne scalar gravimetry have been developed for gravity field determination over the decades.

The satellite missions are mainly designed to obtain medium to long (∼>50 km) wavelength gravity field information, while the other moving base gravimetric systems are used for detecting the medium to short (∼<50 km) wavelength contribution. For instance, in the scalar system, Olesen (2003) reported a spatial resolution of 6km or even better with 1∼2 mGal accuracy. A relatively recent study in the vector system obtained about 2km spatial resolution with 1∼3 mGal precision and as good as sub-mGal (0.64 mGal) repeatability. SGL (Sander Geophysics Limited) showed even better resolution and accuracies (30 0m with RMS=0.4 mGal) in their unique AIRGrav (Airborne Inertially Referenced Gravimeter) system, which is based on a customized gyroscopically stabilized platform, when operating in a slow speed (∼16 m/s). Note: these sub-km spatial resolution and sub-mGal accuracy from

SGL were not along the survey lines as it is customary. They were the grid resolution and grid accuracy, which were based on 1.25 km frequency domain spatial low pass of the 20-second filtered line data that were 50 to 100 meters apart to each other. However, Studinger et al. (2008) indeed showed in a case study that the AIRGrav system is superior to the LCR system in terms of resolution and accuracy.

Beside the mechanical differences of these two systems, where geodesists have limited power to control, the equations in the scalar systems have several ambiguous issues that need to be cleared when compared with the equations used in the 3D cases. At present, the scalar airborne equations used in most of cases ignore the higher order terms in the Eötvös term and have a fuzzy positioning transformation from the phase center of the GPS antenna to the gravimeter's mass center. Several groups tried to analyze these problems in some case studies, and found that these approximations can be 'safely' neglected in their applications. By both rigorous yet succinct derivations and extensive numerical evaluations, this study confirms the magnitudes of these approximation effects are indeed small in the context of the current airborne survey accuracies, i.e., mGal level, especially after filtering, smoothing or de-noising processes. However, these approximations need to be removed for the theoretical completeness and for the future high accuracy systems, μGal level.

Unlike the equations of vector gravimetry that solves the full gravity vector, the scalar system only computes the vertical gravity component. Usually, they are solved in the local navigation frame, which requires the computation of the Eötvös correction that is the gravity changes due to the change in the centrifugal acceleration induced by the horizontal velocities of the reference frame. Even though the closed form equation for this computation had been published for many years, some researchers are still using the approximated version developed by Harlan (1968), where higher order ($O2$) terms of the Earth's flattening were omitted.

Due to the physical limitations in airborne surveying, the position of the GPS antenna cannot coincide exactly with the position of the gravimeter. As a result, the GPS positioning solution needs to be transformed into the gravimeter's position. Thus, the lever-arm correction has to be applied to account for the position difference between the GPS antenna and the gravimeter, $\vec{b} = [\Delta x, \Delta y, \Delta z]^T$. In the 3D cases, this can be done rigorously by using all the attitude angles provided by the IMU. However, for the scalar system based on the LCR system, the lever-arm correction is a gray area in some previous publications, where not too much information was given. Olesen (2003) found in a case study that the RMS value of the filtered lever-arm effect was 0.4 mGal when the "horizontal" component of the lever-arm is 7.2 m, and concluded that for "horizontal" offsets less than 1 meter, the effect can safely be neglected.

Based on a set of real pitch and roll angles that were provided by the on board IMU during a typical airborne flight, the lever-arm effects on the vertical accelerations at various scenarios are computed. By altering the appearance of the attitude angle and the components of the lever-arm, we can easily compute the lever-arm effects in other scenarios, which gives a thorough understanding of the effects resulted from various cases.

The approximations in the Eötvös computation and lever-arm correction in the LCR based scalar gravimetric system are rigorously evaluated based on both simulated and real flight data sets. Numerical analysis shows that the magnitude of the higher order terms (not only the second order effect, but also the combination effect of all high order terms) is indeed very small, at the μGal level. But it shows a systematic characteristic that is largely dependent on latitude and height. Thus, once the meter's observables are corrected into the local navigation frame, the exact formula such as given in Jekeli (2000) needs to be applied if one cannot tolerate these systematic effects or simply wants to avoid any arguments related to this issue. With the on-board IMU provided attitude information, the lever-arm effects are also thoroughly analyzed. Simulation tests clearly show that the "horizontal" components of the lever-arm need to be kept as small as possible to avoid large (hundreds of mGals) errors. For real flights with poor lever-arm setup, large smoothing windows have to be applied if no accurate attitude information is available. However, this will definitely reduce the spatial resolution of the gravity data. Even in the ideal lever-arm setup scenario, where no "horizontal offset" between the GPS antenna and the gravimeter is in presence, accurate (10 arc-minutes for mGal level and 5 arc-minutes for sub-mGal level) attitude information is required in order to totally remove the lever-arm induced noise that is in the accuracy range of most of the current airborne surveys. The benefit is that the wrong signal is directly removed from the raw gravity observables instead of by using various filters which are essentially stochastic tools whose result is always an estimate.

New Structure for GLONASS Nav Message

Russian scientists propose a new code-division multiple-access signal format to be broadcast on a new GLONASS L3 signal. Once implemented across the modernizing GLONASS constellation, this will facilitate interoperability with — and eventually interchangeability among — other GNSS signals. The flexible message format permits relatively easy upgrades in the navigation message, if required.

Navigation messages (NM) developed and broadcast so far, by both GPS and GLONASS, are fixed, regular structures including pages (frames), subframes (rows), and words. Despite their simplicity, such structures are very conservative. The only possibility to update such navigation messages is restricted to the use of previously allocated backup frames. Increasing numbers of such frames make for ineffective use of navigation message transmission capacity. Conversely, the relatively small number of backup frames restricts the potential for future navigation-message upgrades.

If we assume a data equivalence transmitted in the GLONASS and GPS navigation solutions, we can see that data transmission rate in GLONASS is five times as much as in GPS. This is explained by the higher redundancy of the GPS NM. Besides the roughly 11 percent of subframes kept in backup, the GPS superframe reserves field for transmission of 32 satellite almanacs, although the number of satellites in GPS constellation is always less than 32. As a result, the NM transmission channel in GPS used ineffeciently.

For GLONASS, the situation is different. The NM includes only about 3 percent of backup bits, and the superframe reserves field for transmission of only 24 satellite almanacs. This significantly increases the NM transmission channel efficiency relative to GPS, but causes big problems during any process of system update.

In these cases, upgrades or updates should only occur when they furnish backward compatibility, which means that previously manufactured user equipment can still maintain its compatibility with the updated system. When generating a NM in the form of fixed, strictly regular structures including pages (frames), subframes (rows), and words meeting the backward compatibility principle, this means that update sonly can be done using backup frames, because modification of basic, non-redundant frames will produce problems with earlier user equipment health. From this point of view, a large number of backup frames in very preferable.

Difficulties. As an example, let us consider the problems that arise in the process of a GLONASS upgrade, the purpose of which is to increase the number of GLONASS satellites in the constellation up to 30. Such an upgrade can be done in order to exclude areas of dilution of precision (DOP) degradation that arise due to GLONASS's symmetrical constellation geometry. To provide that the rule of backward compatibility is met, it is necessary that almanacs of six extra satellites be placed in backup bits of the superframe. But the number of such bits in the GLONASS superframe allows placement of only one satellite almanac. Thus in the case of such an upgrade, the almanac of the first basic 24 salellites will be transmitted within the time of 1 superframe, that is, 2.5 minutes, and the almanac of the xis extra satellites will be transmitted consequently in backup rows within the time of six superframes, that is, $2.5 \times 6 = 15$ minutes.

A New Way. Avoiding such difficulties associated with NMs with fixed, strictly regular structures including pages (frames), subframes (rows), and words is possible through the use of a NM with flexible row structure. Such a structure was formed for the first time for the GPS L5 signal. In this structure, the NM is formed as a variable-row flow of different types. Each row type has a unique structure and contains specified information type, for example: ephemeris, almanacs of specified satellites, parameters of Earth pole movement models, parameters of ionosphere delay models, and so on.

User equipment allots a successive row from the flow, defines its type, and in accordance with the type allots data contained in this row. When using such NM structure, strict regularity of different data types received by user equipment is disturbed, but GNSS control system guarantees that data transmission delays for each data type in NM will not exceed maximum values previously defined in the interface control document (ICD). For example, rows with ephemeris data in the GPS L5 signal are transmitted a minimum of once every 24 seconds, the so-called restricted almanac of the system is transmitted minimum once every 10 minutes, and so on.

Deploying a Growing GNSS. A flexible row structure of the NM provides more effective use of NM transmission channel capacity, especially during the stage of system deployment which, as experience has shown, may last several years. During this stage, the GNSS orbital constellation is not complete and thus the NM may be generated as a row flow containing almanacs of only those satellites that are actually included in the orbital constellation. Reducing the number of rows with satellite almanacs allows reducing the time interval per which ephemeris are transmitted. Obviously a NM with fixed regular structures does not permit this capability.

The main advantage of a NM with flexible row structure is the possibility of its evolutional upgrade meeting the rule of backward compatibility. For this purpose, the ICD of respective signals for developers of user equipment states that if the user equipment encounters unknown row types, it should ignore them. This allows adding new row types in the process off GNSS upgrade. Including rows of new types in the NM certainly lowers the transmission rate, relative to rows of old types.

Previously manufactured user equipment ignores rows with new types and therefore does not use innovations introduced in the process of GNSS upgrade, but at the same time its health is not affected. More recent user equipment gets the opportunity to use data both from old and new row types and therefore to use introduced innovations.

In this case, user equipment upgrade replaces old software versions with new ones. This replacement is not due to any invalidity of old software version, but the equipment owner’s desire to benefit from the innovations introduced by GNSS.

Very old row types may on the other hand be removed from NM. At that point, very old and not-upgraded user equipment would become non-operational. This situation is quite normal because it may be considered as excluding excessively obsolete user equipment from operation.

When using flexible row structure, a GLONASS NM upgrade as in the previous example on exceeding the number of satellites up to 30 would mean simply exceeding the number of rows with the type defining the structure of almanac data. In this case, transmission rate of ephemeris and almanac would certainly degrade a little, but it would require no conversion of user-equipment software.

Status. Currently GLONASS uses signals with frequency separation in L1 (1592.9 – 1610 MHz) and L2 (1237.8 – 1256.8 MHz). The system upgrade now underway will in the long-range outlook turn to signals with code-division multiple-access (CDMA) in L1, L2, and L3 (1190.35 – 1212.23 MHz). One satellite has been launched transmitting signals with code separation in L3.

The NM of all new GLONASS signals with code separation, or CDMA, will have flexible row structure. Documents are now being developed concerning NM row structure of this type.

Introduction to joint analysis of SLR and GNSS data

The Global Geodetic Observing System (GGOS) is currently one of the main concerns of the International Association of Geodesy (IAG). It plays a crucial role in the implementation of the Global Earth Observing System of Systems (GEOSS), which links different systems of observation. The main aim of GGOS is to deliver geodetic products for Earth monitoring (e.g. for climate changes investigation) and to create one coherent observation system divided into three main parts (called pillars) of modern geodesy: gravitational field, Earth rotation and geokinematics. Such a system would integrate various geodetic techniques, models and data processing strategies and would deliver solutions which would provide a stable and accurate reference frame determination. Reference frames have a crucial role here, because they link different techniques and measurement methods by combining all three GGOS pillars.

International Terrestrial Reference Frame (ITRF), as a practical realization of the International Terrestrial Reference System (ITRS) is determined on the basis of long-term observations by the following four techniques: Global Navigation Satellite System (GNSS), Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) and Very Long Baseline Interferometry (VLBI). Each technique has its own specific character, so each one delivers different products and brings a different contribution to ITRF (e.g. the origin of ITRF2008 was determined on the basis of SLR observations, the scale was obtained by using SLR and VLBI methods and the orientation was a result of all four techniques). Joint analysis of the data delivered by different techniques provides a stable reference frame determination, because the use of different methods of measurement increases the solutions reliability and, above all, permits additional control of the results. Improvement in further ITRS realizations requires an increase in the agreement between the local ties used in particular techniques (ground as well as space - between satellites) and improvement in the geometry of co-location network. Ground local ties are calculated from the data provided by the stations applying different observation techniques. Their mutual localization can be precisely determined using classic geodetic measurements or GNSS. Up-to-date investigation is mostly aimed at common processing of the data obtained by various techniques.

The authors' main goal is to process GPS and SLR (LAGEOS-1 and LAGEOS-2 satellites) data using the most coherent and compatible strategies as possible and to compare the results, i.e. the sites coordinates and velocities. The study is a continuation of the investigation performed in 2006-2009, based on a comparison of SLR solutions determined by the Astrogeodynamic Observatory of Space Research Centre in Borowiec with GPS solutions received from various sources (databases). The use of different GPS solutions caused incoherence of the results, which led to the idea of joint analysis which will include solutions obtained by the Centre of Applied Geomatics (Military University of Technology) using the well-known processing strategy with the same models and parameters as SLR data processing. CAG MUT is going to perform these calculations on the basis of the experience gained during processing the regional (EUREF Permanent Network) and national (Active Geodetic Network – European Position Determination System) GNSS networks. The strategy of SLR data processing requires also some changes following especially from the appearance of new models developed since the previous investigation.

The main problem concerning joint analysis of SLR and GNSS data is the inconsistency of some of the models used in previous studies. To unify the processing, the authors will implement suitable models in GEODYN-II and Bernese software (if possible). In further part of the project the authors plan to use the NAPEOS (NAvigation Package for Earth Observation Satellites, http://www.positim.com) software distributed by ESA (European Space Agency), which enables processing of both techniques data using the same models and parameters (it gives a possibility to combine the data on the observations normal equations level). The selection of stations depends mostly on the SLR sites localization (there are fewer SLR sites than GNSS ones). The data from all stations running the observations by both techniques (from the same period of time) will be taken into consideration. Additionally, the network of sites will be strengthened with several globally distributed IGS sites. In the GNSS data processing very long baselines will be analysed, so some difficulties concerning ambiguities determination can appear. It can force some changes in the strategy assumed. The main problem is to build a network of sites ensuring reliable solutions between 1996 and 2000, because of the lack of GNSS sites on some parts of the globe (especially in Africa) at this time. In the beginning it was planned to process also the GPS data gathered between 1993 and 1996, but the tests proved that the results would be unreliable as the dispersion of the solutions (coordinates) would be too high. Observations performed at one SLR site do not affect those made on other sites. GNSS processing concerns a network of sites (it is differential). In the first step baselines between sites are calculated, then in the adjustment process the coordinates of the sites (and other parameters) are determined. Such a procedure can lead to error mitigation in the network. In further part of the project the authors plan to use PPP approach to eliminate this problem.

Up to now, the authors have agreed on the processing strategies and collected all the data necessary for calculations (both GPS and SLR observations for the period 1996-2011). A test GPS processing has been made for the year 1996, as this year is supposed to be the most problematic, because of the small number of GPS stations. The next step is to process the data obtained by both techniques using the settled strategies and models. This part of the project is planned to be finished in the middle of 2012. As a result of the SLR and GNSS observations processing, geocentric and topocentric coordinates of all analysed sites will be determined. They will be expressed for the first day of every month separately for both techniques. Such time series will be analysed in order to verify the agreement between the data provided by both techniques. Besides, the coordinates of all sites in ITRF2008 for the epoch 2005.0 (with their standard deviation) will be calculated. Stability of sites positions and deviation of their coordinates from ITRF2008 values will be investigated. Velocities of all sites in ITRF2008 (for all components) and topocentric NEU frame (vertical and horizontal component) will be determined separately for SLR and GNSS to compare both solutions.

Appendices

Appendix 1

Phrases for summary and rendering

1. The text/ article tells of ...
2. The text/ article shows ...
3. At the beginning the author describes /depicts/ touches upon/ explains/ introduces/ mentions/ characterizes/ points out/ generalizes/ reveals/ exposes
4. The text/ article begins (opens) with a (the) description of introduction of/ the mention of/ the analysis of a summary of/ the characterization of/ (author's) opinion of
5. Then/ after that/ further/ further on/ next the author passes on to/ goes on from ... to/ goes on to say that/ gives a detailed analysis/ description, etc. of
6. In conclusion the author depicts, etc.
7. The author concludes with a/ the description of/ his recollections of/ the generalization of/ the characterization of/ (his) opinion of …
8. To finish with, the author …

Appendix 2

Linking words

Beginning

First(ly)
First of all
For a start
In the first place
Initially
To begin/start with
Let us begin/start by
First and foremost
First and most importantly

Going further

Second(ly)/third(ly)
In the second place
Subsequently
Simultaneously
And then
Next
Formerly/previously

Adding information

And
In addition
As well as
Also
Too
Furthermore
Moreover
Besides
Above all
Along with
Additionally
Besides
Further

Not only . . . but also . . .
Not to mention
One could also say
What is more

Sequencing ideas
The former, … the latter
Firstly, secondly, finally
The first point is
The following

Giving a reason
Due to / due to the fact that
Owing to / owing to the fact that
Because
Because of
Since
As
Well, you see
The (main/basic) reason is that
Let me explain. You see
But the point is
I think … is right for the following reasons …

Giving a result
Therefore
So
Consequently
This means that
As a result

Comparison/Contrast
Although / even though
Nevertheless
In theory…
in practice…
Both… and …
Analogously
Equally

Likewise
Just like
Similarly
Correspondingly
In the same way
In the same manner
By the same token
Alternatively
But/ However
Conversely/ On the contrary
Despite / despite the fact that
In spite of / in spite of the fact that
Differing from/ In contrast\Instead
In comparison
In reality
On the one hand/ On the other hand
Notwithstanding/ Nonetheless/ Nevertheless
Still/ Yet
Unlike
Whereas/ While

Emphasis
Indeed/truly
In fact/actually
Notably
Particularly/specifically Especially/mainly
Admittedly
Of course /certainly/surely
No doubt
Obviously
Needless to say
As a matter of fact
For this reason

Clarification
In other words
That is
Namely
That is to say

To put in another way,
One example of this is
For example/for instance
Such as
Frequently
As an illustration
To demonstrate
To illustrate

Transitions
Accordingly
As a consequence
For this/that reason
Hence
In that case
On account of this
Therefore
Thus

Summarising
In short
In brief
In summary
To summarise
To conclude
In conclusion
Eventually
In the end (I'd like to say that)
Weighing up all pros and cons
To crown it all

Concluding
Summing up/to sum up
To conclude/in summary
Finally
In short/in brief
On the whole
Ultimately
Last/lastly

Last of all
Last but not the least

Personal or other people's opinion
In my opinion/In my view/To my mind
To my way of thinking
Personally I believe that/ I think that…
It strikes me that
I feel very strongly that
I'm inclined to believe that
It seems to me that
As far as I am concerned
As far as I know
It's popularly believed that
People often claim that
It is often alleged that
Some people argue that
A lot of people think/believe that
As I see it
From my point of view
If I'm not mistaken
To my way of thinking
I'll say straightforwardly

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