



Variability in precipitation, temperature and river runoff in W Central Asia during the past ~2000 yrs

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ABSTRACT

The tributary rivers Amu Darya and Syr Darya contribute major amounts of water to the hydrological budget of the endorheic Aral Sea. Processes controlling the flow of water into rivers in the headwater systems in Tien Shan (Kyrgyzstan) and Pamir (Tajikistan) are therefore most relevant. Lake water mineralization is strongly dependent on river discharge and has been inferred from spectrometrically determined gypsum and other salt contents. Comparison of high-resolution mineralization data with tree ring data, other proxies for tracing temperature and snow cover in NW China, and accumulation rates in the Guliya Ice Core indicate that mineralization over the past ~2000 yrs in the Aral Sea reflects snow cover variability and glacier extent in Tien Shan and Pamir (at the NW and W edges of the Tibetan Plateau). Snow cover in W Central Asia is preferentially a winter expression controlled by temperature patterns that impact the moisture-loading capacity over N Europe and NW Asia (Clark et al., 1999). We observed that the runoff, resulting from warmer winter temperatures in W Central Asia and resulting in a reduction of snow cover, decreased between AD 100–300, AD 1150–1250, AD 1380–1450, AD 1580–1680 and during several low frequency events after AD 1800. Furthermore, we observed a negative relationship between the amount of mineralization in the Aral Sea and SW summer monsoon intensity starting with the Little Ice Age. Based on these observations, we conclude that the lake level changes during the past ~2000 yrs were mostly climatically controlled. Around AD 200, AD 1400 and during the late 20th century AD, human activities (namely irrigation) may also have synergistically influenced discharge dynamics in the lower river courses.

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1. Introduction

People living today in the Aral Sea Basin region suffer serious water stress (Micklin, 2007). This is the result of intensive irrigation along the two river tributaries, the Amu Darya and the Syr Darya. The technologically ambitious irrigation programme started some 60 yrs ago. However, it is not a recent phenomenon that populations living in regions with semi-arid to arid climates try to improve arable conditions to facilitate an easier life. In fact, for ancient cultures in the Aral Sea Basin, irrigation was a necessary survival strategy to overcome water deficiencies. Evidence for artificial watering has existed for at least two to three millennia, and relevant infrastructure older than Early Antiquity has been observed (Boroffka et al., 2006; Boroffka, 2010). Men have successively influenced the geometry of

braiding river courses along the course of the Amu Darya by building systems of channels and dams (Tolstov, 1962; Létolle et al., 2007). According to historical documents, the lower Amu Darya was at some point redirected into the Caspian Sea through the Sarykamysch depression and the Uzboj channel (Fig. 1) (Barthold, 1910; Boroffka et al., 2006; Létolle et al., 2007; Boroffka, 2010). However, the dates of the redirection and the extent of occasional destruction of the irrigation infrastructure during the past millennia are not well known.

Importantly, irrigation has not only affected the river water balance but has also had consequences for the Aral Sea, which until a few years ago, was nourished by the two tributaries. Past lake-level drops therefore, are often attributed to anthropogenic influences (e.g., Boomer et al., 2000). For the past few thousand years, several decadal to centennial transgressive/regressive phases have been reported (Tolstov, 1962; Rubanov et al., 1987; Létolle and Mainguet, 1996; Maev and Karpyshev, 1999; Boomer et al., 2000, 2009; Létolle et al., 2005; Boroffka et al., 2006; Sorrel et al., 2006, 2007a; Austin et al., 2007; Boroffka, 2010; Boomer et al., 2009). A major regression

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