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Ice regime of lakes and inland seas from multi-sensor data fusion - natural and anthropogenic factors

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Studies of ice regime of lakes and inland seas require continuous weather-independent observations, covering large and often remote areas. Satellite microwave observations very well suit these requirements. Additional improvement lies in the complementing passive microwave observations by active ones, thus enhancing the radiometric resolution of studies and providing new insights for cryospheric studies. We present results of studies of sea ice conditions in the Caspian and Aral seas and Baikal lake using multi-sensor satellite data fusion.

Our main source of information is data from the TOPEX/Poseidon satellite, operating since 1992 and followed by Jason-1 in 2002. These platforms have two nadir-looking instruments - a dual-frequency radar altimeter and a passive microwave radiometer. This information is further complemented by long series of passive microwave data from the SMMR (Scanning Multichannel Microwave Radiometer) instrument onboard the satellite NIMBUS-7 (since 1979) and the SSMI (Special Sensor Microwave Imager) instrument on board the DMSP (Defense Meteorological Satellite Program) series (since 1987).

We demonstrate benefits, drawbacks and potential for application of use of the TOPEX/Poseidon simultaneous active (backscatter coefficient at 13 GHz) and passive (brightness temperature at 18 and 37 GHz) microwave measurements together with SMMR and SSM/I data to estimate sea, lake and river ice extent and roughness. Var-

ious factors, such as differences in the footprint size for various sensors and changes in radiometric properties of sea ice and snow at different stages of their temporal evolution are considered. This approach for combination of active (radar altimeter) and passive (radiometers) microwave data may be successfully used for new satellite missions, such as Jason-1 and ENVISAT.

The Caspian and Aral seas, located on the far southern boundary of sea ice cover development in the Northern Hemisphere, are characterised by significant variability of ice extent and duration of ice season, with strong warming signal in recent time. We discuss the reasons for these changes and their impact on industrial activity, navigation and marine environment. Baikal lake, a UNESCO World Heritage site, also has significant variability of ice cover in relation with large-scale climate changes. We show the potential of satellite data for studies of ice cover extent and phenology, as well as snow extent and depth.

Of special concern is the assessment of influence of anthropogenic and natural factors on ice regime of enclosed seas. Aral sea has undergone dramatic changes in the last 40 years due to dramatic decrease of sea level under anthropogenic influence (uptake of water from Amu Darya and Syr Darya rivers for irrigation). The reduction of sea level was reflected in changes in the sea shape and depth and, as a result, in many oceanographical parameters, such as the heat storage capacity, water salinity (thus shift in the freezing temperature), water exchange and circulation etc. The decrease of heat storage capacity have resulted in an earlier start of ice formation in autumn and an earlier ice break-up and melting in the spring, while the increase of salinity would lead to general decrease of ice season duration and ice extent.

However, recent variability of the dates of beginning and end of ice season and the decrease of ice extent is also evident in the neighbouring Caspian sea, where no significant changes in heat storage capacity and water salinity were observed. This indicates that changes in thermal regime, resulting in abnormally mild winters, are taking place recently in both Caspian and Aral seas and the observed variability is related to both anthropogenic and natural factors.

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