

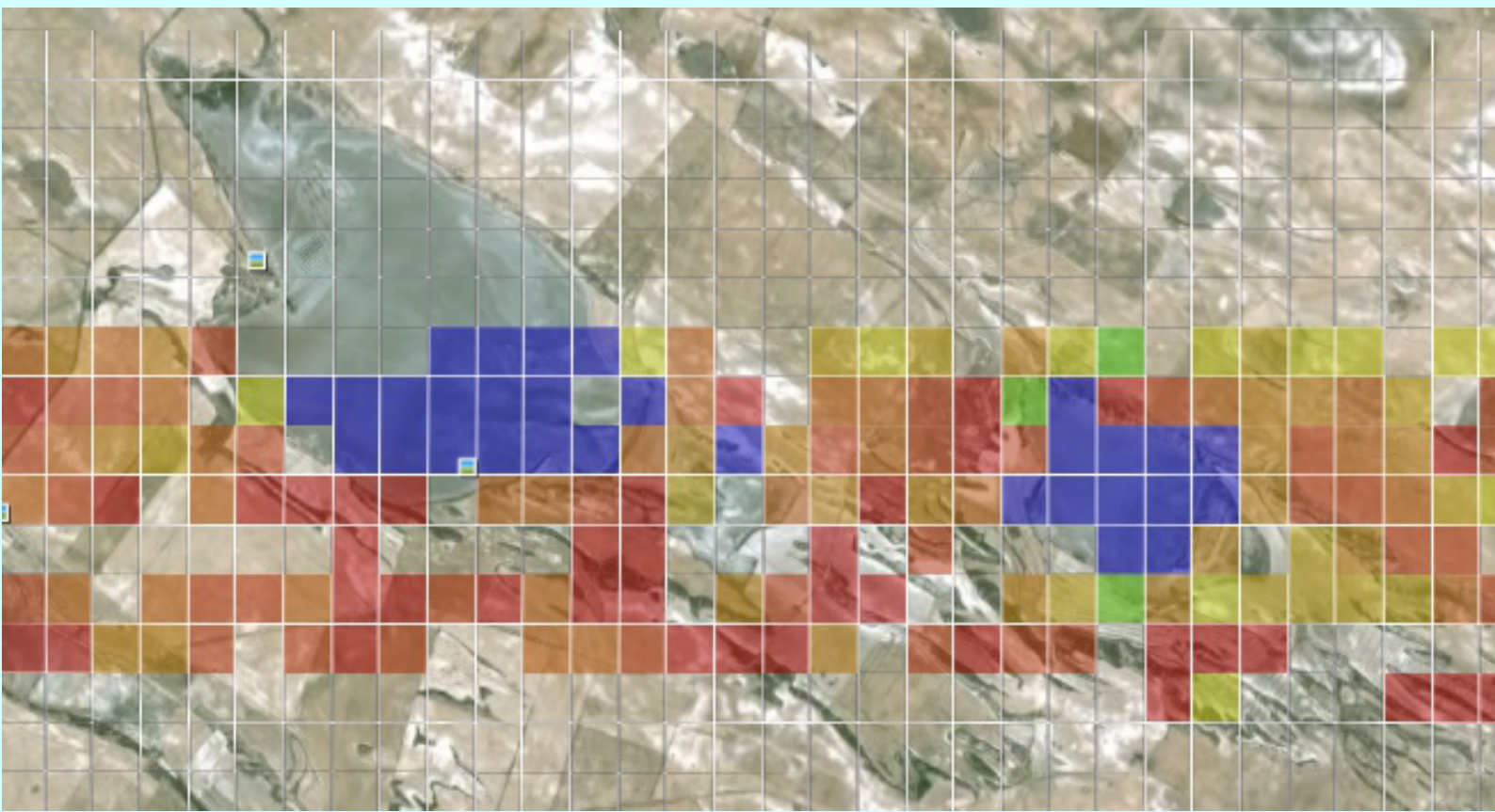
# GNSS for global Earth observation: an update from the European coordination action Gfg<sup>2</sup>

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**Introduction** — The Gfgsquared (GfG<sup>2</sup>) project is an international research related project with focus on the use of Global Navigation Satellite Systems (GNSS) for Earth observation in a more general sense. Novel GNSS applications with outstanding social importance are identified. These applications can be classified into the nine Social Benefit Areas (SBAs), which include current crucial problems of mankind: agriculture, biodiversity, climate, disasters, ecosystems, energy, health, water, and weather. They are identified and described by the Group of Earth Observations (GEO, see: [www.earthobservation.org](http://www.earthobservation.org)).

**Agriculture** — GNSS techniques are widely used for agriculture. Related to positioning are machinery guidance, mapping, and livestock monitoring. Reflected GNSS signals can be used for soil moisture estimation, land classification, crop development monitoring, and biomass monitoring.



A soil moisture map, generated by using GNSS reflectometry measurements (red: dry; blue: wet) (© A. Egido, Starlab).

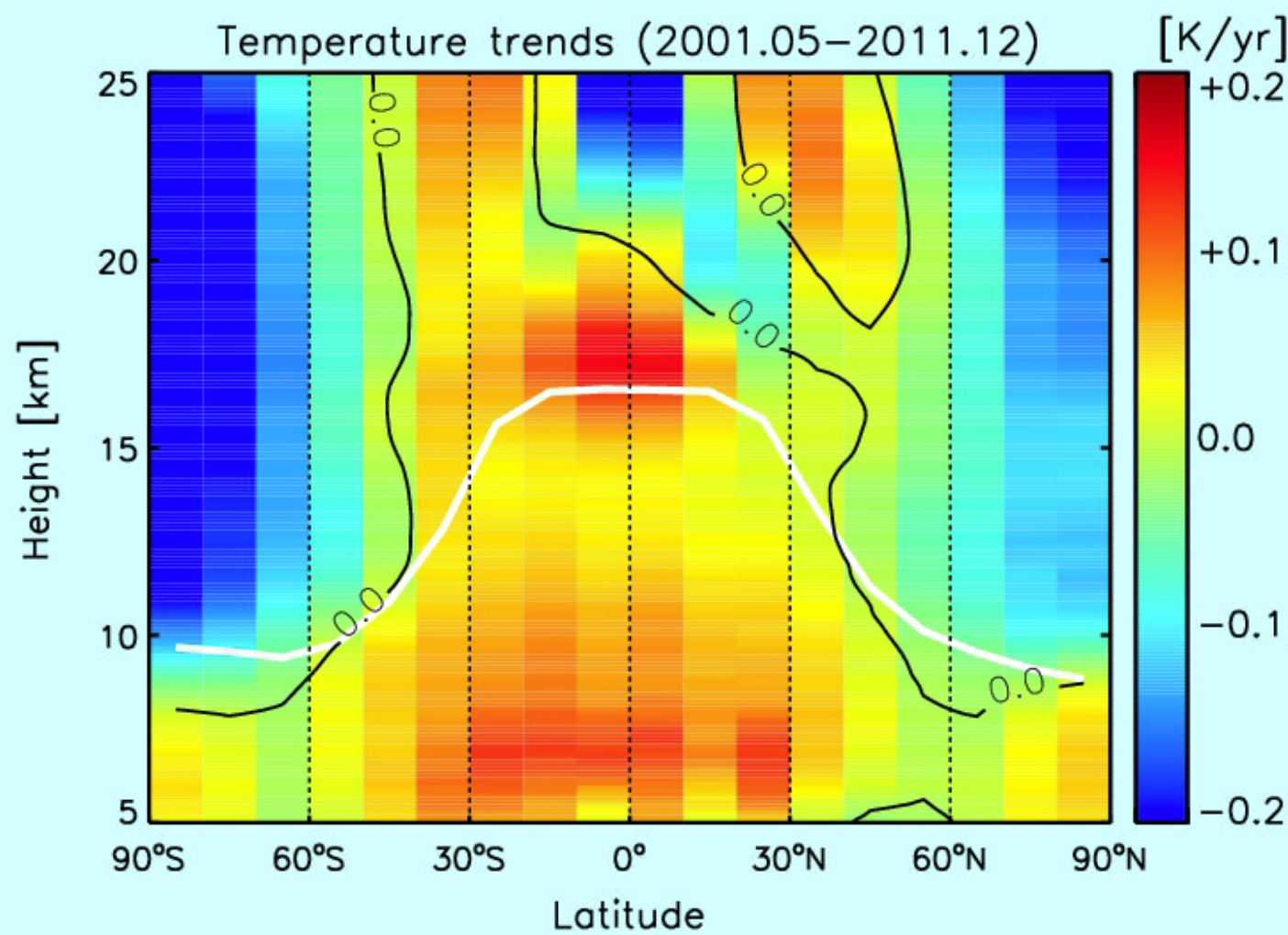
**Energy** — Many GNSS applications are related to energy, e.g. tracking of goods, time synchronization in smart grids, space weather, subsidence in mining, wind scatterometry, and lake level monitoring.



GNSS-R installation at the Onsala Space Observatory, for monitoring of the sea level.

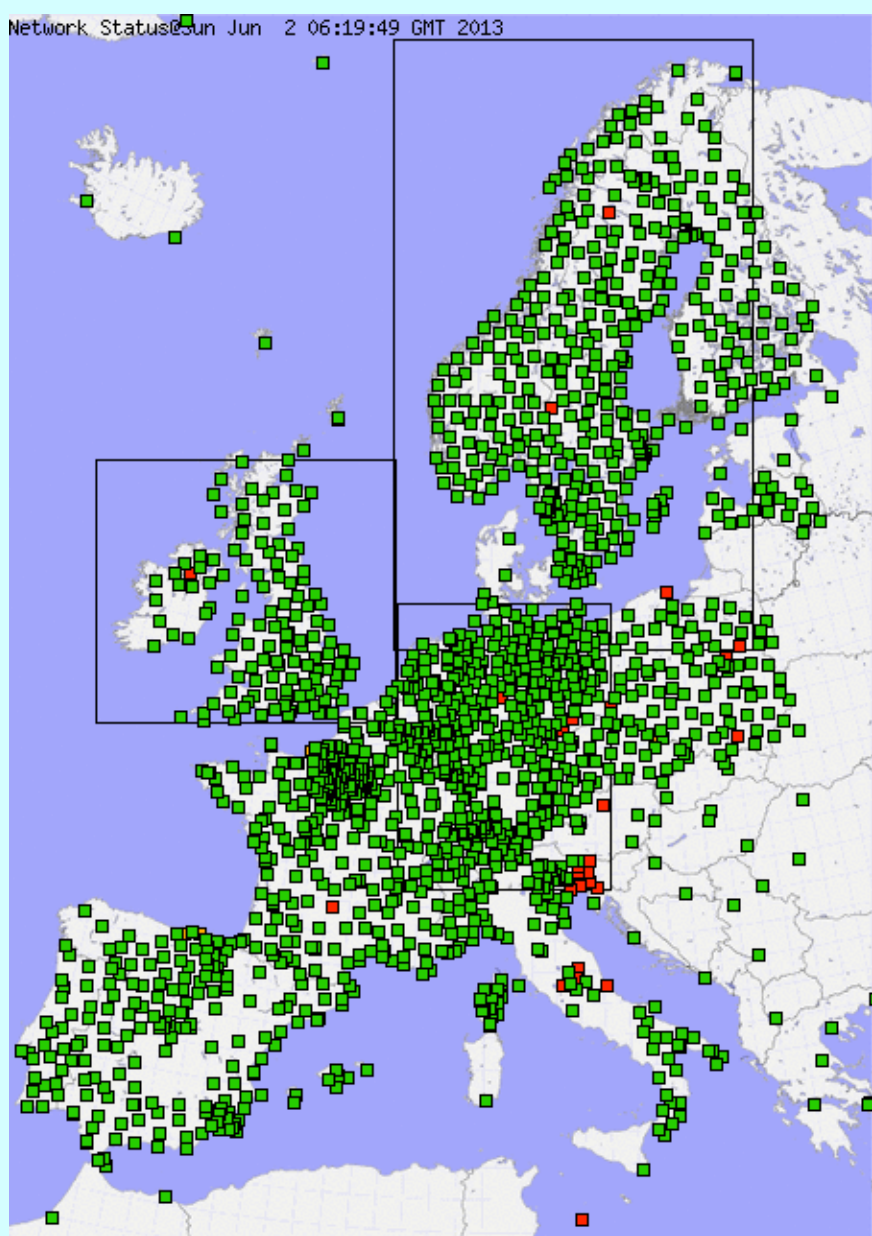
**Health** — Health organizations use GNSS positioning services to manage people and equipment, monitor disease propagation, and direct search and rescue operations.

**Climate** — The GNSS occultation technique offers globally distributed estimates of temperature profiles covering the interesting region including the upper troposphere and the lower stratosphere. Ground-based networks provide observations of the water vapour content above each site.

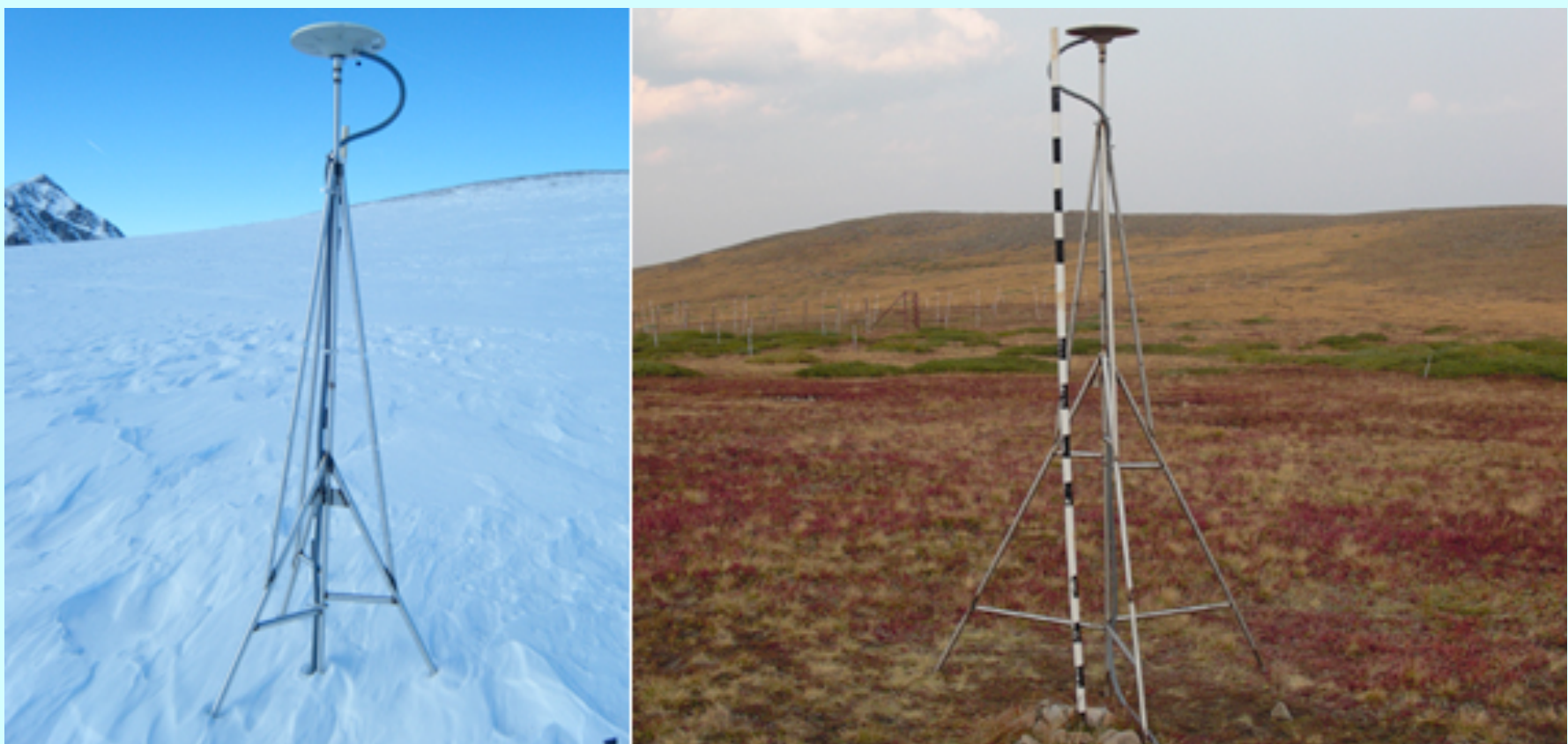


Temperature trends in the atmosphere inferred from the GNSS occultation technique (© T. Schmidt, GFZ)

**Weather** — This SBA is mainly about improving weather information, forecasting and warnings. GNSS contributes by providing meteorological data, which are already operationally used. The two major applications are based on occultation and ground-based geometries. EUMETSAT operates the METOP satellites carrying GNSS receivers for sounding of temperature and humidity profiles by observing the occultation of GNSS satellite signals. E-GVAP is a ground-based network operated by EUMETNET. Present sites are shown on the map ((© <http://egvap.dmi.dk>).

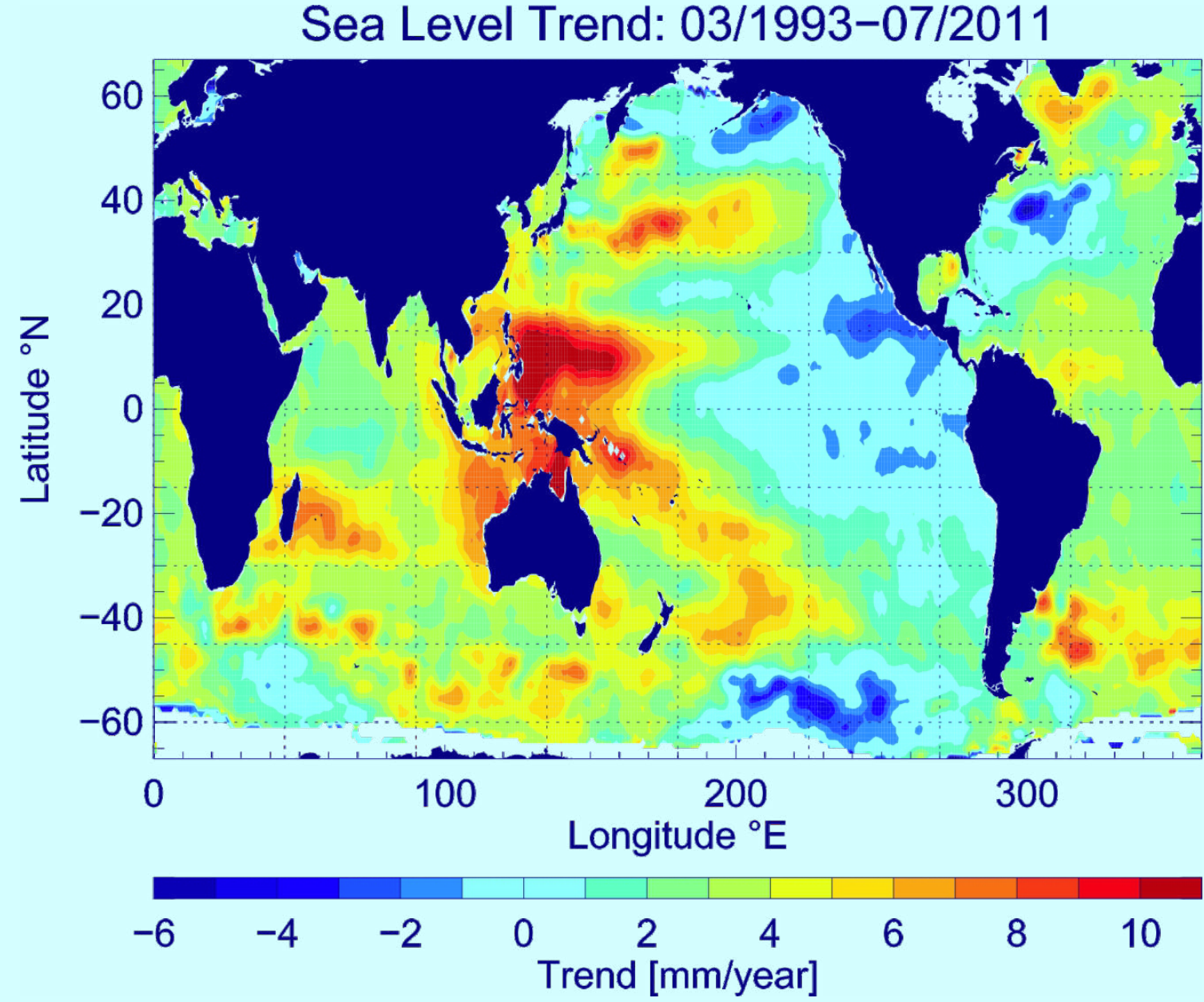


Parameters which can be estimated from GNSS data are: temperature, pressure, humidity, precipitation, soil moisture, snow cover and snow depth, ice cover, and wind/turbulence.



The GNSS station NWOT in Boulder, CO, USA used to measure snow depth by means of reflections of GNSS signals (© K. Larson, Univ. of Colorado).

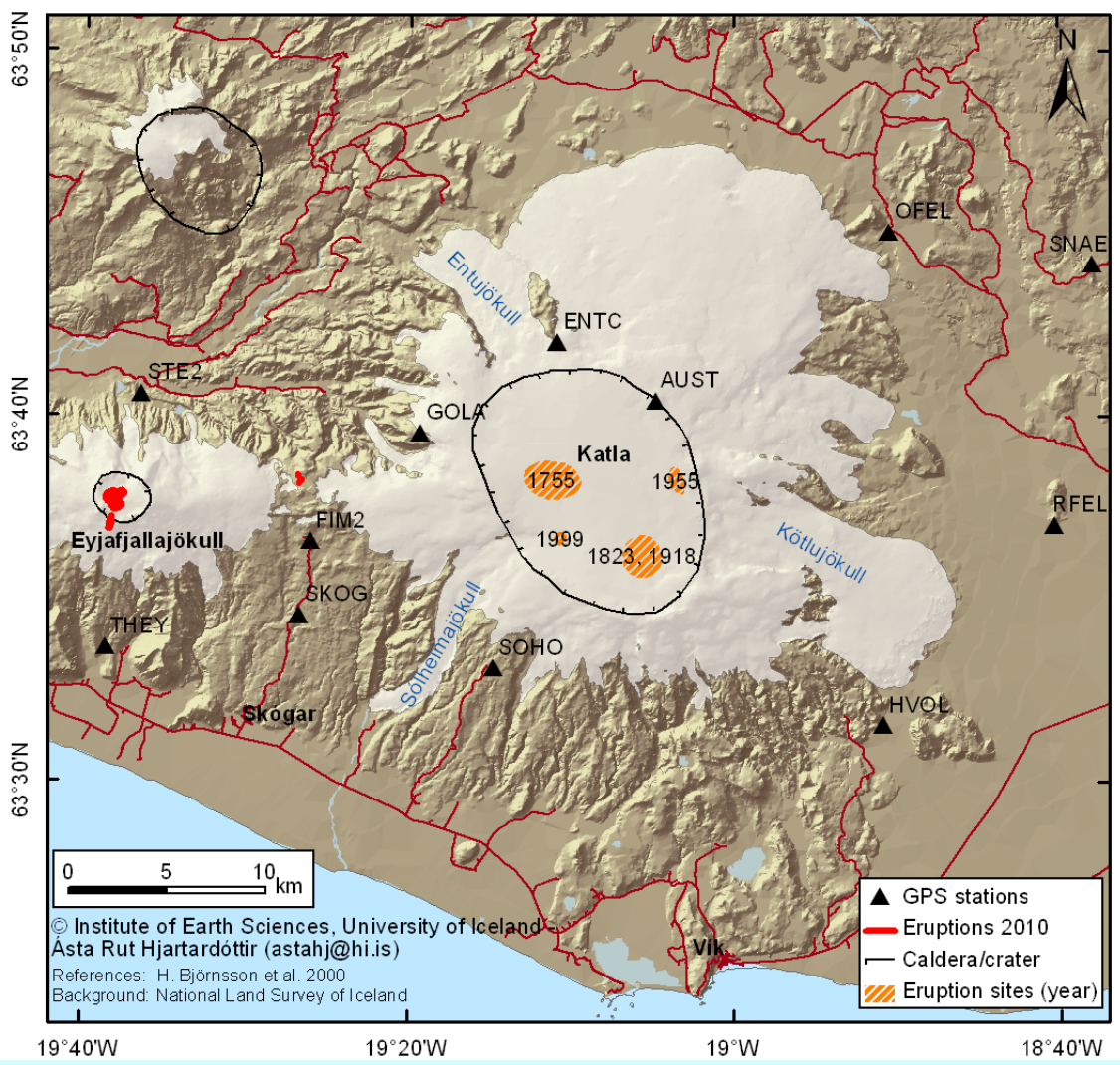
**Water** — Global accurate observations of the sea level are not possible without GNSS. The orbit determination of radar altimetry satellites uses the international terrestrial reference frame (ITRF), which is also used to connect reference surfaces and for tide gauge calibration.



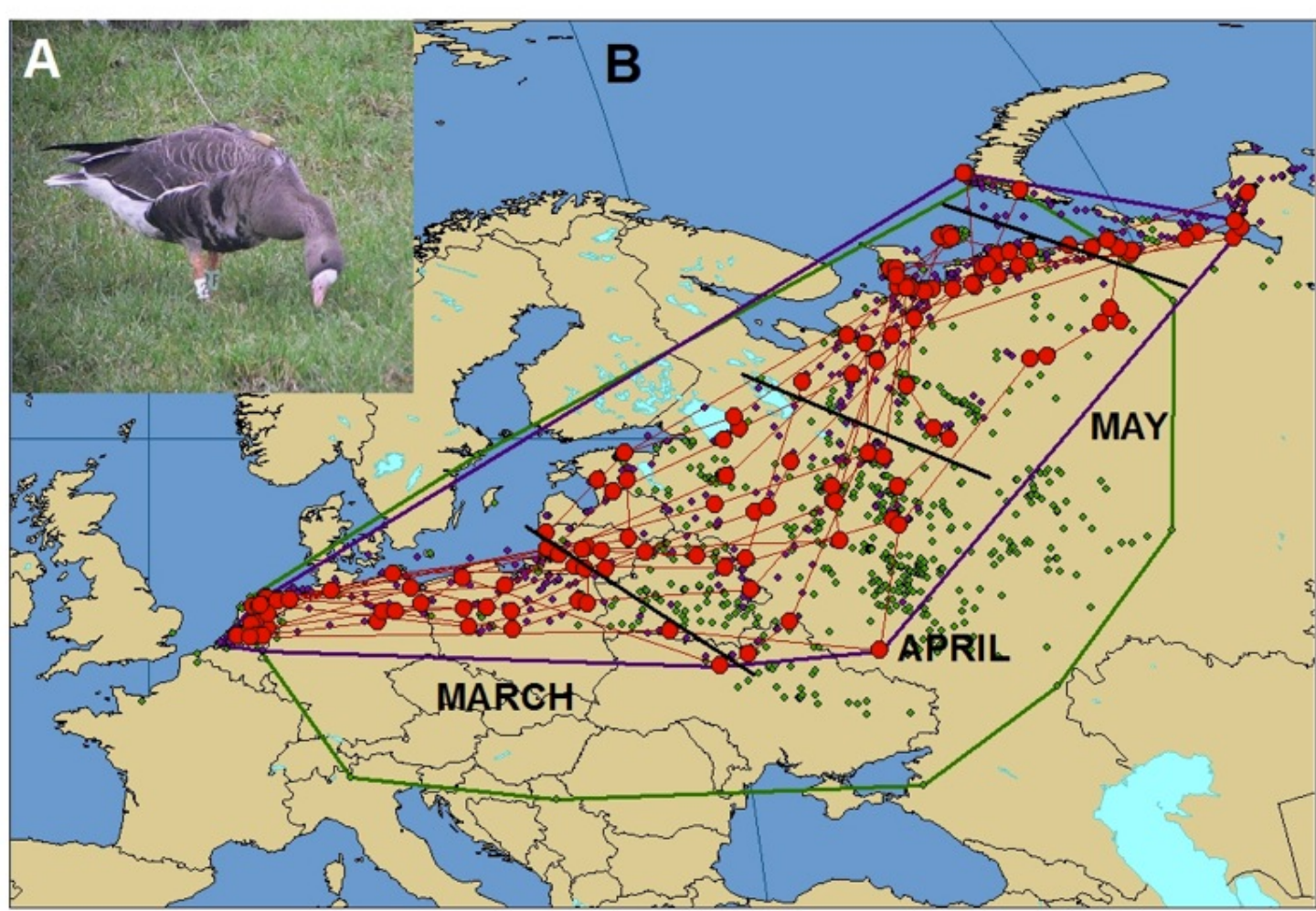
An example of estimates of the sea level trend (© S. Esselborn, GFZ).

**Disasters** — GNSS applications for all phases of the risk management cycle associated with hazards (mitigation and preparedness, early warning, response, and recovery) are: critical infrastructure (such as dams and bridges), earthquakes, volcanoes, landslides/avalanches and floods.

A GNSS monitoring network on the Katla volcano on Iceland.



**Biodiversity and Ecosystems** — GNSS are used for animal tracking and positioning. The motion pattern of an animal may reveal information about its health. Another application is satellite image analysis for habitat mapping (spatial aspects, mapping, surveying, and digital elevation models).



Recording of white-fronted goose in 2006-2008. Red: GPS positions, green additional metal ring recording