Met Office

The GNSS component of the Copernicus Climate Change Service (C3S)

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The Copernicus Climate Change Service

The Copernicus Climate Change Service (C3S) is one of six thematic services provided by the Copernicus Earth Observation Programme, providing authoritative climate information.

C3S will combine climate observations with the latest science to develop authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide. C3S will provide key indicators on climate change drivers and impacts. The service will build upon and complement existing capabilities at national level and through a number of climate-change research initiatives it will become a major contribution from the European Union to the WMO Global Framework for Climate Services and its Climate Monitoring Architecture. It will maximise the use of earth observations (from in-situ and satellite observing systems) in conjunction with modelling, supercomputing and networking capabilities.

C3S is implemented in several sub-services, one of which is C3S2 311 Lot 2 'Comprehensive Upper-Air, Baseline and Reference in-situ observations'. The main goal of this activity is to rationalise, harmonise and improve access to; observations to facilitate climate monitoring, estimation of non-gridded Essential Climate Variables (ECVs) and quantified uncertainties. In addition, the service shall provide access to the comprehensive historical upper-air record, with a particular focus on their suitability for use in climate reanalysis.

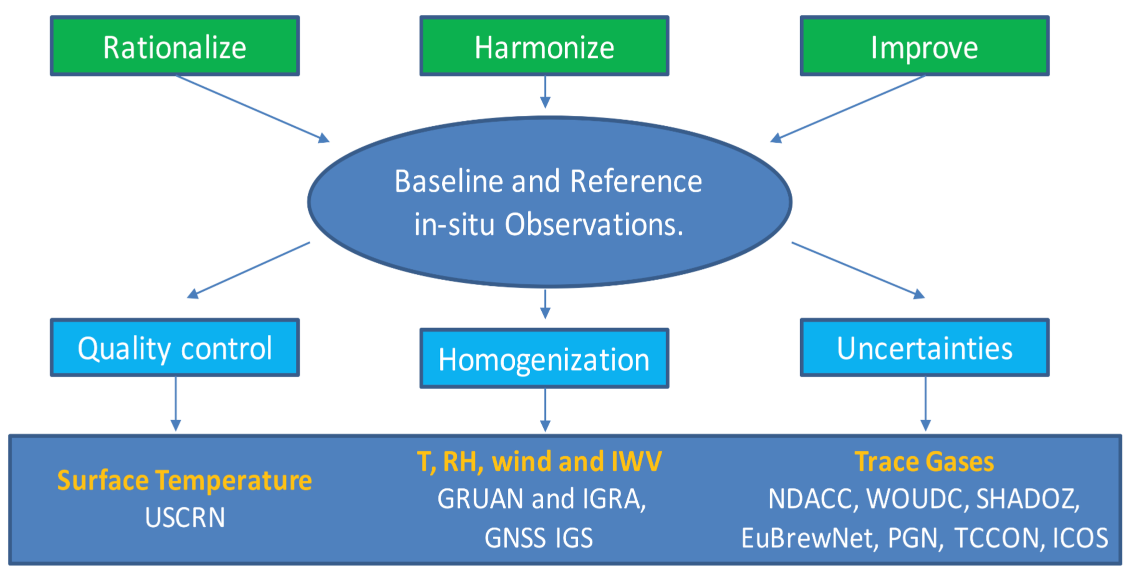

Figure 8: C3S flowchart for baseline and reference observations.

Essential Climate Variables

ECV observations above the Earth's surface fill an important gap in the current global observing system, providing long-term, high-quality climate data records from the surface to the stratosphere and are being used to determine trends, constrain and calibrate data from more spatially-comprehensive observing systems such as satellites and radiosonde networks, and to provide data for studying atmospheric processes. The World Meteorological Organization (WMO) Global Climate Observing System Reference Upper Air Network (GRUAN) has determined water vapour to be one of three Priority 1 ECVs.

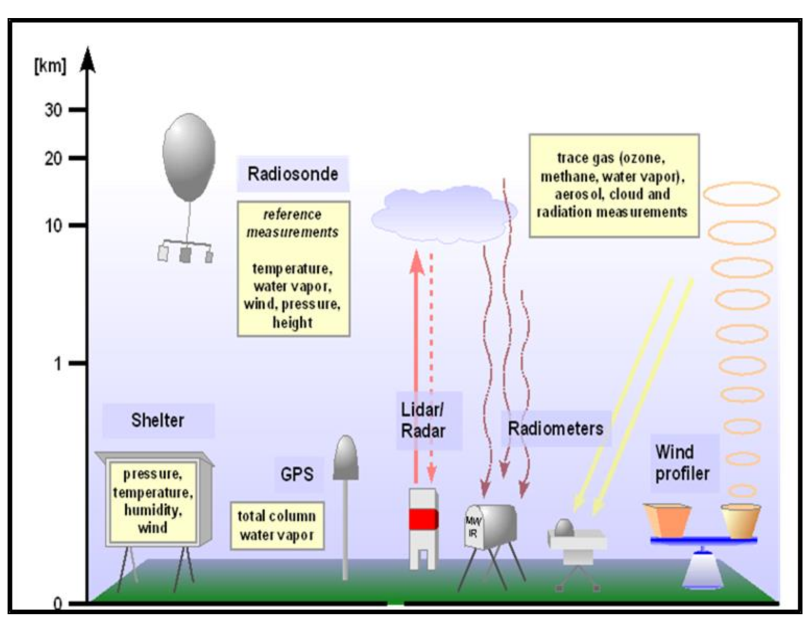

Figure 1: GRUAN Observation types: GNSS is Priority 1.

GNSS Meteorology

Atmospheric delay data from Global Navigation Satellite Systems (GNSS) has become an established meteorological observing system that can accurately sense atmospheric water vapour, the most abundant greenhouse gas, accounting for 60-70% of atmospheric warming. Water vapour observations are currently under-sampled in meteorology and obtaining and exploiting additional high-quality humidity observations is essential to improve weather forecasting and climate monitoring.

Near real-time GNSS tropospheric products, such as those provided by the EIG EUMETNET E-GVAP Programme, are unsuitable for climate applications due to time series inhomogeneities resulting from equipment or processing changes. Raw data must be carefully reprocessed in a consistent manner to achieve climate-quality datasets. Reprocessed, climate-quality GNSS products such as the International GNSS Service (IGS) and EUREF Permanent Network (EPN) Repro ZTD data are essential resources for understanding long-term changes in atmospheric water vapour content and climate change. These datasets enable validation of systematic biases from a range of instrumentation, improve knowledge of climatic trends in atmospheric water vapour, and are potentially of great benefit to global and regional NWP reanalyses and climate model simulations (e.g., IPCC AR5).

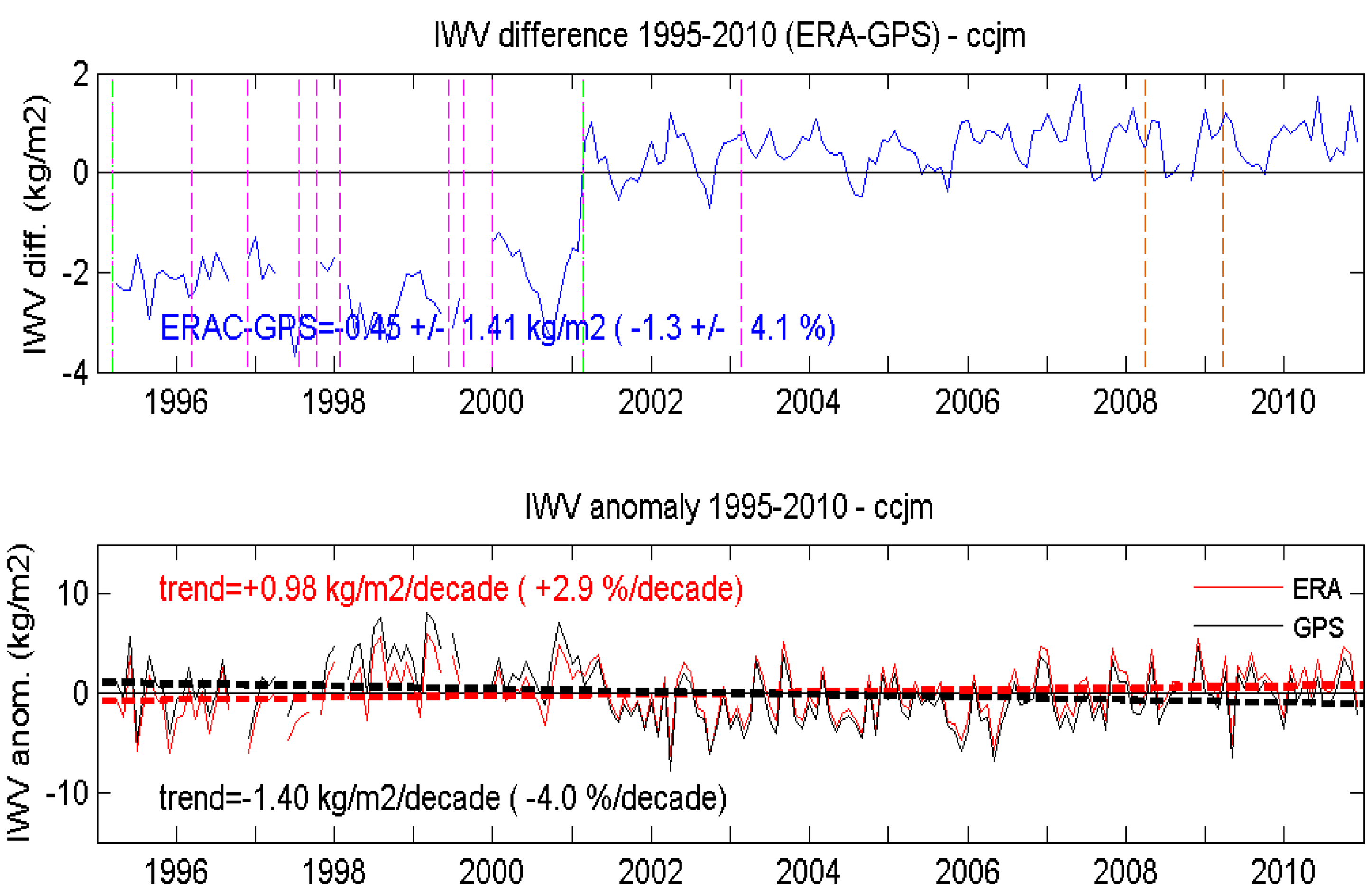

Figure 2: Impact of discontinuities on trend estimates, Bock and Parracho (2016).

GNSS Datasets

The initial dataset is collected from two in-situ ground-based networks of GNSS receivers – the International GNSS Service (IGS) and EUREF Permanent Network (EPN). The IGS collects, archives, and freely distributes GNSS data from a cooperatively operated global network of more than 500 ground-based GNSS stations since 1994. The EPN is a European network of more than 300 continuously operating GNSS reference stations with precisely known coordinates.

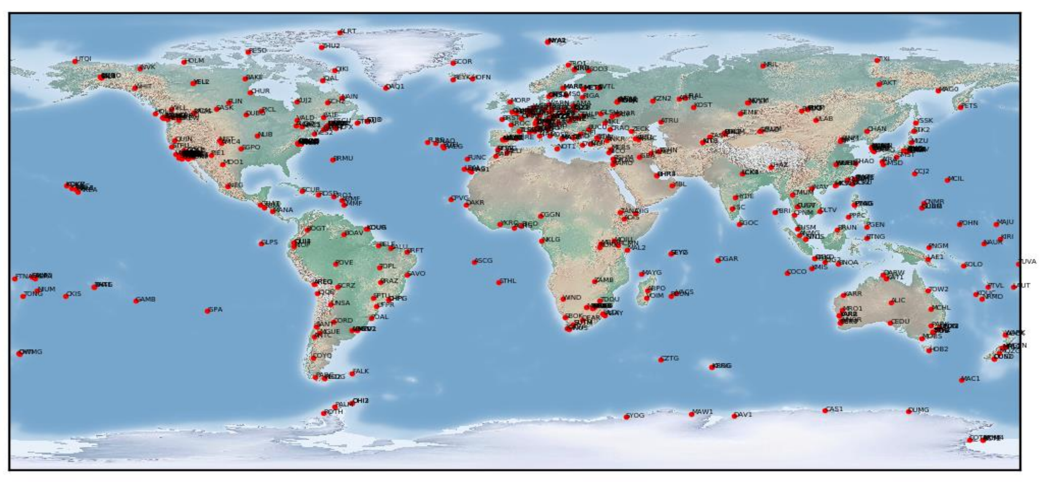

Figure 3: Global IGS GNSS network.

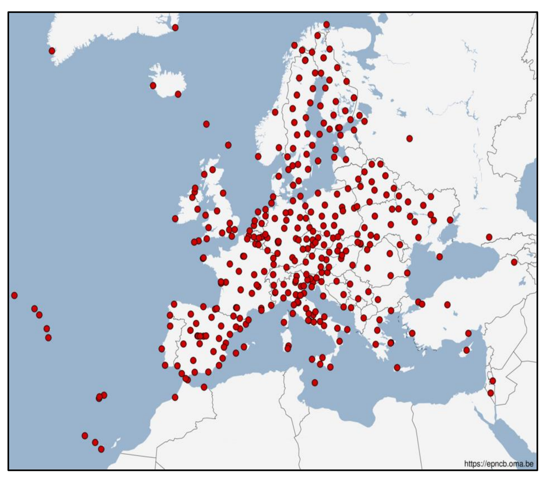

Figure 4: EUREF EPN Network.

Whist the IGS and EPN Repro datasets are invaluable, their horizontal resolution is not sufficient to meet the goal of regional climate monitoring with a requirement for data every 100km. The EPN network for example consists of 350 stations whilst the number of European stations providing data to E-GVAP is over 2000 and the true number of stations is higher again as many data providers (some commercial, some in countries not yet involved in E-GVAP) do not yet contribute data.

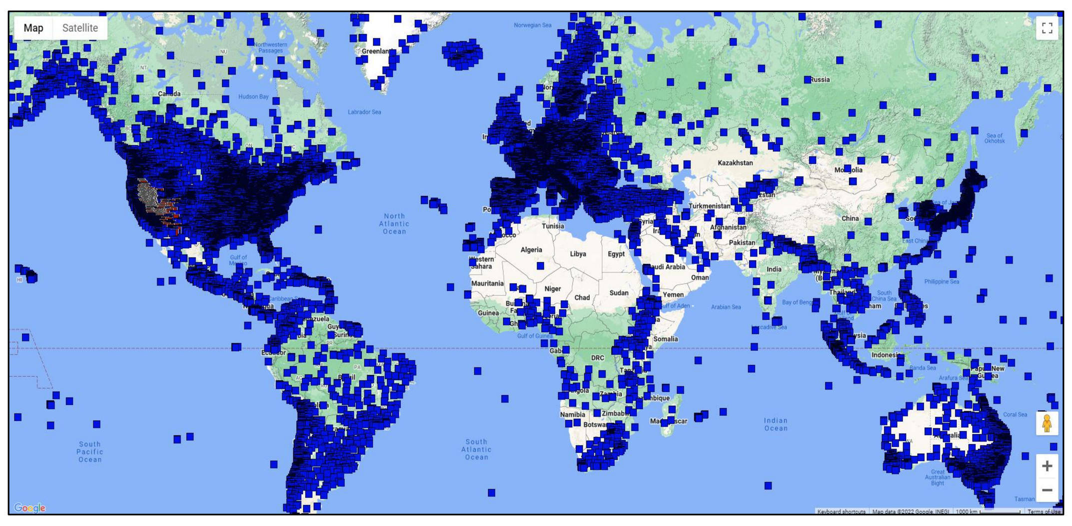

Figure 5: Global GNSS network (courtesy of the Nevada Geodetic Labs).

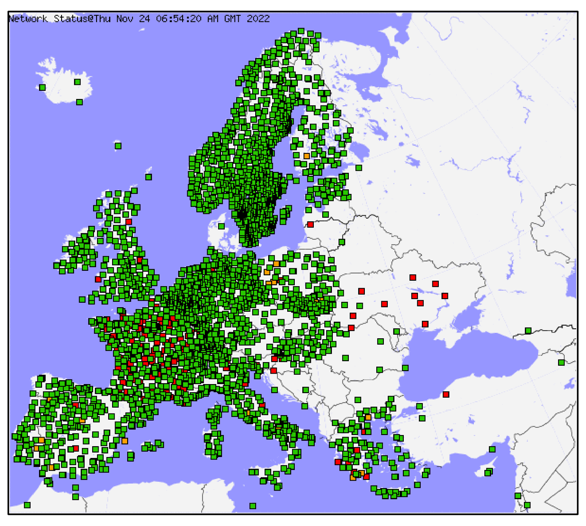

Figure 6: E-GVAP GNSS Network.

If all 2000+ European GNSS stations were reprocessed to climate standards, a far greater understanding of regional climate change could be attained. Additionally, vast amount of raw GNSS data are potentially being deleted as the data owners may only be interested in the short-term application of their data – commercial operators or even national mapping agencies may not be aware the data has potential for climate monitoring. It is therefore vital that all available raw GNSS data (and associated metadata) be archived and made available for future reprocessing activities.

The GNSS component of the Copernicus Climate Change Service will:

1. **Create and populate a globally recognized Climate Data Store (CDS) of reprocessed GNSS ZTD and PWV, including quantification of uncertainty budgets.**
2. **Create and populate a globally recognized Climate Data Store (CDS) of all available RINEX data (and associated metadata) to permit future reprocessing activities.**

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