WG3 MEETING – POTSDAM – SEP 1, 2016, 12:00-17:10 AGENDA AND ABSTRACTS

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COST ES1206 http://gnss4swec.knmi.nl

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Sep 1, 2016

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Can horizontal delay gradients estimated from GNSS data be used in climate research?

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Abstract

It is a common view that because the basic observable in GNSS is the differential time of arrival of the positioning signals the system is well suited for climate monitoring of the atmospheric water vapour content. This is obtained via the estimates of the total equivalent zenith delay and thereafter the delay due to water vapour. At the same time it is common practice to estimate two-dimensional horizontal linear gradients for each site in the GNSS data processing. We will here address the question if also these estimated parameters could be used in applications of climate research.

It is worth noting that linear gradients is a first-order approximation of a much more complicated structure, often caused by atmospheric turbulence and rapid variability in the distribution of water vapour. Therefore, the angular resolution of the actual observations, i.e. the distribution of satellites on the sky, and the temporal resolution of the estimates will affect the size and direction of the gradients. The mean value of wet delay gradients averaged over 15 min was shown to be more than twice as large as when they are averaged over one day (Gradinarsky and Elgered, 2000).

This presentation is an attempt to quantify these effects and to investigate if we can see any long term systematic differences. We use 17 years (1997–2013) of estimated gradients from the GNSS sites at the Onsala Space Observatory and the Geodetic Observatory Wettzell. The highest temporal resolution of the estimated gradients used is one hour, although the original data have updated vales every 5 min. When averages over six hours are calculated we can subtract the hydrostatic gradients based on the ECMWF data (Boehm and Schuh, 2007) in order to study the wet gradients only. These data are available from the mid of 2005, resulting in a subset of almost nine years of data.

At the Onsala site we also have a water vapour radiometer (WVR) mounted at about a distance of 11 m from the continuously operating IGS site ONSA. The WVR performs actual observations in specific directions and observations can cover a large part of the sky in say 10–15 minutes thereby providing independent estimates of the wet gradients. This gives us an opportunity to validate the horizontal wet delay gradients from GNSS data.

Boehm, J., H. Schuh (2007). Troposphere gradients from the ECMWF in VLBI analysis, *J. Geod., 81*, 403–408, doi:10.1007/s00190-0144-2.

Gradinarsky, L.P., G. Elgered (2000). Horizontal gradients in the wet path delay derived from four years of microwave radiometer data, *Geophys. Res. Let., 27*, 2521–2524, doi: 10.1029/2000GL011427.

The uncertainty of the atmospheric integrated water vapour estimated from GNSS observations

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Abstract

Based on the path delay, which radio signals undergo when propagating through the neutral atmosphere, the Global Navigation Satellite System (GNSS) measurements can be used to estimate the atmospheric integrated water vapour (IWV) with a temporal resolution of an order of minutes and with a continuously improving spatial resolution. In order to interpret GNSS measurements correctly and draw valid conclusions on the quality of the resulting IWV estimates, the uncertainty of the GNSS-derived IWV must be carefully evaluated and quantified. This has a specific relevance to the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) where an assessment of the uncertainty in the IWV estimated from GNSS observations is important.

In this work, all relevant error sources in GNSS-derived IWV are investigated. We present two approaches, a statistical and a theoretical analysis, for the assessment of the uncertainty of the IWV. The method is valuable for all applications of GNSS IWV data in atmospheric research and weather forecasting. It will be implemented into the GNSS IWV data stream for GRUAN in order to assign a specific uncertainty to each data point. By combining the uncertainties associated with the input variables in the estimations of the IWV, we calculated the IWV uncertainties for several GRUAN sites with different weather conditions. The results show a similar relative importance of all uncertainty contributions where the uncertainties in the estimated zenith total delay (ZTD) dominate the error budget of the IWV, contributing with more than 75 % of the total IWV uncertainty. The impact of the uncertainty associated with the conversion factor between the IWV and the zenith wet delay (ZWD) is proportional to the amount of water vapour and is therefore more important during moist weather conditions.

Screening and validation of new reprocessed GNSS IWV data in Arctic region

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Abstract

Two new reprocessed GNSS solutions are analysed: the CODE IGS repro-2 solution referred to as CO2 (Steigenberger et al., 2014) and the GOP EPN repro-2 solution referred to as GO4 (Dousa et al.). Both solutions were produced with Bernese software (v5.3 for CO2 and v5.2 for GO4), using CODE repro-2 orbits and clocks and VMF1 mapping function. ZTD estimates and their formal errors for 10 stations in the Artic region were used in this study for the period from 1996 to 2013 (2014 for GO4). This presentation will exemplify the implementation of the state-of-the-art post-processing methods for screening of ZTD data, conversion to IWV, and validation. The time series are inspected for outliers and statistical properties are analysed to set adequate thresholds for the screening procedure. The screening based on range check and outlier check rejected 1.7% and 1.3% of the ZTD estimates for CO2 and GO4. It is observed that less data are rejected in the more recent years, reflecting that ZTD estimates are becoming more accurate over time. The ZTD data are converted to IWV using ERA-Interim pressure level data and compared to ERA-Interim IWV data for final validation. Trends and discontinuities are evidenced at some of stations (e.g. KELY, THU1, THU2). The two solutions (CO2 and GO4) are shown to be in very good agreement, but with biases up to 10% with respect to ERA-Interim.

Trends and diurnal cycle of IWV in Europe based on 16-year long GNSS datasets

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Abstract

In this work we have focused on (1) the GNSS-derived integrated water vapour (IWV) data quality, (2) seasonal diurnal cycle of the IWV and (3) its long-term variations during 2000–2015. We aim to detect regional changes and regularities, not global. The data from 46 GNSS stations belonging to the European Reference Frame Permanent Network (EPN) were processed with the GAMIT software. Nine out of these stations (in the area defined by 35–68°N and 17–33°E) with relatively long record were included in the analysis of the IWV diurnal cycle. In addition, data from seven stations were used in the receiver antenna elevation cut-off angle and IWV trend analysis, where radiosonde and AERONET Sun photometer were used as reference methods.

Total Column of Water Vapor measured above the Arctic from space and from the ground: Seasonal and Monthly Trends for 2001-2015

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Abstract

Integrated (Total) Water Vapor IWV (TCWV) monthly means time series from MODIS near infra-red spectrometer onboard NASA/TERRA and ground-based from GPS were studied over three Arctic stations: Sodankyla - Finland (2001-2014), Ny Alesund - Svalbard (2001-2014), and Thule – Greenland (2005-2014).

In order to overcome the satellite/GPS timing error due to limited hours of MODIS measurements compared to the GPS hourly IWV availability, MODIS/TERRA passing hours over the three arctic stations were defined through the IXION (freely available public site by the Laboratory of Dynamic Meteorology and the university Paris6), and only the GPS coincidence with MODIS time passing hourly data were used to discuss their monthly, seasonally, and yearly differences and biases. Results will be presented and discussed.

Also, TCWV monthly means from SCIAMACHY and GOME-2B ultraviolet/visible spectrometers on board of ENVISAT, METOP-A satellites respectively will also be compared to GPS over the same three arctic stations with a similar approach.

This study is an introduction to a trend study of IWV over the arctic using the MODIS data for the last 15 years at both monthly and seasonally scales.

IWV trends and variability from GPS, ERA-Interim and climate model simulations

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Abstract

A GPS precipitable water (PRW) dataset based upon IGS repro1 ZTD solution is used to assess IPSL's LMDZ climate model simulations. Four different configurations of the climate model are considered, combining two different physics (new and old physics) and both free runs and nudged simulations (with 3-hourly ERA-Interim wind fields). ERA-Interim PRW data are used together with GPS PRW data for the validation of the climate model simulations along. The study compares mean PRWs, time-series and linear trends for the period 1995-2010, globally, and assesses representativeness limitations in GPS to model comparisons.

Results show an improvement with the nudged simulations, for both model physics, with an increase in the correlation coefficient between GPS and model PRW time series and anomalies. In addition, for the nudged versions of the model, both absolute and relative trends are closer to the estimated GPS PRW trends. These results obtained for the nudged configurations are consistent with the comparison between GPS and ERA-Interim PRW data, which yielded similar outcomes for the trends and correlation coefficients.

The ERA-Interim data was also compared with each model configuration, in terms of spatial variability. The differences between trends and variability are slightly lower for the nudged versions, especially over the ocean. However, the differences in the mean PRW are of the same order of magnitude for all 4 configurations. Finally, the model configurations were also spatially inter-compared. In general, the new physics appears to be more sensitive to the nudging, while the differences between nudged versions are smaller in trend and variability. The results also suggest some feedbacks between model dynamics and physics.

Relationship between the variation in sea surface temperature and GNSS-derived precipitable water vapor

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Abstract

Water vapor (WV) is a principal atmospheric variable and a central component in earth energy budget and global water cycle. Investigation into long-term variation in WV in both spatial and temporal domains is significant for studying the dynamics of the Earth's climate system and climate change. Quantifying the variation and distribution of WV at a high accuracy and high resolution is often a challenge if only traditional meteorological sensors are used due to their low temporal and spatial resolutions. Nowadays, using Global Navigation Satellite Systems (GNSS) to remotely sense the precipitable water vapor (PWV) contents in the atmosphere has heralded a new era for climate research due to their 24-hour availability, global coverage, high accuracy, high resolution and low cost. In this study, the long-term trend and seasonal oscillations in PWV time series for the period 1994−2013 across the GNSS stations located in the tropical regions were investigated. The PWV time series were obtained from GNSS-derived zenith wet delay and ECMWF-derived water-vapour-weighted mean temperature. An enhanced time series analysis method, named singular spectrum analysis (SSA), was investigated to study the trend and seasonal oscillations in the PWV time series. An investigation into the relationship between the variation in monthly PWV and monthly sea surface temperature was also conducted. Results indicate a strong correlation existing between these two variables. Moreover, comparisons between the PWV time series and the occurrence of the El Niño and La Niña events were also performed for an investigation of correlation between them. The result shows that the variation in the PWV is strongly affected by the El Niño and La Niña events.

A homogenization of GNSS tropospheric data with autoregressive process

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Abstract

During a processing of Global Navigation Satellite System (GNSS) observables the tropospheric data are also estimated. These are characterized by offsets that arise from changes in hardware equipment or any other artificial event. These offsets are all a subject of a task of homogenization. This is aimed at a proper identification of epochs of offsets since they may artificially under- or over-estimate trend and its uncertainty when undetected. In this research, we analysed a common data set of differences of Integrated Water Vapour (IWV) from GPS and ERA-Interim (1995-2010) provided for a homogenization group working within ES1206 COST Action GNSS4SWEC. We analysed daily IWV records of GPS and ERA-Interim in terms of trend, seasonal terms and noise model with Maximum Likelihood Estimation in Hector software. We found that this data has a character of autoregressive process (AR). Basing on results, we simulated 25 years of data with white and white and autoregressive process. We also added few strictly defined offsets. This dataset was subjected to a task of automatic/statistical and manual homogenisation. We found that simulated offsets were easily detected in series with white noise, with no influence of seasonal signal. The autoregressive series were much more problematic when offsets had to be determined. We found few epochs, for which no offset was simulated. This was mainly due to strong autocorrelation of data, which brings an artificial trend within. Due to regime-like behaviour of AR it is difficult for statistical methods to properly detect epochs of offsets, which was also previously reported by climatologists.