ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

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**Subject title:**

**Detection and mitigation of biases and inhomogeneities in GNSS time series for climate monitoring**


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## *Presentation of the subject:*

Time series of GNSS station coordinates and tropospheric delays have been widely used for monitoring a variety of geophysical and geodynamical processes, ranging from global tectonic processes to mesoscale weather events [1]. However, their capacity to retrieve small signals, such as sea level rise and atmospheric water vapour trends connected with climate variability and change, is still limited [2]. Improving the accuracy and homogeneity of historical GNSS products is thus necessary to better apprehend the magnitude and spatial distribution of climatic processes. Decadal variability and trend estimates are especially obscured by biases and inhomogeneities in the GNSS time series. Recent studies have shown that GNSS time series from the International GNSS service (IGS) are affected by an average of one change-point every 10 years [3, 4]. The source of many of these change-points could be tracked back to equipment changes at the GNSS stations as well as changes in the data processing.

The traditional approach to homogenize climatic time series consists in a two-step, detection and correction, post-processing procedure [5, 6]. In recent years, we have developed a statistical detection method made available in the form a R package (GNSSseg) [4]. This method has been shown to be one of the best in a benchmark assessment [6] and is currently used to produce to a global GNSS water vapour climate record. However, a significant fraction (~40%) of detected change-points cannot be explained by known equipment changes at the GNSS stations. Missing or erroneous meta-data may hamper the validation. On the other hand, some false detections may also be present. Moreover, the comparison of various GNSS data sets has shown that segmentation results depend somehow on the used data processing scheme. In this thesis, we thus want to explore an alternative approach consisting in tuning the GNSS data processing scheme in order to produce raw time series that are more homogeneous by nature. This approach is referred to as “homogenization at the observation processing level”.

The specific goals of this thesis will thus be:

1) to better understand the origin of biases, inhomogeneities, and noise in long-term (20-30 years) GNSS series of station coordinates and tropospheric delays;
2) to mitigate these errors by a proper tuning of the GNSS data processing scheme;
3) to elaborate a global reference climate record of GNSS positions, tropospheric delays, and integrated water vapour (IWV) data based on the tuned data processing completed by the traditional statistical post-processing homogenization procedure.

This work will help to answer a number of fundamental questions such as:

a) what is the absolute accuracy of GNSS IWV estimates?
b) can we improve the homogeneity of GNSS time series at the processing level?
c) what are the causes of the geographical and temporal variations (namely seasonal) of the noise in the GNSS series?

The absolute accuracy of the GNSS solutions will be assessed on the basis of IWV comparisons with external data sources such as reference radiosonde observations and satellite products [7]. The homogeneity can be assessed with the GNSSseg segmentation tool [3, 4, 5]. The GNSS processing parameters and improving several modelling aspects that will be tuned are, e.g., mapping functions, stochastic models, and observations error models. This approach will lead to an optimized data processing parametrization for each and every station. It will be applied to produce a new global reference climate record of station positions and IWV estimates from which sea level rise and atmospheric water vapour trends and variability will be investigated.

This work will be developed in a national and international collaborative framework, namely with ENSTA-Bretagne[1], CLS[2], GET[3], and GFZ[4], GRUAN[5], RSS[6]. It will contribute to the IAG Inter-Commission Committee on Geodesy for Climate Research (ICCC, https://iccc.iag-aig.org/). This work benefits from financial support of CNES through the TOSCA programme.

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[3] GET (Géosciences Environnement Toulouse), Toulouse, France.
[4] GFZ (Deutsche GeoForschungsZentrum), Potsdam, Germany.
[5] GRUAN (GCOS Reference Upper Air Network) Lead Centre, Lindenberg, Germany
[6] RSS (Remote Sensing System), Santa Rosa, California, USA