Research frame work at LACCOST, UFPE, Brazil

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Abstract

After finishing PhD sandwich (Rodrigo) under co-supervision of Professor Bernhard Heck in 2010 at GIK (Geodetic Institute of Geodesy) KIT, new ideas came true to start a laboratory of research dedicated to coastal studies (LACCOST) at Federal University of Pernambuco, Brazil. Also the contact made at GIK with Professor Joseph Awange spreading his ideas about "Environmental Geodesy" add latter an international cooperation with Curtin University, Australia, improving this team and including beside coastal related studies researches with spatial geodesy as background to support questions about the environment, using Brazil and South America as study case. The objectives of this paper is firstly to thank Professor Heck for keeping always looking for international cooperation with naturally become an example and model to follow up and his incredible skills to support researches all over the world. Secondly propagate what has been the topic of master's students showing researches under development at this laboratory.

1 Introduction

The Federal University of Pernambuco (UFPE), Recife, Brazil houses the Department of Cartographic Engineering. This department among its tasks supports the under graduation in survey engineering and also a post-graduation program in Geodetic Science and Technology of Geoinformation. It is considered the only post-graduation program in this field that is covering north and north-east regions of Brazil and has been training human resources in Geodetic Sciences. In 2011 was created the Coastal Cartography Laboratory called LACCOST to support research concerning ICZM (Integrated Coastal Zone Management) and coastal monitoring. After this, naturally research projects were submitted and founded by different Brazilian agencies of research like CAPES, CNPq and FACEPE. Nowadays are under developing two research projects called "Climate Change Impacts on the Brazilian Water Resources" supported by CAPES and "Environmental Geodesy: Monitoring of Water Resources, Shoreline and Related Impacts" by CNPq, both related with the primary task of Geodesy that is measuring the Earth's surface and using some modern techniques to map and model the environment.

According to Awange and Kiema (2013) "Environmental Geodesy" can be argued as that branch of

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geodesy that applies geodetic techniques to monitor the environment by appropriate decision making. Using this general concept this paper has the aim to show research topics that has been under developing by master's students in LACCOST. The structure of this paper is divided into five keywords to present its research characteristics and among of them are: UAVs (Unmanned Aerial Vehicle), GNSS RO (Global Navigation Satellite Systems, Radio Occultation), AVHRR (Very High Resolution Radiometer)/TRMM (Tropical Rainfall Measuring Mission) and MSWEP (Multi-Source Weighted-Ensemble Precipitation). All of them used as baseline to give support to environmental challenges in Brazil and South America.

2 UAVs

The use of UAVs has become a current paradigm in research in several areas, however they are still a novelty for coastal mapping. Monitoring coastal stability is vital for environmental management and is part of the set of tasks and activities that contribute to coastal management (Gonçalves et al., 2012). In particular, it becomes crucial to determine the spatial position of the shoreline and beach profiles. Through the continuous monitoring of these elements, decision makers are able to analyze the agents and factors involved in coastal zone behaviour.

For Turner et al. (2016) UAVs brings practicality and agility to the execution of coastal activities, and can be used for different types of studies, such as natural disaster analysis, coastal vulnerability to erosion, shoreline mapping, and geomorphology, among others.

The present research aims to evaluate the potential of UAVs for three-dimensional mapping and coastal monitoring considering horizontal information through the spatial position of the shoreline as well as vertical with the extraction of beach profiles from DTM (Digital Terrain Models), having as case study the Coroa do Avião Islet, located in the municipality of Igarassu, Pernambuco state, north-east of Brazil.

The accuracy of this mapping will be compared with reference to the Technical Specification for Quality Control of Geospatial Data, in Brazil. This document is part of a set of norms and standards that must be observed by all public and private entities that producing and use cartographic services and related activities.

In order to validate the spatial information generated, a comparisons will be made regarding the positional quality of the UAVs data (restitution of the shoreline from orthophoto mosaic and beach profiles through DTM) with data obtained through GNSS survey.

It is expected that UAVs complement coastal monitoring activities and give more options to support decision makers to preserve and plan coastal environment.

3 GNSS meteorology

The tropopause is the transition zone in the atmosphere between the upper troposphere and lower stratosphere, being of great importance for thermal equilibrium and energy balance between stratosphere and troposphere. The height and temperature of the tropopause were sensitive to temperature changes in the troposphere and stratosphere (Melbourne et al., 1994). One of the mechanisms that leads to an increase in the height of the tropopause is the warming of the troposphere due to more CO2 (greenhouse effect) and a cooling of the lower stratosphere due to the decrease of stratospheric ozone, both observed in the last decades (Schmidt et al., 2008).

The global height of the tropopause presents an upward trend in the reanalysis and radiosonde observations for the period from 1979 to 2001 (Santer et al., 2004). Thus, the height and temperature of the tropopause can be considered as a parameter for the detection of climate change processes and, therefore, identifying and monitoring the tropopause is an important objective in climate research (Santer et al., 2003; Schmidt et al., 2008).

In South America, tropopause studies use data from radiosonde stations, reanalysis models and recently radio occultation data and are related to meteorological events or the quality of the reanalysis products (e.g. Santos (2016), Fontinele (2012), Holzschuh (2010)). However, no study presented the temporal variation of the height and temperature of the tropopause over the entire region of South America based on radio occultation data.

GNSS radio occultation (GNSS-RO) uses GNSS (Global Navigation Satellite Systems) signals in conjunction with LEO (Low Earth Orbit) satellites, this method has the potential to overcome the limitations of classical methods (radiosondes and reanalysis models) due to high accuracy, greater vertical profile, data distributed almost uniformly across the globe and long-term stability of the system, excluding problems such as discontinuities in time series (Melbourne et al., 1994).

3.1 GNSS RO

In April 1995, the United States launched the Microlab-1 LEO satellite to investigate the potential of the GNSS RO method in obtaining neutral atmosphere and ionosphere data. The mission became known as GPS/MET and collected atmospheric data for the period 1995-1997. Following the success of the mission, several countries carried out their own scientific missions, such as: CHAMP (Challenging Minisatellite Payload of Geophysical Researche and Applica-tion) launched by Germany collecting data from 2001 to 2008. FORMOSAT-3/COSMIC (Constellation Observing System for Meteorology Ionosphere & Climate) of the US and Taiwan consortium, has been in operation since 2006. GRACE (Gravity Recovery and Climate Experiment) and TERRASAR-X both launched by Germany and in operation since 2001 and 2008 respectively. South Korea's KOMPSAT-5 (Korea Multi-Purpose Satellite-5) mission in operation since 2015. And the European Union's Meteorological Operational Satellite (METOP) operating since 2007.

The LEO satellite equipped with a GNSS receiver orbiting around the Earth will receive navigation signals from the satellites of the GNSS constellation. A occultation event occurs when the GNSS satellite that is opposite to the LEO satellite transmits a tangent signal to the atmosphere, as the LEO and GNSS satellites move, the signal traverses the various layers of the atmosphere which leaves the path traveled by the signal slightly flexed (see Figure 3.1). The other satellites of the GNSS constellation that are not in the geometric position to perform the radio occultation are used to accurately determine the positions, speeds and errors of the clocks in the GNSS transmitter and LEO receiver (Jin et al., 2014).

A single radio occultation event lasts approximately 1 to 3 minutes, performing 4000 measurements per profile, ranging from 100 *km* in the ionosphere to approximately 1 *km* in the troposphere (Sapucci, 2014).

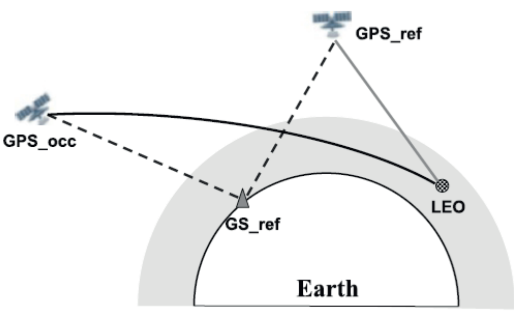

Figure 3.1: Geometry of the radio occultation composed of atmospheric GNSS that transmits the RO signal, a GNSS as a reference (not hidden), GNSS LEO receiver and a ground station.

3.2 Formosat-3/COSMIC

The Corporate University for Atmospheric Research (UCAR) in partnership with the National Space Organization of Taiwan (NSPO) is responsible for the Formosa Satellite Mission - 3/Constellation Observing System for Meteorology, Ionosphere and Climate (Formosat-3/COSMIC) project. This is a scientific mission to develop observation techniques using signals from the Global Satellite Navigation System (GNSS) in weather forecasting and climate analysis. On April 14, 2006 the Formosat-3/COSMIC mission entered orbit with a constellation of six low-orbit (LEO) satellites generating 2,500 probes per day, distributed globally, with data available as of April 22, 2006.

Due to the success of COSMIC-1, US and Taiwanese agencies have decided to move forward with a subsequent RO-GNSS mission called FORMOSAT-7/COSMIC-2, which will launch 12 satellites until 2020. With continued operation of COSMIC-1 and COSMIC-2 mission, which will increase the time series and the amount of radio occultation data to support atmospheric research for years to come.

The GNSS RO Formosat-3/COSMIC data is provided by the COSMIC Data Analysis and Data Center (CDAAC) of the UCAR and from the Doppler displacement they provide the angle of refraction (α) in each signal, (N), which is related to total pressure (P), temperature (T) and water vapour pressure (Pw) (Awange and Grafarend, 2005).

The level 2 data format, available from the CDAAC, contains refractivity profiles inverted by the Abel transformation with air temperature, water vapour, air pressure, height above mean sea level and location of radio occultation (Khandu et al., 2011).

In the proposed study under development, the altitude, temperature and hiding position will be used as variables for South America from April 2006 to April 2017, during which time the COSMIC satellites recorded 543,909 atmospheric profiles distributed over the study area.

This study aims to investigate the regional trends in tropopause height and temperature in relation to South America through: (i) Validation of COSMIC atmospheric profiles in relation to radiosonde station data; (ii) Compare the atmospheric profiles obtained through the COSMIC mission with the CPTEC/INPE PNT (Numerical Time Forecast) reanalysis product for South America; (ii) To determine the annual variations of the height and temperature of the tropopause in South America (2006-2017) and to compare with global estimates present in the literature; (iv) To correlate the variations of the height and temperature of the tropopause with latitudinal and longitudinal variations over the Americas and (v) Generate a map that represents the annual variations of the tropopause covering the surface of South America.

4 AVHRR and TRMM

Monitoring drought in agriculture consists of measuring its intensity and capturing its spatial extent and temporal persistence (Wardlow et al., 2012). In Brazil, a country whose Gross Domestic Product relies on agricultural production, drought is a phenomenon that often negatively impacts it (Mariano, 2015). The present study was based on the hypothesis that it is possible to detect the occurrence of drought in agriculture using Remote Sensing data, together with vegetation indexes and precipitation. Thus, it would be possible to propose an effective methodology for the characterization and monitoring of drought and its effects on agriculture, using data from the visible and infrared spectral for the NDVI from the Advanced Very High Resolution Radiometer (AVHRR) sensor and Tropical Rainfall Measuring Mission (TRMM) products, as well to evaluate the efficacy and relationship of these indicators with the national data of agricultural production, during the study period.

4.1 Advanced very high resolution radiometer (AVHRR)

The AVHRR system is a five-channel imager radiometer, sensitive to portions of the visible, near infrared and thermal of the electromagnetic spectrum, by “cross track” imaging system (Kidwell, 1991).

In 1982 the Global Inventory and Monitoring Modeling Group (GIMMS) of the National Aeronautics and Space Administration (NASA) dedicated to multitemporal vegetation studies using AVHRR/NOAA data. The main objective of the group was to evaluate the use of satellite data of low spatial resolution to provide information on the distribution and phenology of vegetation.

Although the spectral channels have been chosen to provide meteorological, oceanographic and hydrological parameters, the system has characteristics that make it possible to study vegetation monitoring. Channel 1 corresponds to the visible region of the spectrum where there is the peak of radiation absorption by chlorophyll (0.67 *mm*), related to the photosynthetic activity of the vegetation. Channel 2 is in the infrared portion of the spectrum where the reflectance of this radiation by the vegetation is intense. Associates, channels 1 and 2 allow to infer about photosynthetically active foliar biomass in the forest community (Tucker et al., 1991).

The AVHRR, time series with the NDVI product, was used to calculate VCI (Kogan, 1995). According to Du et al. (2013) the climatic variation that impacts the vegetation will be evidenced by the VCI, thus exerting its potential in the monitoring of agricultural drought.

4.2 Tropical rainfall measuring mission (TRMM)

The TRMM (Kummerow et al., 1998) satellite was launched in 1997 by the National Aeronautics and Space Agency (NASA) and the National Space Development Agency of Japan (JAXA). The satellite was put into a near circular orbit of approximately 350 *km* height with a period of 92.5 minutes, characterizing a short period of translation. The objective of the TRMM satellite is to monitor precipitation in the tropical and subtropical regions of the terrestrial globe (Kummerow et al., 2000).

The TRMM 3B43 product consists of a 0.25° × 0.25° grid providing daily and three-hourly estimates that were calibrated with the support of observed monthly precipitation rates (Huffman et al., 2007). In this work, daily TRMM data covering Brazil's terrestrial surface will be aggregated to obtain monthly estimates of precipitation through the product TRMM 3B43. Time series (1983-2013) for each cell will be analyzed in order to derive the SPI for durations corresponding to one, three and six months, respectively. The main objective of the study will be to characterize, through the vegetation condition index (VCI) and the standardized precipitation index (SPI), detecting the agricultural drought events occurring in Brazil.

4.3 MSWEP

Beck et al. (2016) and Beck et al. (2017a,b) presented Multi-Source Weighted-Ensemble Precipitation (MSWEP) retrospective, that is a new fully global precipitation dataset (1979-2016) of high resolution with 3-hourly temporal and 0.25° or 0.1° global gridded precipitation, by merging gauge, satellite, and reanalysis data.

The MSWEP, whose temporal variability was determined based on several data products including TMPA 3B42 RT, is one of the most recent data set for climatic and environmental researches. Some scientific projects have been devoting effort to assess MSWEP precipitation products among them are. Alijanian et al. (2017) performing the evaluation of satellite rainfall climatology using CMORPH (NOAA CPC Morphing Technique), PERSIANN-CDR (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks- Climate Data Record), Tropical Rainfall Measuring Mission (TRMM) and MSWEP over Iran. These satellite rainfall estimates (SREs) were evaluated against gauge data based on different rainfall regimes over Iran. The evaluated SREs are Climate Prediction Center Morphing Technique, Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN). As results they showed that MSWEP, PERSIANN-CDR, and TRMM performed well to distinguish rain from no-rain condition.

On the other hand, Nair and Indu (2017) have assessed the quality of MSWEP over India, evaluating the performance of the newly released multi-satellite (MSWEP) product. The assessment was conducted with respect to the IMD-gauge-based rainfall for pre-monsoon, monsoon, and post-monsoon seasons at daily scale for a 35-year (1979-2013) period and presented that while the MSWEP was observed to perform well for daily rainfall, it suffered from poor detection capabilities for higher quantiles, making it unsuitable for the study of extremes.

In the same way, looking for new results and expanding the horizon, the main goal of the project approaching MSWEP in LACCOST is to assess precipitation products and their future use in monitoring extreme hydro-climatic changes over South America. This continent chosen as the study area to perform experiments, presents a large territory (about 17,840,000 square kilometers) and extremes climatic conditions, being home to the world's largest river (the Amazon) as well as the world's driest place (the Atacama Desert).

So, evaluating the MSWEP performance by comparing with TRMM, CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data), GPCC (Global Precipitation Climatology Centre) and a Global Network of Micrometeorological Tower Sites (Fluxnet), this research will be conducted to analyses data set ranging 1979 to the latest year, using Cross Correlation and Principal Component Analysis to compare and extract the information from these satellite rainfall estimatives.

4.4 Conclusion

In this work, we highlight master's projects that are under development in a postgraduate program in Geodetic Sciences and Technologies of Geoinformation at UFPE, Brazil. It is noteworthy that in all cases the background is topics related with environment using Brazil/South America as study case. Thereby it represents the importance to have a postgraduate program in geodesy for training human resources in this region of the country.

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