Haystack Observatory Analysis Center

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Abstract

Analysis activities at Haystack Observatory are directed at improving the accuracy of geodetic measurements, whether from VLBI, GNSS, SLR, or any other technique. In this article the analysis done in 2010 that contributes to technique improvement as a result of improved geophysical measurements, modeling, and analysis is reported. The focus was on reduction of the error produced by inaccurate correction of atmosphere effects. Analysis activities that were related to technology development are reported elsewhere in this volume.

1. Introduction

The research at Haystack Observatory that directly affects geophysical and geodetic results has historically been related to atmosphere effects, and that was the case in 2010. The thrust of that activity during the past year was to define a framework for meteorological data systems that will enable access to more accurate meteorological data for the individual geodetic techniques and will, at the same time, facilitate common meteorological calibration of the techniques.

While this framework, as currently conceived, is not dependent on significant new technology development, it will rely on implementation of the Monitor and Control Infrastructure that is an integral part of the VLBI2010 system.

2. The Role of the Meteorological Data System

The Earth's atmosphere affects geodetic results both through integrated effects, such as the additional delay due to water vapor, and by in situ effects, such as the response to temperature changes of the VLBI, SLR, or GNSS supporting structure. In addition to the importance of using the most accurate meteorological data for determining these effects for each geodetic technique, the accuracy of the overall geodetic system, as constituted in the GGOS project, will be enhanced by the use of consistent meteorological data. In the simplest case, for example for closely located systems, the same well-calibrated pressure sensor would be used for all of VLBI, SLR, and GNSS. In other cases, where different sensors must be used, for example when the temperature needed is inside a radome for one technique but outside for another co-located system, the relative calibration should be readily verifiable by easy access to both sets of measurements. Yet another requirement is for the measurements to be taken continuously in order to be available for performance monitoring and for calibrating effects that might have significant latency, such as structural deformation which may have a time lag of hours.

At the center of this framework is adoption of the concept that the meteorological data are observables with the same value as the delay observations themselves and with the same requirements for understanding the uncertainties and calibration.

In order to facilitate these objectives, the data from each meteorological ("met") sensor must be available remotely along with the position of the sensor in global coordinates. The data should include time, value, and sufficient information to assign an uncertainty that can be related to the uncertainties of the geodetic observables.

3. Model for the Met Sensor Data System

Because there may be several sensors of each meteorological quantity at a site, the data from each sensor should be accessible individually. One way to do this is to have the information for each sensor stored in a file with a descriptive name. One possibility is 'station_sensortype_index.txt'. The index would allow for multiple sensors at a site. An example would be westford_pressure_1.txt.

An example of the need for multiple sensors of the same type is the situation at VLBI sites with a radome. One (or more) temperatures inside the radome or embedded in the antenna support structure is needed for thermal deformation, while an outside temperature is needed for deformation of a co-located GPS structure. In the analysis process the appropriate sensor for each technique would be selected (and could be easily changed if necessary) by specifying it in a wrapper.

The data in the file might be:

First line:

```
% Name yr mm dd hh mm value sig cal_corrn uncert X Y Z
```

Then for each measurement:

```
w_p1 2009 12 11 23 05 1004.5 0.2 9.9 0.5 6378000 4577000 1200000
```

By providing the location of the sensor in geocentric coordinates each technique can make the correction to its antenna/telescope location since that is also well known in geocentric coordinates. Although this particular format would be highly redundant and inefficient in having quantities such as position and calibration repeated for each measurement, it serves to visualize the minimum information needed.

The data files should be stored both locally (at least for some period of time) and on a globally accessible server, such as cddis. Local access during and between observing sessions is necessary for station health and safety, such as remote monitoring of wind speed or temperature for unattended operation, while global longterm availability is needed for the data analysis.

4. Implementation

As an example of the value of complementary data sources, a comparison was made in 2005 of the meterological data at Westford obtained using the GSOS sensors, the Suominet met data, and a third set of instruments, called yoda, which were located 1.2 km away at the Haystack antenna. The GSOS instruments were the primary met sensors for the Westford site at the time. After adjusting the Suominet and yoda data to the height of the GSOS pressure sensor, it was clear that the GSOS data time tags were off by -1.5 hours. After correction the GSOS and Suominet data agreed to 0.1 hPa in mean with an RMS difference of 0.2 hPa. The results are shown in Figure 1.

Currently two sets of met sensors are operating at Westford: the Suominet sensors are still recording data from the site less than 1 km from the Westford antenna, and recently a new set of met sensors was installed near the Westford GPS and VLBI antennas. The Suominet data from the site designated SA01 are available almost continuously from 2001doy200 to the present. The Met3 data sequence began only last year but is continuous. The metadata for each site are not complete in the current data records since calibration and sensor position information are not included, but such information can be added after-the-fact.

As is true for many sites, Westford has a poor record of maintaining met sensors. Fortunately the availability of the Suominet data may help overcome that shortcoming at Westford. The use of alternative sources of met data is being implemented by the Goddard analysis group using only a simple height difference correction for the pressure. Hopefully the new way of storing and applying met data proposed here will become more widespread.

5. Outlook

Westford and the new VLBI2010 site at the Goddard Space Flight Center should serve as testbeds for the meteorological data system. In the next year the goal is to fill out the data fields for calibration and location and to develop, in cooperation with the analysts of all techniques, a better format.

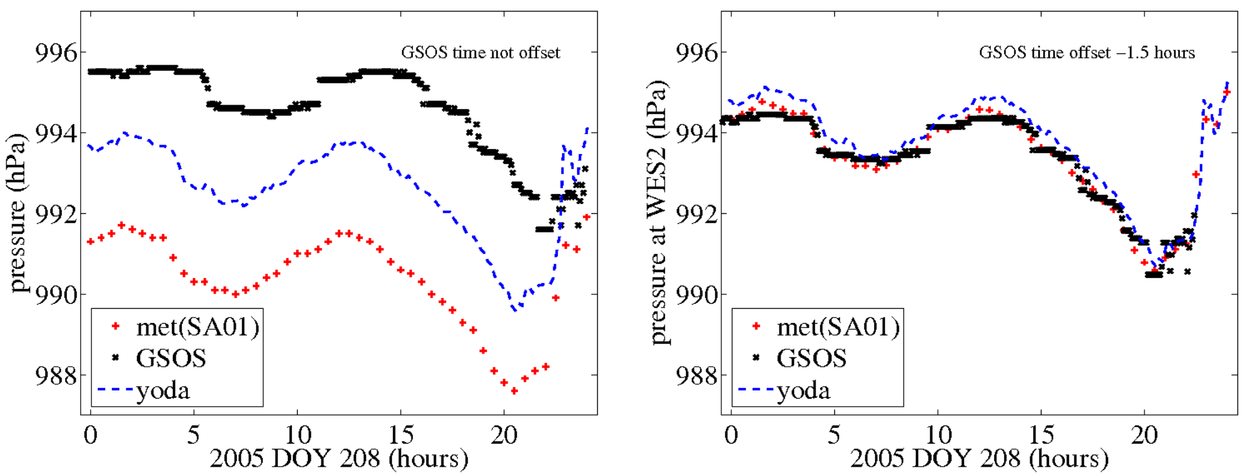

Figure 1. Data from three pressure sensors near the Westford antenna: a) before correction for height difference and for a time offset of 1.5 hours in the GSOS data and b) after correction.