The IVS Technology Development Center at the Onsala Space Observatory

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Abstract

In last year's report we presented a method for assessing the instrumental noise of a water vapor radiometer by using theory of atmospheric turbulence in order to separate the observed variability due to instrumental noise and atmospheric variability. We have applied this to the radiometer data observed with the two co-located radiometers, Astrid and Konrad, at the Onsala Space Observatory during CONT02 and CONT05.

1. Introduction

In last year's report [1] and in [2] we showed how atmospheric turbulence models can be used together with slant wet delays inferred from microwave radiometer observations in order to assess the atmospheric variability as well as the radiometer noise level. This is done by modeling the squared difference between two observed slant wet delays in different directions (i and j) as:

$$\left\langle \left(\frac{\hat{l}_i}{m_i} - \frac{\hat{l}_j}{m_j} \right)^2 \right\rangle = k^2 \left\langle \left(\frac{l_i}{m_i} - \frac{l_j}{m_j} \right)^2 \right\rangle \Bigg|_0 + \left(m_i^{-2} + m_j^{-2} \right) \cdot Var[B] \qquad (1)$$

where $\langle \ldots \rangle$ denotes expectation value; $\hat{l}_i$ is the slant wet delay measured by the radiometer in the direction i; m_i is the mapping function in the direction i; $\left\langle \left(\frac{l_i}{m_i} - \frac{l_j}{m_j} \right)^2 \right\rangle \Big|_0$ is the expectation value for the squared difference between the slant wet delays (mapped to zenith) from turbulence models [5]; k^2 is a constant describing the atmospheric variability; and $Var[B]$ is the variance of the radiometer noise. The constant k^2 is needed because the coefficients used in the turbulence model, from which $\left\langle \left(\frac{l_i}{m_i} - \frac{l_j}{m_j} \right)^2 \right\rangle \Big|_0$ is calculated (i.e. the turbulence constant C_n and the effective tropospheric height of turbulence h [5]), might vary. By using slant wet delay data from a radiometer, k^2 and $Var[B]$ can be estimated [2]. Using two co-located radiometers provides an opportunity to apply the method to both radiometers and to compare the results, in order to assess the accuracy of the method.

2. Results

During CONT02 (15–31 October 2002) and CONT05 (12–27 September 2005) two radiometers, Astrid [3] and Konrad [4], were operated simultaneously at the Onsala Space Observatory. The Konrad radiometer was slaved to the VLBI schedule, while the Astrid radiometer operated in a continuous sky-mapping mode. During CONT05 the azimuth drive of Astrid was broken so it was only scanning in elevation, while during CONT02 it moved both in azimuth and elevation. The retrieved values of k^2 and $Var[B]$ are shown in Figure 1 (CONT02) and Figure 2 (CONT05).

From the figures we note that for both CONT02 and CONT05 the noise level is lower for Konrad than for Astrid. One reason for this is the longer integration time used by Konrad (~10 s compared

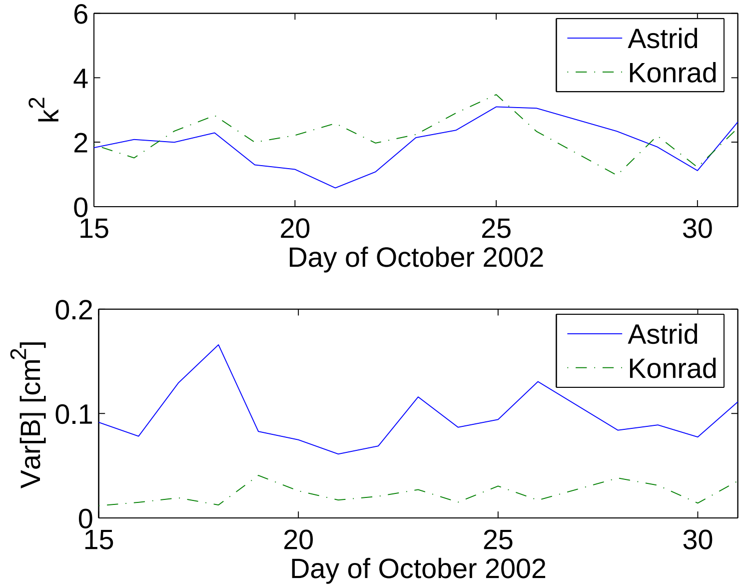

Figure 1. Plots of k^2 and the radiometer noise variance (see Equation 1) during CONT02, estimated from Astrid and Konrad radiometer data.

to ~1 s for Astrid). Another explanation is that Konrad is a newer radiometer, with a more stable and accurate data acquisition system. The data acquisition system of Astrid was upgraded in 2003 resulting in a lower noise level in CONT05 — 0.066 cm^2 compared to 0.098 cm^2 during CONT02 (the variance of the noise was on average 0.025 cm^2 for Konrad in both experiments).

The k^2 parameter describes how variable the atmosphere is. We expect that days with very variable sky conditions would have a high k^2 value, and days with stable sky conditions a low value of k^2. During CONT05 the sky conditions at Onsala Space Observatory were observed with a web-camera, hence we could test how k^2 correlated with sky conditions. Figure 3 shows snap-shot pictures of the sky at different times during September 20, a day with a high k^2 value. As can be seen, the sky conditions vary between clear sky and very cloudy. September 23 was a day with a low k^2 value, and snap-shot pictures of the sky during this day are shown in Figure 4. It appears that the sky was clear during the entire day.

3. Future plans

We will continue to evaluate the turbulence models and the instrumental noise of the radiometers by continuing to acquire simultaneous observations with the two co-located radiometers. We will investigate how the integration time of the radiometer affects the instrumental noise. Other instrumental effects, so far neglected in our investigations, will be studied. For example, the impact of the antenna beam-width of the two radiometers on the results (6° for Astrid and ~3° for Konrad). The correlation between the k^2 parameter and the variability of the sky conditions will also be studied. We plan to install a zenith-looking camera close to the two radiometers that will continuously monitor the sky.

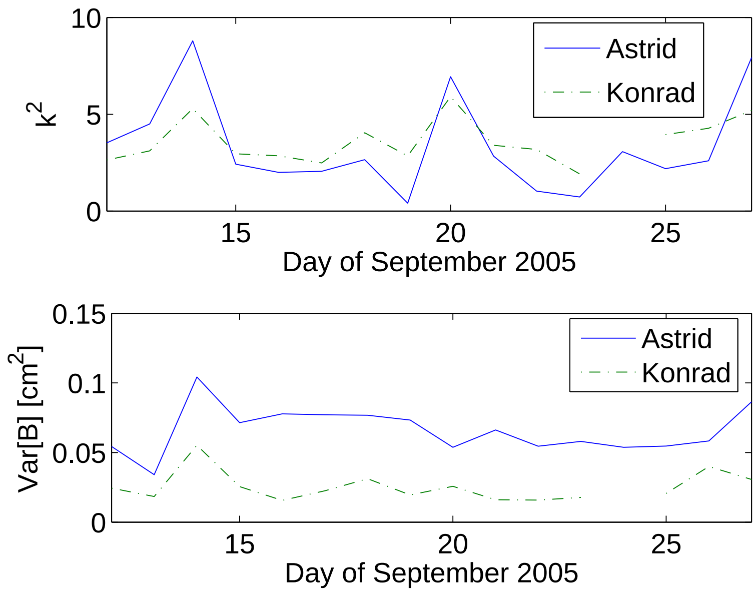

Figure 2. Plots of k^2 and the radiometer noise variance (see Equation 1) during CONT05, estimated from Astrid and Konrad radiometer data.

References

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[5] Treuhaft, R. N., and G. E. Lanyi, The effect of the dynamic wet troposphere on radio interferometric measurements, *Radio Science*, vol. 22, pp. 251–265, 1987.

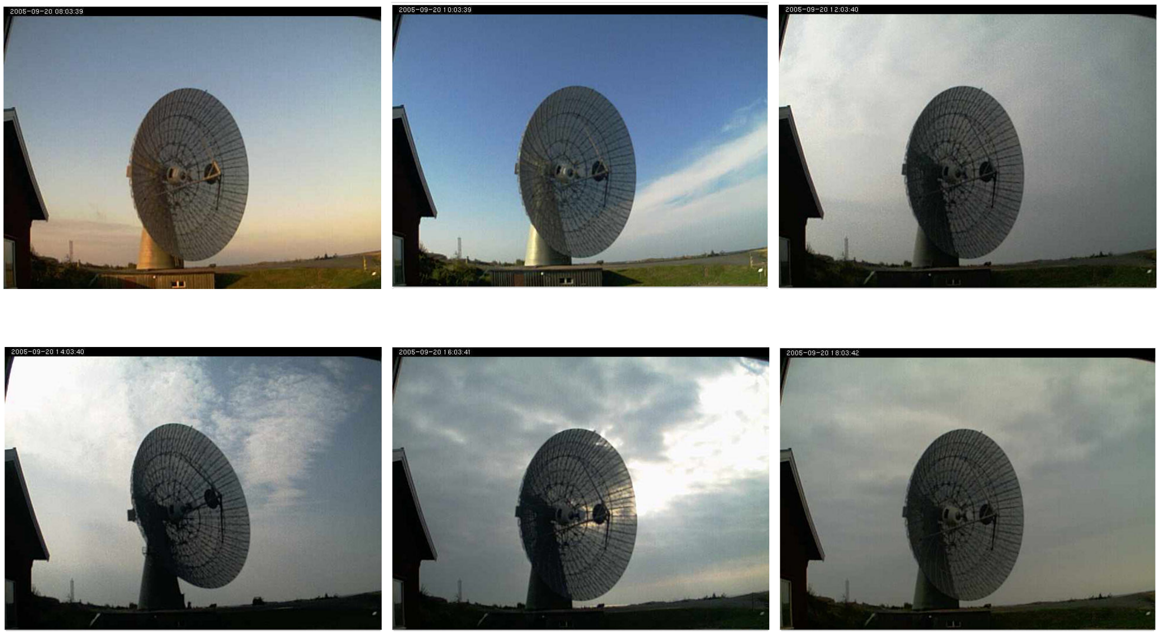

Figure 3. Snap-shot pictures of the sky at Onsala Space Observatory, during September 20 2005, at 8:00, 10:00, 12:00, 14:00, 16:00, and 18:00 local time (UTC+2 hr).

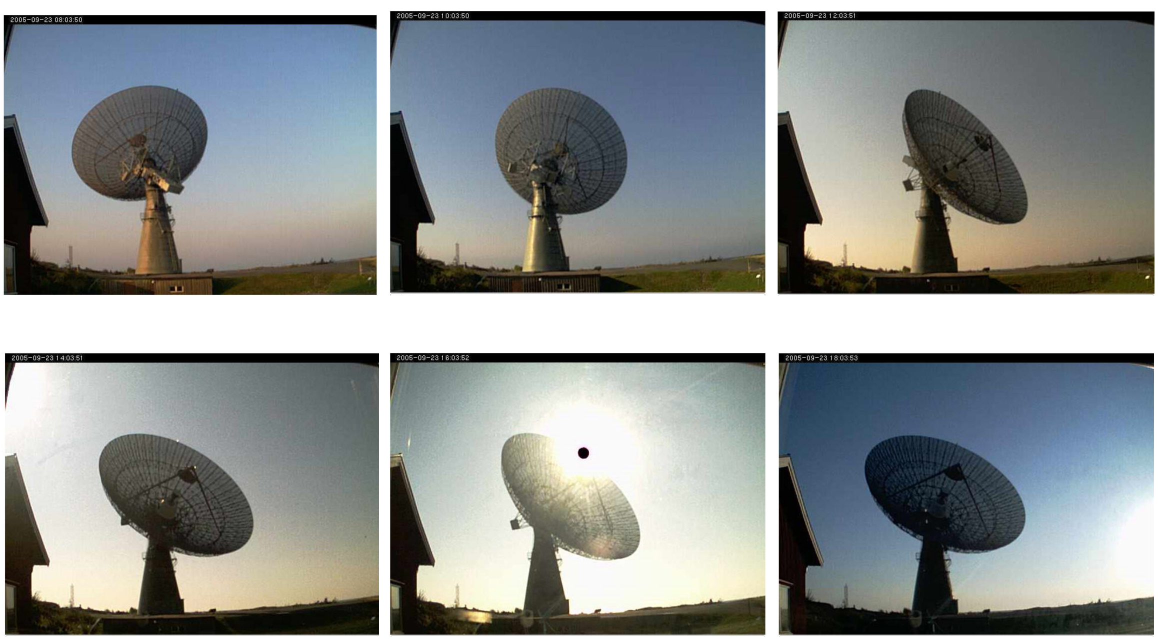

Figure 4. Snap-shot pictures of the sky at Onsala Space Observatory, during September 23 2005, at 8:00, 10:00, 12:00, 14:00, 16:00, and 18:00 local time (UTC+2 hr).