Optimal configuration of a far infrared radiometer based on information content
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Introduction

Data assimilation optimally combines numerical weather predictions (NWP) and large amounts of observations to provide the best estimate of the state of the atmosphere. In this context, a large part of the observations comes from satellite radiiances primarily in the mid-infrared (M-IR), from sensors such as AIRS and IASI. However, the M-IR constitutes only half of the Earth’s emitted radiance, the other half being the far infrared (F-IR), ranging from 15 to 1000 μm. Recently, a number of theoretical studies have shown the added-value of F-IR observations for remote sensing of water vapor and clouds, especially in dry and cold regions for already existing instruments. For this study, we consider a synthetic F-IR radiometer and we will discuss the optimal configuration with respect to its spectral resolution and the noise needed with information content calculations. Also, the added-value of F-IR radiometry, with the analysis error, in polar regions is shown alone and in complement to M-IR measurements with the instrument AIRS.

Objectives

To determine the added-value of assimilating F-IR radiiances in NWP systems
- Explore the trade-off between spectral and radiometric resolution for a radiometer in the F-IR (15 to 1000 μm)
- Quantify the added information brought in by F-IR measurements alone and when added to those in the M-IR in polar regions

Theory and instruments

Data assimilation

Observations (y)

Model F

Analysis (s)

Background state (x)

- The humidity Jacobian (H) is obtained by finite difference taken around a background state, which is taken from a radiosonde profile at Eureka, Canada.
- B is the background error covariance matrix, which is the stationary components of the background term in the ECM system
- Degrees of freedom per signal (DFS)

DFS = tr(HB) (HBH^T + R)^-1

= the added-value of a set of observations

F-IR Radiometer

- Synthetic spaceborne F-IR radiometer
- Measures radiation in the F-IR with a spectral coverage of 16.5-1000 μm
- Fixed detector noise of 0.01 W/m^2 sr
- Performance of Jacobian’s
- Bandwidth configuration

Sensitivity to sensor noise

- Stand-alone, F-IR measurements reduces the analysis error between 700-200 hPa
- When assimilated on top of AIRS, for the target NER, the principal gain is between 350-200 hPa

Conclusions

- The position and width of the bands have a big impact on the DFS
- We examine three configurations, which are equi-energetic, equi-bandwidth and equi-Jacobians peak, to optimize the instrument. The configuration with equi-bandwidth given the largest DFS, which is 2.63
- These variations are linked to the atmospheric transmittance since there are large variations in it in the F-IR region
- The positive peak is due to the inversion layer whereas the negative peak is due to the greenhouse effect

References

6. There is a gain when assimilated on top of AIRS of 6.4%, for the current NER
- Reducing the NER has a large impact, it increases the DFS by 15.5% when the F-IR measurements are assimilated on top of AIRS

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- We examine three configurations, which are equi-energetic, equi-bandwidth and equi-Jacobians peak, to optimize the instrument. The configuration with equi-bandwidth given the largest DFS, which is 2.63
- Results show that measurements in the F-IR over broader bands increases the SNR and results in a gain of information content, up to 25 bands
- There is a gain in DFS of 15.5% when radiation measurements in the F-IR are assimilated on top of AIRS for the target NER

DFS Analysis of various configurations

Figure 5: DFS as a function of the number of bands assimilated for the F-IR radiometer for the three different configurations. The dashed lines represent where the maximum DFS is for each configuration.

Sensitivity to sensor noise

- Only a few bands (6-11) are needed to obtain most of the information

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- Results show that measurements in the F-IR over broader bands increases the SNR and results in a gain of information content, up to 25 bands
- There is a gain in DFS of 15.5% when radiation measurements in the F-IR are assimilated on top of AIRS for the target NER