Retrieval of atmospheric parameters at a vertical and horizontal kilometric resolution using an infrared tomographic imager combining nadir and limb views

E. Pequignot¹, JL. Vergely², S. Ferron², A. Hauchecorne³, F. Montmessin³, JL. Bertaux³

¹CNES, ²ACRI-ST, ³LATMOS

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Motivations

- Is hyperspectral sounding the only way to get relevant information on the vertical?
- New meteorological models will take into account perturbations at a kilometre scale on the vertical and horizontal. They need to be validated using independent data.
- Water vapour spatial and temporal variability
Tomographic acquisition

Backward limb

Forward limb

Vsat

nadir

ground
WINTI instrument characteristics
(Wide field INfrared Tomographic Imager)

Line-Of-Sight Network (in the orbital plan, along track)

• One scanning along track (Backward limb, "Nadir", Forward limb) every 0.4s
• 100 Line-Of-Sight (LOS) for each scanning
• Nadir point horizontal sampling on-ground = 3 km (LEO orbit)
• Limb tangent point vertical sampling 2km
WINTI instrument characteristics
(Wide field INfrared Tomographic Imager)

- LEO orbit

- Detectors: IR 2D-array detectors with spatial resolution of 1km at nadir

- Spectral resolution of 30-200 cm\(^{-1}\) depending on spectral bands (this is compatible with current imager specifications)

- Typical NedT@280K = 0.05 K

- Spectral bands
  - 10-20 IR bands for temperature and water vapour sounding
  - 1-3 IR bands for the inversion of each atmospheric gas
Approach: atmospheric states

- 3 atmospheric states have been simulated
  - "Gurvich": anisotropic (stable and stratified atmosphere)
    - Temperature anomaly field ($\delta T$): 
      
      \[-10 \text{ K} < \delta T < 10 \text{ K}\]
  
  - "Gaussian": isotropic (unstable atmosphere) – typical structure size 3km
    - Temperature ($\delta T$) or $H_2O$ ($\delta H_2O$) anomaly fields.
      
      \[-10 \text{ K} < \delta T < 10 \text{ K} \quad (\sigma_T=3 \text{ K})\]
      
      \[-0.8 < \delta H_2O / H_2O < 0.8 \quad (\sigma_{H2O}/H_2O=0.25)\]
  
  - "Meso-NH": realistic from Meso-NH model, Lomé-Niamey June 13th, 2006

- RTM: 4A + Noise
Approach: Inversion scheme

Classical Bayes theorem

d = data = radiances, m = geophysical parameters, g = forward model

\[
f_{\text{post}}(m/d) \propto L(d/m) f_{\text{prior}}(m)
\]

\[
f_{\text{post}}(m/d) \propto \exp \left( -\frac{1}{2} (d - g(m))^T C_d^{-1} (d - g(m)) - \frac{1}{2} (m - m_0)^T C_0^{-1} (m - m_0) \right)
\]

Cost function to be minimized

\[
C = \frac{1}{2} (d - g(m))^T C_d^{-1} (d - g(m)) + \frac{1}{2} (m - m_0)^T C_0^{-1} (m - m_0)
\]

Raphson-Newton method for convergence

Note: in the linear case

\[
G = \frac{\partial g(m)}{\partial m} = g
\]

\[
\hat{m} = m_0 + C_0 G^T (C_d + G C_0 G^T)^{-1} (d - G (m_0))
\]

Continuous formalism (Tarantola, Valette, 1982)
Results: temperature

Reference (temperature anomaly)

IASI like instrument with 3 km spatial resolution (continuous)

WINTI (broad bands tomographic imager)
Results: H₂O

Reference (humidity anomaly)

IASI like instrument with 3 km spatial resolution (continuous)

WINTI (broad bands tomographic imager)
Results: temperature and $\text{H}_2\text{O}$

Temperature

H$_2$O

IASI like instrument with 3 km spatial resolution (continuous)

WINTI (broad bands tomographic imager)
Results : CO ([2145-2195 cm\(^{-1}\)])
Conclusions

- Hyperspectral sounding is not the only way to get relevant information on the vertical

- A 15 bands imager with multiple angle observation along track from backward limb to forward limb provide an information on the vertical at least as valuable as hyperspectral sounders for temperature, humidity and trace gases

- Such an imager can also provide an horizontal resolution of 1km thanks to imagery. From instrument design & complexity point of view, it is much simpler than a spectro-imager

- Future works: potential of the tomographic approach in cloudy conditions (cloud mask, cloud top pressure, multiple layer clouds, information below the clouds,...)