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

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ITSC-19, March 2014, Jeju, South Korea

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.**

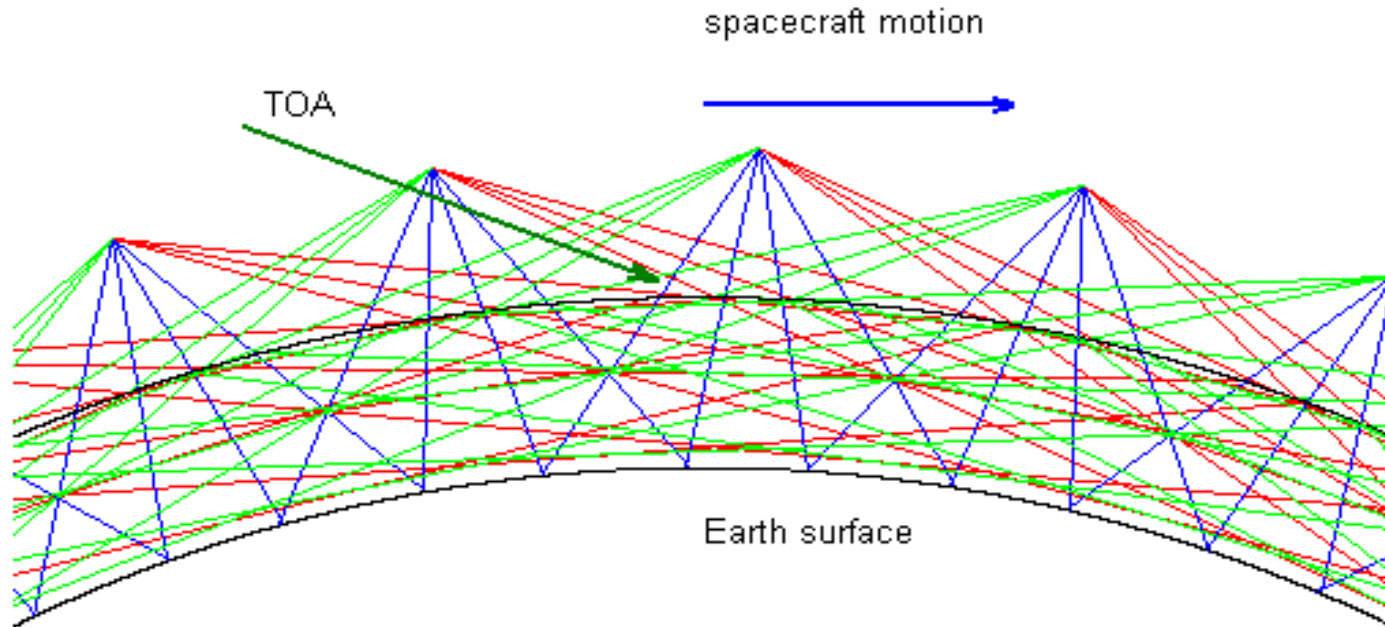- **Water vapour spatial and temporal variability**
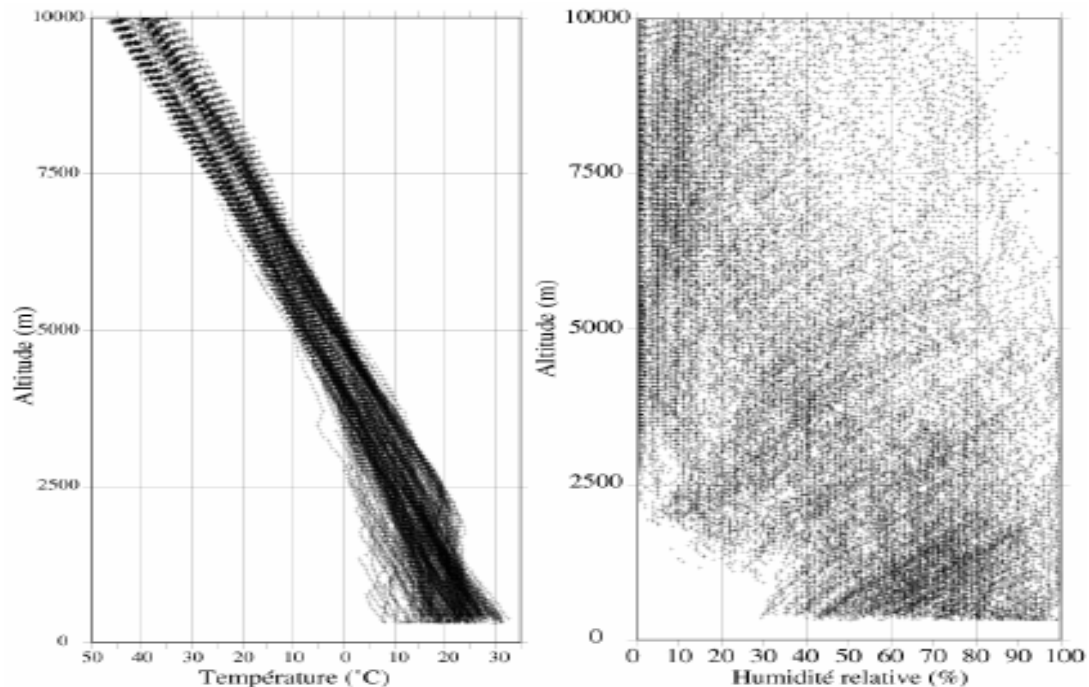
Tomographic acquisition
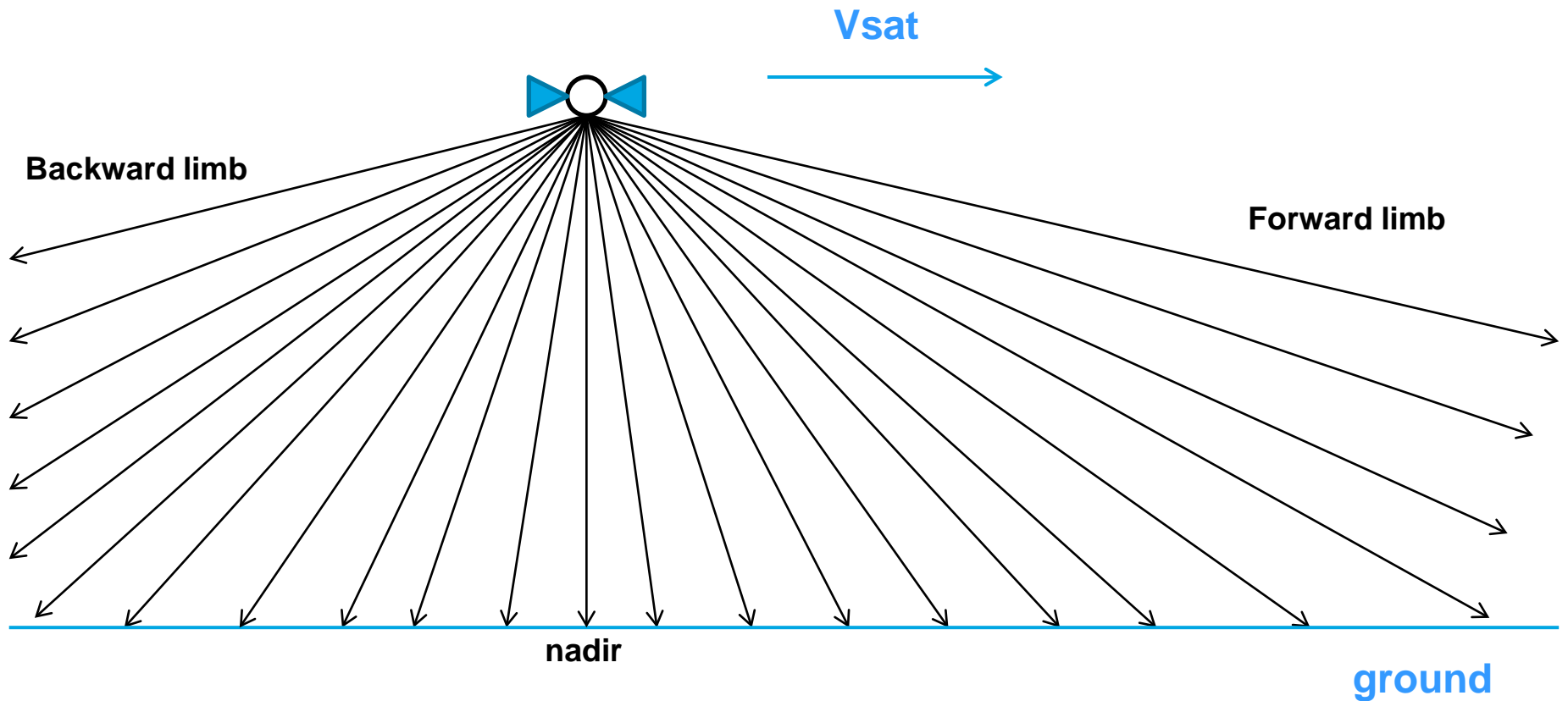
WINTI instrument characteristics
(**W**ide field **IN**frared **T**omographic **I**mager)

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
(<u>W</u>ide field <u>IN</u>frared <u>T</u>omographic <u>I</u>mager)

- **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

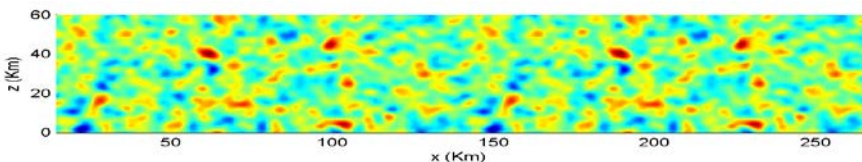- **3 atmospheric states have been simulated**
  - ✦ **"Gurvich" : anisotropic (stable and stratified atmosphere)**
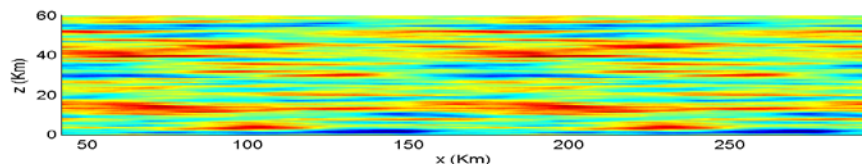
    Temperature anomaly field (δT)
    $-10\ K < \delta T < 10\ K$

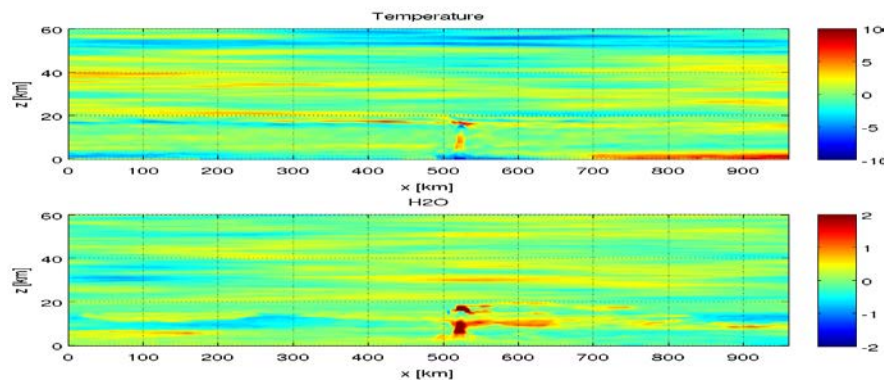 - ✦ **"Gaussian" : isotropic (unstable atmosphere) – typical structure size 3km**

    Temperature (δT) or H_2O (δH_2O) anomaly fields.
    $-10\ K < \delta T < 10\ K$ (σ_T=3 K)
    $-0.8 < \delta H_2O\ /H_2O < 0.8$ (σ_{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

$$f_{post}(m/d) \propto L(d/m) f_{prior}(m)$$

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

Cost function to be minimized

$$C = \frac{1}{2}(d - g(m))^T C_d^{-1}(d - g(m)) + \frac{1}{2}(m - m_0)^T C_0^{-1}(m - m_0)$$
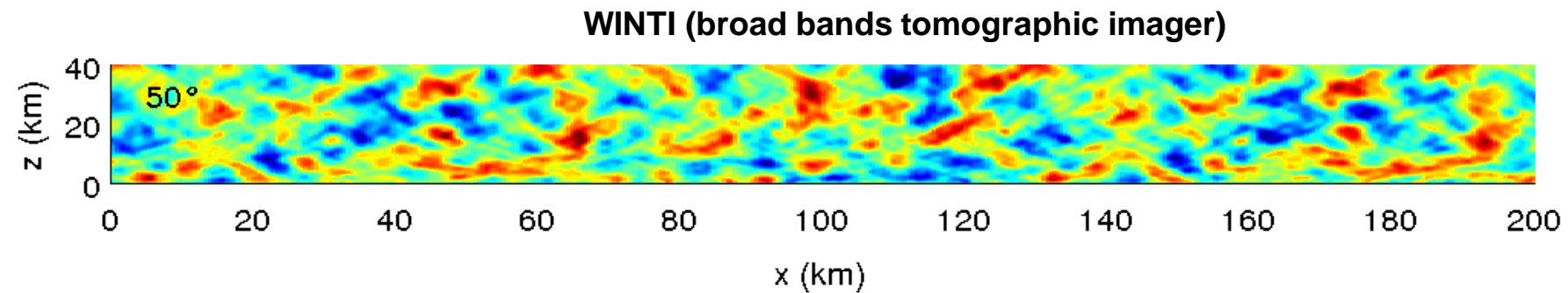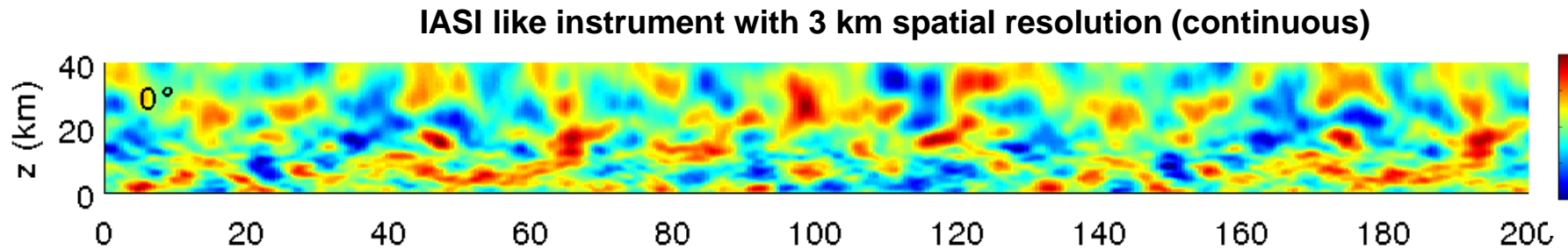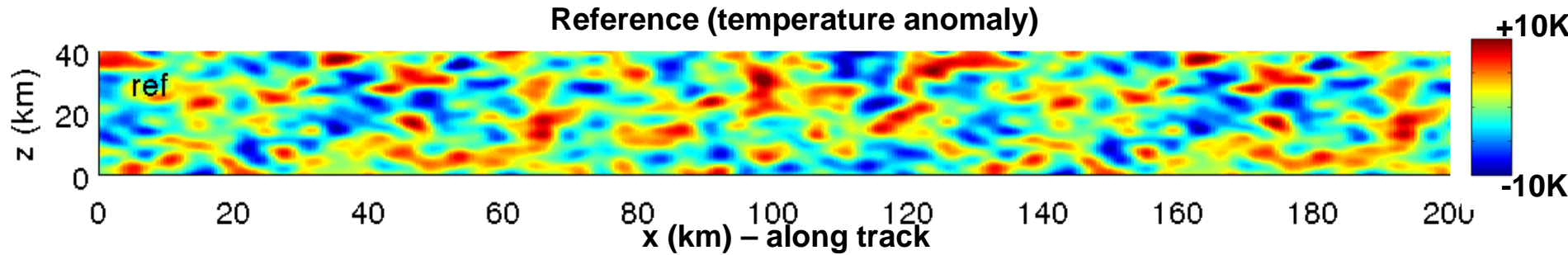
Raphson-Newton method for convergence

Note : in the linear case

$$G = \frac{\partial g(m)}{\partial m} = g$$

$$\tilde{m} = m_0 + C_0 G^T (C_d + G C_0 G^T)^{-1}(d - G(m_0))$$
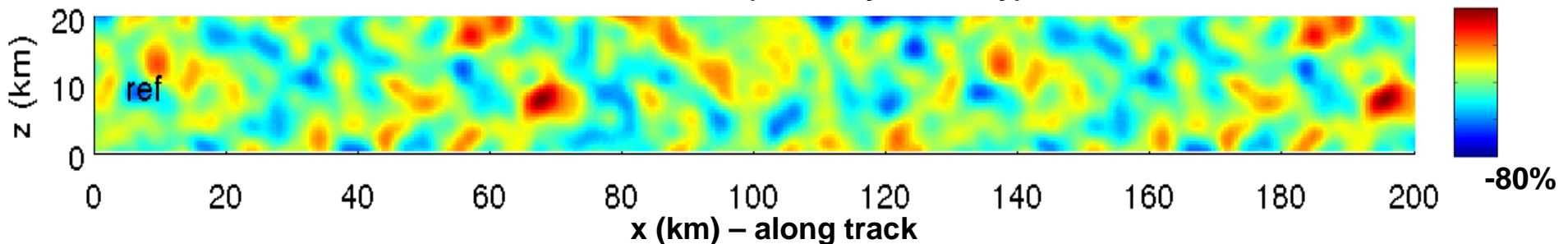
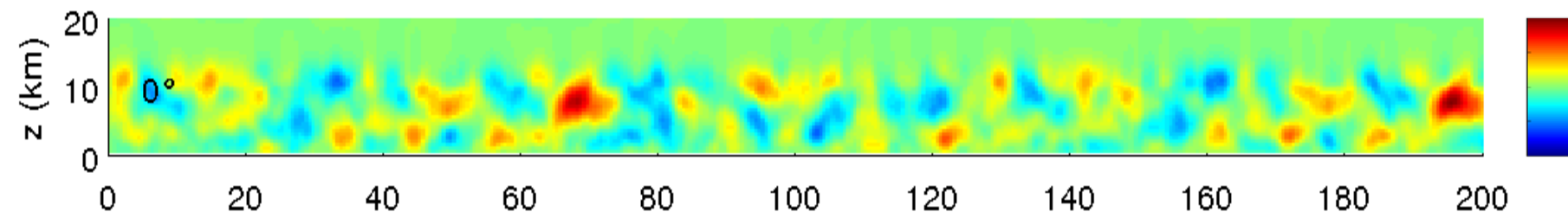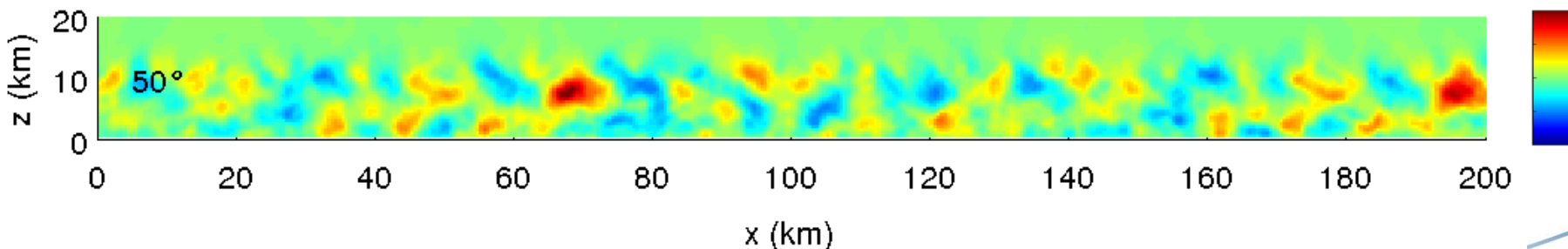**Continuous formalism (Tarantola, Valette, 1982)**

Results : temperature

Reference (temperature anomaly)

IASI like instrument with 3 km spatial resolution (continuous)

WINTI (broad bands tomographic imager)

Results : H$_2$O

Reference (humidity anomaly)

x (km) – along track

IASI like instrument with 3 km spatial resolution (continuous)

WINTI (broad bands tomographic imager)

x (km)
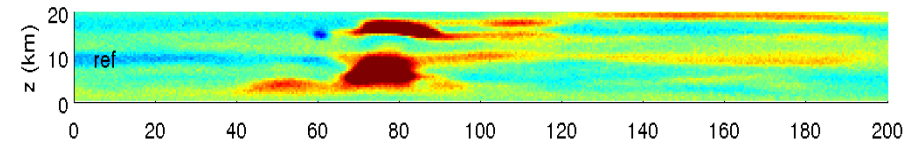
Results : temperature and H$_2$0

Temperature

H$_2$O

Reference
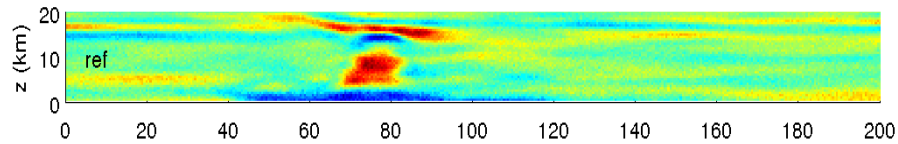
IASI like instrument with 3 km spatial resolution (continuous)
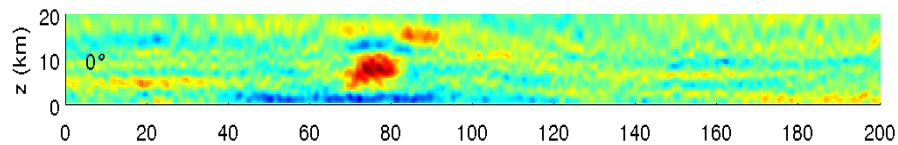
WINTI (broad bands tomographic imager)

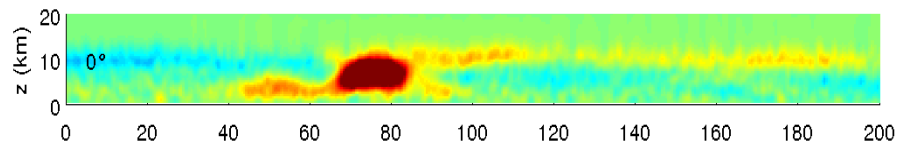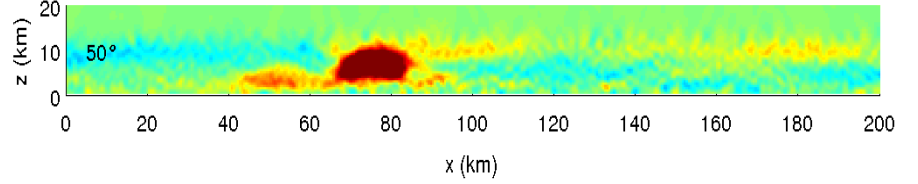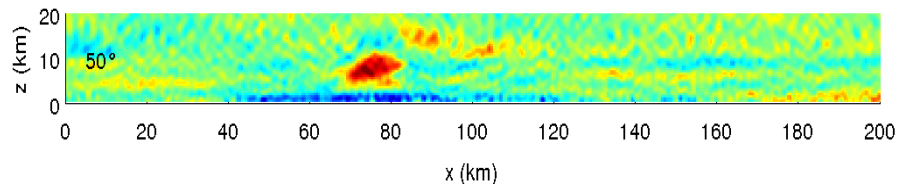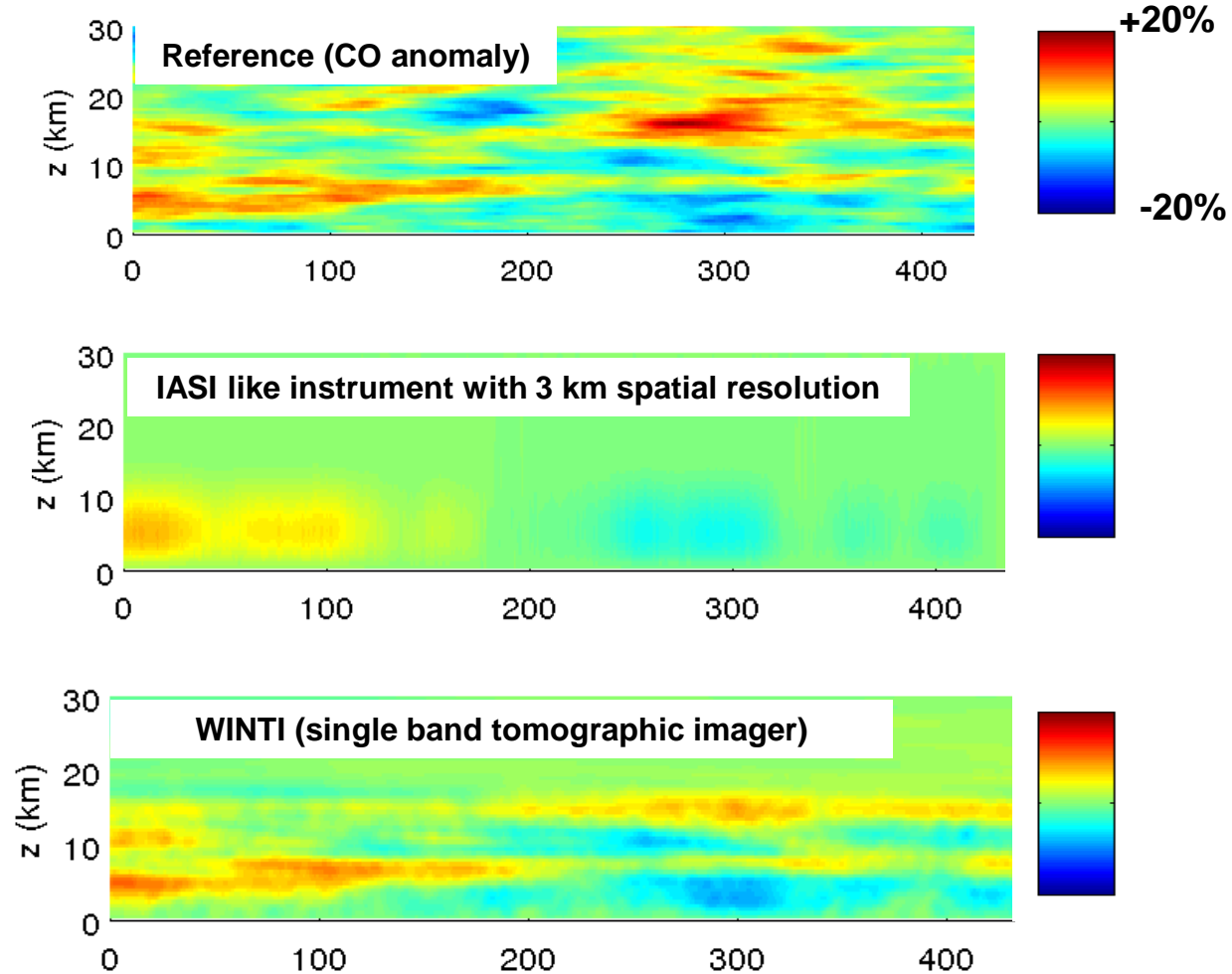# Results : CO ([2145-2195 cm^{-1}])

Reference (CO anomaly)

IASI like instrument with 3 km spatial resolution

WINTI (single band tomographic imager)

+20%

-20%

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,…)