# Joint Temperature, Humidity, and Sea Surface Temperature Retrieval from IASI Sensor Data

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# Outline:

- **Metop - IASI**
- **Forward Model and Retrieval**
- **Results**
- **Summary and Outlook**

# Metop - IASI

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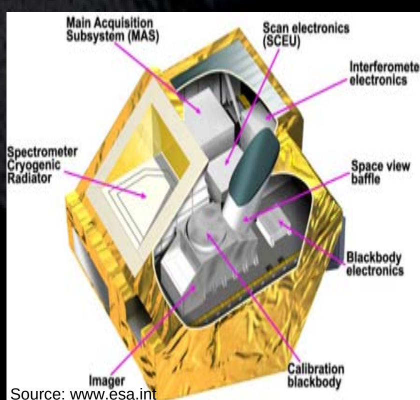
## instruments on board of metop


Source: www.space-technology.com/

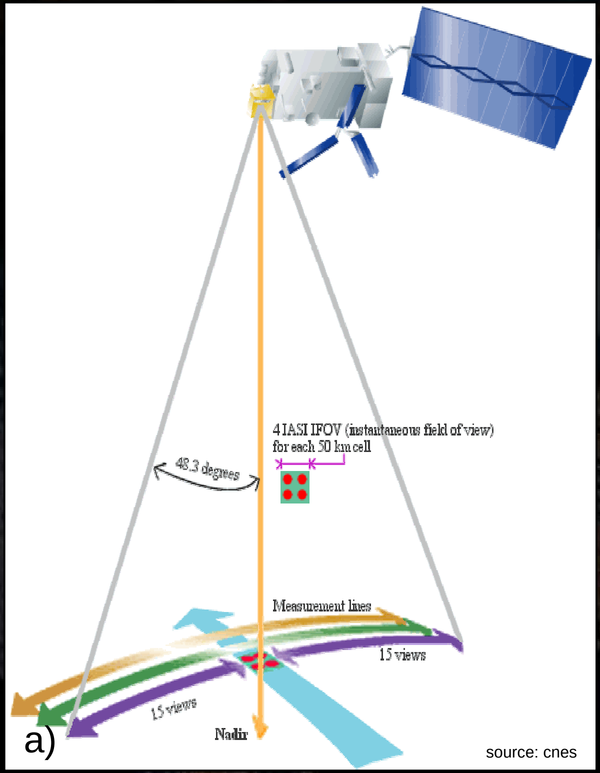
- **IASI**
- **AMSU – A**
- **ASCAT**
- **AVHRR**
- **GOME – 2**
- **GRAS**
- **HIRS**
- **MHS**



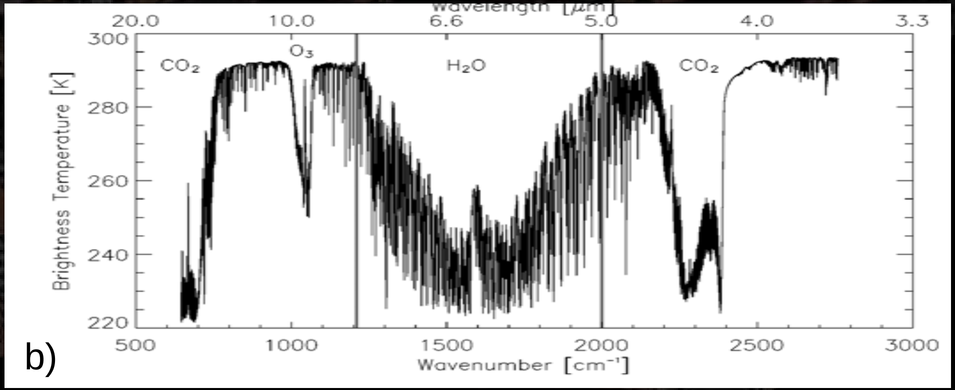
Source: www.esa.int

| | |
|---|---|
| **Spectral Range:** | **645 –2760 $cm^{-1}$ (15.5-3.6 µm)** |
| **Data Rate:** | **1.5 Mbits/s** |
| **Lifetime:** | **5 years** |
| **Power:** | **200 Watt** |
| **Mass:** | **210 kg** |
| **Size:** | **1.2m x 1.1m x 1.1m** |

## iasi – infrared atmospheric sounding interferometer




- 8461 channels, divided into 3 bands
- water vapor absorption: 1250 – 2000 $cm^{-1}$
- $C0_2$ absorption : near 645 and 2325 $cm^{-1}$
- additional absorption of $O_3$, $CH_4$, $N_2O$, CO, $SO_2$




a) IASI scanning procedure.

b) brightness temperature spectrum of IASI simulated by RTIASI

# Forward Model and Retrieval

## the forward model

**the fast radiative transfer model RTIASI:**

- simulation of the IASI measurements at 43 pressure levels between 0.1 and 1013.25 hPa
- Calculation of regression coefficients
- Calculation of level to space transmittances
- Solution of the radiative transfer equation to estimate
- Brightness Temperatures $\mathbf{T}_B$ (or radiances, respectively)

**tangent linear and adjoint model to calculate:**

- Jacobians for T, q, $O_3$, and SST – $\partial \mathbf{T}_B/\partial \mathbf{T}$, $\partial \mathbf{T}_B/\partial \ln \mathbf{q}$, $\partial \mathbf{T}_B/\partial \ln \mathbf{O}_3$, and $\partial \mathbf{T}_B/\partial SST$

# Forward Model and Retrieval

## connecting the forward model and the retrieval

- the forward model reads

$$\mathbf{y} = \mathbf{F}(\mathbf{x}) + \boldsymbol{\varepsilon}$$

  - **y**, **x**... measurement and state vector
  - **F**... forward model operator, Jacobian matrix **K** times **x**.
  - ε... measurement error vector
  - rows of Jacobian **K** can be interpreted as "weighting functions"

- the direct inversion reads

$$\mathbf{x}_r = \mathbf{K}^{-g}\mathbf{y}$$

  - ill-conditioned problem
  - over-determined for m>n

## the retrieval

- Optimal estimation
  - incorporates sensibly *a priori* knowledge
  - statistically optimal combination of unbiased measurements and prior data
- linearized iterative optimal estimation scheme

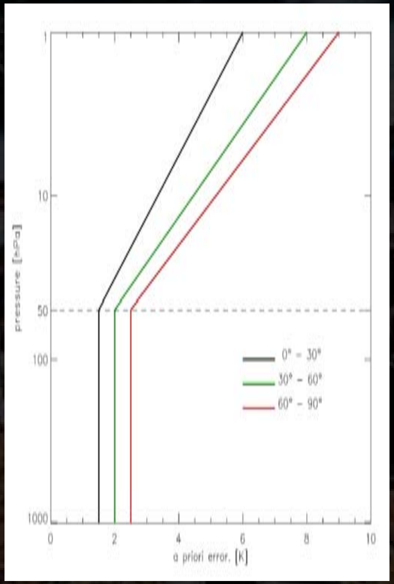
$$\mathbf{x}_{i+1} = \mathbf{x}_{ap} + \mathbf{S}_i \mathbf{K}_i^T \mathbf{S}_\varepsilon^{-1} \left[ (\mathbf{y} - \mathbf{y}_i) + \mathbf{K}_i \left( \mathbf{x}_i - \mathbf{x}_{ap} \right) \right]$$

$$\mathbf{S}_i = \left( \mathbf{K}_i^T \mathbf{S}_\varepsilon^{-1} \mathbf{K}_i + \mathbf{S}_{ap}^{-1} \right)^{-1}$$

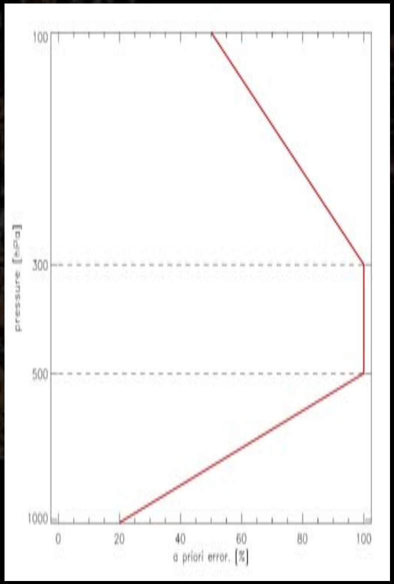
  - $\mathbf{S}_\varepsilon$... observation and forward modeling error covariance matrix
  - $\mathbf{S}_i$... retrieval error covariance matrix
  - $\mathbf{S}_{ap}$... *a priori* error covariance matrix
  - $\mathbf{x}_{ap}$... *a priori* profile
  - $\mathbf{x}_{i+1}$ ... *retrieved* profile (iteration *i* )

## the a priori error covariance matrix

- **for temperature:**
  off diagonal elements:
  - exponential drop off
  - 6 km correlation length



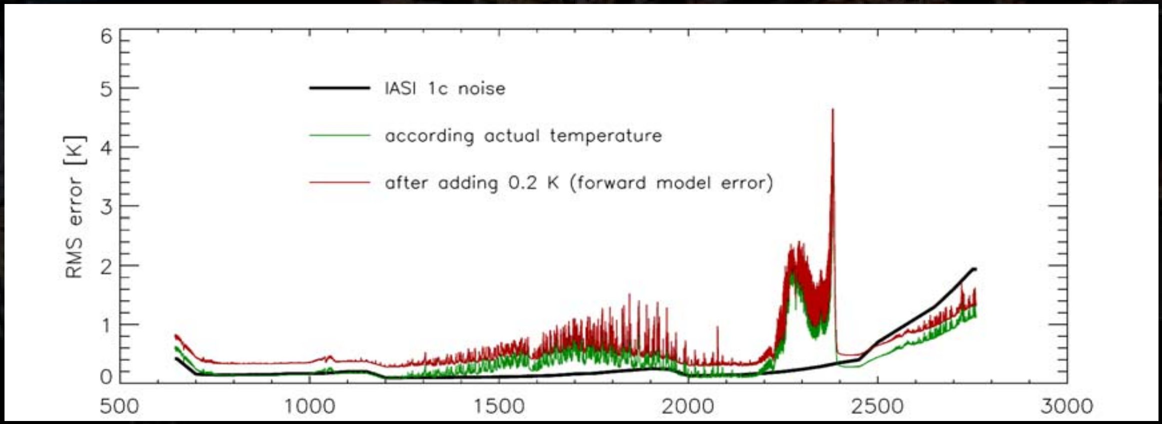

- **for humidity:**
  off diagonal elements:
  - exponential drop off
  - 3 km correlation length



## the measurement error covariance matrix

- **diagonal elements:**
  - IASI 1c noise levels
  - adapted to actual brightness temperature
  - + 0.2 K forward model error

- **off diagonal elements:**
  correlation of 3 nearest neighbor channels:
  1) - * 0.75
  2) - * 0.25
  3) - * 0.04

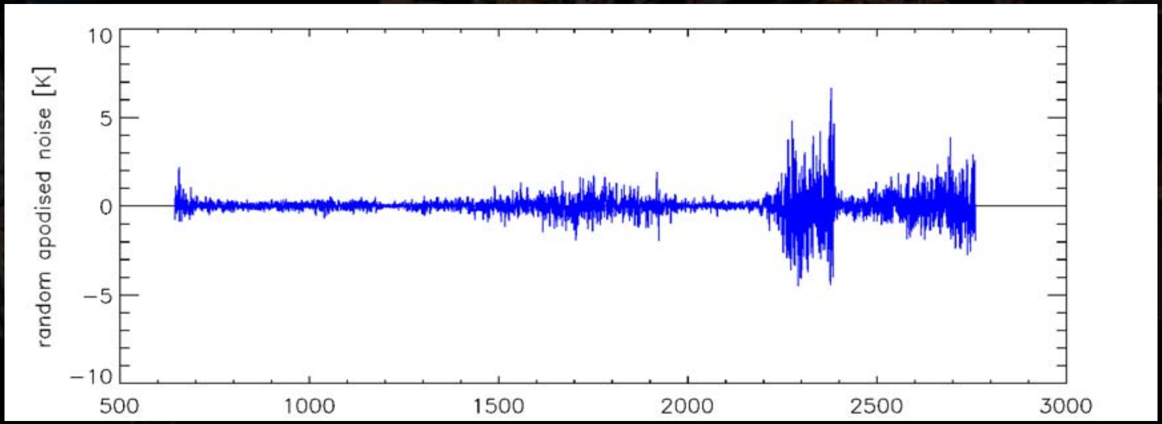


# Results

# Results

## the simulation of the measurement vector

- calculation  with the fast radiative transfer model RTIASI
- superposition of radiometric noise $\Delta\mathbf{y}$, consistent with $\mathbf{S}_{\varepsilon}$, according to iasi-1c noise levels to get quasi realistic data



# Results

## channel selection

- **removal of channels over 2500 cm-1 and of channels with trace gas absorption:**

975 – 1100 cm-1: $O_3$
1220 – 1370 cm-1: $CH_4$
2085 – 2200 cm-1: $CO$, $O_3$

→ 5781 channels

- **information content theory:**

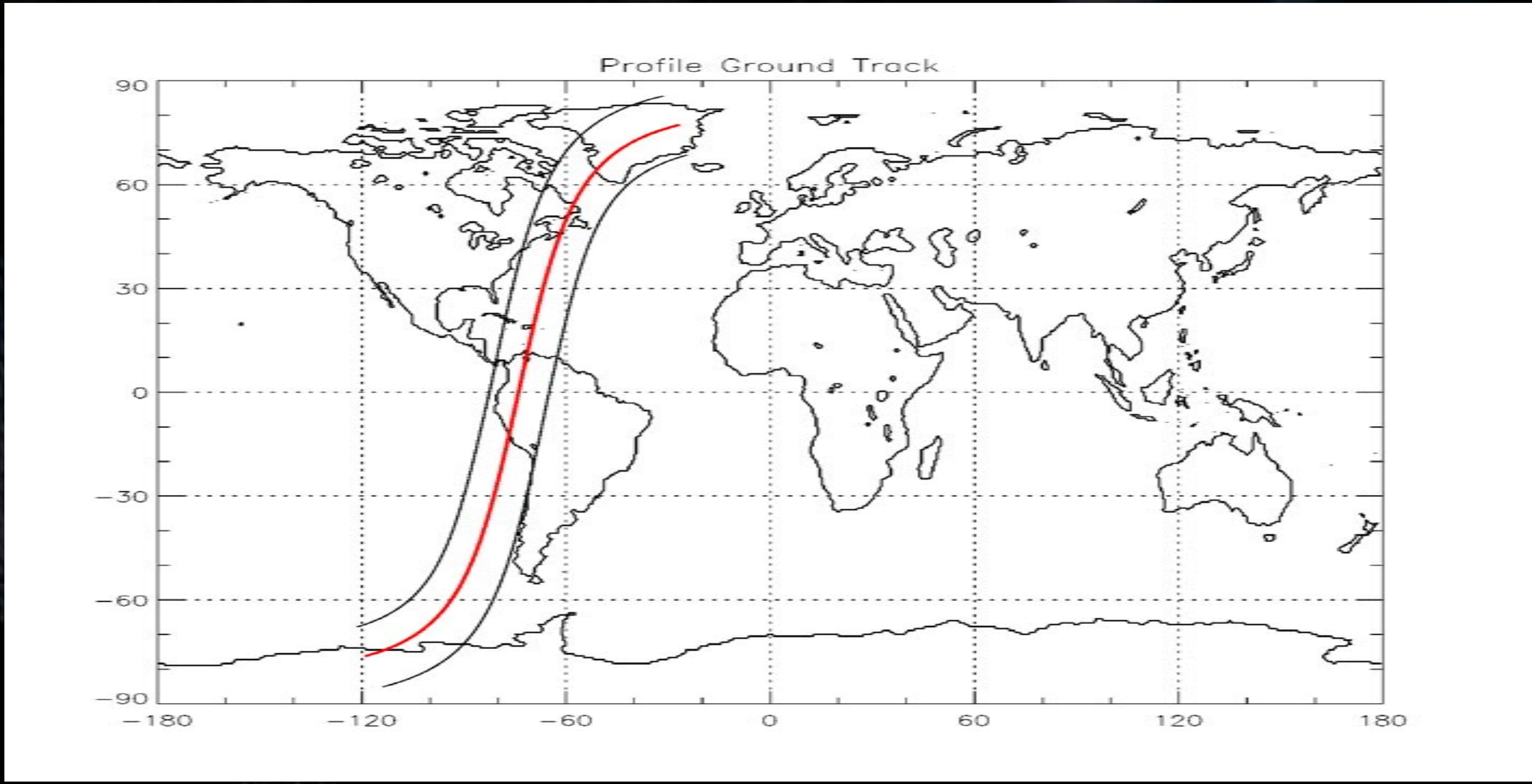
$$H = \frac{1}{2}\log\left|\mathbf{S}_{ap}\mathbf{S}^{-1}\right| \quad \text{with:} \quad \mathbf{S}_i = \left(\mathbf{K}_i^T\mathbf{S}_\varepsilon^{-1}\mathbf{K}_i + \mathbf{S}_{ap}^{-1}\right)^{-1}$$

- **maximum sensitivity approach:**

$$\mathbf{M} = \mathbf{S}_\varepsilon^{-\frac{1}{2}}\mathbf{K}$$

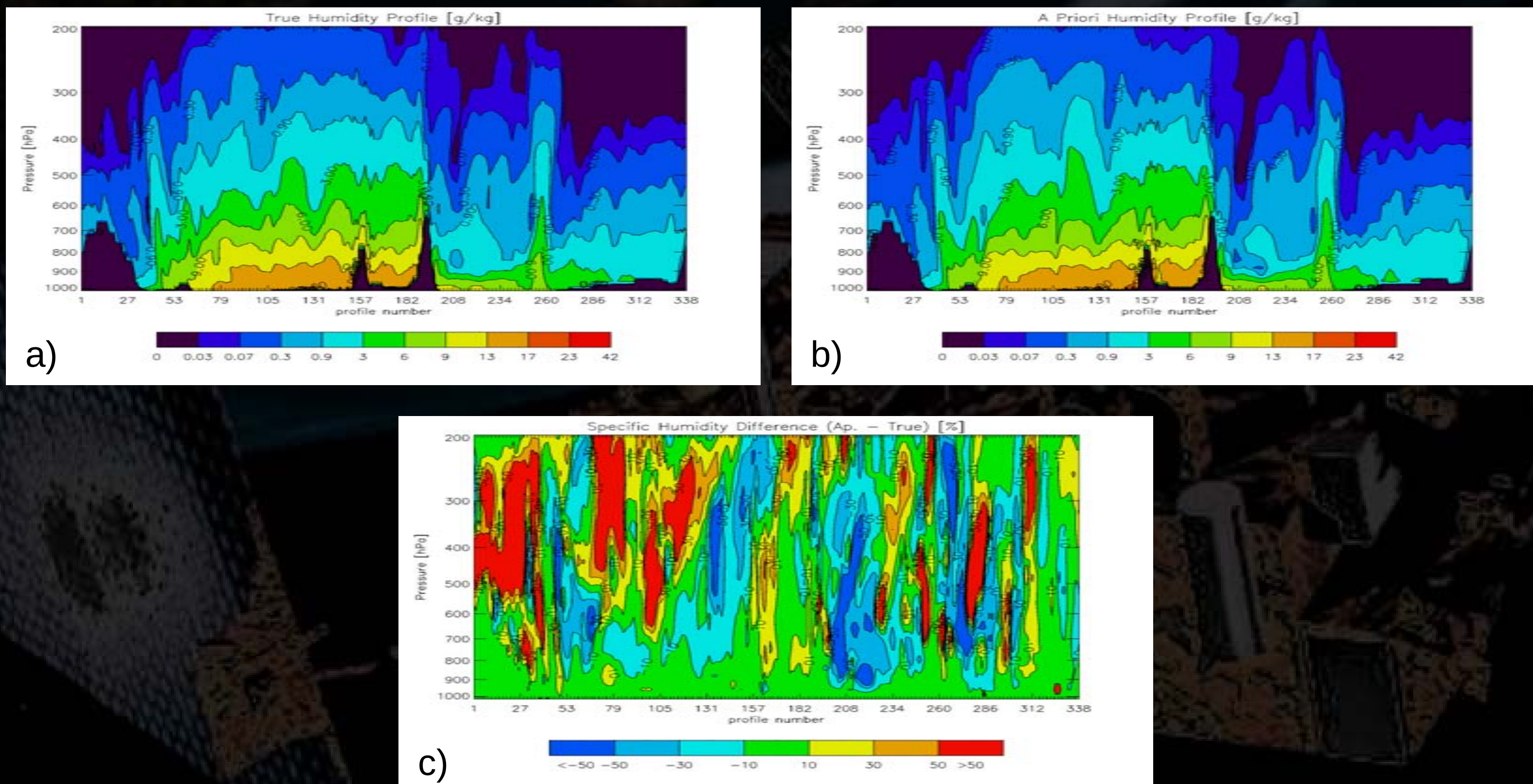
# Results

## simulation region



# Results

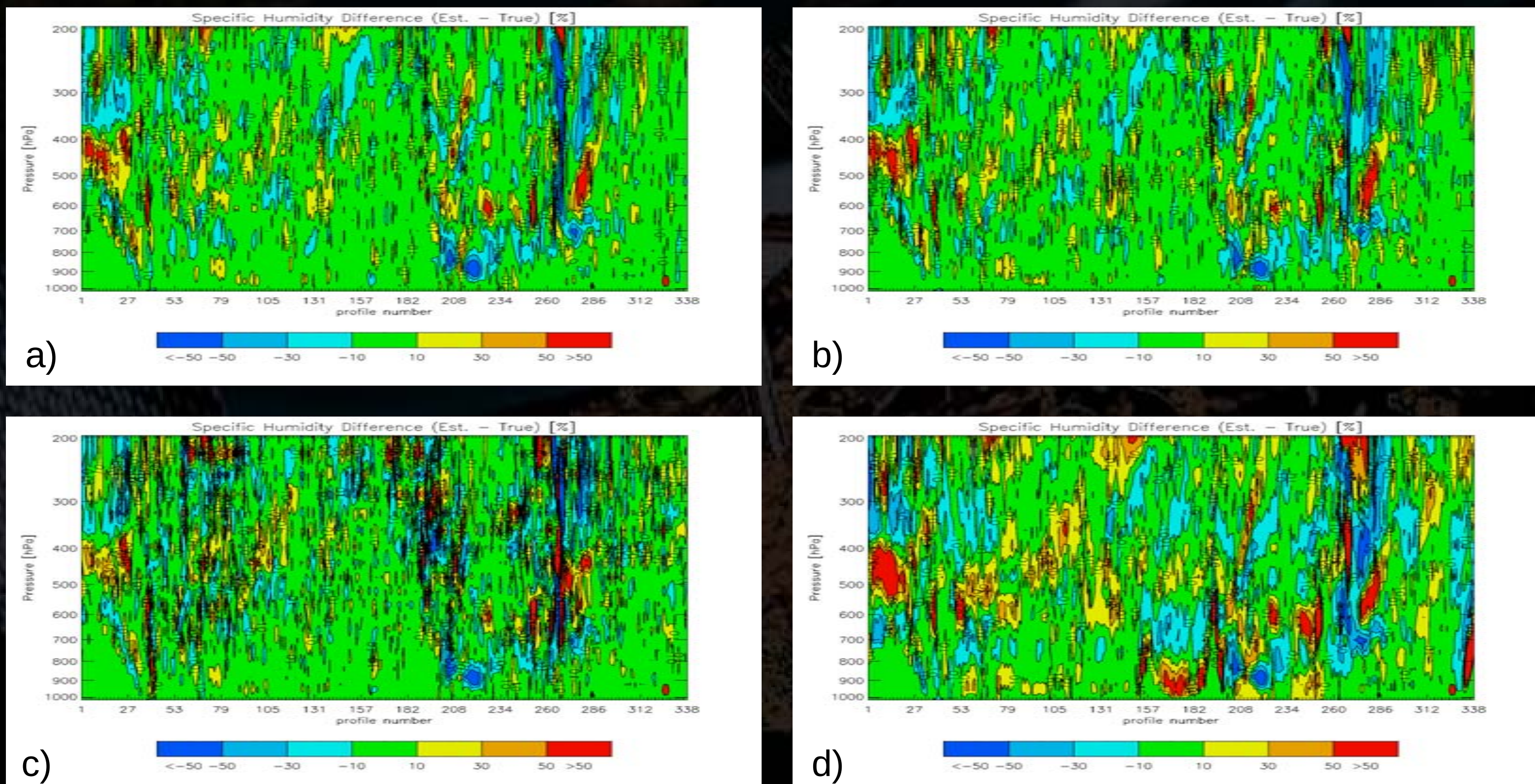
## humidity profiles




a) true humidity profile, b) a priori humidity profile, c) specific humidity difference (ap - true) [%].

# Results

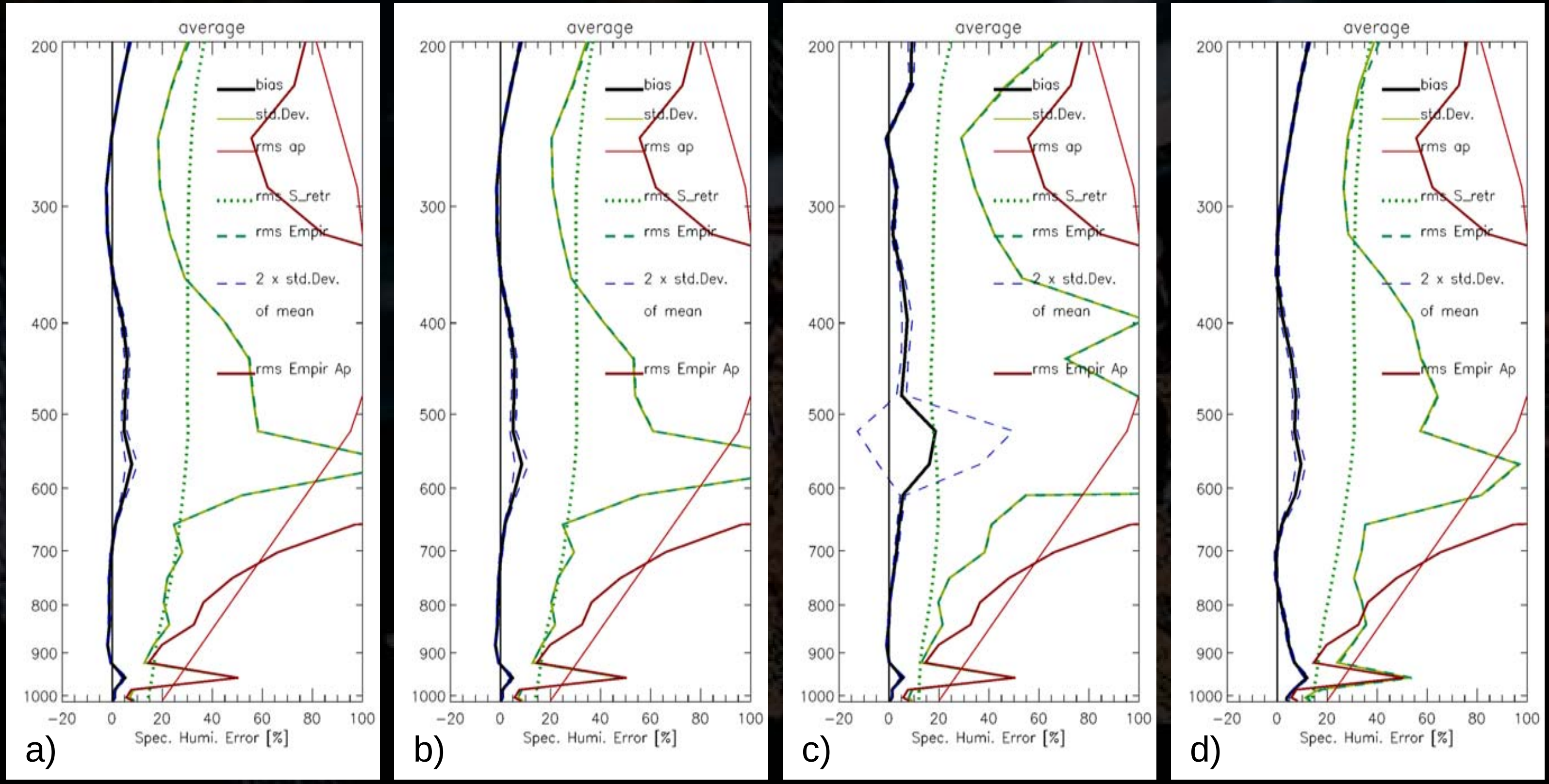
## humidity profiles – estimation comparison




a) IC – few channels, b) MS – few channels, c) IC – many channels, d) humidity only retrieval.

# Results

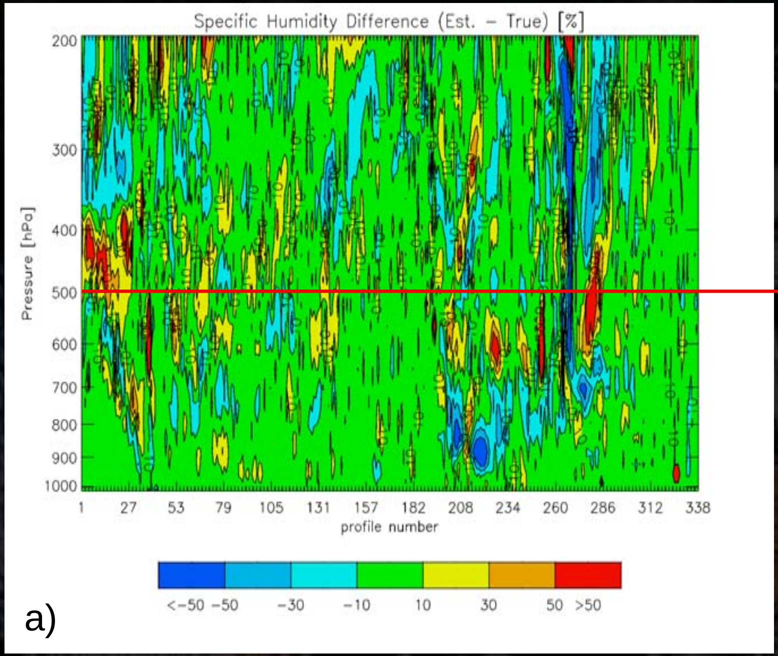
## humidity profiles – error analysis

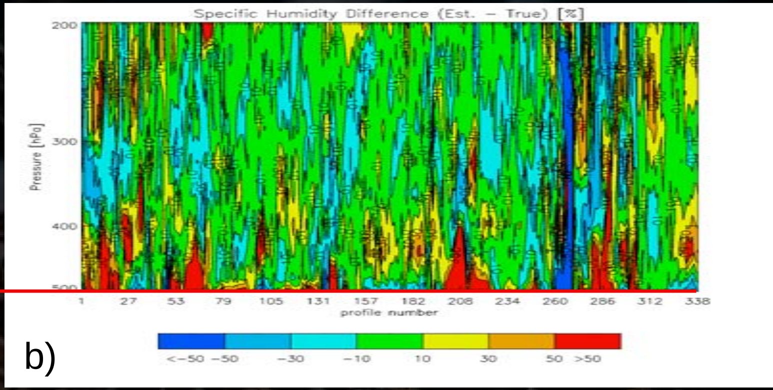



a) IC – few channels, b) MS – few channels, c) IC – many channels, d) humidity only retrieval.

# Results

## humidity profiles UTH - estimation comparison

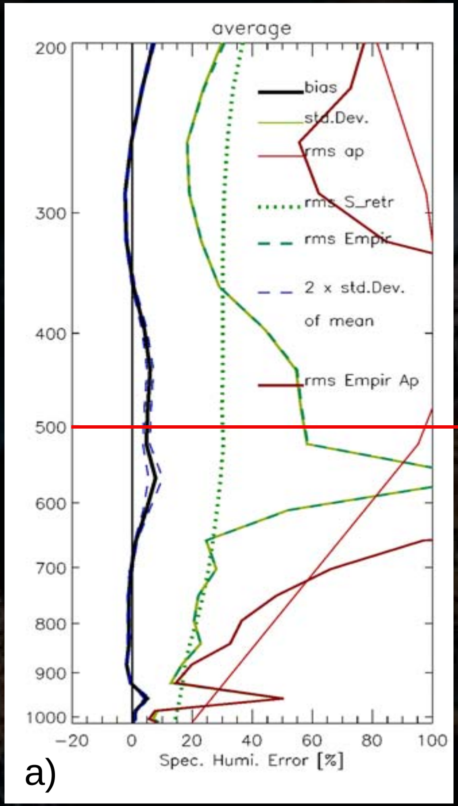


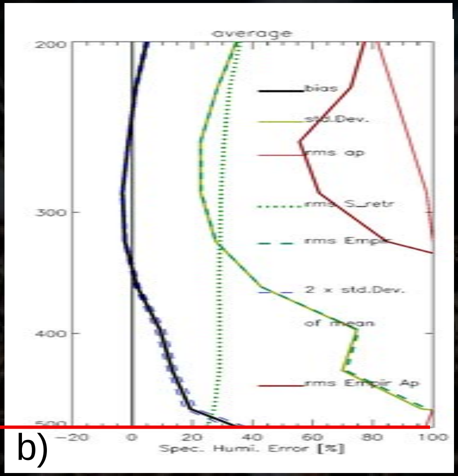




a) IC – few channels, b) UTH – IC – few channels.

# Results

## humidity profiles – UTH

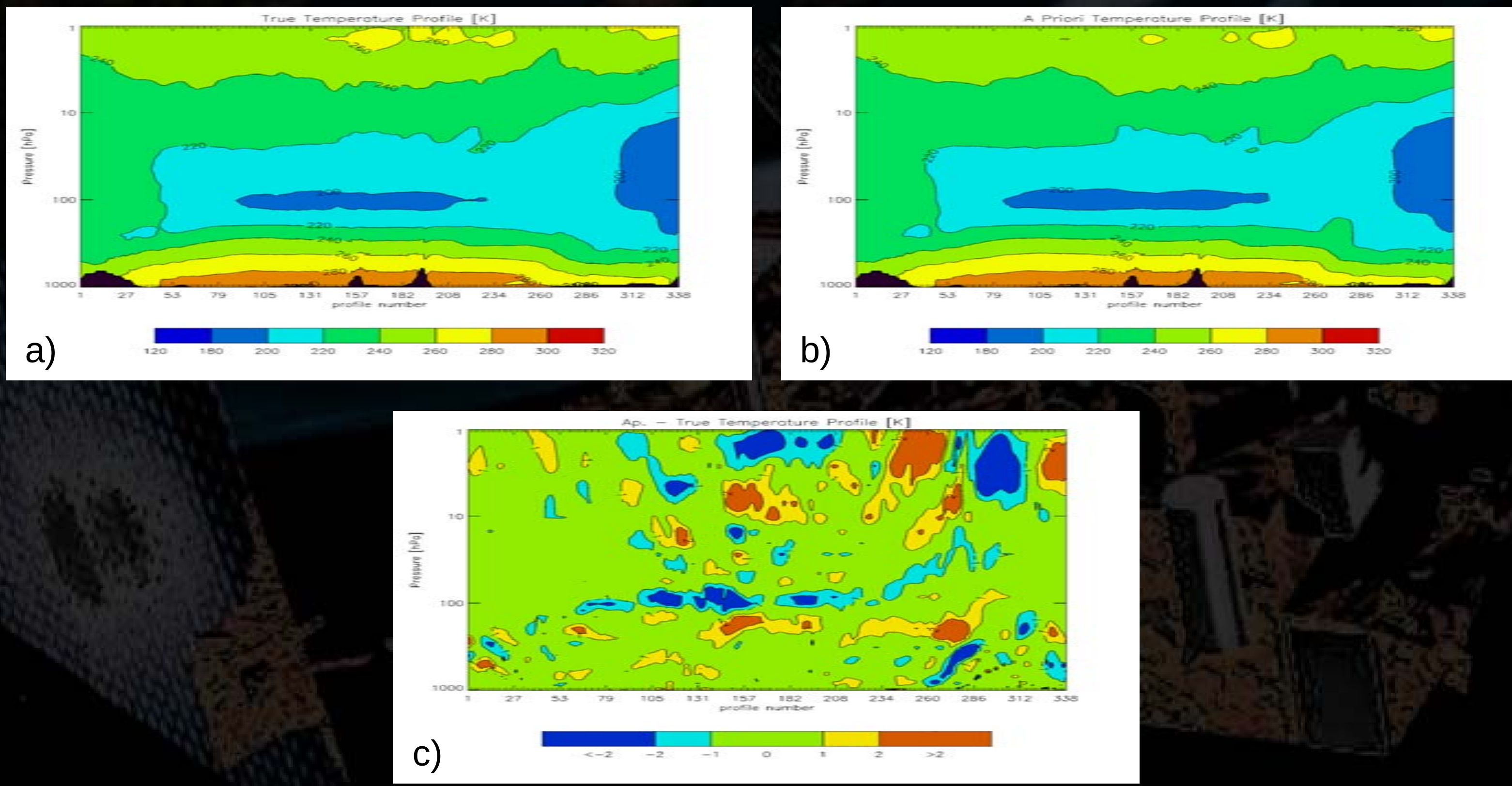



a) IC – few channels, b) UTH – IC – few channels.

# Results

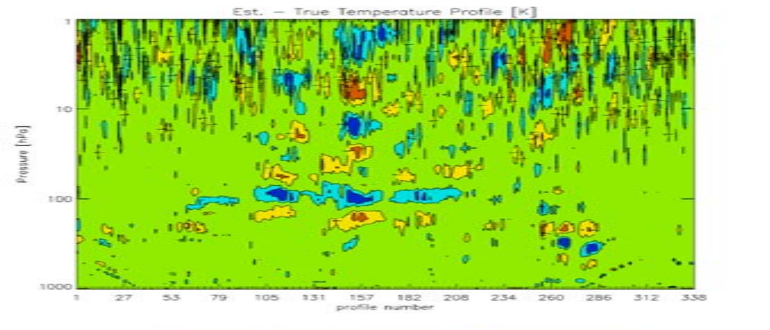
## temperature profiles



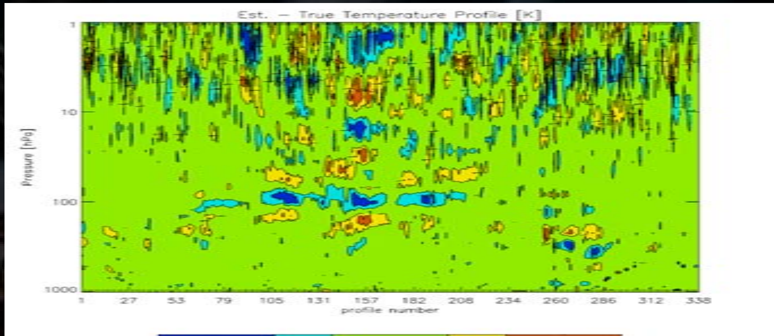

a) true temperature profile, b) a priori temperature profile, c) temperature difference (ap - true) [K].

# Results

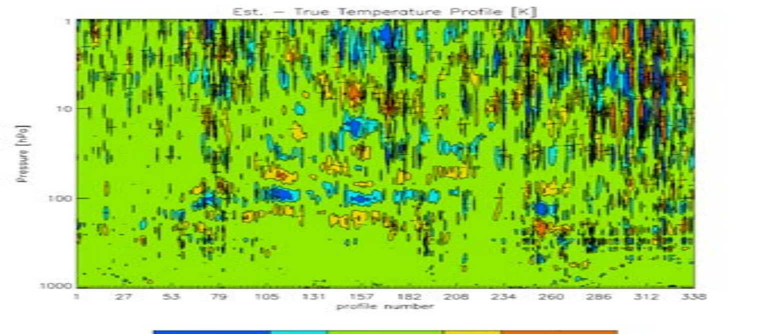
## temperature profiles - estimation comparison



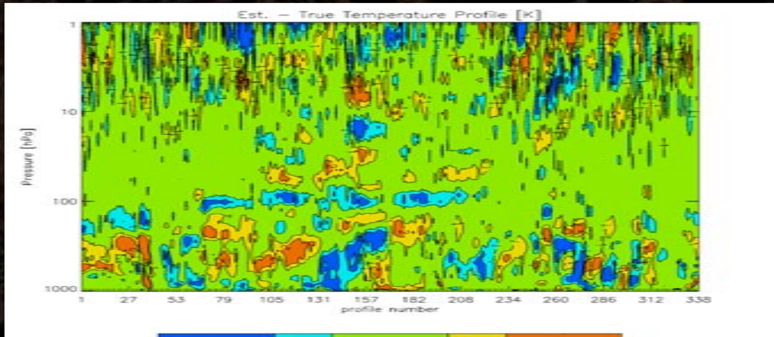

a)




b)




c)

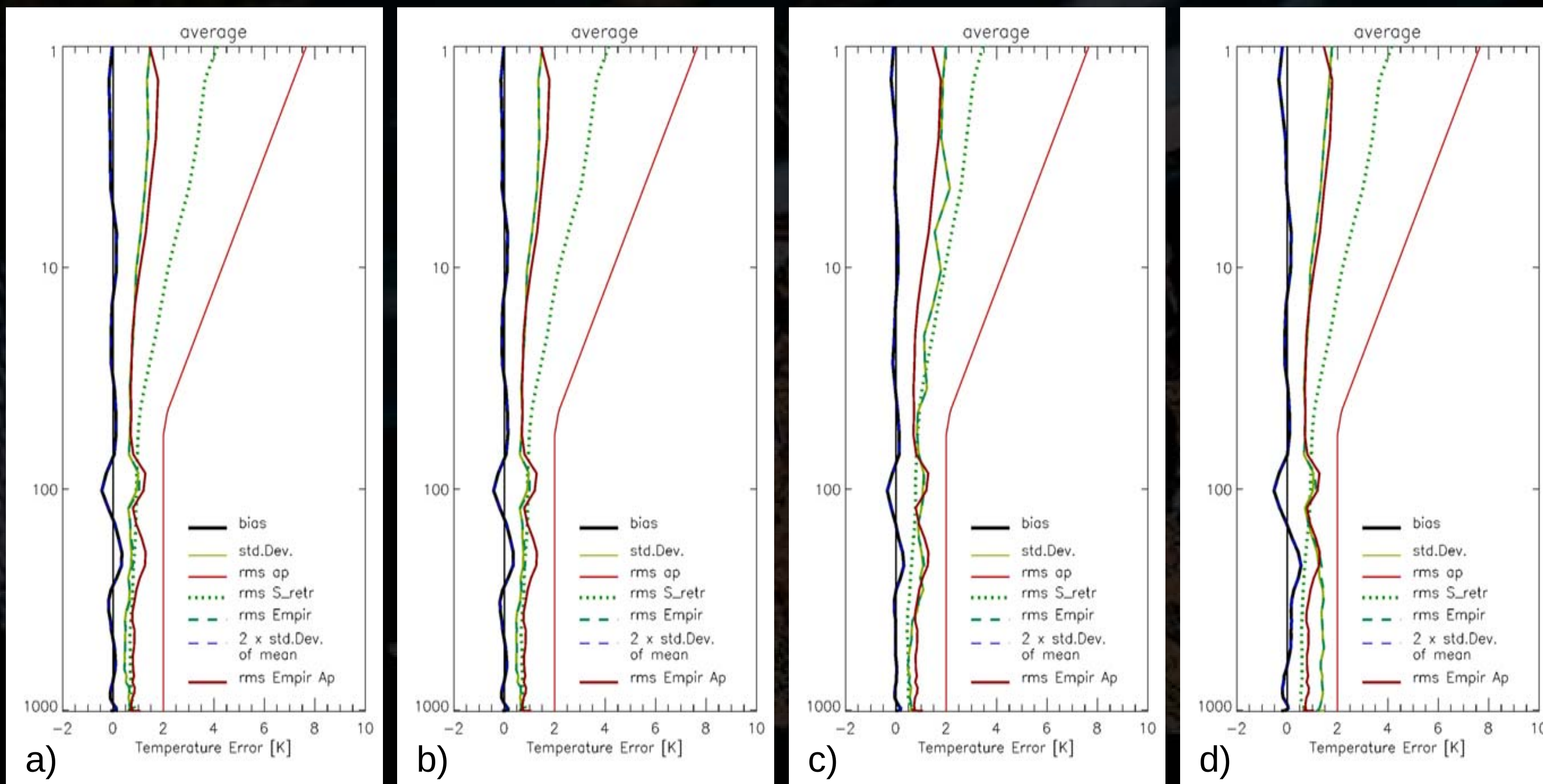



d)

a) IC – few channels, b) MS – few channels, c) IC – many channels, d) temperature only retrieval.

# Results

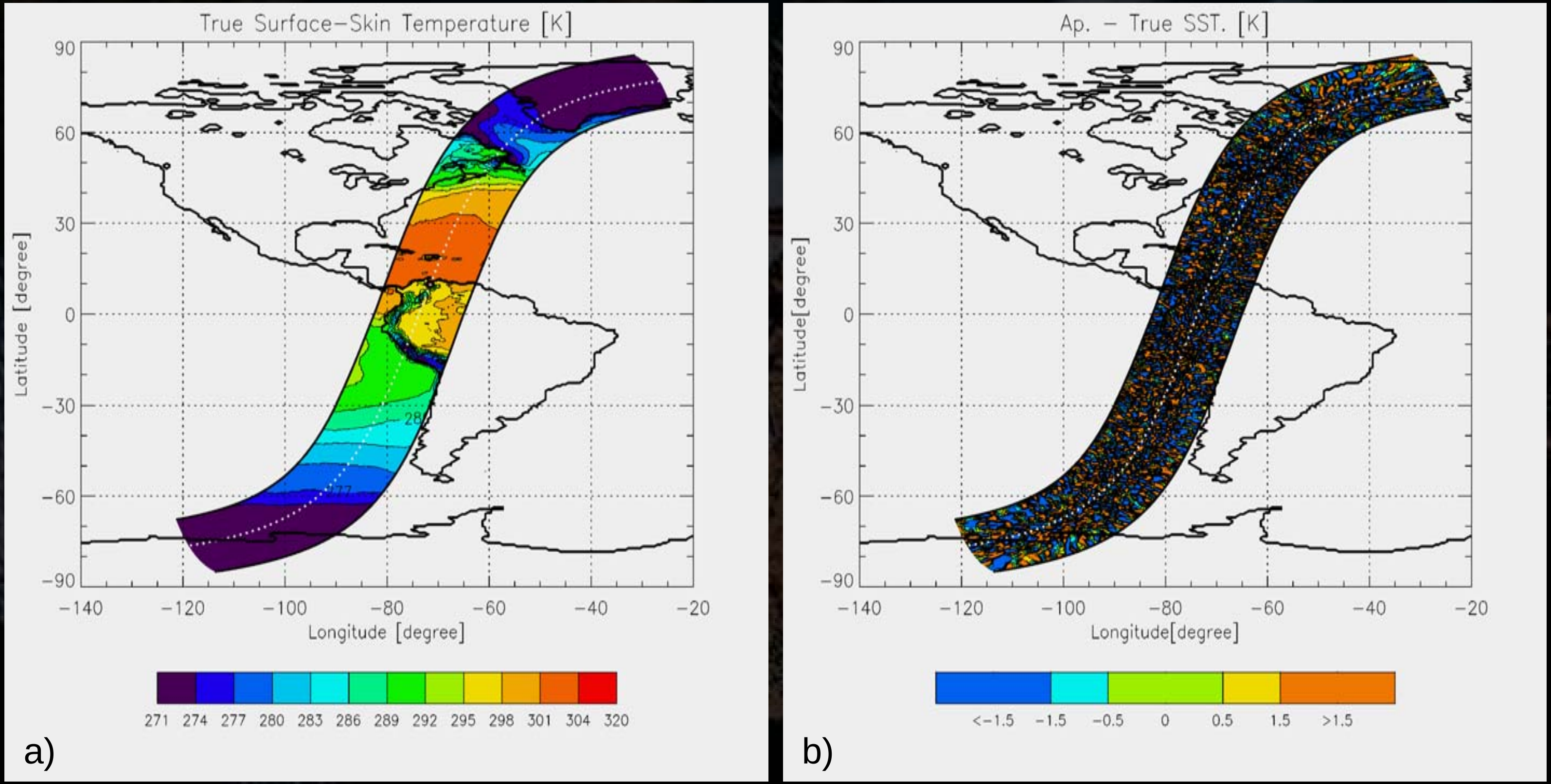
## temperature profiles – error analysis




a) IC – few channels, b) MS – few channels, c) IC – many channels, d) temperature only retrieval.

# Results

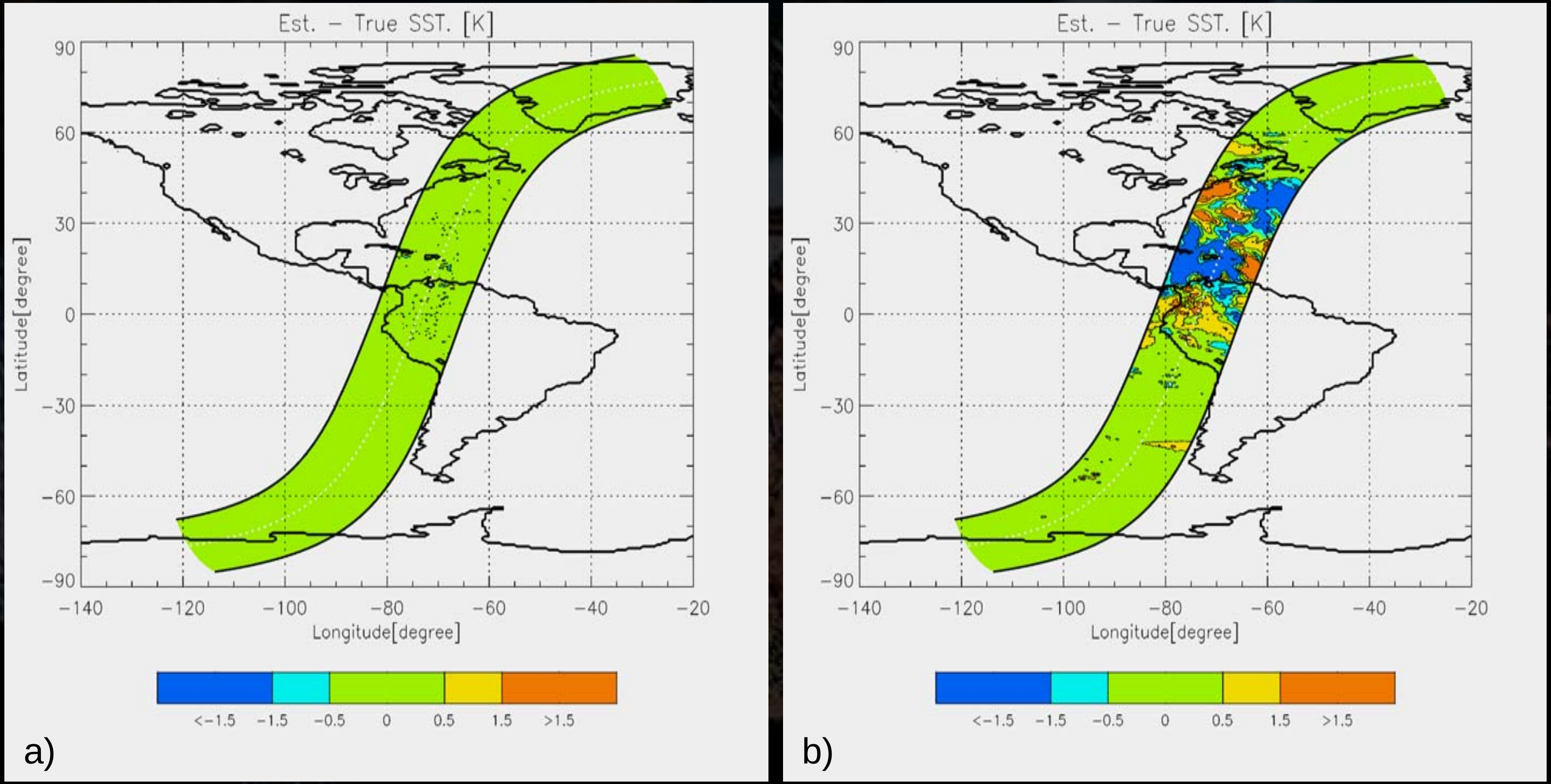
## sea surface temperature




a) true surface skin temperature, b) a priori – true surface skin temperature [K].

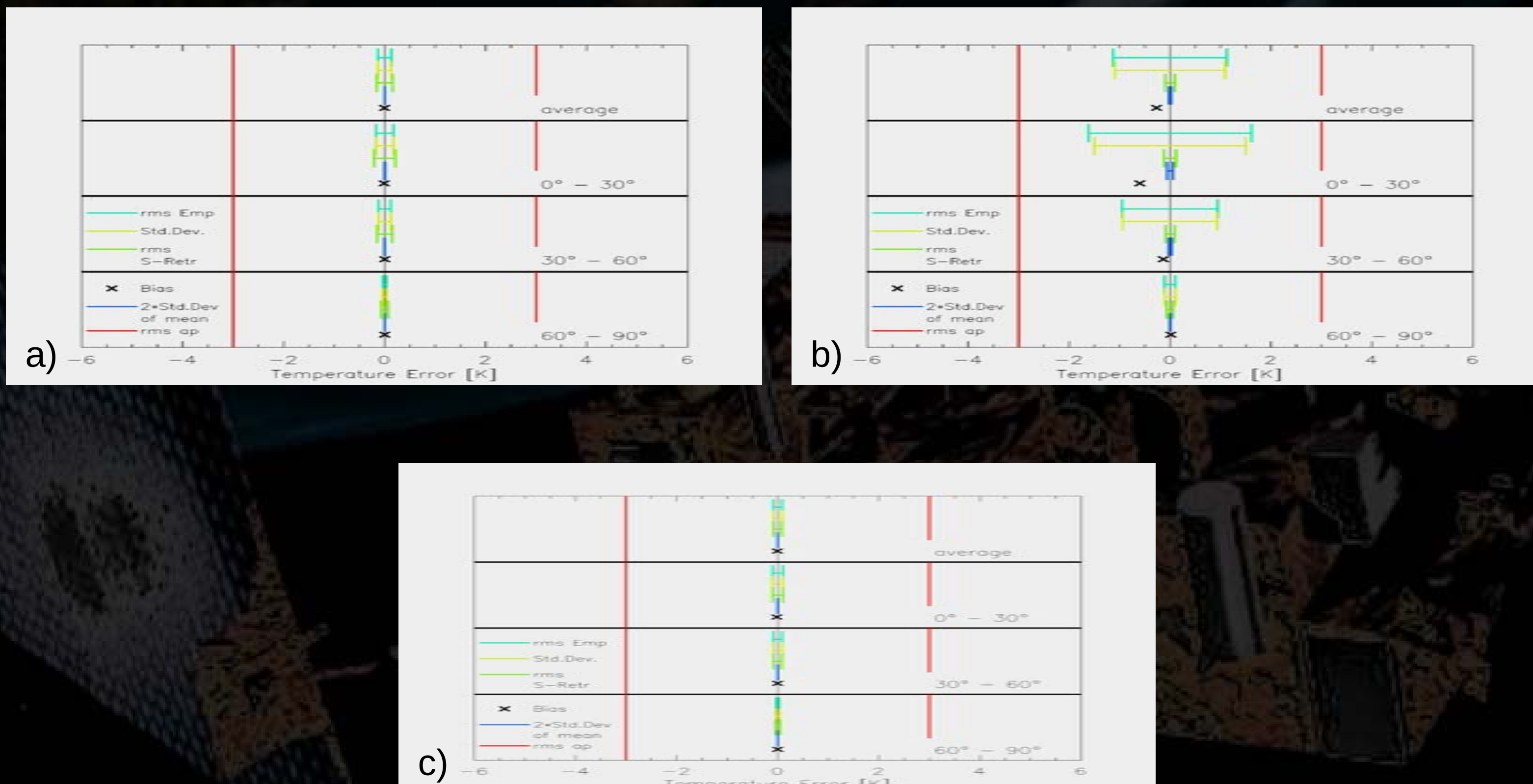
# Results

## sea surface temperature - estimation comparison

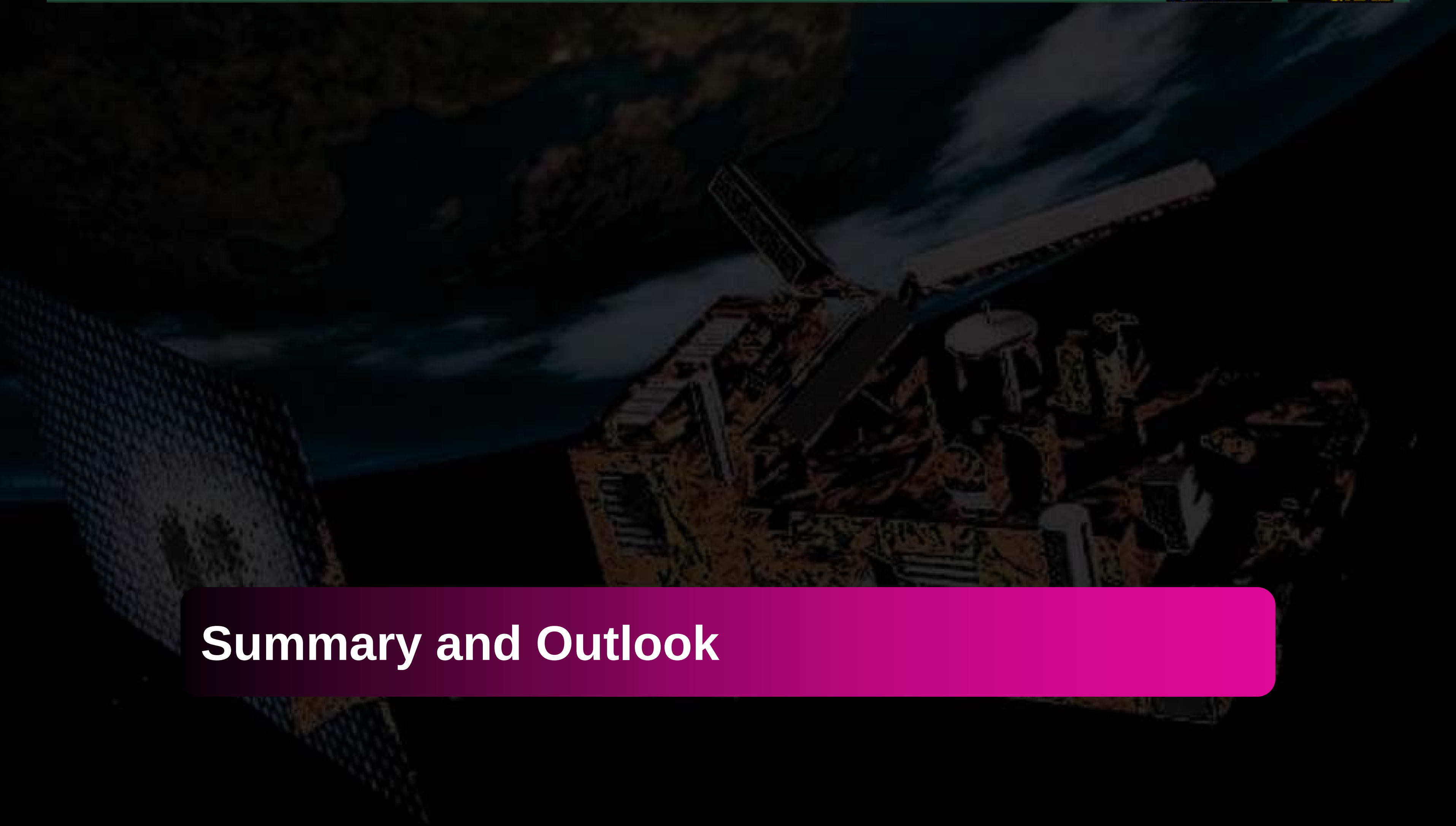



a) IC – few channels, b) sst only retrieval.

## sea surface temperature – error analysis




a) IC – few channels, b) sst only retrieval, c) IC – many channels.



# Summary and Outlook

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## summary

- IASI is the most advanced IR sounder to be launched in the near future
- the IC based channel reduction makes the retrieval efficient – reduction from > 8400 to ~ 3 %  only (~ 250).
- the joint algorithm shows an clearly improved performance compared to more specific retrieval setups.
- retrieval accuracy: ~1K (T) and 15% (q) at 1 – 3 km in the troposphere.
- a priori data exhibit important influence in the stratosphere.
- some challenging areas are found in the mid-latitude regions and at heights with weak sensitivity of the weighting functions.

# Summary and Outlook

**outlook**

- **improvements:**
  - direct use of the relevant ECMWF *a priori* covariance matrices for T and q.
  - testing with another ground track region.

- **next steps:**
  - inclusion of an ozone retrieval into the joint algorithm.
  - application of the algorithm to AIRS data is planned.


Thank You!

International TOVS Study Conference, 13th, TOVS-13, Sainte Adele, Quebec, Canada, 29 October-4 November 2003. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2003.