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

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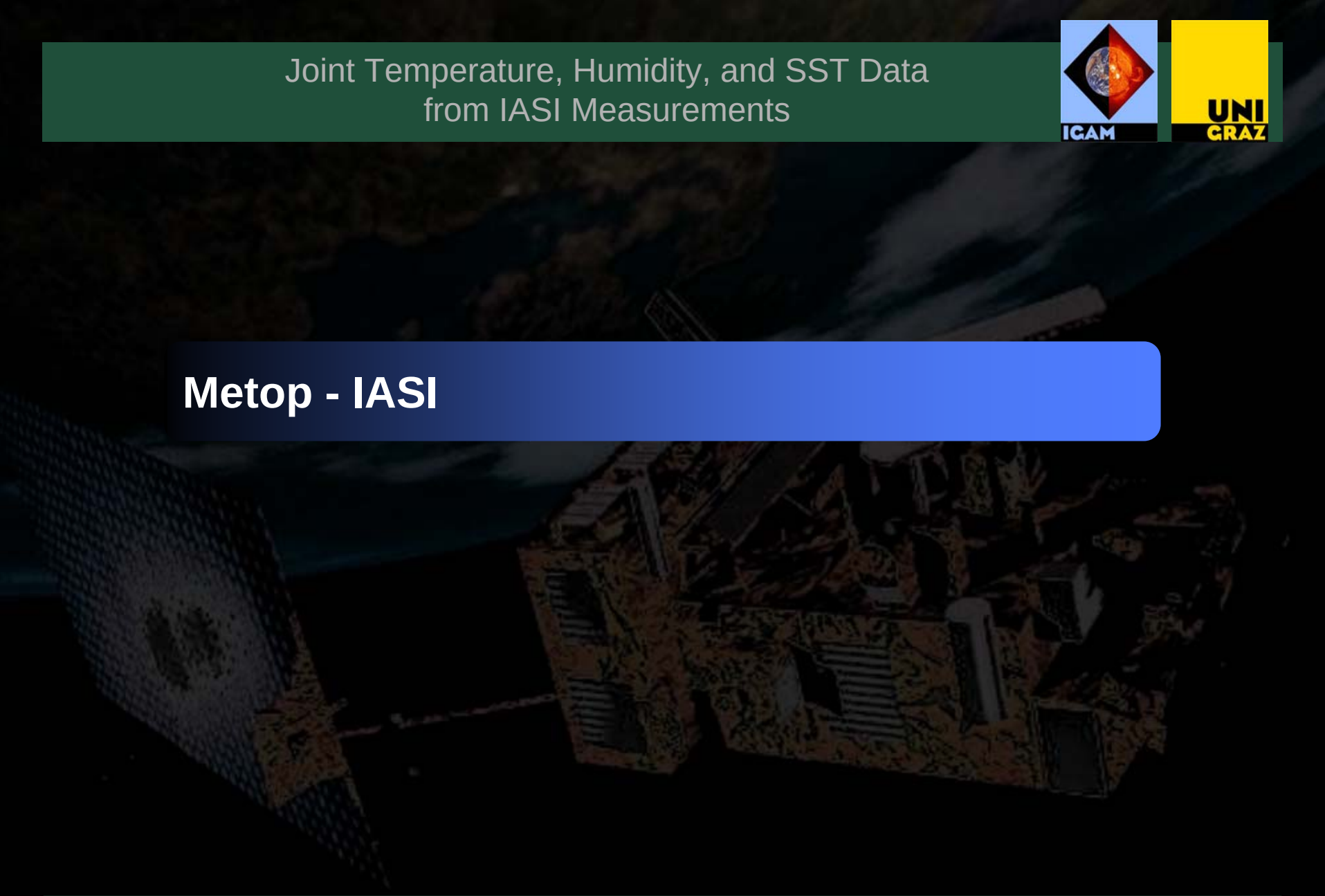
Outline:

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

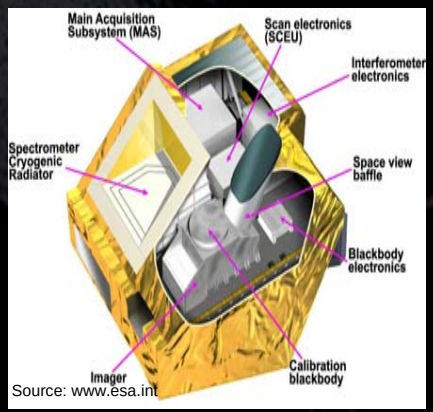


Metop - IASI

Metop - IASI

instruments on board of metop

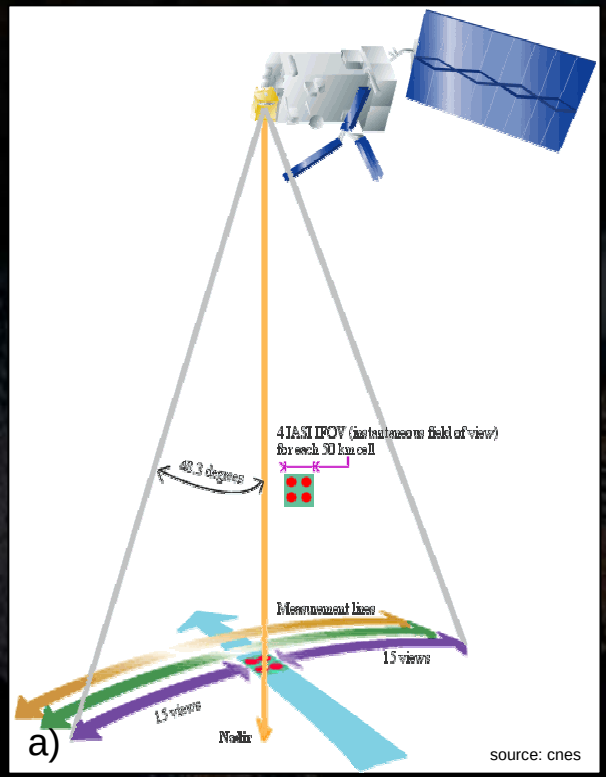
- **IASI**
- **AMSU – A**
- **ASCAT**
- **AVHRR**
- **GOME – 2**
- **GRAS**
- **HIRS**
- **MHS**



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**

Metop - IASI

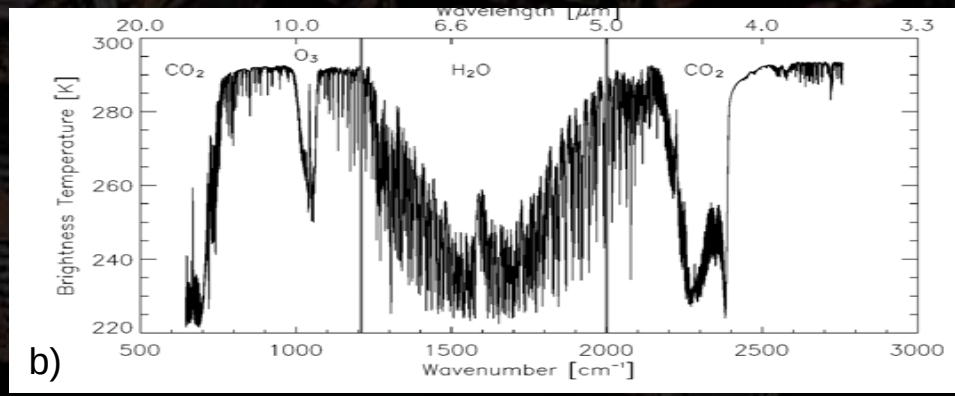
iasi – infrared atmospheric sounding interferometer



a)

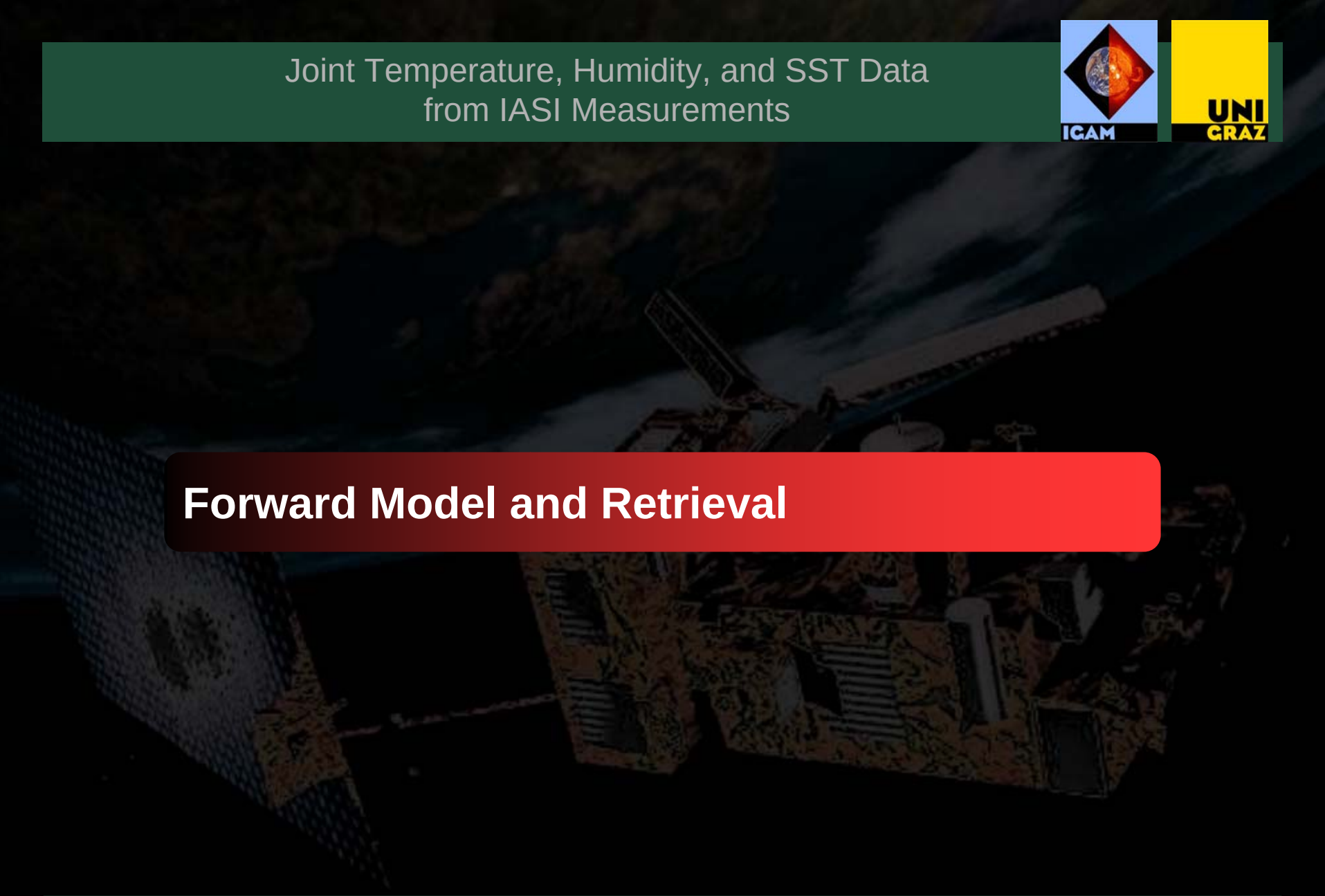
a) IASI scanning procedure.

- 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



b)

b) brightness temperature spectrum of IASI simulated by RTIASI



Forward Model and Retrieval

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

Forward Model and Retrieval

the retrieval

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

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

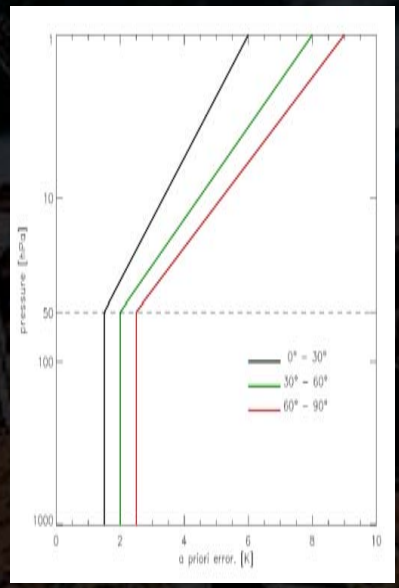
$$\mathbf{S}_i = \left(\mathbf{K}_i^T \mathbf{S}_\varepsilon^{-1} \mathbf{K}_i + \mathbf{S}_{ap}^{-1} \right)^{-1}$$

- $\mathbf{S}_\varepsilon$... 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*)

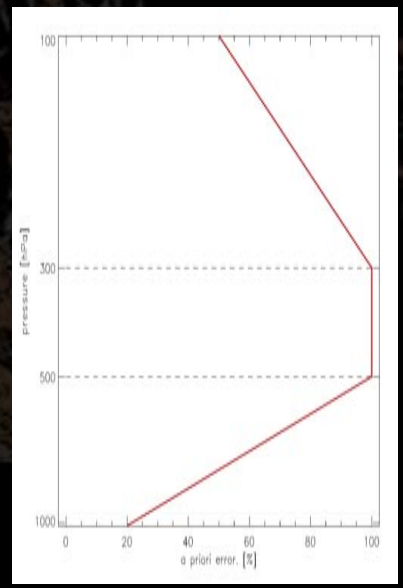
Forward Model and Retrieval

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

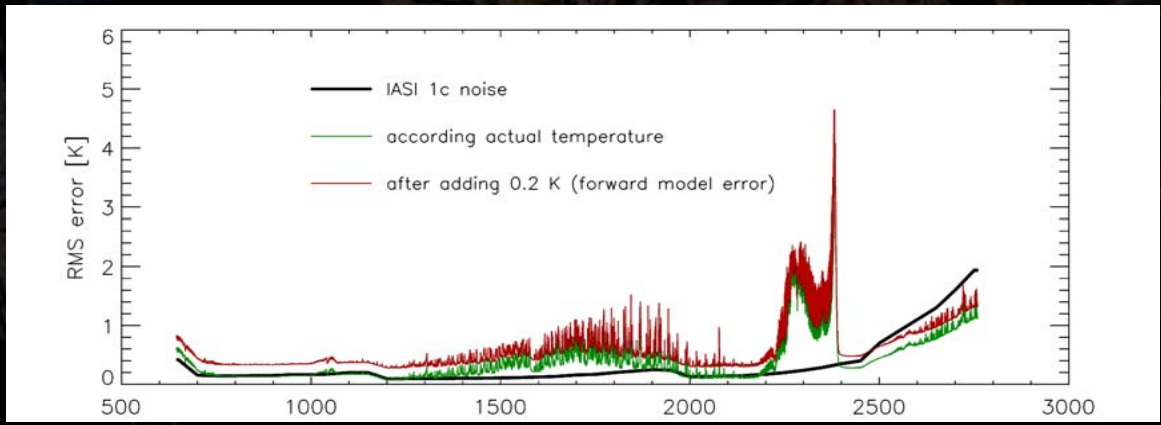


Forward Model and Retrieval

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

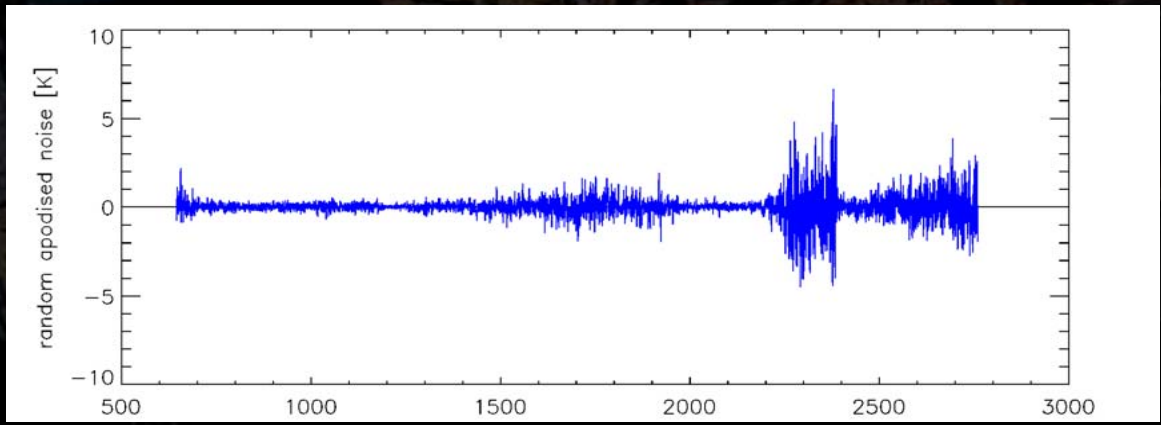


Results

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:**

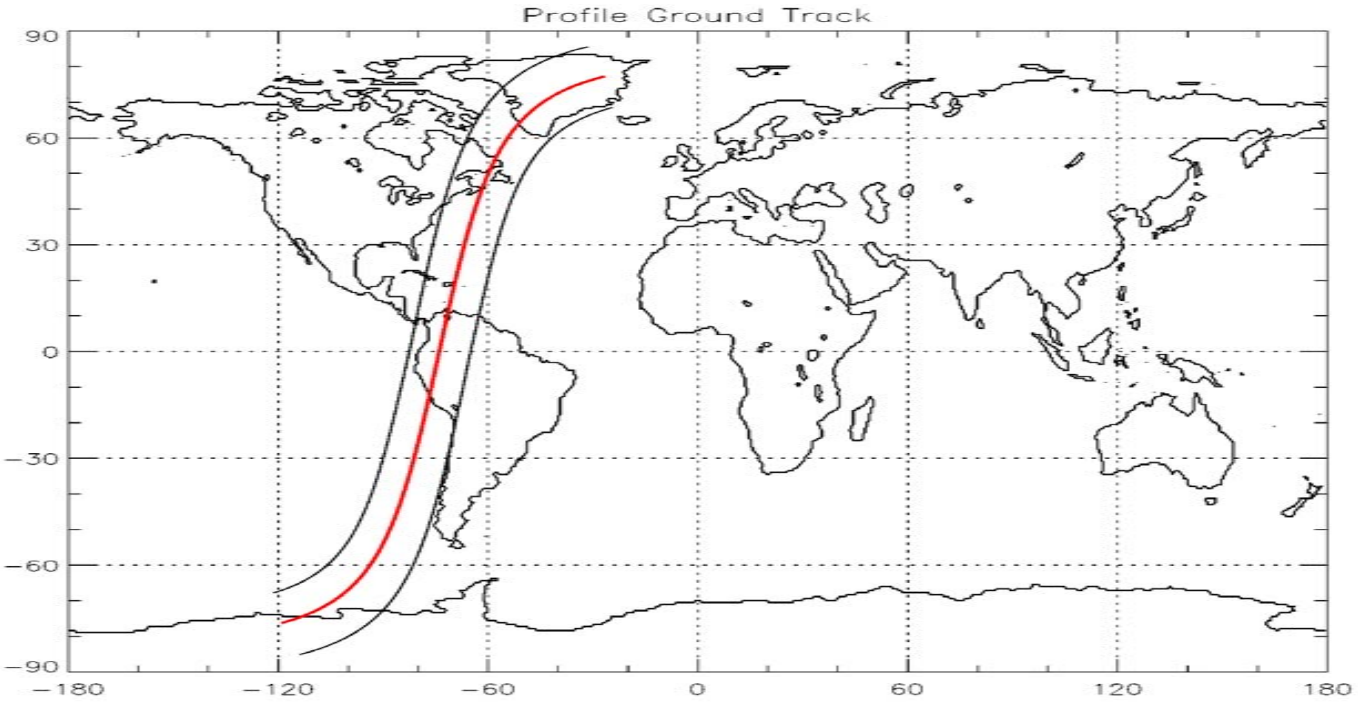
$$H = \tfrac{1}{2}\log\left|\mathbf{S}_{ap}\mathbf{S}^{-1}\right| \quad \text{with:} \quad \mathbf{S}_i = \left(\mathbf{K}_i^T\mathbf{S}_\varepsilon^{-1}\mathbf{K}_i + \mathbf{S}_{ap}^{-1}\right)^{-1}$$

- **maximum sensitivity approach:**

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

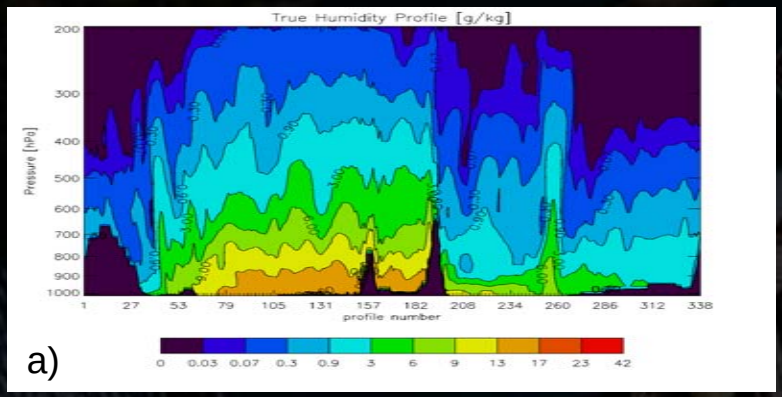
Results

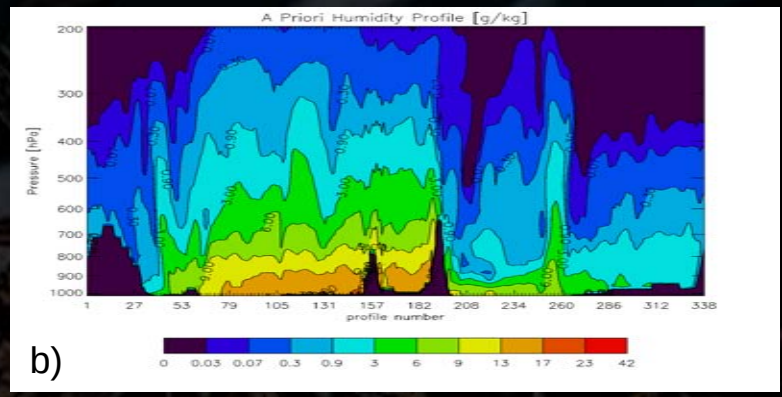
simulation region

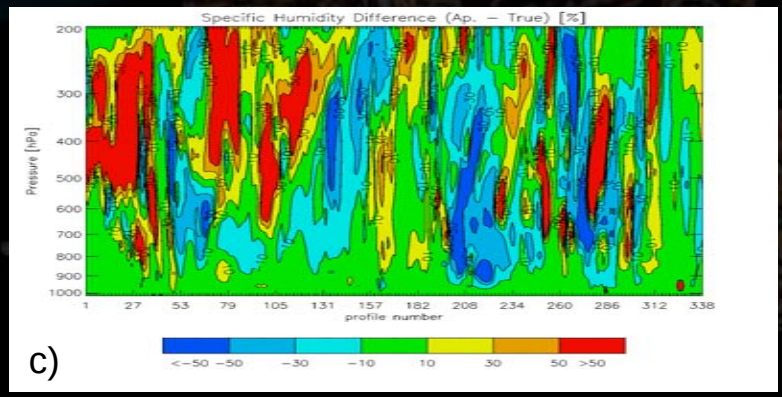


Results

humidity profiles



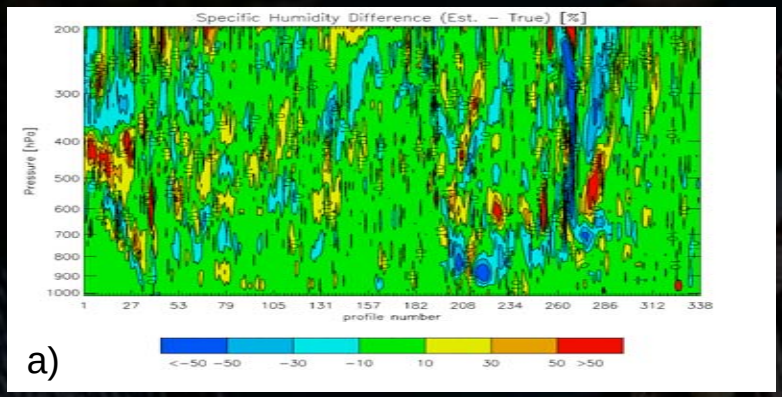


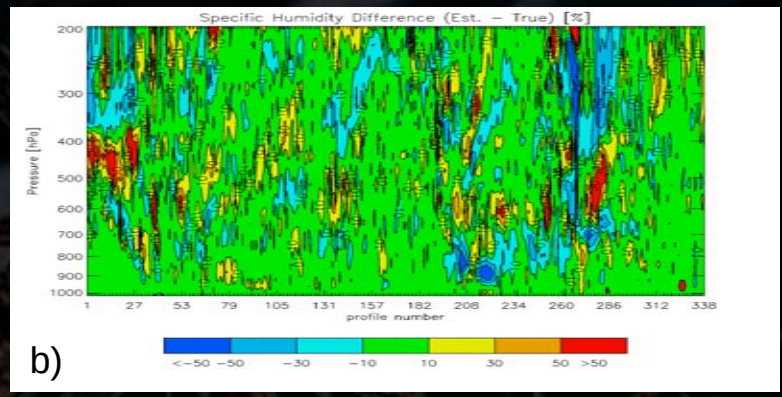


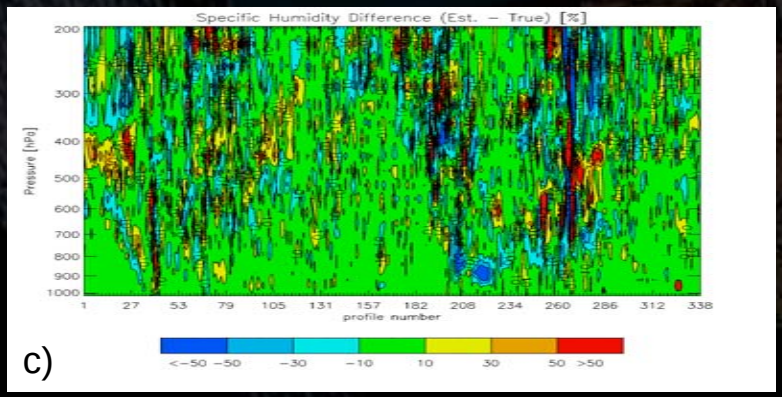
a) true humidity profile, b) a priori humidity profile, c) specific humidity difference (ap - true) [%].

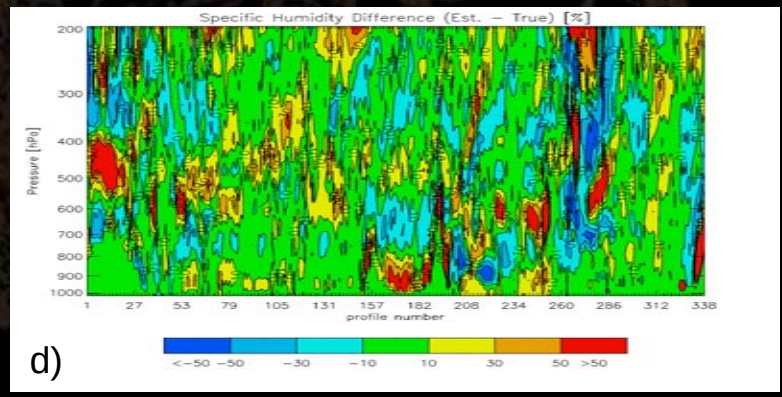
Results

humidity profiles – estimation comparison





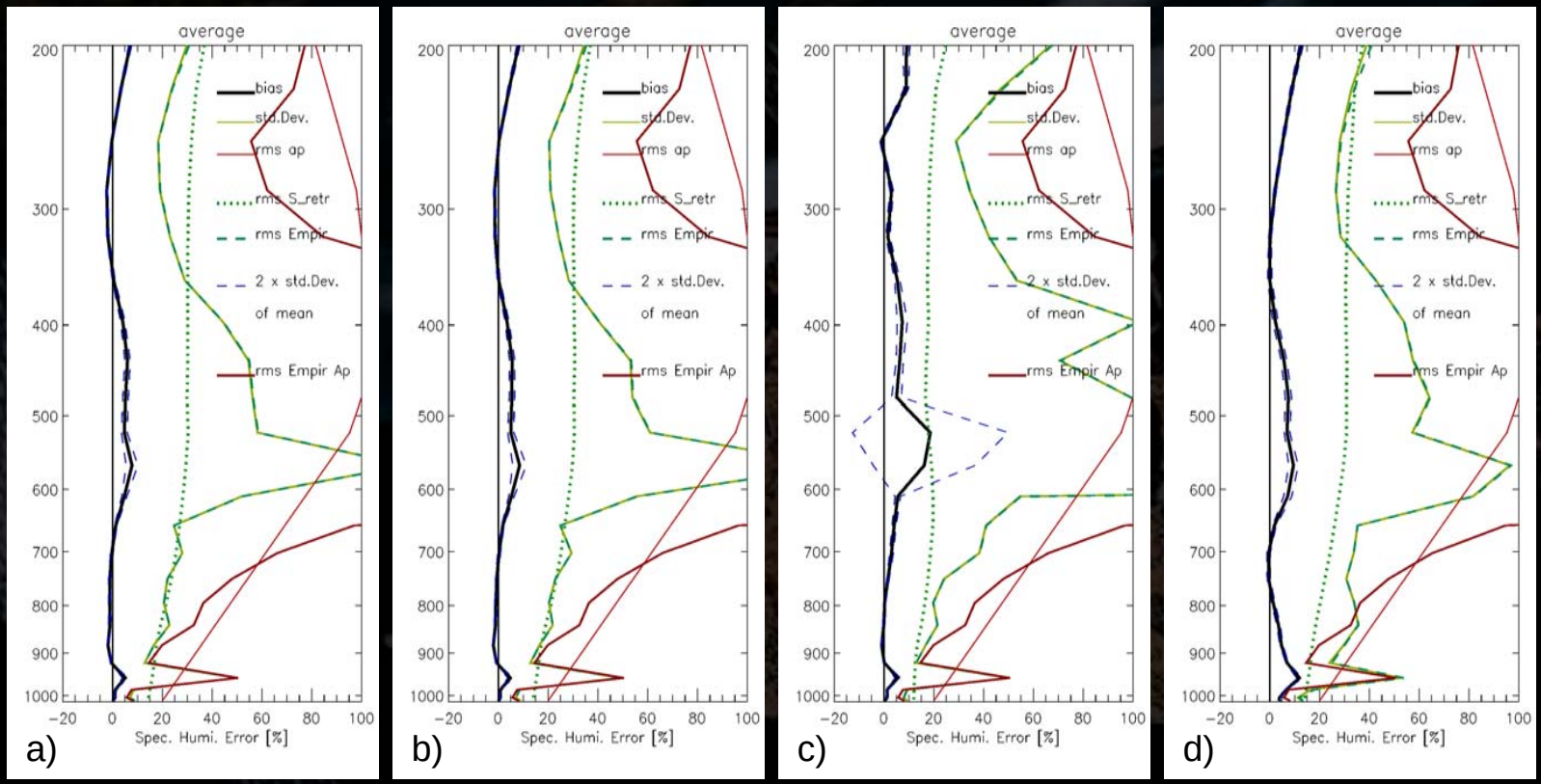




a) IC – few channels, b) MS – few channels, c) IC – many channels, d) humidity only retrieval.

Results

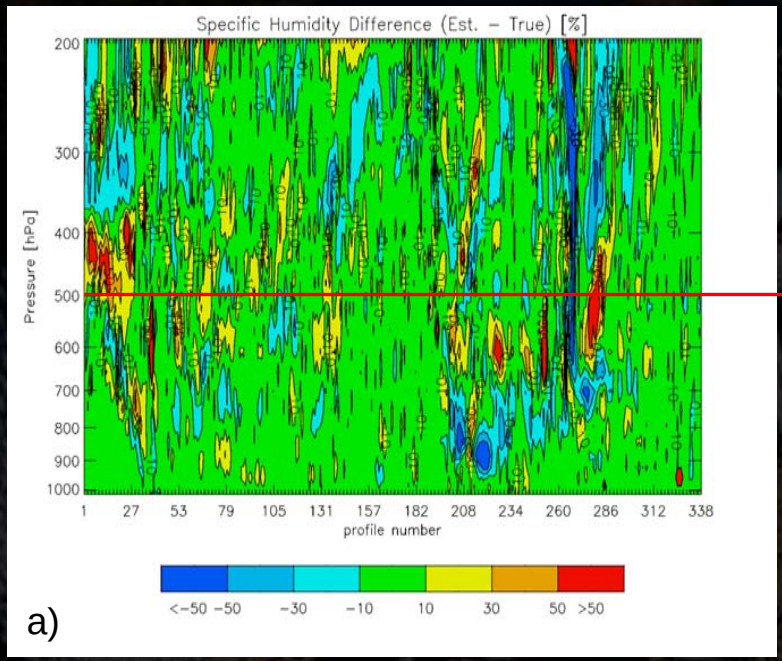
humidity profiles – error analysis

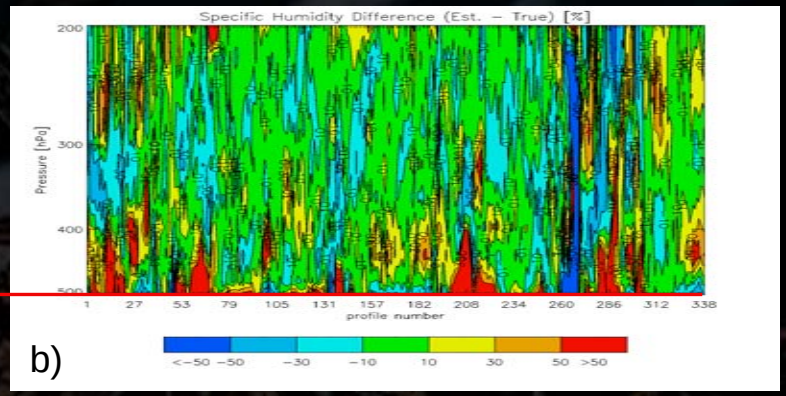


a) IC – few channels, b) MS – few channels, c) IC – many channels, d) humidity only retrieval.

Results

humidity profiles UTH - estimation comparison

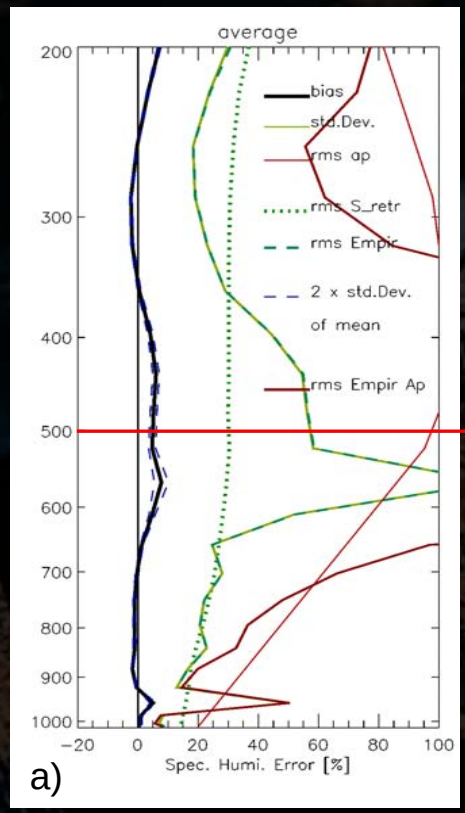


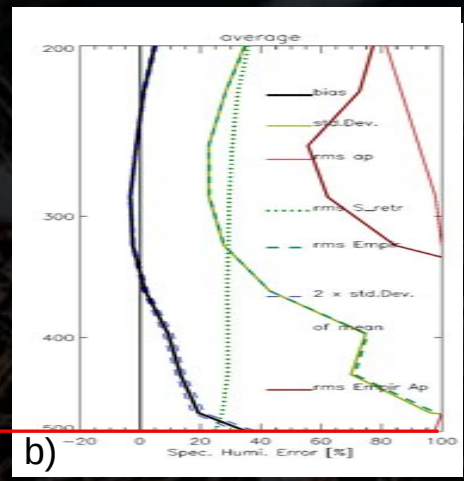


a) IC – few channels, b) UTH – IC – few channels.

Results

humidity profiles – UTH

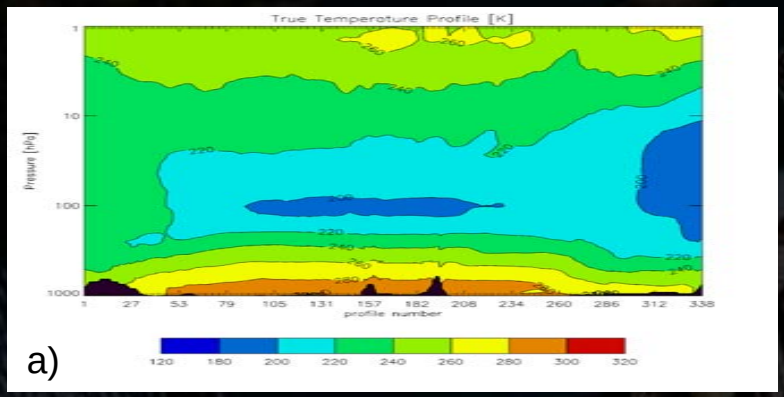


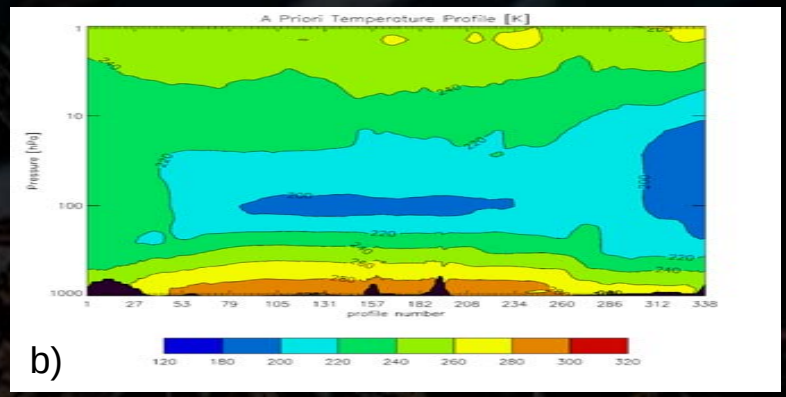


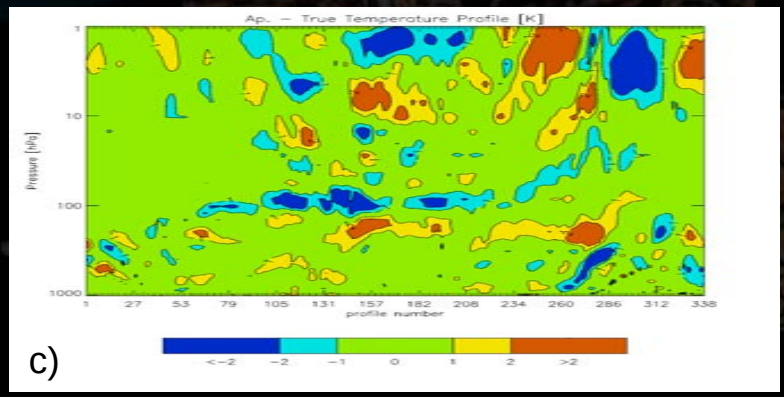
a) IC – few channels, b) UTH – IC – few channels.

Results

temperature profiles



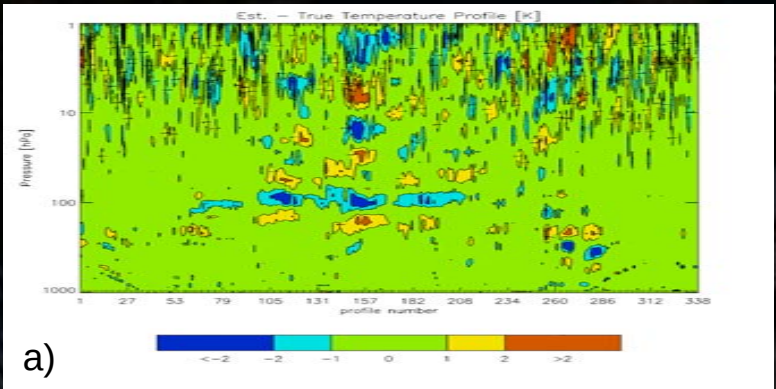


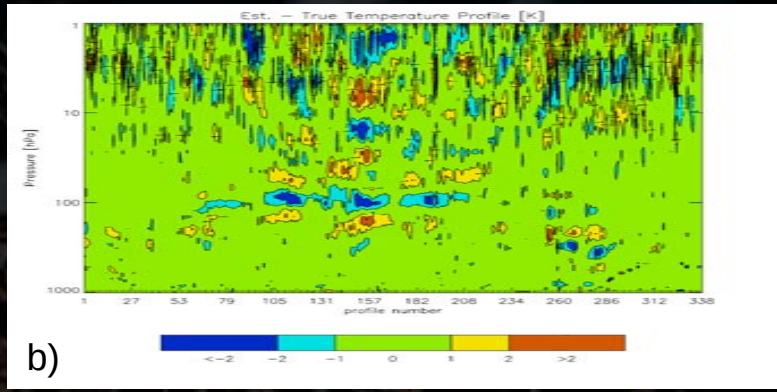


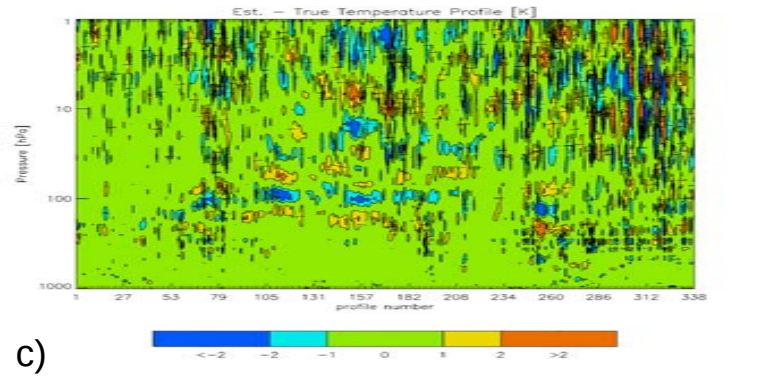
a) true temperature profile, b) a priori temperature profile, c) temperature difference (ap - true) [K].

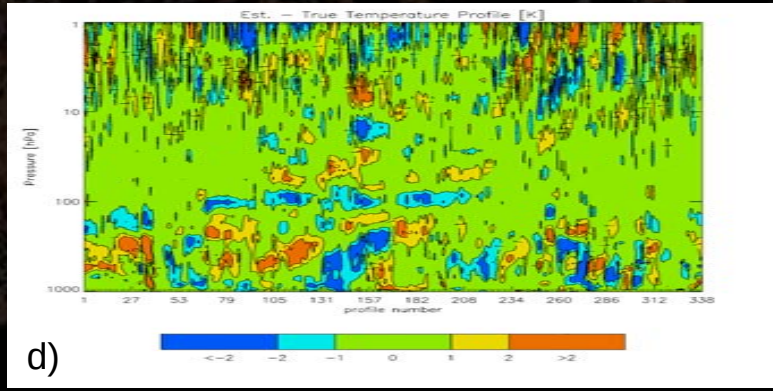
Results

temperature profiles - estimation comparison





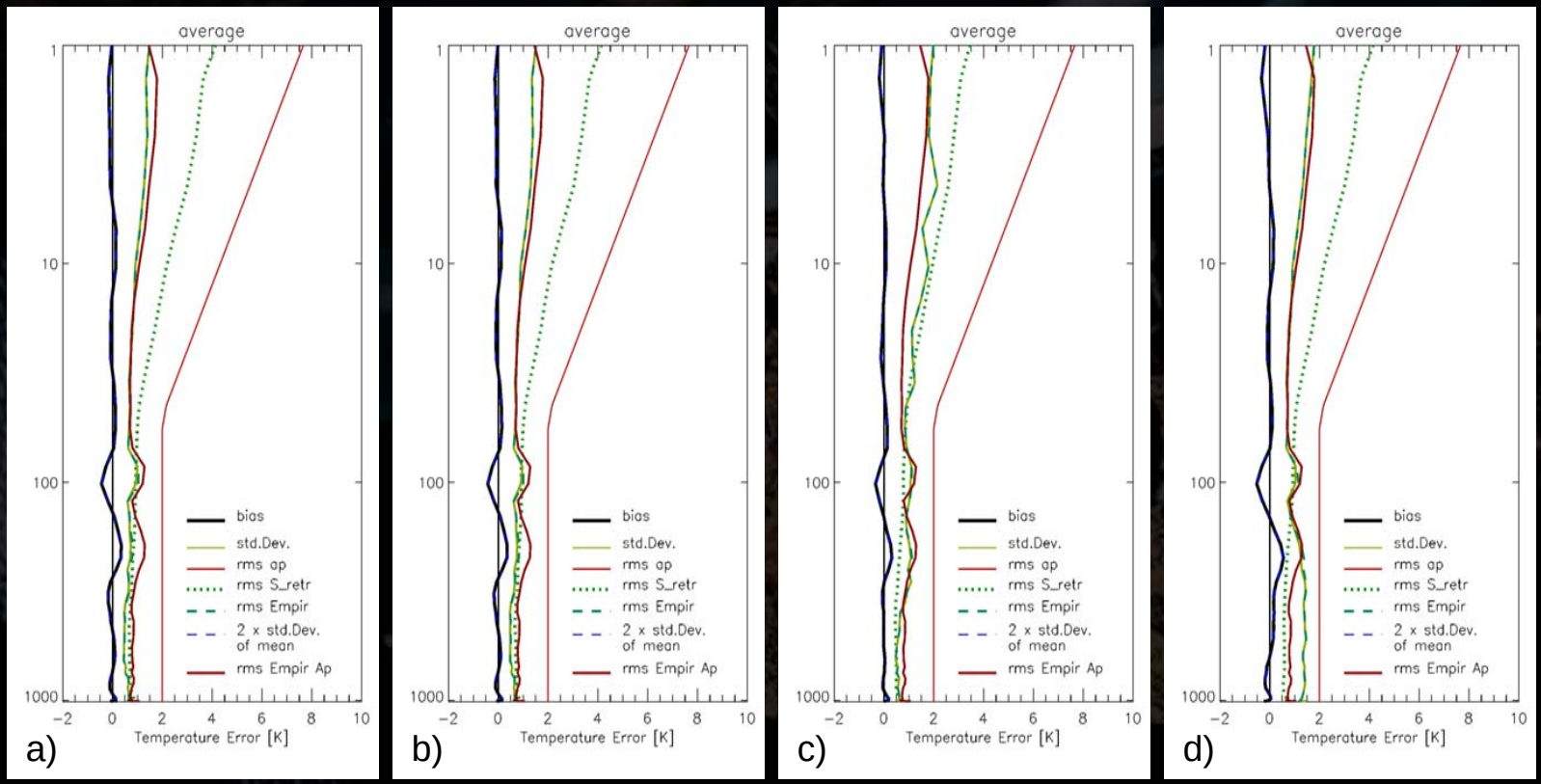




a) IC – few channels, b) MS – few channels, c) IC – many channels, d) temperature only retrieval.

Results

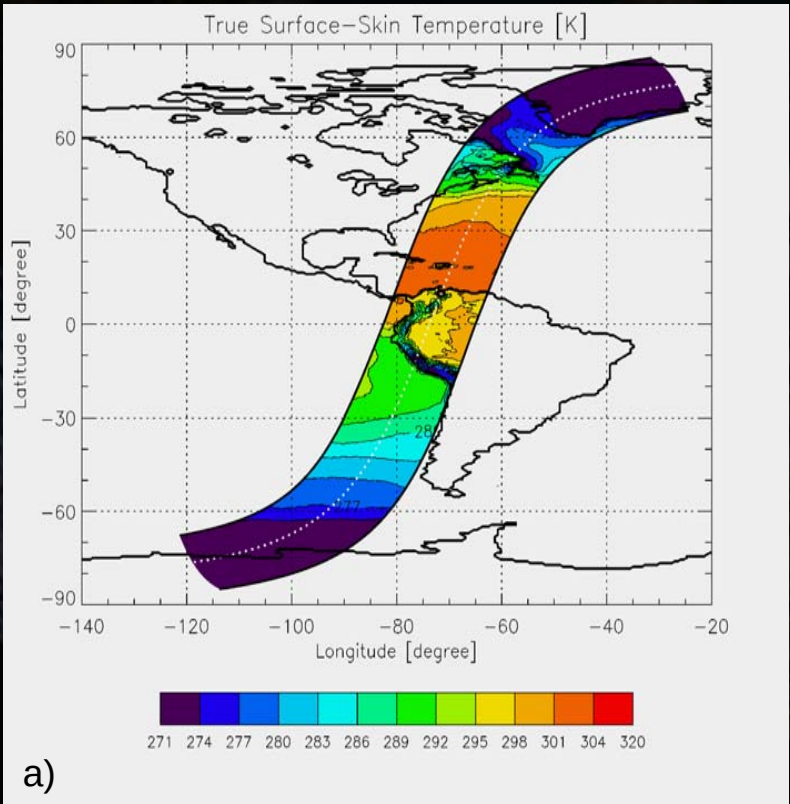
temperature profiles – error analysis

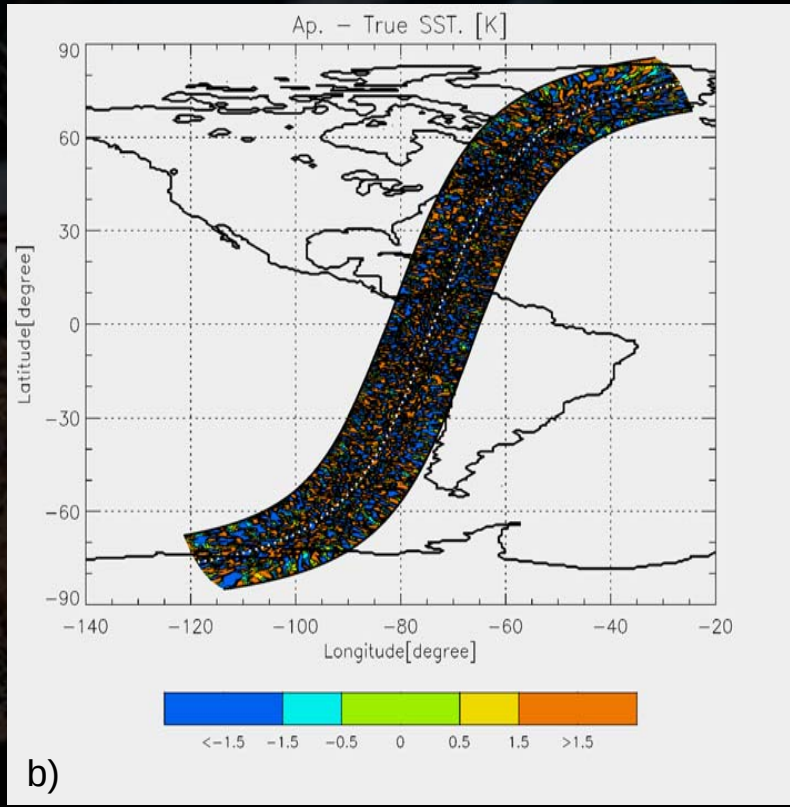


a) IC – few channels, b) MS – few channels, c) IC – many channels, d) temperature only retrieval.

Results

sea surface temperature

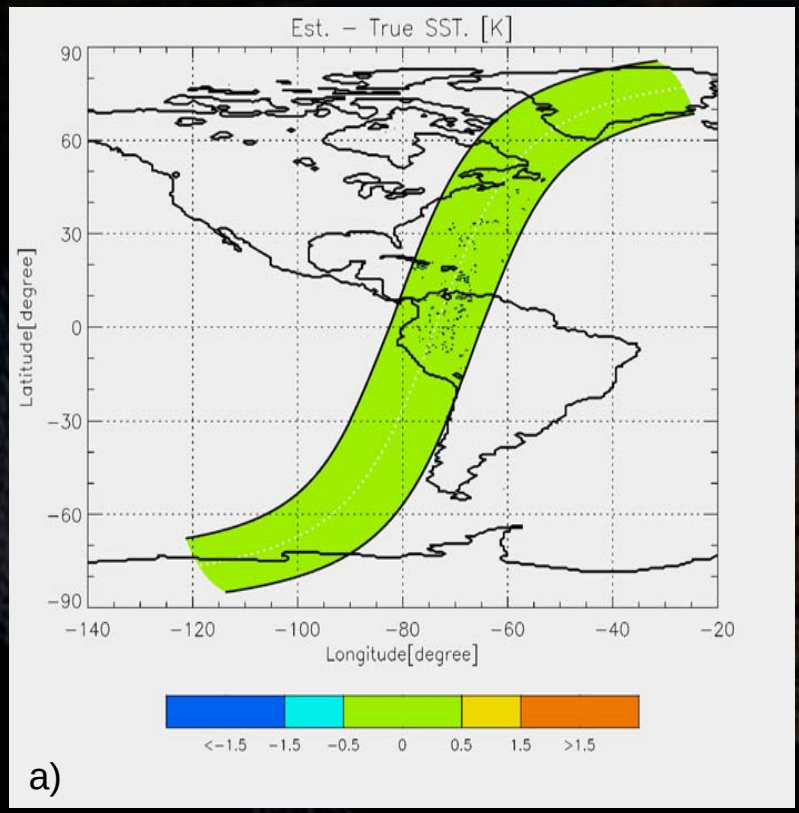


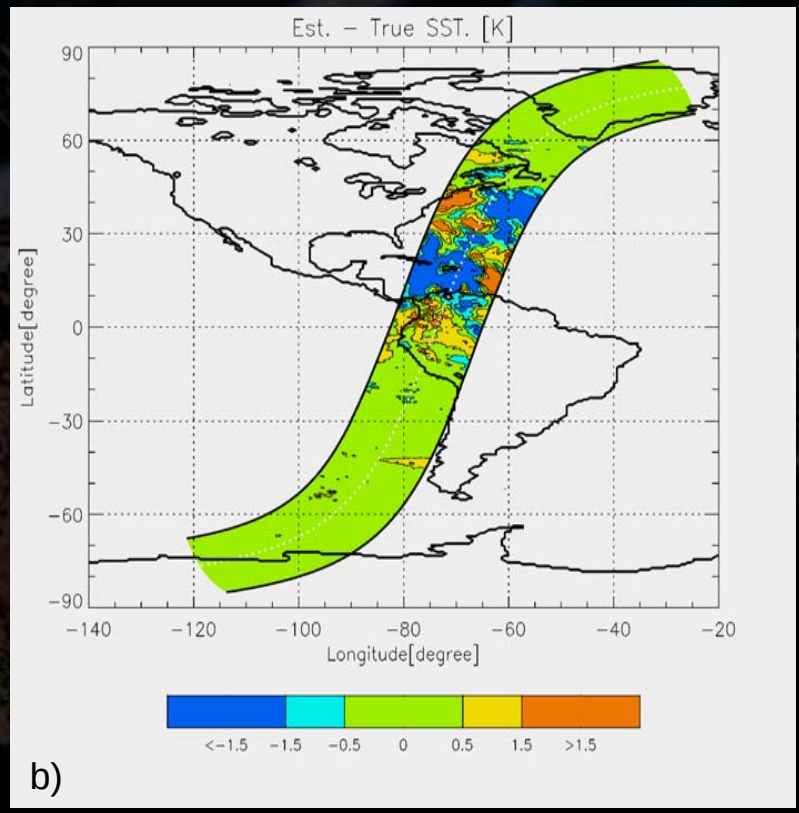


a) true surface skin temperature, b) a priori – true surface skin temperature [K].

Results

sea surface temperature - estimation comparison

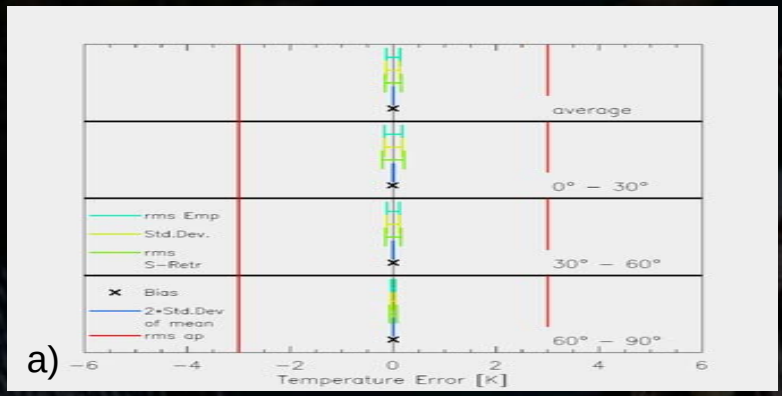


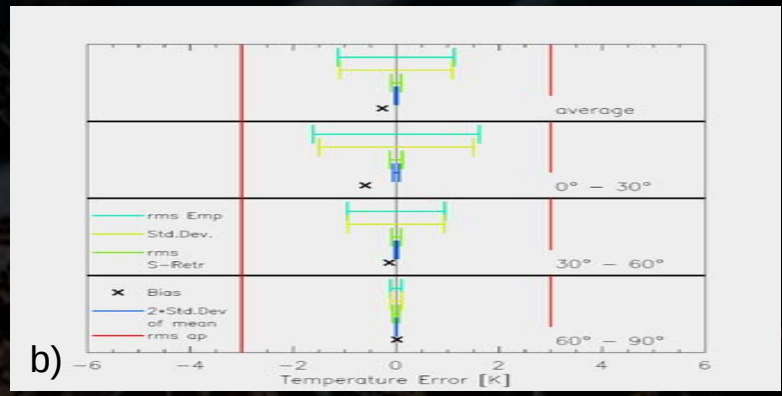


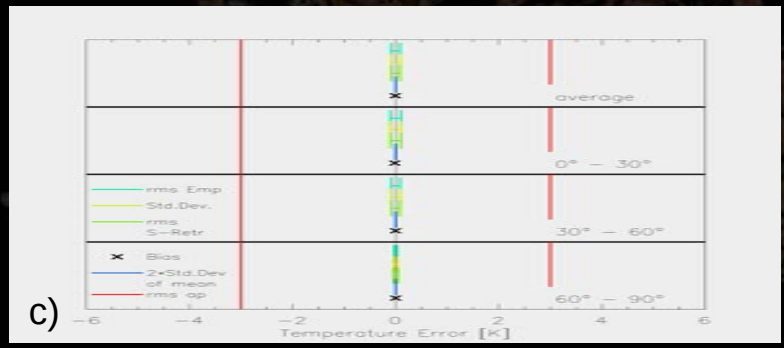
a) IC – few channels, b) sst only retrieval.

Results

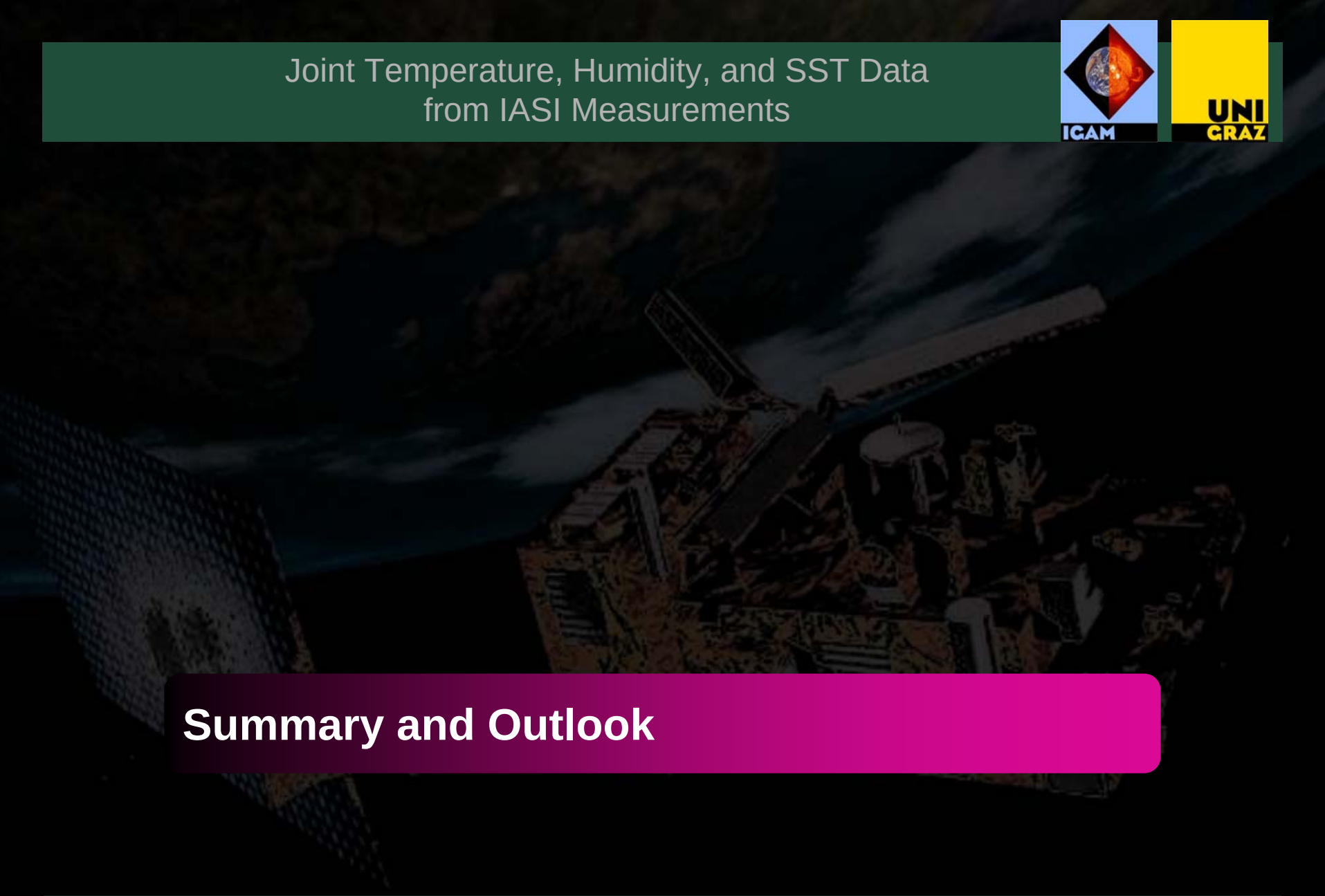
sea surface temperature – error analysis







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



Summary and Outlook

Summary and Outlook

summary

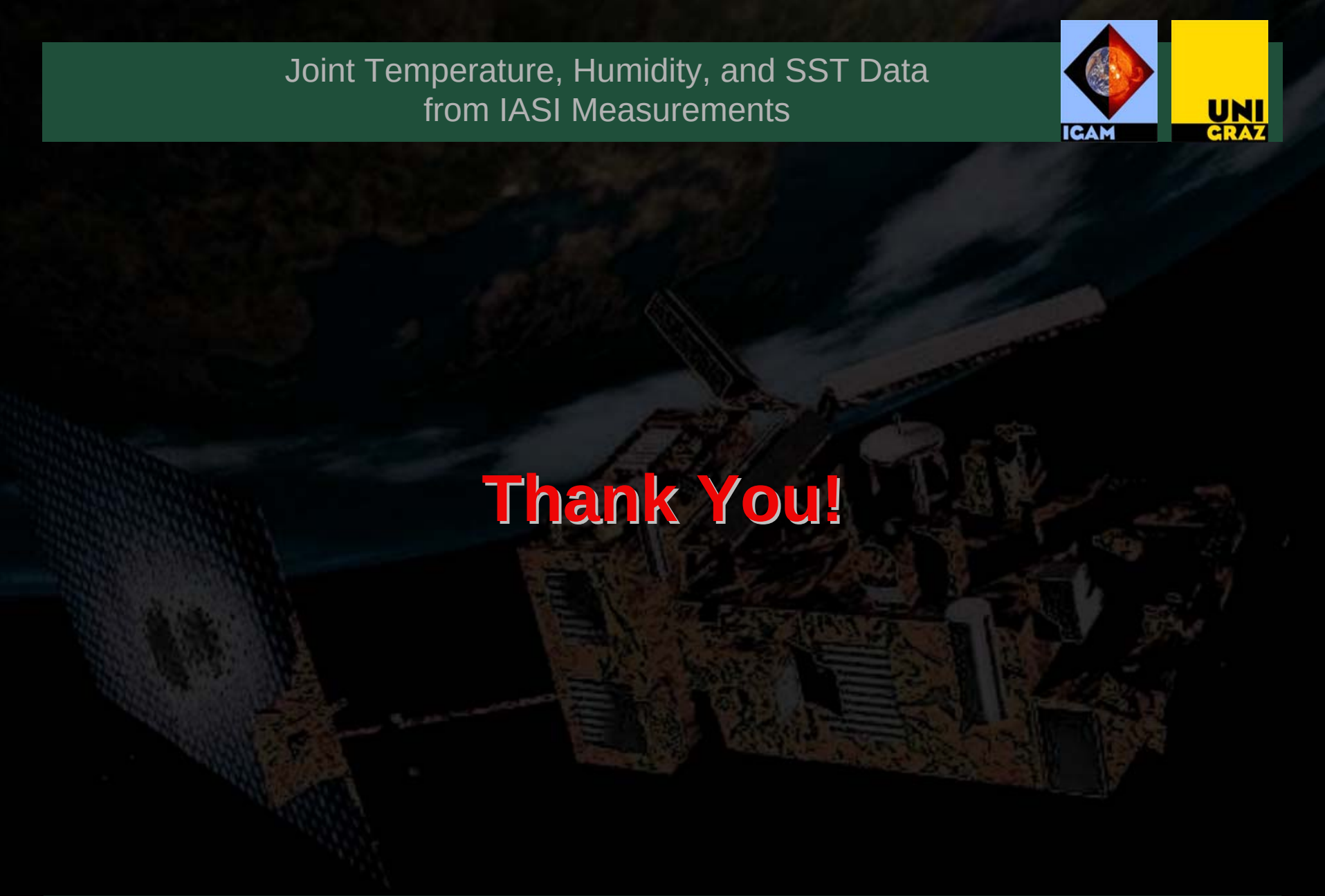
- IASI is the most advanced IR sounder to be launched in the near future
- the IC based channel reduction makes the retrieval efficient – reduction from > 8400 to ~ 3 % only (~ 250).
- the joint algorithm shows an clearly improved performance compared to more specific retrieval setups.
- retrieval accuracy: ~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!