A Fast Channel Selection Method and Joint Humidity and Temperature Retrieval from IASI Measurements

Marc Schwärz and Gottfried Kirchengast
(marc.schwaerz@uni-graz.at, gottfried.kirchengast@uni-graz.at)
Institute for Geophysics, Astrophysics, and Meteorology (IGAM), University of Graz, Austria

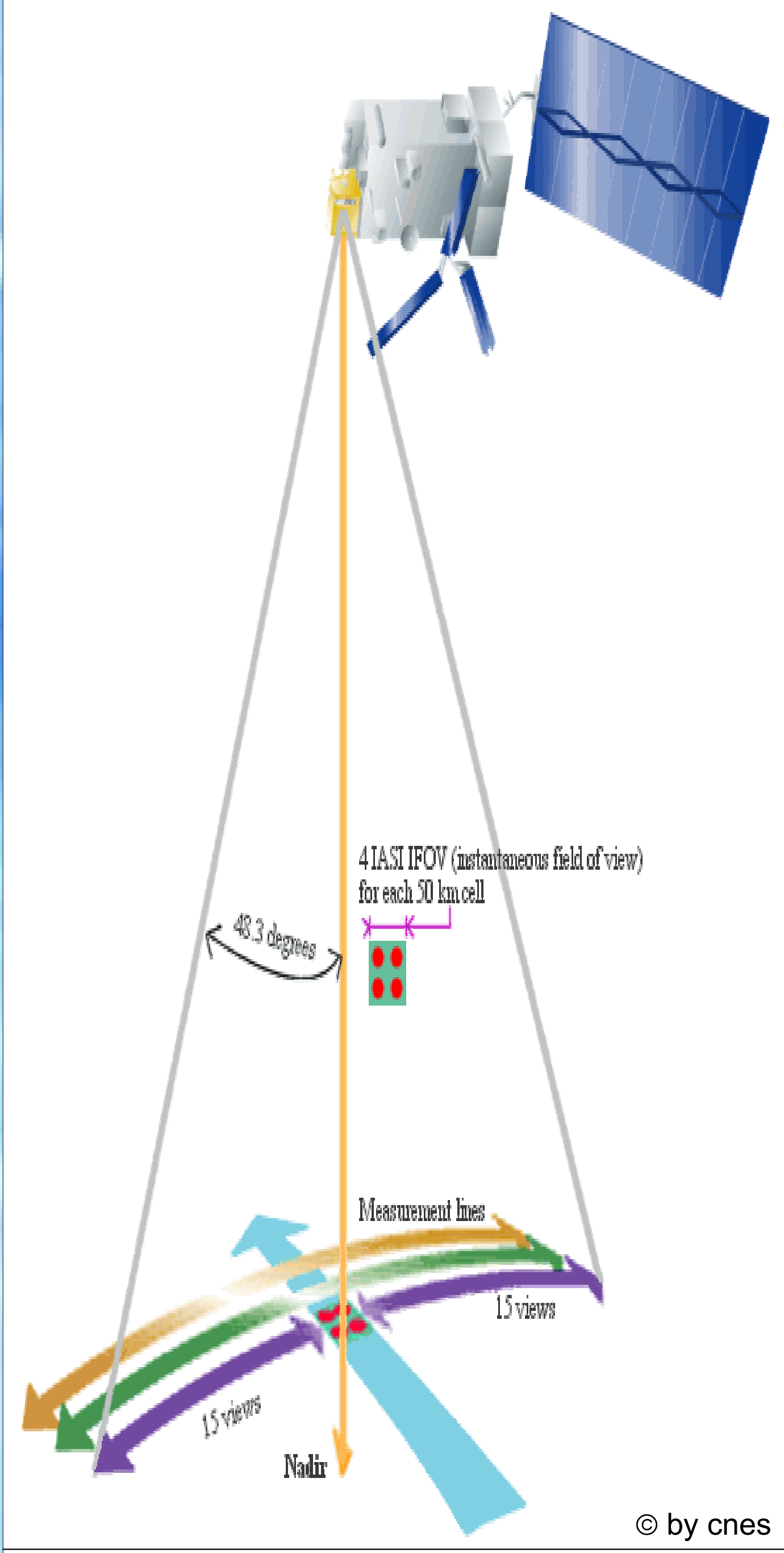

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Figure 1: Scanning procedure of the IASI instrument.

The Infrared Atmospheric Sounding Interferometer IASI

- IASI[1] is part of the core payload of the METOP series of polar orbiting meteorological satellites (1st launch scheduled 2005).
- Spectral Range: 645 - 2760 cm^{-1} (15.5 - 3.6 µm), sampling at 0.25 cm^{-1}.
- Temperature Range: 180 - 315 K with radiometric noise (NEΔT @ 280 K) ~0.2 to 0.5 K; radiometric calibration < 1 K.
- Geometric Performance: swath width ~±1100 km, IFOV (nadir): ~48×48 km^2, 30 Earth views per scan, total scan period: ~8 seconds (see also Figure 1).
- 8461 channels, water vapor absorption 1250 - 2000 cm^{-1}, CO_2 bands near 645 cm^{-1} and 2325 cm^{-1}, furthermore, absorption by O_3, CH_4, N_2O, CO, and SO_2.

The Fast Radiative Transfer Model RTIASI

The fast transmittance model RTIASI[2] was used to simulate IASI measurements (brightness temperatures $\mathbf{T}_B$) and to calculate temperature, **T**, and specific humidity, **q**, Jacobians, $\partial\mathbf{T}_B/\partial\mathbf{T}$, and $\partial\mathbf{T}_B/\partial\ln\mathbf{q}$, respectively. RTIASI simulates the measurements at 43 fixed pressure levels from 0.1 mbar to surface (1013.25 mbar) over the IASI spectral range. With convoluted line-by-line (LBL) transmittances and selected predictors, the model computes regression coefficients to derive level-to-space transmittances for any input profile. Based on these transmittances RTIASI finally estimates the brightness temperatures (or the radiances, alternatively) viewed by the IASI sensor.

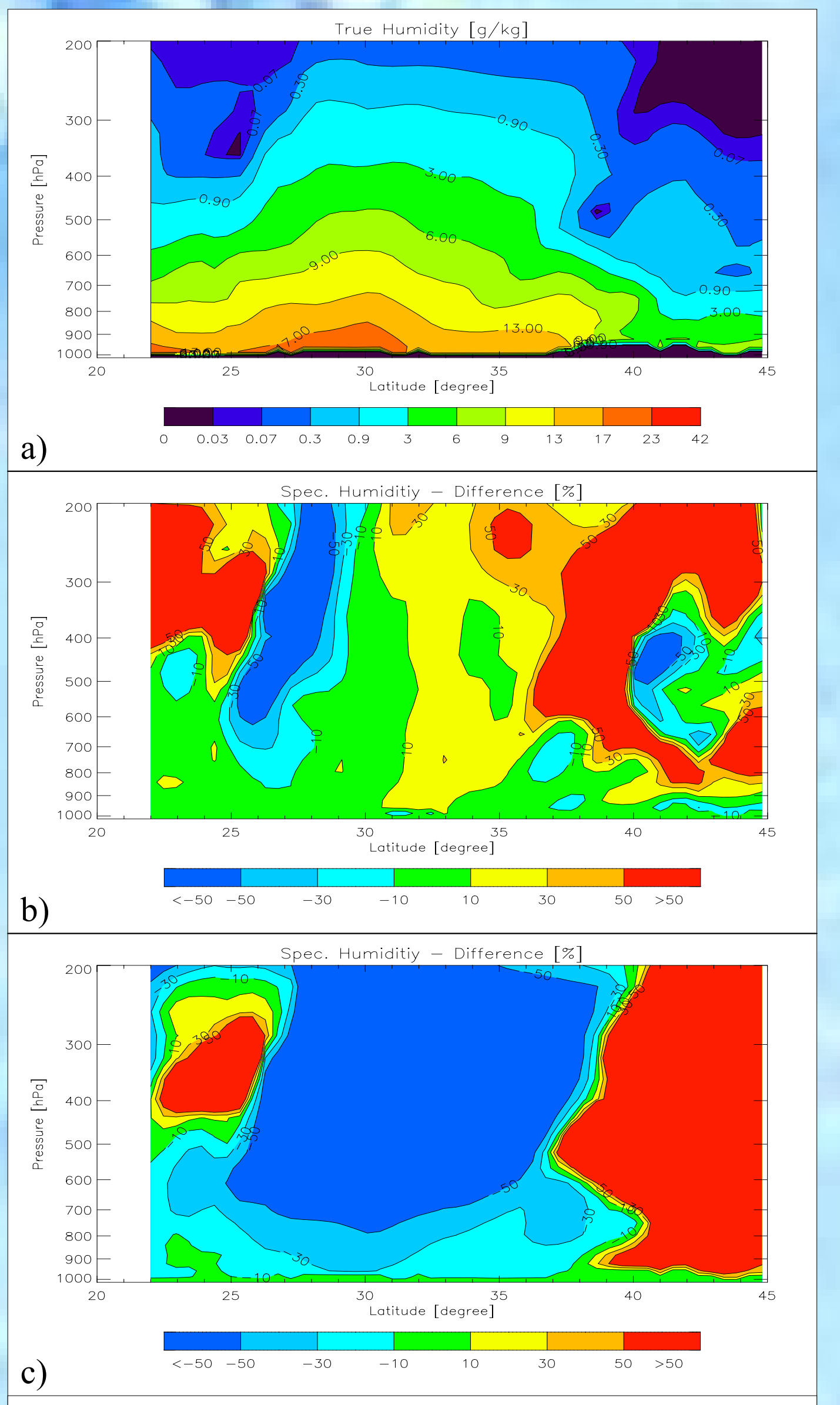

Figure 2: a) True Spec. Humidity Field; ECMWF T213L50 analysis, Sep 15, 1999 - 1200 UTC.
b) *A Priori* Field minus True Field (as *a priori* field the ECMWF 6-hr forecast was chosen).
c) *A Priori* Field minus True Field (*a priori* field from CIRA86aQ model[3]).

Channel Reduction and Retrieval Algorithm

Channel Reduction:

- Exclusion of the channels > 2500 cm^{-1} and of those of "foreign" bands (O_3, CH_4,CO), which results in ~5180 channels.
- **Channel Reduction by Information Content (IC) Theory**[5]:
  The IC content *H* is calculated for each channel according to
  $$H = \tfrac{1}{2}\log_2|\mathbf{S}_{ap}\mathbf{S}^{-1}|, \qquad (1)$$
  with $\mathbf{S}_{ap}$ and **S** according to Eq. (4).
- **Channel Reduction by the Maximum Sensitivity (MS) Approach**[6]**:**
  As a fast approximation to the IC as defined by Eq. (1) we take those channels for which the elements *H* of the matrix
  $$\mathbf{H} = \mathbf{S}_{\varepsilon}^{-1/2}\,\mathbf{K} \qquad (2)$$
  are largest.

Retrieval Algorithm:

For retrieving the humidity, **q**, and temperature, **T,** profiles, we use the **iterative** (iteration index i) **non-linear optimal estimation algorithm**[4]

$$\mathbf{x}_{i+1} = \mathbf{x}_{ap} + \mathbf{S}_i\,\mathbf{K}_i^T\,\mathbf{S}_{\varepsilon}^{-1}\,[(\mathbf{y} - \mathbf{y}_i) + \mathbf{K}_i(\mathbf{x}_i - \mathbf{x}_{ap})], \qquad (3)$$

where $\mathbf{x}_{i/i+1}$ and $\mathbf{x}_{ap}$ are the iterated and the *a priori* state vector (ln**q** and **T** combined in one state **x**), $\mathbf{S}_{\varepsilon}$ is the measurement error covariance matrix, $\mathbf{K}_i$ is the Jacobian matrix, **y** and $\mathbf{y}_i$ are the measurements corresponding to the true and iterated state vector (**y** perturbed by noise consistent with $\mathbf{S}_{\varepsilon}$), and $\mathbf{S}_i$ is the retrieval error covariance matrix given by

$$\mathbf{S}_i = (\mathbf{S}_{ap}^{-1} + \mathbf{K}^T\,\mathbf{S}_{\varepsilon}^{-1}\,\mathbf{K})^{-1}, \qquad (4)$$

with $\mathbf{S}_{ap}$ as the *a priori* error covariance matrix.

For **q**, the diagonal elements of $\mathbf{S}_{ap}$ increase from 20% (surface) to 50% (at 400 hPa) and are then constant at 50%, the non-diagonal elements follow exponential drop-off correlation with corr.length 3 km (**T** errors are modeled as by Weisz, 2001[6]). The diagonal elements of $\mathbf{S}_{\varepsilon}$ follow the "IASI level 1c noise table" (P. Schluessel/EUMETSAT, priv. communications, 2000) and error correlation between three neighbouring channels is accounted for.

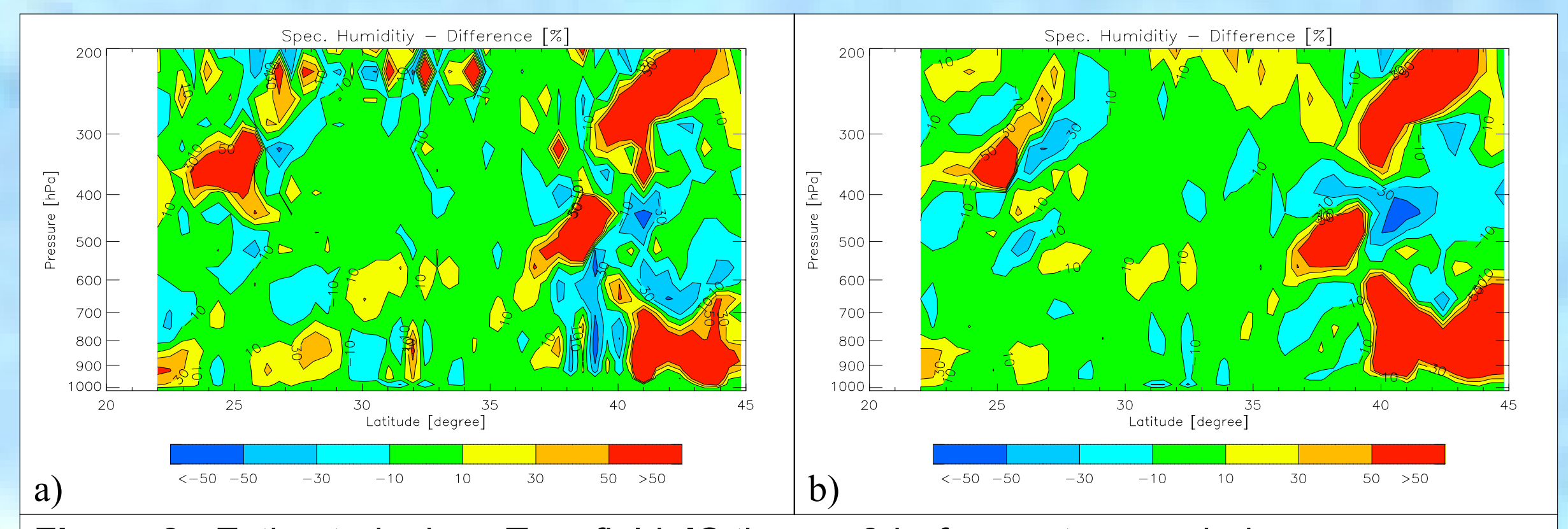

Figure 3: Estimated minus True field, **IC** theory, 6-hr forecast as *a priori*.
a) ~1400 channels, b) ~170 channels.

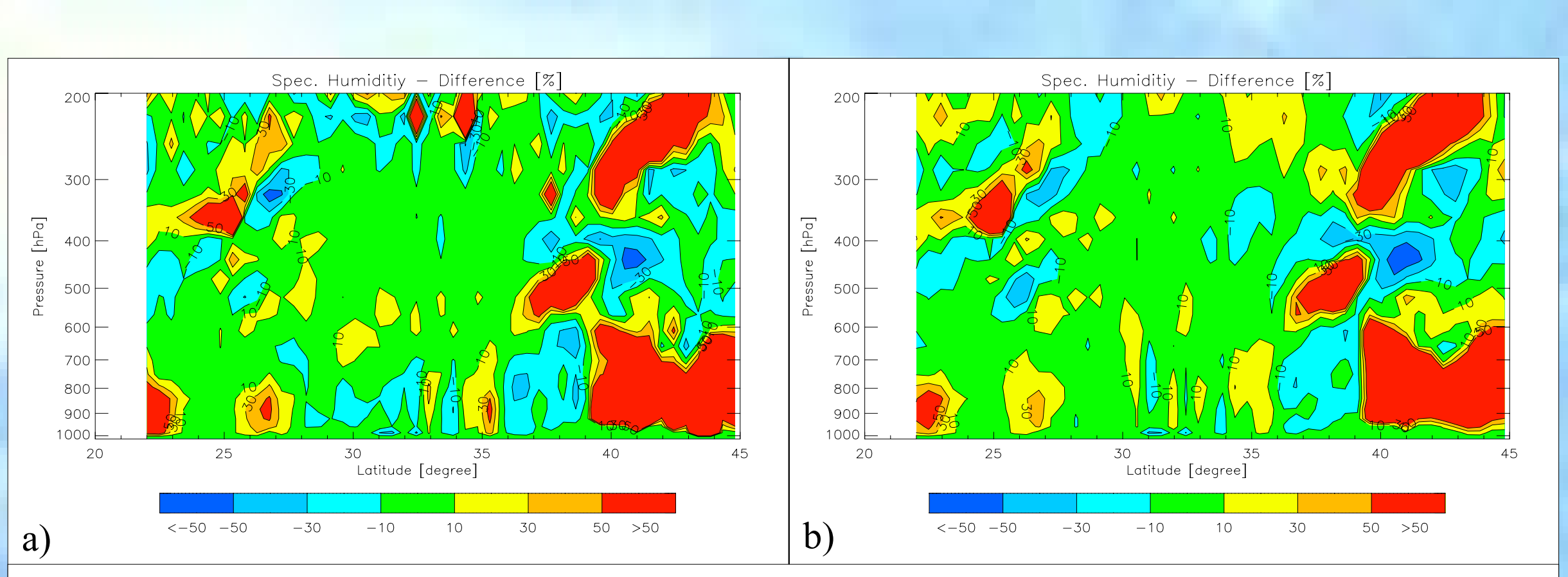

Figure 4: Estimated minus True field, **MS** approach, 6-hr forecast as *a priori*.
a) 850 channels, b) 170 channels.

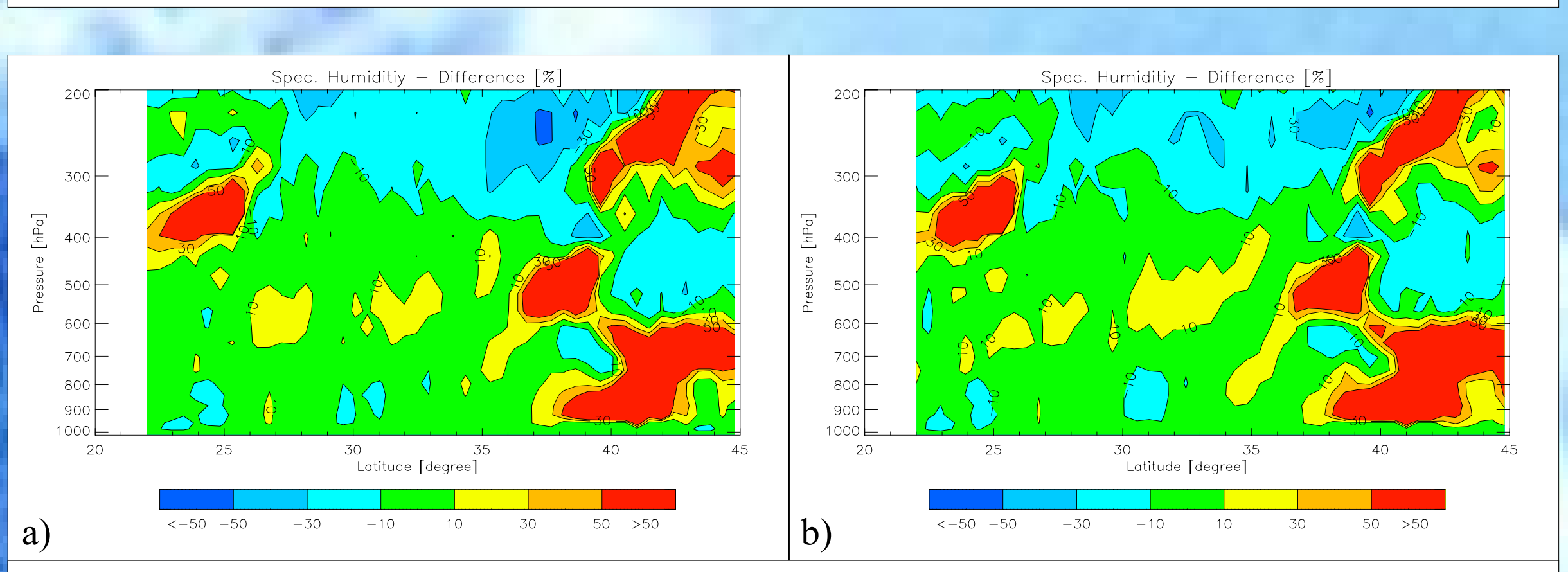

Figure 5: Estimated minus True field, with the CIRA86aQ model[3] as *a priori*.
a) using **MS** approach (170 channels), b) using **IC** theory (~170 channels).

Results, Conclusions, and Perspectives

We introduced an effective channel selection method, which we used to reduce the total number of IASI channels from more than 8000 to about 2% (~170). The method allows to select channels with highest information content on the treated atmospheric parameters and we observe that the best achievable retrieval accuracy is obtained already with <200 channels. The retrieval was implemented as a joint humidity and temperature retrieval based on optimal estimation methodology. We focus here on showing humidity retrieval performance under realistic conditions (for IASI temperature retrieval results see, e.g., Weisz, 2001[6]). Figure 2 shows the basic data for an exemplary humidity field (cross-section through "Hurricane Floyd"). Comparing Figures 3a-b and 4a-b indicates that using fewer channel with high information content still yields high retrieval accuracy (compared to using many times more channels). Figure 5 shows that, though the CIRA86aQ model[3] is insensitive to the special meteorological event (Hurricane Floyd), the results with this *a priori* are not worse in the lower troposphere (>500 hPa), even better near surface, than those with the 6-hr forecast (24-hr forecasts used in future may perform better). Generally the humidity retrieval is accurate to within 10% in the majority of the domain.

A next step is focusing on retrieval of Sea Surface Temperature (SST) and Upper Troposphere Humidity (UTH) profiles for large-scale climatological application. Based on the present encouraging results, SST and UTH data of very high quality are expected.

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