Impact of AIRS data over the Antarctic region

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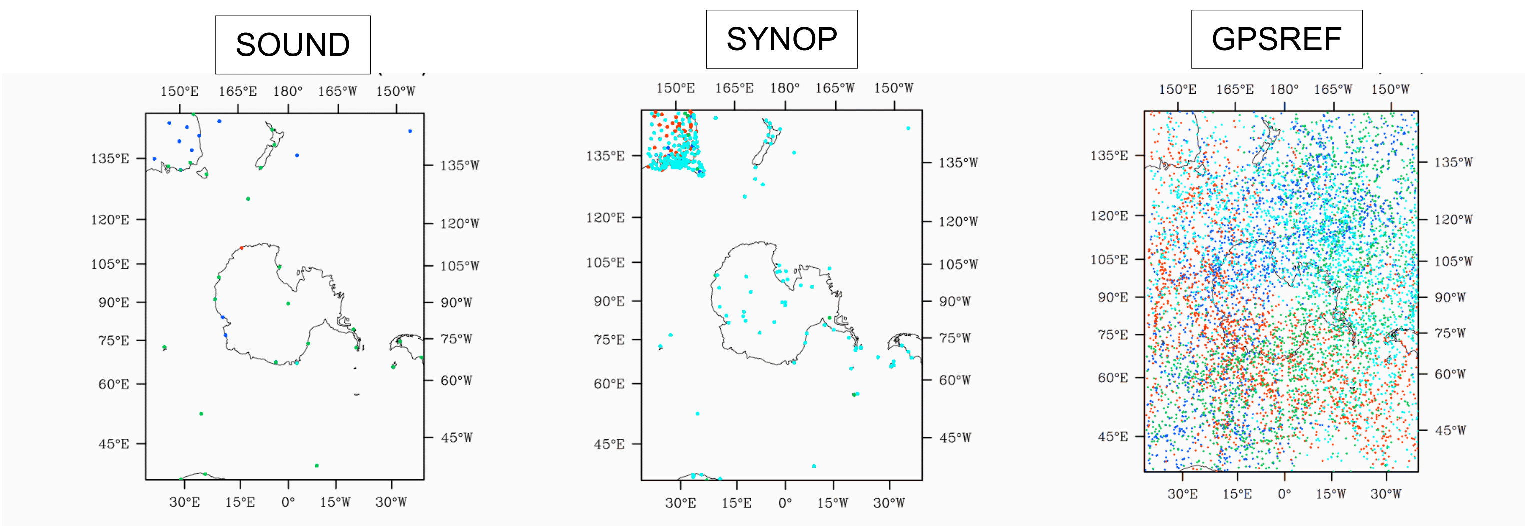
Introduction: AMPS

The Antarctic Mesoscale Prediction System (AMPS)

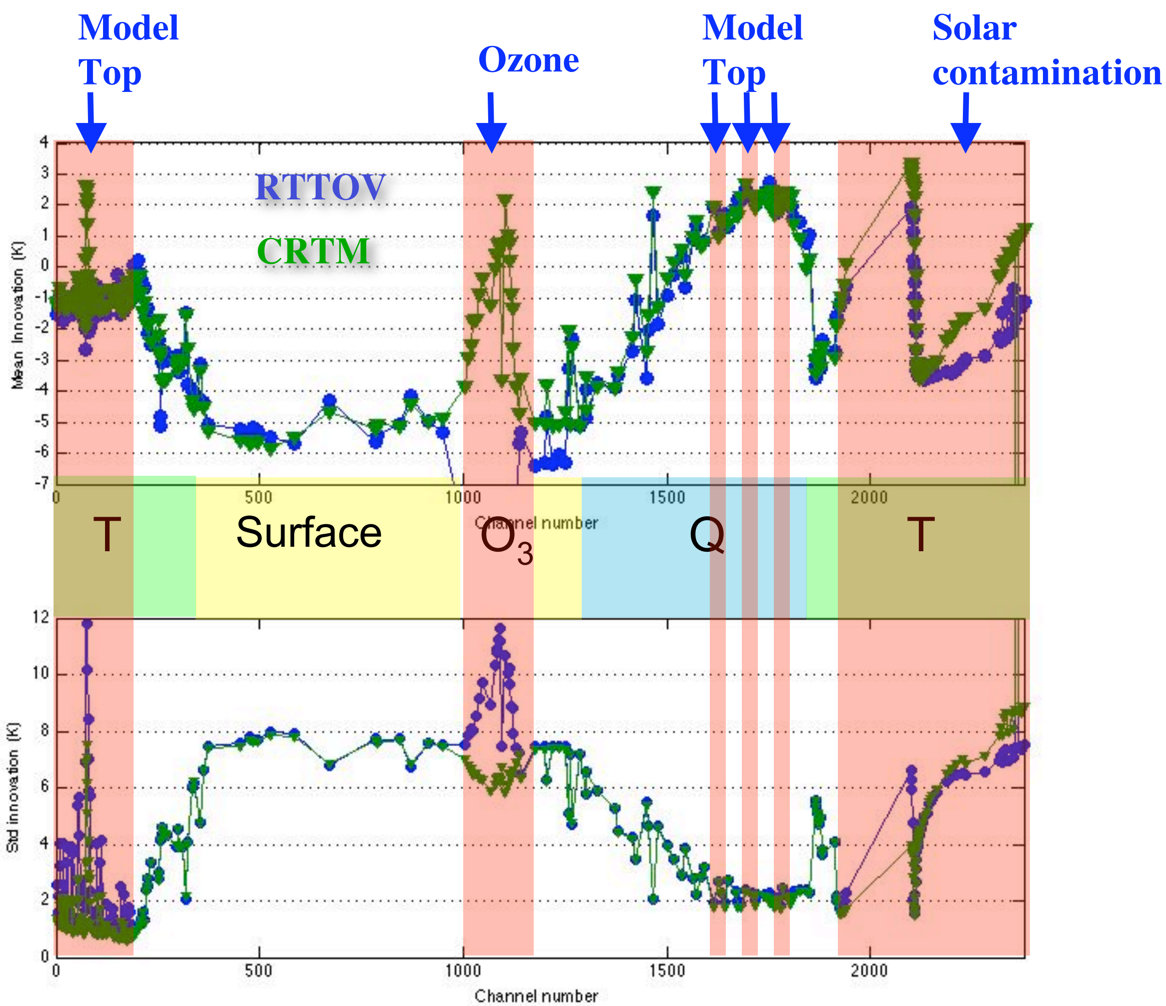
- Real-time, experimental NWP modeling capability for Antarctica
- Purposes: Support of weather forecasting and scientific activities

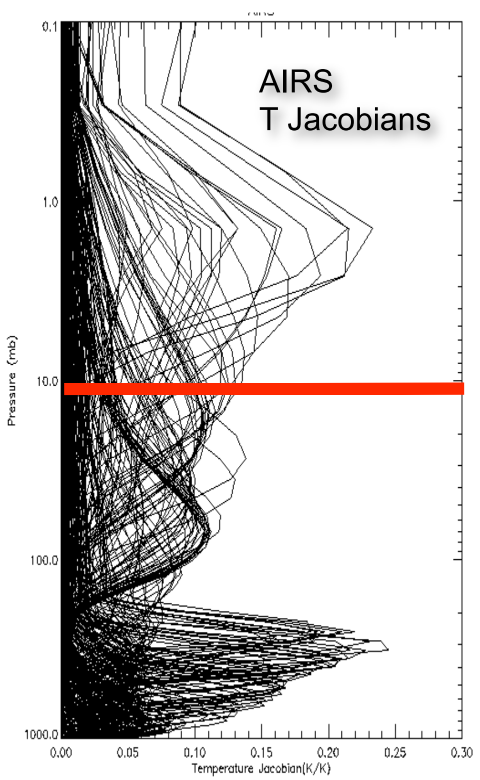
WRF-Var (3DVar)

- Specific Background Error Covariances
- Lateral Boundary Conditions from FNL



AIRS innovations: Channel Selection



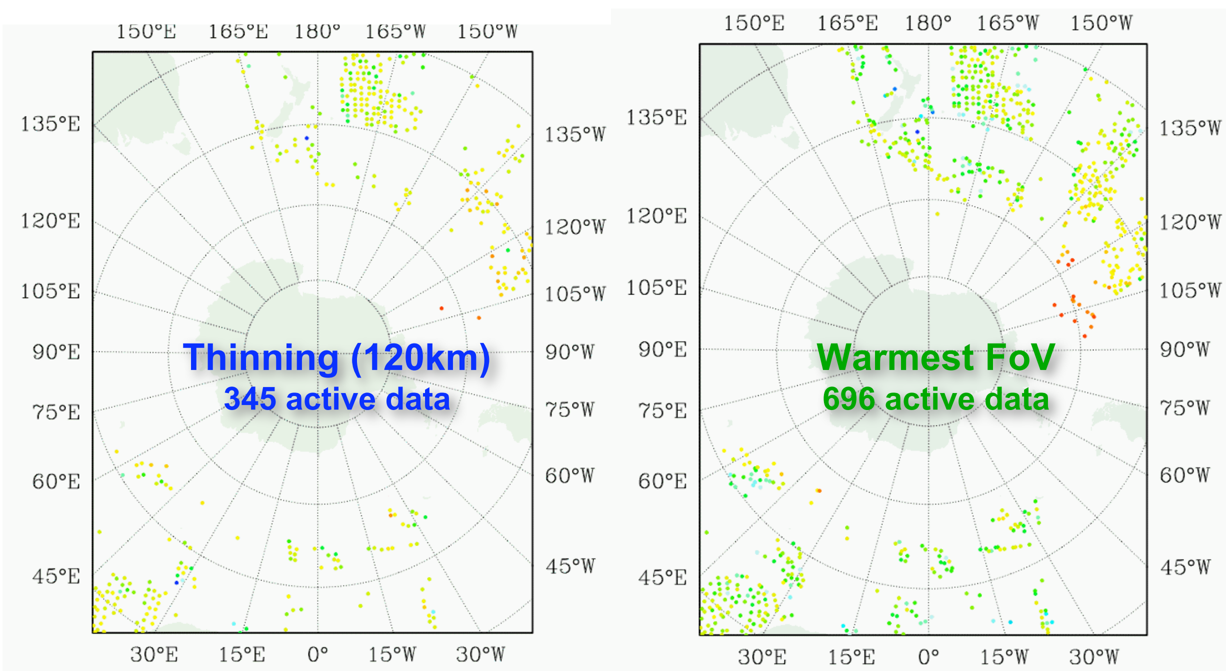


AIRS innovations: QC & Thinning

- **Pixel-level QC**
  - Reject **limb** observations
  - Reject pixels over **land** and **sea-ice**
- **Channel-level QC**
  - **Gross check** (innovations <15 K)
  - **First-guess check** (innovations < $3\sigma_o$). Error factor tuned from objective method (Desrozier and Ivanov, 2001)
- **NESDIS Cloud detection**
  - LW window channel > 271K
  - Thresholds on model SST minus SST from 4 AIRS LW channels
- **Imager AIRS/VIS-NIR**

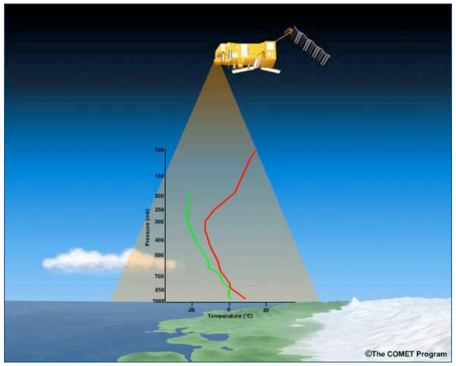
  Day only (cloud coverage within AIRS pixel <5%)

- **Thinning**

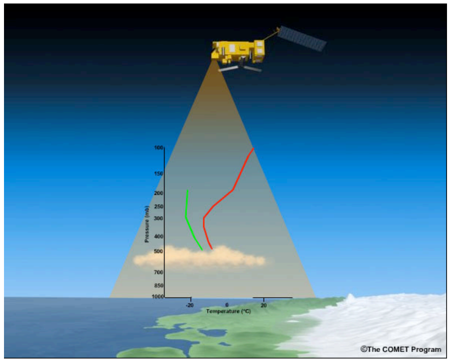


AIRS innovations: Cloud detection strategy

From « hole hunting »
(identifying clear pixels)…



… to identifying clear channels
(insensitive to the cloud).



Cloud Detection: MMR scheme

RTM

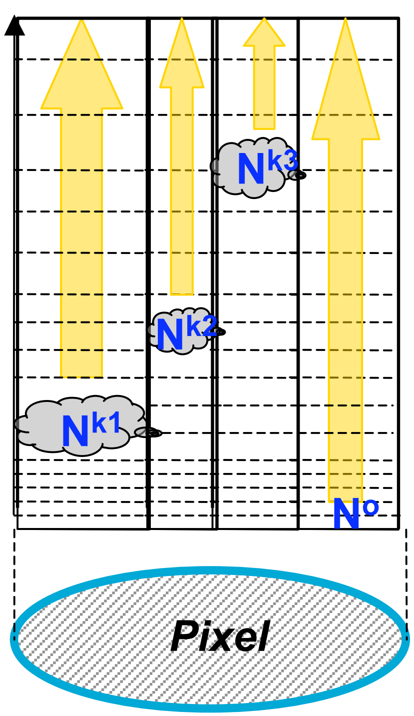
- R_ν° = Radiance calculated in **clear** sky
- $R_\nu^{\bullet k}$ = Radiance calculated for **overcast black cloud** at level k

Minimum Residual:

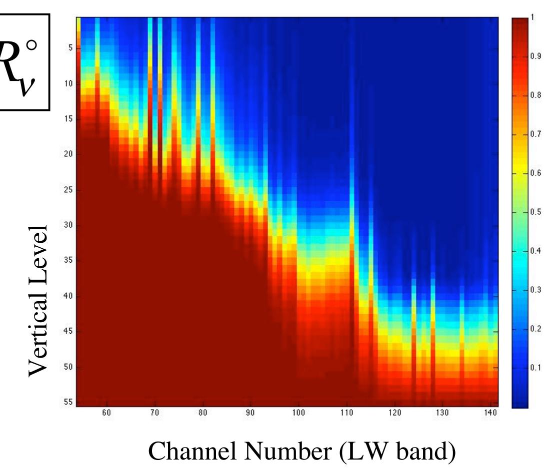
$$R_\nu^{Cld}(N,k) = (1-N)R_\nu^\circ + NR_\nu^{\bullet k}$$

Multivariate Minimum Residual (MMR):

$$R_\nu^{Cld}(N^\circ, N^1, \ldots, N^n) = N^\circ R_\nu^\circ + \sum_{k=1}^{n} N^k R_\nu^{\bullet k}$$



$R_\nu^{\bullet k} \,/\, R_\nu^\circ$

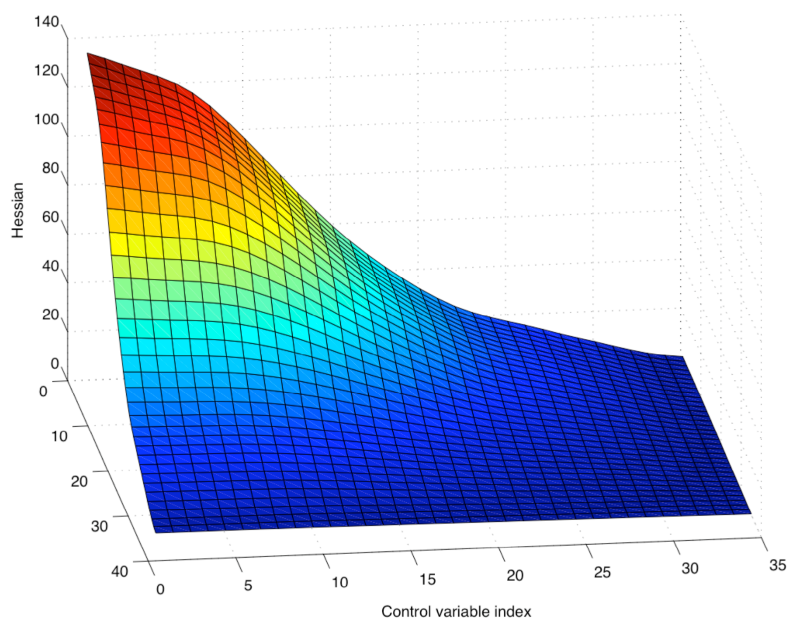


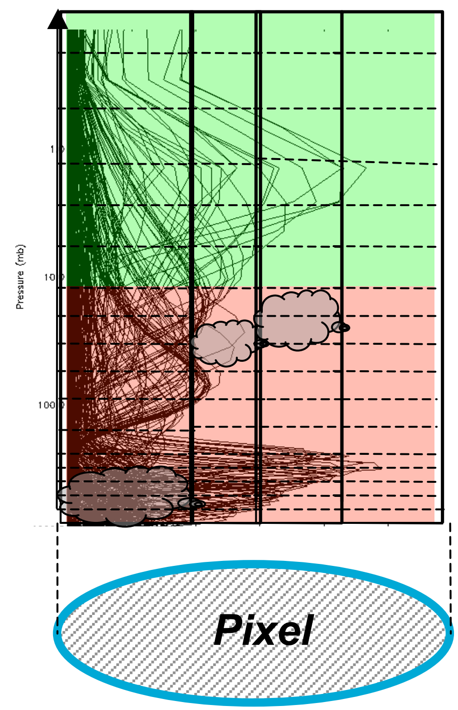
Cloud Detection: MMR scheme

$$R_\nu^{Cld} = N^\circ R_\nu^\circ + \sum_{k=1}^{n} N^k R_\nu^{\bullet k}$$

Cloud fractions $\mathbf{N^k}$ are ajusted **variationally** to fit observations:

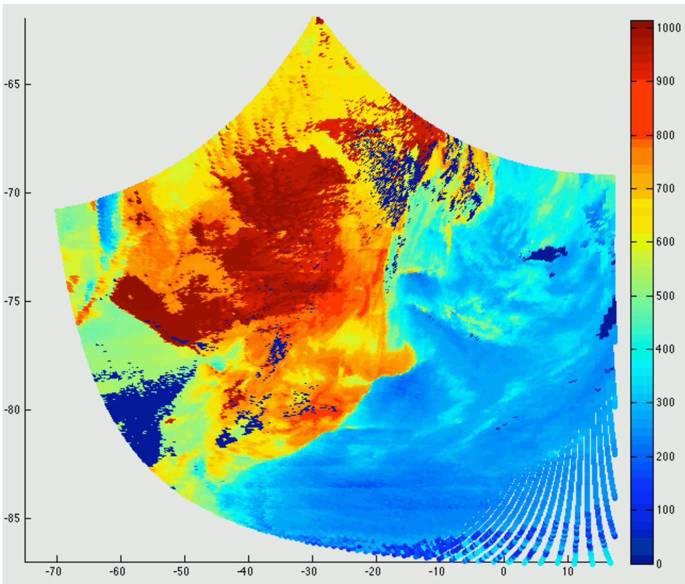
$$J(N) = \frac{1}{2}\sum_\nu \left(\frac{R_\nu^{Cld} - R_\nu^{Obs}}{R_\nu^\circ} \right)^2 \quad \text{with} \quad \begin{cases} 0 \le N^k \le 1 \\ N^\circ + \sum_{k=1}^{n} N^k = 1 \end{cases}$$



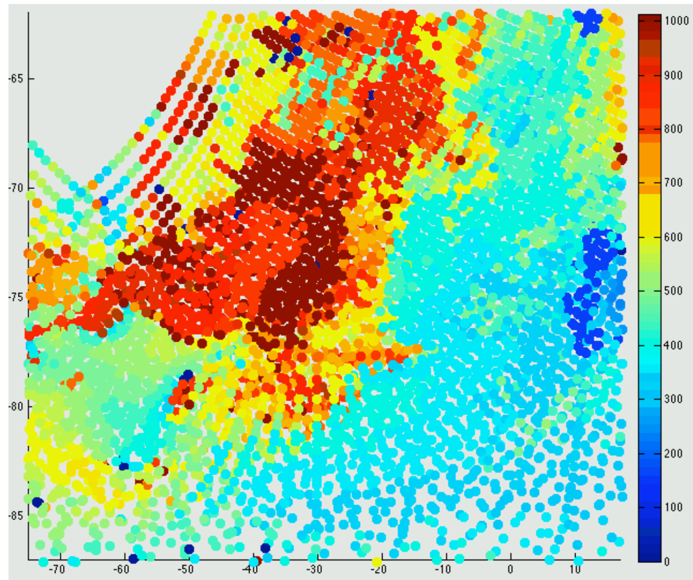


Cloud Detection: Initial Validation

Cloud Top Pressure (hPa)



MODIS Level 2 Product



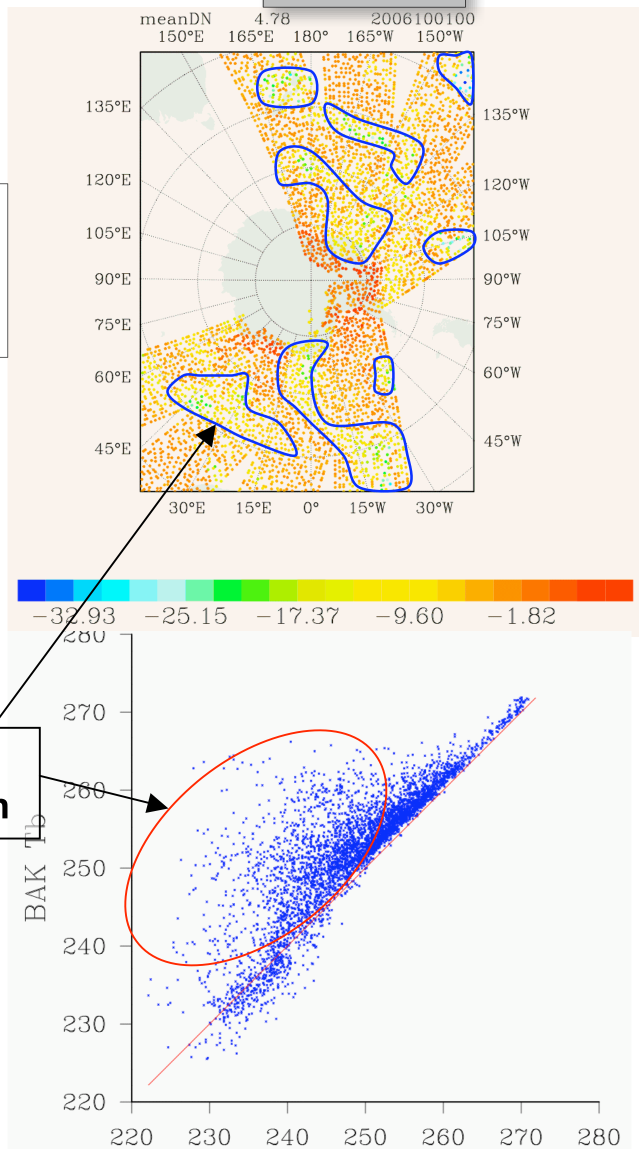
AIRS MMR

Perspective: Cloudy Radiances

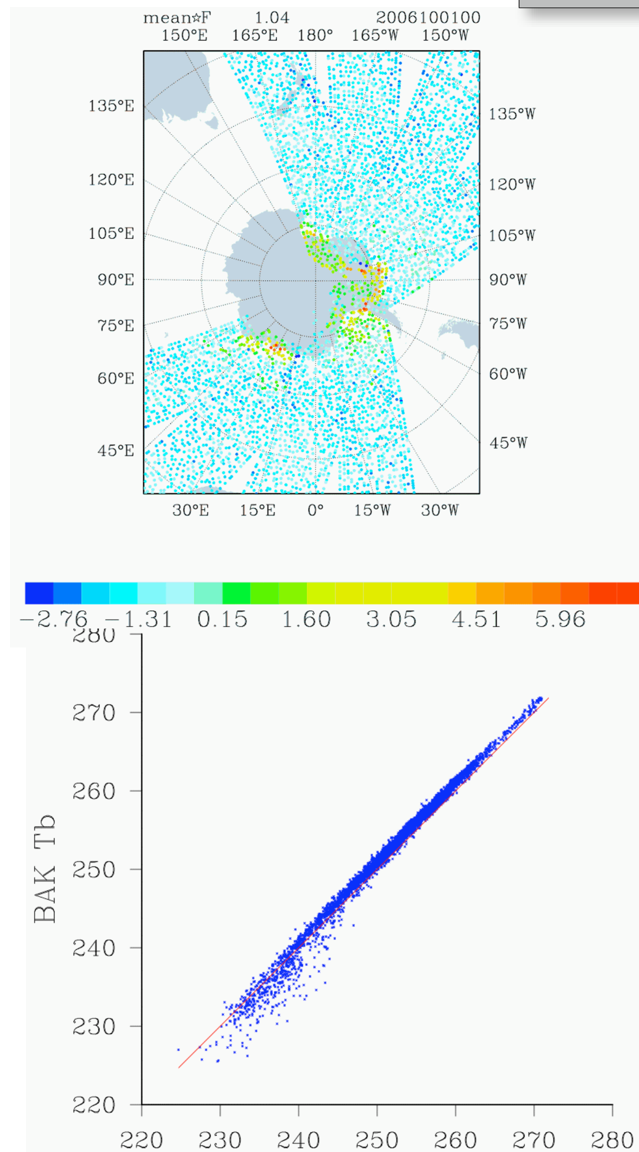
Innovations: $R_\nu^{Obs} - R_\nu^{o}$

« Retrieved » Innovations: $R_\nu^{Obs} - R_\nu^{Cld}$

Innovations for AIRS Channel #787 (surface)



Cloud Contamination



Bias Correction: Variational Bias Correction

Modeling of errors in satellite radiances:

$$y = H(x_t) + B(\beta) + \varepsilon \qquad \begin{cases} \langle \varepsilon \rangle = 0 \\ B(\beta) = \sum_{i=1}^{N} \beta_i p_i \end{cases}$$

Parameters (β_i)

Predictors (p_i):
- Offset
- scan, scan^2, scan^3

Bias parameters can be estimated within the **variational assimilation**, jointly with the atmospheric model state (Derber and Wu 1998) (Dee 2005) (Auligné et al. 2007)

Inclusion of the bias parameters in the control vector : $x^T \rightarrow [x, \beta]^T$

J_b: background term for x

J_o: corrected observation term

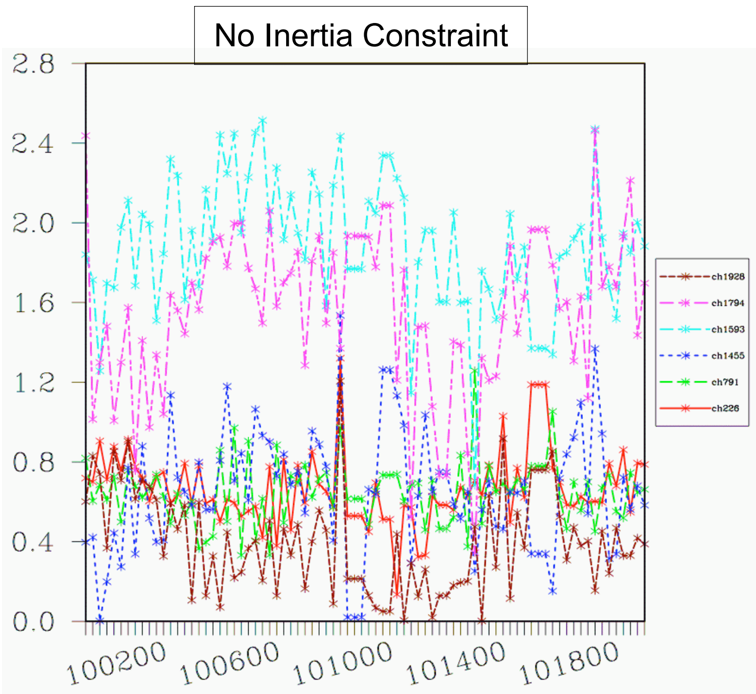
$$\mathbf{J}(\mathbf{x},\beta) = (\mathbf{x}_\mathbf{b} - \mathbf{x})^\mathrm{T} \mathbf{B}_\mathbf{x}^{-1} (\mathbf{x}_\mathbf{b} - \mathbf{x}) + [\mathbf{y} - H(\mathbf{x}) - B(\beta)]^\mathrm{T} \mathbf{R}^{-1} [\mathbf{y} - H(\mathbf{x}) - B(\beta)]$$
$$+ (\beta_\mathbf{b} - \beta)^\mathrm{T} \mathbf{B}_\beta^{-1} (\beta_\mathbf{b} - \beta)$$

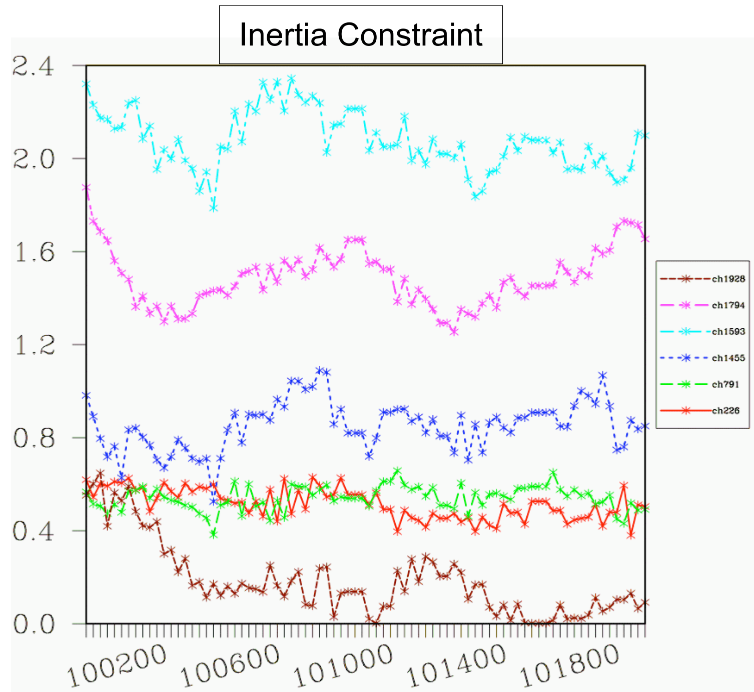
J_β: background term for β

«Optimal » bias correction considering all available information

Bias Correction: VarBC Timeseries

Time evolution of Offset bias parameter for various AIRS channels





Inverse Modeling: Adjoint Parameter Estim.

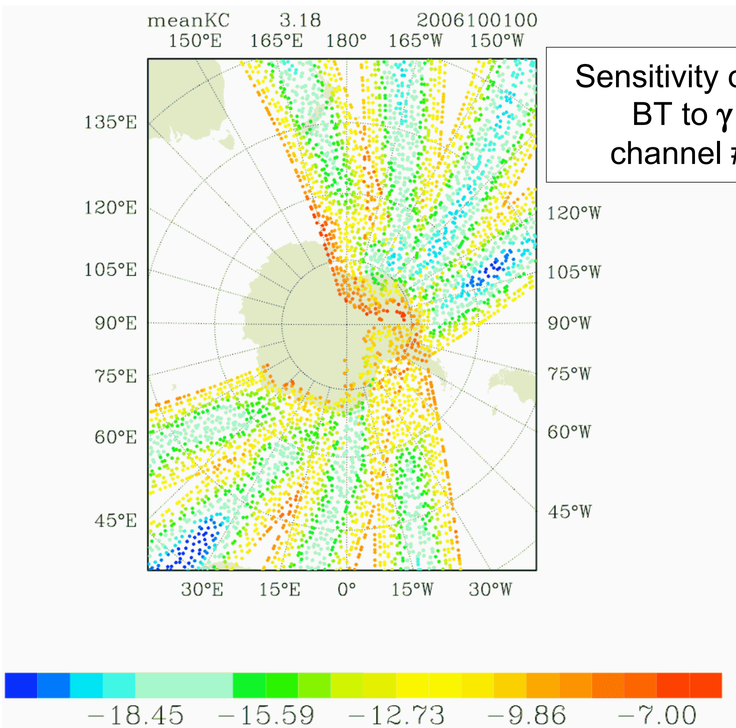
$$R_\nu^{atm} = \int_{z_0}^{\infty} B_\nu(T(z)) \left[\frac{d\tau_\nu(z,\theta)}{dz} \right] dz$$

$$\tau_\nu(z_1,\theta) = \exp\{-\gamma_\nu \sec\theta \int_{z_1}^{\infty} k_\nu(z) c(z) \rho(z) dz\}$$

B = Planck function
τ = transmittance
T = temperature
θ = incident angle
z = altitude coordinate
k_ν = absorption coefficient
c = mixing ratio
P = atmospheric density

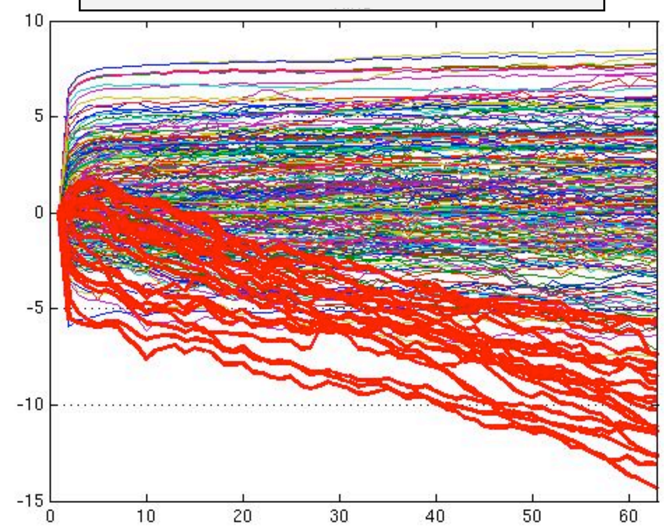
γ modulates atmospheric absorption to compensate for:

- **poor knowledge of gas concentrations (CO_2, …)**
- **errors in definition of ISRF**
- **errors in mean absorption coefficient**



Sensitivity of AIRS BT to γ for channel #221

Timeseries of γ estimations



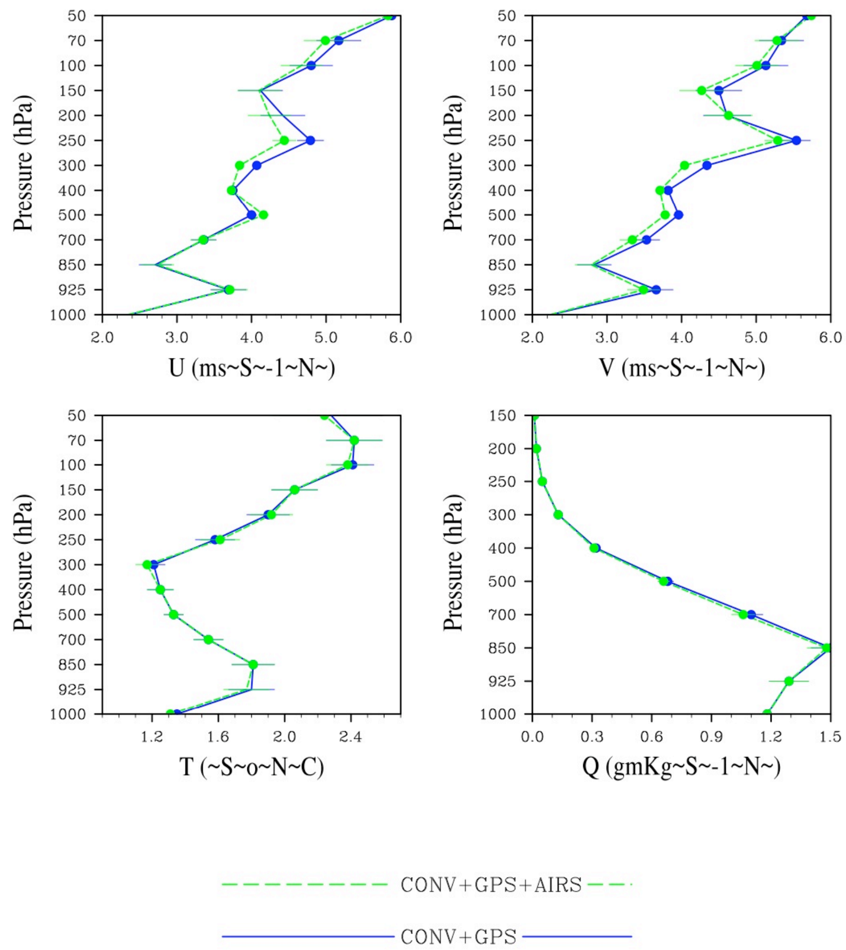
Auligné (2007)

AIRS Impact: 36h Forecast *vs*. Radiosondes

<u>Initial assessment of AIRS impact:</u>

- 60km horizontal resolution
- 50hPa model top
- 6-hourly cycling with WRF 3DVar
- Period = 01-19 Oct 2006
- CTRL Expt = Conventional Data + COSMIC GPS refractivity
- AIRS Expt = CTRL + AIRS radiances
- Radiance thinning = 120km
- No radiance over land / snow / sea-ice

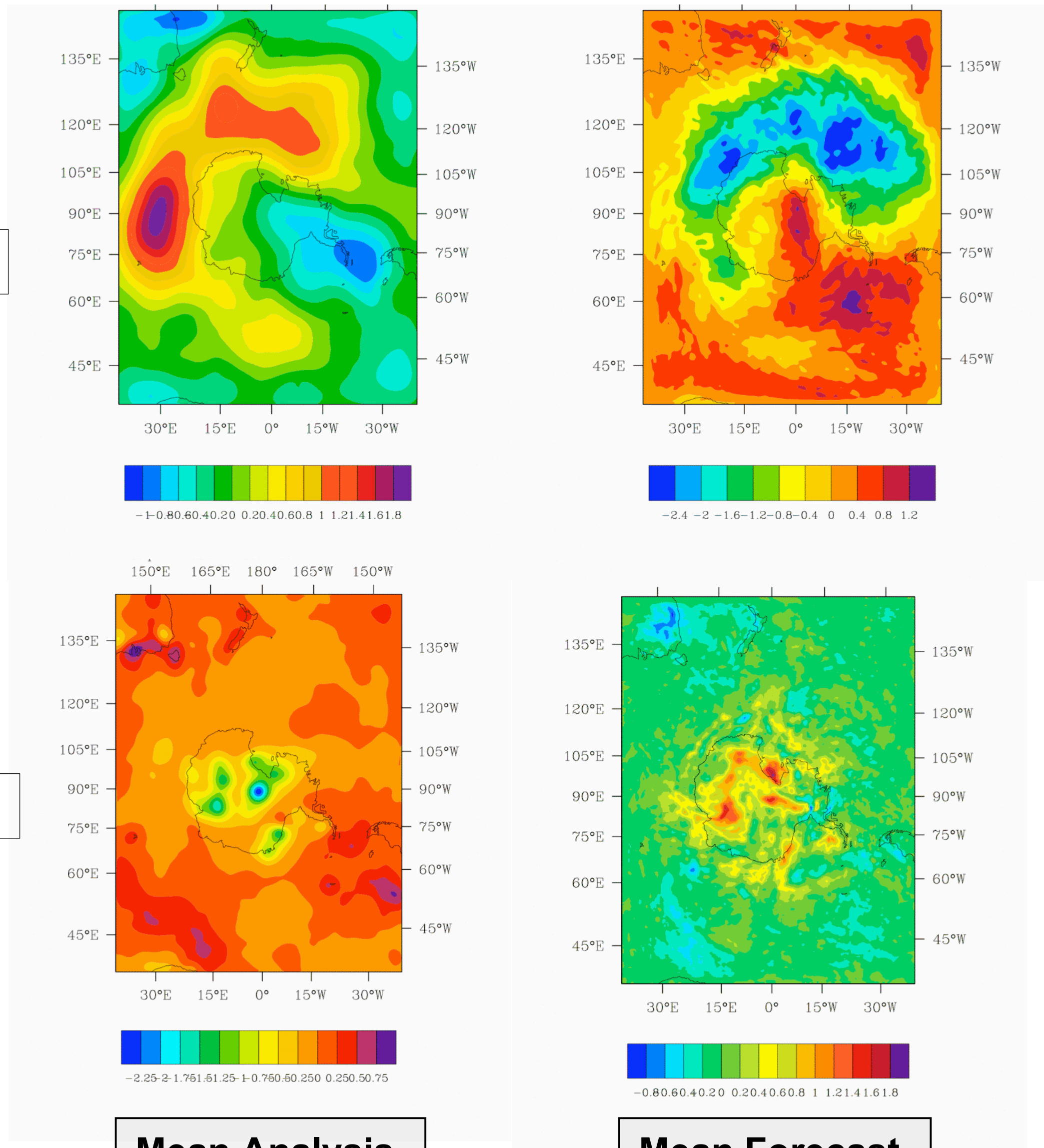
RMSE (averaged over 18 days)



Major limitation: Systematic model error

50 hPa

Surface



Mean Analysis Increments

Mean Forecast Error (24h - 12h)

Conclusions and future work

- **Encouraging results**
  - Initial test with conservative implementation
  - Neutral impact, slightly positive on wind forecast
- **Short-term improvements**
  - Raise model top
  - Use more AIRS channels
  - Improved estimation of surface emissivity over land
- **Longer-term developments**
  - Compare with impact of retrievals
  - Address systematic model errors
  - Assimilate cloud-contaminated radiances