Impact of AIRS and AMSUA over the Antarctic region

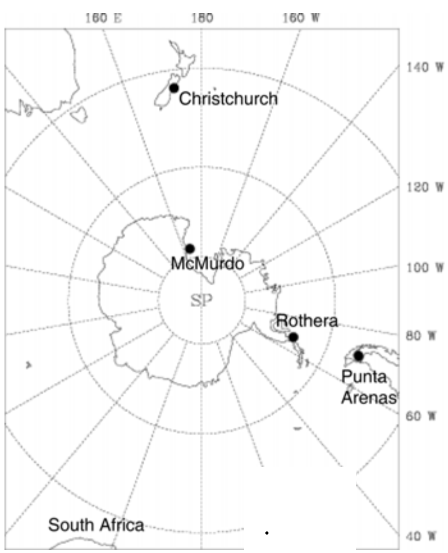
Tom Auligné, Dale Barker, Zhiquan Liu, Hui-Chuan Lin, Hui Shao

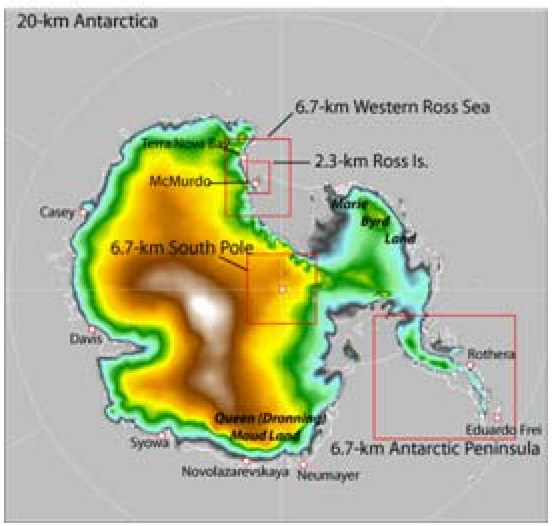
National Center for Atmospheric Research

Introduction: AMPS

The Antarctic Mesoscale Prediction System (AMPS)

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





AMPS Forecasts

Frequency: 2 / day

Initializations: 00 & 12 UTC

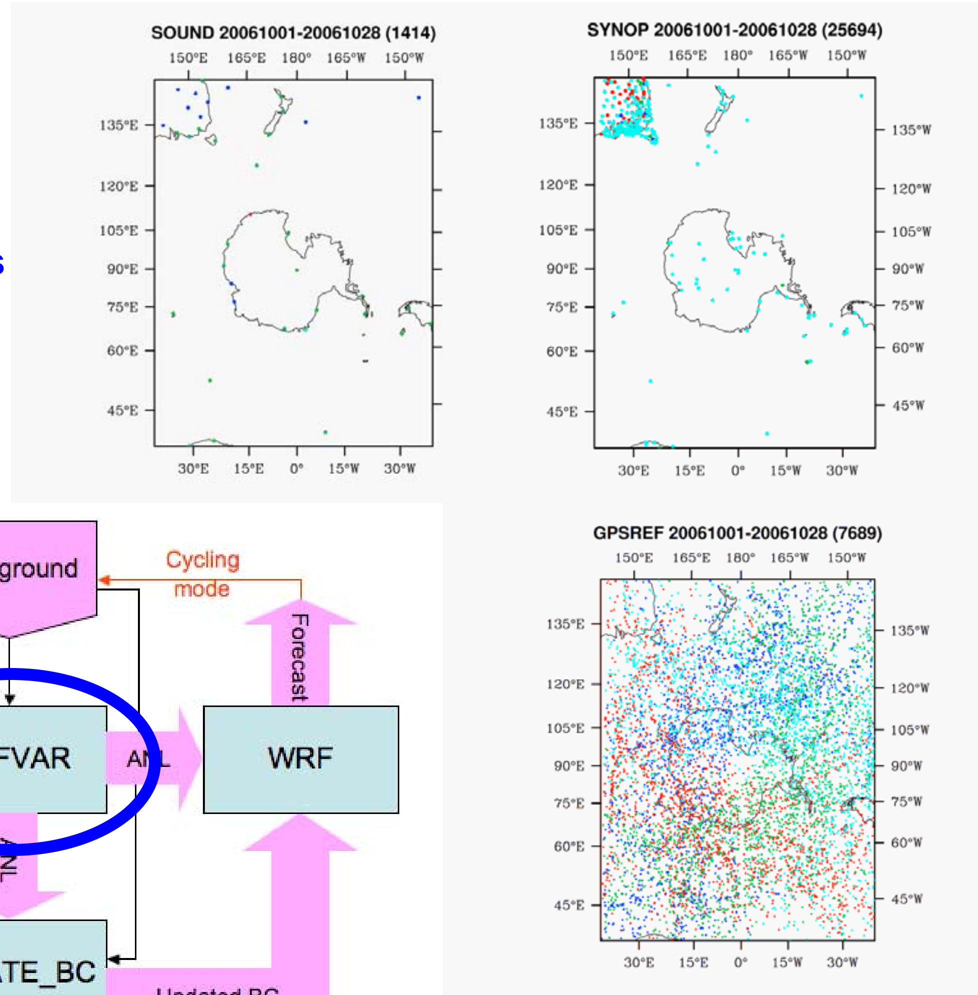
Duration: 36–120 hours

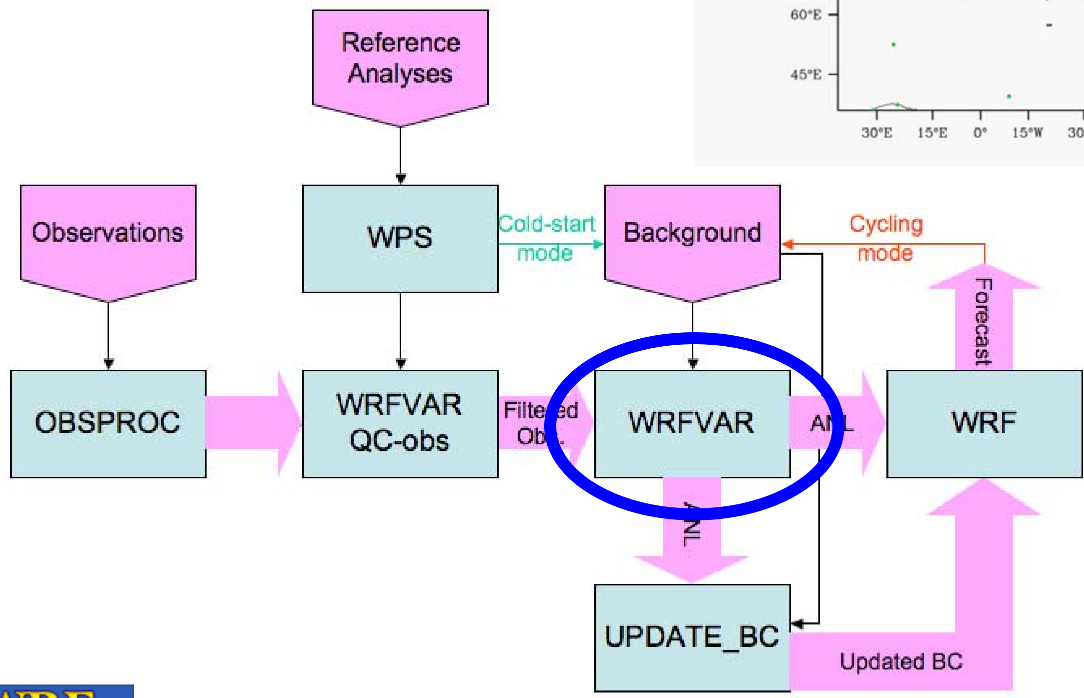
60-km **20-km, 6.7-km, 2.3-km**

WRF

Introduction: WRF-Var

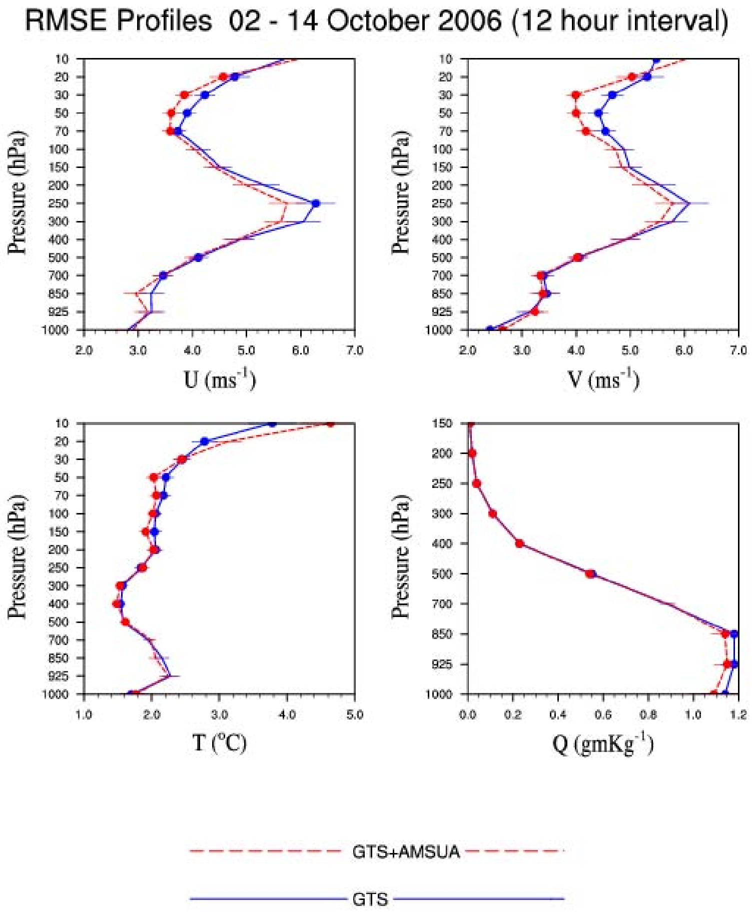
- Variational DA system (3DVar)
- Lateral Boundary Conditions from FNL
- Specific Background Error Covariances



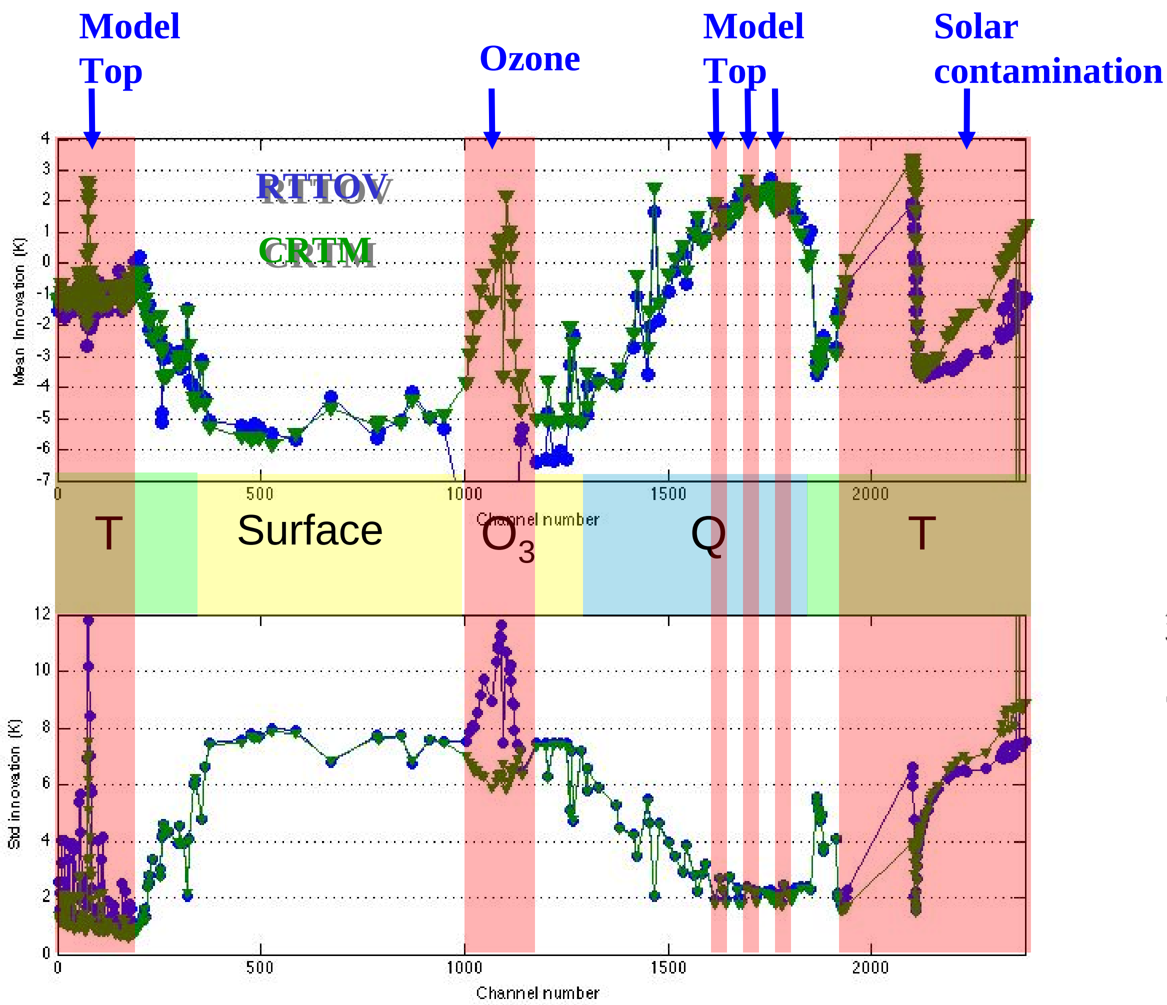


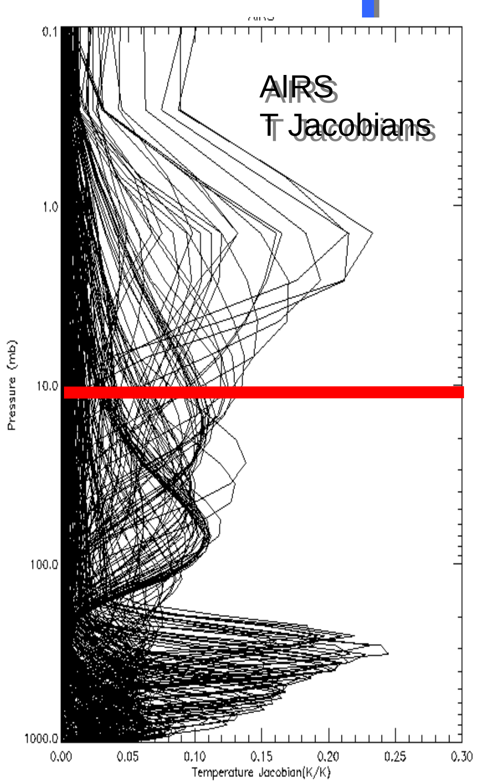
AMSUA Impact: Forecast Score *vs.* RS

- **Horiz. resolution = 60km**
- **57 Levels, Model top = 10hPa**
- **Full cycling**
- **NOAA 15/16/18 AMSU-A channels 4 to 9**
- **Radiance over ocean only**
- **Static Bias Correction (Harris and Kelly, 2001): 4 predictors**
- **Thinning 120km**
- **QC = thresholds on innovations**



AIRS innovations: Channel Selection



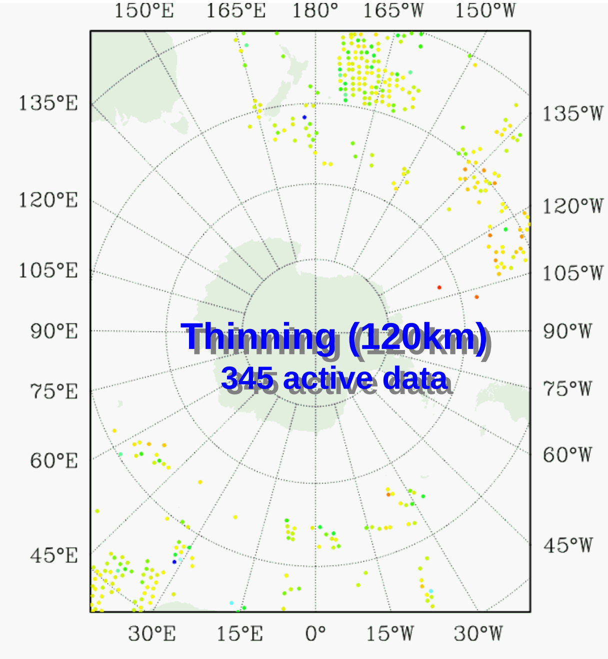


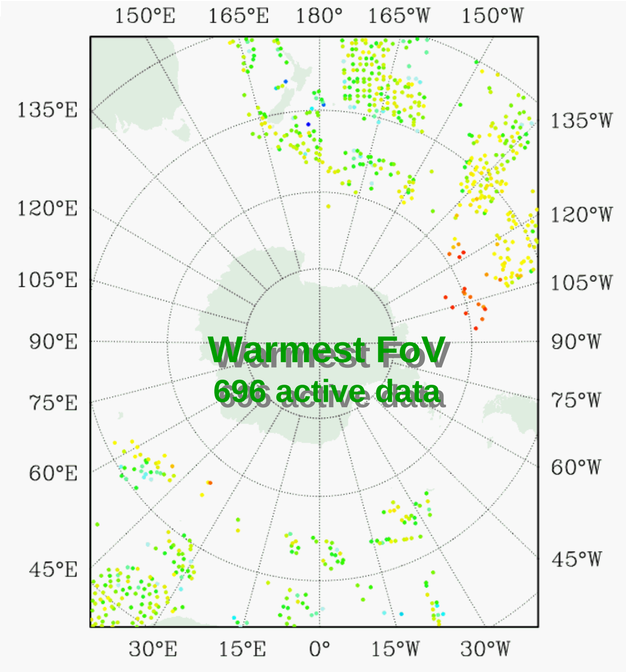
AIRS innovations: QC & Thinning

- **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**

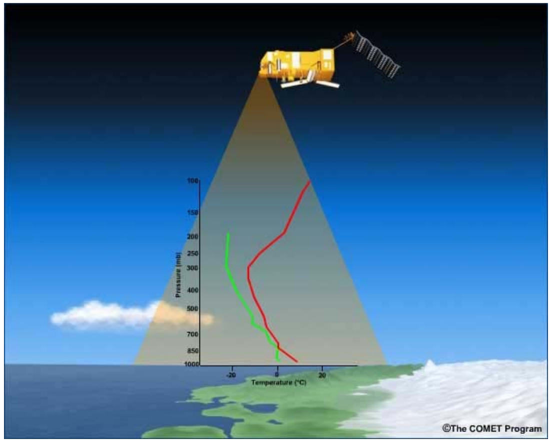
  Day only (cloud coverage within AIRS pixel <5%)

- **Thinning**

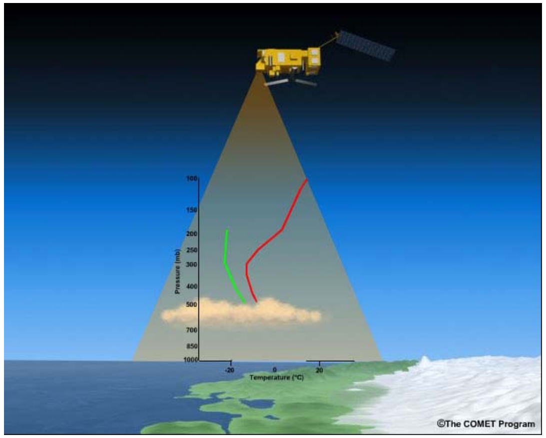




AIRS innovations: Cloud detection strategy



From « hole hunting »
(identifying clear pixels)…



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

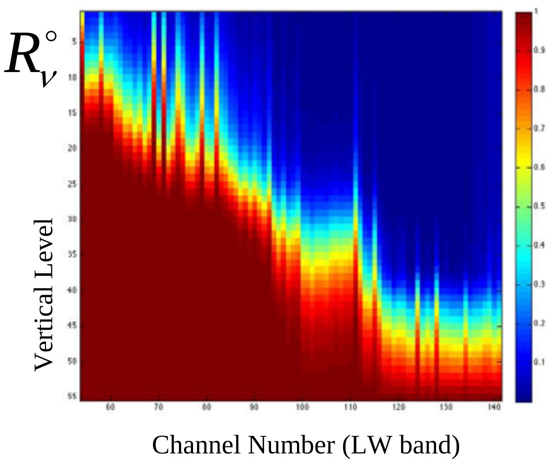
Cloud Detection: MMR scheme

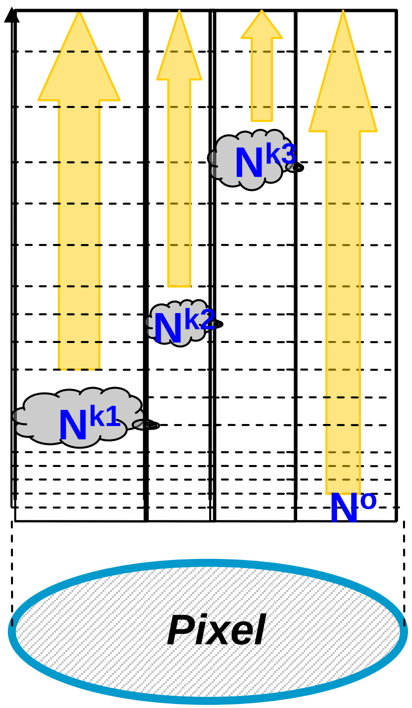
RTM
- R_ν° = Radiance calculated in **clear** sky
- $R_\nu^{\bullet k}$ = Radiance calculated for **overcast black cloud** at level k

Minimum Residual:

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

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





Multivariate Minimum Residual (MMR):

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

Cloud Detection: MMR scheme

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

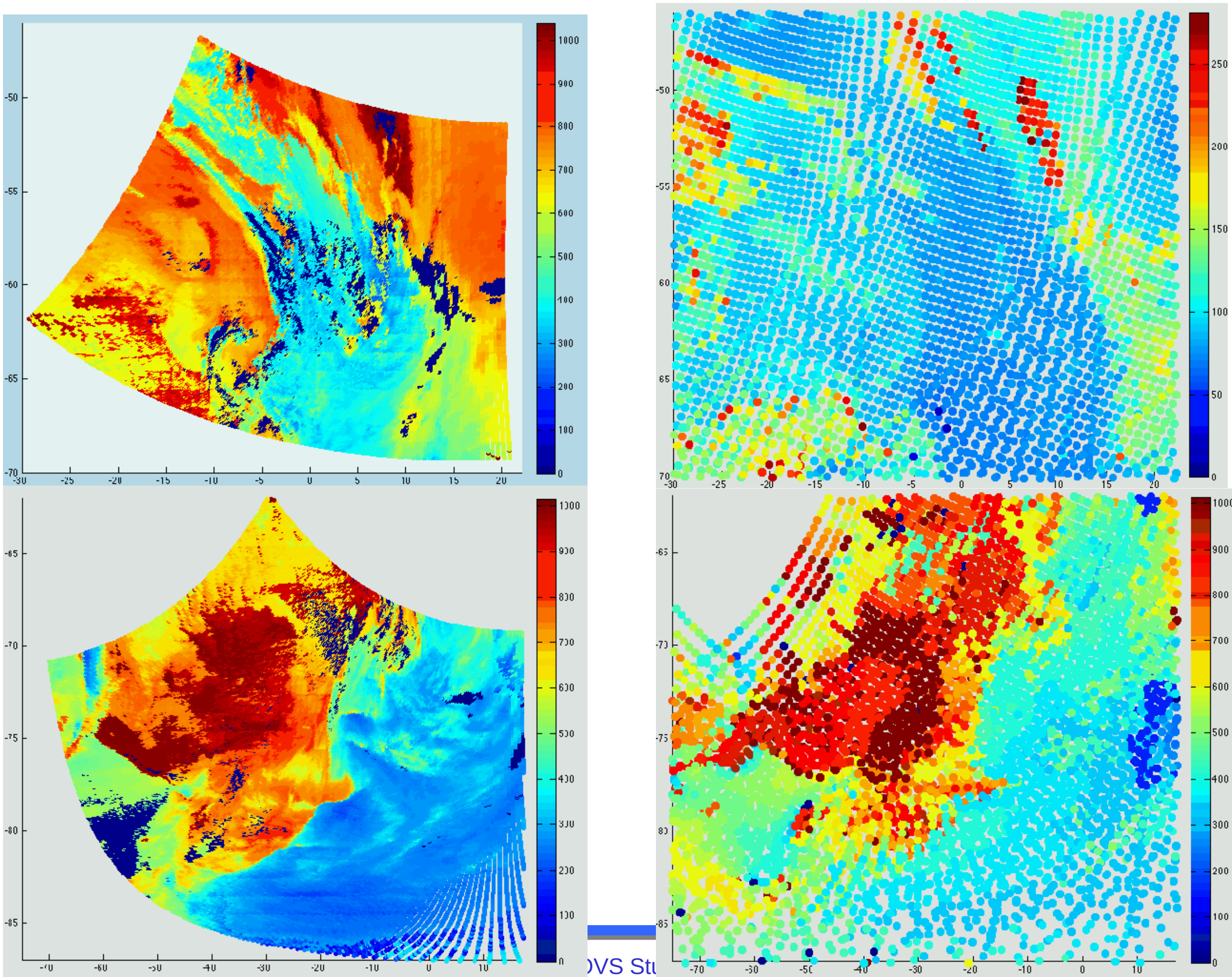
Cloud fractions **N^k** are ajusted **variationally** to fit observations:

$$J(N) = \frac{1}{2} \sum_{\nu} \left(\frac{R_\nu^{Cld} - R_\nu^{Obs}}{R_\nu^{\circ}} \right)^2$$

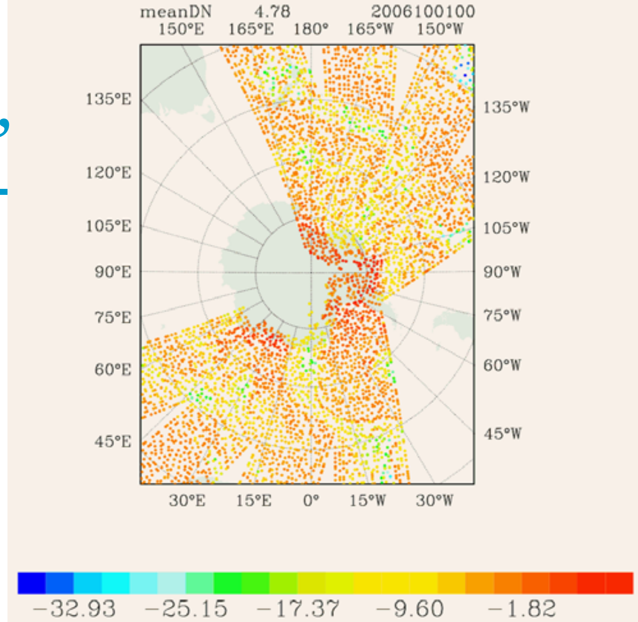
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

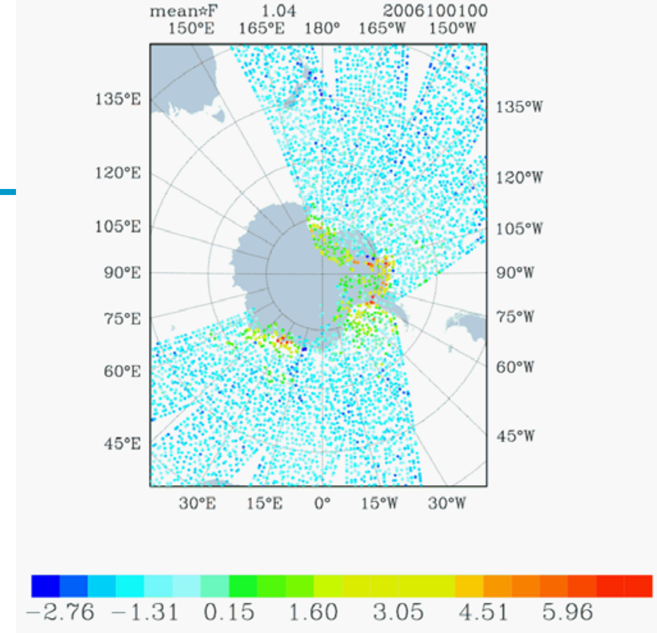
with
$$\begin{cases} 0 \leq N^k \leq 1, \forall k \in [0, n] \\ N^{\circ} + \sum_{k=1}^{n} N^k = 1 \end{cases}$$

Cloud Detection: comparison with MODIS

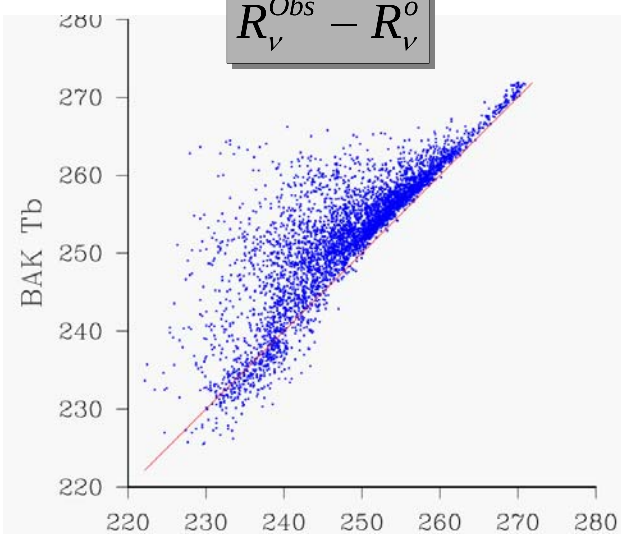


"Cloud Clearing"

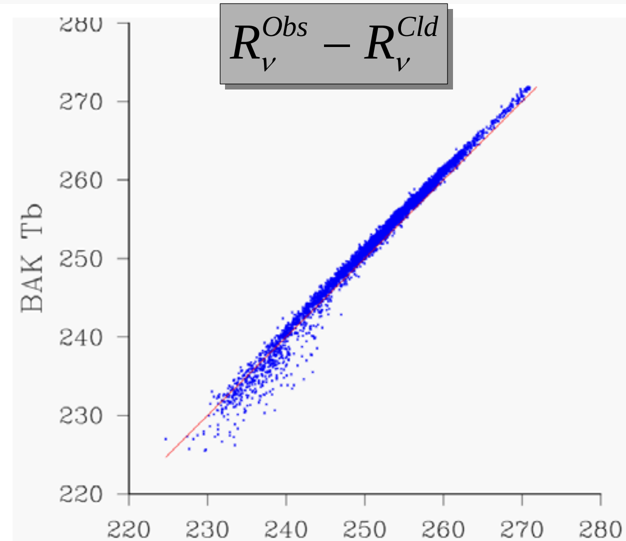


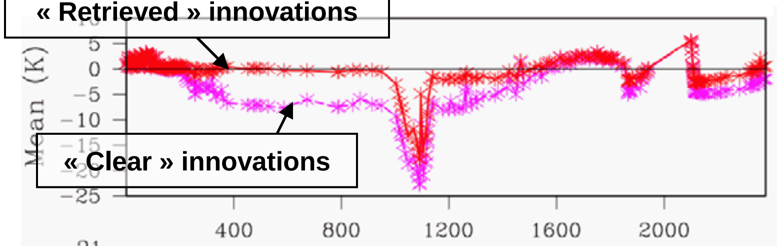


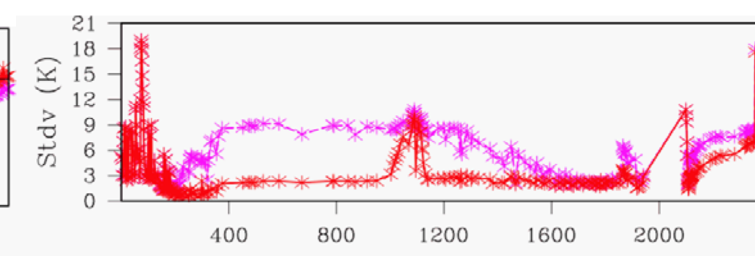
$R_\nu^{Obs} - R_\nu^{o}$



$R_\nu^{Obs} - R_\nu^{Cld}$







Bias Correction: Variational BC

Modeling of errors in satellite radiances:

$$y = H(x_t) + B(\beta) + \varepsilon$$

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

Parameters

Predictors:

- 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

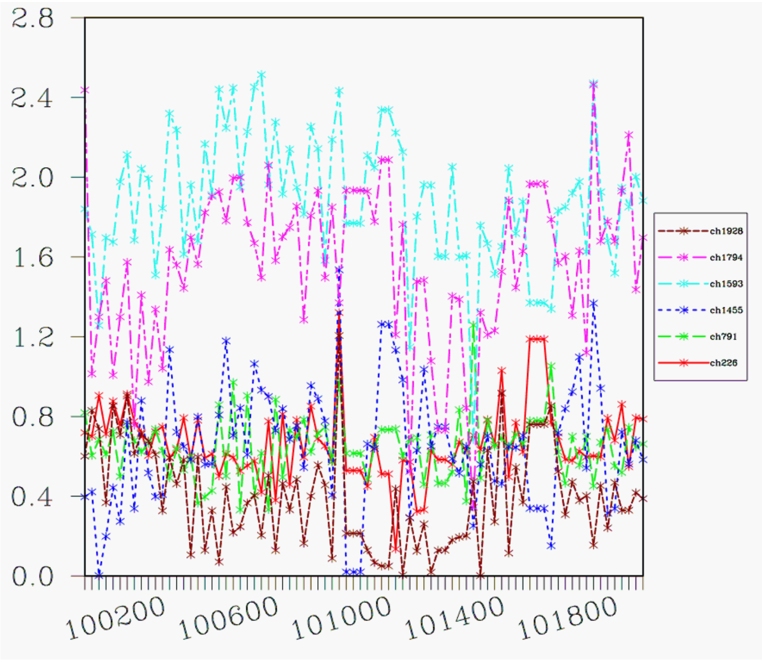
$$\mathbf{J}(\mathbf{x},\beta) = (\mathbf{x_b} - \mathbf{x})^T \mathbf{B_x^{-1}} (\mathbf{x_b} - \mathbf{x}) + [\mathbf{y} - H(\mathbf{x}) - B(\beta)]^T \mathbf{R}^{-1} [\mathbf{y} - H(\mathbf{x}) - B(\beta)]$$
$$+ (\beta_b - \beta)^T \mathbf{B}_\beta^{-1} (\beta_b - \beta)$$

J_β: background term for β

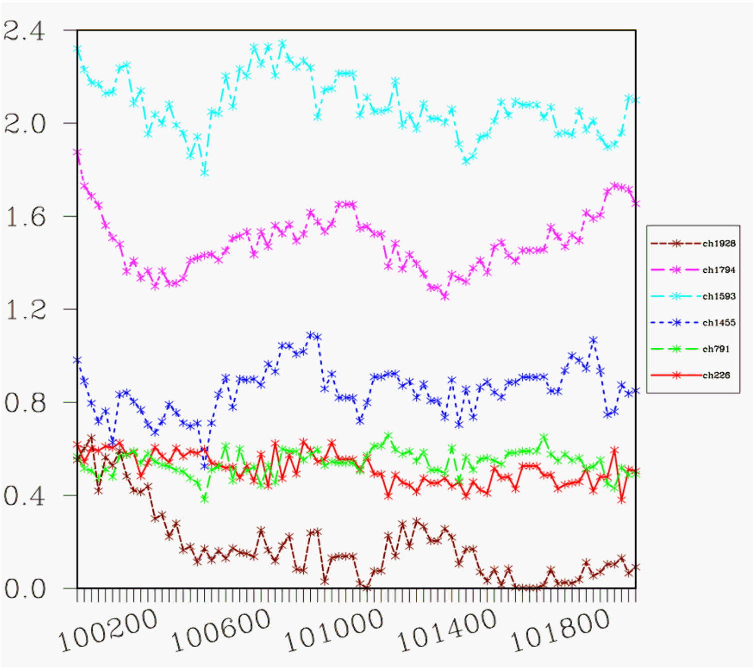
«Optimal » bias correction considering all available information

Bias Correction: VarBC Timeseries

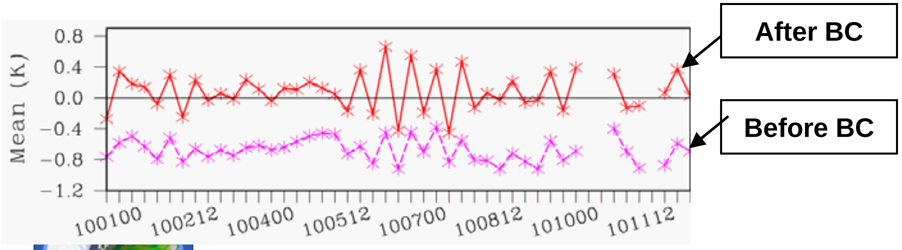
No Inertia Constraint

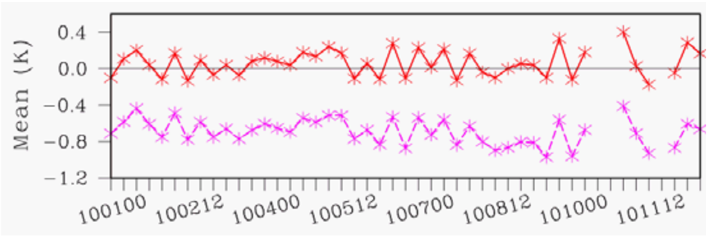


Inertia Constraint



Innovations for AIRS window channel #787





Inverse Modeling: Adjoint Parameter Estim.

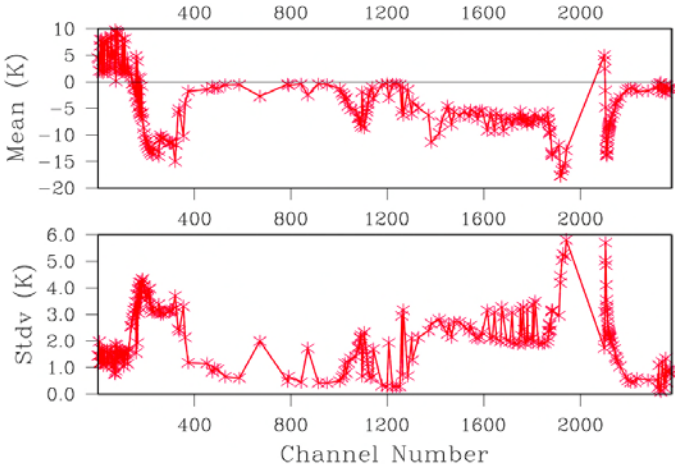
$$R_\nu^{atm} = \int_{z_0}^{\infty} B_\nu(T(z)) \left[\frac{d\tau_\nu(z,\theta)}{dz} \right] dz$$

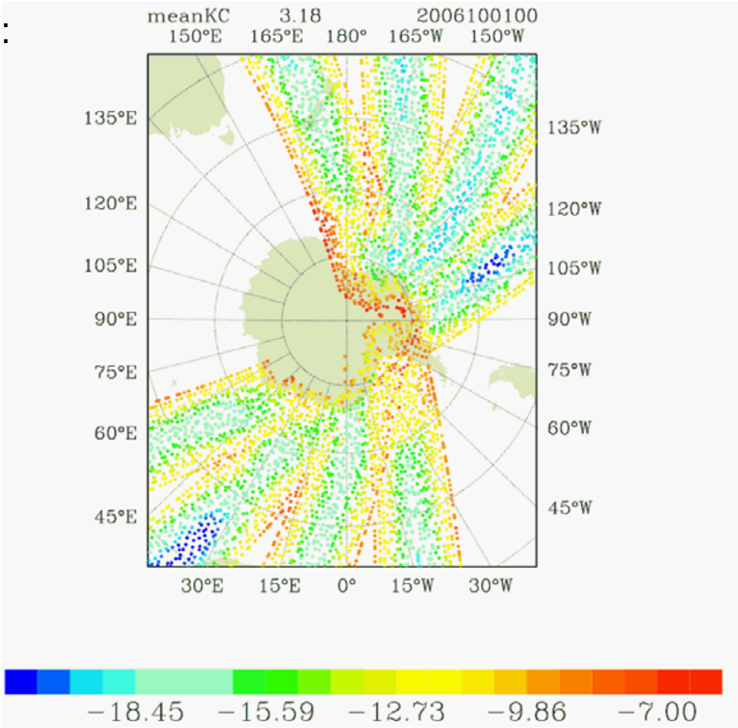
$$\tau_\nu(z_1,\theta) = \exp\{-\gamma_\nu \sec\theta \int_{z_1}^{\infty} k_\nu(z) c(z) \rho(z) dz\}$$

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

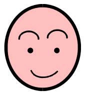
γ modulates atmospheric absorption to compensate for:

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

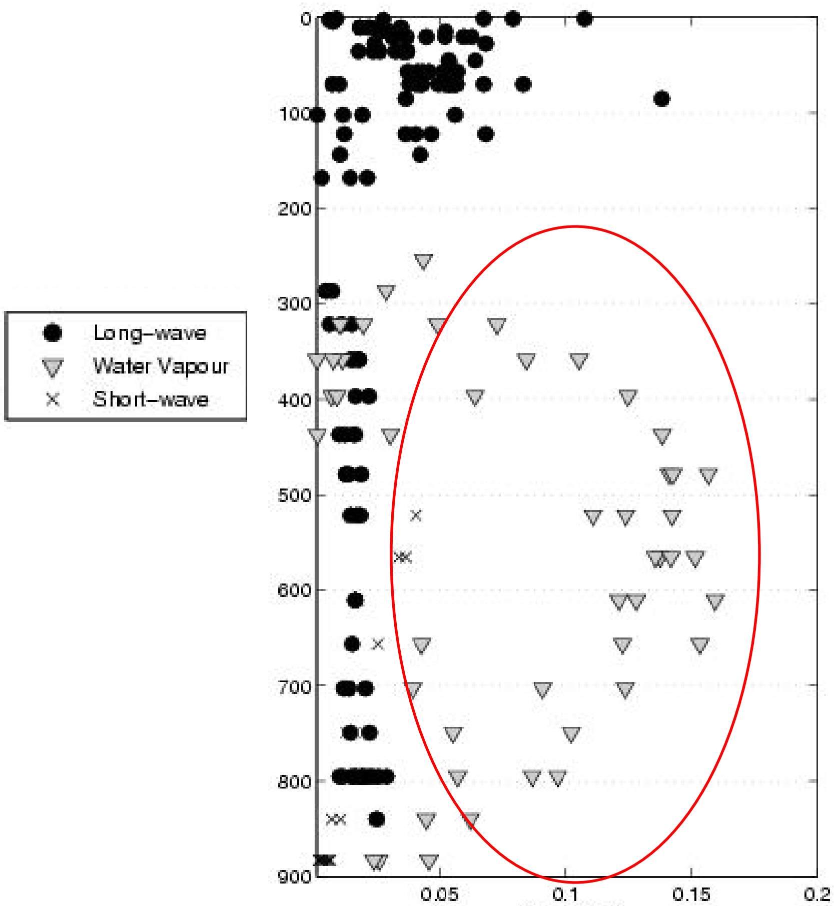




Inverse Modeling: Parameter Estimation

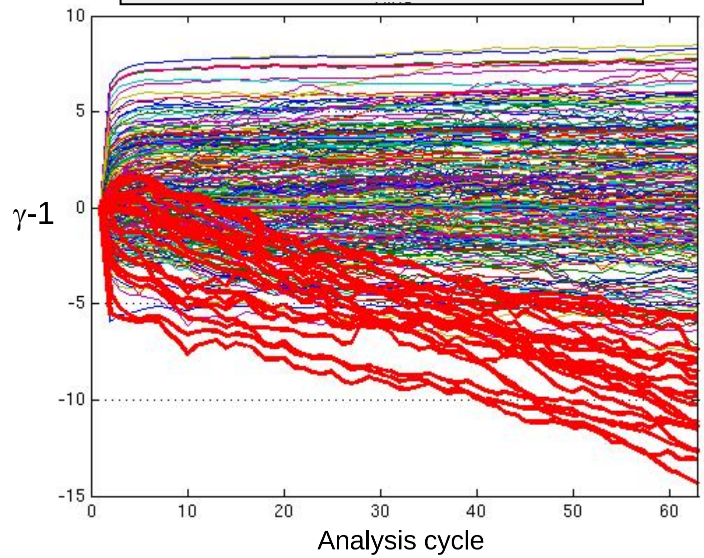


Sensitivity to model error

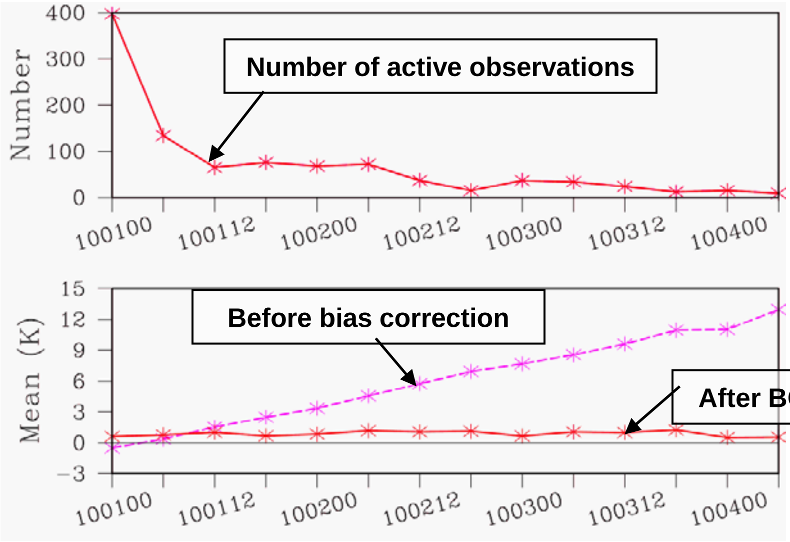


Auligné (2007)

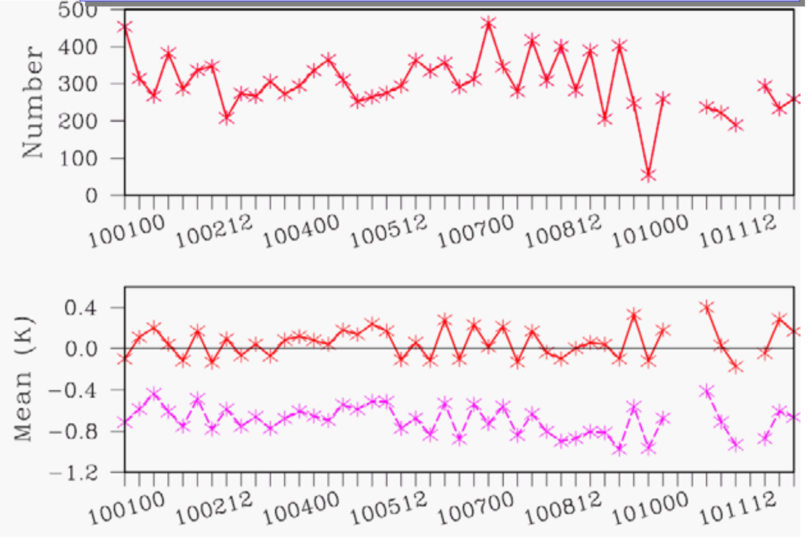
Timeseries of γ estimations

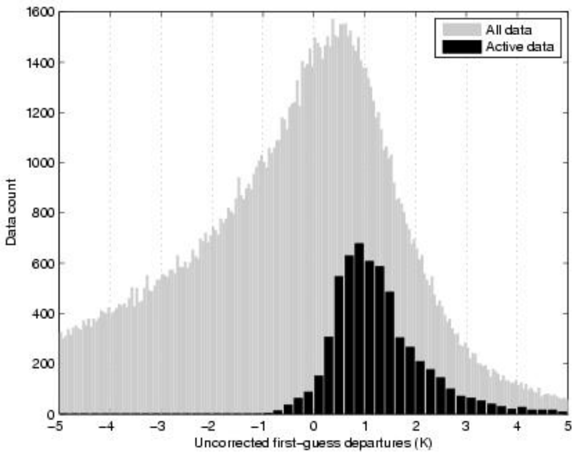


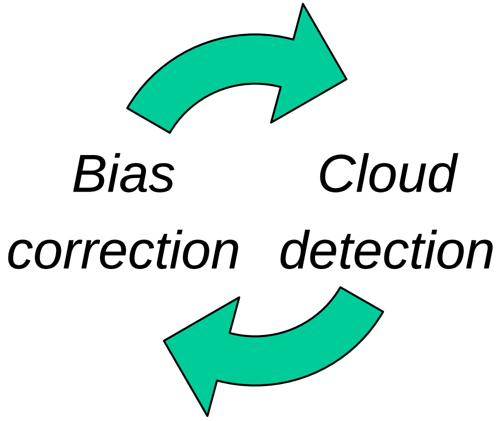
Feedback: Bias Correction and Cloud Detection



Cloud Detection <u>Independent</u> from VarBC



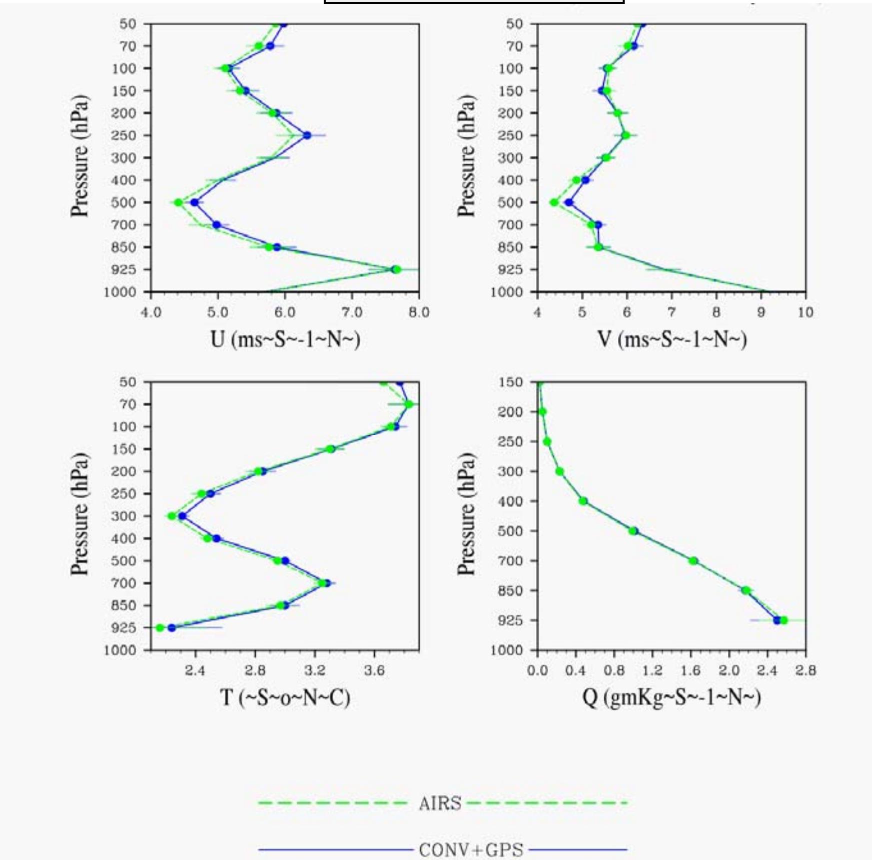




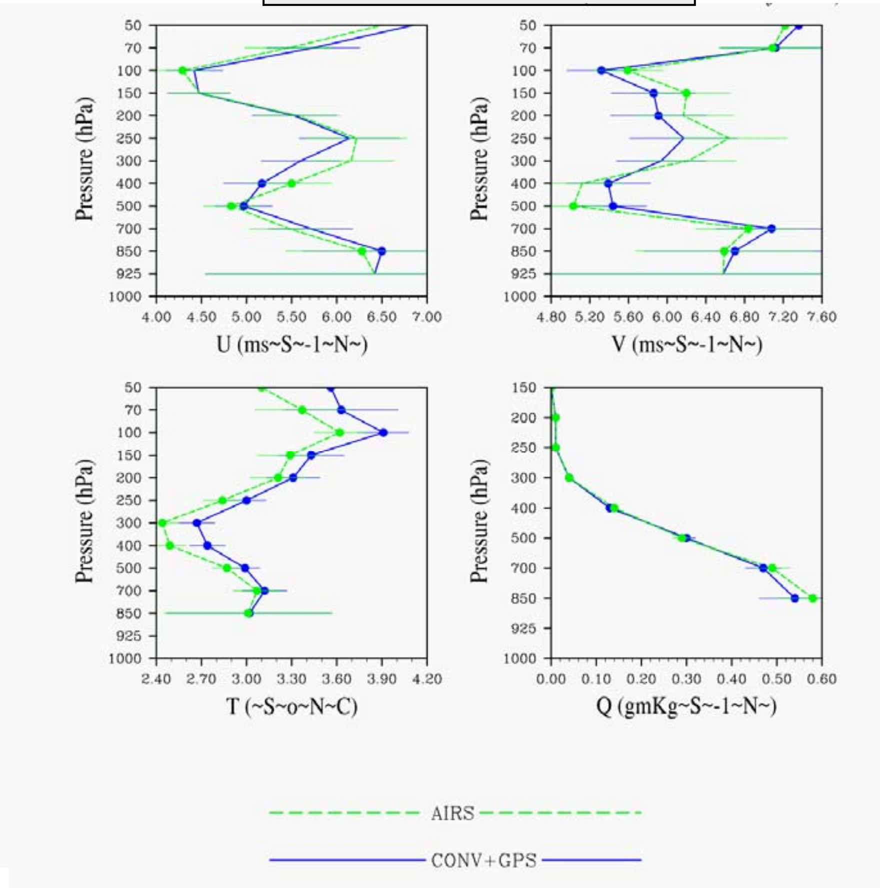
Auligné and McNally (2007)

AIRS Impact: Forecast Score *vs*. Radiosondes

Whole Domain



High Latitudes (> 60S)



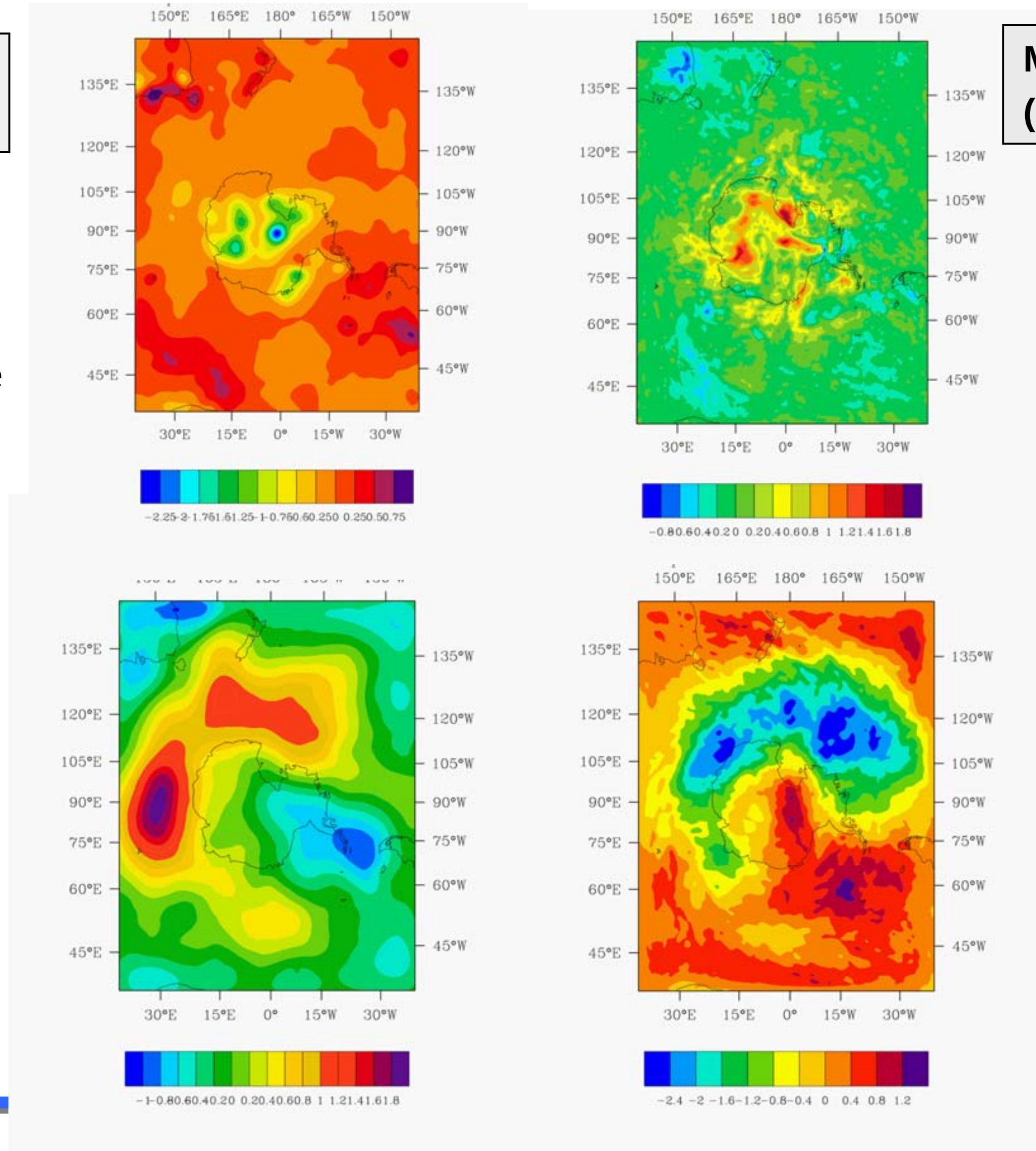
Model Error: Major Limitation

Mean Analysis Increments

Mean Forecast Error (24h-12h)

Surface

50 hPa



Conclusions and future work

- **Encouraging results**
  - Conservative implementation
  - Slightly positive impact on forecast quality
- **Short-term improvements**
  - Raise model top
  - Use more AIRS channels
  - Test simple hybrid DA schemes (random+systematic errors)
  - Compare impact to retrievals
- **Longer-term developments**
  - Improved estimation of surface emissivity over land
  - Assimilate cloud-contaminated radiances