

Impact of AIRS and AMSUA over the Antarctic region

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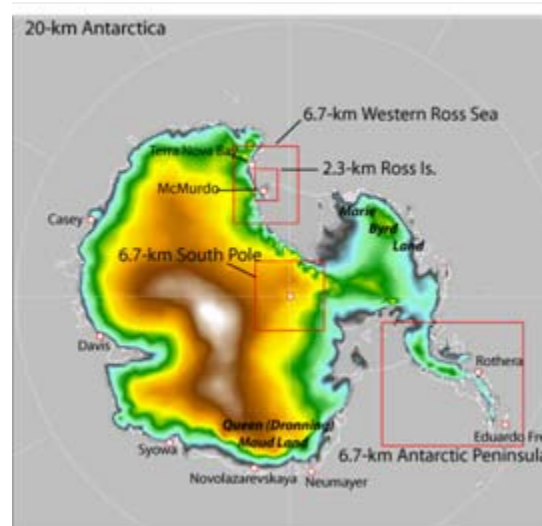
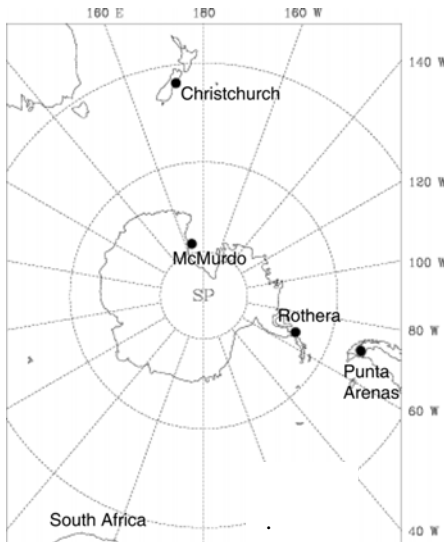
National Center for Atmospheric Research



Introduction: AMPS

The Antarctic Mesoscale Prediction System (AMPS)

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

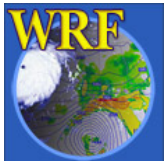


AMPS Forecasts

Frequency: 2 / day

Initializations: 00 & 12 UTC

Duration: 36–120 hours

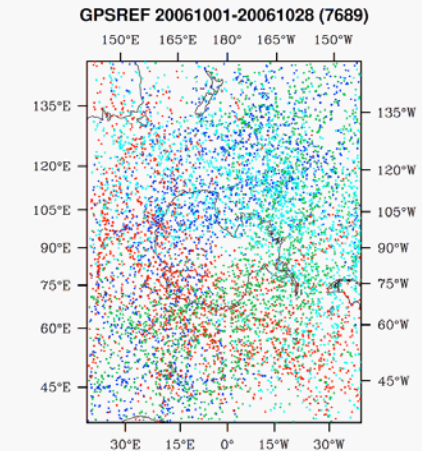
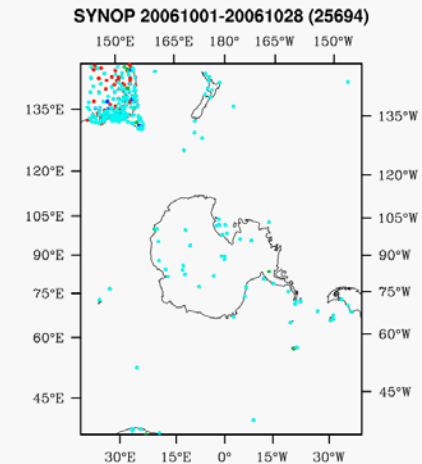
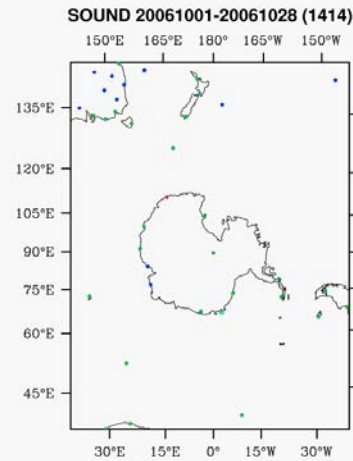
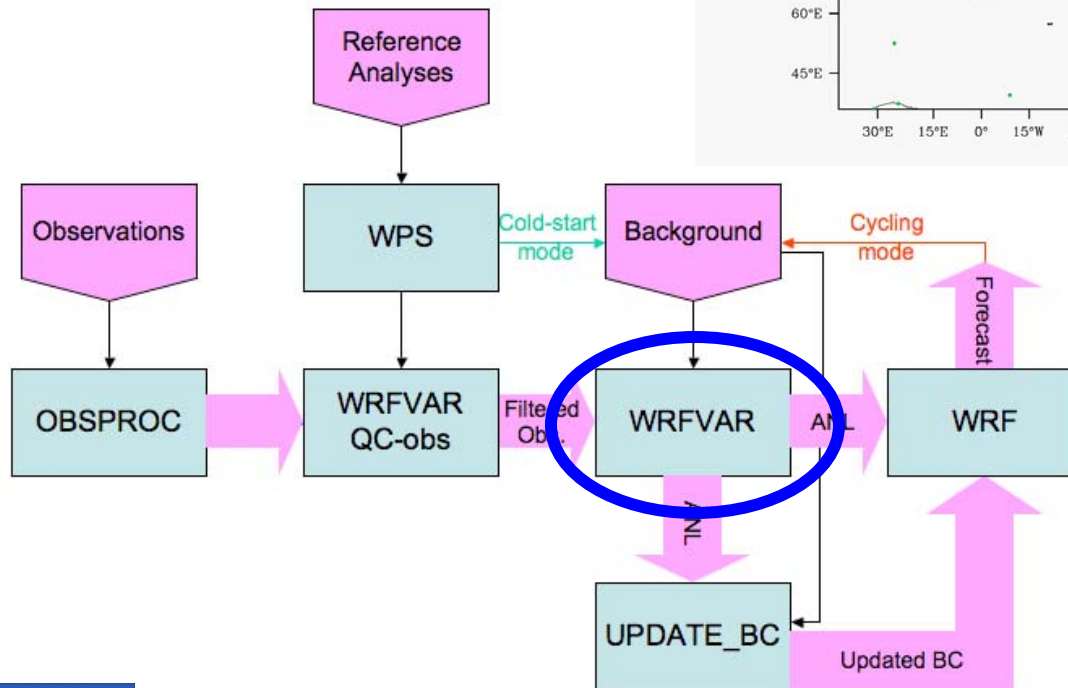


60-km

20-km, 6.7-km, 2.3-km

Introduction: WRF-Var

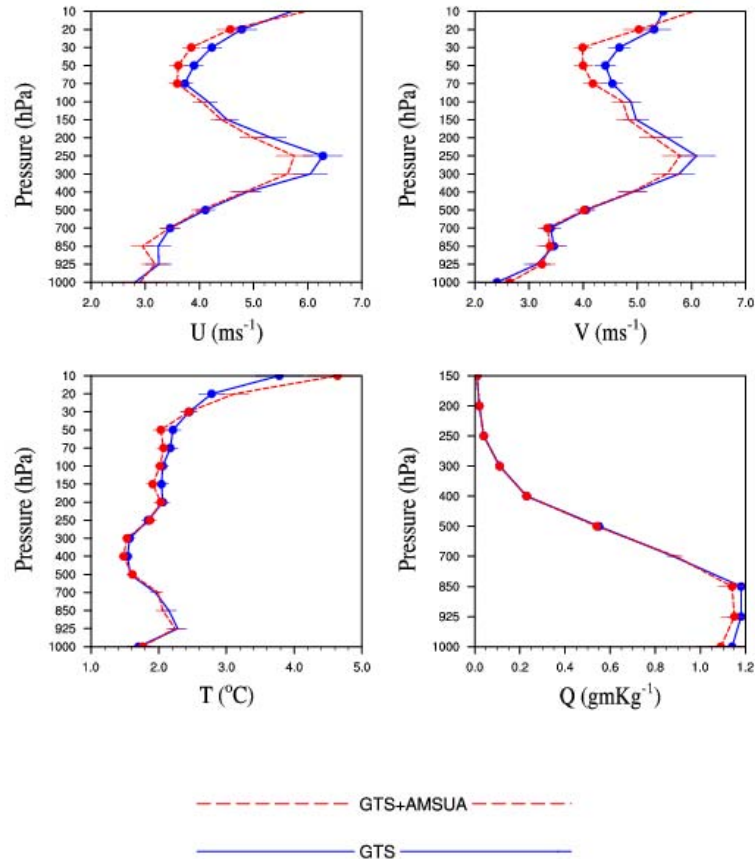
- Variational DA system (3DVar)
- Lateral Boundary Conditions from FNL
- Specific Background Error Covariances



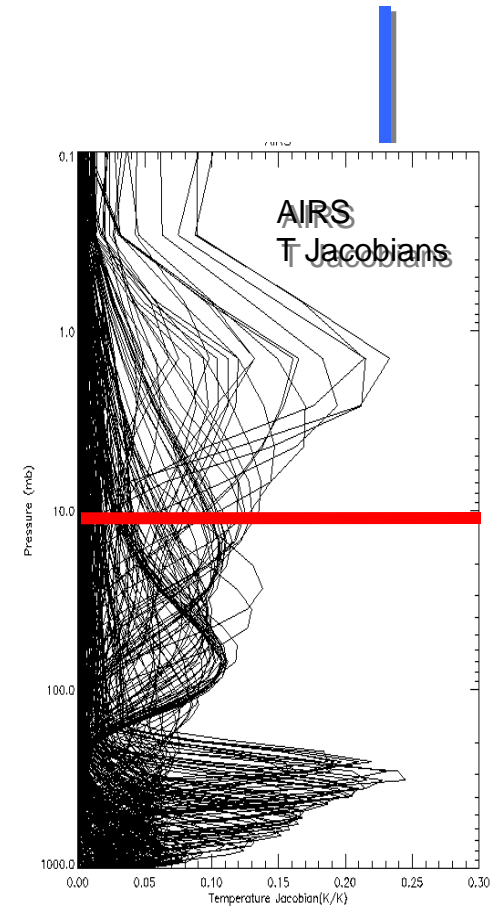
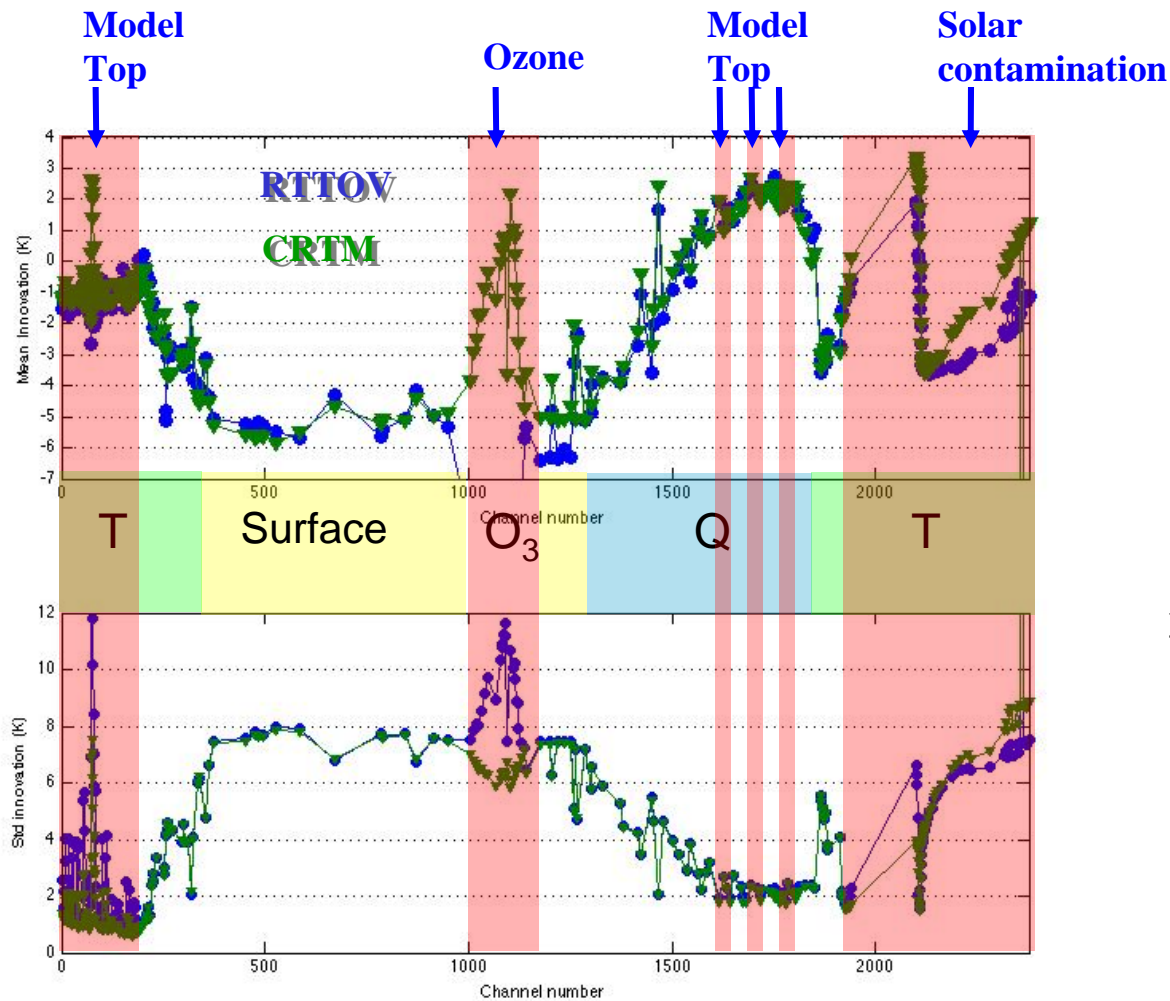
AMSUA Impact: Forecast Score vs. RS

- 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

RMSE Profiles 02 - 14 October 2006 (12 hour interval)



AIRS innovations: Channel Selection



AIRS innovations: QC & Thinning

- Pixel-level QC

- Reject **limb** observations
- Reject pixels over **land** and **sea-ice**

- NESDIS Cloud detection

- LW window channel > 271K
- Thresholds on model SST minus SST from 4 AIRS LW channels

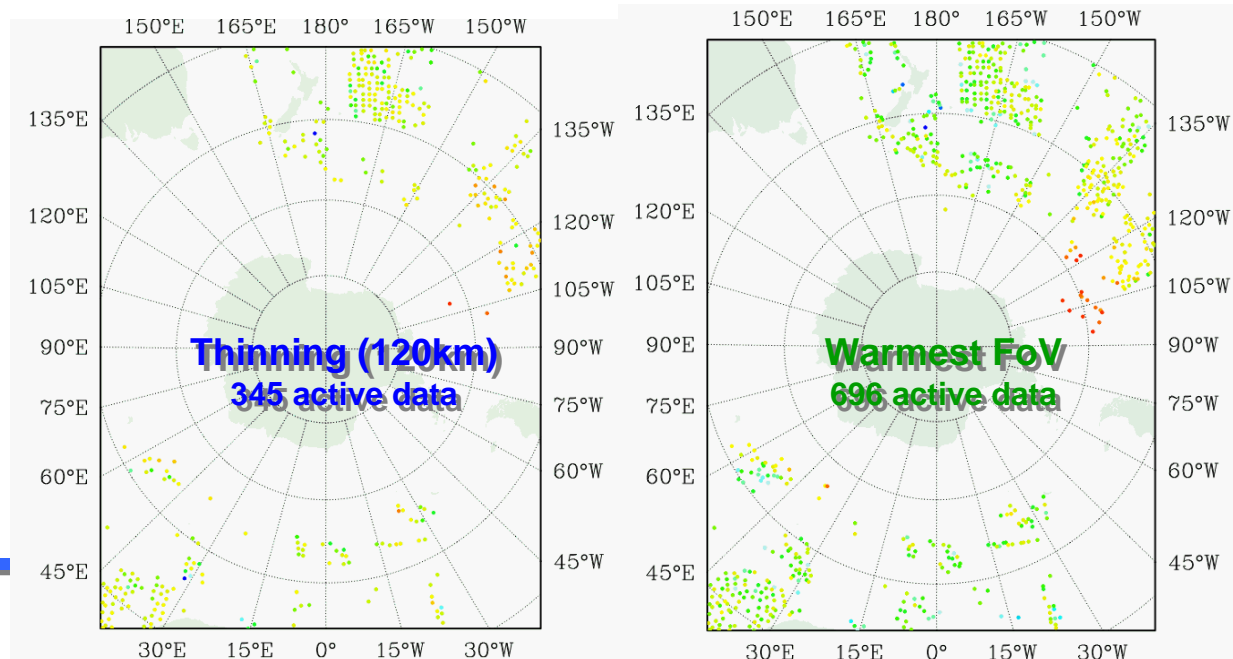
- Channel-level QC

- **Gross check** (innovations < 15 K)
- **First-guess check** (innovations < $3\sigma_0$). Error factor tuned from objective method (Desrozier and Ivanov, 2001)

- Imager AIRS/VIS-NIR

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

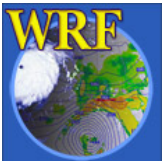
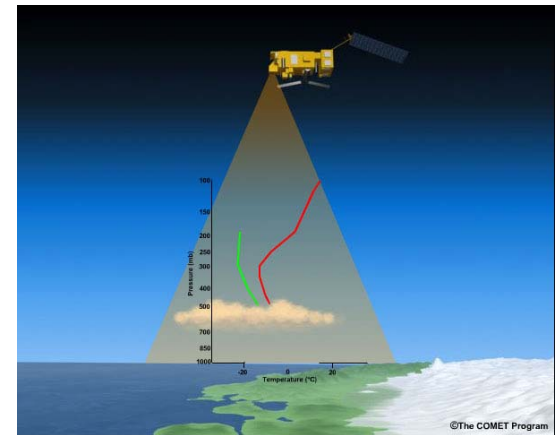
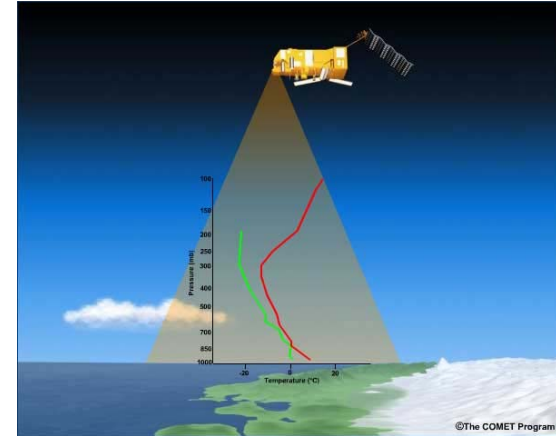
- Thinning



AIRS innovations: Cloud detection strategy

From « **hole hunting** »
(identifying clear pixels)...

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

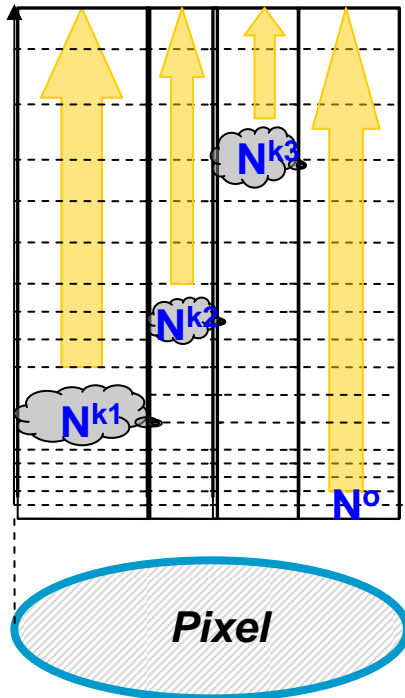


Cloud Detection: MMR scheme

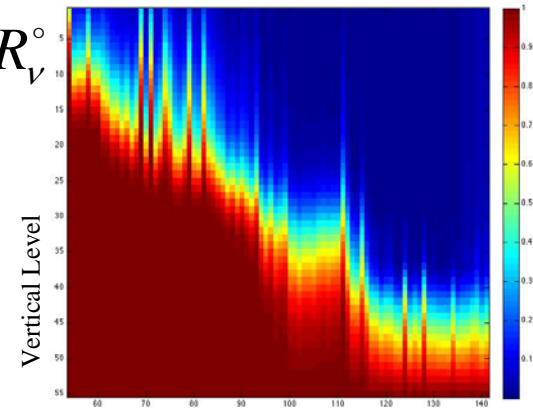
RTM { R_v^o = Radiance calculated in **clear sky**
 $R_v^{•k}$ = Radiance calculated for **overcast black cloud** at level k

Minimum Residual:

$$R_v^{Cld} = (1 - N)R_v^o + NR_v^{•k}$$



$$R_v^{•k} / R_v^o$$



Channel Number (LW band)

Multivariate Minimum Residual (MMR):

$$R_v^{Cld} = N^o R_v^o + \sum_{k=1}^n N^k R_v^{•k}$$



Cloud Detection: MMR scheme

$$R_v^{Cld} = N^o R_v^o + \sum_{k=1}^n N^k R_v^{*k}$$

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

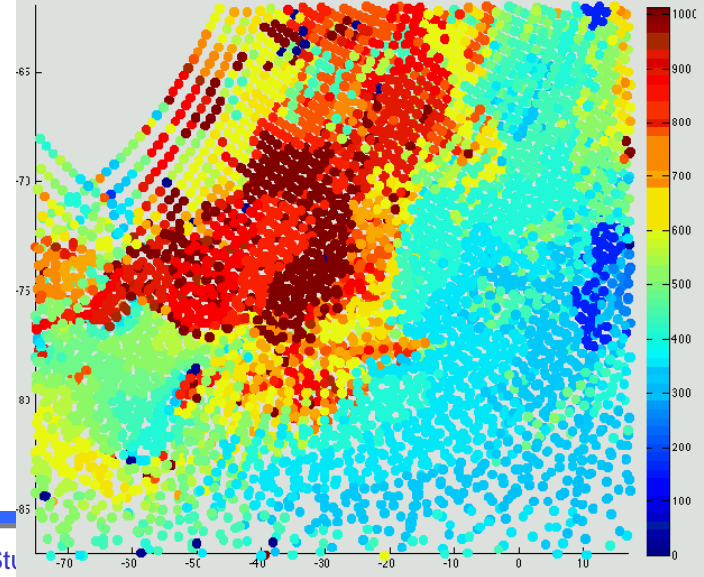
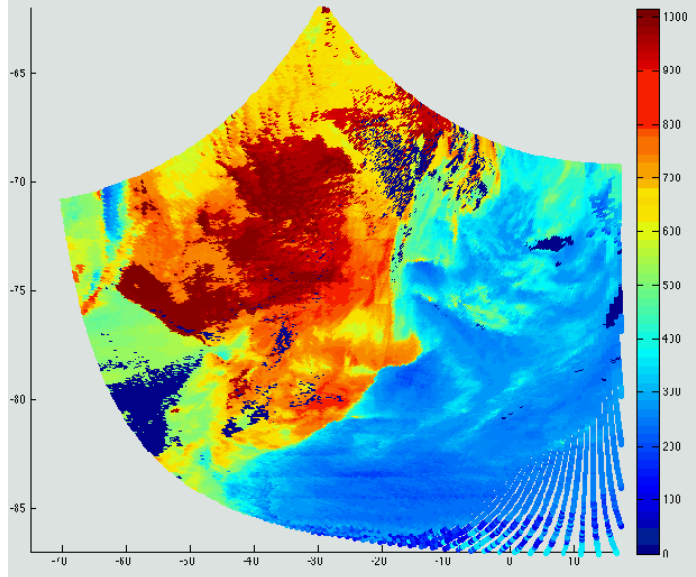
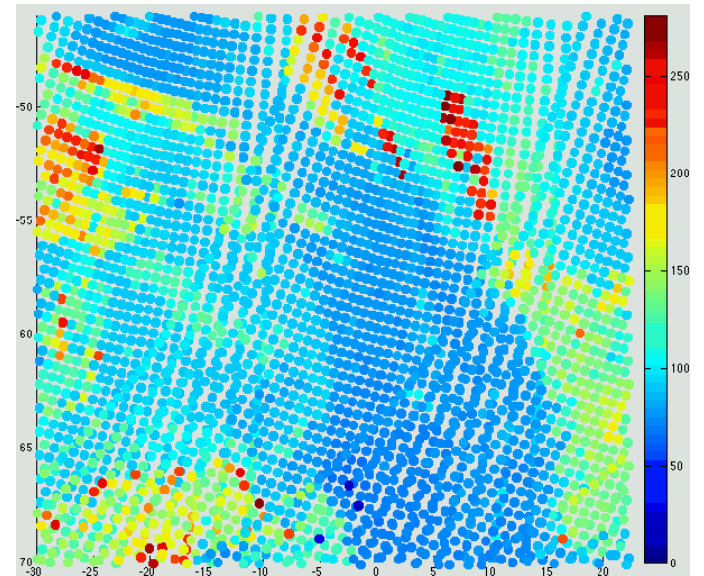
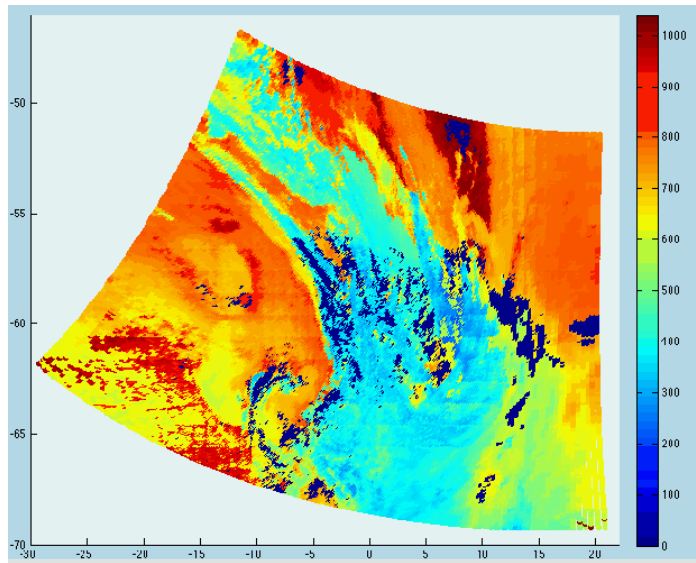
$$J(N) = \frac{1}{2} \sum_v \left(\frac{R_v^{Cld} - R_v^{Obs}}{R_v^o} \right)^2$$

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

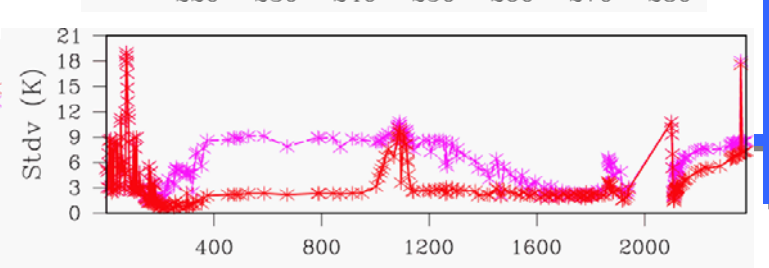
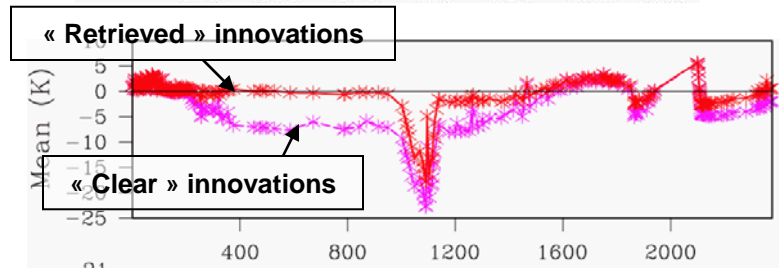
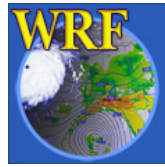
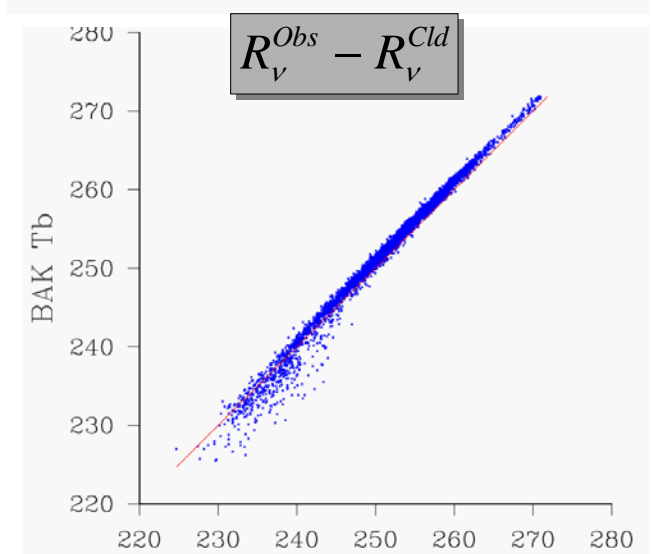
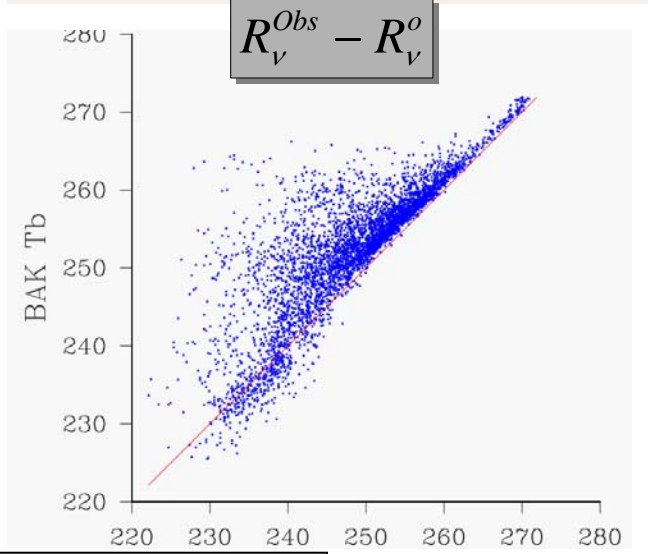
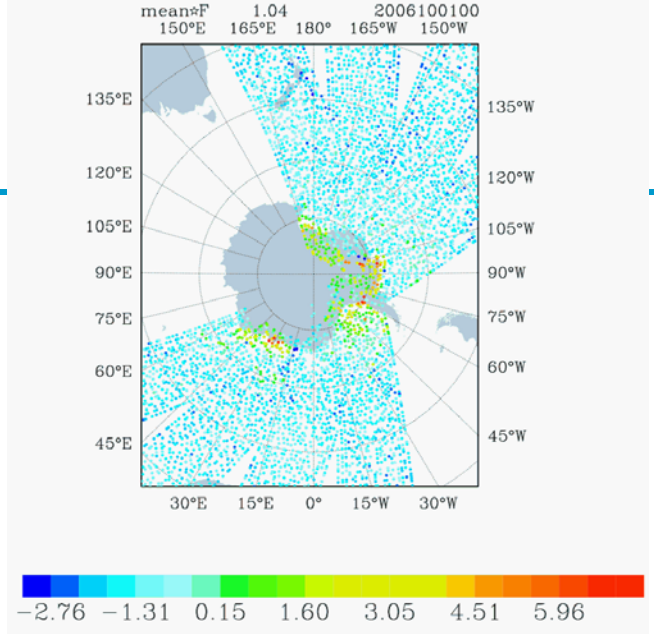
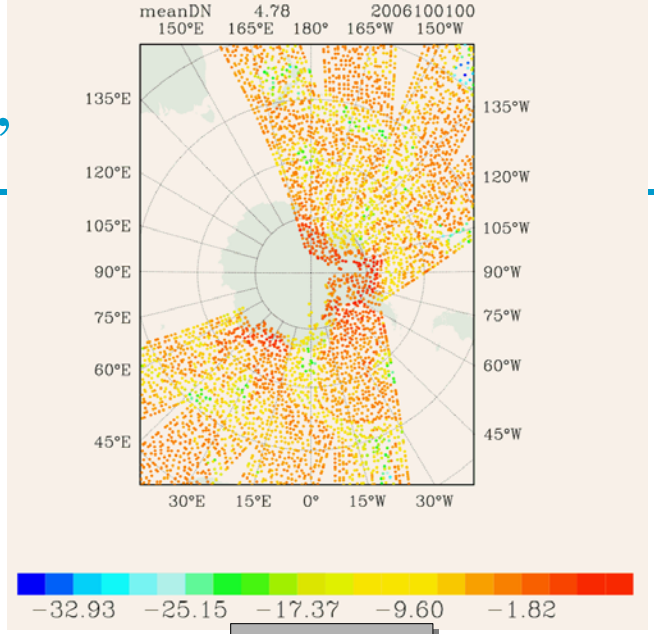
$$\text{with } \begin{cases} 0 \leq N^k \leq 1, \forall k \in [0, n] \\ N^o + \sum_{k=1}^n N^k = 1 \end{cases}$$



Cloud Detection: comparison with MODIS



“Cloud Clearing”



Bias Correction: Variational BC

Modeling of errors in satellite radiances:

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

$$\left\{ \begin{array}{l} \langle \varepsilon \rangle = 0 \\ B(\beta) = \sum_{i=1}^N \beta_i p_i \end{array} \right.$$

β_i

p_i

Parameters

Predictors:

- Offset
- scan, scan², scan³

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 : $x^T \ni [x, \beta]^T$

J_b : background term for x

J_o : corrected observation term

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

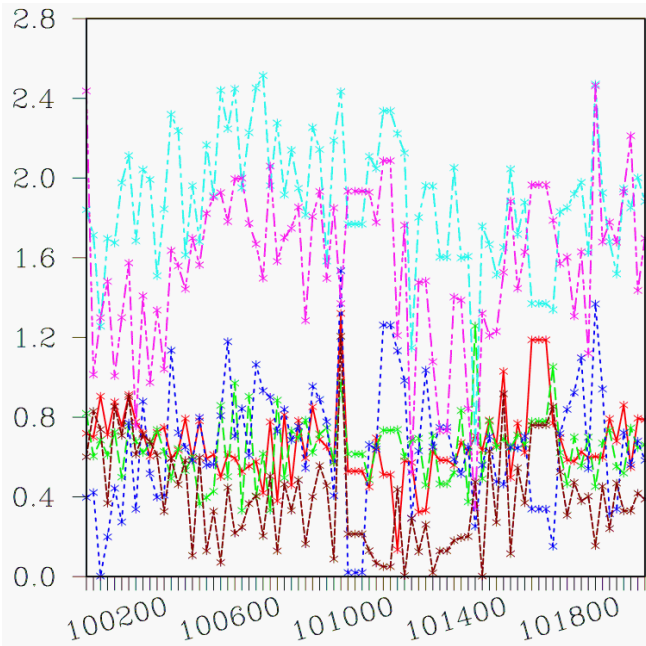
J_β : background term for β

«Optimal » bias correction
considering all available information

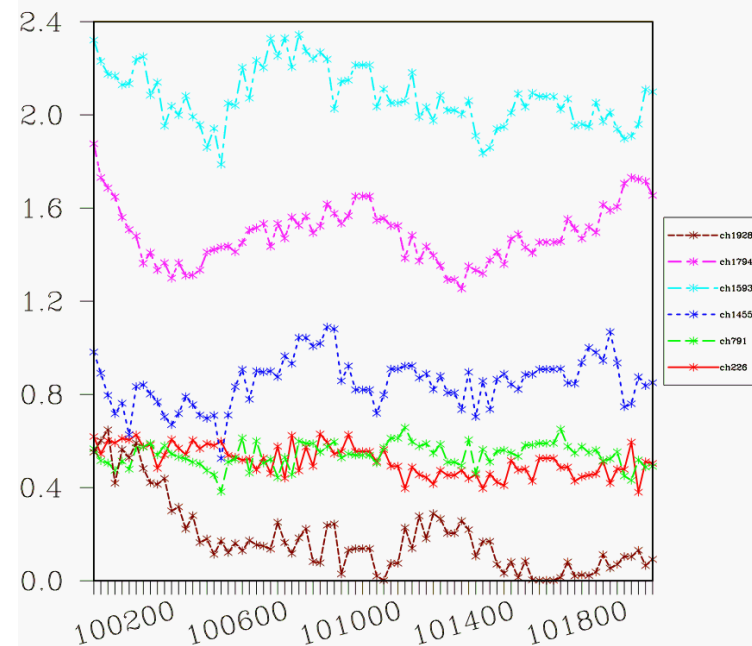


Bias Correction: VarBC Timeseries

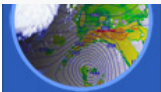
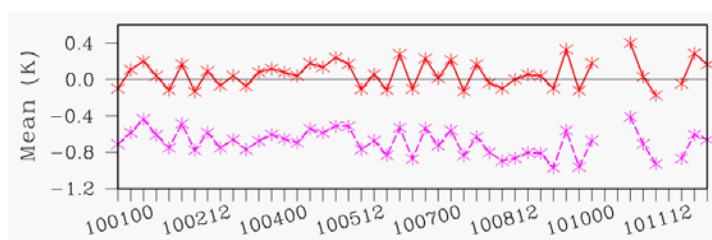
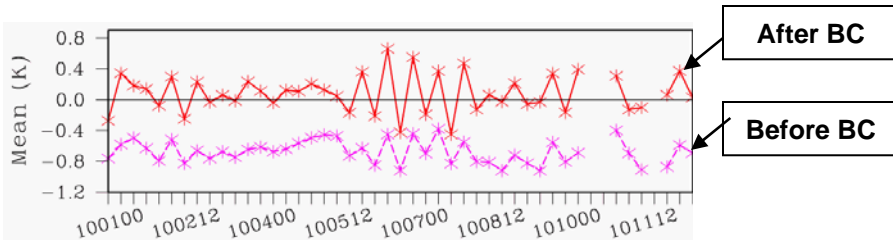
No Inertia Constraint



Inertia Constraint



Innovations for AIRS window channel #787



Inverse Modeling: Adjoint Parameter Estim.

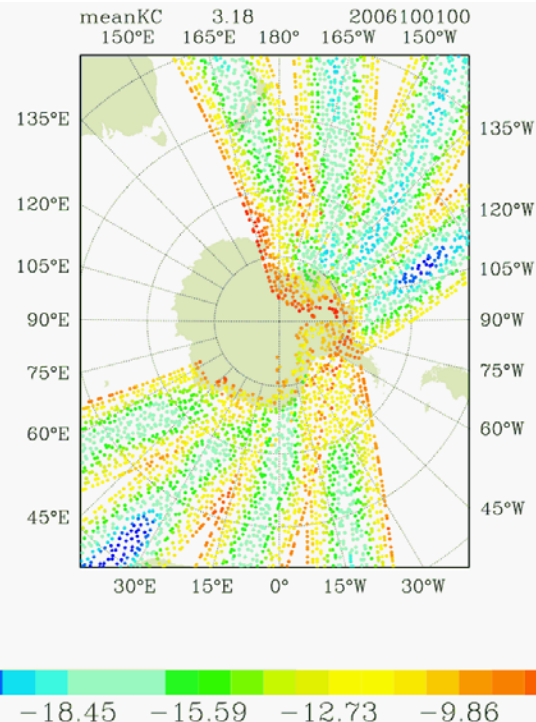
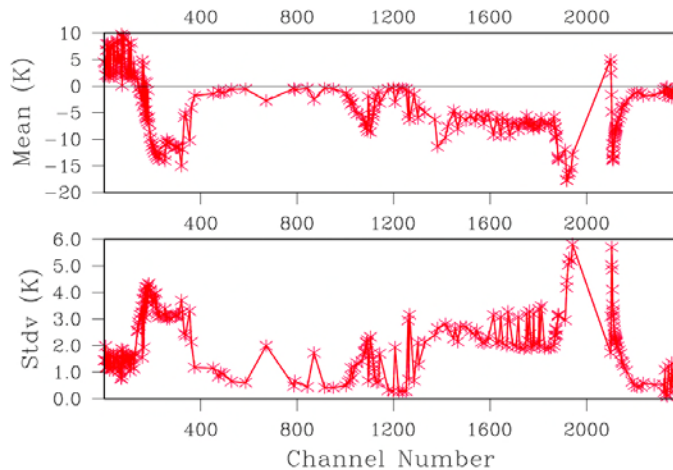
$$R_{\nu}^{atm} = \int_{z_0}^{\infty} B_{\nu}(T(z)) \left[\frac{d\tau_{\nu}(z, \theta)}{dz} \right] dz$$

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

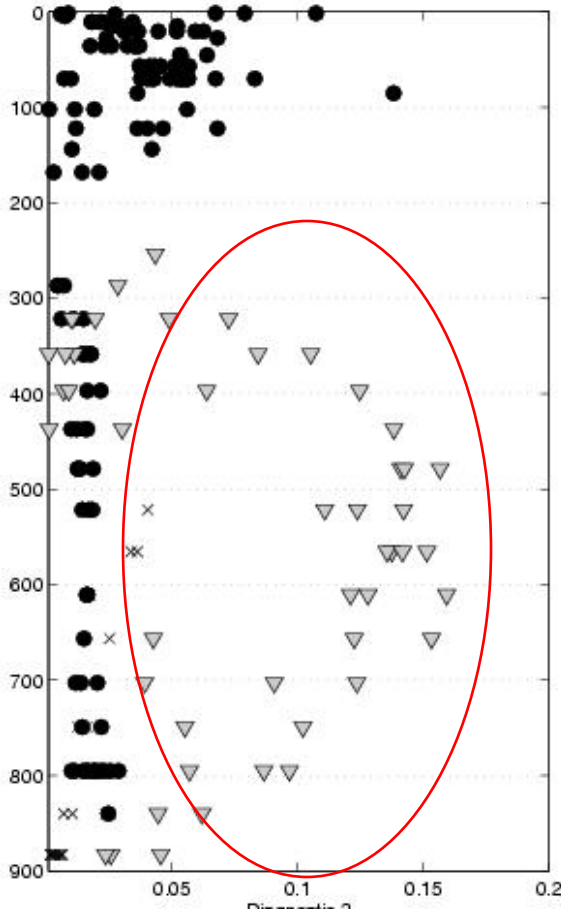
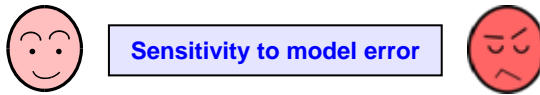
B = Planck function
τ = transmittance
T = temperature
θ = incident angle
z = altitude coordinate
k_ν = absorption coefficient
c = mixing ratio
P = atmospheric density

γ modulates atmospheric absorption to compensate for:

- poor knowledge of gas concentrations (CO₂, ...)
- errors in definition of ISRF
- errors in mean absorption coefficient

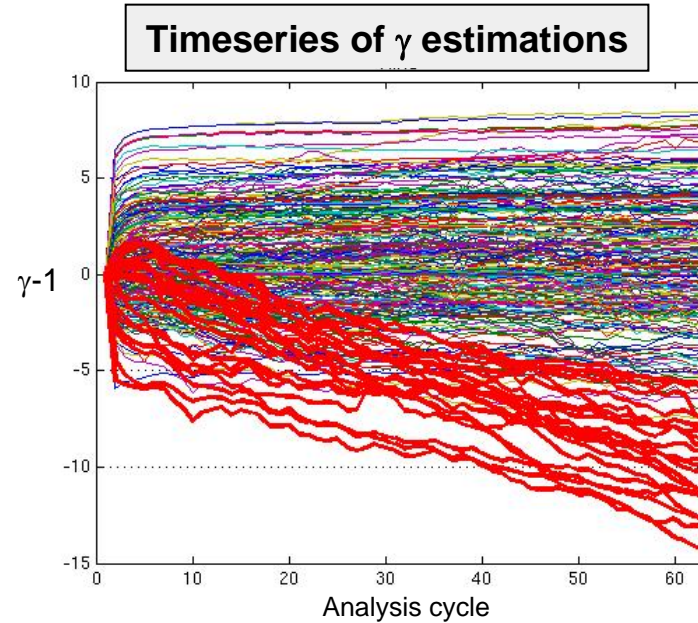


Inverse Modeling: Parameter Estimation



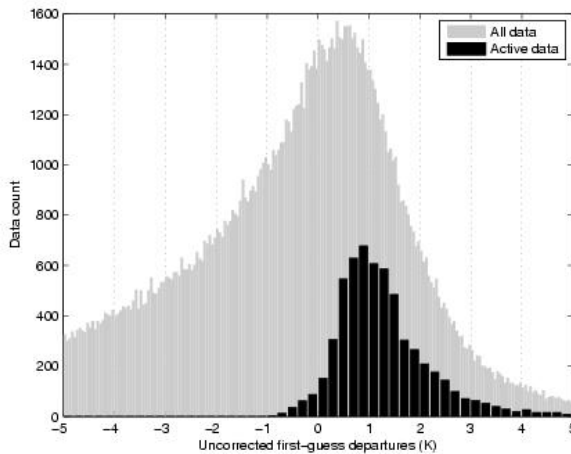
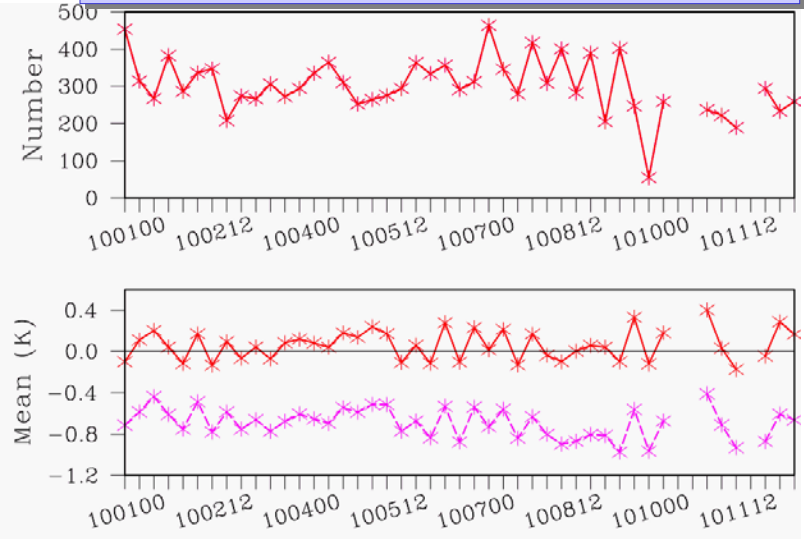
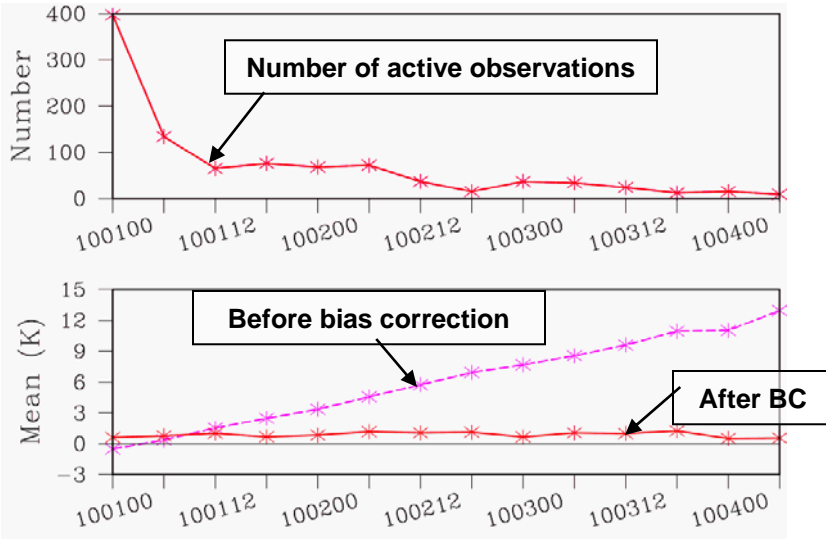
- Long-wave
- ▽ Water Vapour
- × Short-wave

Auligné (2007)



Feedback: Bias Correction and Cloud Detection

Cloud Detection Independent from VarBC



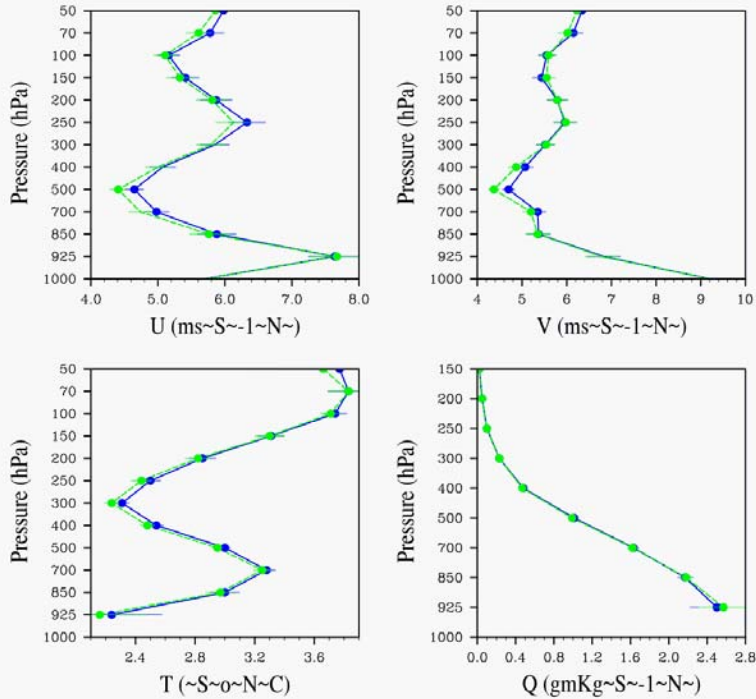
Bias correction *Cloud detection*

Auligné and McNally (2007)



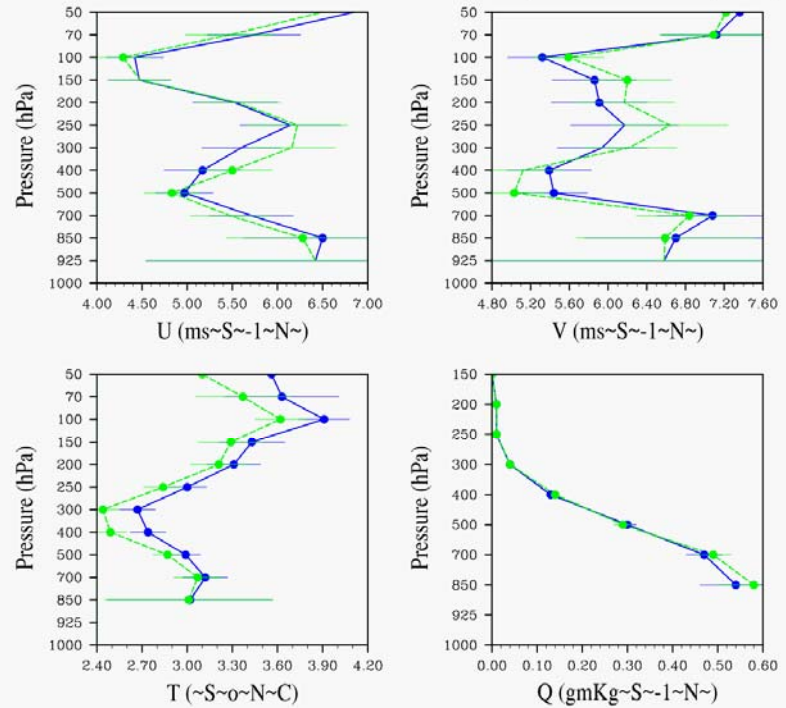
AIRS Impact: Forecast Score vs. Radiosondes

Whole Domain



--- AIRS
 — CONV+GPS

High Latitudes (> 60S)



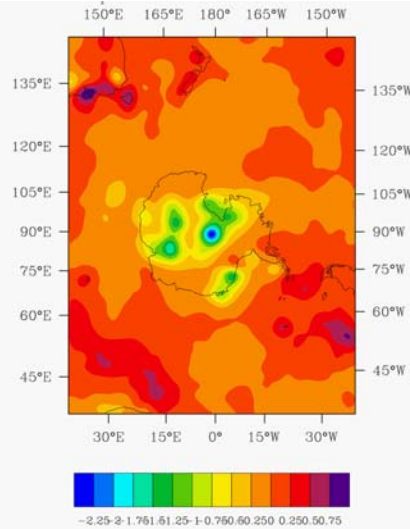
--- AIRS
 — CONV+GPS



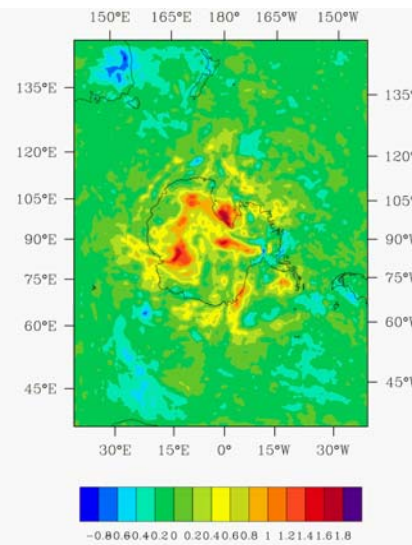
Model Error: Major Limitation

Mean Analysis
Increments

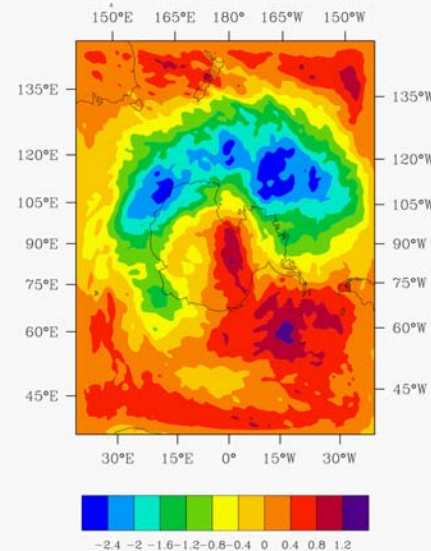
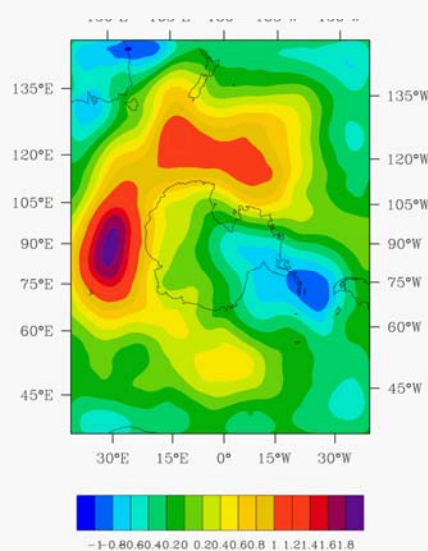
Surface



Mean Forecast Error
(24h-12h)

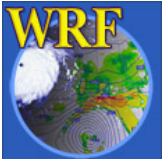


50 hPa



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



International TOVS Study Conference, 16th, ITSC-16, Angra dos Reis, Brazil, 7-13 May 2008.
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2008.