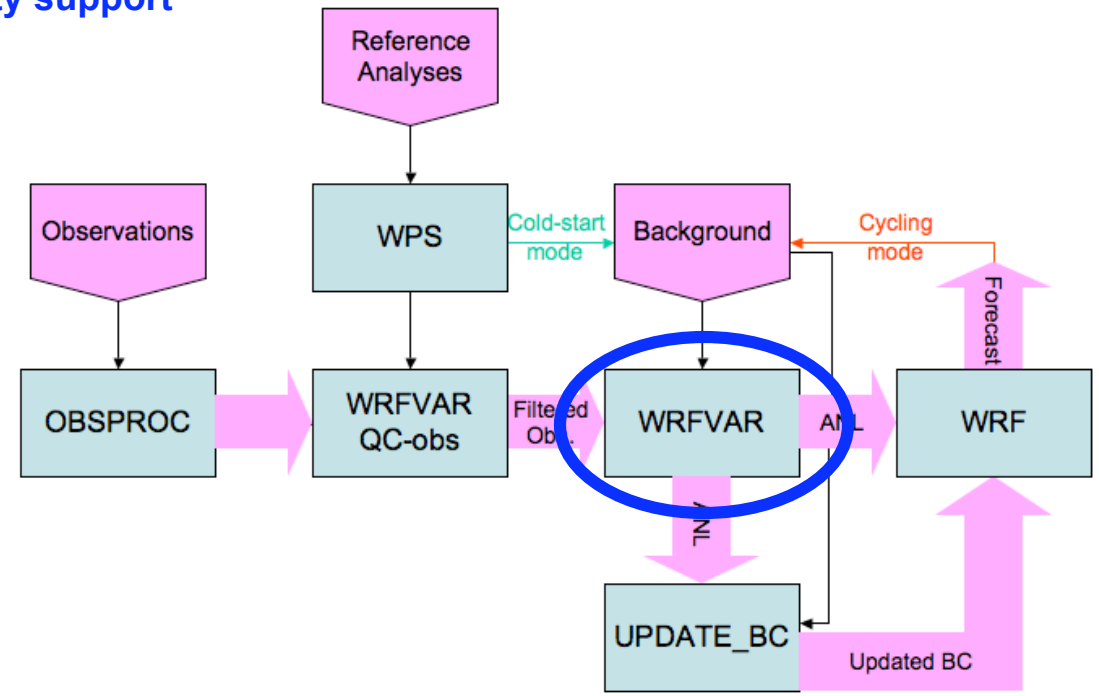
Introduction: Data assimilation at NCAR

- WRF-ARW: Local Area Model (with global version) + TL/ADJ version
- DART: Ensemble Data Assimilation (EnKF, ETKF, …) (no radiances yet)
- WRF-Var: Variational Data Assimilation (3DVar, FGAT, 4DVar) + Hybrid system
- Community support



Satellite DA: WRF-Var capabilities

- **Retrievals (T / Q profiles)**
  - SATEM (from AMSU)
  - AIRS retrievals (NASA version 5)
- **GPS Radio Occultation**
  - Retrieved refractivity from COSMIC
- **Winds**
  - Retrieved winds: polar MODIS, SATOB
  - Active sensors: Quikscat
- **Radiances** (BUFR format from NCEP/NRL/AFWA/NESDIS)
  - **HIRS** from NOAA16, 17, 18
  - **AMSU-A** from NOAA15, 16, 18, EOS-Aqua, METOP-2
  - **AMSU-B** from NOAA15, 16, 17
  - **MHS** from NOAA18, METOP-2
  - **AIRS** from EOS-Aqua
  - **SSMIS** from DMSP16

Satellite DA: WRF-Var capabilities

- **Radiative Transfer Model**

  CRTM (**C**ommunity **R**adiative **T**ransfer **M**odel)

  JCSDA (Joint Center for Satellite Data Assimilation)

  ftp://ftp.emc.ncep.noaa.gov/jcsda/CRTM/

  Latest released version: CRTM REL-1.2_beta, September 2008

  Version used in WRF-Var: CRTM REL-1.1

  Documentation still under development

  RTTOV (**R**adiative **T**ransfer for **TOVS**)

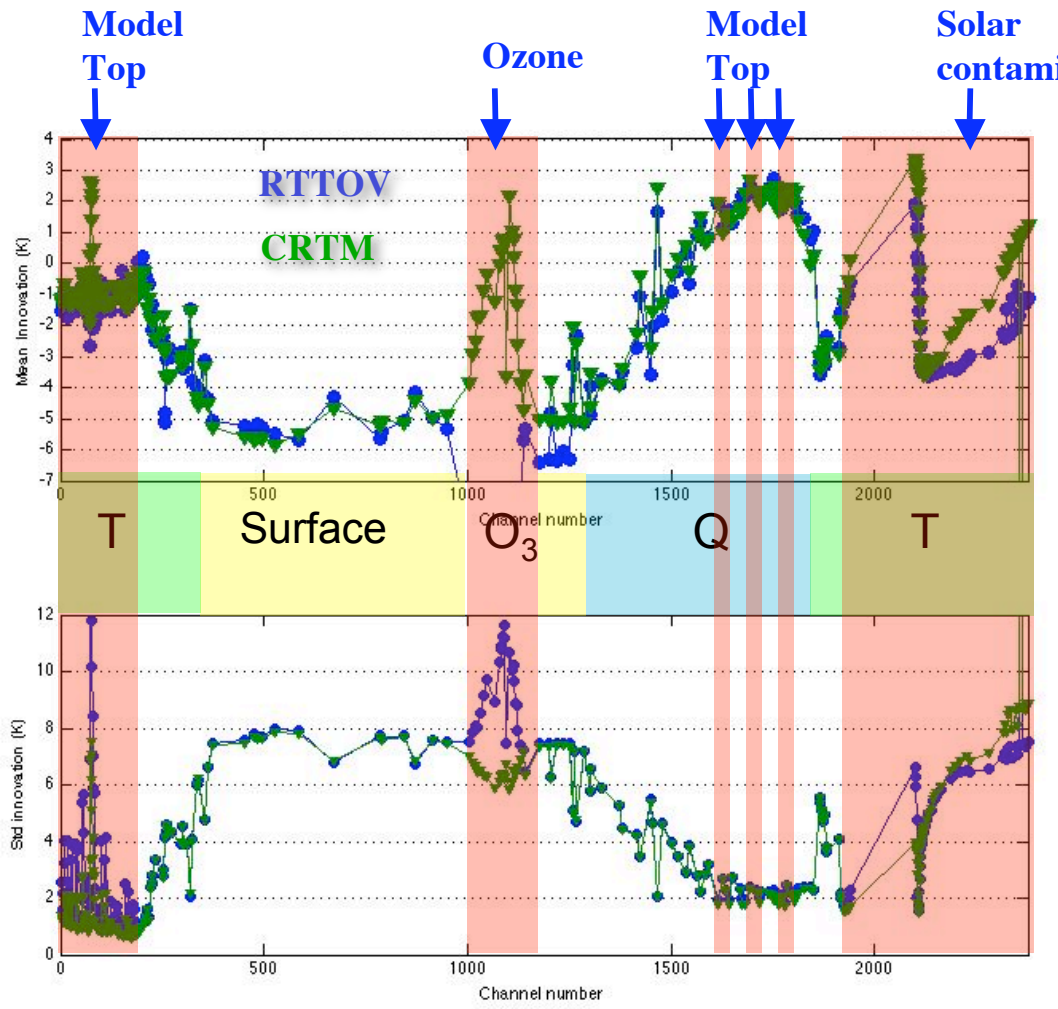
  EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites)

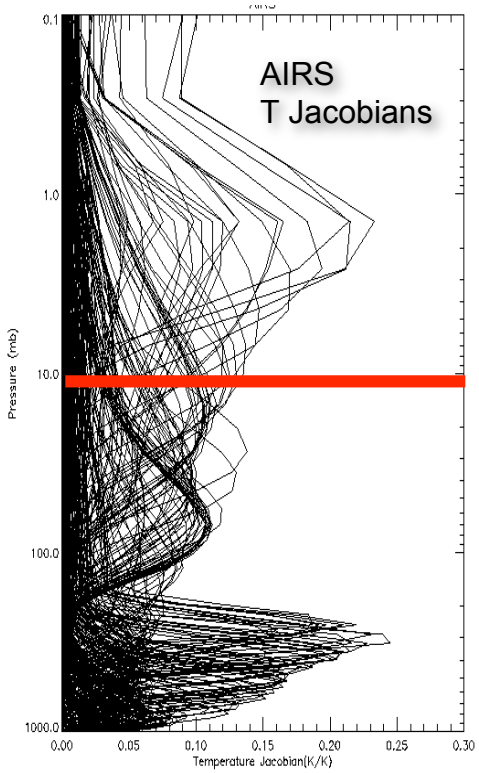
  http://www.metoffice.gov.uk/research/interproj/nwpsaf/rtm/index.html

  Latest released version: RTTOV_9_2, July 2008

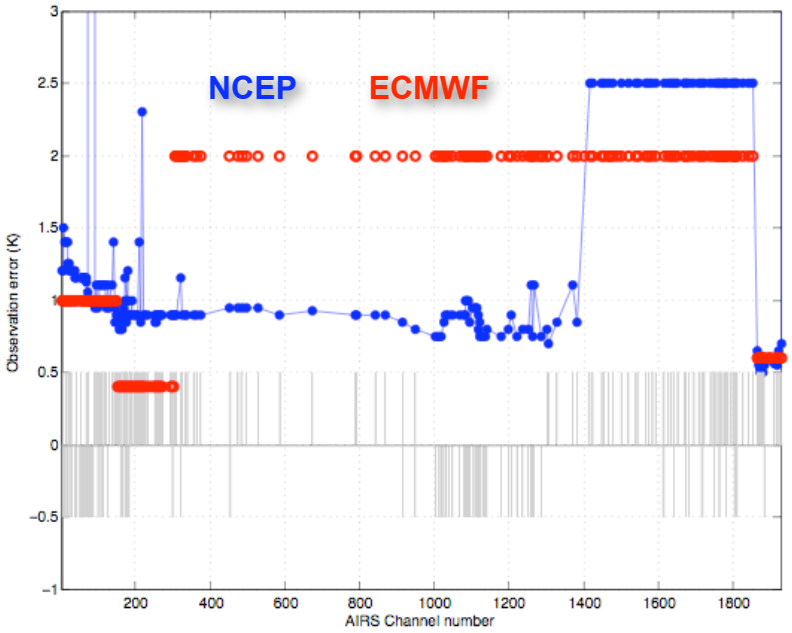
  Version used in WRF-Var: RTTOV_8_7 (with a small bug fix)

AIRS Channel Selection: 10hPa model top

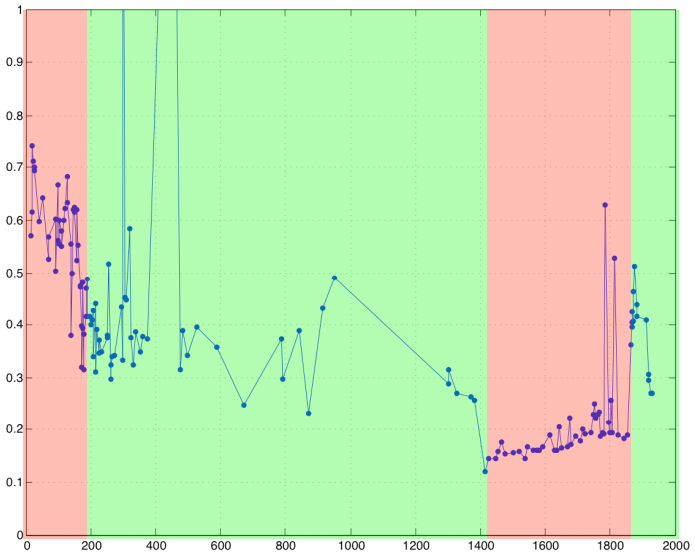




Observation Error: Tuning of statistics



NCEP (and most ECMWF) observation errors statistics consistent with innovations

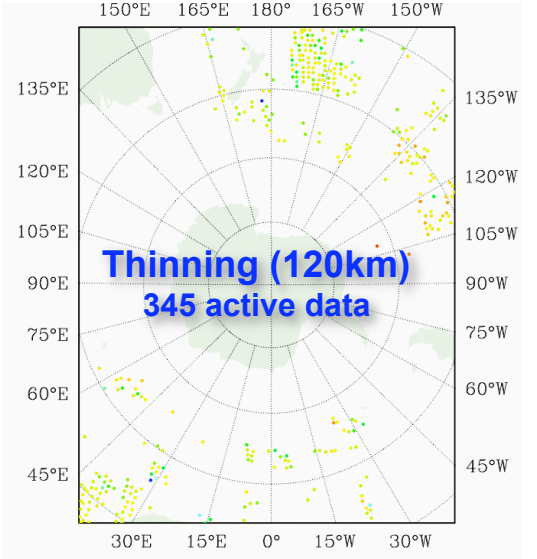


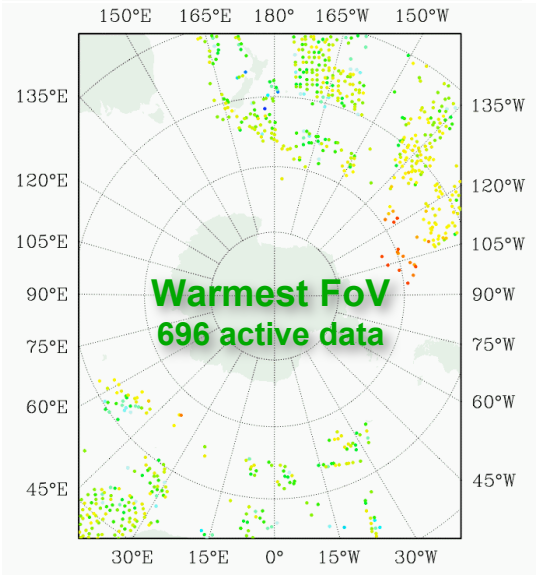
Error factor tuning from objective method (Desrozier and Ivanov, 2001)

Quality Control and Thinning

- **Pixel-level QC**
  - Reject **limb** observations
  - Reject pixels over **land** and **sea-ice**
  - **Cloud/Precipitation** detection (NESDIS)
  - **Synergy** with imager (AIRS/VIS-NIR)
- **Channel-level QC**
  - **Gross check** (innovations <15 K)
  - **First-guess check** (innovations < $3\sigma_o$).
- **Thinning**

  Warmest Field of View





Bias Correction: Static and Variational

Modeling of errors in satellite radiances:

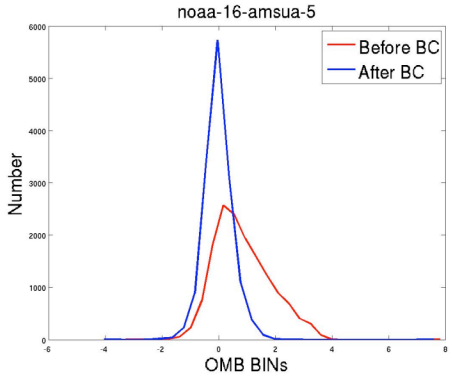
$$y = H(x_t) + B(\beta) + \varepsilon$$

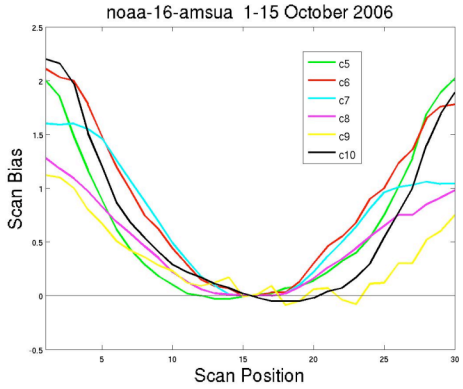
$$\begin{cases} \langle \varepsilon \rangle = 0 \\ B(\beta) = \sum_{i=1}^{N} \beta_i p_i \end{cases}$$

Parameters

Predictors:

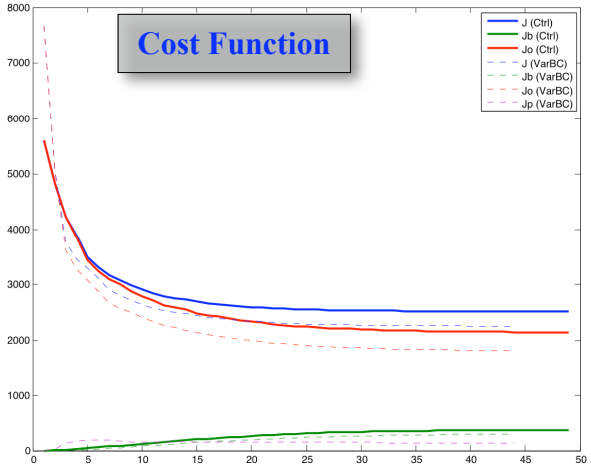
- Offset
- 1000-300mb thickness
- 200-50mb thickness
- Surface skin temperature
- Total column water vapor
- Scan, scan^2, scan^3





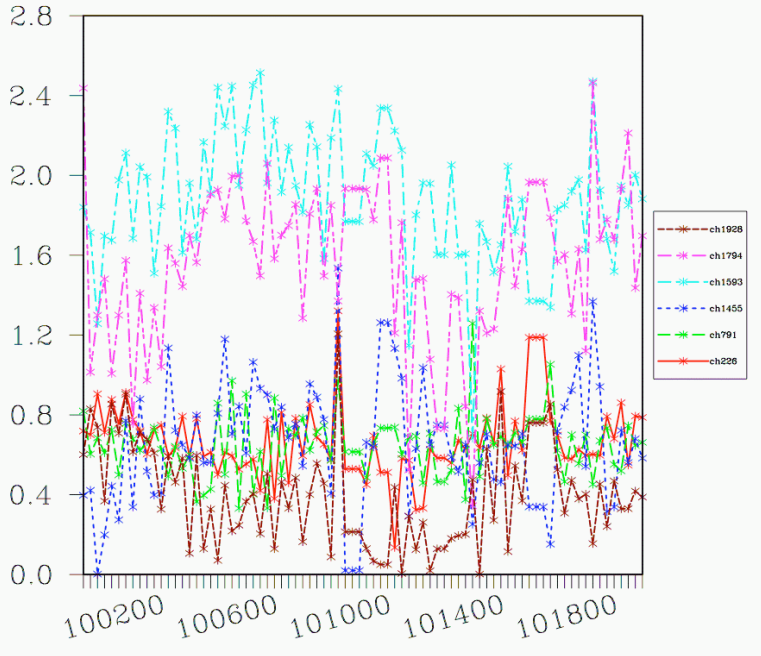
"Offline" bias correction

"Variational" bias correction

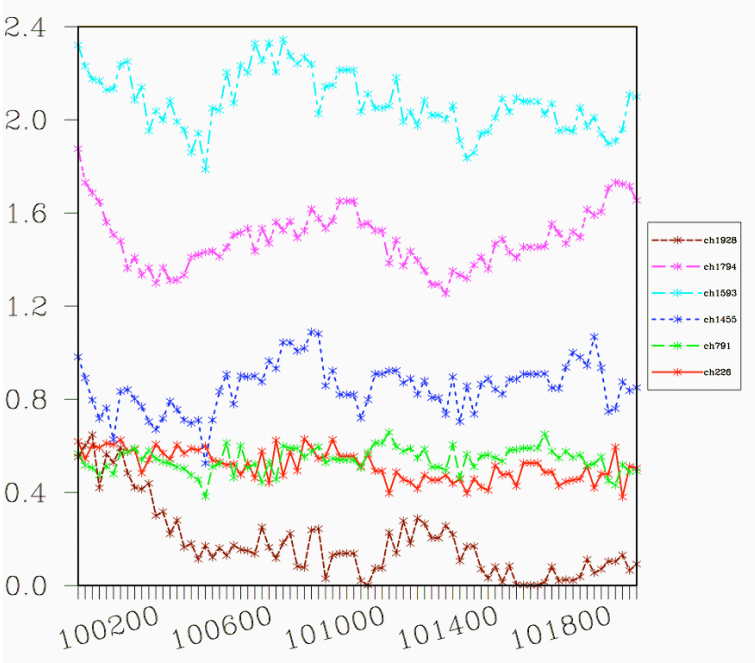


Bias Correction: WRF-Var capabilities

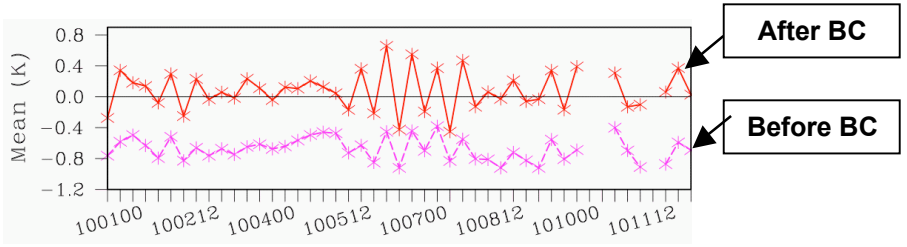
No Inertia Constraint



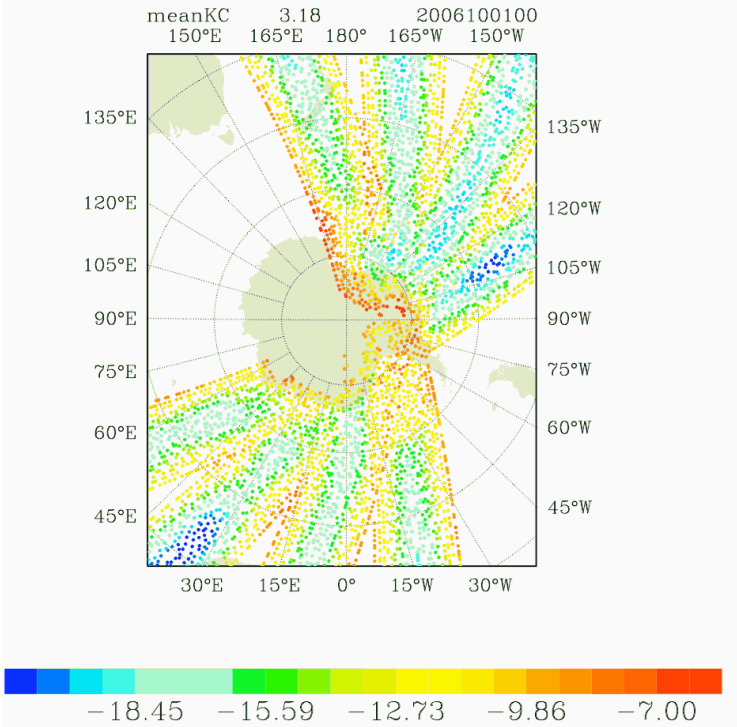
Inertia Constraint

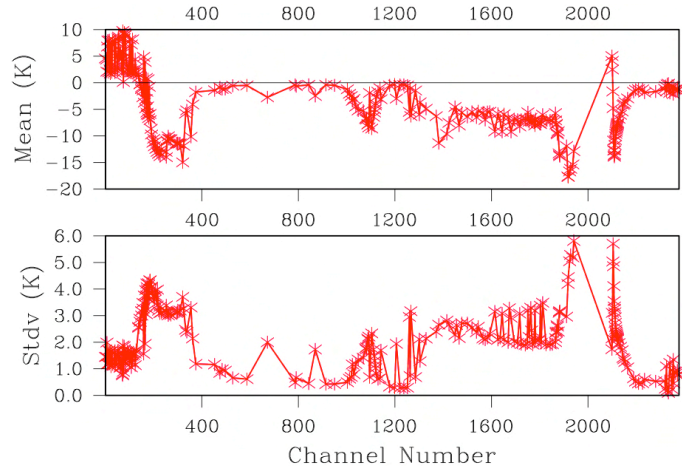


Innovations for AIRS window channel #787



Inverse Modeling: Adjoint Parameter Estim.





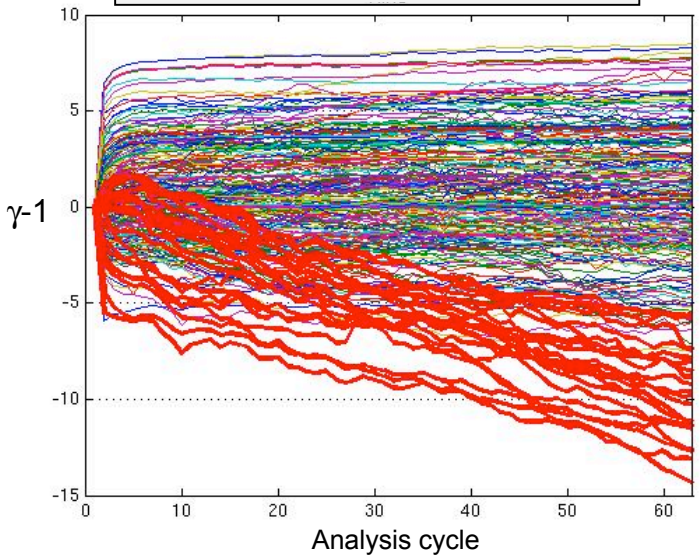
$$R_\nu^{atm} = \int_{z_0}^{\infty} B_\nu(T(z)) \left[\frac{d\tau_\nu(z,\theta)}{dz} \right] dz$$

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

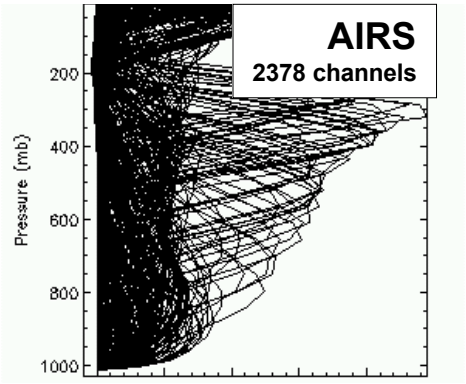
γ modulates atmospheric absorption to compensate for:

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

Timeseries of γ estimations



Practical issues: AIRS Cloud Detection

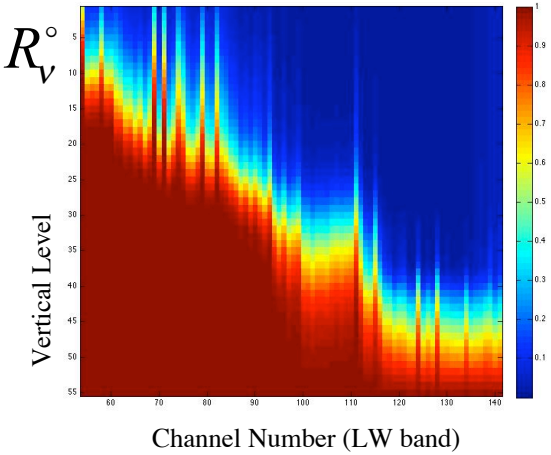


RTM

R_ν° = Radiance calculated in **clear** sky

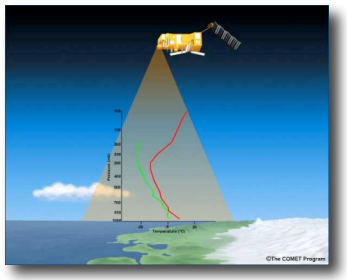
$R_\nu^{\bullet k}$ = Radiance calculated for **overcast black cloud** at level k

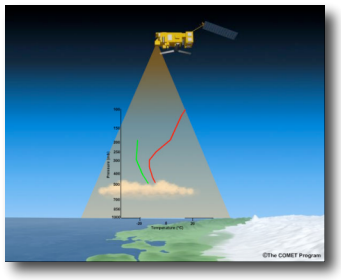
$R_\nu^{\bullet k} / R_\nu^\circ$

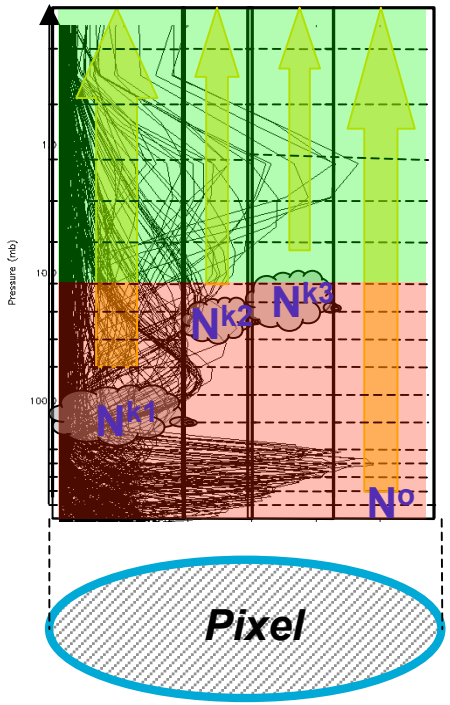


From « hole hunting » … to identifying clear channels

(identifying clear pixels)… **(insensitive to the cloud).**



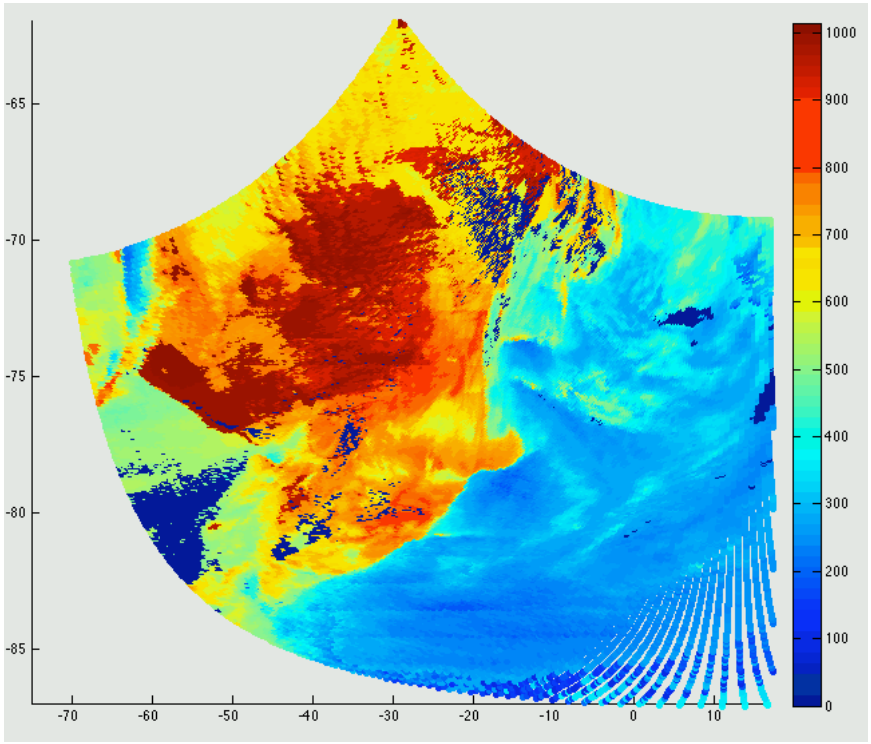




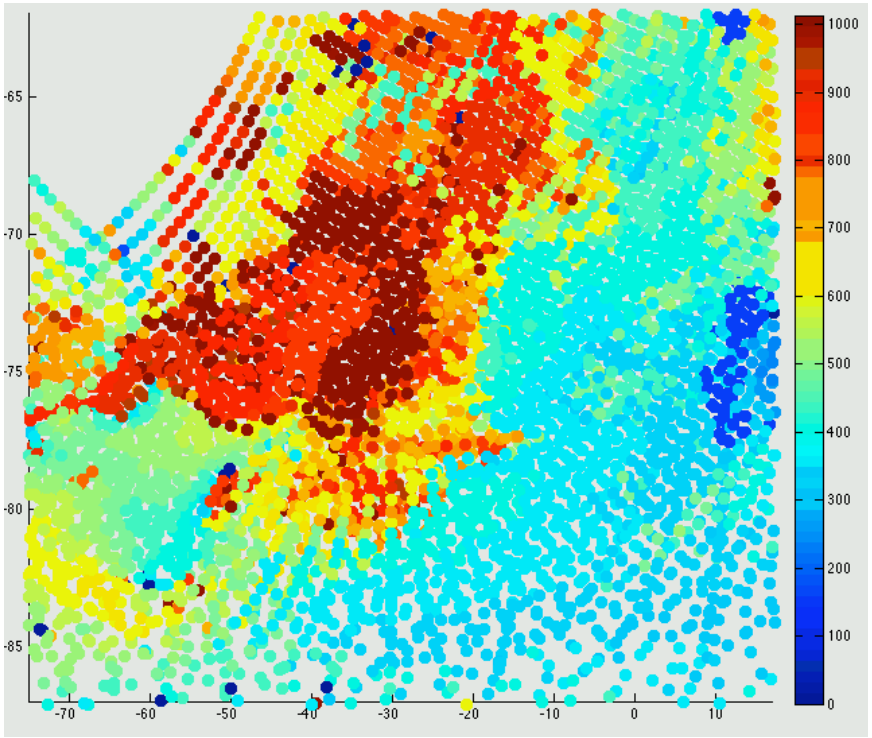
Cloud fractions N^k are ajusted **variationally** to fit observations.

Practical issues: AIRS Cloud Detection

MODIS NASA Level 2 Product



AIRS Cloud Detection



Cloud Top Pressure (hPa)

”Cloudy Radiances”