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 (Community Radiative Transfer Model)**
  
  JCSDA (Joint Center for Satellite Data Assimilation)
  
  
  Latest released version: CRTM REL-1.2_beta, September 2008
  
  Version used in WRF-Var: CRTM REL-1.1
  
  Documentation still under development

  **RTTOV (Radiative Transfer for TOVS)**
  
  EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites)
  
  
  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

![Thinning (120km) 345 active data](image1)

![Warmest FoV 696 active data](image2)
Modeling of errors in satellite radiances:

\[ y = H(x_i) + B(\beta) + \varepsilon \]

\[ \langle \varepsilon \rangle = 0 \]

\[ B(\beta) = \sum_{i=1}^{N} R_i \rho_i \]

**Parameters**

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

**Cost Function**

"**Offline**" bias correction

"**Variational**" bias correction
Bias Correction: WRF-Var capabilities

No Inertia Constraint

Inertia Constraint

Innovations for AIRS window channel #787

After BC

Before BC
Inverse Modeling: Adjoint Parameter Estimation

\[ R_{v_{\text{atm}}} = \int_{z_0}^{\infty} B_v(T(z)) \left[ \frac{d\tau_v(z, \theta)}{dz} \right] dz \]

\[ \tau_v(z_1, \theta) = \exp\left\{ -\gamma_v \sec\theta \int_{z_1}^{\infty} k_v(z)c(z)\rho(z)dz \right\} \]

\( \gamma \) 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 \( \gamma \) estimations
Practical issues: AIRS Cloud Detection

From «hole hunting» ... to identifying clear channels (identifying clear pixels)...

... (insensitive to the cloud).

Cloud fractions $N^k$ are adjusted variationally to fit observations.

- $R^\circ_V$ = Radiance calculated in clear sky
- $R^k_V$ = Radiance calculated for overcast black cloud at level $k$
- $R^k_V / R^\circ_V$

Pixel

AIRS
2378 channels

Channel Number (LW band)

Vertical Level

Pressure (m)
Practical issues: AIRS Cloud Detection

MODIS NASA Level 2 Product

AIRS Cloud Detection

Cloud Top Pressure (hPa)
"Cloudy Radiances"