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

Model Top

Ozone

Model Top

Solar contamination

RTTOV

CRTM

T Surface O₃ Q T

Old innovation (f_j)

Channel number

AIRS T Jacobians

Pressure (hPa)

Temperature Jacobian (K/K)
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$\sigma_o$).
    Error factor tuned from objective method (Desrozier and Ivanov, 2001)

- **Imager AIRS/VIS-NIR**
  - Day only (cloud coverage within AIRS pixel <5%)

- **Thinning**
  - Thinning (120km) 345 active data
  - Warmest FoV 696 active data
AIRS innovations: Cloud detection strategy

From «hole hunting»
(identifying clear pixels)…

… to identifying clear channels
(insensitive to the cloud).
Cloud Detection: MMR scheme

\[ R_v^\circ = \text{Radiance calculated in clear sky} \]
\[ R_v^{\bullet k} = \text{Radiance calculated for overcast black cloud at level } k \]

Minimum Residual:
\[ R_v^{Cld}(N,k) = (1 - N)R_v^\circ + NR_v^{\bullet k} \]

Multivariate Minimum Residual (MMR):
\[ R_v^{Cld}(N^\circ, N^1, \ldots, N^n) = N^\circ R_v^\circ + \sum_{k=1}^{n} N^k R_v^{\bullet k} \]

\[ R_v^{\bullet k} / R_v^\circ \]

Pixel

Channel Number (LW band)
Cloud Detection: MMR scheme

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

$$R^C_{\text{ld}} = N^c R^c_v + \sum_{k=1}^{n} N^k R^k_v$$

$$J(N) = \frac{1}{2} \sum_v \left( \frac{R^C_{\text{ld}} - R^\text{obs}_v}{R^c_v} \right)^2$$

with

$$0 \leq N^k \leq 1$$

$$N^c + \sum_{k=1}^{n} N^k = 1$$
Cloud Detection: Initial Validation

Cloud Top Pressure (hPa)

MODIS Level 2 Product

AIRS MMR
Perspective: Cloudy Radiances

Innovations: $R^O_{\nu} - R^o_{\nu}$

« Retrieved » Innovations: $R^O_{\nu} - R^C_{\nu}$

Innovations for AIRS Channel #787 (surface)

Cloud Contamination
Bias Correction: Variational Bias Correction

Modeling of errors in satellite radiances:

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

\[ \langle \varepsilon \rangle = 0 \]
\[ B(\beta) = \sum_{i=1}^{N} \beta_{p_i} \]

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: \( x^T \rightarrow [x, \beta]^T \)

**Parameters**

- Offset
- scan, scan^2, scan^3

**Predictors**

- Offset
- scan, scan^2, scan^3

\[ J_b: \text{background term for } x \]
\[ J_\beta: \text{background term for } \beta \]

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

«Optimal » bias correction considering all available information
Bias Correction: VarBC Timeseries

Time evolution of Offset bias parameter for various AIRS channels

No Inertia Constraint

Inertia Constraint
Inverse Modeling: Adjoint Parameter Estim.

\[ R_{v}^{\text{atm}} = \int_{z_{0}}^{\infty} B_{v}(T(z)) \left[ \frac{d\tau_{v}(z,\theta)}{dz} \right] dz \]

\[ \tau_{v}(z_{1},\theta) = \exp\{-\gamma_{v}\sec \theta \int_{z_{1}}^{\infty} k_{v}(z)c(z)\rho(z)dz\} \]

\( \gamma \) modulates atmospheric absorption to compensate for:
- poor knowledge of gas concentrations (\( \text{CO}_2 \), ...)
- errors in definition of ISRF
- errors in mean absorption coefficient

\[ B = \text{Planck function} \]
\[ \tau = \text{transmittance} \]
\[ T = \text{temperature} \]
\[ \theta = \text{incident angle} \]
\[ z = \text{altitude coordinate} \]
\[ k_{v} = \text{absorption coefficient} \]
\[ c = \text{mixing ratio} \]
\[ \rho = \text{atmospheric density} \]

\[ \text{Sensitivity of AIRS BT to } \gamma \text{ for channel #221} \]

\[ \text{Timeseries of } \gamma \text{ estimations} \]

Auligné (2007)
**AIRS Impact: 36h Forecast vs. Radiosondes**

**Initial assessment of AIRS impact:**

- 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
Major limitation: Systematic model error

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