Towards the assimilation of cloudy radiances

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Status of the AIRS clear sky radiances assimilation at METEO France

with contrib of Thomas Auligne, D. Lacroix, P. Poli, V. Guidard F. Rabier, N. Fourrié M. Sczczech-Gajewska, H. Zhang, A. Babqiqi, F. Karbou

- In operations
  - 20 stratospheric channels operationaly assimilated since 19 september 2006 (over land and sea)
    - Positive impact in the stratosphere in the Tropics and in SH for T and Q
  - 70 other channels are monitored

- Current research works
  - Bias correction (depending on the latitude and the fov)
  - Assimilation of tropospheric channels
  - Assimilation over land : surface emissivity computation
Preparation of the assimilation of cloudy radiances

- AIRS 4D-Var assimilation in the French ARPEGE model
- Dahoui et al, QJRMS (2005): study of various cloud detection scheme for AIRS
  - 4 cloud detection schemes evaluated
  - Evaluation with MODIS observations
  - Linearity of a diagnostic cloud scheme
- 3 methods implemented for cloudy radiance assimilation:
  - CO2slicing
  - CO2slicing adjusted with 1DVar
  - Diagnostic scheme
CO2 slicing methods
Chahine 1974, Menzel et al 1983

- CO2 slicing is used for the retrieval of Ptop and cloud fraction.

\[ F_{k,p} = \frac{(R_{clr}^k - R_{obs}^k)}{(R_{clr}^{ref} - R_{obs}^{ref})} - \frac{(R_{clr}^k - R_{cld}^{ref, p})}{(R_{clr}^{ref} - R_{cld}^{ref})} \rightarrow P_{c,k} \]

\[ p_c = \frac{\sum p_{c,k} w_k^2}{\sum w_k^2} \]

\[ N_{\varepsilon} = \frac{R_{clr}^{ref} - R_{obs}^{ref}}{R_{clr}^{ref} - R_{cld}^{ref}} \]

- Variant: 1DVar used to adjust the Ptop and cloud fraction
Implementation of the CO2slicing in ARPEGE

- Control variables \(T, Q, Ps\)
- RTTOV
- Radiances
- CO2slicing
- Cloud top + cloud fraction
- Screening
  - Radiances + \(T, Q, Ps\)
  - 1DVar
  - Increments of control variable
  - Adjoint of RTTOV
  - Radiance Increments
- Computation of \(\nabla J\)
- Computation of \(J\)
Use of simplified cloud diagnostic scheme from ARPEGE for **large scale stratiform clouds** \((Q_l, qi, cc)\)

**Screening**
- Cloud detection and characterization

**RTTOVCLD**
- Cloud variables into control variable
Set up of the experiments

- Ten days period (from 8 to 17 June 2005)
- 102 channels assimilated per field of view over sea
- For cloudy pixels, assimilation only if:
  - $|\text{Lat}| > 40^\circ$
  - Low clouds: $600 \text{ hPa} < P_{\text{top}} < 950 \text{ hPa}$
- 3 exp for cloudy radiances
  - Diagnostic scheme
  - CO2slicing
  - CO2slicing + adjustment with 1DVar
  - Same bias correction and observation errors for cloudy and clear pixels.
- Comparison with
  - **Reference**: clear pixel with CO2 slicing.
  - « ECMWF » experiment: assimilation of the clear channels
Impact on the assimilated observations

For 8/6/2005:

<table>
<thead>
<tr>
<th>Exp</th>
<th>Observations: Clear/cloud/total</th>
<th>Channels: Clear/cloudy/total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>1033/0/1033</td>
<td>103561/0/103561</td>
</tr>
<tr>
<td>Diag</td>
<td>994/515/1509</td>
<td>99713/15622/115335</td>
</tr>
<tr>
<td>CO2</td>
<td>985/549/1534</td>
<td>98812/34094/132906</td>
</tr>
<tr>
<td>CO2+1DVar</td>
<td>966/750/1716</td>
<td>96891/49101/145992</td>
</tr>
<tr>
<td>ECMWF</td>
<td>1696/0/1696</td>
<td>106319/0/106319</td>
</tr>
</tbody>
</table>

- Background departure similar for the other observation types
- Weak increase of the assimilated AMSU-B number in the CO2 and the CO2 +1D experiments.
Background and analysis departures for AIRS observations
Cloudy observations
Impact on the forecasts

- Weak impact in the forecast, mostly in southern hemisphere.
- Non significant impact

Exp-REF RMS error vs RS for Geopotential

Diag  CO2slicing  CO2+1DVar  clear ECMWF

NORD20  TROPIQ  SUD20  NORD20  TROPIQ  SUD20  NORD20  TROPIQ  SUD20
Conclusions

- Feasibility study of the assimilation of cloudy radiances in the ARPEGE model over a ten day period
- 3 methods were tested for the 4D-Var of ARPEGE and compared with the clear sky radiance assimilation (ARPEGE and ECMWF)
- Small number of cloudy assimilated observations
- Small impact on the analysis and on the forecast
Future work

- Extension to the other level of clouds and a longer period
- Observation errors for cloudy pixels, bias correction
- Observation correlation
- Cloud top pressure and cloud cover included in the 4D-Var minimisation