Toward the 4D-Var assimilation of cloudy ATOVS observations

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Abstract:
The assimilation of cloud information within the ECMWF four-dimensional variational (4D-Var) system is being developed. This poster describes the strategy chosen for this involving work and summarises the results obtained so far.

ECMWF

To-do list for the assimilation of cloudy ATOVS observations

- ✔ Development of the radiation model (direct+linearised versions)
- ✔ Evaluation of the forecast model in terms of Brightness Temp.

- ✔ 1D-Var cloud retrievals from ATOVS
  control variables = cloud variables
- ❑ 1D-Var cloud retrievals from ATOVS
  control variables = T, q (uses diagnostic cloud scheme)

- ✔ Introduction of cloud-radiation processes in the 4D-Var physics
- ❑ Plug-in of the cloudy ATOVS observations in the 4D-Var

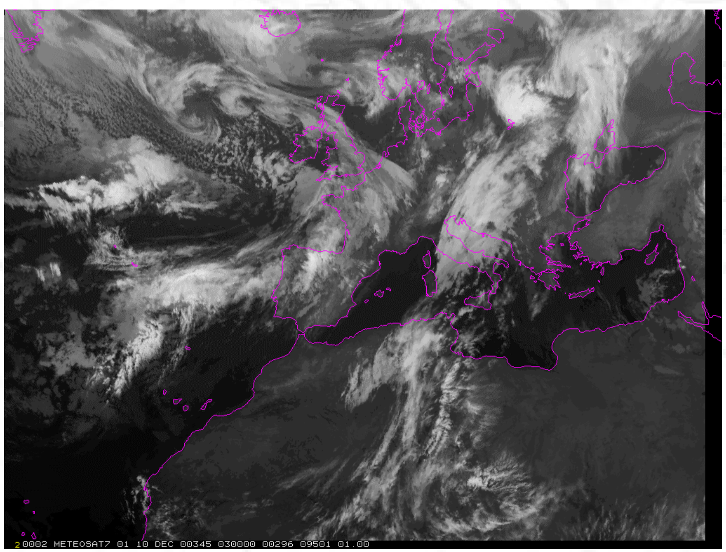
- ❑ Re-evaluation of the approach
  - Coherence with clear-sky T/q assimilation
  - T/q background error structures

✔ = done (cf. below)

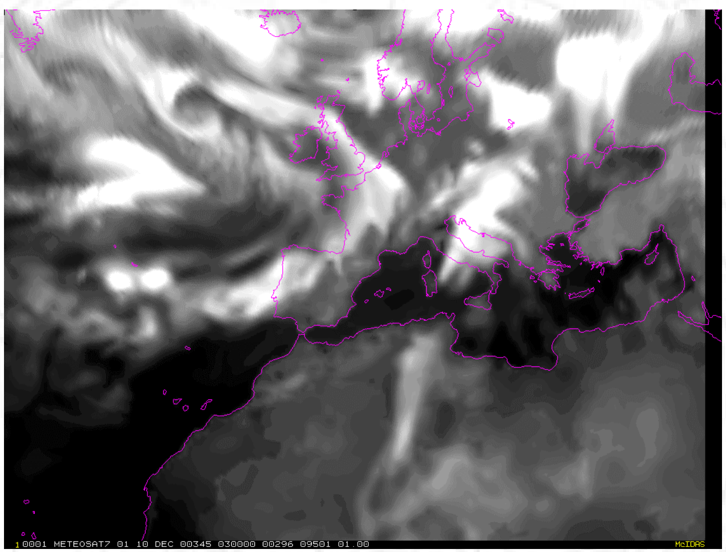
Radiation model

- Gas absorption: RTTOV
- Cloud absorption: emissivity parametrisation (IR+MW) from model cloud profiles (cc, iwc, lwc)
- Overlap assumption: maximum-random (Räisänen 1998)

☛ Now part of RTTOV-7 (Saunders 2002)



Meteosat 11µm (10/12/2000)



ECMWF 3-h fc simulation (different grey scale)

Evaluation of the forecast model

- The major large-scale structures of clouds are well represented by the ECMWF model. The seasonal cycle is realistically depicted

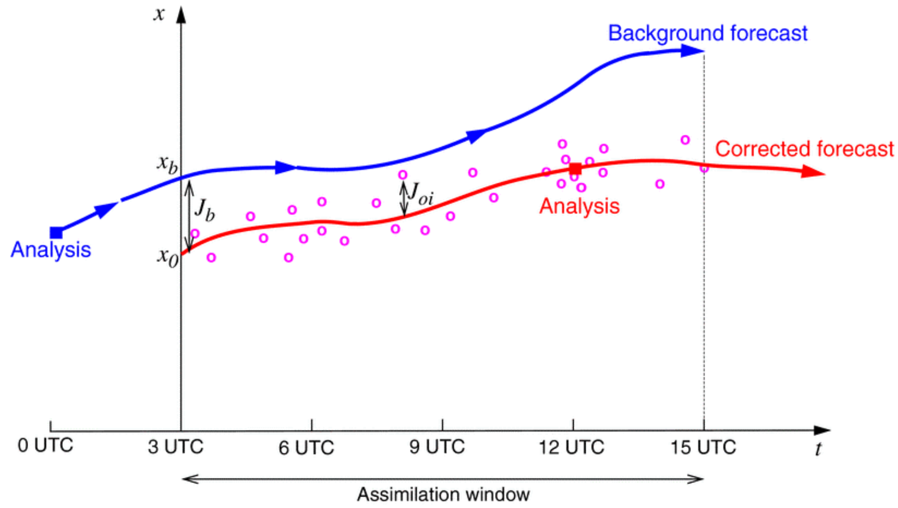
- Some weaknesses are identified:
  - likely underestimation of cloud ice water content
  - overestimation of liquid clouds contents/occurrence
  - representation of the variations of the ITCZ over short time scales (< month)
  - underestimation of the stratocumulus off the West coast of the continents

  ☛ issues = resolution, parameterisation

4D-Var and 1D-Var

- 4D-Var minimises a cost function
  (background departure + observation departure)

$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x_b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x_b}) + \sum_{\mathbf{t}} (\mathbf{y_t} - H(\mathbf{x_t}))^T \mathbf{R}^{-1} (\mathbf{y_t} - H(\mathbf{x_t}))$$



- 1D-Var : idem with single column and no time dimension

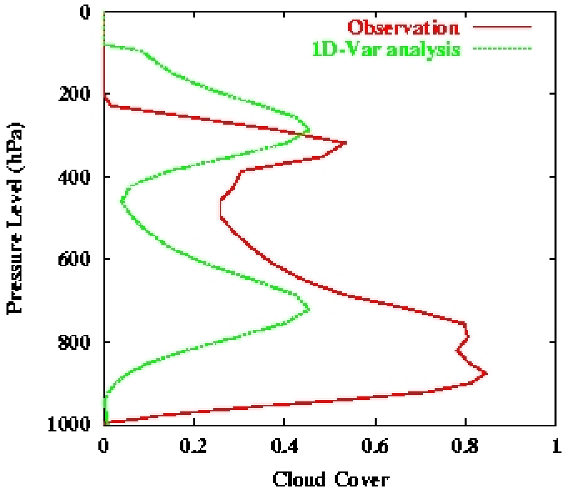
$$J(\mathbf{x}) = (\mathbf{x} - \mathbf{x_b})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x_b}) + (\mathbf{y} - H(\mathbf{x}))^T \mathbf{R}^{-1} (\mathbf{y} - H(\mathbf{x}))$$

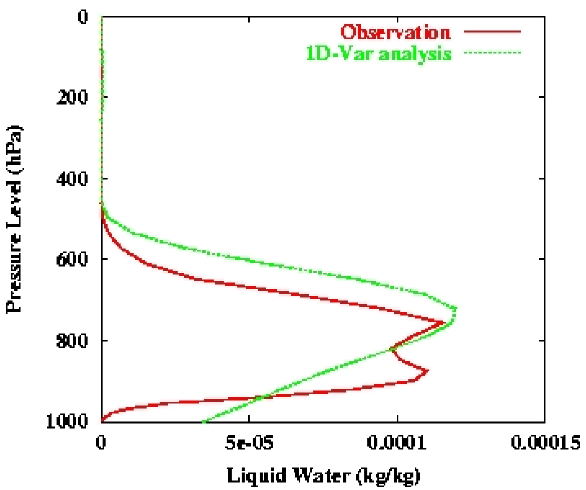
1D-Var assimilation (1)

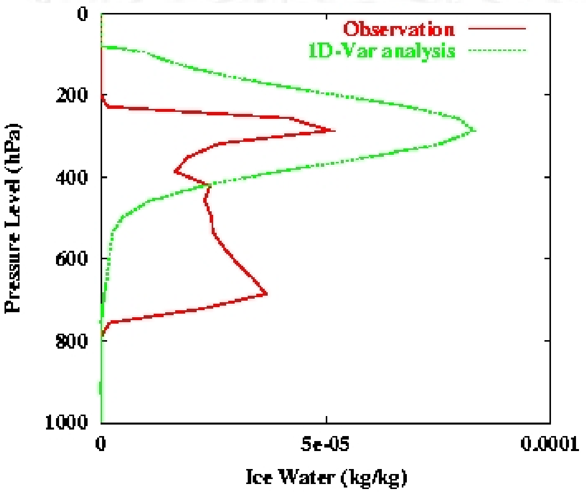
- Synthetic case
- Observations = HIRS 4-8, AMSU-A 1-6 (simulated)
- Background = cloud variables set to ε

☛ Good behaviour of the 1D-Var

☛ Some degree of realism of the cloud profiles







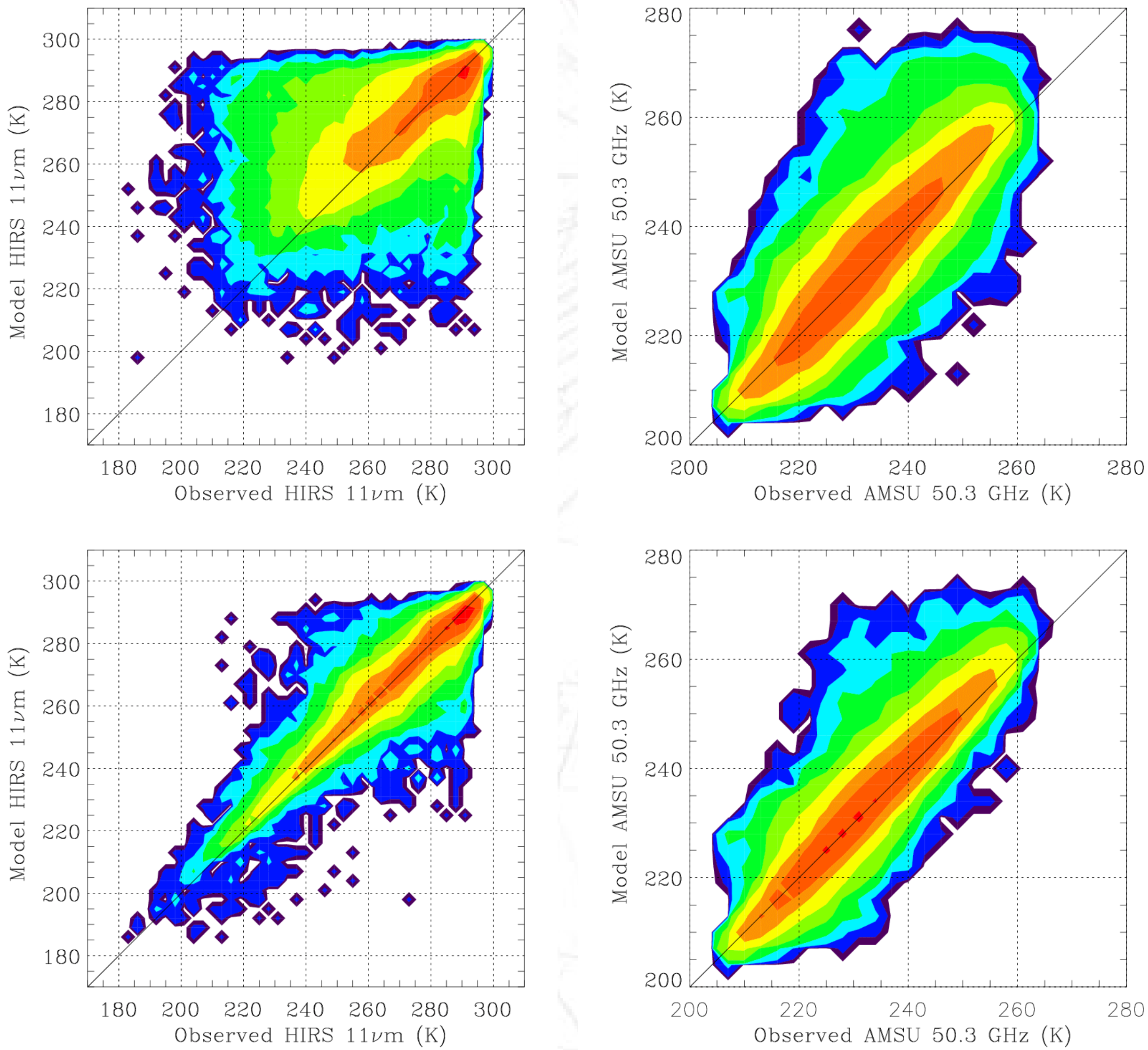
1D-Var assimilation (2)

Toward the 4D-Var assimilation of cloudy ATOVS observations

15 March 2001
NOAA-15

Background histograms:

Analysis histograms:



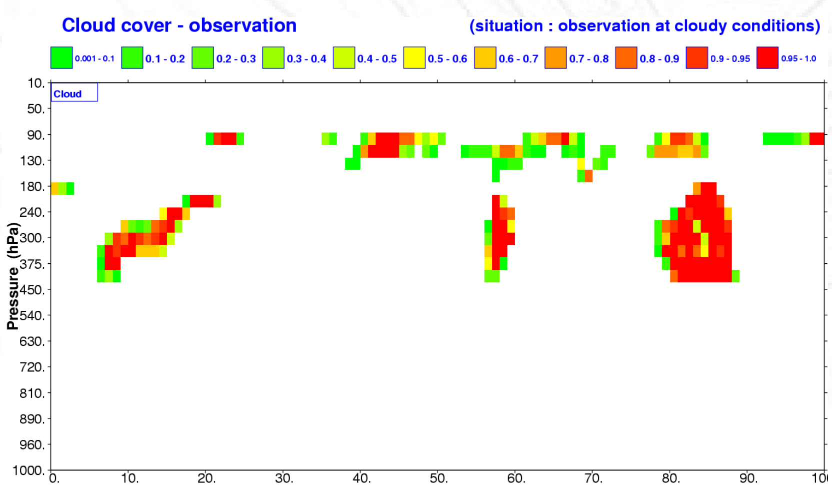
Log-linear contours

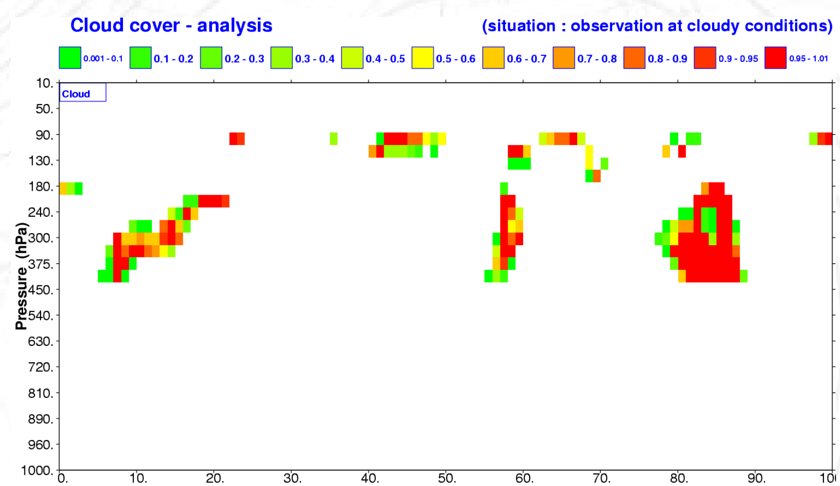
Coupling with the physics

- Control variables = T, q only
- A diagnostic cloud scheme computes cloud profiles from T and q before the radiation model is used
- Tests have been performed with broadband IR and visible ARM-SGP observations

☛ Good behaviour of the 1D-Var

No cloud in the first-guess





Time series of cloud cover observed and analysed

Improved 4D-Var physics (1)

- The 4D-Var linearised physics has been modified so as to take cloud-radiation interaction into account

  - Current operational 4D-Var radiation:
    - o LW radiation = constant emissivity formulation
    - o SW radiation = no
    - o Cloud scheme = no

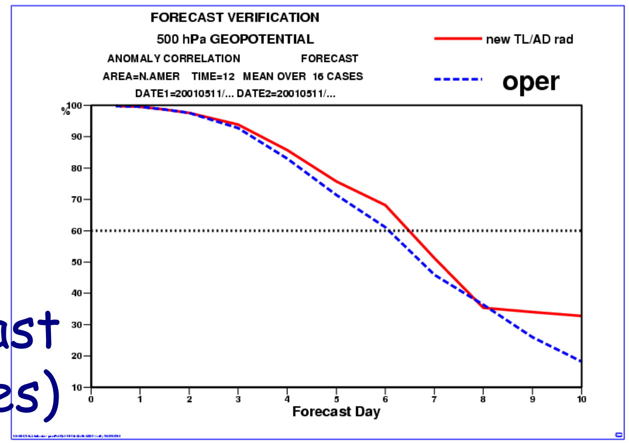
  - Improved 4D-Var radiation:
    - o LW radiation = Neural network-based + Jacobian matrices
    - o SW radiation = linearised version of the broad-band scheme used in the forecast model
    - o Cloud scheme = diagnostic formulation

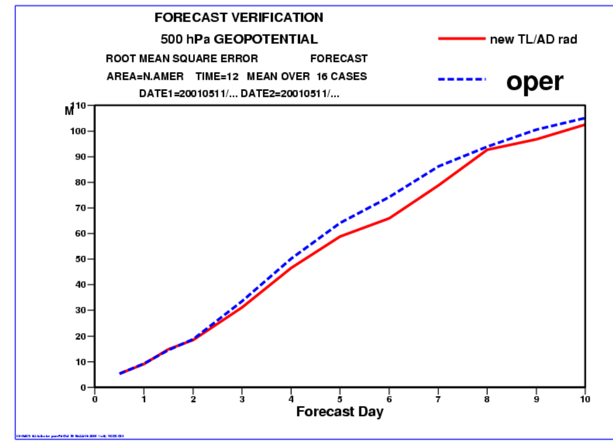
Improved 4D-Var physics (2)

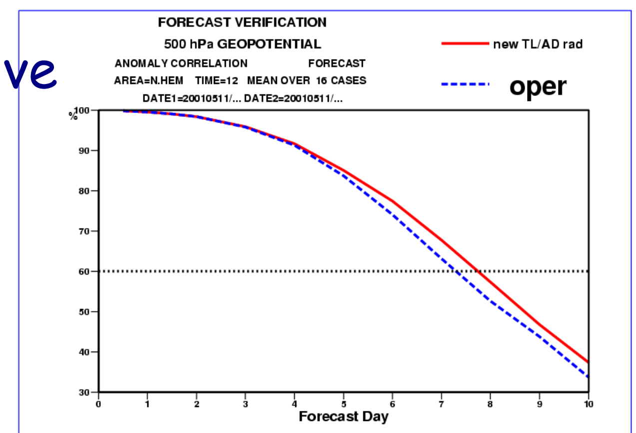
- The new linearised physics is already being tested within the currently operational configuration (i.e., no new observations)

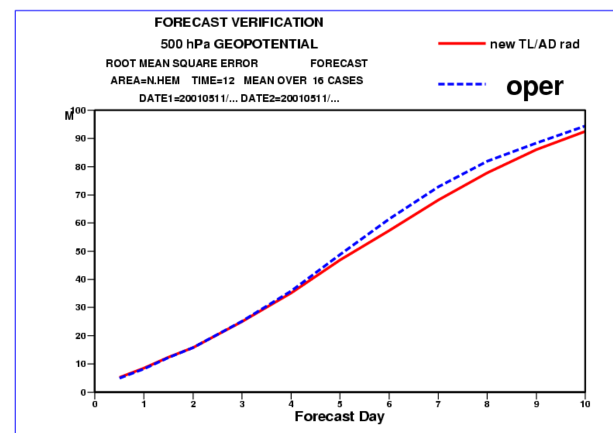
☛ Better forecast quality (cf. scores)

☛ More expensive (TL=2x)









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