RTTOV 10 implementation in the COSMO model

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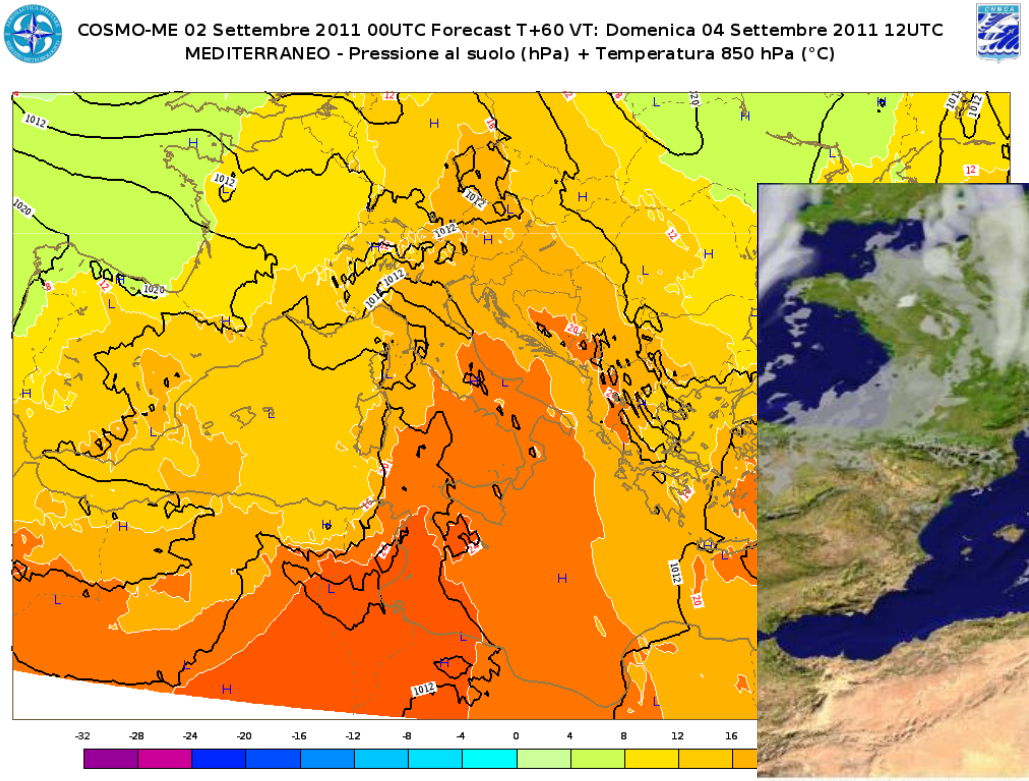
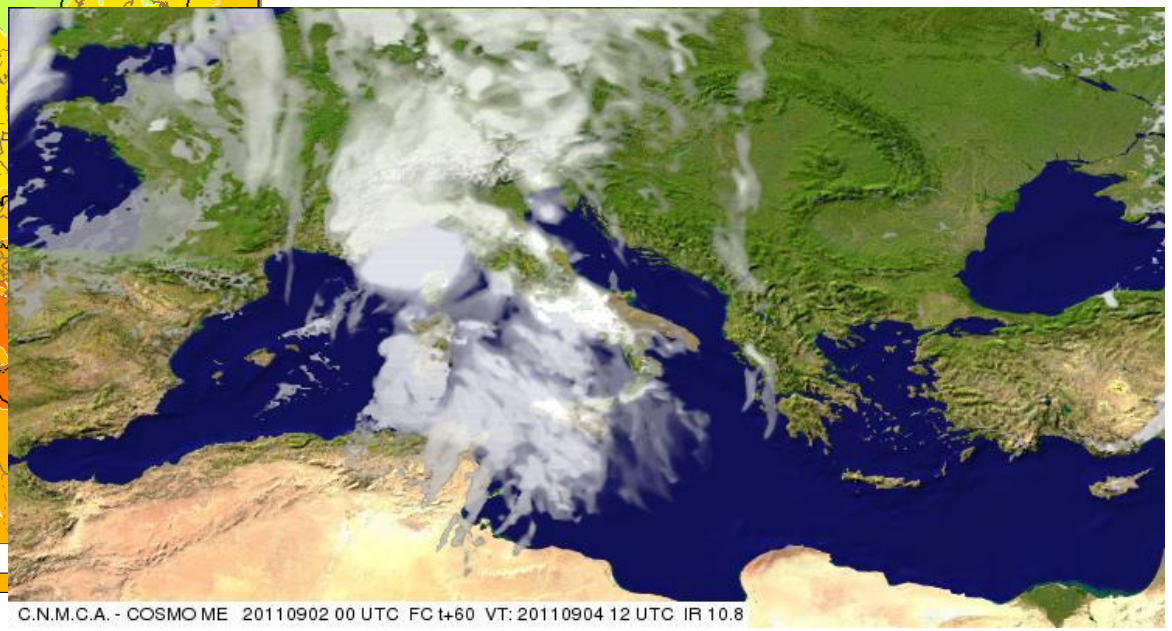
What is RTTOV?

- NWP SAF's fast radiative transfer model *H*.
- Computes top of the atmosphere radiances $\mathbf{y} = H(\mathbf{x})$ from a given atmospheric profile **x**.
- Set of FORTRAN 90 routines and libraries and sensor dependent coefficient files.
- Includes routines for tangent linear $\boldsymbol{\delta y} = \mathbf{H}(\mathbf{x}_0)\boldsymbol{\delta x}$ as well.

Why do we need it? (1/2)

Simulation of satellites observations from atmospheric forecasts:





Why do we need it? (2/2)

Assimilation of satellite observations in atmospheric forecasts:

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{K}\,[\mathbf{y} - H(\mathbf{x}^b)].$$

Observation increment is computed in observation space

To sum up: we need RTTOV both in the data assimilation (DA) and postprocessing (PP) phases of a NWP system!

Several versions of RTTOV…

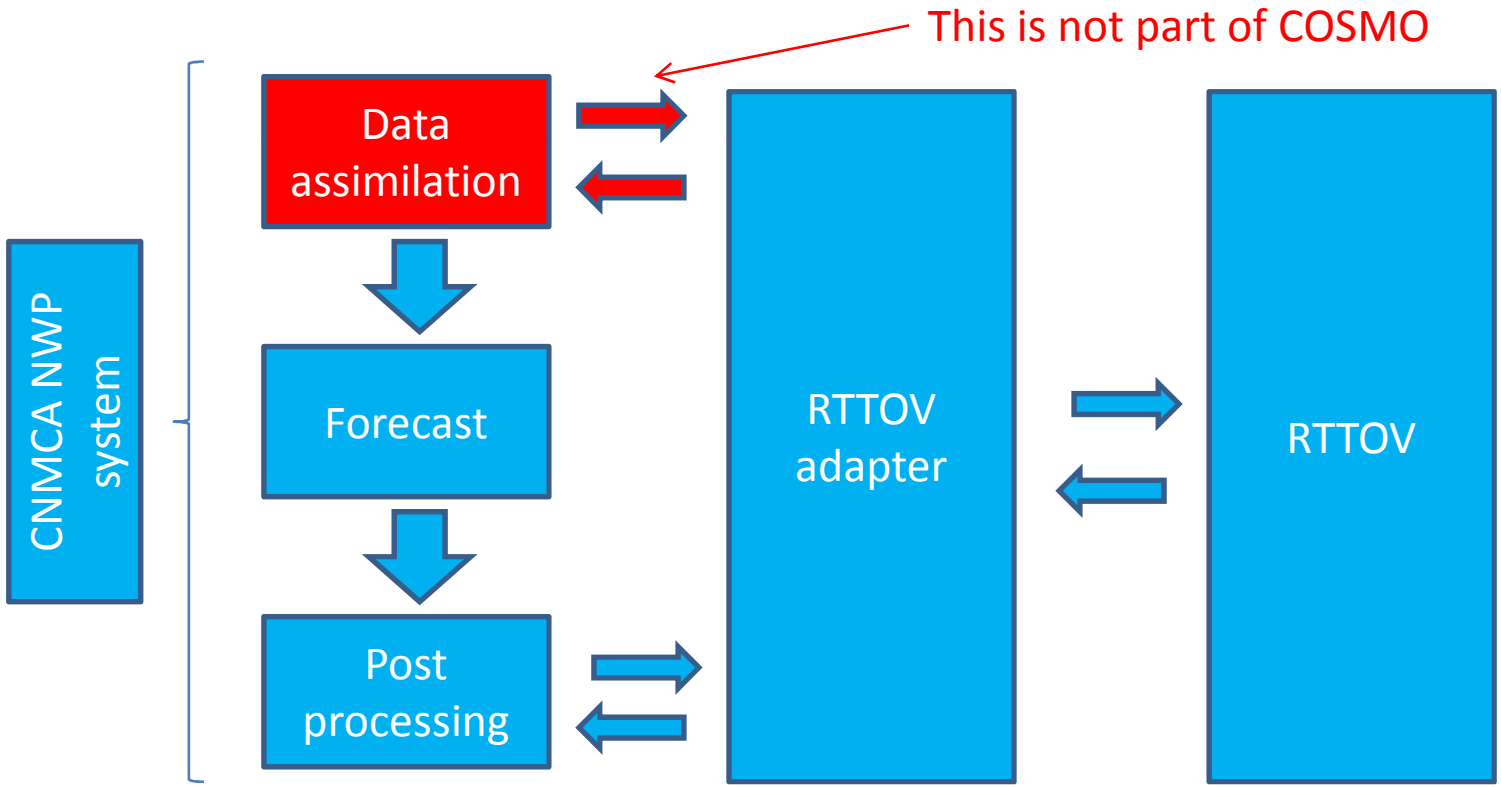
- Version 8:
  - FASTEM-3 sea surface emissivity model;
  - Cloudy radiances simulated through wrapper routines.

- Version 9:
  - Interpolation from model levels to user defined levels;
  - Cloudy radiances simulation part of main code.

- Version 10:
  - FASTEM 4 sea surface emissivity model;
  - From 43 vertical levels to 51;
  - Major changes to the routines' interfaces and structures.

…and the need for an interface.

The changes between each version of RTTOV require the development of an adapter module that makes the model independent of future changes.



RTTOV adapter

- Mainly developed by DWD (Marc Schwaerz, Detlef Pingel and Robin Faulwetter…);
- F90 wrapper module comprising several routines that are called by COSMO modules;
- In turn, it organizes the inputs for the RTTOV routines call;
- On return, it adapts and passes the output of RTTOV to COSMO modules;
- It is changed when either COSMO or RTTOV are changed, but neither should be changed when the other is;
- It is part of the COSMO distribution thus it is continuously maintained.

Adapter routines

- Initializes RTTOV modules and structures and reads instrument specific coefficients;
- Fills RTTOV atmospheric variables profiles (main program doesn't know RTTOV structures!);
- Calls RTTOV in forward (Direct) mode;
- Calls RTTOV in tangent linear (TL) mode (includes forward calculation);
- Cleans up (i.e., deallocation…).

RTTOV v10 variables

- *Chanprof*: channels and profiles structure,
  - e.g., channel 3 for profile 5 is ponted by *chanprof(15)%prof* = 3, *chanprof(15)%chan = 5*

- *Profiles*: atmospheric data structure, e.g., *profiles%p, profiles%t* …

- *Options*: control flags structure, e.g., *opts%addinterp*, *opts%addclouds*, *opts%apply_reg_limits*, *opts%ozone*…

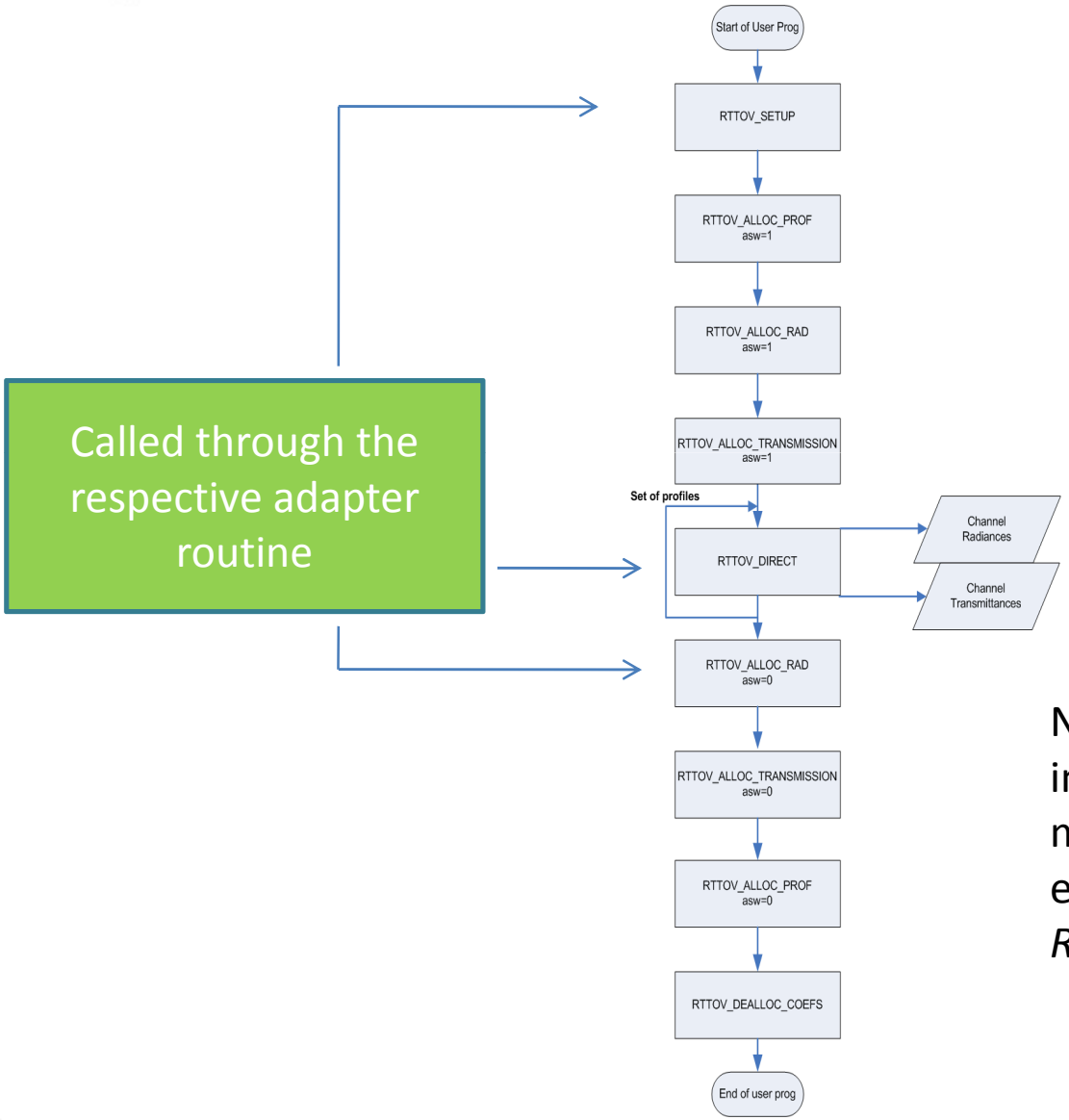
- *Coefficients* structure;

- *Transmission* structure, includes integrated value and the contribution from each level;

- *Radiance* structure, includes *brightness temperature;*

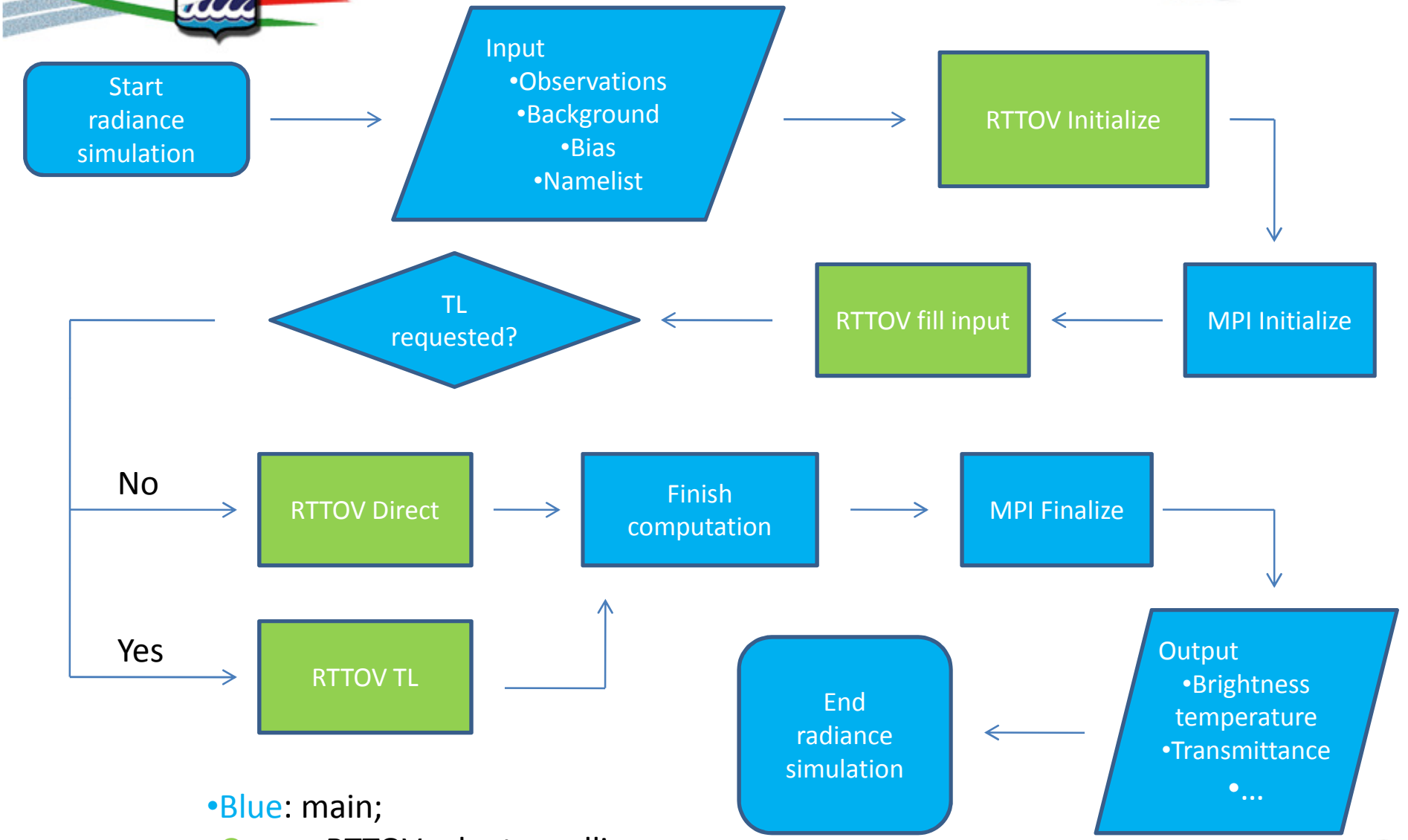
- *Emissivity:* surface emissivity, can be entered or calculated through FASTEM.

Process diagram of a RTTOV v10 call



NB: RTTOV tangent linear includes also the forward model calculation, so it is either *RTTOV_direct* or *RTTOV_TL*

Radiance simulation flowchart



•Blue: main;
•Green: RTTOV adapter calling respective RTTOV routine.

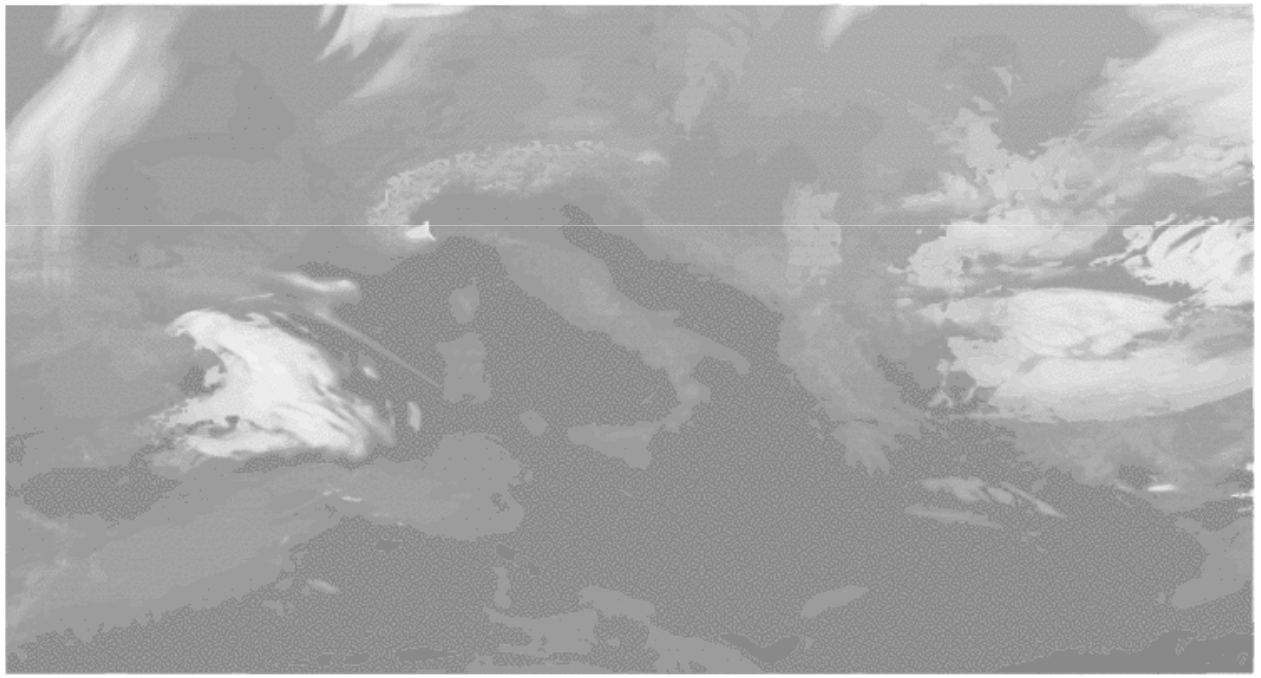
Changes to the v9 adapter

To upgrade the adapter to RTTOV version 10 and to the CNMCA forecasting system's needs we had to (among other things):

- Use v10 constants and types;
- Change the wrapper interfaces;
- Remove the regression limits check as it is now built in RTTOV;
- Add transmission as an out variable;
- Pass the increment (*T*, *qv*) to the TL routines.

Simulation of satellite observations

11/04/2011 00:00 UTC MSG SEVIRI IR sensor simulation



- RTTOV 7

Simulation of satellite observations

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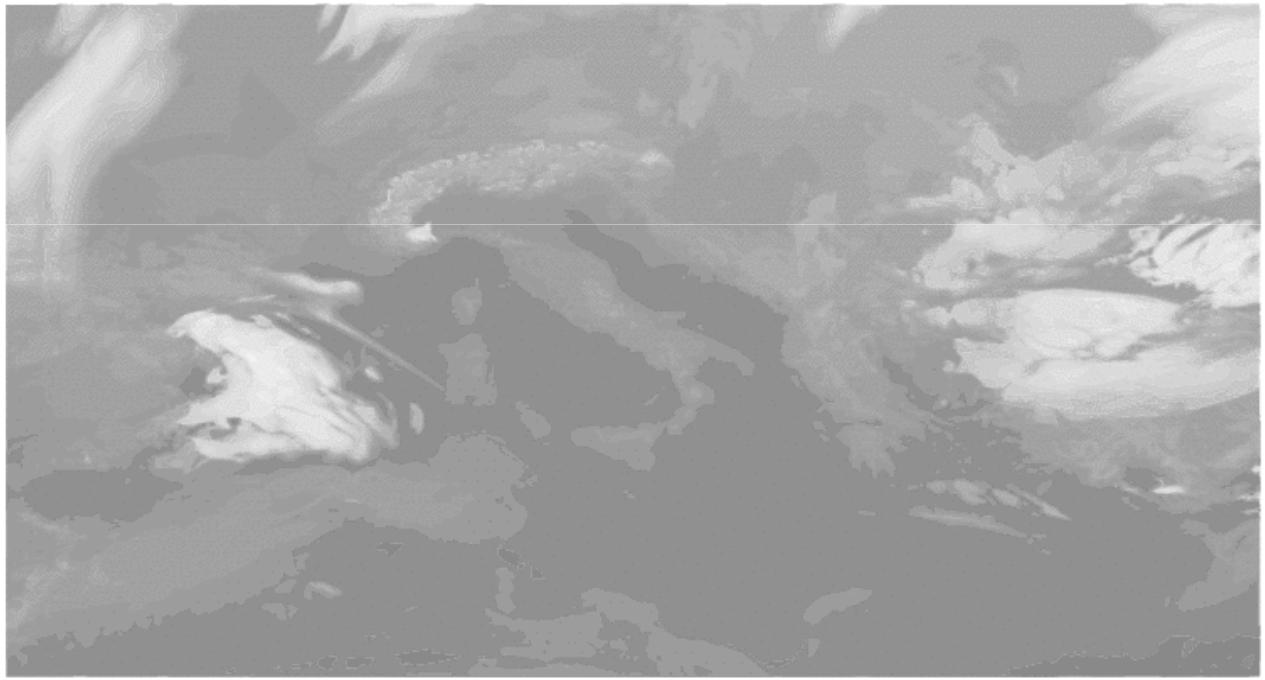


- RTTOV 10: seems to be slightly drier

Use of radiances in DA

- CNMCA's 3D Var scheme uses RTTOV to assimilate AMSU-A observations. The TL mode is used to compute the gradient of the cost function. This is not necessary for EnKF.

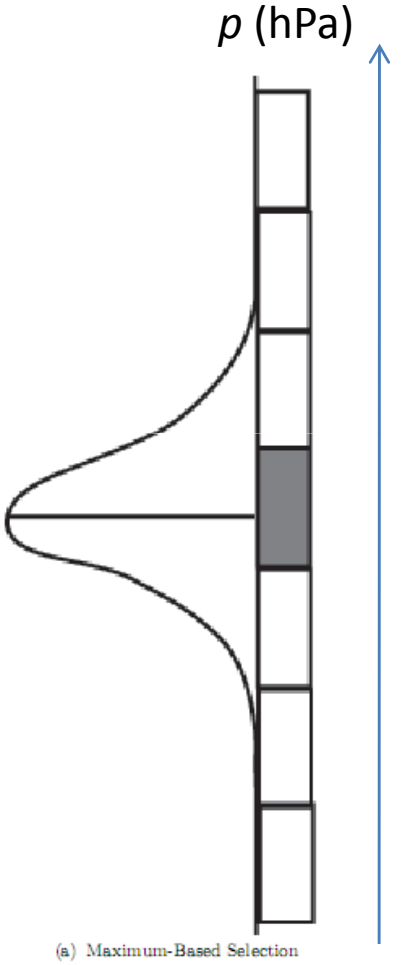
- However, top of the atmosphere radiances cannot be directly used in EnKF because of lack of vertical localization, thus in CNMCA's LETKF system uses **Maximum Based Selection** method (*Fertig et. al, 2007*).

- Accordingly:
  - Radiance observations are assigned to the model level corresponding to the maximum of the weighting function;
  - They are treated as "single-level" observations;
  - The weighting function shape is the vertical covariance localization function.

- The weighting function is the vertical derivative of the transmittance:

$$w_{\nu,k} = (\tau_{\nu,k-1} - \tau_{\nu k}) / (\ln(p_k) - \ln(p_{k-1}))$$

where ν is the channel, τ the transmittance and k the level.



(a) Maximum-Based Selection

Assimilation preliminary experiments

- V9 and v10 were compared using the 3D Var scheme;
- We used FASTEM-3 because of a known bug with FASTEM-4;
- Satellite observations from channels 4 through 10 of AMSUA-A instrument mounted on NOAA and METOP satellites;
- The results are very similar, but the bias behavior is slightly worse for lower channels.

Conclusions

- Our goal was the implementation of RTTOV v10 in CNMCA's NWP system;
- We built upon DWD's wrapper module, upgrading it to v10 and expanding its scope, as we believe there should be only one COSMO-RTTOV interface (possibly the official one!);
- These changes have already been delivered to DWD;
- While the call to satellite observations simulation is already built in COSMO, we had to write similar modules to call the CNMCA DA scheme;
- The assimilation of ASMU-A observed radiances is now in the testing phase;
- There is still some work to do to generalize the DA interface, namely its output routines, to other sensors (i.e., AMSU-B and MHS).