A closer look at fog, clouds in cold conditions and precipitation in HARMONIE-AROME

A joint presentation by:

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HARMONIE working group on clouds and convection

- Lisa Bengtsson, SMHI
- Karl-Ivar Ivarsson, SMHI
- Sami Niemelä, FMI
- Wim de Rooy, KNMI
- Sander Tijm, KNMI
- Javier Calvo, AEMET
- Gema Morales, AEMET
- Daniel Martin, AEMET
- Kristian Pagh Nielsen, DMI
- Bent Hansen Sass, DMI

First meeting held in Norrköping in October

https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Clouds201210

Identified problem areas:

1) Too persistent fog layer over sea. (Also over-prediction of fog over land).

2) Too “spotty” behavior of deep convection.

3) Dynamically weakly forced deep convection. (Too active).

4) Too low cloud base associated with weak top entrainment in stratocumulus.

5) “On/off” behavior of clouds?

6 a) Too much low level ice clouds and ice fog in cold situations. (generally also too much cirrus year round).

6 b) Too little mixed-phase clouds in cold situations

Clouds in cold conditions

- Too few mixed-phase clouds. Potentially related to a too active generation of cloud ice and solid precipitation, which too quickly removes moisture.
- Too much ice clouds (cirrus, ice clouds or fog near ground in winter). Clouds appear as soon as the relative humidity is close to 100%.

Suggestions for improvements of clouds in cold conditions

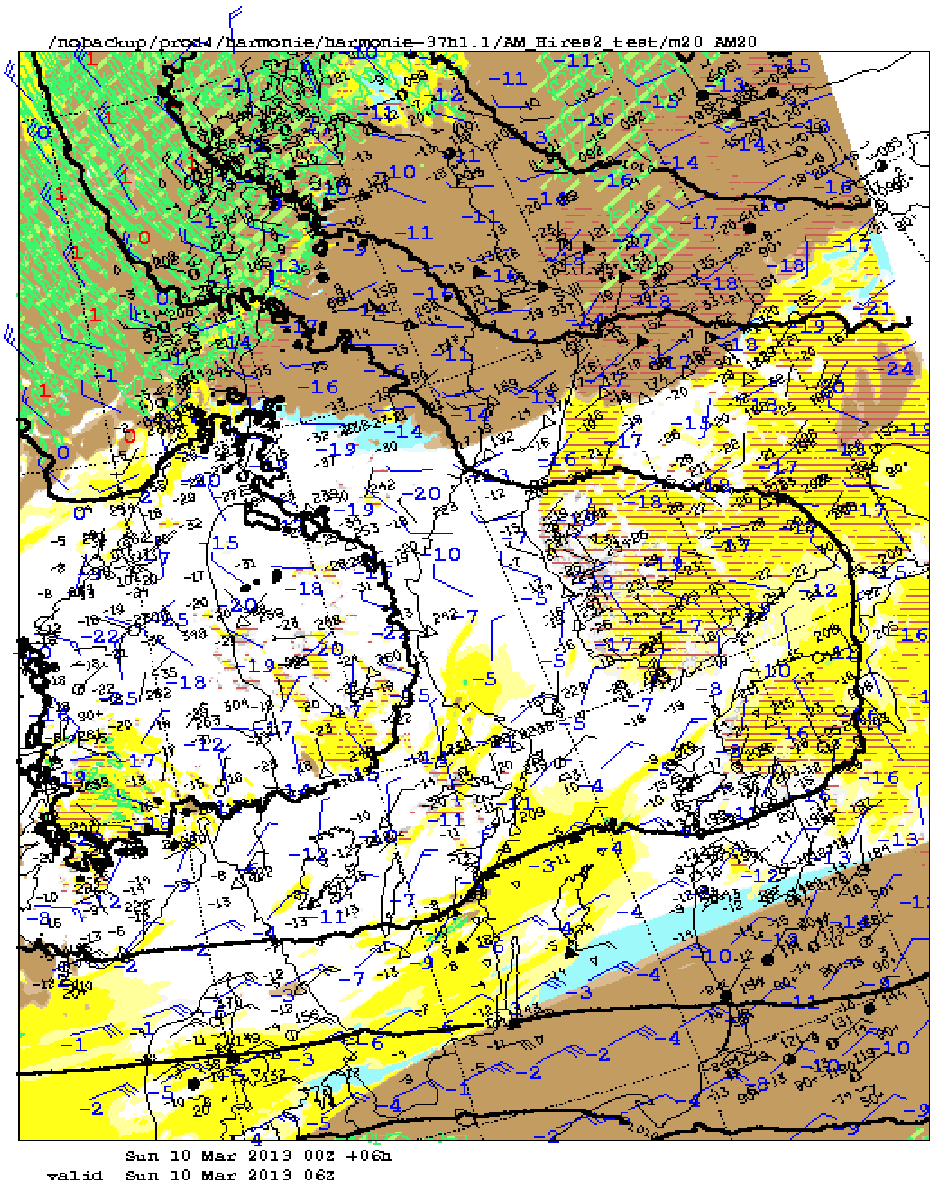
A clear separation of fast liquid water and slow ice water processes:

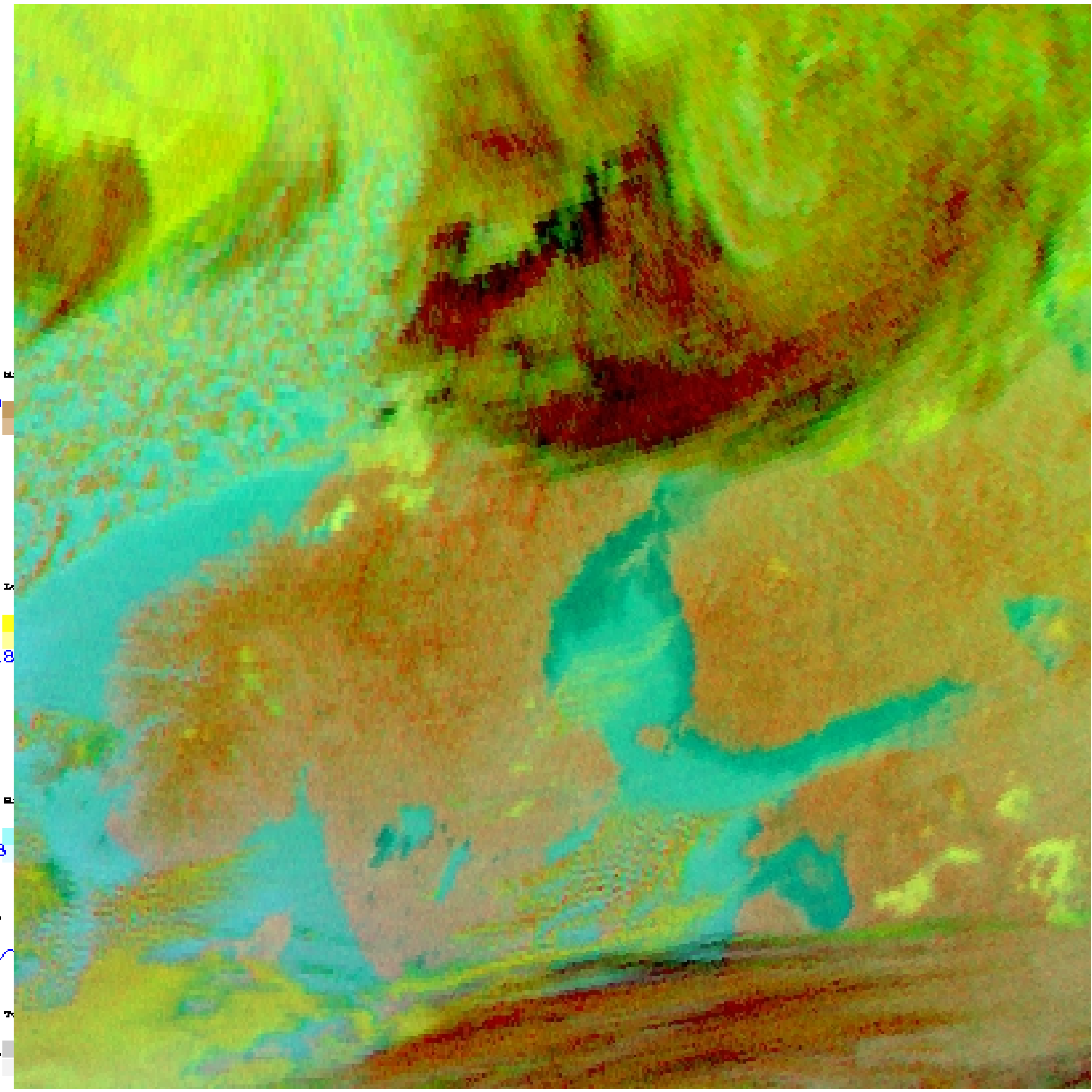
- The statistical cloud-scheme only handles water- and mixed phase cloud cover. Only the amount of cloud-liquid is calculated from this scheme.
- The Bergeron-Findeisen process is derived as a conversion from vapor to ice.
- A separate ice cloud fraction is derived. It is related to the content of cloud ice water, and to the relative humidity with respect to ice.
- The content of solid precipitation contributes to the cloud fraction, since the optical properties of solid precipitation are 'cloud-like' and not too different from that of cloud ice.
- Total cloud cover is the sum of the liquid fraction and ice fraction.
- The ice cloud fraction is dependent of model thickness, since ice clouds are generally considerable optical thinner than water clouds

Zhang et. al. (2003), Liu et al. (2007), Ivarsson et al. (2013)

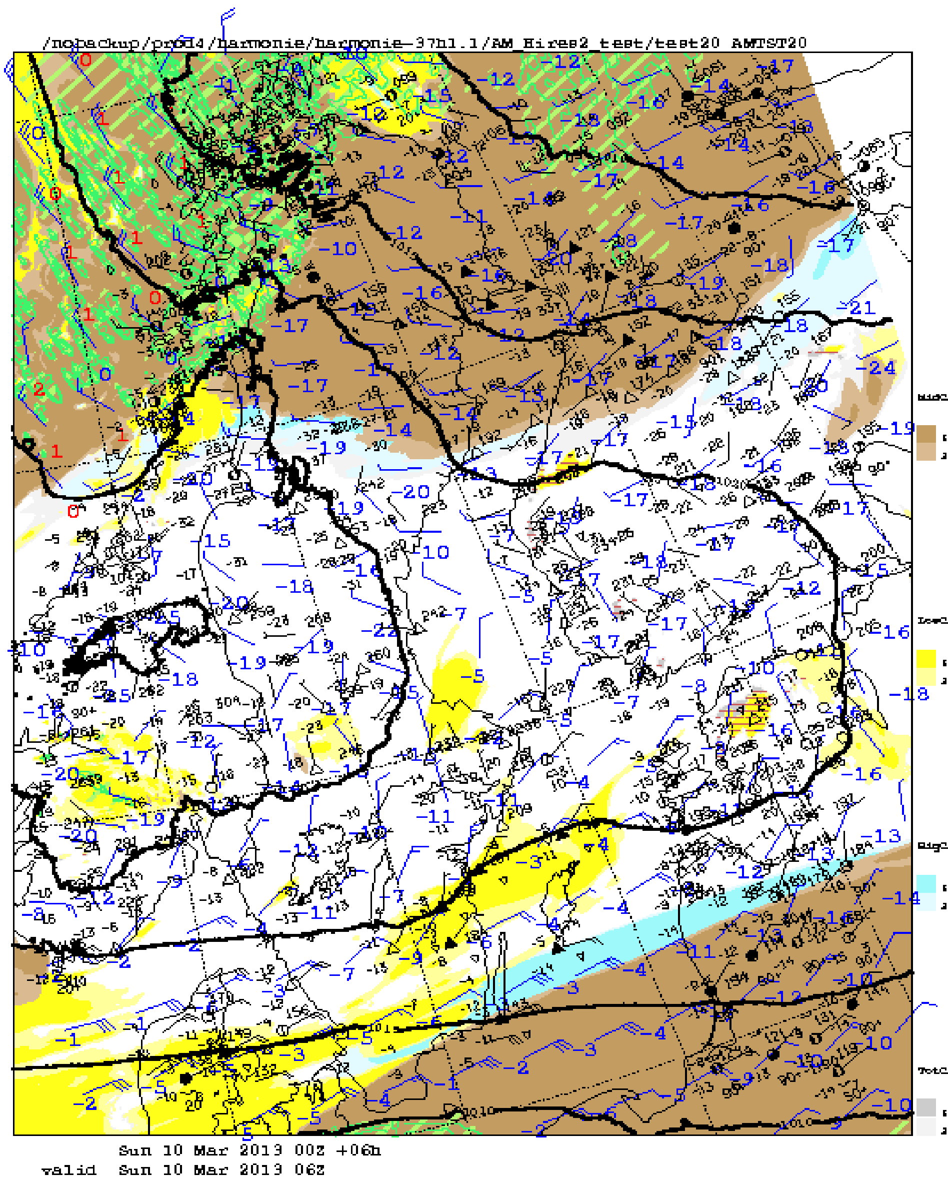
First results (6 hours fc.)

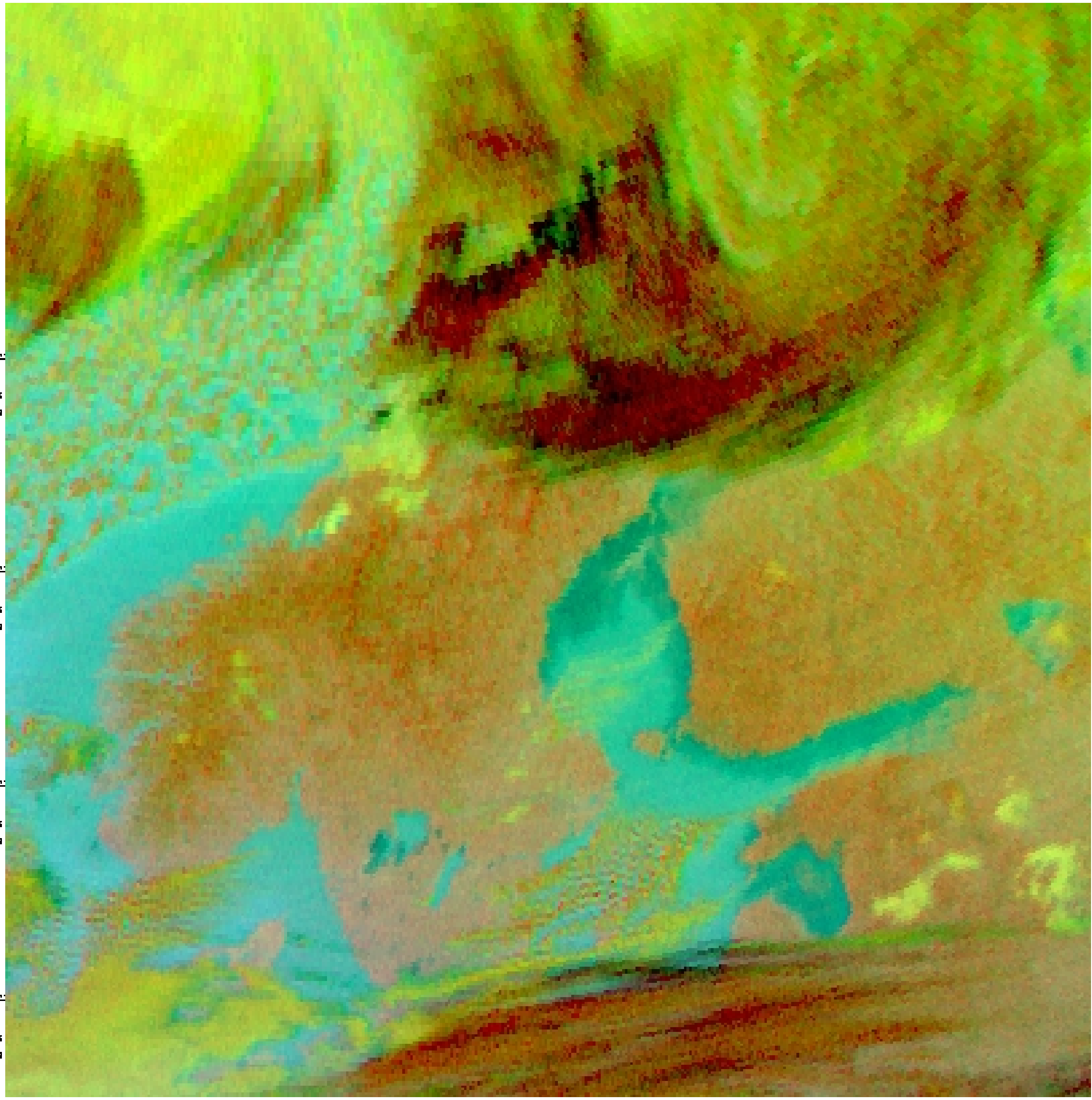
A case with too much low-level ice clouds (left : reference 37h1.1 AROME , right satellite picture (yellow=low clouds, brown or blue high or middle level clouds March 10 2013, 06 UTC Scandinavia+Finland)



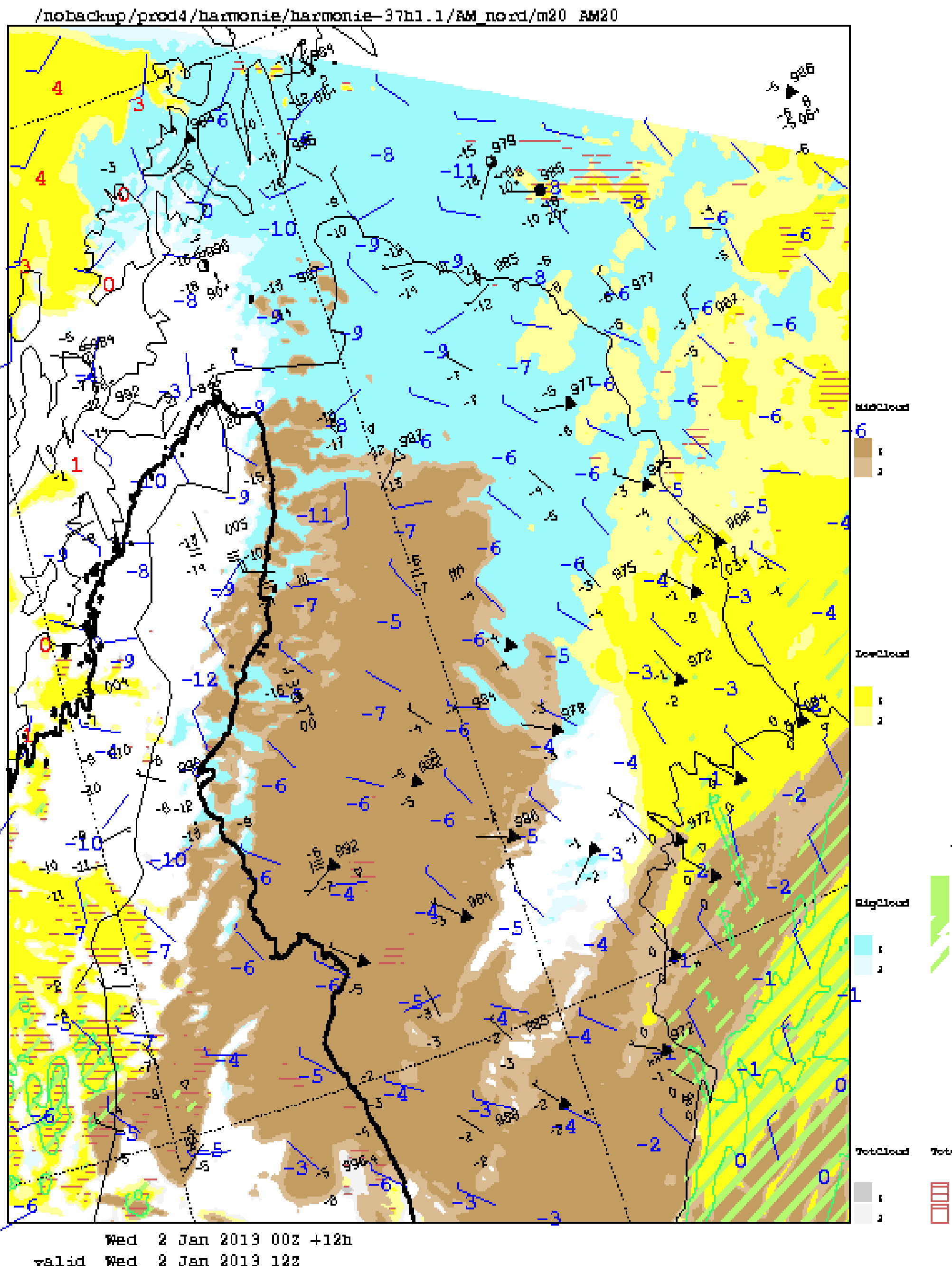


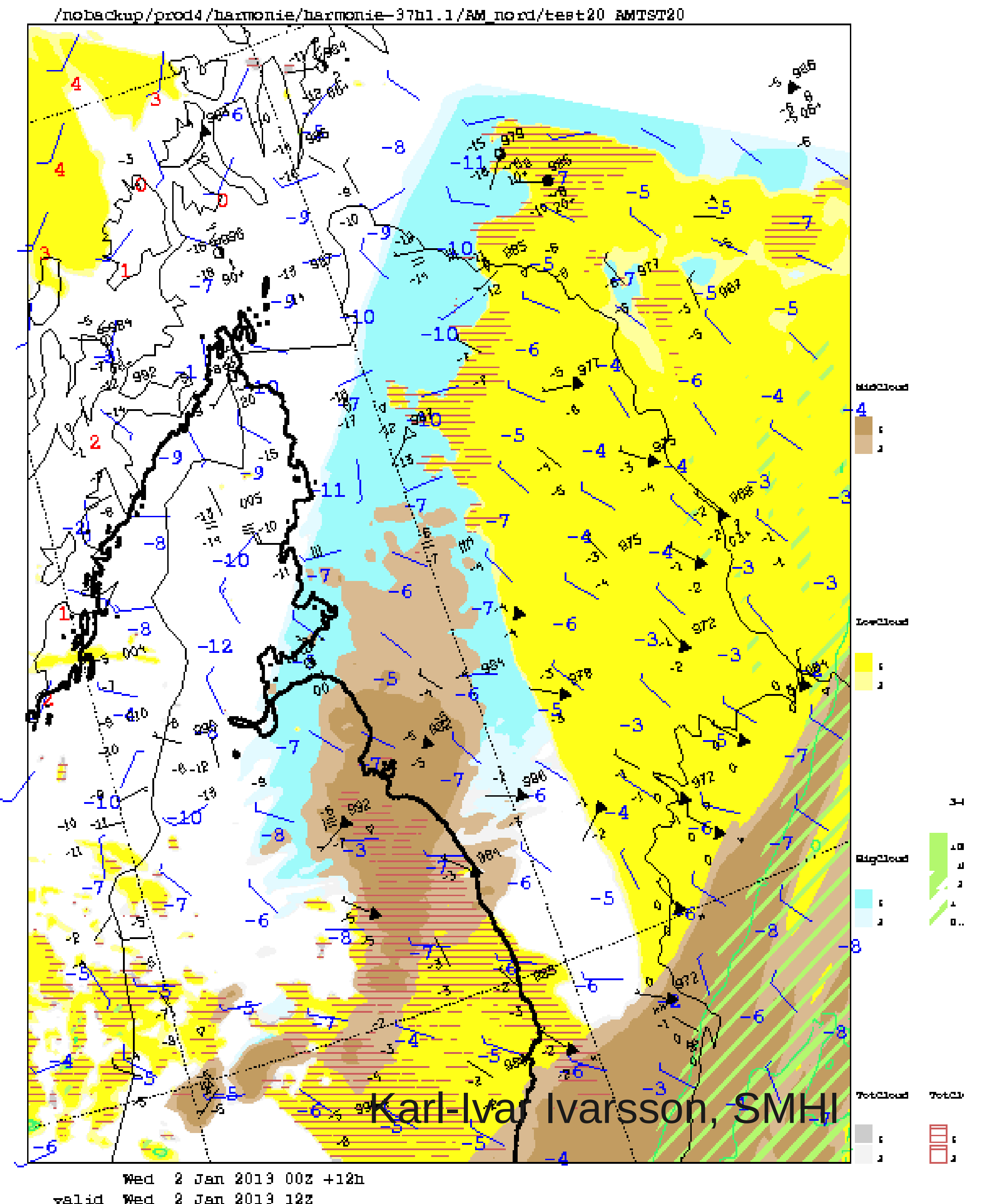
Impact of modified parmeterization





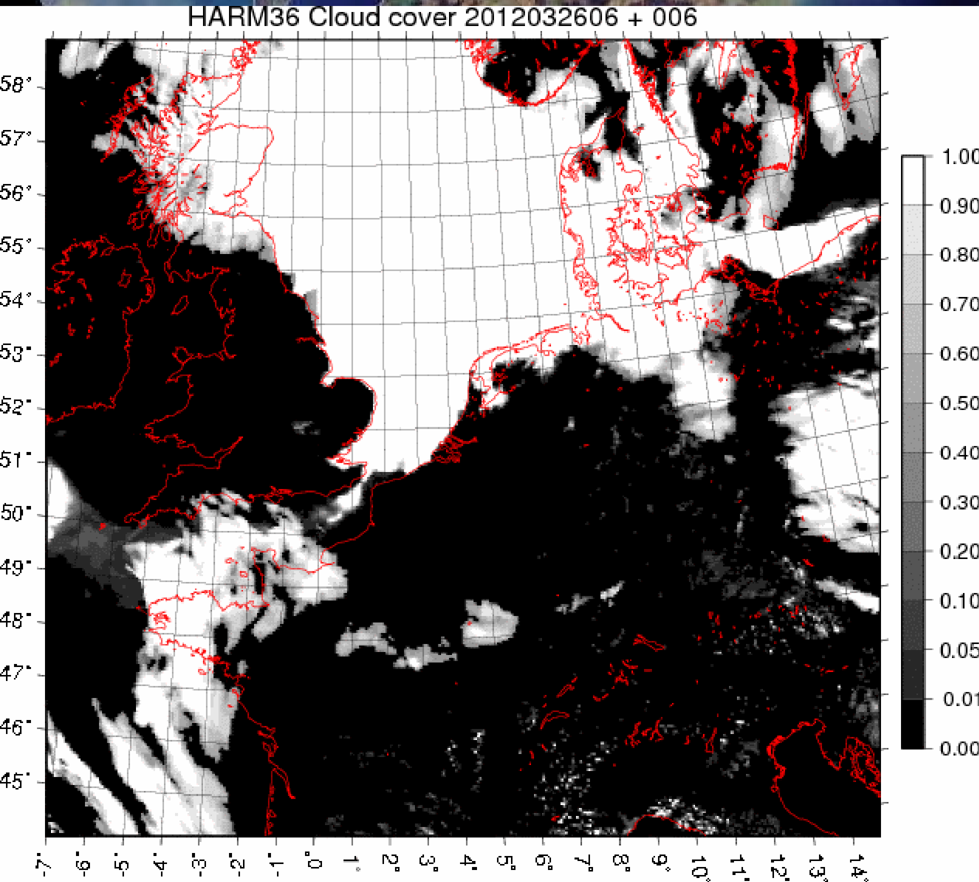
12 hour forecasts with reference version (left) and modified version (right). More mixed-phase low clouds and (unfortunately) also more fog with the modified version

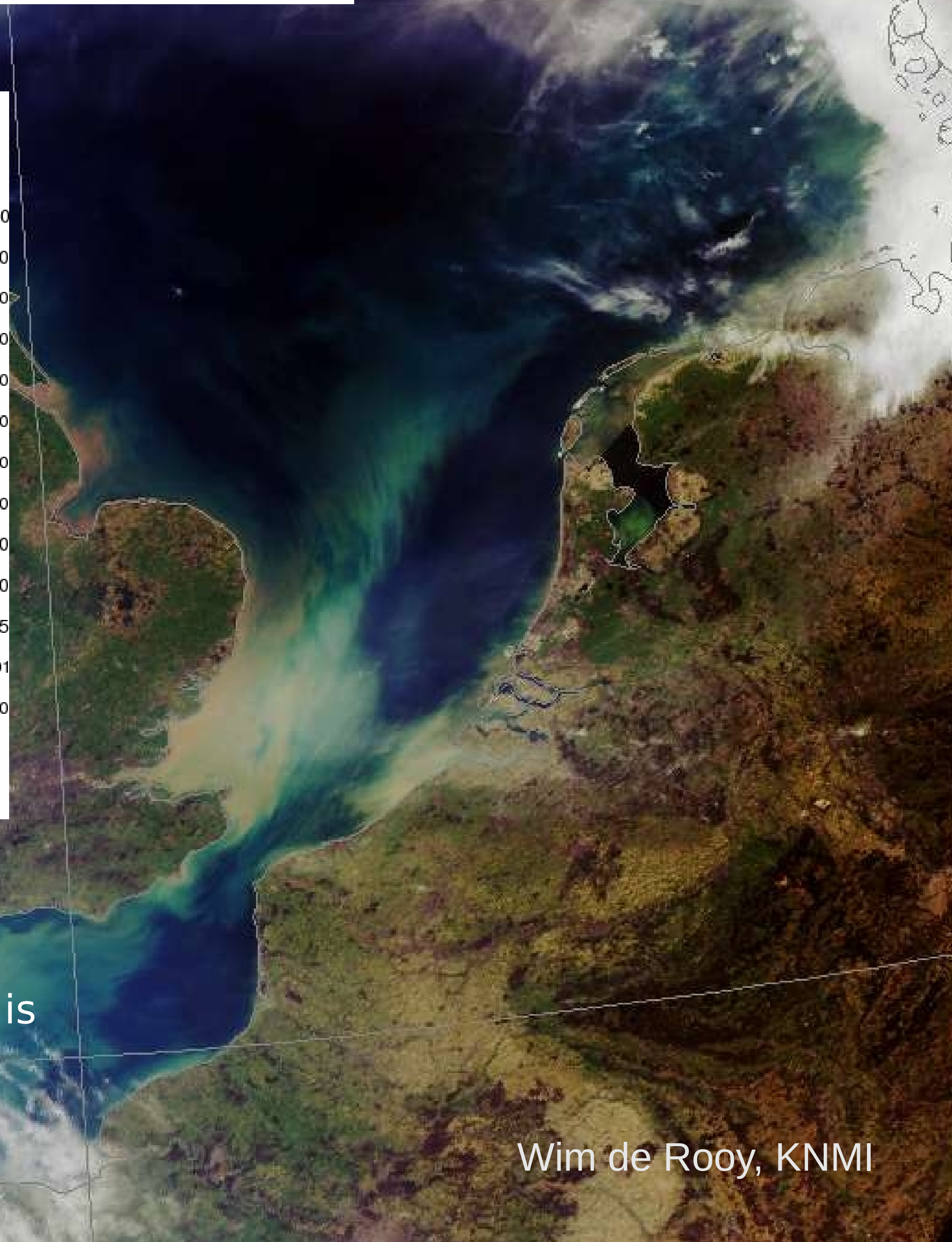




Karl-Ivar Ivarsson, SMHI

Bad forecasts: Fog above sea





Severe problem:

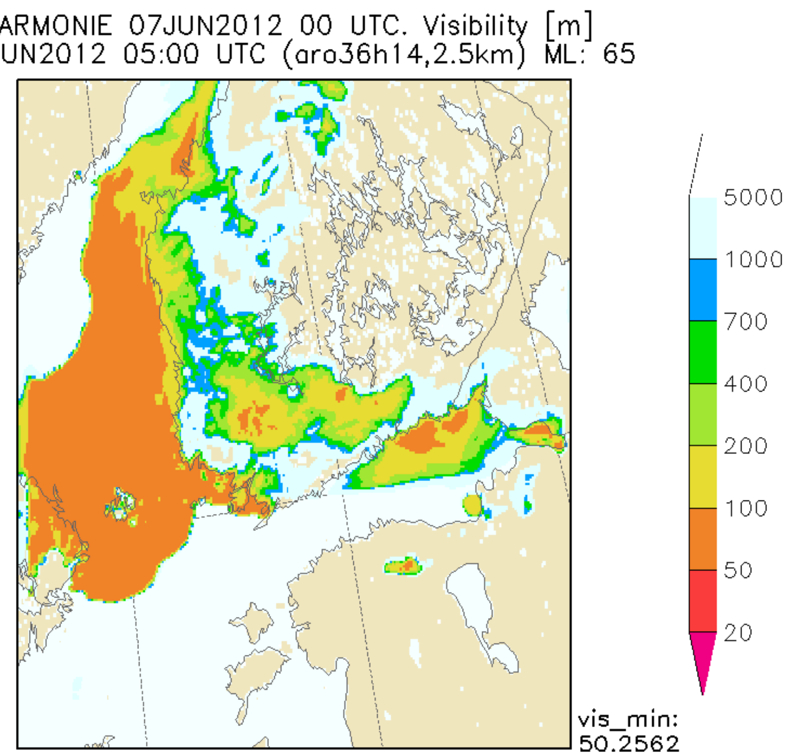
- on a large scale
- persistent
- impact on aviation (schiphol is located near the coast)

Wim de Rooy, KNMI

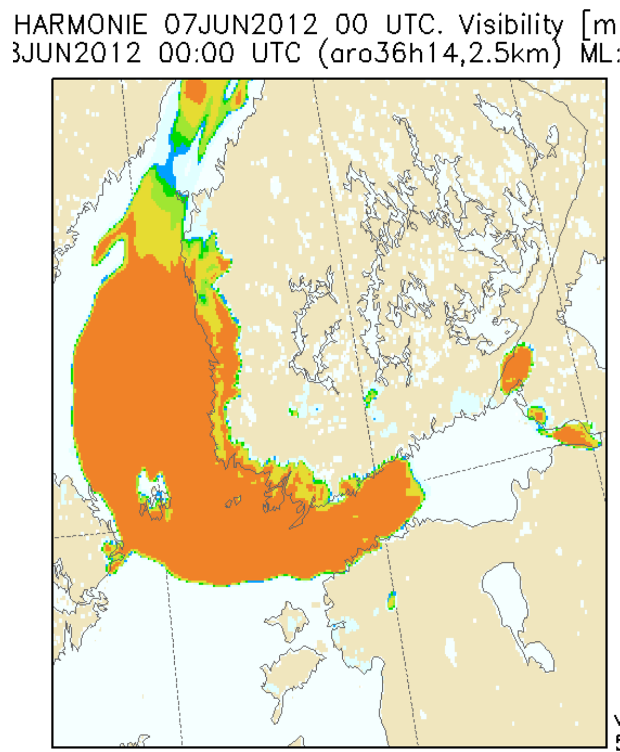
Visibility

- fog over sea/land, 7.6.2012 -

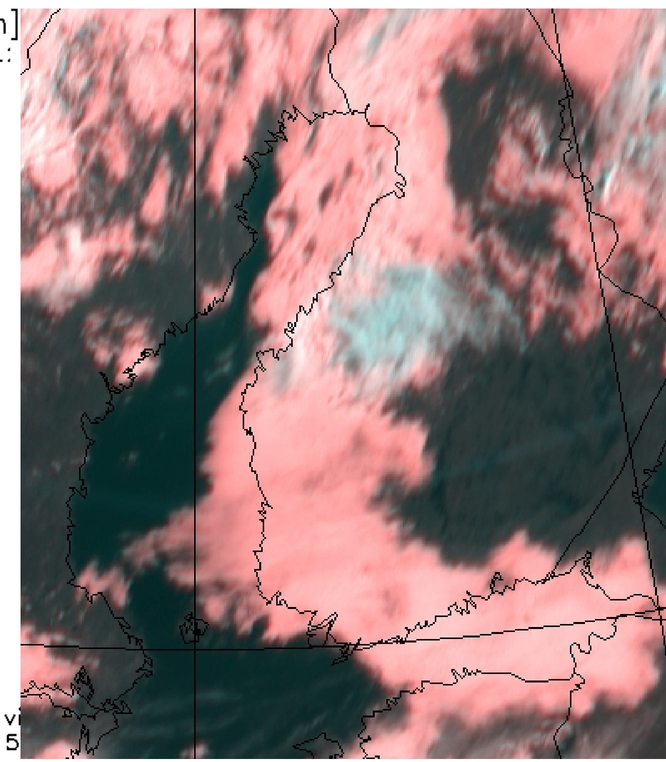
HARMONIE, +5h



HARMONIE, +24h



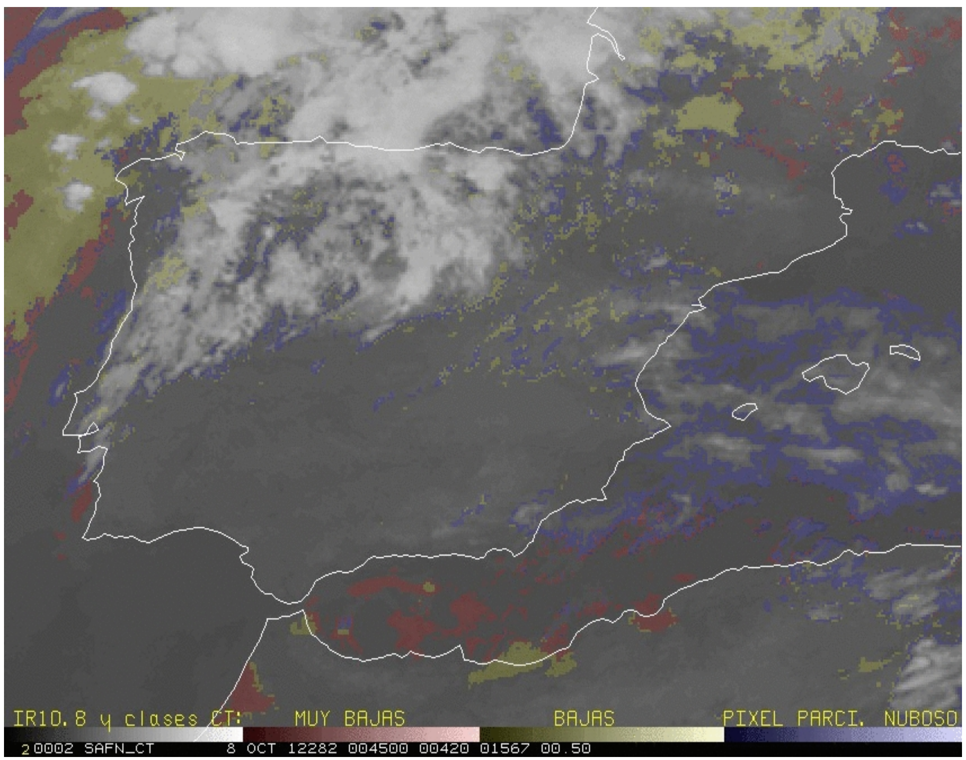
Satellite: HRV-fog 5 UTC

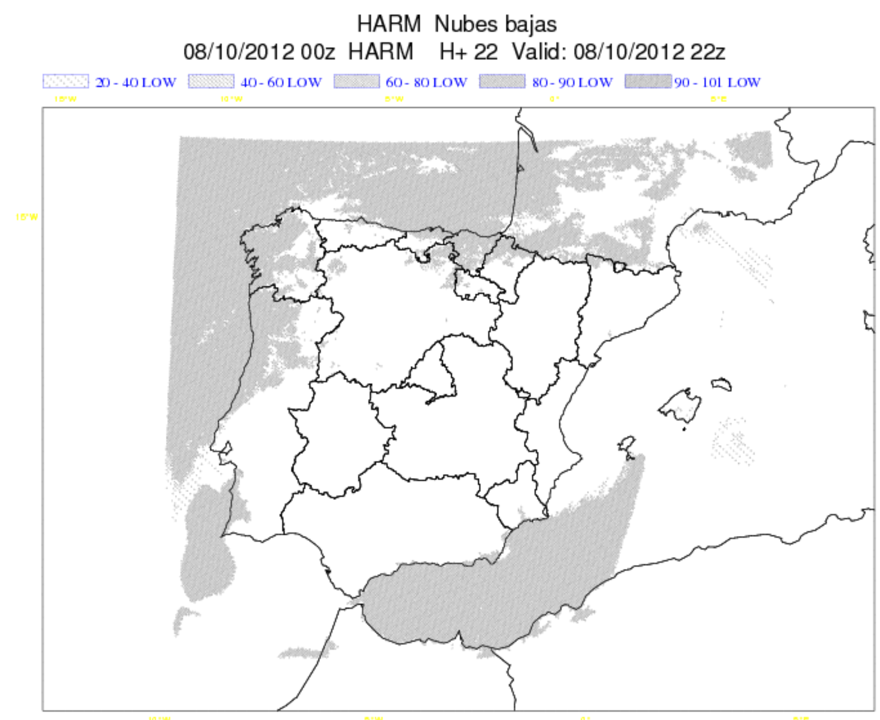


Pink color = low clouds or fog (?)

Sami Niemelä, FMI

Mediterranean Sea, 8 October, 2012



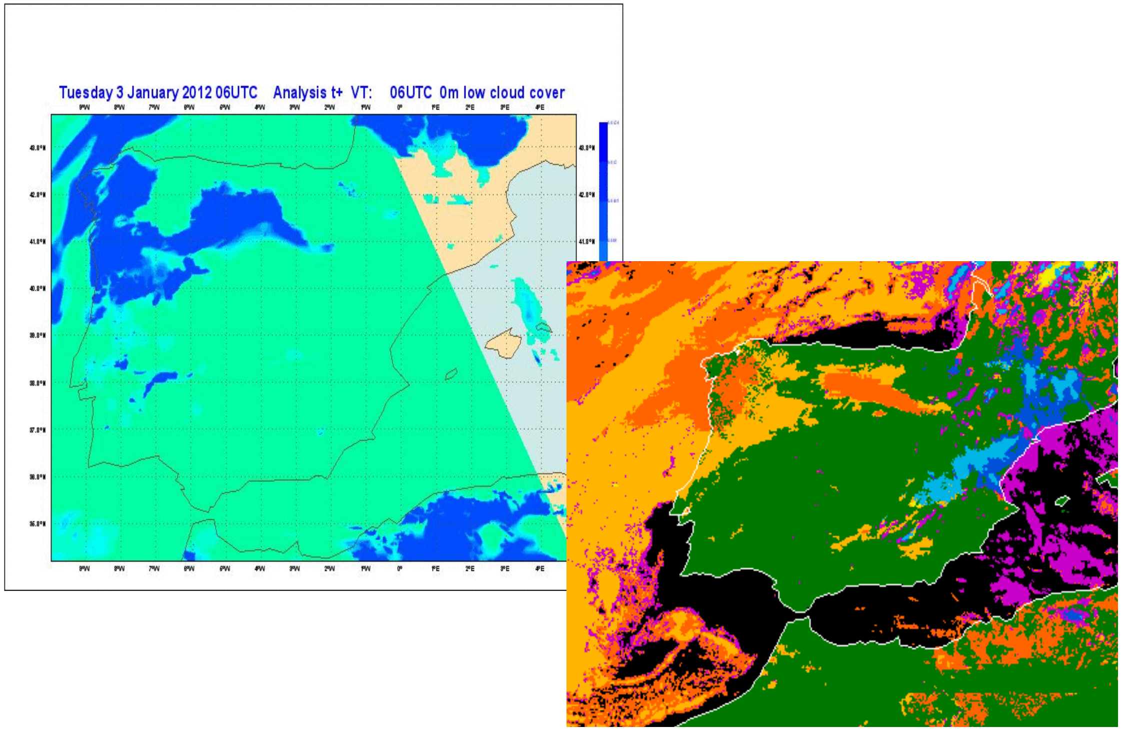


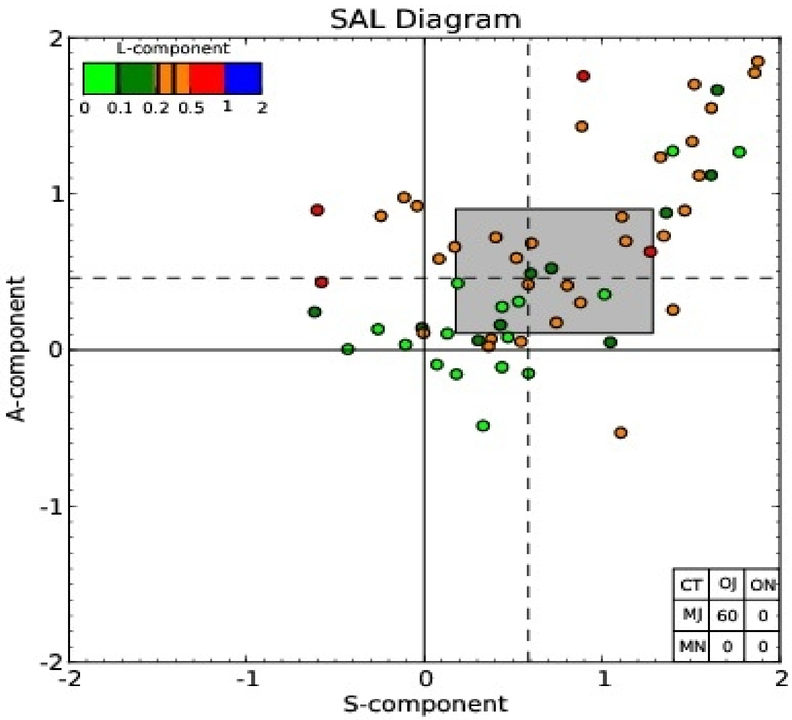
Gema Morales,
AEMET

SAL diagnostics of low level clouds

Structure Amplitude Location

- S requires the definition of objects
- Components address quality of the three independent components: structure (S), amplitude (A) and location (L)
- According to SAL a forecast is perfect if S = A = L = 0





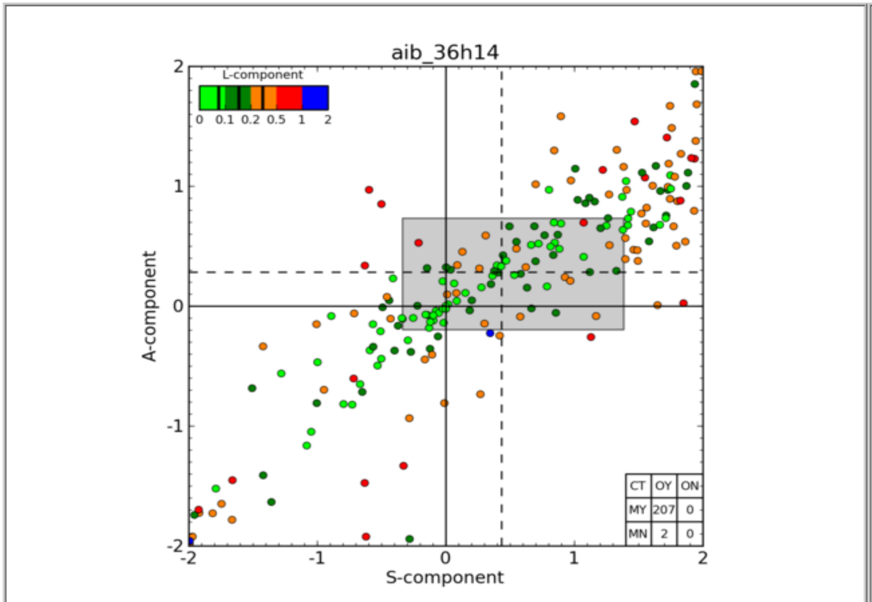
Comparison between HARMONIE/AROME low level clouds and satellite low level clouds.

"Object threshold" = 0.8

Gema Morales, AEMET

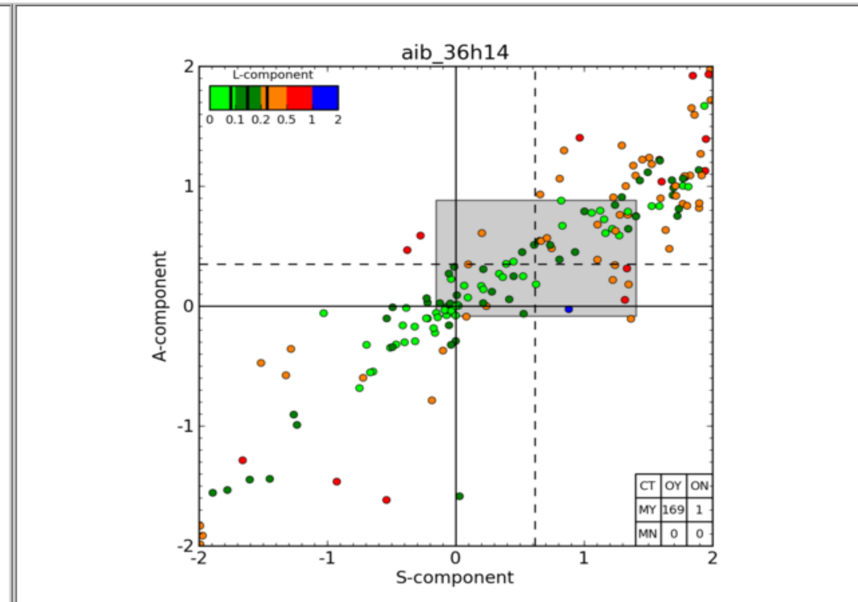
SAL verification, Iberian Peninsula

+06



SAL_Plotaib_36h14_mesetanorte_enero_H+006.png

+12



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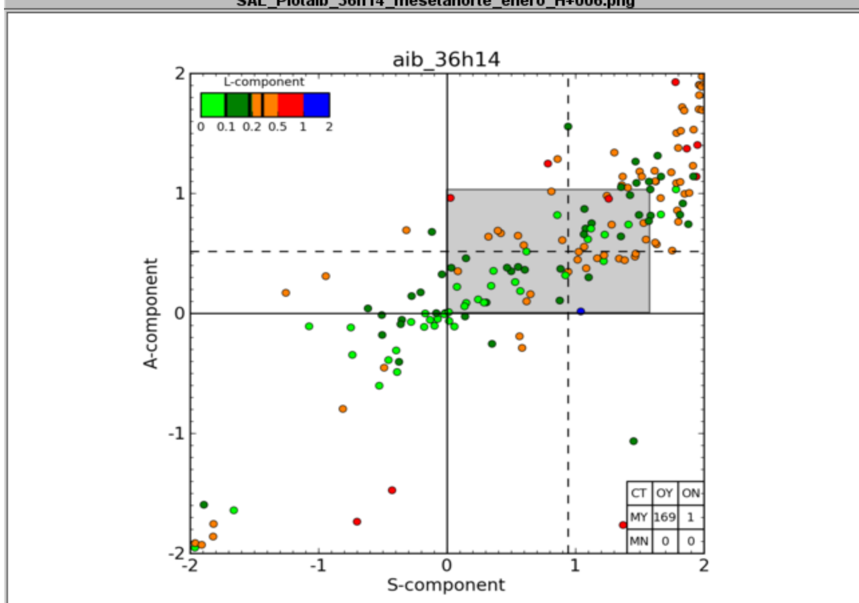
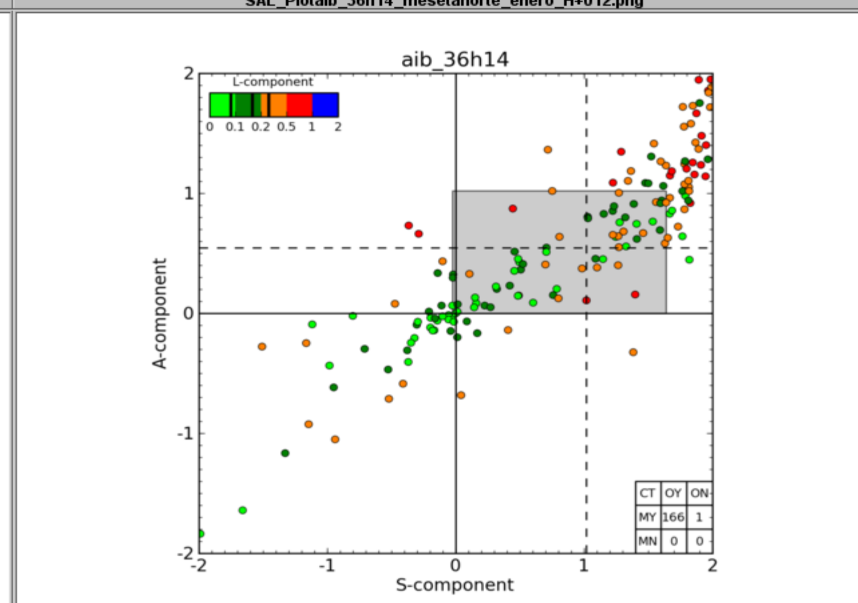
+18



SAL_Plotaib_36h14_mesetanorte_enero_H+018.png

+24



SAL_Plotaib_36h14_mesetanorte_enero_H+024.png

Gema Morales, AEMET

Sensitivity experiments

- Investigate impact of separating Cloud Droplet Number Concentration (CDNC) in the cloud sedimentation between land/sea/urban areas.

  LAND = 300 cm^{-3}

  SEA= 100 cm^{-3}

  URBAN= 500 cm^{-3}

- Investigate impact of a consistent treatment of CDNC in cloud scheme and radiation scheme.

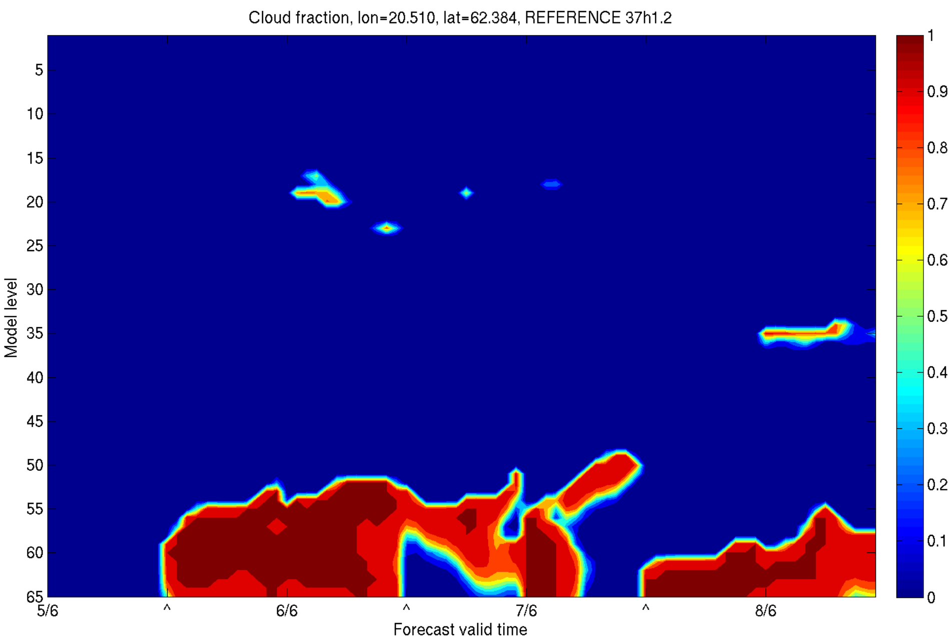
  LAND = 313.2 cm^{-3}

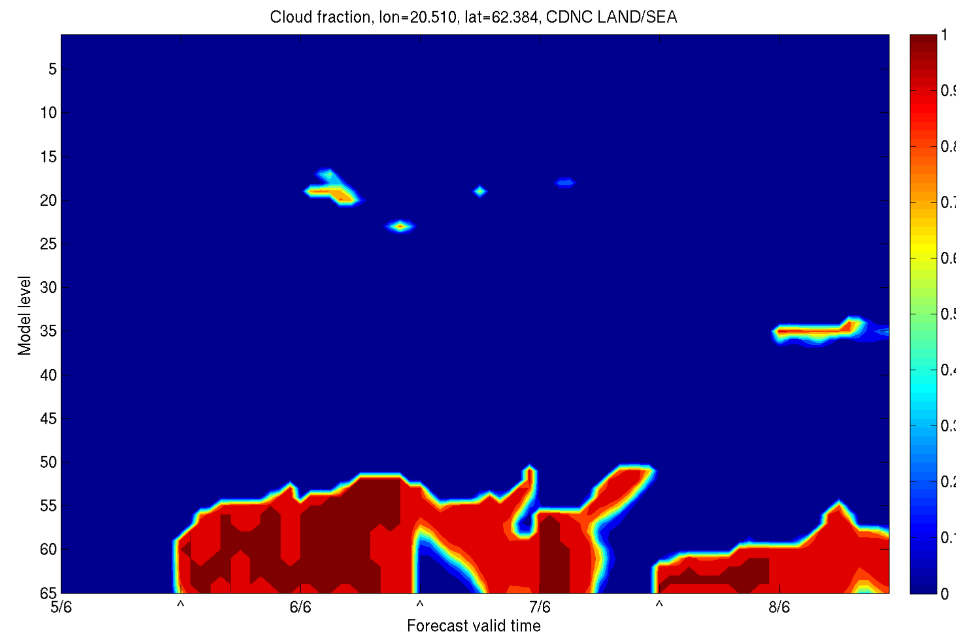
  SEA= 50.575 cm^{-3}

  URBAN = 313.2 cm^{-3}

- MUSC sensitivity experiments to various cloud physics options.
- Sensitivity to number of vertical levels, data assimilation cycling, input parameters from LBC...

Impact of differing CDNC land/sea





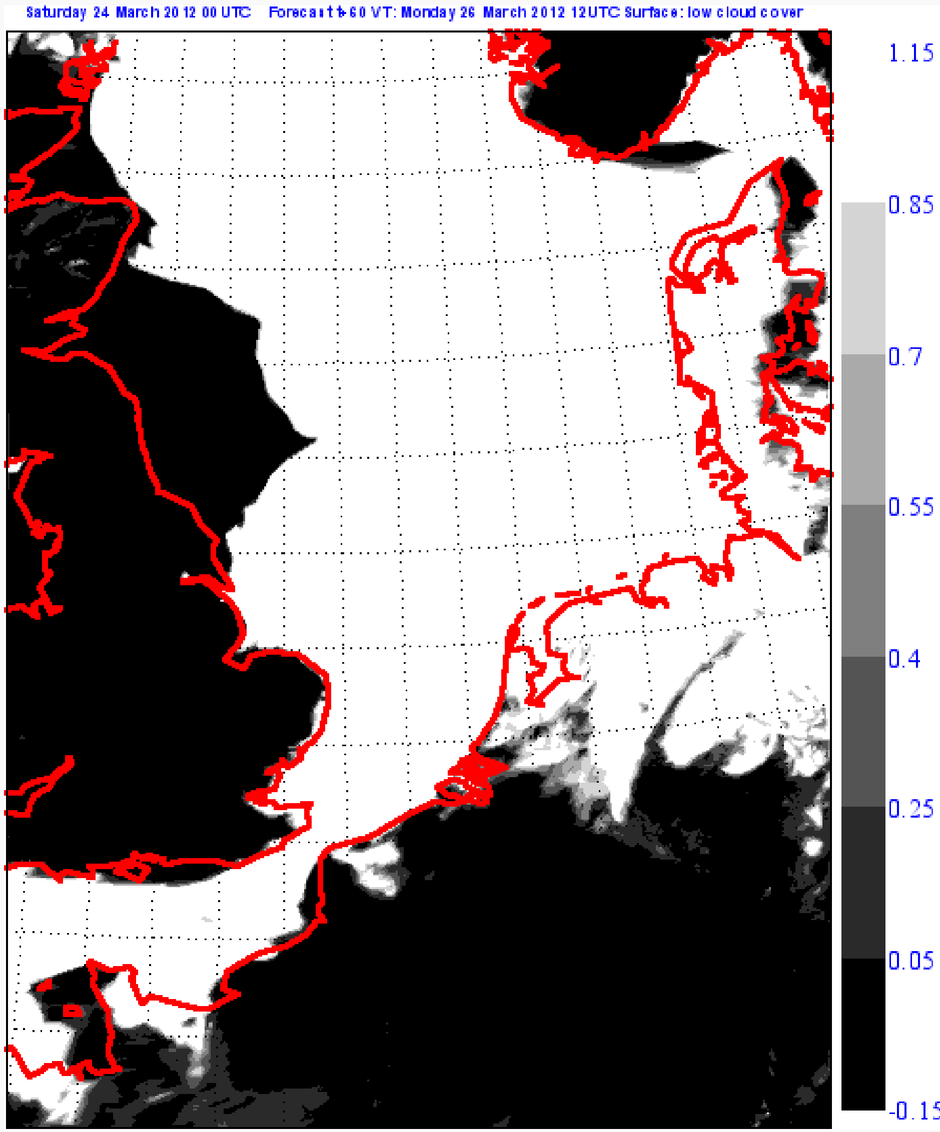
REFERENCE

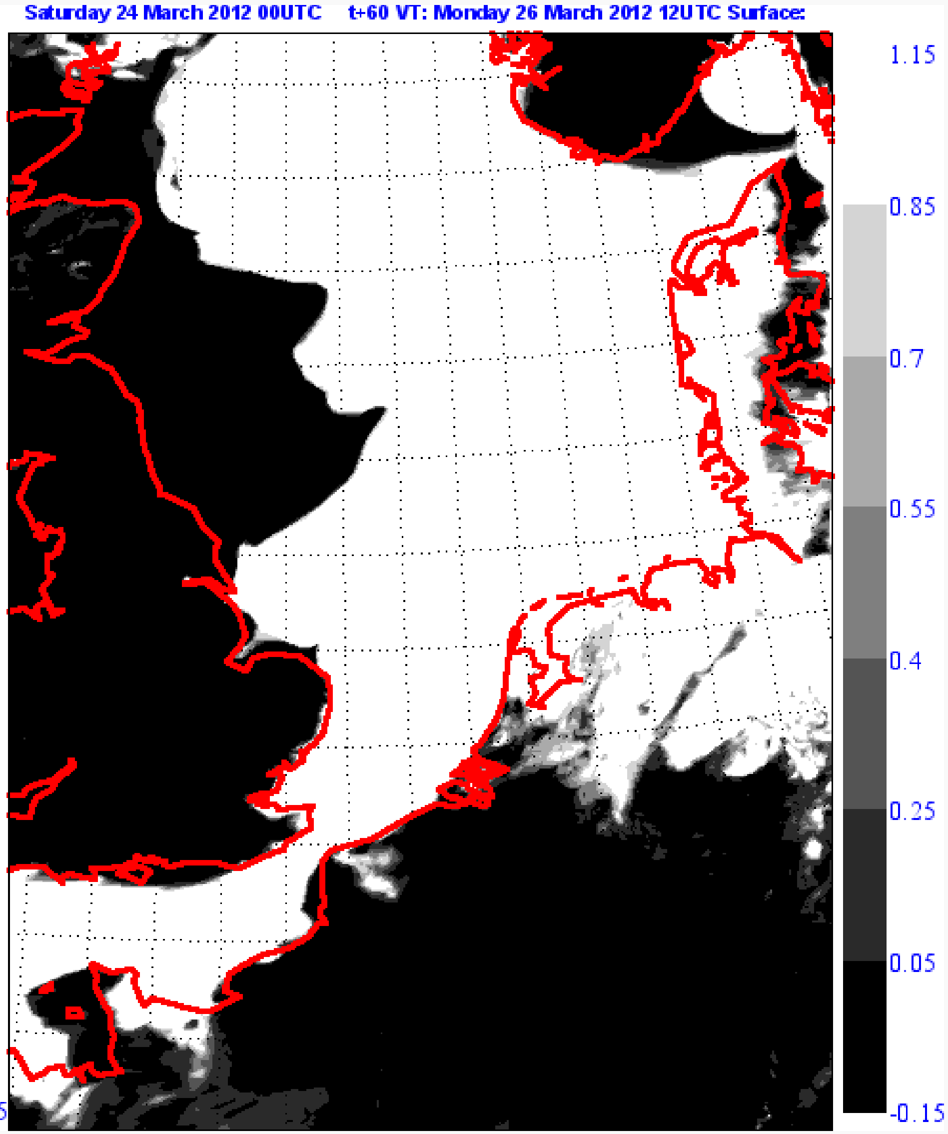
Cloud Droplet Number Concentration, CDNC, split between land and sea and urban areas.

Impact of CDNC land/sea/urban

Reference 37h1.2

CDNC exp

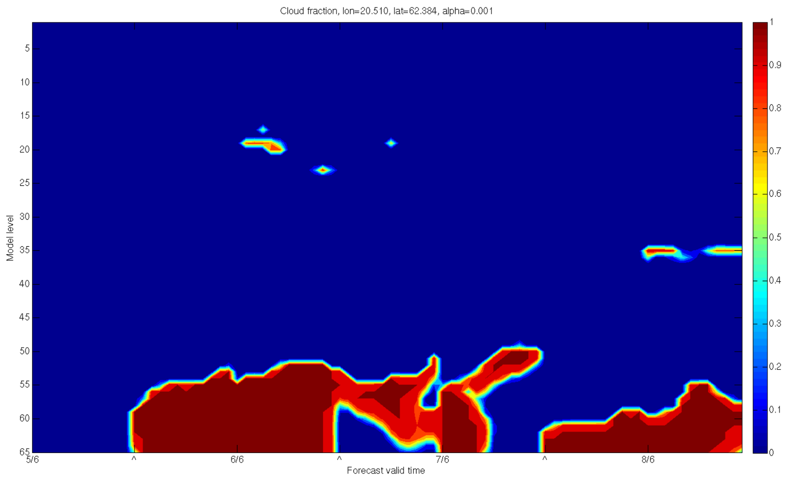




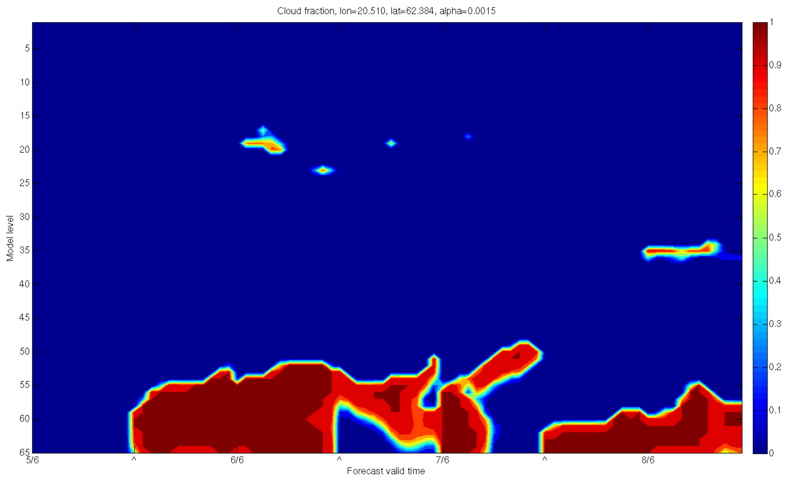
+60 h

Sander Tijm, Toon Moene, KNMI

Impact of added variance term



alpha = 0.01



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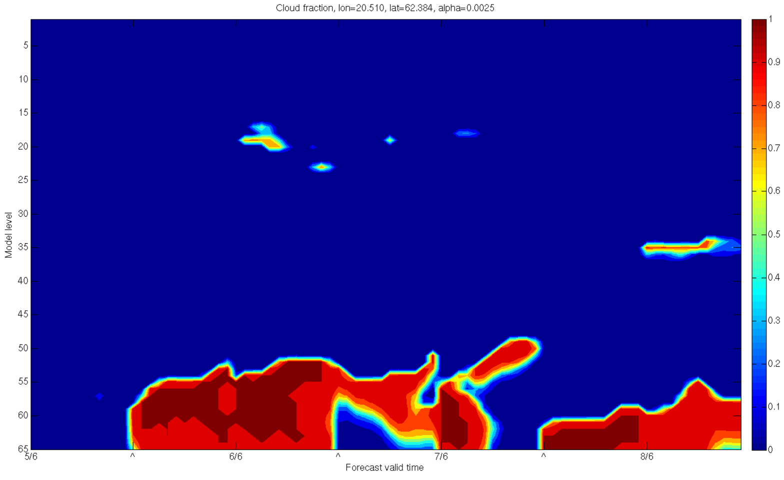
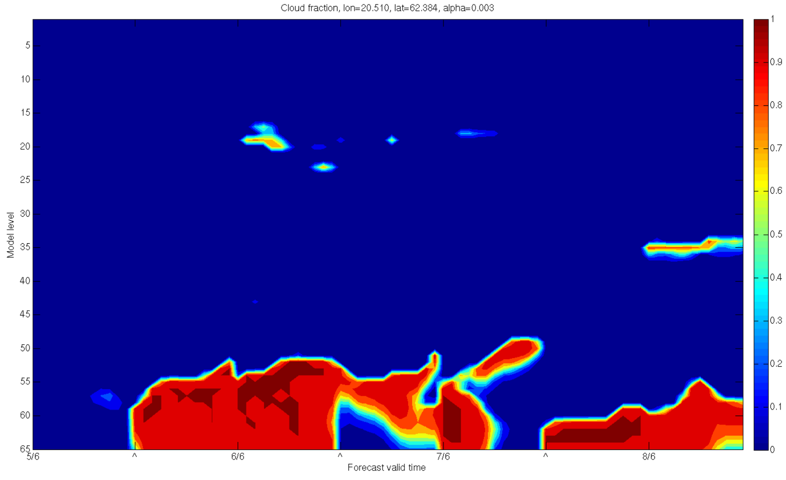
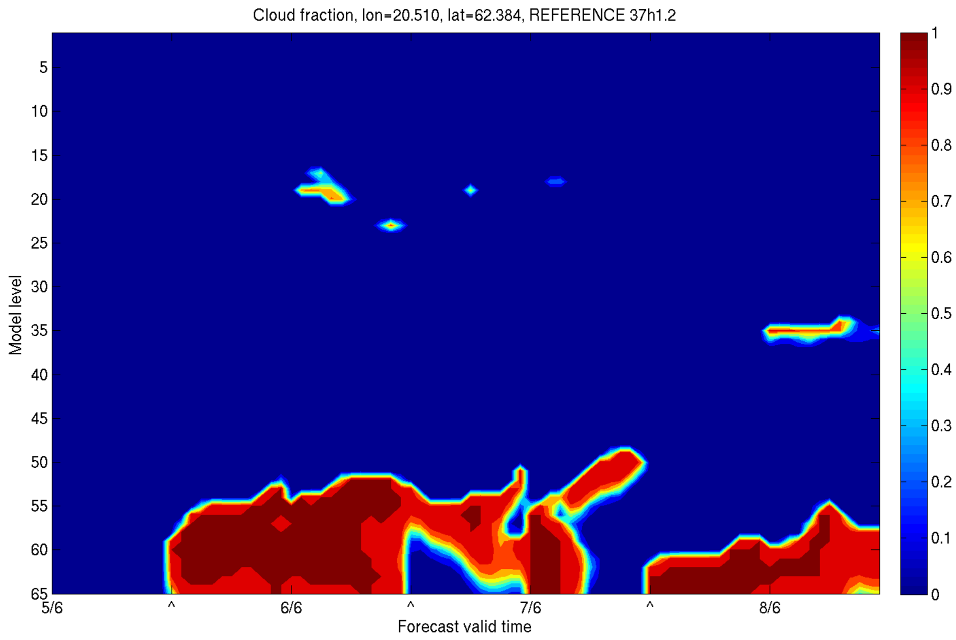


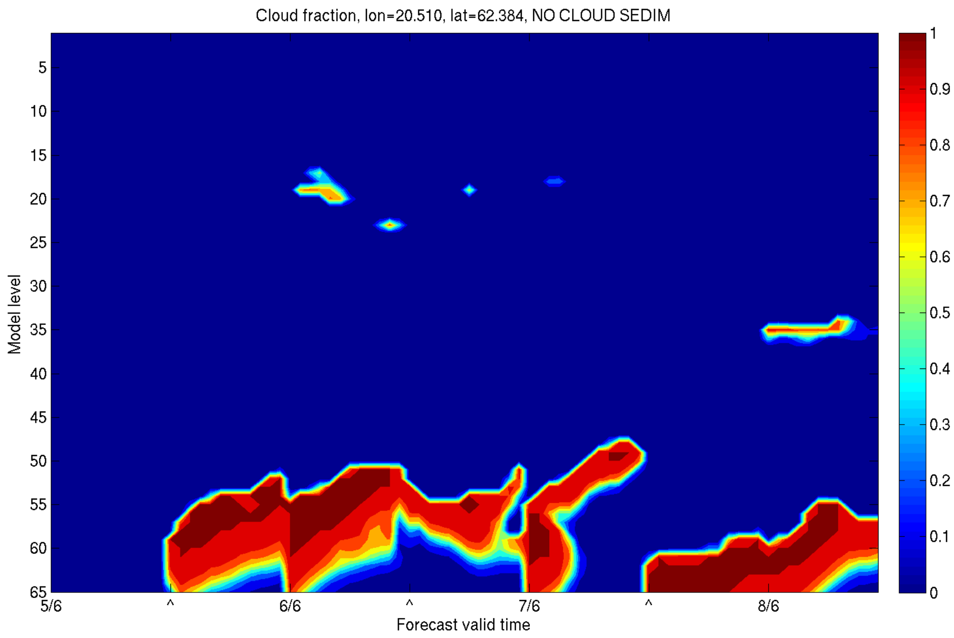
alpha = 0.025



alpha = 0.03

Reference vs No cloud sedimentation





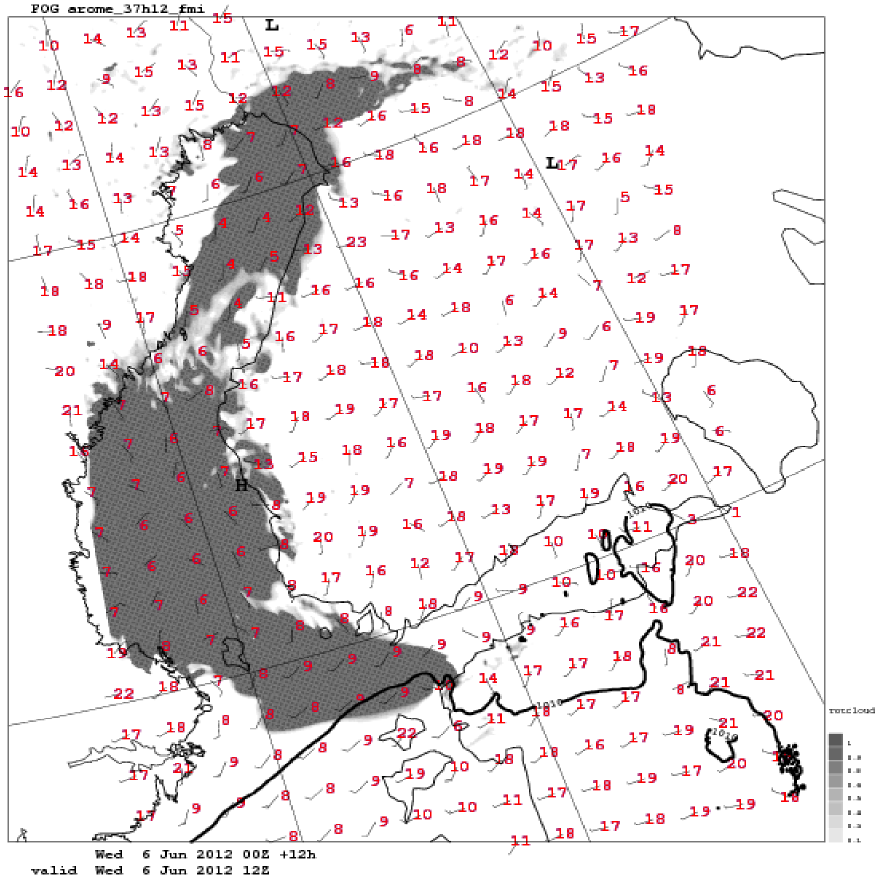
REFERENCE

No sedimentation of cloud droplets and cloud ice.

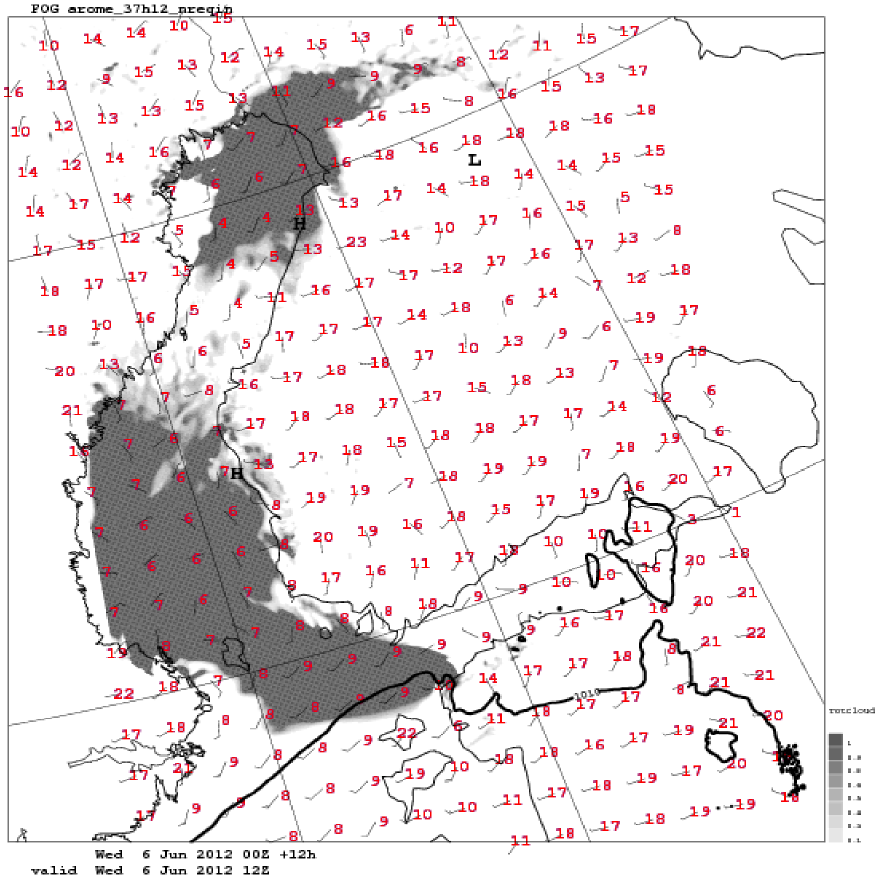
(e.g. LOSEDIC = FALSE)

Impact of No cloud sedimentation, 3D.

Reference

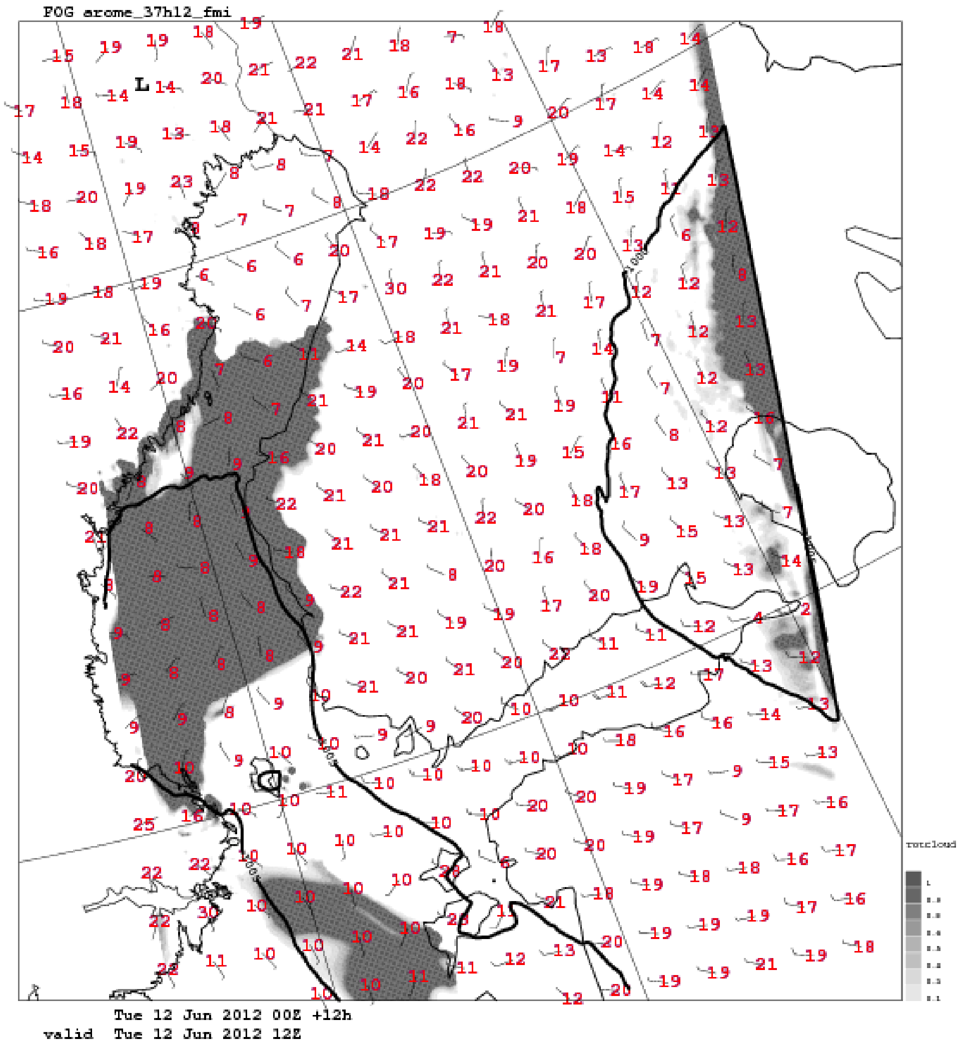


LOSEDIC=FALSE

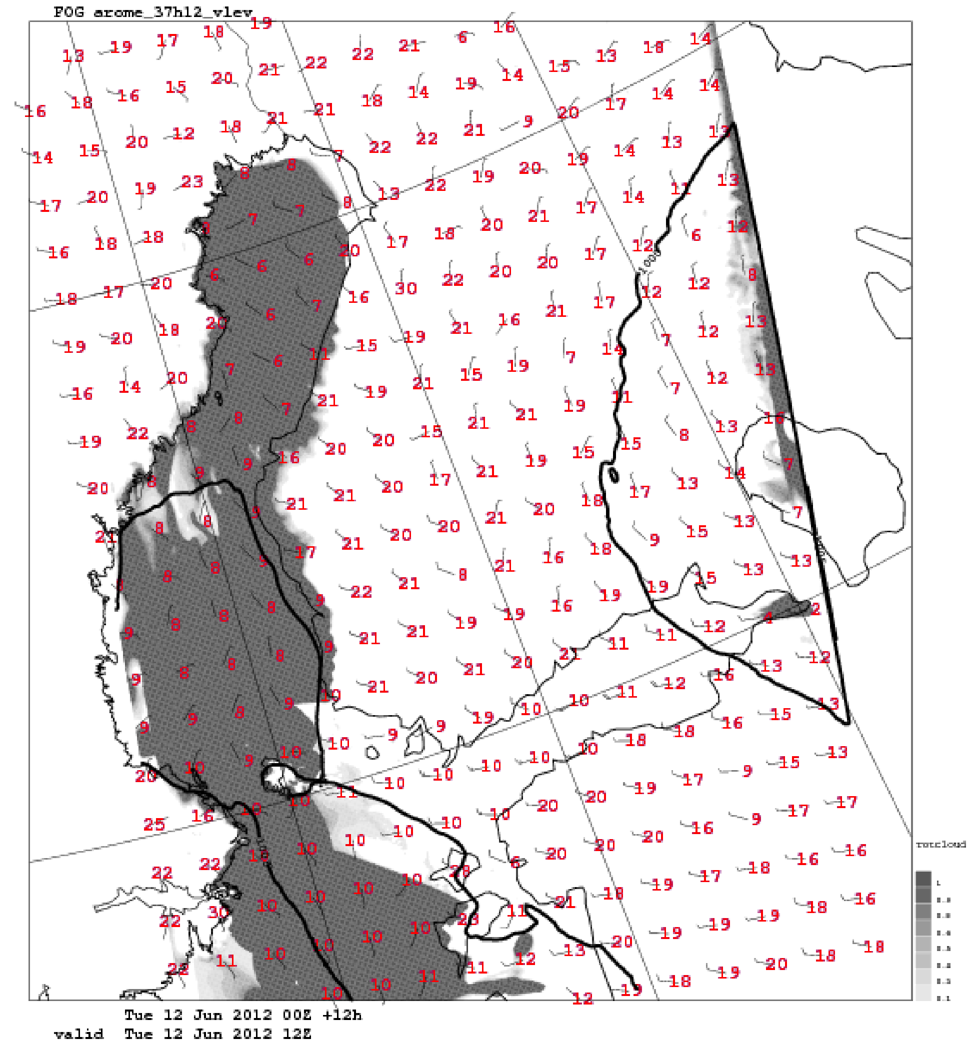


Cloud fraction at lowest model level

Impact of number of vertical levels

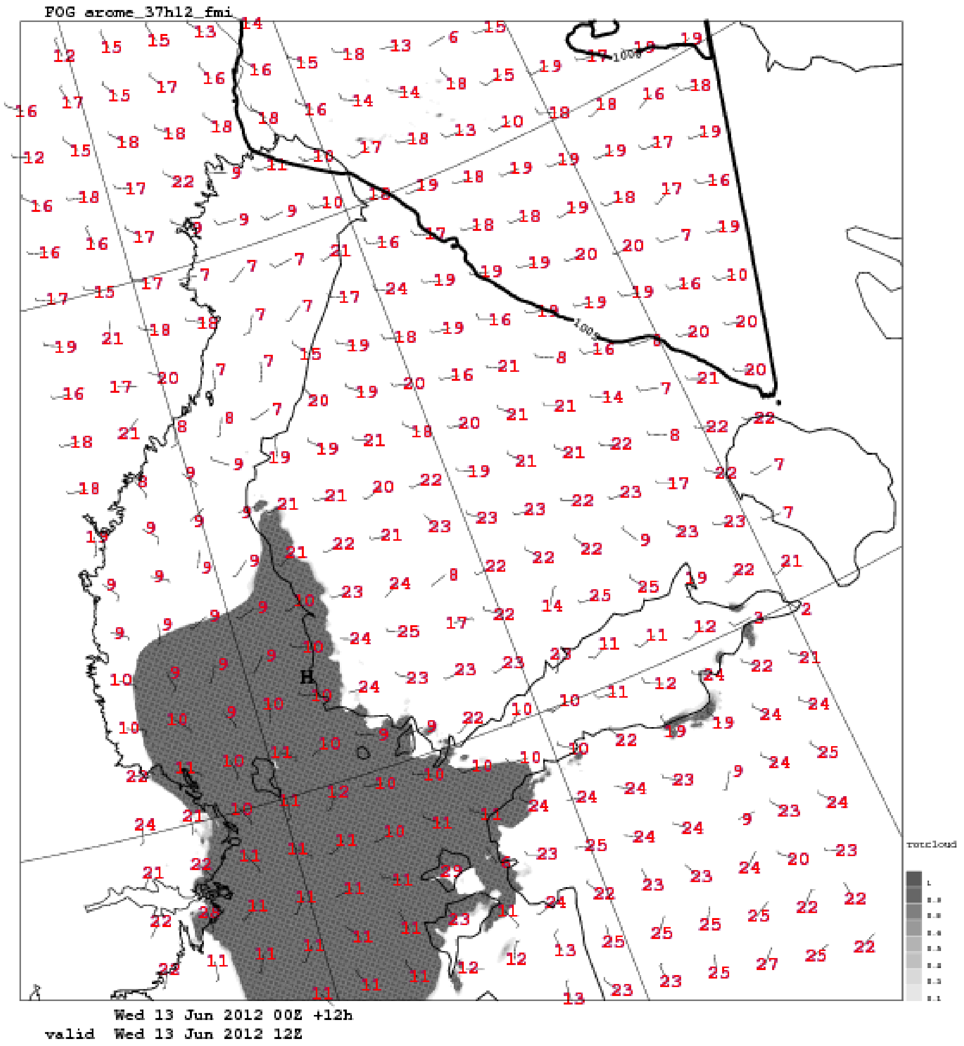


65 vertical levels

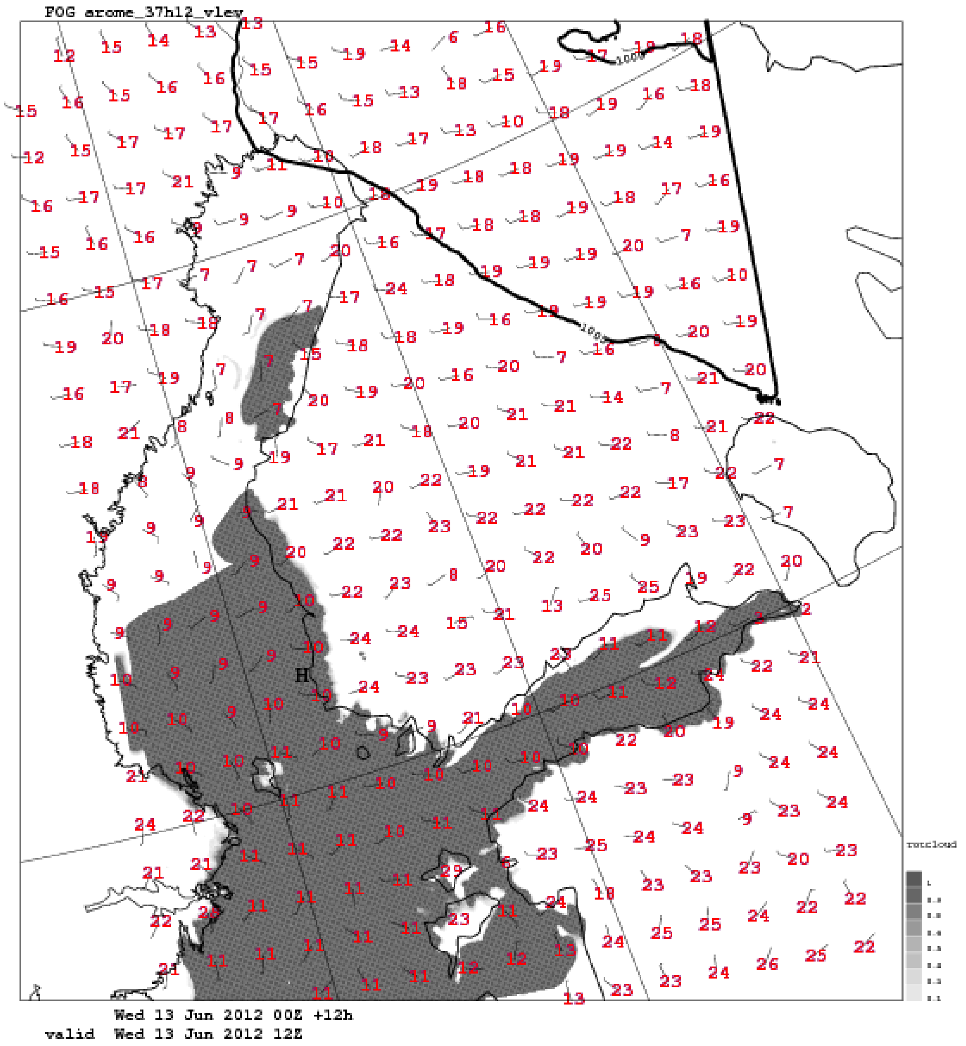


MF 60 vertical levels

Impact of number of vertical levels



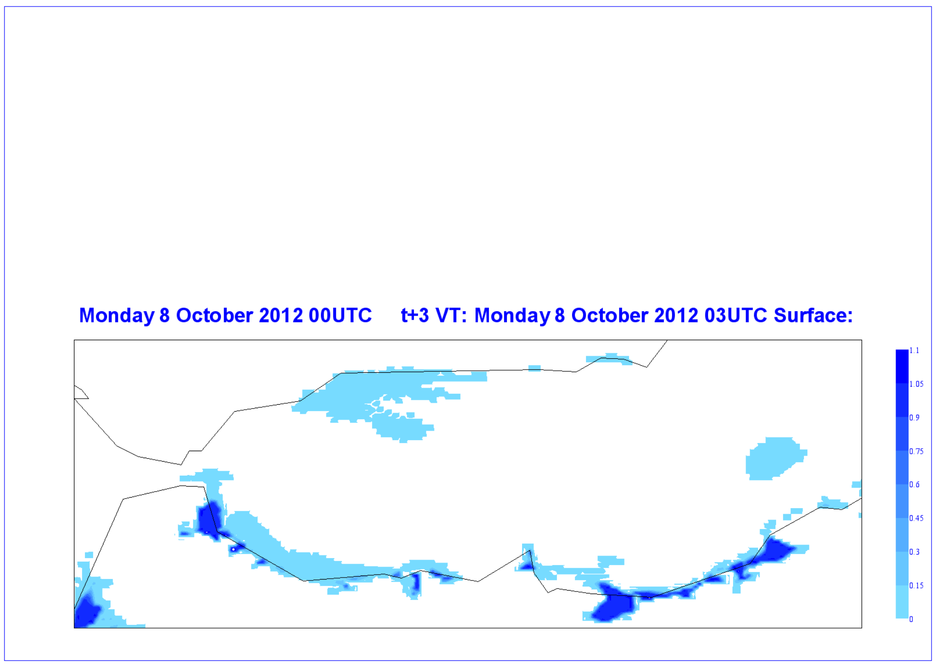
65 vertical levels

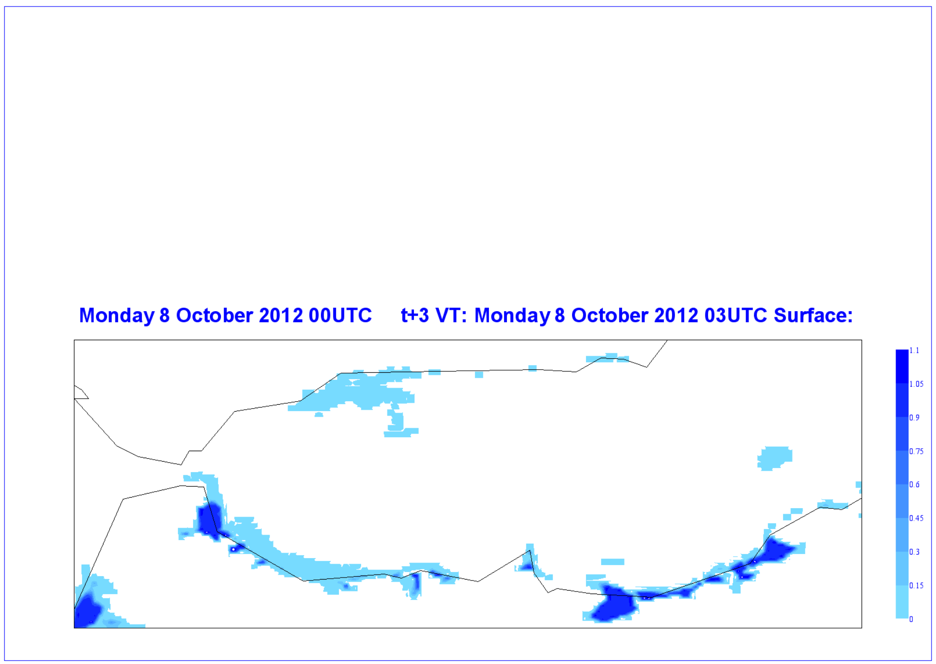


60 vertical levels

HARM 37h12
20121008 Fog in Alboran sea

NLEV=65 NLEV=60





Daniel Martin, AEMET

HARM 37h12
20121008 Fog in Alboran sea

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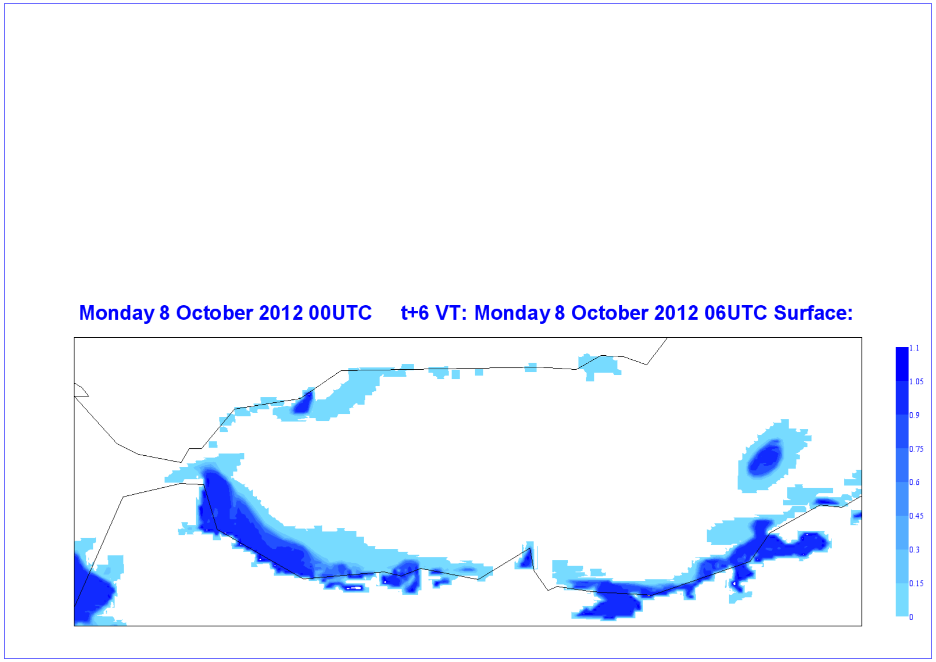

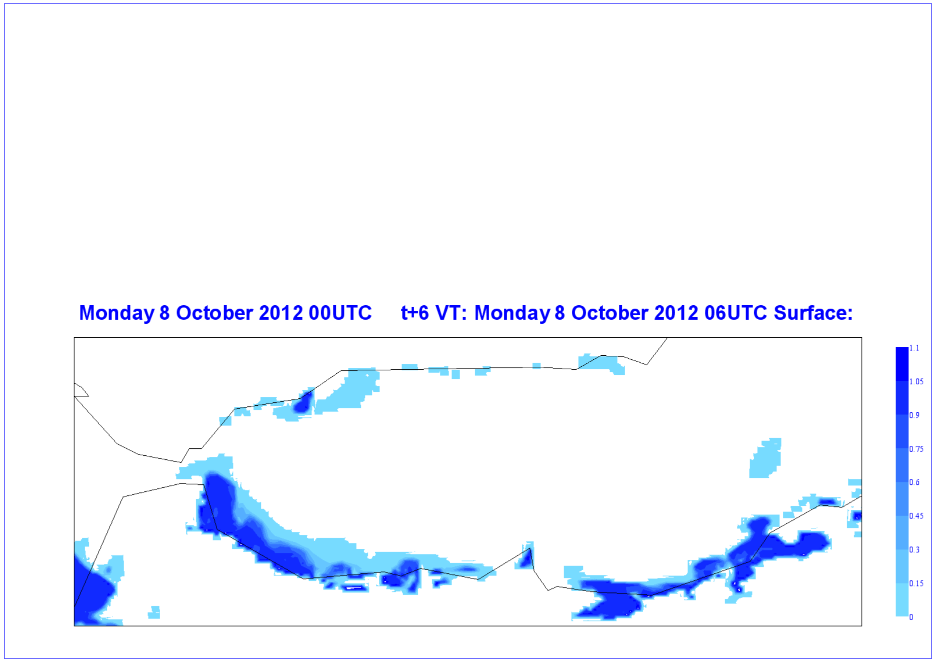

Daniel Martin, AEMET

HARM 37h12

20121008 Fog in Alboran sea

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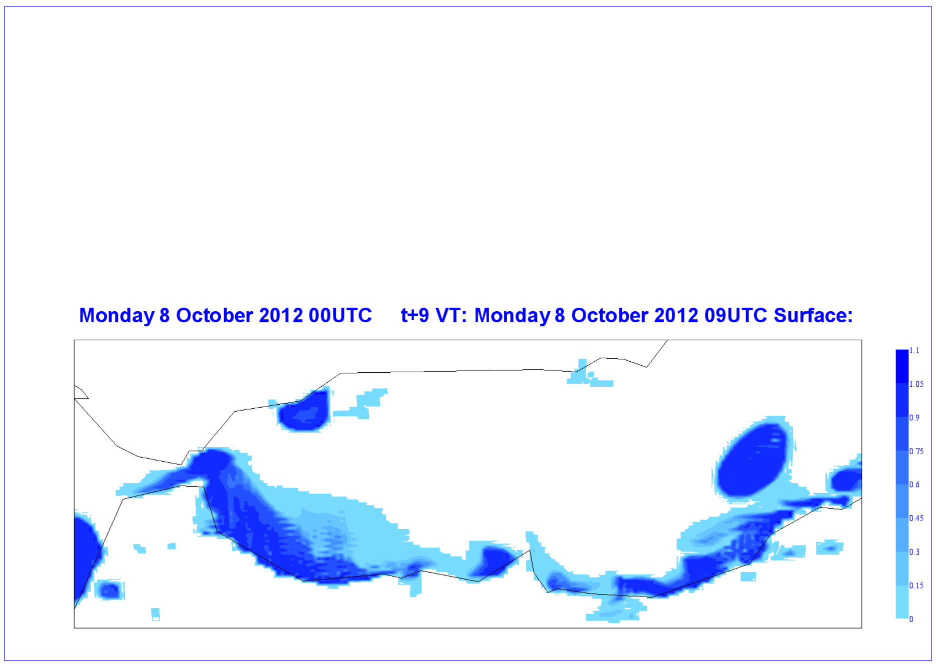
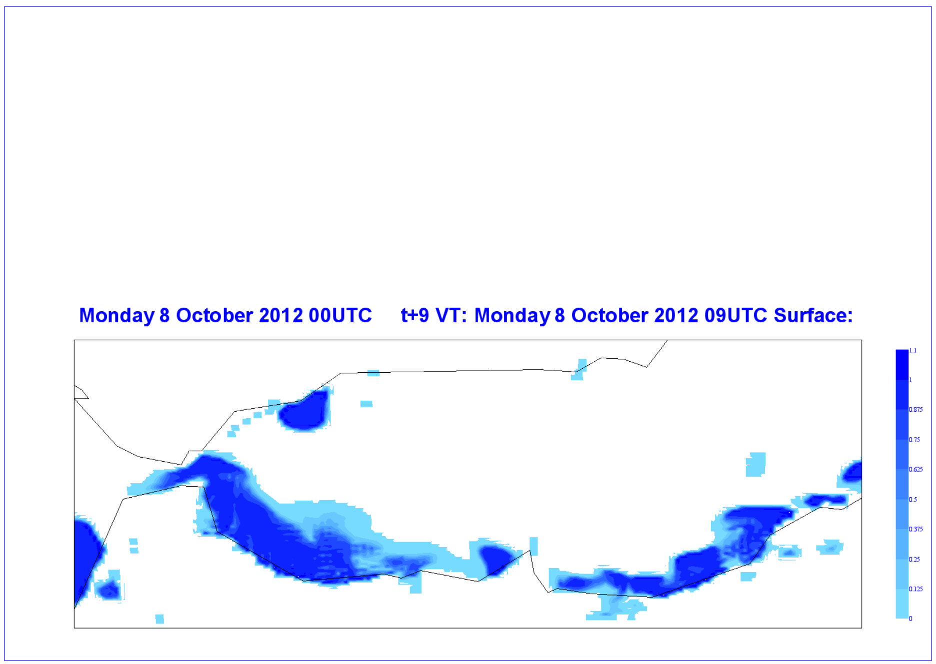


NLEV=60



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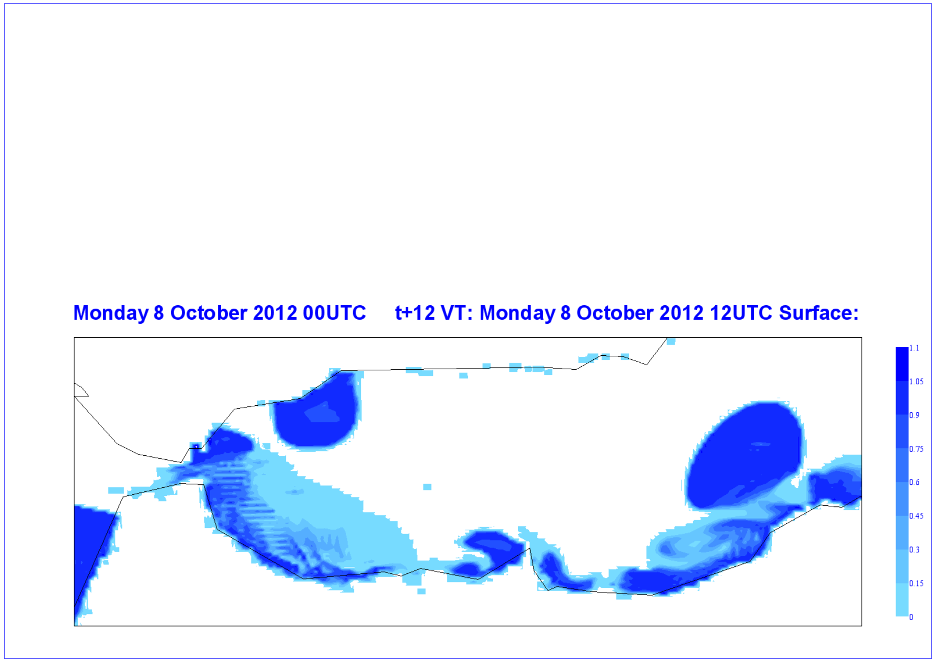

Daniel Martin, AEMET

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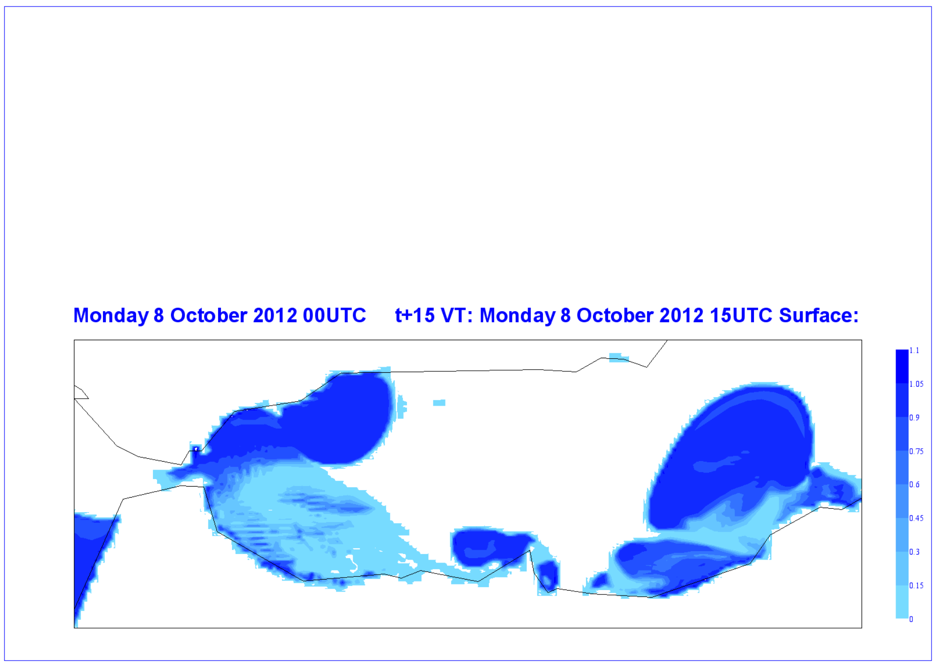

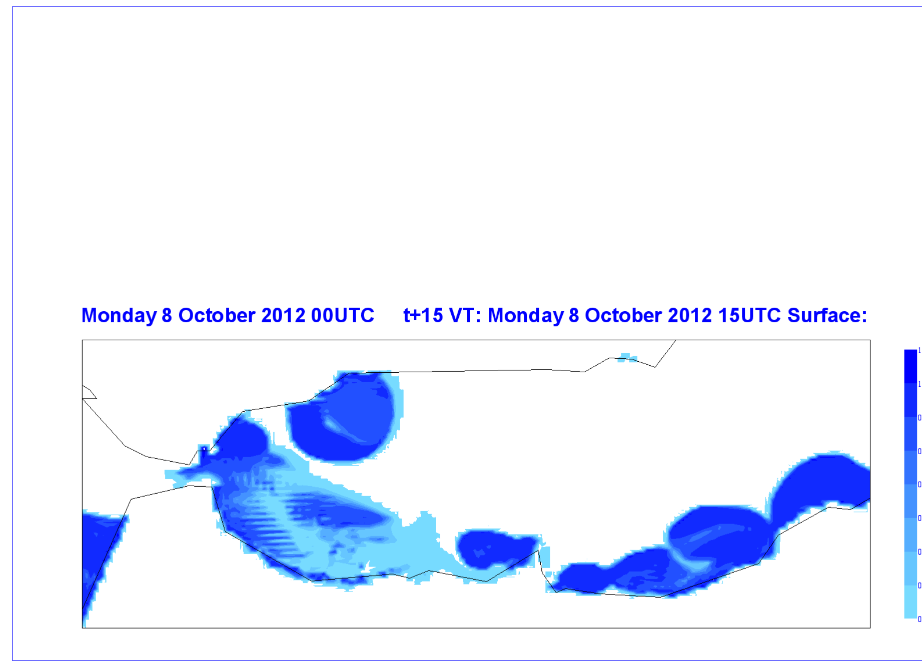

Daniel Martin, AEMET

HARM 37h12
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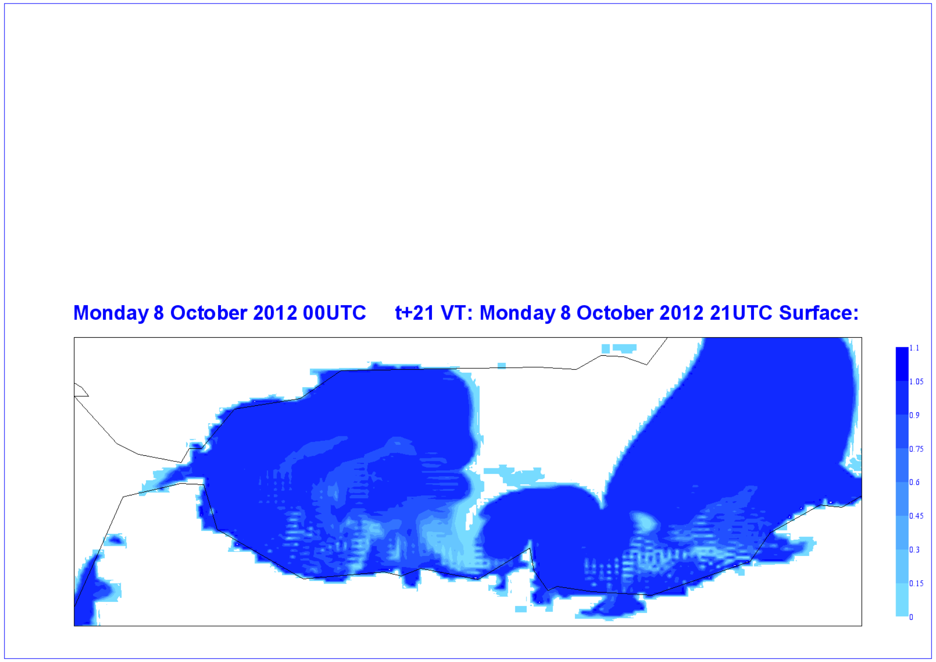

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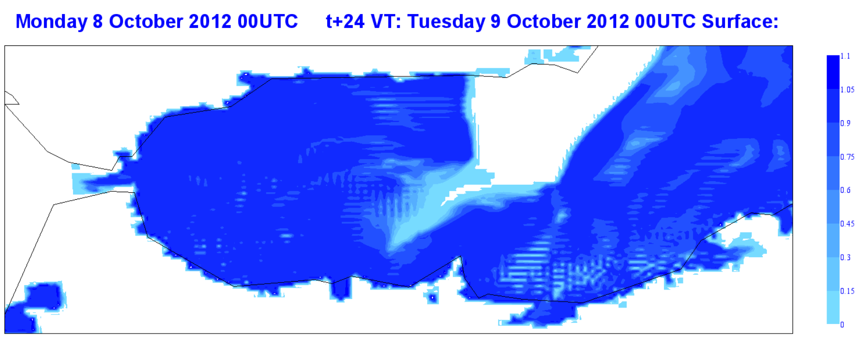
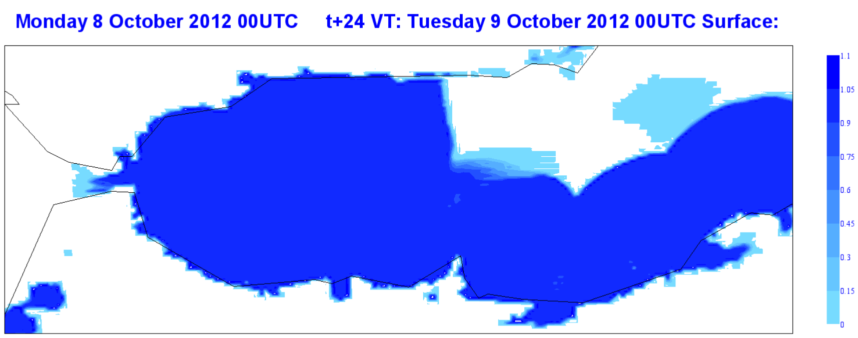


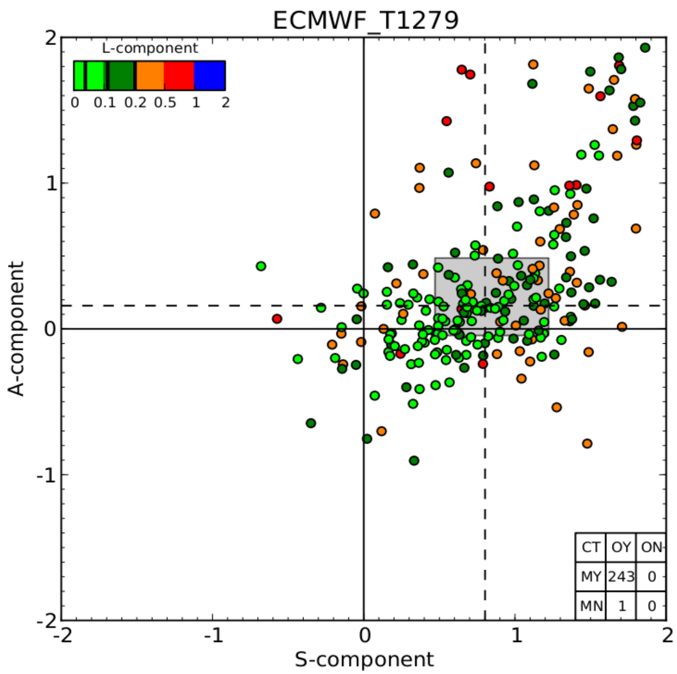


Daniel Martin, AEMET

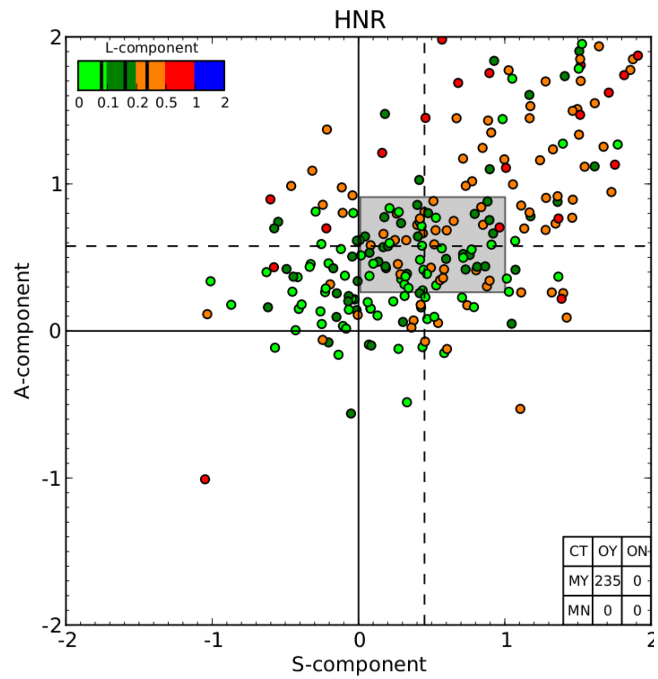
Fog over land/sea

- Fog appears to be over-predicted both over land and sea. Stays persistent for long time, over large areas over sea.
- MUSC and 3D simulations reveals small sensitivity to options in the statistical cloud scheme, and cloud microphysics. Although the role of using sedimentation of cloud droplets may be investigated further.
- Fog of pure water phase are not affected by the modifications to mixed-phase and ice clouds implemented by Karl-Ivar Ivarsson. It appears to be a separate problem from the problems related to clouds in cold conditions.
- Consistent treatment of CDNC play a small role as the CDNC only enters within the “cloud sedimentation” process.
- The forecast of fog seems sensitive to data-assimilation (not shown). A more careful investigation of the structure functions in the boundary layer could be considered.
- The forecast of fog is sensitive to number of vertical levels, and its distribution.
- Water phase low clouds and fog over land/sea are still subject for further investigation
  - Surface fluxes
  - Long wave radiation
  - Turbulent mixing
- Water phase clouds found too transparent for short wave radiation, see next talk.

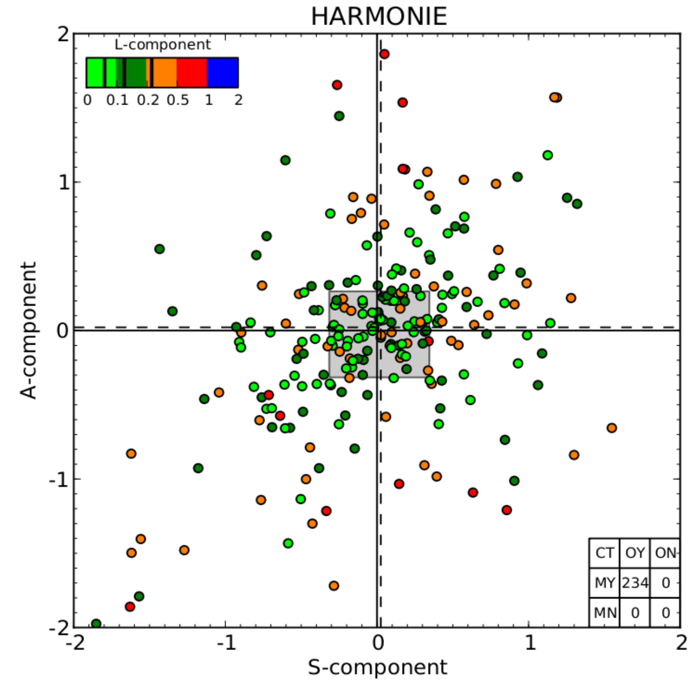
SAL 24 h precipitation, 8 months



ECMWF ~16 km



HIRLAM ~5 km



AROME 2.5 km

Verification against 3000 AEMET climatic stations.
Object threshold = 95th percentile/15.

Javier Calvo, AEMET

Precipitation

- Precipitation forecasts with AROME are generally quite good.
- Captures most very high precipitation events.
- A tendency to also produce more false alarms than other models (ECMWF, HIRLAM).
- In weakly forced convective situation AROME tends to overestimate the amount of precip. “Predictability problem”.
  - Consider probabilistic methods.
  - How to best forecast uncertainty from a physics perspective?
  - Explore stochastic parameterizations. Can a cellular automata approach be translated to “convection permitting” scales?
  - Investigate “organization” of convective clusters at increased horizontal resolution.

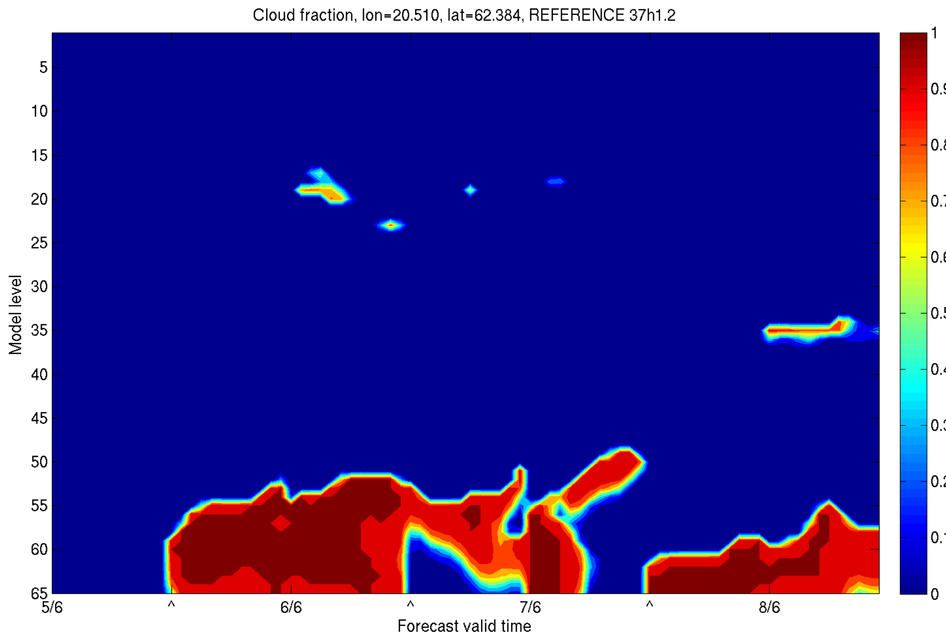
Joint SRNWP Workshop on Model Physics and Ensemble Prediction Systems will be held in Madrid (E) from 18 to 20 June 2013, hosted by AEMET.

Registration deadline April 30th

MUSC sensitivity experiments

- The reference MUSC run is using the source code and namelist of cycle 37h1.2
- Eulerian advection from the 3D model each hour
- Initialized every 12 hours with a new atmospheric and surface forcing file from the 3D model
- Forecast lead time is 12 hours

Reference vs No advection



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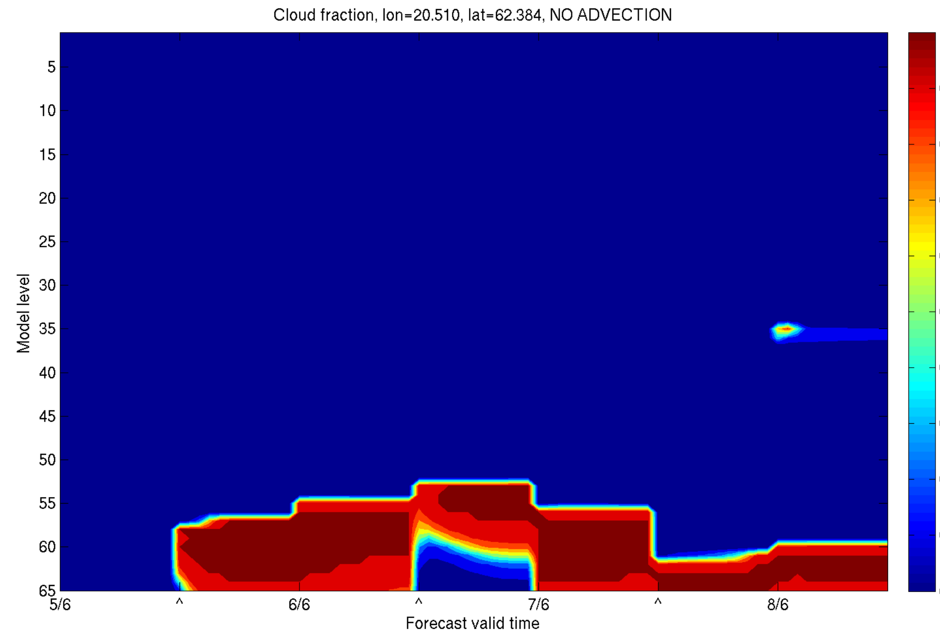

No advection

Vertical levels definition