Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

Hirlam implementations and ideas on RUC/RAP

LACE Kick-off meeting on 1-h RUC

17-18 March, ZAMG, Vienna

Jan Barkmeijer

Hirlam RUC landscape

- FMI runs an experimental configuration Harmonie-LAPS
- MET Norway will develop a RUC in externally funded project SAWIRA.
- SMHI is developing the nowcasting/very short range forecasting system in the context of DniCAST project (http://www.dnicast-project.net/).
- AEMET will try FA+3DVAR approach for nowcasting purposes
- DMI is running HIRLAM 3.3 km resolution RUC system
- METIE are running HIRLAM 7.2 at 7 km resolution with hourly update
- LHMS, IMO and Estonian Weather Service have no specific plans yet.
- KNMI is running a HIRLAM 7.2 at 11 km resolution with hourly update

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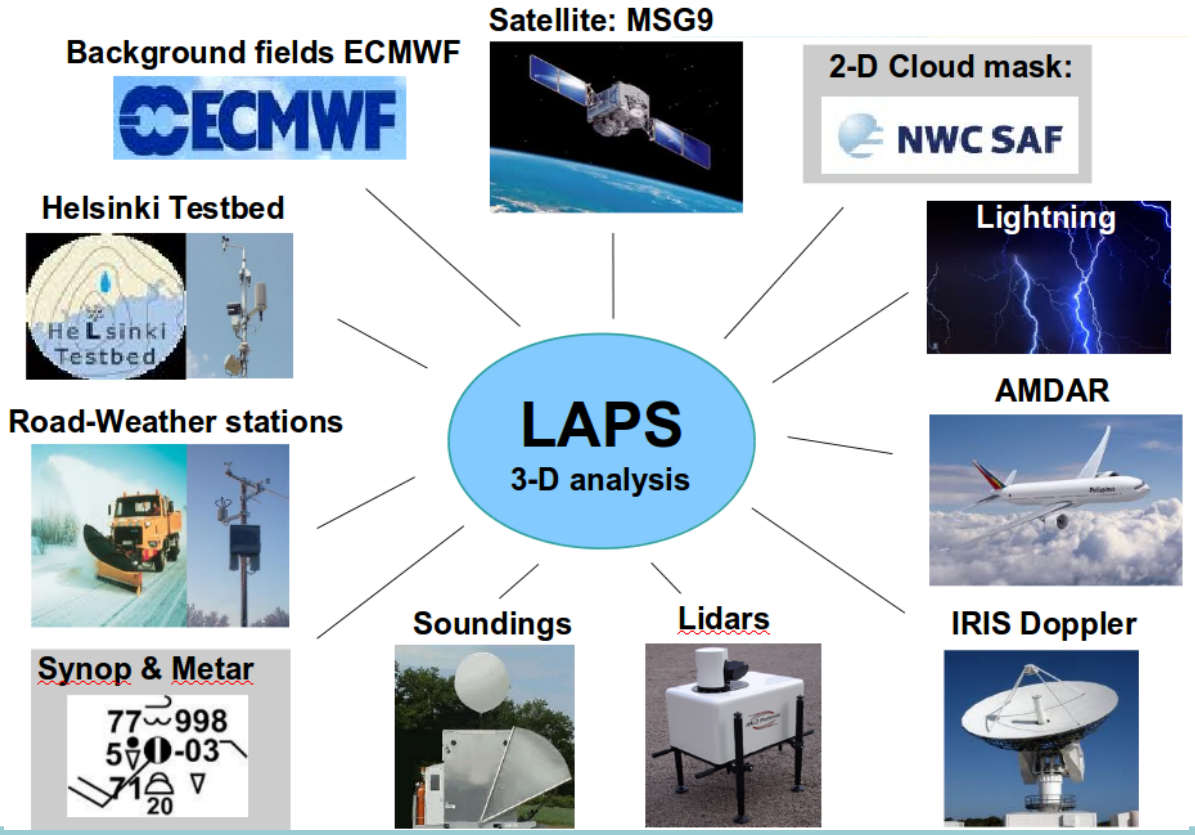
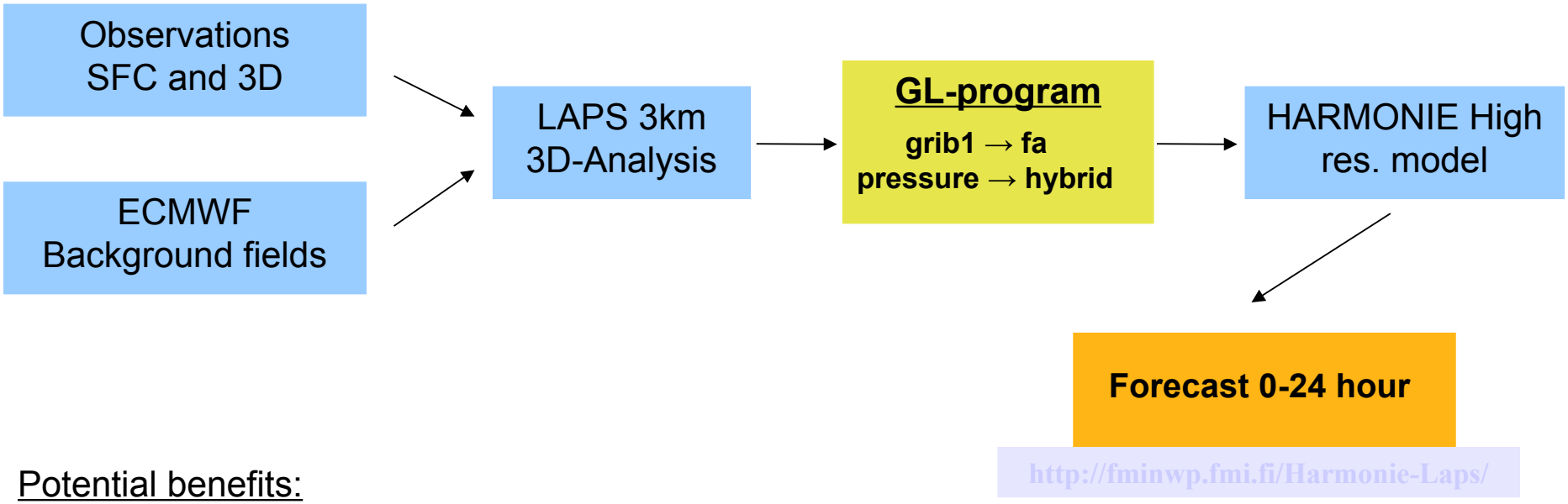
FMI-LAPS:

- Free software from NOAA, USA (user-community developments, user-forums etc.)
- 3D-analysis of atmosphere (both surface and upper air) at Every hour
- LAPS has the capability to assimilate a wide range of observational datasets
- Vertical resolution: 44 pressure levels (higher res. at lower alt.)
- Observational ingest at FMI:



LAPS-HARMONIE

Hot-start of high resolution forecast model; HARMONIE (38h1.1), using LAPS analyzes

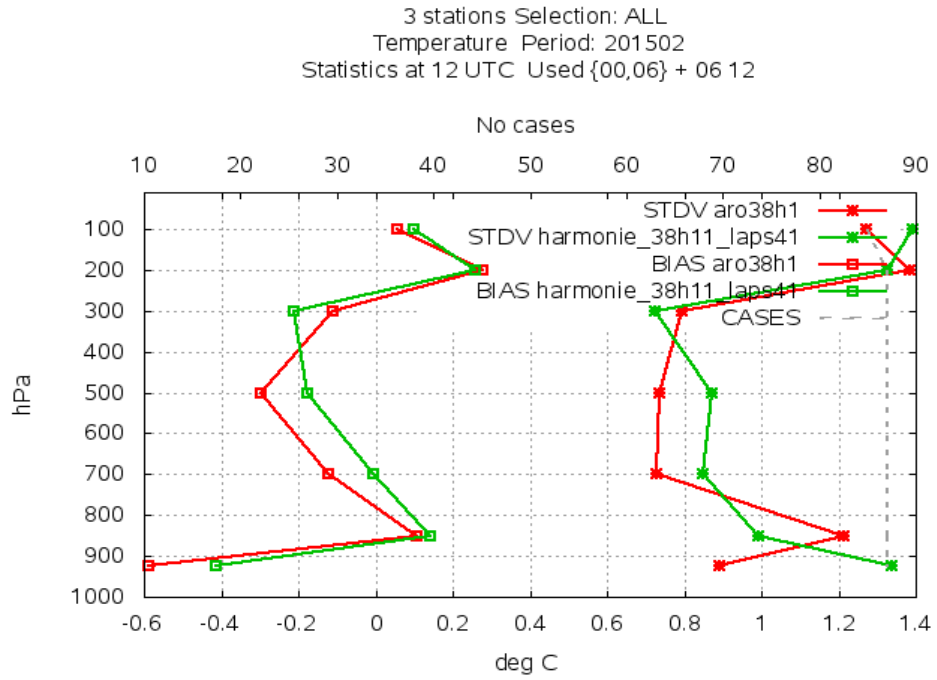


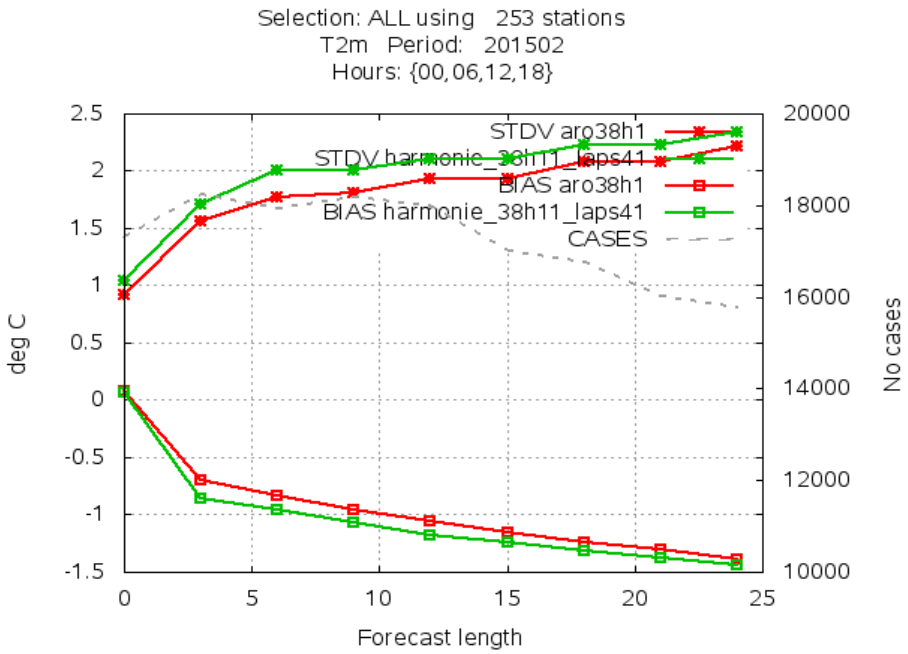
Potential benefits:

- Filling gap for now-casting purposes and fast available forecasts
- Through LAPS, satellite and radar information are brought into the forecast
- Possibly, wind-, cloud- and precipitation fields could be better captured from the beginning of the forecast (especially in convective situations)

LAPS-HARMONIE: Verification

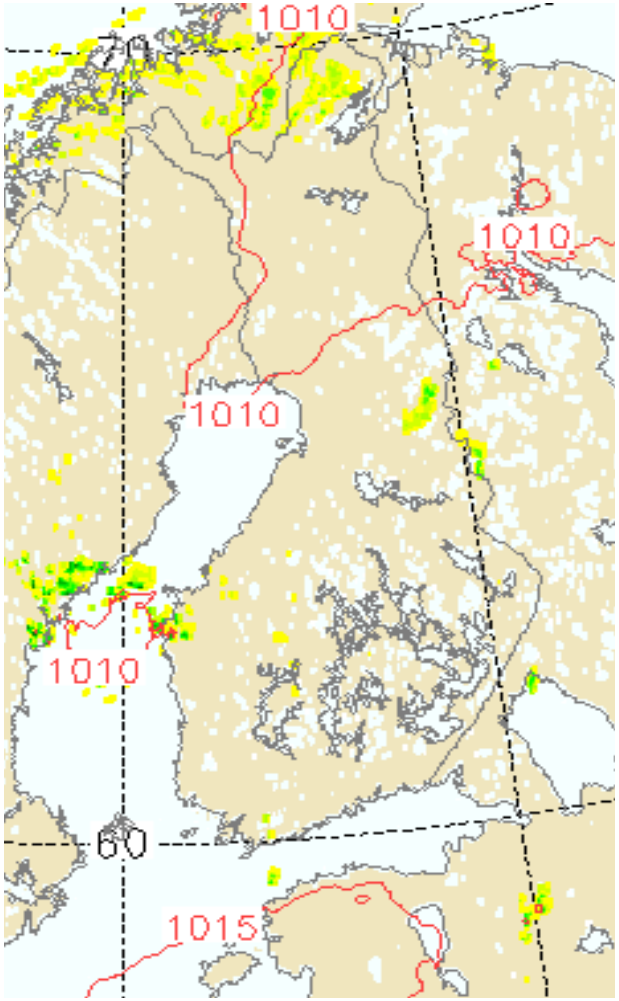
- LAPS is ingested to Harmonie (v. 38h11)
- Running as experimental since 2012, in parallel to operational Harmonie
- LAPS-Harmonie is included in the verification-system of FMI



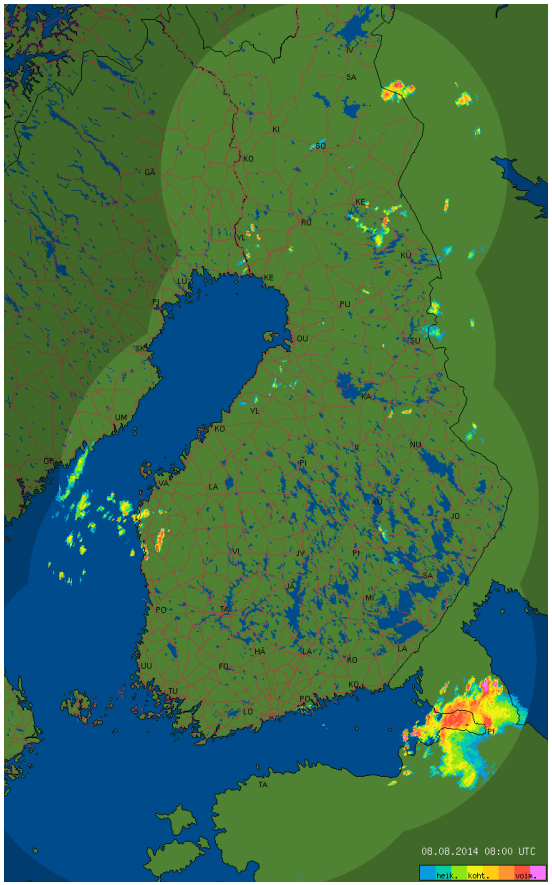


Harmonie (version 38h1.1)
LAPS-Harmonie (version 38h1.1)

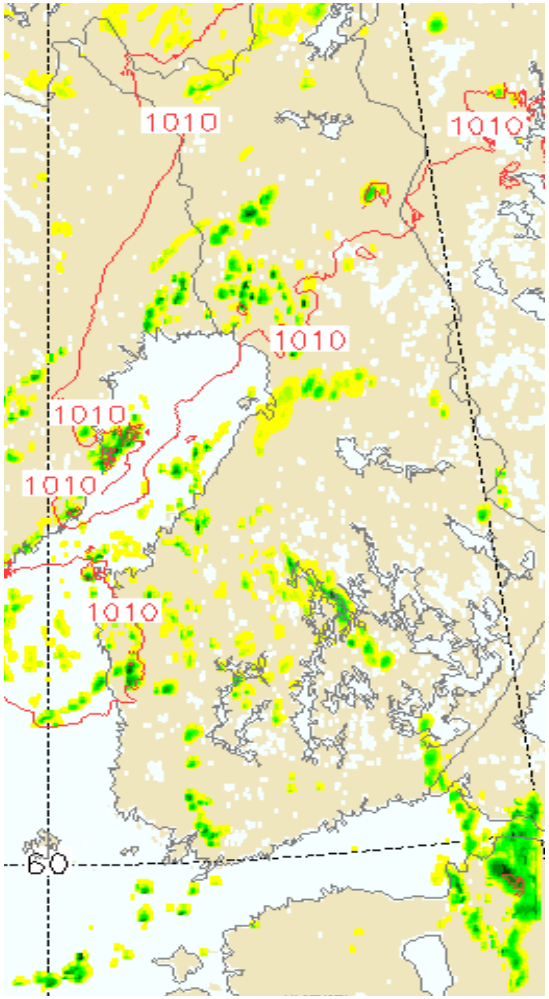
Example of cases: 08 August 2014, 08UTC



Harmonie 2.5 km (+2h forecast)



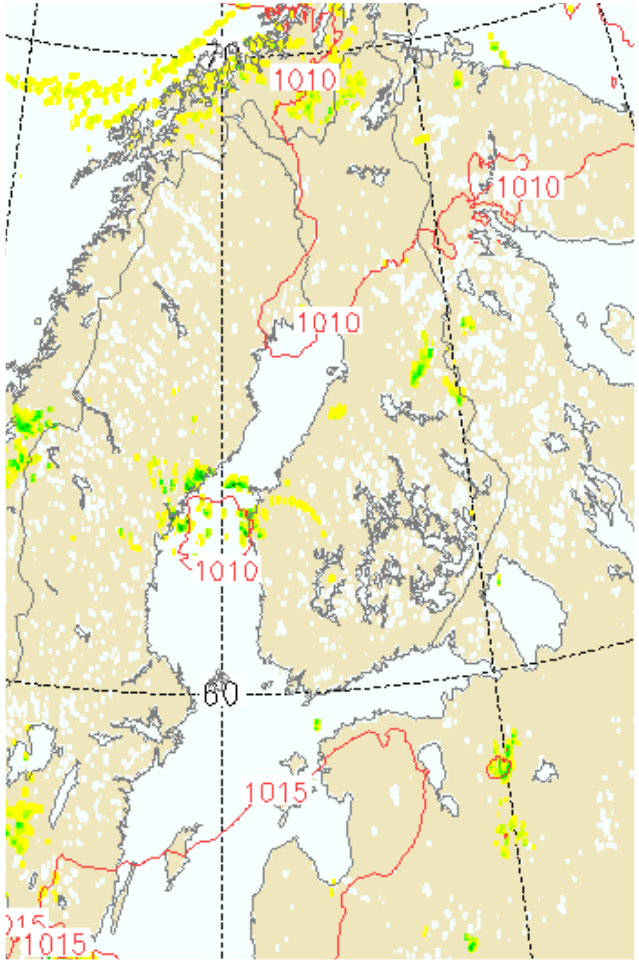
Radar



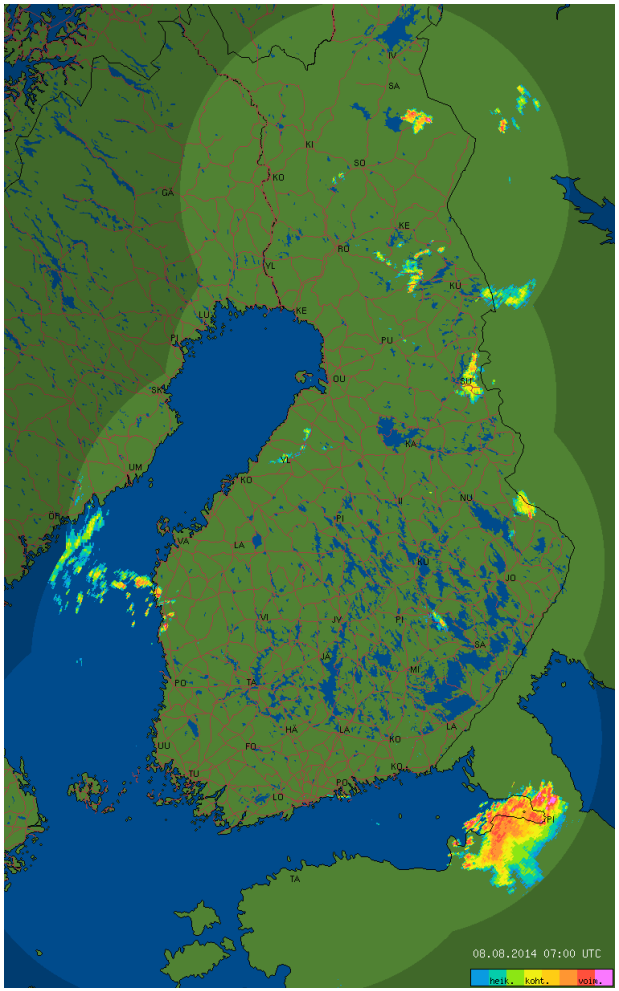
LAPS-Harmonie 2.5 km (+2h fc)

Example of cases: 08 August 2014, 07-13UTC

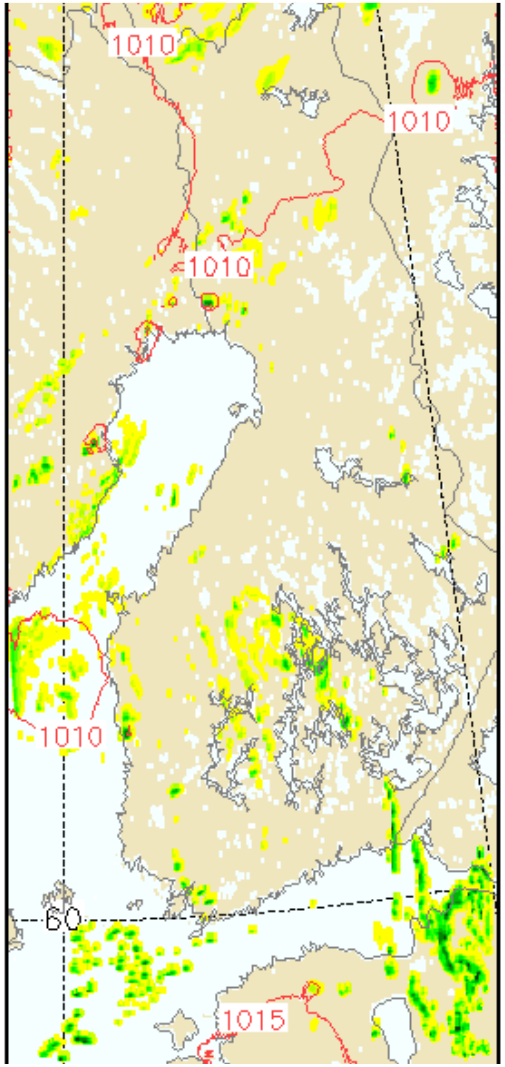
Harmonie 2.5 km



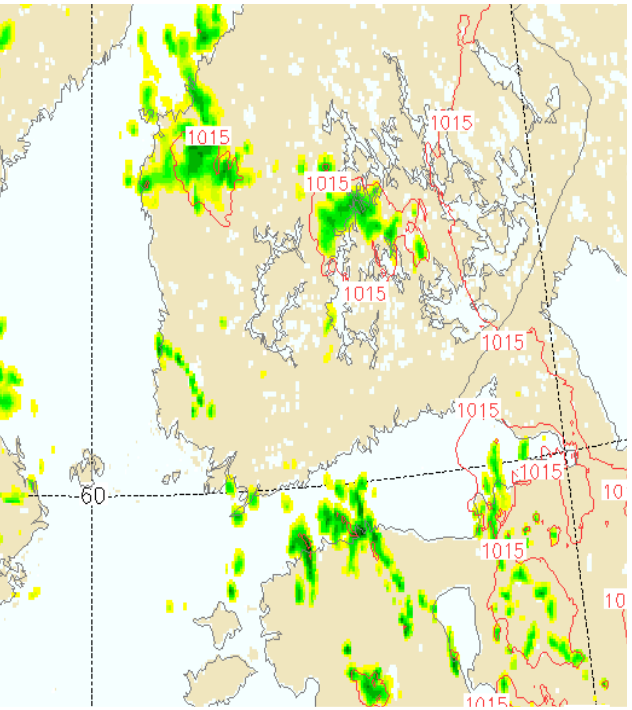
Radar



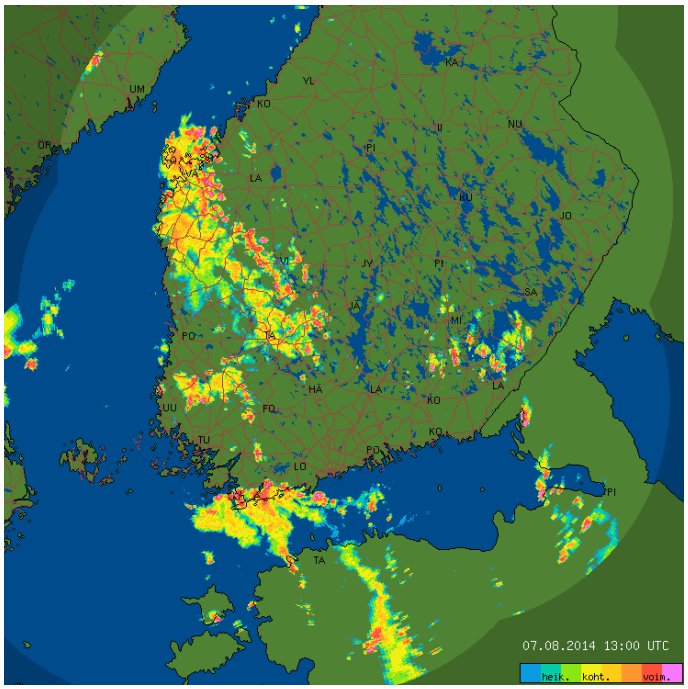
LAPS-Harmonie 2.5 km



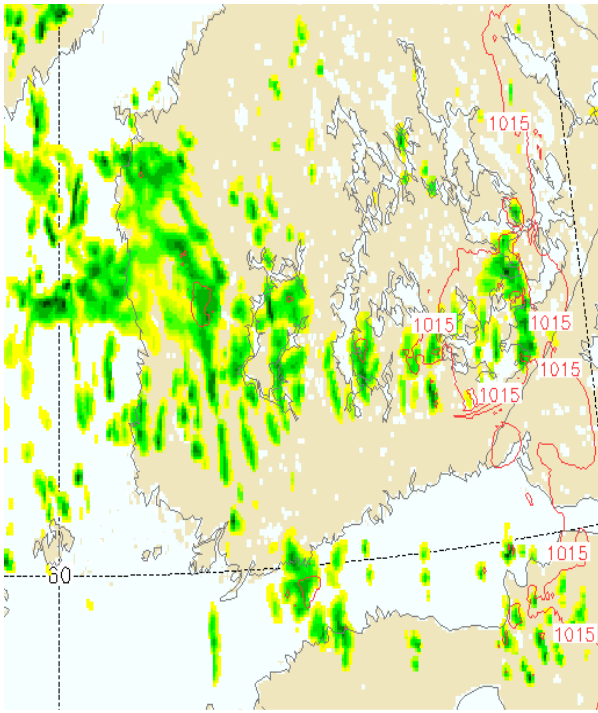
Example cases: 07 August 2014, 13UTC



Harmonie 2.5km (7h fc)



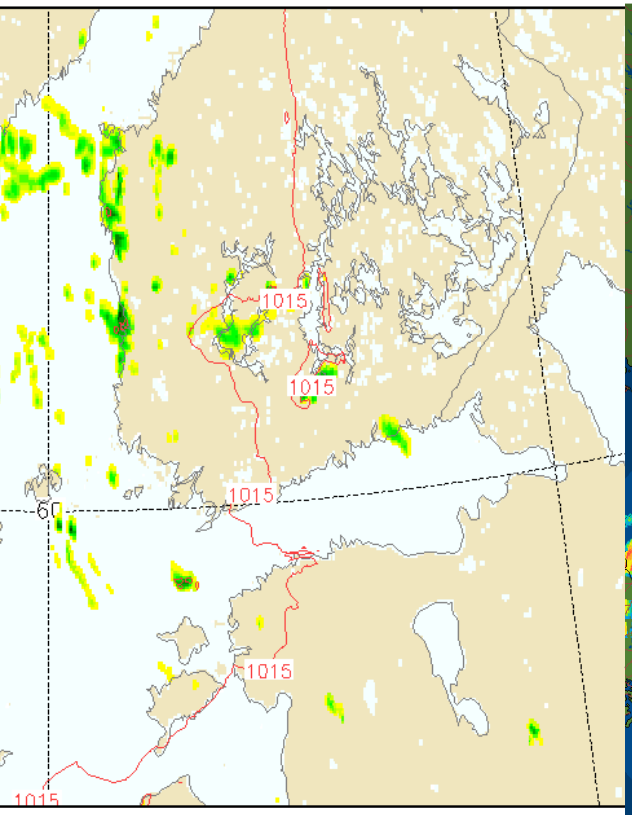
Radar



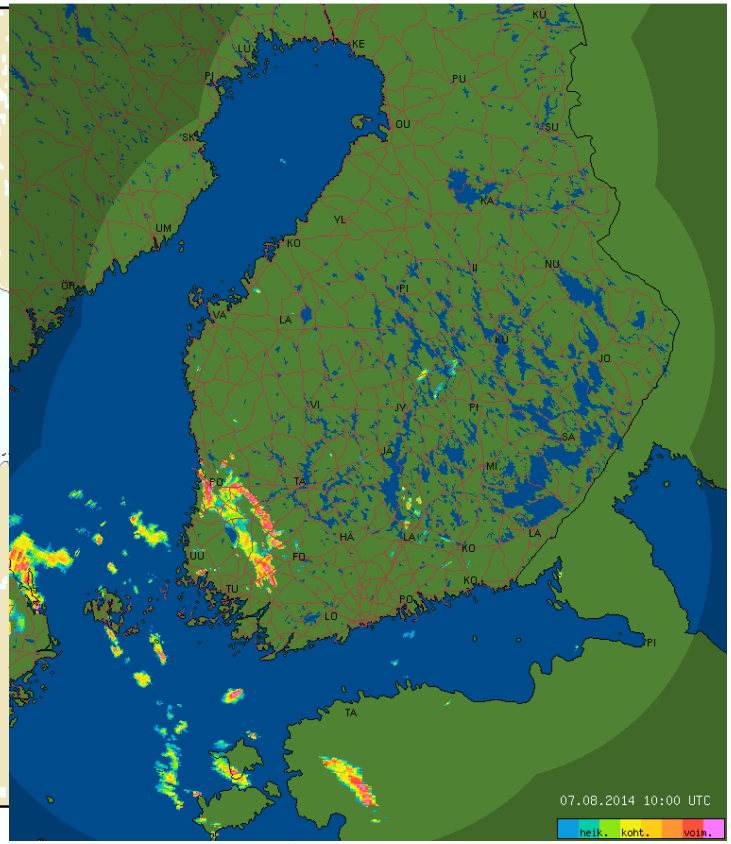
LAPS-Harmonie 2.5km (7h fc)

Example cases: 07 August 2014, 10-18UTC

Harmonie 2.5km (7h fc)



Radar



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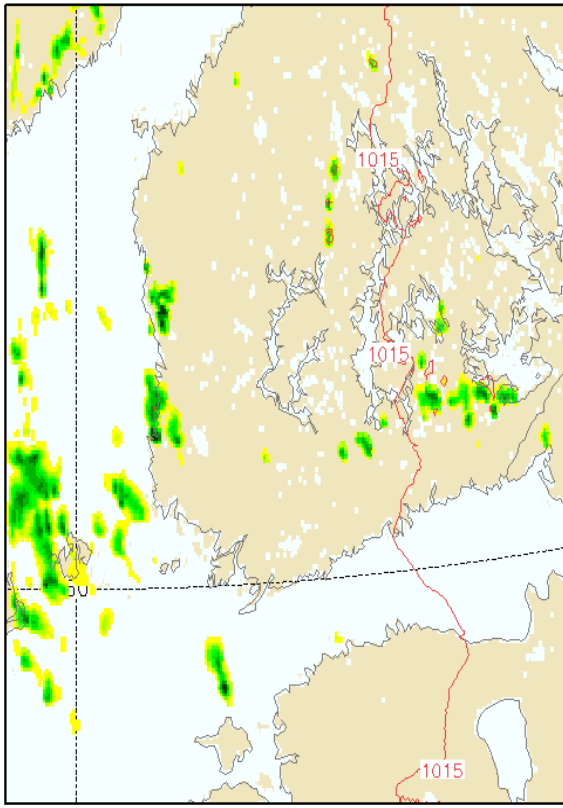


NWP nowcasting system at DMI

- The purpose of the NWP nowcasting is to predict important weather phenomena that has low predictability because they occur on small scales in time and space, leaving them very difficult to predict properly with traditional NWP setups.
- Examples of importance to DMI are:
  - Convective, heavy, local precipitation (risk of floodings).
  - Road temperatures, humidity, precip., cloud cover (e.g. slippery road forecasts, used by road authorities when planning salting)
  - Short term changes in wind and cloudiness, changing energy production from wind turbines and solar panels.

- Important components of a NWP nowcasting system are
  - Observations providing relevant information with high time frequency, high timeliness, and high spatial resolution.

    The most promising are radar data, ground-based GNSS data, Mode-S data, and certain types of satellite cloud data. Exchange of more SYNOP data with some nearby countries would also help.
  - An NWP/computer system capable of doing frequent assimilation and short range NWP forecasts, so-called ”rapid update cycling” (RUC). With new runs every hour (or more often) and 6 to 12 hour forecasts.

The RUC system data assimilation is a two step procedure

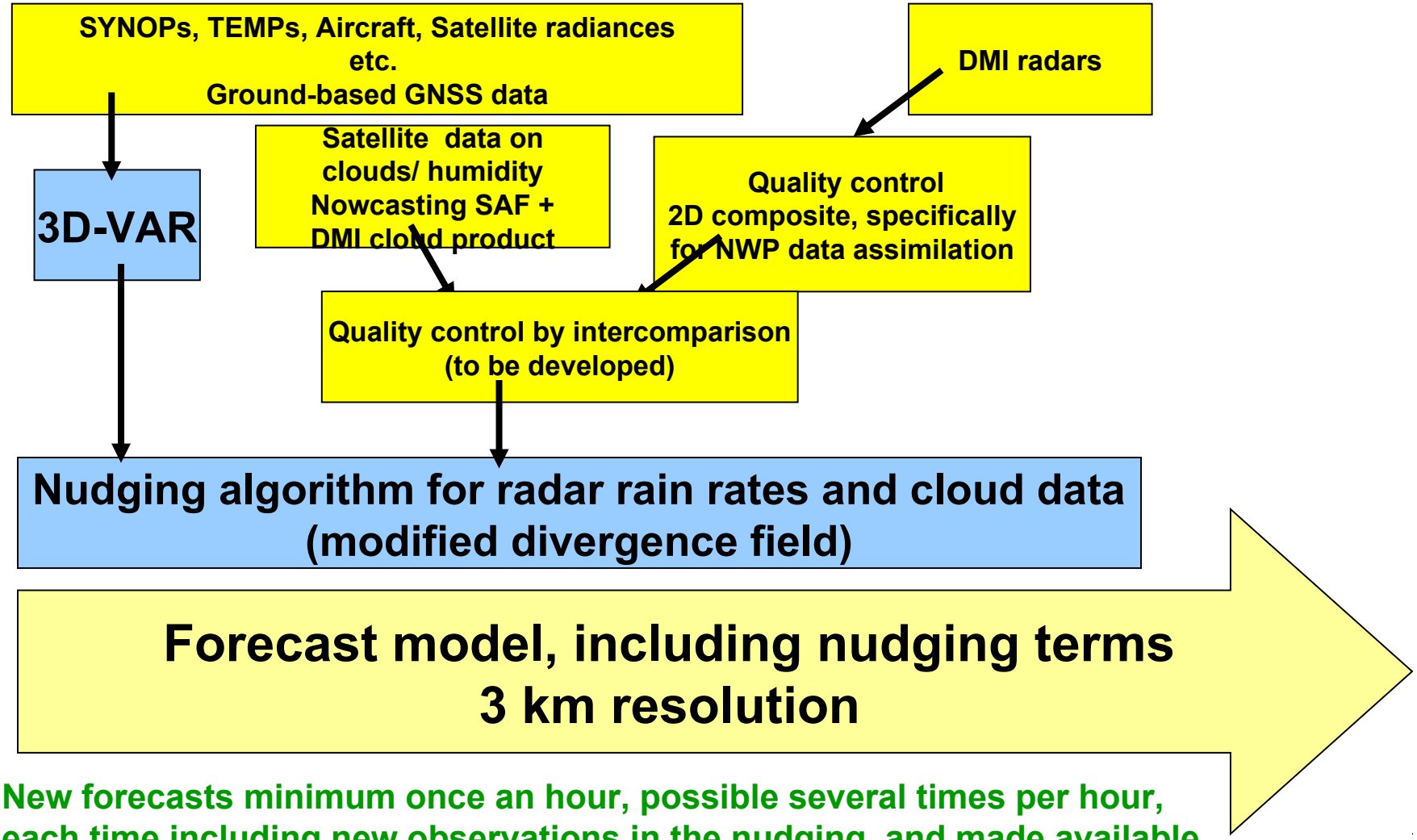
1. 3DVar of ”standard” observations with a cutoff of about 1:30 h.
2. Nudging of satellite cloud data and 2D radar composite ”rain” observations that have arrived since the nominal time of the 3DVar analysis. The youngest observations have an age of just about 10-15 min relative to the wall clock time for the start of the forecast cycle. The DMI radar observations are available with 10 min intervals.

The radar data are included via nudging of the divergence term in the continuity equation, with the strength of the forcing being determined from a relation between enhanced convergence/divergence and precipitation.

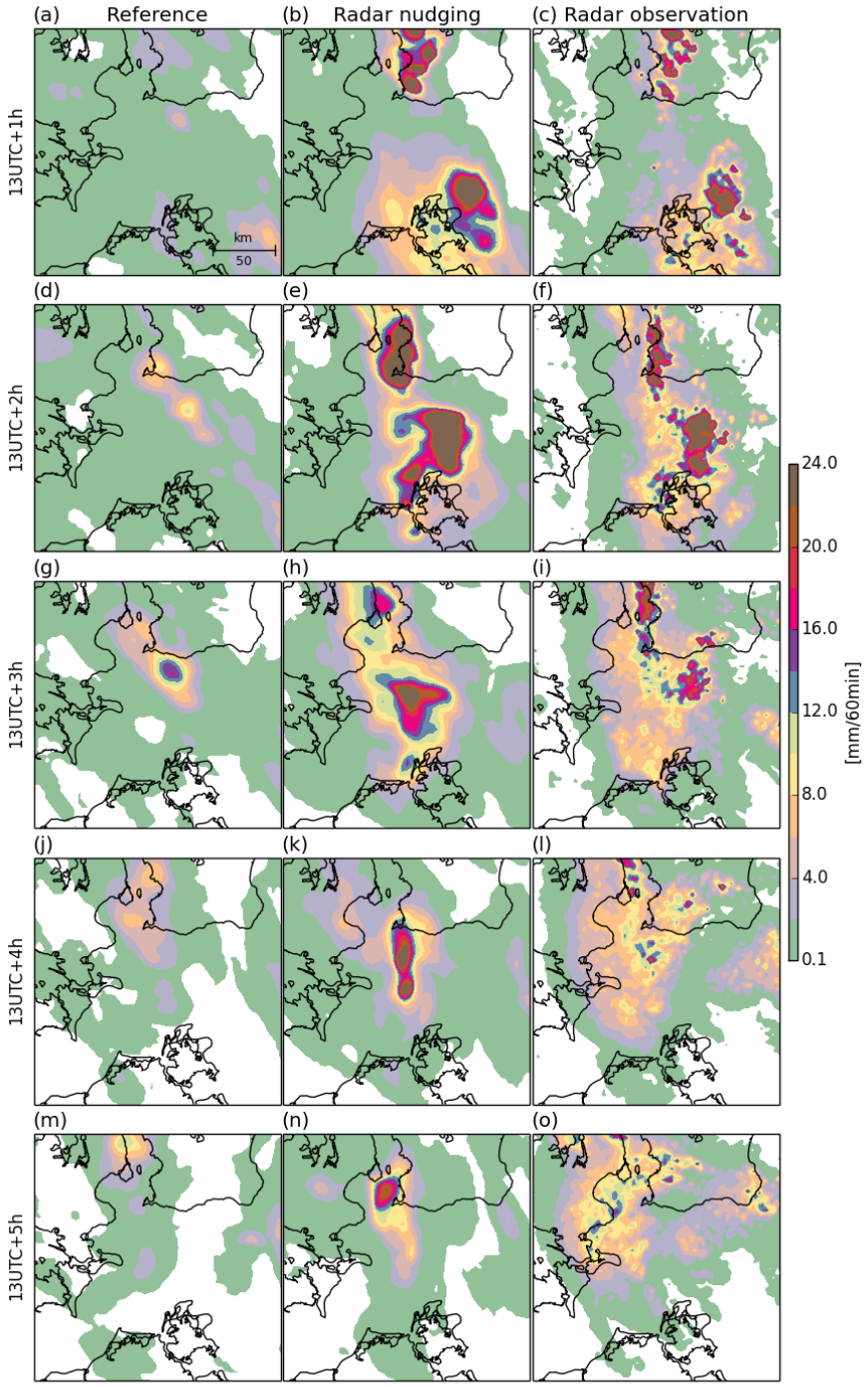
The idea is somewhat similar to use of latent heat nudging: that changes in precipitation are related to changes in convergence/divergence and associated vertical motions. We here work on the velocity field, because on the small scales velocities drive the mass. The scheme is found to be very efficient, with a quick forcing of the precipitation field.

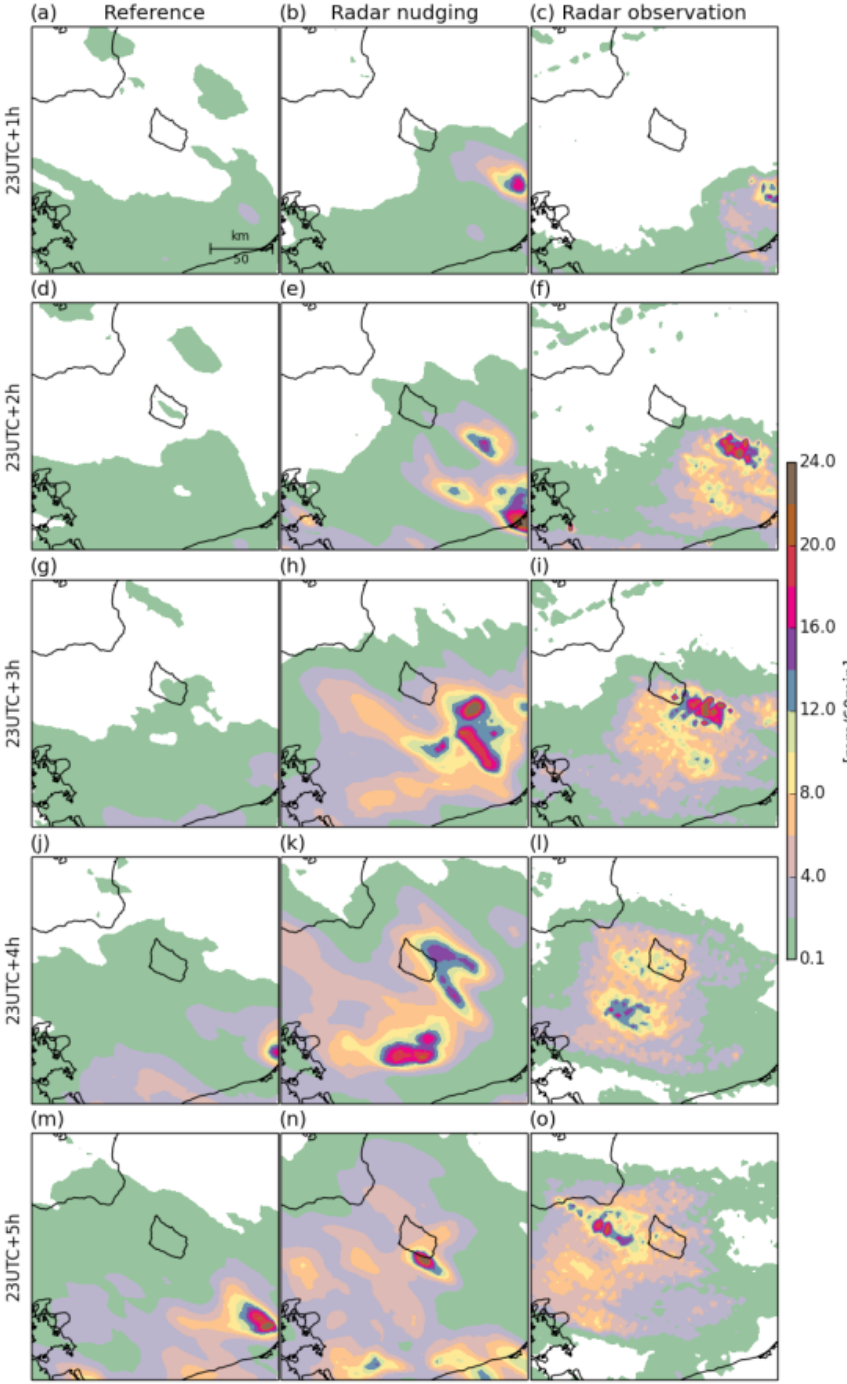
1: 3DVAR, done hourly, with cut-off time of approx. 1.5 h.

2: Nudging, done hourly with very small cut-off time.



New forecasts minimum once an hour, possible several times per hour, each time including new observations in the nudging, and made available shortly after the valid time of the observations. The forecast takes about 5 min.


(a) Reference
(b) Radar nudging
(c) Radar observation
13UTC+1h
13UTC+2h
13UTC+3h
13UTC+4h
13UTC+5h
km
50
24.0
20.0
16.0
12.0
8.0
4.0
0.1
[mm/60min]


(a) Reference
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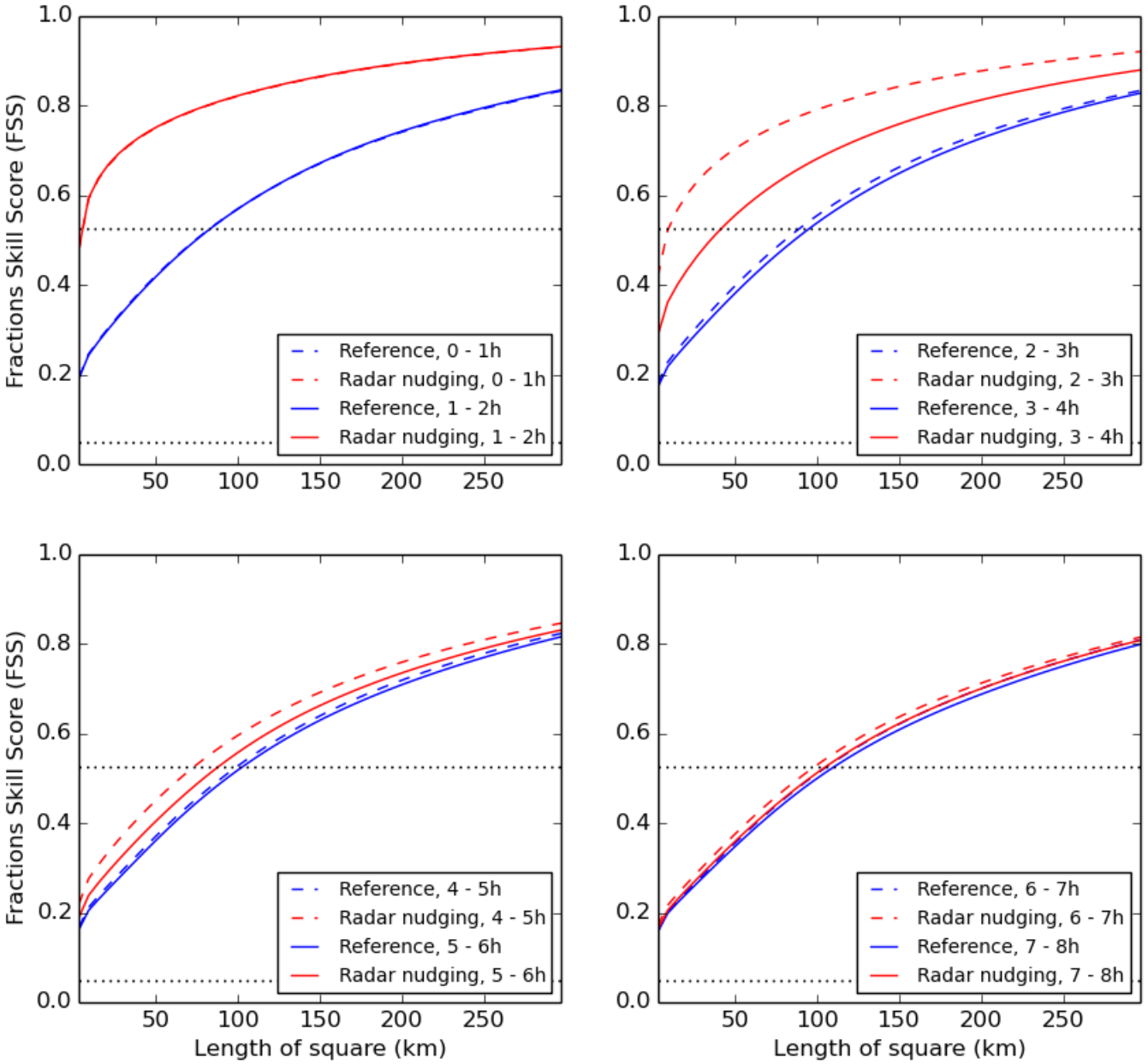
23UTC+3h
23UTC+4h
23UTC+5h
km
50
24.0
20.0
16.0
12.0
8.0
4.0
0.1

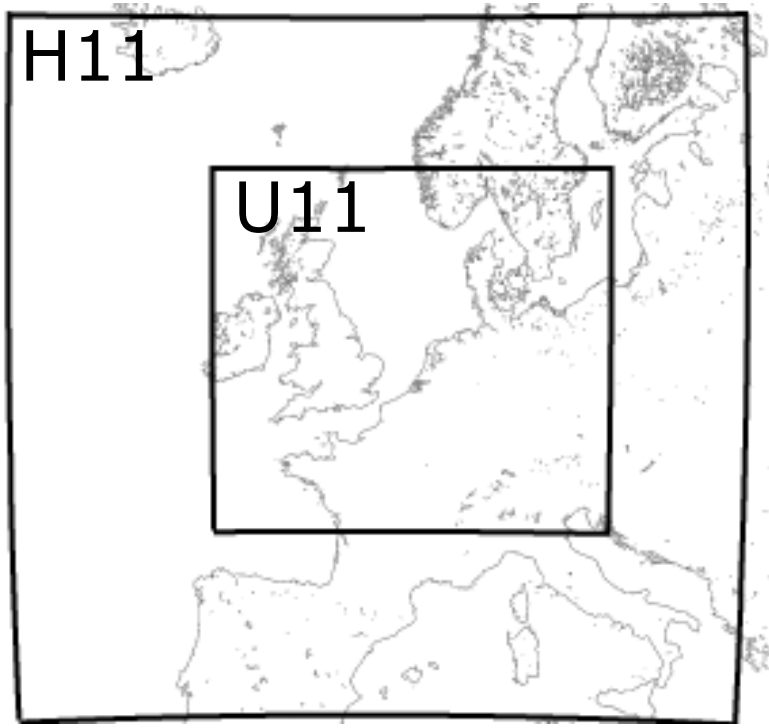
10 - 26 August 2010, 95th Percentile of 1hour accumulated precipitation



Numerical Weather Prediction Models

HIRLAM
- 11 km Resolution (U11)
- Observation cut-off time : 10 minutes
- 9 hours forecast
- Hourly 3DVAR Assimilation: **p,u,v,T,q**
- Operational (U11)
  - Synoptic (land, ship, buoy) p
  - AMDAR/Mode-S u,v,T
  - Groundbased GNSS ≈ q
  - Radar radial winds (NL) ≈ u/v
- Simultaneous test (pre-operational)
  - MSG clouds/ceilometer (initialization) ≈ q,T
  - MSG Seviri (ch 6.2,7.3,13.4) ≈ q,T
  - AMSU-A ≈ q,T

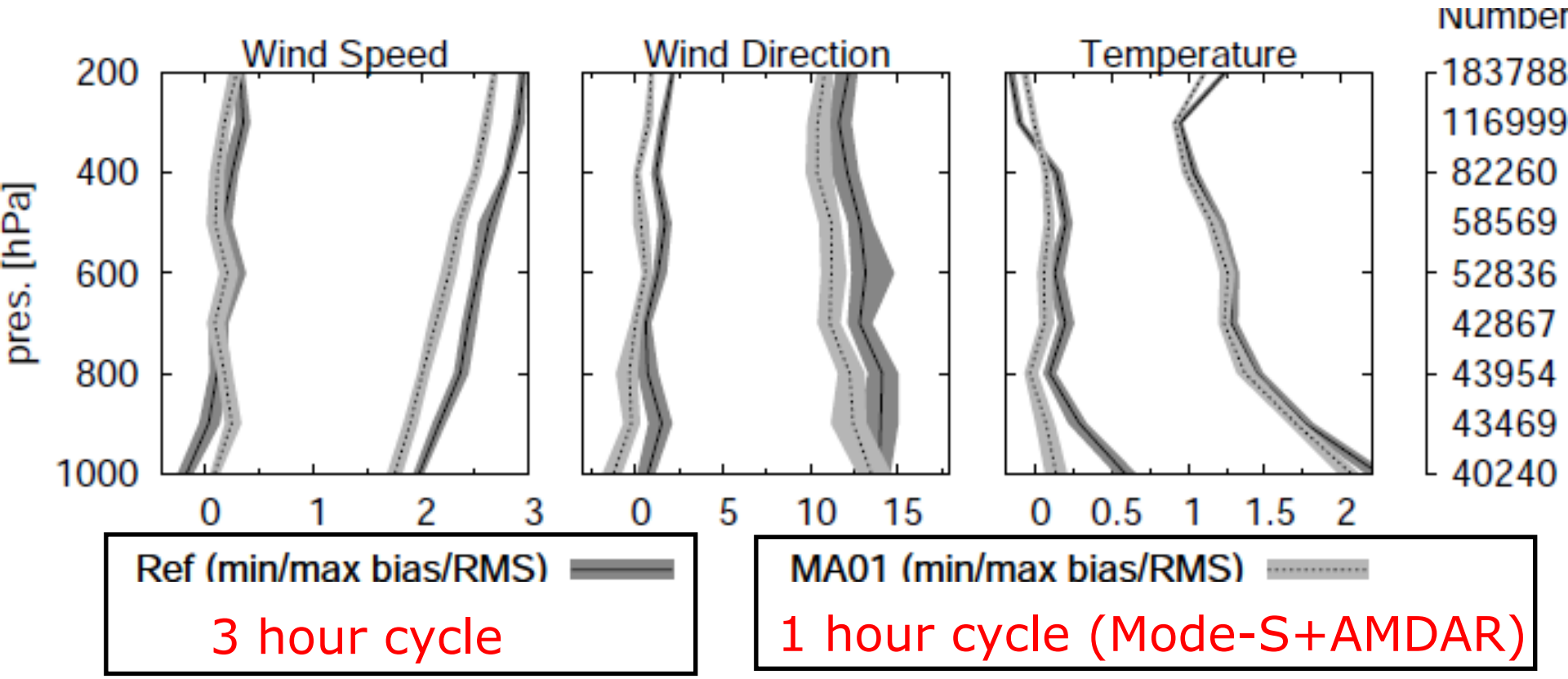
Operational (H11)
3 hour 3DVAR cycle:
- Synoptic (land, ship, buoy)
- Radiosonde
- AMDAR



Real-time Forecast skill

At observation time compared with available forecast

5% reduction in wind speed RMS



3 hour cycle

1 hour cycle (Mode-S+AMDAR)

Assimilation of GNSS and radar radial winds

Radar radial winds

Lowest elevations have an unambiguous velocity of 24 m/s

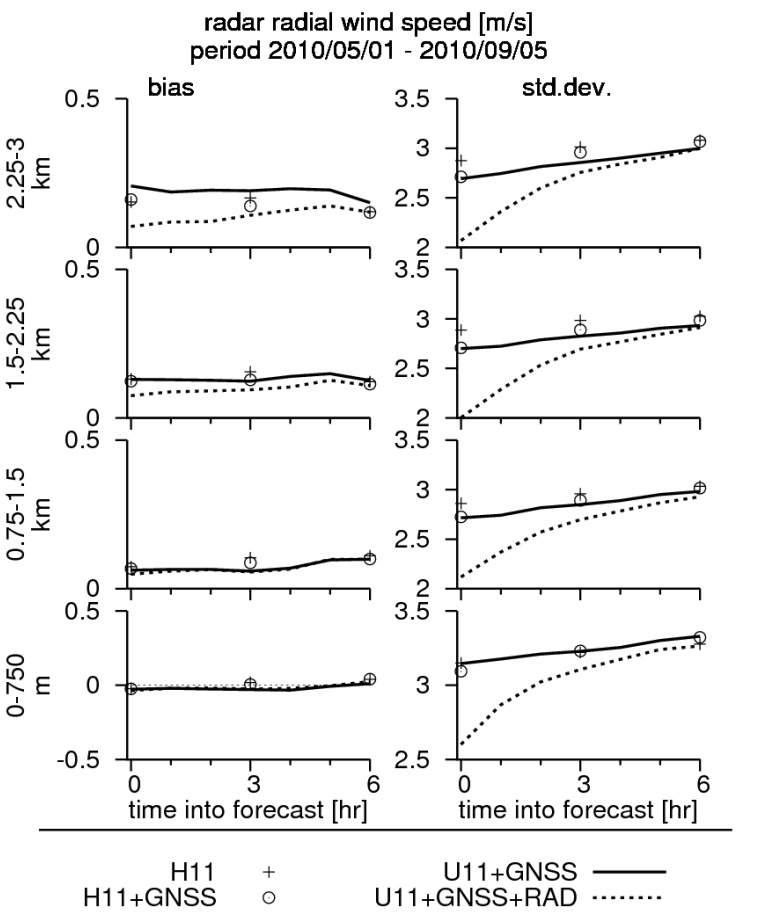
Dealiasing using higher elevations

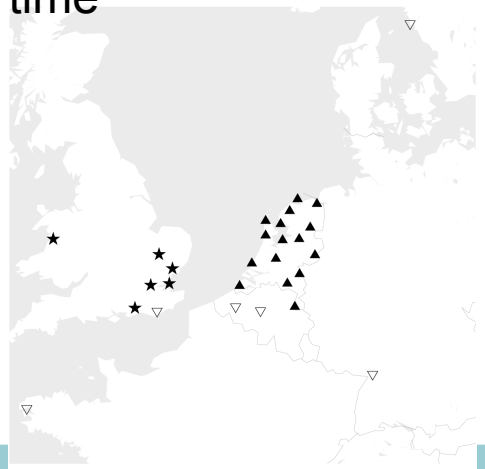
Thinning to 20x20 km boxes

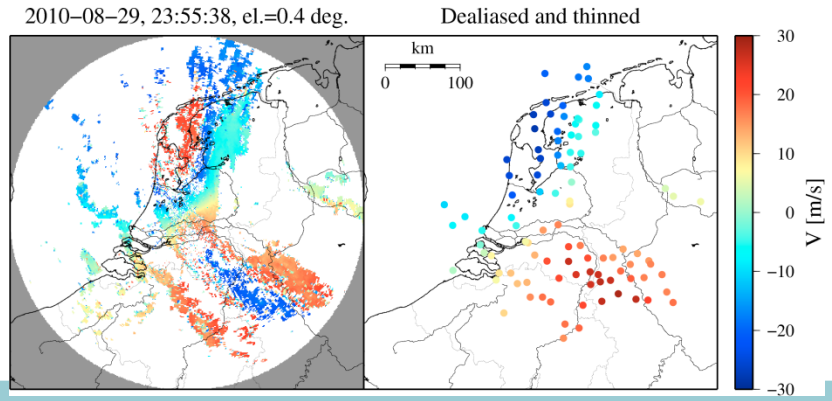
QC checks

GNSS ZTD observations

Processing of within 5 minutes after observation time





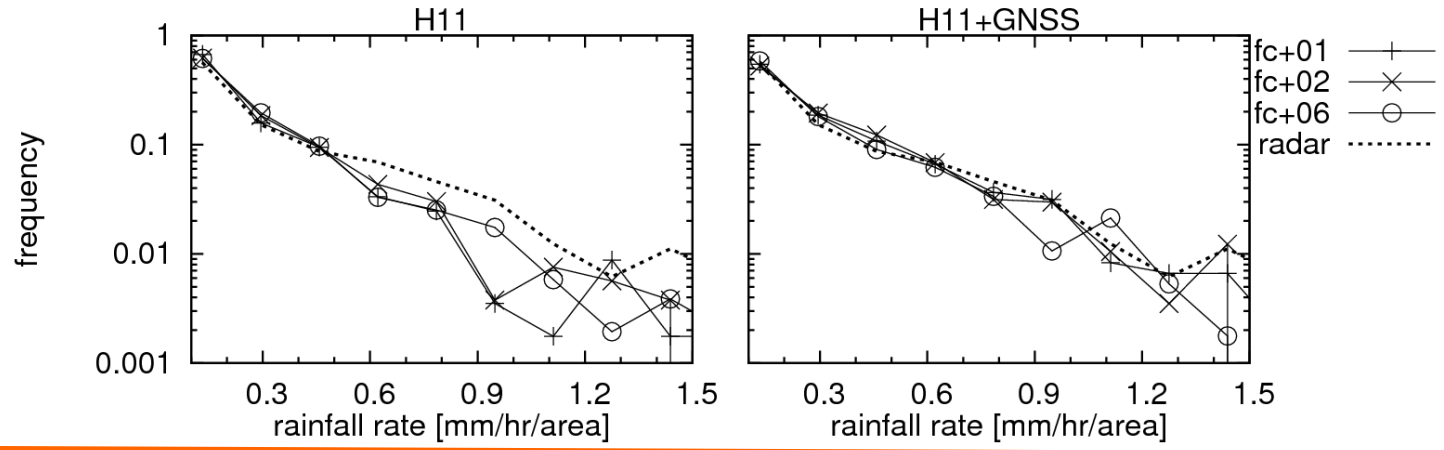


DeHaan, QJRMS, 2012 revised

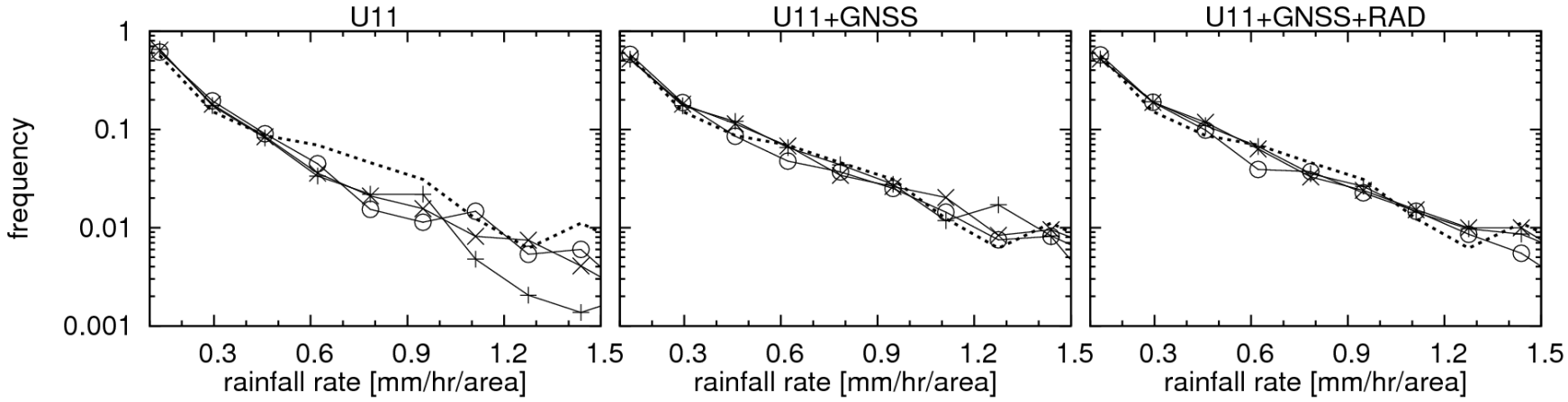
Assimilation of GNSS and radar radial winds

Hourly Rainfall Frequency Distribution (2010/05/01 - 2010/09/05)

3 hour cycle



1 hour cycle



DeHaan, QJRMS, 2012 revised

Cloud mask initialisation

Uses:

- cloud mask nowcasting SAF
- MSG cloud top temperatures
- synoptic cloud base heights

After 3dvar, the q-profile of the analysis is modified, while leaving virtual temperature constant.

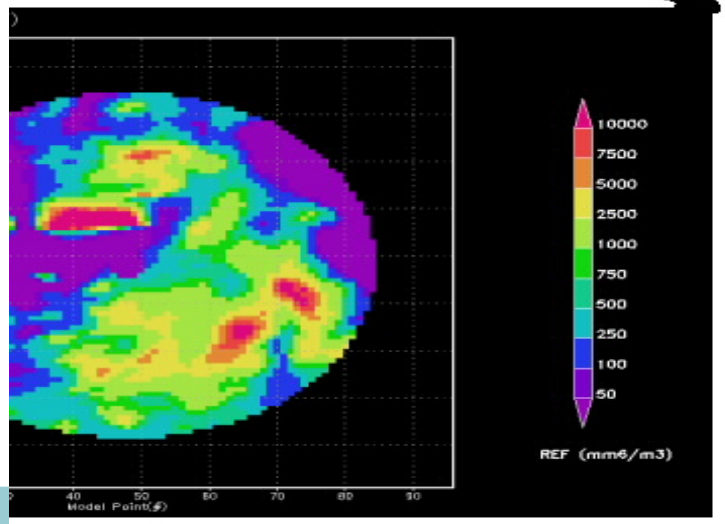
Field Allignment (FA)

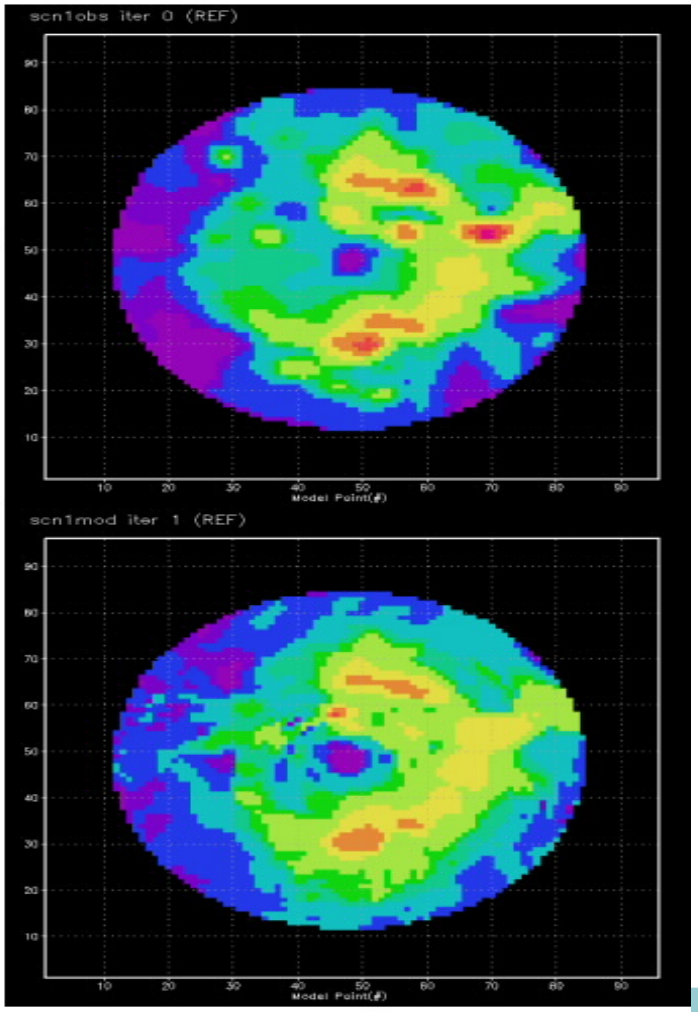
ilation of Z by FA

in PPI geometry

OBS

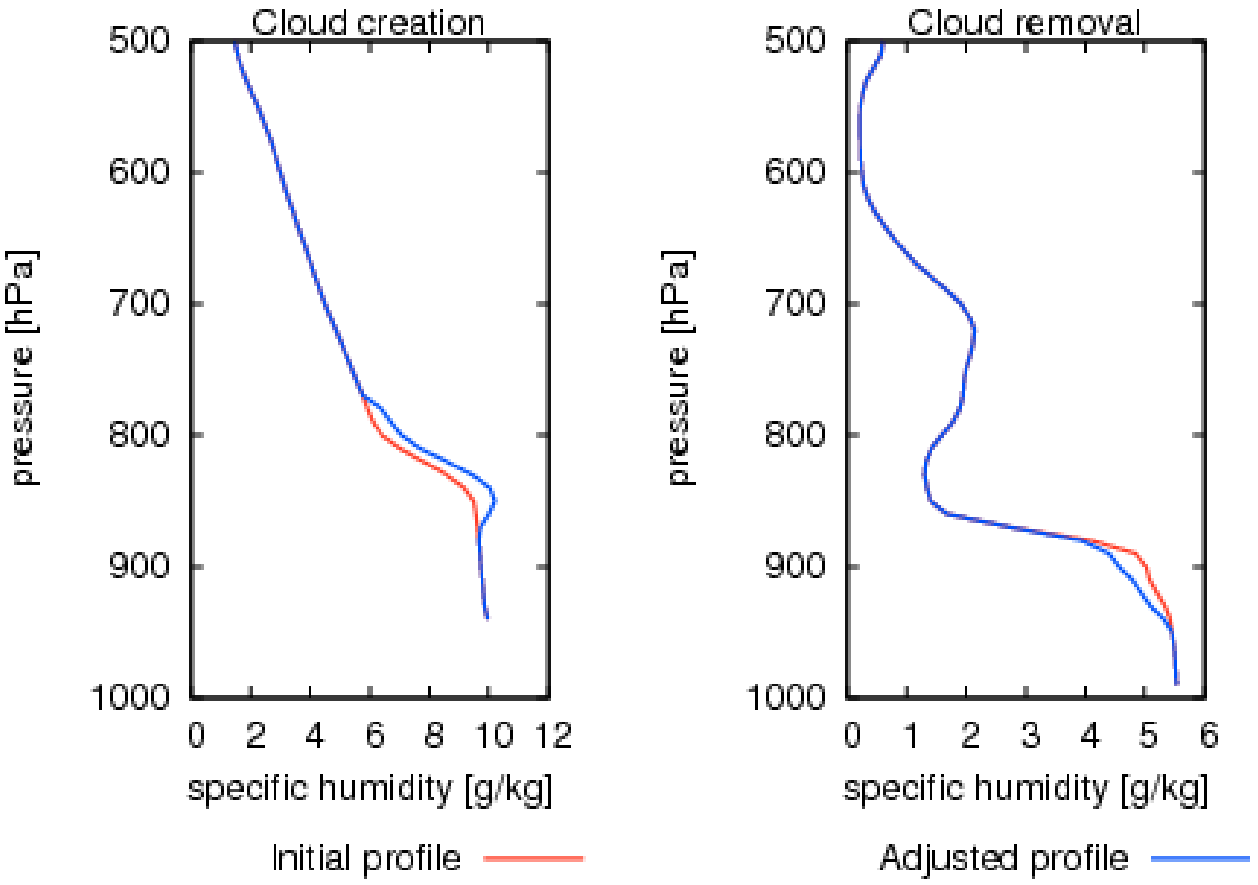
corrected FG



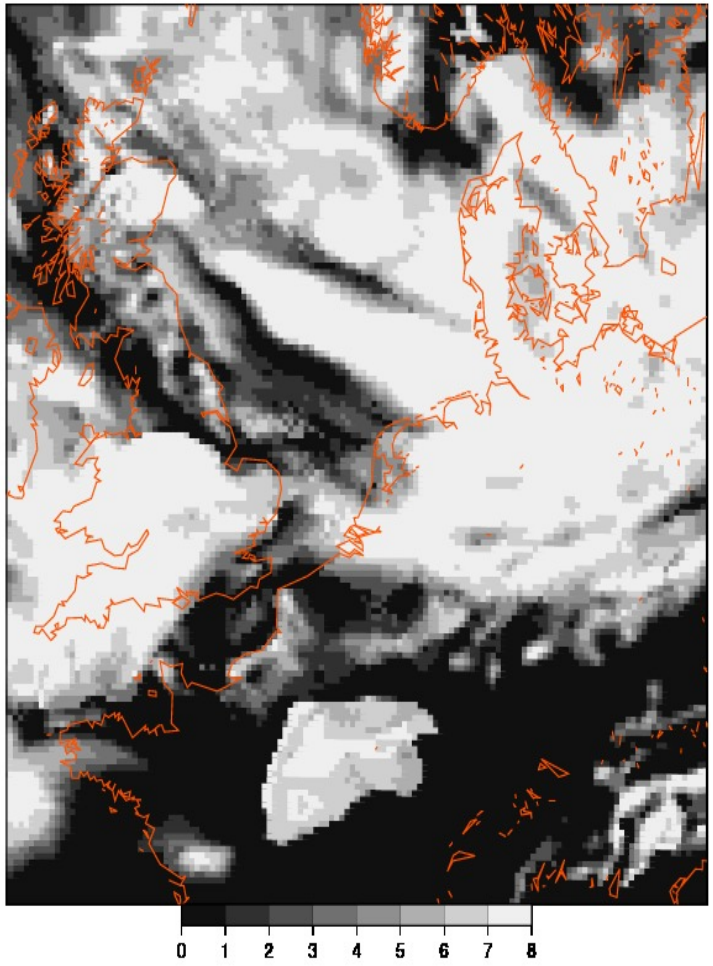


Carlos Geijo, AEMET)

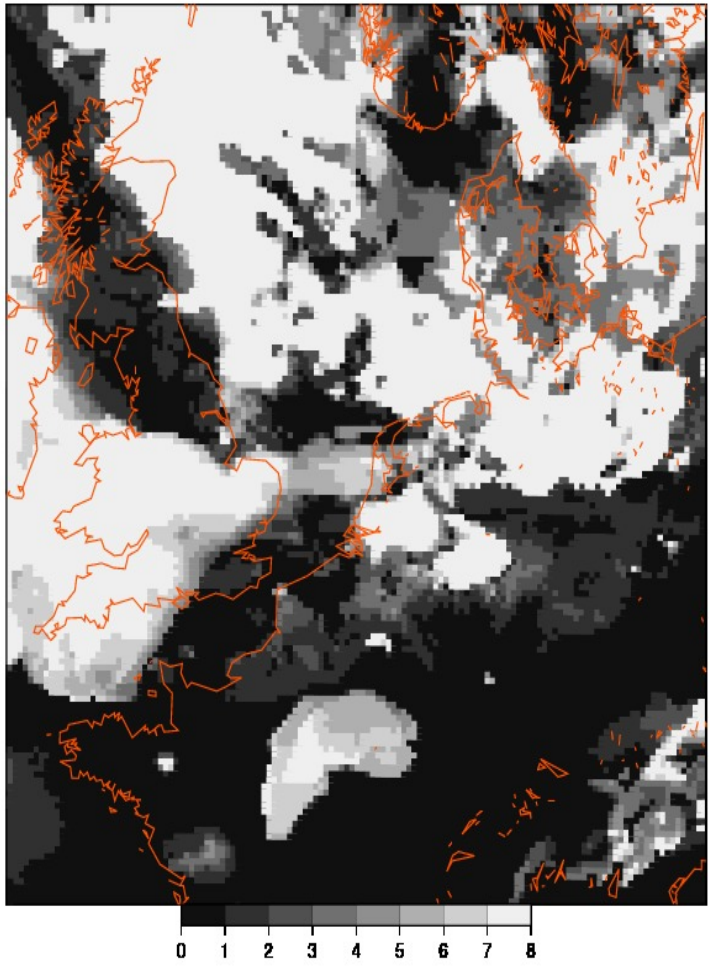
Example:
cloud creation and cloud removal



REF cloud cover 20110915_12+000



MSG cloud cover 20110915_12+000



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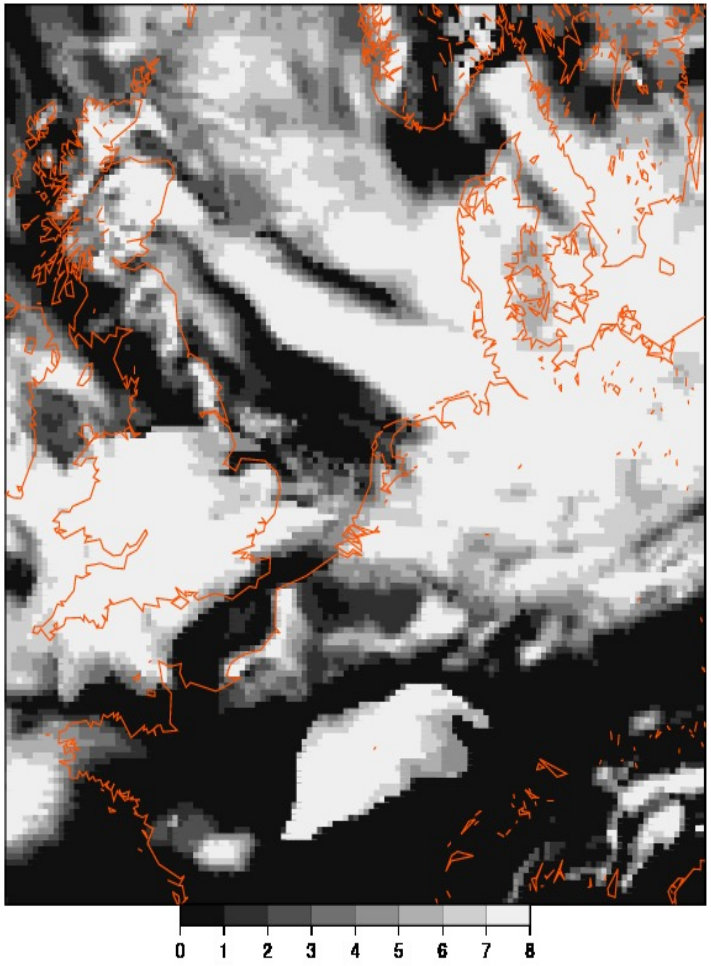
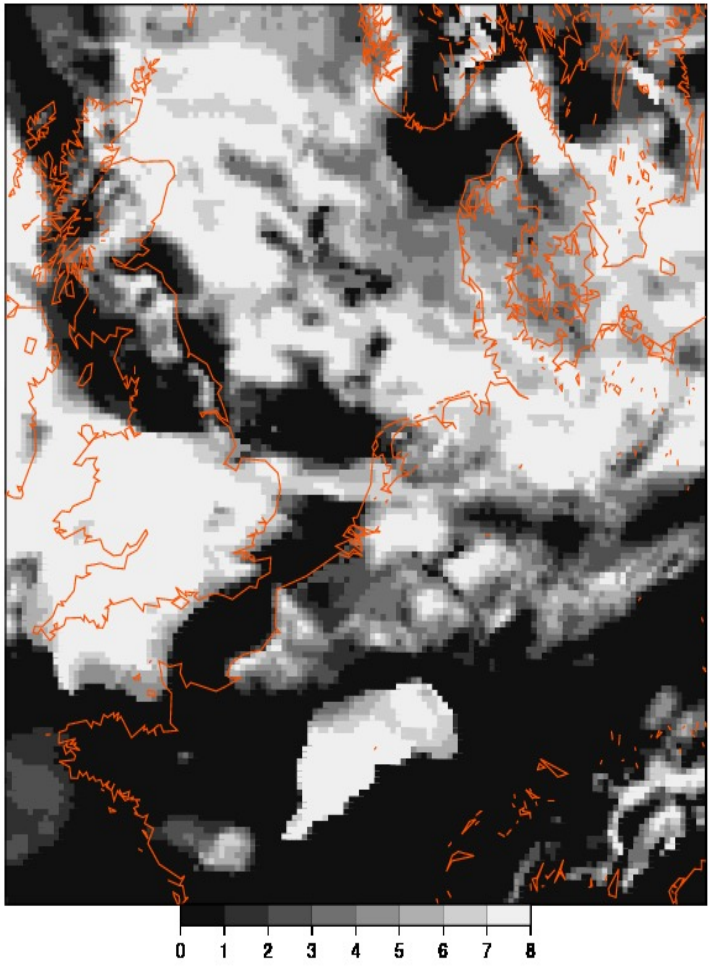


MSG cloud cover 20110915_12+001



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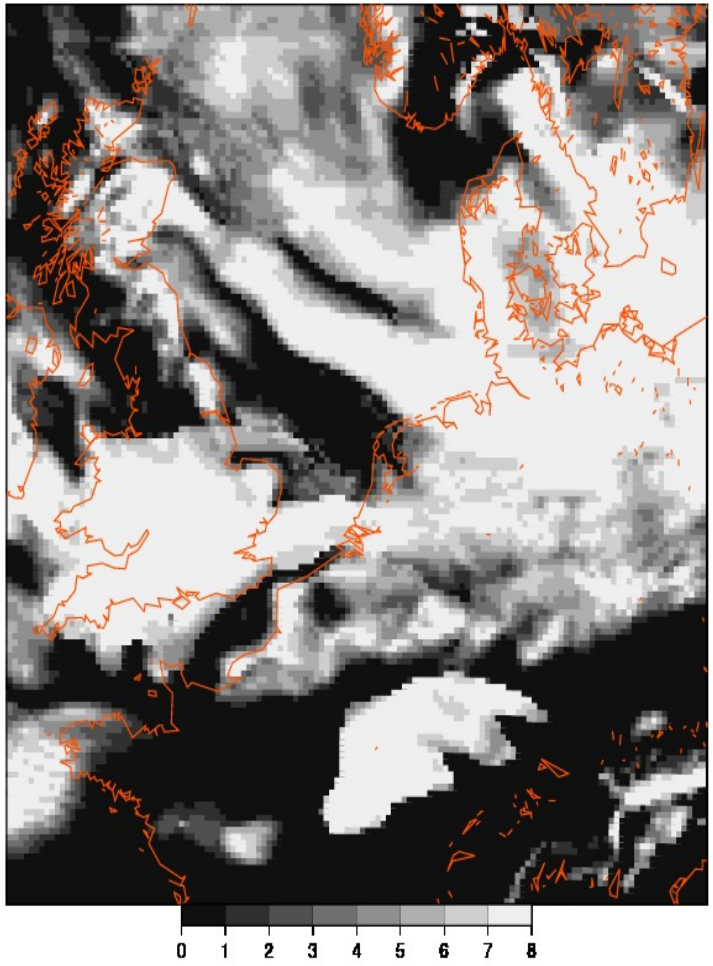

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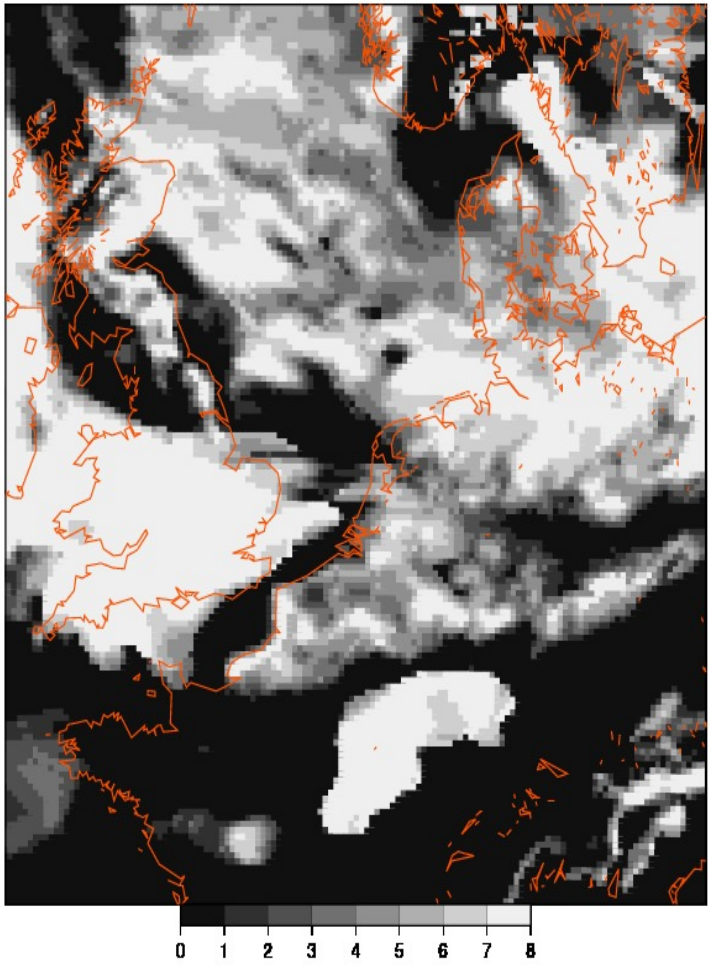

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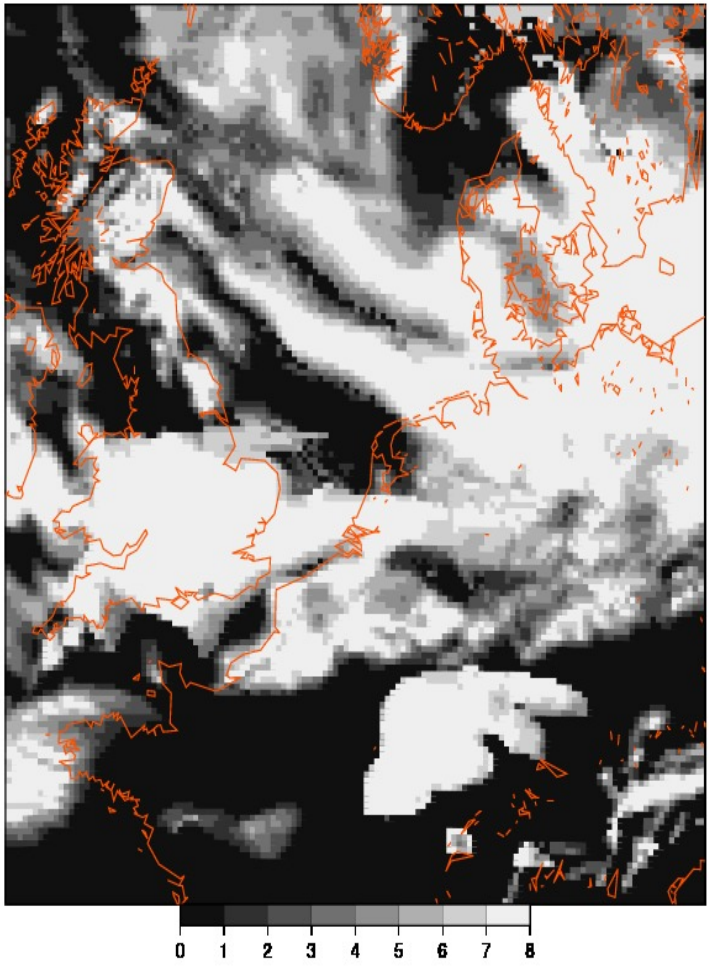

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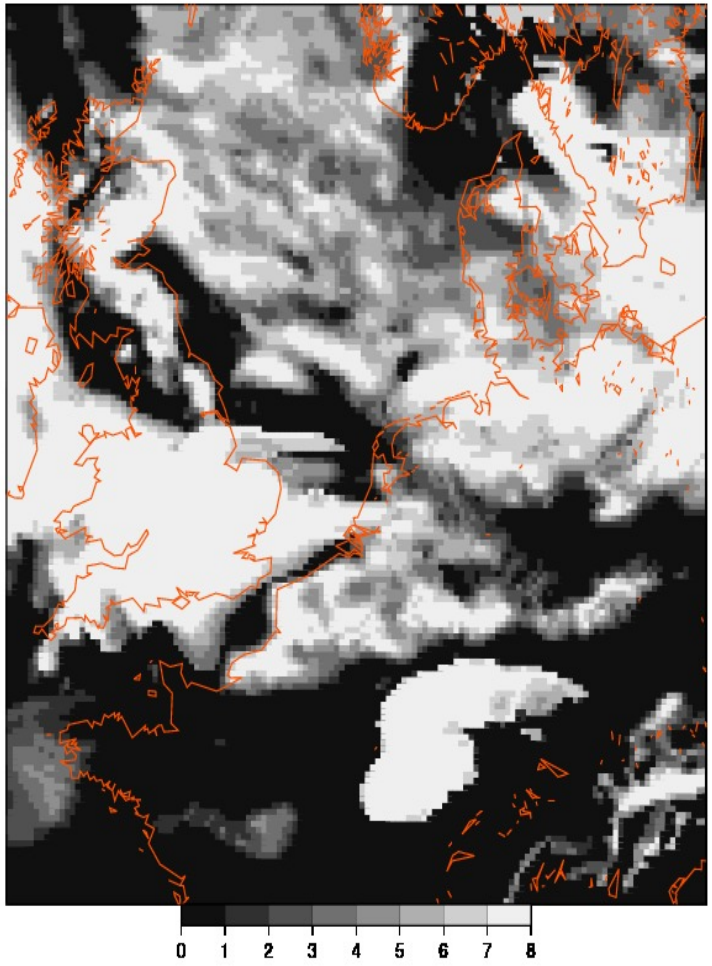

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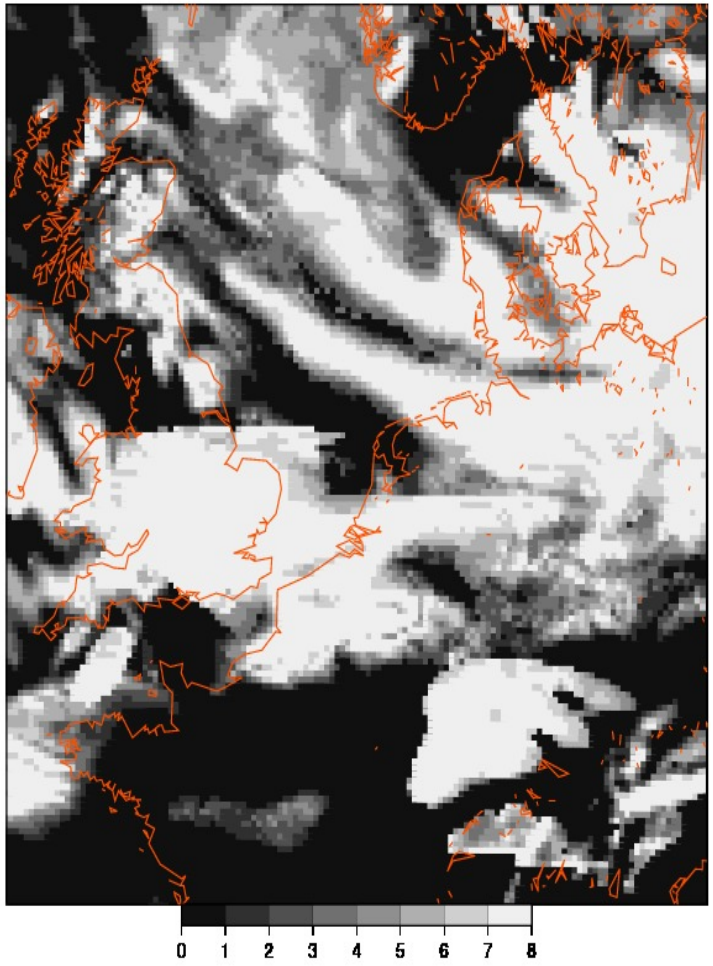

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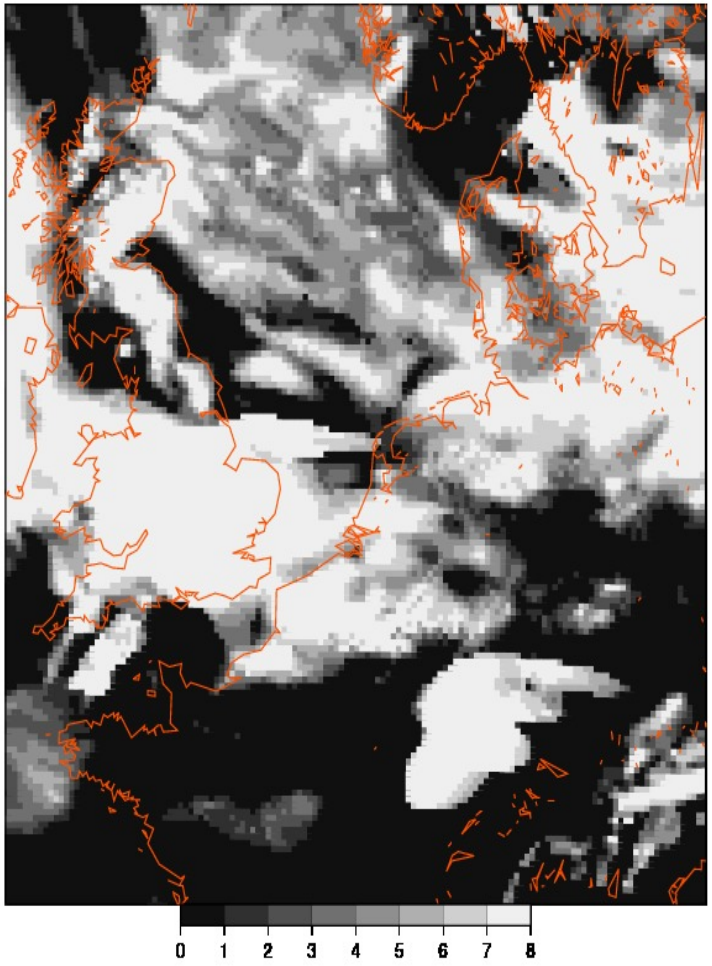

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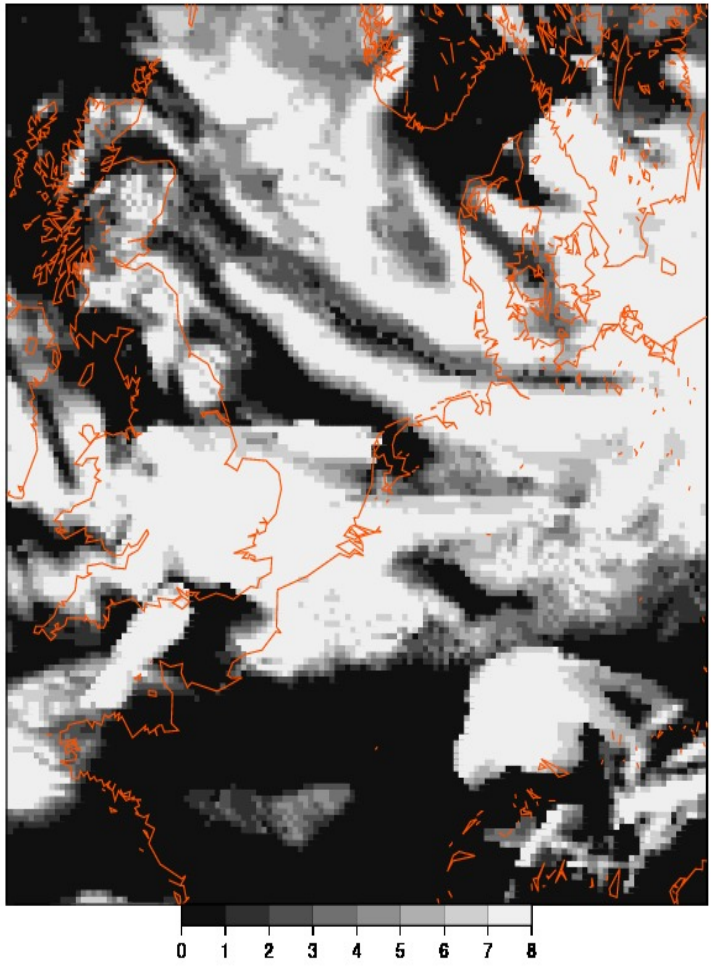
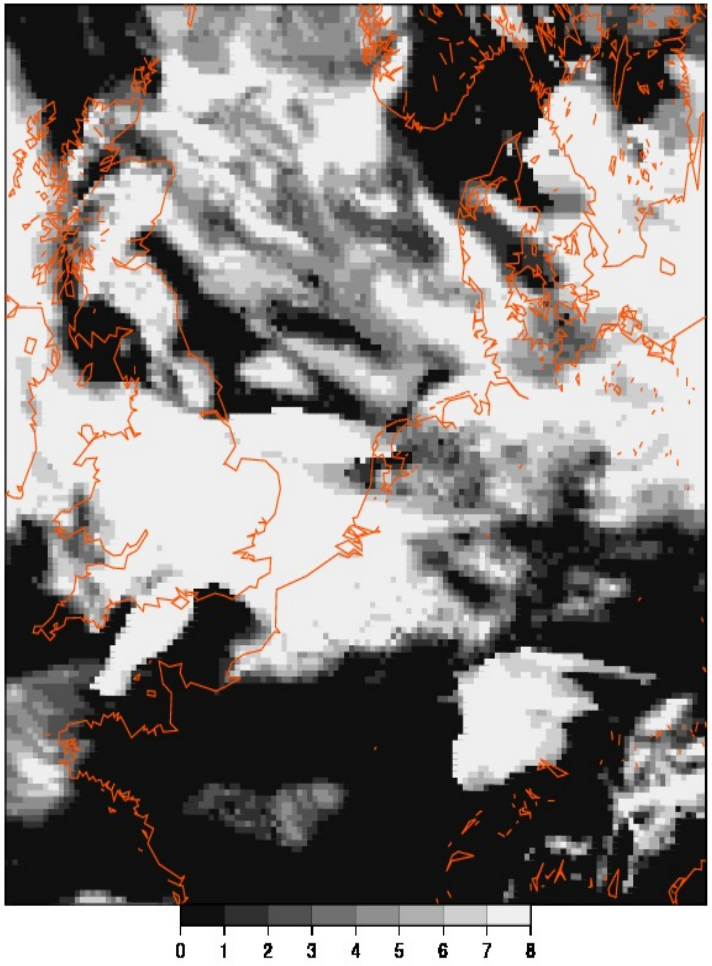


MSG cloud cover 20110915_12+005



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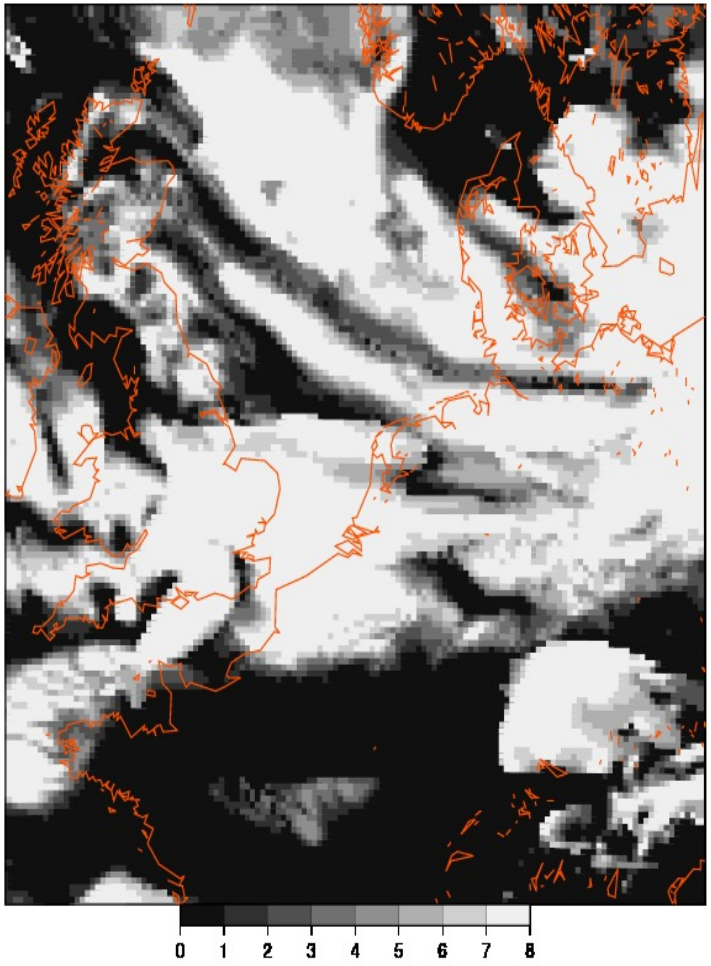
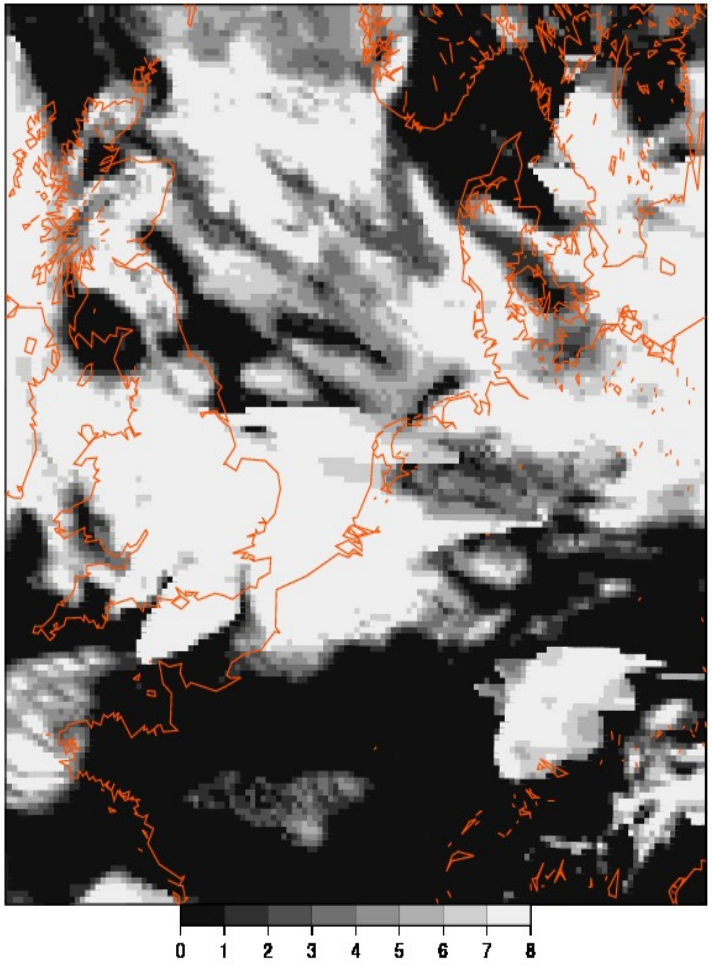
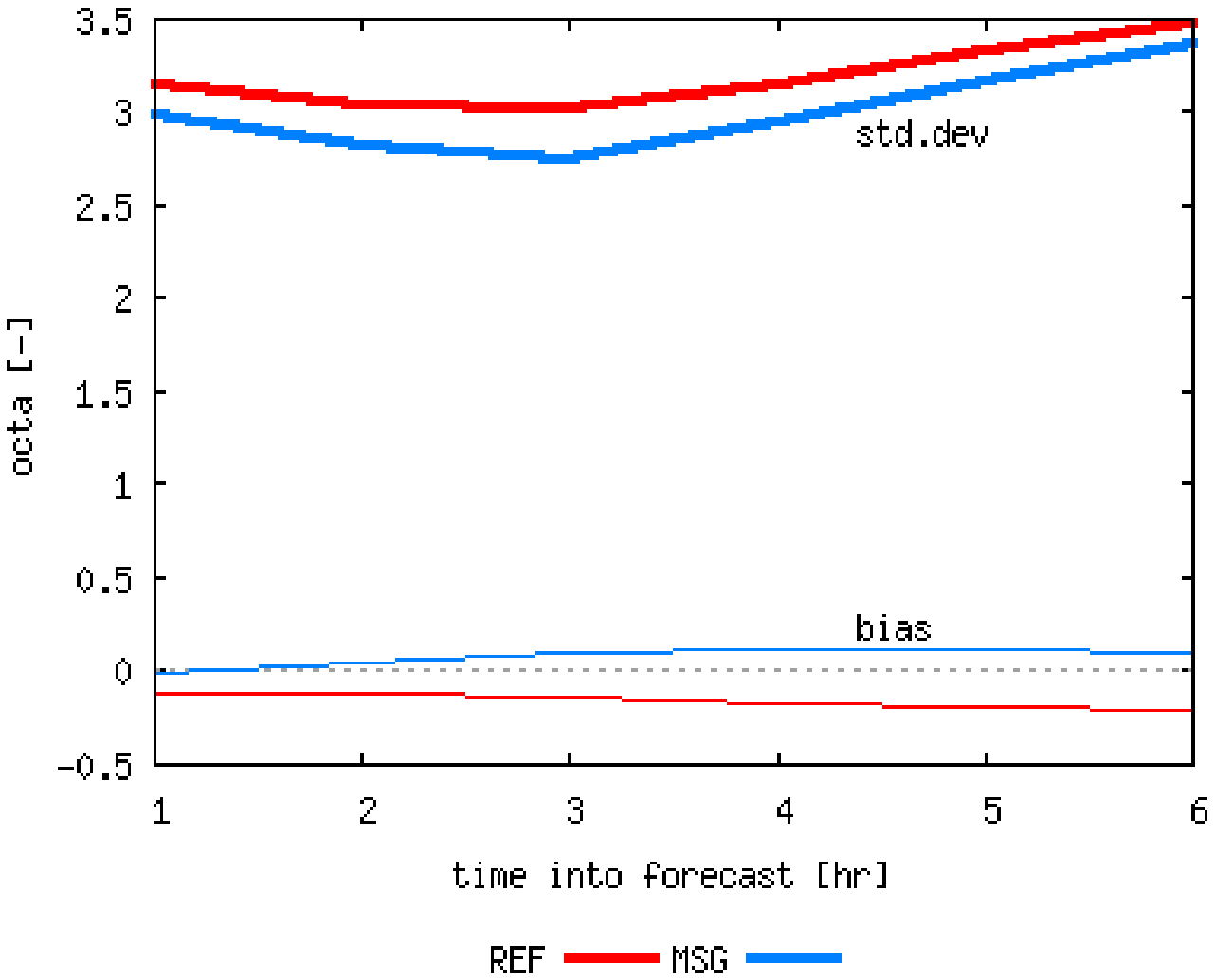


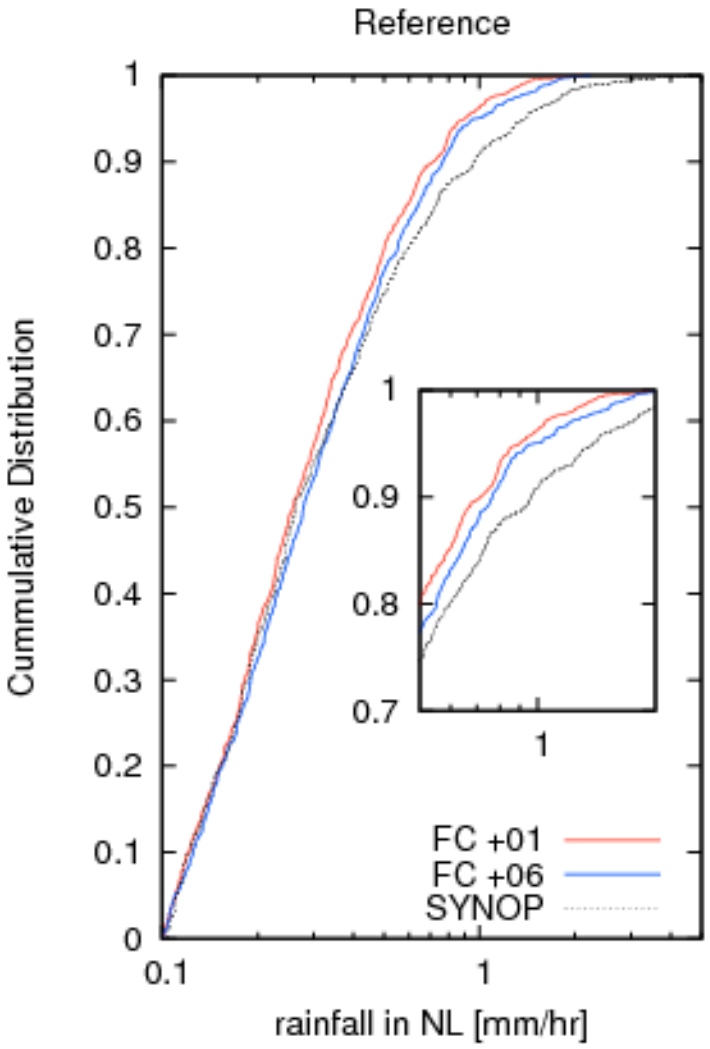
MSG cloud cover 20110915_12+006

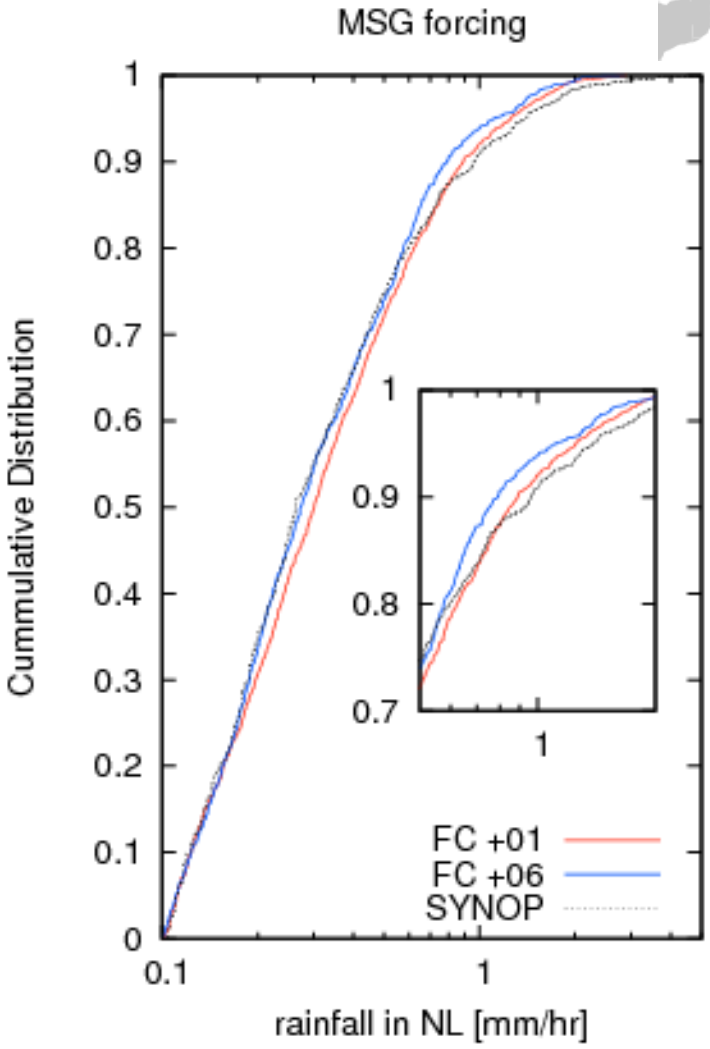


Standard deviation / bias cloudiness averaged over whole period

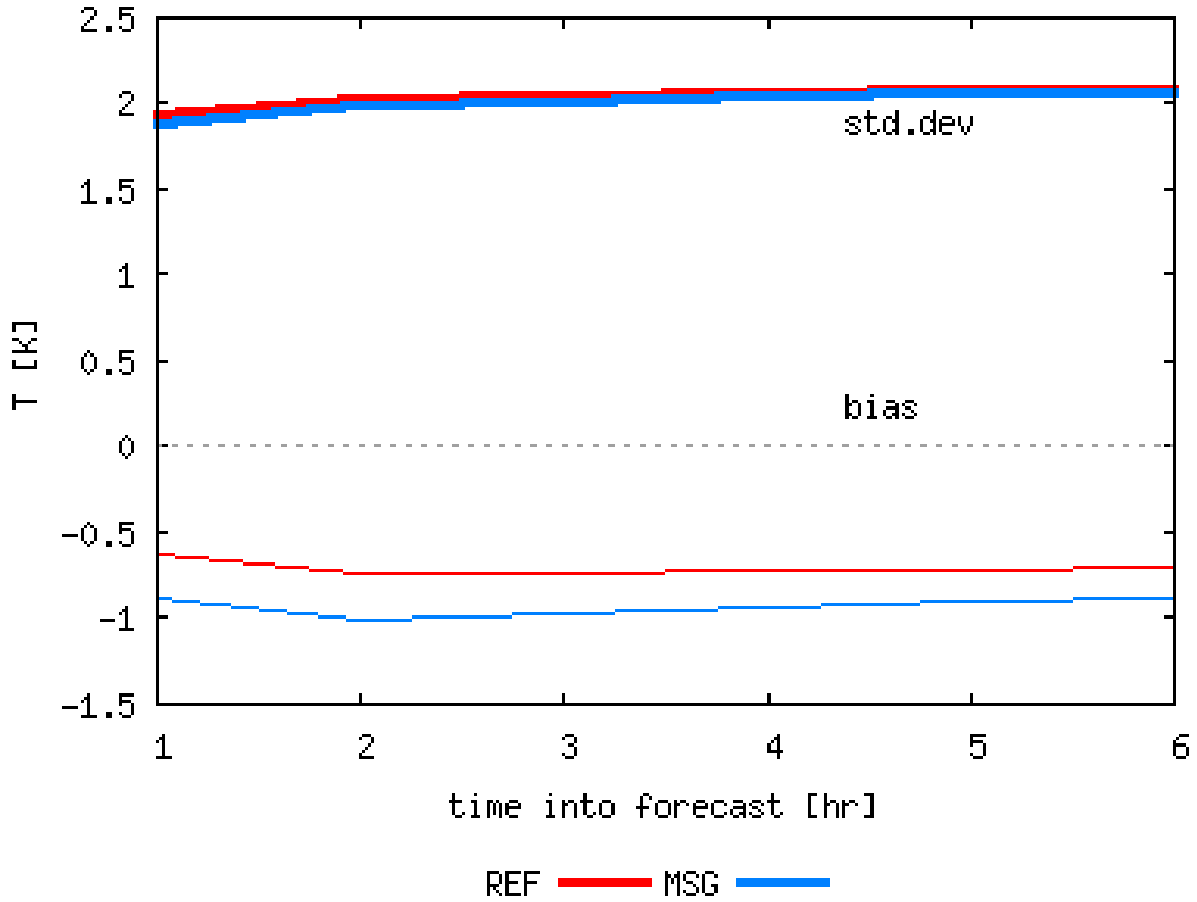


Verification of precipitation forecasts

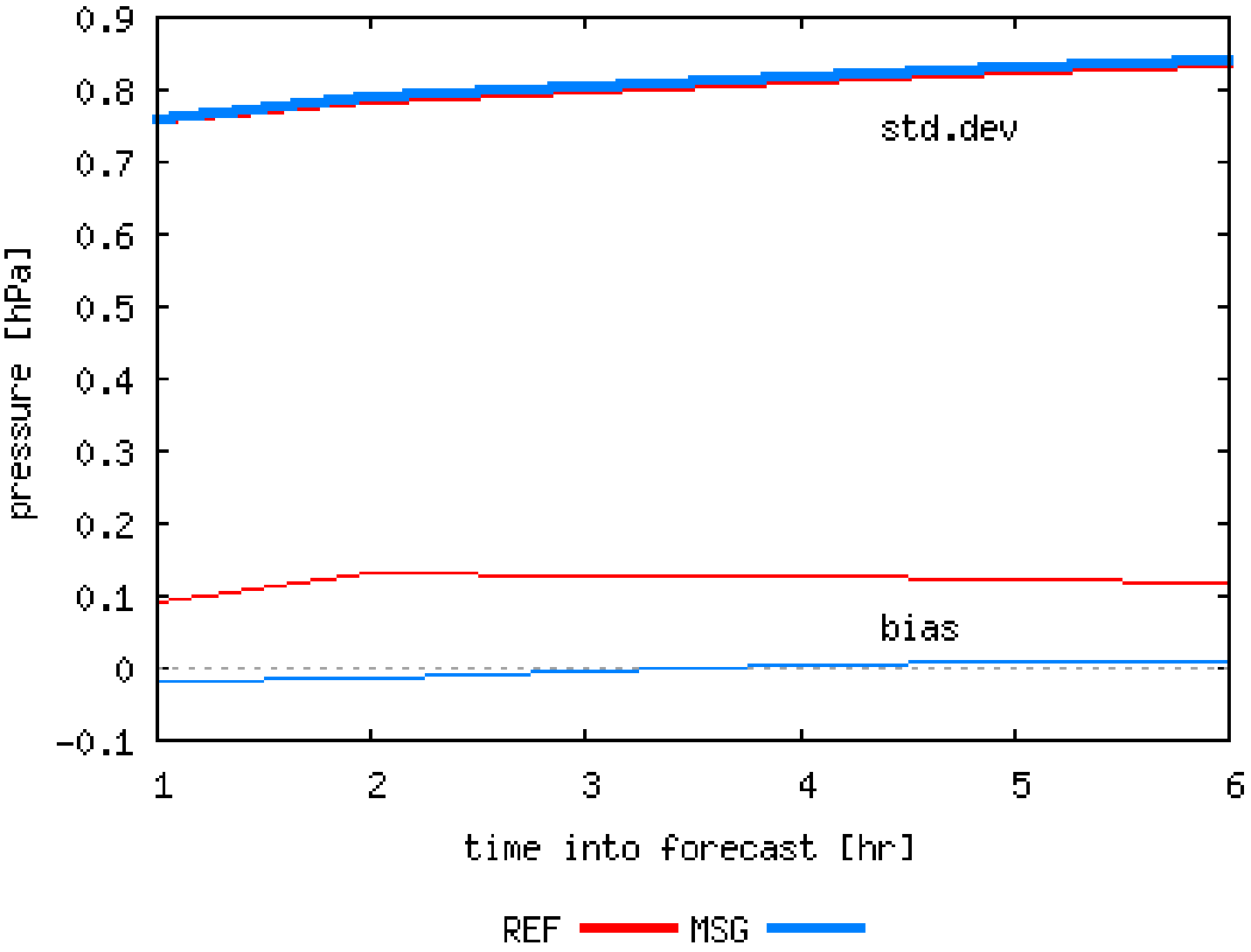




- Verification of 2-m temperatures:
- Standard deviation: slightly better
- Bias: worse! *(radiation module?)*



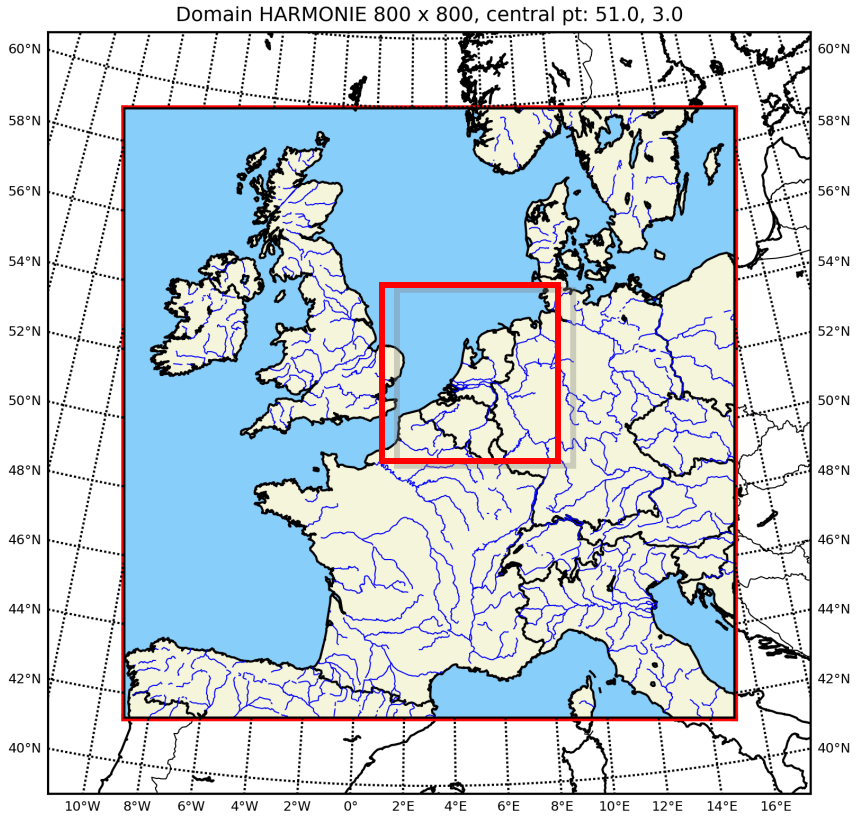
Verification of forecast surface pressure:



Summary

- Hourly HIRLAM beneficial for ATC/CDA
  - Improved wind forecasts for real-time usage
- Use of GNSS observations essential for humidity/rainfall forecast
- Use of radar radial winds improves the wind forecast (locally)
- MSG initialization
  - improves cloud cover forecast even up to 6 hour (not shown)
  - Positive effects observed for rainfall rate
- Recycle of HIRLAM to use “delayed” observations
  - Radiosondes
  - AMSU-A
  - Bias corrections for AMSU-A and SEVIRI seems necessary
- More observations from surrounding countries:
  - radars (BEL/FRA/GER/UK)
  - Mode-S observations

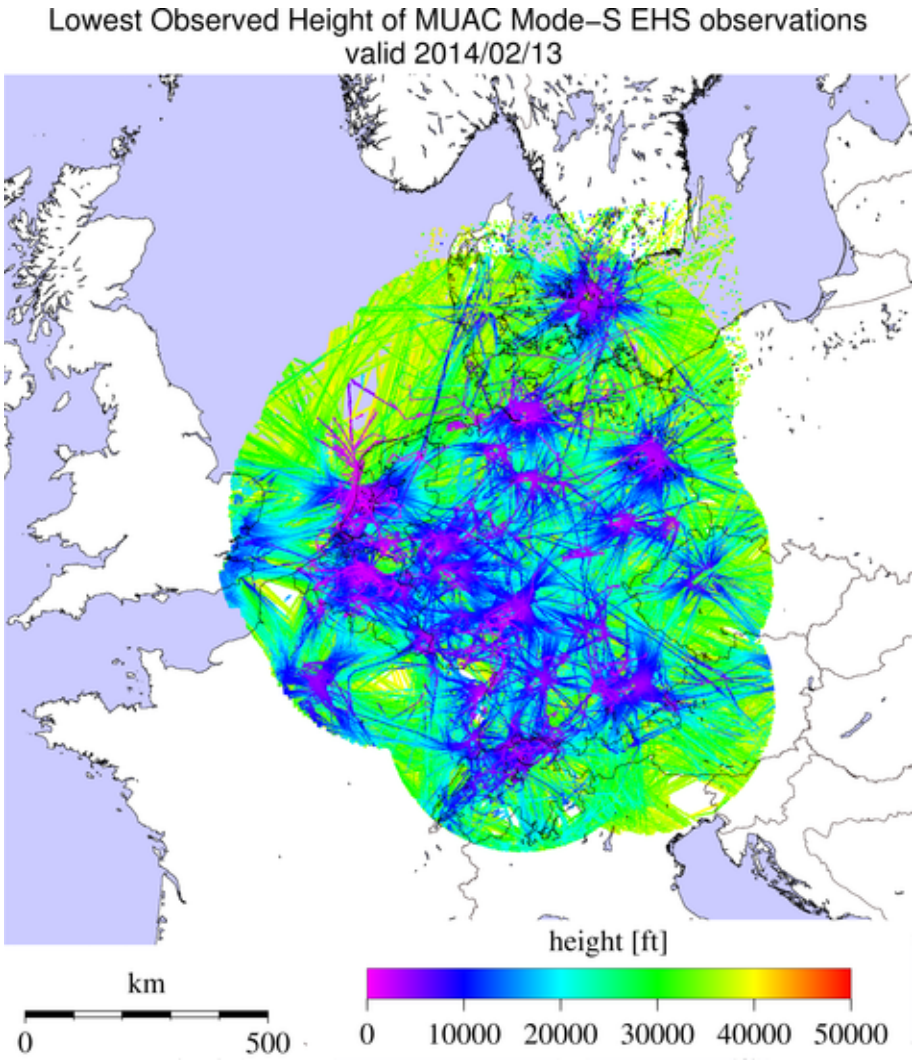
- **Three Harmonie runs**
  - (semi) operational
  - Default synoptic observations
  - **HarOper** (large area)
    - Cycle 36h1.4
    - Three hour cycle
    - Hirlam boundaries
  - **HarRUC** (small area)
    - Cycle 37h1.2
    - Hourly cycle
    - ECMWF boundaries
    - Thinned MUAC Mode-S EHS
    - Radar radial velocities
    - No radiosonde
  - **Har4DVAR** (small area)
    - Cycle 37h1.2
    - Three hour cycle
    - ECMWF boundaries
    - Thinned MUAC Mode-S EHS
      - Every 20 minutes!
    - Radiosonde



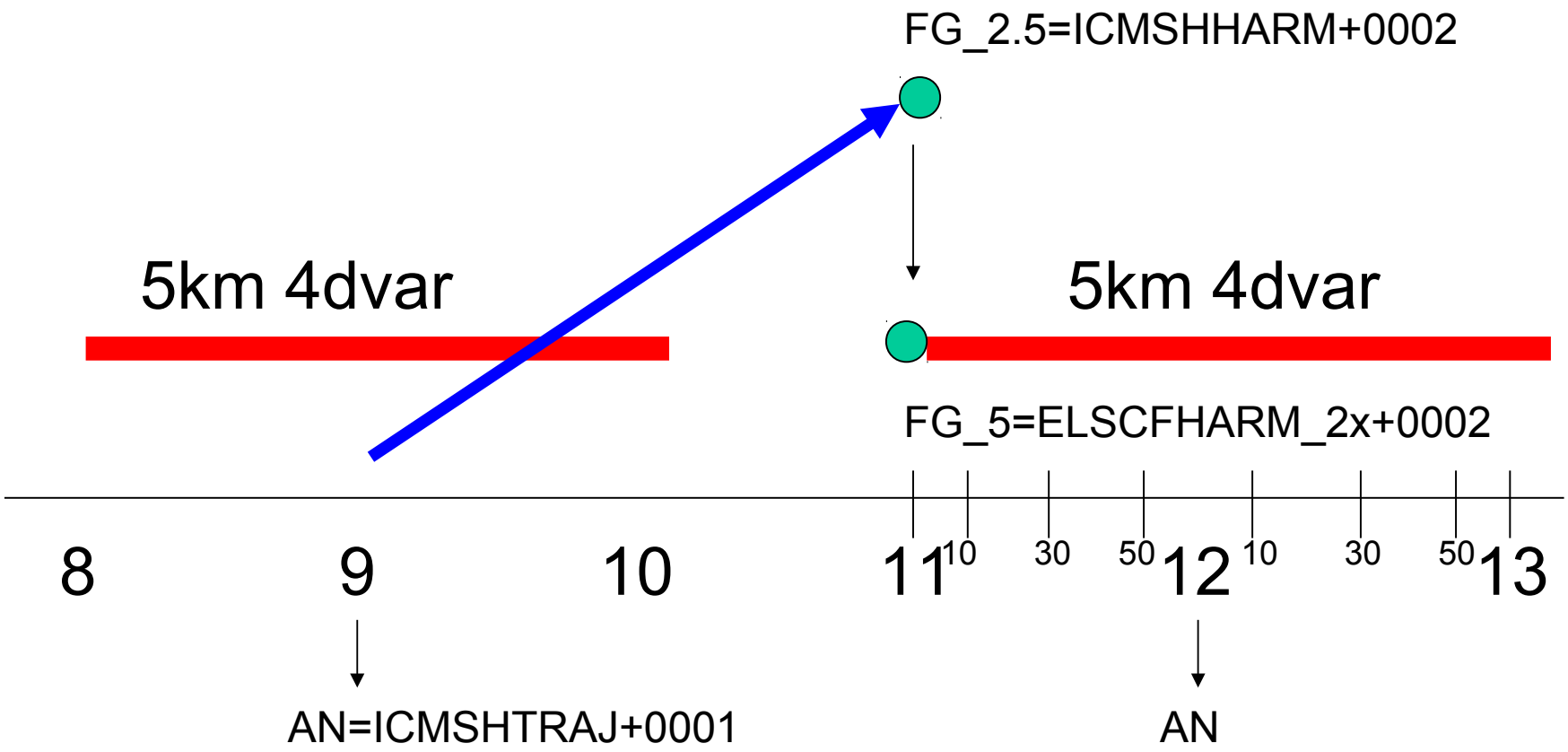
Mode-S EHS

Agreement with EUROCONTROL

- Every 15 minutes (u,v,T)
- All ATC radar information from
  - 2 Belgian
  - 1 Danish
  - 6 Dutch
  - 12 German
- 12 minutes latency
- Anonymous ICAO-id
- http://mode-s.knmi.nl



4D-VAR setup


FG_2.5=ICMSHHARM+0002
5km 4dvar
5km 4dvar
FG_5=ELSCFHARM_2x+0002
8
9
10
11
10
30
50
12
10
30
50
13
AN=ICMSHTRAJ+0001
AN

NOT fair comparison!!

Period: 17 Jan – 14 February 2014

Only Dutch surface wind observations

Collocation of all three runs

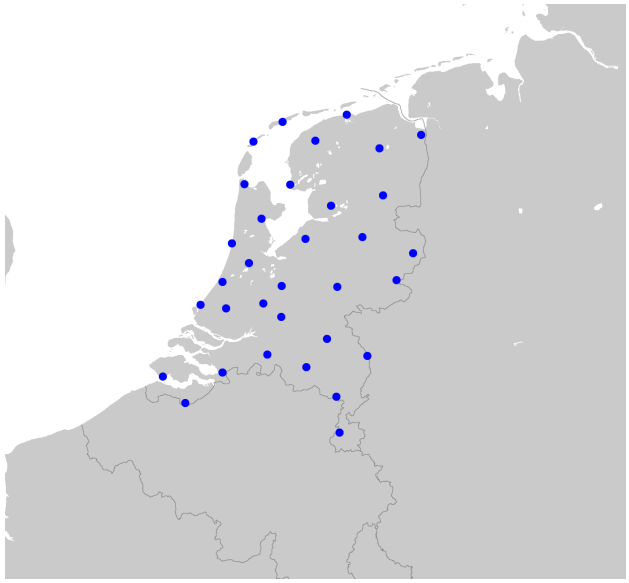
- Wind direction

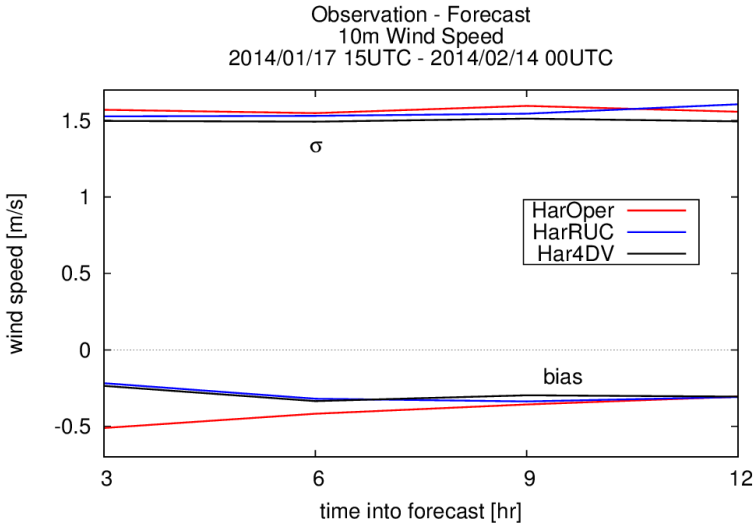
  bias is reduced for Har4DVAR

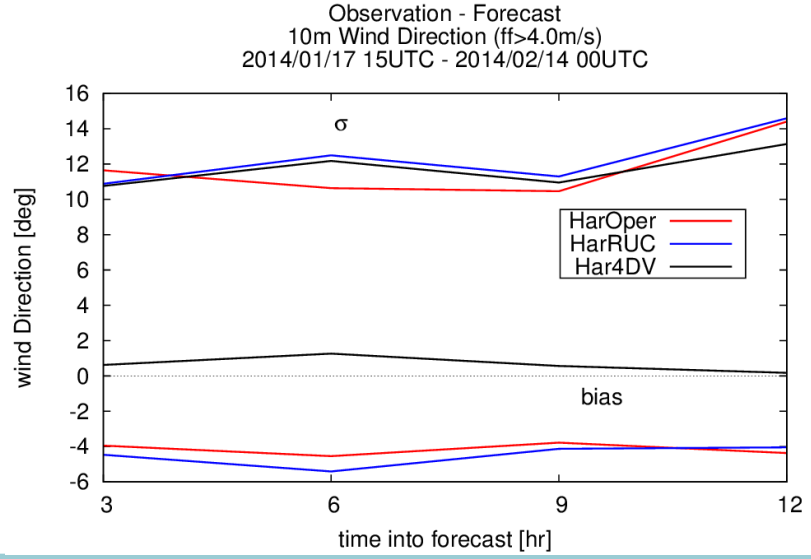
- Wind speed

  standard deviation is slightly smaller for Har4DVAR

  Bias is reduced in the first hours for Har4DVAR and HarRUC







Conclusions

Positive impact on wind forecast

- Hirlam: 1 hour cycle with MUAC data shows a positive impact up to 9 hours compared to 3 hour cycle
  - More data from a large area is better!
- Harmonie (no fair comparison!)
  - 3DVAR one/three hour cycle
    - Improved observation minus background statistics when compared to AMDAR observations
  - 4DVAR three hour cycle
    - System is working and shows promising results

ATC : Continuous Descent Approaches profits from improved “nowcasting” of wind and temperature

Mode-S EHS observations after corrections:

Quality of Temperature compared to ECMWF

- small bias
- Standard deviation larger than AMDAR

Quality of Wind information compared to ECMWF

- Small bias
- Standard deviation of around 2 m/s

Available for NMHSs and partner universities/institutes

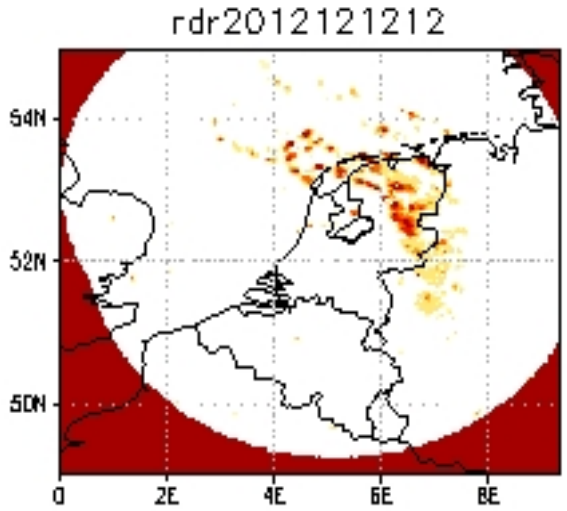
- Non-discloser Agreement
  - DWD, DMI

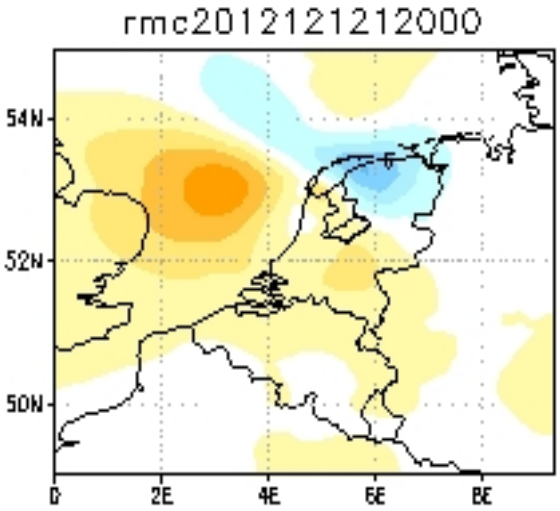
http://mode-s.knmi.nl

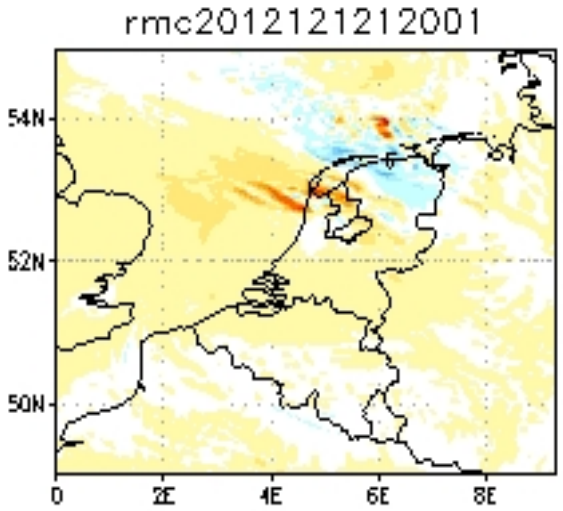
Impact of radar data (radial wind only)

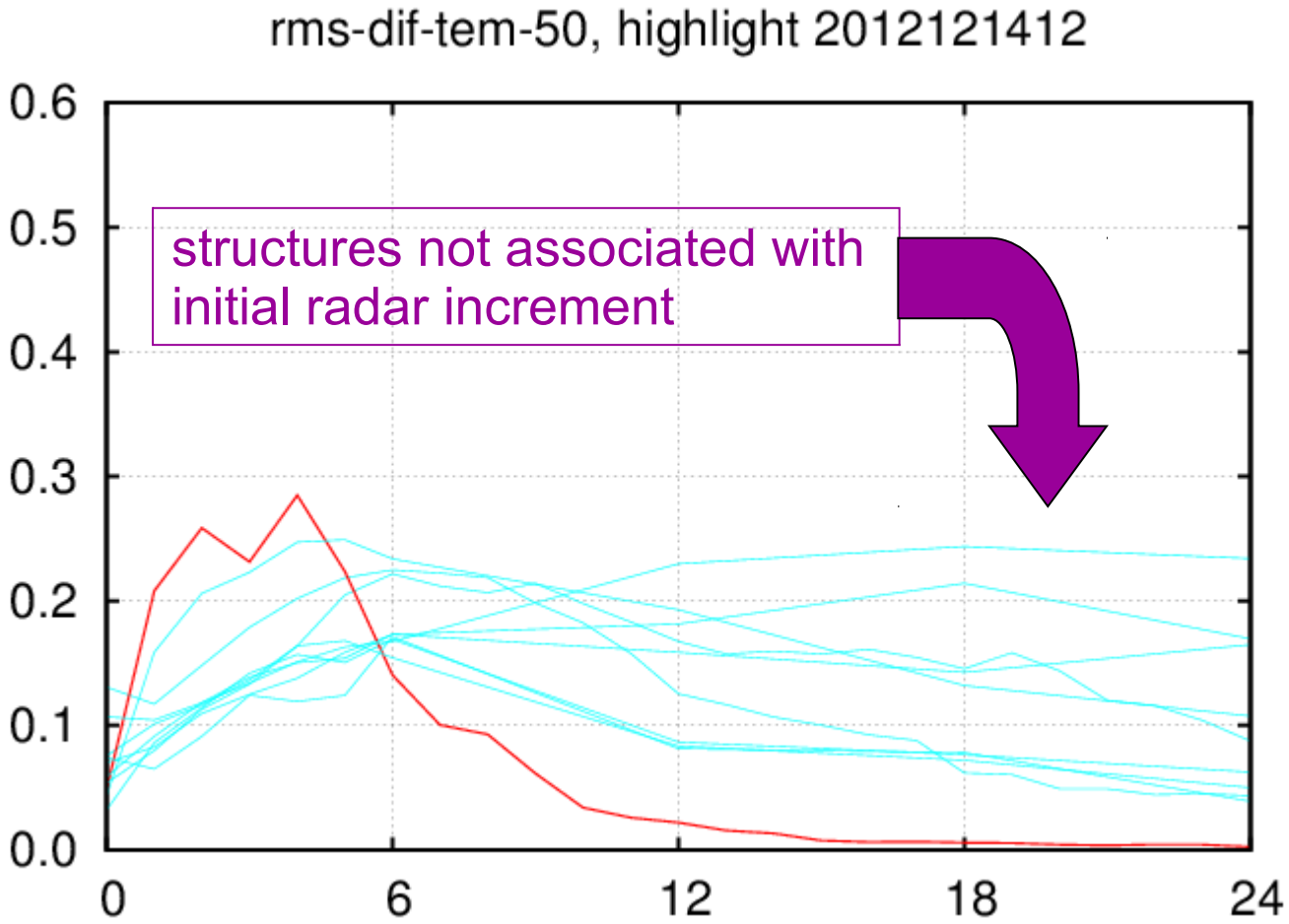
an(radar) - an(no radar)
temperature

1 hour later



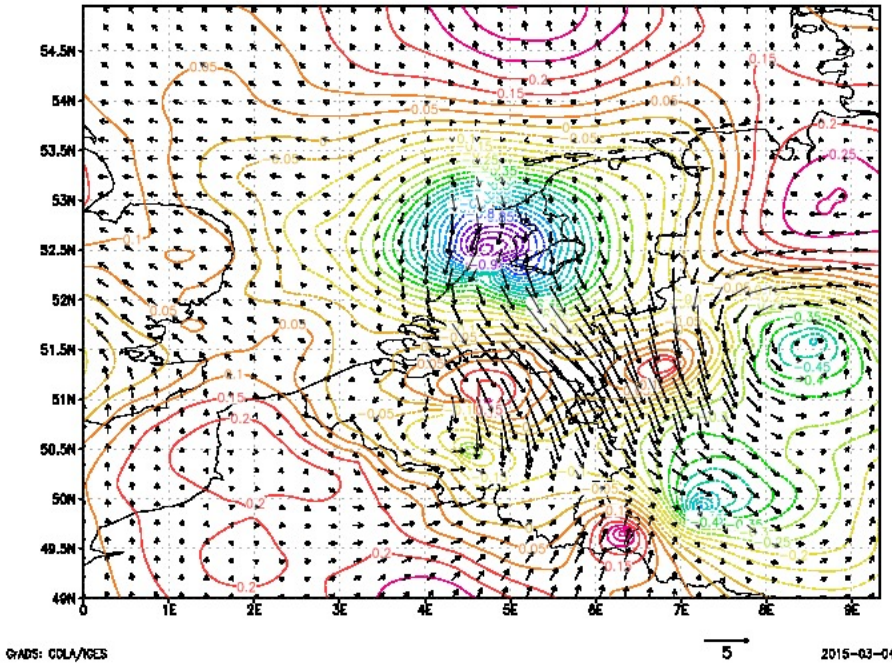




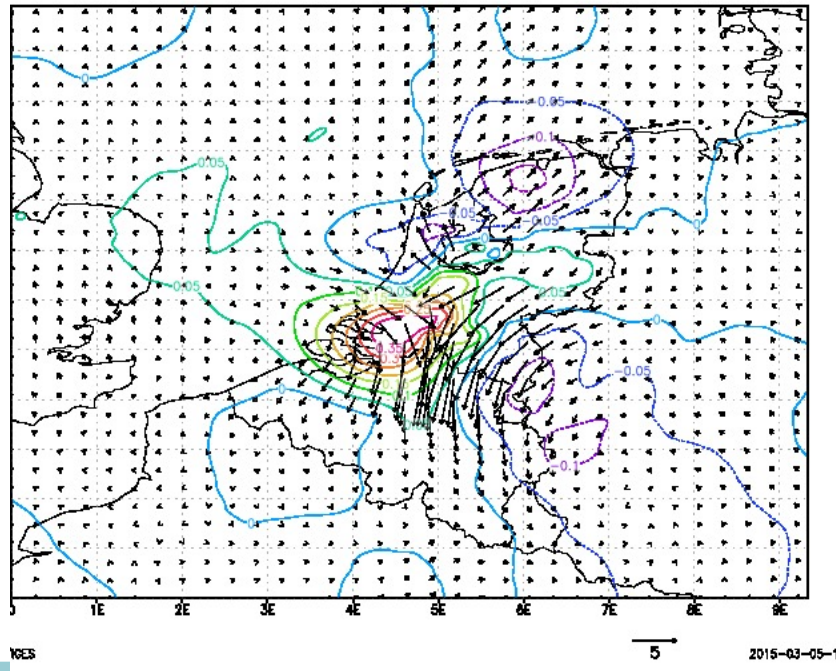

rms-dif-tem-50, highlight 2012121412
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
6
12
18
24
structures not associated with
initial radar increment

Analysis increments (wind and T) due to

Mode-S EHS



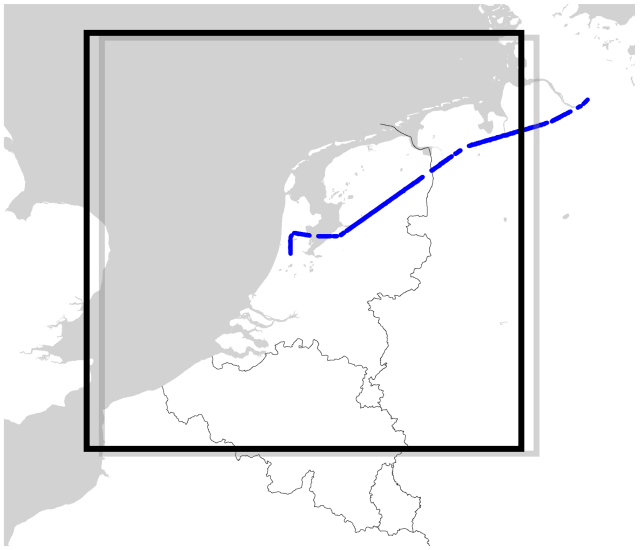
Radar

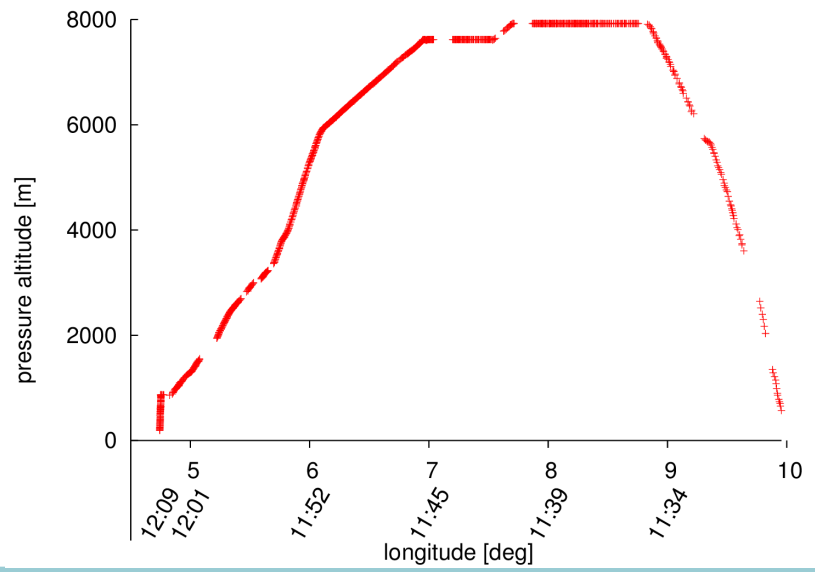


Harmonie 4DVAR

Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

- **4DVAR**
  - Cycle 37h1.2
  - Small area 300x300
  - Inner loop at 5km
  - Observation window 2 hours
  - Cycle 3 hours
  - Observations every 20 min:
    -60' -40' -20' 0 +20' +40' +60'
  - 5km increments added to 2.5 km first guess
  - "single" observation test



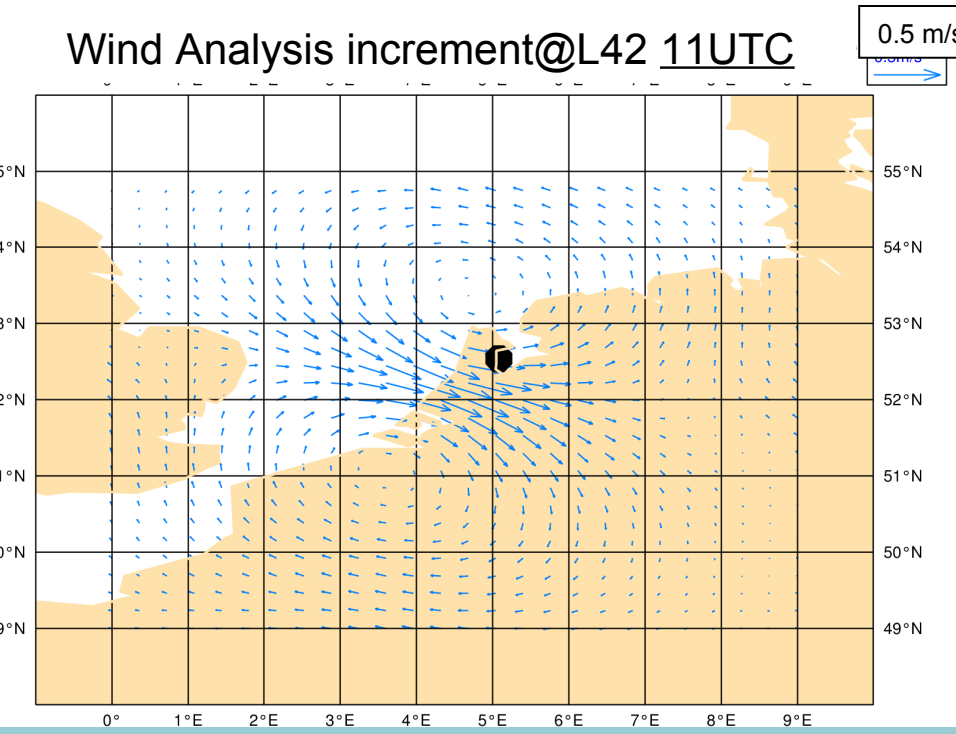


Harmonie 4DVAR
"Single" observation (1.1)

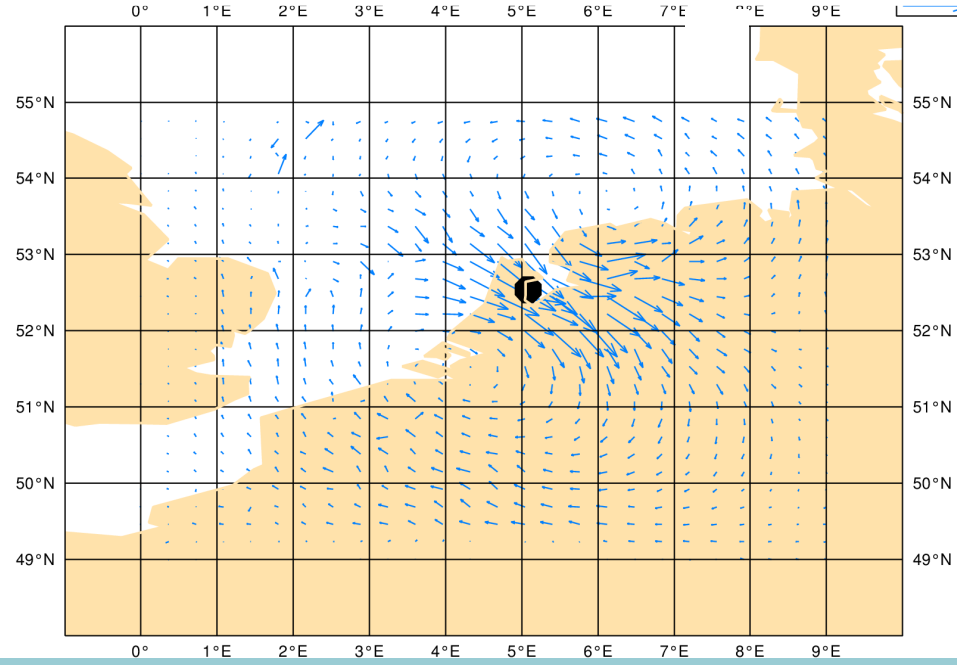
Royal Netherlands
Meteorological Institute
Ministry of Transport,
Public Works and Water Management

- **Assimilation window : 11 UTC – 13 UTC**
- **Temperature and wind observation at 12 UTC**
- **Increment is projected downstream**
- **Maximum wind vector increment is at 12 UTC at observation location**

Wind Analysis increment@L42 11UTC



Wind Analysis increment @L42 12UTC

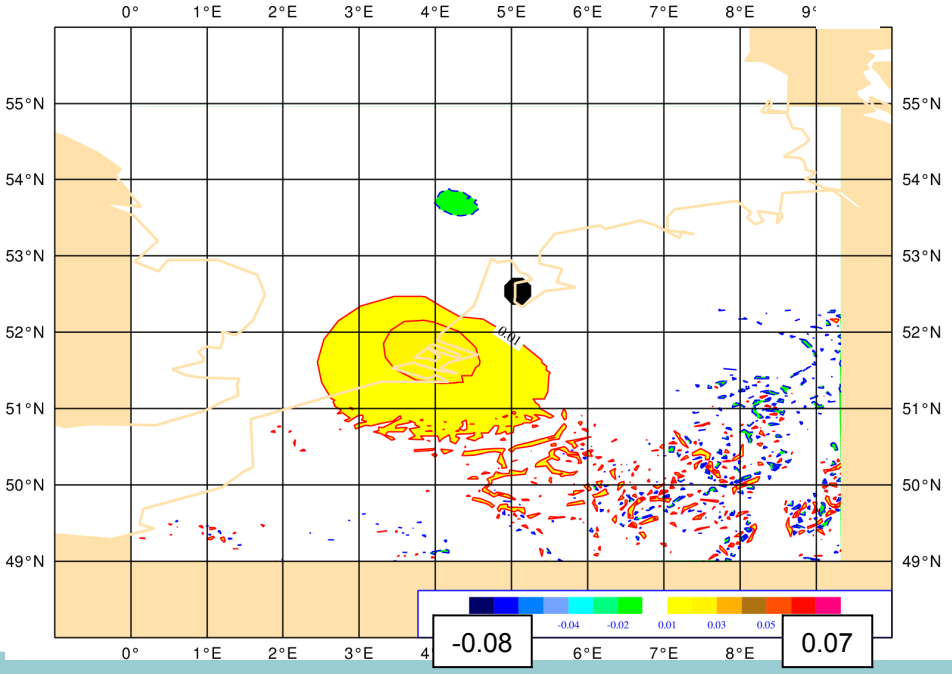


Harmonie 4DVAR
"Single" observation (1.2)

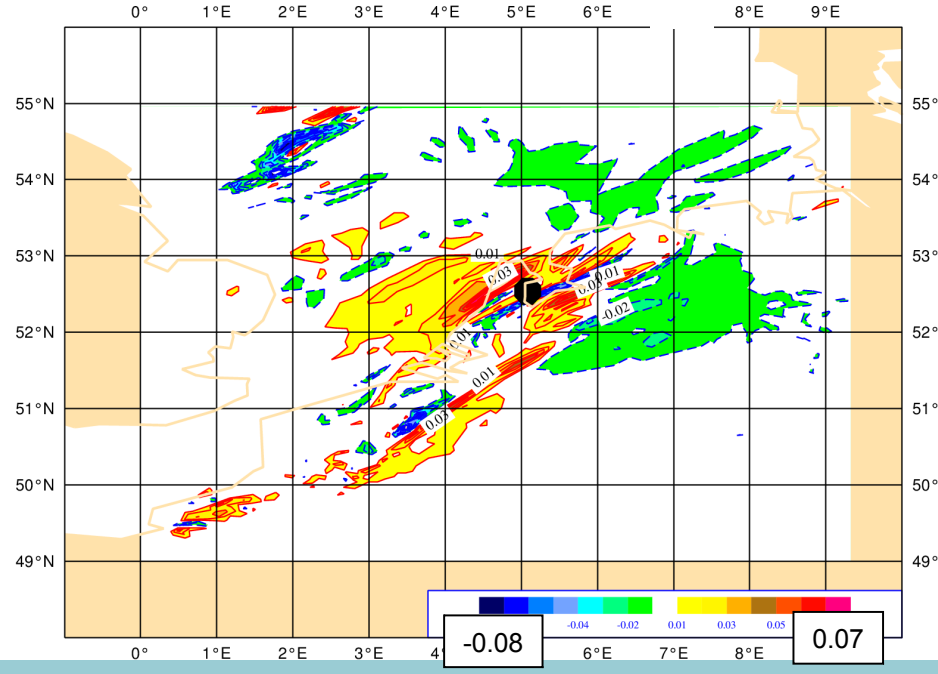
Royal Netherlands
Meteorological Institute
Ministry of Transport,
Public Works and Water Management

- **Increment is projected downstream**
- **Small positive increment**
- **Combined effect of wind and temperature assimilation is observed at 12 UTC**

Temp Analysis increment @L42 11UTC



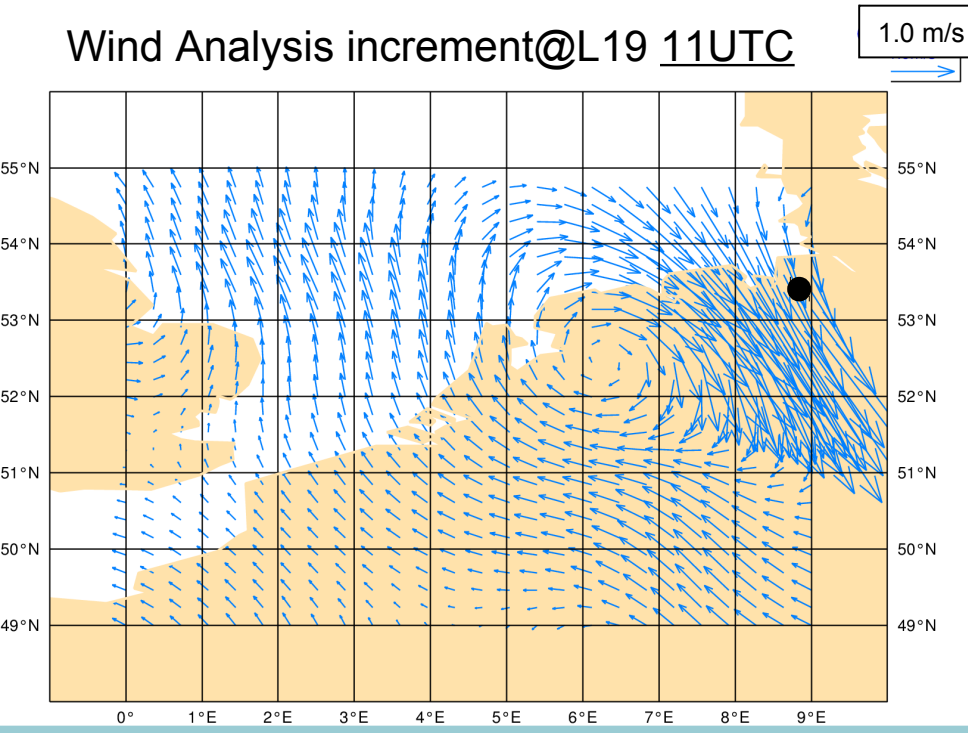
Temp. Analysis increment @L42 12UTC

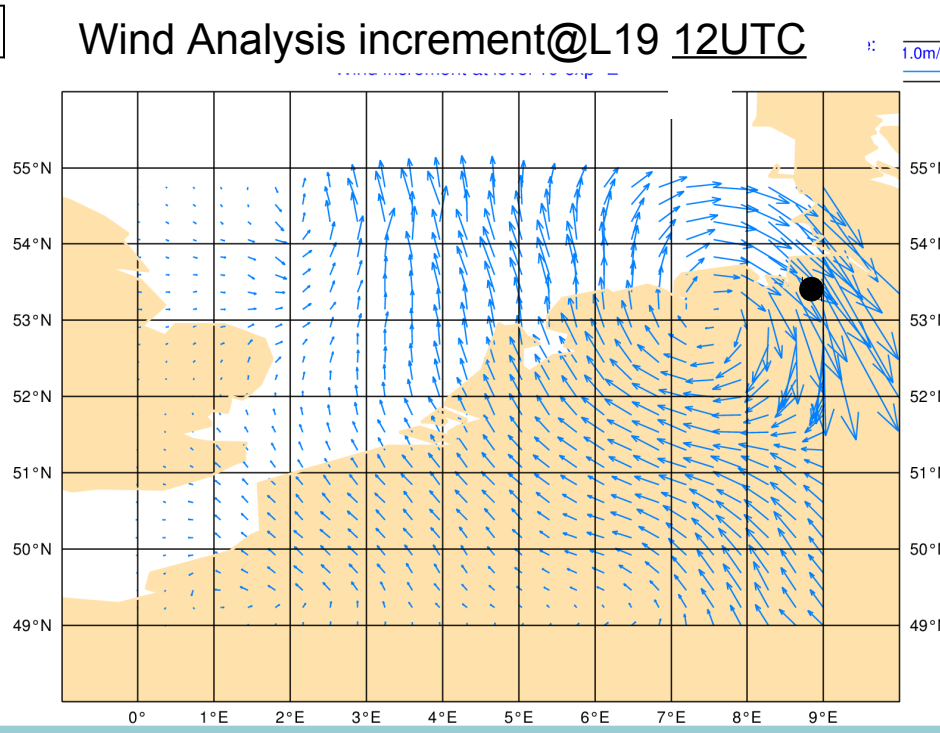


Harmonie 4DVAR
"Single" observation (2.1)

Royal Netherlands
Meteorological Institute
Ministry of Transport,
Public Works and Water Management

- **Observation at 11:34 at the edge of the domain**



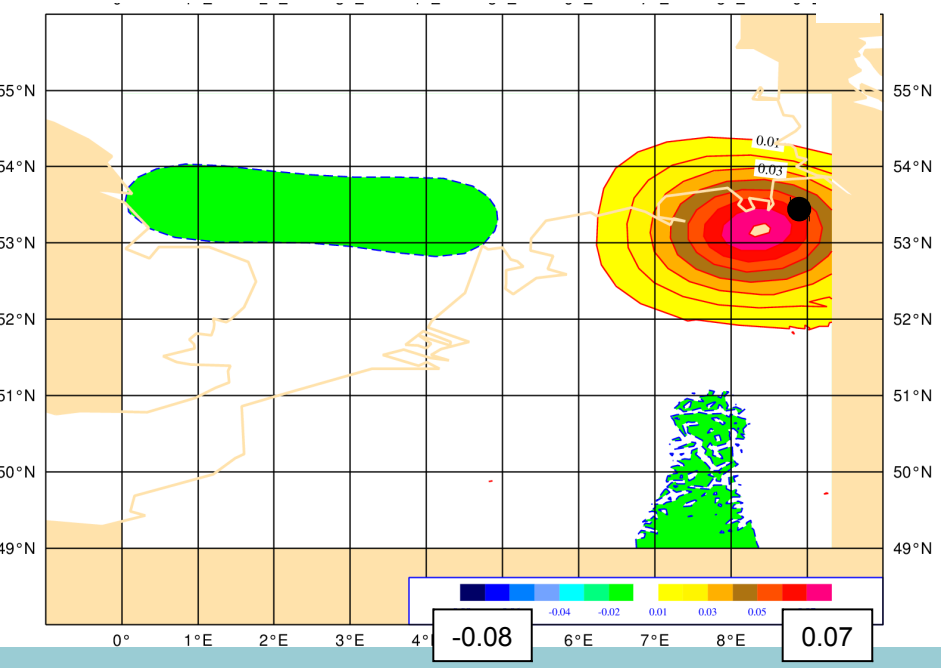


Harmonie 4DVAR
"Single" observation (2.2)

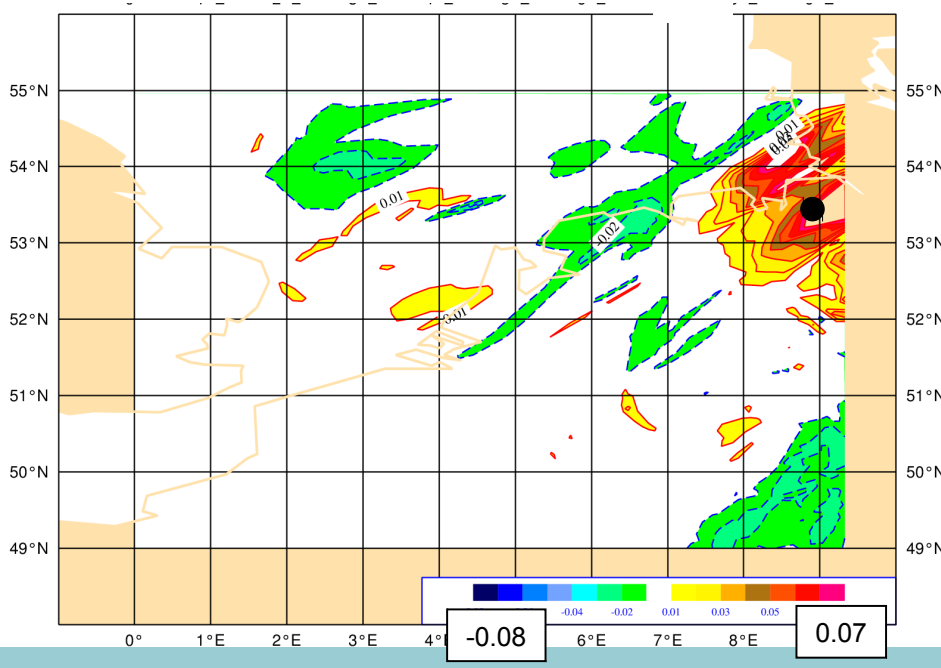
Royal Netherlands
Meteorological Institute
Ministry of Transport,
Public Works and Water Management

- **Observation at 11:34 at the edge of the domain**
- **Symmetric increment at 11 UTC**
- **(Small) edge effect visible (green area's)**

Temp Analysis increment at 11 UTC



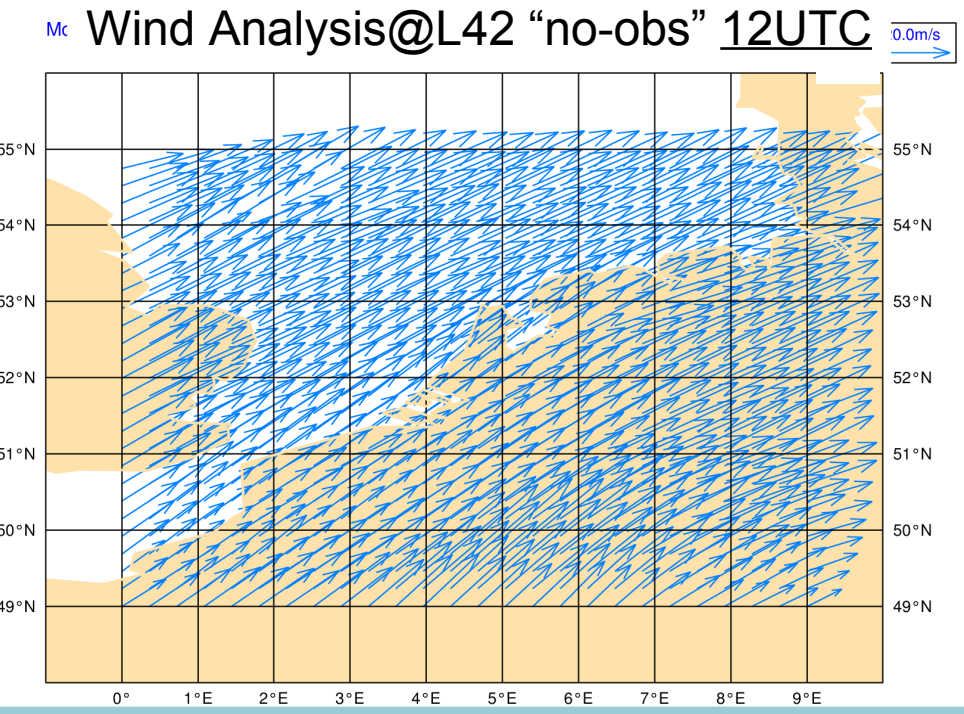
Temp. Analysis increment at 12 UTC

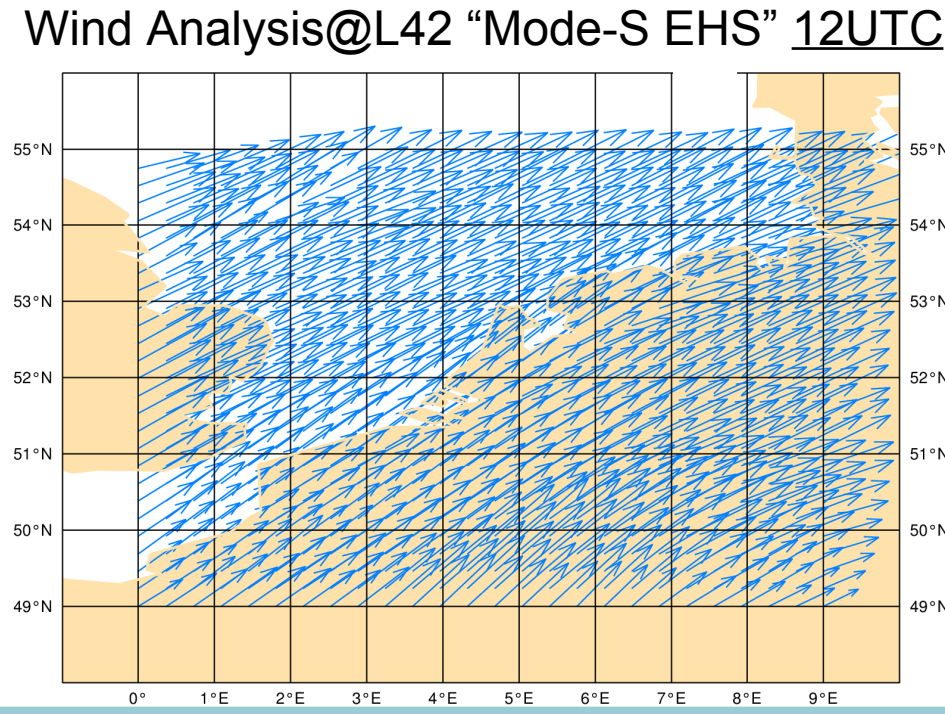


Harmonie 4DVAR single flight obs. (3.2)

Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

- **Assimilation of whole Mode-S EHS flight**
  - 11:34 – 12:09
- **Wind pattern at level 42 (approx 700hPa) is shifted in position**

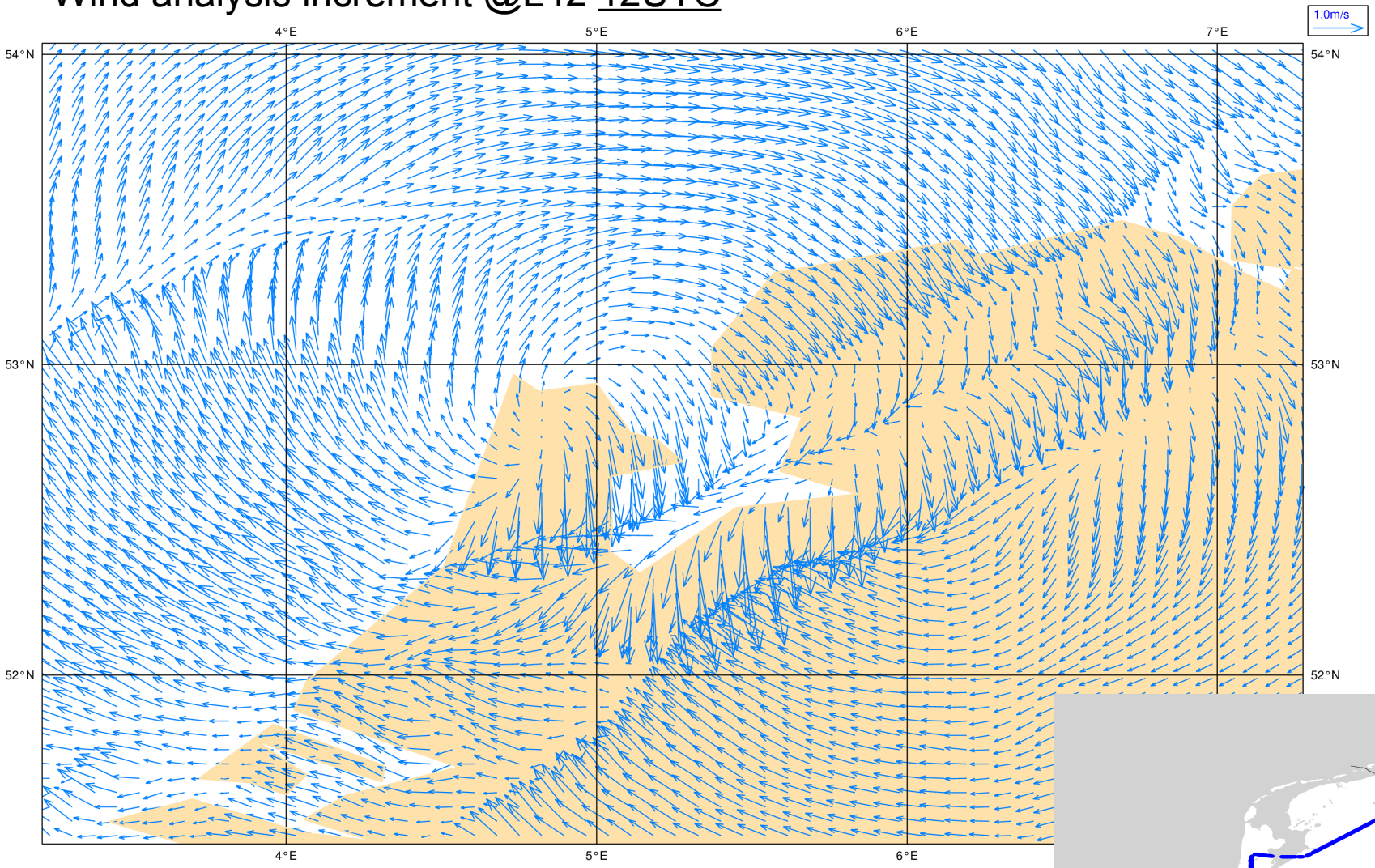


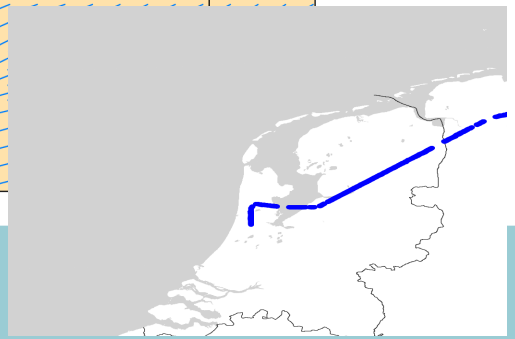


Harmonie 4DVAR single flight obs. (3.1)

Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

Wind analysis increment @L42 12UTC

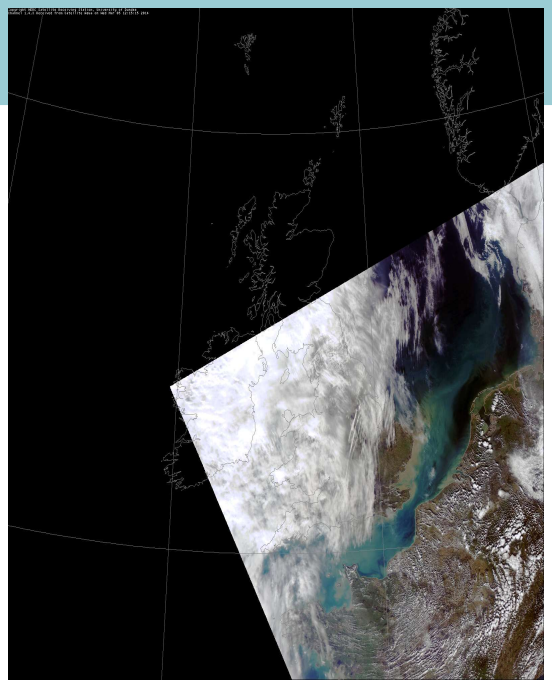




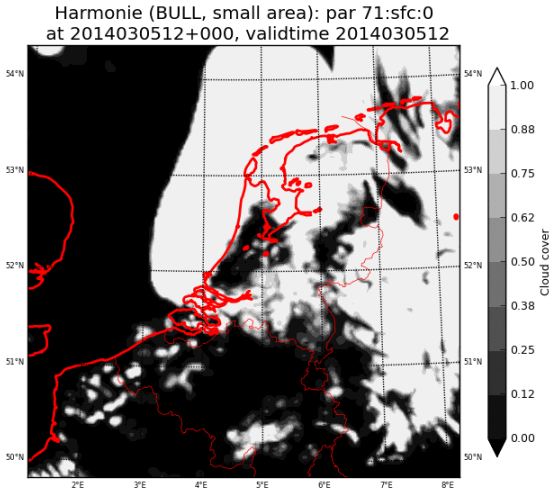
RUNS 5 maart 2014 12UTC +12h

(NB cold start at 2014030312 for (at least) RACMO version)

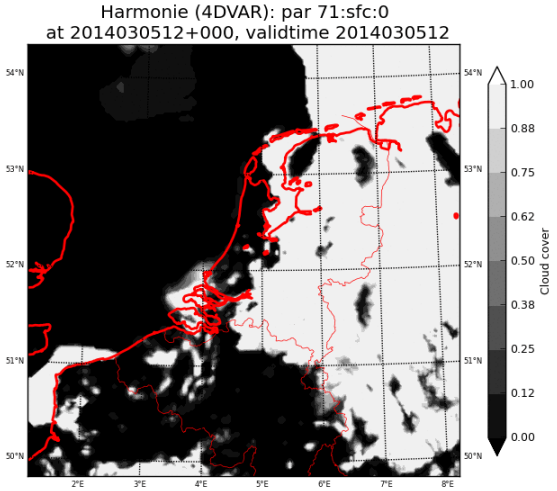
Example of fog caused by initialisation?



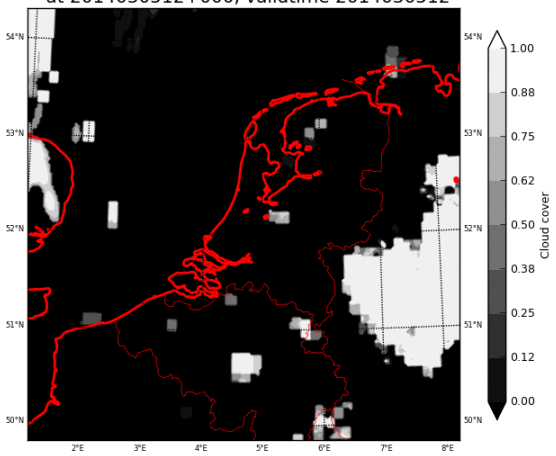
BULLSA



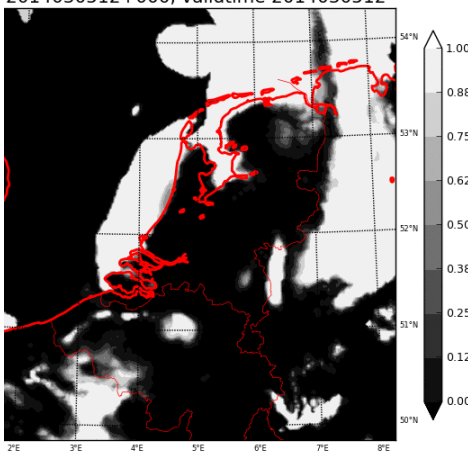
4DVAR



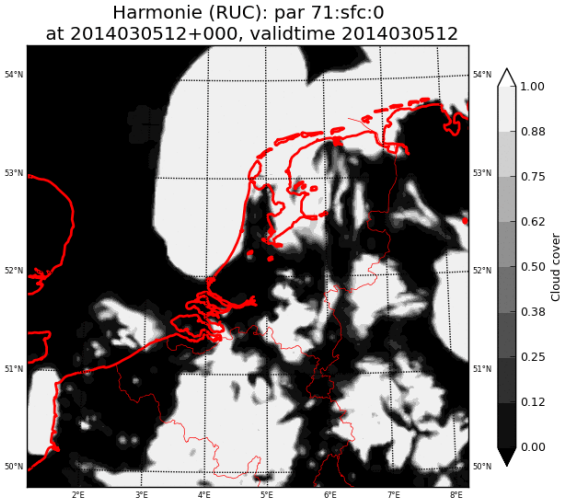
MSG



RACMO



RUC



Future plans

- Restart of a 1-hour RUC HARMONIE suite pending GNSS & radar development and employing cloud masking
- Extend current 4D-Var (frequency, domain, observation types)
- Improve background error statistics (EDA)
- Explore GaussianQuadrature-4D-Var