Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

Experiences with HARMONIE 4D-VAR

HIRLAM-ALADIN meeting
13-16 April 2015
Copenhagen, Danmark

Jan Barkmeijer
KNMI

Magnus Lindskog
SMHI

and many others!

Brief HARMONIE 4D-Var History

- Nils, Magnus and Ole visit Météo-France 8-12 Dec. 8-12, 2008, to learn how Bernard Chapnik had set up first version of ALADIN 4D-Var (in OLIVE system).
- First HARMONIE 4D-Var working week at met.no June 8-11, 2009 (Nils, Magnus, Ole, Trygve), during which HARMONIE 4D-Var mini-SMS prototype is developed.
- During second working week at met.no Sept. 7-11, 2009 (Nils, Magnus, Ole, Trygve). First working version of HARMONIE 4D-Var is established.
- Third working week at SMHI 30 Nov-4 Dec 2009, was devoted to careful testing of the HARMONIE 4D-Var components. Planning for future developments (multiple outer loop iterations, more advanced simplified physics). HIRLAM, Météo-France and LACE participants.
- Fourth working week at met.no 3-7 May, 2010 (Nils, Magnus, Ole, Trygve, Roger). Work towards introduction of satellite data and phasing to cy 36.
- Fifth working week at SMHI 22-26 November 2010. Cleaning and various enhancemens of HARMONIE 4D-Var. HIRLAM and LACE (Météo-France in teleconference part).
- Assimilation experiments carried out during 2011 demonstrated encouraging results for HARMONIE 4D-Var using ALARO together with ISBA surface scheme.
- Sixth 4D-Var working week at Oslo, Norway, 7-11 Nov, 2011. HIRLAM staff resources put on 4D-Var decreased and focus completely on AROME 4D-Var.
- During 2013 Jan and Magnus have worked together with AROME 4D-Var.
  Working HARMONIE CY37 version in 2014 and modset communicated with MF
- Begin 2015 Jan, Magnus and Ulf, with help from Pierre Brousseau, **try to get 4DVAR working in HARMONIE CY38.**

Harmonie 4DVAR

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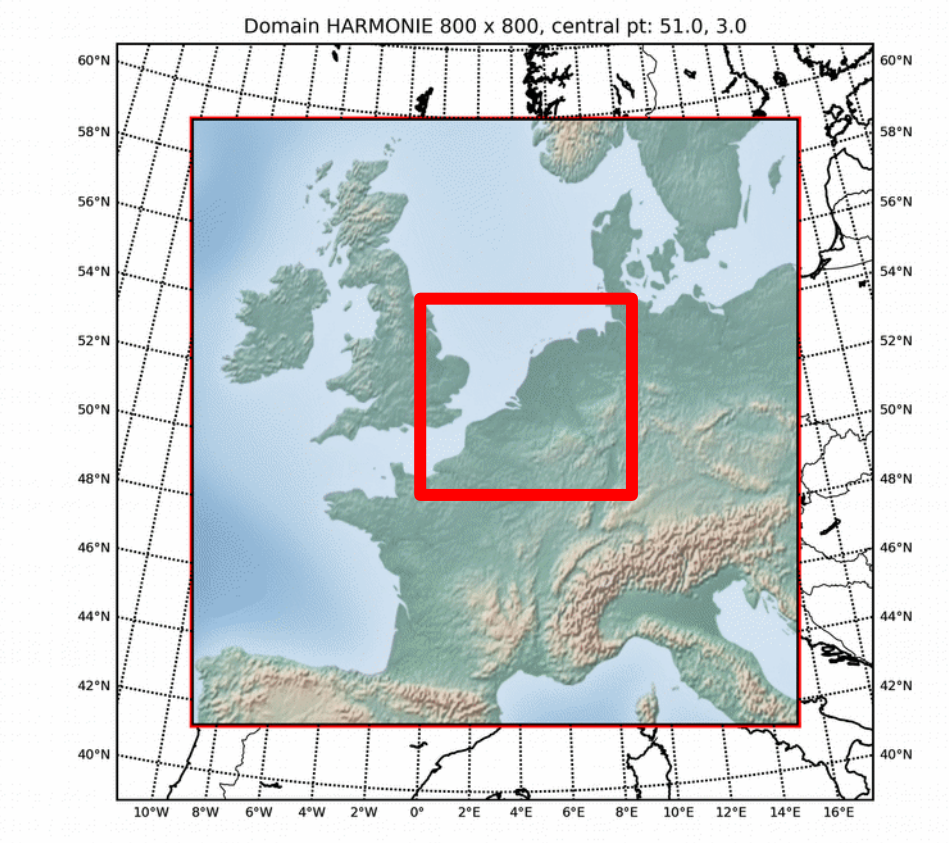
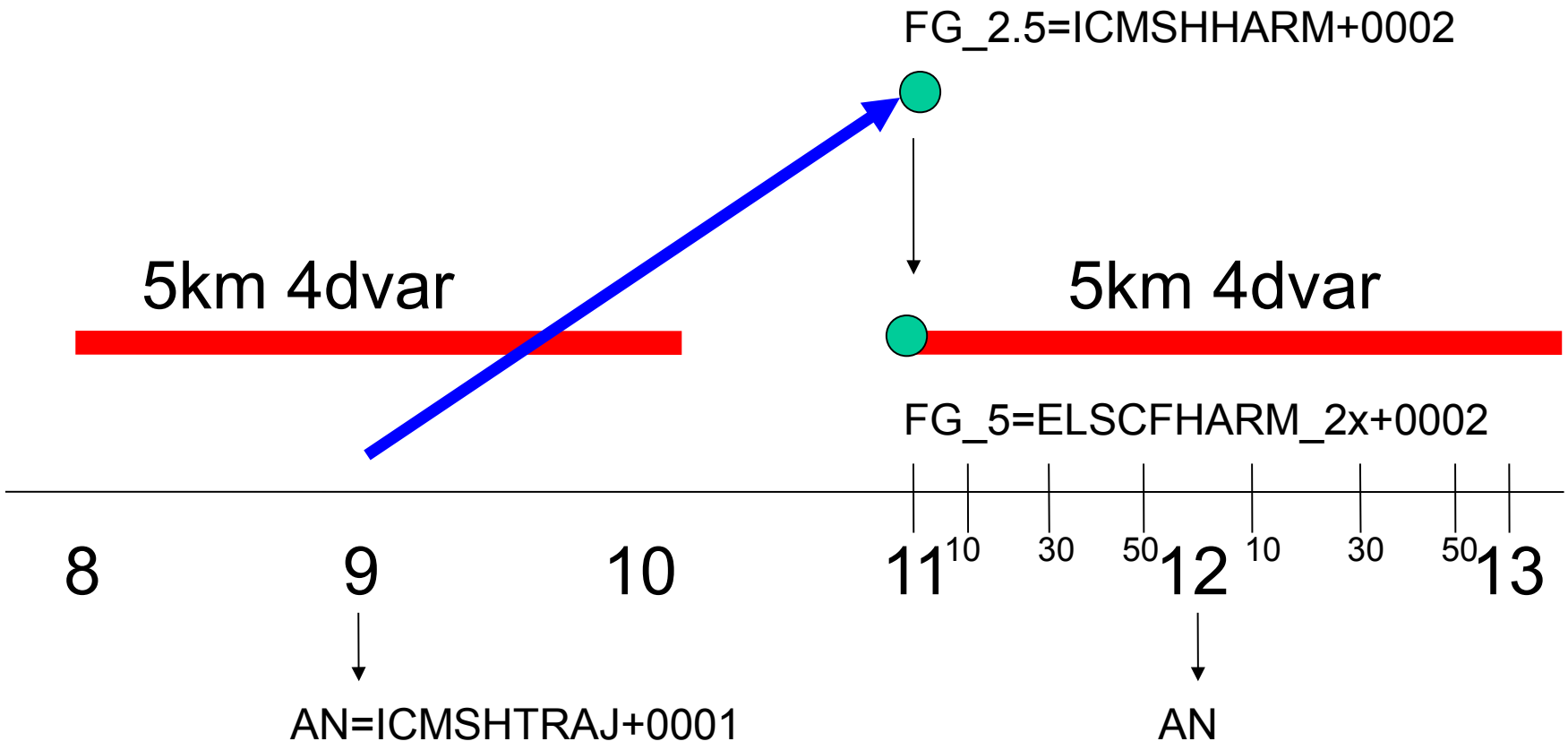
Ministry of Transport, Public Works and Water Management

- Cycle 37h1.2
- Small area 300x300 gp
- Inner loop at 5km
- Observation window 2 hours
- Cycle 3 hours
- Hydrostatic nonlinear run and simplified linear physics
- Observation set: Conventional + Mode-S EHS + (Radar)

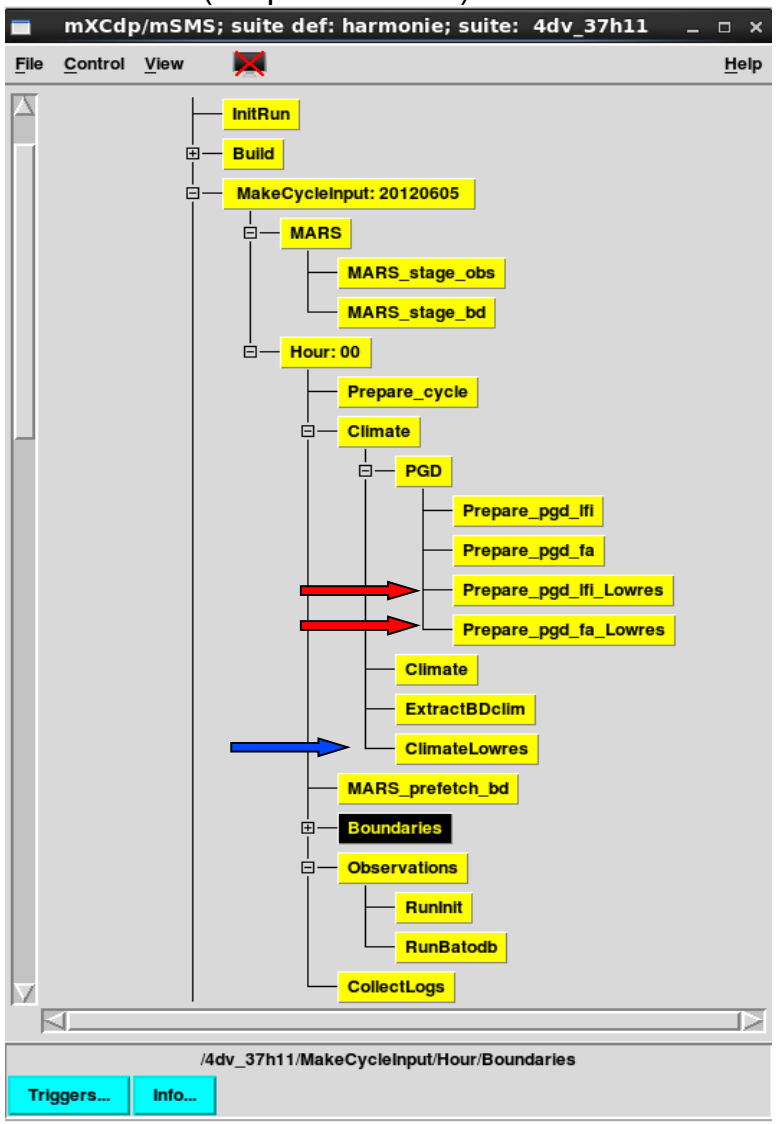


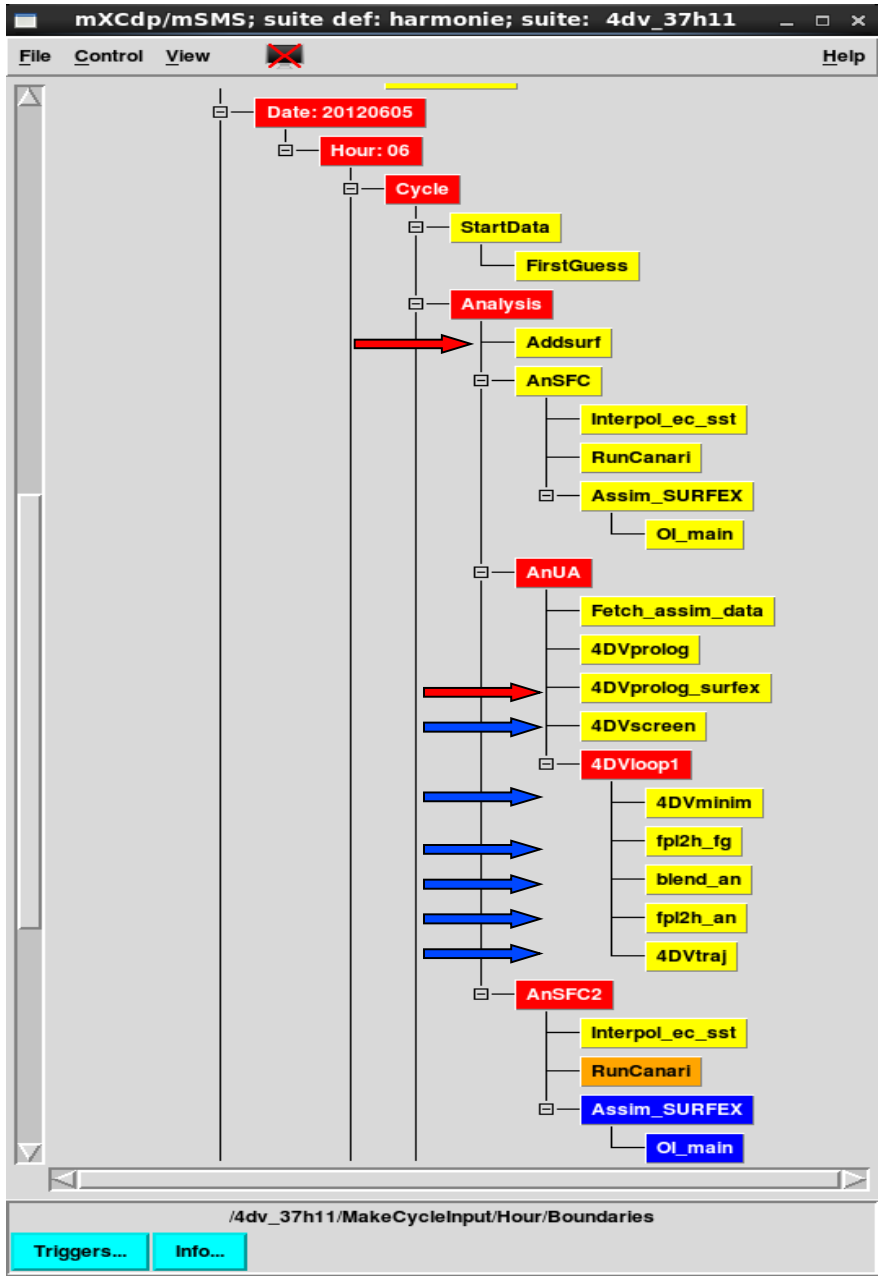
4D-VAR Configuration (2)

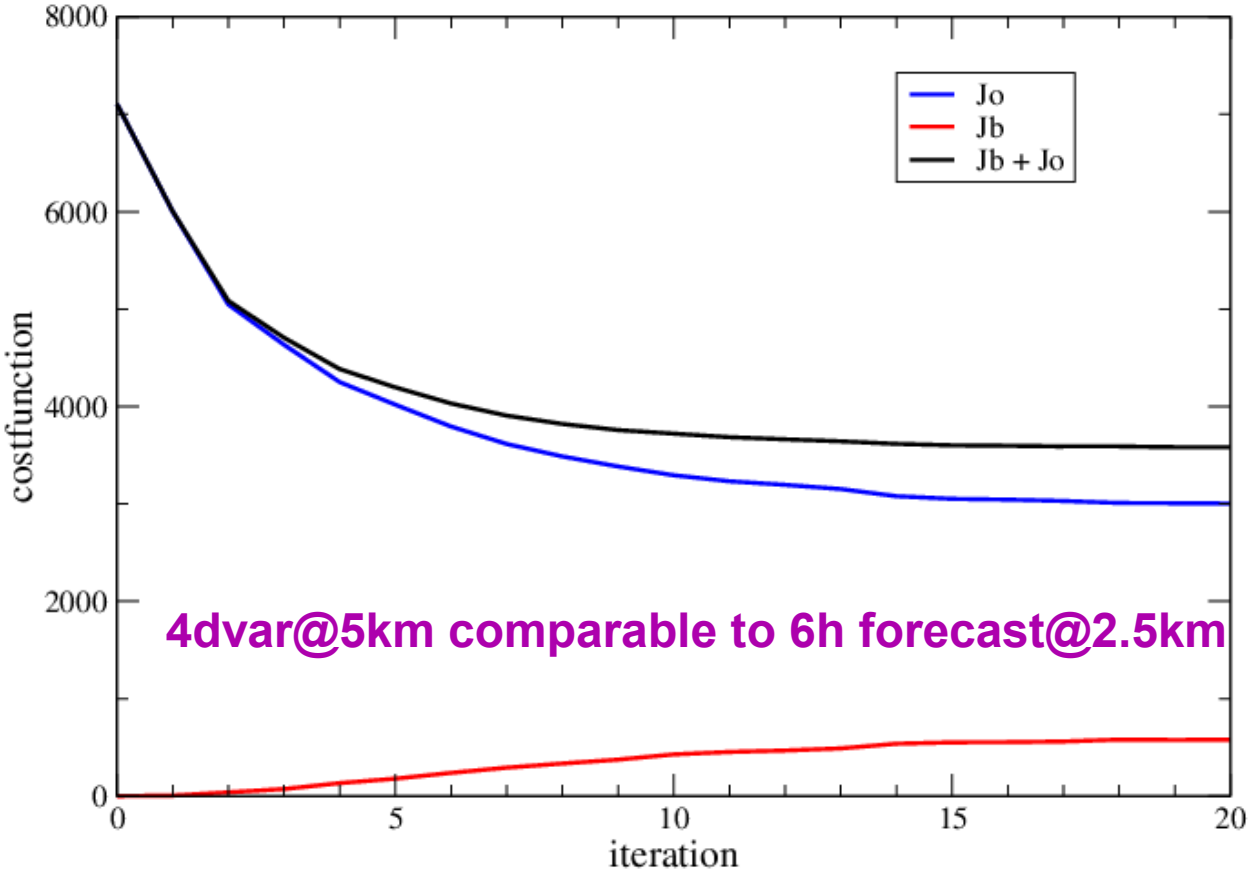


HARMONIE 4D-Var ported to cy 37
Overview of changes needed for AROME and surfex

Modified (script and/or src) New







4dvar@5km comparable to 6h forecast@2.5km

Single obs experiment

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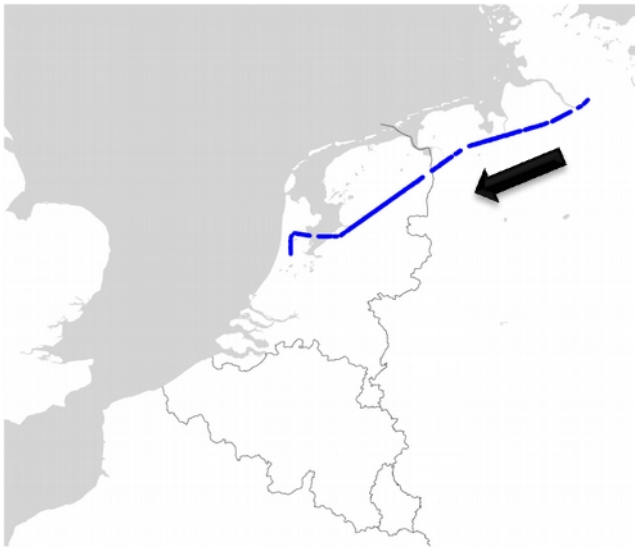
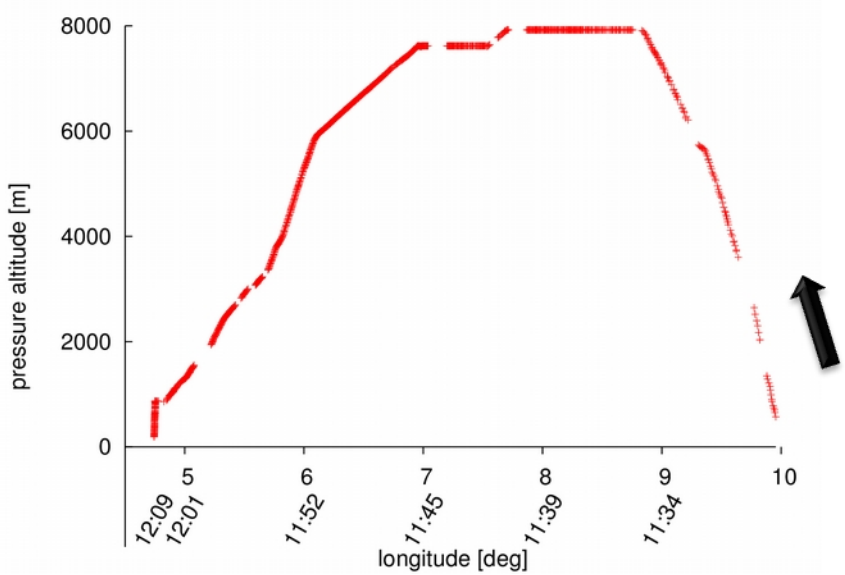
Data: Mode-S EHS (U,V and T)
Obs window is 11-13 UTC





Harmonie 4DVAR
"Single" observation (1.1)

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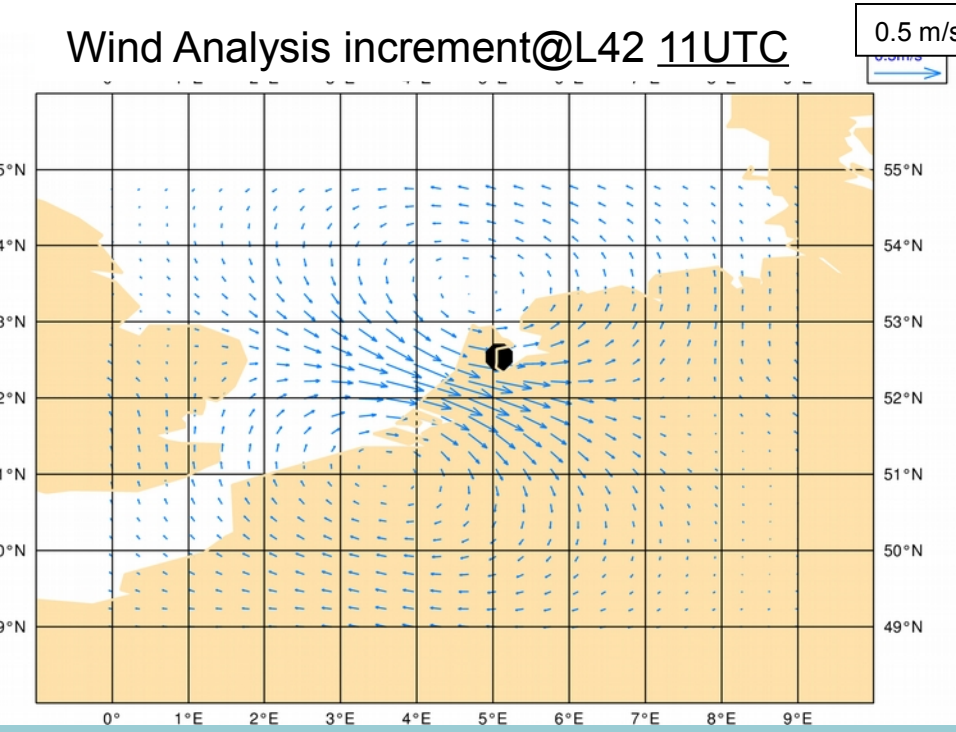
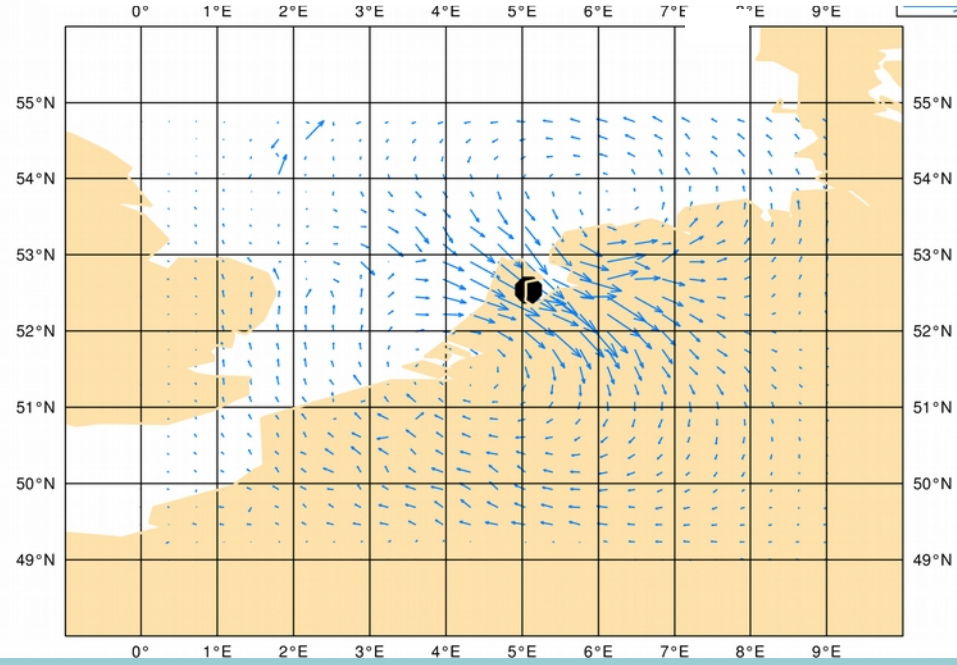
- **Assimilation window : 11 UTC – 13 UTC**
- **Temperature and wind observation at 12 UTC**
- **Increment is projected downstream**
- **Maximum wind vector increment is at 12 UTC at observation location**

Wind Analysis increment@L42 11UTC



Wind Analysis increment @L42 12UTC



Harmonie 4DVAR
"Single" observation (1.2)

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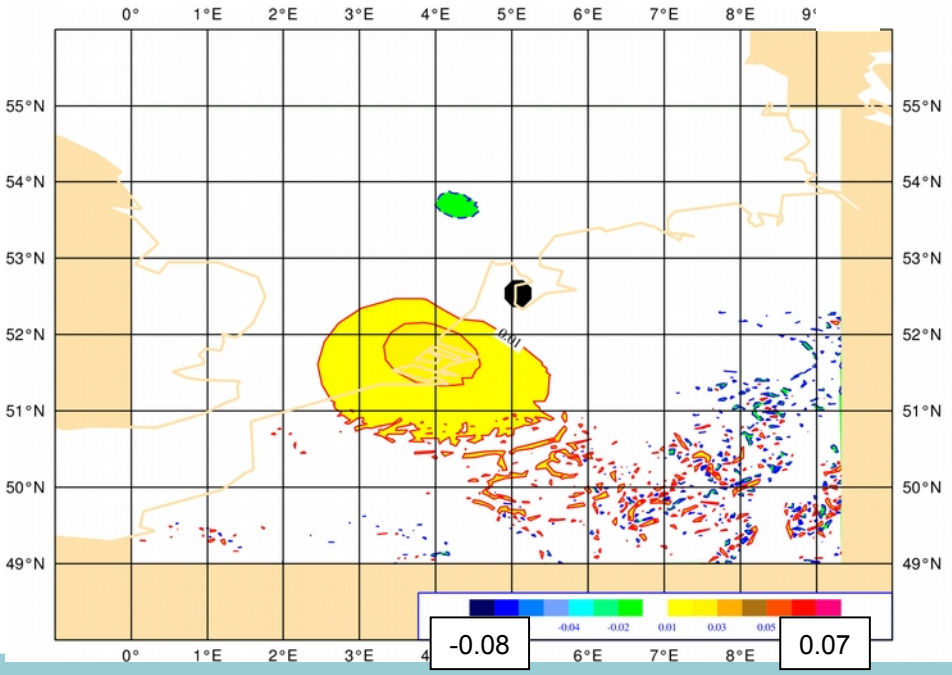
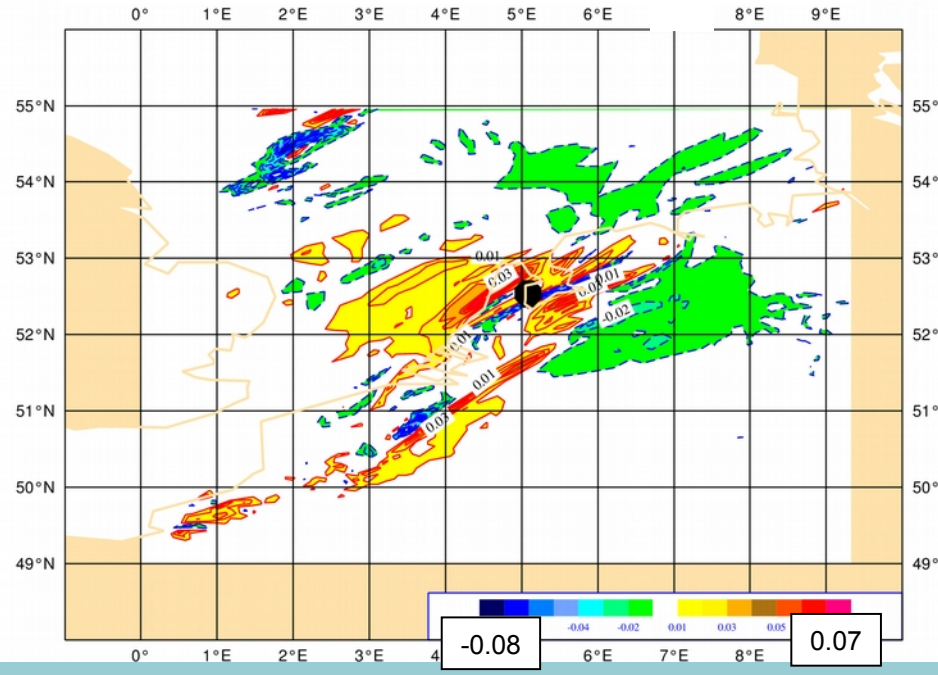
Ministry of Transport, Public Works and Water Management

- 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)

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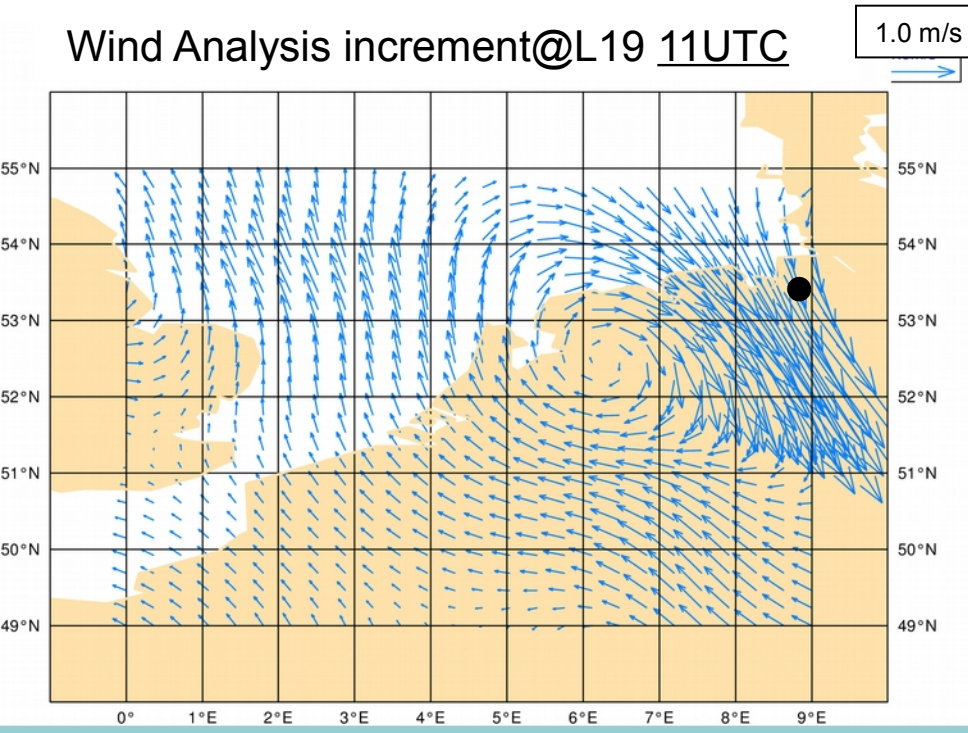
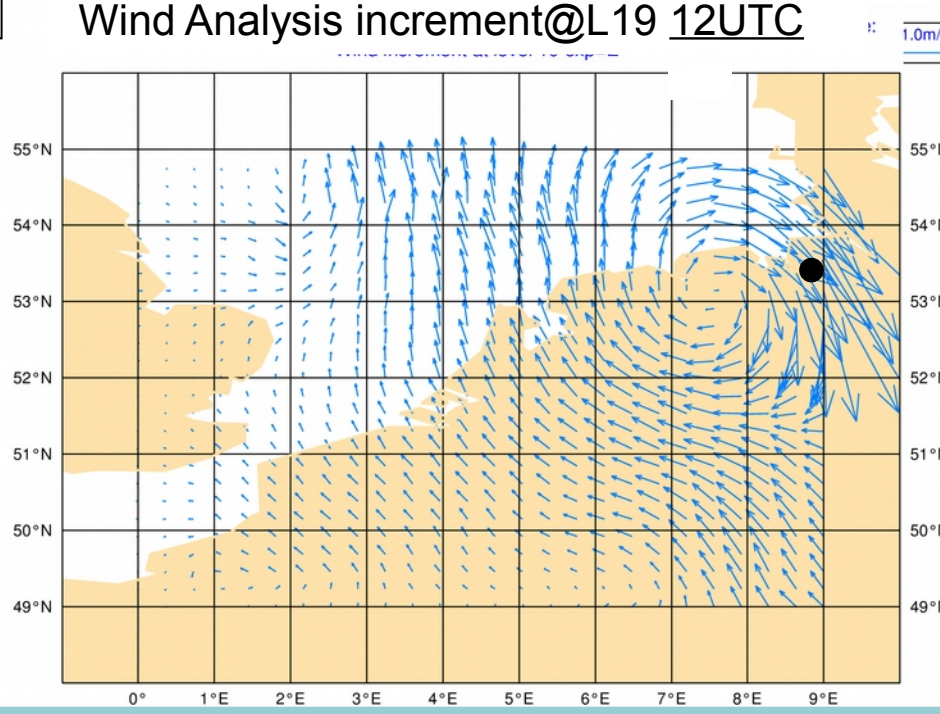
- **Observation at 11:34 at the edge of the domain**

Wind Analysis increment@L19 11UTC



Wind Analysis increment@L19 12UTC



Harmonie 4DVAR
"Single" observation (2.2)

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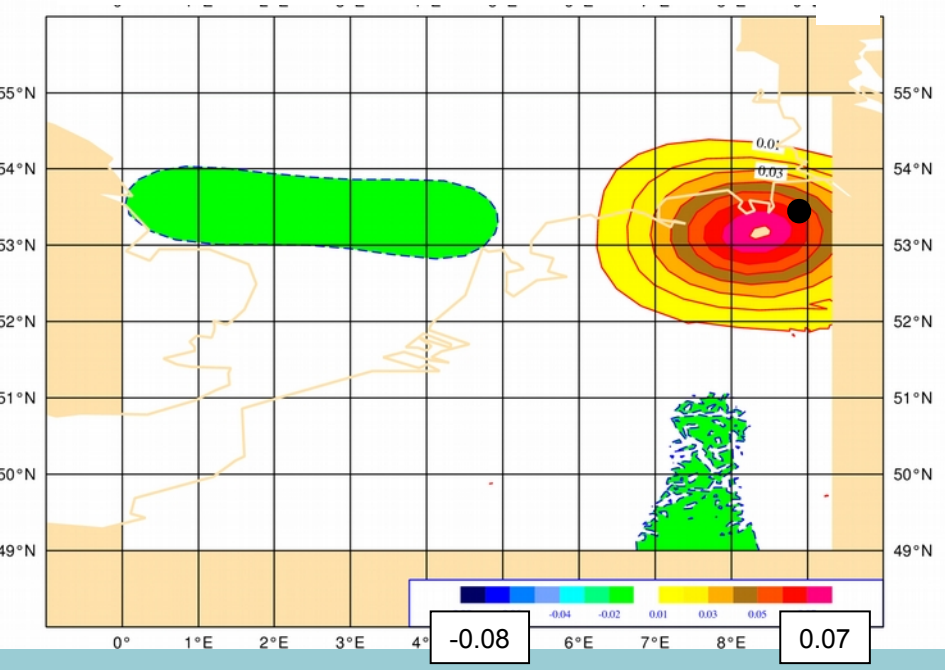
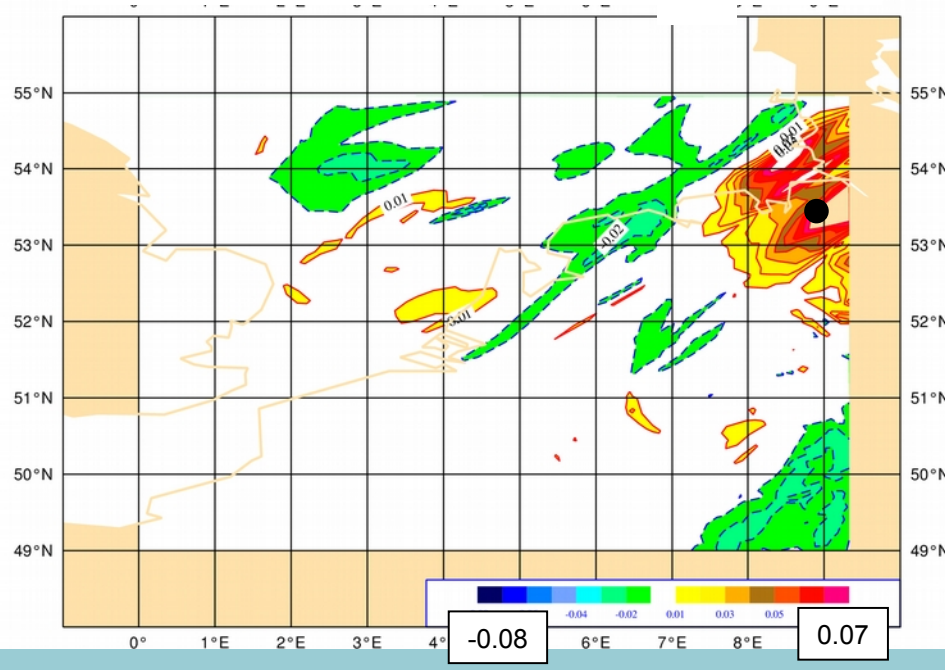
- **Observation at 11:34 at the edge of the domain**
- **Symmetric increment at 11 UTC**

Temp Analysis increment at 11 UTC



Temp. Analysis increment at 12 UTC



Harmonie 4DVAR single flight obs. (3.1)

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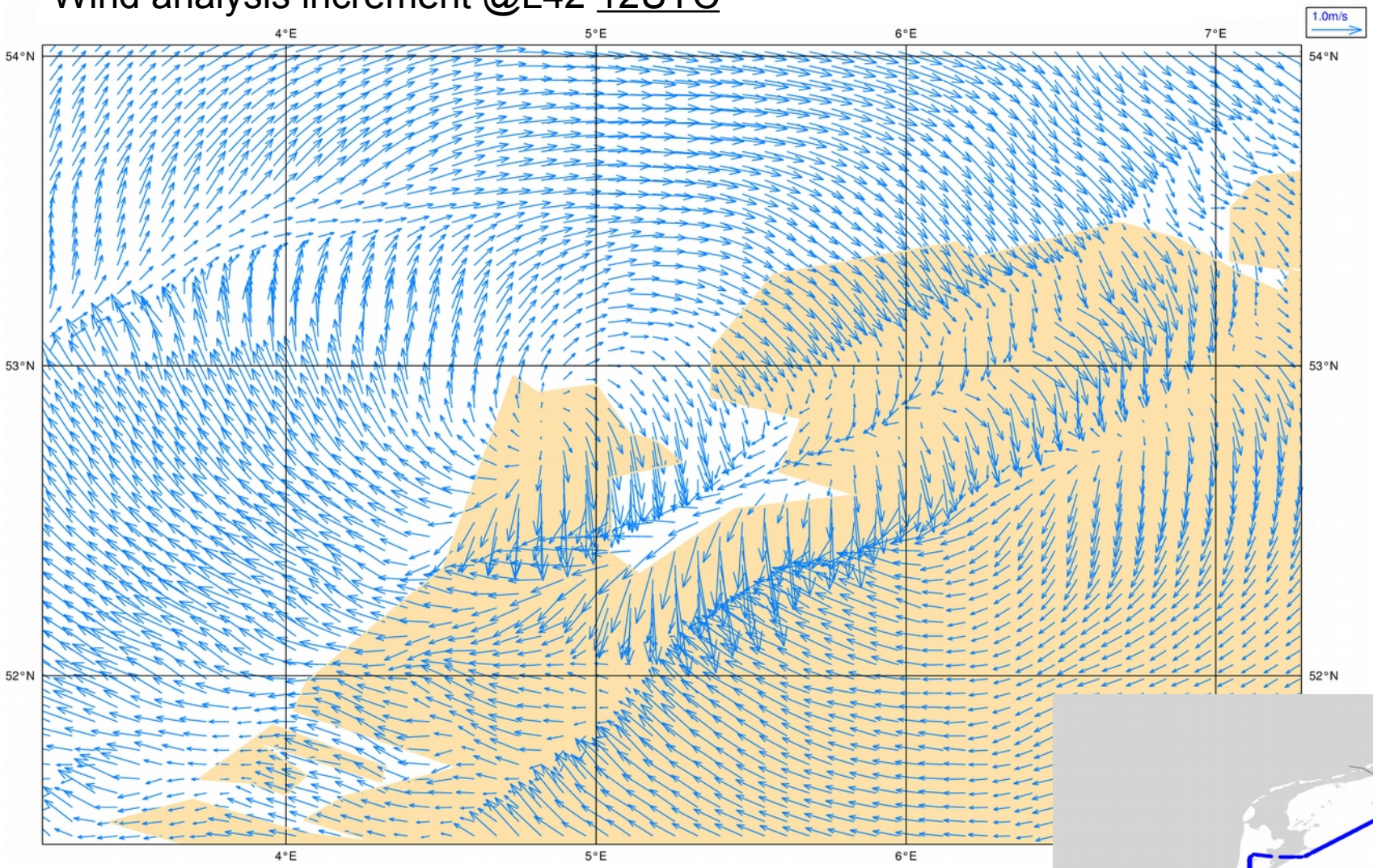
Wind analysis increment @L42 12UTC



costfunction checks

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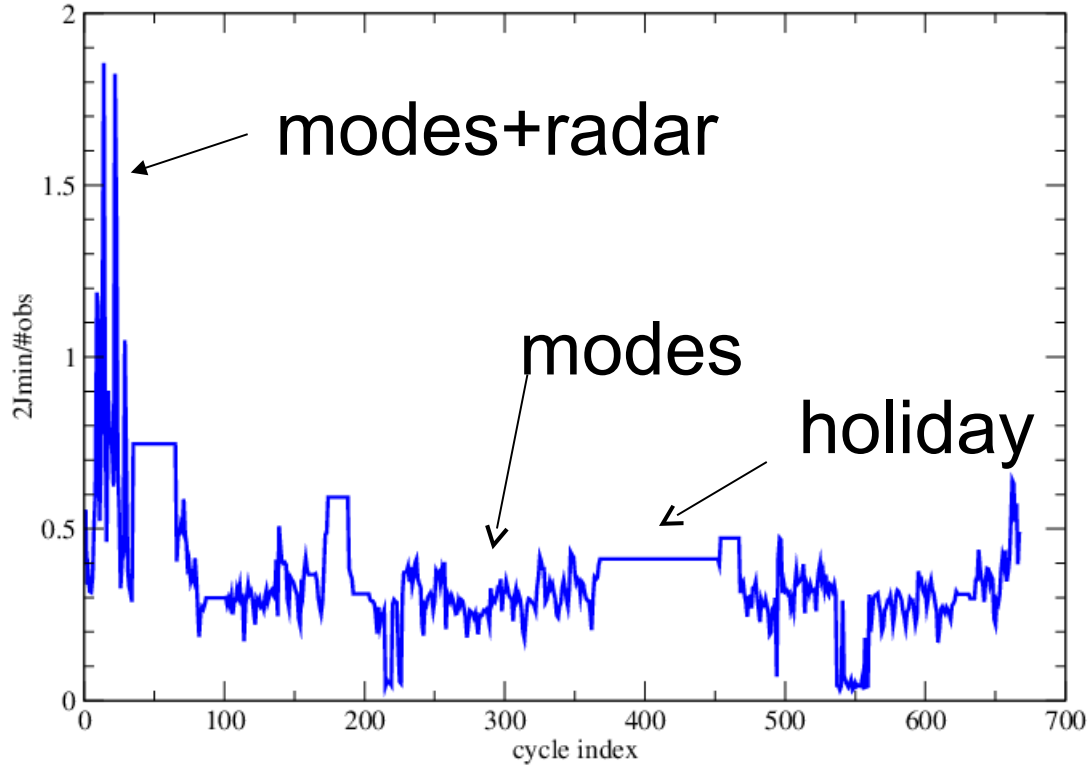
At the minimum $2J_{min}(x) = 2J_b(x) + 2J_o(x)$ has a χ^2 distribution with p parameters and therefore:

E(2J/p)=1 (Bennet at al (1993), Talagrand(1999) and Desroziers and Ivanov (2001))



costfunction checks (2)

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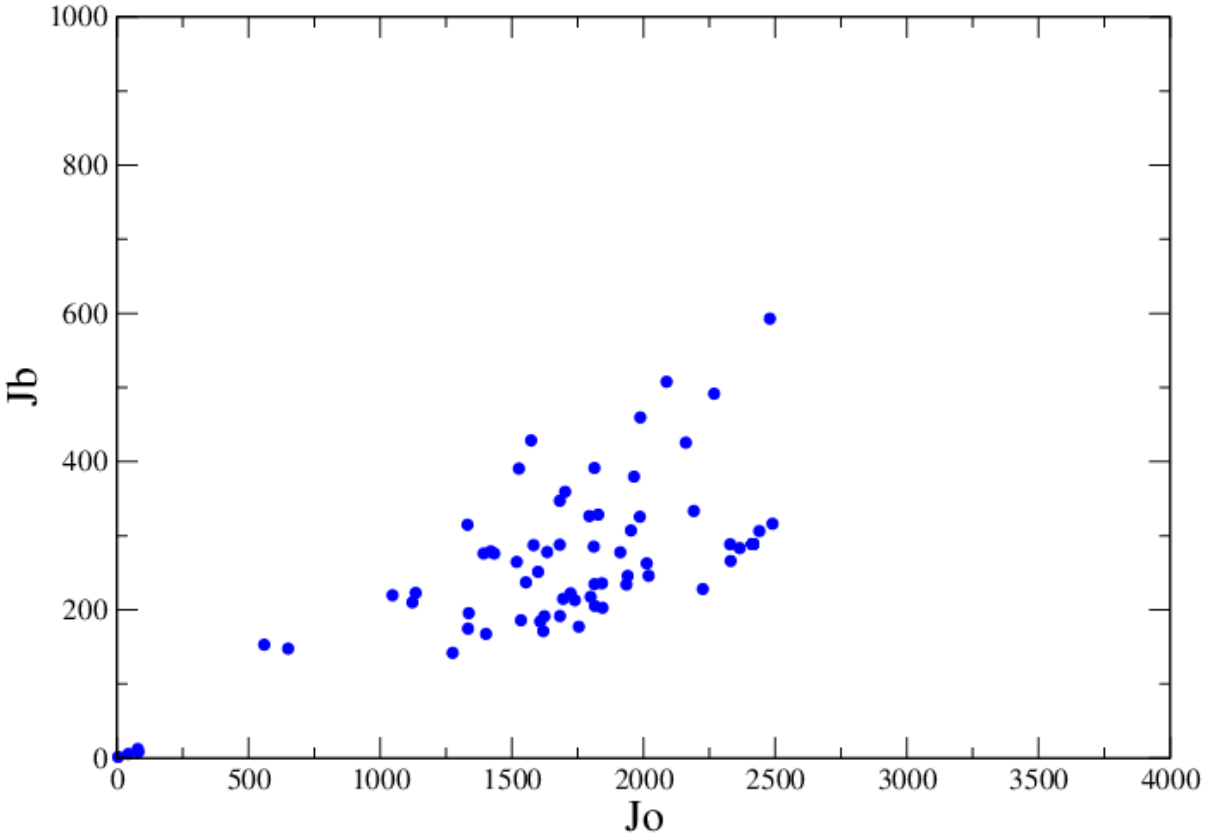
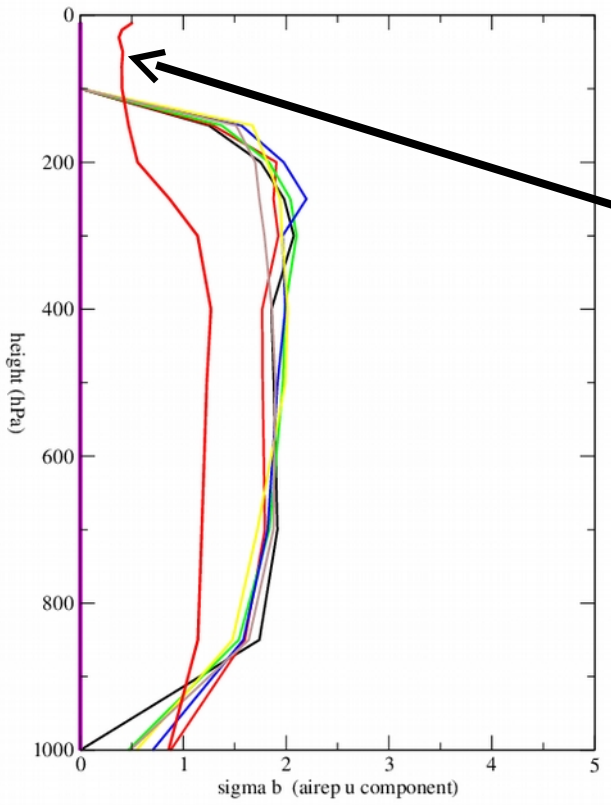
In a DA system with well-specified statistics (i.e., B and R), *J_b and J_o at the minimum should be positively correlated.*

(Y. Michel, 2014)

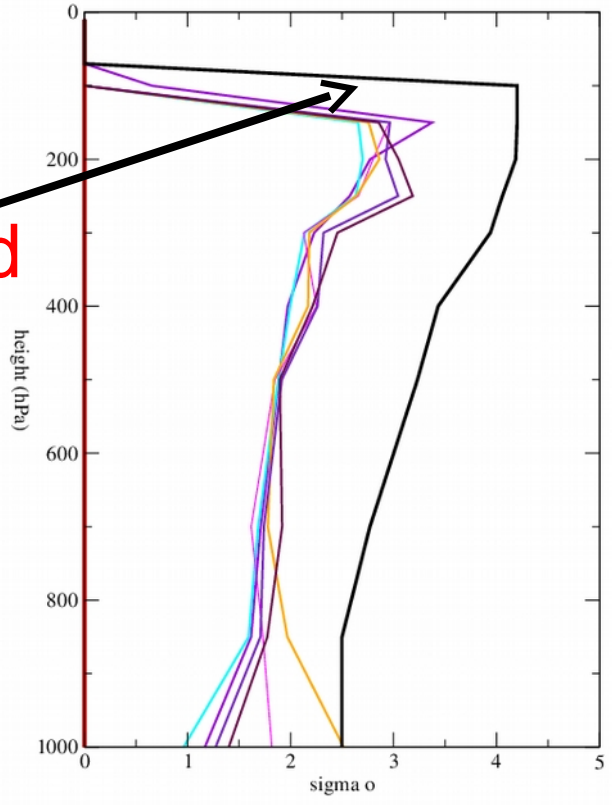


Estimation of sigma-b and sigma-o per sub-time window of 4D-Var following Desroziers 2005.



prescribed values

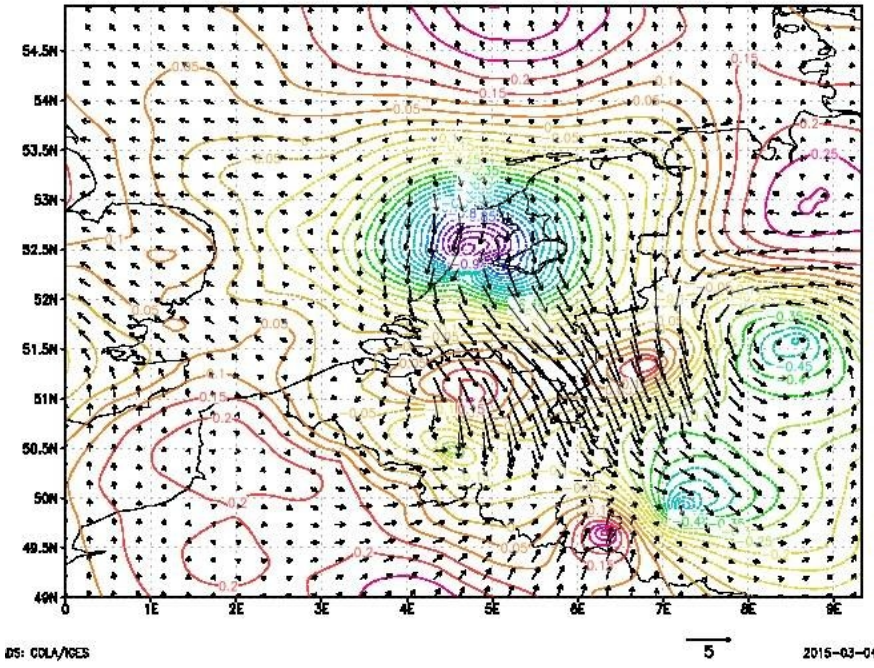
2 months data (12 UTC)



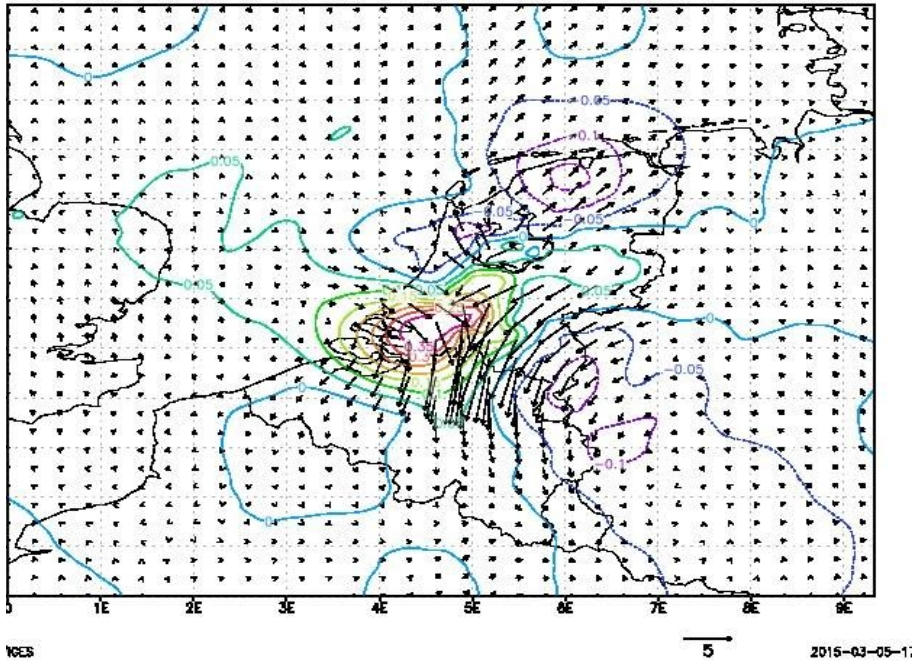
Thank you Jana Sanchez

Analysis increments (wind and T) due to

Mode-S EHS



Radar



Current coverage of available Mode-S EHS

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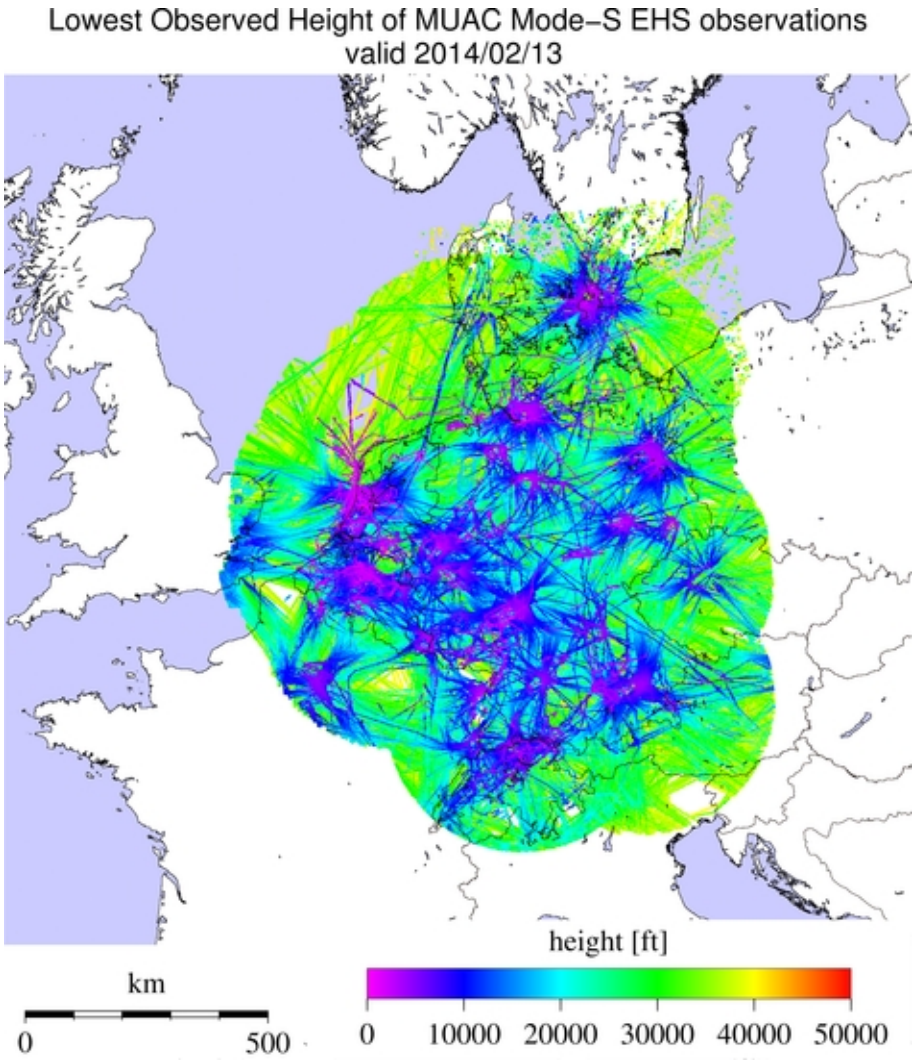
- **Agreement with EUROCONTROL**
  - Every 15 minutes
  - All ATC radar information from
    - *2 Belgian*
    - *1 Danish*
    - *6 Dutch*
    - *12 German*
  - 12 minutes latency
  - Anonymous ICAO-id
  - Parameters: U, V and T
  - http://mode-s.knmi.nl



Harmonie trial

10m wind forecast verification

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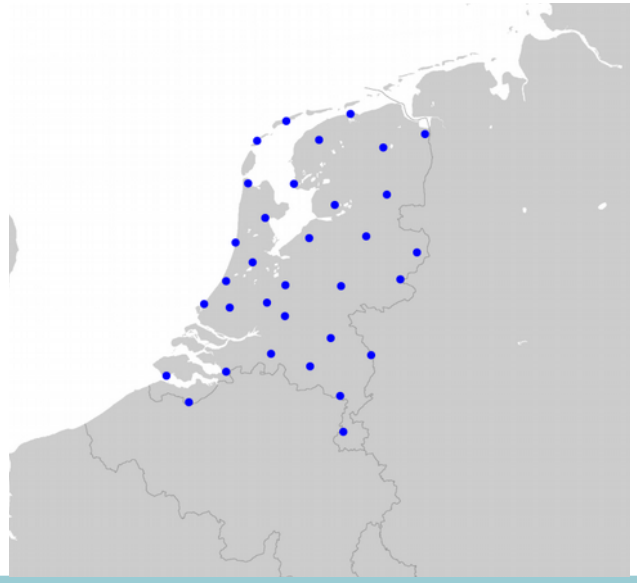
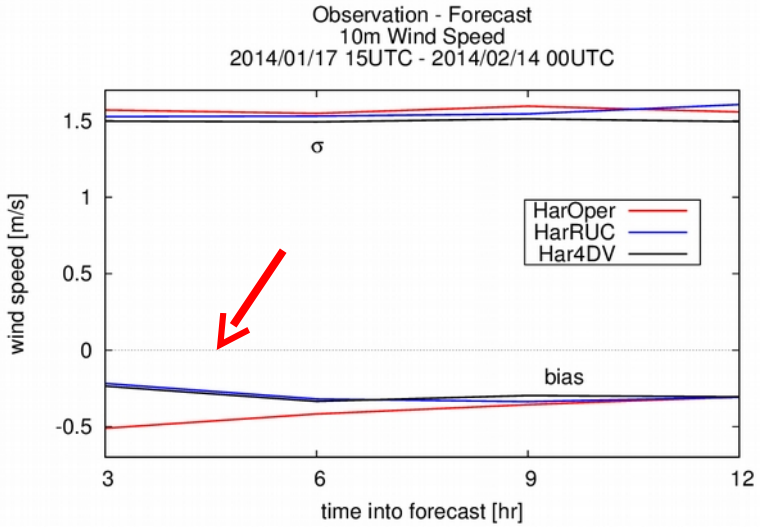
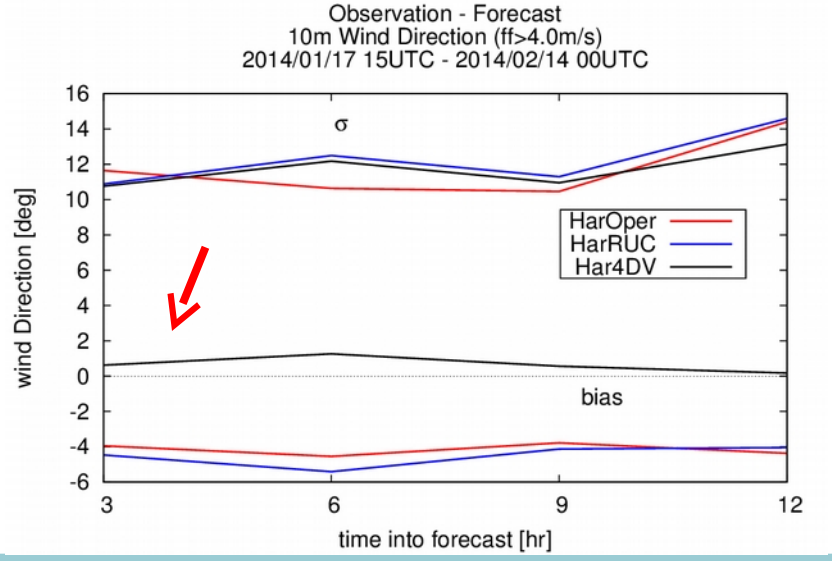
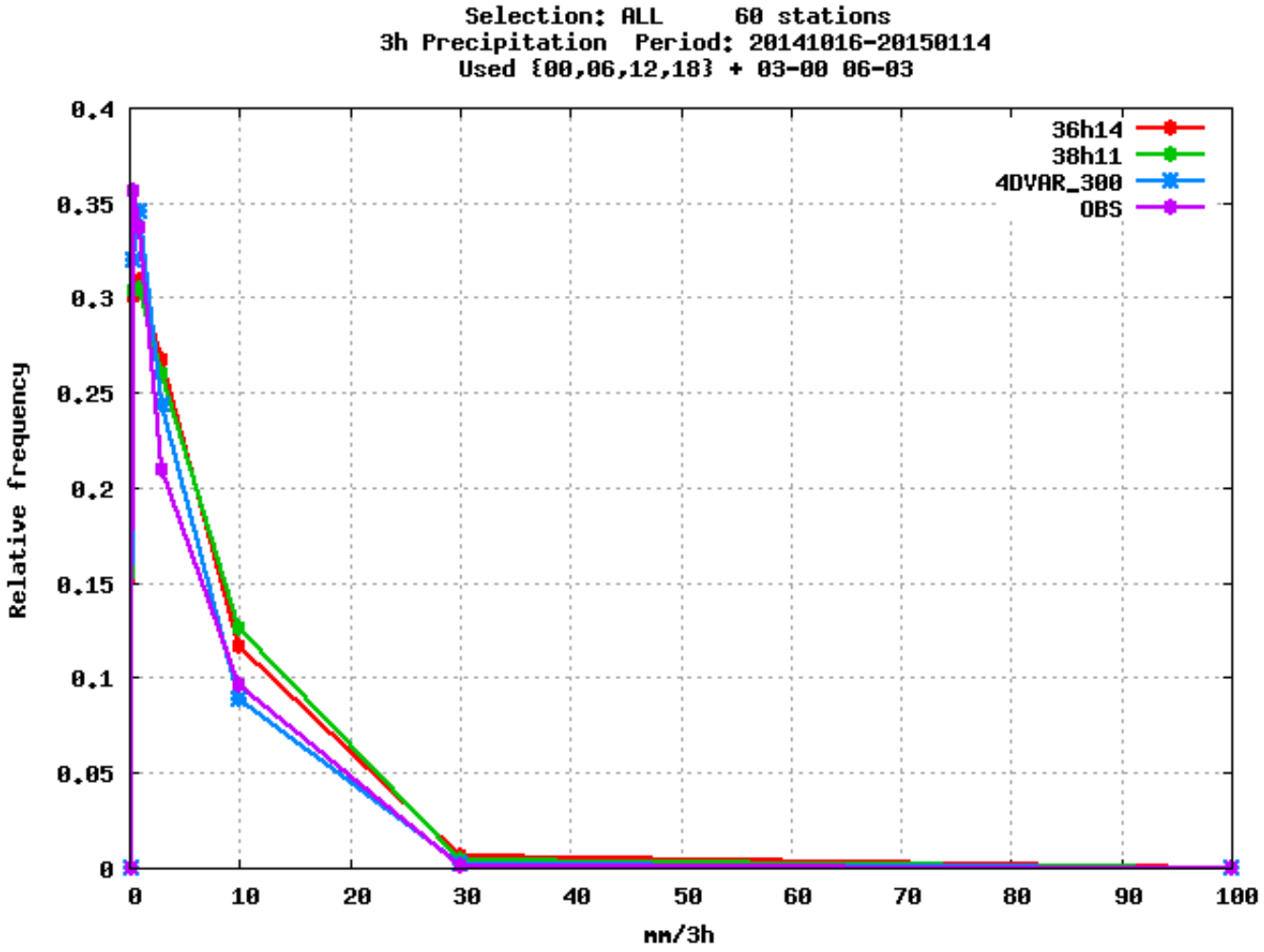
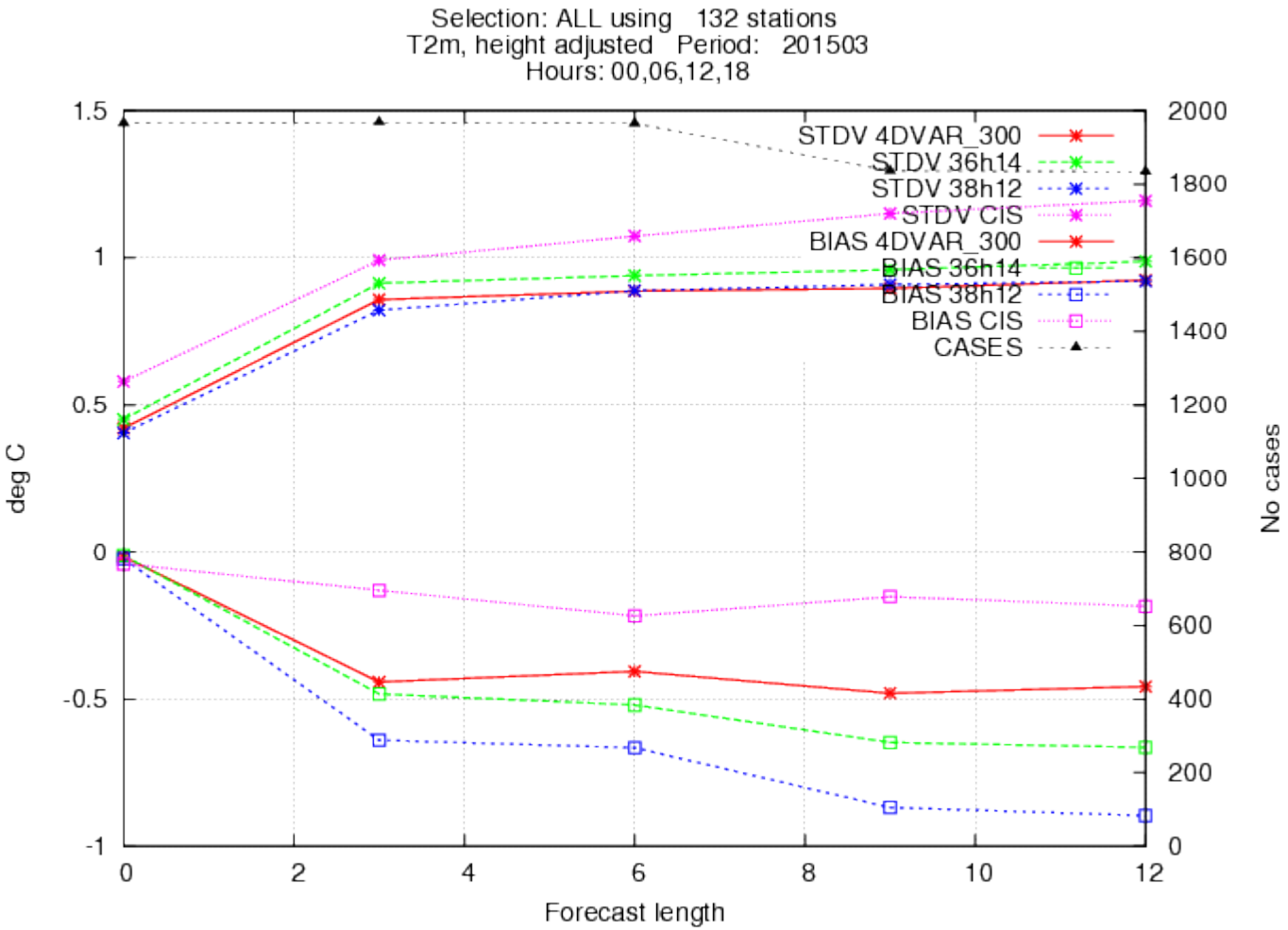
- **NOT fair comparison!!**
- **Period: 17 Jan – 14 February 2014**
- **Only Dutch surface wind observations**
- **Collocation of all three runs**
- **Wind direction**
  - bias is reduced for Har4DVAR
- **Wind speed**
  - standard deviation is slightly smaller for Har4DVAR
  - Bias is reduced in the first hours for Har4DVAR and HarRUC

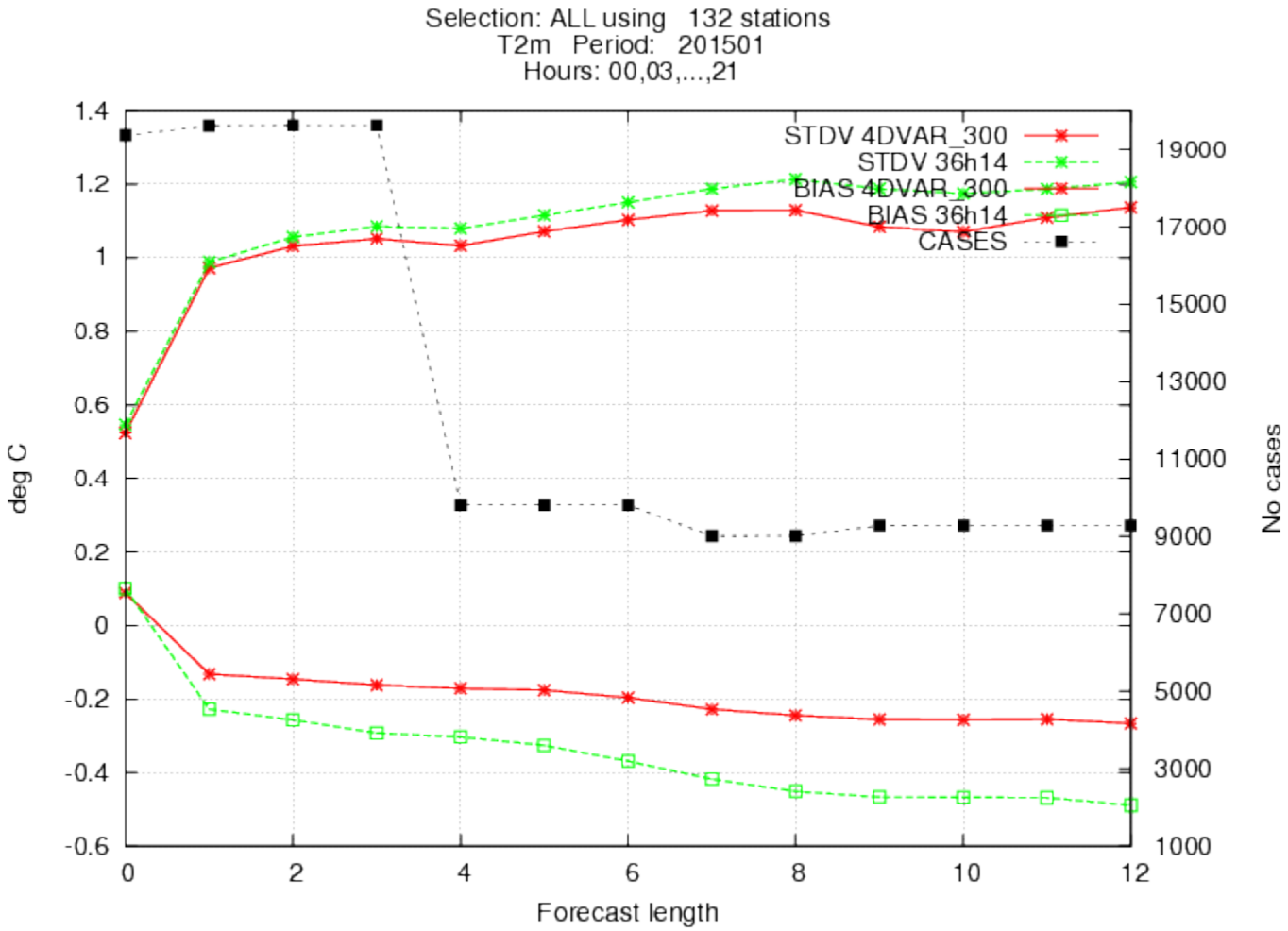


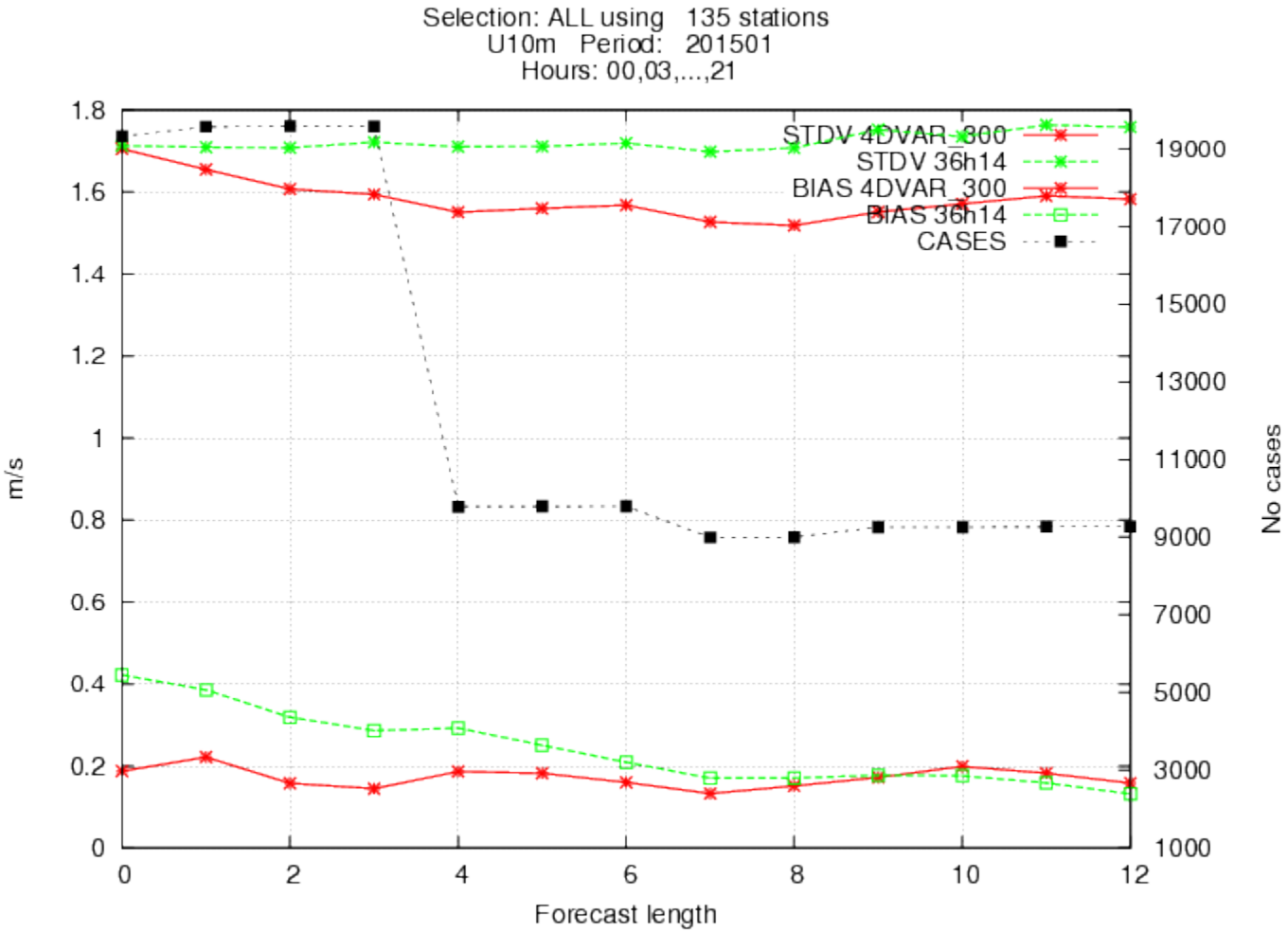


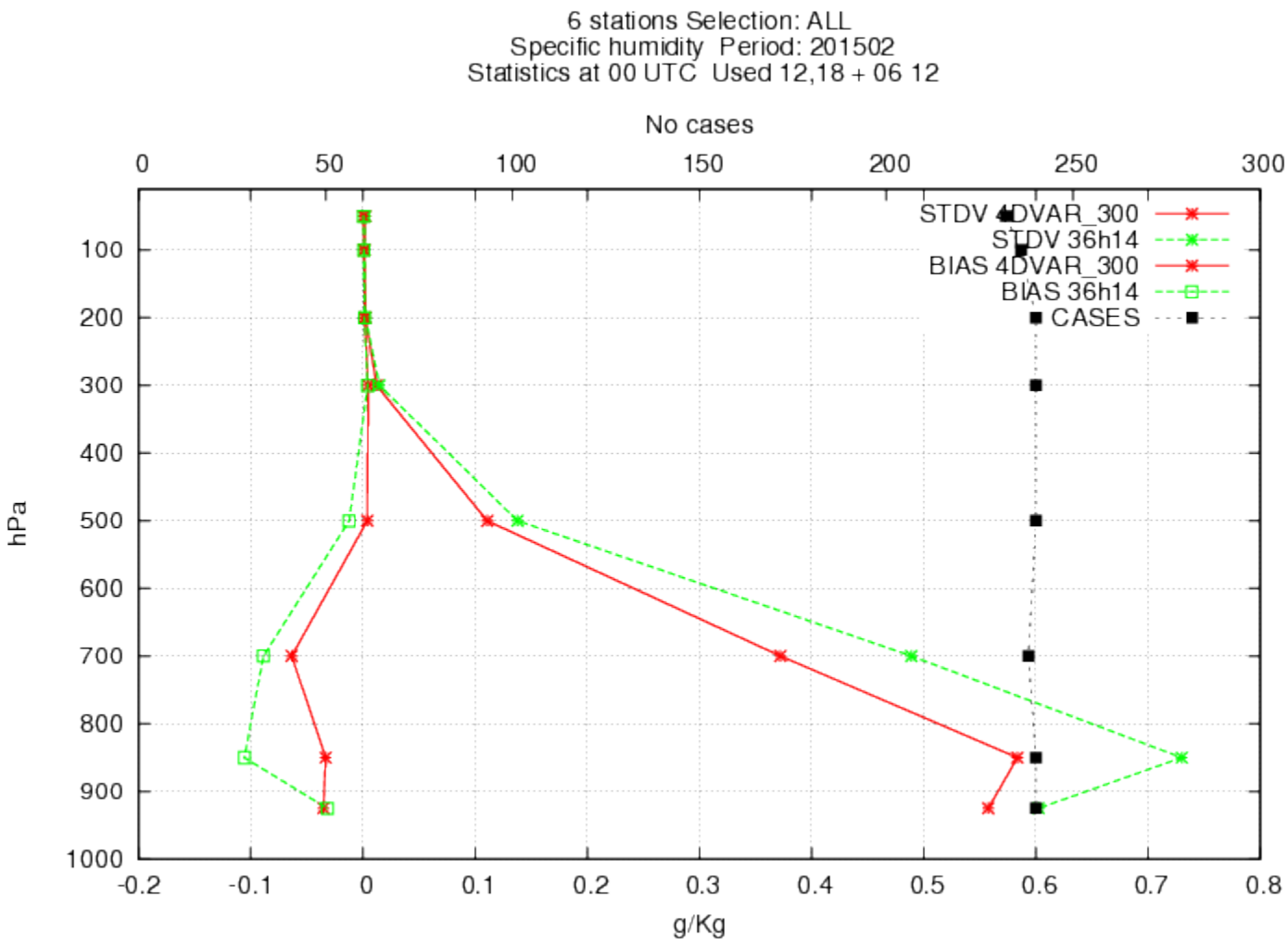



Selection: ALL 60 stations
3h Precipitation Period: 20141016-20150114
Used {00,06,12,18} + 03-00 06-03
36h14
38h11
4DVAR_300
OBS
Relative frequency
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
mm/3h

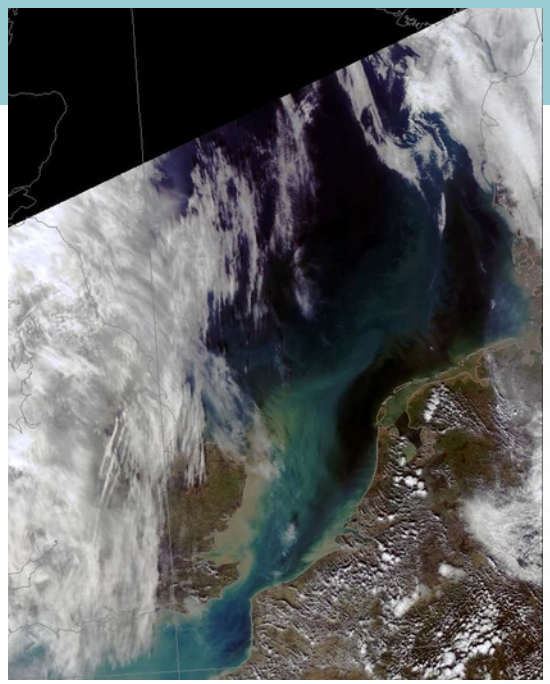

Selection: ALL using 132 stations
T2m, height adjusted Period: 201503
Hours: 00,06,12,18
STDV 4DVAR_300
STDV 36h14
STDV 38h12
STDV CIS
BIAS 4DVAR_300
BIAS 36h14
BIAS 38h12
BIAS CIS
CASES
deg C
No cases
Forecast length
1.5
1
0.5
0
-0.5
-1
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12


Selection: ALL using 132 stations
T2m Period: 201501
Hours: 00,03,...,21
STDV 4DVAR_300
STDV 36h14
BIAS 4DVAR_300
BIAS 36h14
CASES
deg C
No cases
Forecast length
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
19000
17000
15000
13000
11000
9000
7000
5000
3000
1000
0
2
4
6
8
10
12

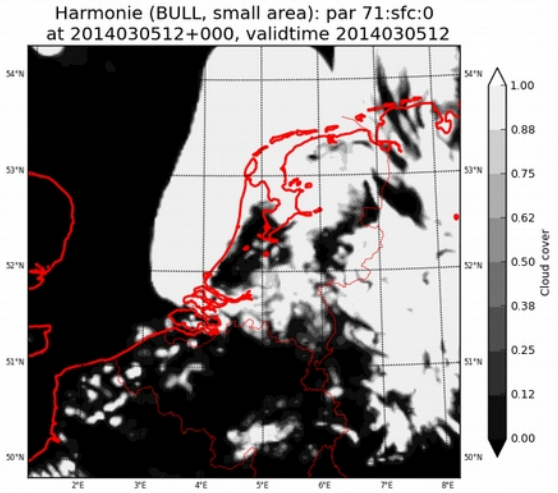

Selection: ALL using 135 stations
U10m Period: 201501
Hours: 00,03,...,21
STDV 4DVAR_300
STDV 36h14
BIAS 4DVAR_300
BIAS 36h14
CASES
m/s
No cases
Forecast length
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1000
3000
5000
7000
9000
11000
13000
15000
17000
19000
0
2
4
6
8
10
12


6 stations Selection: ALL
Specific humidity Period: 201502
Statistics at 00 UTC Used 12,18 + 06 12
No cases
0
50
100
150
200
250
300
STDV 4DVAR_300
STDV 36h14
BIAS 4DVAR_300
BIAS 36h14
CASES
hPa
100
200
300
400
500
600
700
800
900
1000
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
g/Kg

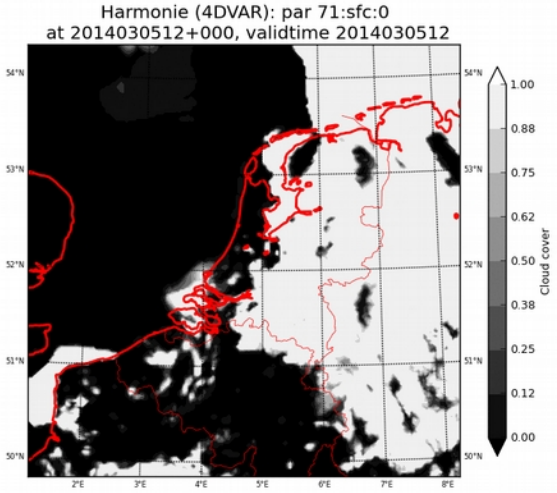
5 RUNS
for 5 maart 2014 12UTC +12h
FOG or no FOG



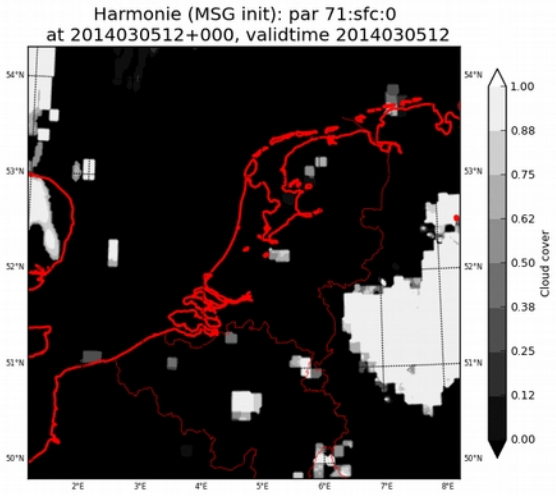
BULLSA



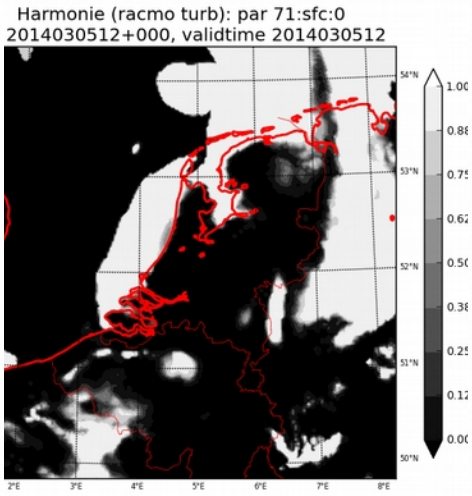
4DVAR



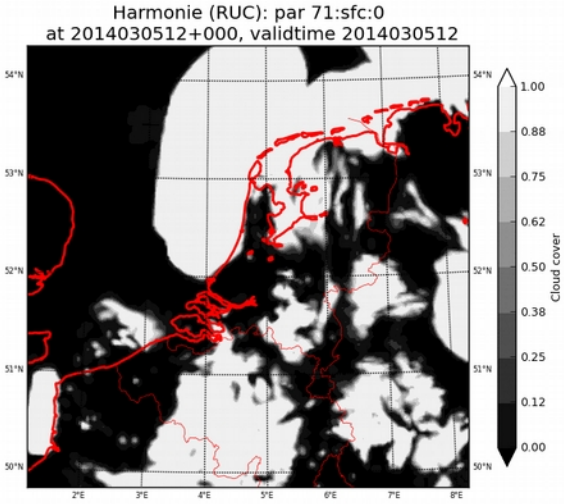
MSG



RACMO



RUC



Final remarks

- Working HARMONIE 4D-Var in CY38 has high priority
- Add RADAR and GNSS to the 4D-Var observation set
  - Screening and Minimization statistics for reflectivity do not match yet.
- HARMONIE 4D-VAR part of a series of observation impact suites (CY38)
- Try to understand the time evolution of analysis increments and added value of observation sets (FSO, o-b/o-a for radar?)
- Explore the possibility of decreasing the cycling time in 4D-Var (1h-cycling, overlapping observation window)