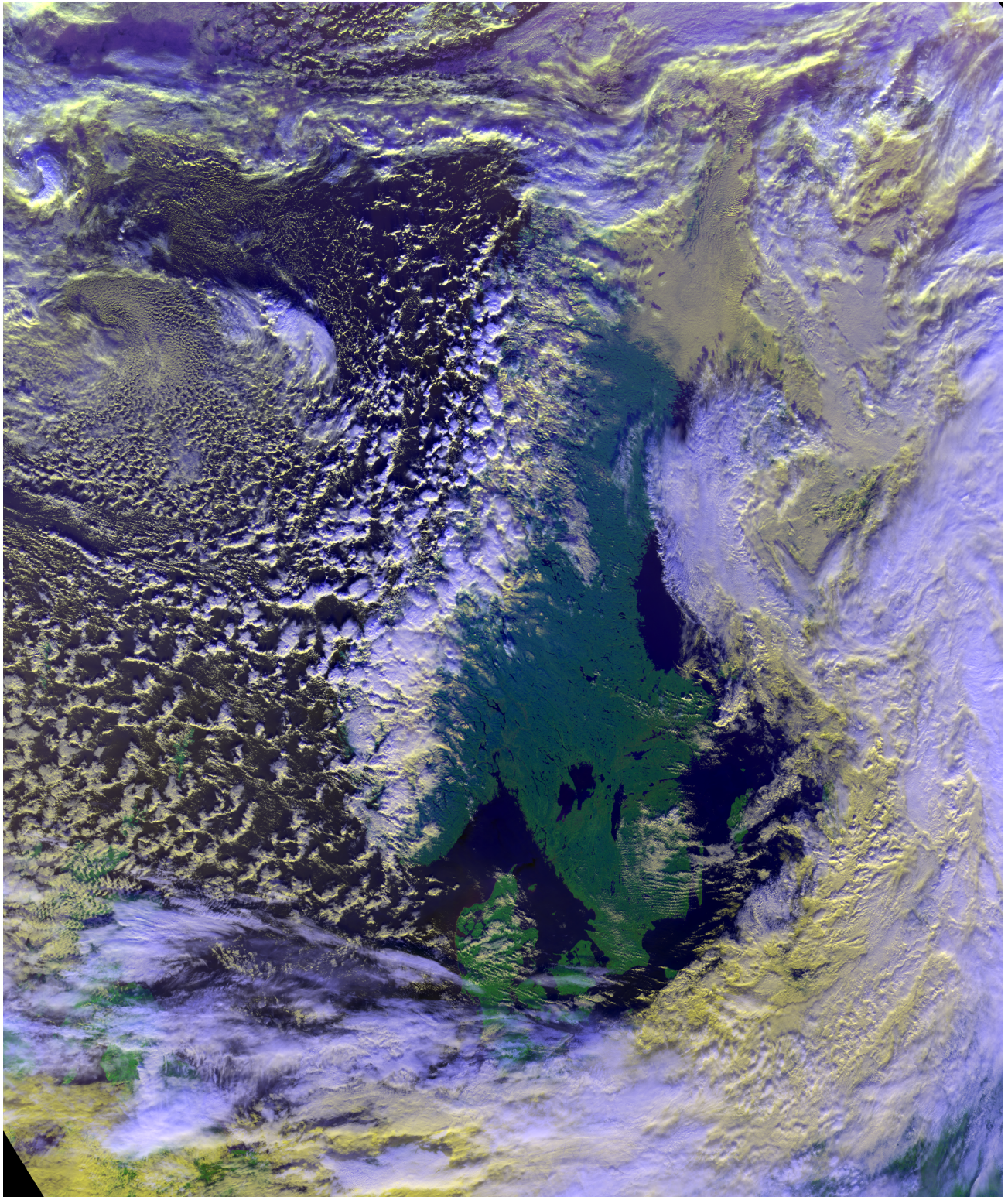
Convective Precipitation in HARMONIE-AROME

Lisa Bengtsson, SMHI

2017 ASM, FMI

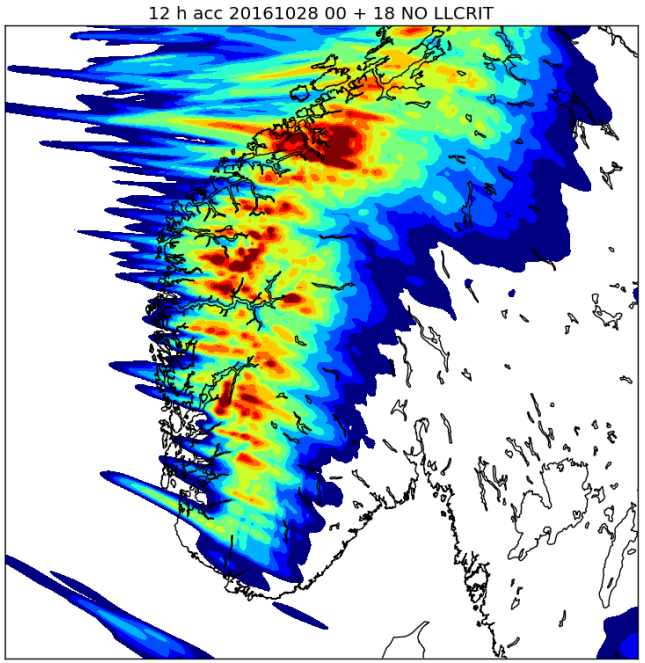


Shallow convection over the North Sea

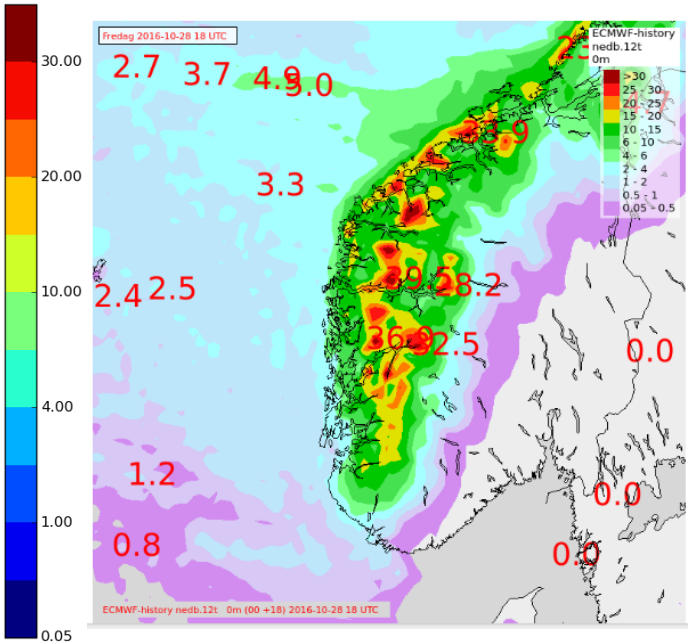
In northerly flow, Arctic cold air advection over the (relatively) warm sea surface generates shallow convection, which can organize into precipitating shallow to deep convection in over land.

VIIRS on NPP-Suomi RGB
2016-10-28

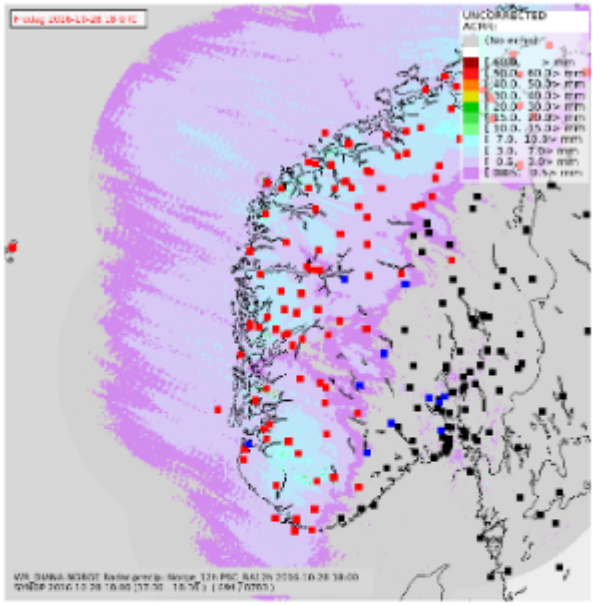
Complaint from forecasters



HARMONIE-AROME
cycle 38h1.2 (2.5 km)



ECMWF ~9 km



Radar + synop

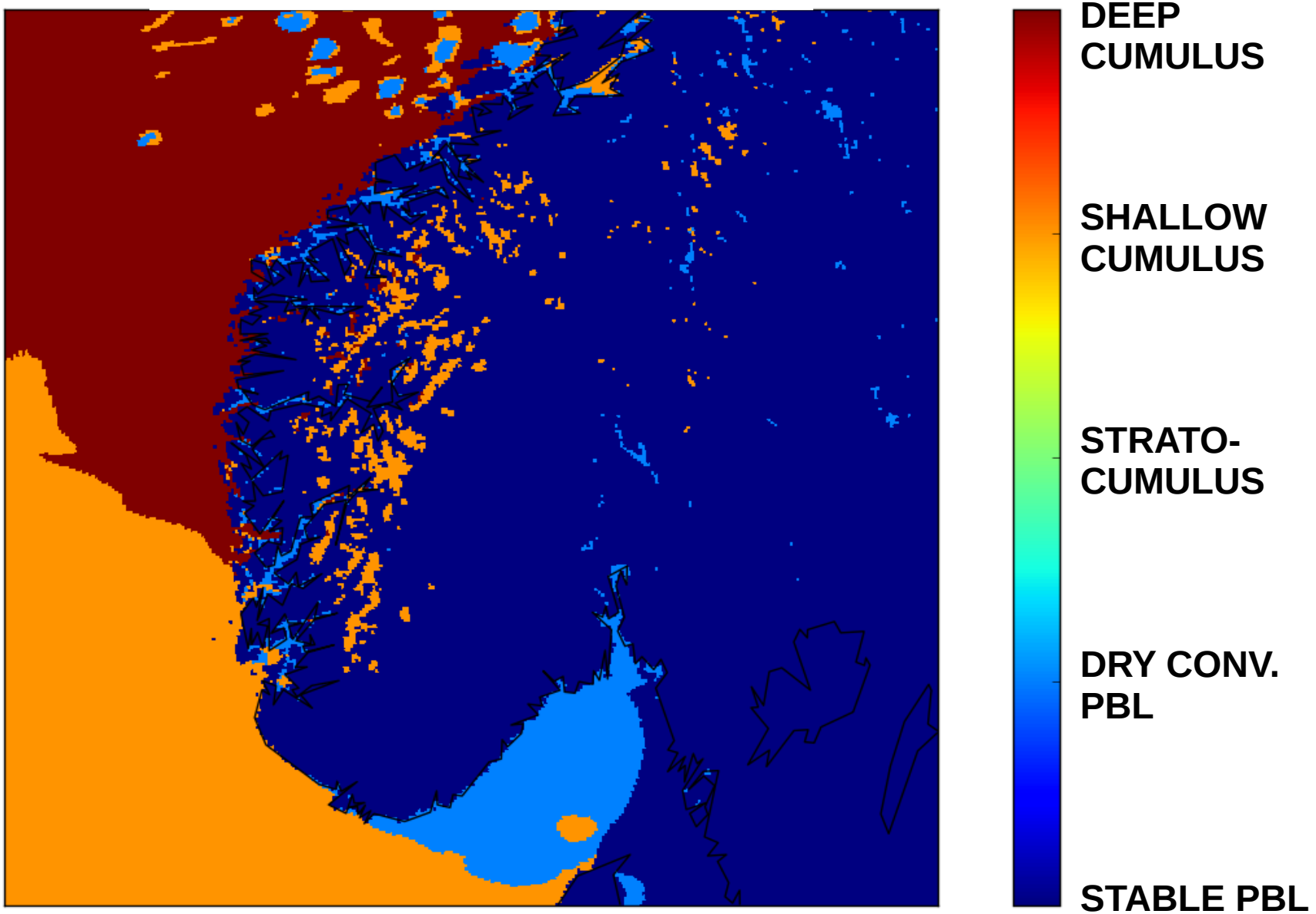
black = 0mm
blue = 0.1 - 0.4mm
red >= 0.5mm

The model underestimates precipitation (snow showers) from convection over sea and in over the coast in fall/winter/spring.

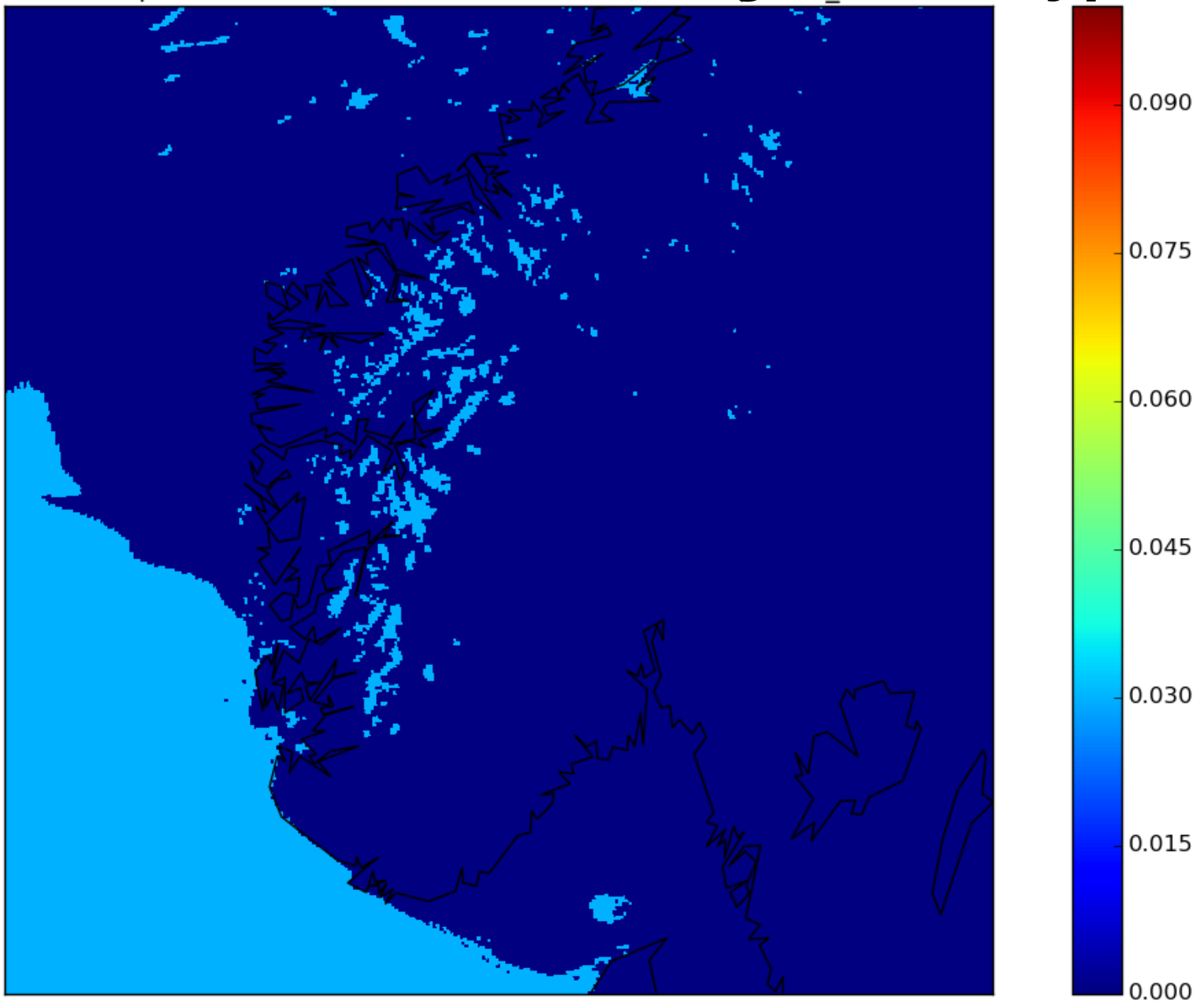
EDMFm and sub-grid precipitation

- The HARMONIE-AROME reference configuration uses EDMFm as the default mass-flux scheme.
- EDMFm is a dual mass-flux scheme (for dry and moist convective plumes), which can generate rain and snow on the sub-grid scale given the following crude description:

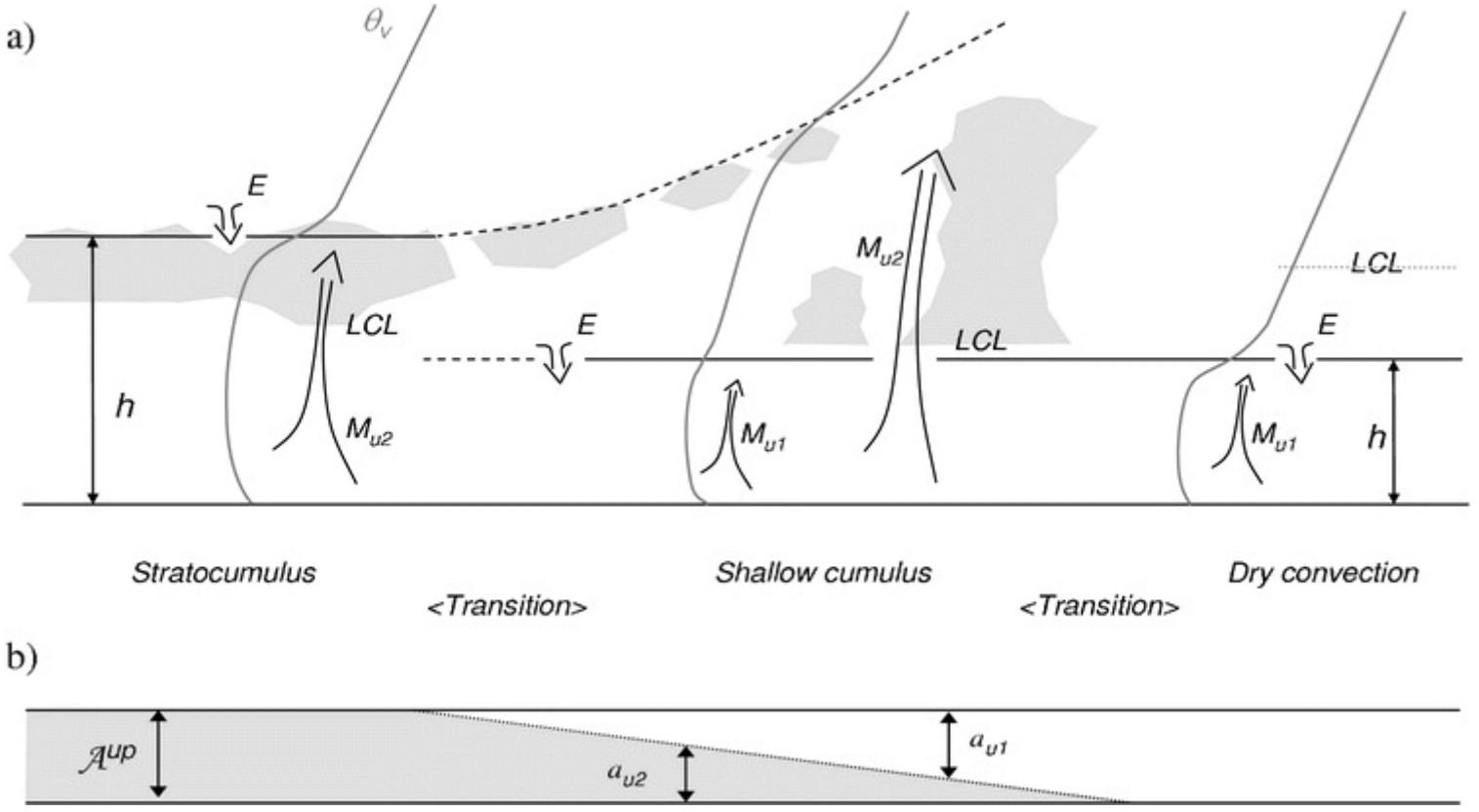
First determine the boundary layer type based on the surface bouyancy flux and height of lifting condensation level.

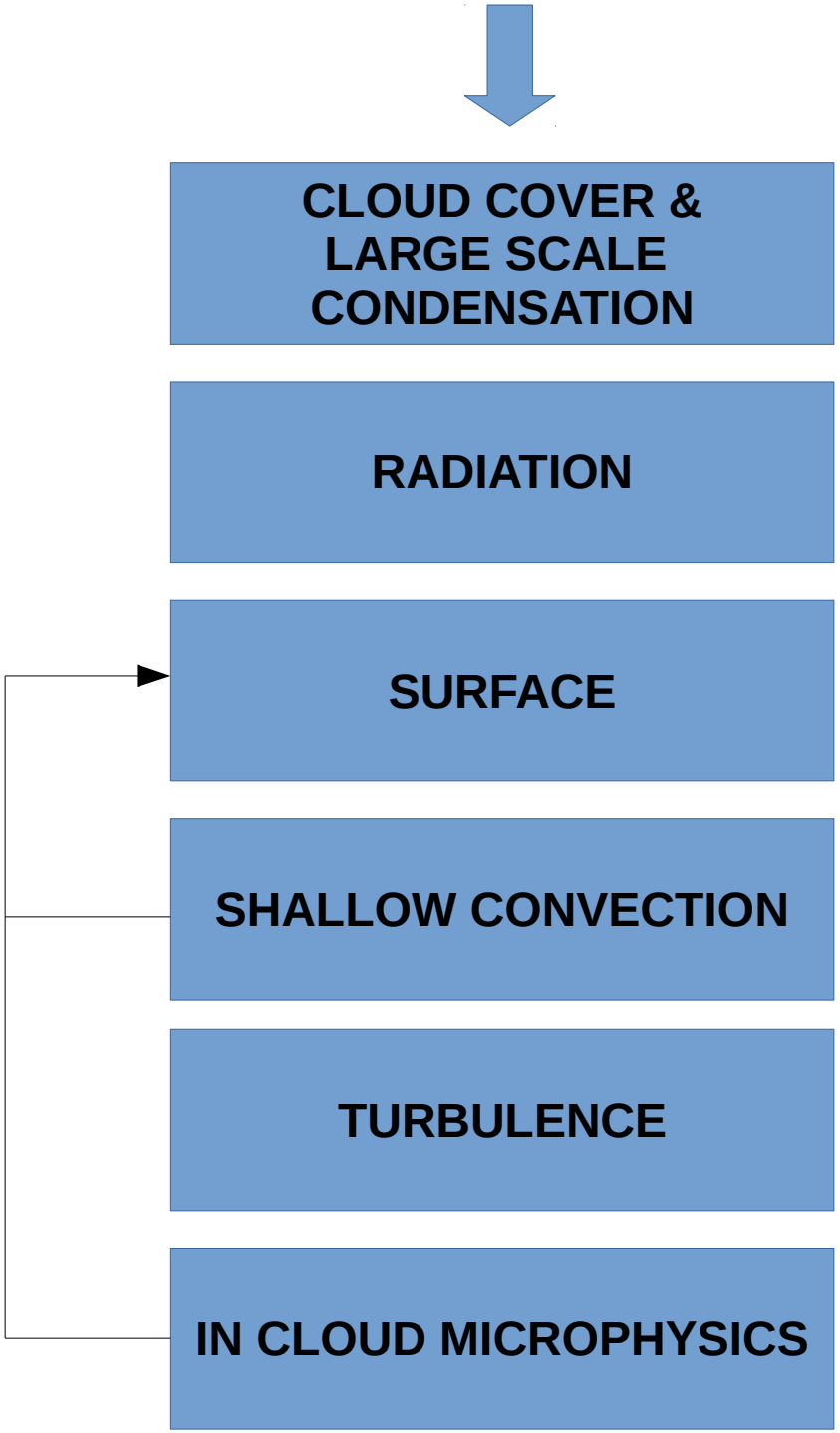


Assign a constant updraft mesh fraction at cloud base, according to PBL type.



Compute the mass-flux following entrainment/ detrainment formulations of Siebesma et al. (2003, 2007), Simpson and Wiggert (1969), de Rooy and Siebesma (2008, 2010). Compute locally shallow convective cloud condensate if LCL is found, following Neggers et al. 2009.

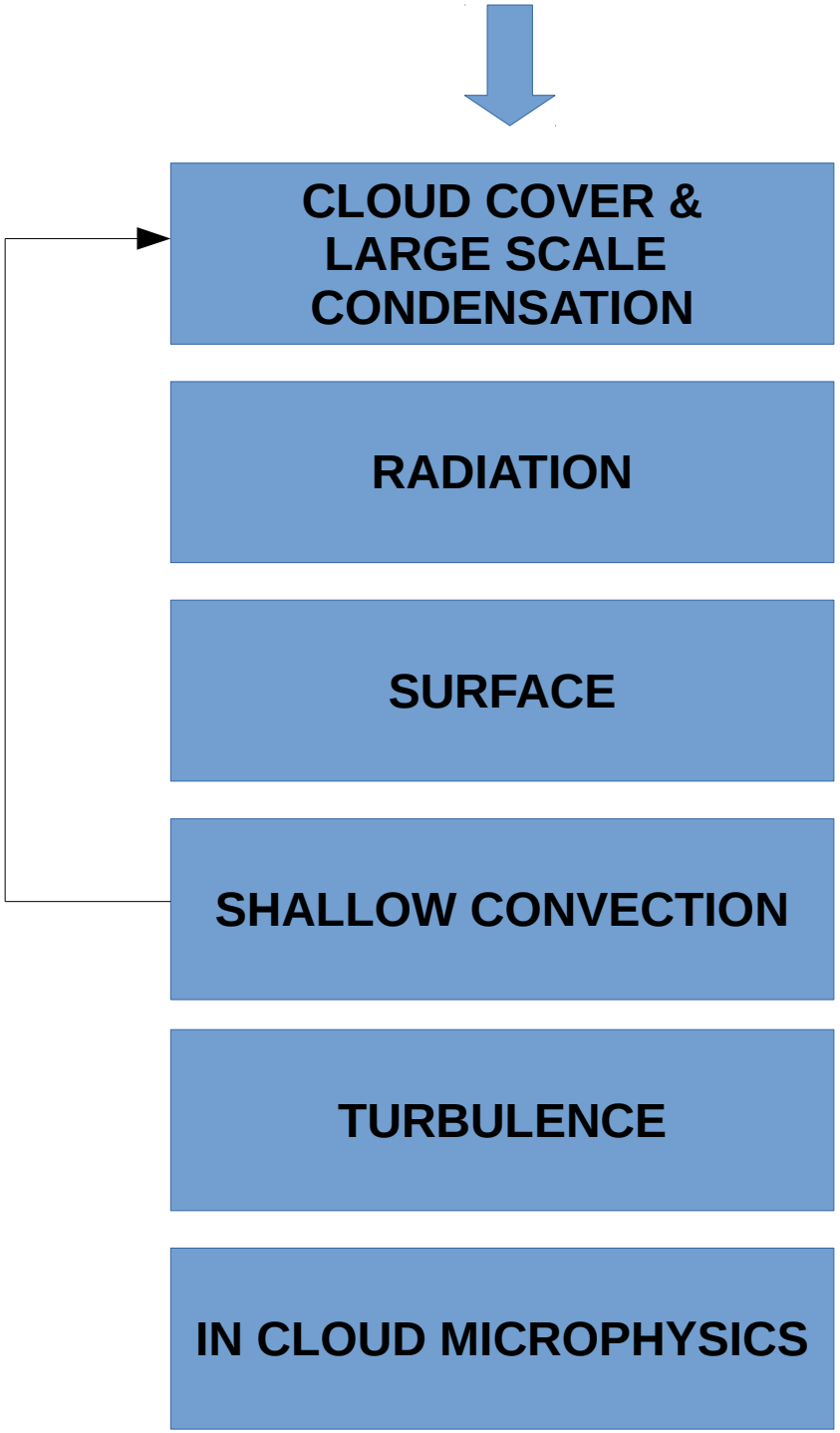




Diagnose rain and snow at the surface, following Sundqvist type generation.

Precipitation is activated if the amount of condensation is larger than a given critical threshold.

Grid-box mean is scaled by updraft-mesh-fraction.



Pass total specific humidity and variance from the mass-flux and turbulence to the statistical cloud scheme at the next time step to create a cloud cover.

Experiments preformed to try to improve convective precipitation from shallow cumulus.

- **Lower critical threshold for precipitation generation when the temperature at cloud-base is less than 0 C. (LLCRIT)**
- Add precipitation generated from the EDMFm scheme to the hydrometeors passed to cloud microphysics (on all levels). Advect the total hydrometeors with the wind. (LTOTPREC)
- **Scale by updraft cloud-fraction rather than the fixed (low) value of the updraft mesh-fraction: 0.03. (LTOTPREC)**
- Move the domain westward.
- **Couple all hydrometeors at the lateral boundary**
- Introduce coupling using probabilistic cellular automata to enhance organization.

Experiments LLCRIT+LTOTPREC

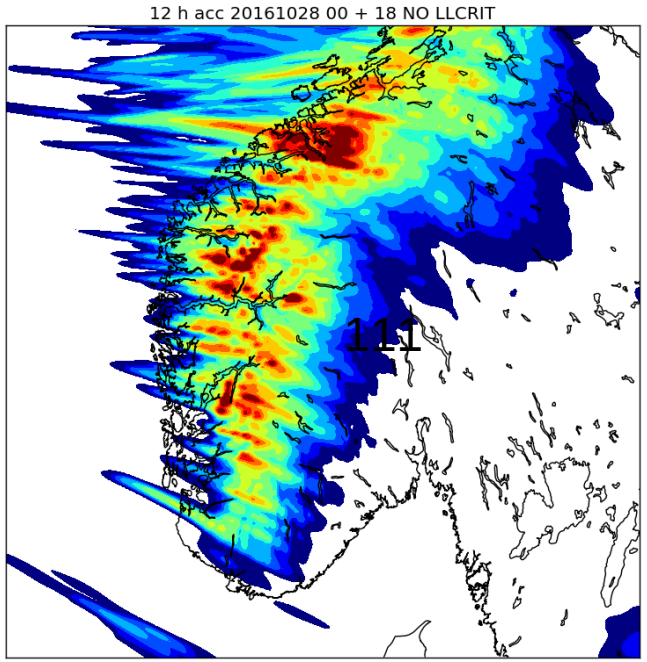
Cases:

- April 22nd, 2016 – Norwegian coast. Snow/rain showers.
- March 5th, 2015 – Icelandic coast. Snow/rain showers.
- October 28th, 2016 – Norwegian coast. Snow/rain showers.
- February, 7th, 2017 – Swedish inland. Snow showers.
- February 17th, 2017 – Norwegian coast. Snow showers.
- February 21-22nd, 2017 – Norwegian coast. Snow showers.
- July 4th, 2016 – Swedish inland. Summer-time small scale rain showers.

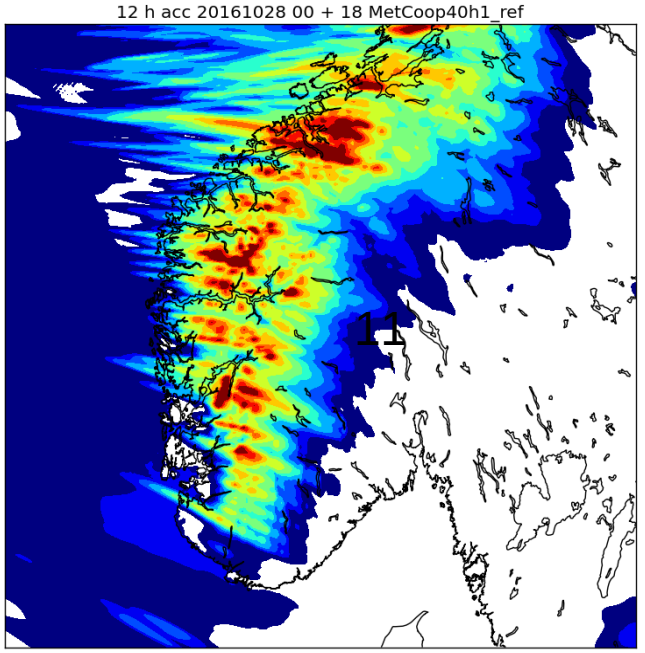
Longer run:

- February 2017.

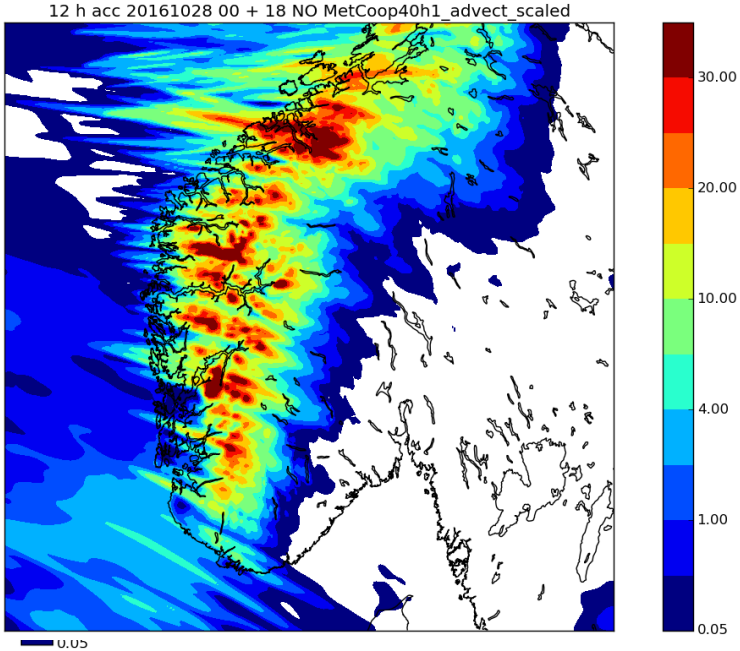
October 28th, 2016



REFERENCE 40h1.1 With LLCRIT=FALSE



LLCRIT = TRUE



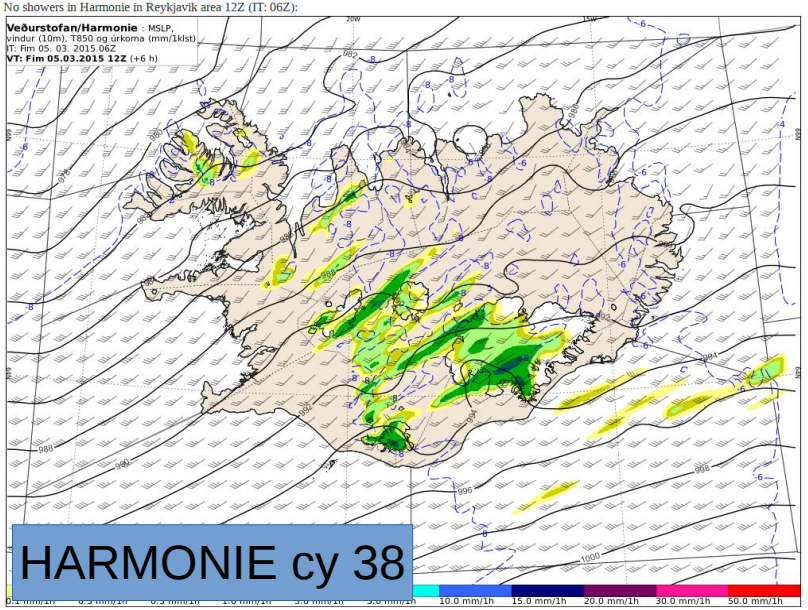
LLCRIT+LTOTPREC = TRUE

Precipitation fields get better, larger amounts and more precipitation over the coast. Sub-grid precip. not as uniform.

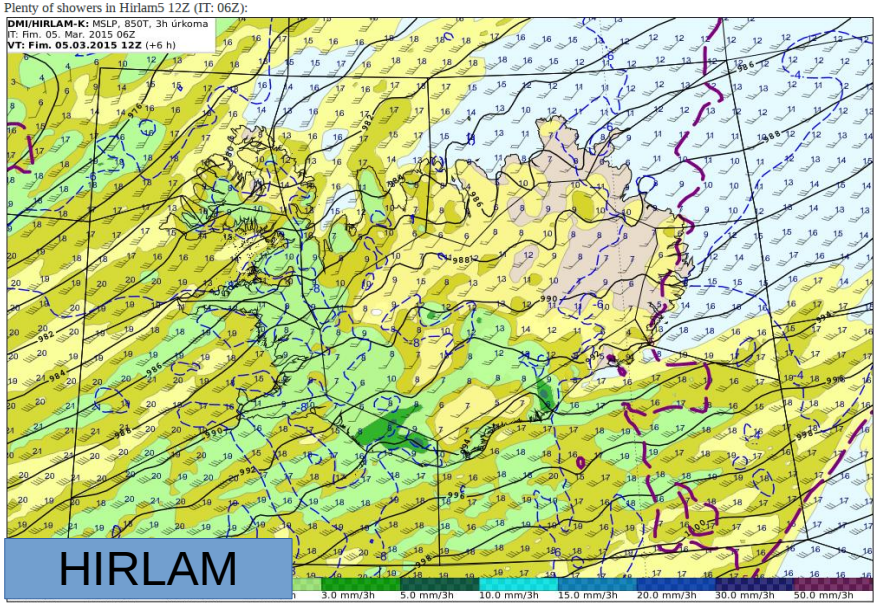
12 h acc precip.

Snow showers, Iceland 20150305

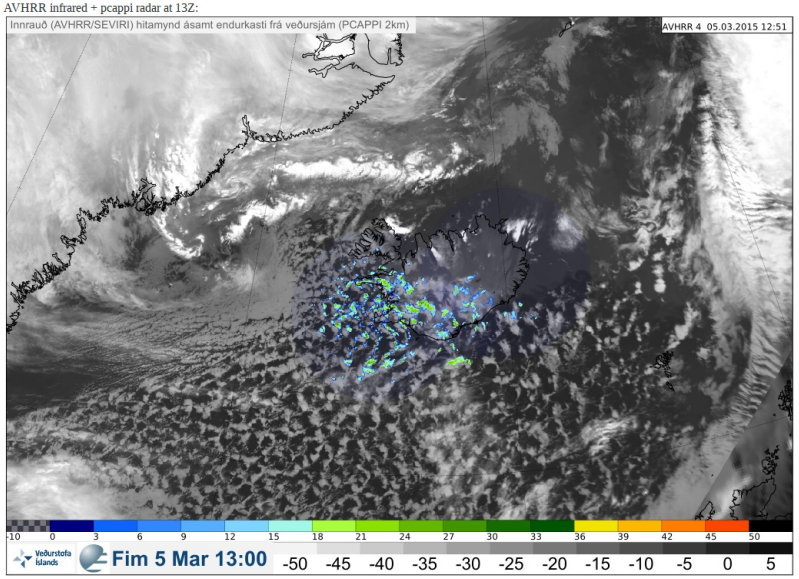
No showers in Harmonie in Reykjavik area 12Z (IT: 06Z):



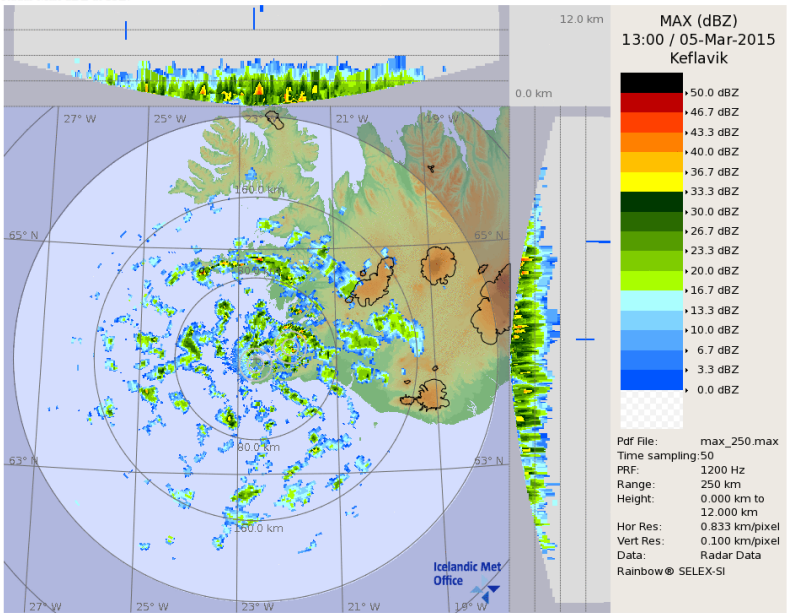
Plenty of showers in Hirlam5 12Z (IT: 06Z):

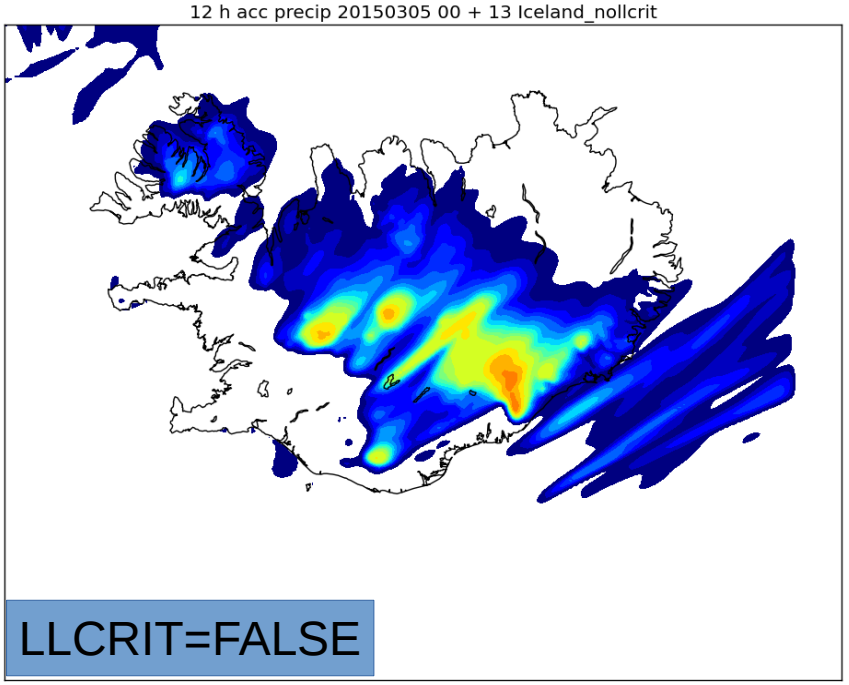


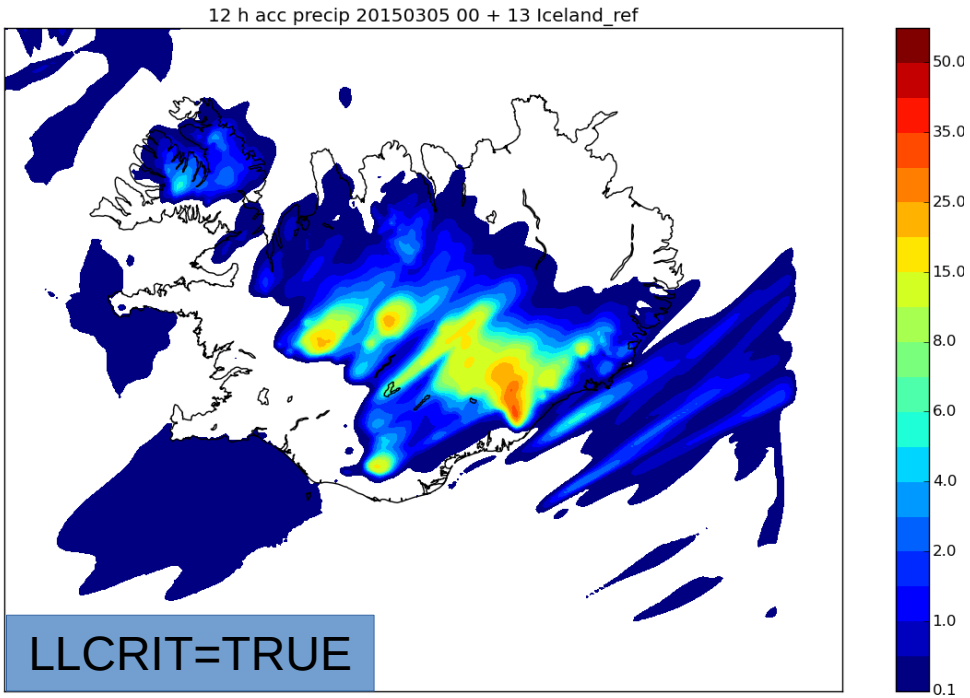
AVHRR infrared + pcappi radar at 13Z:

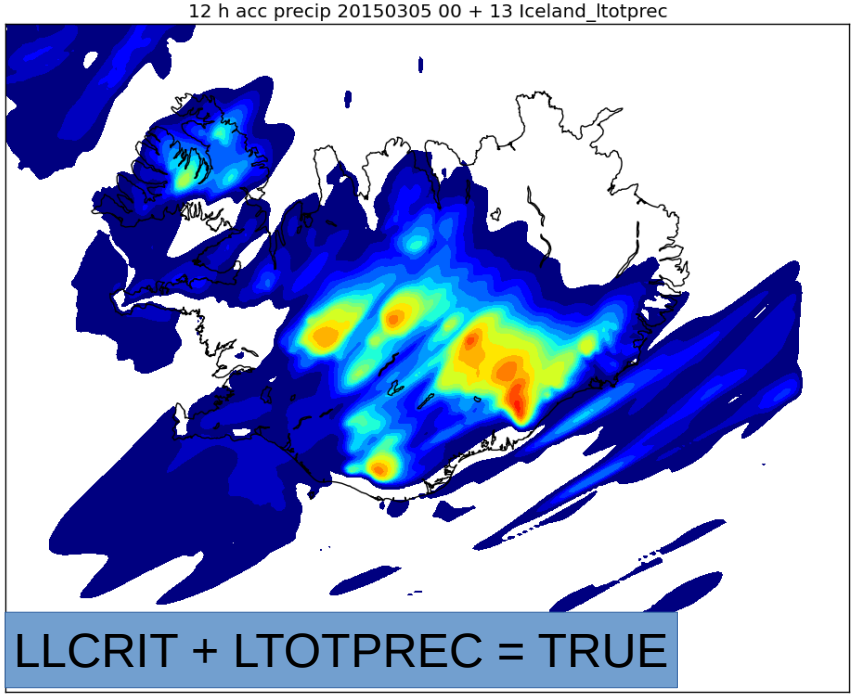


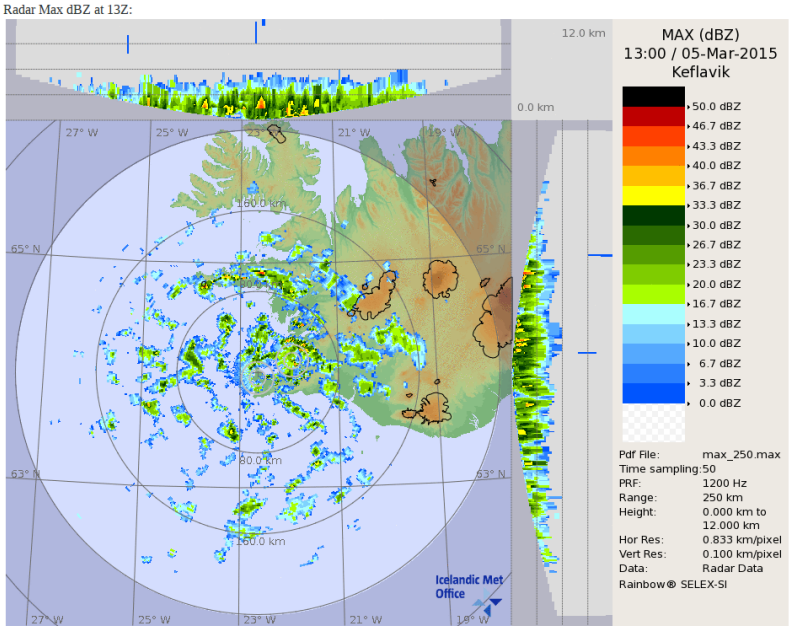
Radar Max dBZ at 13Z:




12 h acc precip 20150305 00 + 13 Iceland_nollcrit
LLCRIT=FALSE
50.0
35.0
25.0
15.0
8.0
6.0
4.0
2.0
1.0
0.1

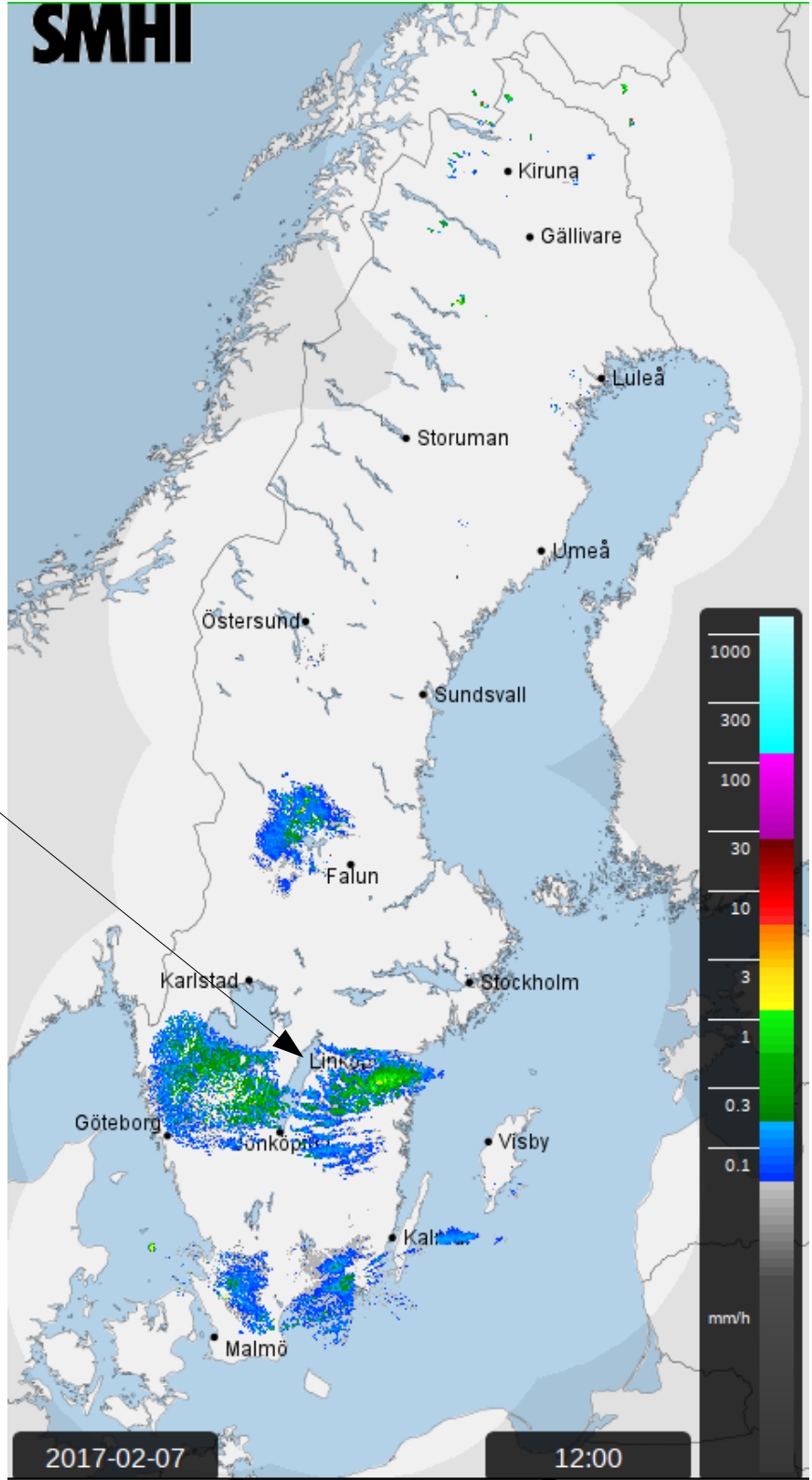

12 h acc precip 20150305 00 + 13 Iceland_ref
LLCRIT=TRUE
50.0
35.0
25.0
15.0
8.0
6.0
4.0
2.0
1.0
0.1


12 h acc precip 20150305 00 + 13 Iceland_ltotprec
LLCRIT + LTOTPREC = TRUE
50.0
35.0
25.0
15.0
8.0
6.0
4.0
2.0
1.0
0.1


Radar Max dBZ at 13Z:
MAX (dBZ)
13:00 / 05-Mar-2015
Keflavik
50.0 dBZ
46.7 dBZ
43.3 dBZ
40.0 dBZ
36.7 dBZ
33.3 dBZ
30.0 dBZ
26.7 dBZ
23.3 dBZ
20.0 dBZ
16.7 dBZ
13.3 dBZ
10.0 dBZ
6.7 dBZ
3.3 dBZ
0.0 dBZ
Pdf File: max_250.max
Time sampling: 50
PRF: 1200 Hz
Range: 250 km
Height: 0.000 km to 12.000 km
Hor Res: 0.833 km/pixel
Vert Res: 0.100 km/pixel
Data: Radar Data
Rainbow® SELEX-SI
Icelandic Met Office

Very light snow showers Norrköping (and surrounding areas)

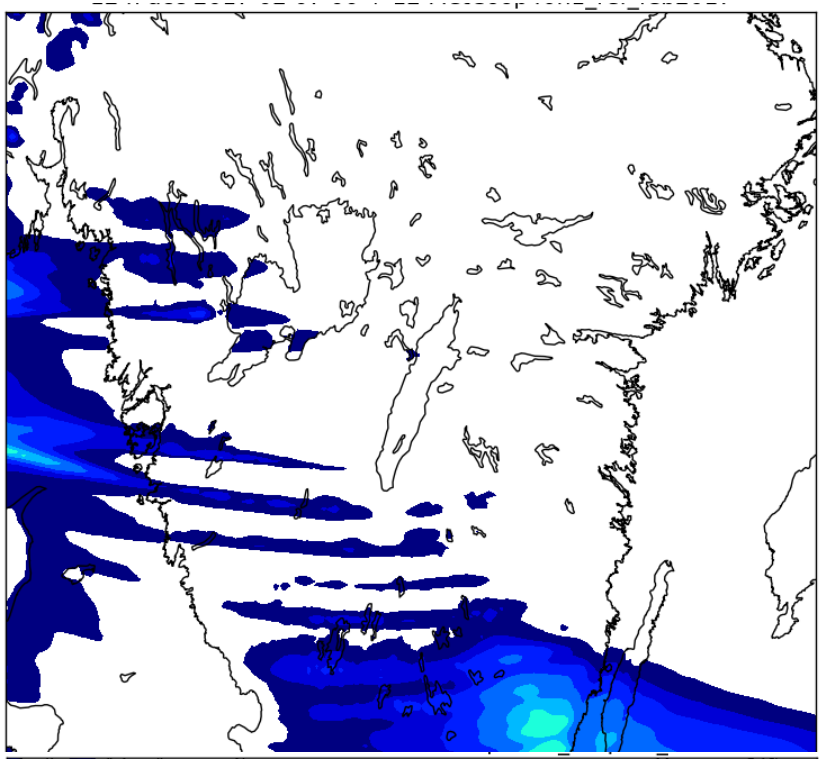
February, 7 – 2017. Operational runs of HARMONIE-AROME did not indicate any snow showers in the region.

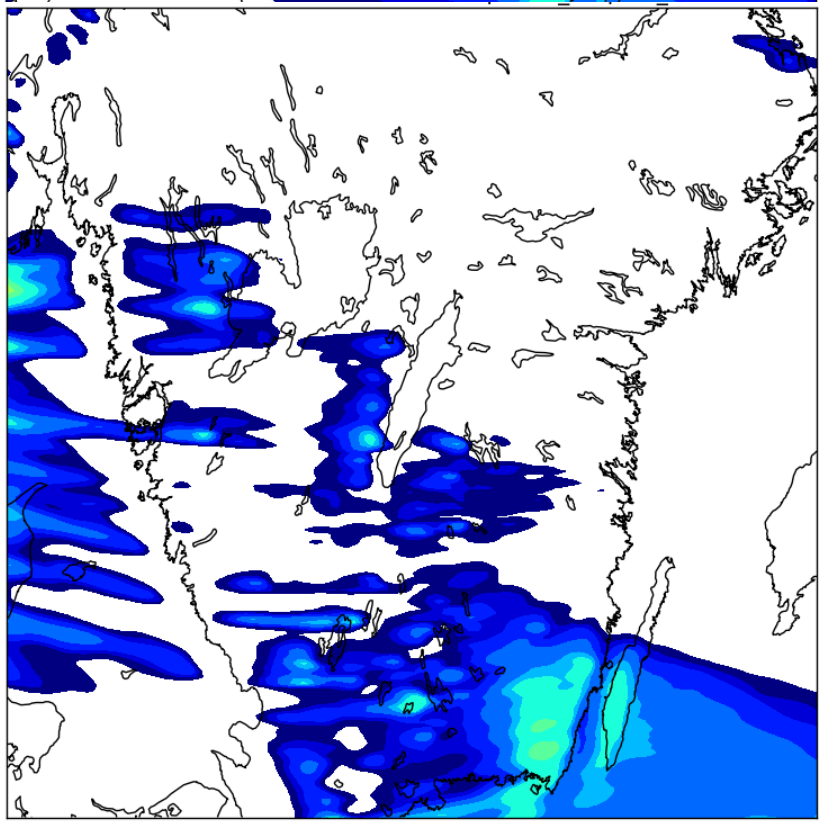


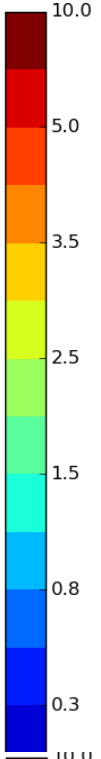
LLCRIT =TRUE

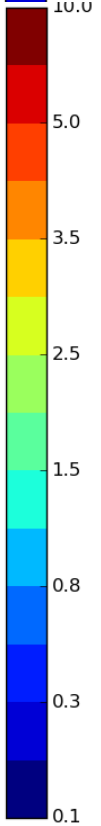
6h acc. Precip.

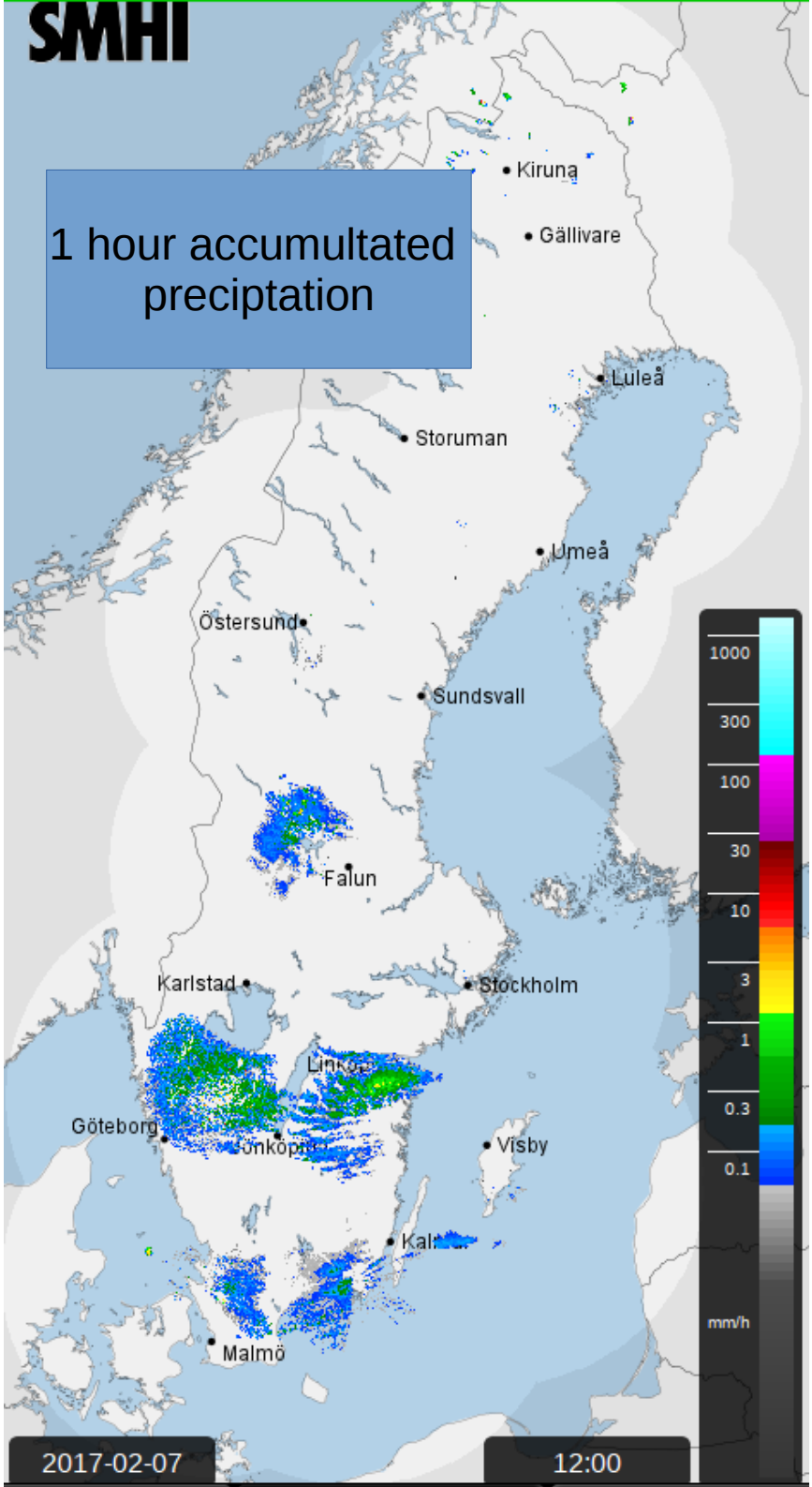
LLCRIT + LTOTPREC =TRUE







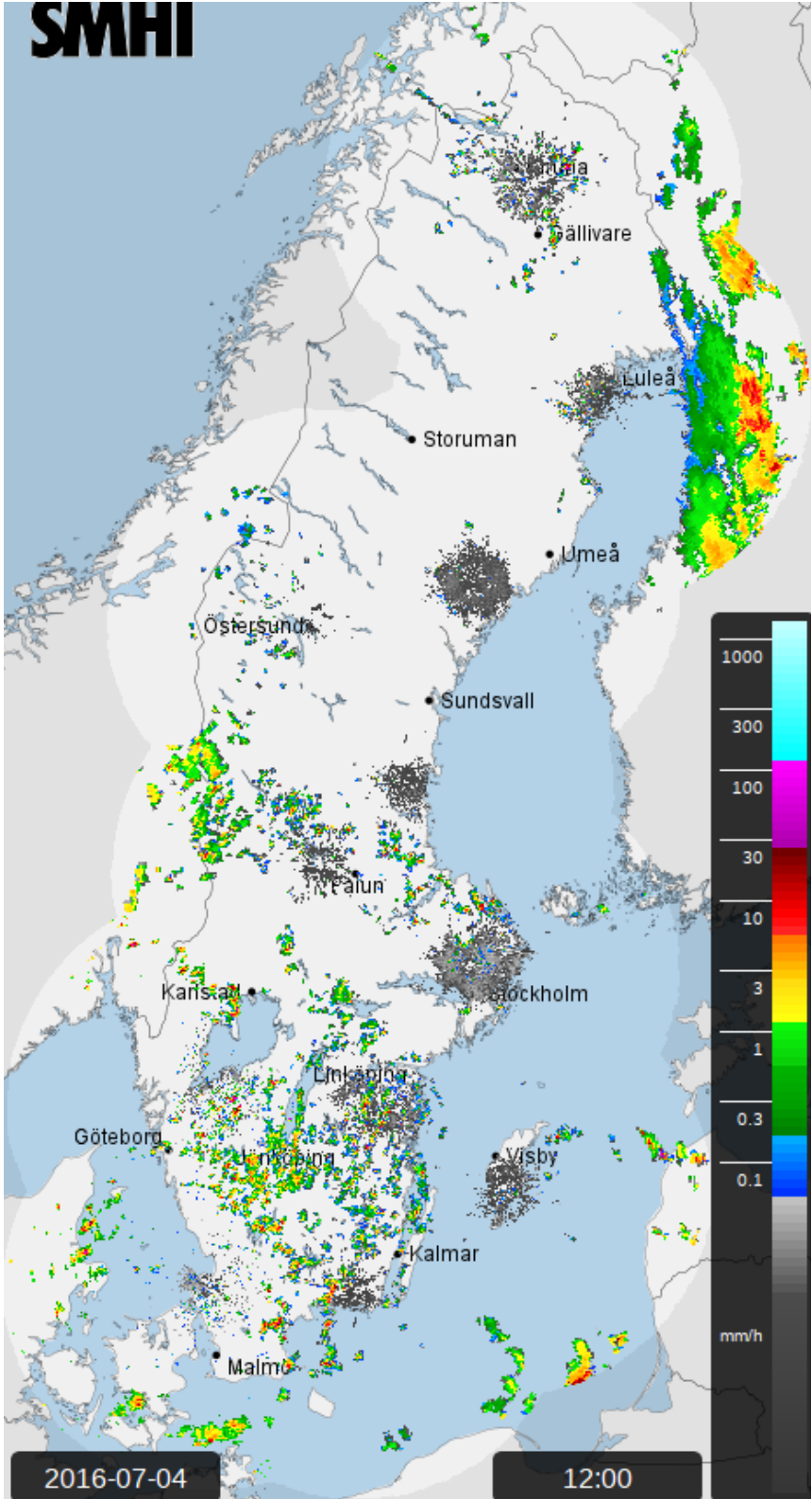




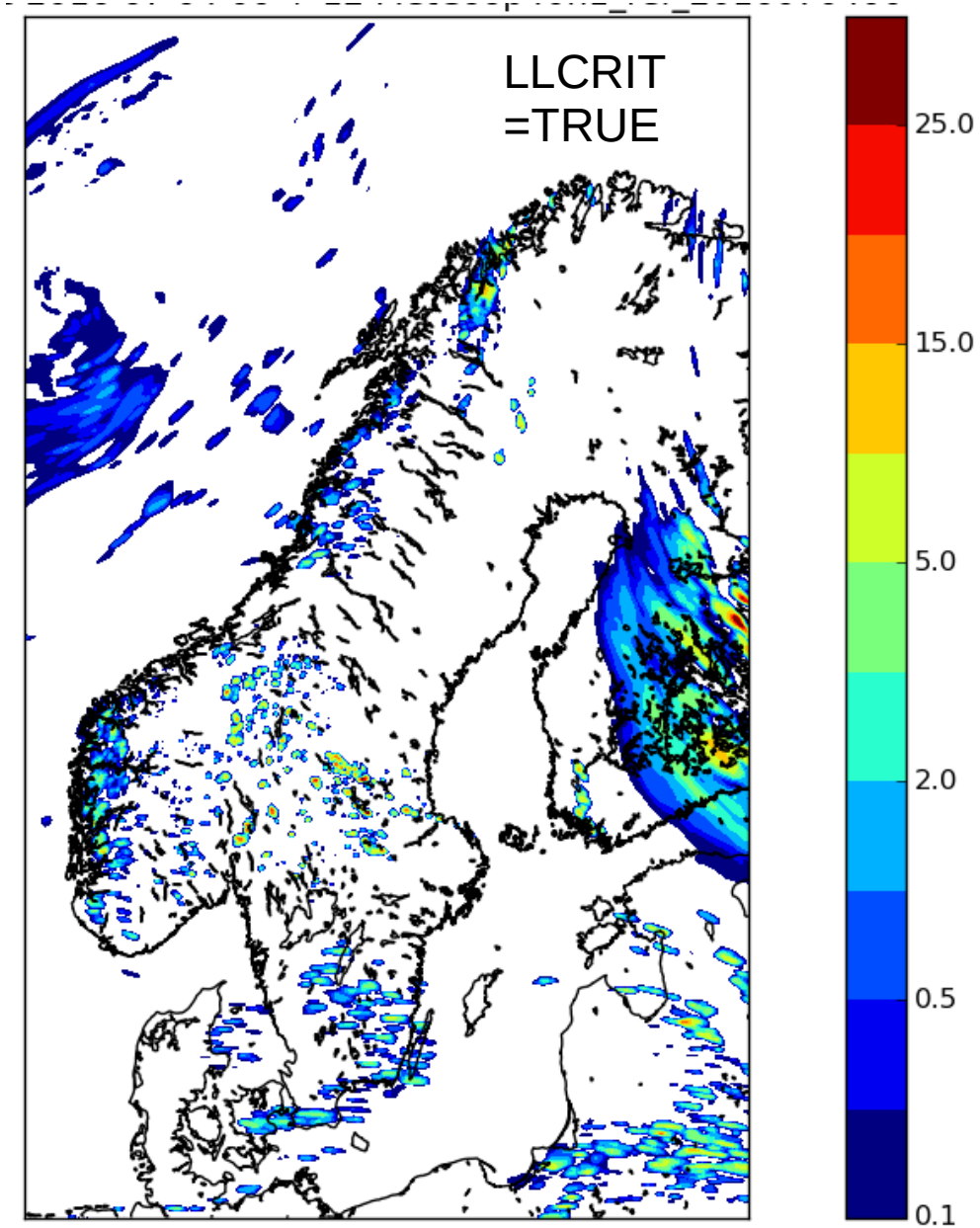
Summer-time convection

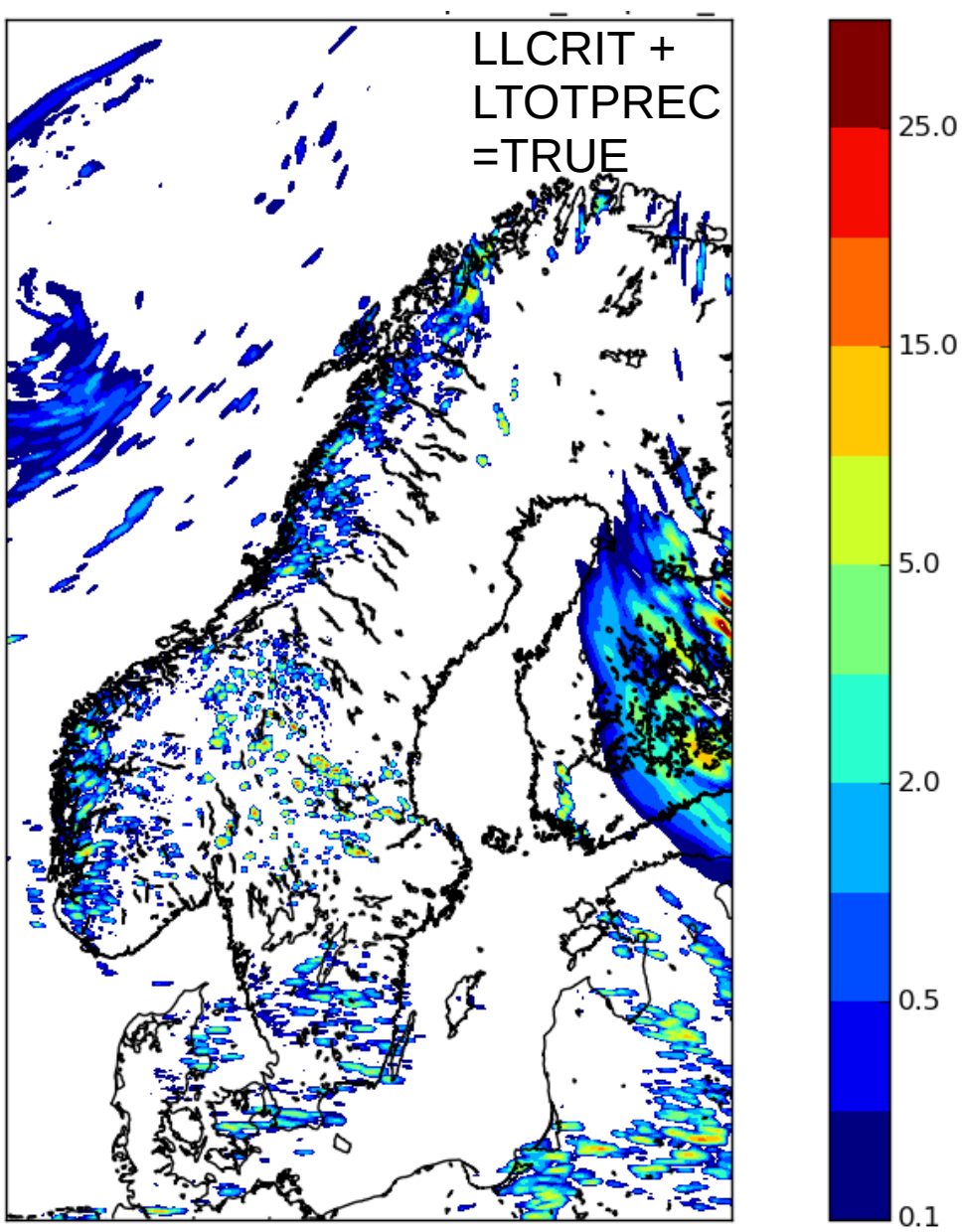
2016-07-04: “Typical Swedish summer”.

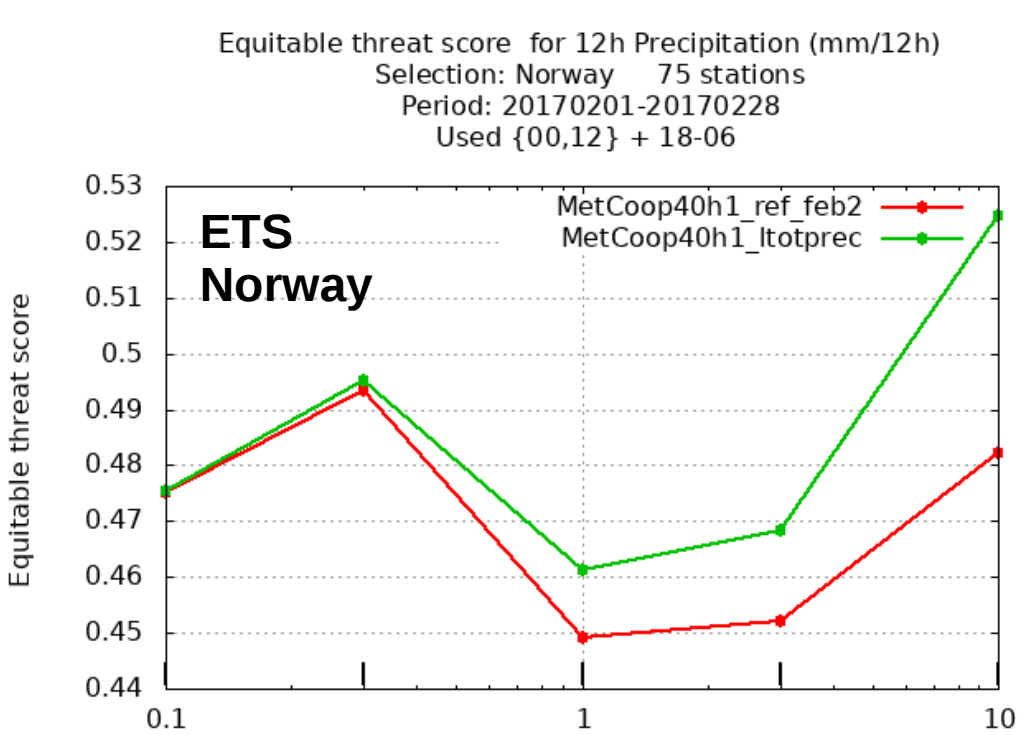
Small-scale showers developing after day-time heating, with colder air aloft.

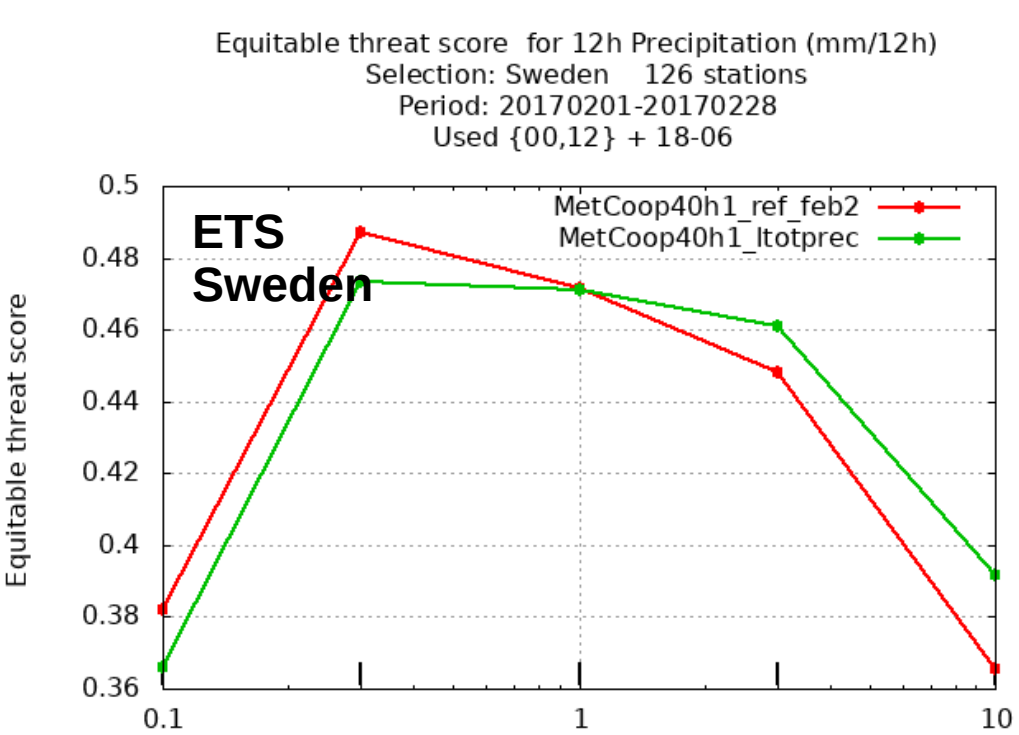


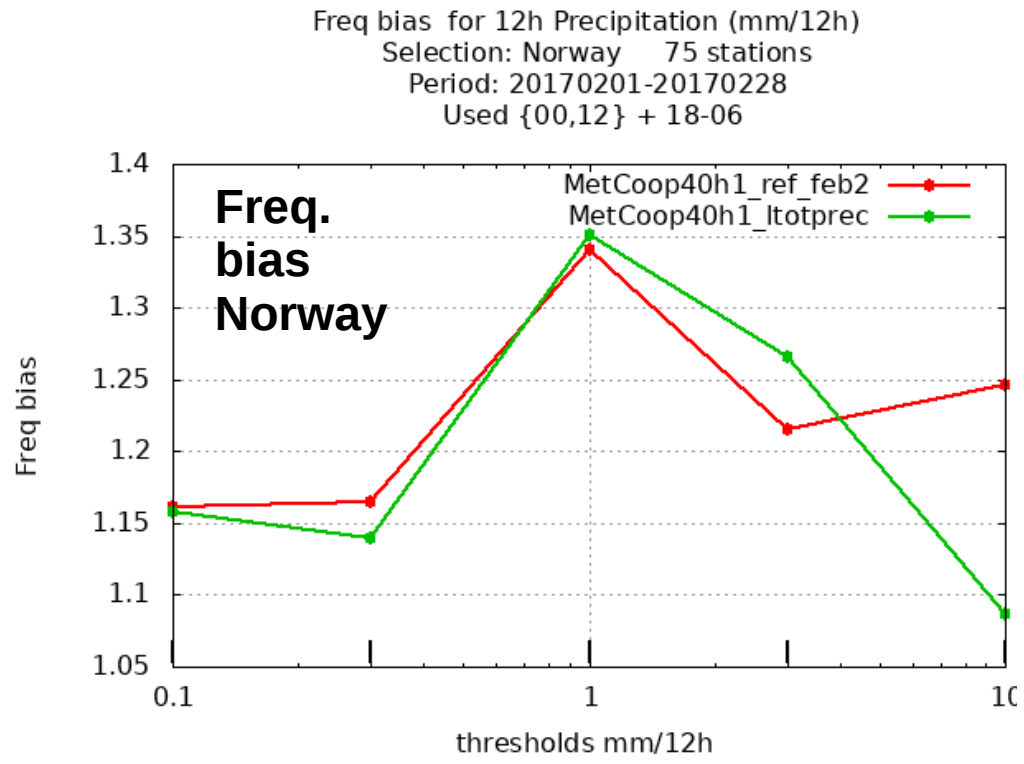
1 hour accumulated precipitation

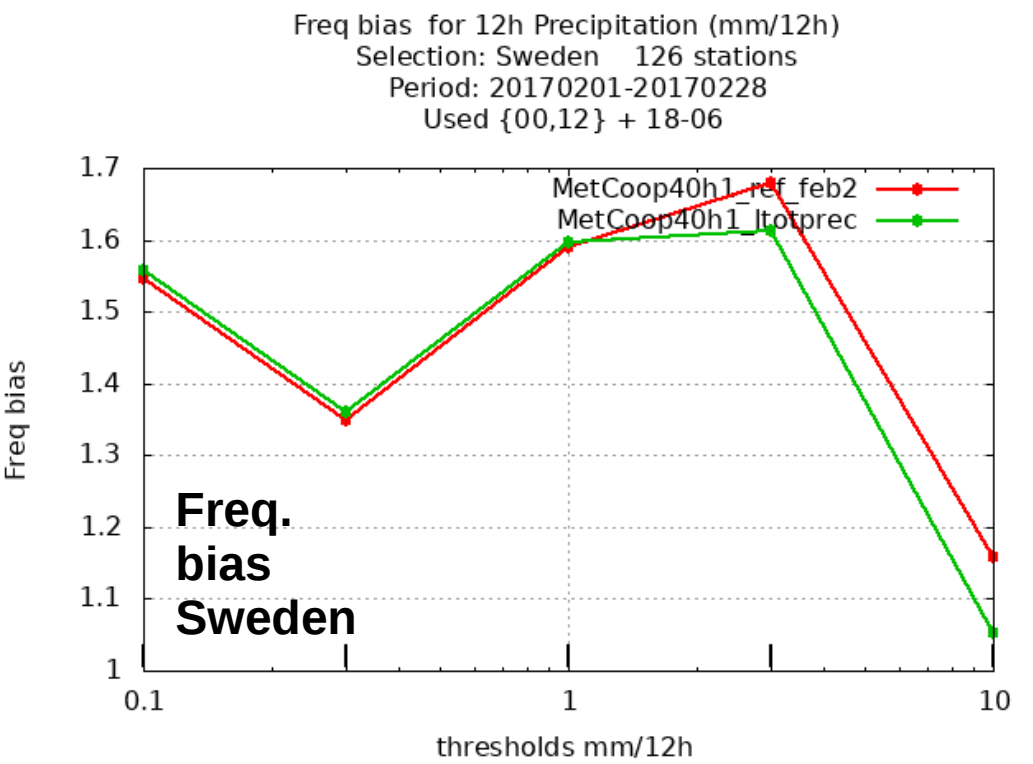




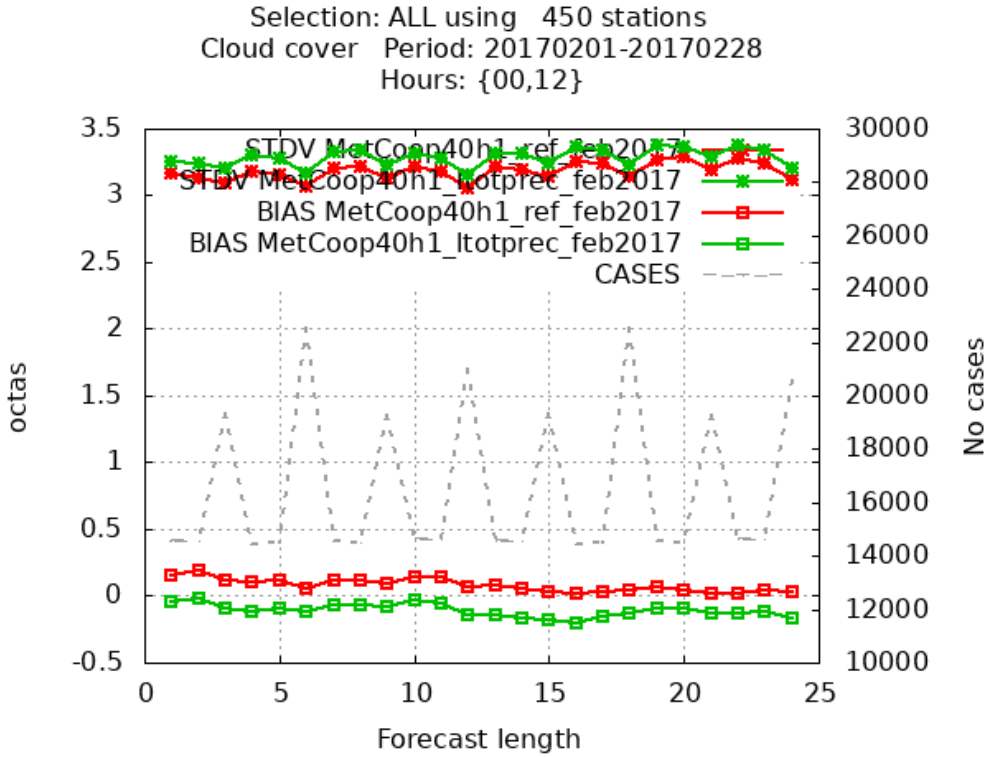

Equitable threat score for 12h Precipitation (mm/12h)
Selection: Norway 75 stations
Period: 20170201-20170228
Used {00,12} + 18-06
ETS
Norway
MetCoop40h1_ref_feb2
MetCoop40h1_ltotprec
Equitable threat score
0.53
0.52
0.51
0.5
0.49
0.48
0.47
0.46
0.45
0.44
0.1
1
10

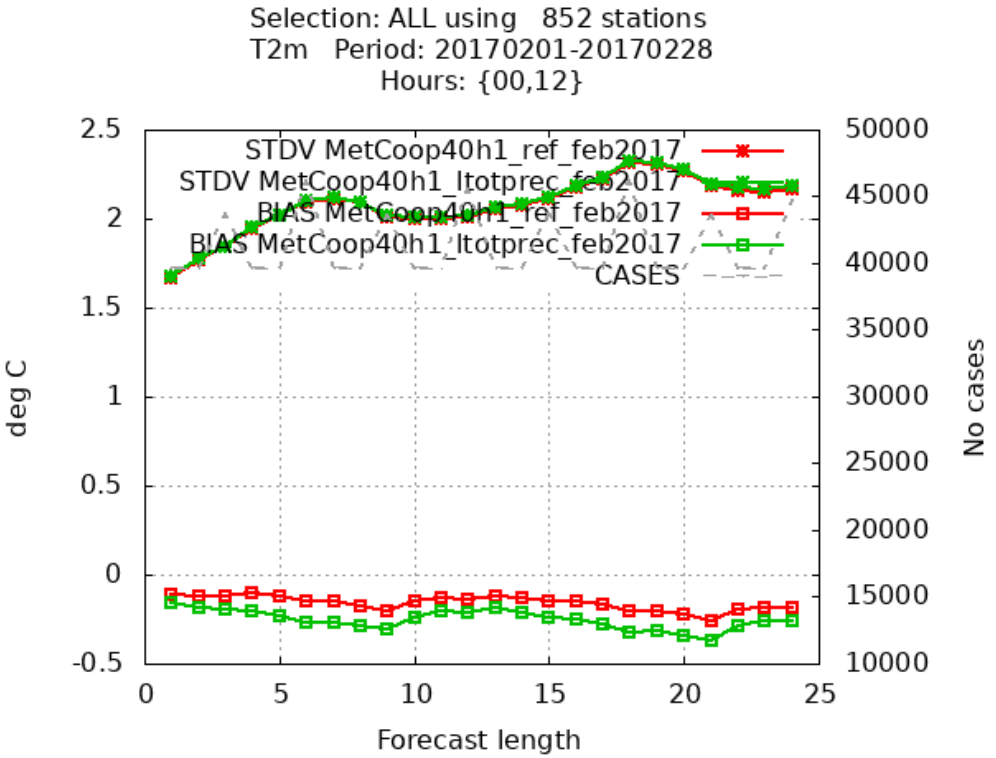

Equitable threat score for 12h Precipitation (mm/12h)
Selection: Sweden 126 stations
Period: 20170201-20170228
Used {00,12} + 18-06
ETS
Sweden
MetCoop40h1_ref_feb2
MetCoop40h1_ltotprec
Equitable threat score
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
0.1
1
10


Freq bias for 12h Precipitation (mm/12h)
Selection: Norway 75 stations
Period: 20170201-20170228
Used {00,12} + 18-06
Freq.
bias
Norway
MetCoop40h1_ref_feb2
MetCoop40h1_ltotprec
Freq bias
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
0.1
1
10
thresholds mm/12h


Freq bias for 12h Precipitation (mm/12h)
Selection: Sweden 126 stations
Period: 20170201-20170228
Used {00,12} + 18-06
Freq.
bias
Sweden
MetCoop40h1_ref_feb2
MetCoop40h1_ltotprec
Freq bias
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.1
1
10
thresholds mm/12h

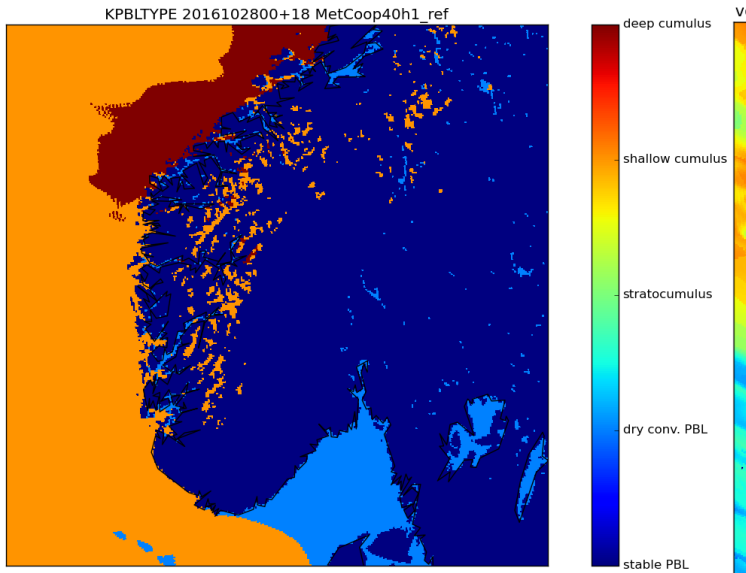
Cloud cover and 2m temperature



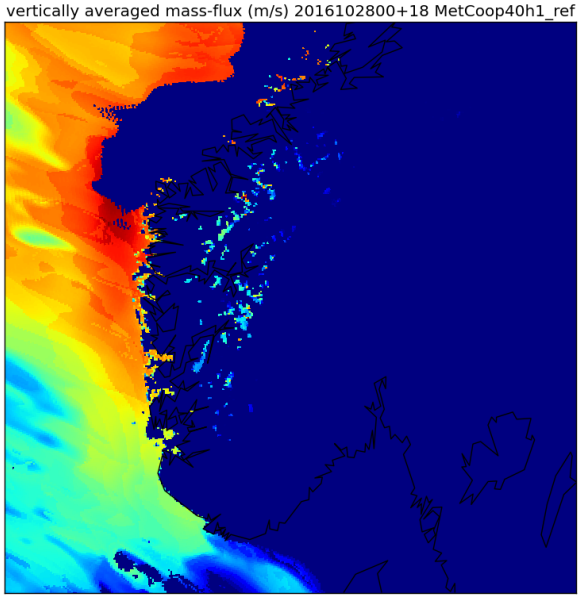


Diagnostic convection closure

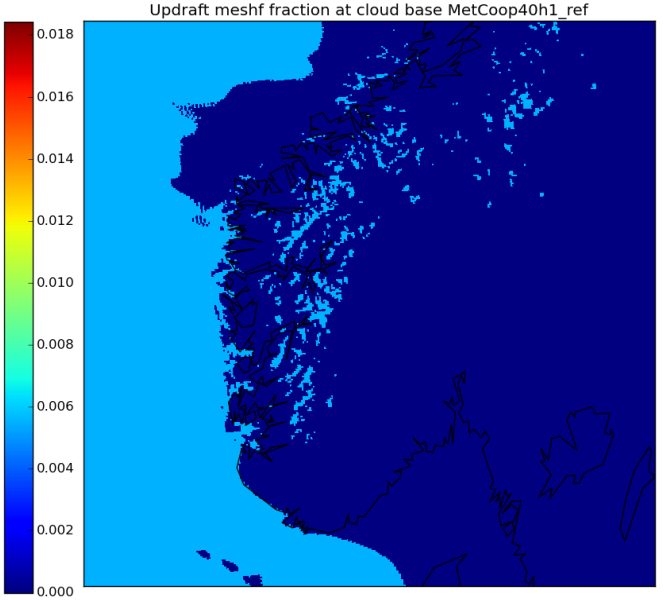
When the convective closure is diagnostic, based on the stability in a 1D column, we don't get the desired advection (or organized propagation of cells) in over the coast. Fields strictly follow the coast line due to the warmer sea surface temperatures.



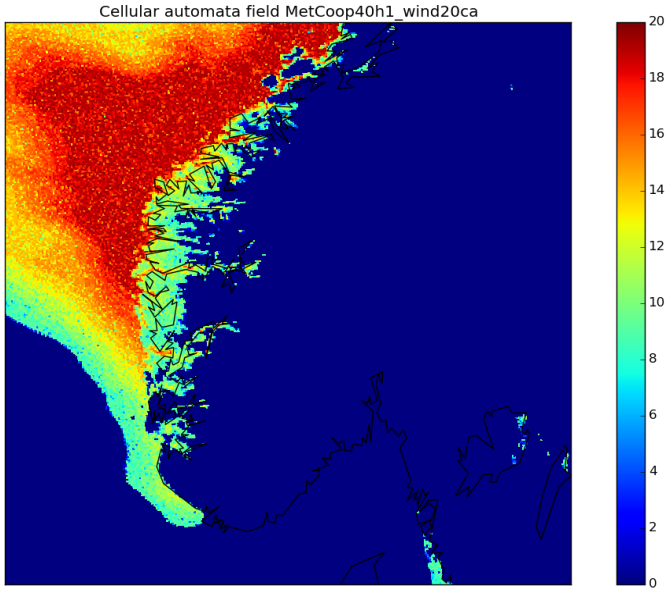
Type of boundary layer



Vertically averaged mass-flxu (m/s)



Updraft mesh fraction at cloud base, ZFRACB

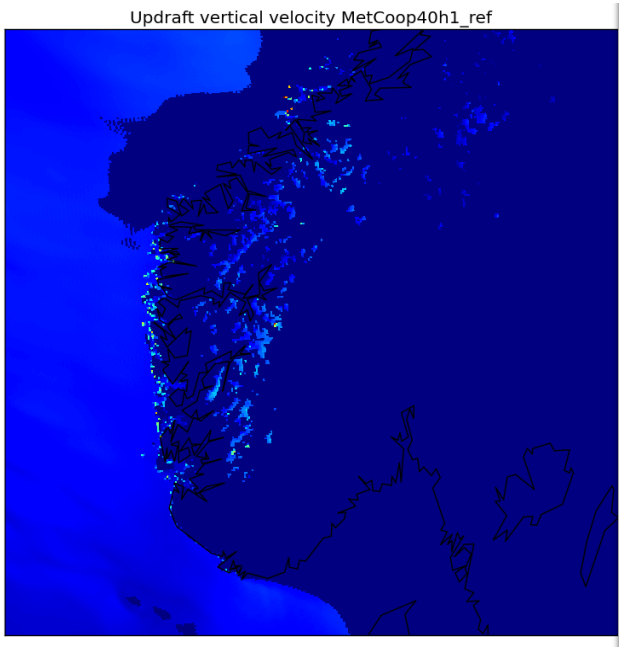


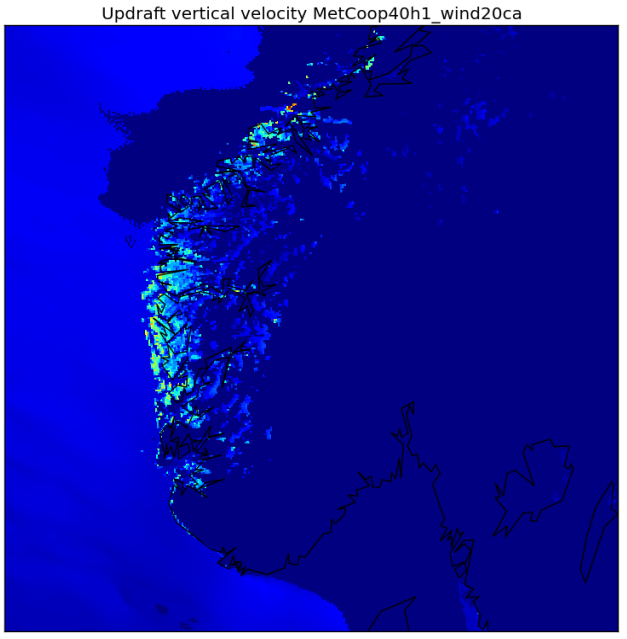
Cellular automata initialized where CAPE > 100 J/kg (each time-step, thus very “dense” field). Use probabilities in the “rules” such that cells are likely to organize in the direction of the mean wind between 850 and 500 hPa.

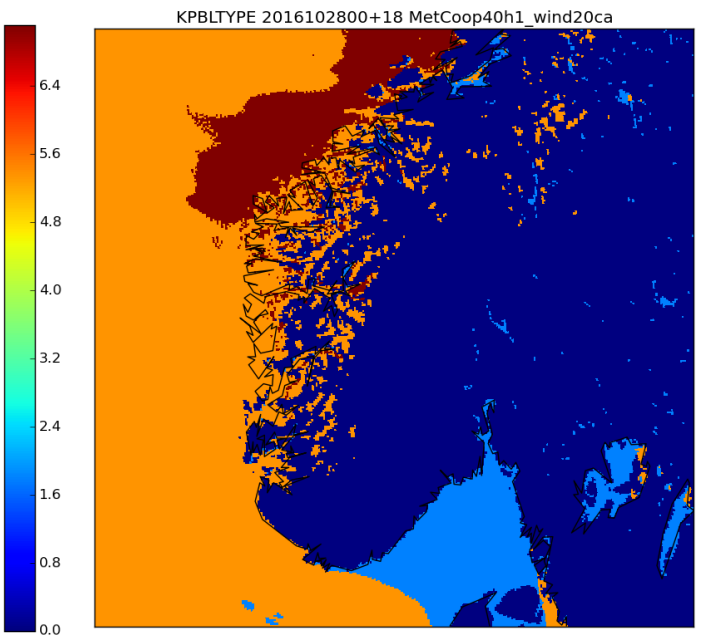
If the mean CA fraction in a grid-box is larger than 0, allow for a “shallow cumulus boundary layer”.

Updraft vertical velocity increases in the region of active CA cells.

Type of boundary layer with CA scheme

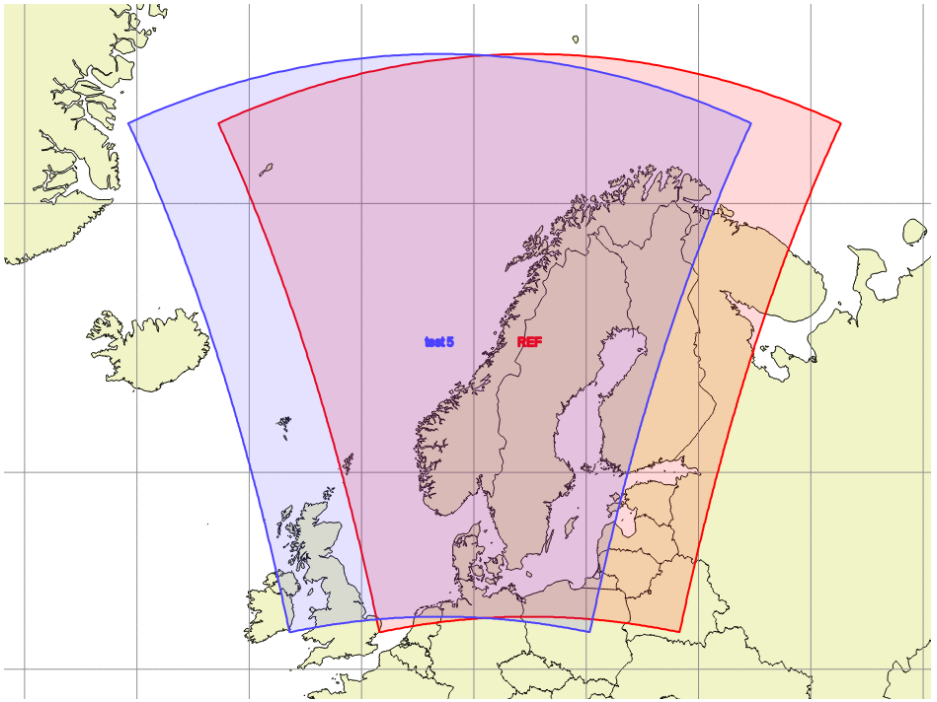






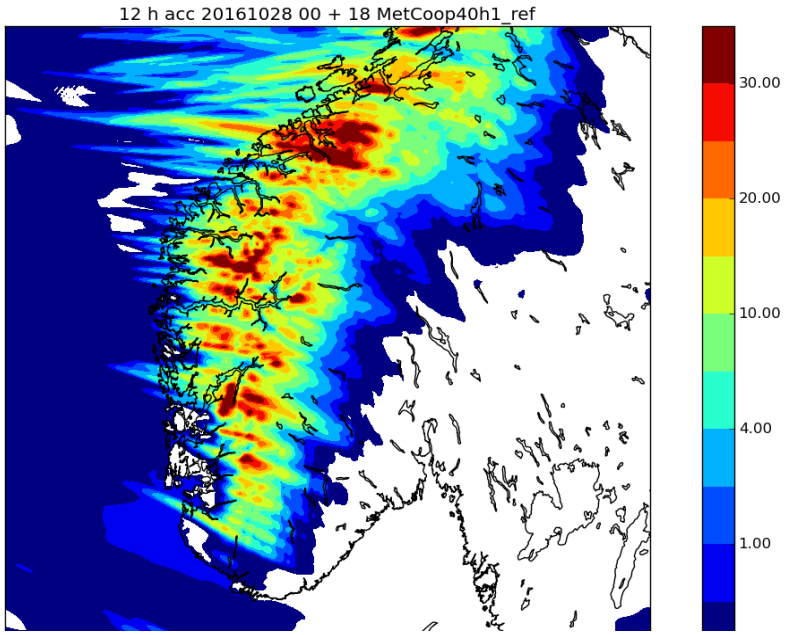
Moving the domain westward

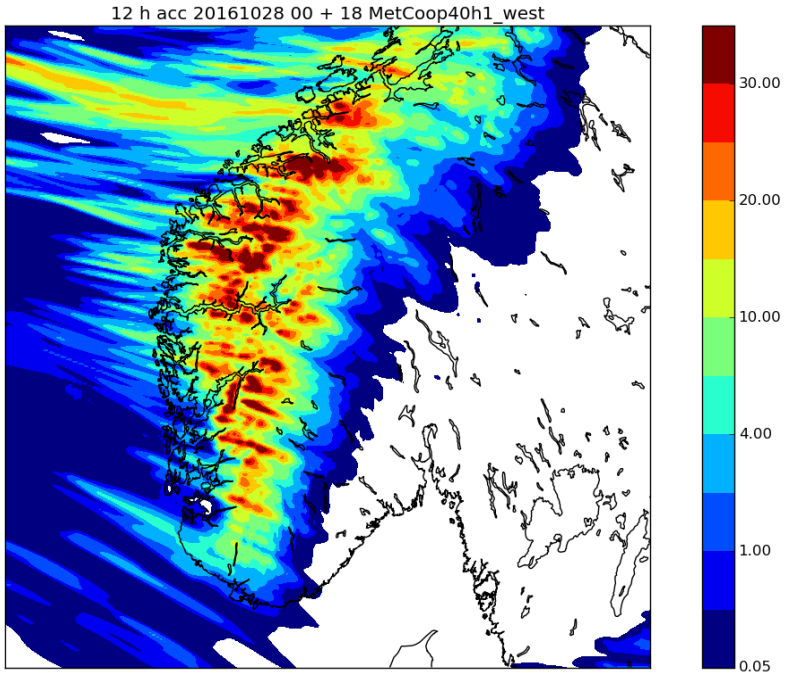
REFERENCE
40h1.1



More convection is treated as deep conv.

Moving the domain westward





Summary and conclusions

- From case studies it seems that the proposed update to the EDMFm precipitation treatment (LLCRIT + LTOTPREC) improves the forecast of snow/rain showers from shallow cumulus.
  - Generally more impact in spring/fall compared to winter.
  - Difficult to verify precipitation over sea.
- The increase in precipitation leads to a reduction in cloud-cover. In winter (february 2017) this leads to a negative bias in both cloud-cover and 2 m Temperature.
- Cellular automata provides interesting characteristics to organize convection and propagate cells in over the coast. Could also be interesting for EPS.
- In the case of October 28th, 2016 it seemed beneficial to move the domain westward to forecast precipitation generated from convection over sea. Probably due to a negative bias in moisture in the ECMWF model at the time.