New tests/developments of cloud physics etc. in MetCoOp (overview)

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OUTLINE:

1: ECUME6: follow up studies

2: LHGT_QS

3: LICERAD

4: Improve forecasts of supersaturation with respect to ICE for contrail forecasts

5: (Deriving the cloud cover from the optical depth of solid water species.)

6: Summary

1: ECUME6: follow up studies

What is ECUME6 ?

ECUME6 is the successor of current ECUME scheme for fluxes over sea in SURFEX. (Developed by Meteo-France.) The fluxes of heat and moisture are generally somewhat larger with ECUME6 than with present ECUME

Earlier tests:

Better clouds and precipitation with ECUME6

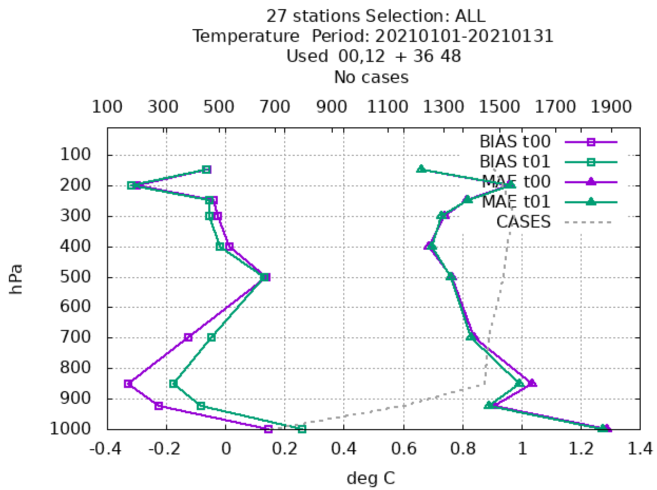
… but too much fog.

Follow-up tests, updated Cy43:

Mostly neutral or marginally better clouds and precipitation with ECUME6, e.g. little more low clouds

Small increase of fog, but since fog is reduced with other tunings (XRIMAX etc) it seems not problematic any more.

Other positive: Better T2M and better T,q verified against soundings



t00 = ECUME,
t01= ECUME6

2: LHGT_QS

Initiated by forecasters complaints about too much fog but too little of low- and middle level clouds.

What is LHGT_QS?

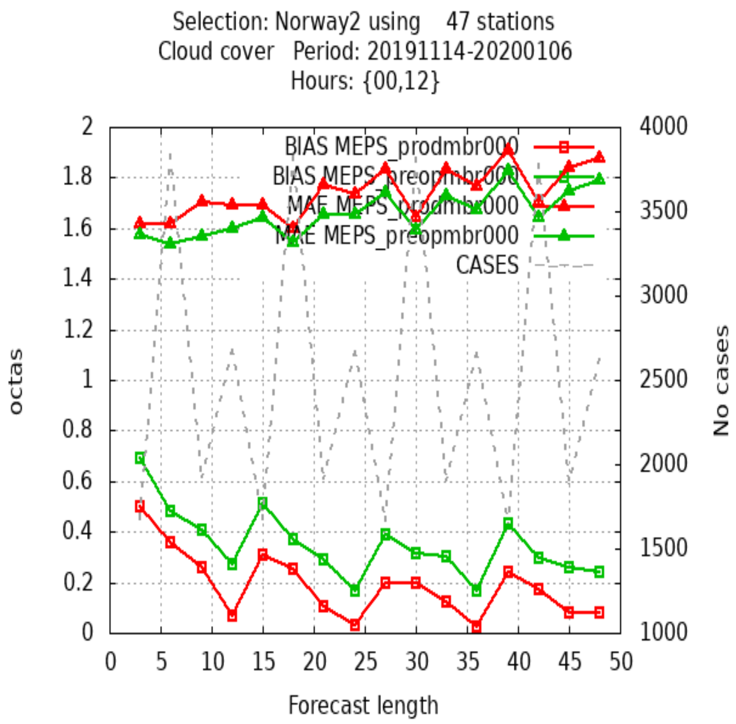
LHGT_QS is a way of **tuning VSIGQSAT** dependent on the model level thickness: Example: VSIGQSAT= 0.02

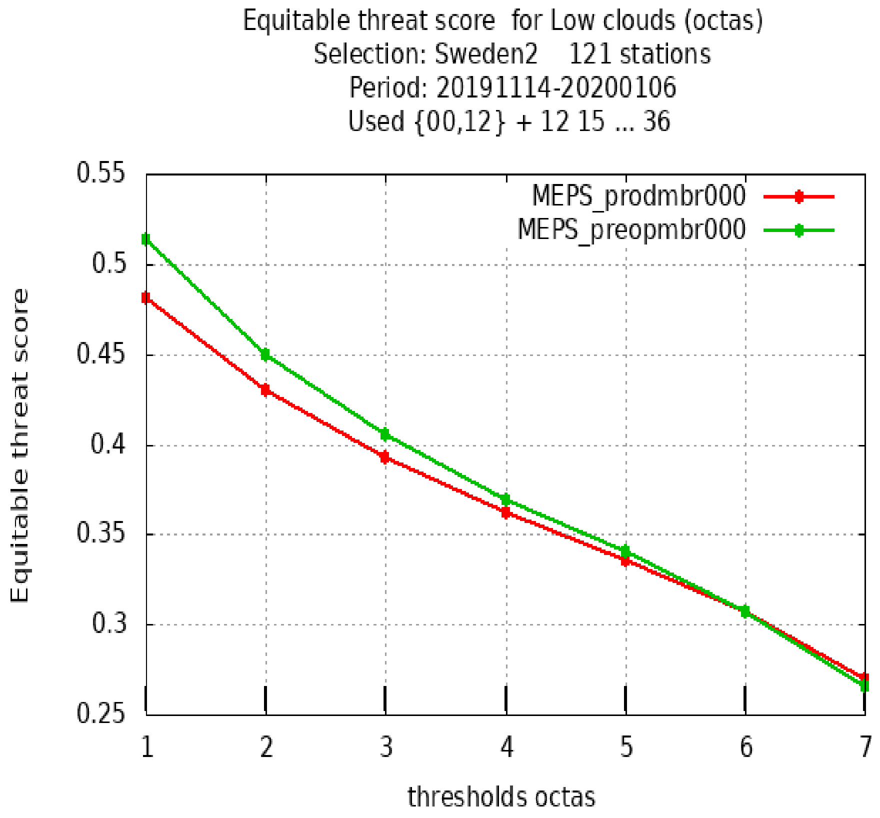
VSIGQSAT is then still 0.02 for a model thickness (DZ) of 30m. For other level thickness's it is VSIGQSAT* DZ/30, with DZ/30 limited to the range [0.5:1.5]. With current 65 levels VSIGQSAT ~ 0.015 at lowest level, unchanged around 200m and 0.03 above 400 m.

The parameters 30m, 0.5 and 1.5 can be changed by RFRMIN:
RFRMIN(23): Lower limit for reduction of VSIGQSAT. Default: 0.5
RFRMIN(24):Upper limit for increase of VSIGQSAT. Default: 1.5 (Higher value → more low clouds)
RFRMIN(25):The level thickness for which VSIGQSAT is unchanged with LHGT_QS. Default: 30m

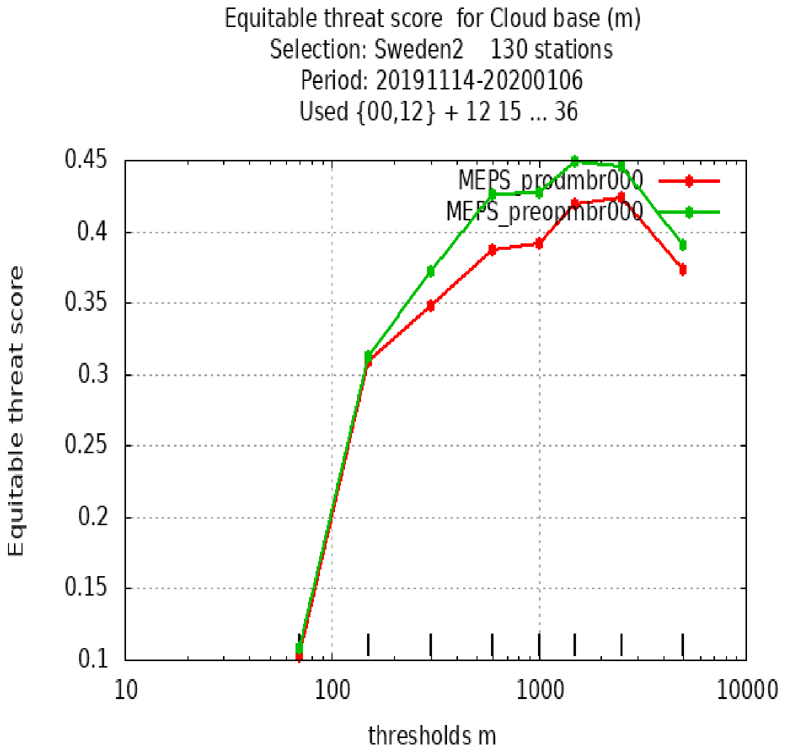
Physical reason for using LHGT_QS: Thicker levels has larger sub grid scale variation of humidity than thinner ones, but this variation is complex so a simple tuning is considered for the moment.

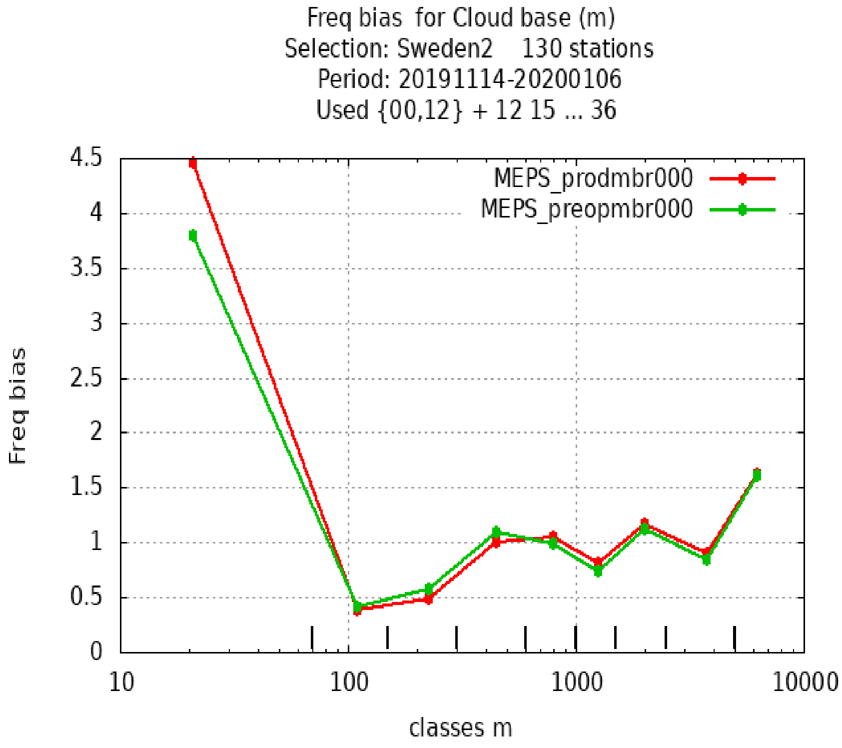
Some results, Total cloud cover and low clouds: (Unfortunately not a completely clean test: The cloud liquid water droplet concentration is also reduced at the lowest model level.) Red: no LHGT_QS. Green: with LHGT_QS





Cloud base: Red: no LHGT_QS. Green: with LHGT_QS





Other results: Mainly neutral impact. A tiny increase of T2m in winter due to more clouds.

3: LICERAD

Initiated by complaints about positive bias of mean sea level pressure at cold season.
What is LICERAD?

With LICERAD, the subgrid fraction of cloud condensate in the radiation scheme is increased in case of ice (and possible snow/graupel)

Why doing this?
Because currently the cloud cover is used as subgrid fraction in radiation, but the cloud cover with mainly ice is reduced when the model level thickness is low and the mixing ratio of frozen water species is low. A way of avoiding too much cirrus and also too much low level ice fog.

But the radiation scheme needs the actual subgrid fraction of frozen water species, which then may be considerably higher than the cloud cover.

LICERAD is a simple solution:

- Use the cloud cover in case of cloud water only, but the grid-fraction 1 (consistent with most of the ice microphysics) in case of only ice/snow/graupel. For a smooth transition, first calculate a fraction of ice, here called F_i:

$$F_i = \frac{r_{stot}}{r_{stot} + r_c + \text{tiny}}$$

The small number 'tiny' is set to 1.E-15, and is there to avoid division with a value very close to zero. r_c is the mixing radio of cloud liquid water and r_{stot} is the mixing ratio of solid water.

- Secondly, make a linear transition from using the cloud cover to using 1 dependent of the fraction of ice.

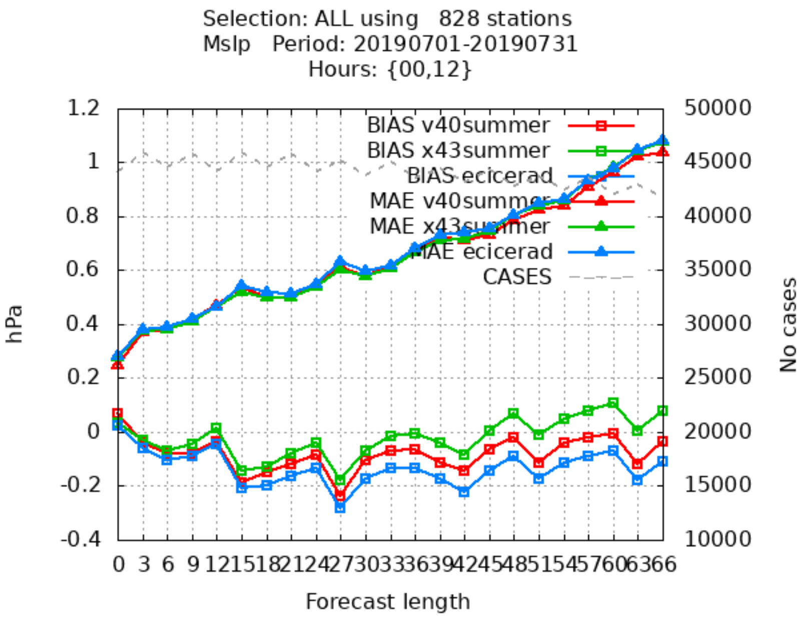
$$C_{tm} = F_i + (1 - F_i)C_t$$

Here, C_t is the original cloud fraction and C_{tm} the new one.

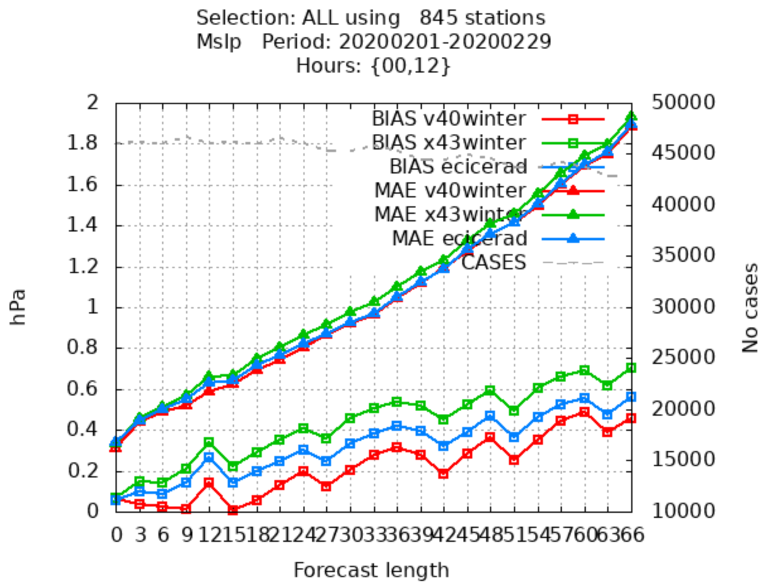
Tests: Thanks to Ole Vignes, met Norway

- Cy40
- Cy43
- Cy43 with LICERAD

MSLP:



MSLP improved in winter, and to some extent in spring/autumn, (not shown), but no general improvement in summer.

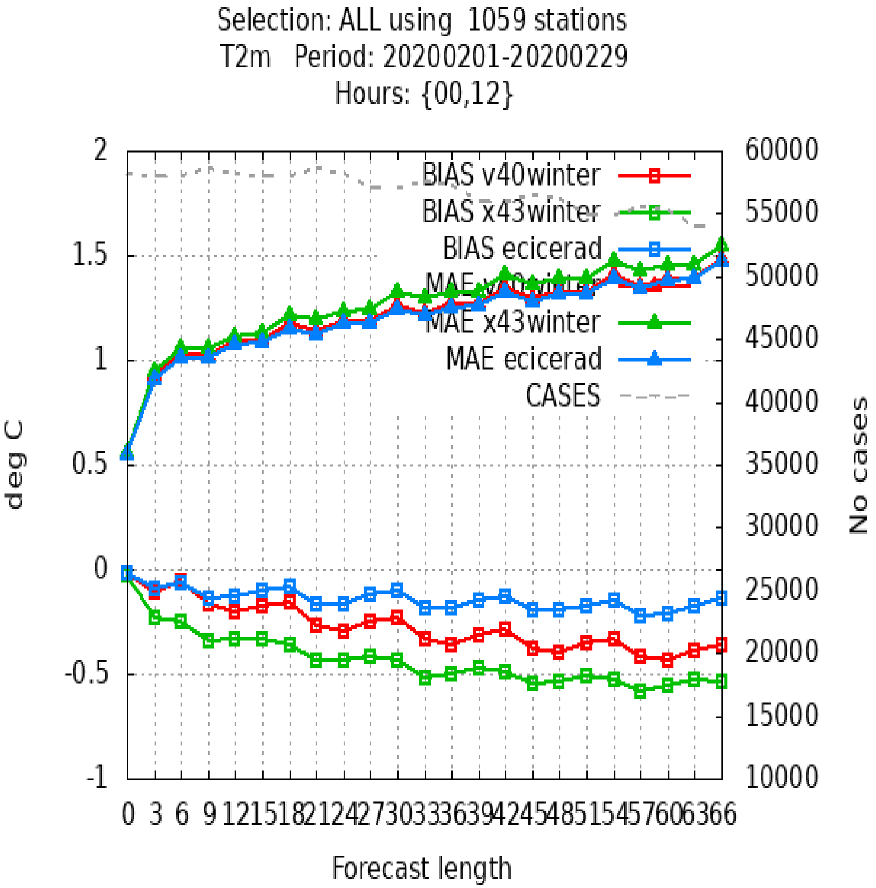


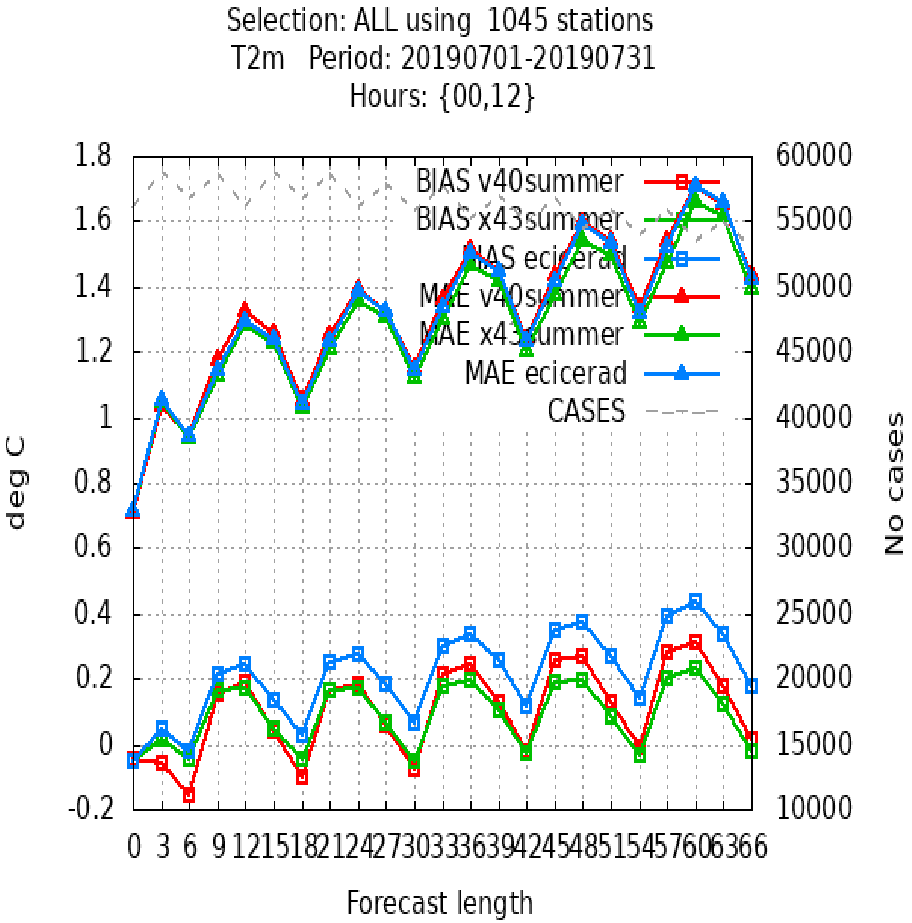
← Winter

↑ Summer

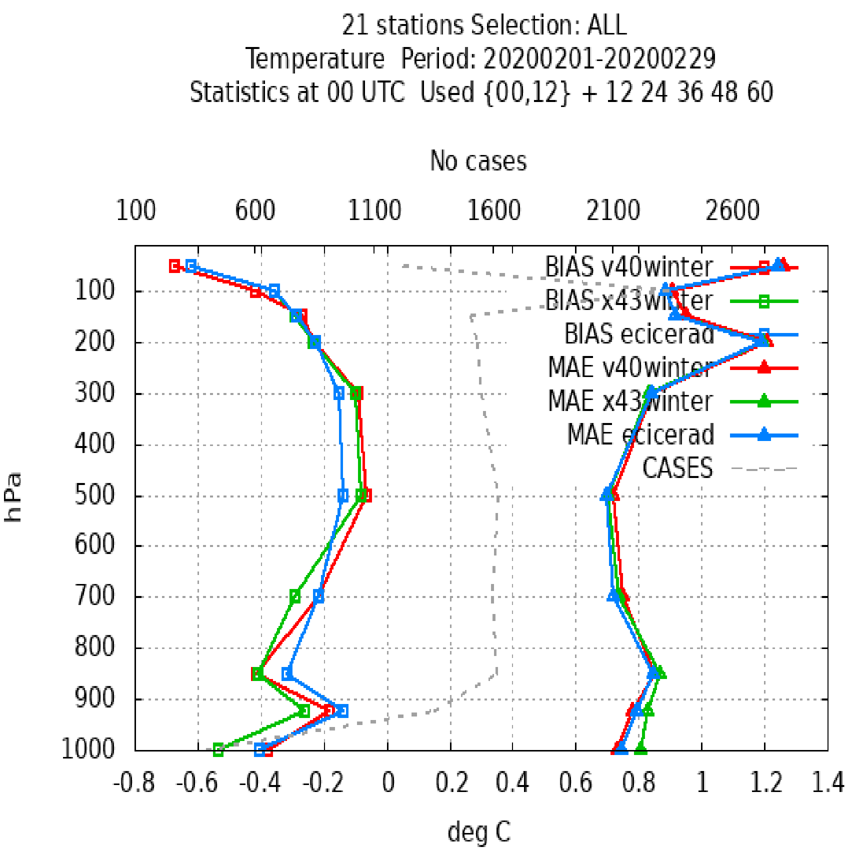
T2m: Left: Winter. Right: Summer

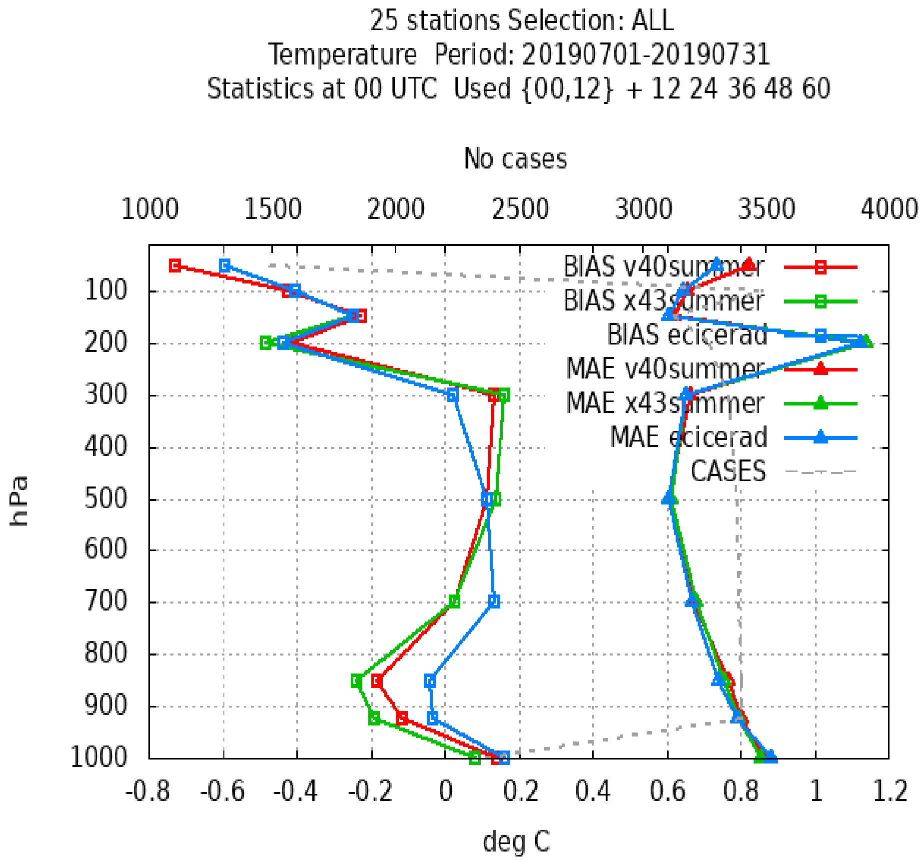
T2m improved in winter (and also in autumn/spring, not shown) but not in summer.





Temperature, soundings. Reduced 'outlyers' of bias with LICERAD

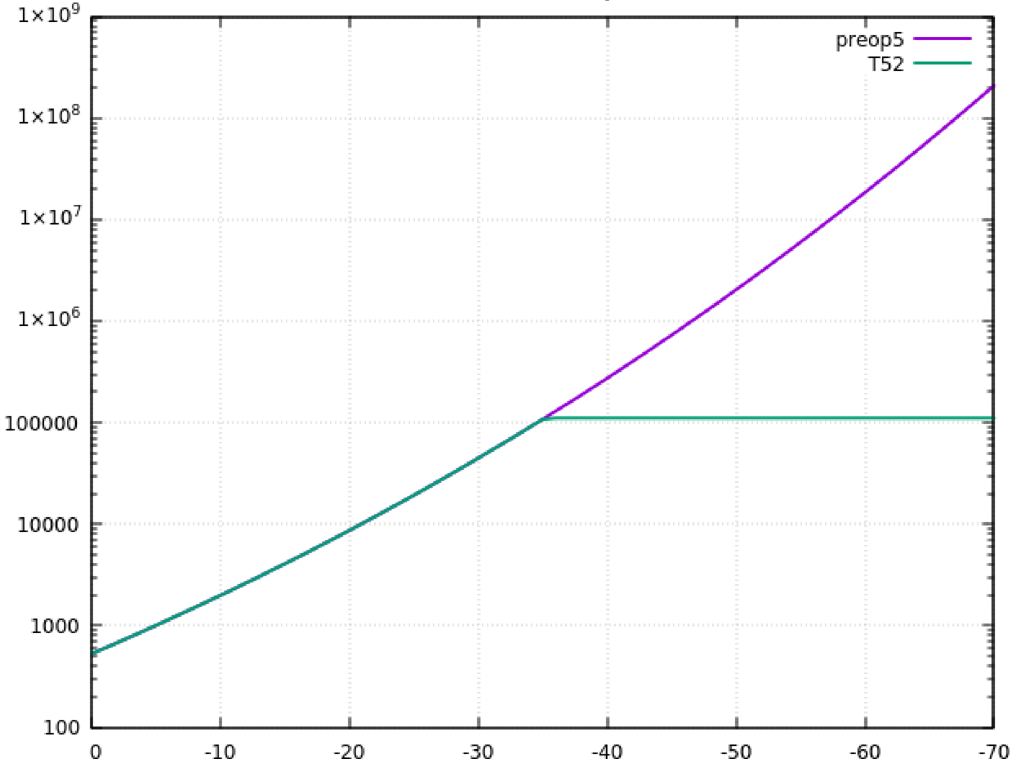




Other findings: When t2m bias is reduced, q2m bias is usually also reduced. Mainly neutral impact in other respects with LICERAD. Note: More advanced surface physics such as ECUME6, ISBA-DIF, ISBA-ES, MEB, may require tuning of RADSN and RADGR if LICERAD is used.

4: Improve forecasts of supersaturation with respect to ICE (e.g. for contrail forecasts)

AROME has too few cases with ice-supersaturation > ~15 % in the region near the tropopause where commercial aircraft have their routes. (Thanks to Ulf Andrae for help with verification!) The ice nucleus (IN) concentration in the microphysics scheme follows Meyers et al (1992), based on measurements between -10C and -30C. However, it is used for all temperatures below -30C, where it perhaps is less valid. ‘Preop5’ follows Meyers formula, see figure below. (x axis, temperature with water saturation (C), y axis: IN concentration, m-3.)



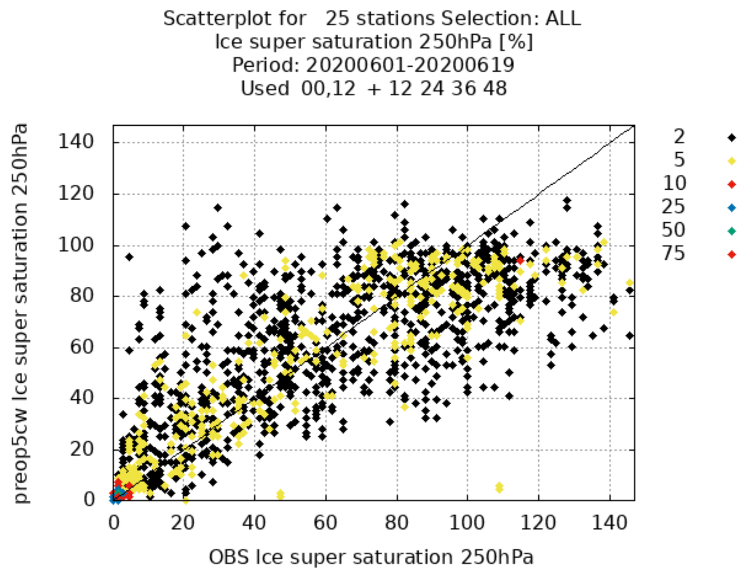
Here, a test by putting an upper limit for the IN-concentration. In the ‘T52’ test it newer exceeds the maximum values for 238K or about
-35 C.

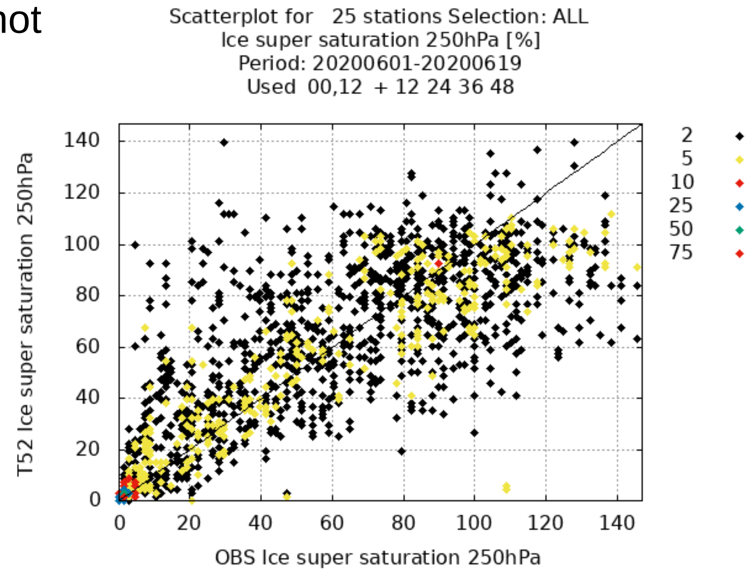
Summary of the results:
Most realistic spread of relative humidity with respect to ice (RHI) with the experiment ‘T52’ near tropopause. See lower plot. The result is fairly the same for summer and winter with mostly neutral result for other verification parameters

To reproduce the test ‘T52’: Set RFRMIN(27) to 238 K.

Be ware of the poor vertical resolution at tropopause level.

It is relative humidity with respect to ice, not supersaturation





5: A test of deriving the cloud cover from the subgrid fraction and the optical depth of solid water species.

Currently, the ice-cloud cover is reduced by B_ci when the model level thickness is low and the mixing ratio of frozen water species is low. Thus avoiding too much cirrus and also too much low level ice fog.

$$B_{ci} = \min(1, A_{ci} r_{stot} (\Delta z / r_{si})^{0.5}).$$

Δz	Thickness of the whole layer	m
A_{ci}	tuning coefficient	$m^{-1/2}$
B_{ci}	tuning coefficient	
r_{stot}	Mixing ratio of solid water	kg kg^{-1}
r_{si}	saturation mixing-ratio of water vapour over ice	kg kg^{-1}

The formula is (partly) based on Xu and Randall, (1996). Here, a similar reduction is performed from the size distribution of water species present in microphysics, in order to adapt it to the current (and upcoming) microphysics.

The 'slice' method: Consider a volume of air with a tiny thickness B, of the same order as the diameters of the particles that are of interest. Assume the area *per volume* hidden by solid water is A. (in m-1) Choosing the thickness of the layer to be the same order as the diameters of the particles, the overlapping of particles within this tiny layer is neglected and the fraction 'hidden' becomes AB.

The next step is to derive the radiative blocking effect of several such thin layers. First, start with two layers only with random overlapping between the layers.
For both layers, the area that is blocked is AB, so the other part is 1-AB. Combined, four alternatives appears, but only (1 − AB)(1 − AB) has no blocking so the total area with blocking becomes 1 - $(1 - AB)^2$

A similar procedure (still random overlapping) with K very thin layers results in 1 - (1 − AB)^ K. For e.g. a model level with a thickness of Δz m, one needs K = Δz/B thin layers.
This leads to the basic expression for the beam blocking effect B2:

$$B2 = 1 - (1 - AB)^{\Delta z/B}.$$

Using the standard microphysics formulas in ICE3, A can be derived for each solid water species: (Valid for spheres and plates, see the table below for the different constants and λ to the left)

$$A = \frac{\pi}{4} C \lambda^{x} \int_0^{\infty} D^2 g(D) d(D) = \frac{\pi}{4} C \lambda^{x-2} \frac{\Gamma(\nu + 2/\alpha)}{\Gamma(\nu)}$$

The cloud cover (C) is computed as C = C_w + (1 -C_w) * min(1,B2*R). C_w is the water cloud fraction and R is a tuning parameter representing how transparent a cloud should be to be regarded as ‘overcast’.

Table 1: Table of constants used for the different water species.

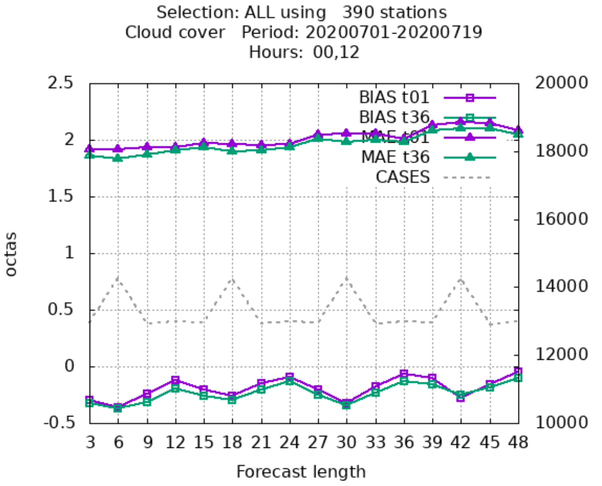
water specie	**a**	**b**	α	ν	C	x
cloud liquid water	524	3	3 on sea 1 on land	1 on sea 3 on land	CCN-conc	0
rain	524	3	1	1	$8\ 10^6$	-1
cloud ice water	0.82	2.5	3	3	IN-conc	0
snow	0.02	1.9	1	1	5	1
graupel	19.6	2.8	1	1	$5\ 10^5$	-0.5

$$\lambda = \left[\frac{r \rho \Gamma(\nu)}{a C \Gamma(\nu + b/\alpha)} \right]^{\frac{1}{x-b}}$$

ρ density of air

r Mixing ratio of water vapour

Described here is basically a new post processing of the total cloud cover, but since low clouds are used in Canari, some other small differences appear for longer experiment with surface data assimilation. Just 19 days in winter and summer has been tested so far, so the results are very preliminary



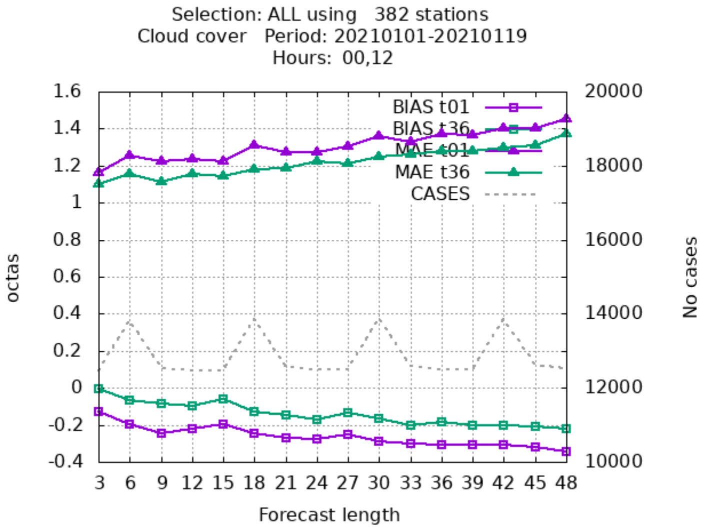
t01 = REF

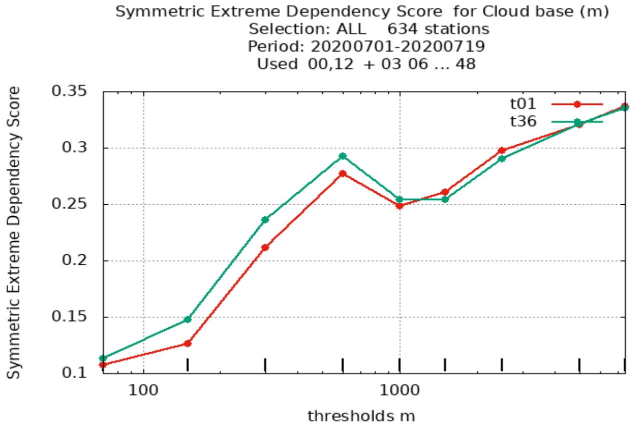
t36 = test

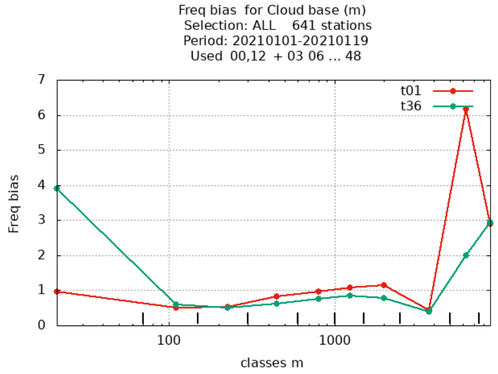
← Summer

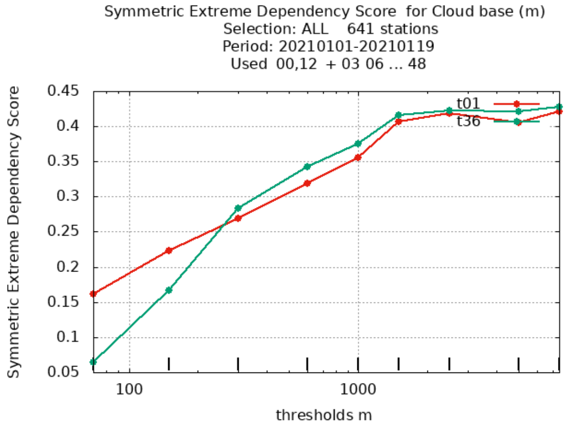
Winter →

Total cloud cover are a little improved during those weeks, more mixed results for cloud base. Somewhat more low- and middle level clouds but somewhat less high clouds.

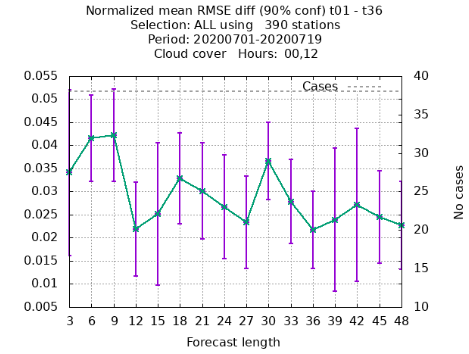




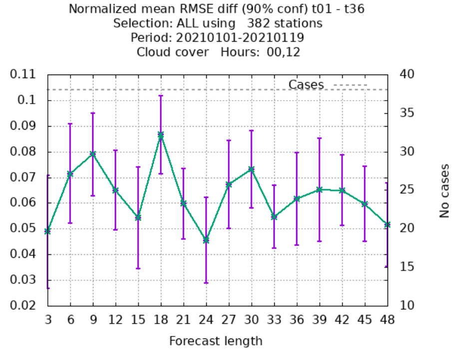


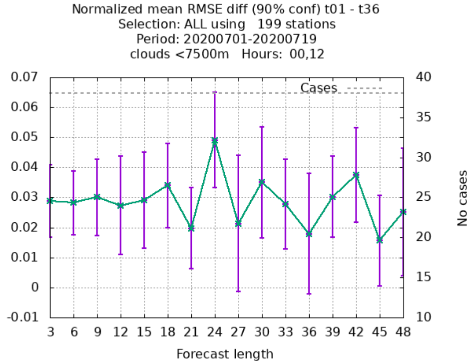


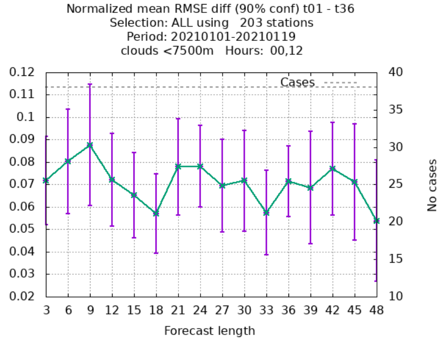
Improvements of RMSE of total cloud, clouds < 7.5km and low clouds are mostly statistical significant

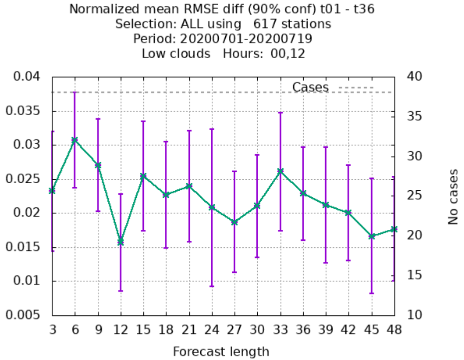


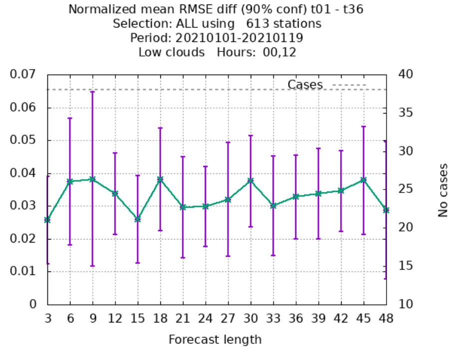
t01 = REF
T36 = test
← Summer
Winter →











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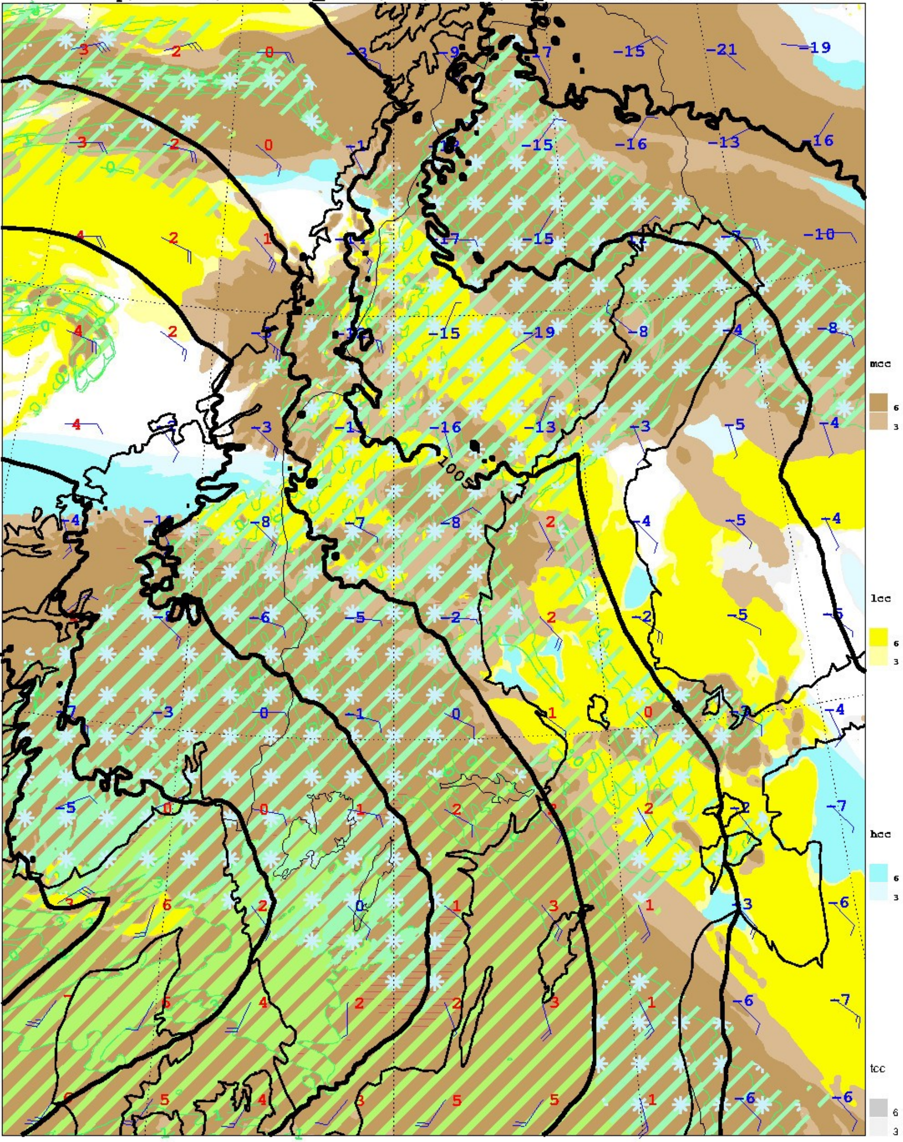


Tue 19 Jan 2021 12Z +24h
valid Wed 20 Jan 2021 12Z

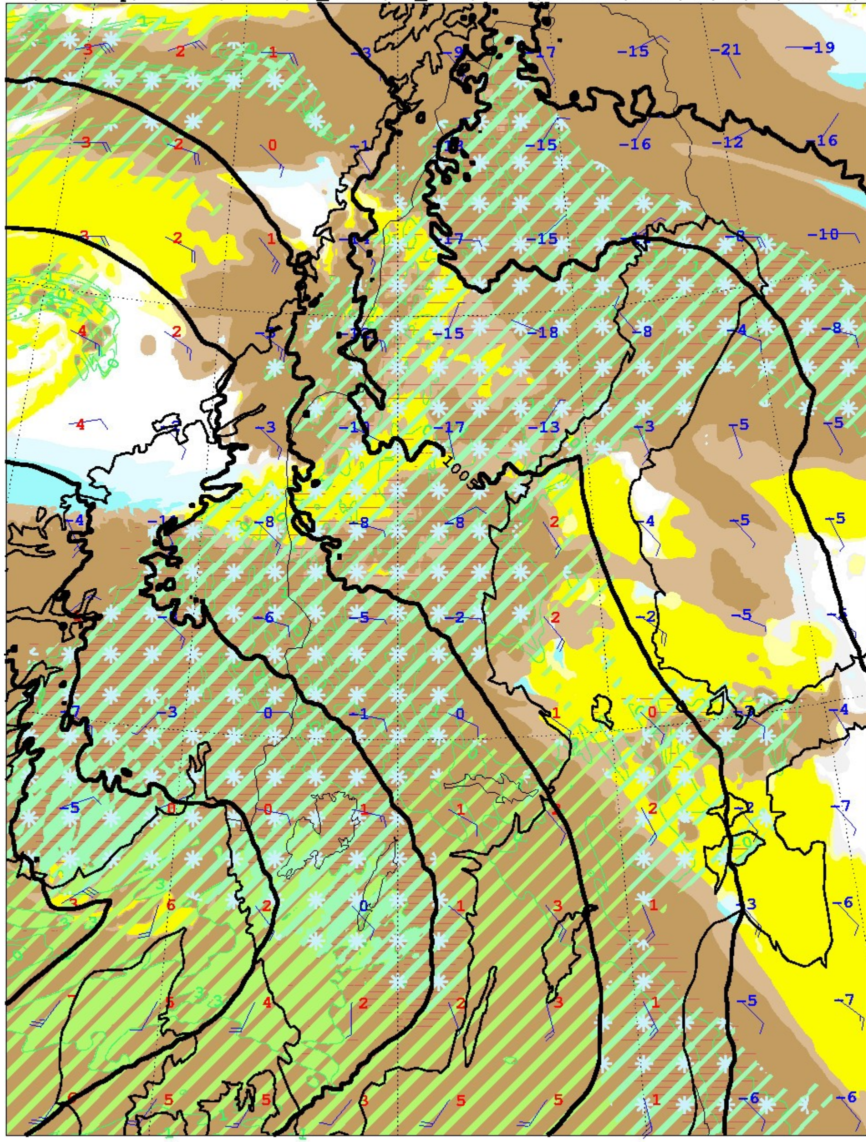
Why degradation of low cloud base in winter?

Answer: Snow and graupel should not be used at the lowest level, since the effect is normally treated as visibility reduction.

← REF MOD →

Colours:
LOW-, MIDDLE- and HIGH CLOUDS.
PRECIPITATION
Horizontal lines: Clouds at lowest level

/nobackup/smhid18/users/sm_kivar/hm_home/43DM2/archive/2021/01/19/12/mbr000/



Tue 19 Jan 2021 12Z +24h
valid Wed 20 Jan 2021 12Z

Summary

- ECUME6 seems promising and LICERAD reduces some systematic errors, but no improvement in summer.
- Tuning with LHGT_QS can give some more low-, and middle level clouds without increasing fog.
- More climatological realistic occurrence of supersaturation with respect top ice with RFRMIN(27), e.g. set to 238 K.
- Deriving cloud cover from the optical depth of solid water species seems promising so far, but longer tests and some adjustments are needed.