Predicting low clouds, fog and visbility : experiences and ideas for future strategy

OUTLINE:

- **Importance of predicting fog and visibility**
- **Processes determining the forecast challenge**
- **Brief estimation of strengths and weaknesses in our process description and some verification results**
- **Ideas for strategy to improve model prediction of fog and visibility**
- **References**

Importance of predicting fog and visibility

- **Traffic including aviation can be strongly influenced by low visibility creating hazards : As a consequence good warnings and forecasts are valuable !**

- **Apart from the forecasting of cloud bursts and quantitative precipitation, fog and visibility are among the most difficult and important parameters that are not yet considered good enough by the users !**

What is the status of Arome-Aladin-Hirlam forecasting of fog- and visibility ?

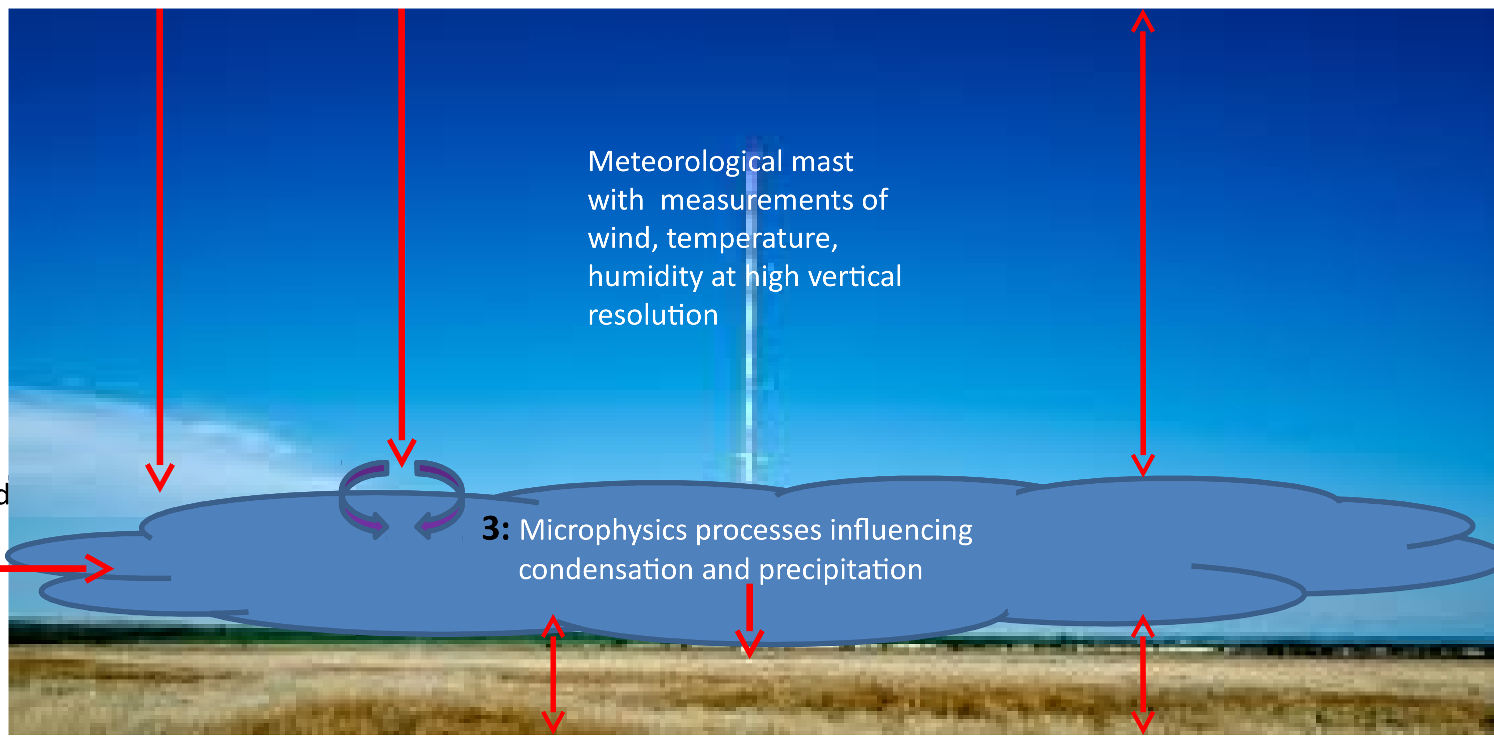
The fog forecast challenge$_{1}$
processes and relevant measurements

1b :Vertical advection

2: Turbulent eddy transports at cloud top

4: Radiation (solar + thermal) at cloud top influencing energy budget and cloud processes

1a: Horizontal advection of heat and humidity variables



5: Surface fluxes: radiation, heat, momentum, humidity

6: Surface analysis/data-assimilation : proper interaction with atmosphere ?

Estimation of strengths and weaknesses in our process description

Processes 1a-b: Dynamics transports

- The main limitation seems to be related with model resolution, both horizontal and vertical in view of the small scales involved with the prediction of fog/low cloud.

- It is hard to point to accute issues needed to be corrected in model dynamics , latest improvement in CY40h1.1 is option `COMAD' reducing potential noise

Process 2: Turbulence parameterization:

- Recent verification reports of Harmonie CY40h1.1 shows that HARATU improves vertical profiles, e.g. wind profiles. Also a detailed report (under review) from KNMI focusing on process evaluation indicates that CY40 performs better than previous model cycles

Estimation of strengths and weaknesses in our process description

Processes 2+3: Interaction between turbulence and microphysics

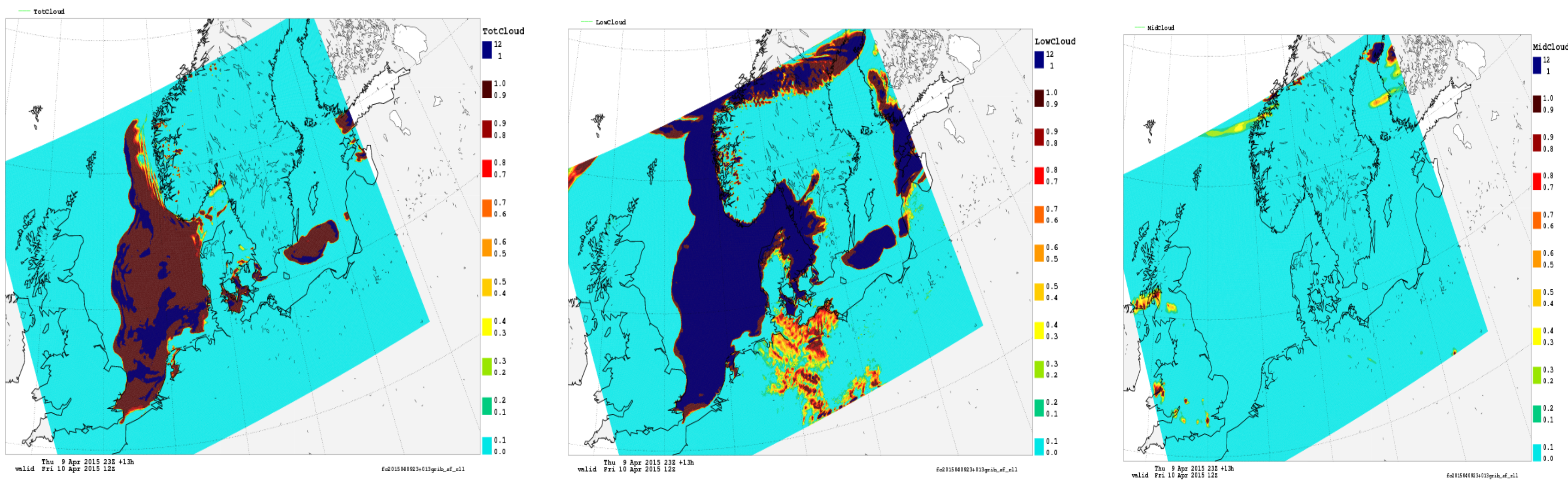
Is fog too persistent in Harmonie-Arome under conditions of very weak dynamical forcing ? That was the experience among forecasters in several institutes, at least before CY40 was implemented !

Examples of this have been given in 2015, e.g. overprediction of fog in Spring 2015 on 10 April in Southern Scandinavia: Parameteriztions were developed and tested during 2015 to alleviate too persistent fog. An example is gíven of a modified autoconversion (scheme presented in September 2015 by Sass and Yang). Results for 10 April are presented on next slide

When CY40 using a modified turbulence scheme was under test it was found that the overprediction of fog was significantly reduced and the suggested modifications for autoconversion were not considered so important anymore.

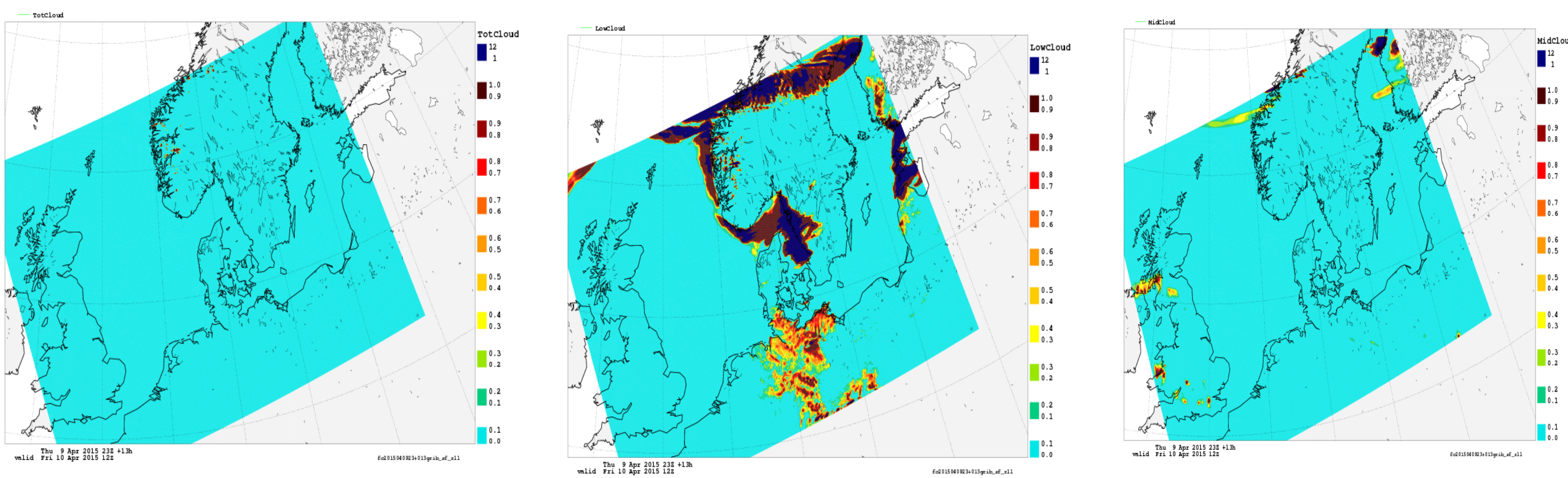
However : When fog is formed, recent experiences, e.g. at DMI, indicate that it is too persistent and cloud water may become too high. Hence it seems still relevant to consider improving microphysics + possibly turbulence !

Reference forecast (+13h) valid at 12 UTC 10 April 2015



fog | low cloud | medium

New update forecast (+13h) valid at 12 UTC 10 April 2015



Estimation of strengths and weaknesses in our process description

Processes 2+3: Interaction between turbulence and microphysics

- Early study from litterature -

Brown and Roach , 1976: The physics of radiation fog: II . A numerical study. *Q.J.R. Meteorol. Soc., 112, 335-354 :*

- **“The liquid water content of the fog was a small fraction of the total condensed out by cooling. The balance of water appears to have been deposited on the ground”**
- **“It is shown that these features are consistent with the suggestion that the development of radiation fog is primarily controlled by a balance between radiative cooling, which encourages fog, and turbulence, which inhibits it. <u>Gravitational settling of fog droplets and soil heat flux also emerge as important factors.</u> The role of cloud microphysics is not passive, but is less clearly defined as yet”**

Estimation of strengths and weaknesses in our process description

Processes 2+3: Interaction between turbulence and microphysics

- Several studies from the litterature indicate that the interaction between turbulence and microphysics is important.
- Rodgers and Yau (1989), p 123 mention studies of the importance of <u>inhomogeneous mixing processes leading to droplet spectrum broadening.</u>
- Gerber (1991) : "Droplet sizes, larger than expected, and transient water vapor supersaturations were measured in radiation fog". He concludes that non-local mixing processes are important to account for the observed broadening of droplet spectra in fogs.
- The measurements of Price (2011) of small droplet concentrations 20-50 near the ground in fog supports the hypothesis of larger droplets close to the surface.
- <u>Droplet diameters larger than 20 µm which may be produced in the fog lead according to existing theory to initiation of autoconversion and collision-coalescence processes, that is, droplet settling as a sink of liquid water in the fog</u>

Estimation of strengths and weaknesses in our process description

Process 3: Microphysics :

- Microphysics processes near the surface (ground) could in priciple be more correct with a more sophisticated impact of real time aerosol treatment (LIMA scheme)

Processes 1+2+3 as input to Process 4:

- Radiation towards low cloud and ground are affected by the amount of clouds higher up which in turn depends on a realistic subgrid scale description (dynamics feeding to turbulence feeding to microphysics). It has been verified that tuning of subgrid scale condensation works as expected to increase fractional cloud cover. The radiation processes as such are expected to be less problematic provided the details of clouds are captured.

Estimation of strengths and weaknesses in our process description

Process 5 : Surface scheme

- **The present force-restore scheme is being critized for being ”unphysical”. A multilayer scheme will be implemented which is hoped to be more accurate. However, the surface physiographic data need to be as accurate as possible.**

Process 4 (radiation) interacting with Process 6 (surface data-assimilation)

- **A negative surface- and near surface temperature bias has been detected in winter for some areas, e.g. over Spain, seen initially in connection with too few clouds. Increasing subgrid scale cloud cover, however, did NOT reduce the surface temperature bias. This problem must be understood (see remarks on future strategy).**

Quality status of visibility prediction in Harmonie

Visibility

Verification contingency tables at DMI , November –December 2016
(DKA , CY38 compared with NEA , CY40, Danish station list)
Results of NEA –CY40 is somewhat better than DKA CY38 e.g. in terms of general bias
(smaller **overprediction** in poor visibility for fog situations)

Table 1: Kontingenstabeller for sigtbarhed for 1612

DKA 1612 (71.46 %)						
	[0:1[	[1:5[	[5:10[	[10:20[	[20:]	sum
F1	**20**	55	43	32	26	176
F2	12	**91**	72	57	37	269
F3	2	26	**90**	136	107	361
F4	3	15	63	**94**	140	315
F5	4	17	60	99	**111**	291
sum	41	204	328	418	421	1412
%FO	49	45	27	22	26	29

Table 2: Kontingenstabeller for sigtbarhed for 1612

NEA 1612 (75.57 %)						
	[0:1[	[1:5[	[5:10[	[10:20[	[20:]	sum
F1	**16**	23	10	9	14	72
F2	14	**112**	119	90	46	381
F3	6	41	**86**	113	91	337
F4	3	18	67	**102**	69	259
F5	2	10	46	104	**201**	363
sum	41	204	328	418	421	1412
%FO	39	55	26	24	48	37

Table 3: Kontingenstabel(ler) for sigtbarhed for 1611

DKA 1611 (72.8 %)						
	[0:1[	[1:5[	[5:10[	[10:20[	[20:]	sum
F1	**26**	28	25	20	12	111
F2	10	**60**	59	41	61	231
F3	2	18	**48**	93	147	308
F4	2	14	38	**81**	212	347
F5	0	5	55	104	**252**	416
sum	40	125	225	339	684	1413
%FO	65	48	21	24	37	33

Table 4: Kontingenstabel(ler) for sigtbarhed for 1611

NEA 1611 (74.9 %)						
	[0:1[	[1:5[	[5:10[	[10:20[	[20:]	sum
F1	**16**	16	11	5	6	54
F2	18	**67**	60	53	55	253
F3	5	21	**63**	95	151	335
F4	1	15	44	**70**	174	304
F5	0	6	47	116	**298**	467
sum	40	125	225	339	684	1413
%FO	40	54	28	21	44	36

Quality status of visibility prediction in Harmonie

Verification of low visibility at KNMI:

Sander Tijm has made a verification of Harmonie visibility forecasts over the Netherlands and the North Sea during Autumn 2016. He mentions a resolution of fog into 5 classes:

- **HA36h1.4 has a significant overestimation of cases with a very low visibility (too dense fog) and an underestimation of the cases with 100-1000 metres. There seems to be a slow decrease in the number of cases with fog as a function of forecast length**

- **Version 38h1.2 (including HARATU) has an overestimation of the number of cases with very low visibility, although that is much less than HA36h1.4. In addition there is a much larger underestimation of the cases with fog than with 36h1.4.**

Quality status of visibility prediction in Harmonie

Verification of low visibility at KNMI:

Remarks by Sander Tijm:

- **Effects of vertical resolution:**

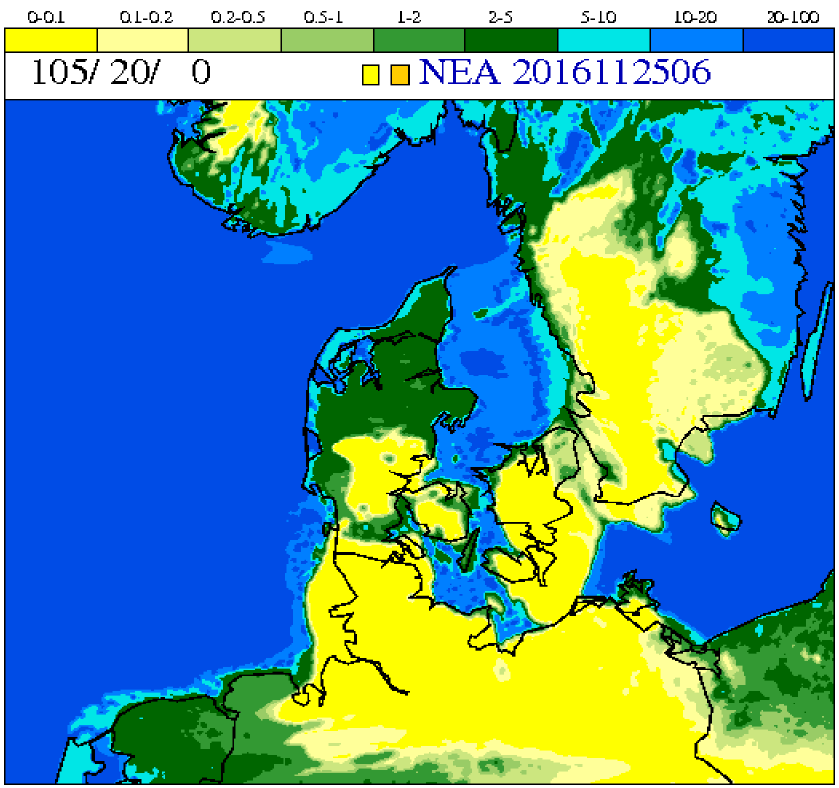
Shallow fog banks that may cause the visibility to become lower than 1000 metres are seen as hazy conditions in the model, as only a part of the lowest model layer is saturated. So what the model should look like is quite difficult to determine until we have a lowest model level at 2 metres.

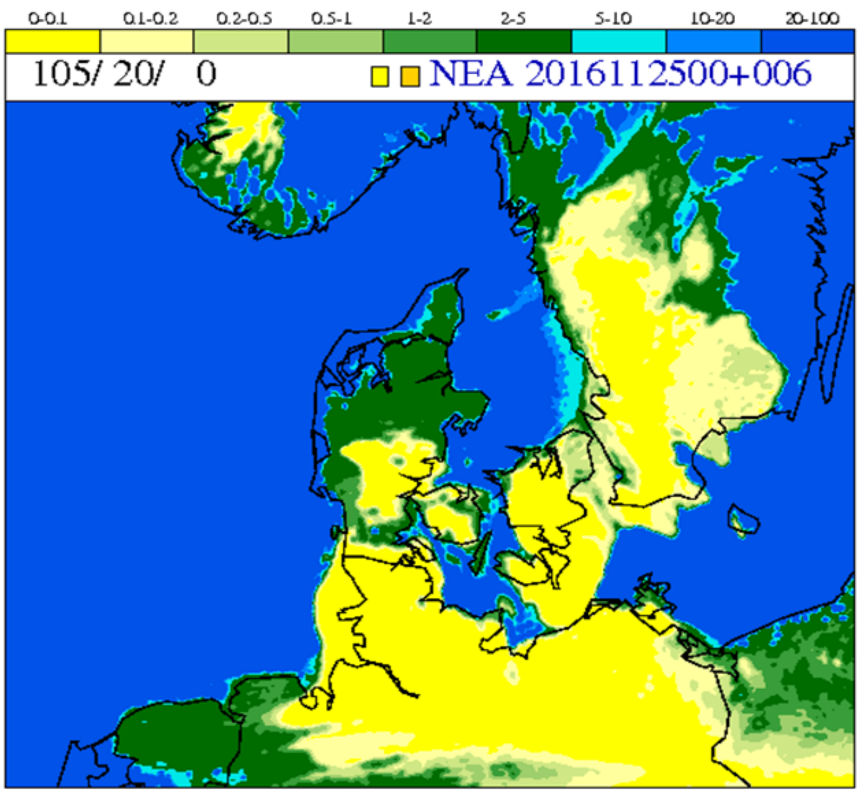
- **Impact of data-assimilation (based on older cycles than CY40)**

There seems to be a significant negative impact of the data assimilation on the ability of the model to forecast fog. There is almost a doubling of the fog cases going from +1-+6 to +43-+48 hours forecasts. This may be a result from the synoptic scale impact of radiosonde observations. There is no input to the atmospheric model from the temperature and dewpoint, so the model does not know from SYNOP if there is fog or not. Radiosondes taken far away may have a drying impact on the entire atmosphere close to the surface.

CY 40 at DMI Example of low visibility forecast and related subsequent analysis:

DMI model NEA visibility investigated for a low visibility case:
left: model analyzed visibility 25/11, 06 UTC
Right: Forecast (NEA, cycle 40h1.1), same time 25/11 , 06 UTC
RESULT: The analysis does NOT reduce fog (visibility) when correcting first guess. For the parameterized visibility in Harmonie CY40h1.1 the borderzone between very low visibility and relelatively good visibility is very narrow (sharp contrast).





Ideas for strategy to improve model prediction of fog/visibility

Basic assumed prerequisite:

- Experimentation using both MUSC and full scale 3D experiments linked with currently available verification tools and observation data.

- If complex computations, e.g. related to aerosols, are becoming part of a strategy it seems vital to pay attention to computational efficiency , e.g. solutions currently under development in ”scalability” projects.

Basic assumed principle in strategic development:

- Apply verification and diagnostics in a way which focus on improved parameterization of the individual processes , that is, trying to avoid improvements as a result of compensating errors.

Ideas for strategy to improve model prediction of fog/visibility

Suggestions:

- Continue case experiments , possibly continue separate studies over sea and over land. This is because of the different conditions and less complexity of surface conditions over sea.

- Possibly use high resolution (e.g. LES studies) to gain insight to parameterization deficiencies and from that try to improve microphysics parameterizations, e.g. autoconversion in fog.

- Use as much as possible high resolution mast data including humidity data in the high resolution studies to see if vertical structures close to the ground can be predicted well enough.

- The lacking impact of increased fractional cloud cover in Harmonie during winter to reduce negative temperature bias must be understood, e.g. from surface energy balance studies and model drift in forecasts without surface data-assimilation.

- Consider various studies in the litterature in order to improve the presently used visibility diagnosis in Harmonie which is mainly based on Kunkel (1984)

Examples of improved diagnostic formulation of visibility[1]

Sander suggests to consider a link to an interesting study on the visibility and the cloud water concentration in China.
lageo.iap.ac.cn/uploads/1412080139104229hgfl7rxpl.pdf

The interesting conclusion from this is that the Kunkel relations that we base our visibility upon give too high visibility in the very dirty air over China, whereas in our areas the visibility is too low when using the Kunkel relations. I think the visibility is better in our areas than you get from the Kunkel relations because the air is cleaner than when these relations were derived in 1980/81 (NE USA).

So probably it is good to make a correction for these relations where the visibility is higher, probably around a factor of 2 for the lowest visibilities and reducing this correction for higher visibilities.

I have tested something like vis=(1+(1-vis/1000))*vis (so no correction when the visibility is 1000m) and this draws the distribution much closer to the observed one.

Ideas for strategy to improve model prediction of fog/visibility

Examples of improved diagnostic formulation of visibility$_2$

Use information on cloud droplet size :

Parameterization of visibility from Gultepe et al (2006) depends on cloud droplet number concentration N$_d$

Figure below from Journal of Appl. Meteorology and climatology, vol. 45 1469-1480

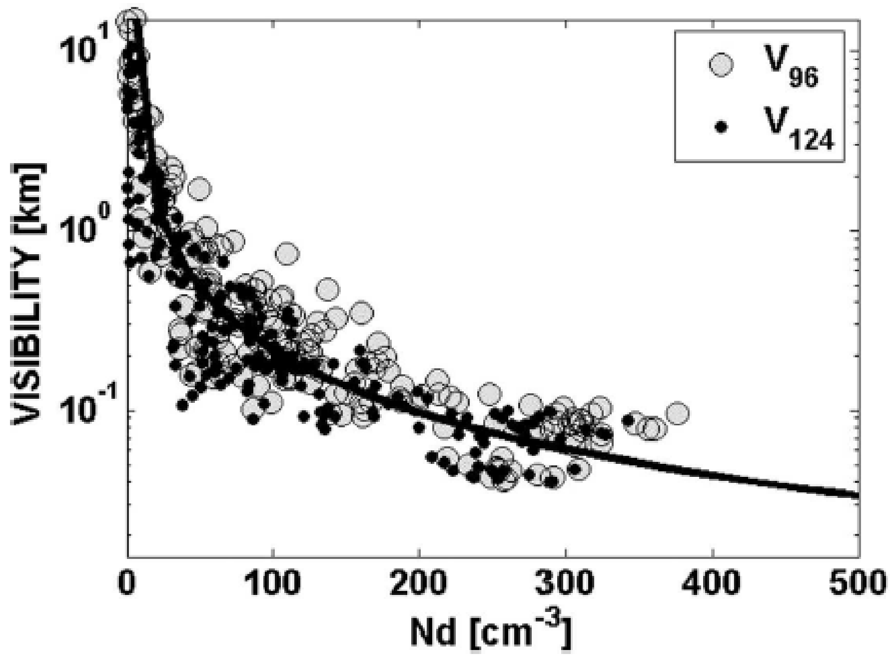


FIG. 2. Visibility vs N_d from the FSSP measurements; each data point represents a scale of 1 km. The solid-line fit is for FSSP96. The V_{96} and V_{124} are for FSSP-96 (over original size ranges) and FSSP-124 (over extended size ranges) observations, respectively.

Ideas for strategy to improve model prediction of fog/visibility

- It is possible to develop improved parameterizations of visibility, e.g. adapted to a new model version (Nielsen et al. 2016) . It is therefore suggested to develop further the parameterizations of visibility using recent scientific results and ideas.

- Use realtime aerosols, e.g. from ECMWF, for visibility parameterizations

- Schemes with prognostic aerosols , e.g. LIMA, - and prognostic cloud droplet number concentrations form a more complete basis of describing condensation, radiation and visibility.

  However, implementation of more complex aerosol schemes require attention on code efficiency, ("scalability" projects) for fast enough execution in short range forecasting, e.g. use multigrid concepts.

References

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Sass, B.H. and Yang 2015: A simple approach to improve prediction of fog in forecasts with HARMONIE (presentation at the EWGLAM meeting October 2015)

Seity , Y et al., 2011: The AROME-France convective-scale operational model. *Mon. Wea.Rev. , Vol.139, March 2011*

END

Additional remarks regarding graphical presentations related to fog/visibility

- **Forecasters often request predictions of**
  cloud base height for aviation purposes,

  but currently the practice is to assign on the basis of a fractional cloud threshold which is problematic, and
  the field may become undefined.

  Instead it seems more satisfactory to further develop visibility parameterizations .

- **In view of difficulties to accurately predict**
  saturation in a deterministic model it is recommended to present
  the results of ensembles to the users.

  This has been developed already in preliminary form at DMI in the COMEPS ensemble. Ensemble members are ordered according to increasing/decreasing visibility and the user can see e.g. median and more optimistic/pessimistic forecasts. More work on useful presentations are foreseen.