Physics developments at the Met Office

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Visibility forecast problems

- Problems identified in the forecast of visibility from UKV/UK4 models are:
- A tendency to over-forecast winter fog. The model fog is too thick and extensive and it is not unusual for the model to cover half of the UK with visibilities below 50 metres.
- A tendency to under-forecast radiation fog in summer
- Sea fog survives too long and can advect inland.

Drizzle forecast problems

- Forecasters frequently complain about the UM producing too much light, widespread, spotty drizzle, particularly among inversion conditions and in cloudy high pressure systems.
- Drizzle has a very noticeable land-sea split, with more profuse generation over sea that artificially delineates the coastline.
- Model changes to drizzle and fog are strongly linked as attempts to reduce drizzle will lead to increases in fog through increases in q (evaporation) and qcl (fall out)

Dr Fog (A **Dr**izzle and **Fog** Package)

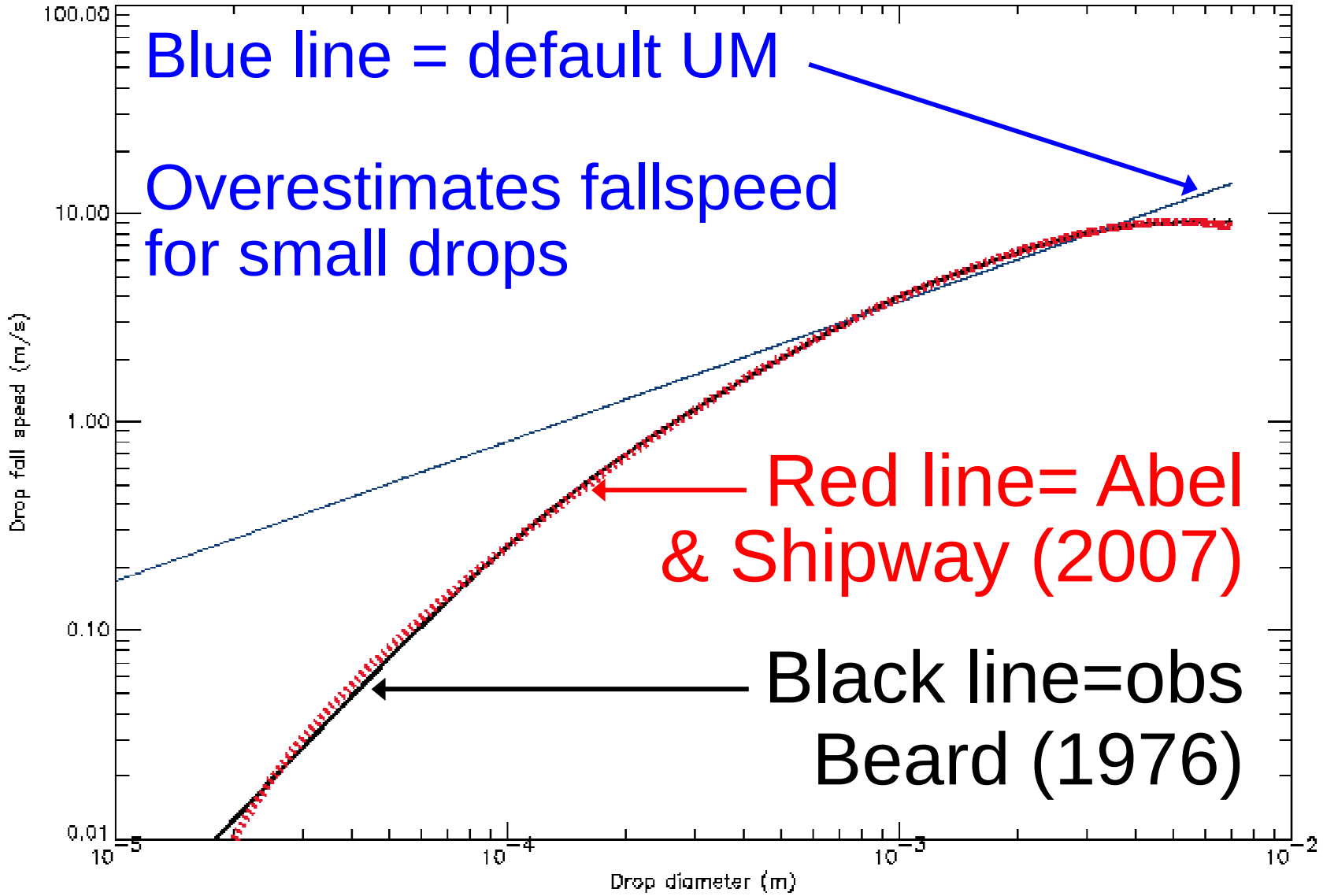
- A project to provide a package of changes for the limited area models to allow improvement in drizzle without adversely affecting fog.
- Ideally, we should also improve the representation of fog too.
- The key components are:

1. Abel and Shipway (2007) rain fall speeds
2. Murk aerosol linked to autoconversion
3. Droplet taper curves

Abel and Shipway fallspeeds

- Abel, S. J. and Shipway, B. J., 2007. A comparison of cloud resolving model simulations of trade wind cumulus with aircraft observations taken during RICO. **Quart. J. Roy. Meteorol.Soc., 133, 781-794**.
- The UM overestimates drizzle velocity (for the smaller droplets) by roughly a factor of ten.
- Inclusion of Abel & Shipway (2007) should in theory allow the drizzle more time to evaporate before it reaches the surface, resulting in a lower surface rainfall rate.

Abel & Shipway fallspeeds



Drizzle land-sea split and droplet number

- The land-sea split in drizzle rates is due to the fact that the drizzle autoconversion rates are initiated at different thresholds depending on whether the surface beneath is land or sea.
- Sea: droplet number is 100 per cm3
- Land: droplet number is 300 per cm3
- The smaller number of droplets over the sea means that for a given air density and cloud water content, the sea drizzles much more rapidly than the land (bigger drops).

MURK aerosol and autoconversion (1)

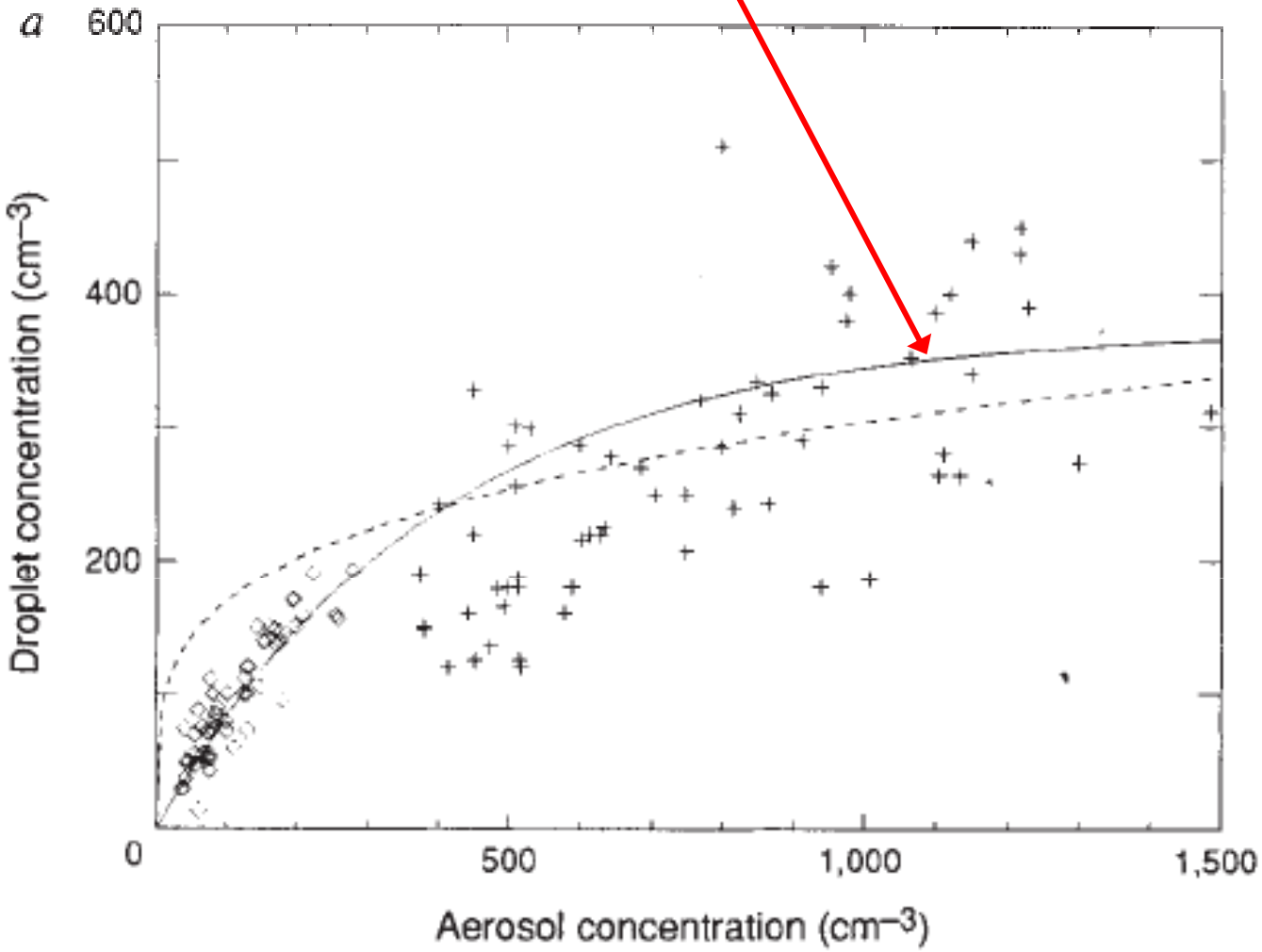
- The idea then is to use a dirty-clean split rather than a land-sea split – why not use the MURK aerosol?
- Clark, P. A et al., 2008. Prediction of visibility and aerosol within the operational Met Office Unified Model. I: Model formulation and variational assimilation. **Quart. J. Roy. Meteorol.Soc., 134, 1801-1816**.
- This provides a tracer aerosol in the boundary layer, based on ammonium sulphate.
- Within the boundary layer, there are certain MURK sources (e.g. chimney stacks, cities) which produce MURK.
- This is then advected horizontally and vertically by the model dynamics.

MURK aerosol and autoconversion (2)

- This idea was tried unsuccessfully in the NAE model in 2008, when it produced too much fog.
- The problem is that if you assume that all the MURK is activated aerosol (which was suggested by Clark), then you can get very large cloud droplet numbers.
- For polluted cases, the cloud droplet number can regularly exceed 1000 per cubic cm, which is not matched by aircraft observations.
- Worst of all, the largest cloud droplet concentration can be found close to the surface, which disagrees with the work of Price et al (2011, Boundary-Layer Meteorology), who suggested droplet number of the order of 20-50 per cubic cm.
- max_drop: Solution is to pass the results of the Haywood scheme through the Jones et al (1994, Nature) scheme (this deals with the activation issue) and to asymptote to a maximum value of 375 per cm3.

Jones et al (1994)

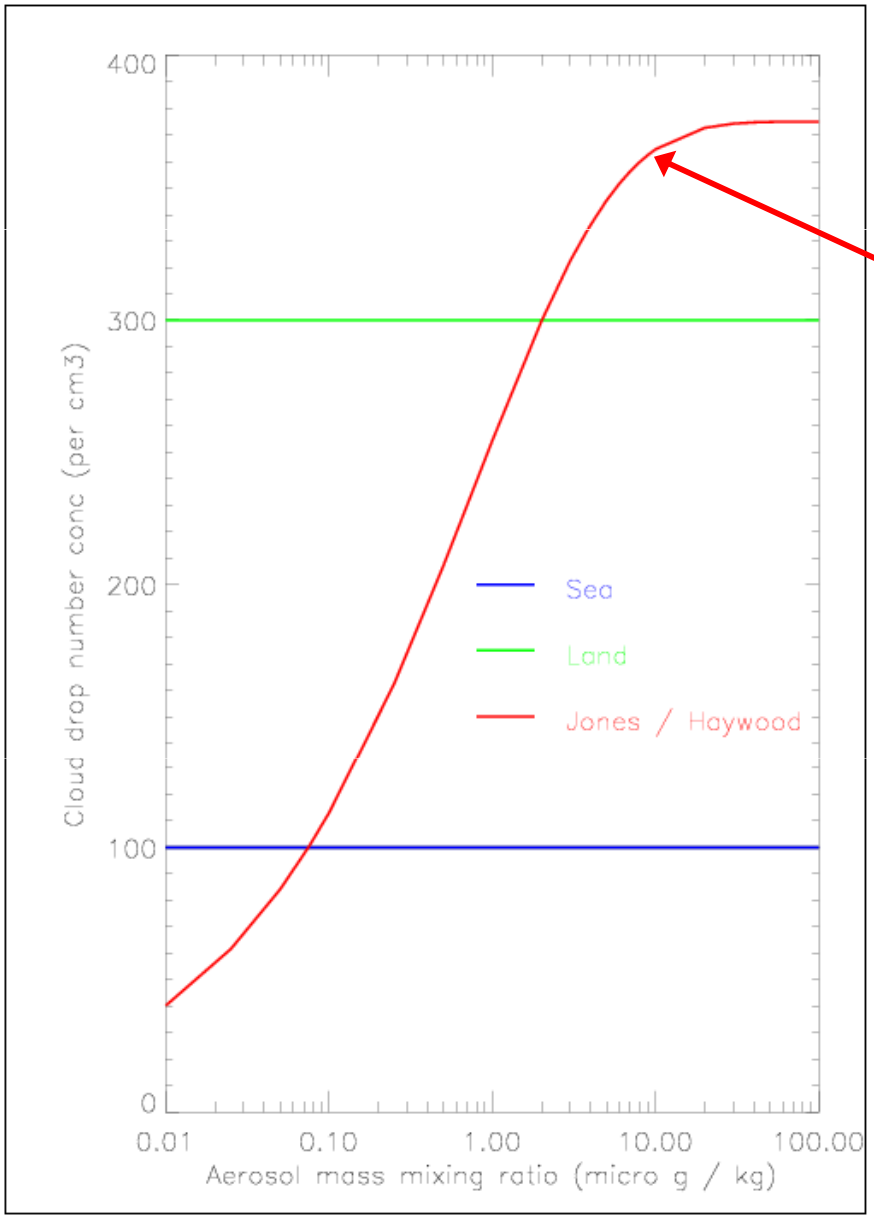
$$N_{tot} = 375(1 - \exp[-2.5 \times 10^{-3} A])$$



Observations of Martin and Johnson:

Diamonds = maritime clouds
Crosses=continental clouds

Jones-Haywood relation

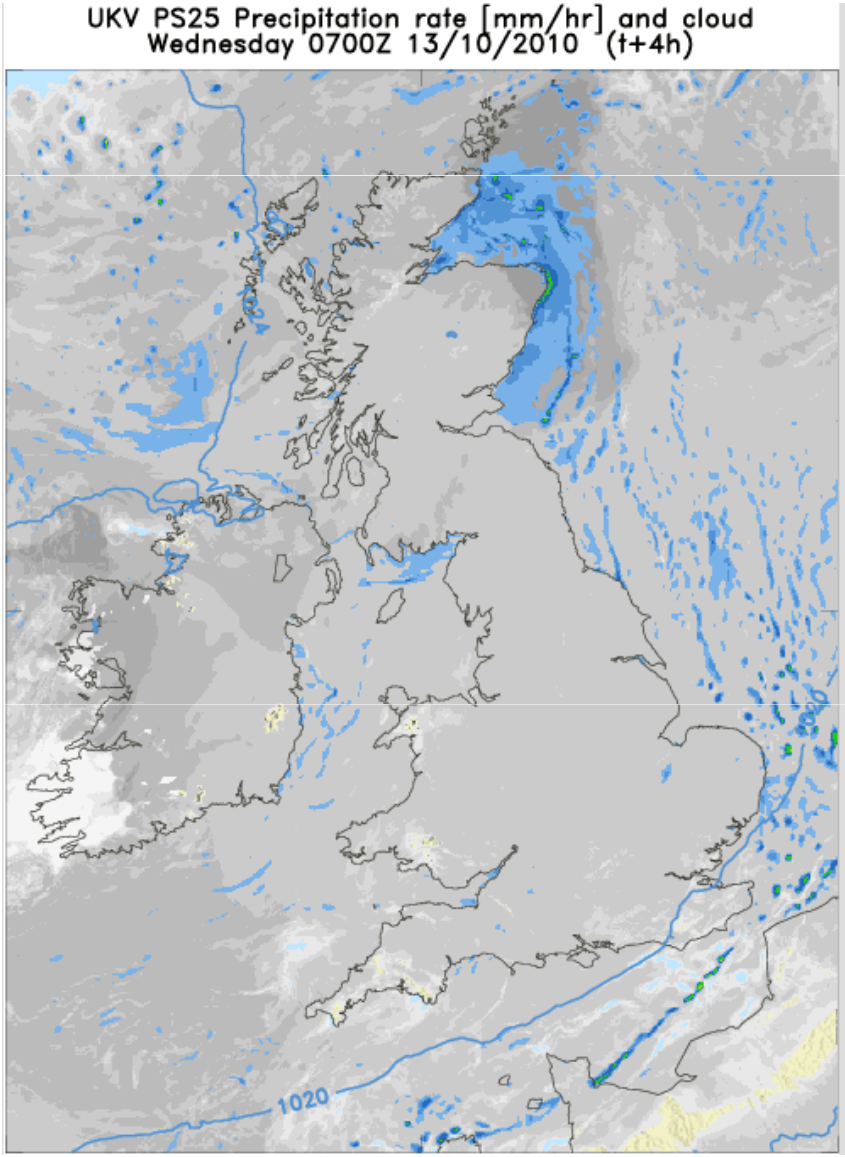


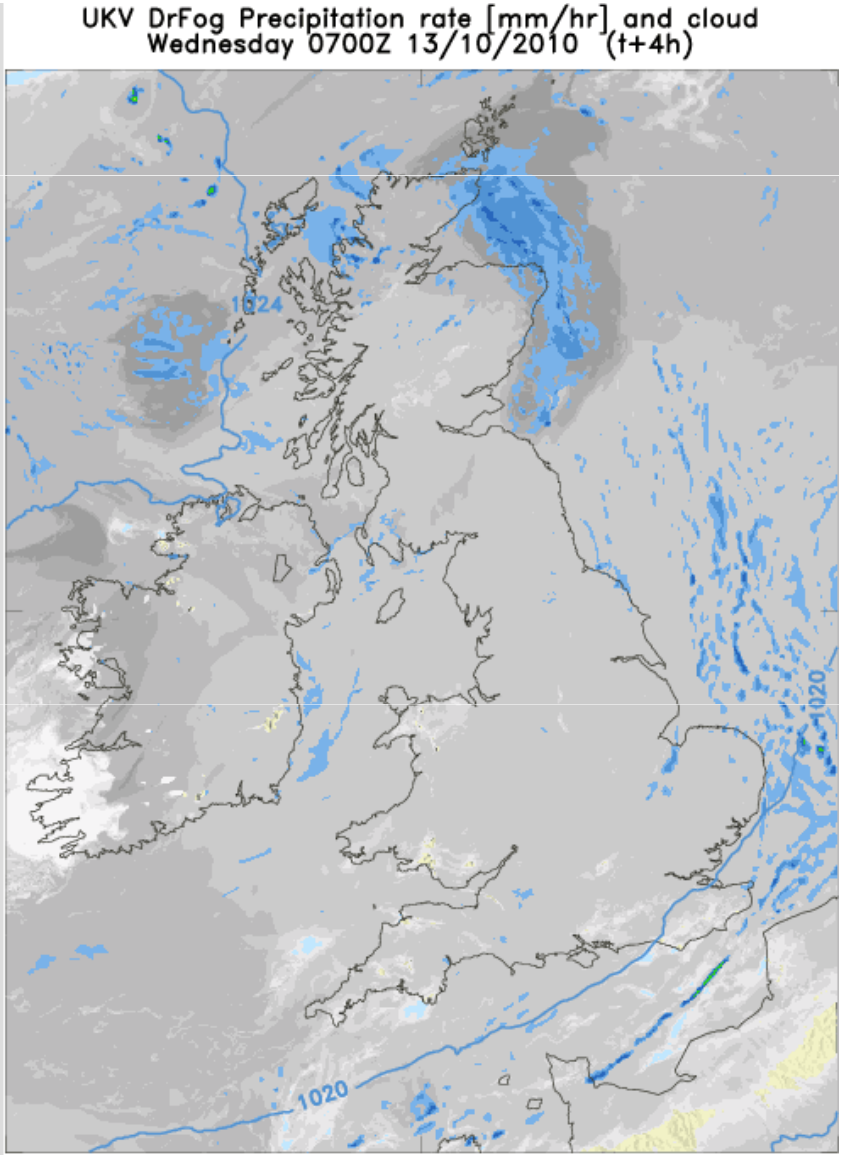
Cloud drop number increases with MURK aerosol mass mixing ratio, but asymptotes to 375 per cm cubed

Land = 300 per cm cubed (Green line)

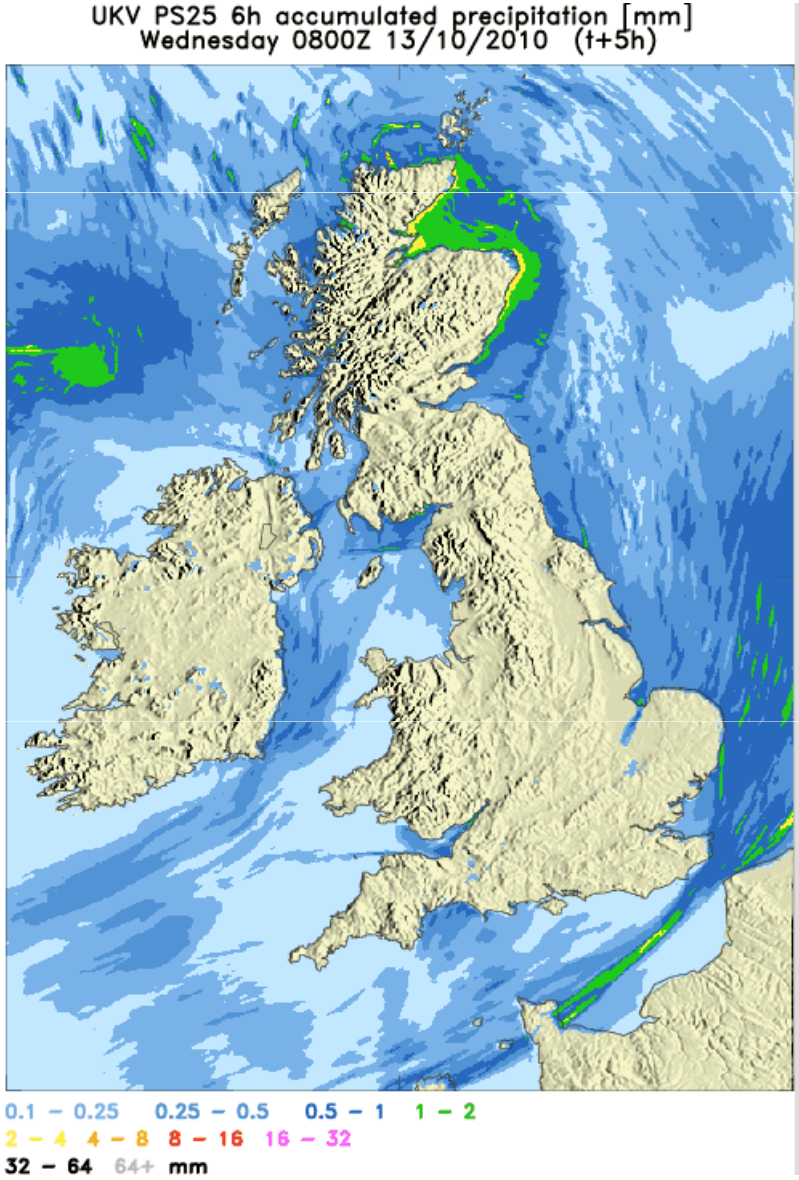
Sea = 100 per cm cubed (Blue line)

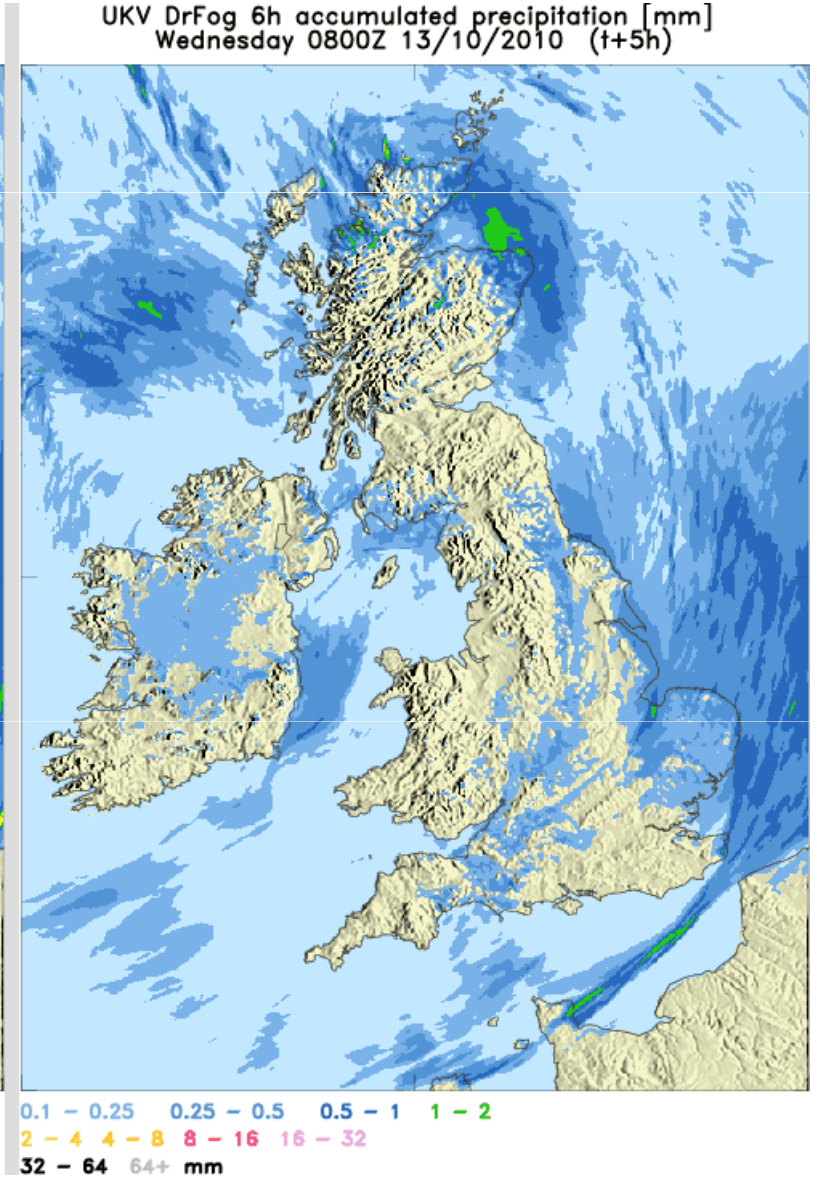
Precipitation rate





6 hour accumulated precipitation





Droplet taper

- Taper the number of droplets in the boundary layer, limiting the active aerosols and increasing the visibility.
- This change has two tunable parameters, the height where the tapering starts and the number of droplets near the surface
- From these we can constrain the maximum number of droplets to values recorded in the literature.
- These vary widely between 20 and 300 droplets/cm3

Height where the tapering starts: z_peak_nd

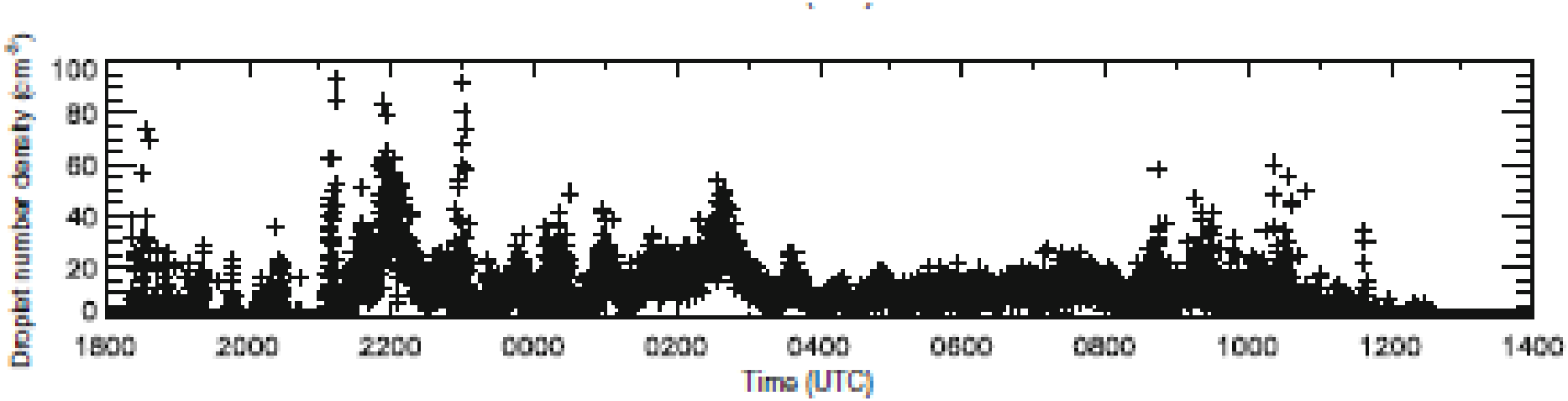
- z_peak_nd: This is the altitude of the peak droplet number, or in other words the altitude below which the droplet number starts tapering towards the surface.
- It is set to 150m which corresponds to model level 6.
- Above this level we use MURK values (modified by the Jones scheme to take into account the activated drops)
- Below this we taper to the number of droplets at the surface.

Number of droplets at the surface: ndrop_surf

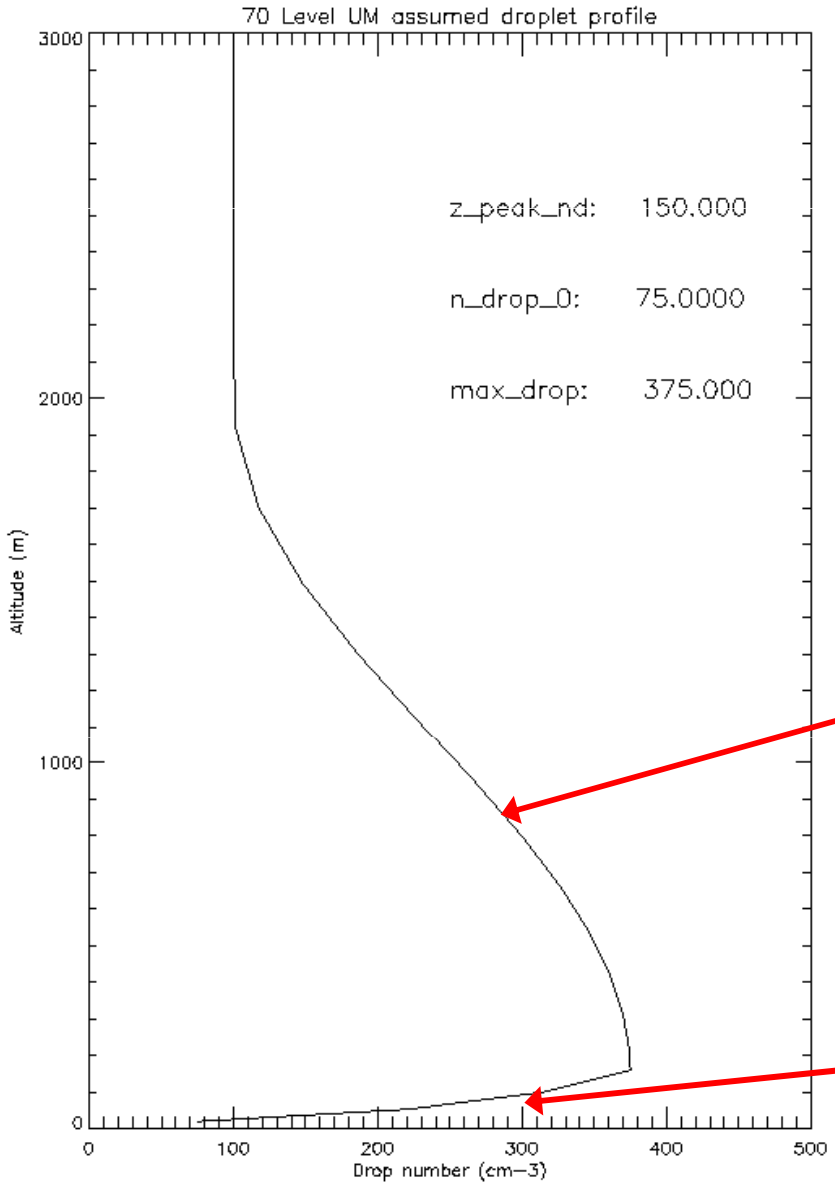
- A number of different values for the surface droplet taper were tested (20, 50, 75, 100 and 150 per cm cubed)
- Subjectively, the best results were achieved by using a value of 75 per cubic cm
- This reduces the extent and thickness of the fog in winter whilst not missing too many events in summer
- An aerosol concentration dependent tapering was also tested.
- However this reduced sea fog too much in areas of low aerosol concentrations.

Price (2011): Observed values of Nd during a winter fog case at Cardington

- Cloud droplet spectra measured with a DMT cloud droplet probe (CDP).
- The values of Nd are broadly consistent with previous observations at Cardington (given the uncertainty of a factor of 2), such as those of Roach et al. (1976).
- They reported values of Nd between 30 and 100 cm−3 for a winter fog case.
- The slightly lower values of Nd seen here may in part be due to the north-easterly wind direction that often advects relatively clean air with fewer condensation nuclei off the North Sea.



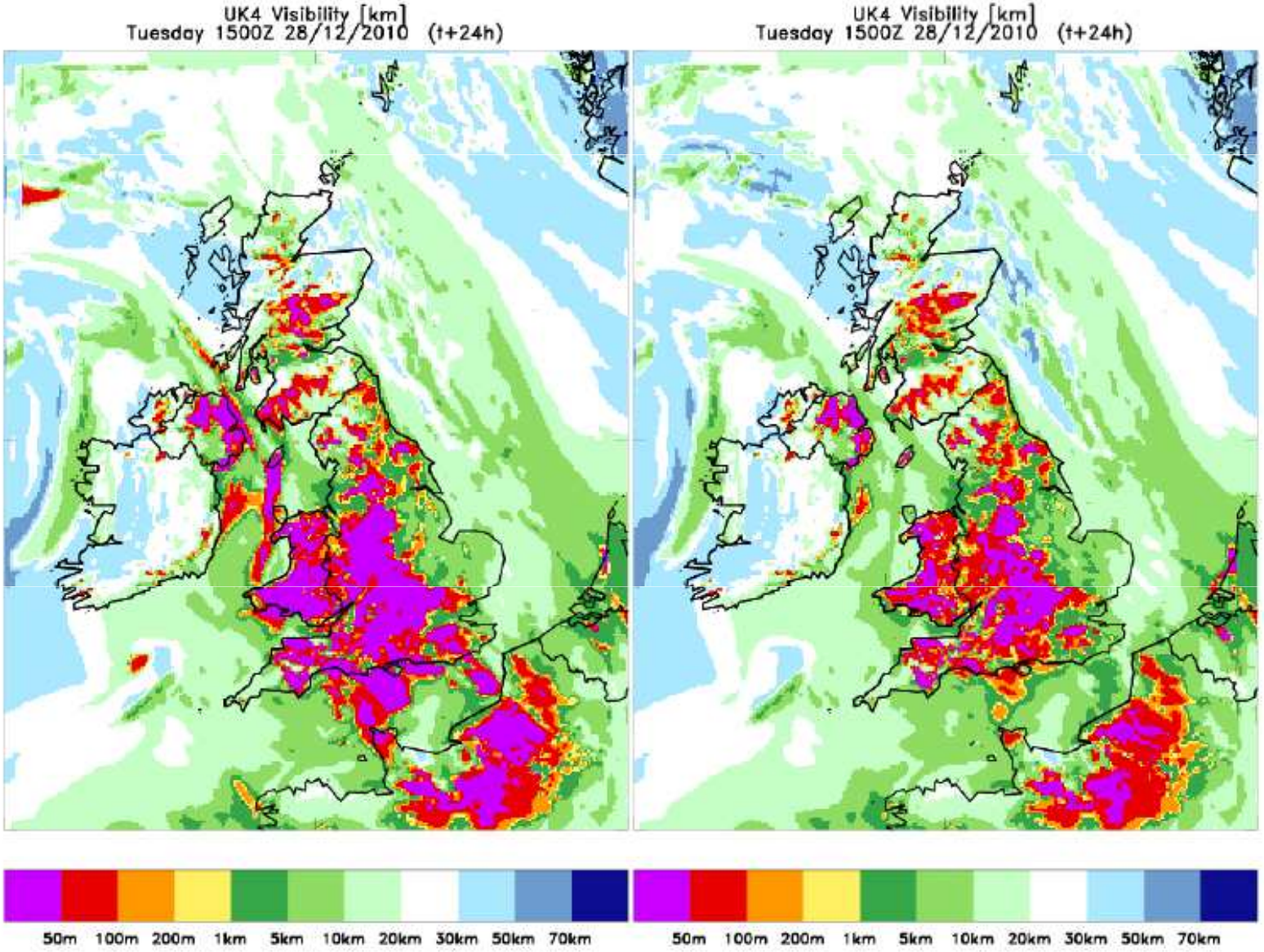
Example taper profile



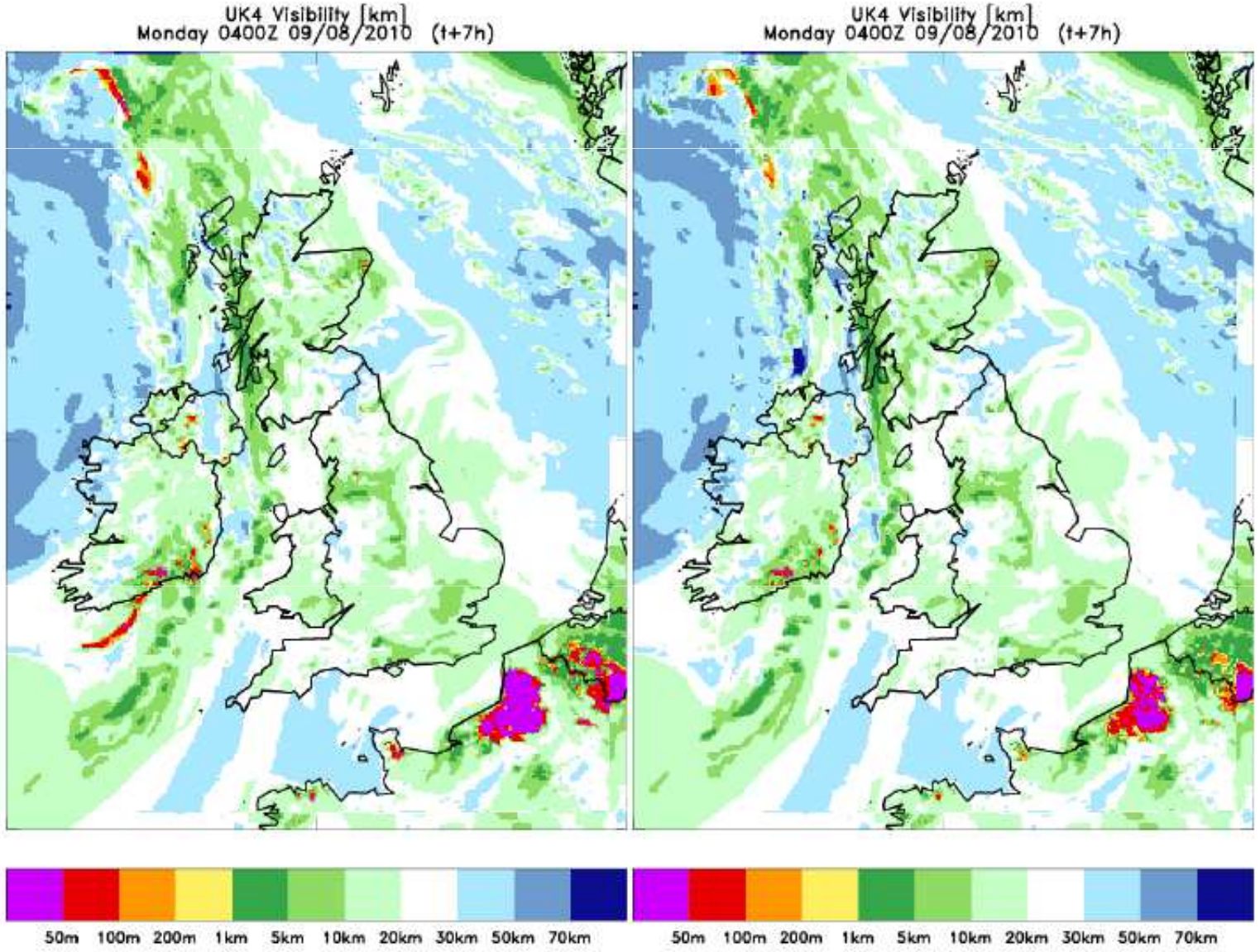
Drop number follows activated MURK values above 150m (with a maximum allowed value of 375/cm3)

Below 150m, drop number tapers to 75/cm3 at model level 1

Reduction in winter fog

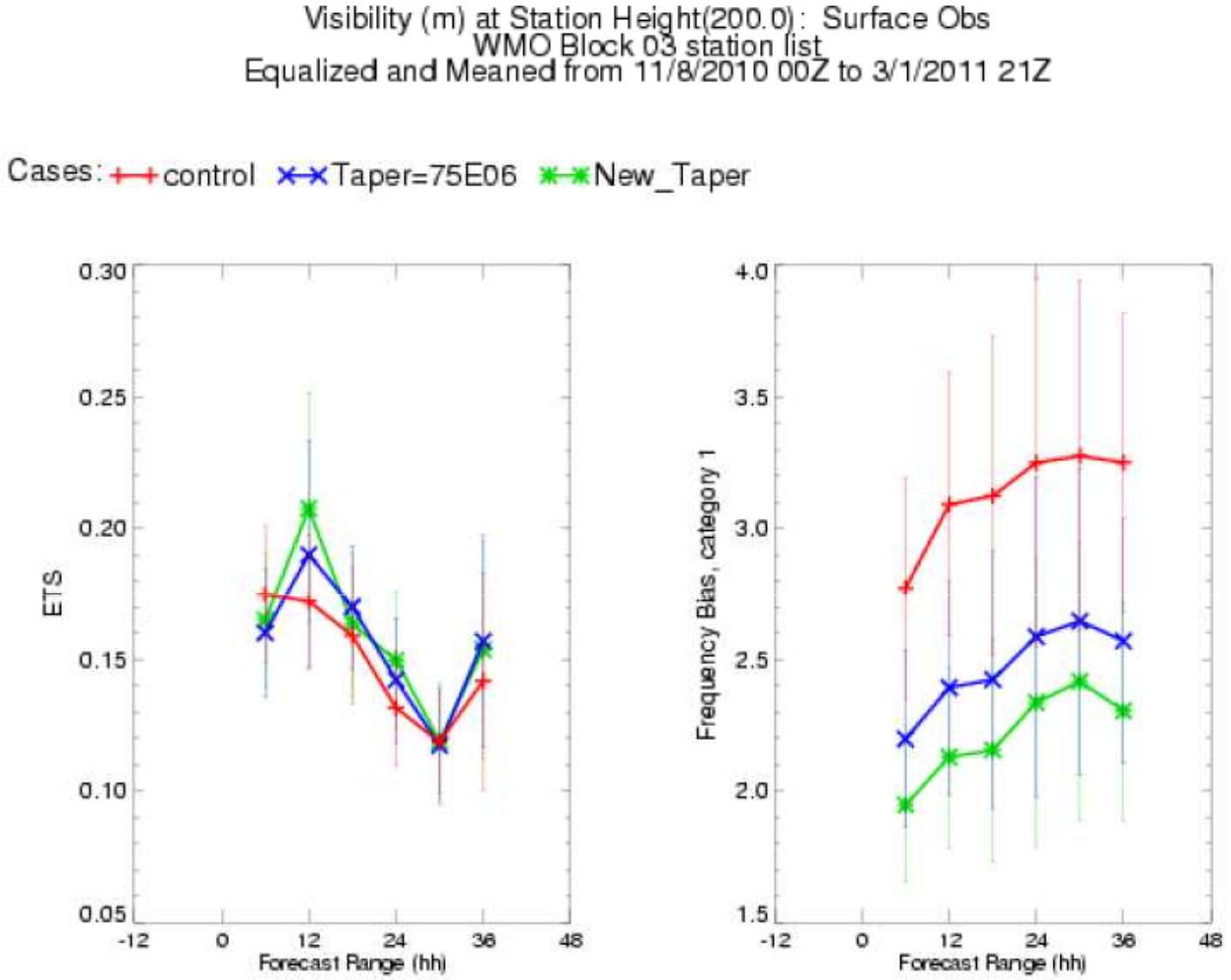


Reduction in summer fog



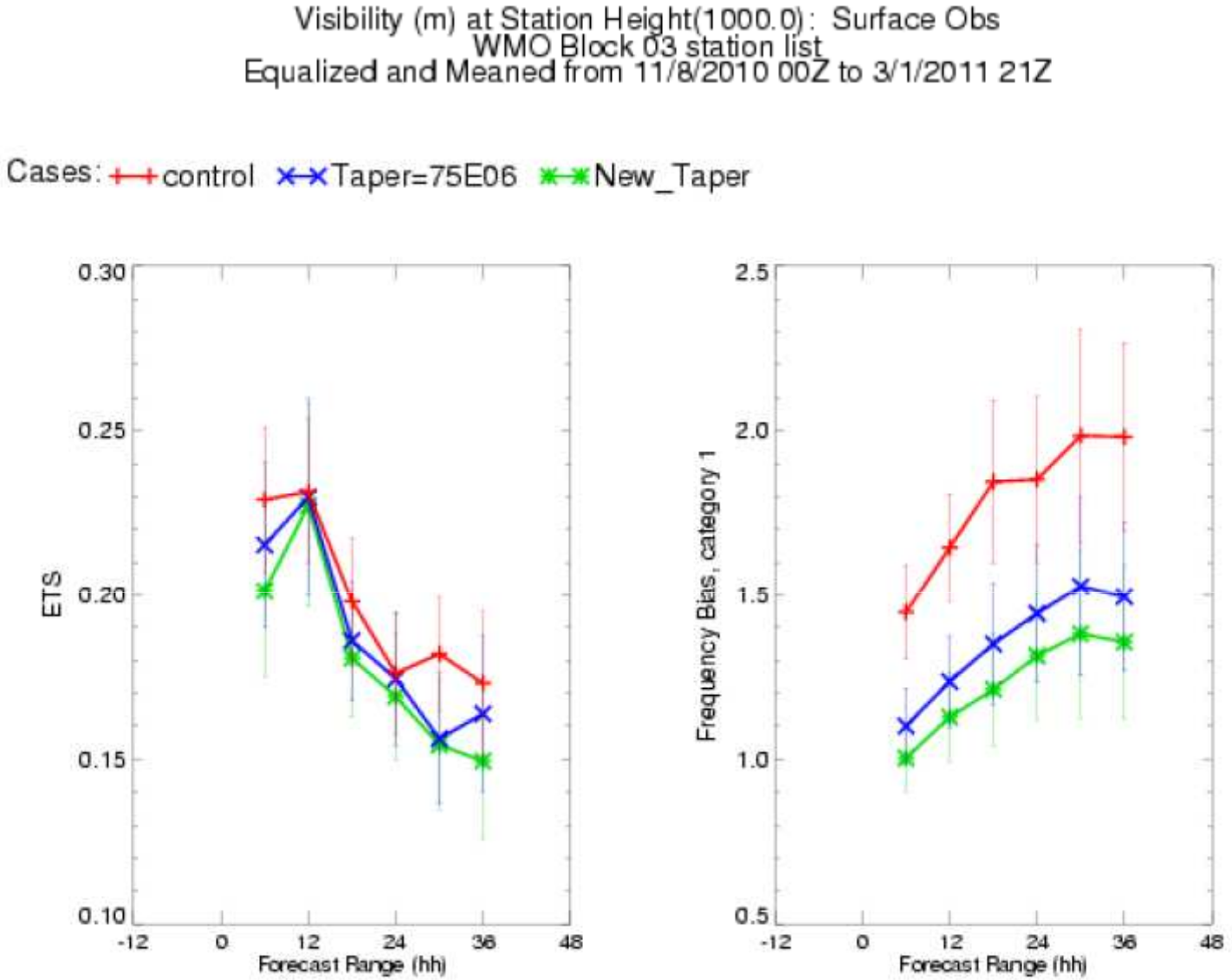
200m visibility verification: UK4

Full DA trial: 10 days winter + 10 days summer



1000m visibility verification: UK4

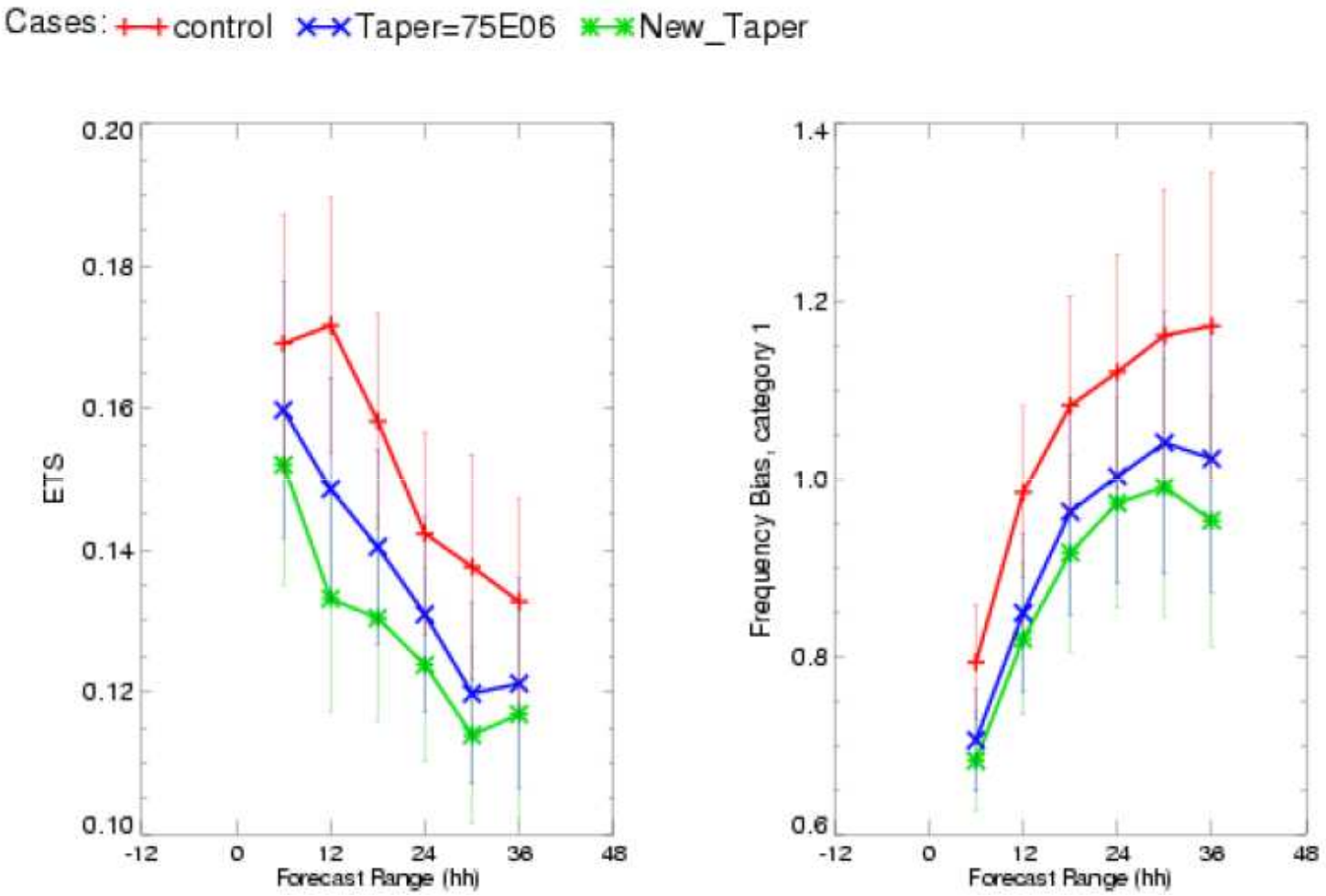
Full DA trial: 10 days winter + 10 days summer



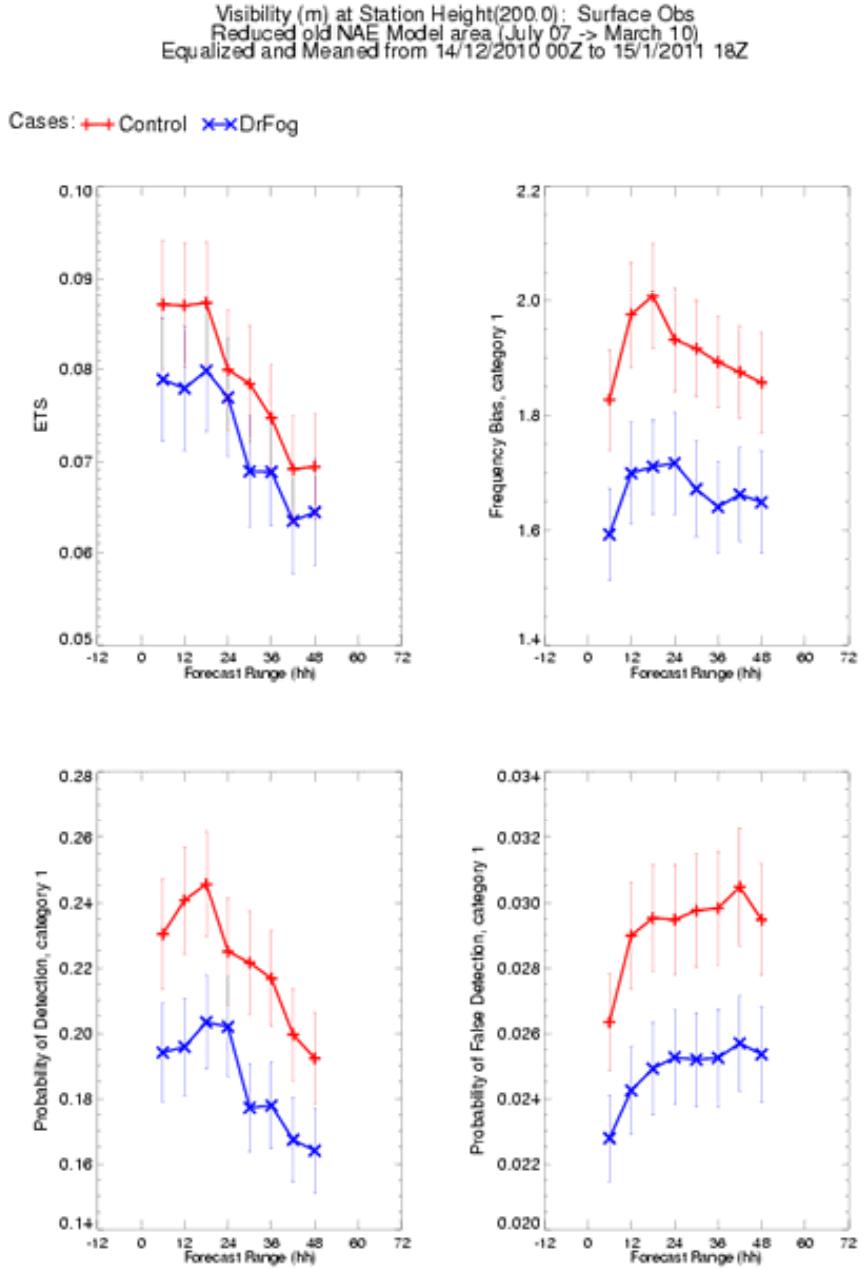
4000m visibility verification: UK4

Full DA trial: 10 days winter + 10 days summer

Visibility (m) at Station Height(4000.0): Surface Obs
WMO Block 03 station list
Equalized and Meaned from 11/8/2010 00Z to 3/1/2011 21Z

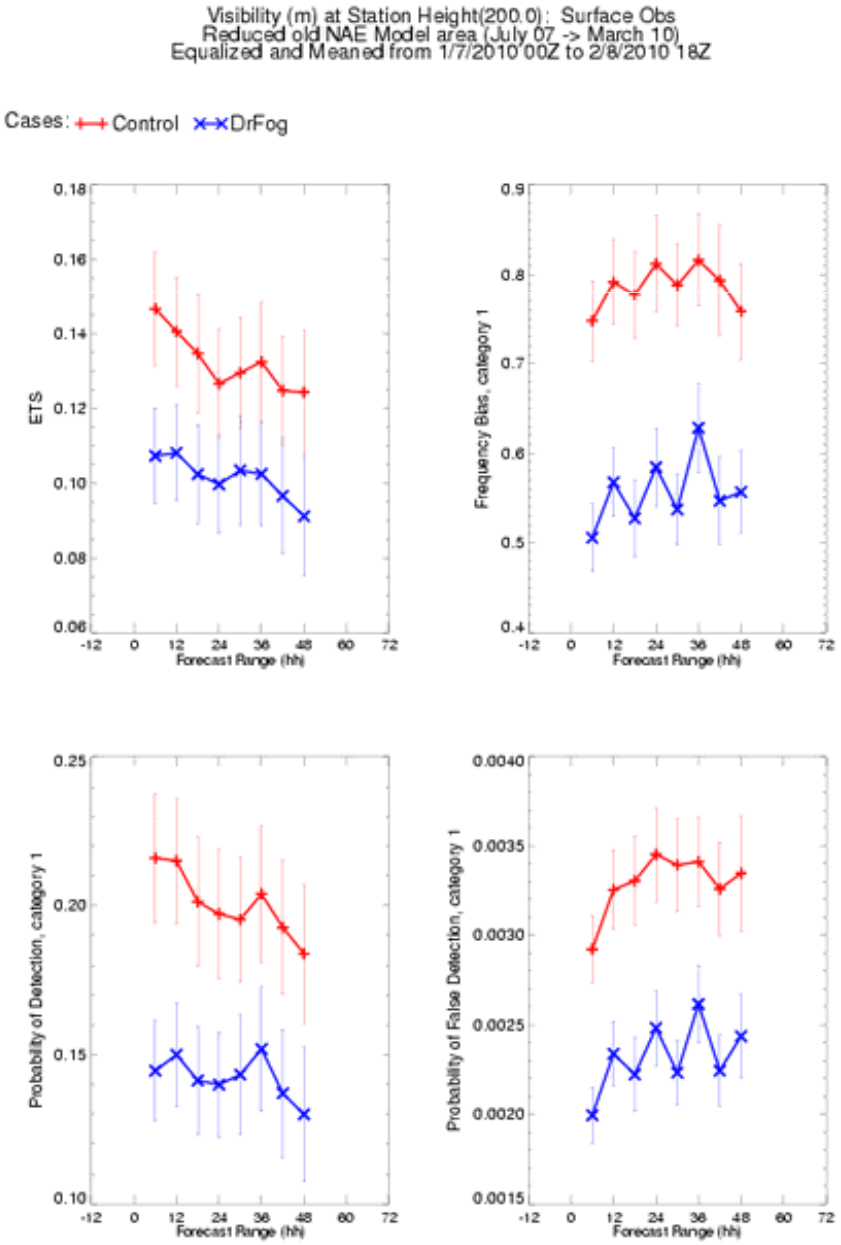


200m visibility in winter: NAE



Full DA trial: One month winter 10/11

200m visibility in summer: NAE



Full DA trial: One month summer 2010

Operational implementation

- The first two parts of the Dr Fog package (Abel and Shipway rain fall speeds and Murk aerosol linked to autoconversion) were made operational in the UKV and UK4 models at PS26
- The remaining part (Droplet taper) was made operational at PS27.
- Dr Fog was tested in the NAE model, but due to the impact on Summer fog, more testing is needed.
- Dr Fog is not yet operational in the Global model, but this will be the subject of future work to try and harmonise ‘best’ physics settings between different UM configurations.

Questions?