Clouds and precipitation:
From models to forecasting

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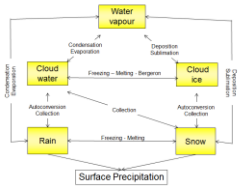
Thanks to Tim Hewson, Ivan Tsonevsky,
Thomas Haiden, Peter Bechtold

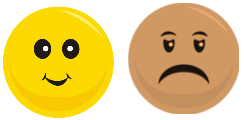
Outline

Clouds and Precipitation: From models to forecasting

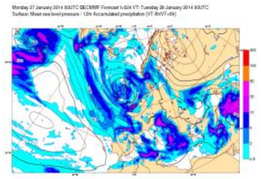
This seminar will (hopefully!) help you to …



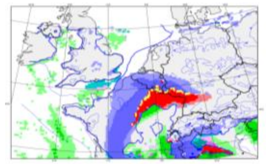
- describe how cloud and precipitation is represented in the ECMWF global model.



- recognise some of the strengths and weaknesses of the forecast cloud/precipitation.



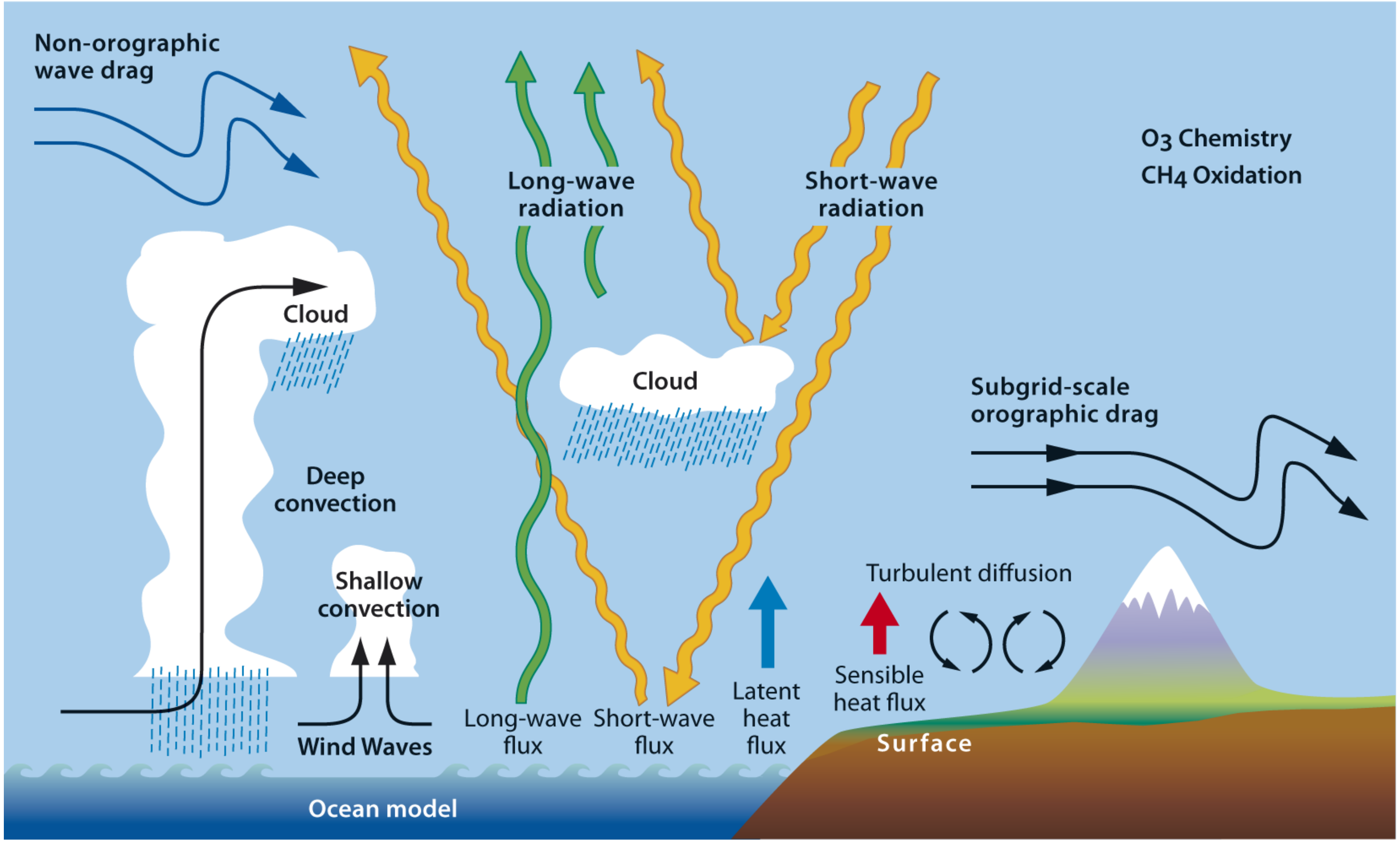
- interpret cloud and precipitation related forecast products.



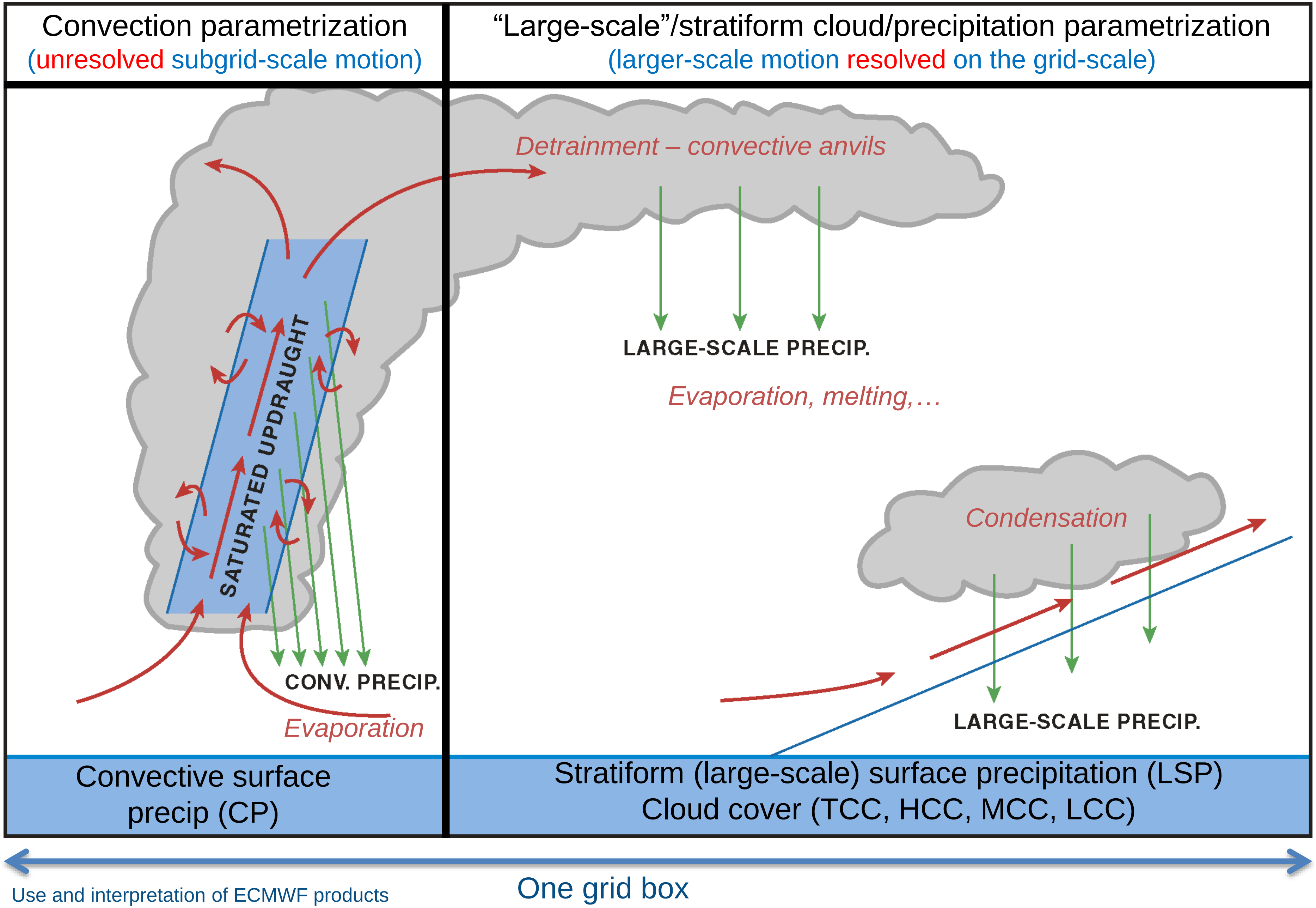
- learn about recent developments from a forecast users perspective …

1. How are cloud and precipitation represented in the ECMWF model?

Parameterized processes in the ECMWF model



Convective and stratiform precipitation and clouds



Time-height cross section of a mid-latitude front from a vertically pointing 94GHz radar at Chilbolton, UK

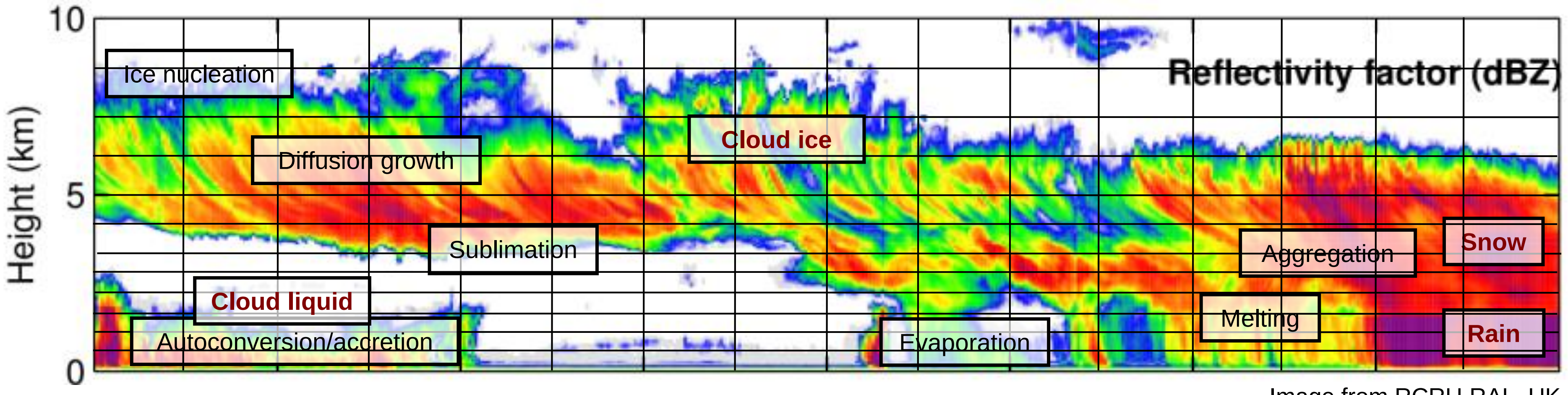
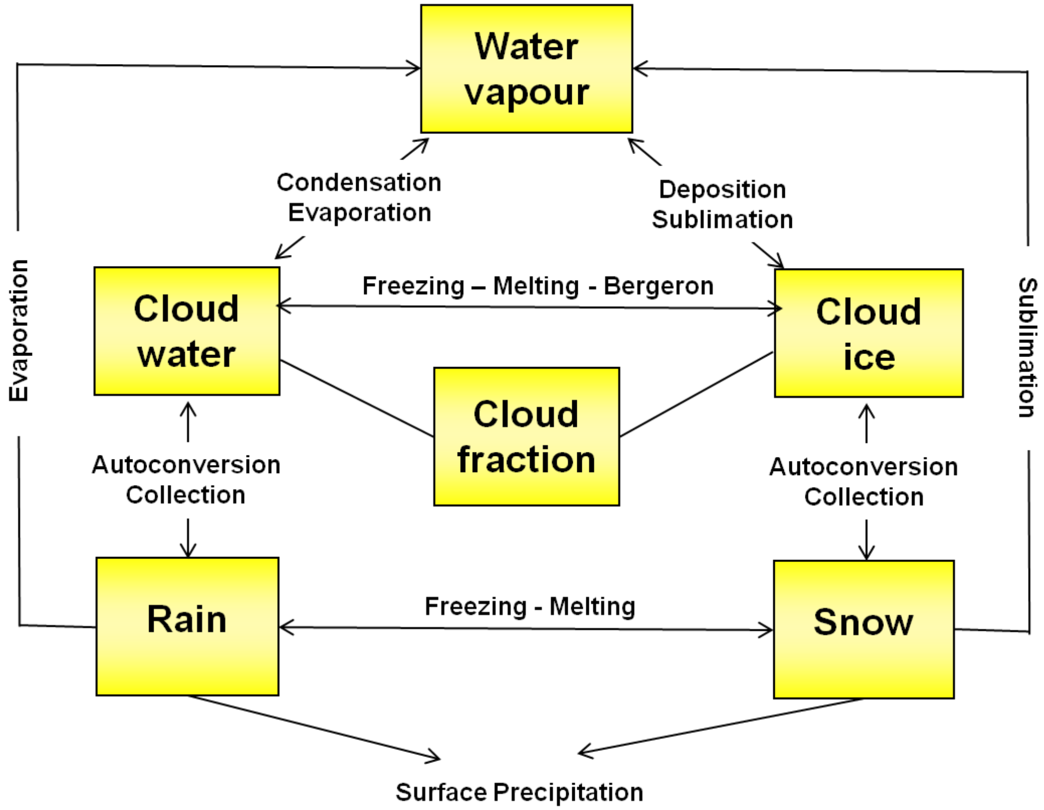


Image from RCRU RAL, UK

- Cloud liquid, cloud ice, rain, snow
- Microphysical processes based on physical understanding
- Forced by the dynamics/turbulence/radiative processes
- Representation of subgrid cloud heterogeneity

IFS representation of cloud and precipitation



- 5 prognostic cloud (mass) variables + water vapour
- Ice and water independent variables
- Snow/rain prognostic (advected with the wind)
- Physically based, increasing realism
- Diagnosed surface precipitation type (melting, ice pellets, freezing rain etc.

Cloud overlap

TCC = Total Cloud Cover

Model level clouds are integrated from surface to top of the atmosphere with overlap assumptions **based on global observations** (degree of randomness depends on distance between layers)

HCC = High-level Cloud Cover

Integrated from top to 450 hPa.

MCC = Medium-level Cloud Cover

Integrated from 450 to 800 hPa.

LCC = Low-level Cloud Cover

Integrated from 800 hPa to surface.

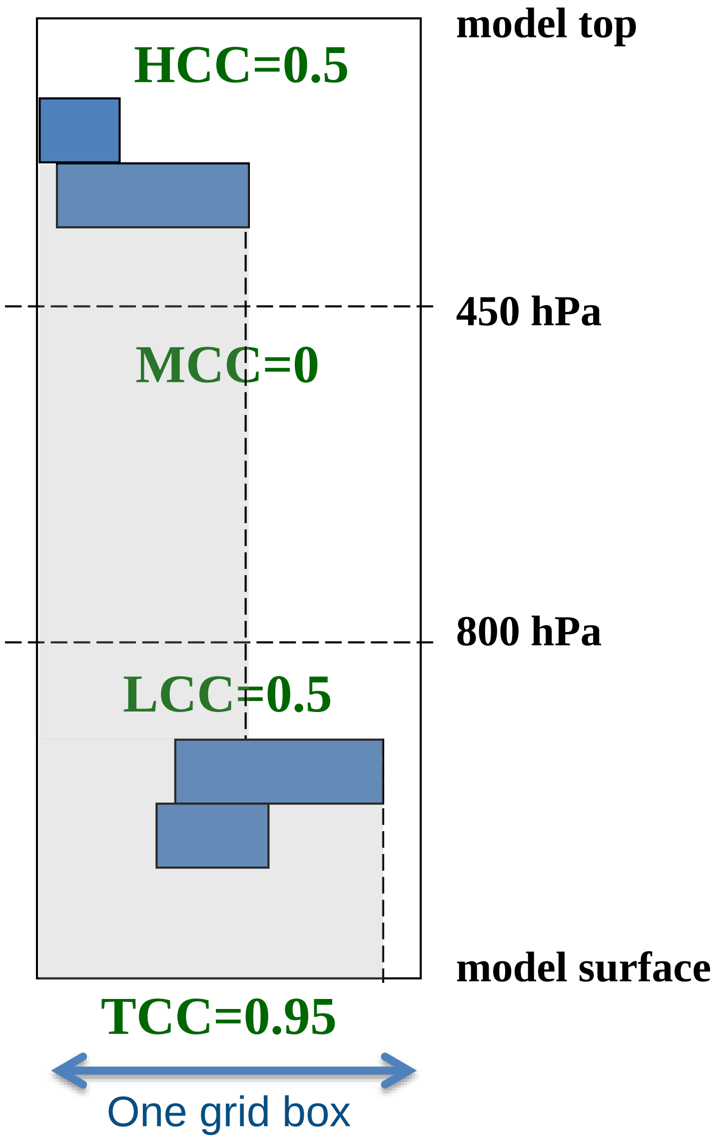
TCC <= LCC + MCC + HCC

An example with:

two layers of high-level cloud (50%)

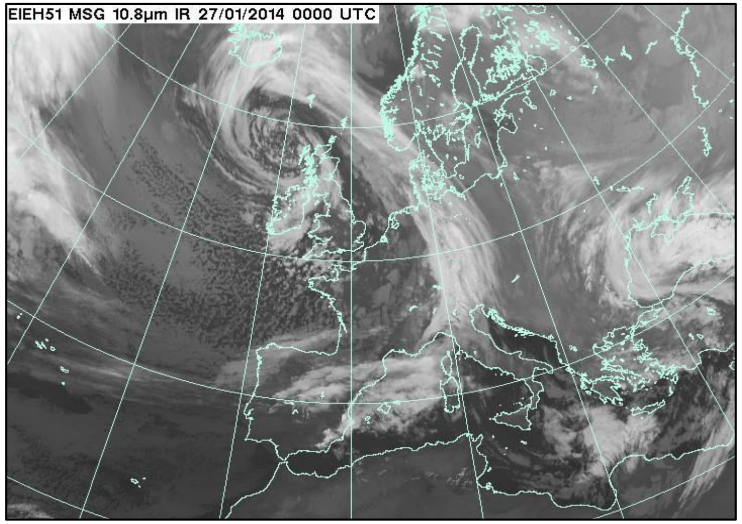
no medium-level cloud

two layers of low-level cloud (50%)

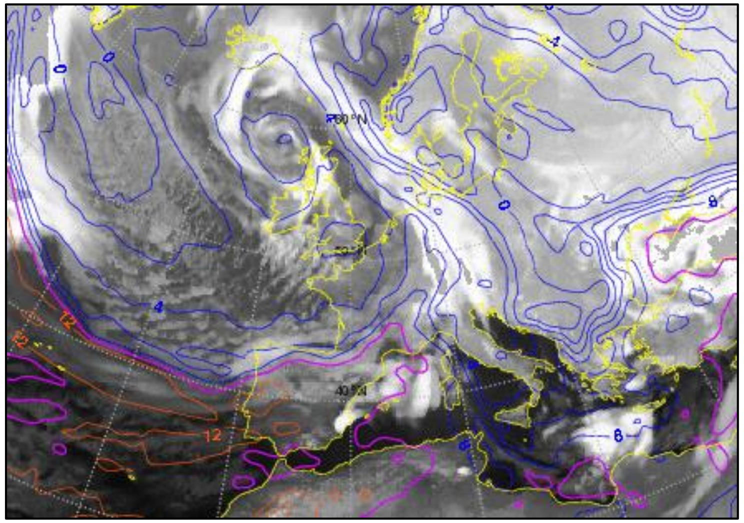


Cloud: 00Z Monday 27 January 2014

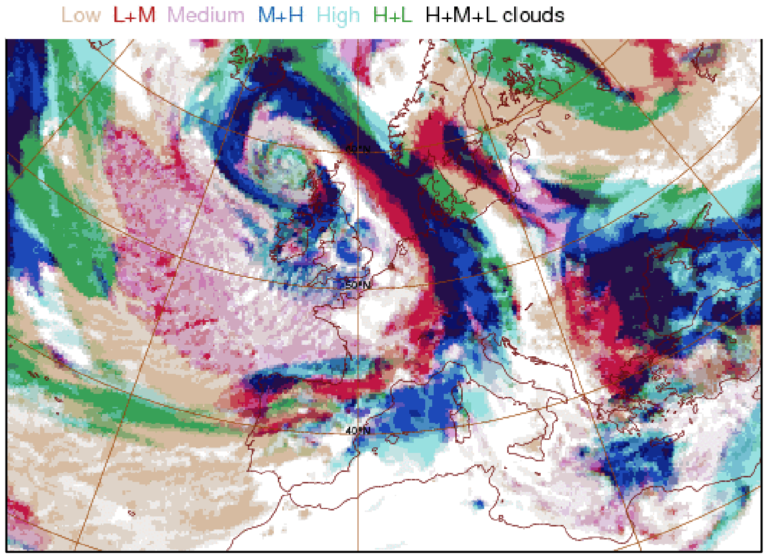
Meteosat IR 10.8µm



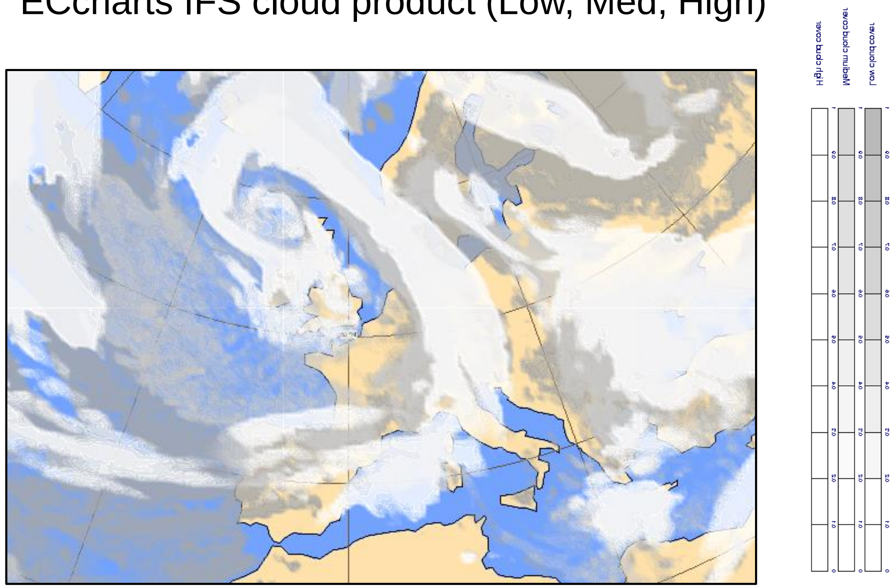
IFS Pseudo-IR 10.8µm



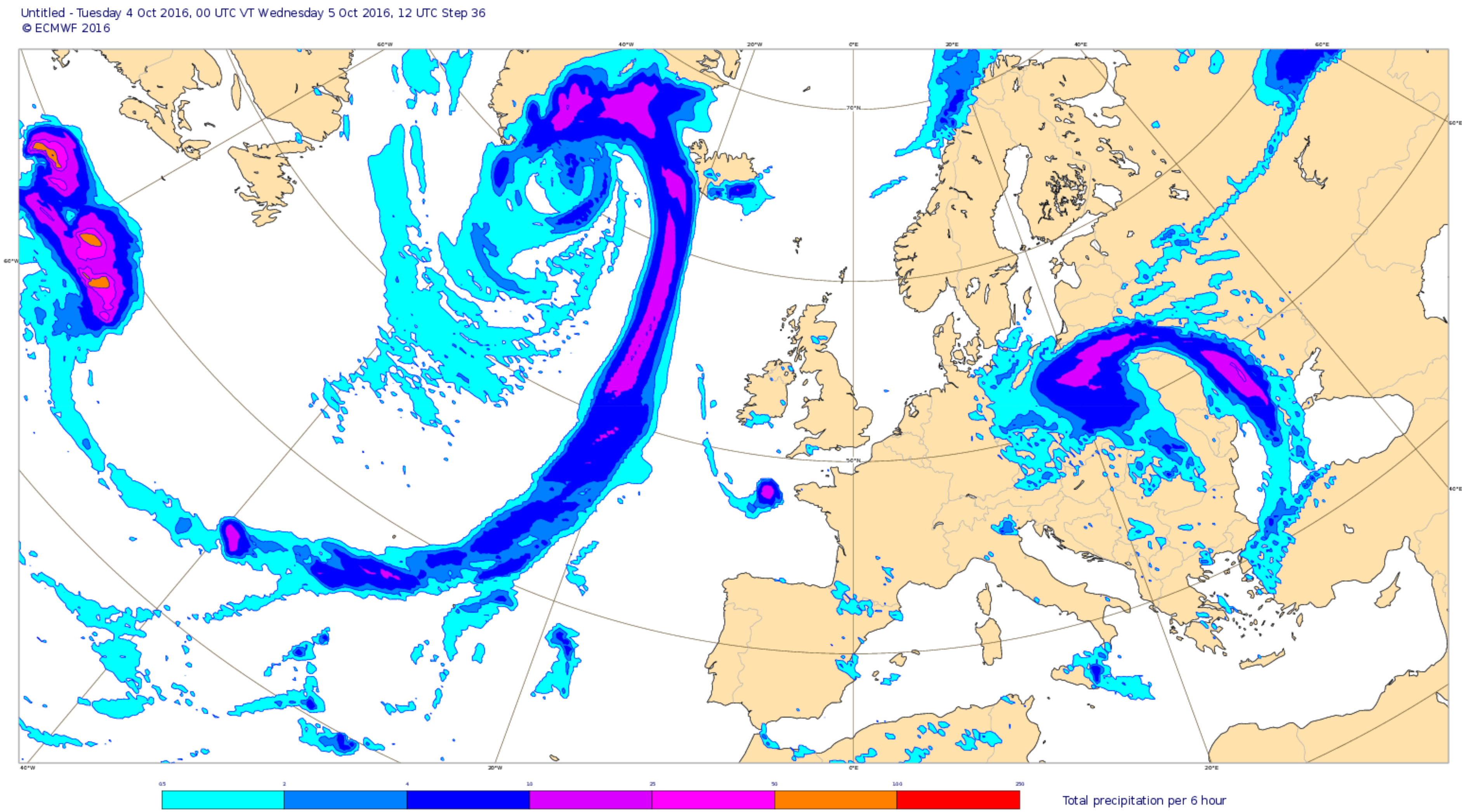
IFS cloud product (Low, Med, High and mixed)



ECcharts IFS cloud product (Low, Med, High)



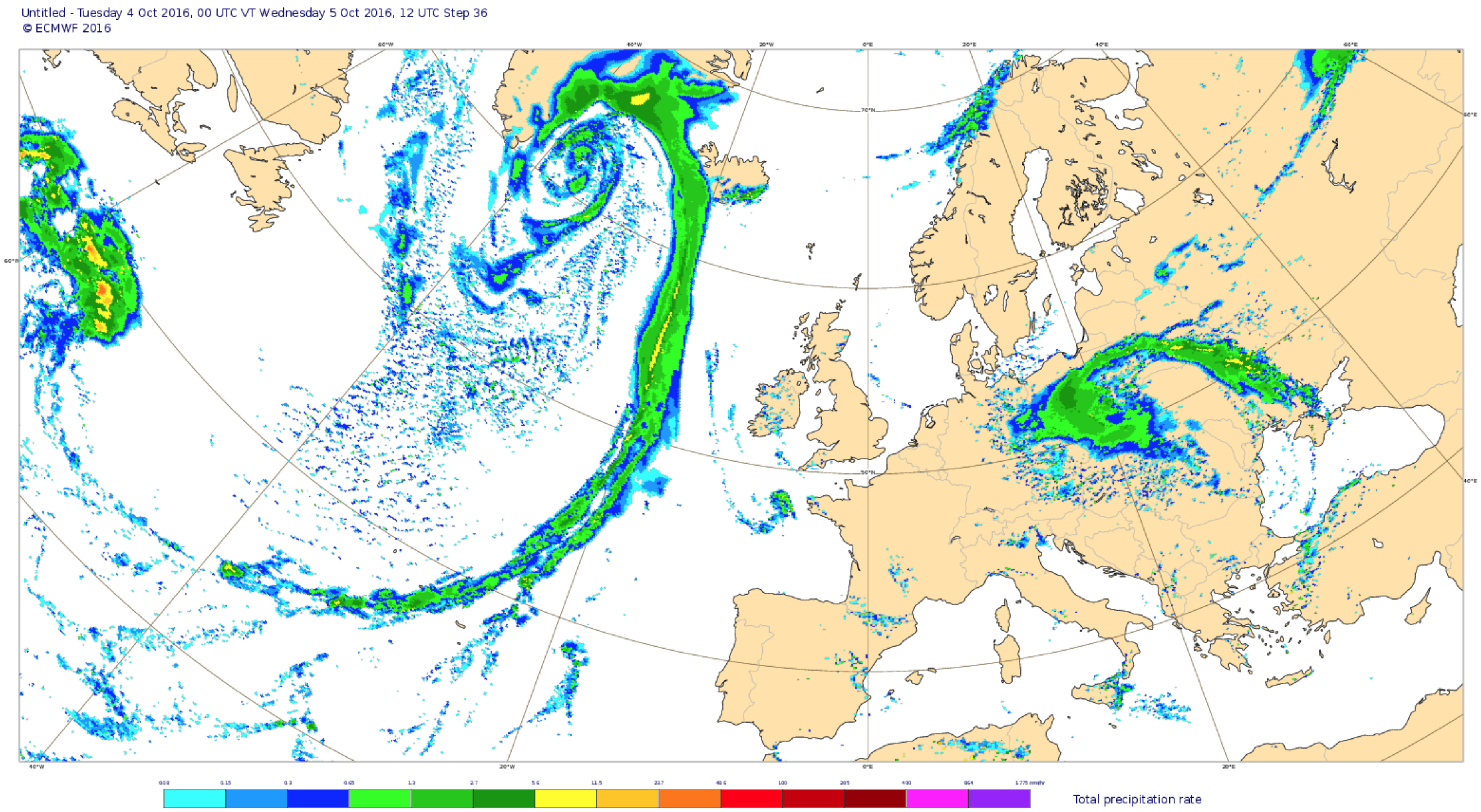
Example 6 hour precipitation accumulation
Forecast for Wed 5 October 2016



Precipitation Accumulation: Large-scale rain + convective rain + large-scale snow + convective snow

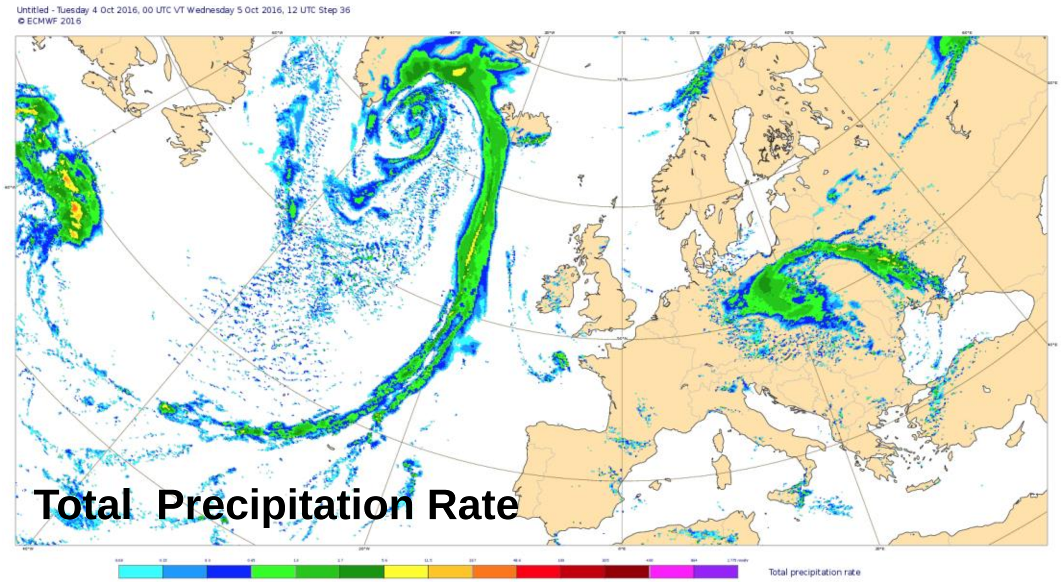
Example precipitation rate

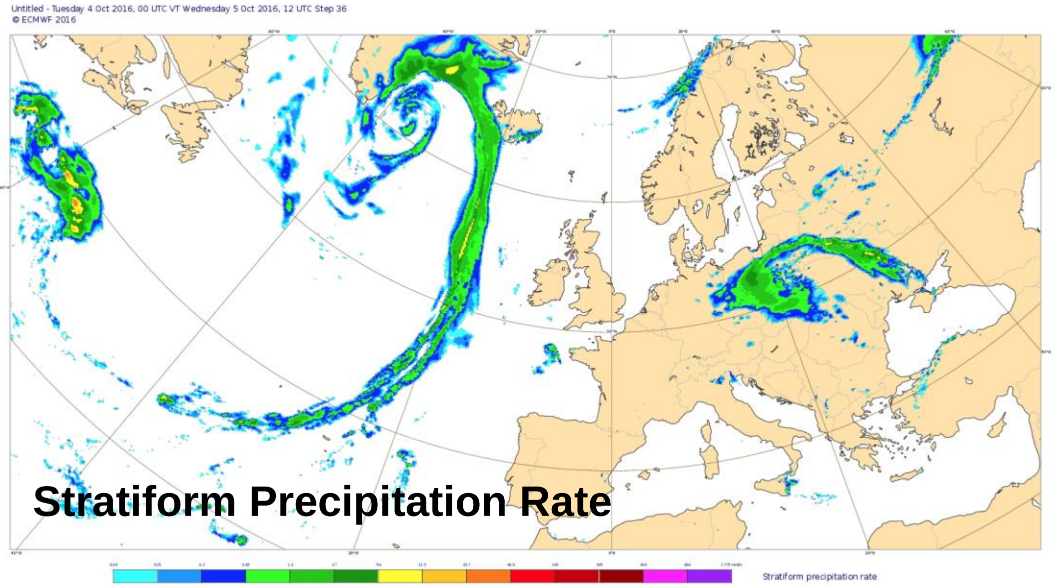
Forecast for Wed 5 October 2016 12Z

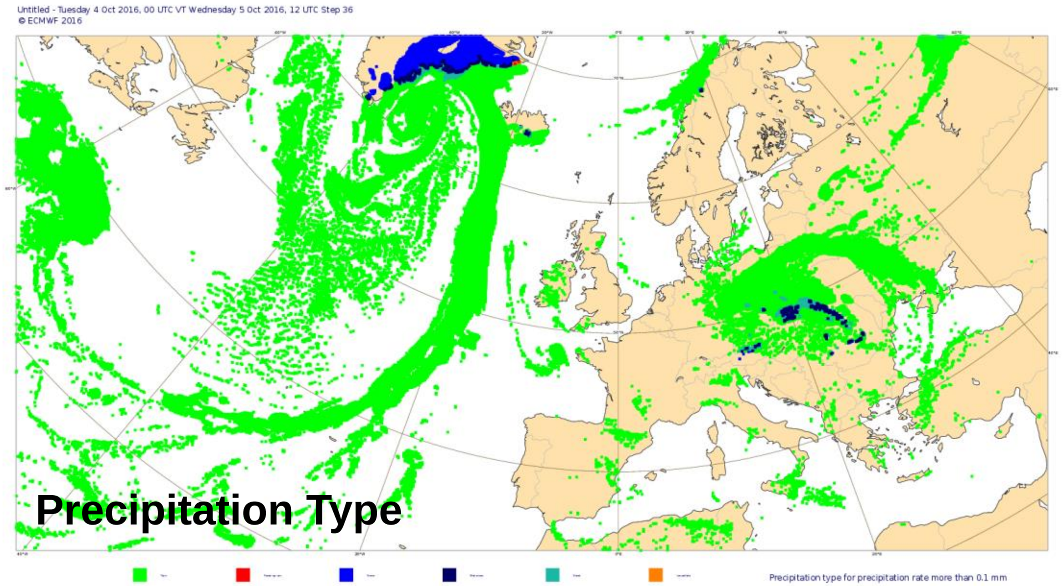


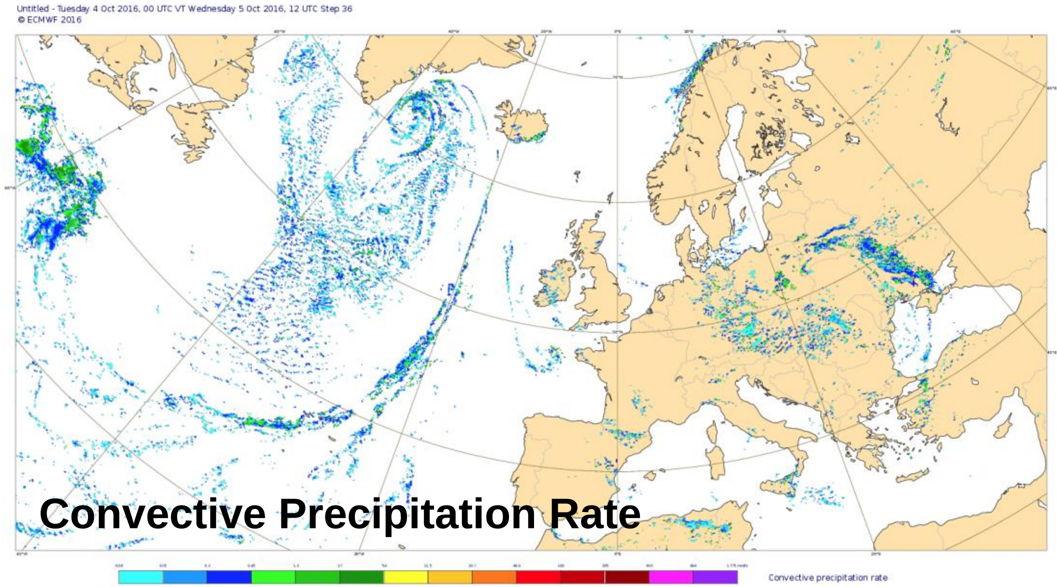
Precipitation Rate: Large-scale rain + convective rain + large-scale snow + convective snow

Precipitation rate and type example: 12 UTC Wed 5 October









2. Difficult situations for cloud and precipitation forecasts

Some of the difficult cloud problems for forecast models…

1. Boundary layer cloud (e.g. high pressure situations). Impact on 2m temperatures.

2. Snowfall in marginal situations – the melting layer

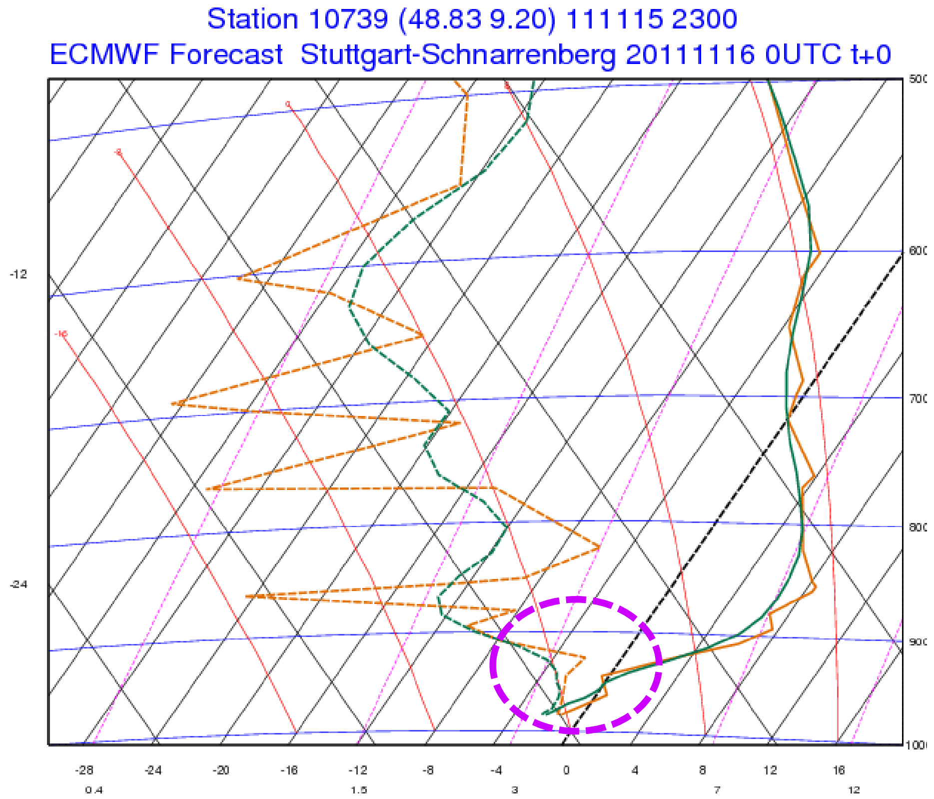
3. Winter precipitation type – freezing rain

4. Fog

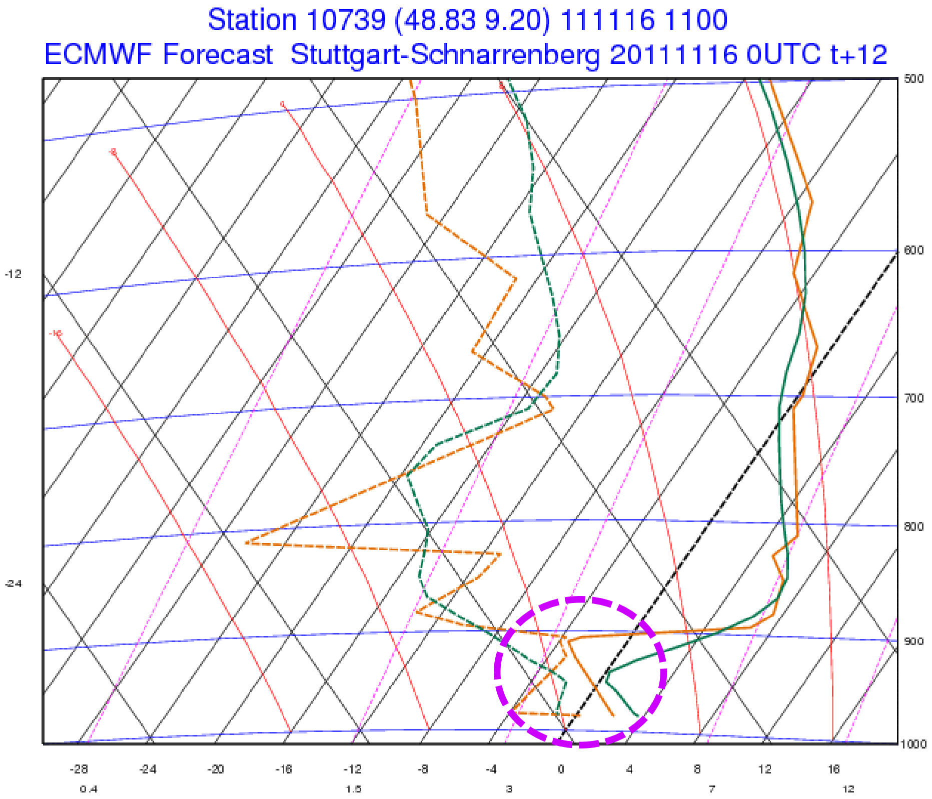
Low cloud cover: Too little in fog rising to stratocumulus example

Sounding Stuttgart 16 Nov, 2011

Too little cloud cover leads to warm bias in central Europe.



Obs Analysis

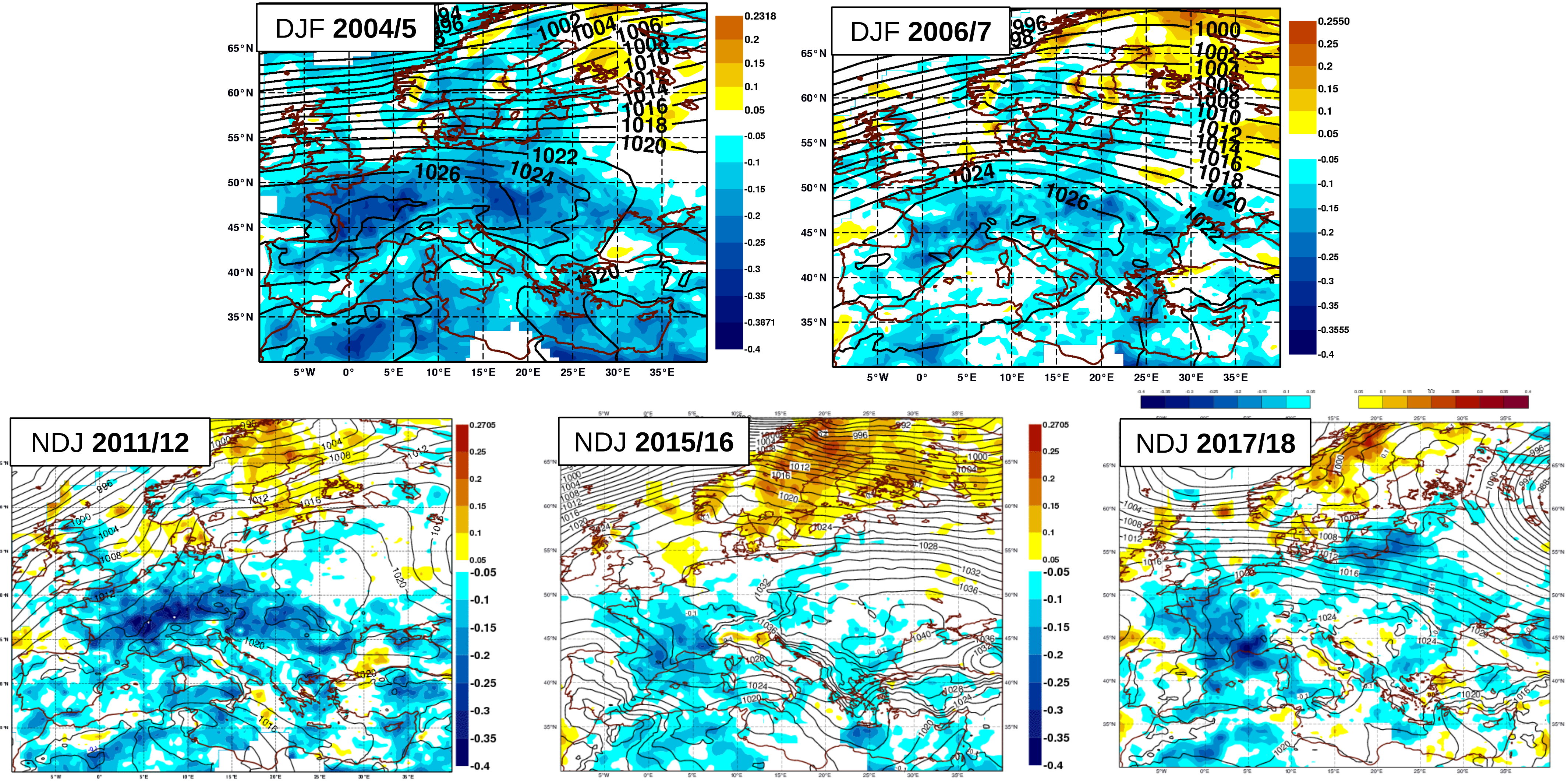


Obs Fc T+12h

Fog rising developing into stratocumulus deck could not be properly represented

Low cloud cover in winter anti-cyclones: 36h forecast versus 12 UTC SYNOP observations

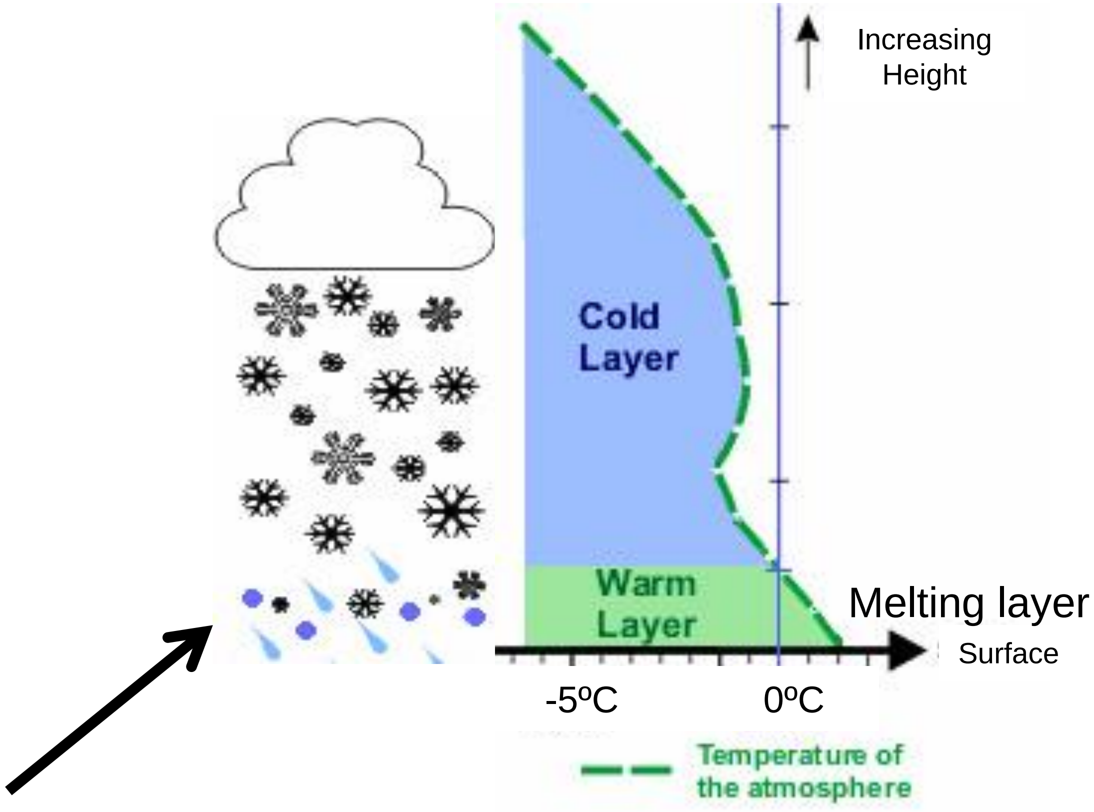
Cloud errors reducing, but still some underestimate of cloud cover on high pressure days over Europe during winter



Snowfall in marginal situations

Snowfall in marginal situations: Melting layer

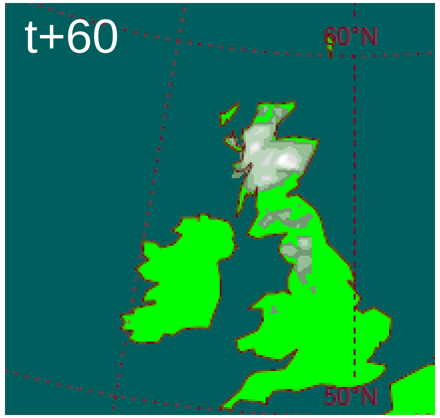
Melting layer often ~ few hundred metres thick
In drier air, snow melts at T > 0°C (due to evaporative cooling)



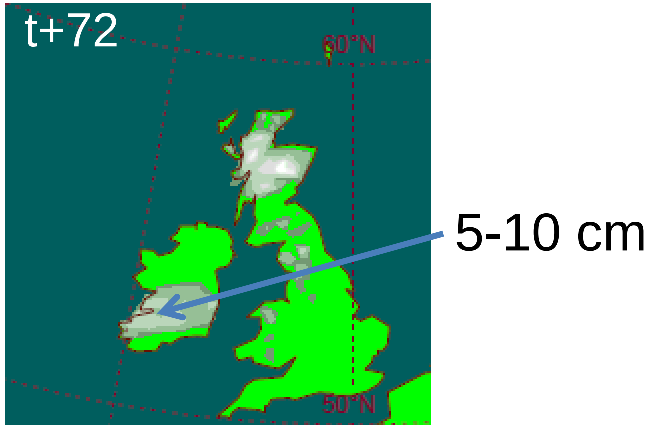
Sleet in melting layer:
Reality = melting particles, liquid surrounding an ice core
In the model = snow gradually transferred to rain variable

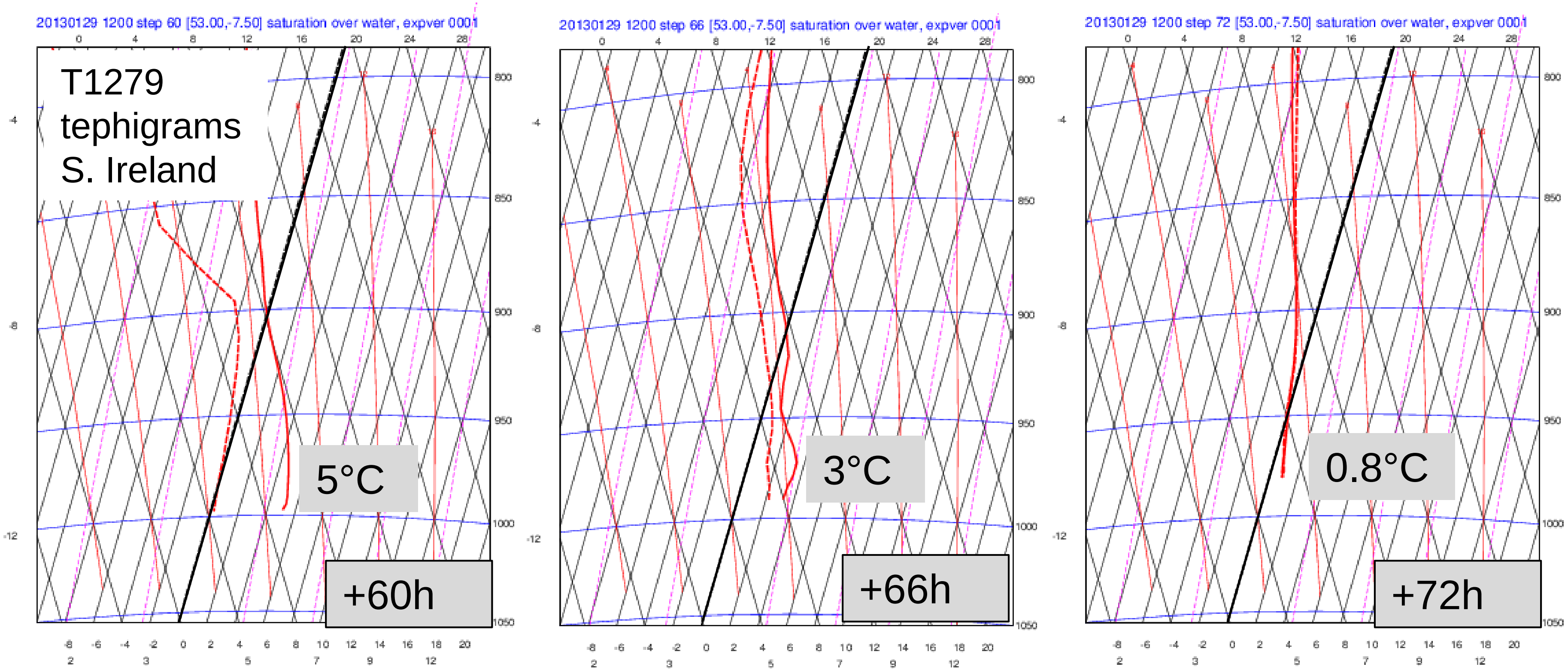
Snowfall in marginal situations

Ireland 01 Feb 2013. Snow depth forecast from basetime 12Z on 29 Jan



In this case, the forecast was a little too cold which lead to an over-forecast of snow accumulation on the ground.





Snowfall in marginal situations

- Difficult to get right. A difference of 1 or 2ºC makes all the difference between snowfall and rainfall (e.g. errors in large scale flow, surface too cold, precipitation rate incorrect)

- In the model, sleet (melting snow particles) is represented by a mix of rainfall and snowfall. Halfway through the melting layer will be 50% snowfall and 50% rainfall. See later on for Precipitation Type..…

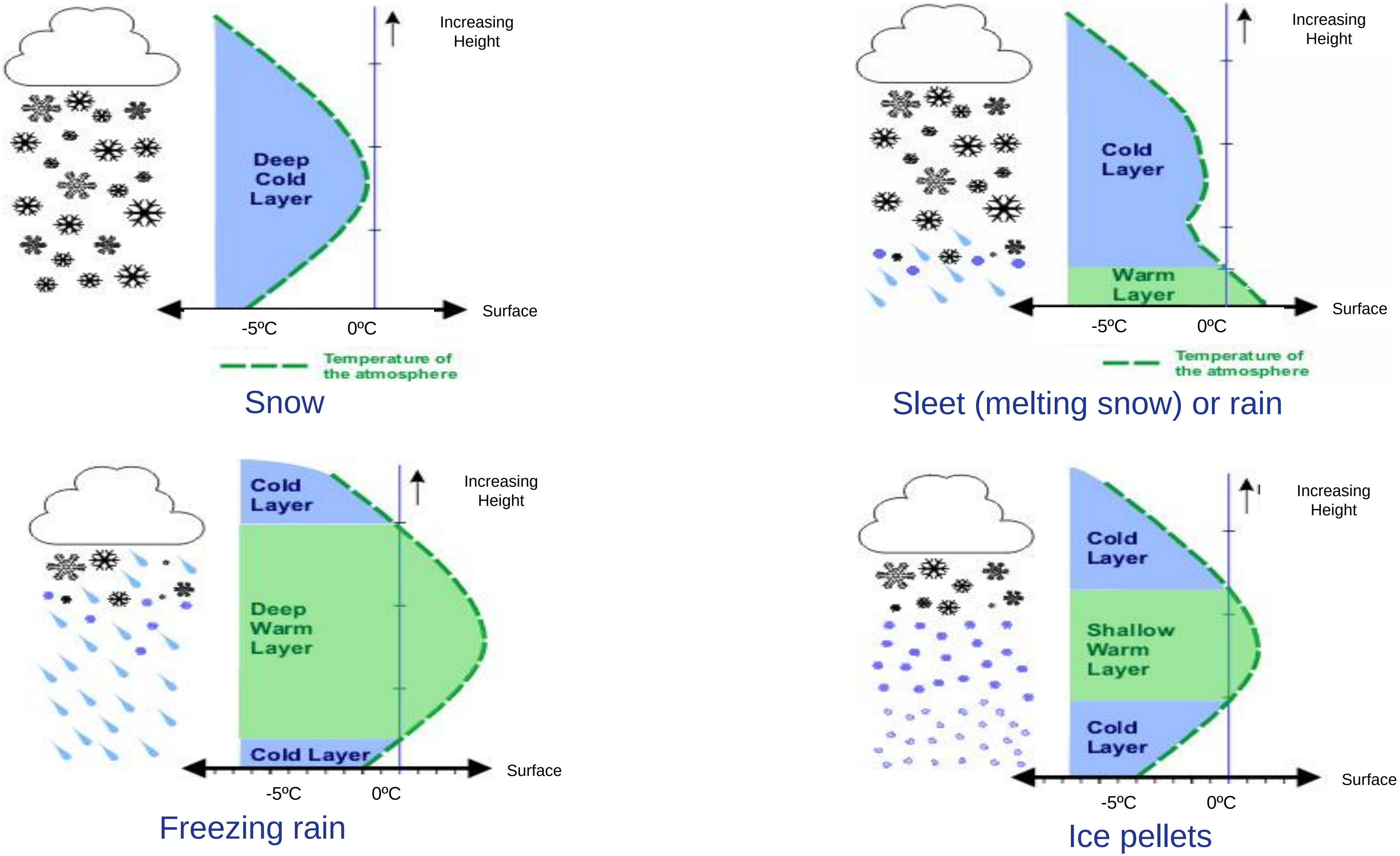
- Once on the ground and temperatures greater than zero, surface snow often takes too long to melt (recognised problem in the ECMWF model)

 - this will hopefully improve in the future with a new multi-layer snow scheme

Winter precipitation type (Freezing rain)

Precipitation type – a diagnostic from the IFS

rain / snow / wet snow / mix rain-snow / ice pellets / freezing rain



Precipitation parameters (from May 2015)

- Precipitation type (valid at a particular time) (**PTYPE**)

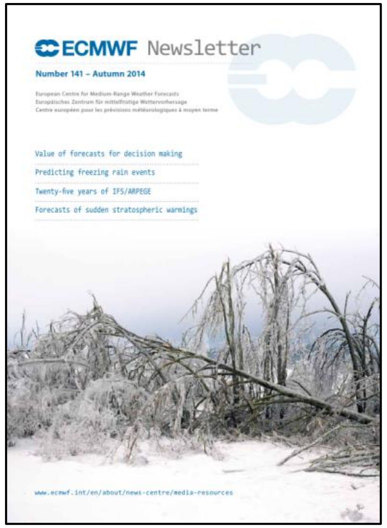
  (=1) Rain T2m > 0ºC, liquid mass more than 80%
  (=7) Mixed rain/snow T2m > 0ºC, liquid mass >20% and <80%
  (=6) Wet snow T2m > 0ºC, liquid mass less than 20%

  (=5) Snow T2m < 0ºC "dry" snow
  (=3) Freezing rain T2m < 0ºC supercooled rain from melted particles aloft
  (=8) Ice pellets T2m < 0ºC refrozen from partially melted particles aloft

- Accumulated precipitation (from the start of the forecast) (**LSP, CP, SF, TP**)
- Accumulated freezing rain at the surface (**FZRA**)
- Graupel/Hail not available
- Instantaneous precipitation rates (valid at a particular time)
  - Stratiform (large-scale) rainfall rate, and snowfall rate (**LSRR, LSSFR**)
  - Convective rainfall rate, and snowfall rate (**CRR, CSFR**)
  - Later this year, will also have total precipitation rate (**TPR**)
- Maximum and minimum total precipitation rates in the last 3 hours/6 hours (**MINTPR3, MAXTPR3, MINTPR6, MAXTPR6**)

Predicting high-impact freezing rain events

- Case Study: Slovenia/Croatia 02 Feb 2014
- Freezing rain caused severe disruption and damage, tranports/power/forests…
- IFS physics at the time (40r1) not able to predict
- New physics in 41r1 (operational from May 2015) enabled prediction of freezing rain
- Evaluation in HRES/ENS shows potential for useful forecasts
- Article in EC Newsletter Autumn 2014



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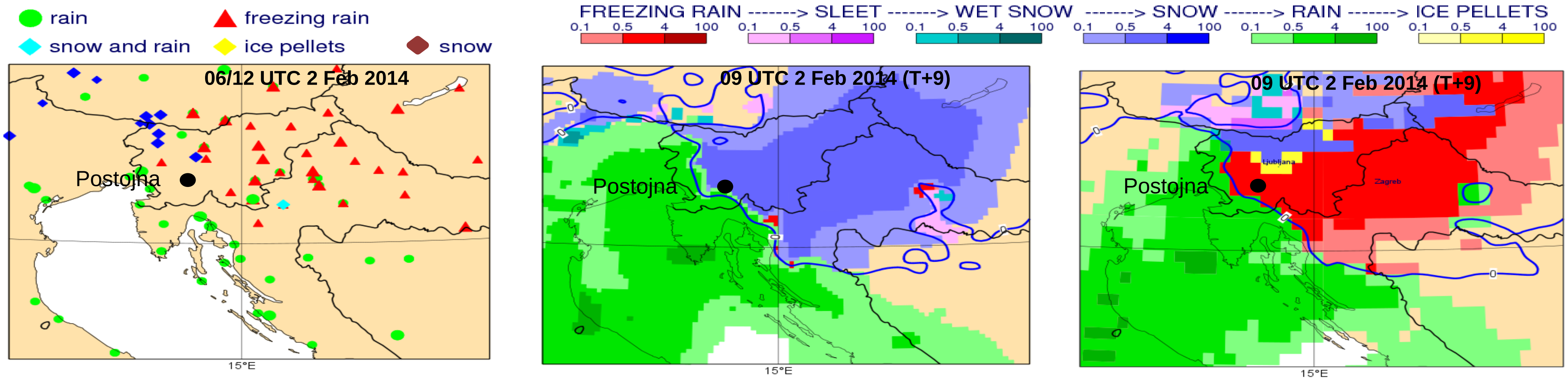
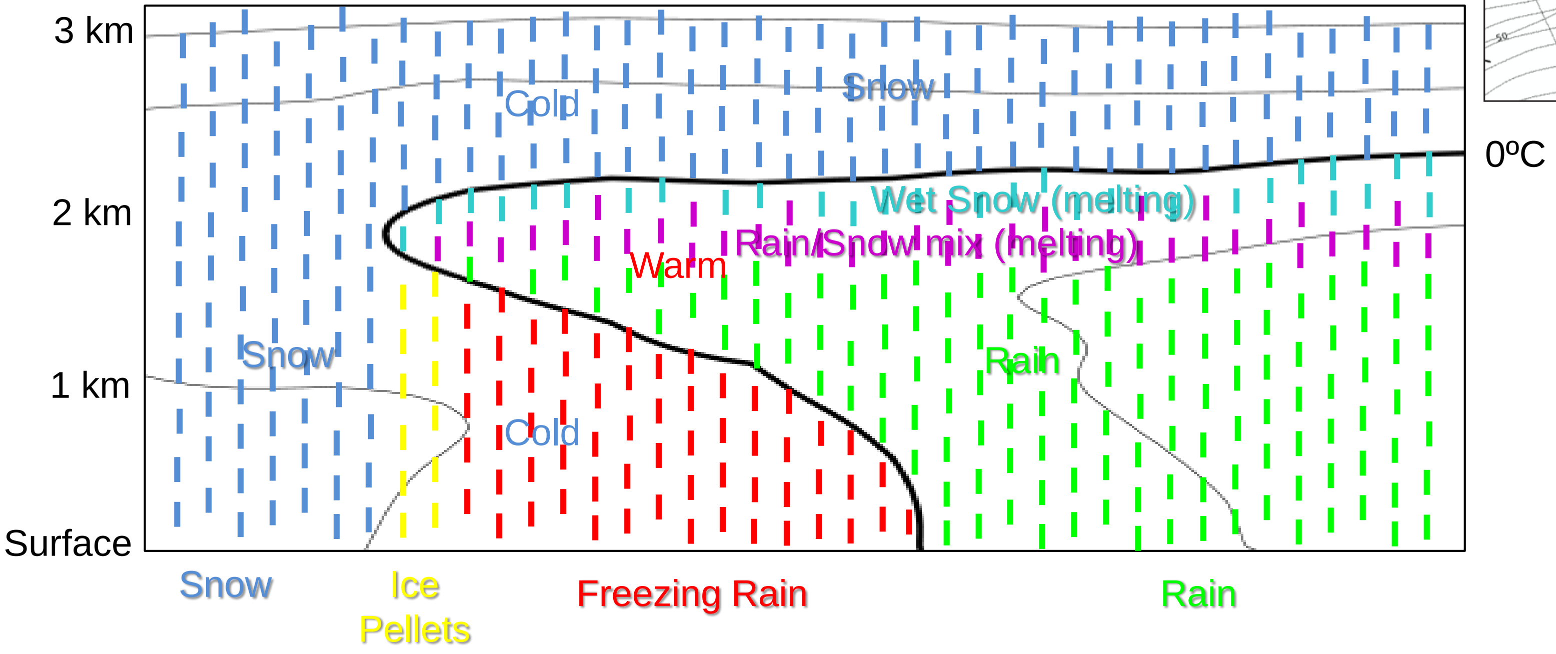
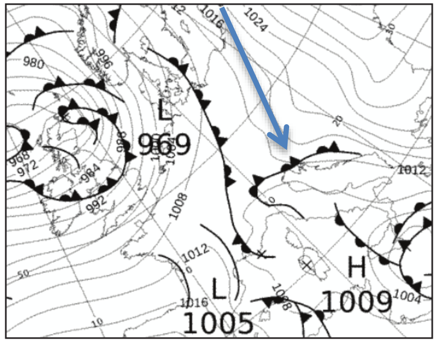


SYNOP Observations | IFS HRES 40r1 | IFS HRES 41r1

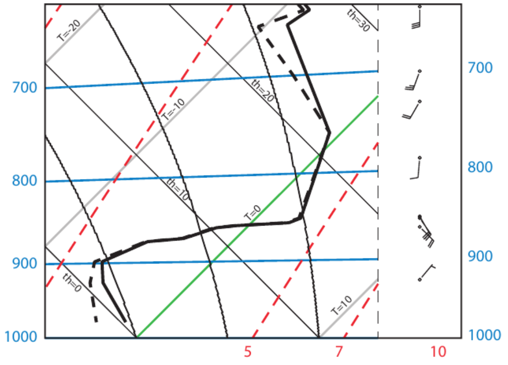
Schematic cross-section (front with elevated warm layer)

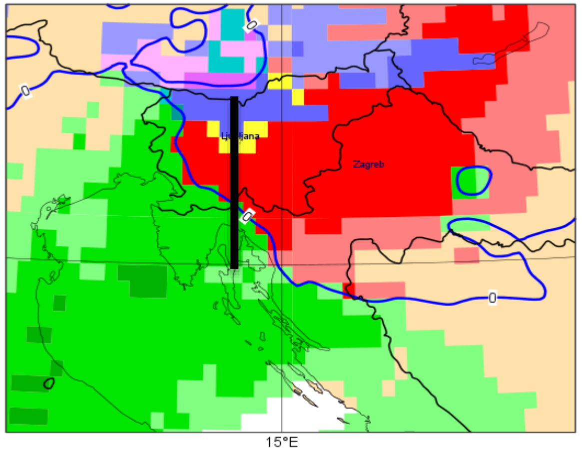


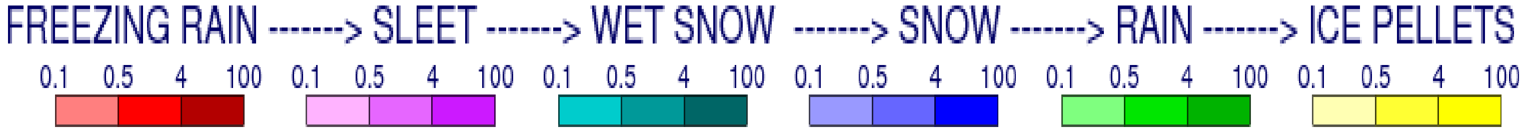
Occluded front



Ljubljana sounding

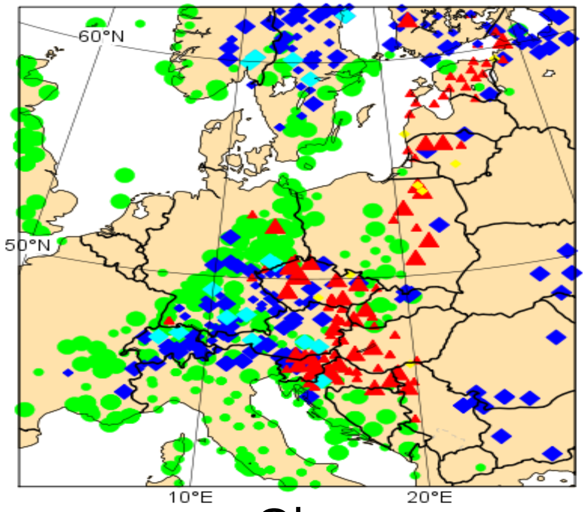






Probability of freezing rain accumulation from the IFS ensemble

Case Study: 02 Feb 2014



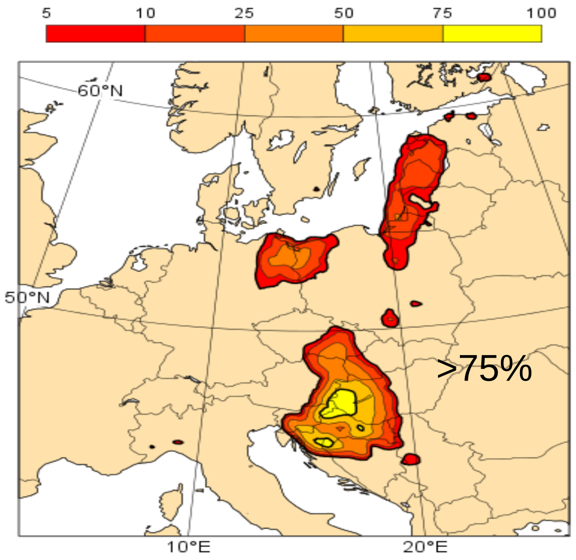
Obs

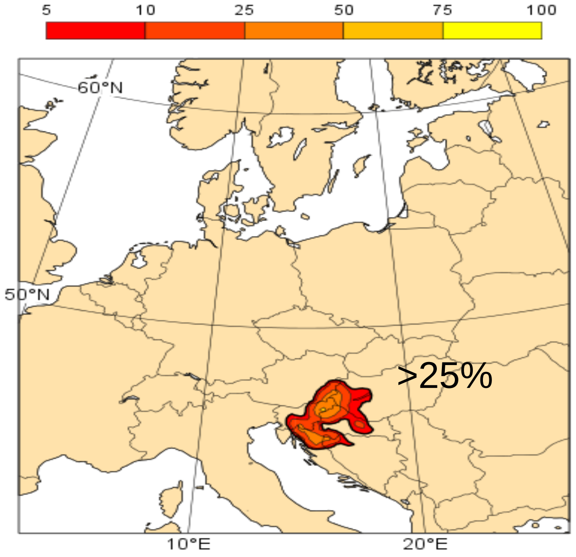
- rain
- snow
- freezing rain
- snow and rain
- ice pellets

Prob (fzra > 1mm)

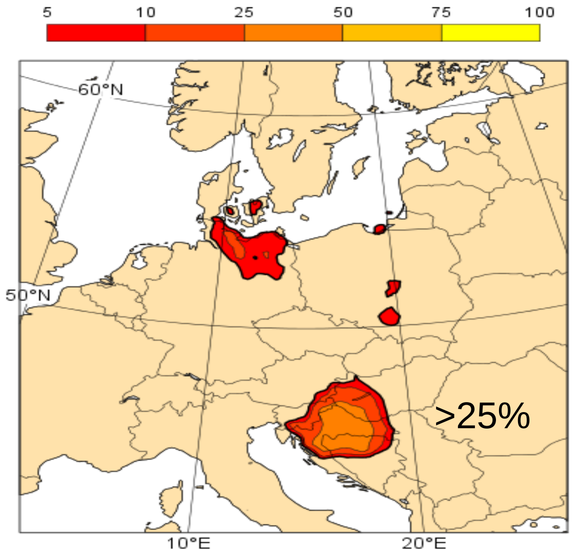
Prob (fzra > 5mm)

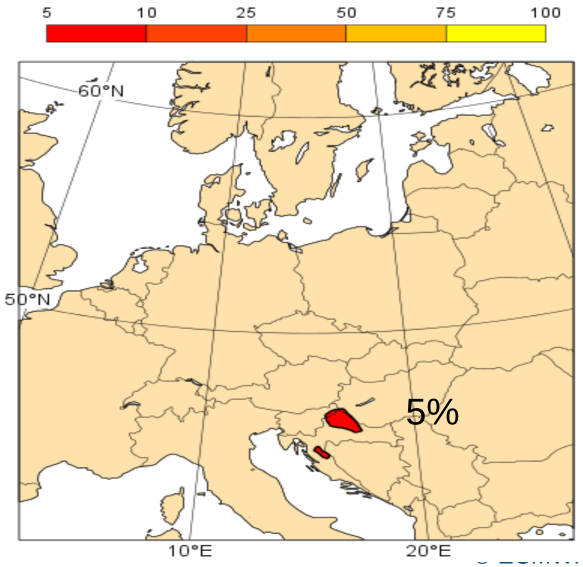
Day 3 forecast





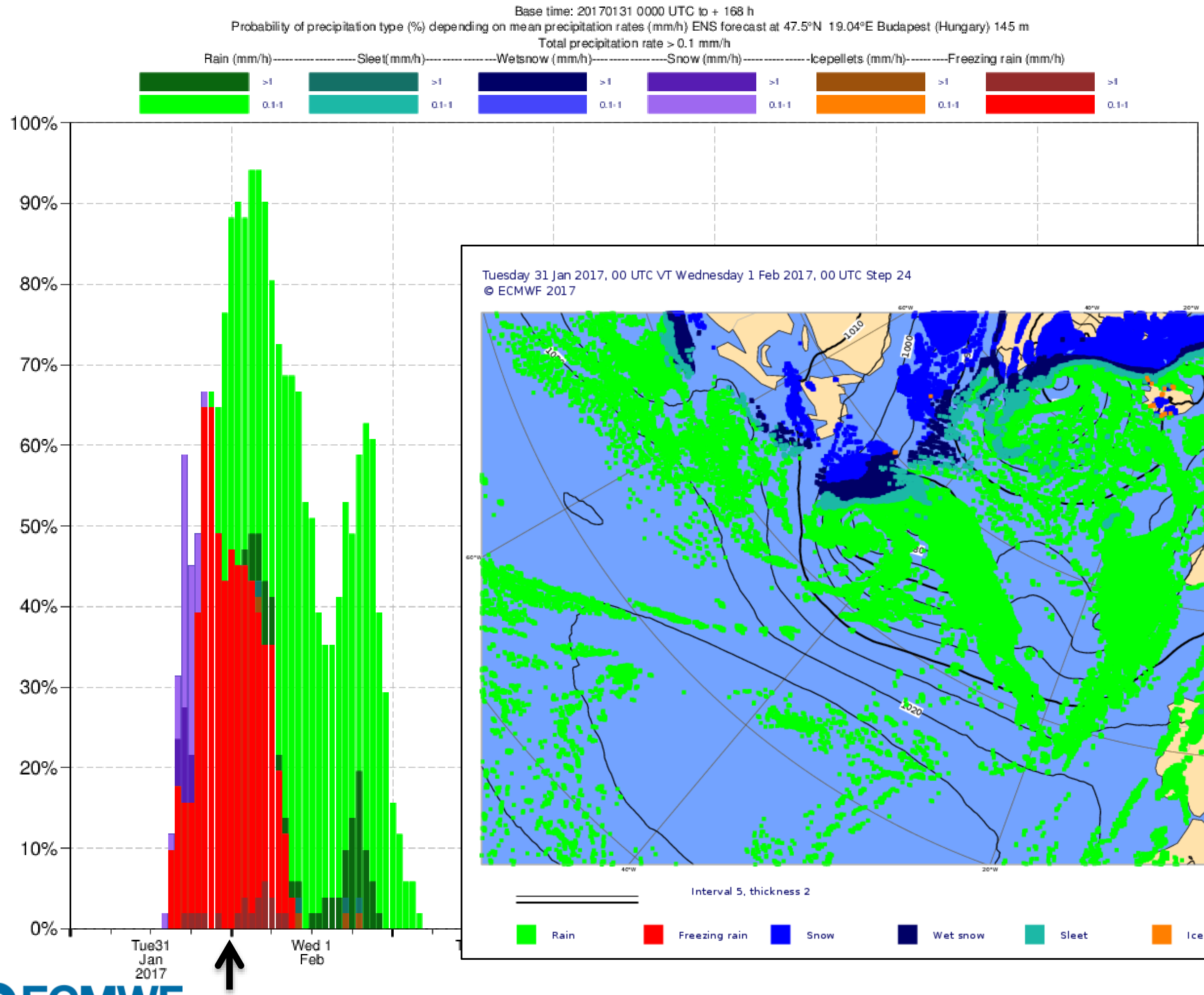
Day 5 forecast

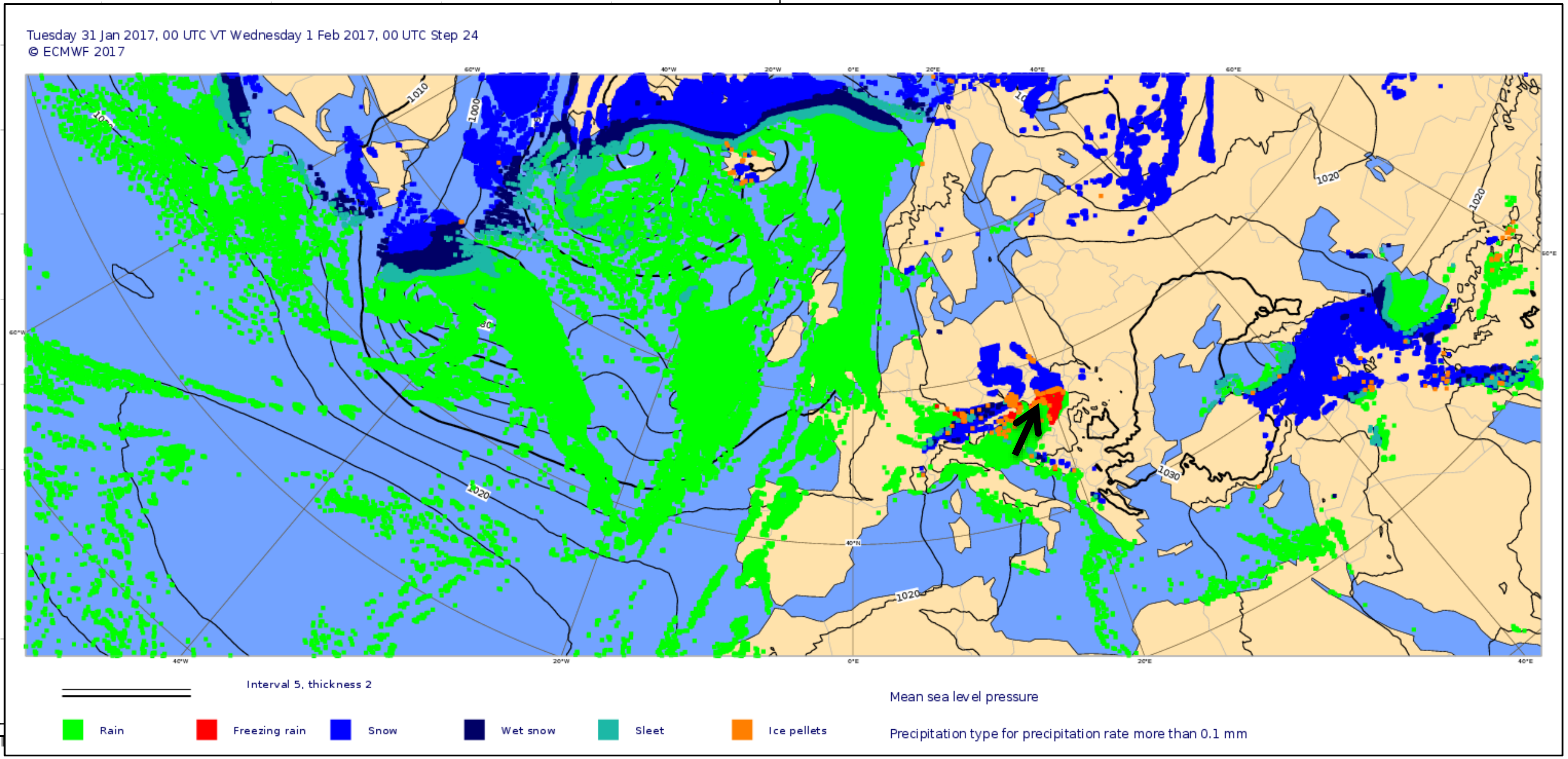




Ensemble probability of precipitation type time sequence

Budapest, 00Z 31 Jan 2010



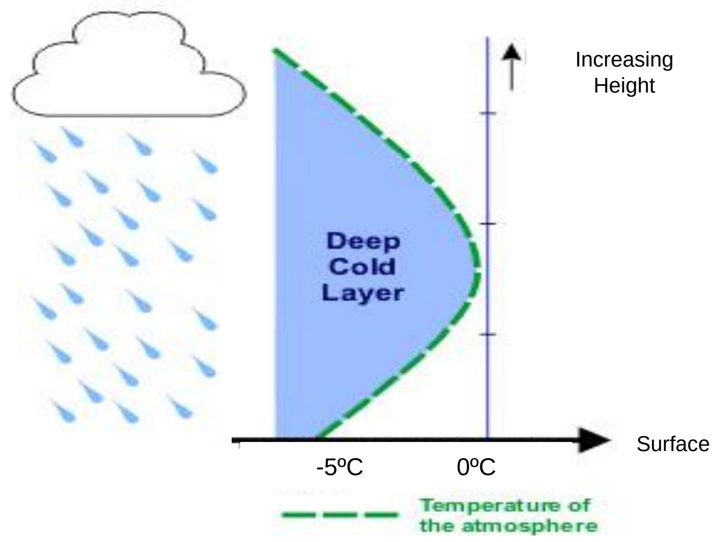


Precipitation type – freezing drizzle

Not yet represented in the IFS but working now on including this in the future…

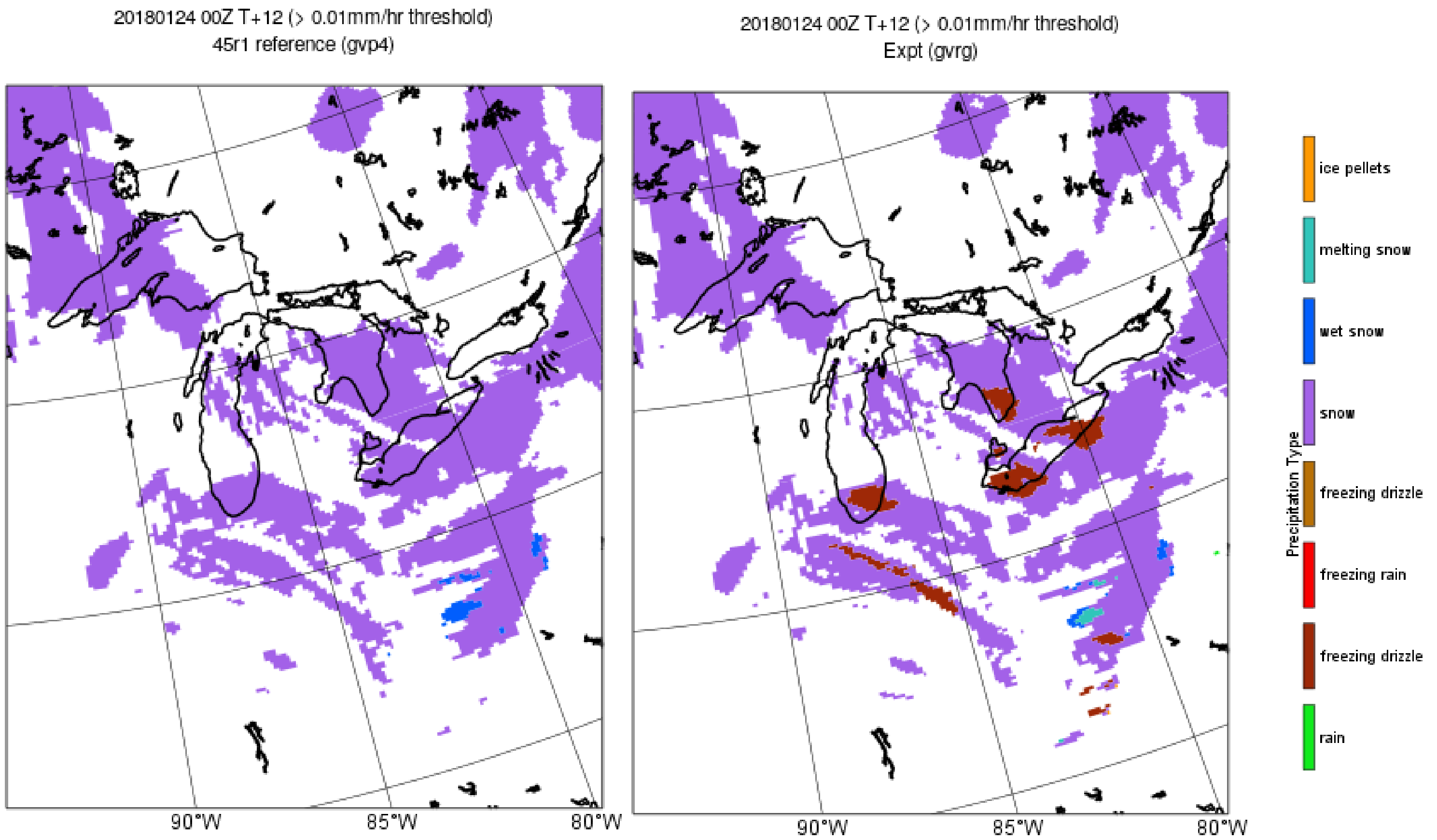
Case study: Chicago 24 January 2018

Freezing drizzle observed in vicinity of Great Lakes. Operational model all snow (left). Experimental version has patches of freezing drizzle (right)



"Freezing drizzle"

Supercooled "warm-rain" process active



Visibility and Fog

Visibility (Fog)

(available operationally since May 2015)

Visibility is calculated using an exponential scattering law and a visual range defined by a fixed liminal contrast of 0.02 based on extinction due to clean air, aerosol, cloud and precipitation near the surface (nominally 10m)

$$\text{Visibility} = \text{fn (clear air} + \text{aerosol} + \text{cloud liquid} + \text{cloud ice} + \text{rain} + \text{snow)}$$

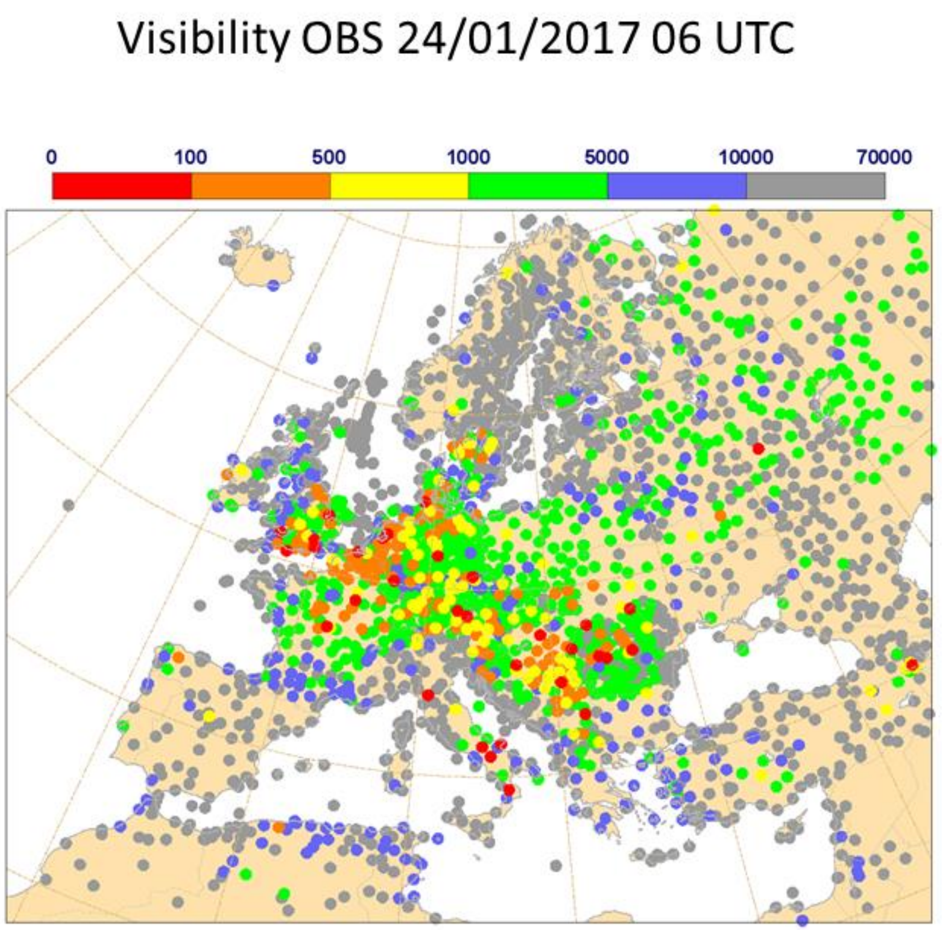
Aerosol:	seasonally varying based on 10 year CAMS aerosol climatology (since July 2017)
Fog:	predicted near-surface cloud liquid water/ice
Precipitation:	reduced visibility due to predicted near-surface falling rain and snow

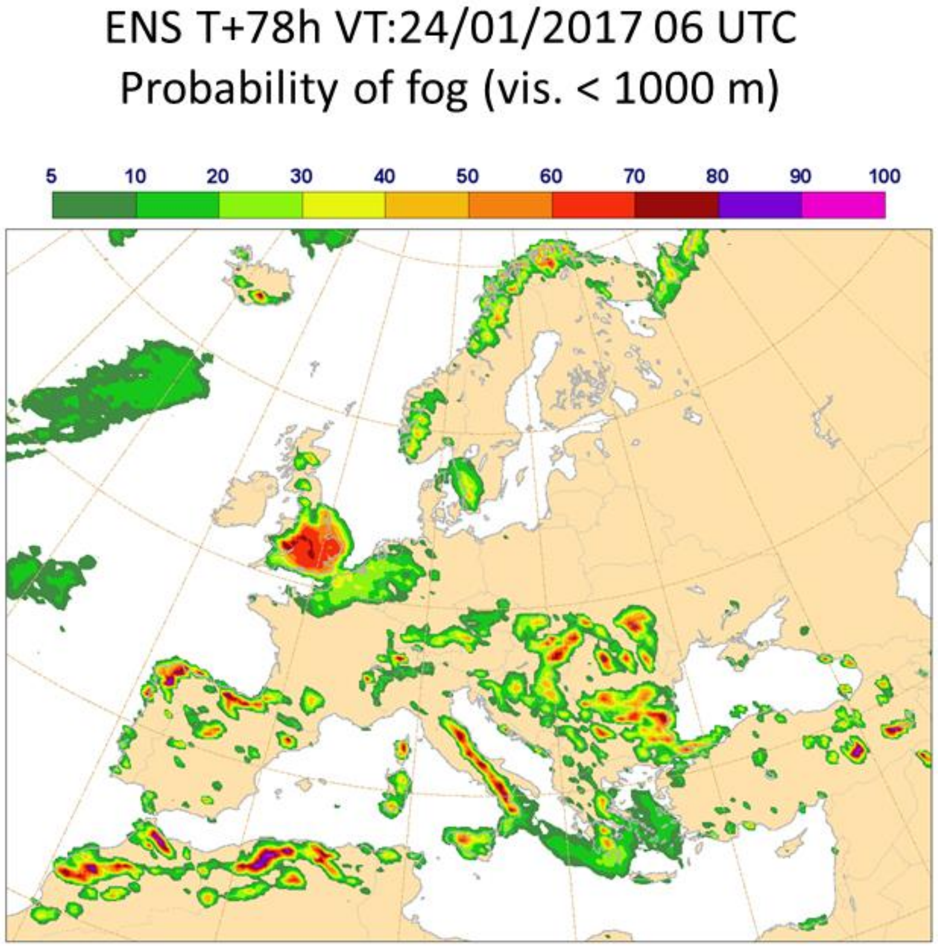
Many limitations!

- "Aerosol climatology" – will not represent reduced visibility with pollution events etc.
- Visibility in fog is on the low side (often < 100m) – need to revisit the assumptions
- Fog is highly spatially variable! – can't capture local effects of orography and surface heterogeneity
- Fog prediction dependent on fine balance of physical processes (radiation, turbulence, microphysics)
- Use of probability of fog (vis < 1 km) from the ensemble potentially useful…

Prediction of severe weather: Visibility/Fog

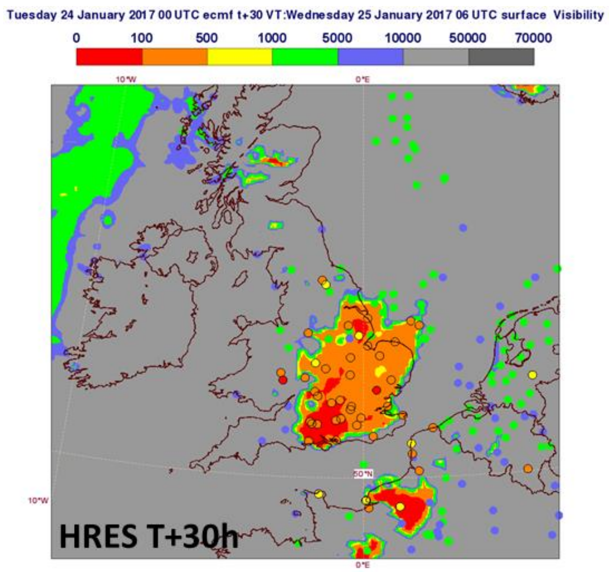
Case study: 24 Jan 2017, 3 day probability forecast from IFS ensemble



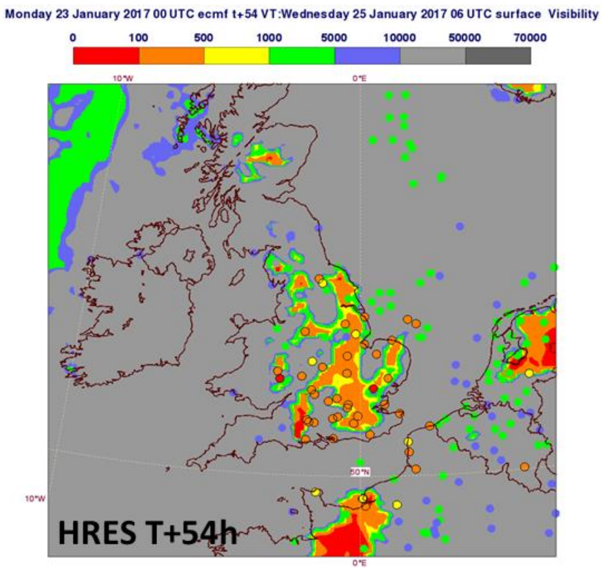


Prediction of severe weather: Visibility/Fog

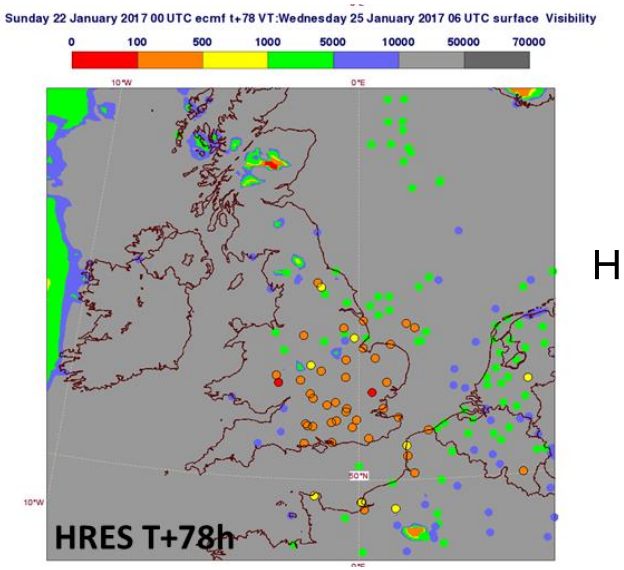
Case study: 06 UTC, 25 Jan 2017



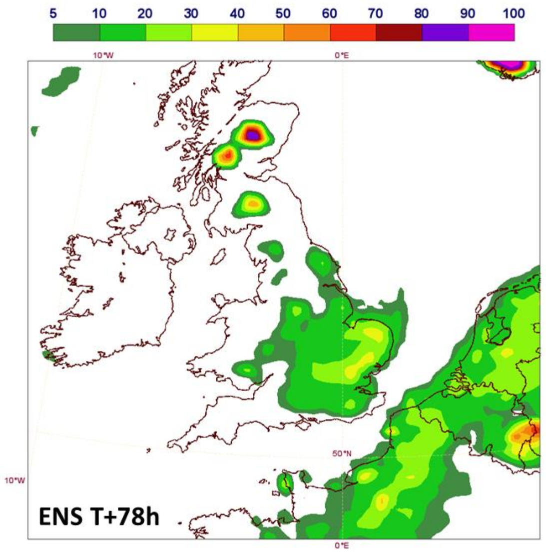
HRES 1 day forecast
Good prediction of fog



HRES 2 day forecast
Less good, some
indication of fog



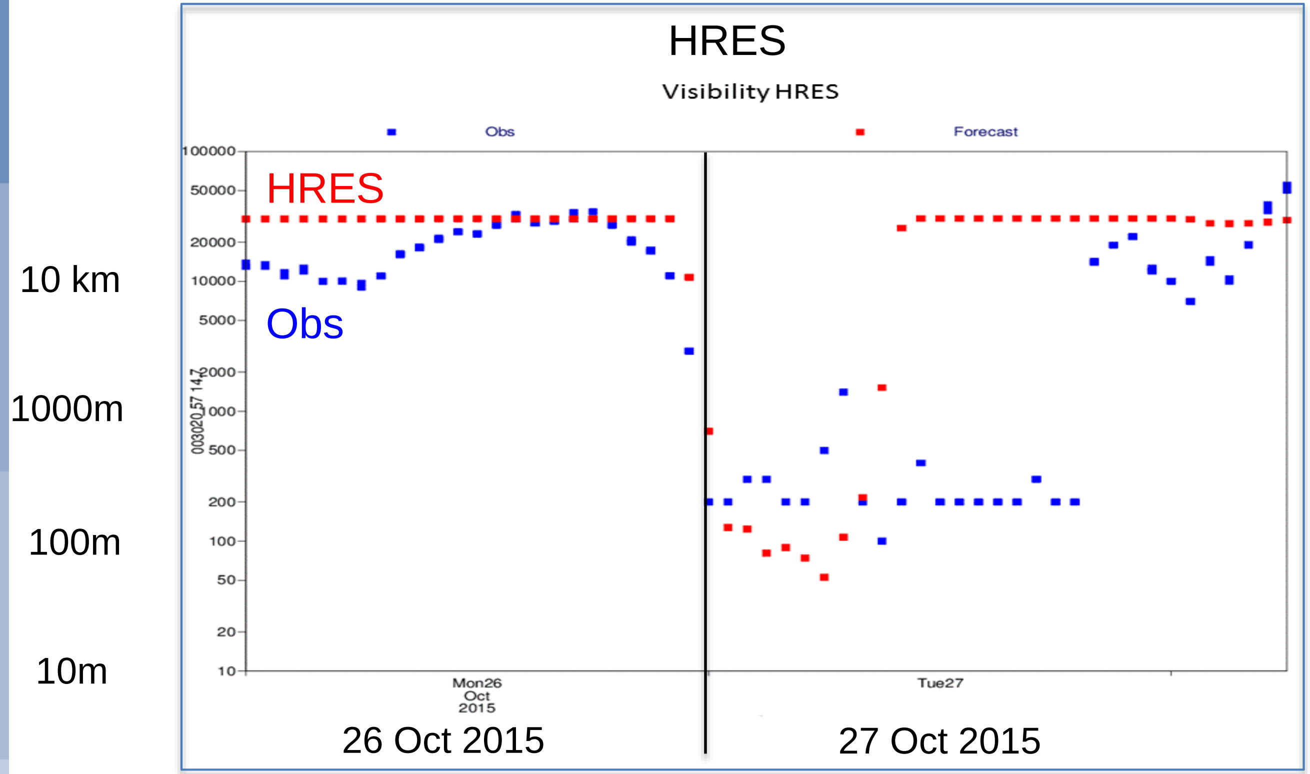
HRES 3 day forecast
No fog predicted

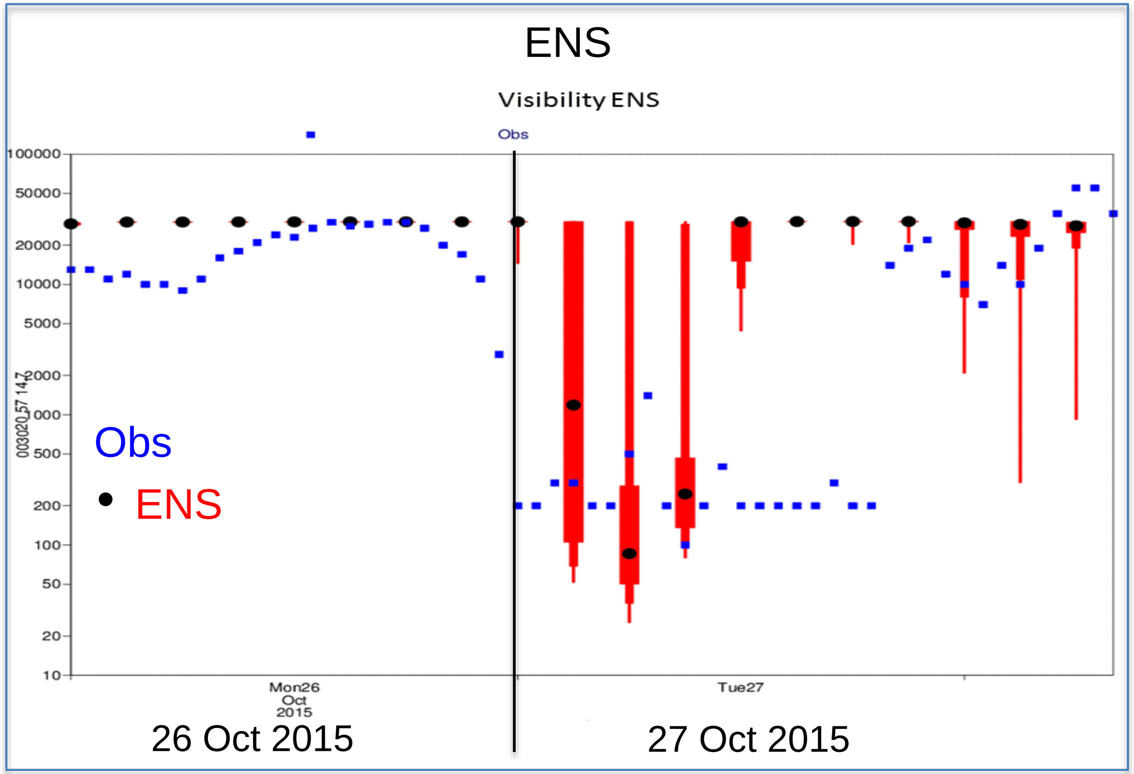


ENS 3 day forecast
20-40% fog probability

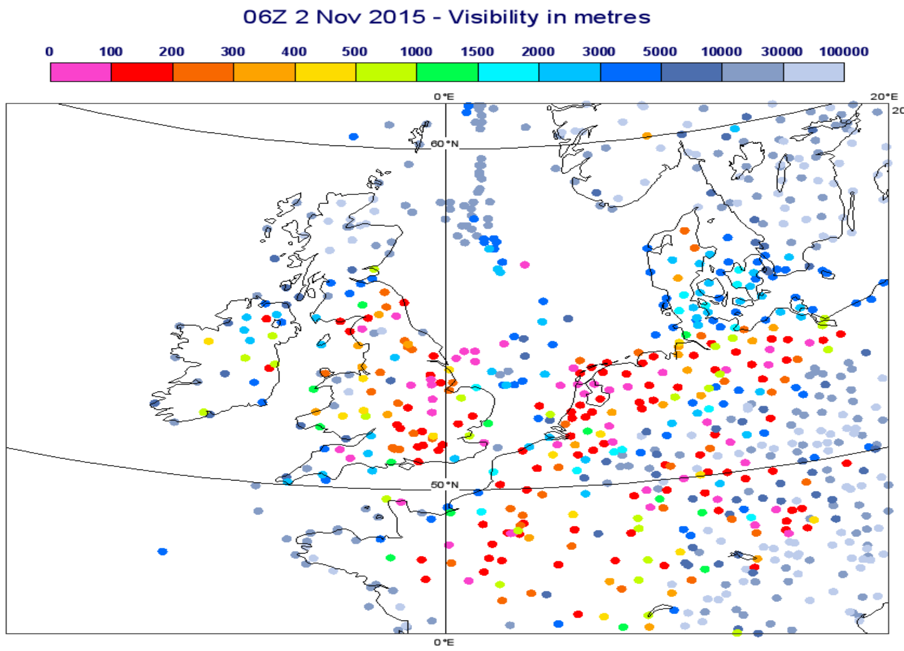
Prediction of severe weather: Visibility/Fog
Case study: 27 Oct 2015 - Fog in southern Sweden

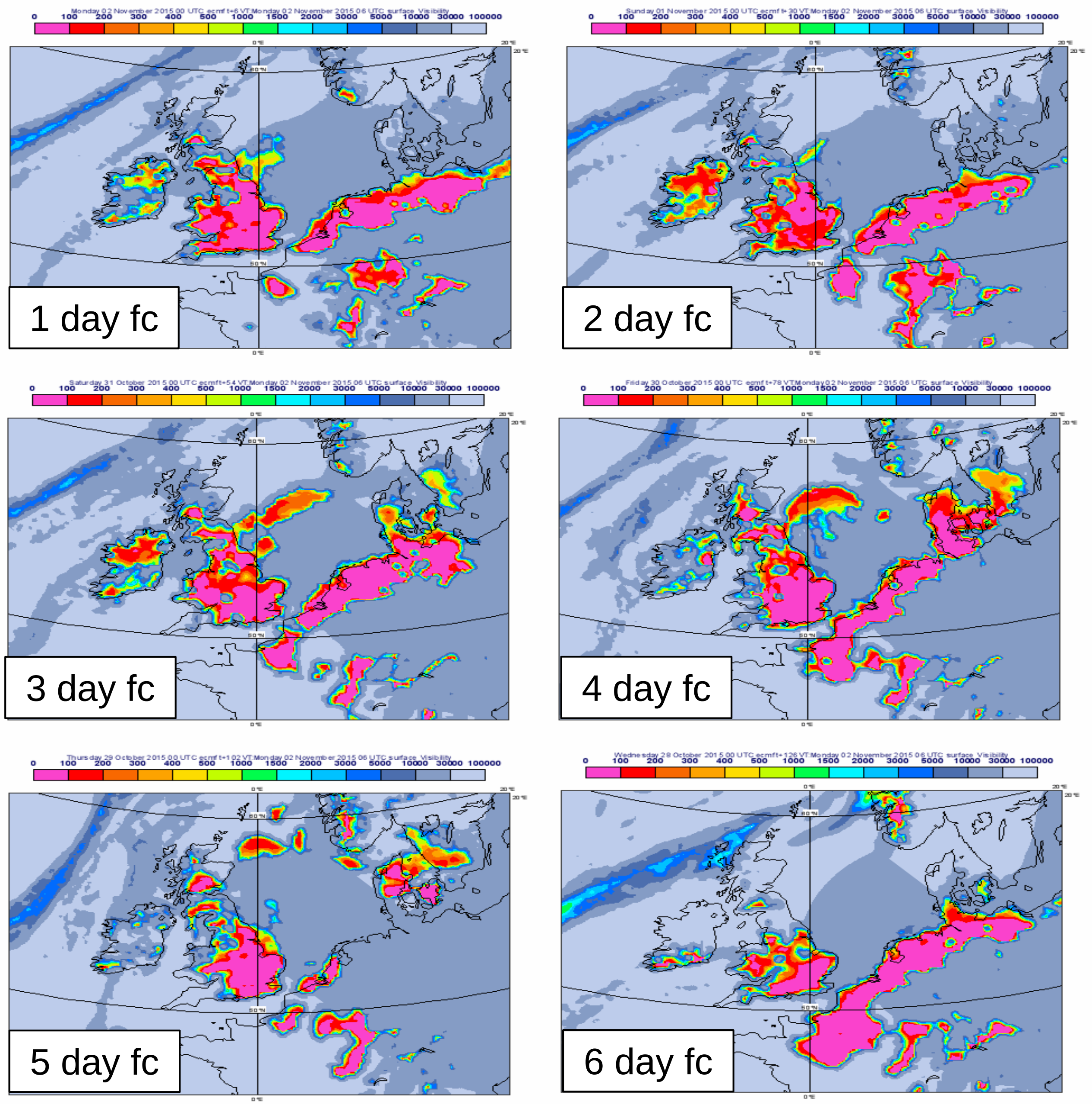
- Onset well predicted by HRES, but clears too early
- ENS shows spread early on but also doesn't capture the fog staying later in the day





Prediction of severe weather: Visibility/Fog
Case study: 02 Nov 2015





- In this case, indication of widespread fog event out to 6-day forecast
- Not always the case!
- Some regions missed
- Visibilities a bit too low in fog?

Summary

Summary
Clouds and Precipitation: From models to forecasting

What we covered…

- Overview of parametrization of cloud and precipitation in the IFS
- Some of the difficult "stratiform" cloud/precip regimes for the model – low cloud, mixed-phase, melting layer, winter precipitation, fog
- Precipitation type – Melting snow, freezing rain
- Visibility / fog
- Ensemble probabilities most useful in medium-range
- Feedback welcome!!!

Thank you for listening! Questions? Feedback?