Clouds and precipitation:
From models to forecasting

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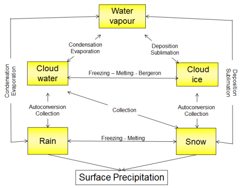
Thanks to Tim Hewson, Ivan Tsonevsky, Thomas Haiden, Peter Bechtold

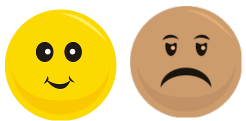
Outline

Clouds and Precipitation: From models to forecasting

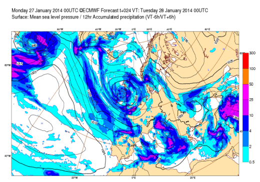
This seminar will (hopefully!) help you to …



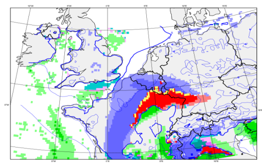
- describe how cloud and precipitation is represented in the ECMWF global model.



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



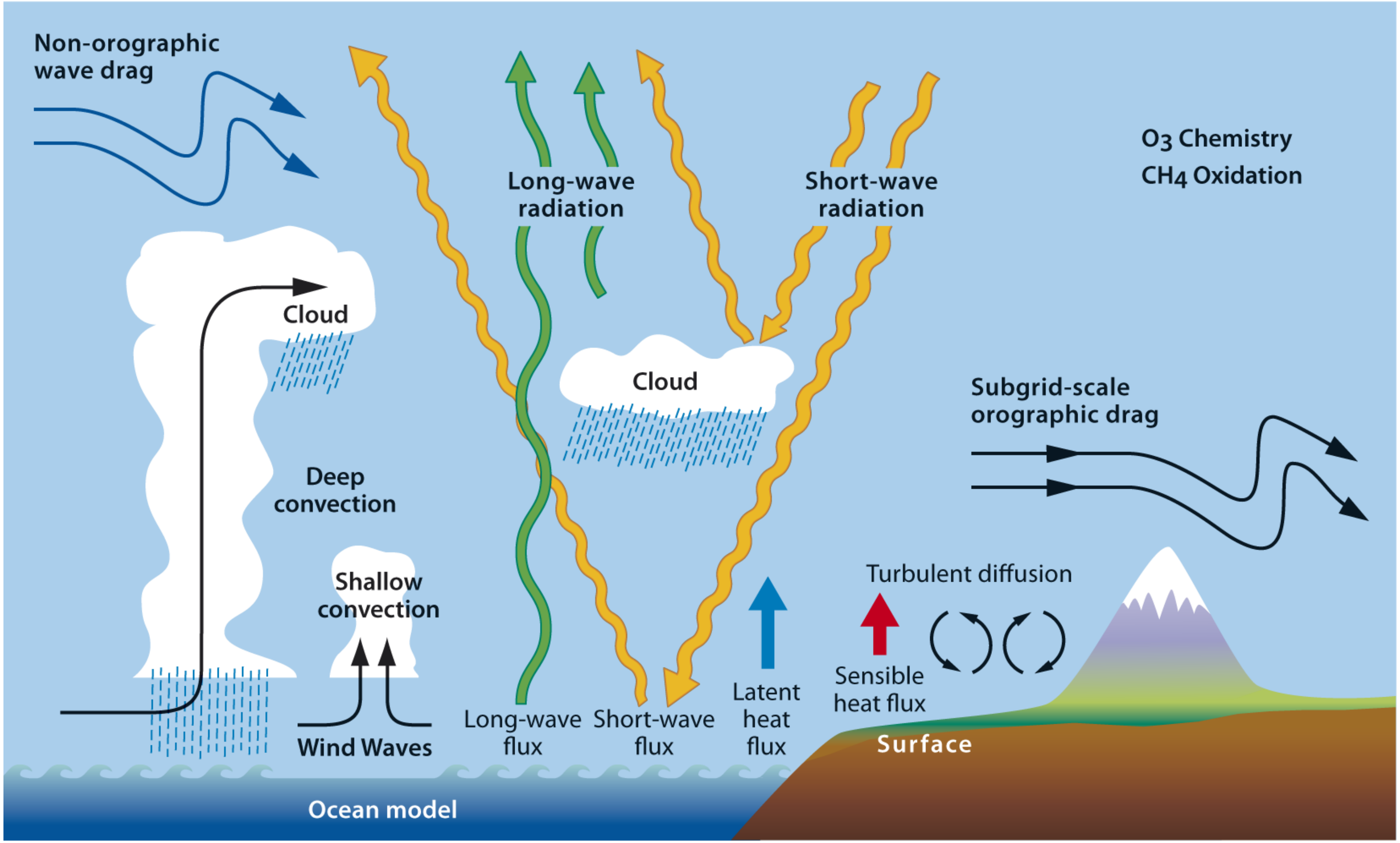
- interpret cloud and precipitation related forecast products.



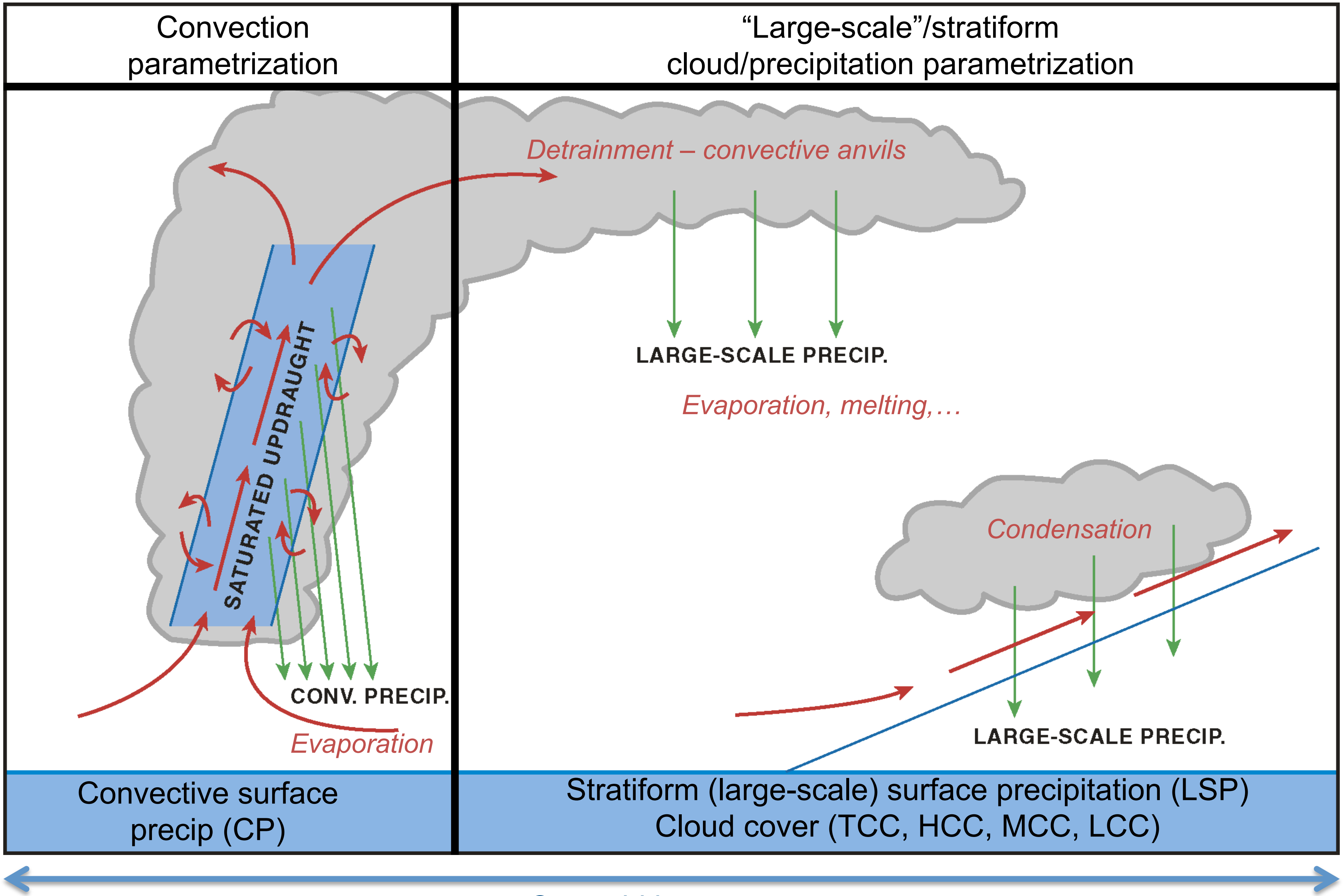
- learn about recent developments from a forecast users perspective …

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

Parameterized processes in the ECMWF model

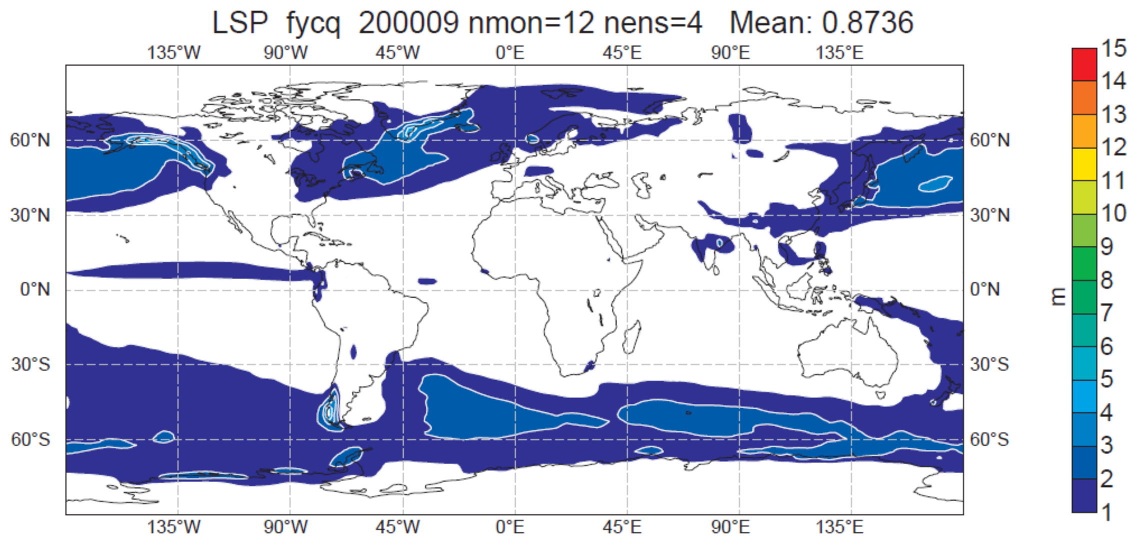


nvective and stratiform precipitation and clouds

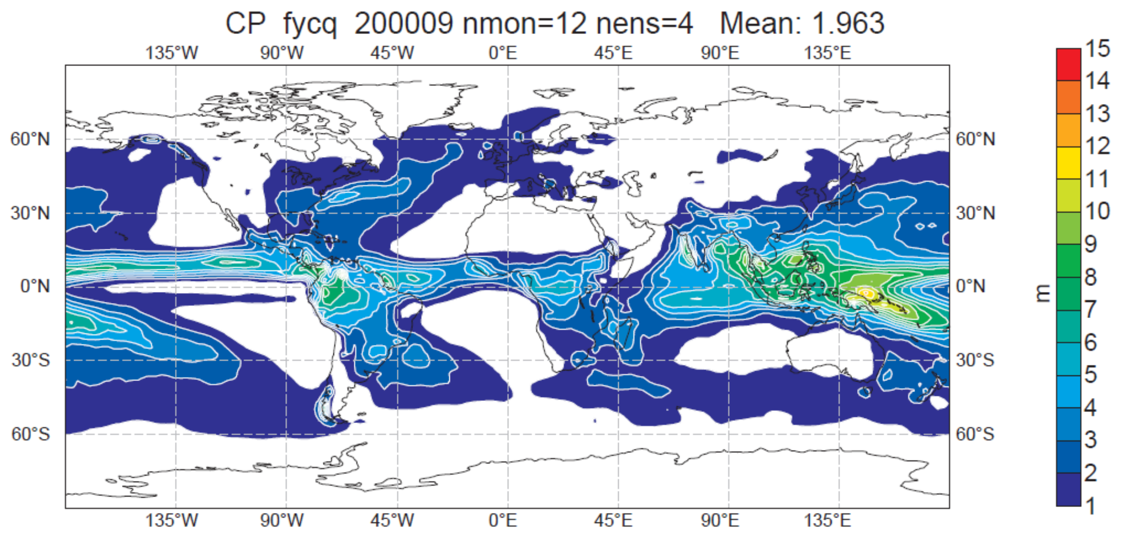


bal annual mean surface precipitation LSP/CP
S Cy40r1)

Stratiform (large-scale) surface precip (LSP)

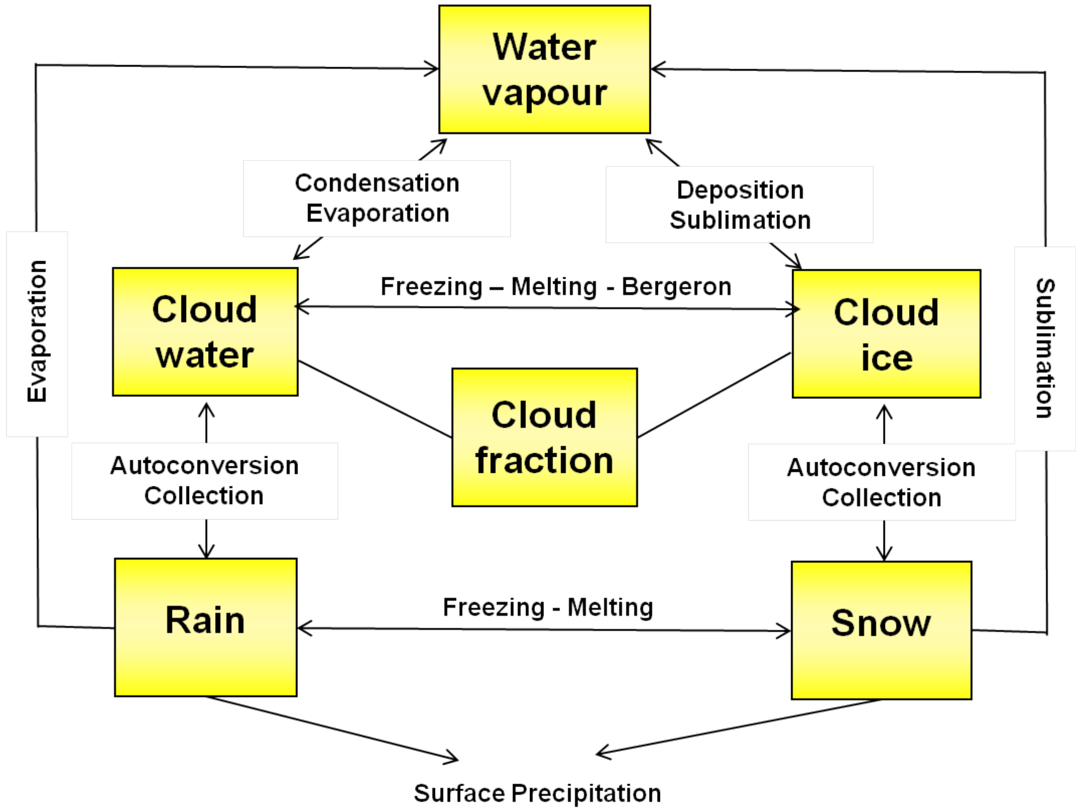


Convective surface precip (CP)



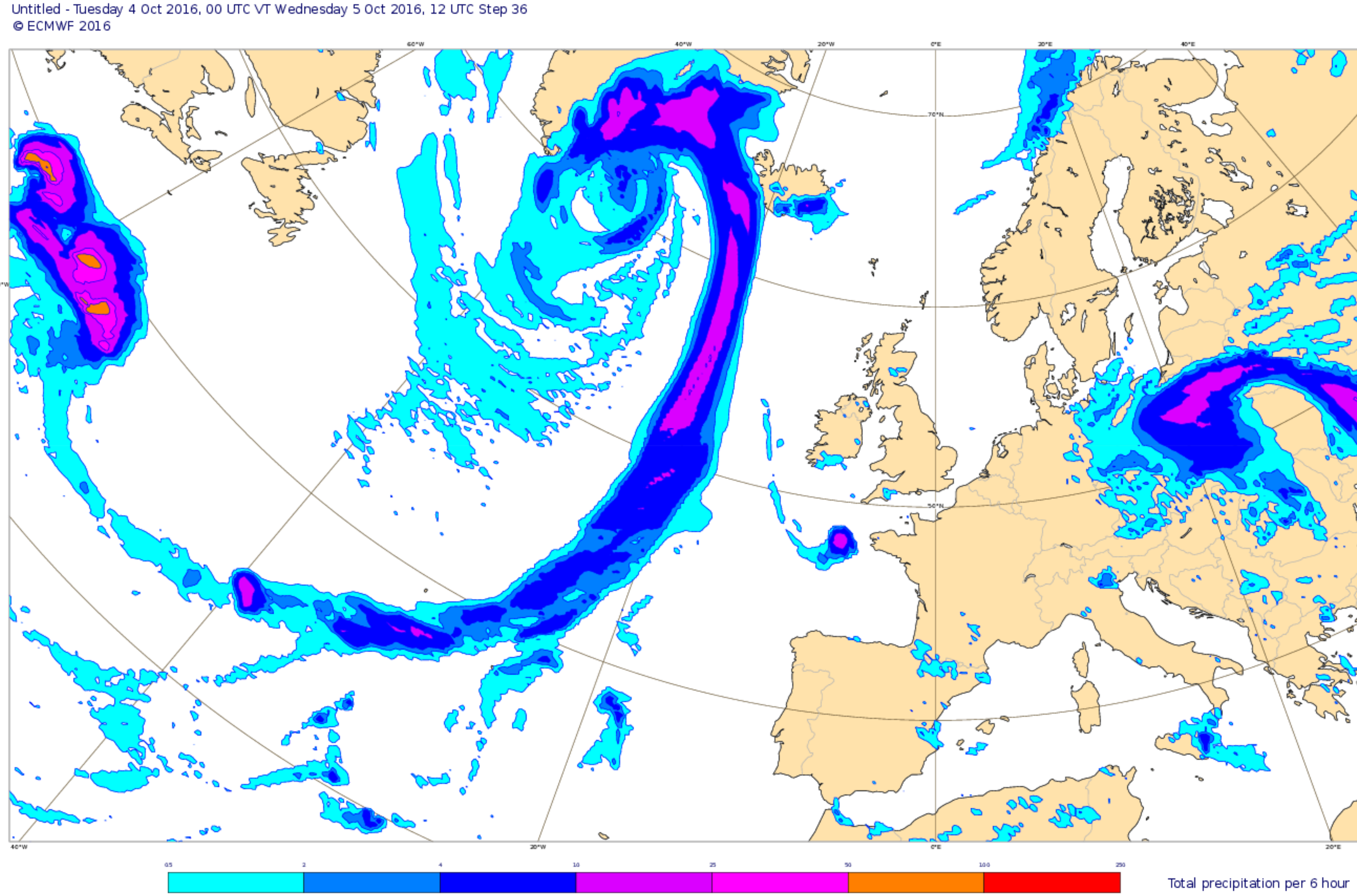
- This is for low resolution T159, but not too different for higher resolutions
- CP is ~2/3 of global precipitation
- but LSP dominant or similar to CP in extratropics

'S stratiform cloud scheme



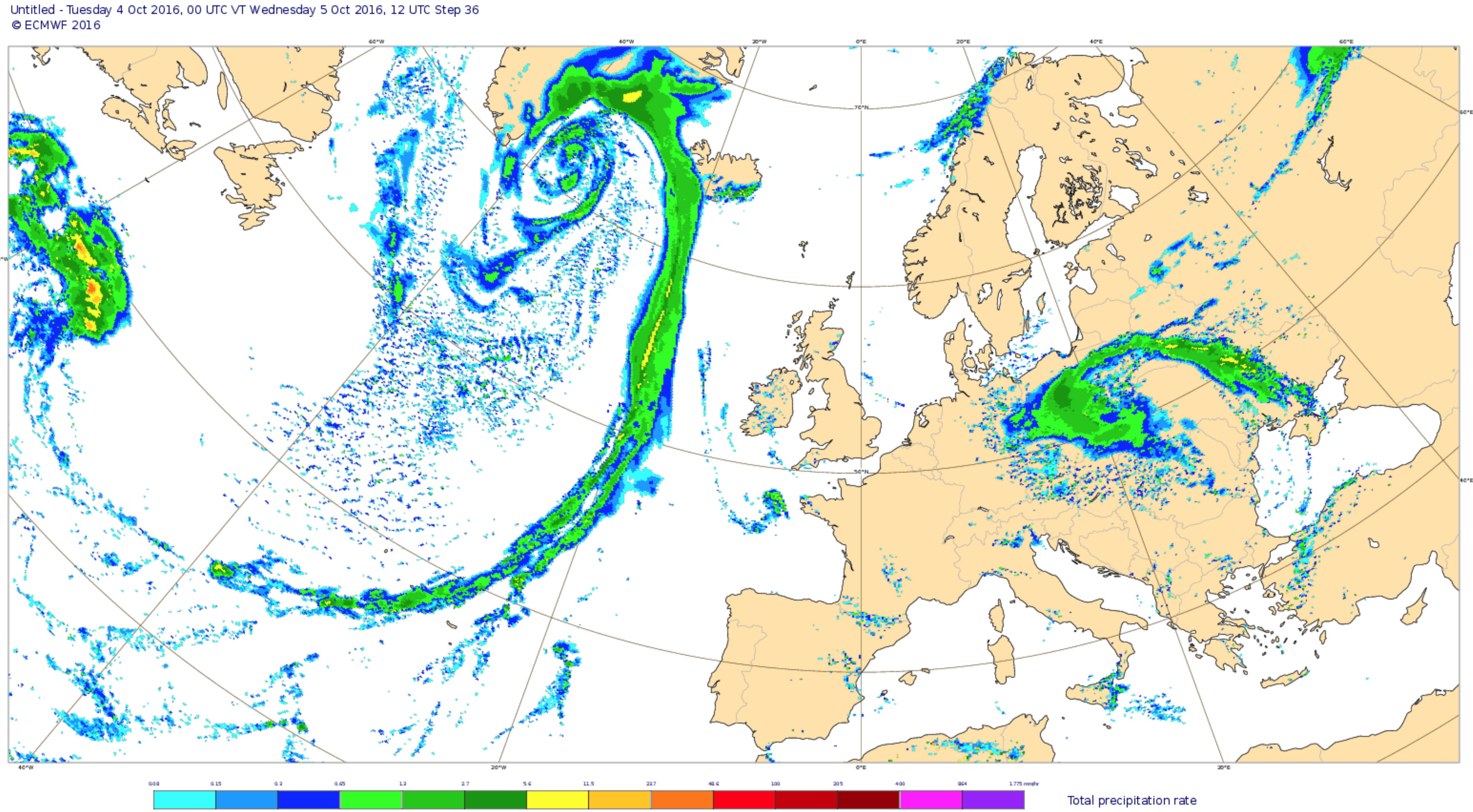
- 5 prognostic cloud variables + water vapour
- Ice and water independent variables
- Snow/rain prognostic, advected with the wind
- Physically based, increasing realism

xample 12 hour precipitation accumulation
recast for Wed 5 October 2016



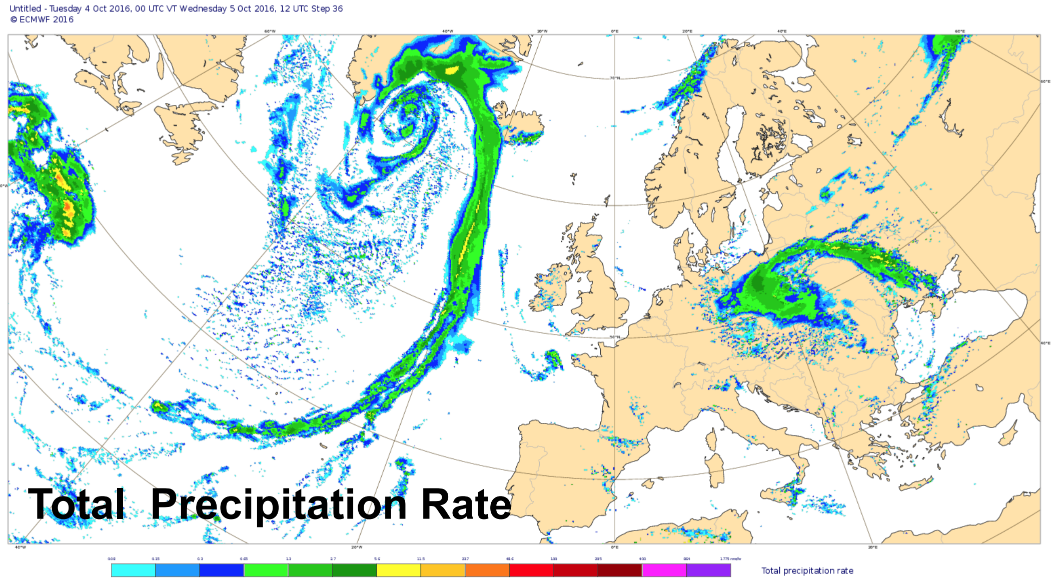
Precipitation Accumulation: Large-scale rain + convective rain + large-scale snow + convective snow

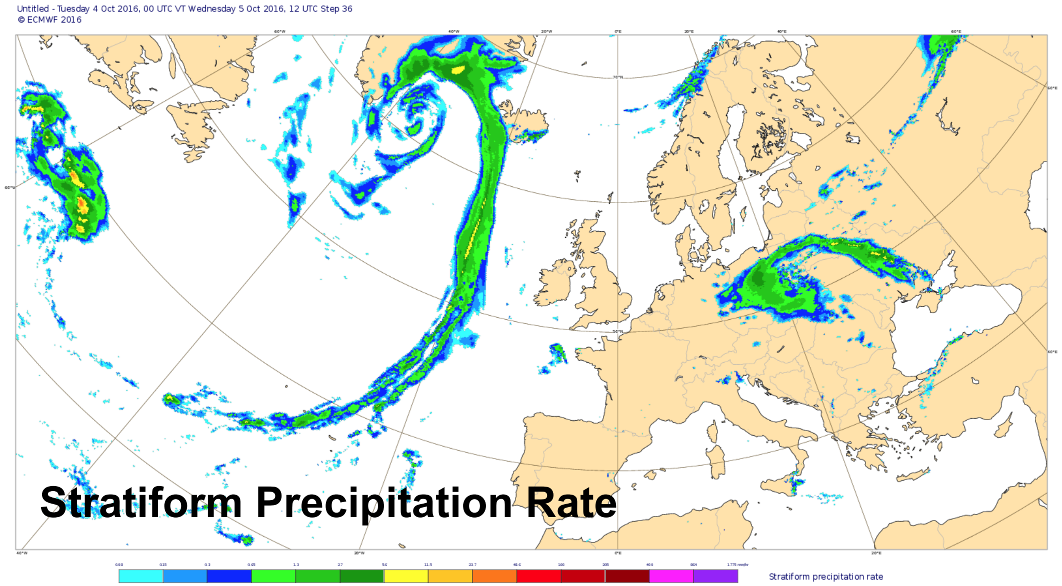
xample precipitation rate
recast for Wed 5 October 2016 12Z

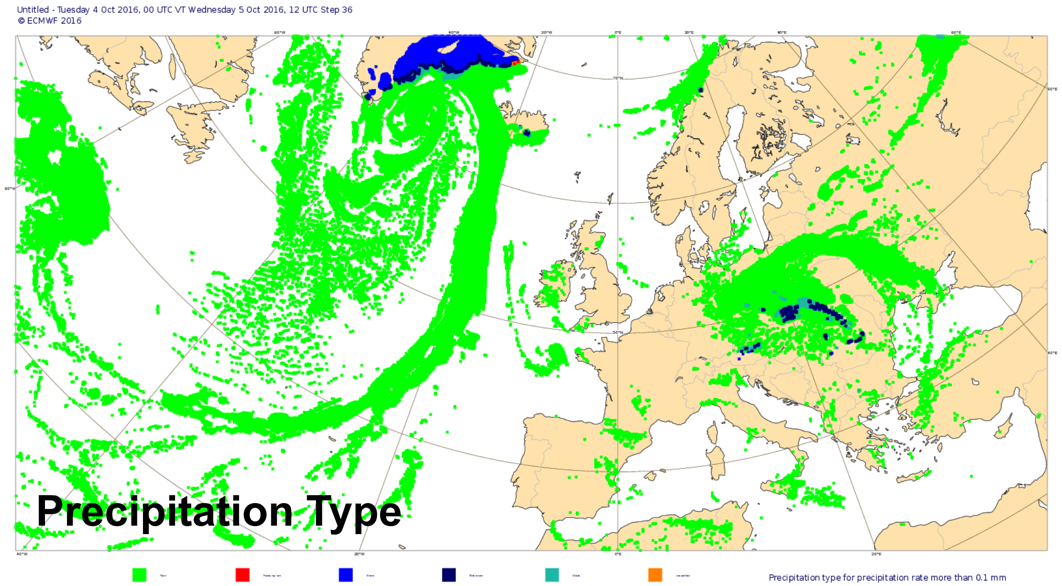


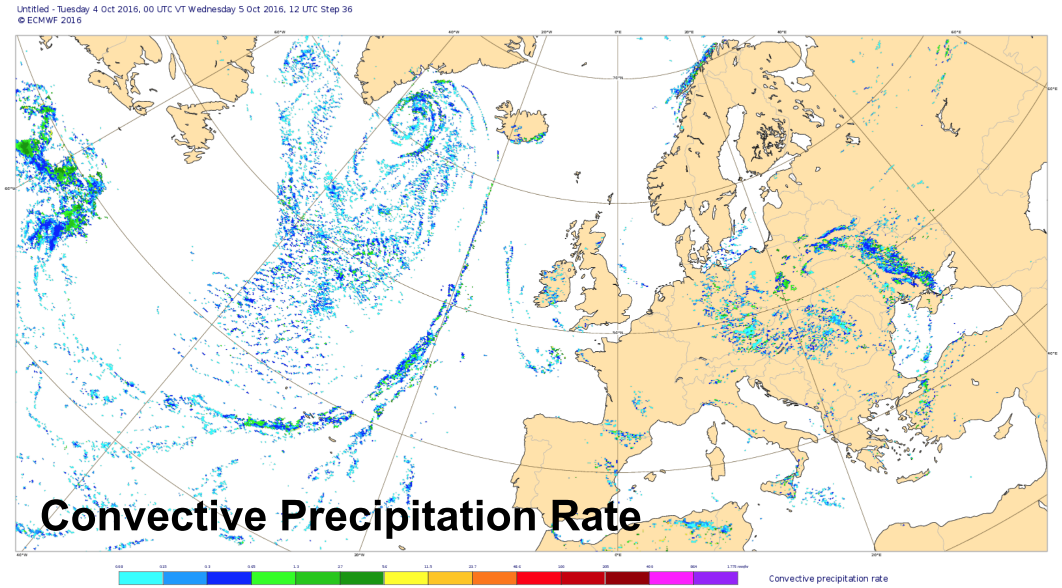
Precipitation Rate: Large-scale rain + convective rain + large-scale snow + convective snow

ecipitation rate and type example: 12 UTC Wed 5 October



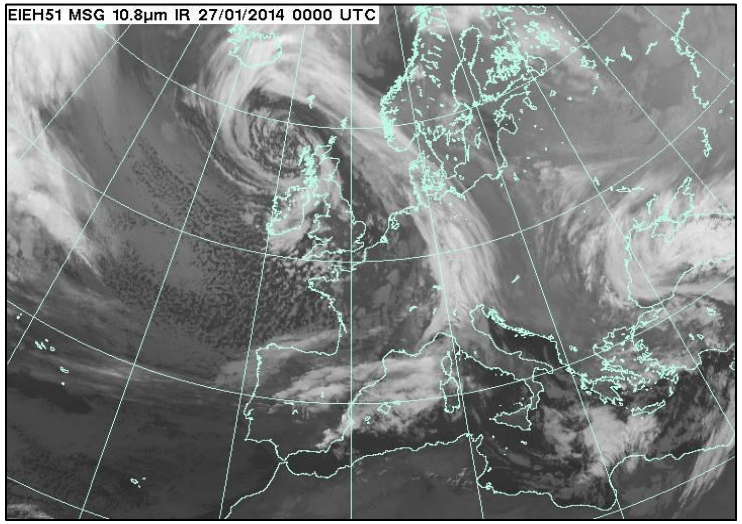




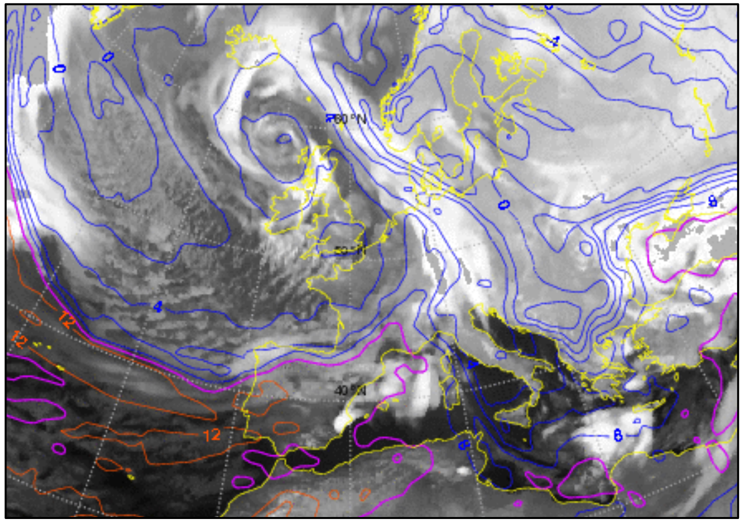


oud: 00Z Monday 27 January 2014

Meteosat IR 10.8μm

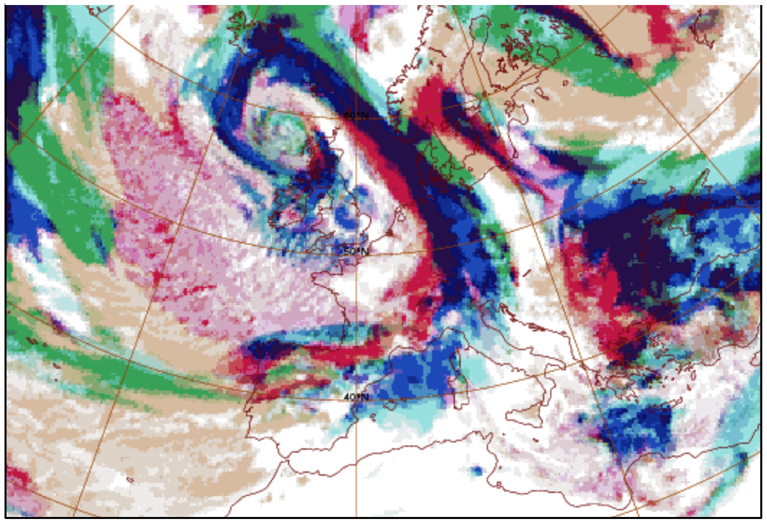


IFS Pseudo-IR 10.8μm

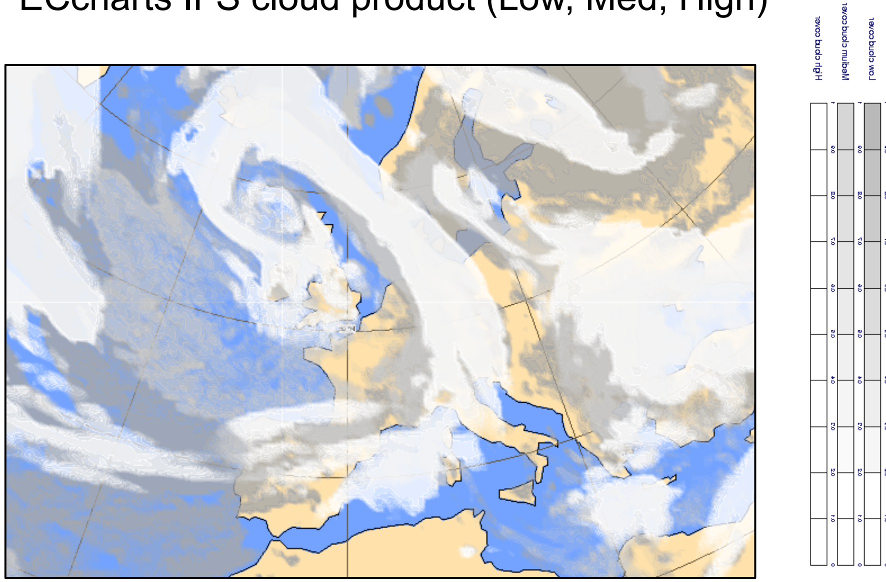


IFS cloud product (Low, Med, High and mixed)

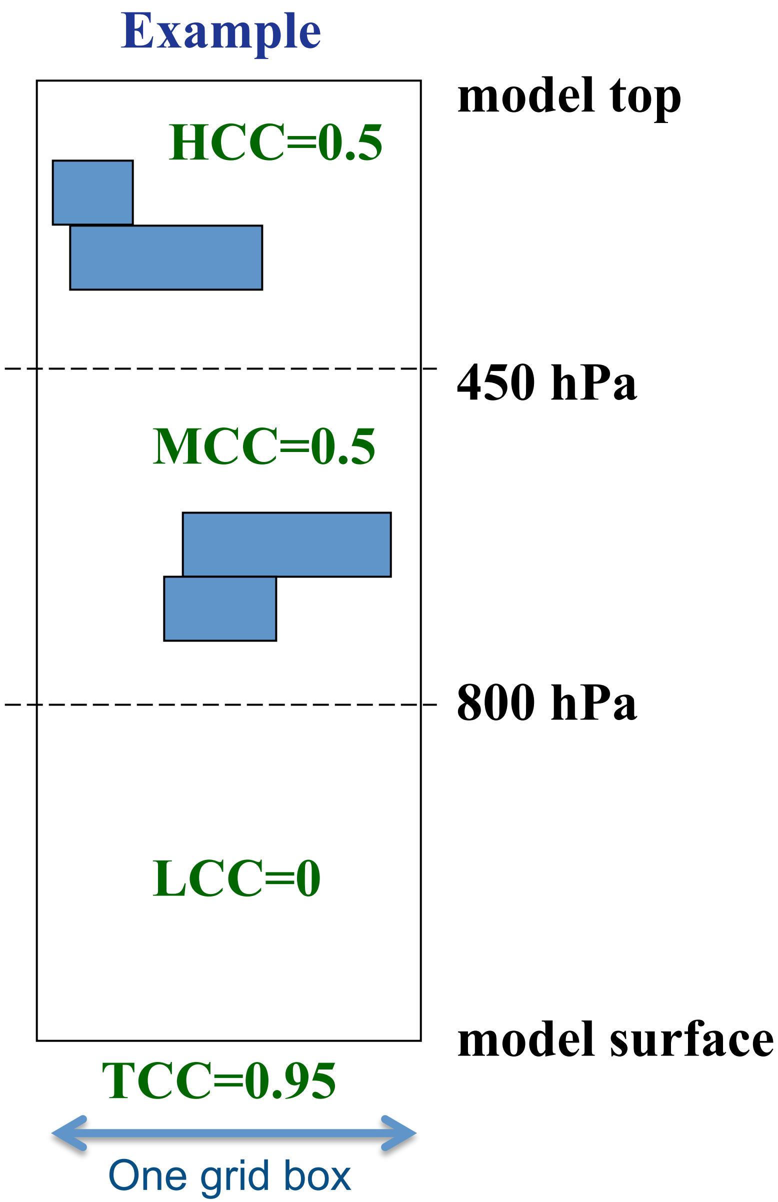
Low L+M Medium M+H High H+L H+M+L clouds



ECcharts IFS cloud product (Low, Med, High)



loud overlap



- TCC (total cloud cover). Model level cl
are integrated from surface to top of th
atmosphere with overlap assumptions
based on global observations (degre
randomness depends on distance betw
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


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.

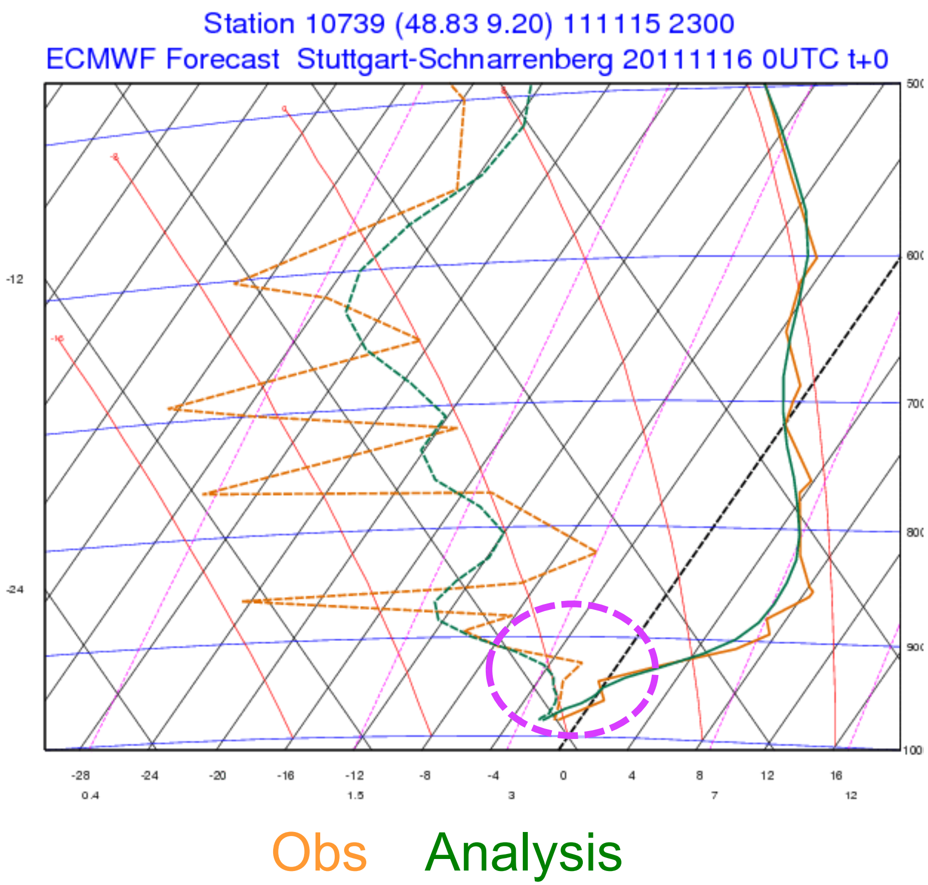
2. Supercooled liquid topped boundary layer cloud.
   Impact on 2m temperatures, particularly higher latitudes

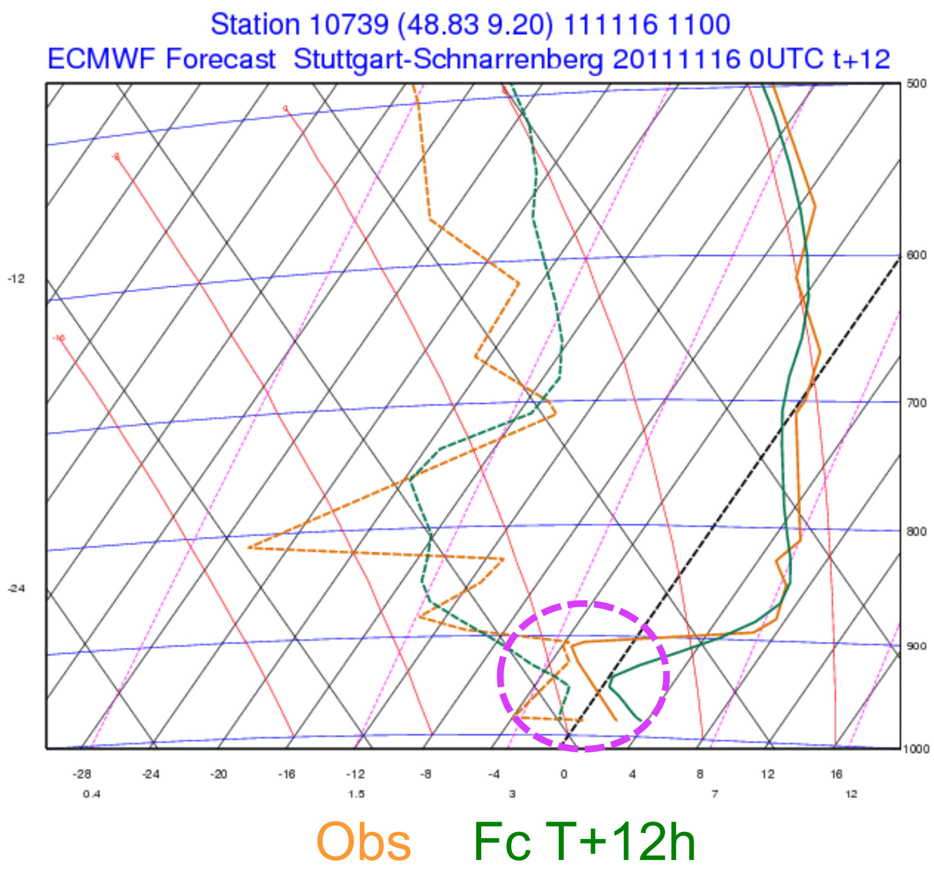
3. Snowfall in marginal situations – the melting layer

4. Freezing rain

5. Fog

(1) Too little low cloud cover: Fog rising to stratocumulus example
Sounding Stuttgart 16 Nov, 2011
Too little cloud cover leads to warm bias in central Europe.

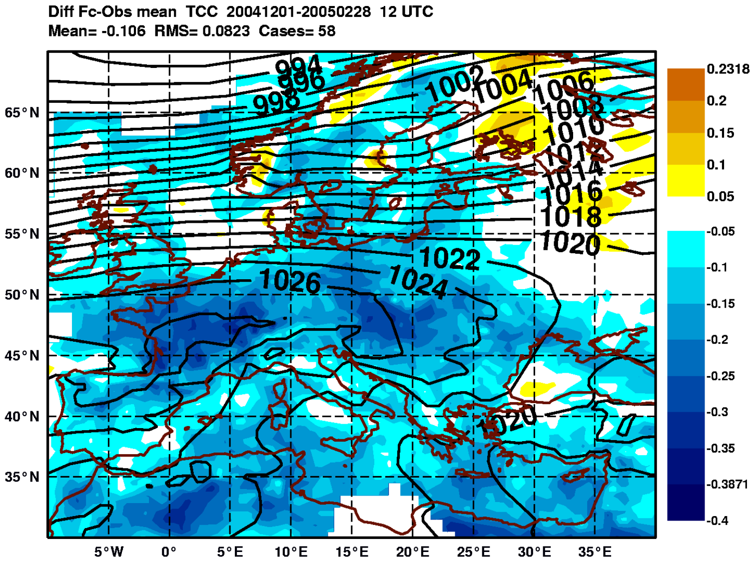


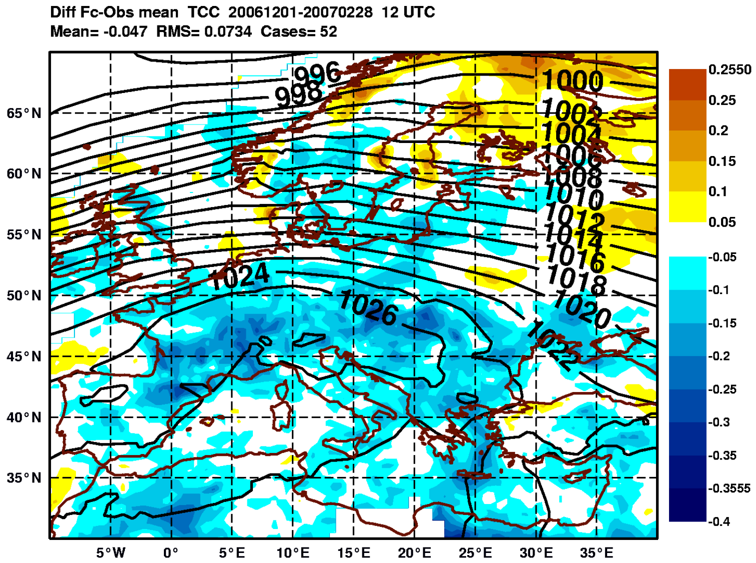


Fog rising developing into stratocumulus deck could not be properly represented

(1) Low cloud cover: 36h forecast versus SYNOP observation
(for high pressure days over Europe during winter)

DJF
2004/5
58 cases



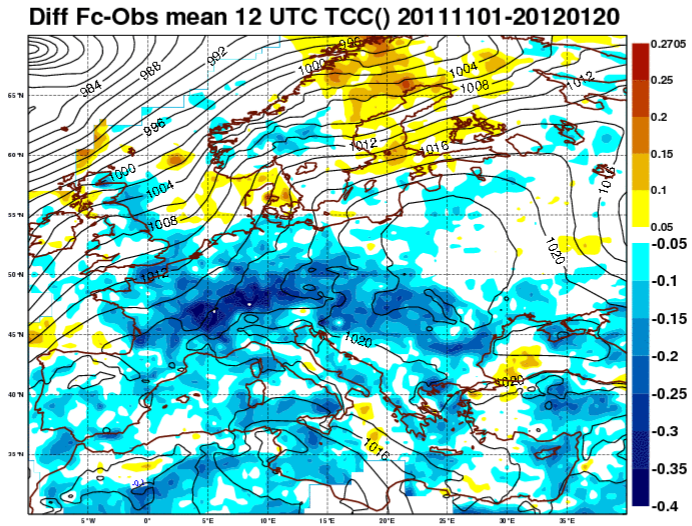


DJF
2006/7
52 cases

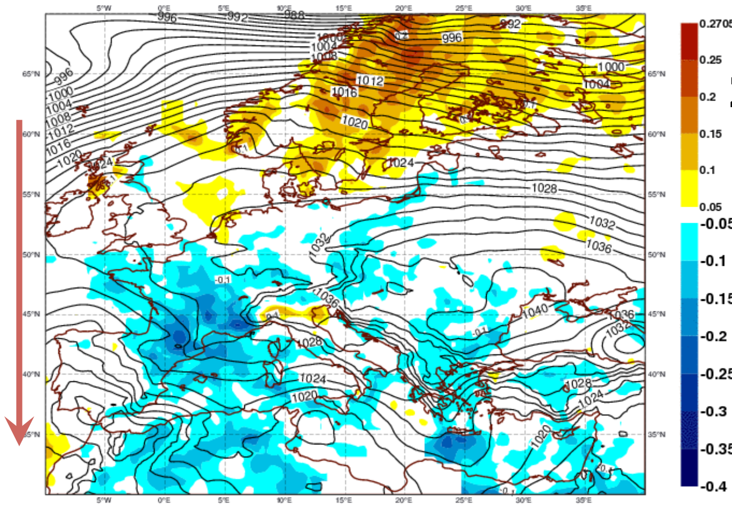
EDMF PBL
M-O diffusion

NDJ
2011/12

NEW MICROPHY



REVISED CLOUD

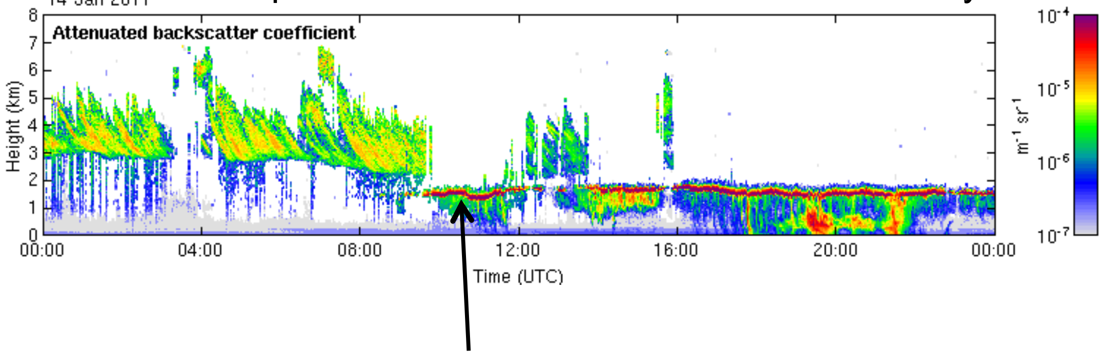


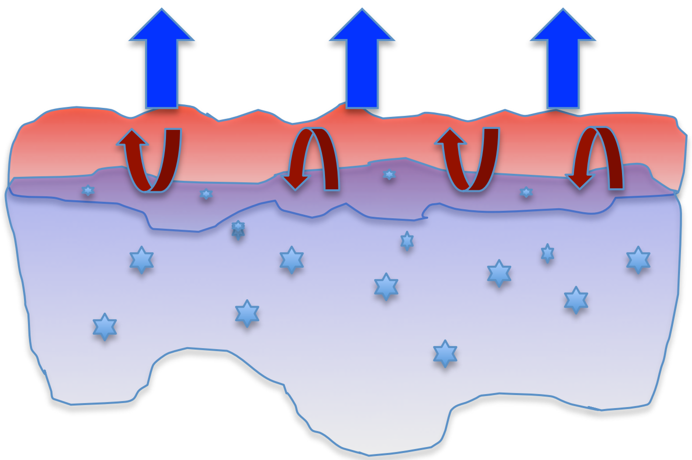
NDJ
2015/16

(4) Super-cooled liquid water

Commonly observed in the atmosphere

Example lidar backscatter timeseries at Sodankylä

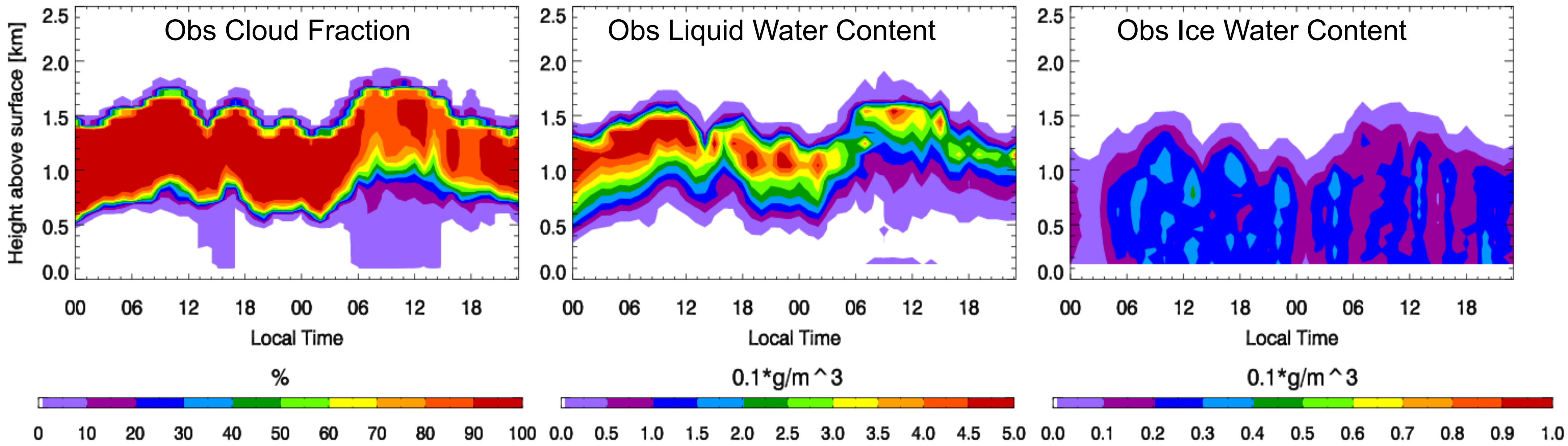




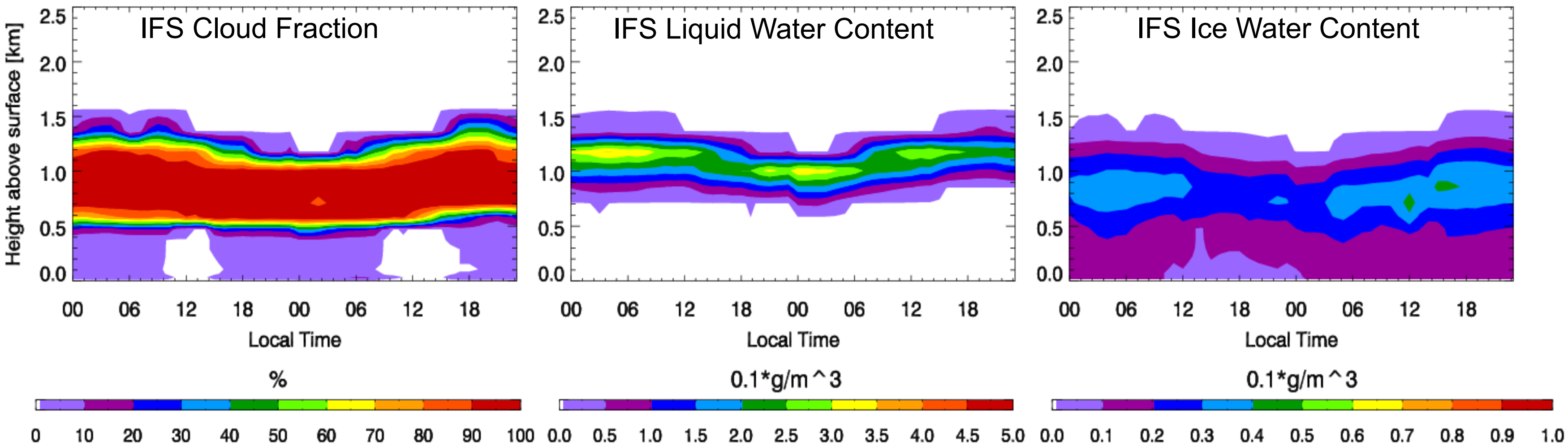
- Super-cooled liquid water (SLW) cloud frequently occurs in atmosphere as observed from aircraft & remote sensing.
- Radiatively important and can increase cloud lifetime (liquid drops suspended, ice crystals grow and fall out)
- Fine balance between turbulent production of water droplets, nucleation of ice, deposition growth and fallout.
- Difficult for models - uncertainties in turbulent mixing, ice microphysics, vertical resolution…
- Can impact 2m temperatures

(4) Mixed-phase cloud and recent IFS model changes

Arctic cloud case study (MPACE) – typical of SLW topped cloud with ice fallout



New cloud scheme (revised 37r3+) – SLW at cloud top with ice fallout as obs

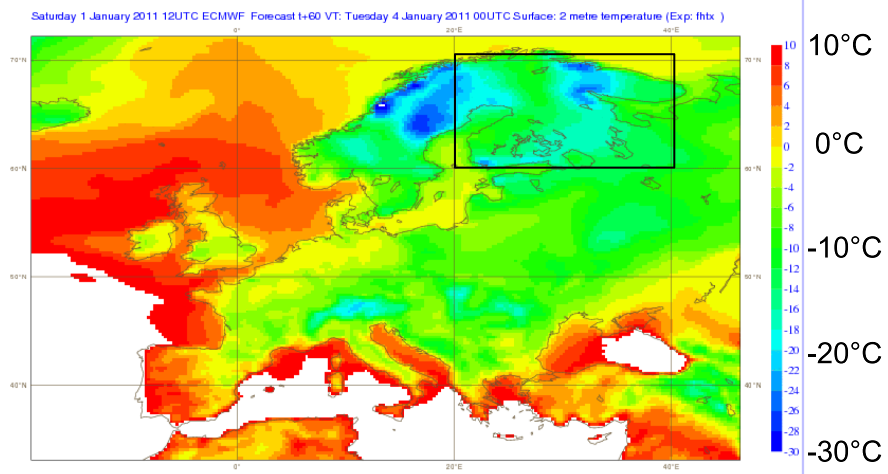


Forbes and Ahlgrimm (2014)

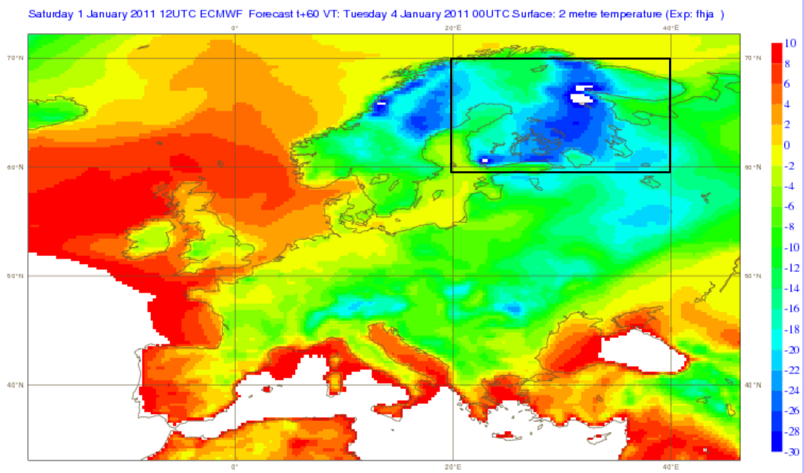
(4) Cold T2m bias in weakly forced mixed-phase

(Example T2mT snapshot from 00Z 4th Jan 2011 – Finland T bias)

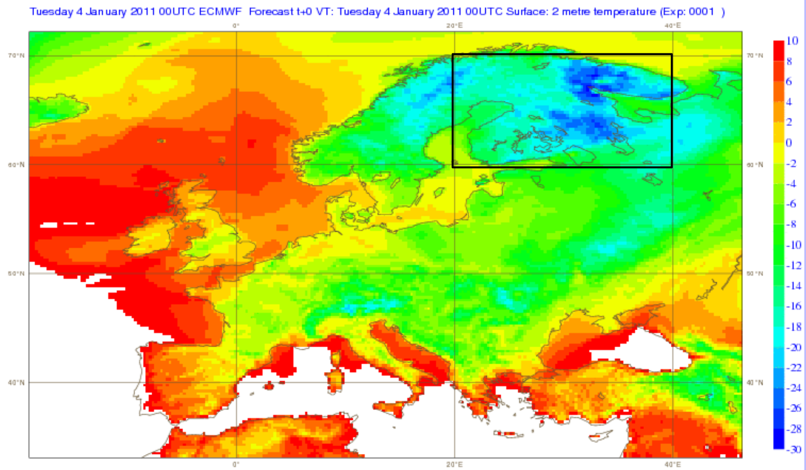
36r3 Diag mixed phase - 2009



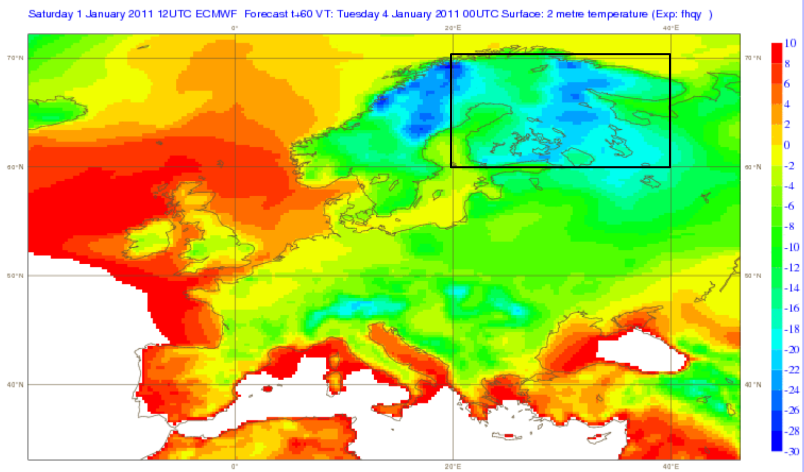
37r1 Prog mixed phase - 2010



Analysis



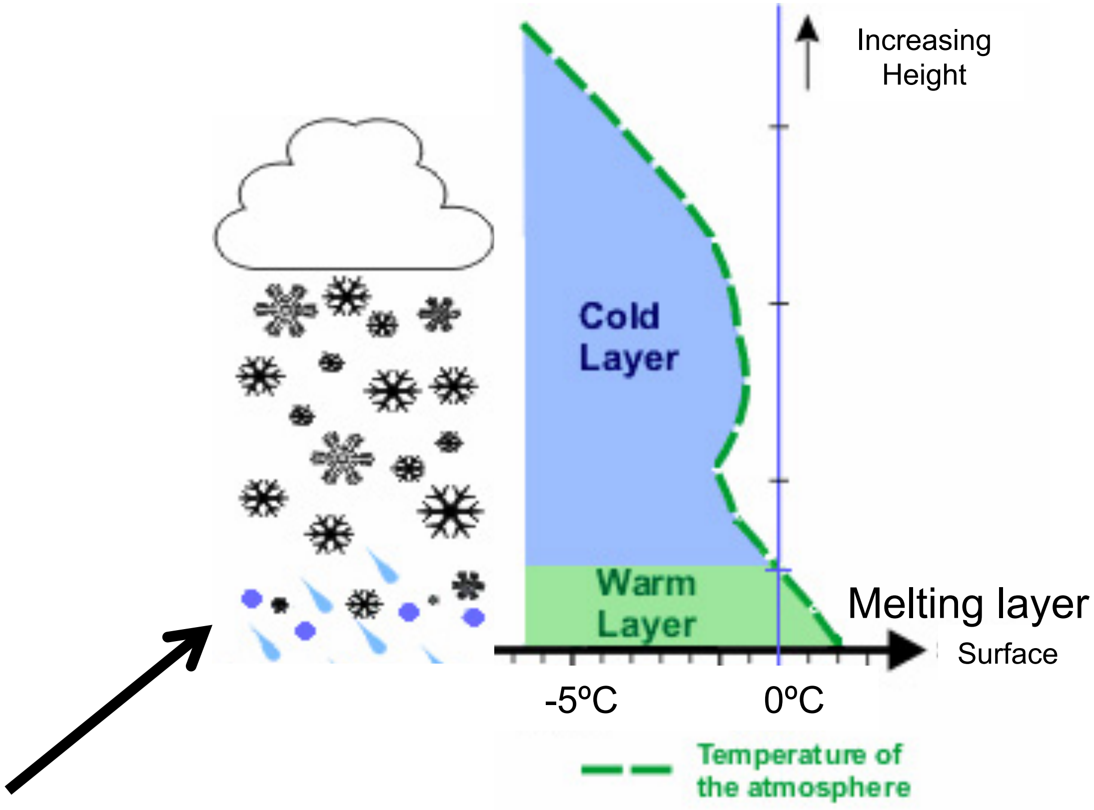
37r3 Prog mixed phase -2011/12



Snowfall in marginal situations

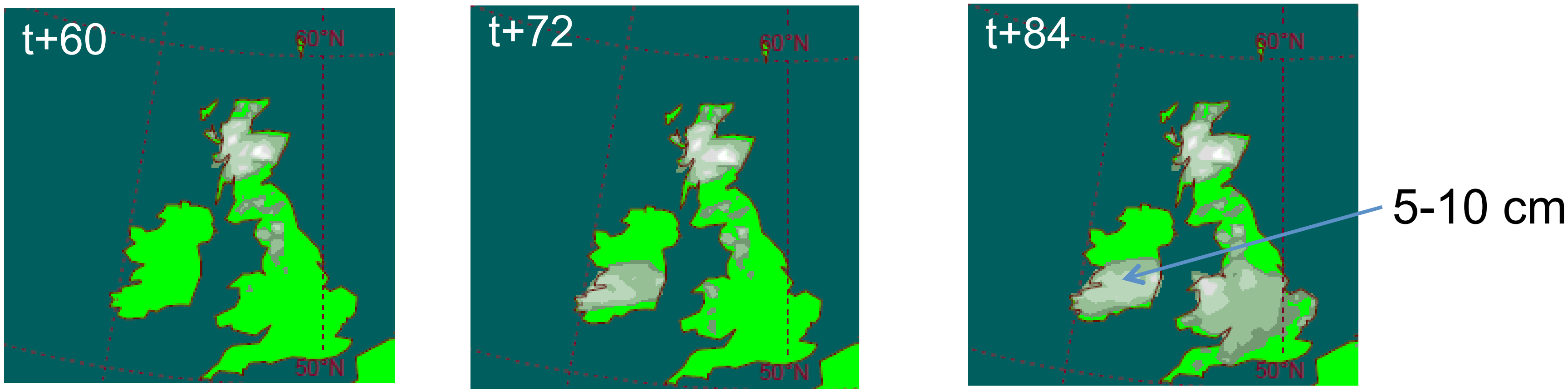
owfall in marginal situations: Melting layer

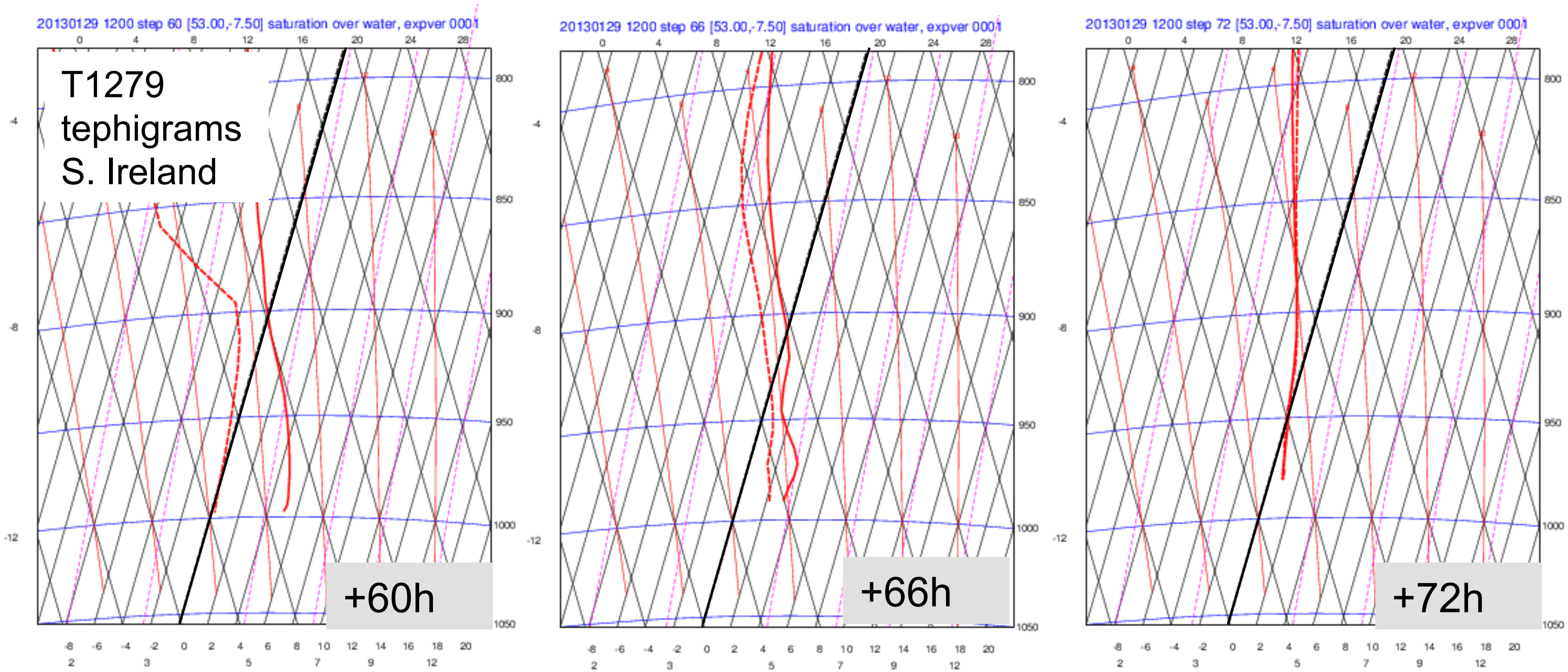
Melting layer often ~ few hundred metres thick
In drier air, snow melts at T > 0°C (due to evaporative cooling)



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





nowfall 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. NOTE: IFS diagnostics TP=totalprecip=(rainfall+snowfall), SF=snowfall

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

New (experimental) precipitation diagnostics (in Cy41r1)

- 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

  (Note: height of (uppermost) freezing level (*deg0l*) diagnostic also available)
  (Graupel/Hail not available)

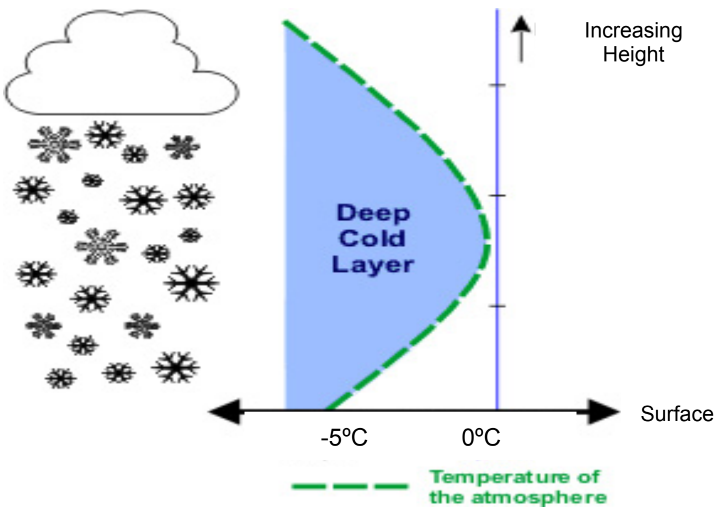
- Instantaneous precipitation rates (valid at a particular time)
  - Stratiform (large-scale) rainfall rate, and snowfall rate (*lsrr, lssfr*)
  - Convective rainfall rate, and snowfall rate (*crr, csfr*)

- Maximum and minimum total precipitation rates in the last 3 hours/6 hours/since last postprocsssing time (*mintpr3,maxtpr3, mintpr6,maxtpr6, mintpr,maxtpr*)

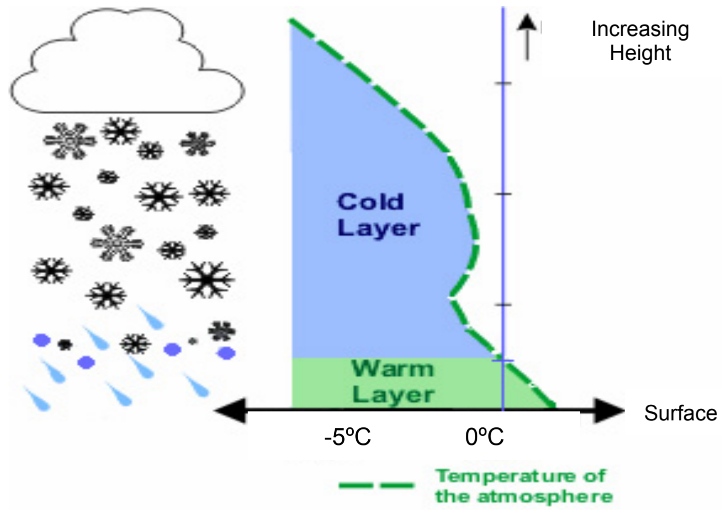
Freezing Rain

Precipitation type – a new diagnostic from the IFS

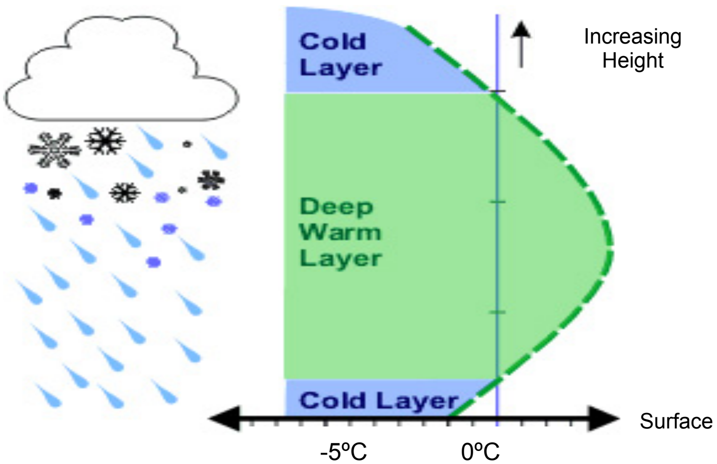
rain / snow / wet snow / mix rain-snow / ice pellets / freezing rain



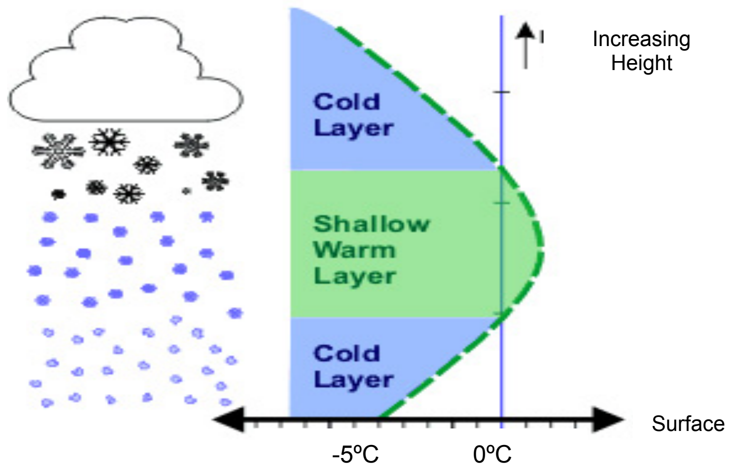
Snow



Sleet (melting snow) or rain



Freezing rain



Ice pellets

edicting high-impact freezing rain events

Case Study: Slovenia/Croatia 02 Feb 2014

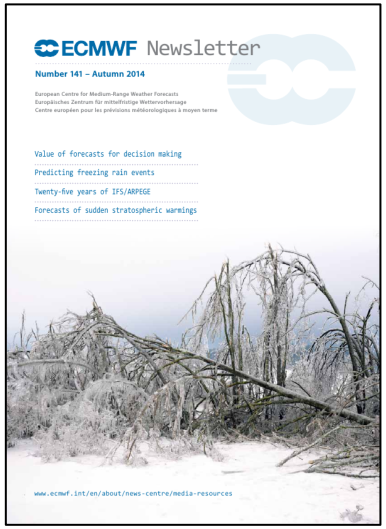
Freezing rain caused severe disruption and damage, tranports/power/forests…

IFS physics at the time (40r1) not able to predict

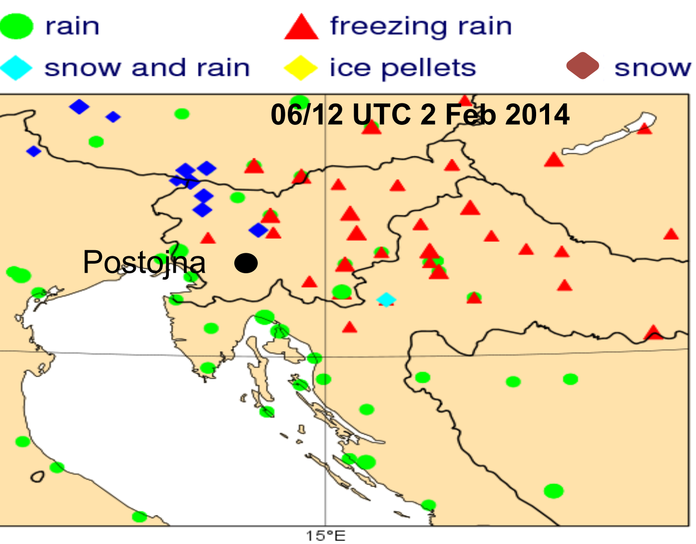
New physics in 41r1 allows prediction of freezing rain events

Evaluation in HRES/ENS shows potential for useful forecasts

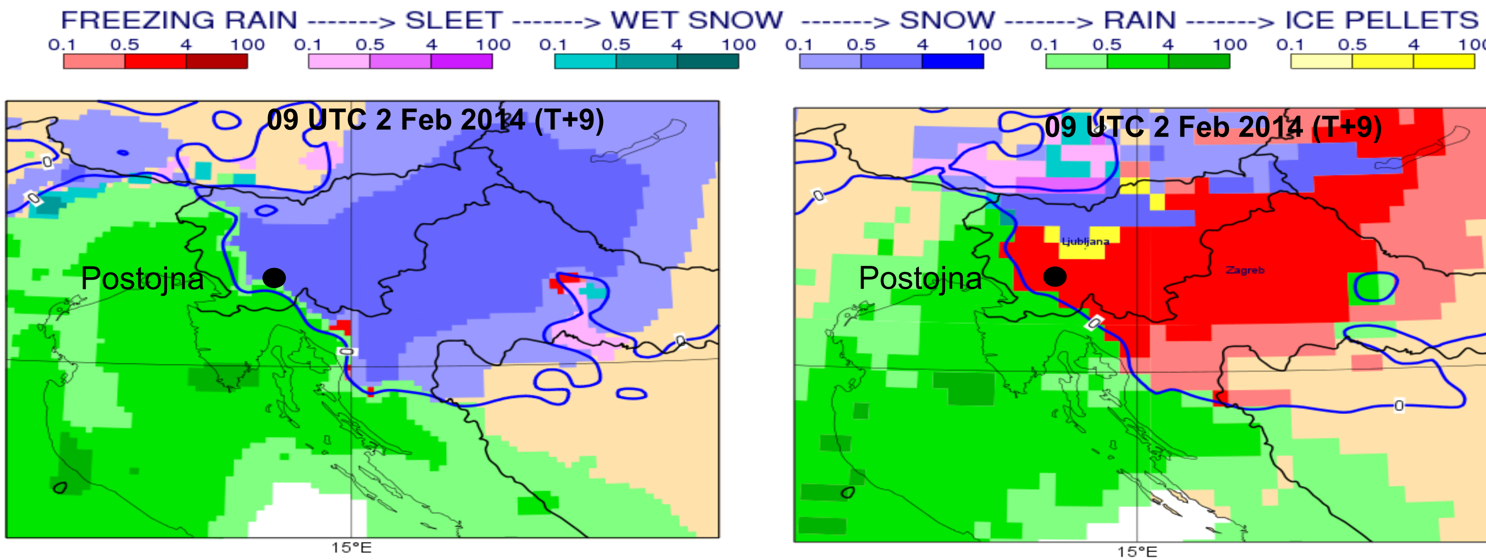
Article in EC Newsletter Autumn 2014 (but note results below are with new rain freezing physics)



ECMWF Newsletter 141



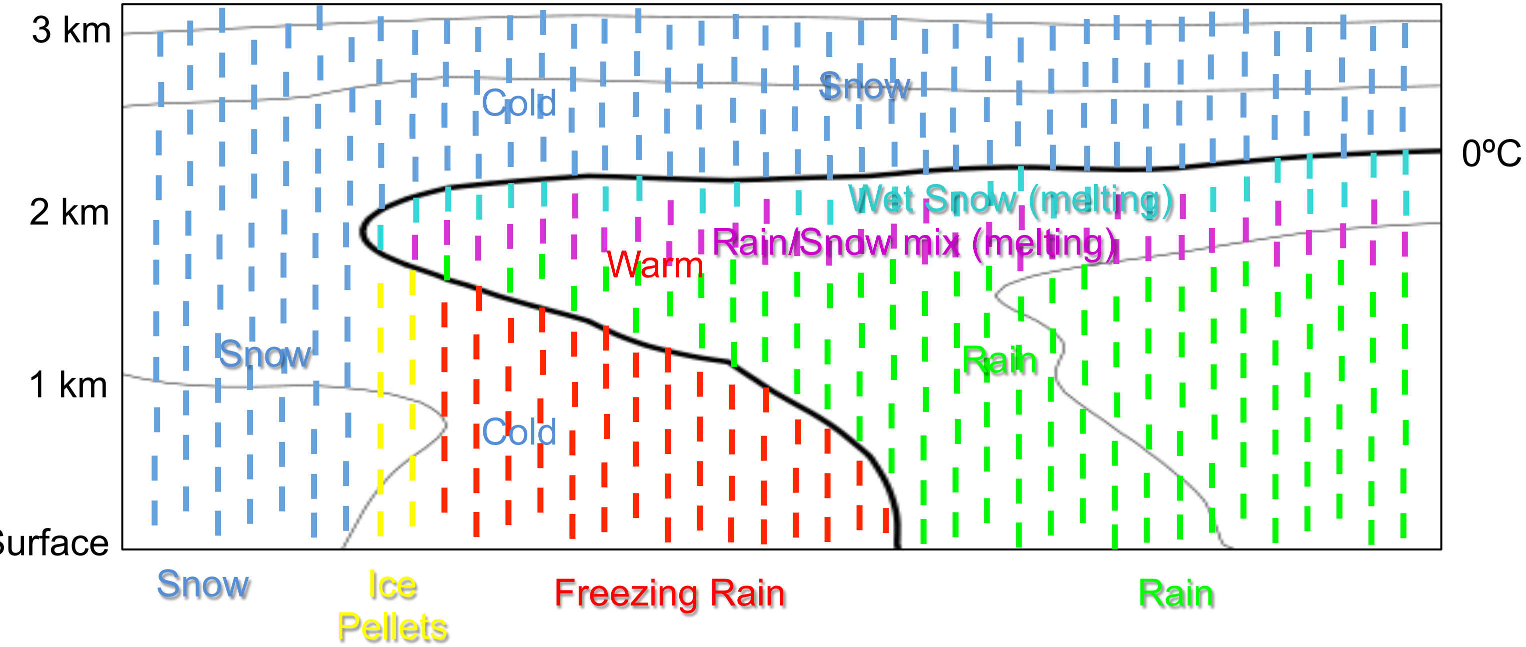
SYNOP Observations

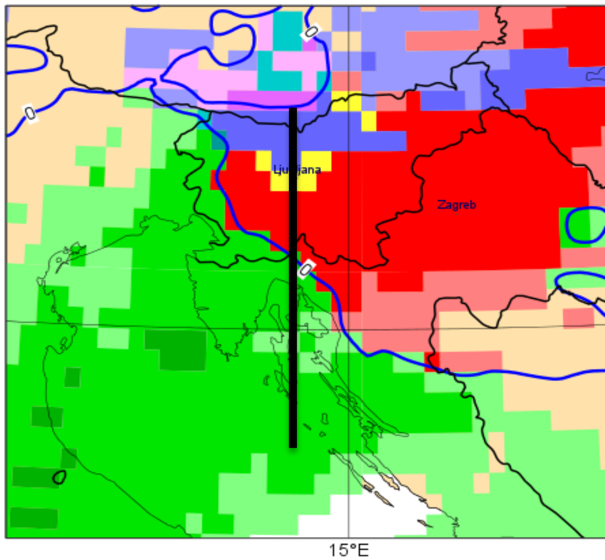


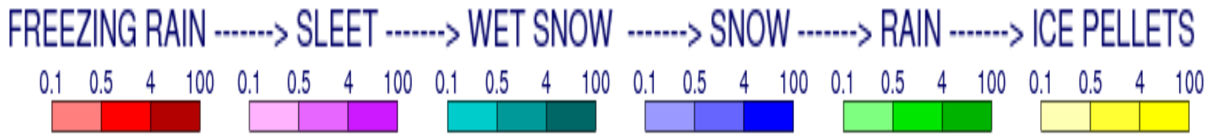
IFS HRES 40r1

IFS HRES 41r1

Schematic cross-section (front with elevated warm layer)

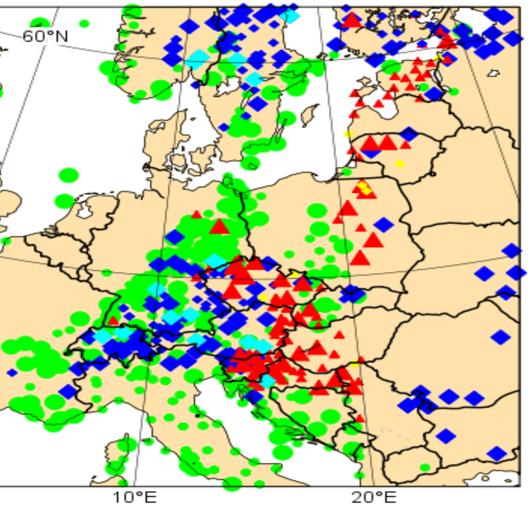






obability of freezing rain accumulation from the IFS ensemble

se Study: 02 Feb 2014



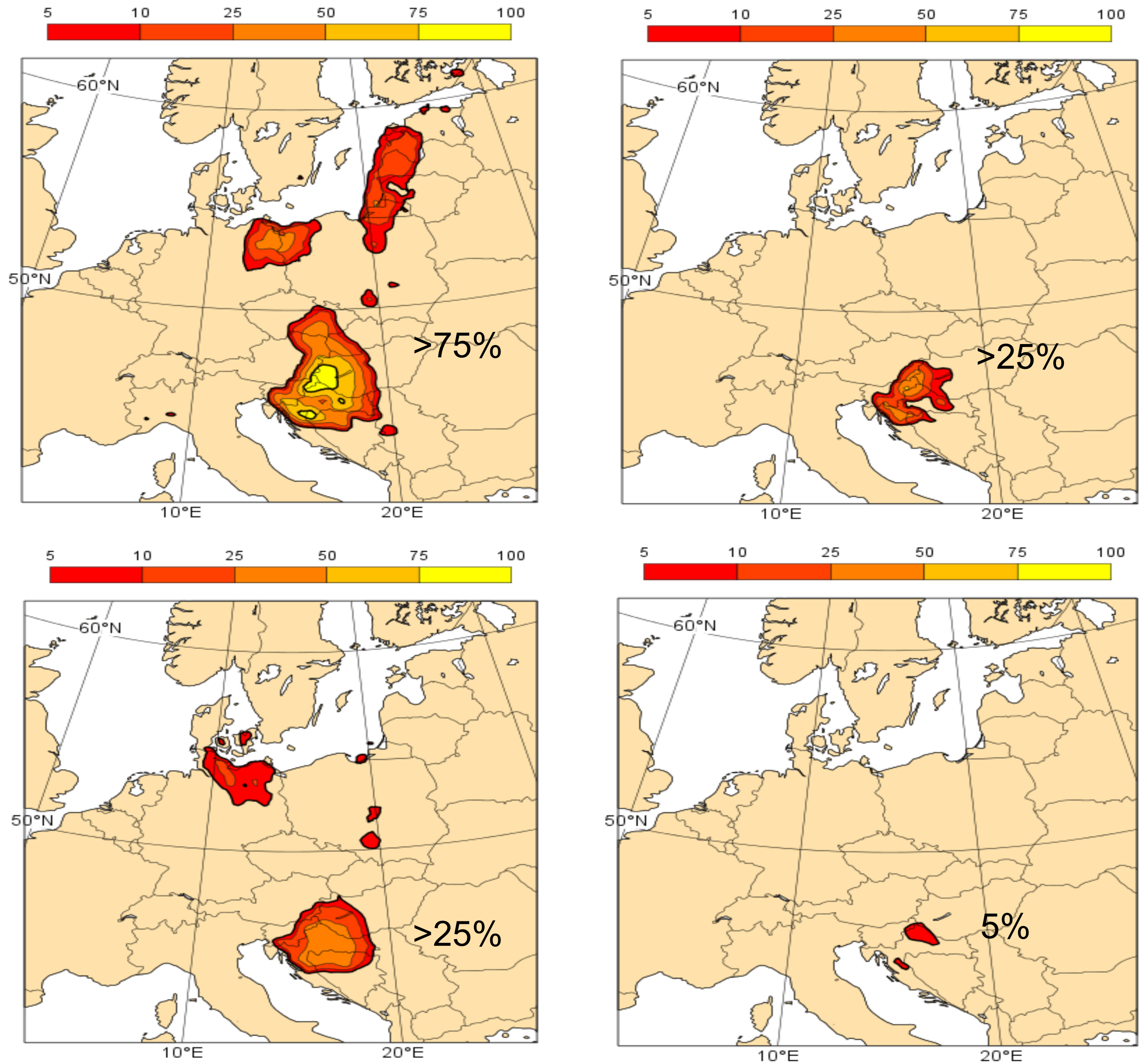
Obs

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

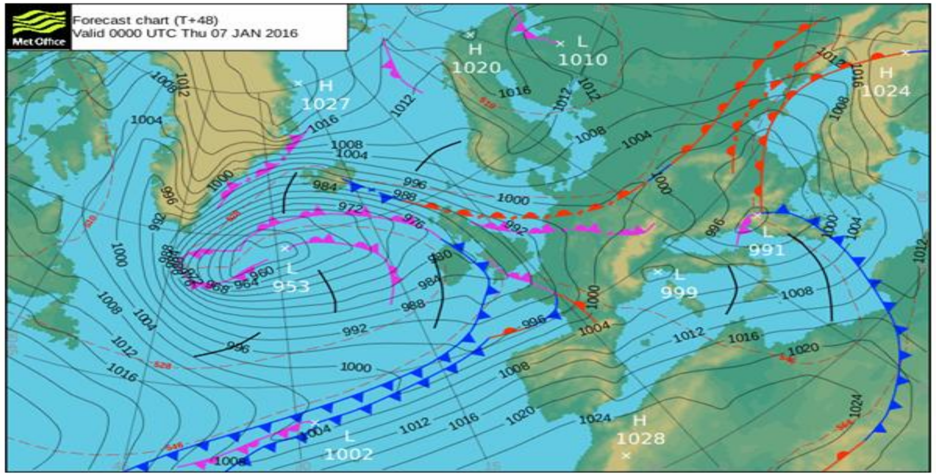
Prob (fzra > 1mm) | Prob (fzra > 5mm)

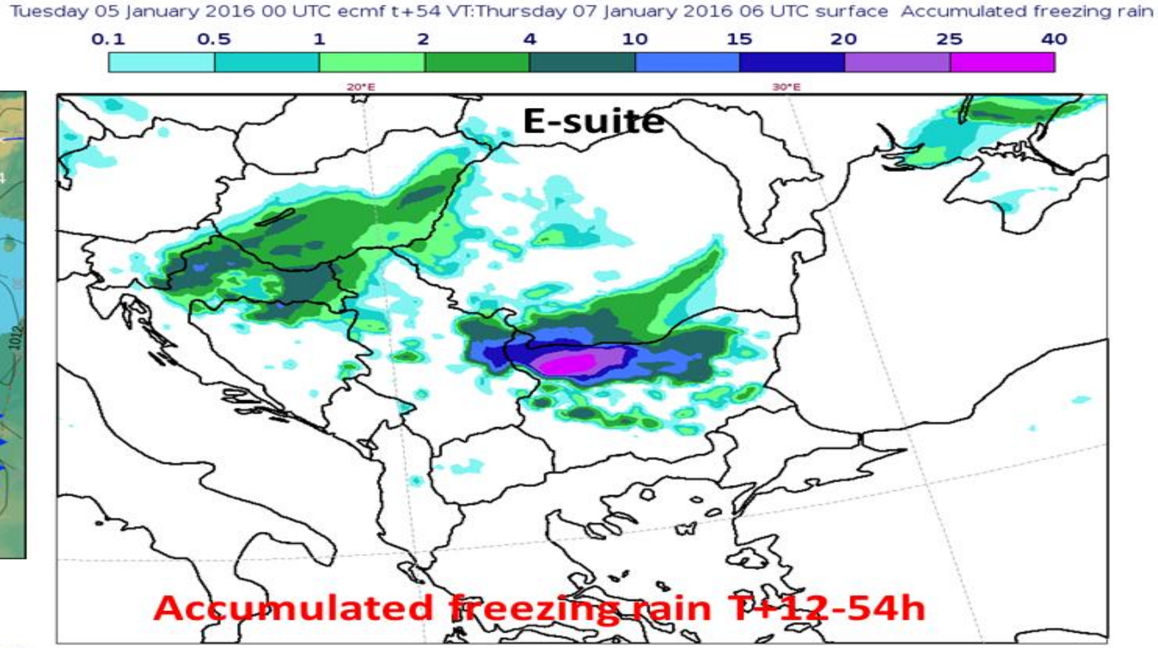
Day 3 forecast

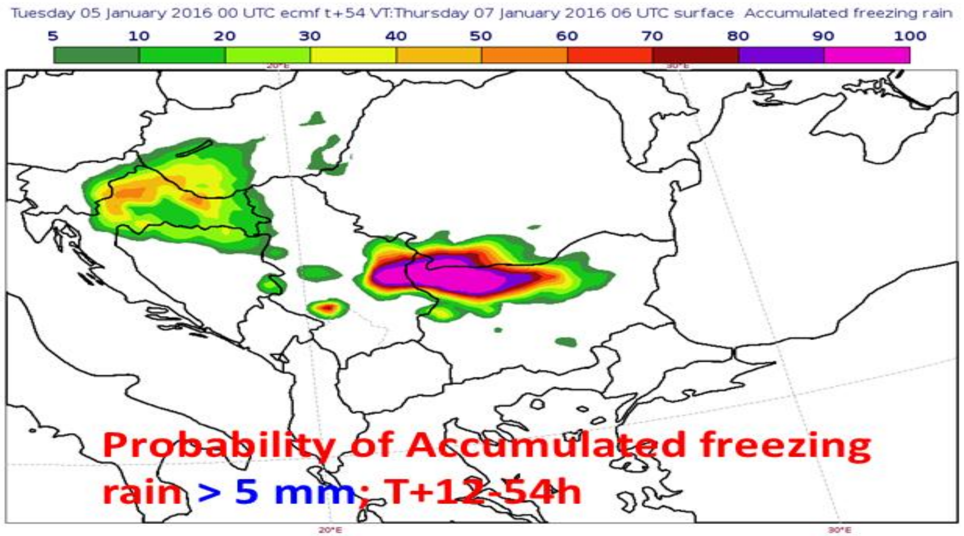
Day 5 forecast

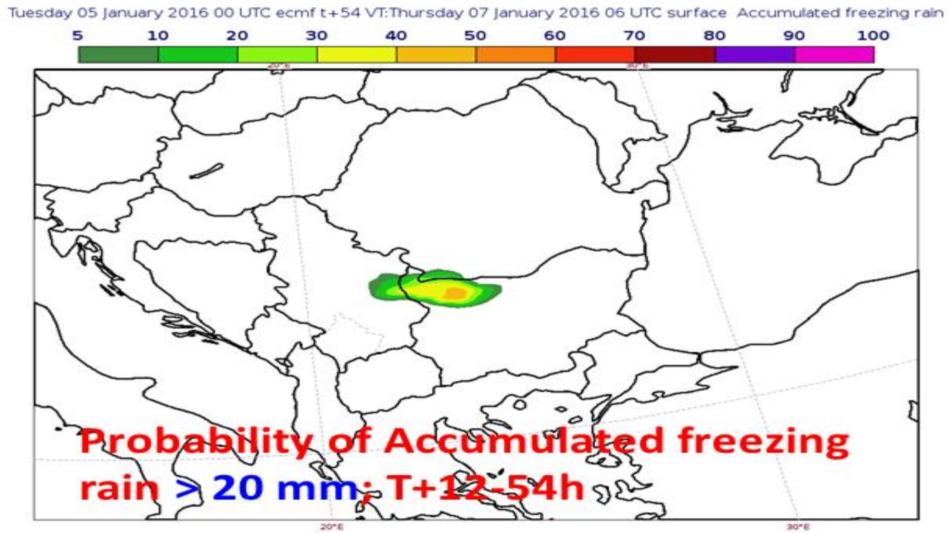


eezing rain case: 6-7 January 2015 Bulgaria/Romania

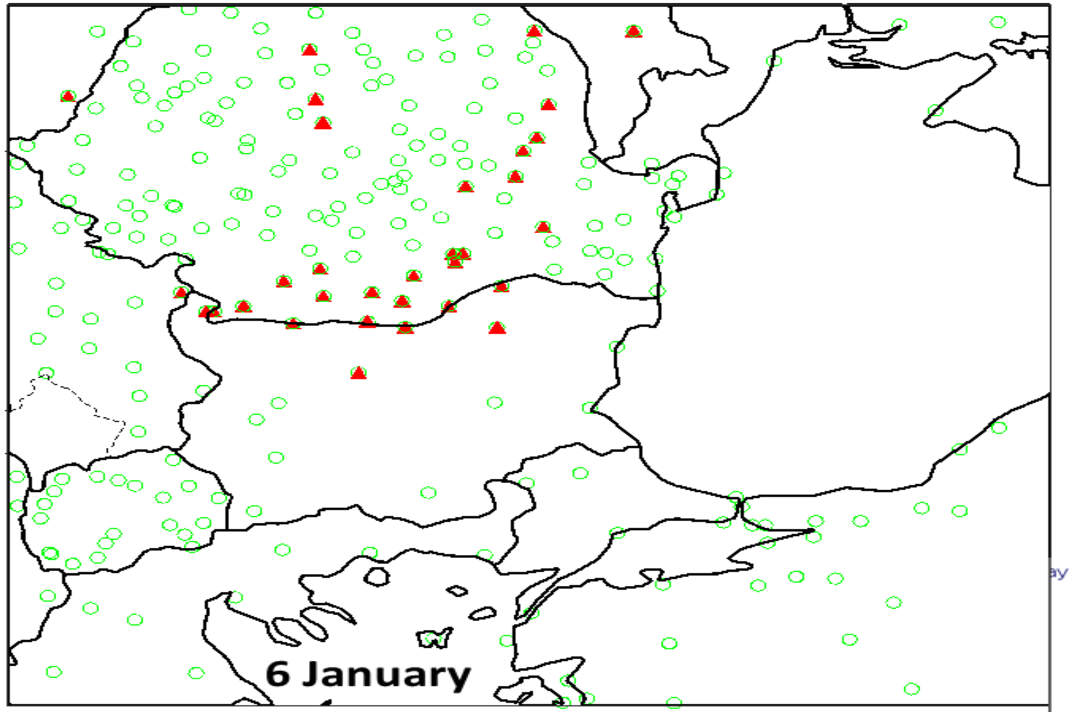


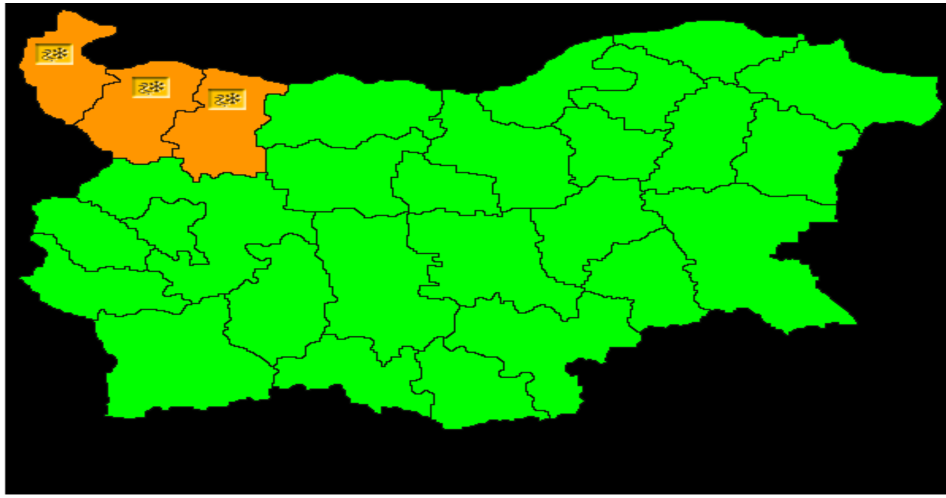


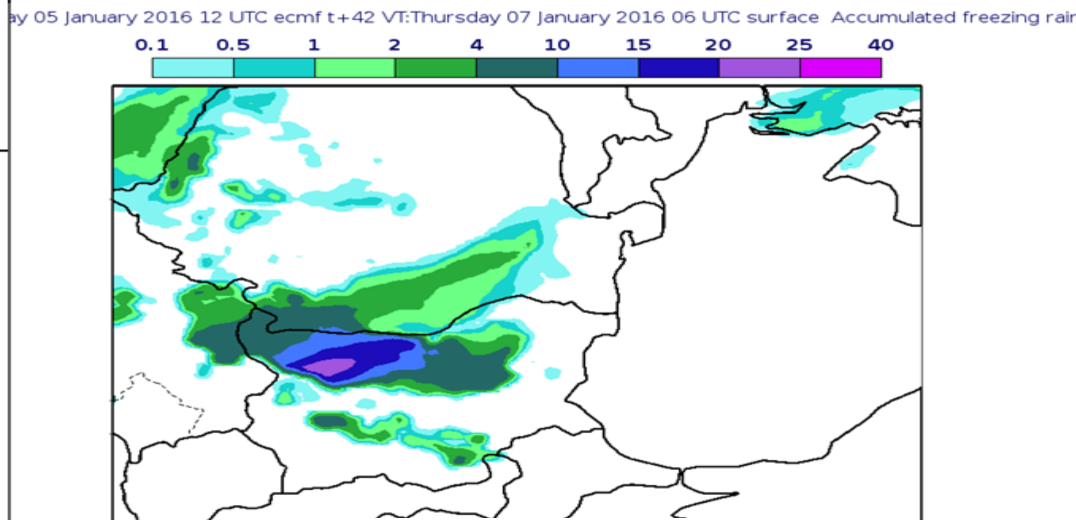




eezing rain case: 6-7 January 2015 – Bulgaria/Romania







IFS predicted freezing rain accumulation 5-7 Jan 2015

Visibility and Fog

rediction of severe weather: Visibility/Fog

ibility – new diagnostic in IFS Cy41r1 (May 2015-)

Background aerosol seasonally varying climatology – currently Tegen et al. 1997

Rain and snow precipitation

Cloud liquid water/ice (i.e. fog)

Visibility is calculated using an exponential scattering law and a visual range defined by a fixed liminal contrast of 0.0 based on extinction due to clean air, aerosol, cloud and precipitation

ny limitations!

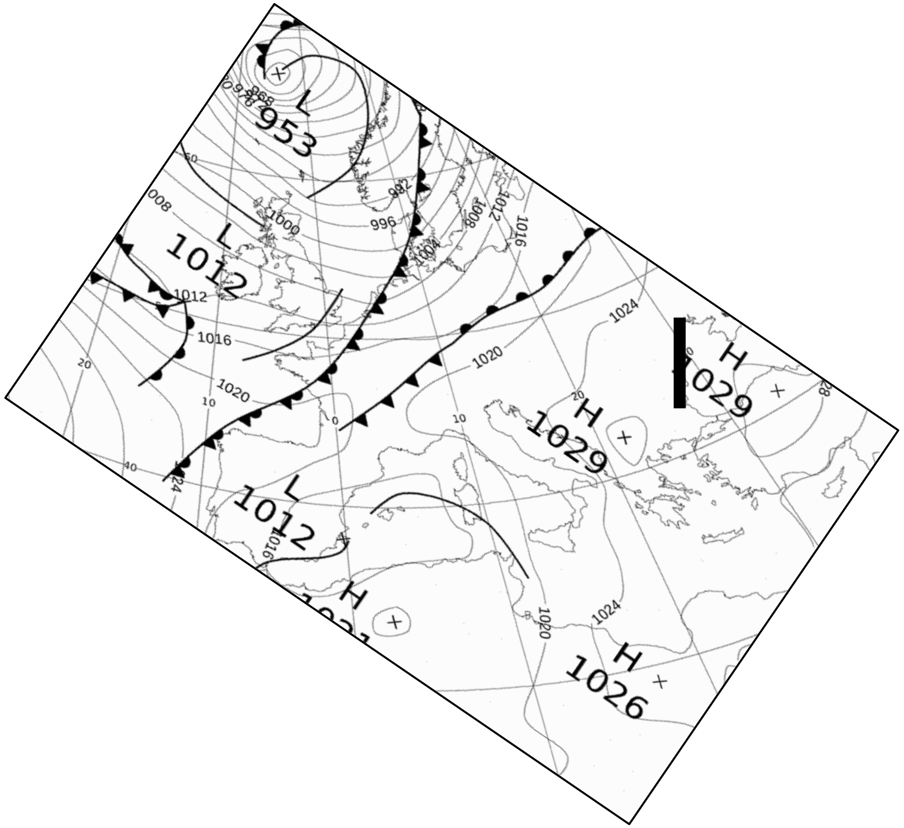
"Fixed aerosol" – will change to MACC-based aerosol climatology with RH-dependent size distribution. Use of prognostic aerosol in MACC at some point in the future…

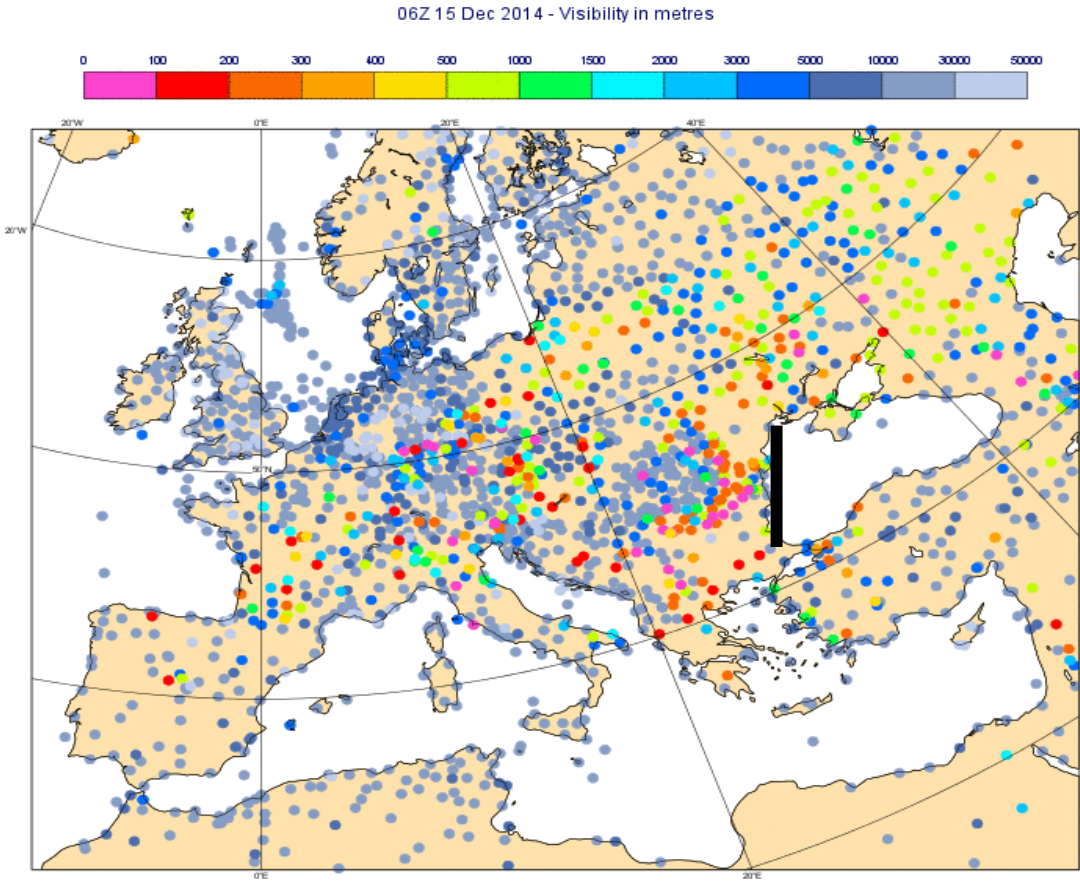
Fixed particle size for cloud and precipitation particles (single moment microphysics), could introduce variable (diagnostic) particle size distributions

Relatively low resolution – orography, 10m lowest model level, correct physics??? (turbulence, microphysics, radiation interactions…)

rediction of severe weather: Visibility/Fog

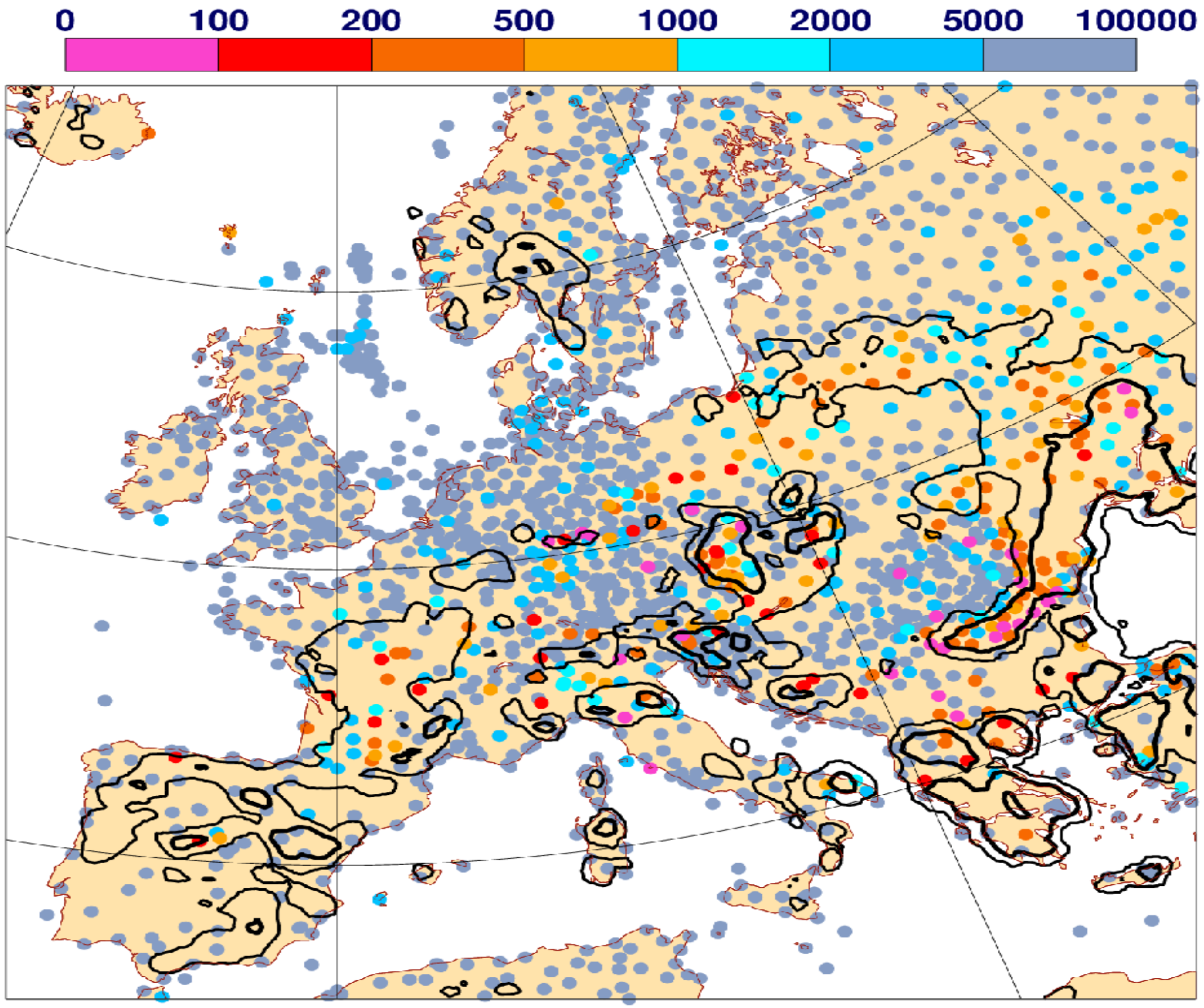
se study: 15 Dec 2014





rediction of severe weather: Visibility/Fog

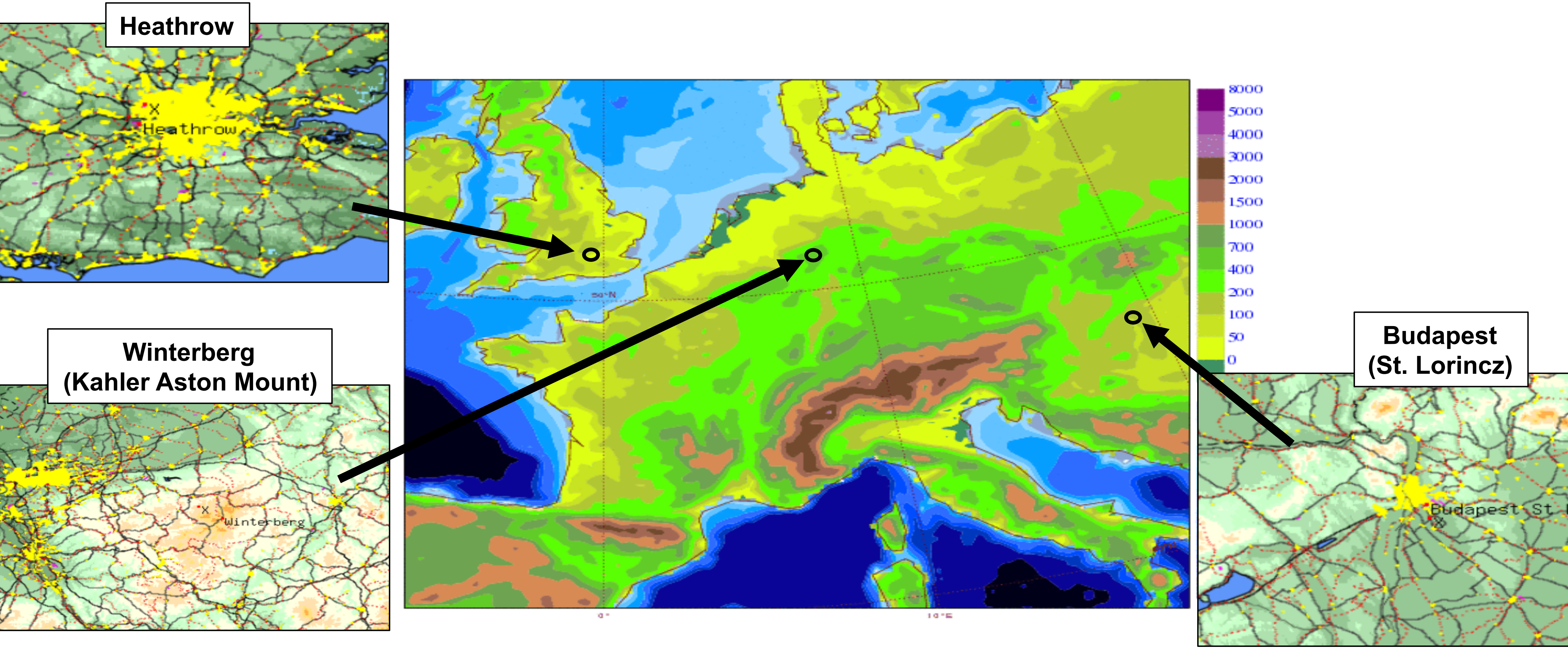
se study: 15 Dec 2014, 3 day probability forecast from IFS ensemble



Observed visibility (m) at 06Z 15 Dec 2014 (dots)
ENS 3-day forecast probability of fog (<1000m) >10% (thin), **>50% (thick)**

rediction of severe weather: Visibility/Fog

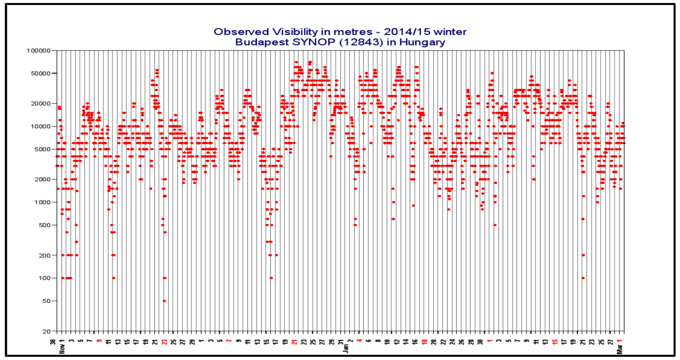
se study: 15 Dec 2014

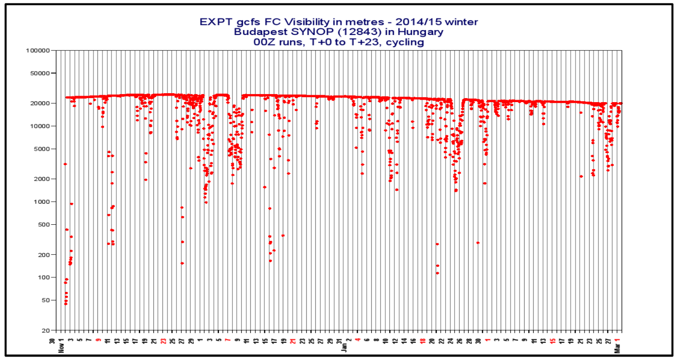


rediction of severe weather: Visibility/Fog

ecific sites: Nov-Mar 2014-2015

Obs | **IFS 24 hr fc**





100km
10km
1km
100m

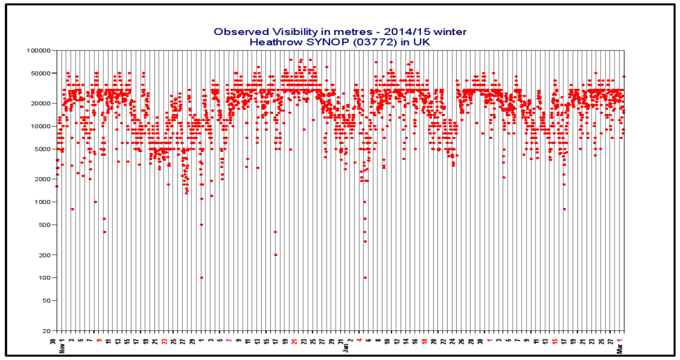
Nov Dec Jan Feb Mar

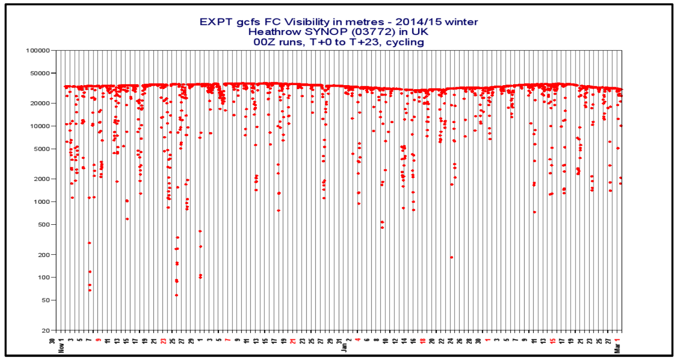
Nov Dec Jan Feb Mar

Budapest

Climate
Continental
Aerosol rich
Low-lying
Fog-prone

Background Vis bit high
Too little variability



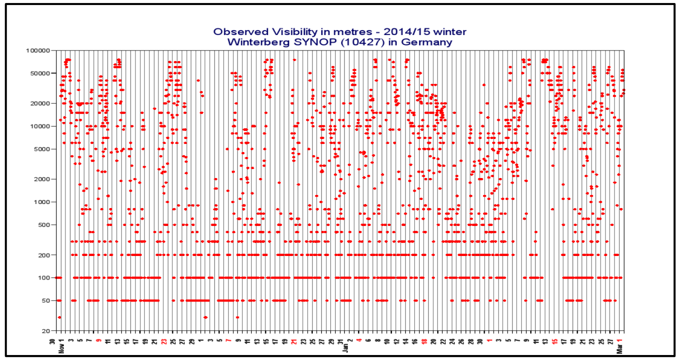


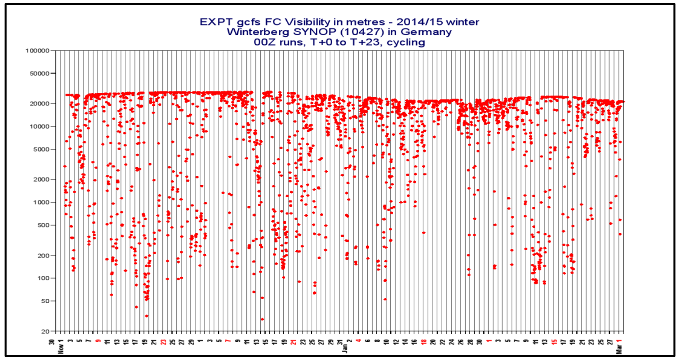
100km
10km
1km
100m

Heathrow

Climate
More maritime
Fewer aerosol
Low-lying
Fog-prone

Background Vis reasonable





100km
10km
1km
100m

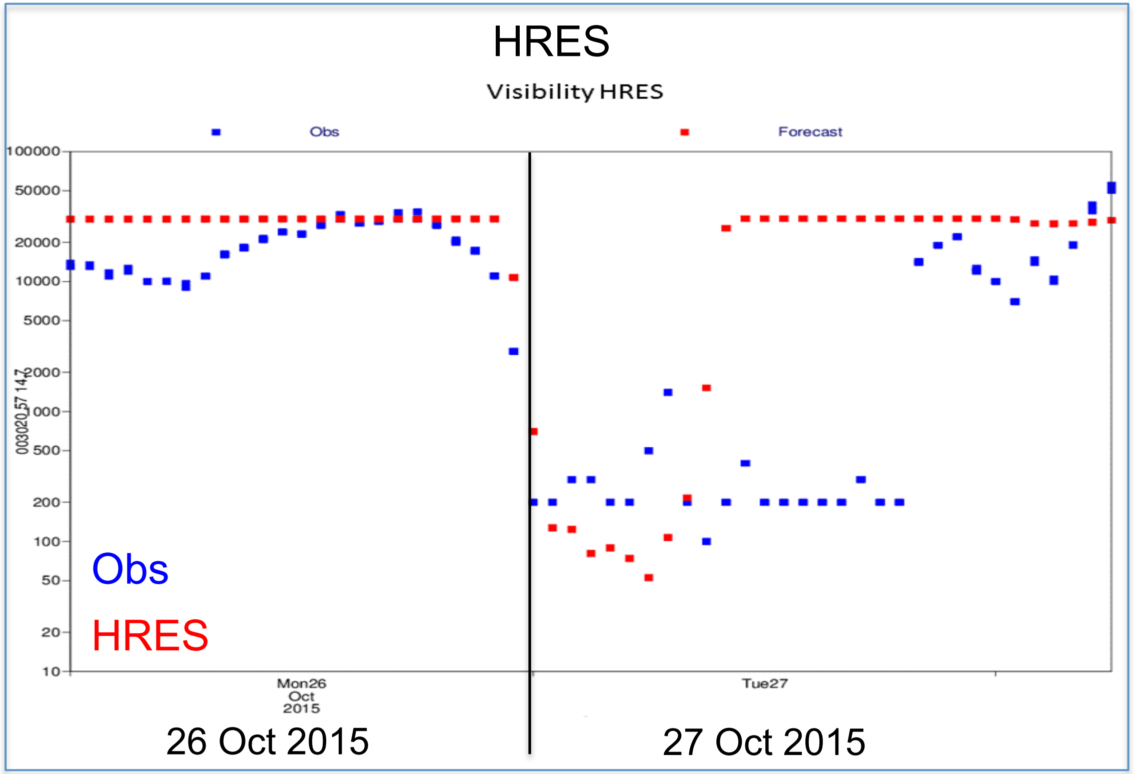
Winterberg

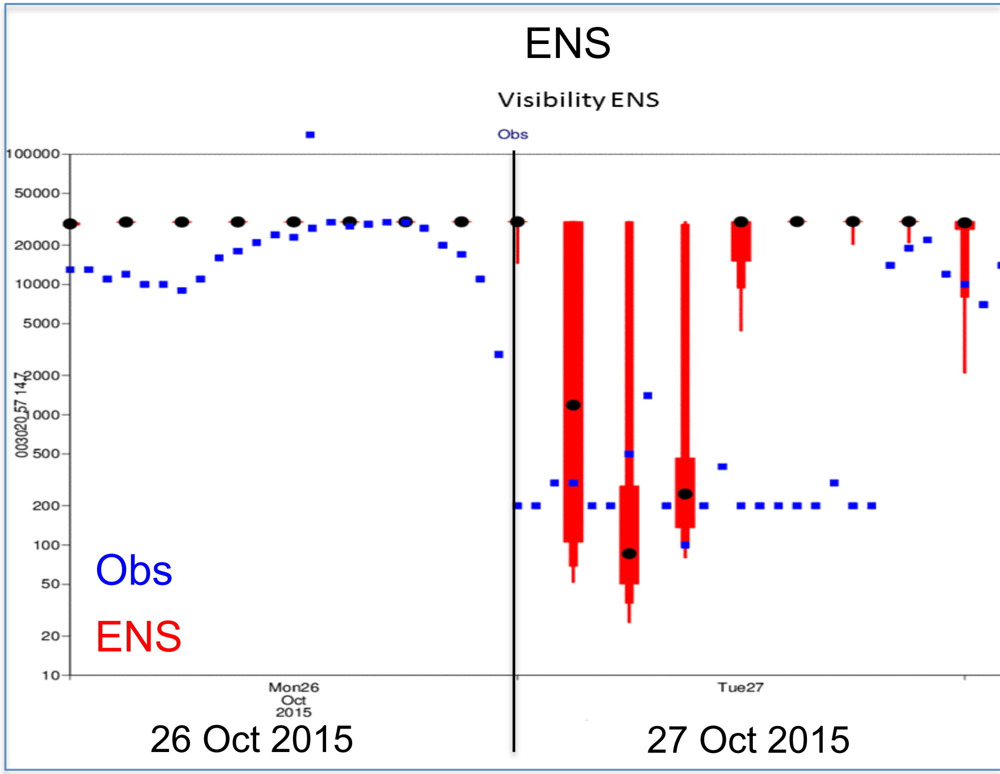
Climate
Exposed
High altitude
Prone to hill fog

Vis too high BUT model grid point is **606m,** obs is **859m**

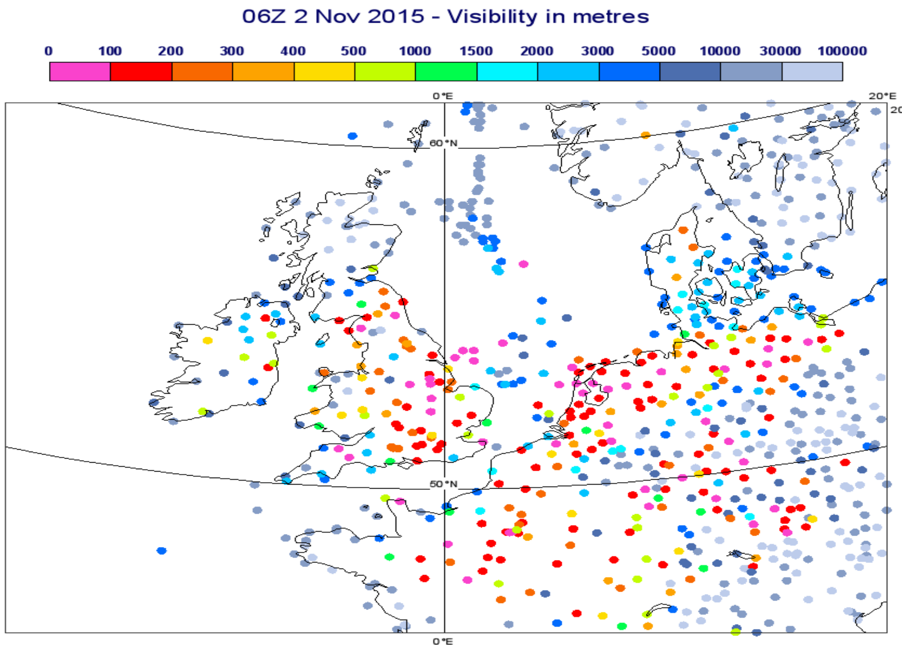
ediction of severe weather: Visibility/Fog
se study: 27 Oct 2015 - Fog in southern Sweden

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

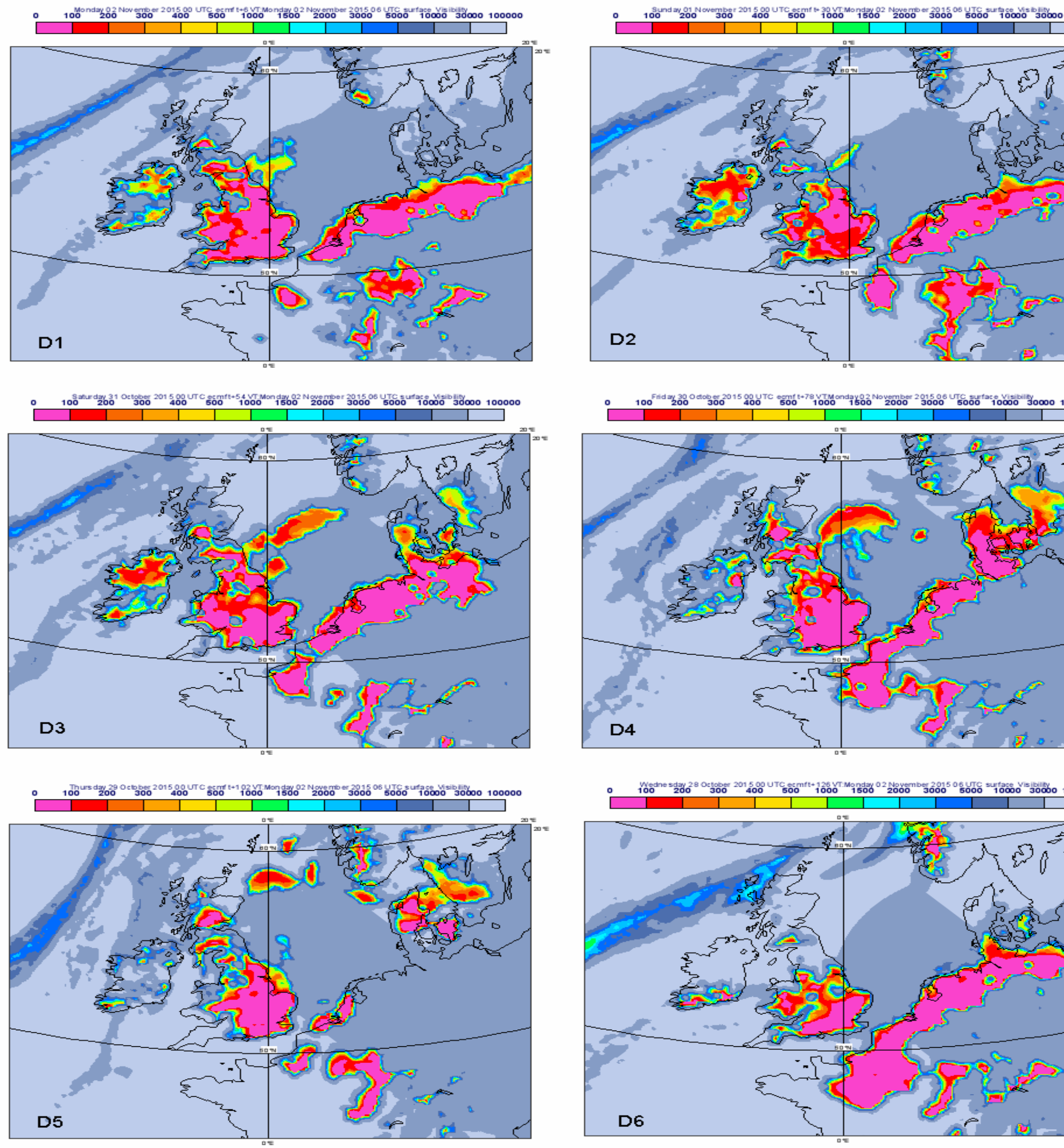




ediction of severe weather: Visibility/Fog
se study: 02 Nov 2015



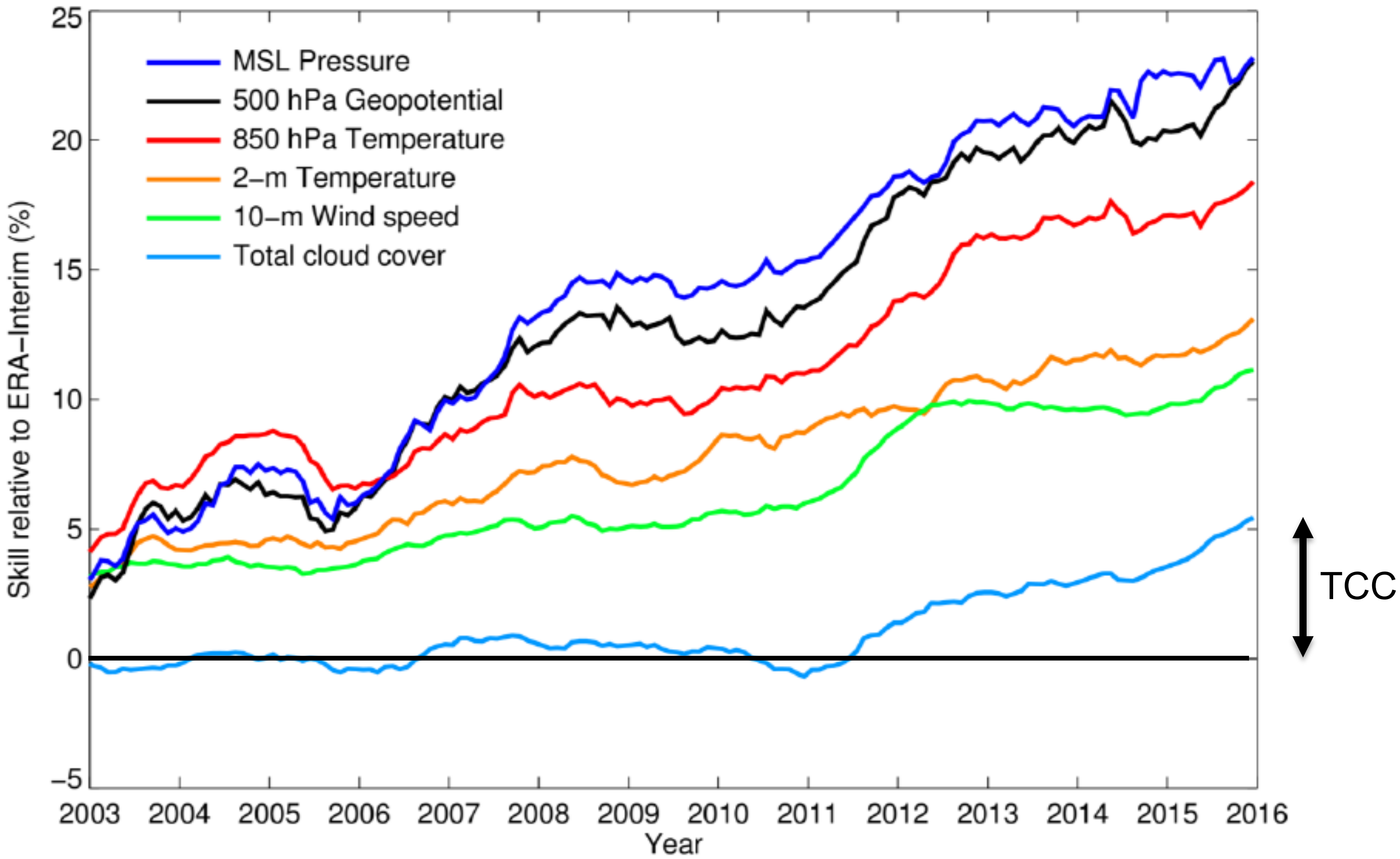
- In this case, indication of widespread fog event out to 6-day forecast
- Not always the case!
- Some regions missed
- Visibilities a bit too low in fog



Summary

Improvement in cloud cover skill – the last decade

See also Haiden et al (2015) ECMWF Newsletter 14



Evolution of skill of the HRES forecast at day 5, expressed as relative skill (stdev) compared to ERA-Interim (12 month running mean)

ummary
ouds and Precipitation: From models to forecasting

What we covered…

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

Thank you for listening! Questions? Feedback?