

Recent progress in forecasting system development

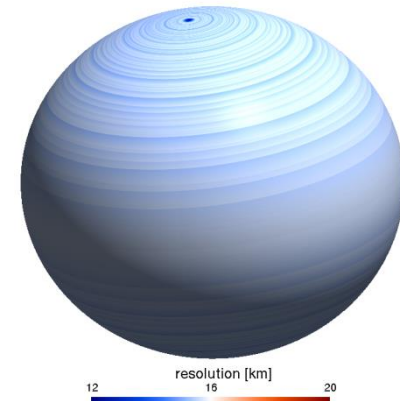
Erik Andersson and colleagues



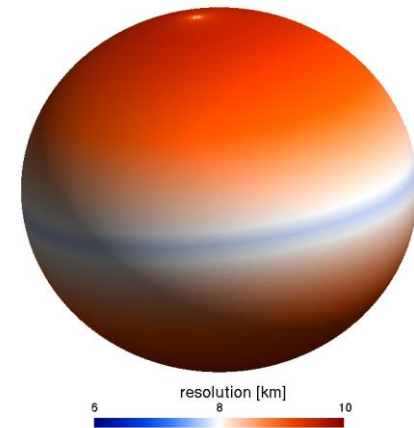
Resolution upgrade – IFS cycle 41r2 – The octahedral grid

Spectral truncation: T1279

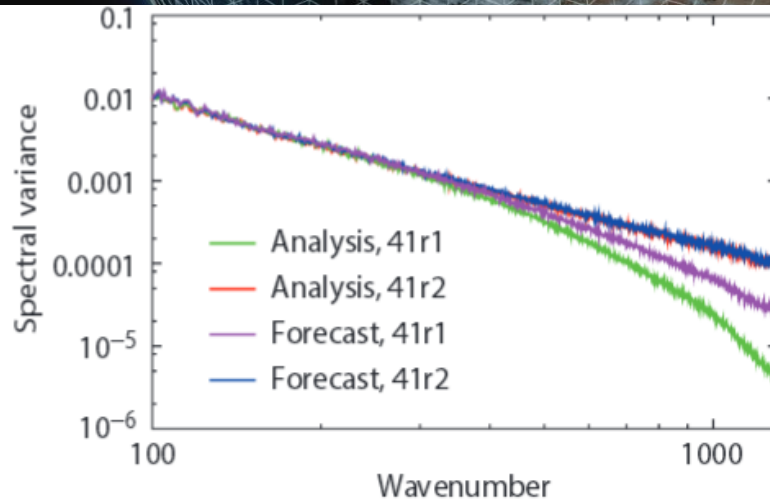
With 4 grid points describing the shortest wave



N640: current reduced Gaussian Grid

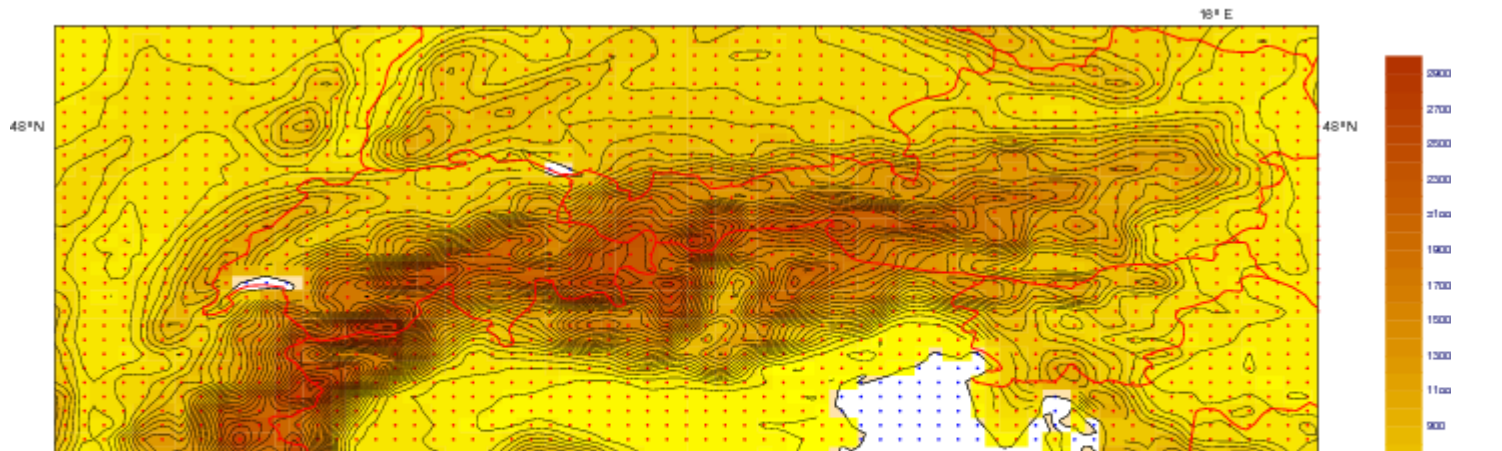


T_{CO} 1279: next model upgrade

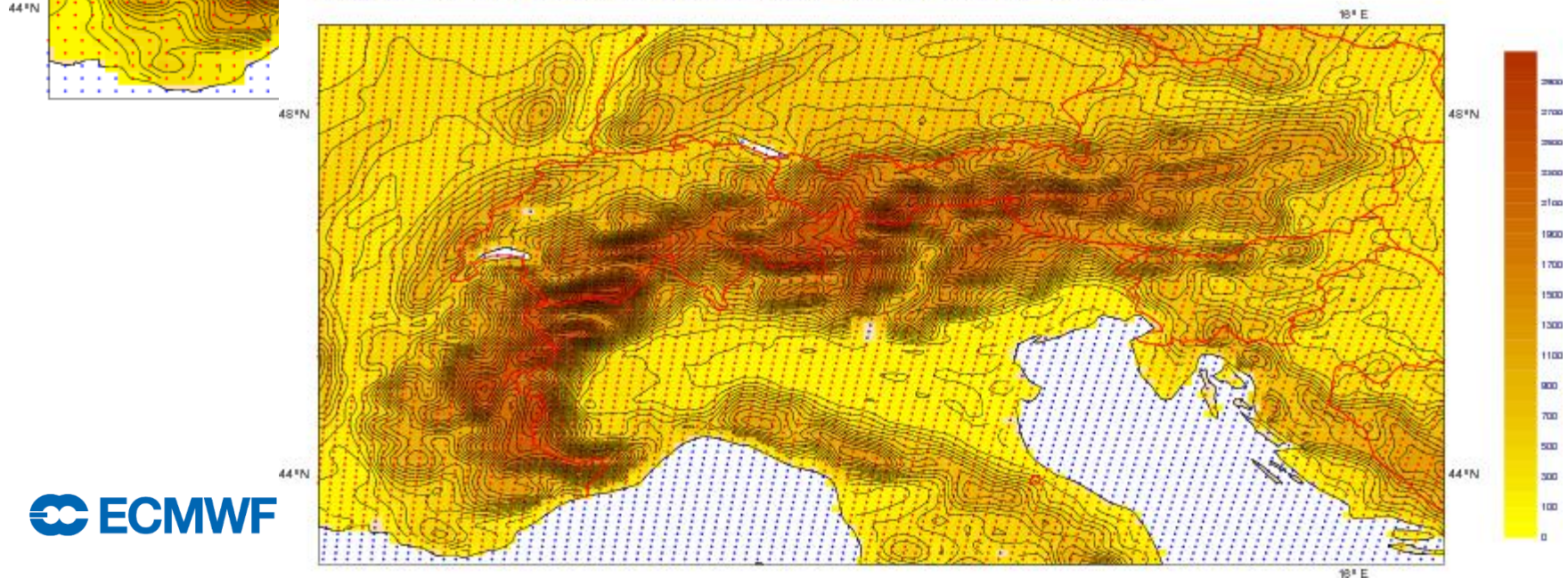


Improved representation of the Alps

OROGRAPHY, GRID POINTS AND LAND_SEA MASK FOR N640 ORIGINAL GRID
orography shaded (height in m), land grid points (red), sea grid points (blue)



OROGRAPHY, GRID POINTS AND LAND_SEA MASK FOR O1280 OCTAHEDRAL GRID
orography shaded (height in m), land grid points (red), sea grid points (blue)



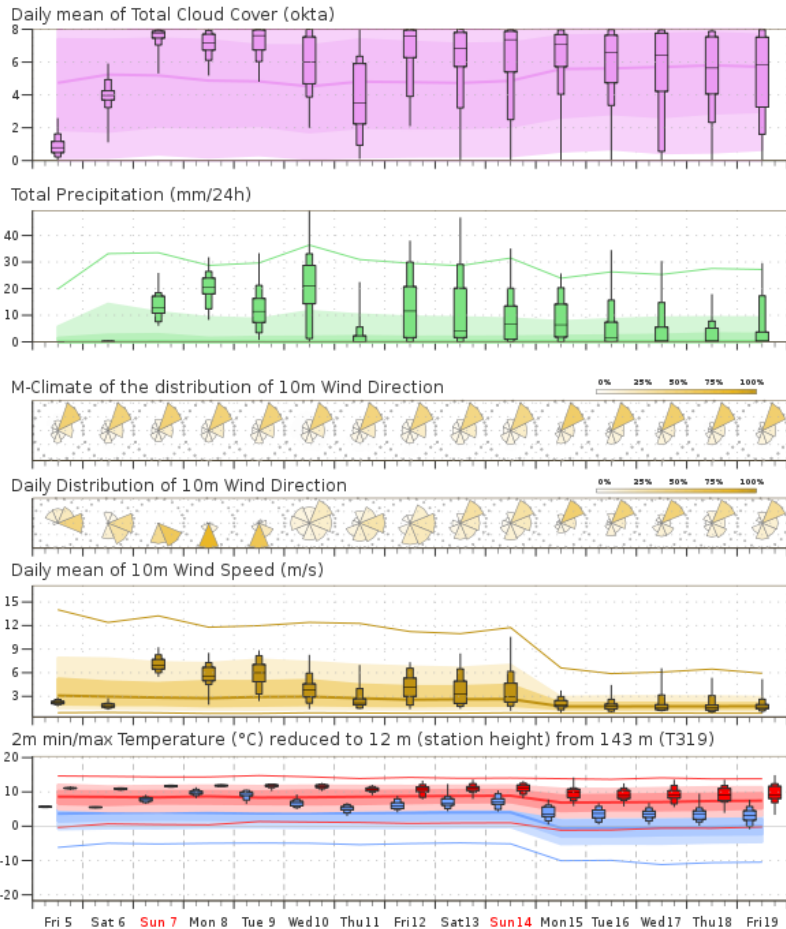
Higher resolution ENS up to 15 days

Improvement on the 15-day MeteoGrams – **NO JUMP at DAY10**

ENS Meteogram
ENS Meteogram
Koper, Slovenia 45.77°N 13.5°E (EPS land point) 12 m
Extended Range Forecast based on ENS distribution Friday 5 February 2016 00 UTC

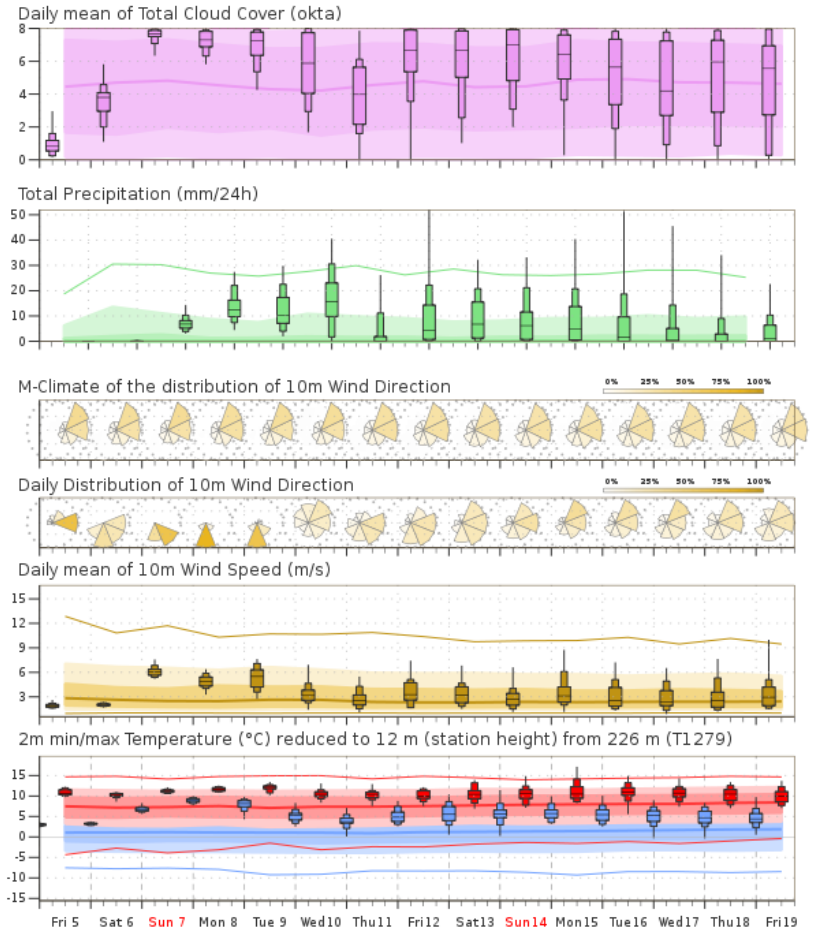
Oper

Koper, Slovenia



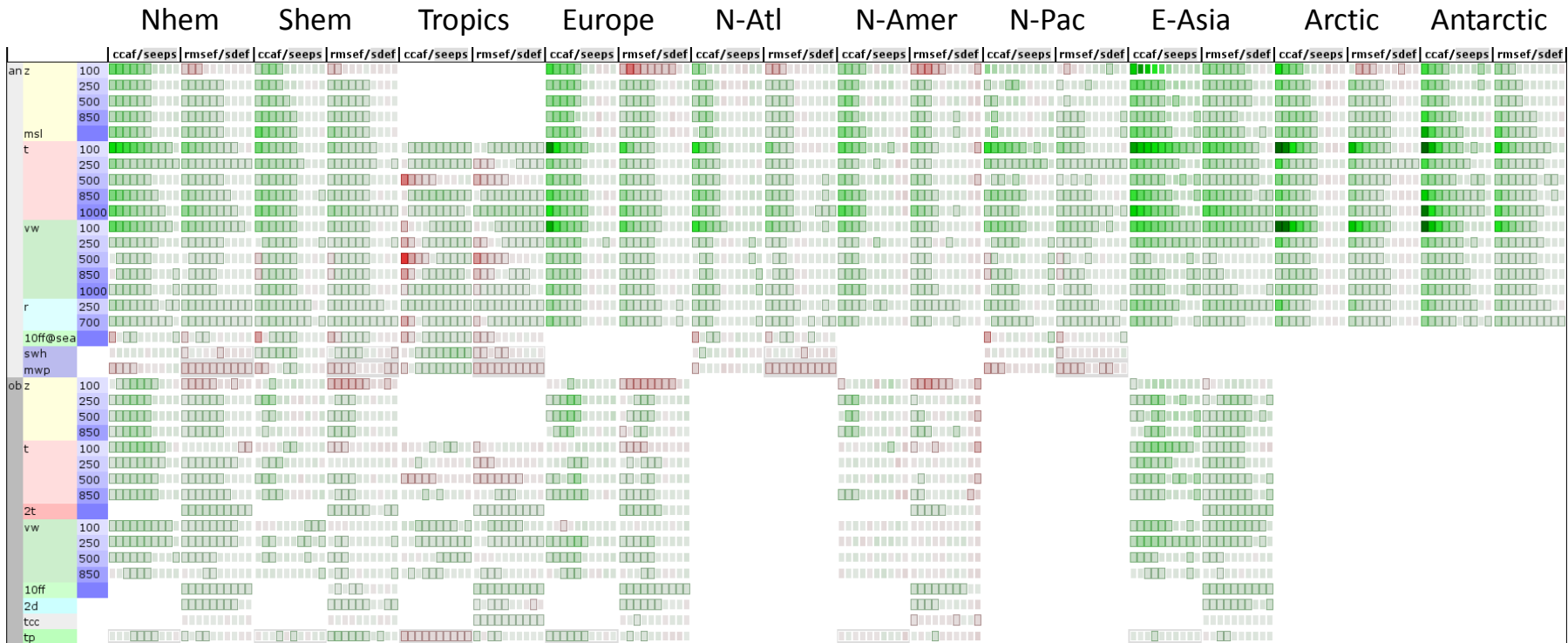
ENS Meteogram [0069]
ENS Meteogram [0069]
Koper, Slovenia 45.61°N 13.78°E (EPS land point) 12 m
Extended Range Forecast based on ENS distribution Friday 5 February 2016 00 UTC

Esuite



Cycle 41r2 – HRES scorecard

Evaluation period: 2015-08-09 to 2016-01-19 (164 days)

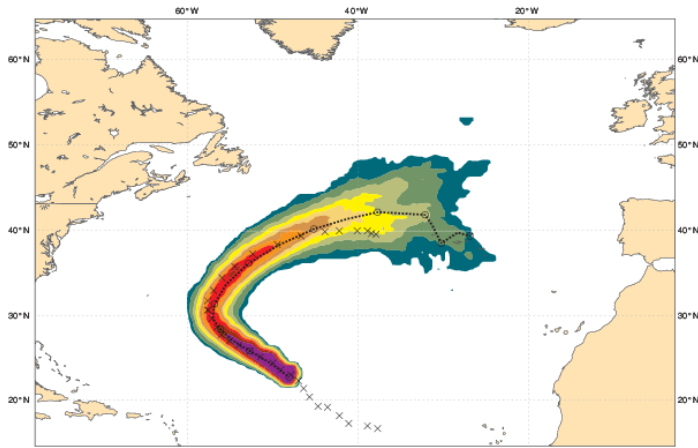


Tropical Cyclones Edouard, resolution upgrade

Date 20140914 00 UTC @ECMWF

Probability that **EDOUARD** will pass within 120 km radius during the next 240 hours tracks: **solid**=HRES; **dot**=Ens Mean [reported minimum central pressure (hPa) **994**]

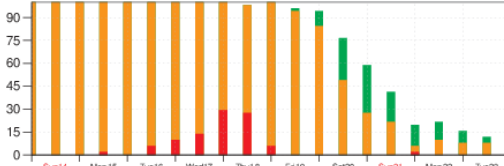
■ 5-10 ■ 10-20 ■ 20-30 ■ 30-40 ■ 40-50 ■ 50-60 ■ 60-70 ■ 70-80 ■ 80-90 ■ > 90 %



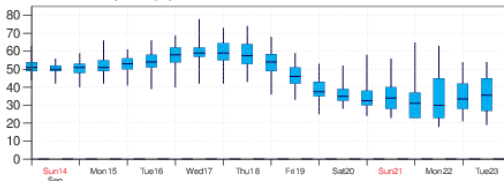
List of ensemble members numbers forecast Tropical Cyclone Intensity category in colours: **TD**[up to 33] **TS**[34-63] **HR1**[64-82] **HR2**[83-95] **HR3**[>95 kt]

+024 h :	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+048 h :	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+072 h :	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+096 h :	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+120 h :	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+144 h :	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	22	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	44	45	46	47	48	49	50			
+168 h :	02	03	04	05	06	10	11	12	13	14	19	20	24	25	27	28	29	30	31	33	34	35	36	37	38	42	44	45	46	47	48	49	50																	
+192 h :	10	20	21	25	27	28	31	34	36																																									
+216 h :	10	20	21	27	28	29	31	34																																										
+240 h :	30	21	31	31																																														

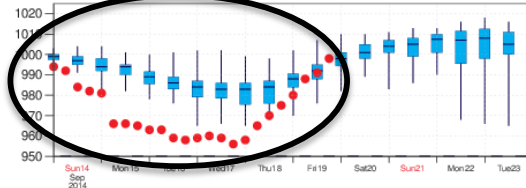
Probability (%) of Tropical Cyclone Intensity falling in each category
TD[up to 33] **TS** [34-63] **HR1**[64-82] **HR2** [83-95] **HR3** [> 95 kt]



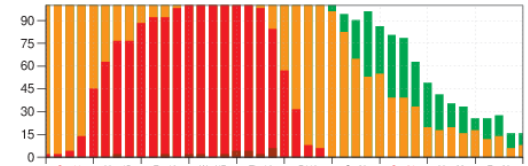
10m Wind Speed (kt) **solid**=HRES; **dot**=Ens Mean



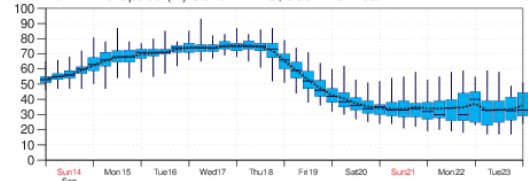
Mean Sea Level Pressure in Tropical Cyclone Centre (hPa) **solid**=HRES; **dot**=Ens Mean



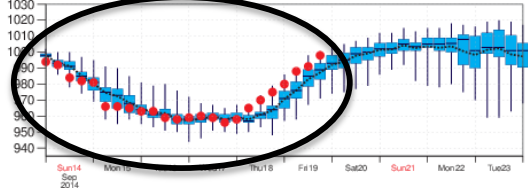
Probability (%) of Tropical Cyclone Intensity falling in each category
TD[up to 33] **TS** [34-63] **HR1**[64-82] **HR2** [83-95] **HR3** [> 95 kt]



10m Wind Speed (kt) **solid**=HRES; **dot**=Ens Mean



Mean Sea Level Pressure in Tropical Cyclone Centre (hPa) **solid**=HRES; **dot**=Ens Mean



Much improved TC predictions

32km ENS
16km HRES

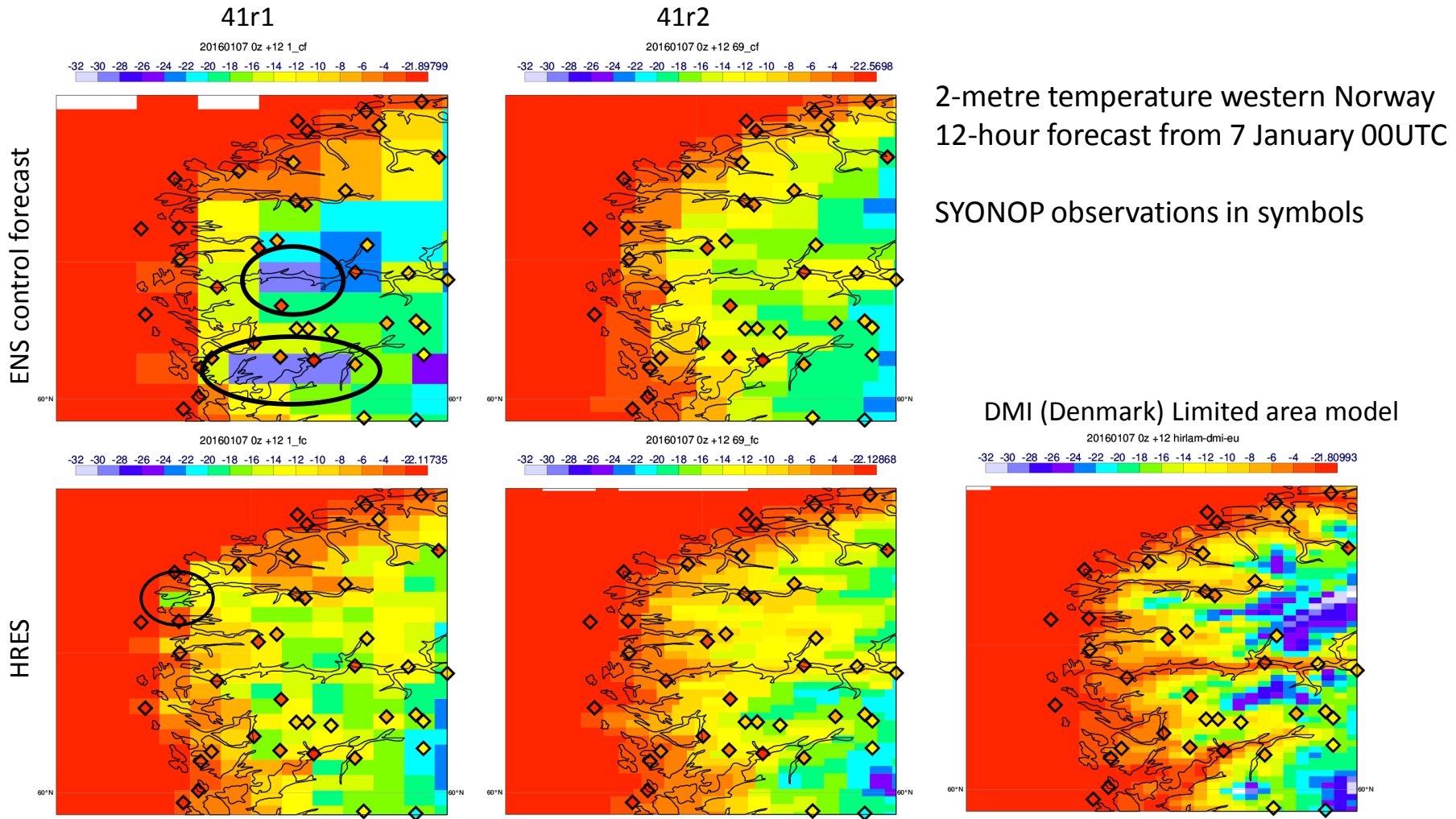
18km ENS
9km HRES

Resolution upgrade – 8 March 2016

41r1 → 41r2

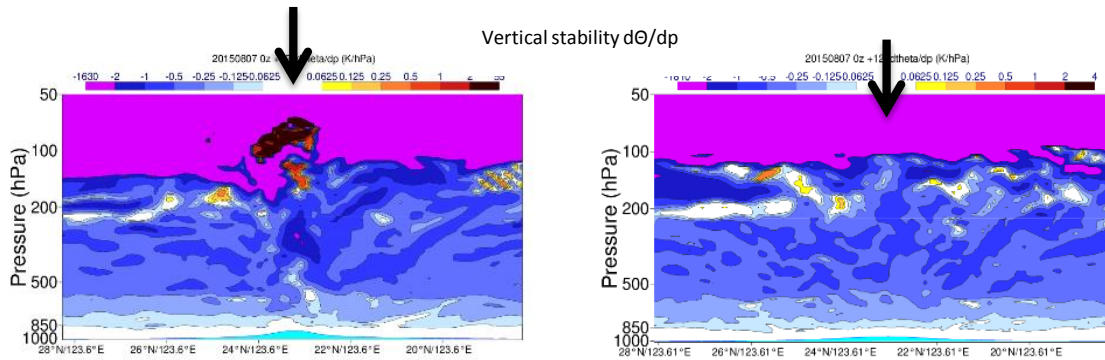
Grid res.	HRES	ENS	4DV inner loops			EDA		
			1 st	2 nd	3 rd	Outer	1 st	2 nd
128 km							TL159	TL159
							TL191	TL191
64 km		D11-D46 TL319	TL255	TL255 TL319	TL255 TL399			
32 km		D1-D10 TL639 D16-D46 TCo319				TL399		
16 km	TL1279	D1-D15 TCo639					TCo639	
9 km	TCo1279							

Improved radiation calculation => T2m



Improved semi-Lagrangian scheme

Instability with 3 iterations for semi-Lagrangian departure point in extreme situations (gravity waves above Himalayas, tropical cyclones); increasing to 5 iteration considerably improves the results



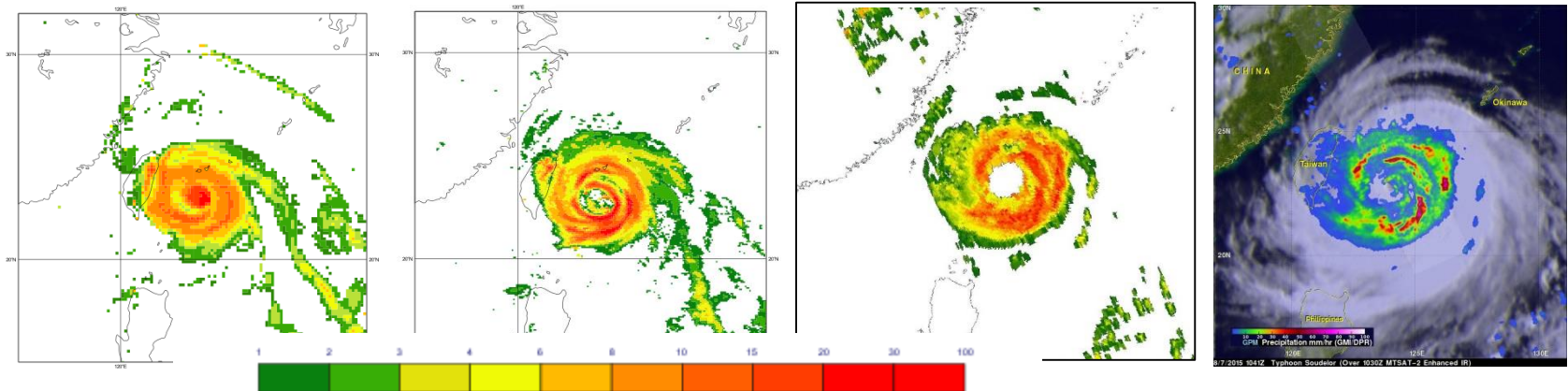
Tropical Cyclone Soudelor
Aug 2015

HRES TL1279 Cy41r1

HRES TCo1279 Cy41r2

GPM observations

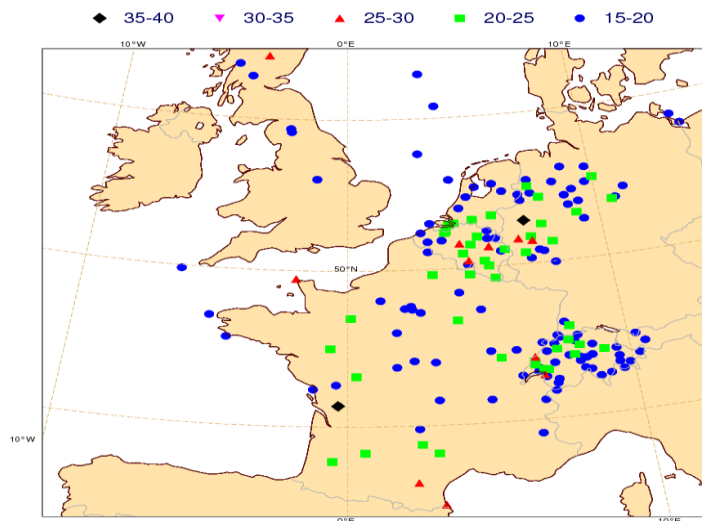
RADAR



CAPE-SHEAR – indicator of severe convection

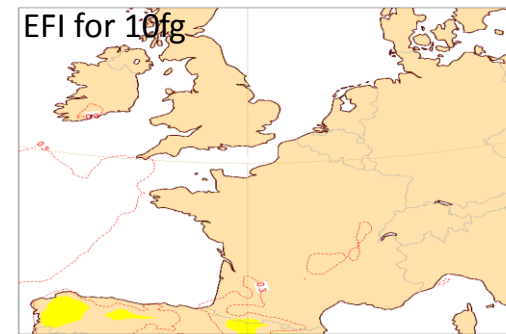
- CAPE is a key ingredient of deep moist convection
- Large vertical wind shear favors organized convection
- Super cells occur where strong shear is combined with large instability

Observed maximum wind gusts on 09 June 2014

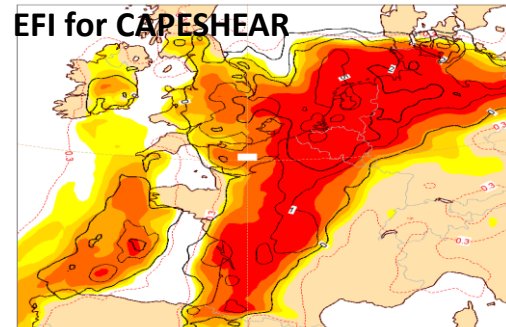


- Severe convection affected Western Europe from southern France to northern Germany on 9 Jun 2014.
- The maximum wind gust at Düsseldorf airport was 42 m/s.

Mon 09 Jun 2014 00UTC @ECMWF expver = 1 VT: Mon 09 Jun 2014 00UTC - Tue 10 Jun 2014 00UTC 0-24h
Extreme forecast index and Shift of Tails (black contours 0, 1, 2.5, 10, 15) for: 10m wind gust



Mon 09 Jun 2014 00UTC @ECMWF VT: Mon 09 Jun 2014 00UTC - Tue 10 Jun 2014 00UTC 0-24h
Extreme forecast index and Shift of Tails (black contours 0, 1, 5, 10, 15) for: SCI
M-CLIMATE (5 members X 20 years every Thursday X 5 weeks)

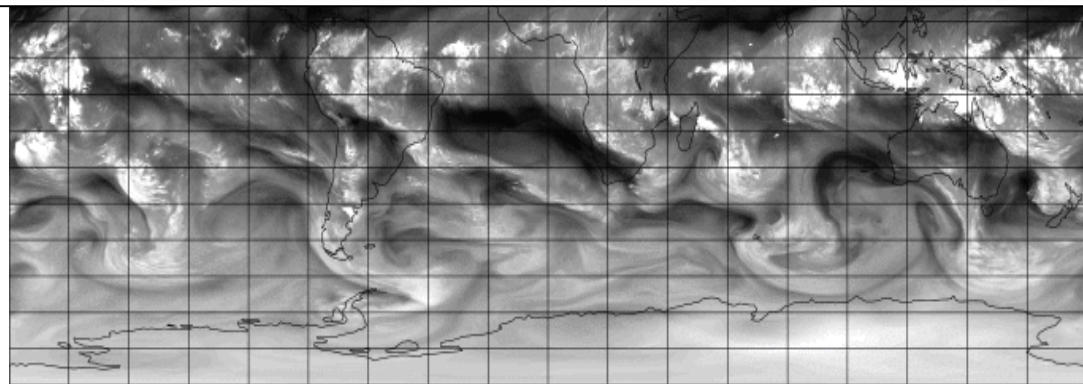
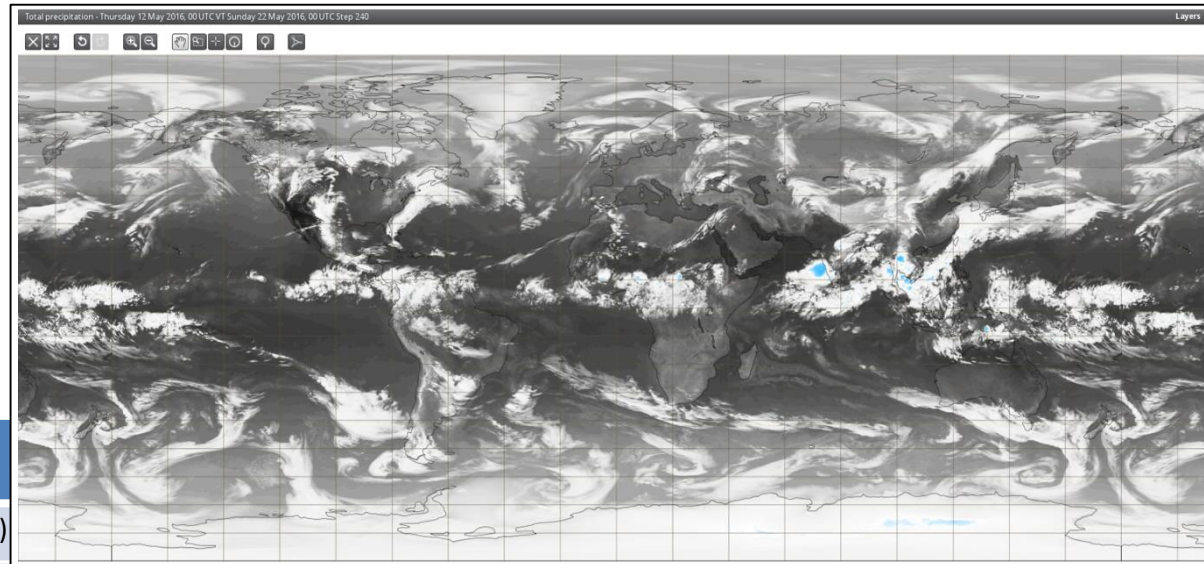


Simulated satellite images

Captures detailed cloud and/or humidity features.

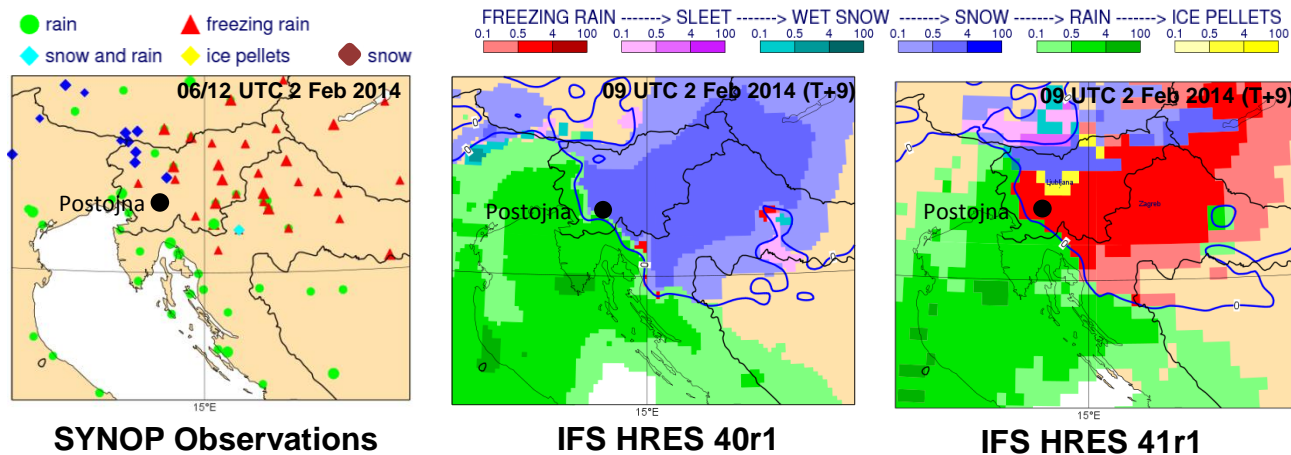
Shows HRFES as a weather satellite would see it.

Central wavelength	Description
6.30 (μm)	Water vapour ($\sim 300\text{hPa}$)
7.36 (μm)	Water vapour ($\sim 500\text{hPa}$)
10.79 (μm)	Clouds (surface)



Microphysics upgrade & new diagnostics for precipitation types – predicting high-impact freezing rain events

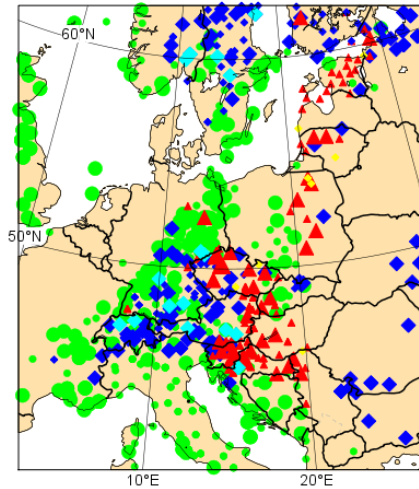
- Case Study: Slovenia/Croatia 02 Feb 2014
- Freezing rain caused severe disruption and damage, transport/power/forests...
- IFS physics at the time (40r1) not able to predict
- New physics in 41r1 allows prediction of freezing rain events
- Evaluation in HRES/ENS has demonstrated potential for useful forecasts



ECMWF Newsletter 141

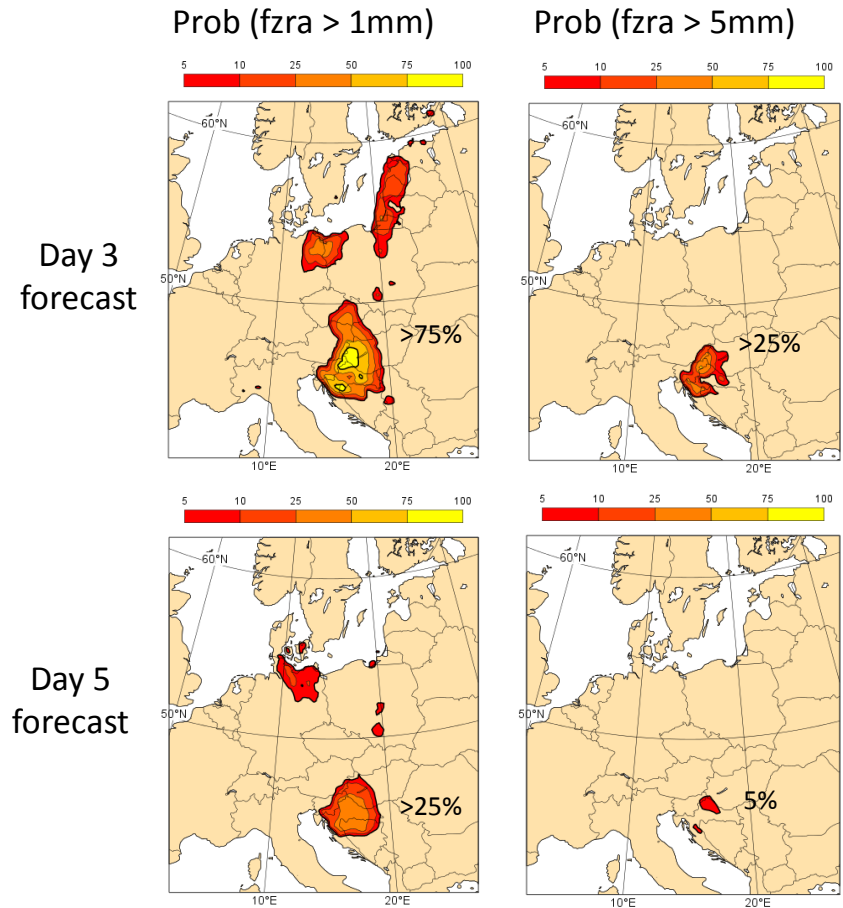
Probability of freezing rain accumulation from ENS

Case Study: 02 Feb 2014



Obs

- rain
- ◆ snow
- ▲ freezing rain
- ◆ snow and rain
- ◆ ice pellets

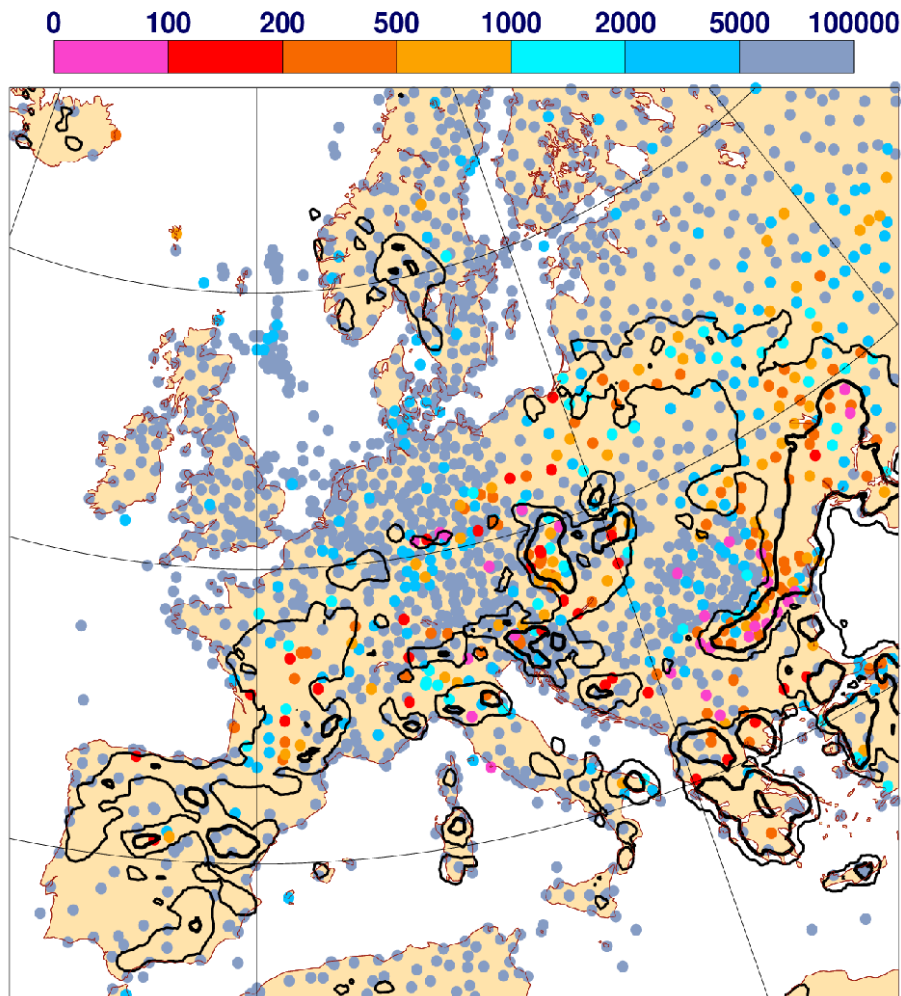


Day 3
forecast

Day 5
forecast

New diagnostic: Visibility/Fog

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

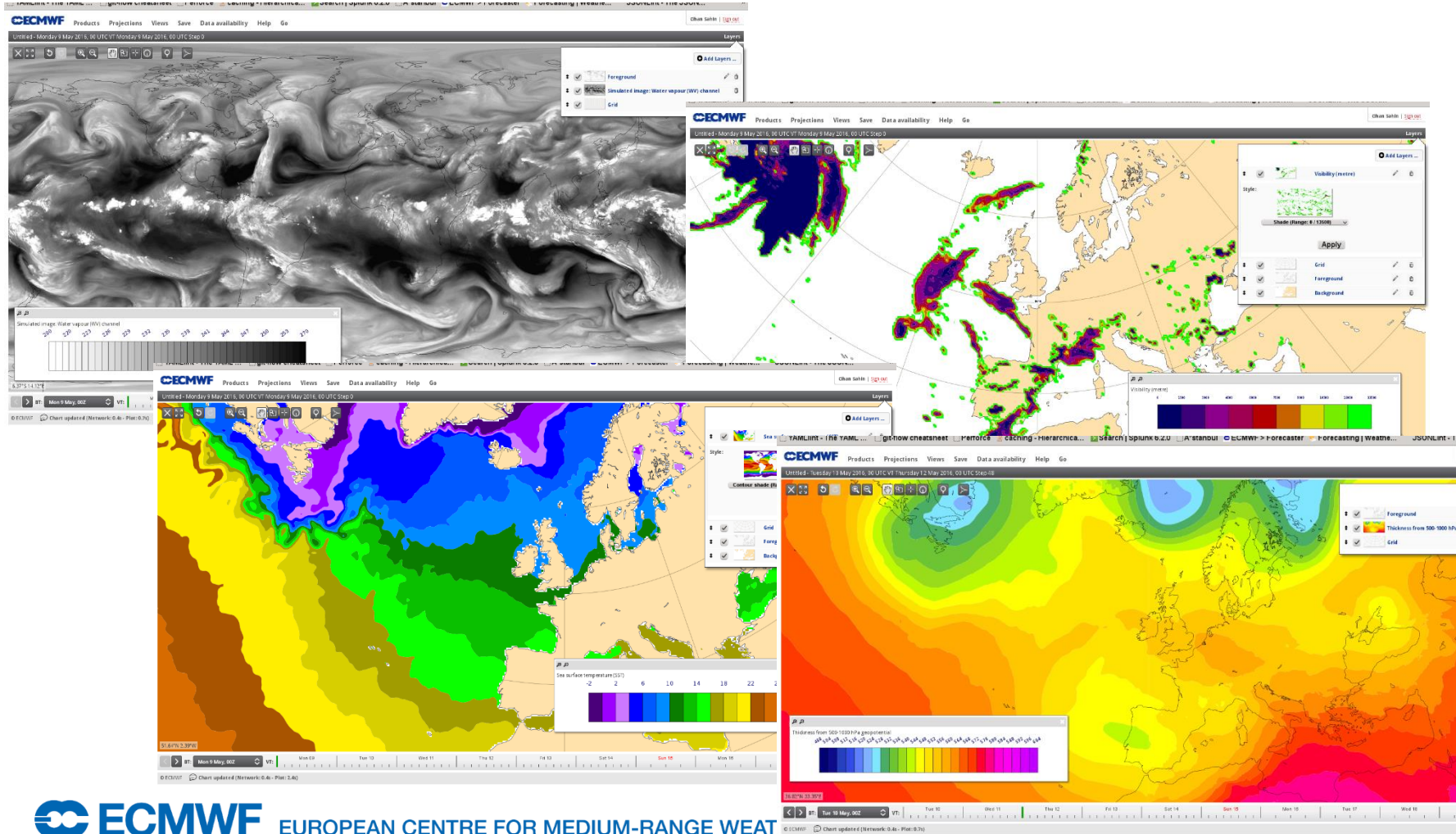


Observed visibility (m) at 06Z 15 Dec 2014 (dots)

ENS 3-day forecast probability of fog (<1000m visibility)
>10% (thin),
>50% (thick)

ecCharts - upgrade June 2016

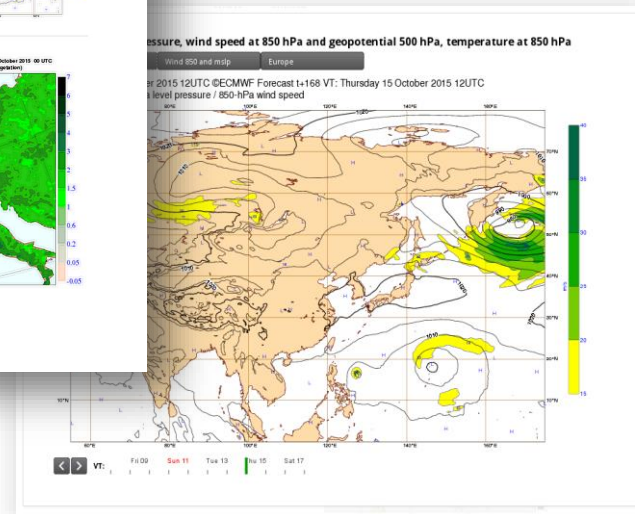
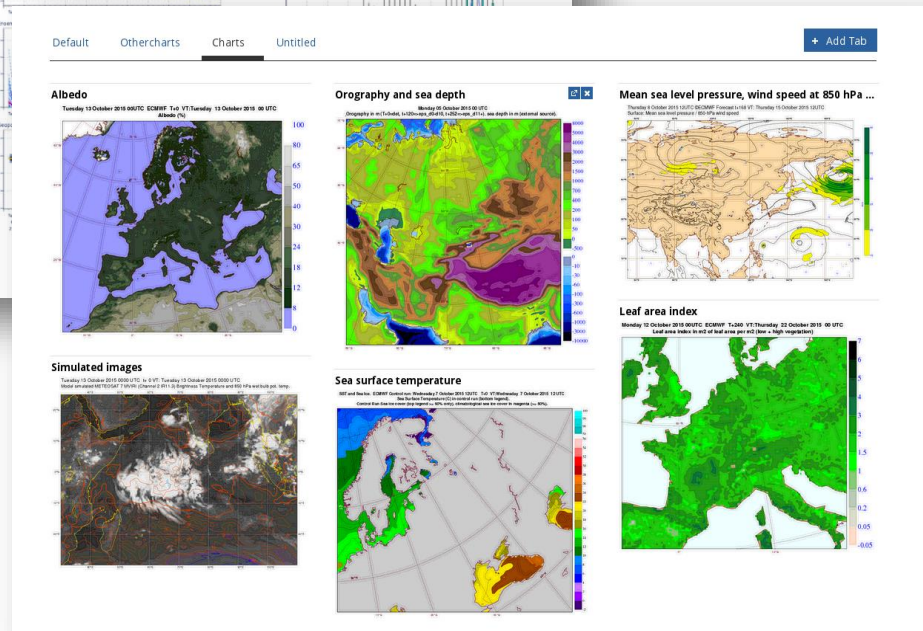
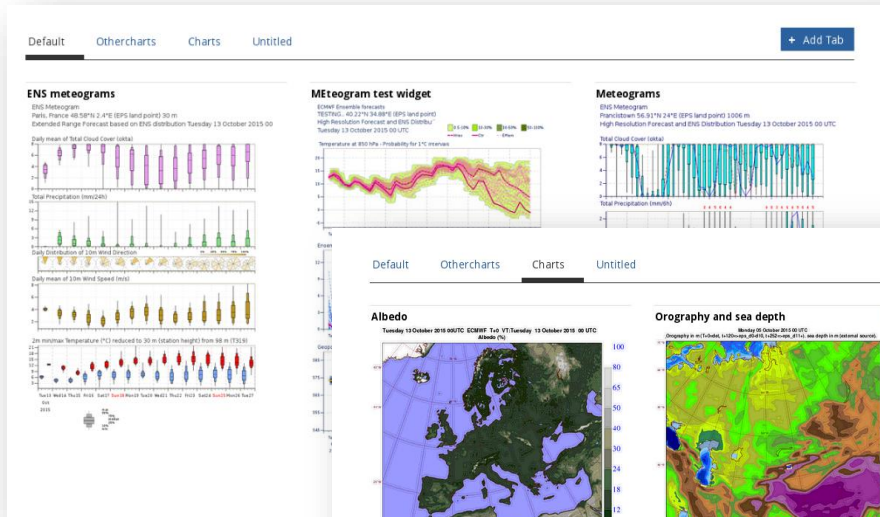
upgrade mainly driven by user requests



The Dashboard – Web Charts and ecCharts

Allows forecasters to create their own working environment

Allows the caching of products



The chart navigator

Charts

Datasets

Quality of our forecasts

Documentation and support

Accessing forecasts

Filters

Show All

Product group

- Climagrams (5)
- Nino plumes (3)
- Spatial maps (10)
- Tropical storms (5)

Model

- ECMWF (23)

Type

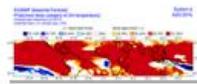
- Forecasts (18)
- Forecasts (Public) (5)

Parameters

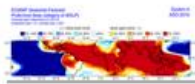
- 2m temperature (2)
- 500 hPa geopotential (1)
- 850 hPa temperature (1)
- MSLP (2)
- Precipitation (5)
- SST (2)
- Temperature (5)

23 matching items

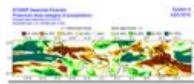
Model: ECMWF



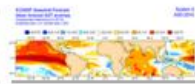
ECMWF 2m temperature Public



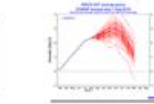
ECMWF mean sea level pressure Public



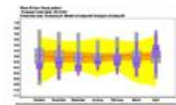
ECMWF rain Public



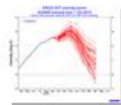
ECMWF sea surface temperature Public



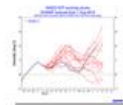
ECMWF nino plumes (Public)



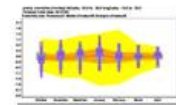
Monsoon Indices



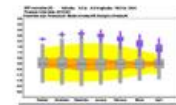
Nino plumes



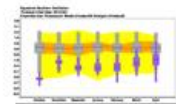
Nino plumes (Annual range)



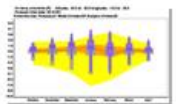
Precipitation area averages



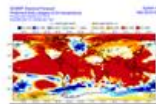
Sea Surface Temperature area



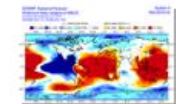
Teleconnection Indices



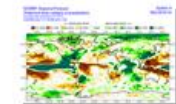
Temperature area averages



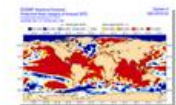
ECMWF 2m temperature



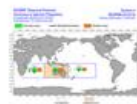
ECMWF mean sea level pressure



ECMWF rain



ECMWF sea surface temperature



Hurricanes Typhoon frequency

Quality of our forecasts

Documentation and support

Accessing forecasts

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Model

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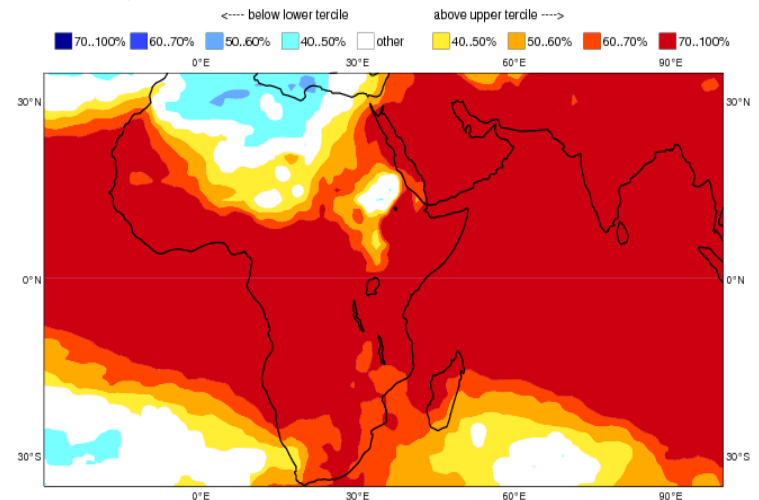
Type

- Forecasts (18)
- Forecasts (Public) (5)

Prob(most likely category of MSLP)

Forecast start reference is 01/07/15
Ensemble size = 51, climate size = 450

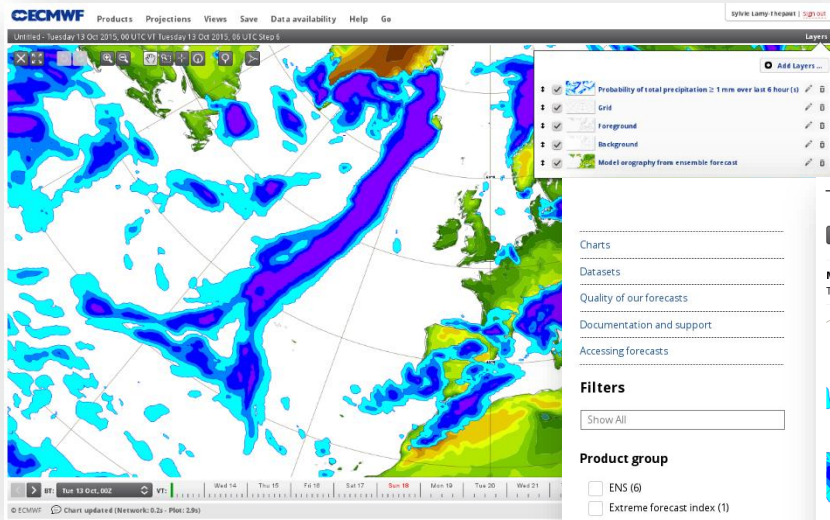
ASO 2015



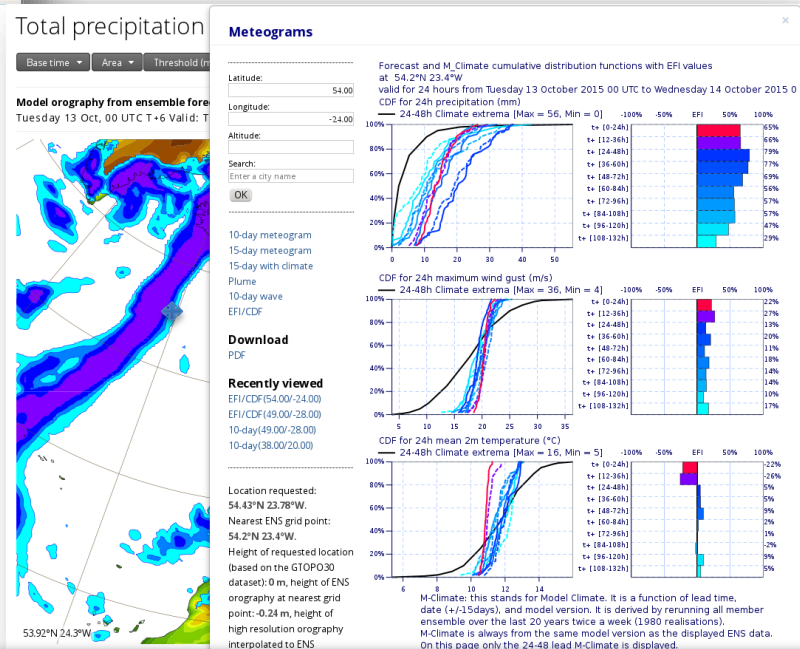
Navigation controls: VT, Nov 2015, Dec 2015

The interactive maps ...

- Simplify the production of charts
- Ease the creation of new products
- Use ecCharts facilities



- Use of full model resolution
- Ensure a consistent look and feel
- Enable clickable features



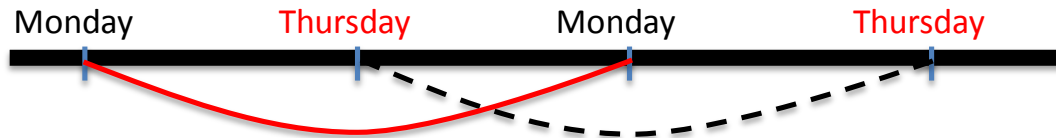
Extension of the re-forecast

Previous:	5 member	Ensemble	once a week	20 years
New:	11 member	Ensemble	twice a week	20 years

Larger ensemble size:
Better estimate of the probability boundaries.
The reforecast could be used for skill assessments.

Higher frequency (twice a week):
Calibration of Monday forecast is consistent with the one of the Thursday.

New calibration is done over a complete 1 week window using a total sample size of 660 (11*3*20)



The operational forecasting system

High resolution deterministic forecast (HRES) :

- twice per day **9 km** 137 levels, to 10 days ahead

Ensemble forecast (ENS):

- twice per day 51 members, **18 km** 91 levels, to 15 days ahead
- Monday/Thursday 00 UTC extended to 1 month ahead (**Monthly Forecast, 18/36 km**)

Ocean waves: twice per day

- **HRES-WAM**: 10 days ahead at **14 km** (coupled)
- **HRES Stand Alone Wave (SAW) model** : 10 days ahead at **11 km**
- **ENS-WAM**: 15 days ahead at **28 km** (coupled)

Seasonal forecast: once a month

- 51-members, **~80 km** 91 levels, to 7 months ahead
- sub-set of 15 members is run for 13 months every quarter (**30 years of hindcasts**)

Summary

- Resolution upgrade was a major achievement, providing forecasts at higher resolution (9 km and 18 km) than any other global NWP centre
- Made possible through coordinated efforts in numerics, physics, data assimilation, HPC, evaluation, diagnostics, software development and scalability efficiency gains
- Significant progress in terms of forecast skill: upper-air, surface and TC-position performance improved
- New forecast products, new chart capabilities on the web, and ecCharts upgrades - responding to user requirements

Focusing on the challenges

- Enhance scalability of meteorological application software
- Fast delivery of very large data volumes
- Develop seamless products and verification into the 2nd week of forecasts
 - persistent anomalies
 - enhanced likelihoods of extremes events, and high impact weather.
- IFS cycle 43r1 and higher-resolution ocean model
- Seasonal forecast system 5