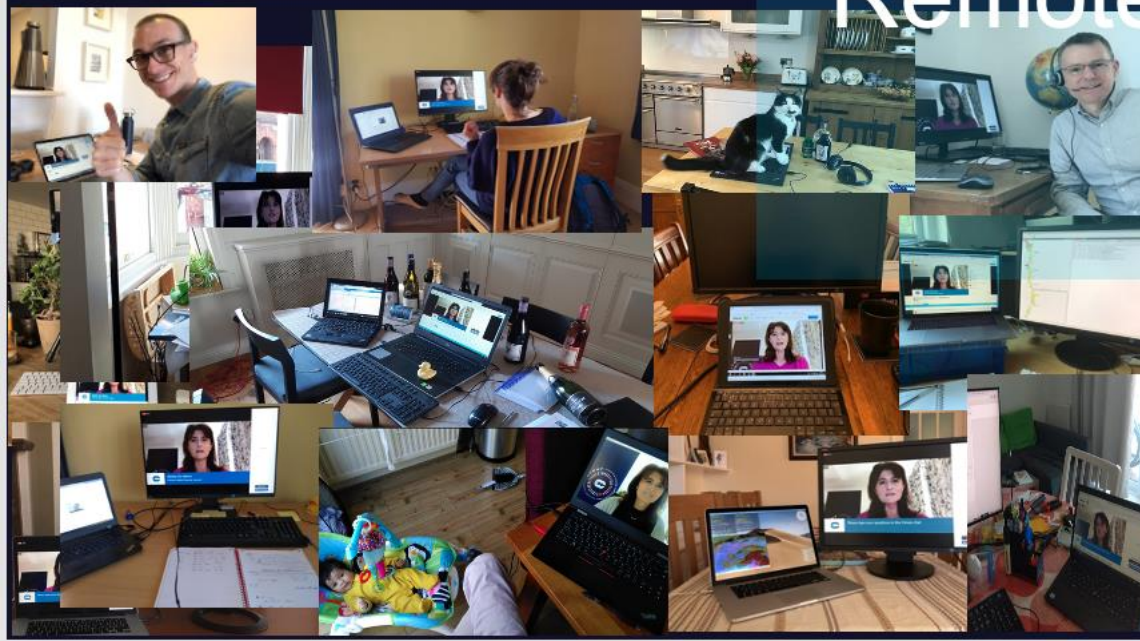


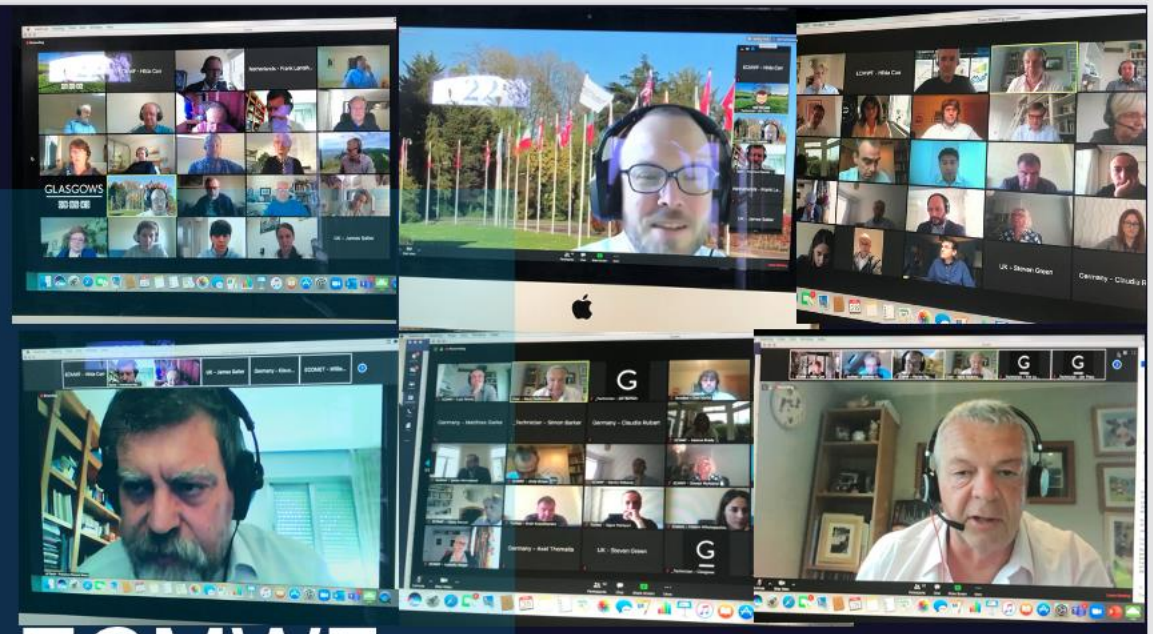
ECMWF, recent developments and severe weather forecasting

VCP Online Workshop on Development of Products from NWP Models and EPS for High-Impact Weather Forecasting

Linus Magnusson



Remote ECMWF




Interactive Analysis of ECMWF

Webinar - May 14, 2020

Iain Russell
Sándor Kertész

Development Section, ECMWF




Processing and Visualizing ECMWF Ensemble Data

Webinar - May 12, 2020

Sándor Kertész
Iain Russell

Development Section, ECMWF



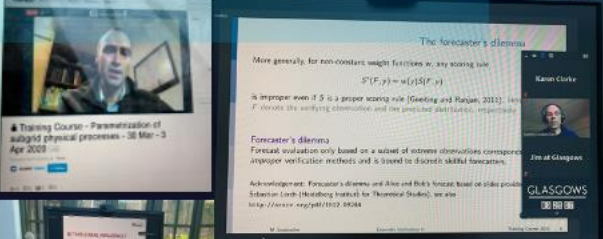
The forecaster's dilemma


More generally, for non-constant weight forecasts w , any scoring rule $S(F, y) = w(S(F, y))$ is improper even if S is a proper scoring rule (Gneiting and Balabdaño, 2010). In F denotes the underlying observation, and the posterior distribution, respectively.

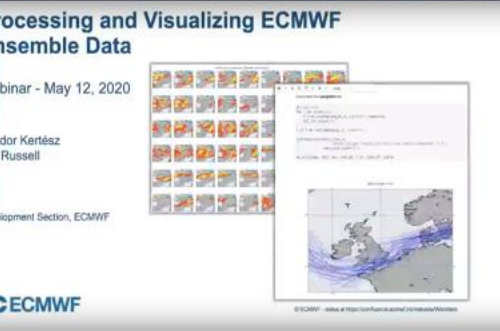
Forecaster's dilemma
Forecast evaluation only based on a subset of extreme observations corresponds to proper verification methods and is biased to biased skillful forecasts.

Acknowledgement: Forecaster's dilemma and also and Risky forecast based on older publication: Lorenz (1989) and Lorenz et al. (2006) and Lorenz et al. (2006)

Training Course - Parametrization of subgrid physical processes - 30 Mar - 3 Apr 2020







The operational ECMWF forecasting system

High resolution deterministic forecast (HRES) :

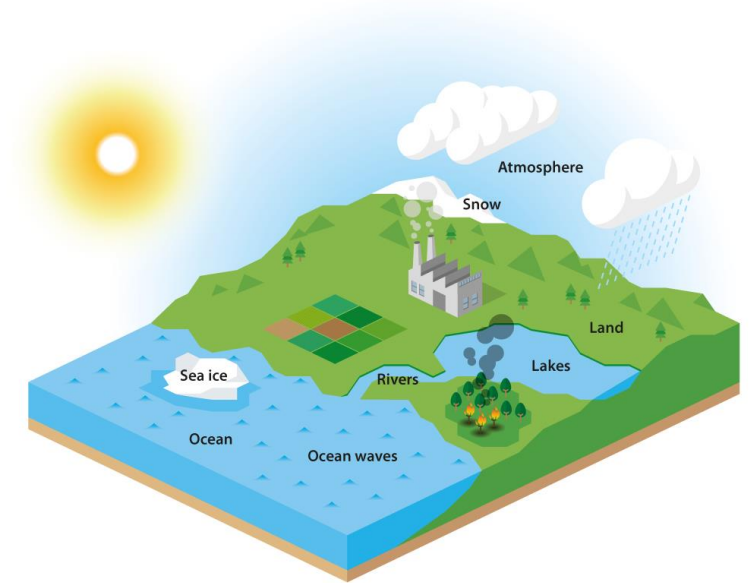
- twice per day 9 km, 137 levels, to 10 days ahead

Ensemble forecast (ENS):

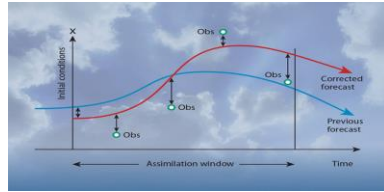
- twice per day 51 members, 18 km, 91 levels, to 15 days ahead
- Monday/Thursday 00 UTC extended to 46 days ahead with 36 km
 - Reforecast dataset with 11 members for past 20 years

Seasonal forecast: once a month

- 51-members, ~35 km 91 levels, to 7 months ahead (~38 years of hindcasts with 25 members)
- sub-set of 15 members is run for 13 months every quarter



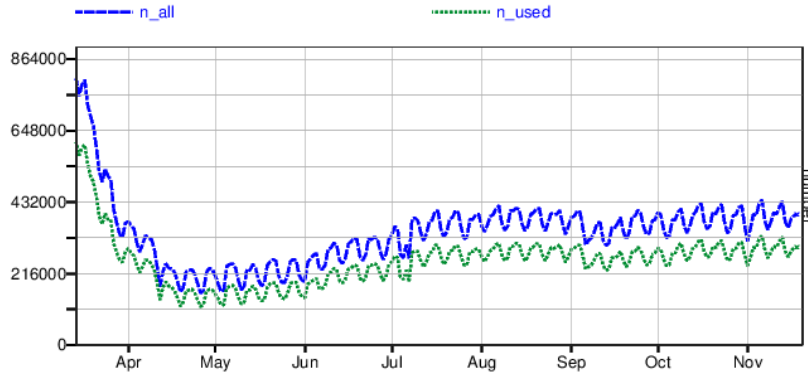
Basic steps in NWP



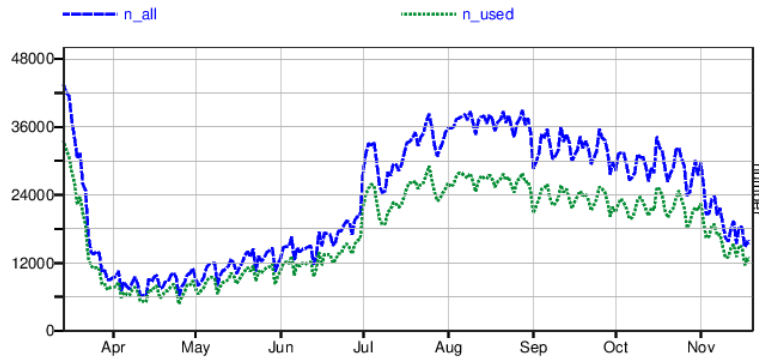
Observations	Quality control	Data assimilation	Forecast	Dissimilation	Evaluation
<u>Observation types</u> Conventional Polar satellites Geostationary sat.	Common issues	Algorithms Background error Observation error Increments	<u>Model components</u> Dynamics Atm. Physics Surface Ocean	Reliability Timeliness Post-processing Products	Daily errors Statistical evaluation Diagnostics Current issues

COVID effect on aircraft observations

Global



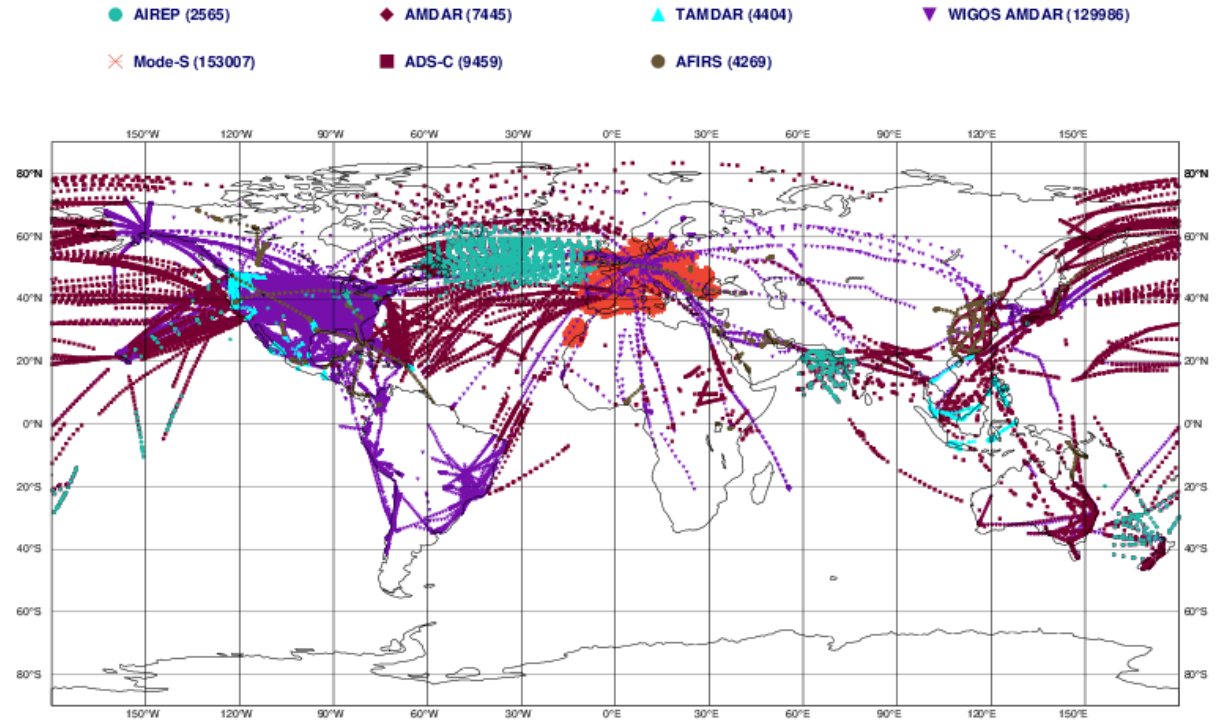
Europe



ECMWF data coverage (all observations) - AIRCRAFT

04/12/2020 00

Total number of obs = 311135



Does it affect the skill?

Model in focus

Integrated Forecasting System (IFS) cycles

- Cycle 45r1

Consistent gains in the extended range. A key plank of the upgrade is enhanced dynamic **coupling between the ocean, sea ice and the atmosphere**. The upgrade extends this coupling to ECMWF's medium-range high-resolution forecasts (9 km horizontal resolution)

- Cycle 46r1

Continuous data assimilation and introduction of a 50-member Ensemble of Data Assimilations; improvements in the wave model, the convection scheme, the radiation scheme and the use of observations.

- Cycle 47r1

Improved treatment of observations. Improvements in the data assimilation and to the model. Quintic vertical interpolation in the semi-Lagrangian advection scheme has been introduced as well as the inclusion of a better surface albedo climatology making use of more data from the MODIS instrument.

- Cycle 47r2

Single precision and increased number of ENS model levels (91 to 137)

2018

6 Jun.

45r1

2019

Q2

46r1

2020

30 Jun.

47r1

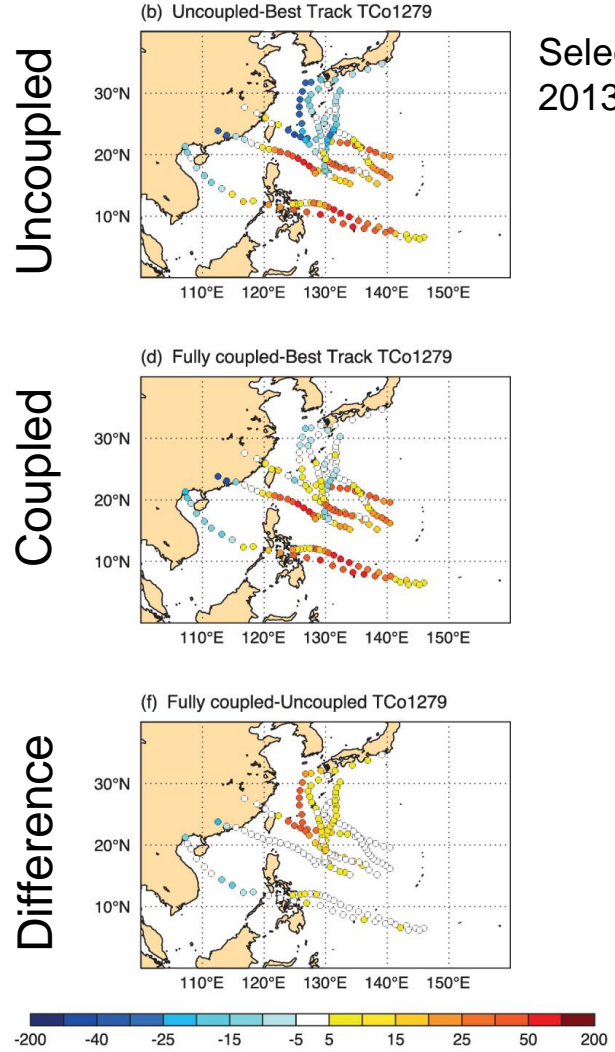
2021

Q2

47r2

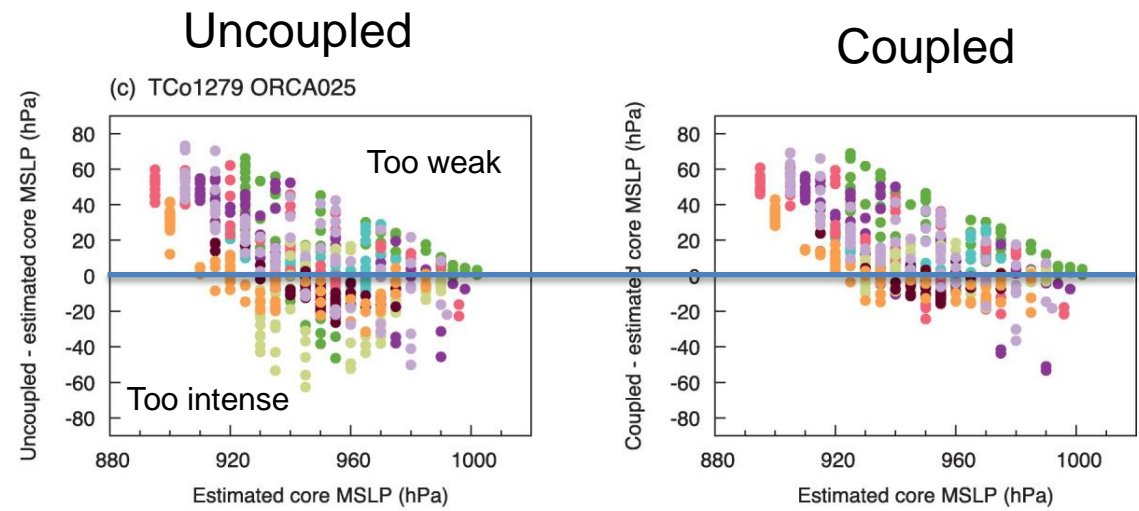
Cycle 45r1: Effect of ocean coupling on tropical cyclones

Central pressure error



Selection of test cases from 2013/2014

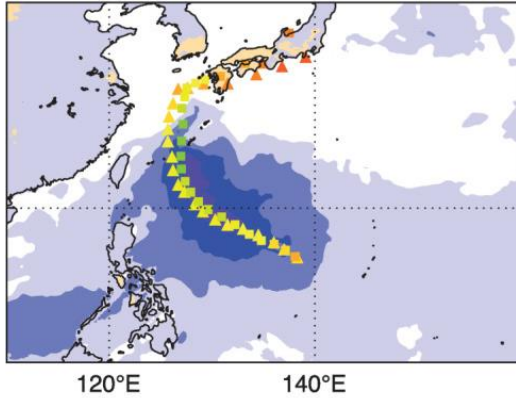
From Mogensen, Magnusson and Bidlot (2017)
<https://doi.org/10.1002/2017JC012753>



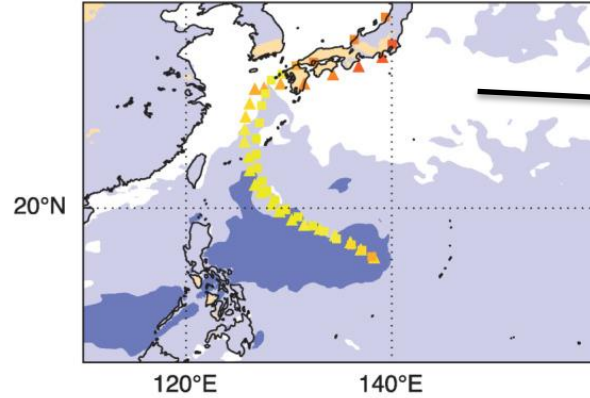
- Soulik
- Usagi
- Francisco
- Haiyan
- Neoguri
- Halong
- Vongfong
- Hagupit

Heat flux under the cyclones

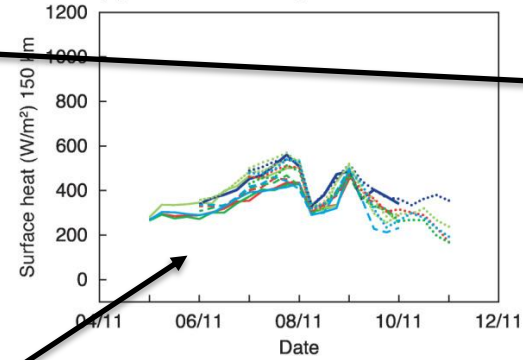
(c) Uncoupled TCo1279



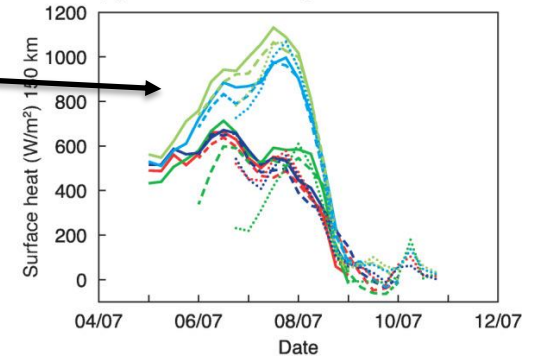
(d) ORCA025 TCo1279



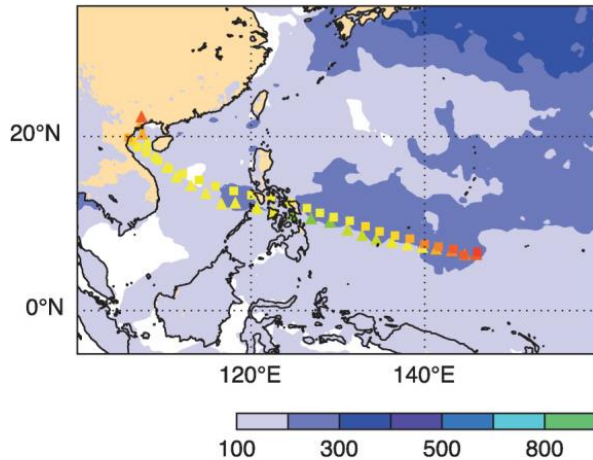
(a) Heat-flux TC Haiyan



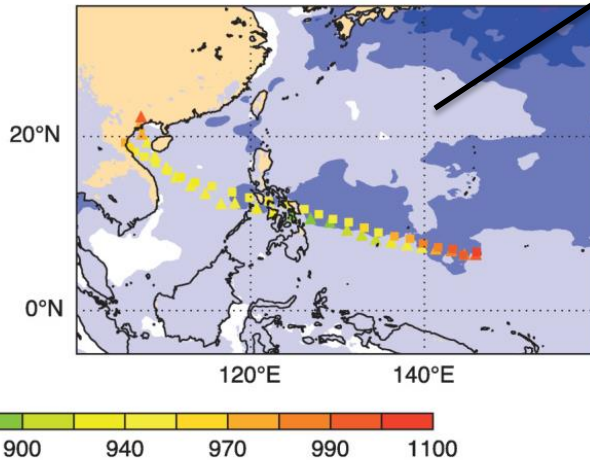
(b) Heat-flux TC Neoguri



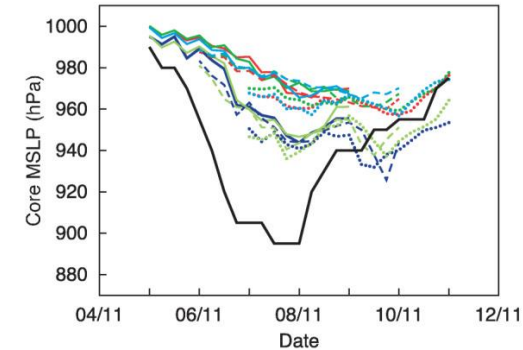
(c) Uncoupled TCo1279 - Haiyan



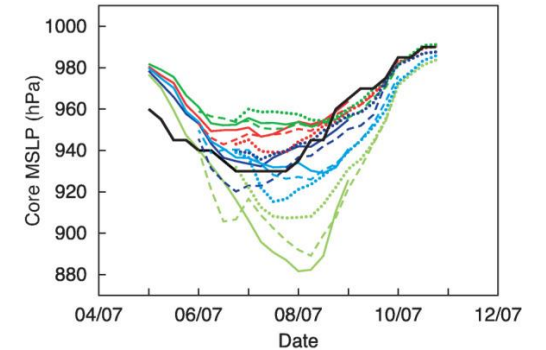
(d) ORCA025 TCo1279 - Haiyan



(c) Minimum pressure TC Haiyan



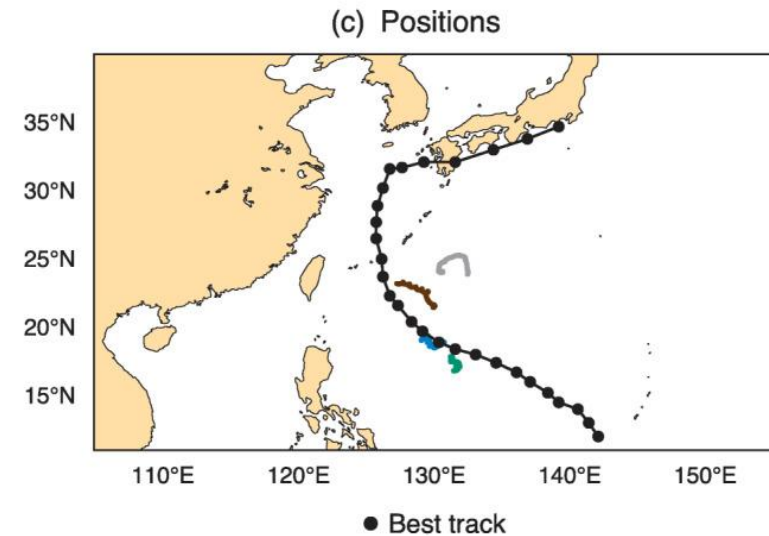
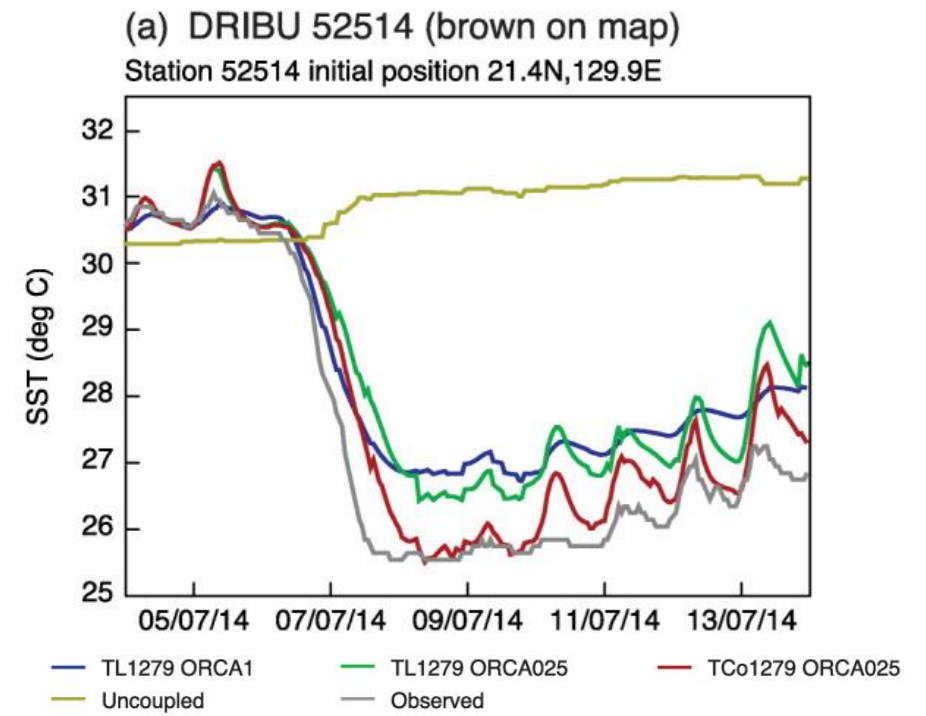
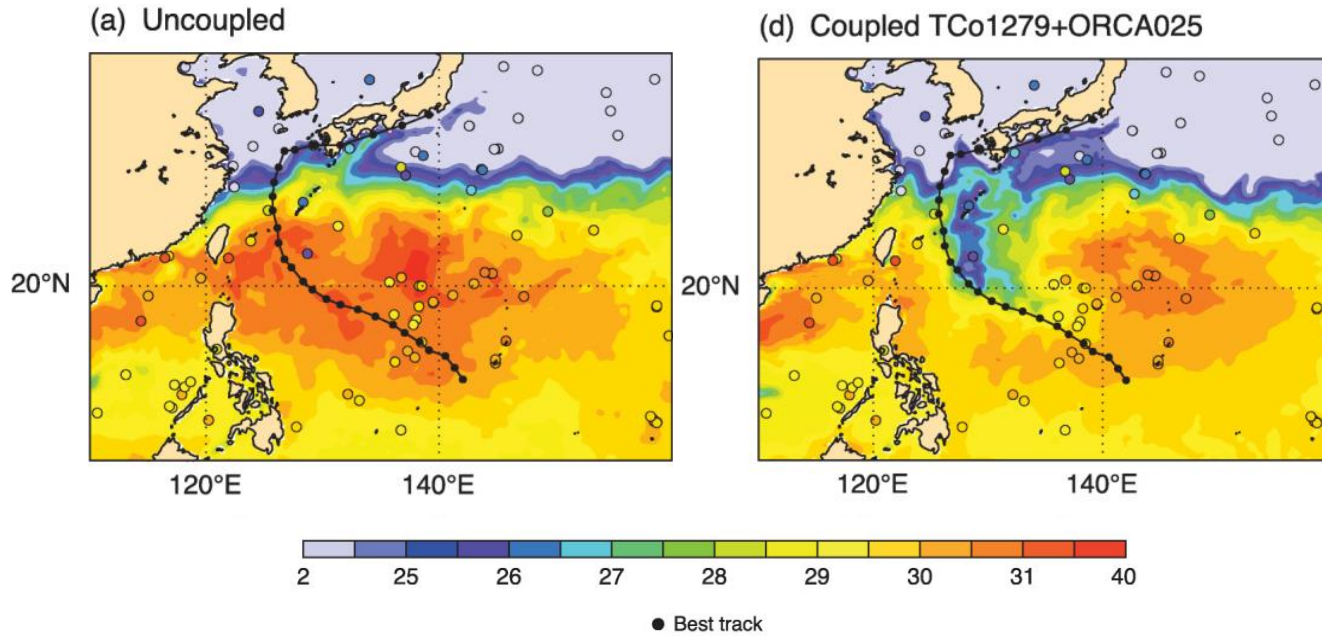
(d) Minimum pressure TC Neoguri



— TL1279 ORCA025 — TL1279 ORCA1 — TCo1279 ORCA025
— TCo1279 Uncoup — TL1279 Uncoup — Estimated

▲ Best estimate ■ Model

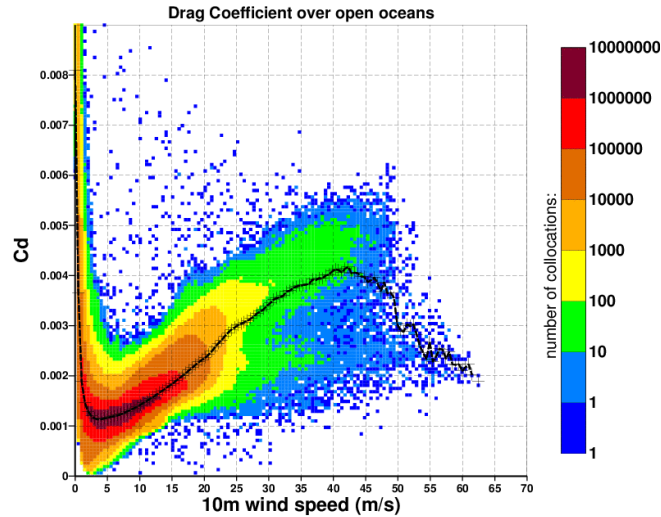
Effect on sea-surface temperature



Cycle 47r1: Changes in the Drag Coefficient

See <https://www.ecmwf.int/en/newsletter/164/meteorology/enhancing-tropical-cyclone-wind-forecasts>

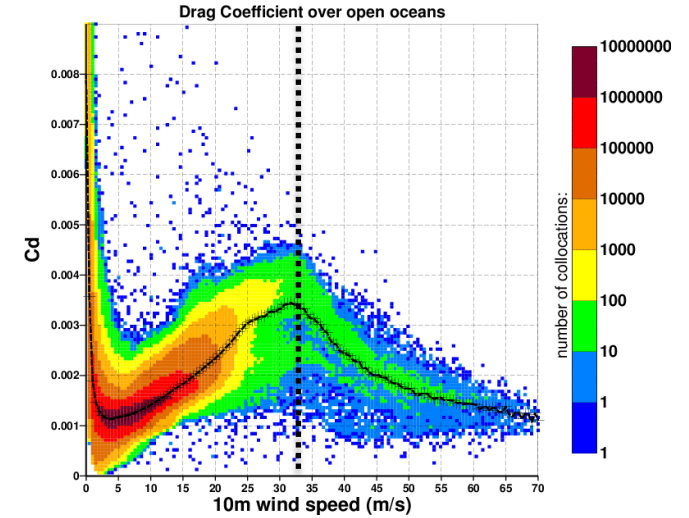
46r1



TCo1999 forecast
h5jx from 20170904 step 6 to 240 by 6

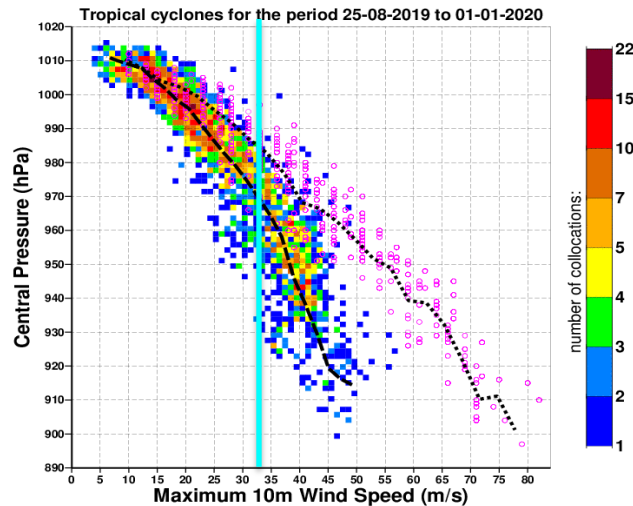
Drag Coefficient & 10 m winds
Tco1999 2017-09-04 00Z +240h
during Hurricane Irma

47r1



TCo1999 forecast
h517 from 20170904 step 6 to 240 by 6

46r1

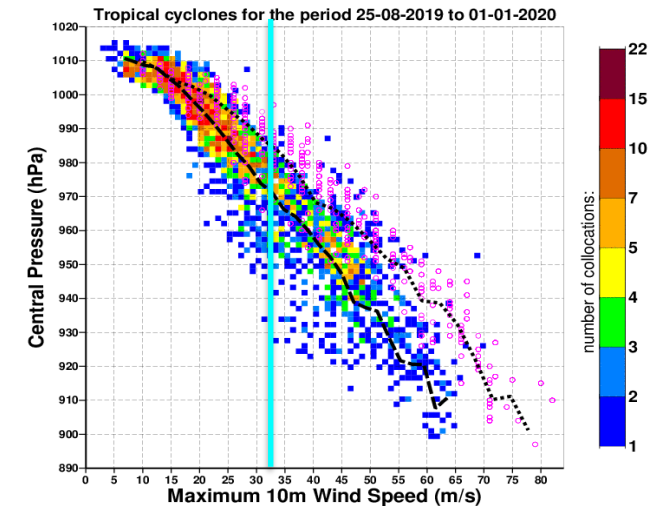


Colour shading and dashed line: TCo1279 forecasts (h9s0), all forecasts initialised from 0 UTC.
Pink symbols and dotted line: Best Track data.

Minimum mslp & Max 10m winds
Tco1279; 25 Aug 2019 to 1Jan 2020

pink squares: Best track data
other colour squares: Tco1279 +240h

47r1

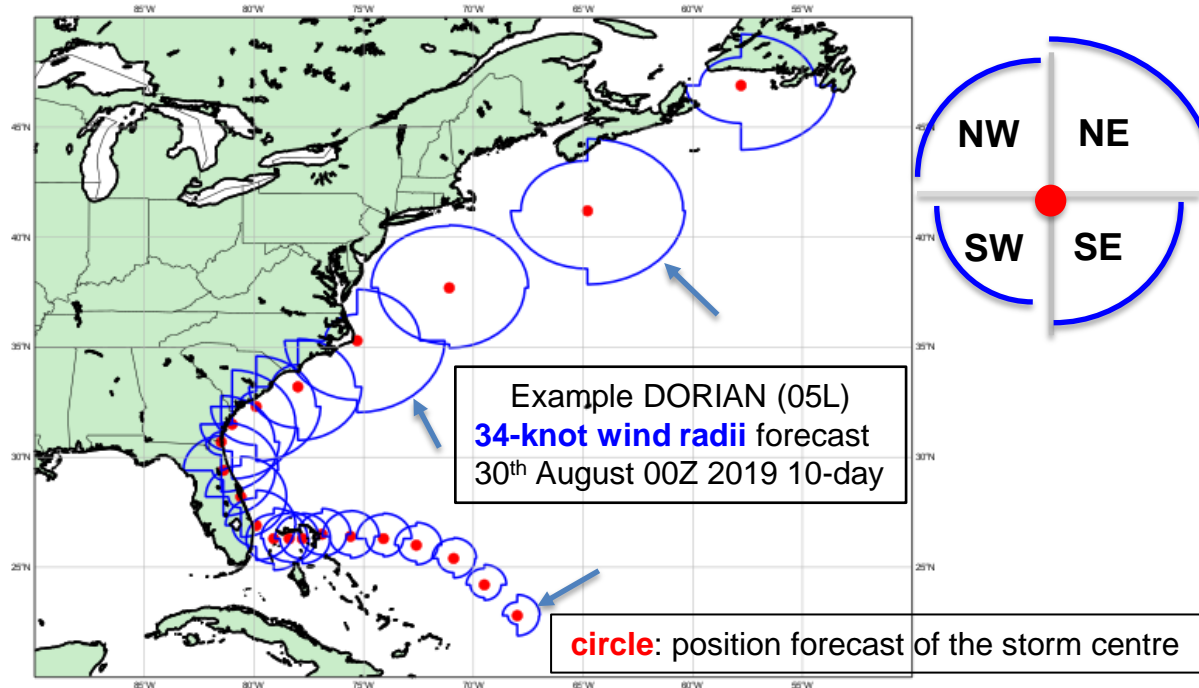


Colour shading and dashed line: TCo1279 forecasts (h9s3), all forecasts initialised from 0 UTC.
Pink symbols and dotted line: Best Track data.

Products in focus

Tropical Cyclone Size: Wind Radii (34-, 50- & 64-kts)

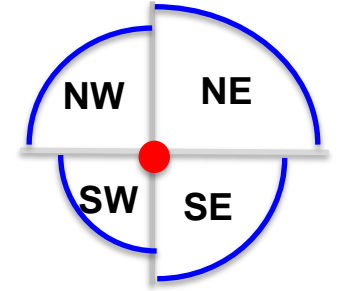
Radii: maximum extent of 10-m wind thresholds (34-, 50 & 64-kt) in each quadrant (NE, SE, SW & NW) from the TC centre (products are freely available)



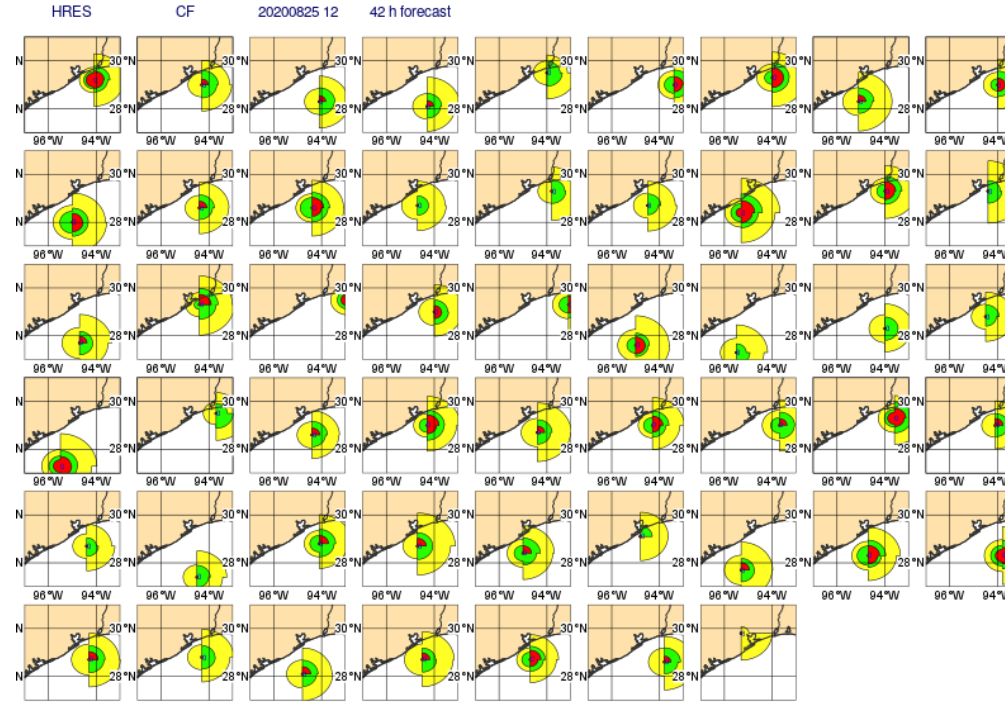
- Product available for the HRES and ENS (all TCs in analysis and those that develop during the forecast –'genesis
- Can be helpful to 1) identifying coastal areas potentially affected by winds of TS strength or higher; 2) ship routing forecast

More information in <https://confluence.ecmwf.int/display/FCST/New+Tropical+Cyclone+Wind+Radii+product>

Tropical Cyclone Size: Wind Radii (34-, 50- & 64-kts)



- Radii: maximum extent of 10-m wind thresholds (34-, 50- & 64-kn) in each quadrant (NE, SE, SW & NW) from the TC centre.



w radii (nmi)

64-kn

50-kn

34-kn

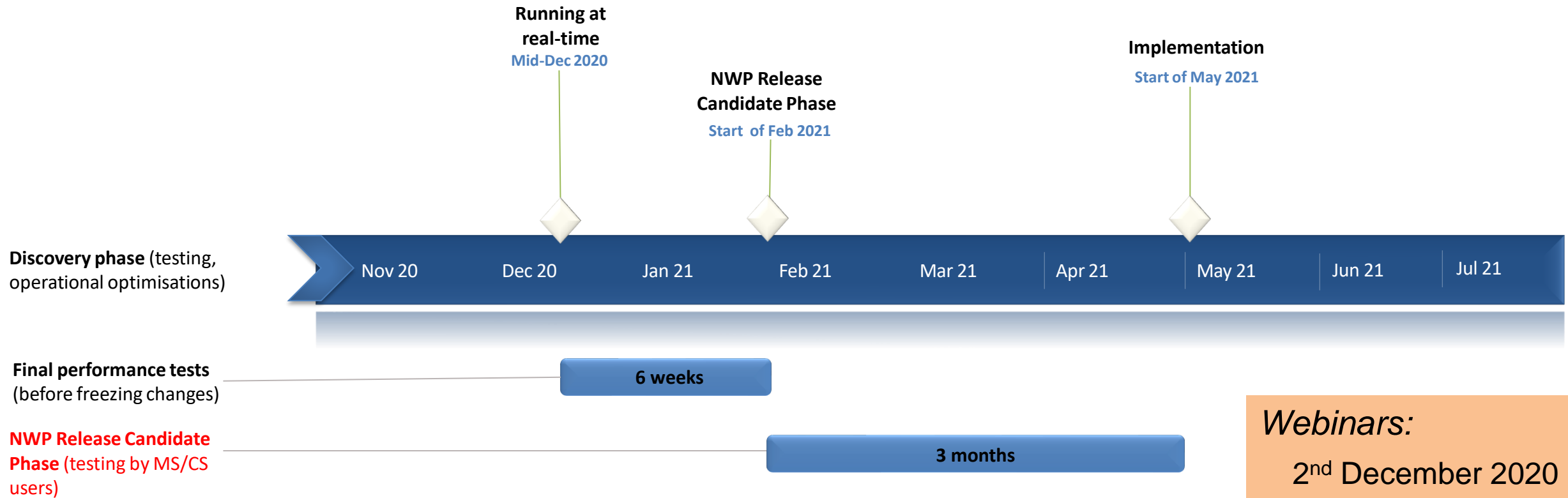
- Product available for the HRES and ENS (all TCs in analysis and those that develop during the forecast –'genesis')
 - **BUFR message for dissemination** <https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+47r1> (under "WMO essential")
- More information in <https://confluence.ecmwf.int/display/FCST/New+Tropical+Cyclone+Wind+Radii+product>

Model in focus

	2019 plans	2020 plans
47r2 (Spring 2021)		<p>Single precision (HRES fc, ENS, extended-range)</p> <p>Unified vertical resolution (ENS, extended-range to L137)</p>
48r1 (2022)	<p>Single precision (HRES fc, ENS, extended-range)</p> <p>Unified vertical resolution (ENS, extended-range to L137)</p> <p>ENS horizontal resolution increase to 9-11 km</p> <p>Daily extended-range ensembles (ideally 51 members)</p> <p>Moist physics upgrade, multi-layer snow scheme</p>	<p>ENS horizontal resolution increase to 9-11 km</p> <p>Daily extended-range ensembles (100 members)</p> <p>Moist physics upgrade, multi-layer snow scheme</p> <p>OOPS (multi-executable) operational implementation</p>
49r1 (2023)	<p>COPE and OOPS operational implementation</p> <p>NEMO 4, SI3</p> <p>Multi-layer surface variables / multi-layer soil scheme</p>	<p>COPE operational implementation</p> <p>NEMO 4, SI3</p> <p>Multi-layer surface variables / multi-layer soil scheme</p>

Model in focus

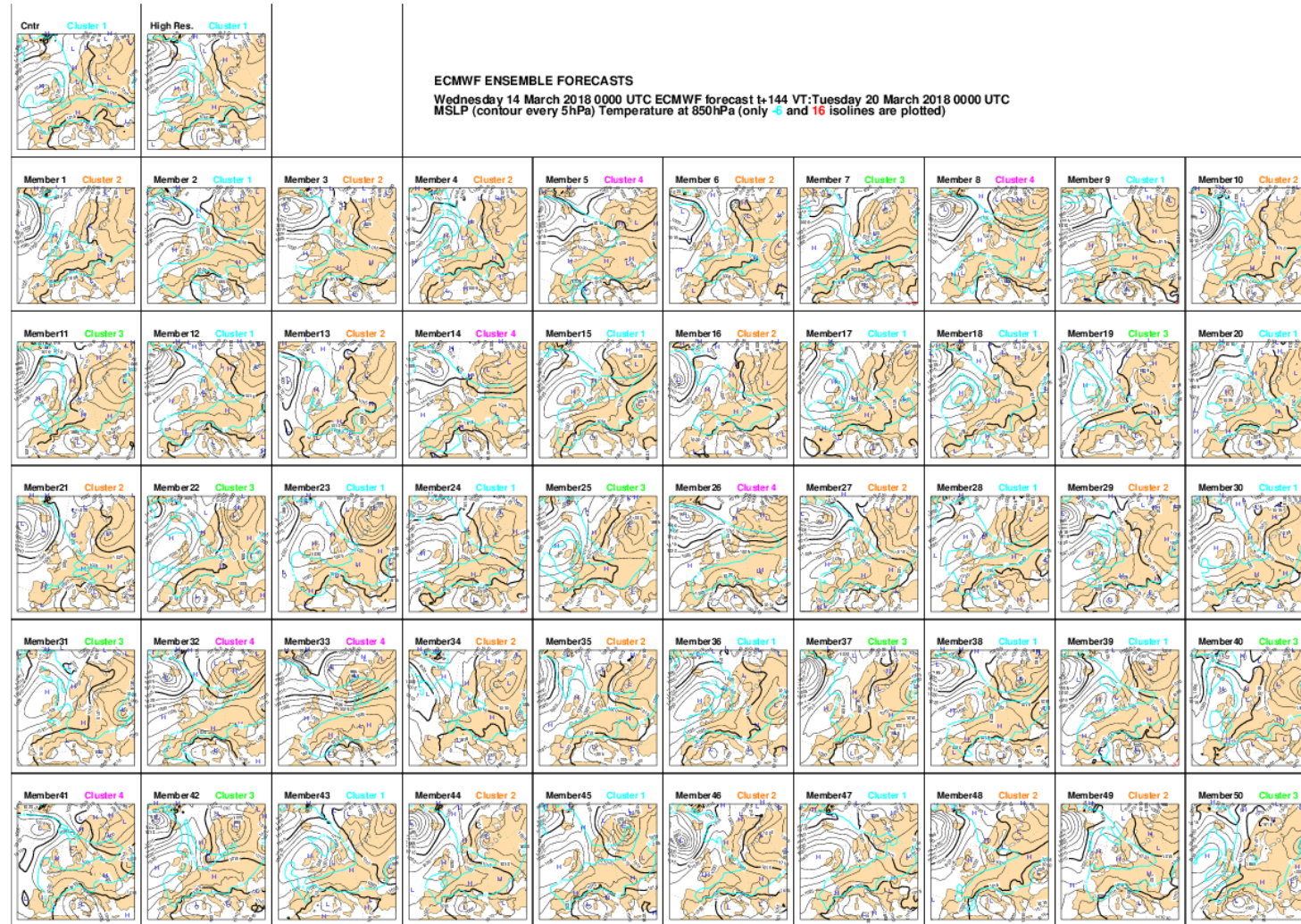
Implementation of cycle 47r2



Webinars:

- 2nd December 2020
- 15th December 2020
- 16th April 2021

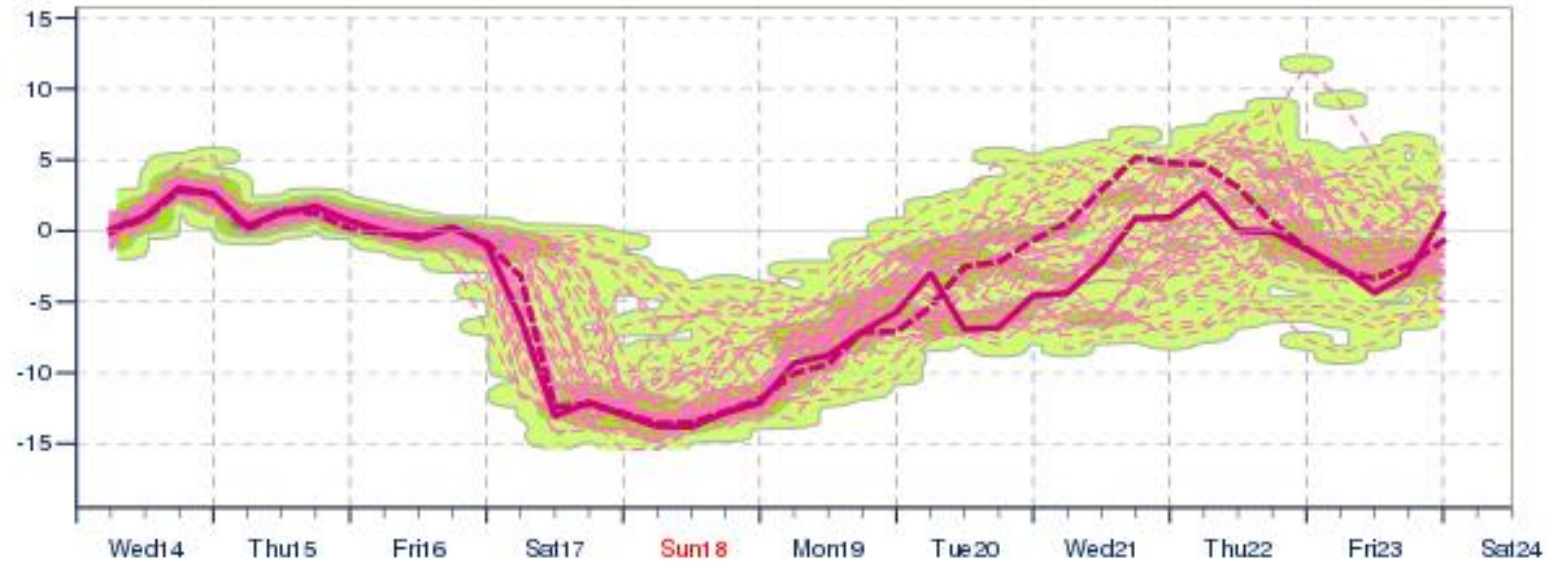
Ensemble aspects



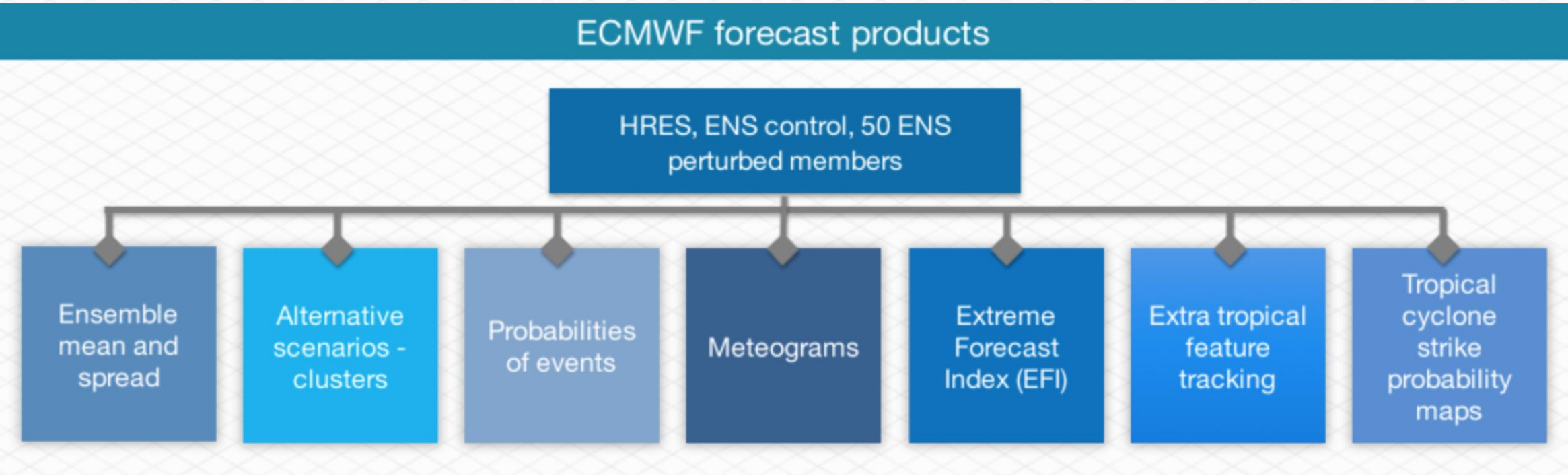
Construction of ensemble members

$$\text{Perturbed forecast} = \text{Optimal analysis} + \text{Initial Perturbations} + \text{Model Perturbations}$$

Perturbations added to a subset or all model variables



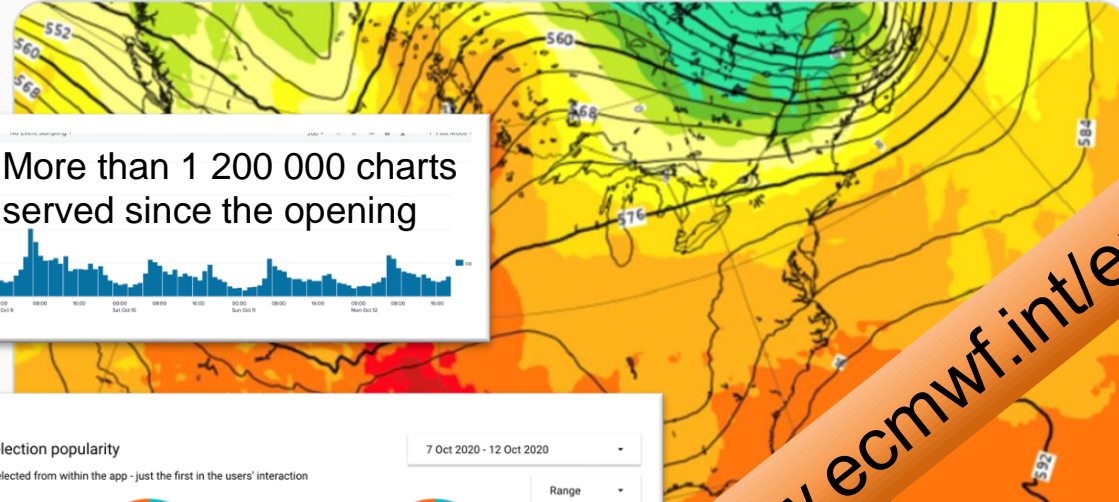
Forecast products



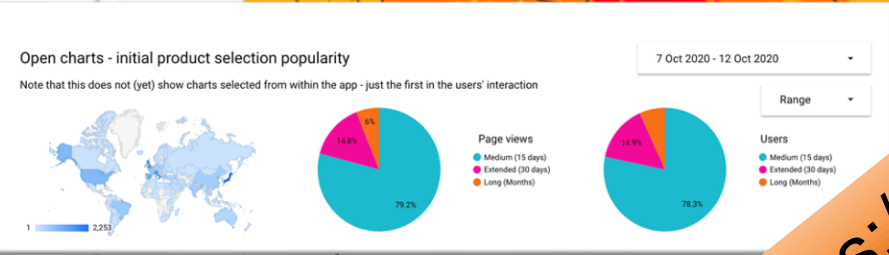
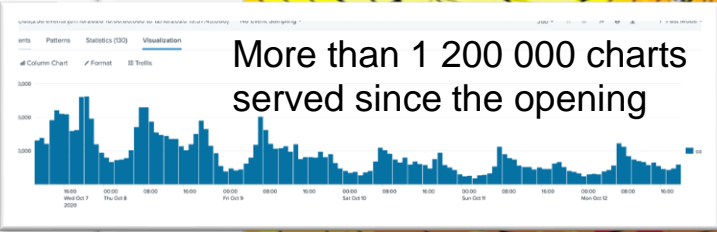
But first



the Weatherboy @theWeatherboy · 19h
Great news from the EU and @ECMWF & @CopernicusECMWF: data & maps that were once under lock & key are now becoming available to the public around the world for free!



<https://www.ecmwf.int/en/forecasts/charts>



When it comes to two global... forecast models, the An...
GFS and the European ECMW...
... as the gold standard
weatherboy.com

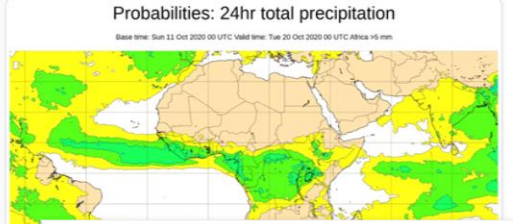


Title	Page Views	Users
1. Rain and mean sea level pressure	5,017	3,540
2. Mean sea level pressure and wind speed at 850 hPa	3,681	2,921
3. Geopotential 500 hPa and temperature at 850 hPa	2,045	1,542

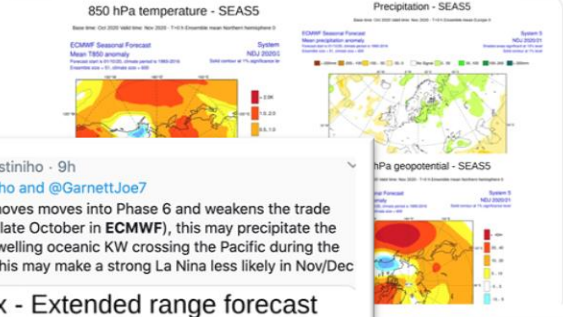
METEOROID @METEOROID · 21
#Gibraltar - 12/10 - as flagged up last week - models continue to steer towards the possibility of some more unsettled weather next week - here is the latest Meteogram from the ECMWF model updated as of Friday 22nd October.



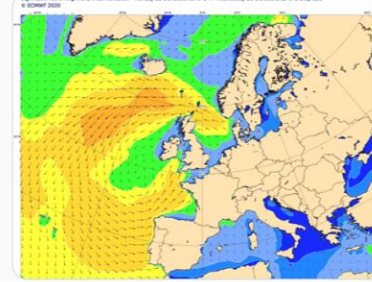
RAM Revista del Aficionado a la Meteorología @RAM_m... · Oct 11
Mapas probabilísticos diarios de que se superen precipitaciones acumuladas de 1, 5, 10 y 20 mm en 24 horas basados en modelo EPS ECMWF



Mehmet Eren @mehmeterenwx
Replying to @mehmeterenwx
vma ecmwf umut vermiyor .akin daha çok erken
Translate Tweet

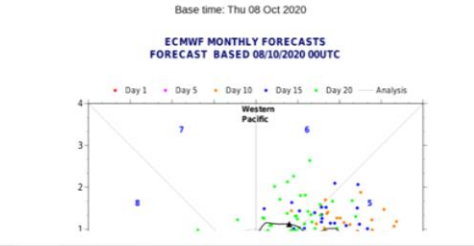


Richard Martin-Barton @RMBwx · 4h
Having a look through the amazing @ECMWF chart repository... big waves simulated around W Europe next week as significant troughing develops. Good for the surfers!



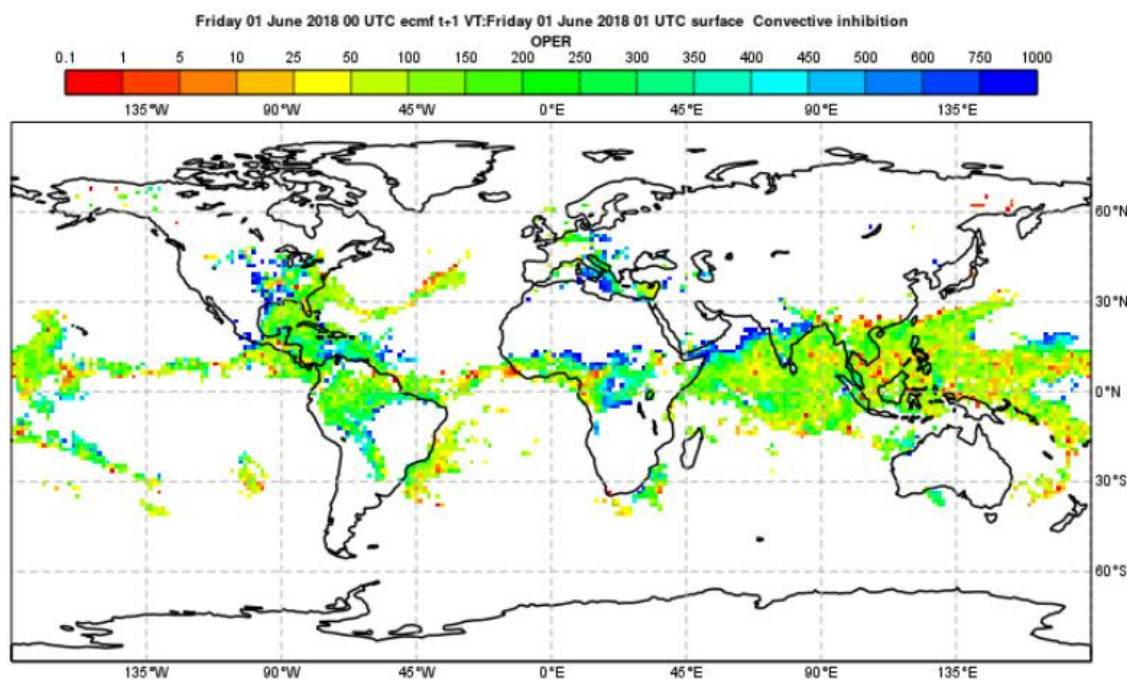
Nick Silkstone @Silkstiniho · 9h
Replying to @Silkstiniho and @GarnettJoe7
I wonder if the MJO moves into Phase 6 and weakens the trade winds (some support late October in ECMWF), this may precipitate the generation of a downwelling oceanic KW crossing the Pacific during the following 2 months. This may make a strong La Nina less likely in Nov/Dec

MJO index - Extended range forecast

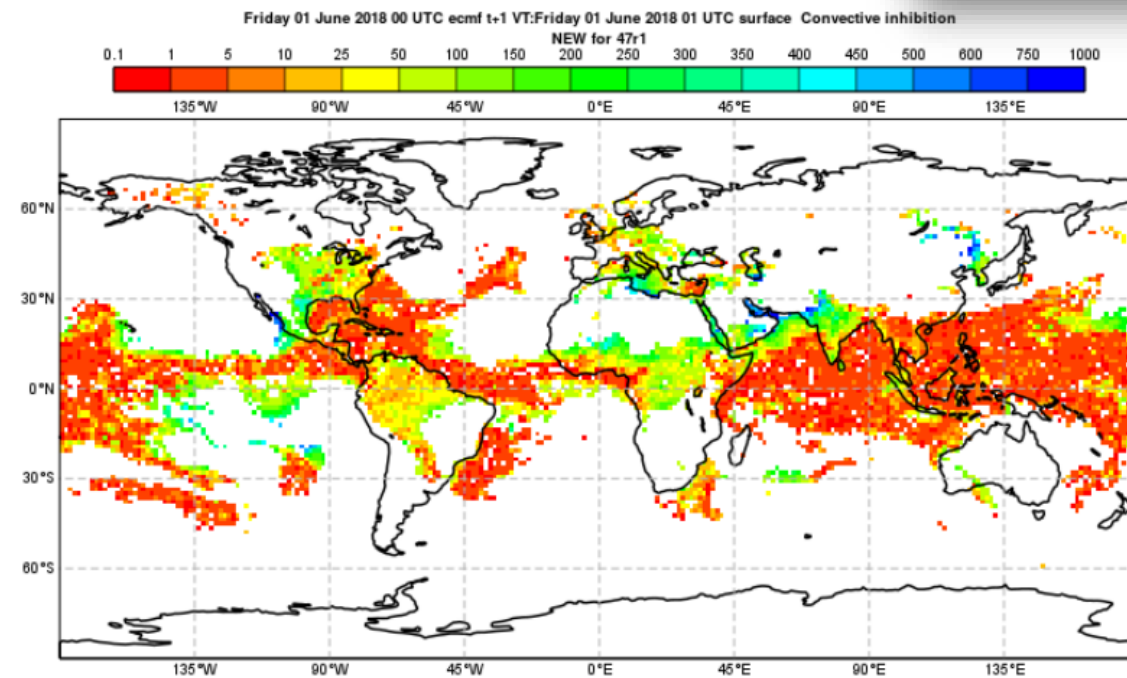


Products in focus

Convective inhibition diagnostic (CIN)



46r1



47r1

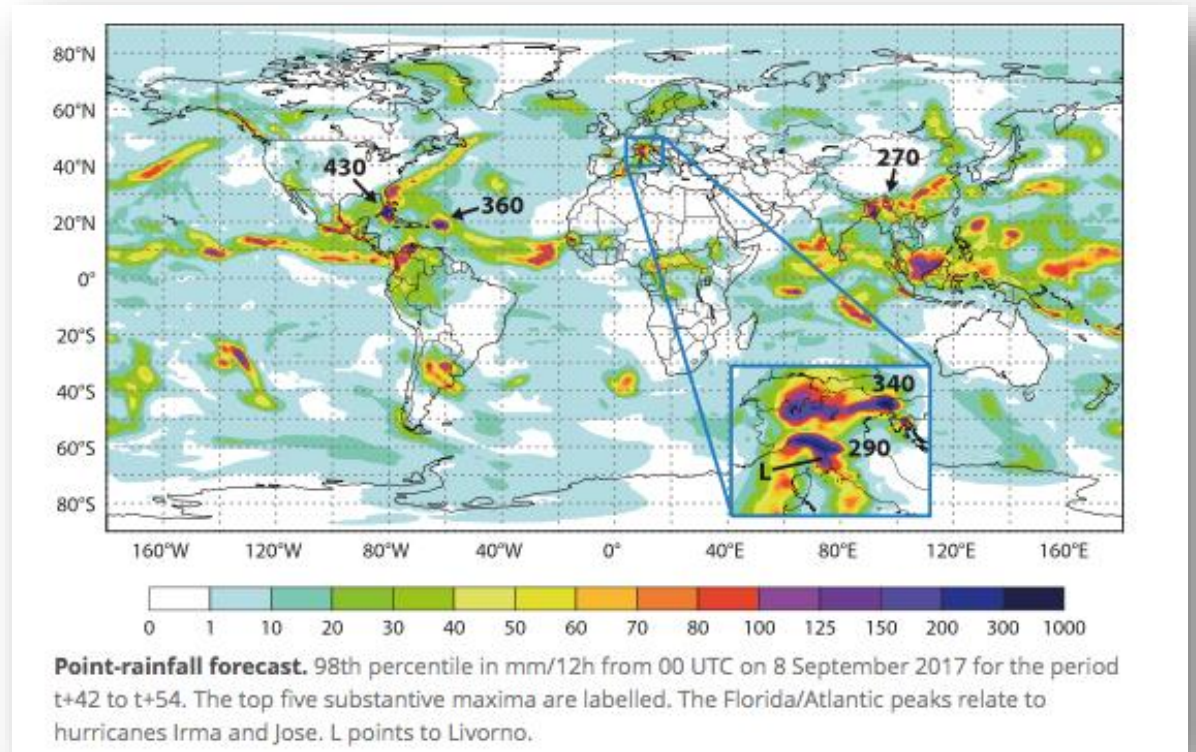
- CIN has been revised to use virtual potential temperature instead of equivalent potential temperature
- Considerable reduction in average CIN values

Products in focus

Point-rainfall forecasts for flash flood predictions

The product aims to bridge the gap between the relatively coarse resolution and higher-resolution limited-area models needed to describe localised heavy rainfall.

Post-processing method blends together information from different locations with similar rainfall generation mechanisms (assumptions: physical mechanisms are universal and dependent on key atmospheric and geographic properties)



<https://www.ecmwf.int/en/newsletter/153/news/new-point-rainfall-forecasts-flash-flood-prediction>

Products in focus

Lightning density parameters

Four lightning density parameters:

- Instantaneous total lightning flash density (litoti)
- Averaged total lightning flash density in the last hour (litota1)
- Averaged total lightning flash density in the last 3 hours (litota3)
- Averaged total lightning flash density in the last 6 hours (litota6)

“Total” - cloud-to-ground and intra-cloud flashes

Parametrization in IFS convective hydrometeor amounts, CAPE and convective cloud base height

Instantaneous - flash density during one model time step of the model (so prone to larger errors)



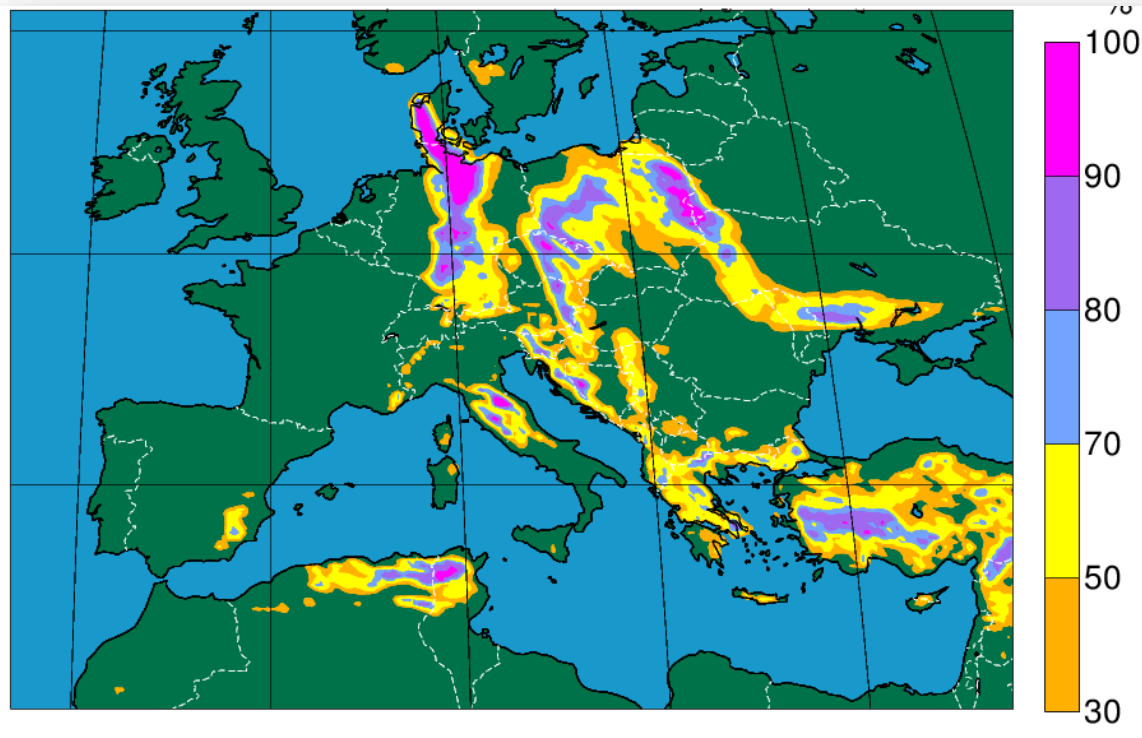
Products in focus

Lightning density parameters

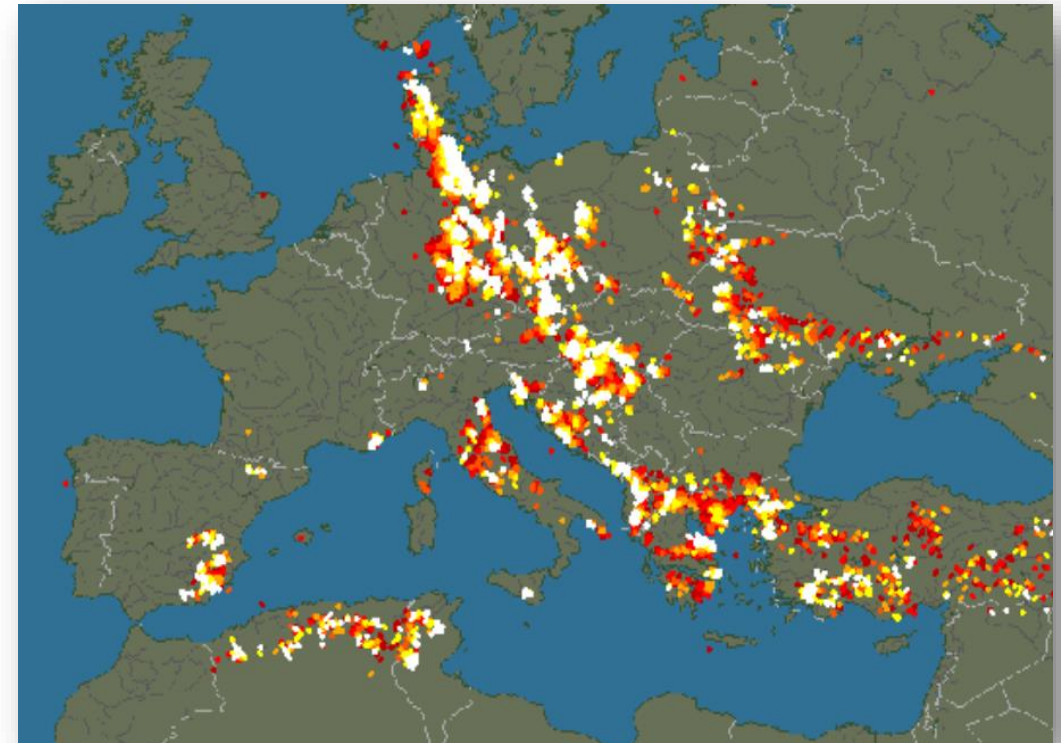
Ensemble forecast from 45r1 esuite

Prob(flash density) > 0.1 fl/100km²/h

10 May 2018 00 UTC, range: 12-15 hours

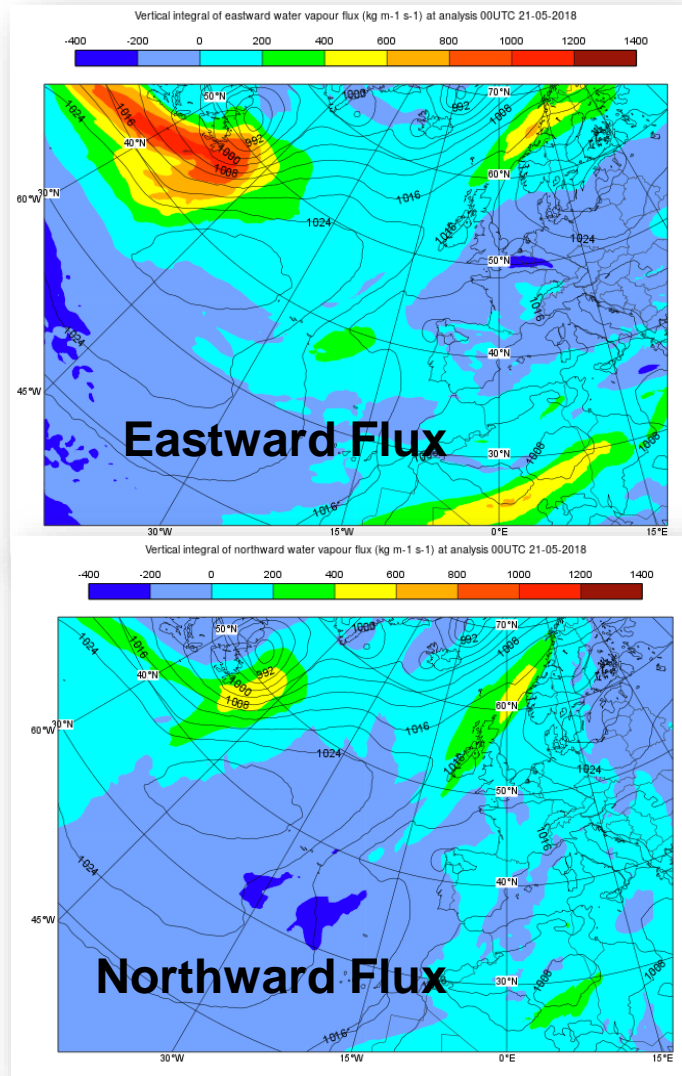


Observed lightning strikes (Blitzortung.org)
10 May 2018 12 to 15 UTC

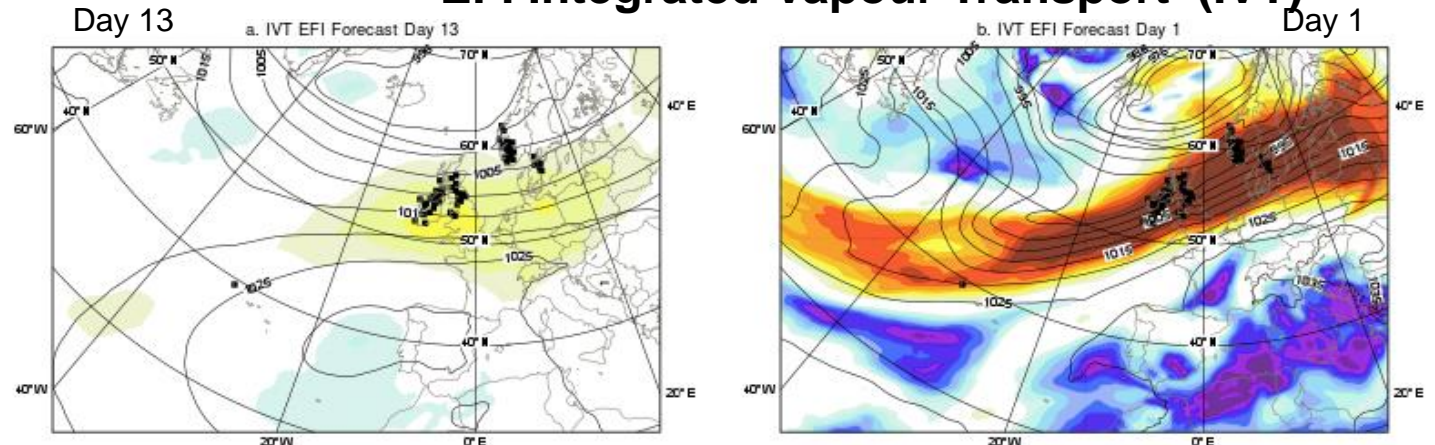


Products in focus

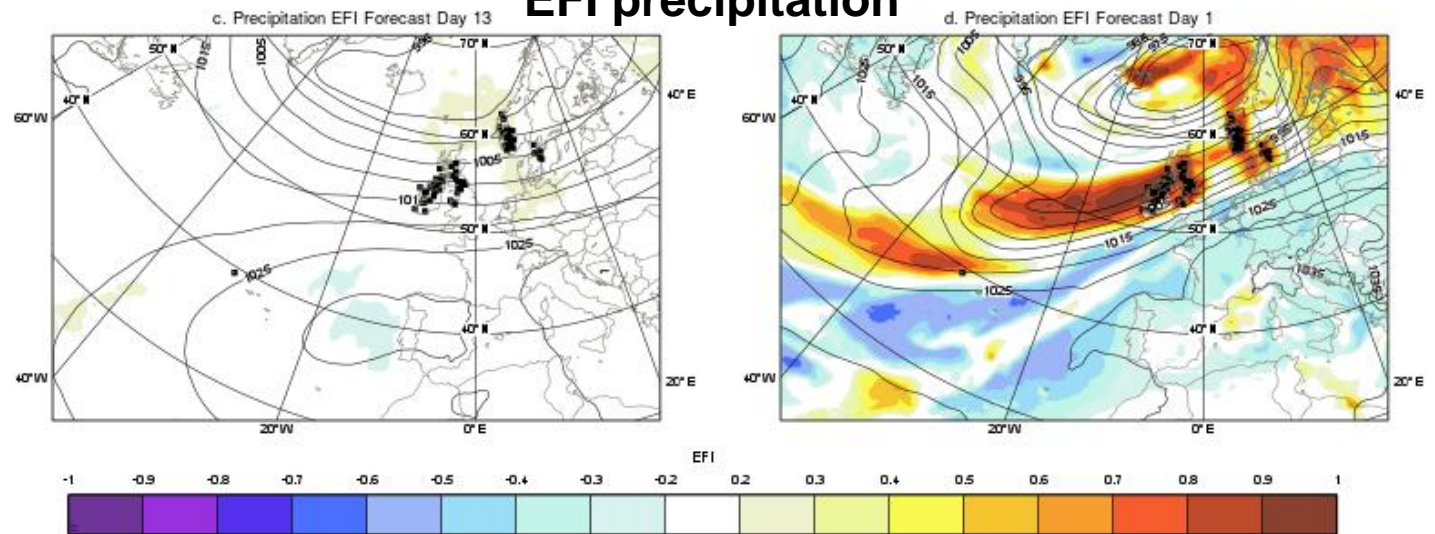
Vertical integral of eastward and northward water vapour flux



EFI Integrated Vapour Transport (IVT)



EFI precipitation



Outreach in focus

User guide to ECMWF products

ECMWF Spaces Calendars Create Search

Forecast User Guide

SPACE SHORTCUTS

- Forecast User Home

PAGE TREE

- 1 Introduction
- 2 The ECMWF Integrated Forecasting System - IFS
- 3 Availability and Interpolation of NWP output
- 4 NWP Evolution versus Reality
- 5 Forecast Ensemble (ENS) - Rationale and Construction
- 6 Using Deterministic and Probabilistic Forecasts
- 7 ENS Products - Dealing with Uncertainty
- 8 ENS Products - What they are and how to use them
- 9 Physical Considerations when Interpreting Model Output
- 10 Interfaces for displaying Model Output
- 11 Conclusion
- 12 Appendices

Pages

Forecast User Guide

Search this user guide for ...

"Behind good forecast practices are often hidden good theories; equally, good theories should provide a basis for good forecast practices." Professor Tor Bergeron, personal communication, 1974

The aim of this User Guide is to help meteorologists make the best use of the forecast products from ECMWF - to increase understanding of the ensemble forecast process, to develop new products, to reach new sectors of society, to satisfy new demands. The User Guide presents the Integrated Forecasting System (IFS) and advises on how best to use the output, not least on how to build up trust in the forecast information. A good forecast that is not trusted is a worthless forecast. The emphasis is on the medium-range forecast products, as this is ECMWF's primary goal, and because medium-range NWP output generally differs significantly from dealing with short-range or seasonal NWP.

This guide is intended to give an outline of structure and use of the ECMWF IFS and how the high-resolution forecast (HRES), ensemble forecast (ENS), extended range forecast and seasonal forecast models inter-depend and interact. Links to more detailed descriptions of processes are given, mainly at the end of each section, whilst separate online ECMWF training resources are also available to explain aspects of the ECMWF IFS more visually. Education is a key component of the work at ECMWF and further educational material is available through the web site (e.g. Webinars (recordings), Slidecasts (slides and audio recordings), Tutorials, Training lectures (presentations in PDF))

Space tools

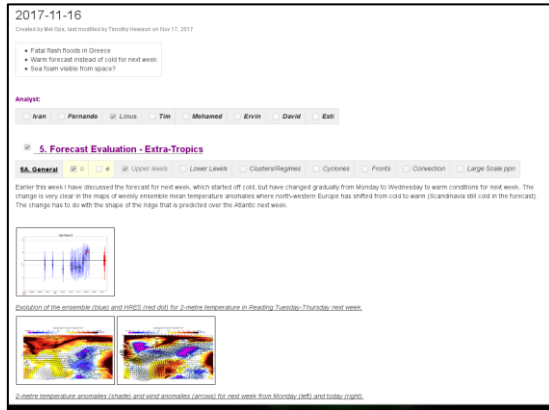
<https://software.ecmwf.int/wiki/display/FUG/Forecast+User+Guide>

Forecast quality monitoring at ECMWF

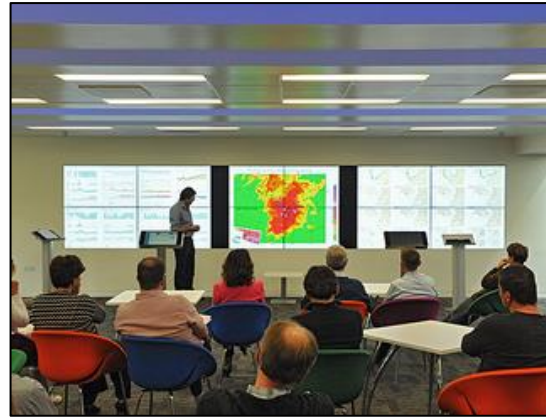
Questions from users



Daily report



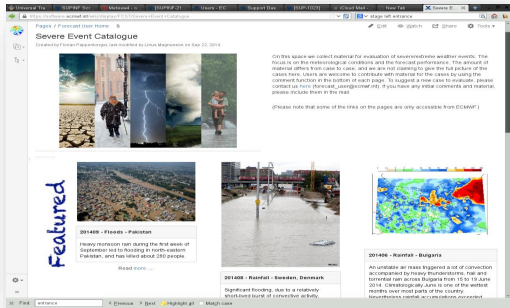
Weekly weather discussions



Quarterly evaluation and development meeting



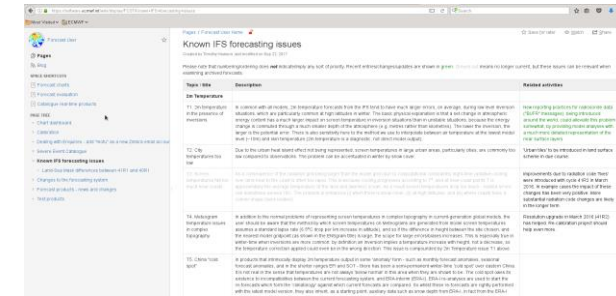
Severe event catalogue



New model cycles

Research activities

Known forecast issues



Forecast performance in focus

Forecast performance: headline scores

2 primary scores

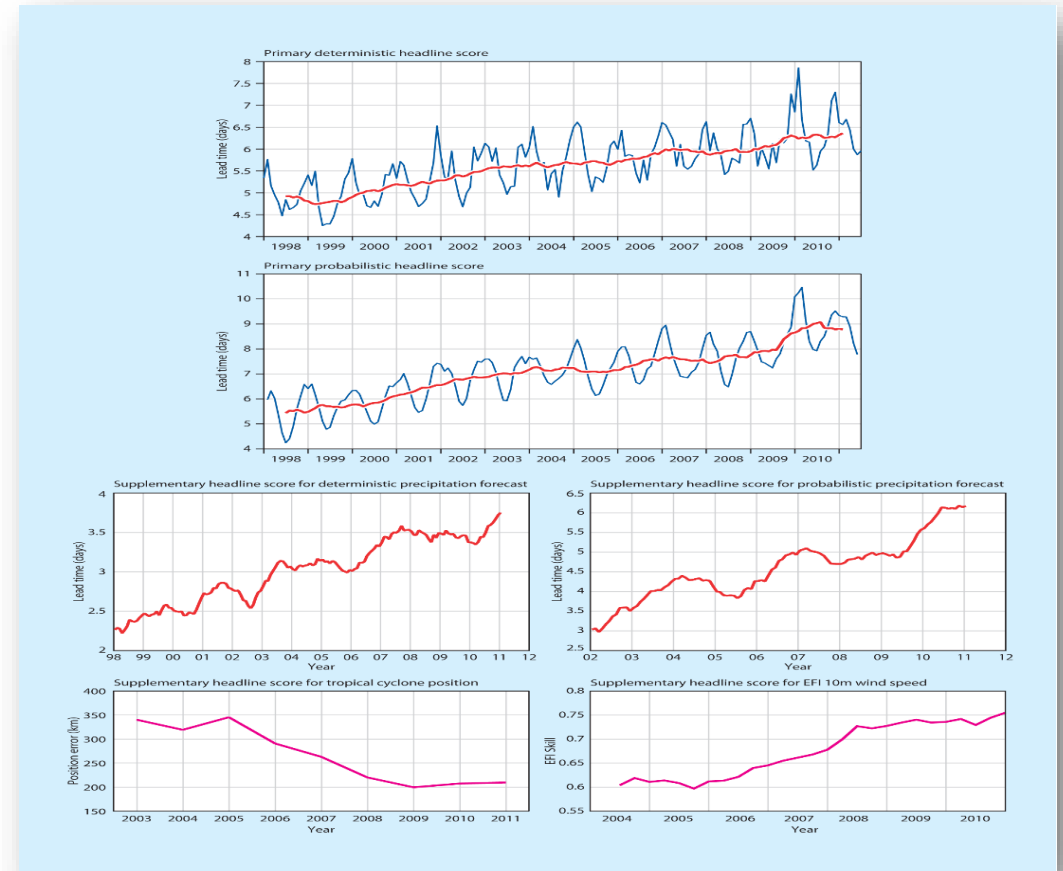
- HRES upper-air skill
- ENS upper-air skill

6 supplementary scores

- Precipitation
- HRES skill
- ENS skill
- Percentage of large temperature errors
- Weekly mean 2m temperature (terciles)

Severe weather

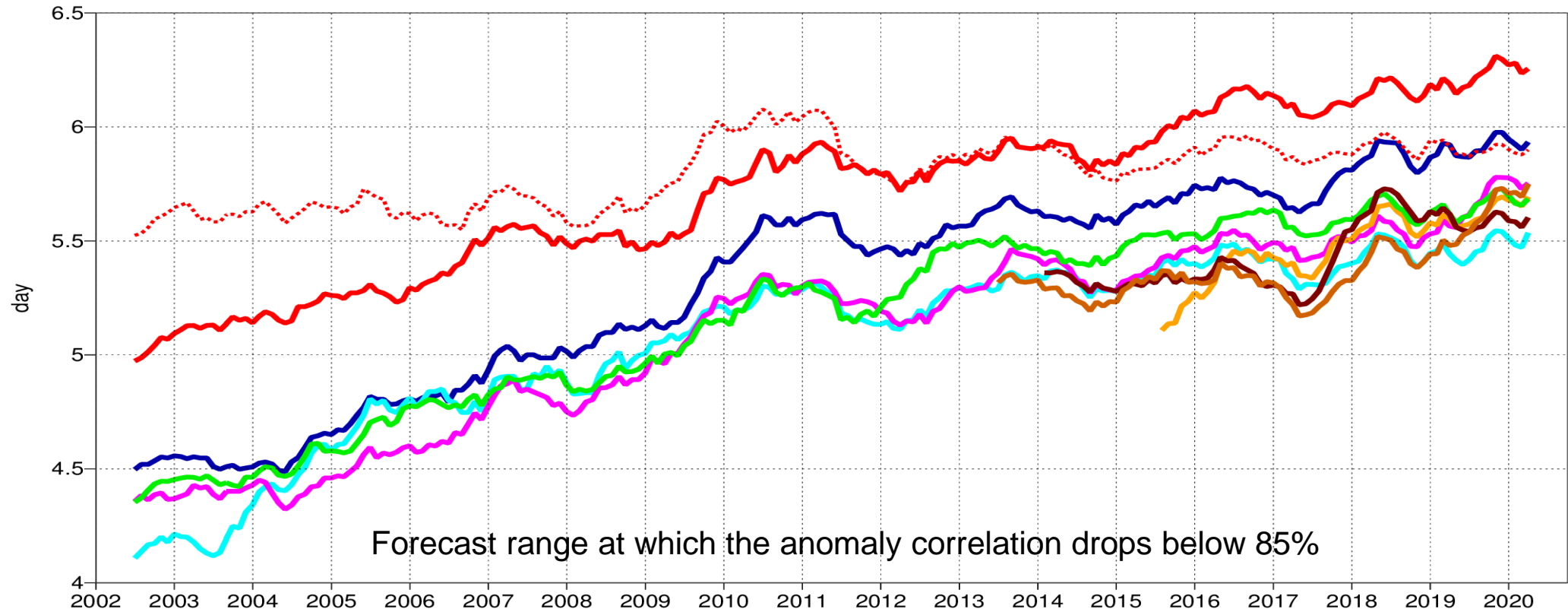
- Tropical cyclone track position error
- EFI skill



Forecast performance in focus

Comparisons with other centres – Z500 Northern Extratropics

500hPa geopotential
Anomaly correlation
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)



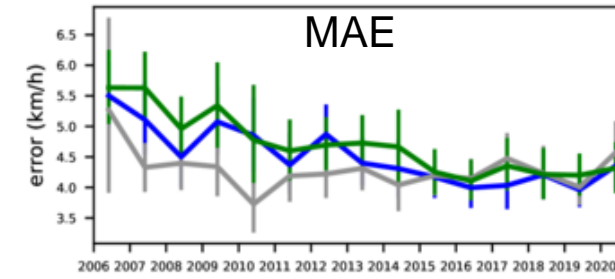
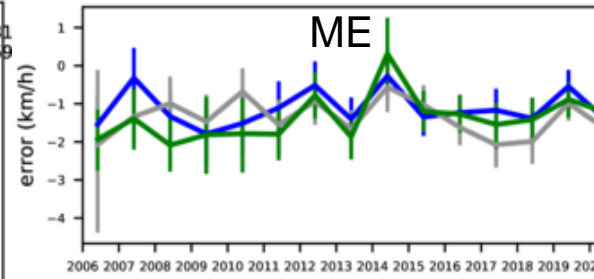
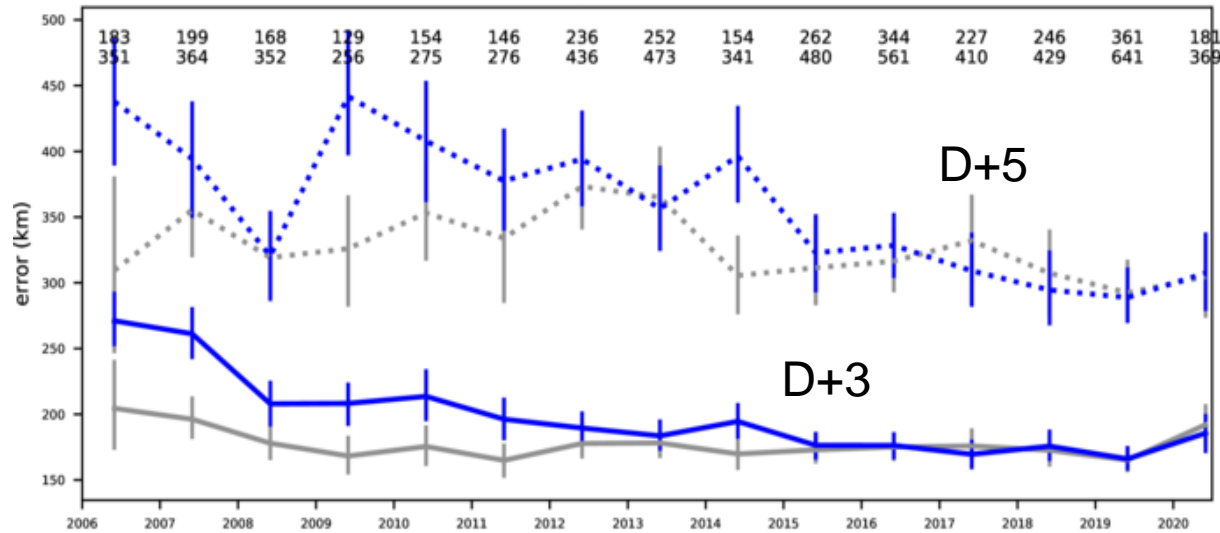
Forecast performance in focus

Position (HRES)

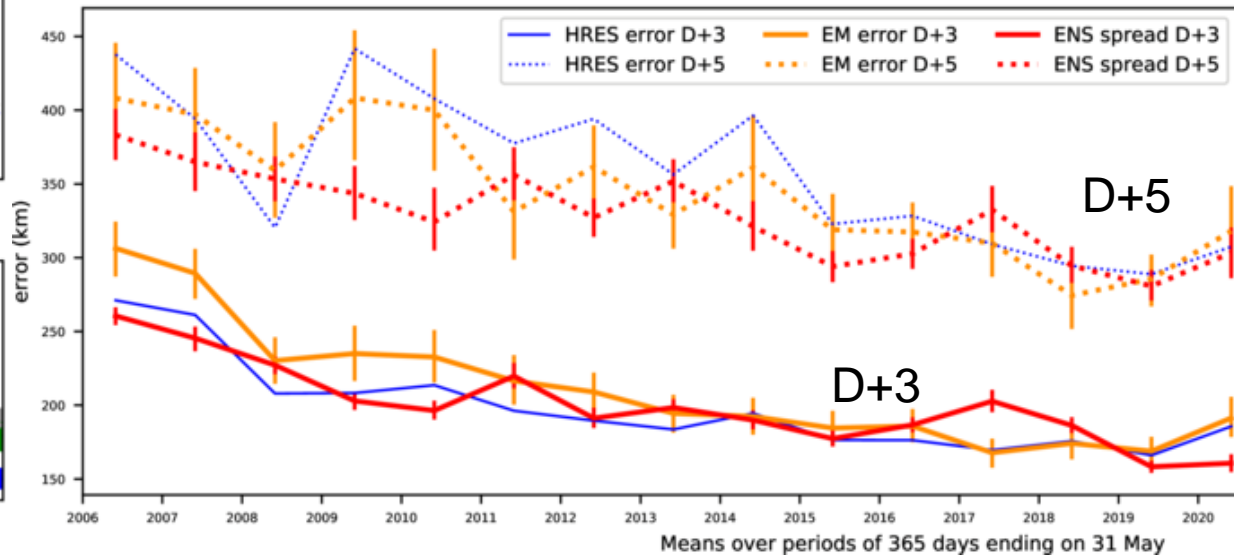
Tropical cyclones

Speed

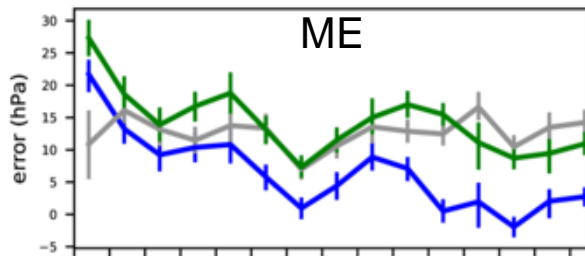
HRES mean position error D+3, D+5



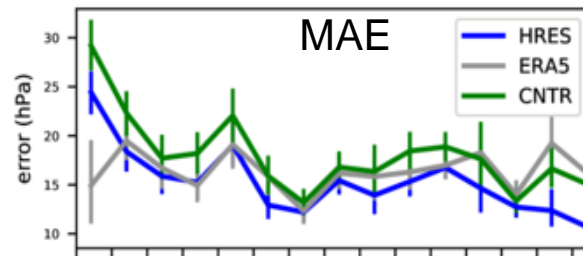
EM mean position error and ENS spread D+3, D+5



Mean intensity error D+3



Mean absolute intensity error D+3



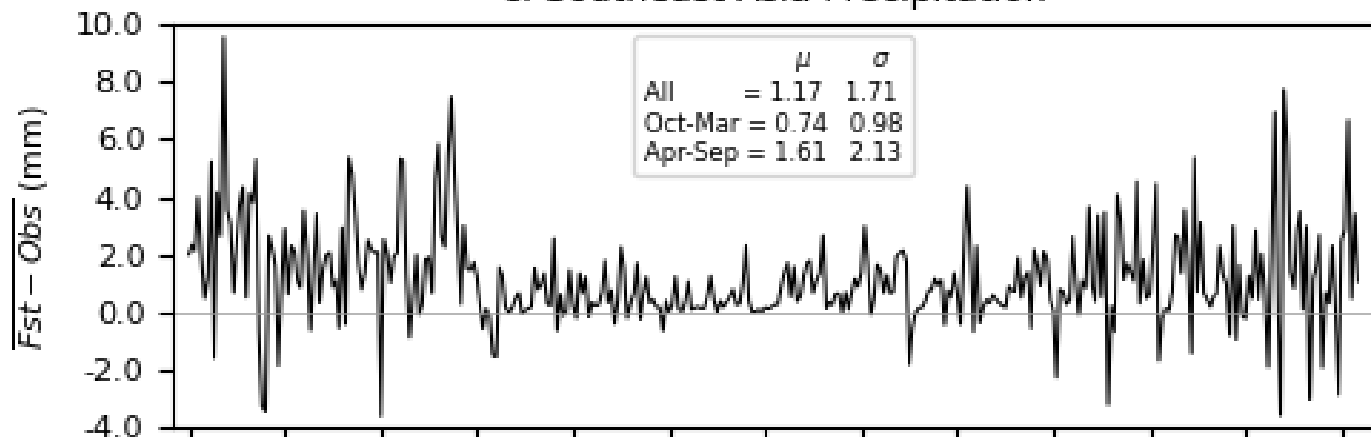
Central pressure

Position (ENS)

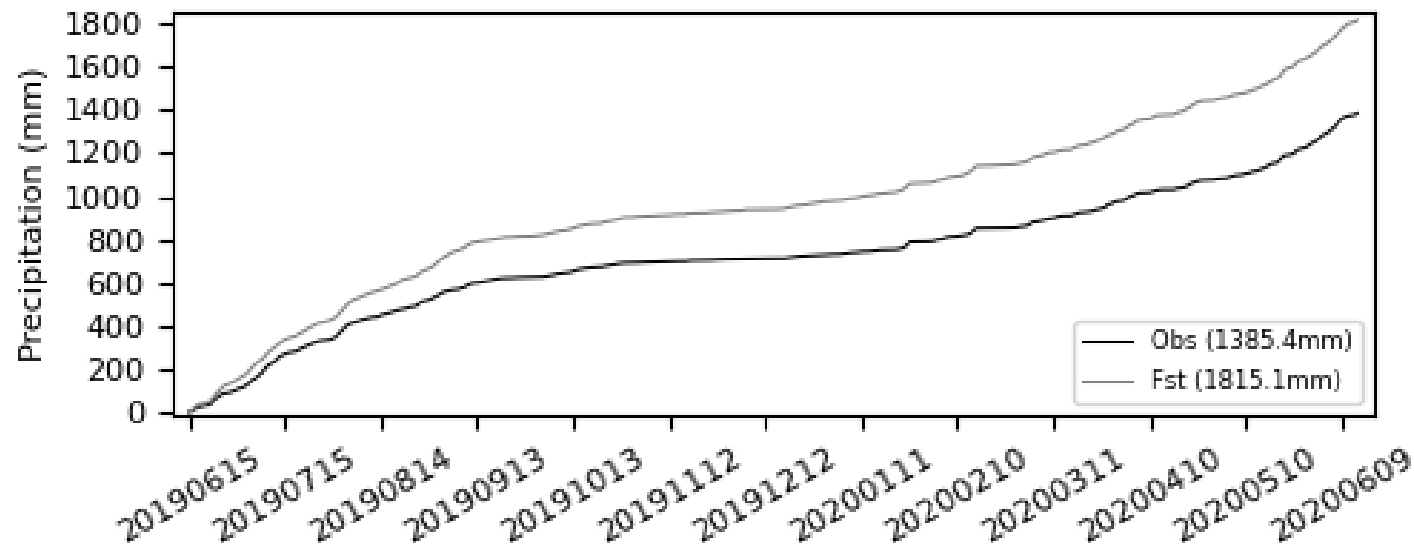
Diagnostics of special problems: IFS wet bias across 20-30N 100-120E (forecast day 3)

Thanks for David Lavers, ECMWF

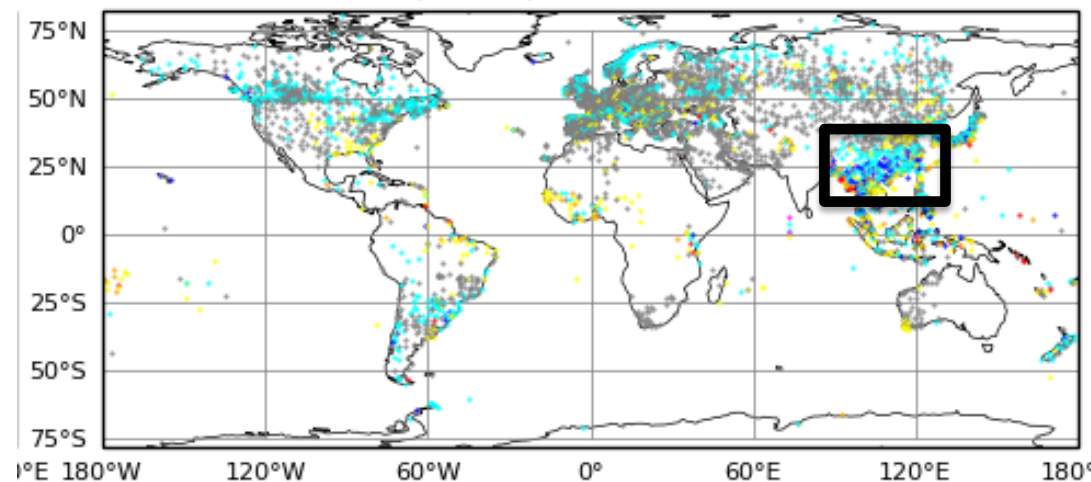
c. Southeast Asia Precipitation



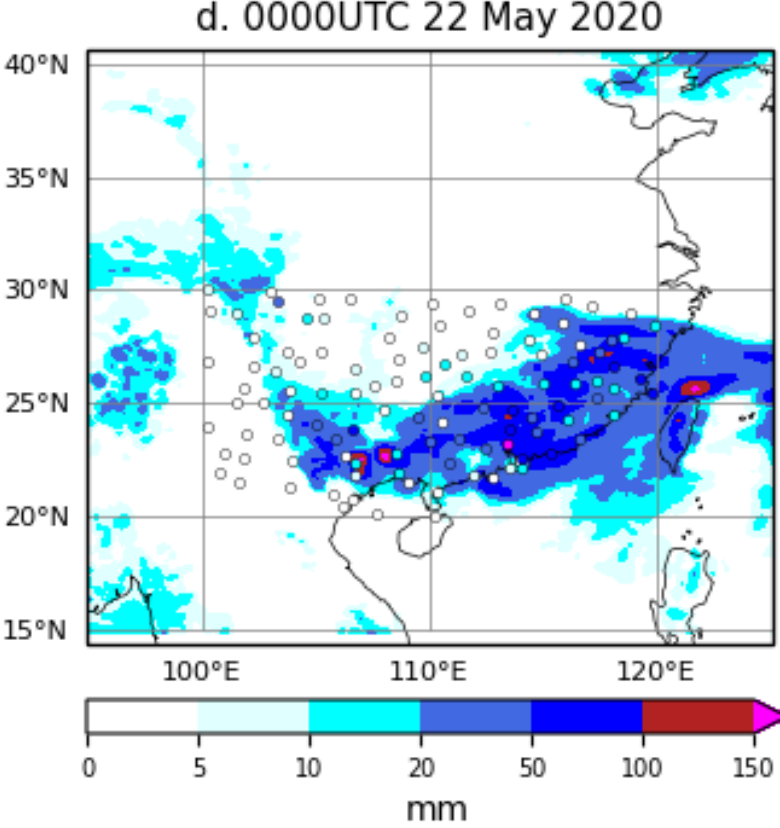
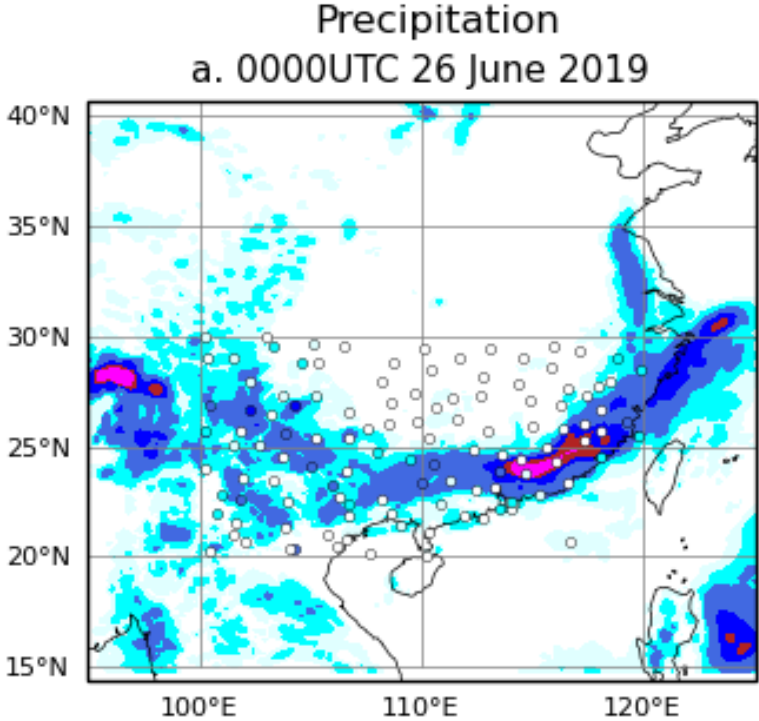
d. Southeast Asia Accumulated Precipitation



b. April-September 0000UTC

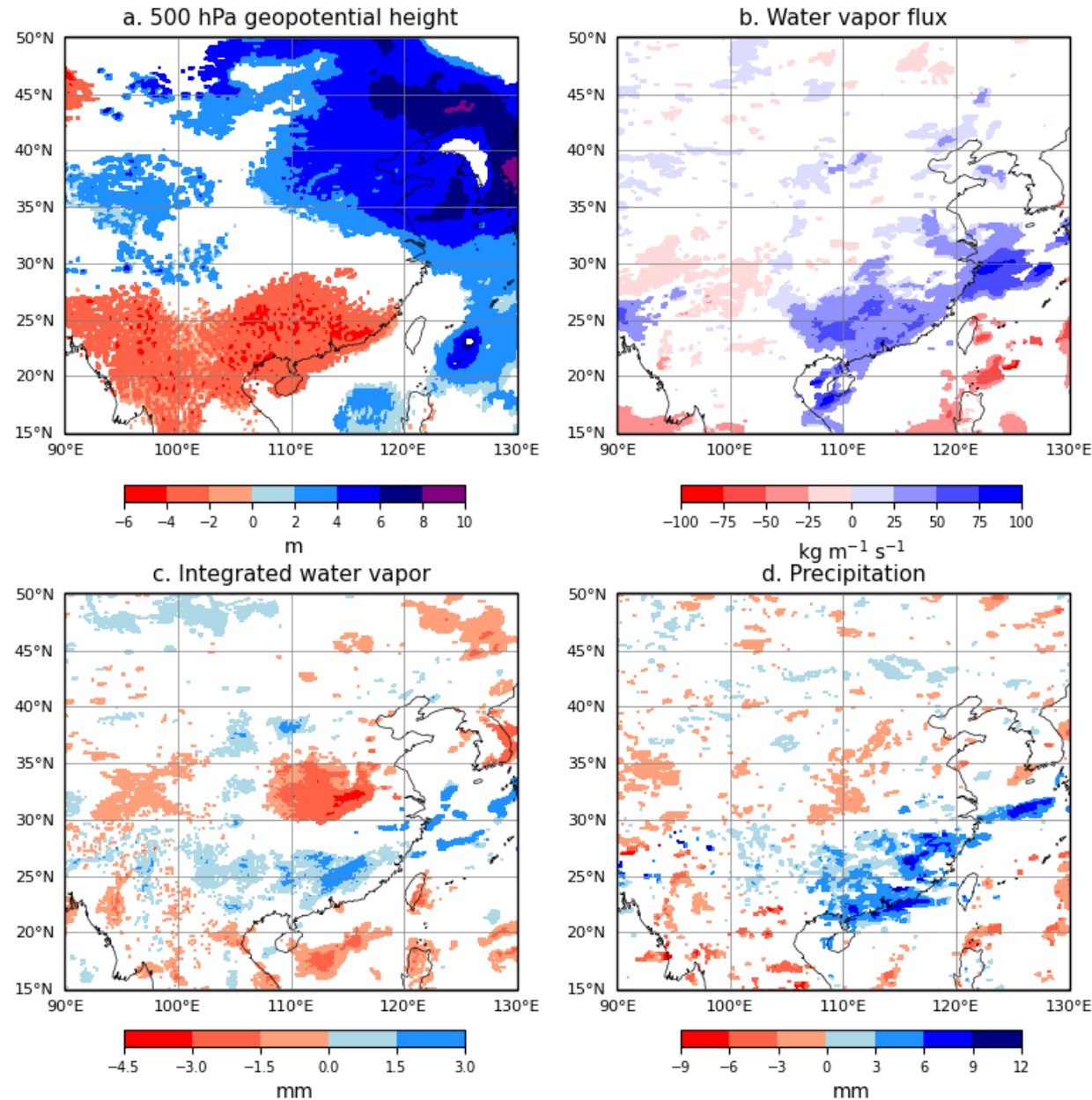


Largest two bias events



Composite mean anomaly patterns for top 10% bias days (36 events)

(T+60 minus T+0)



Summary from wet bias investigation

IFS wet bias in southeast Asia – most evident in boreal summer.

Handling of the Meiyu front appears to be a model issue.

Is there a link to the interaction of the atmospheric circulation with the Himalayas, or to the MJO?

Possible influence on North Pacific storm track and downstream predictability.

Impact on the regional hydrology.

Outreach in focus

Severe event catalogue

Forecast User Home:

<https://software.ecmwf.int/wiki/display/FCST/Forecast+User+Home>

Forecasting issues

Topic / title	Description	Related activities
2m Temperature		
T1. 2m temperature in the presence of inversions	In common with all models, 2m temperature forecasts from the IFS tend to have much larger errors, on average, during low level inversion situations, which are particularly common at high latitudes in winter. The basic physical explanation is that a set change in atmospheric energy content has a much larger impact on screen temperature in inversion situations than in unstable situations, because the energy change is computed through a much smaller depth of the atmosphere (e.g. metres rather than kilometres). The lower the inversion, the larger is the potential error. There is also sensitivity here to the method we use to interpolate between air temperature at the lowest model level (~10m) and skin temperature (2m temperature is a diagnostic, not direct model output).	New reporting practices for radiosonde data ("BUFR" messages), being introduced around the world, could alleviate this problem somewhat, by providing model analyses with a much more detailed representation of the near surface layers.
T2. City temperatures too low	Due to the urban heat island effect not being represented, screen temperatures in large urban areas, particularly cities, are commonly too low compared to observations. The problem can be accentuated in winter by snow cover.	'Urban tiles' to be introduced in land surface scheme in due course.
T3. Screen temperatures fall too much near coasts	As a consequence of the radiation grid being larger than the model grid (due to computational constraints) night-time radiative cooling over land near to the coast is often too rapid. This is because cooling progresses according to T^4 , and at near-coast points T is approximately the average temperature of the land and (warmer) ocean. As a result screen temperatures drop too much - related errors can sometimes exceed 10C. The problem is enhanced (i) when there is snow cover, (ii) at high latitudes, and (iii) where coasts have a convex shape (land-relative).	Improvements due to radiation code 'fixes' were introduced with cycle 41R2 in March 2016. In example cases the impact of these changes has been very positive. More substantial radiation code changes are likely in the longer term.
T4. Meteorogram temperature issues in complex topography	In addition to the normal problems of representing screen temperatures in complex topography in current-generation global models, the user should be aware that the method by which screen temperatures on Meteograms are generated from model screen temperatures assumes a standard lapse rate (6.9C drop per km increase in altitude), and so if the difference in height between the site chosen, and the nearest model gridpoint (as shown in the ENIGram title) is large, the scope for large errors/biases increases. This is especially true in winter-time when inversions are more common: by definition an inversion implies a temperature increase with height, not a decrease, so the temperature correction applied could even be in the wrong direction. This issue is compounded by 2m Temperature issue T1 above.	Resolution upgrade in March 2016 (41R2) has helped. Re-calibration project should help even more.
T5. China 'cold spot'	In products that intrinsically display 2m temperature output in some 'anomaly' form - such as monthly forecast anomalies, seasonal forecast anomalies, and in the shorter ranges EFI and SOT - there has been a semi-permanent winter-time 'cold spot' over eastern China. It is not real in the sense that temperatures are not always below	

Changes to forecasting system

What can we learn from case studies?

List of ECMWF Newsletter articles on severe events:

- 139 - Windstorms in northwest Europe in late 2013
- 140 - Forecasting the severe flooding in the Balkans
- 141 - Recent cases of severe convective storms in Europe
- 142 - Forecasts for a fatal blizzard in Nepal in October 2014
- 143 - Forecasts for US east coast snow storm in January 2015
- 144 - ECMWF forecasts for tropical cyclone Pam
- 145 - Predicting this year's European heat wave
- 146 - Forecasting flash floods in Italy
- 147 - Wind and wave forecasts during Storm Gertrude/Tor
- 148 - Forecasts showed Paris flood risk well in advance
- 149 - Predicting heavy rainfall in China
- 150 - Flash floods over Greece in early September 2016
- 151 - The cold spell in eastern Europe in January 2017
- 152 - ECMWF supports flood disaster response in Peru
- 153 – Predictions of tropical cyclones Harvey and Irma
- 154 – Two storm forecasts with very different skill
- 155 – Predicting extreme snow in the Alps in January 2018
- 156 – Forecasting convective rain events in late May
- 157 – Forecasting the 2018 European heatwave
- 158 – Predicting multiple weather hazards over Italy
- 159 - Forecasts of freezing rain in Romania
- 160 - ECMWF works with universities to support response to tropical cyclone Idai
- 161 - The 2019 western European heatwaves
- 162 - Challenges in forecasting Hurricane Lorenzo
- 163 - Forecasting February's wet and stormy weather in parts of Europe
- 164 - Warm intrusions into the Arctic in April 2020
- 165 – Hurricane Laura and its threat to the United States

Merged version of articles in 139-158:

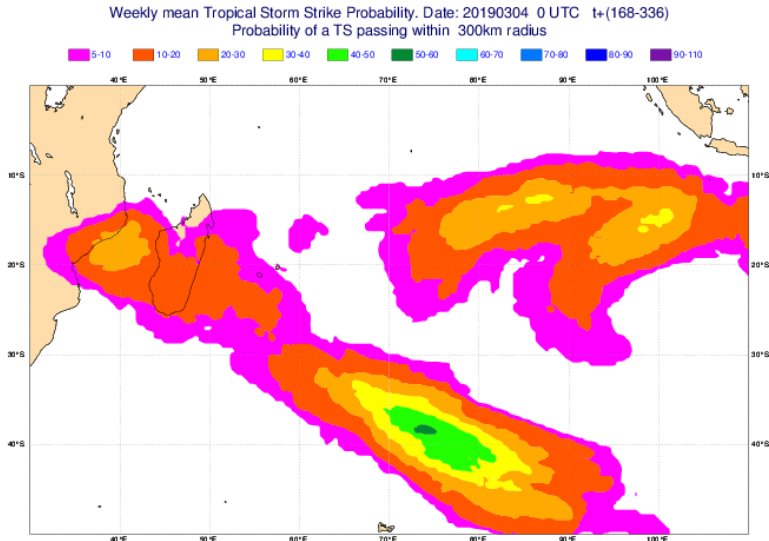
https://www.ecmwf.int/sites/default/files/medialibrary/2019-04/ecmwf_nl_severe.pdf

Example of cases in Asia from the catalogue:

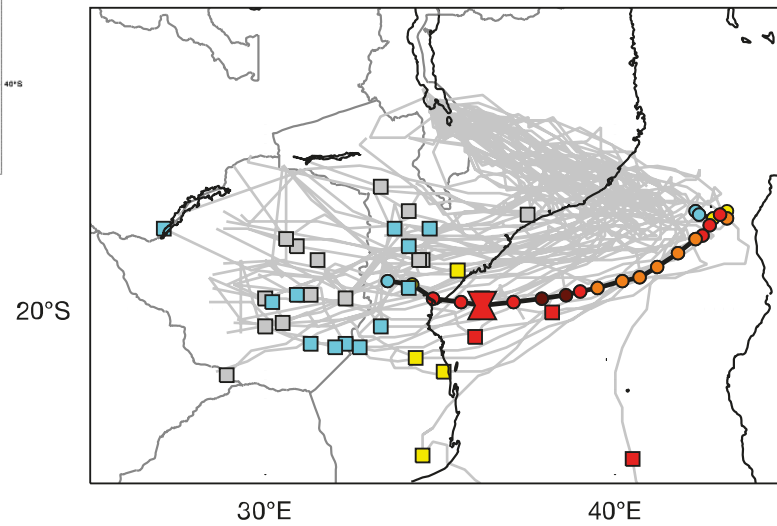
- <https://confluence.ecmwf.int/display/FCST/201607+-+Rainfall+-+China>
- <https://confluence.ecmwf.int/display/FCST/201601+-+Cold+spell+-+China>
- <https://confluence.ecmwf.int/display/FCST/201708+-+Tropical+cyclone+-+Hato>
- <https://confluence.ecmwf.int/display/FCST/201807+-+Heatwave+-+Japan>
- <https://confluence.ecmwf.int/display/FCST/201807+-+Rainfall+-+Japan>
- <https://confluence.ecmwf.int/display/FCST/201808+-+Rainfall+-+India>
- <https://confluence.ecmwf.int/display/FCST/201809+-+Tropical+Cyclone+-+JEBI>
- <https://confluence.ecmwf.int/display/FCST/201809+-+Tropical+Cyclone+-+Mangkhut>
- <https://confluence.ecmwf.int/display/FCST/202007+-+Rainfall+-+Japan>

Example tropical cyclone Idai (2019)

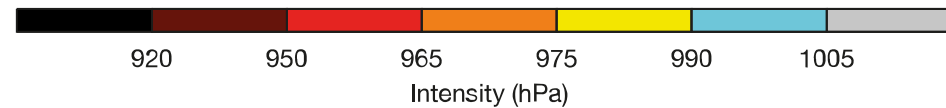
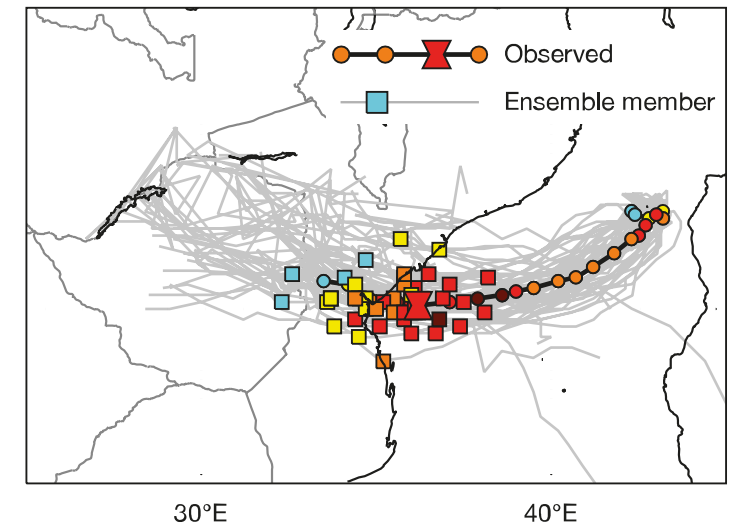
Extended-range forecast from 4 March



Forecast starting 7 March



Forecast starting 10 March

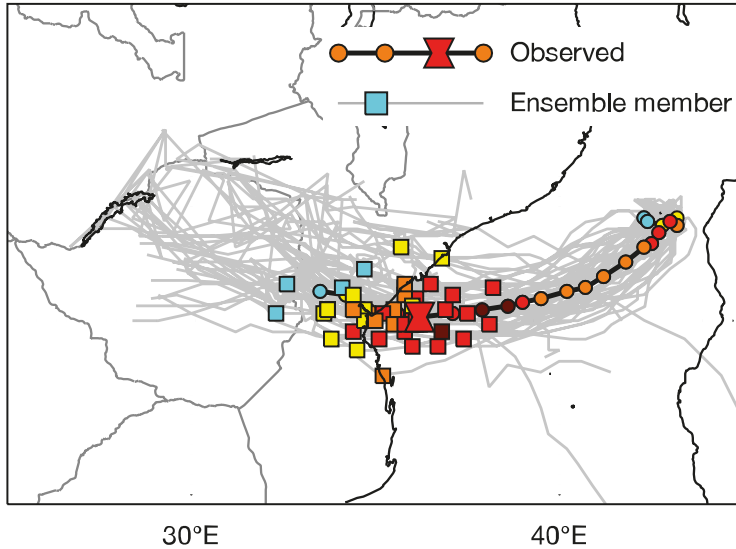


<https://www.ecmwf.int/en/newsletter/160/news/ecmwf-works-universities-support-response-tropical-cyclone-idai>

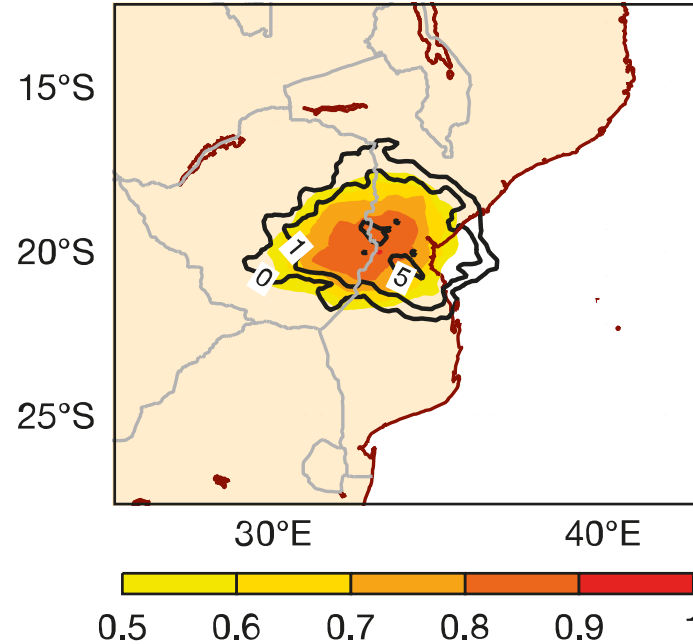
Forecast value chain

Tropical cyclone tracks

Forecast starting 10 March

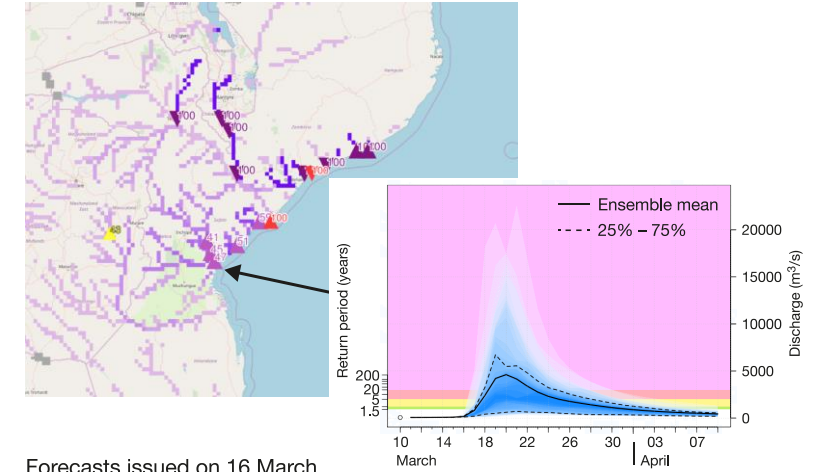


Extreme forecast index for precipitation

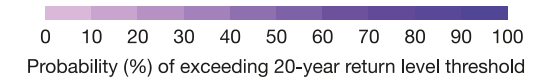
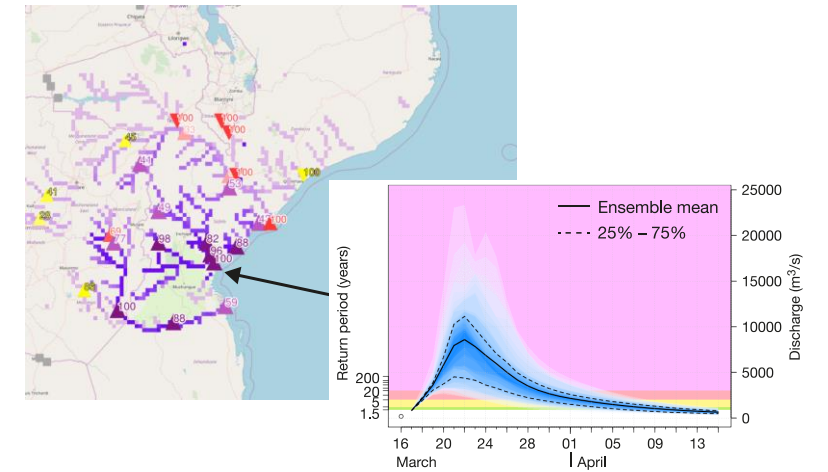


Flood forecast from GLOFAS globalfloods.eu

Forecasts issued on 10 March



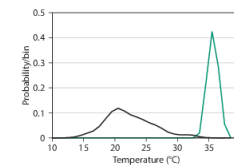
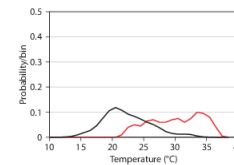
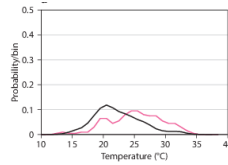
Forecasts issued on 16 March



Emerton et al. <https://www.sciencedirect.com/science/article/pii/S2212420920313133>

Lessons learned on predictability on different time-scales

ECMWF Tech Memo 851



	Extended range (2-4 weeks)	Medium range (3-7 days)	Short range (0-3 days)
European heatwave	Soil moisture, SST anomalies	Rossby wave train	Local heating and evaporation
N. European extreme rainfall	North-Atlantic oscillation	Presence of Atmospheric rivers	Exact position of the system, strength of orographic precipitation
N. European windstorm	North-Atlantic oscillation	Jet-stream propagation	Timing of development, wind gust parameterisation
Tropical cyclones	SST, MJO, African easterly waves	Steering flow	Landfall position and intensity
Flash-floods in S. Europe	Predict S. European flow-regimes(?)	Position of trough/cut-off low and Med. Atmospheric rivers	Evaporation + Moisture advection, precipitation processes (orography), runoff into rivers
Severe convection		Upper-level troughs, Positions of fronts, CAPE, wind shear	Convective triggering, organisation, life-time, wind gust parameterisation
Eastern Asian rainfall	Monsoon strength (?)	Position of frontal zone (Mei-Yu)	Local pattern of precipitation

Long-lived flow patterns, teleconnections and boundary conditions

Capturing synoptic situation, global DA

DA and model physics suitable for extreme conditions

