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

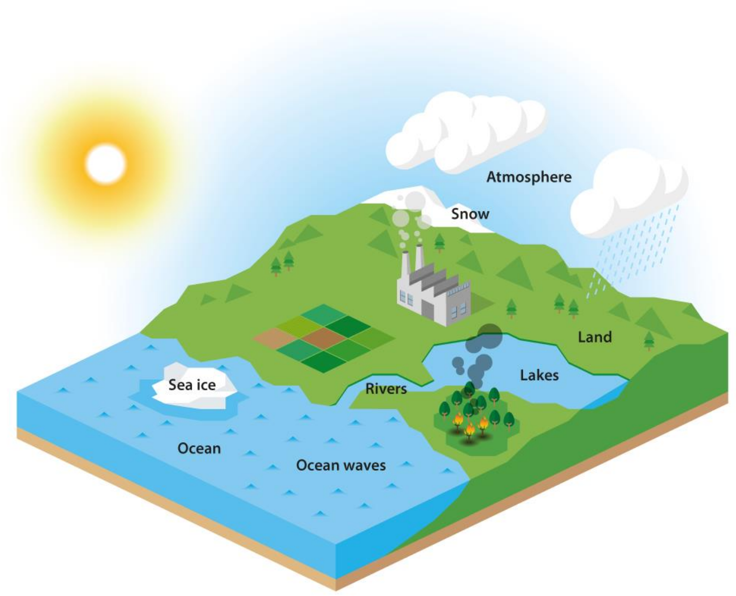
The operational ECMWF forecasting system

High resolution deterministic forecast (HRES) :

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

Ensemble forecast (ENS):

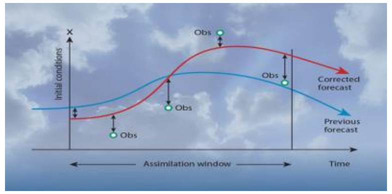
- twice per day 51 members, 18 km, 91 levels, to 15 days ahead
- Monday/Thursday 00 UTC extended to 46 days ahead with 36 km
  - Reforecast dataset with 11 members for past 20 years



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

<u>Observation types</u>
Conventional
Polar satellites
Geostationary sat.

Quality control

Common issues

Data assimilation

Algorithms
Background error
Observation error

Increments

Forecast

<u>Model components</u>
Dynamics
Atm. Physics
Surface
Ocean

Dissimilation

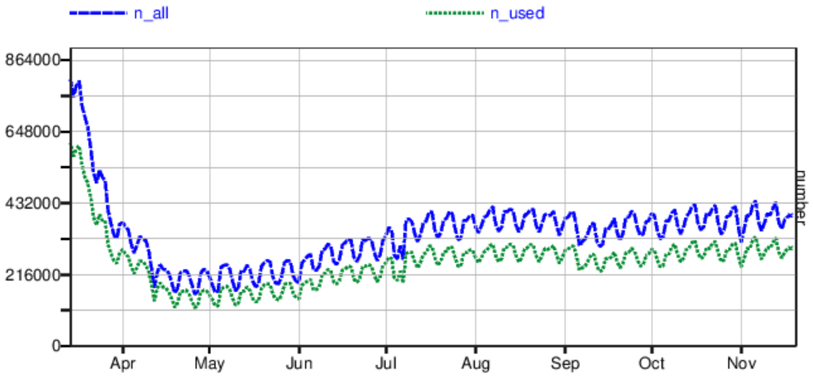
Reliability
Timeliness
Post-processing
Products

Evaluation

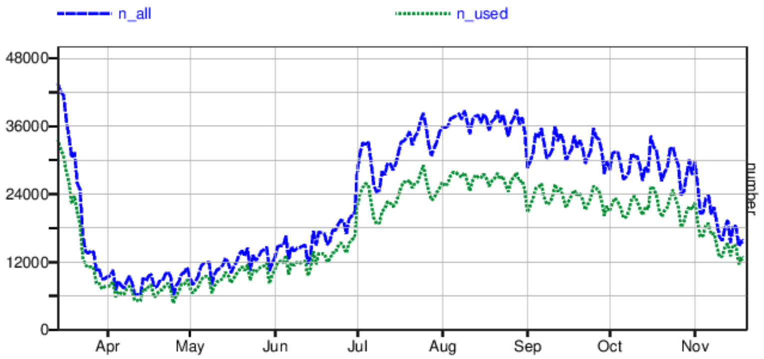
Daily errors
Statistical evaluation
Diagnostics
Current issues

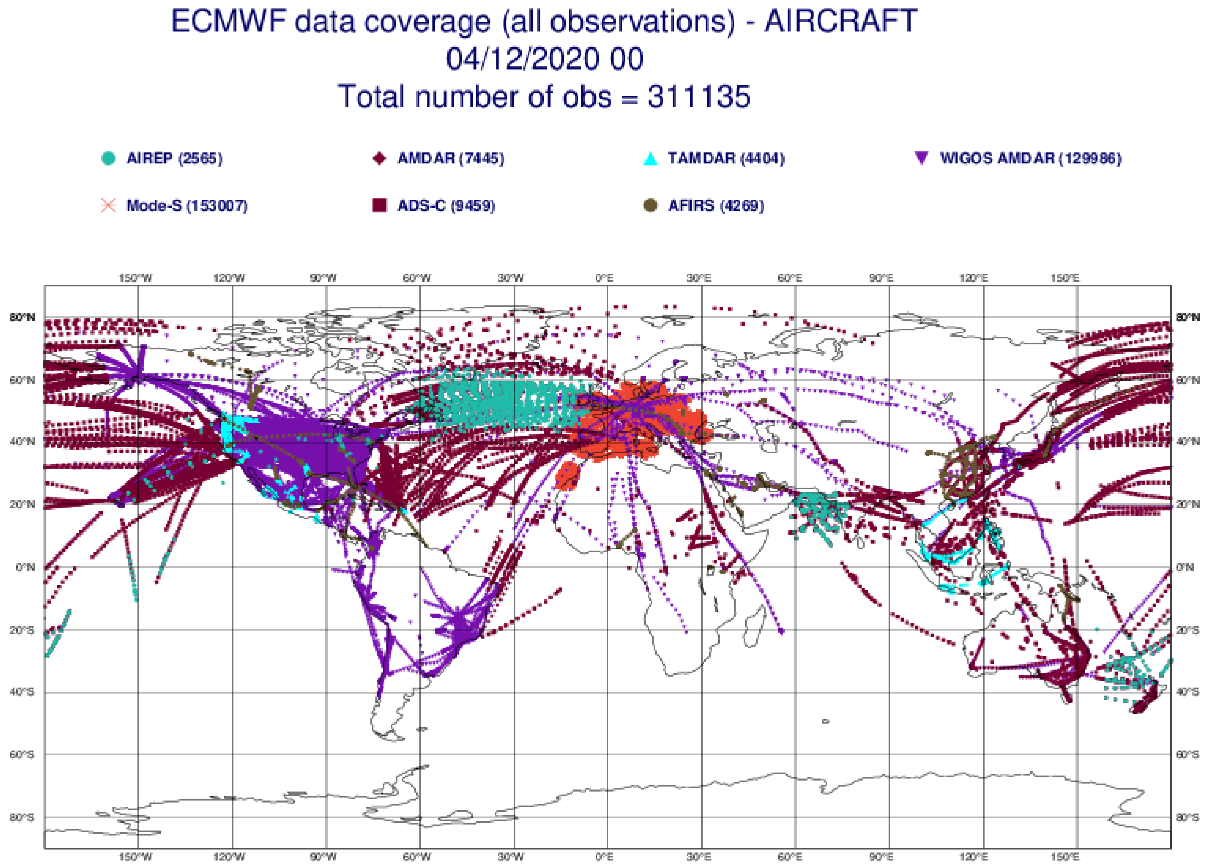
COVID effect on aircraft observations

Global



Europe





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.

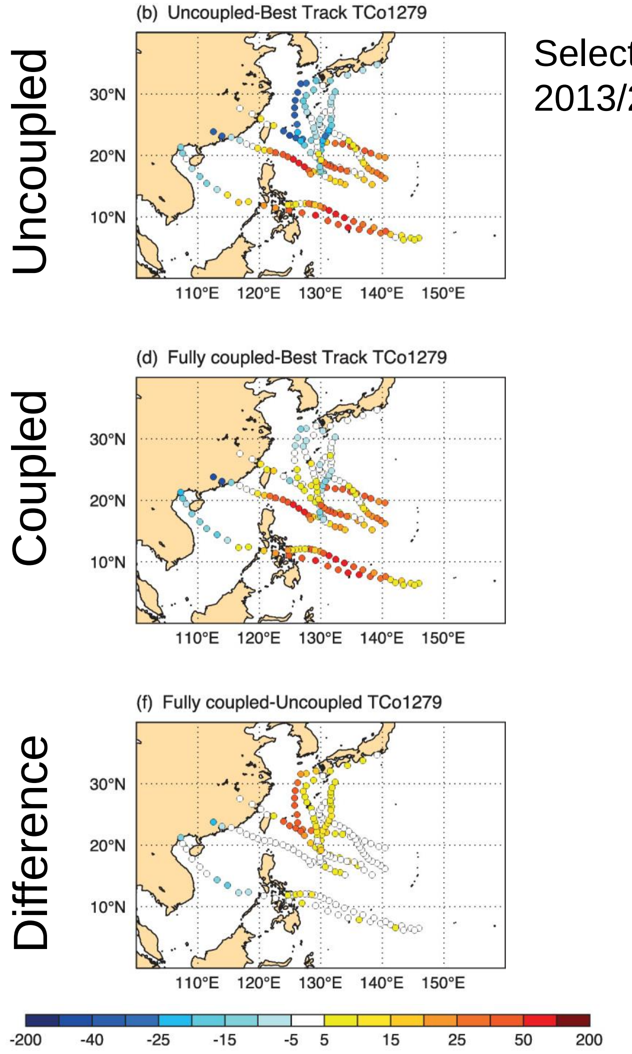
- Cycle 47r2

  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**

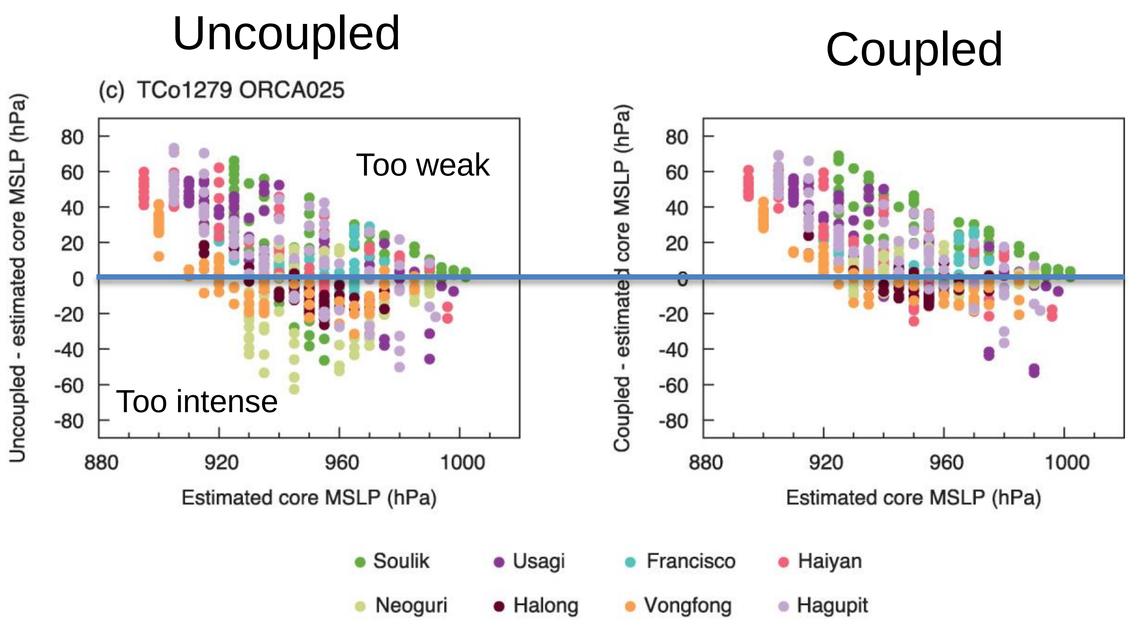
Cycle 45r1: Effect of ocean coupling on tropical cyclones

Central pressure error

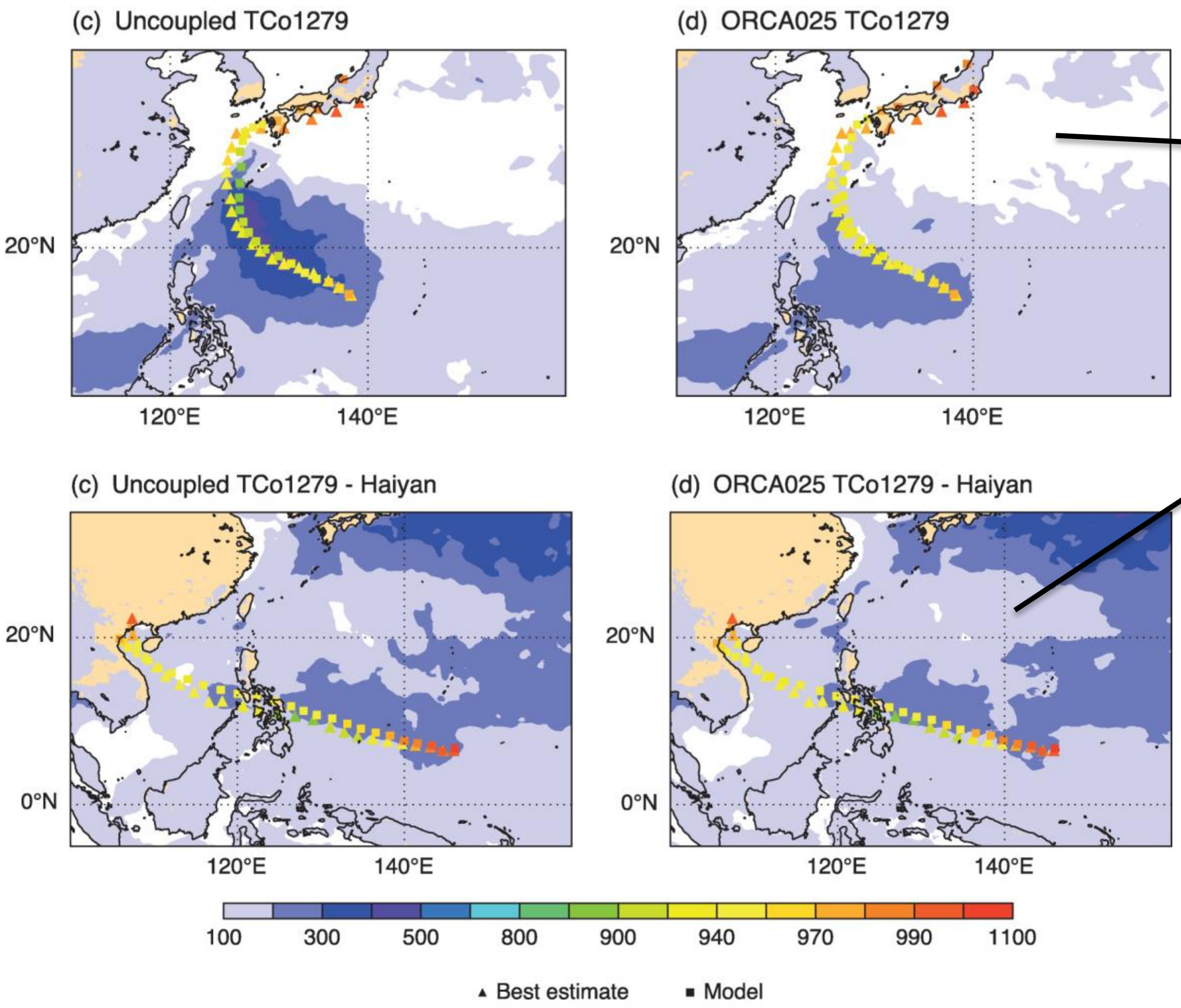


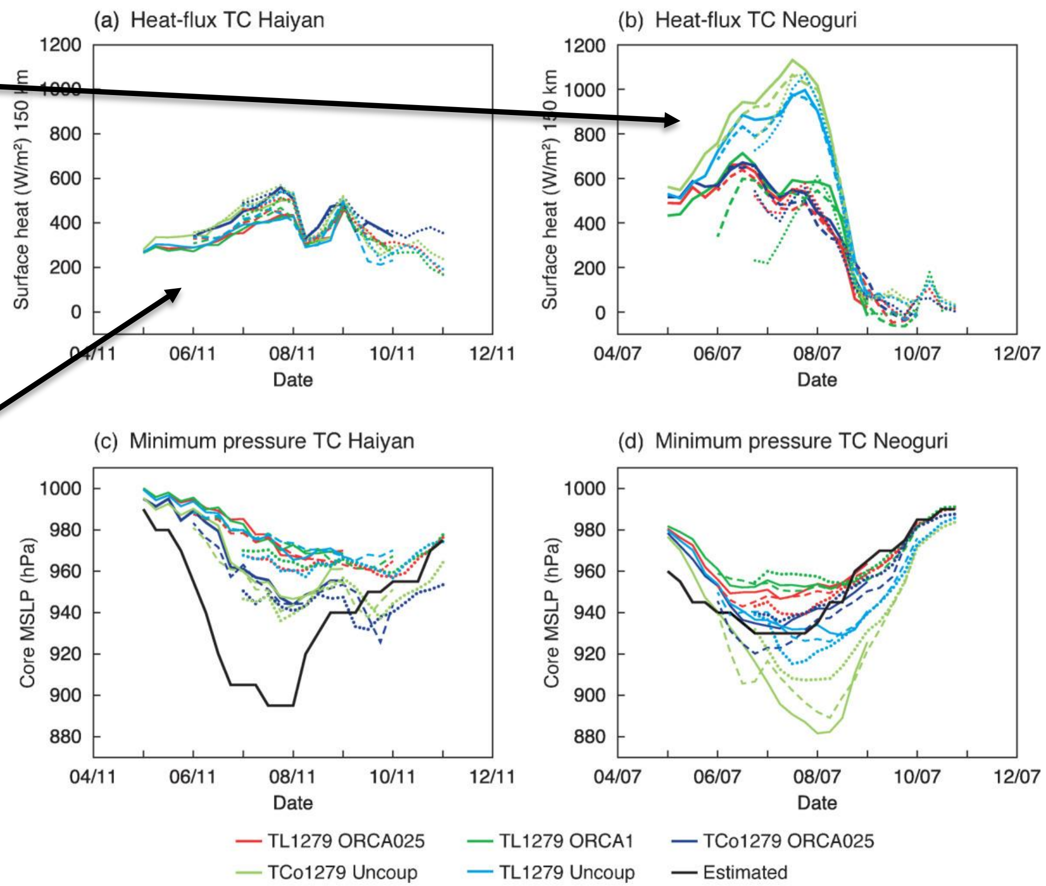
Selection of test cases from 2013/2014

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

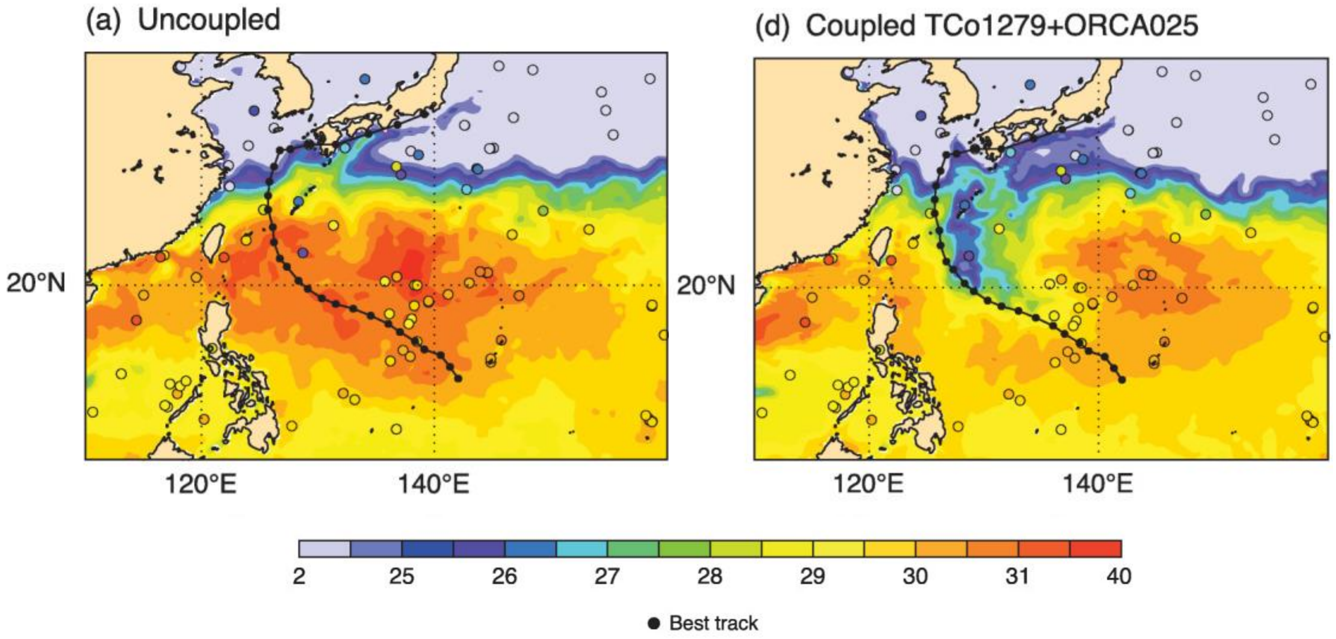


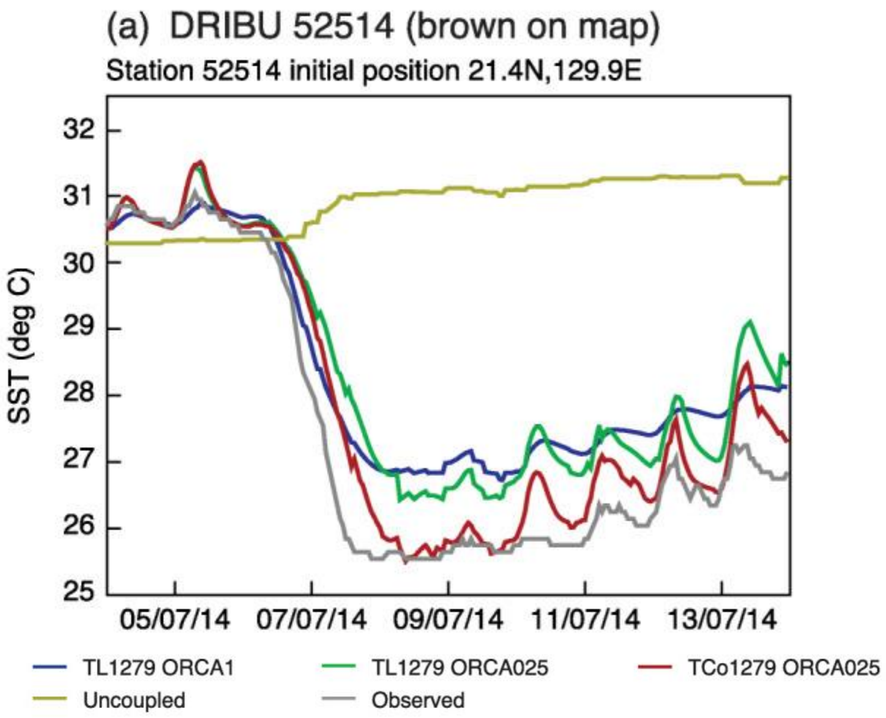
Heat flux under the cyclones

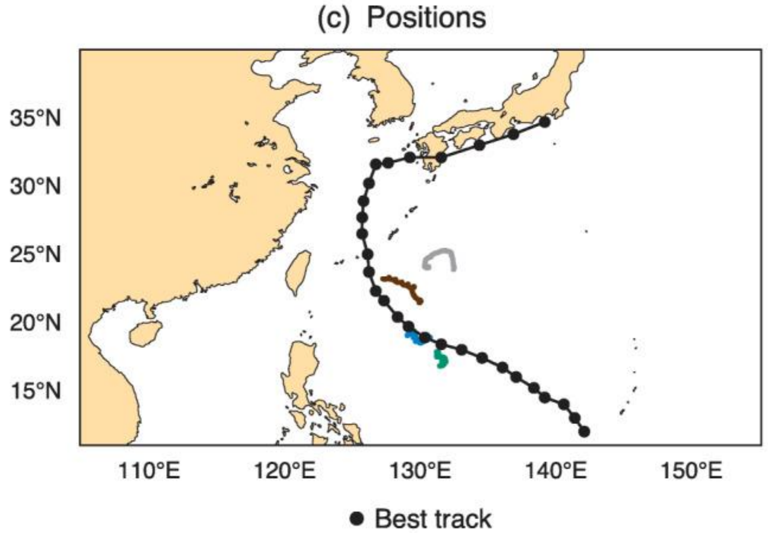




Effect on sea-surface temperature



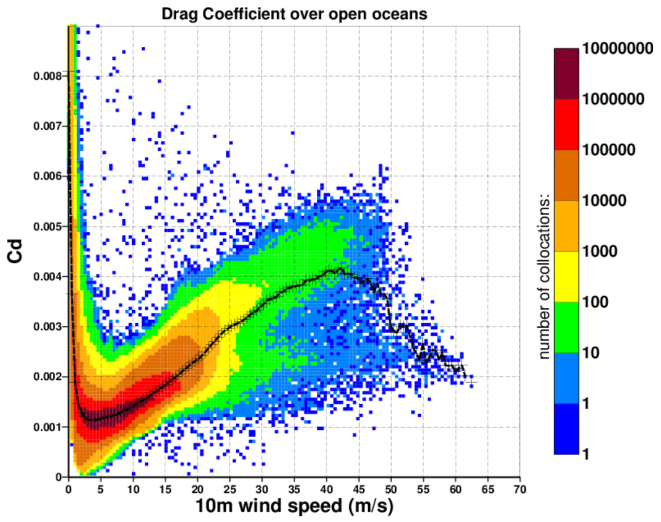




Cycle 47r1: Changes in the Drag Coefficient

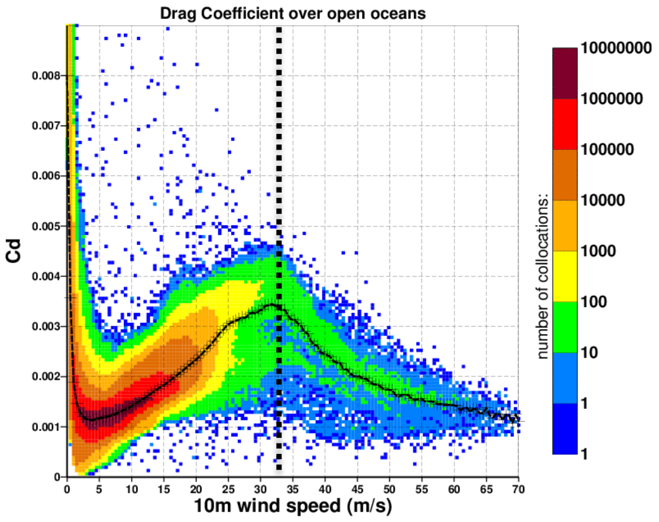
See https://www.ecmwf.int/en/newsletter/164/meteorology/enhancing-tropical-cyclone-wind-forecasts

46r1



TCo1999 forecast
h5jx from 20170904 step 6 to 240 by 6

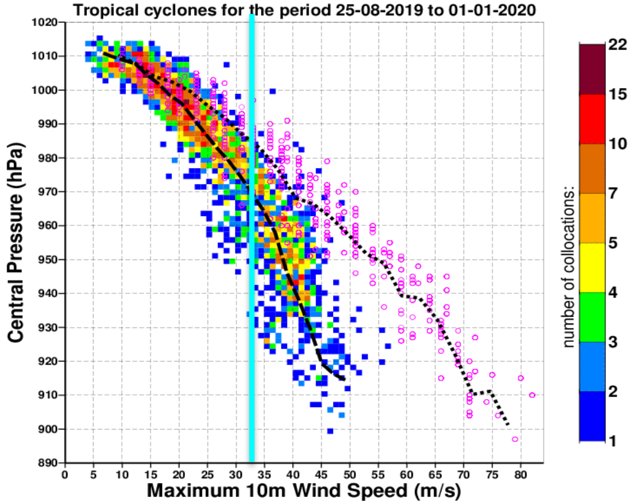
Drag Coefficient & 10 m winds
Tco1999 2017-09-04 00Z +240h
during Hurricane Irma



TCo1999 forecast
h5t7 from 20170904 step 6 to 240 by 6

47r1

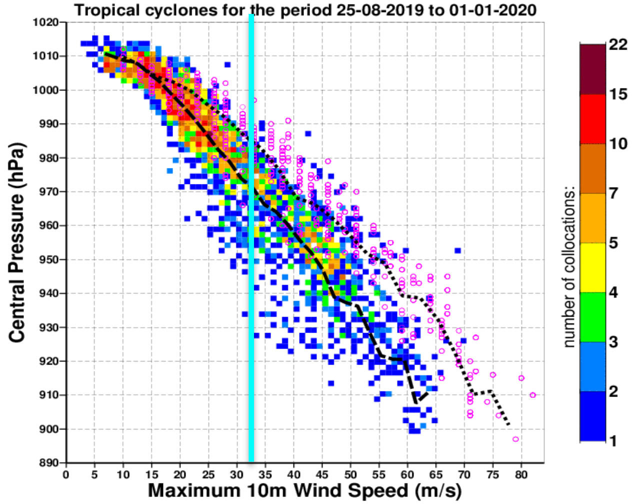
46r1



Colour shading and dashed line: TCo1279 forecasts (h9s0), all forecasts intialised 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



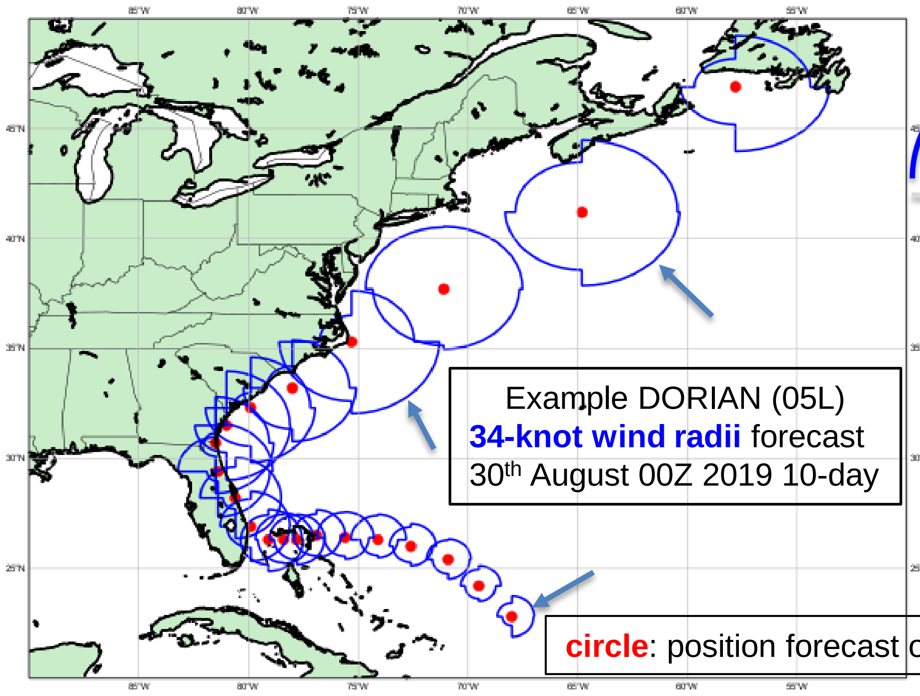
Colour shading and dashed line: TCo1279 forecasts (h9s3), all forecasts intialised from 0 UTC.
Pink symbols and dotted line: Best Track data.

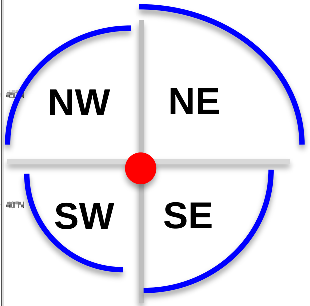
47r1

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)

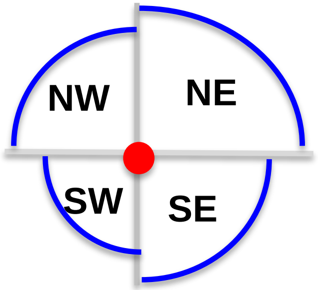




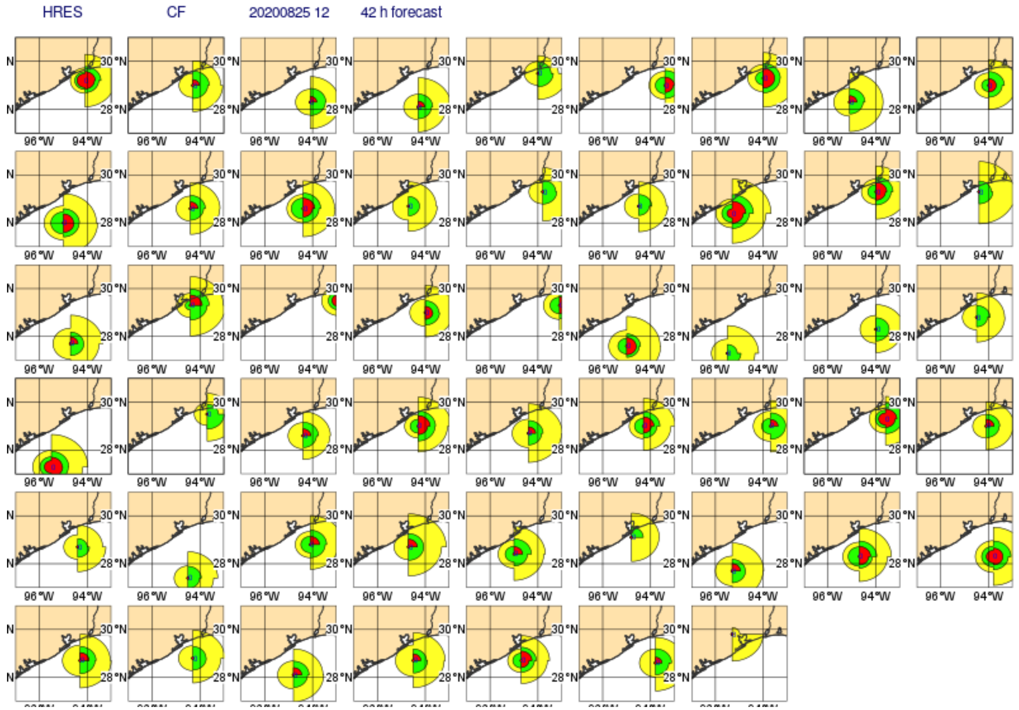
- Product available for the HRES and ENS (all TCs in analysis and those that develop during the forecast –'genesis
- Can be helpful to 1) identifying coastal areas potentially affected by winds of TS strength or higher; 2) ship routing forecast

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

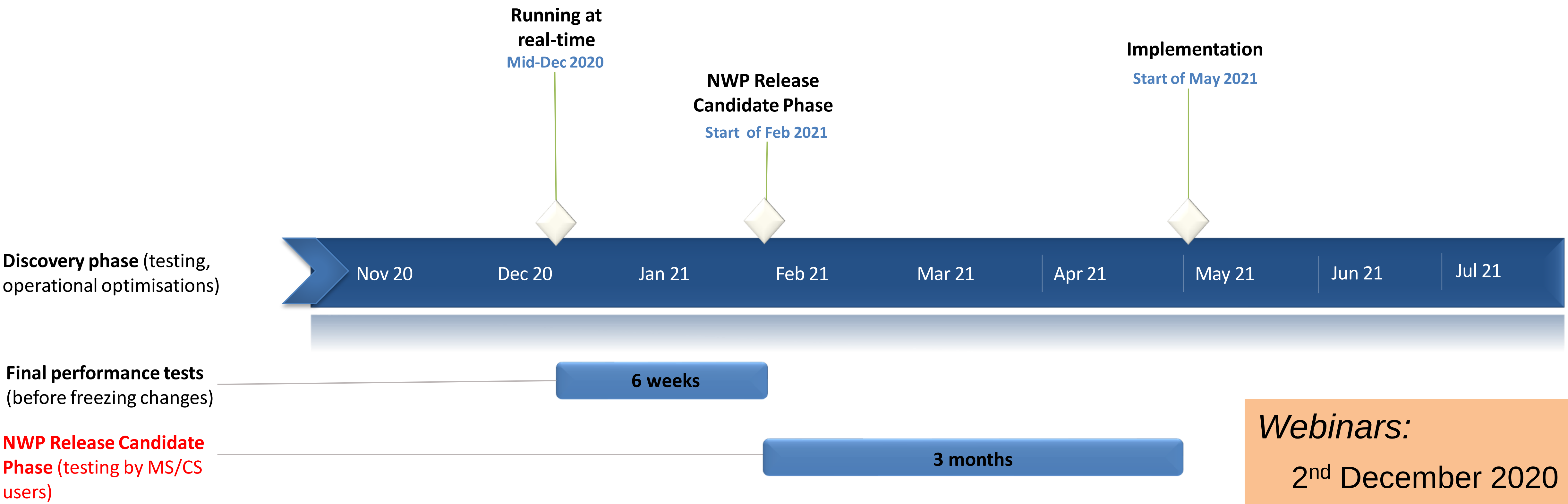
- Product available for the HRES and ENS (all TCs in analysis and those that develop during the forecast –'genesis')
  - **BUFR message for dissemination** https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+47r1 (under "WMO essential")
- More information in https://confluence.ecmwf.int/display/FCST/New+Tropical+Cyclone+Wind+Radii+product

Model in focus

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

Model in focus

Implementation of cycle 47r2



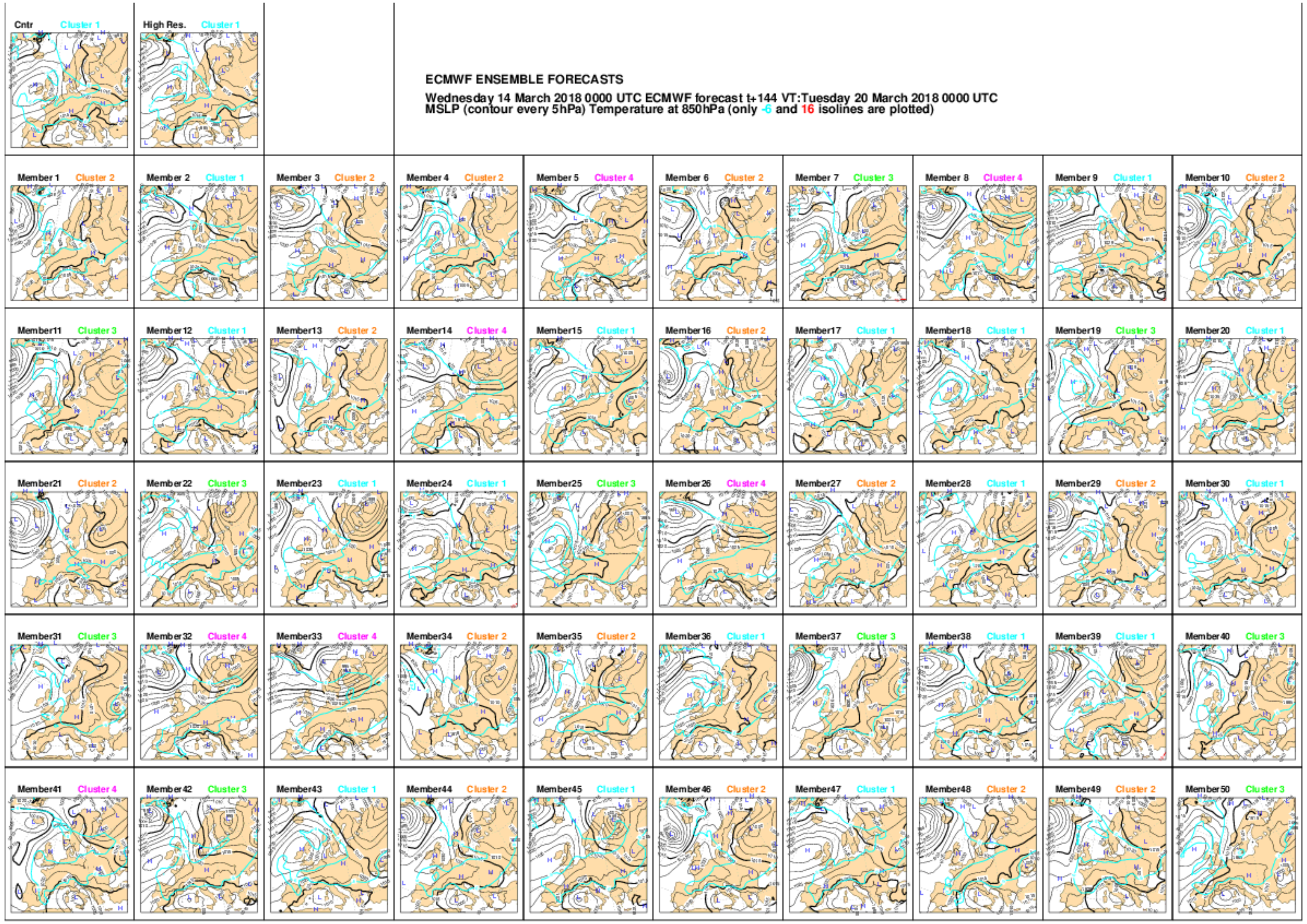
Webinars:

2nd December 2020

15th December 2020

16th April 2021

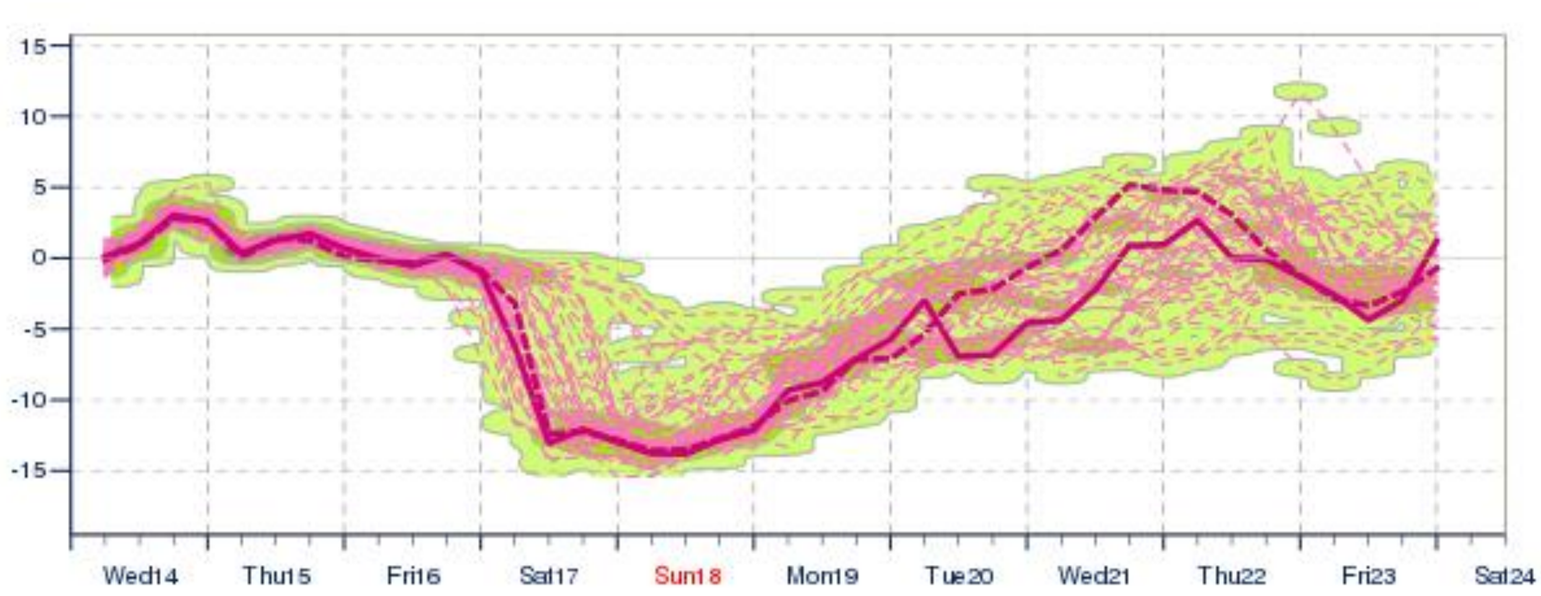
Ensemble aspects



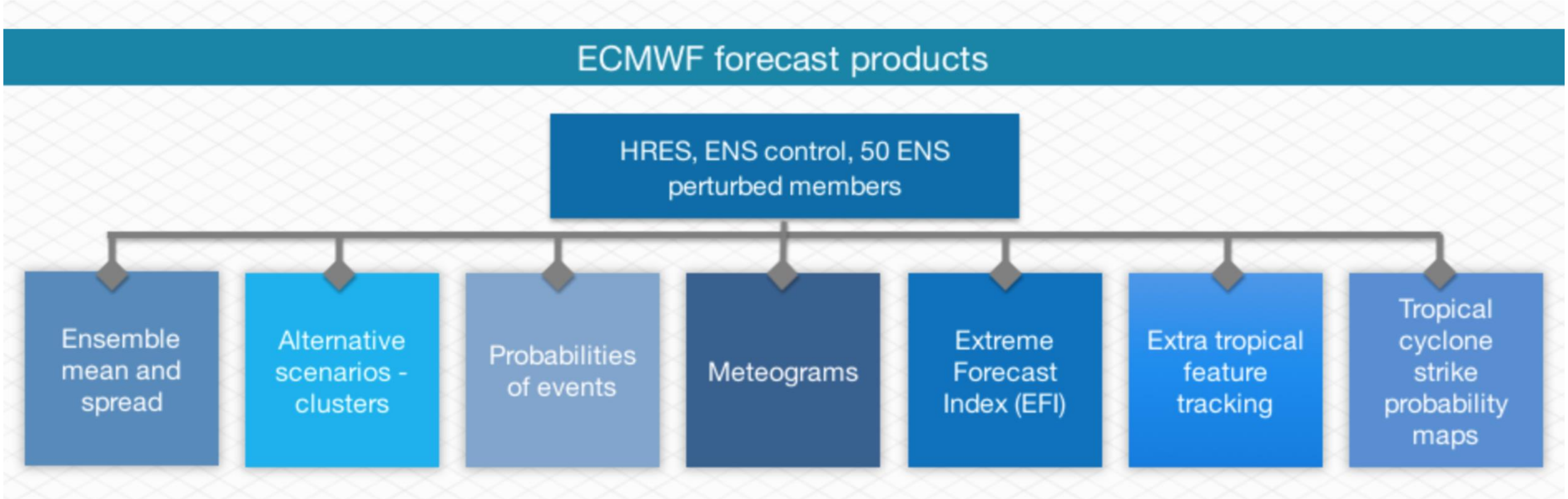
Construction of ensemble members

Perturbed forecast = Optimal analysis + Initial Perturbations + Model Perturbations

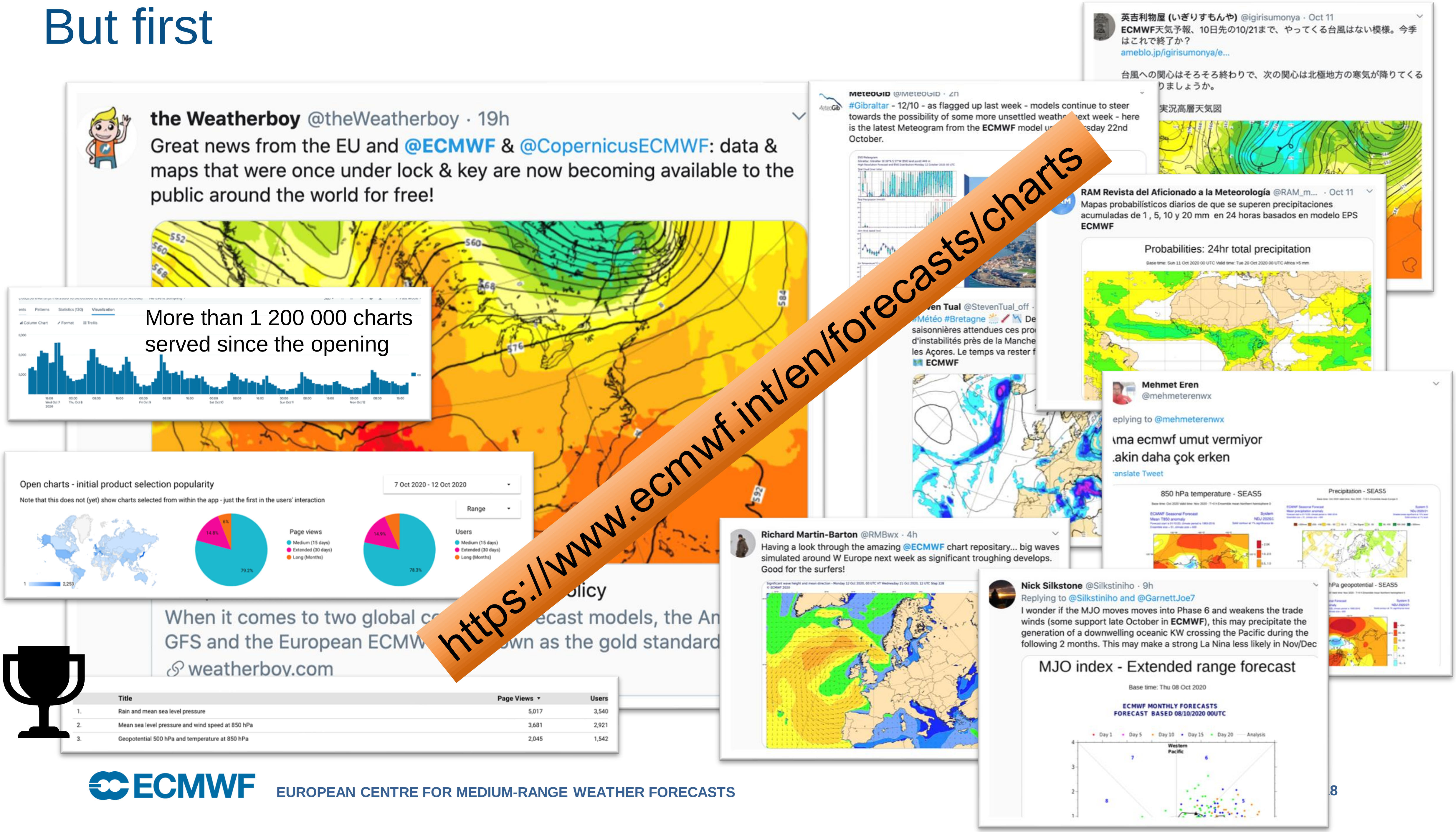
Perturbations added to a subset or all model variables



Forecast products



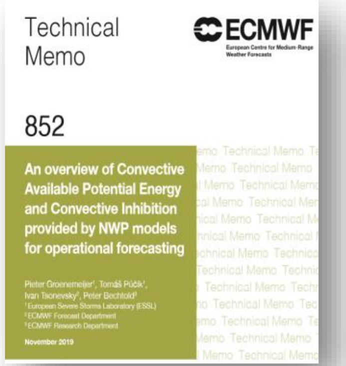
But first



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!
When it comes to two global co... ecast models, the Am... GFS and the European ECMW... own as the gold standard
weatherboy.com
More than 1 200 000 charts served since the opening
Open charts - initial product selection popularity
Note that this does not (yet) show charts selected from within the app - just the first in the users' interaction
7 Oct 2020 - 12 Oct 2020
Range
Page views
Users
Medium (15 days)
Extended (30 days)
Long (Months)
https://www.ecmwf.int/en/forecasts/charts
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
英吉利物屋 (いぎりすもんや) @igirisumonya · Oct 11
ECMWF天気予報、10日先の10/21まで、やってくる台風はない模様。今季はこれで終了か？
ameblo.jp/igirisumonya/e...
MeteoGib
#Gibraltar - 12/10 - as flagged up last week - models continue to steer towards the possibility of some more unsettled weath... ext week - here is the latest Meteogram from the ECMWF model u... sday 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
Probabilities: 24hr total precipitation
Mehmet Eren @mehmeterenwx
Richard Martin-Barton @RMBwx · 4h
Having a look through the amazing @ECMWF chart repositary... 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 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
850 hPa temperature - SEAS5
Precipitation - SEAS5

Products in focus

Convective inhibition diagnostic (CIN)



Technical Memo

852

An overview of Convective Available Potential Energy and Convective Inhibition provided by NWP models for operational forecasting

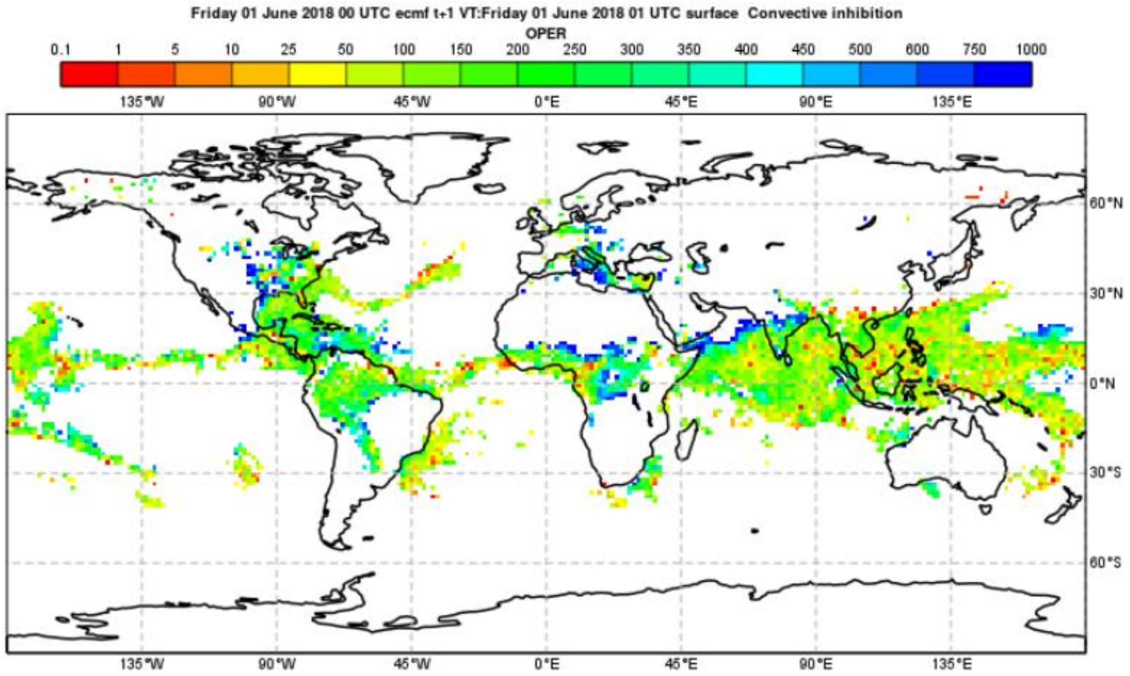
Pieter Groenemeijer[1], Tomáš Púčik[1], Ivan Tsonevsky[2], Peter Bechtold[3]

[1] European Severe Storms Laboratory (ESSL)

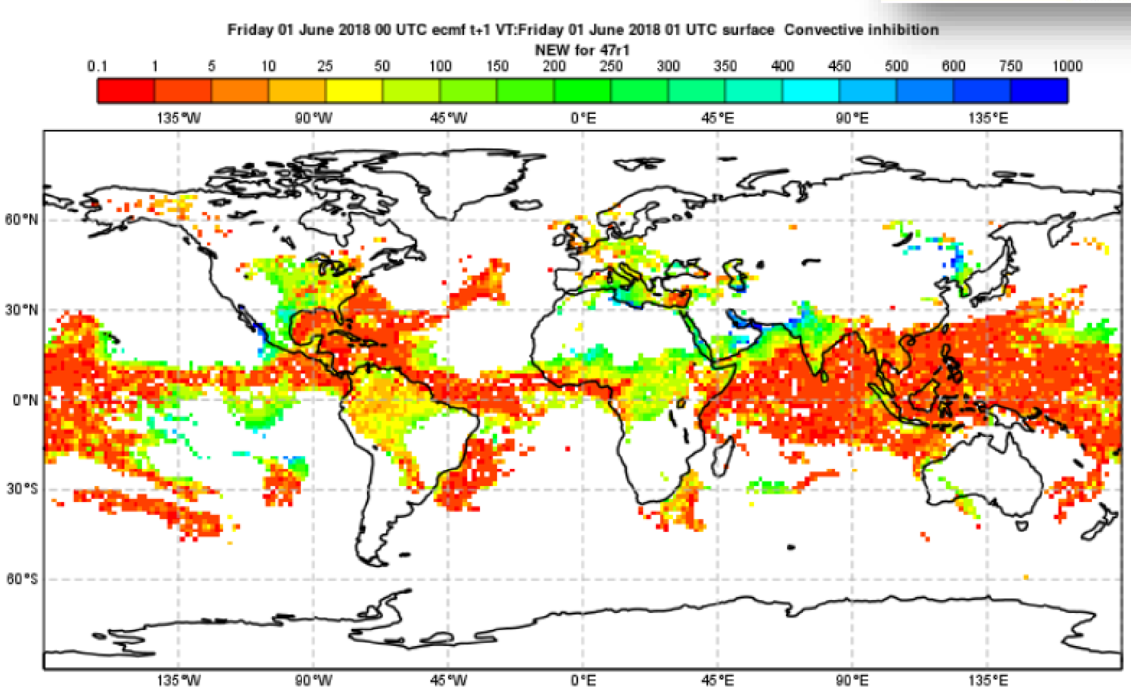
[2] ECMWF Forecast Department

[3] ECMWF Research Department

November 2019



46r1



47r1

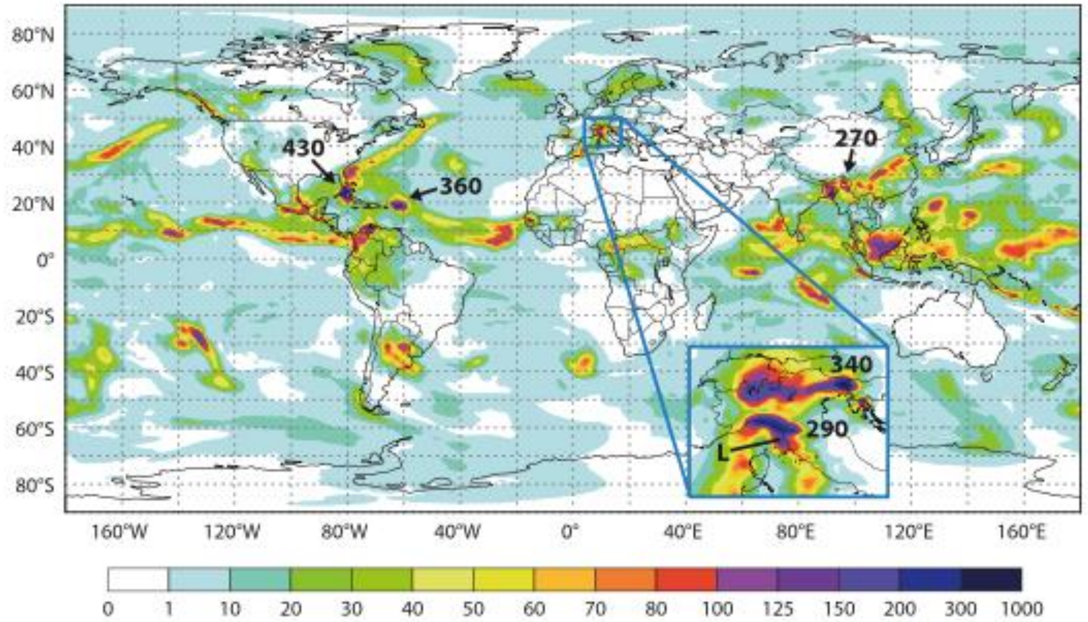
- CIN has been revised to use virtual potential temperature instead of equivalent potential temperature
- Considerable reduction in average CIN values

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)



Point-rainfall forecast. 98th percentile in mm/12h from 00 UTC on 8 September 2017 for the period t+42 to t+54. The top five substantive maxima are labelled. The Florida/Atlantic peaks relate to hurricanes Irma and Jose. L points to Livorno.

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)

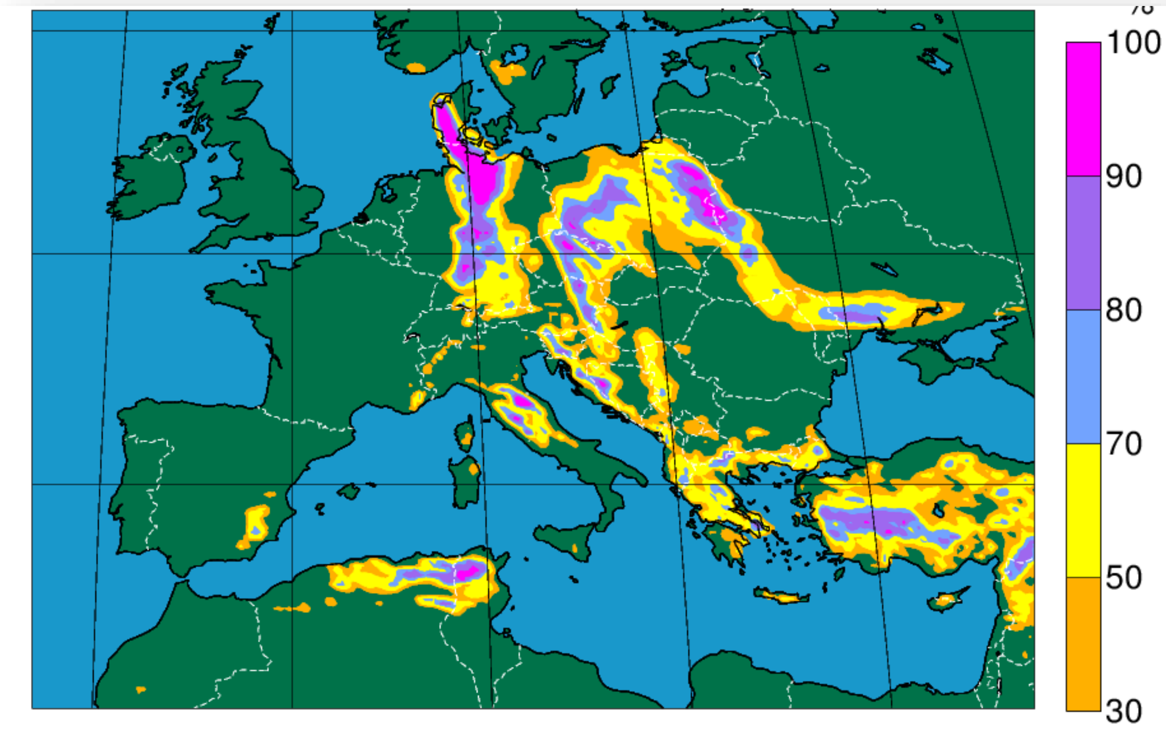
Products in focus

Lightning density parameters

Ensemble forecast from 45r1 esuite

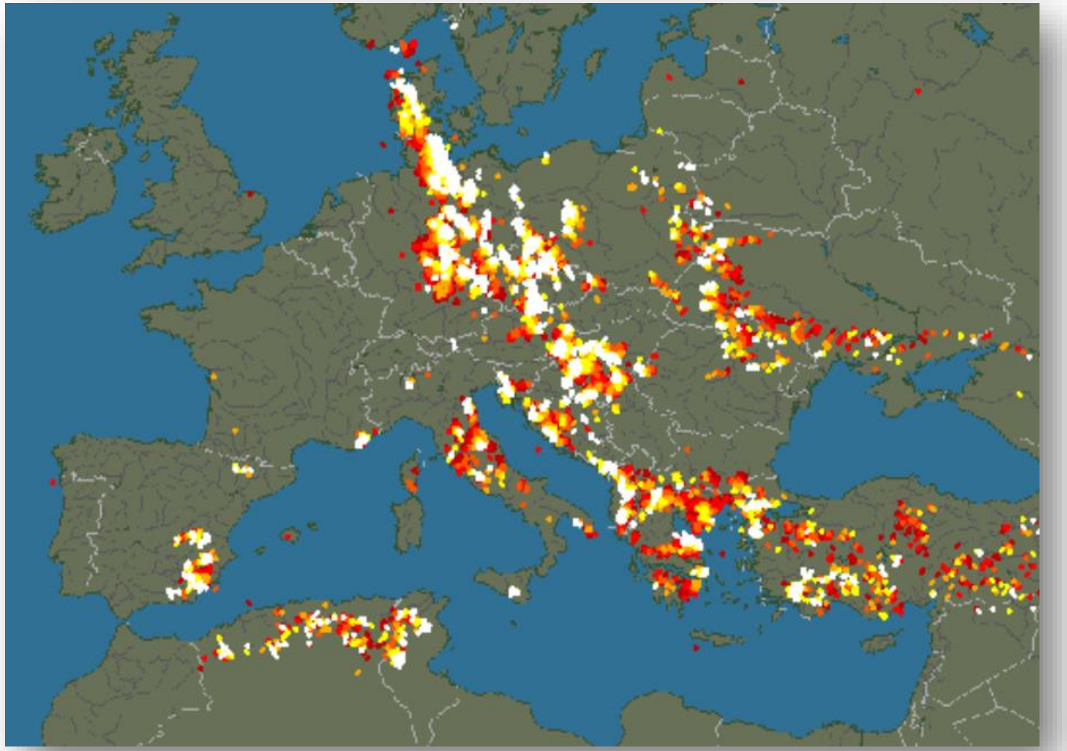
Prob(flash density) > 0.1 fl/100km2/h

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



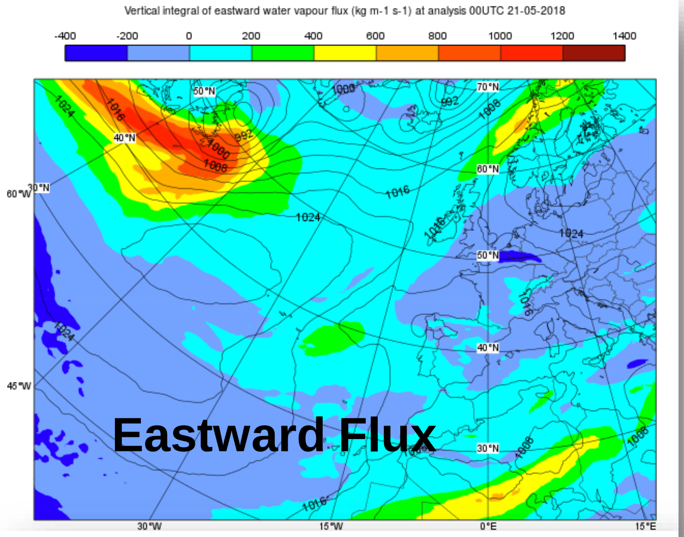
Observed lightning strikes (Blitzortung.org)

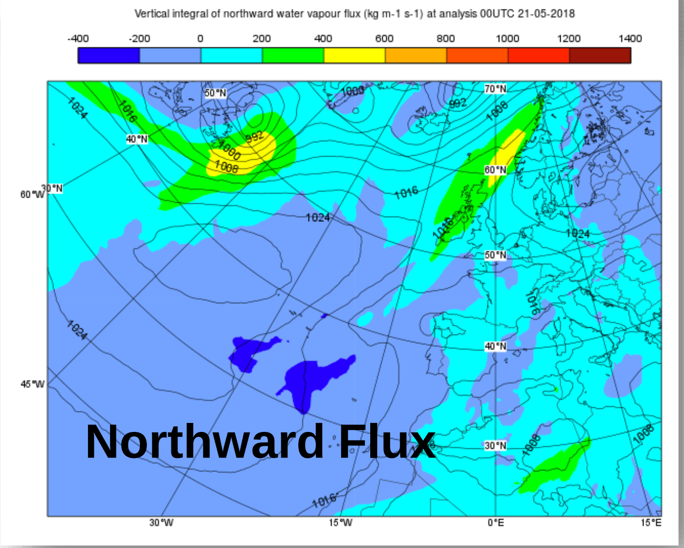
10 May 2018 12 to 15 UTC



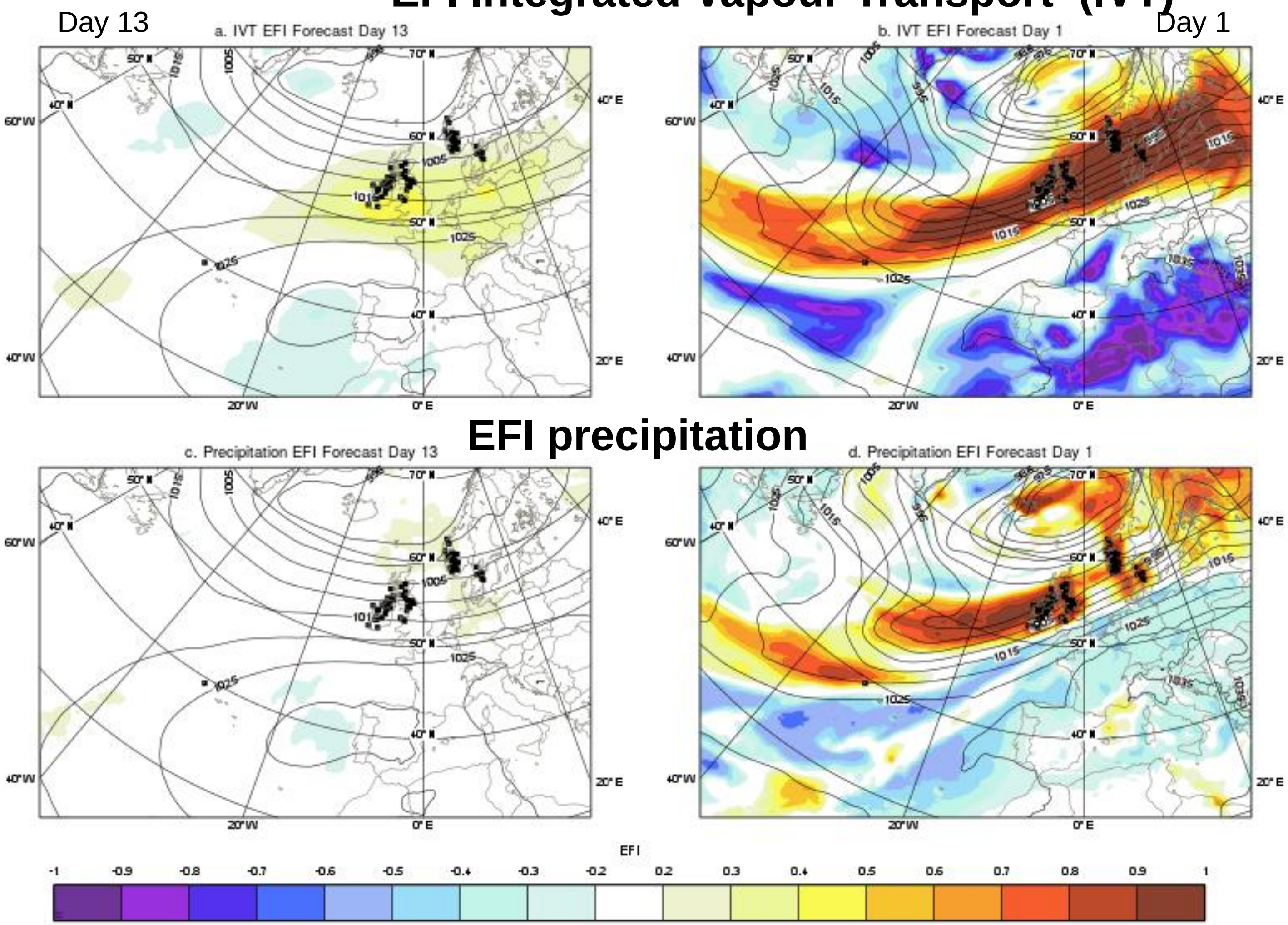
Products in focus

Vertical integral of eastward and northward water vapour flux



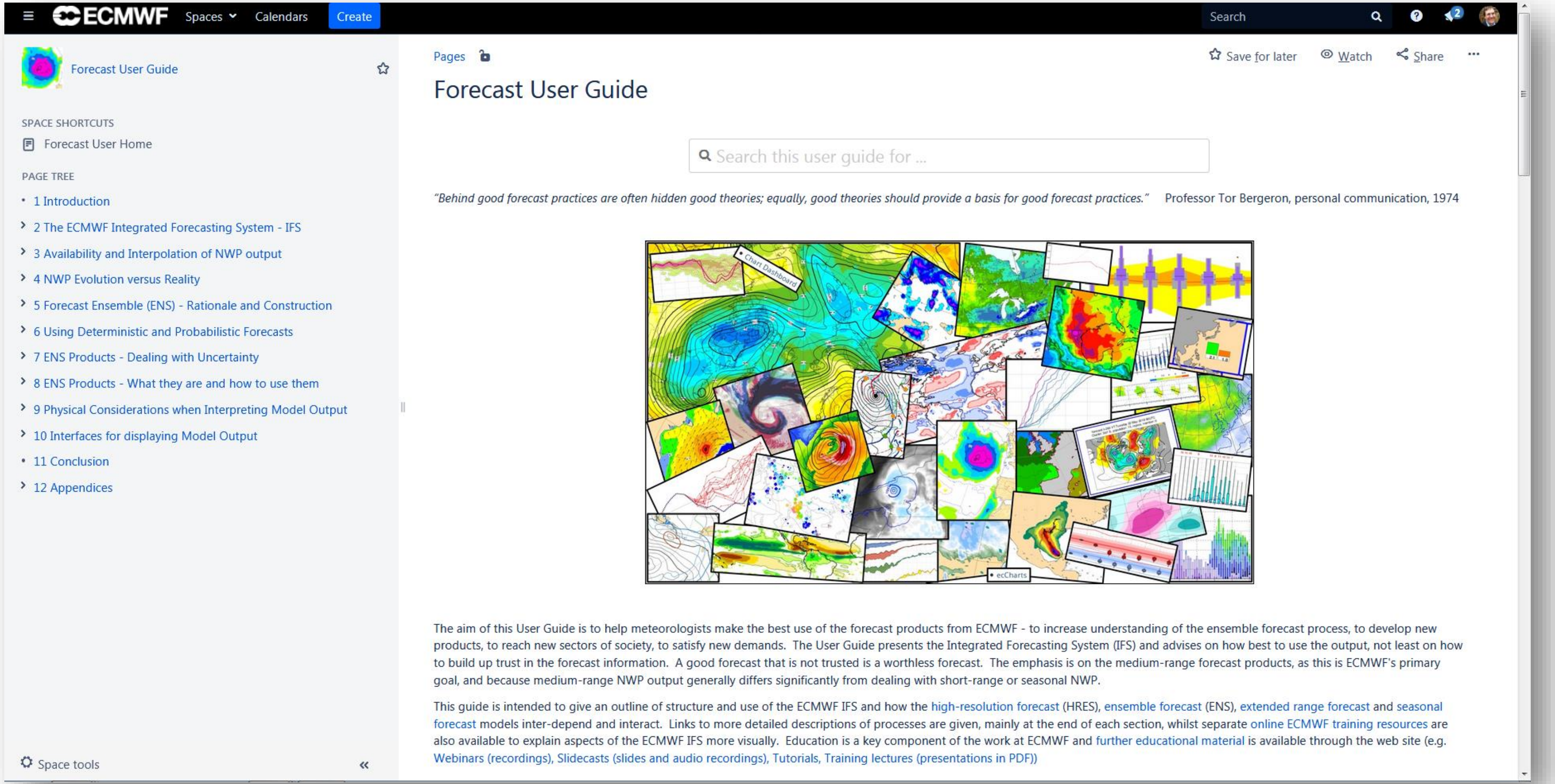


EFI Integrated Vapour Transport (IVT)



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

Space tools

Pages

Save for later Watch Share

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.

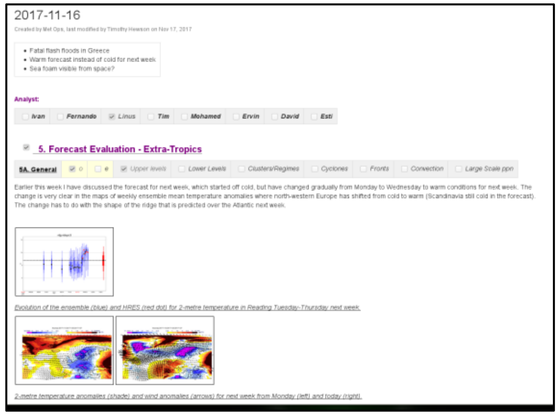
This guide is intended to give an outline of structure and use of the ECMWF IFS and how the high-resolution forecast (HRES), ensemble forecast (ENS), extended range forecast and seasonal forecast models inter-depend and interact. Links to more detailed descriptions of processes are given, mainly at the 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))

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

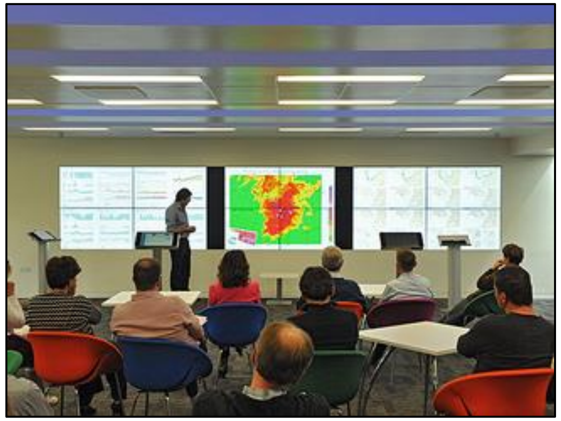
Forecast quality monitoring at ECMWF

Questions from users

Daily report

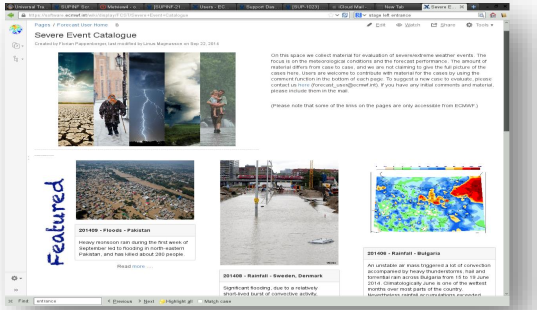


Weekly weather discussions



Quarterly evaluation and development meeting

Severe event catalogue



New model cycles

Research activities

Known forecast issues

ECMWF

Forecast performance in focus

Forecast performance: headline scores

2 primary scores

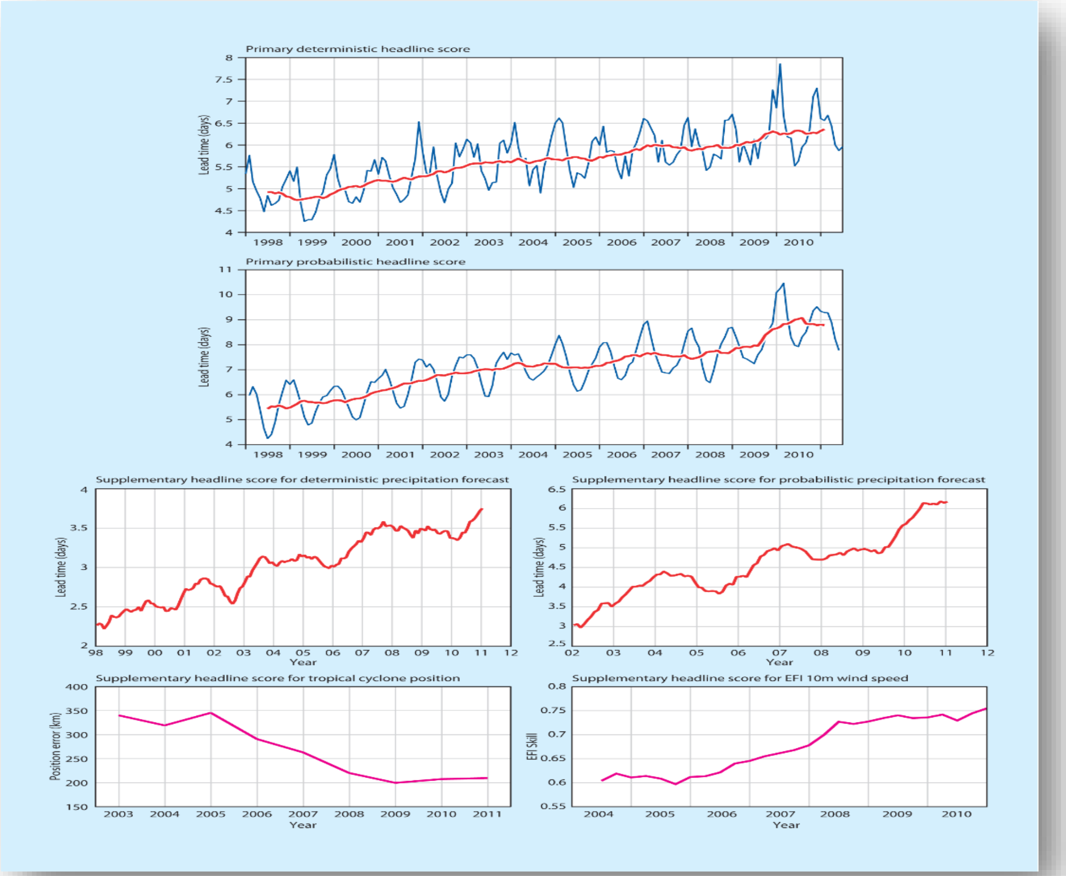
- HRES upper-air skill
- ENS upper-air skill

6 supplementary scores

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

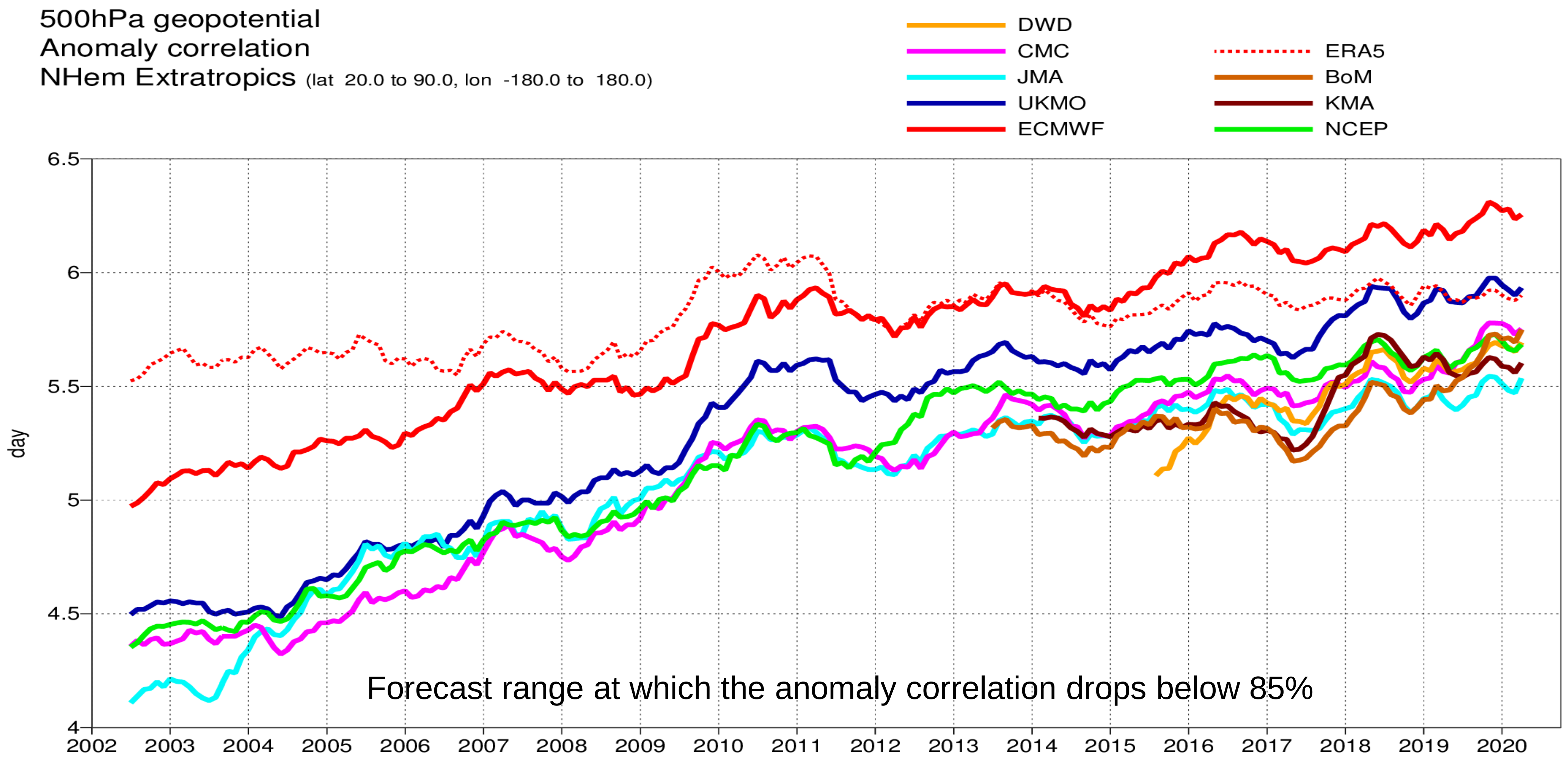
Severe weather

- Tropical cyclone track position error
- EFI skill



Forecast performance in focus

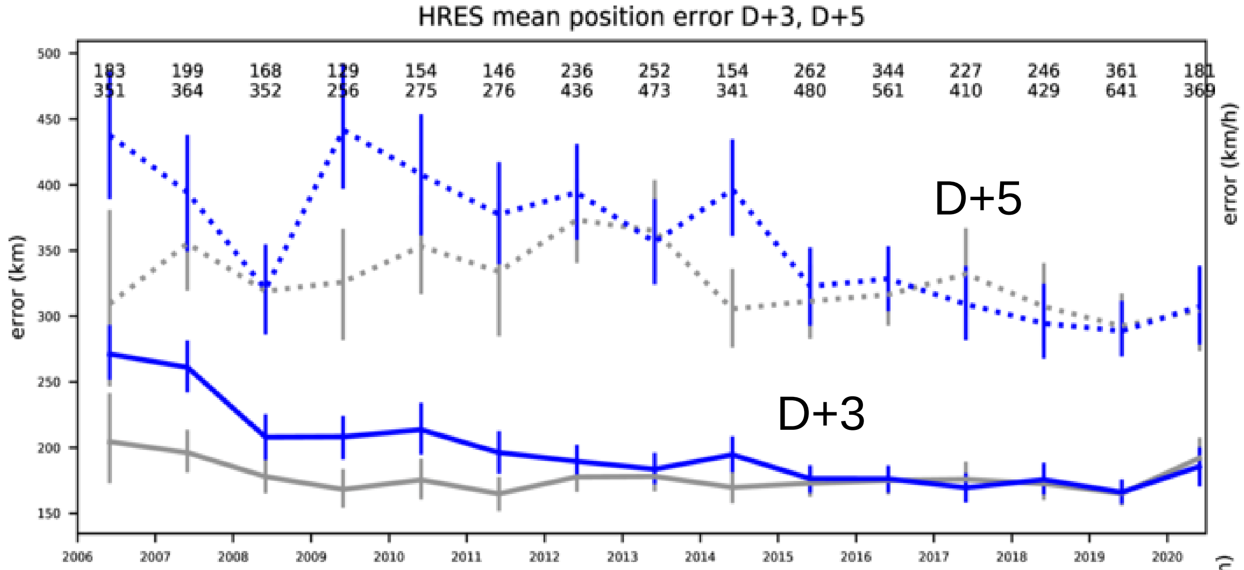
Comparisons with other centres – Z500 Northern Extratropics

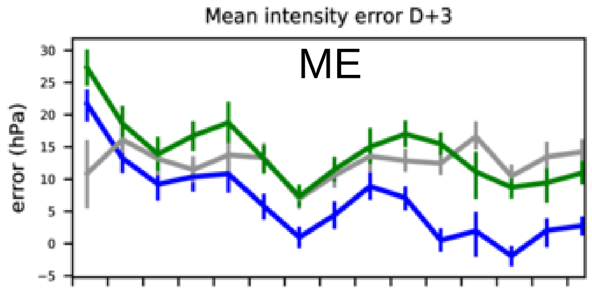


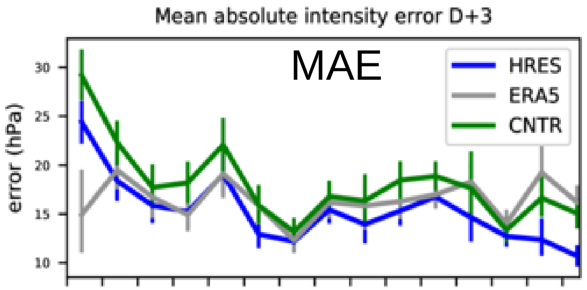
Forecast performance in focus

Tropical cyclones

Position (HRES)

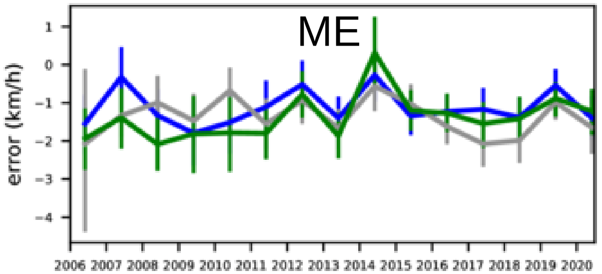


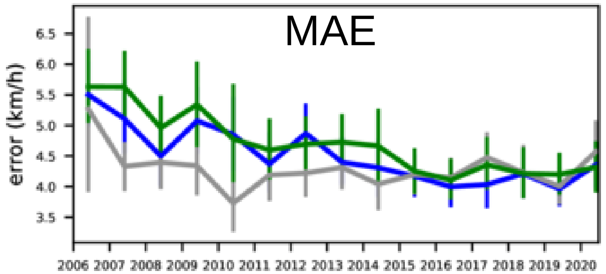


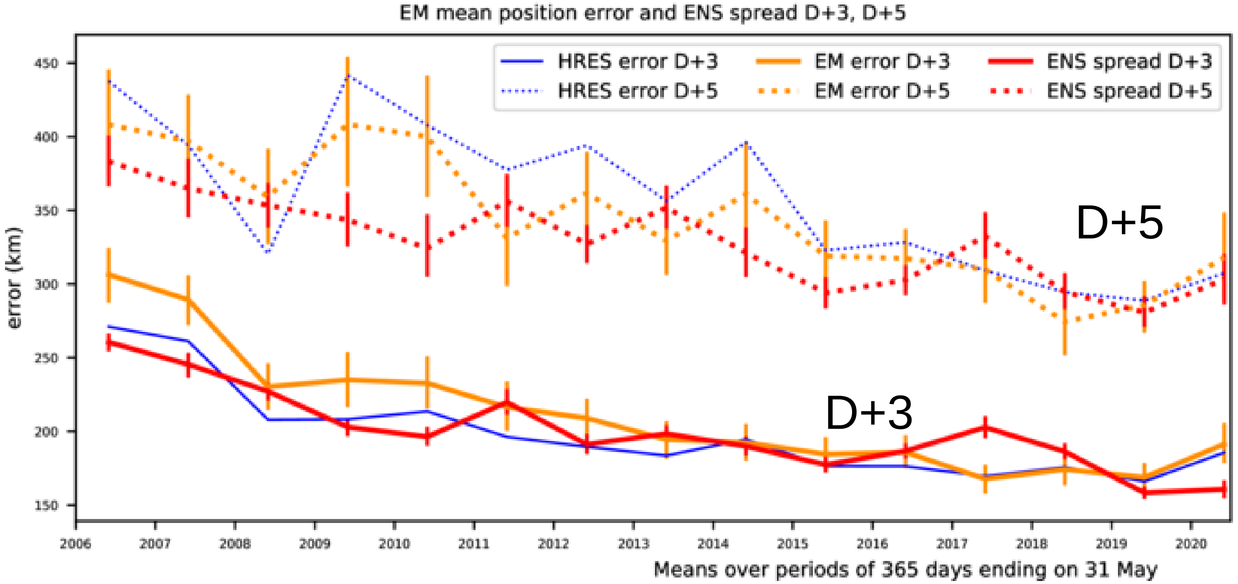


Central pressure

Speed



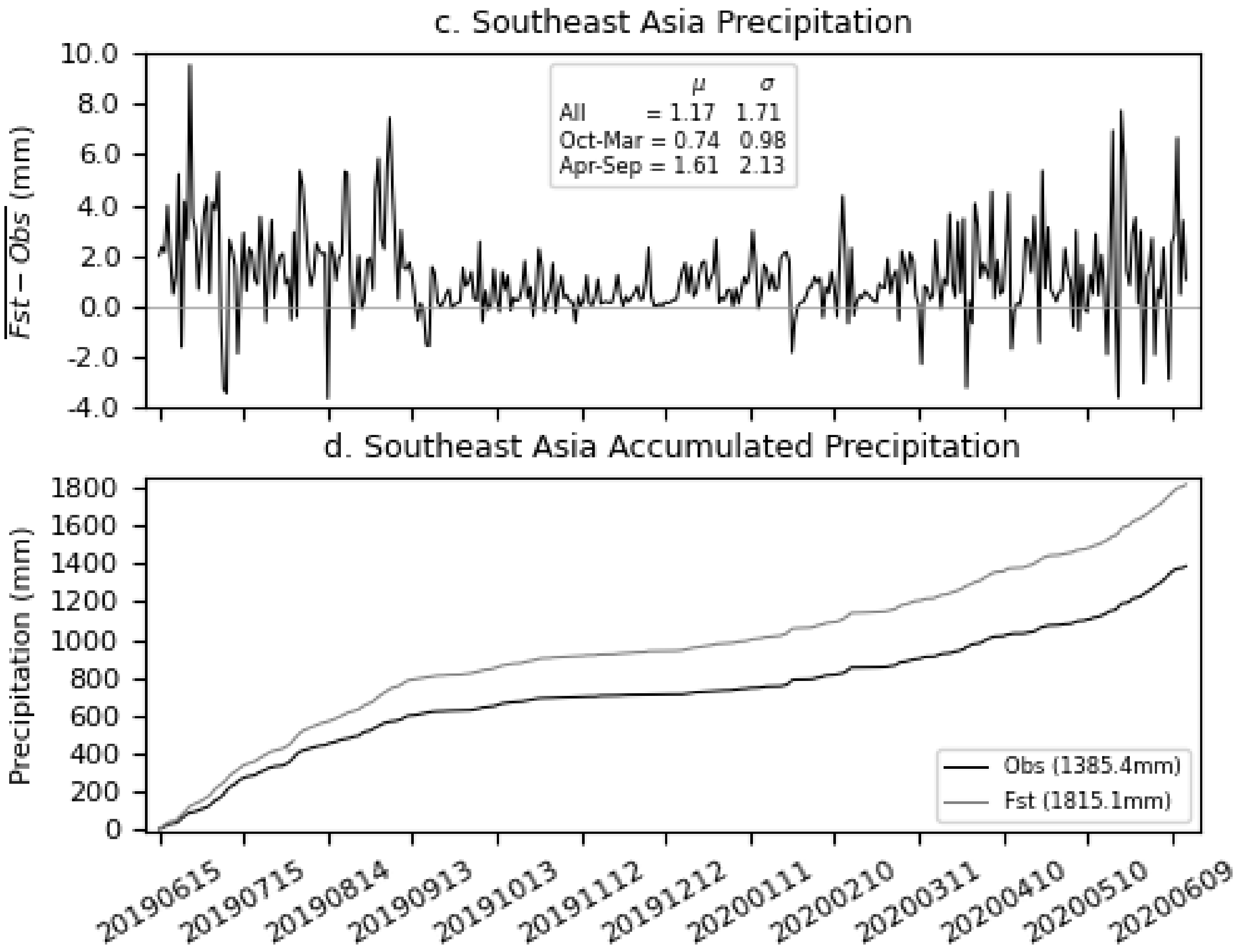


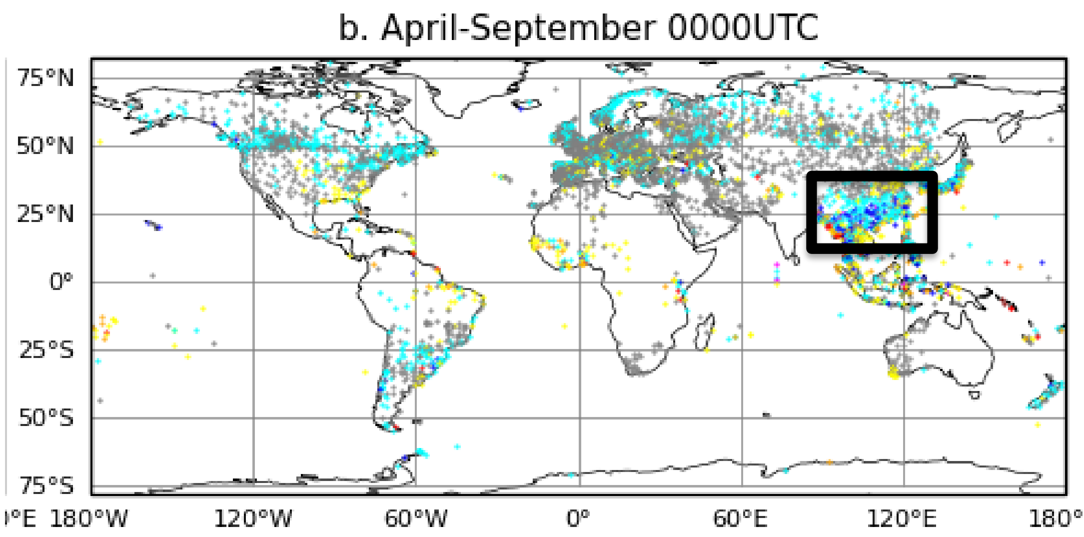


Position (ENS)

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

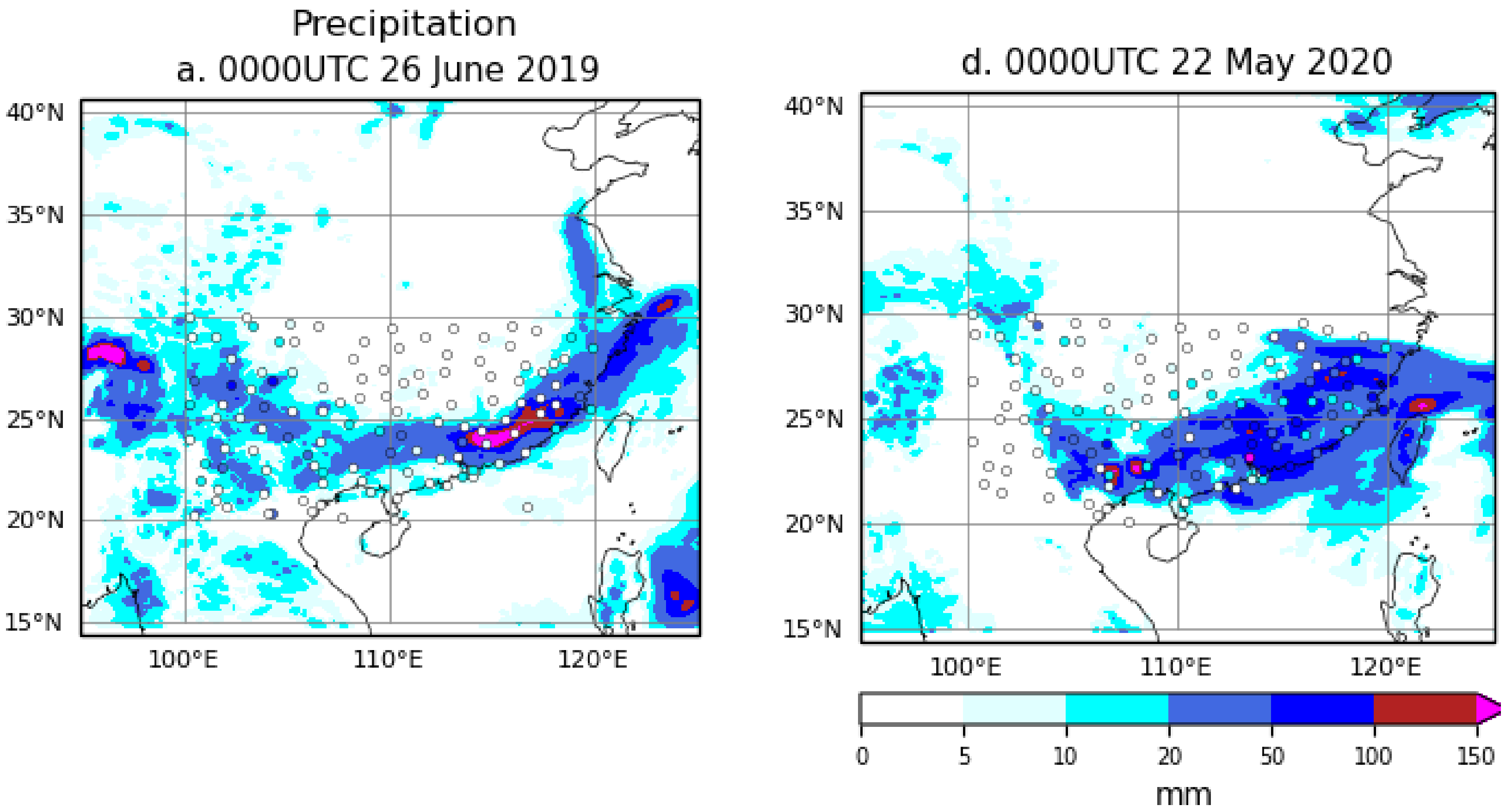
Thanks for David Lavers, ECMWF





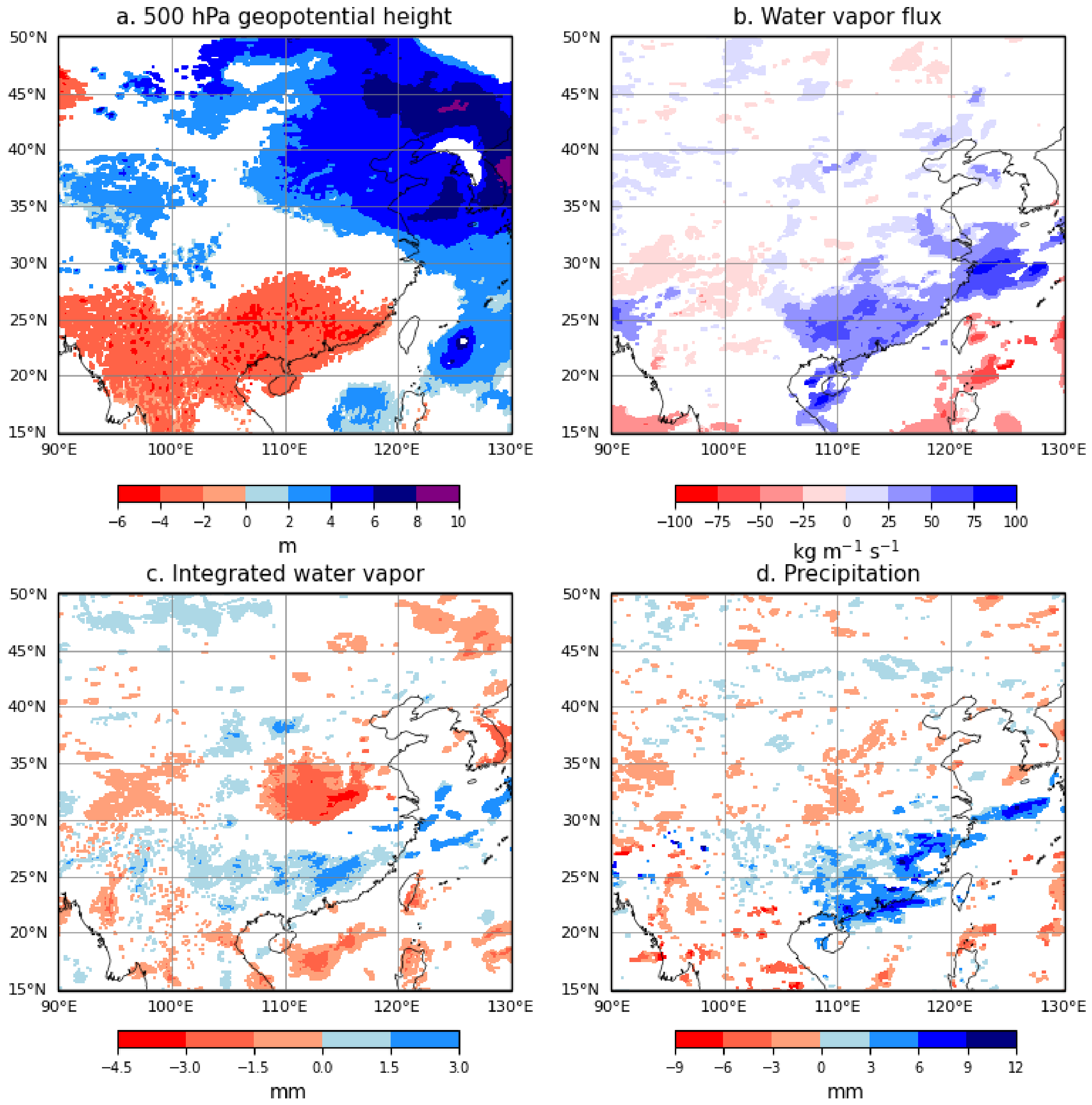
ECMWF

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.

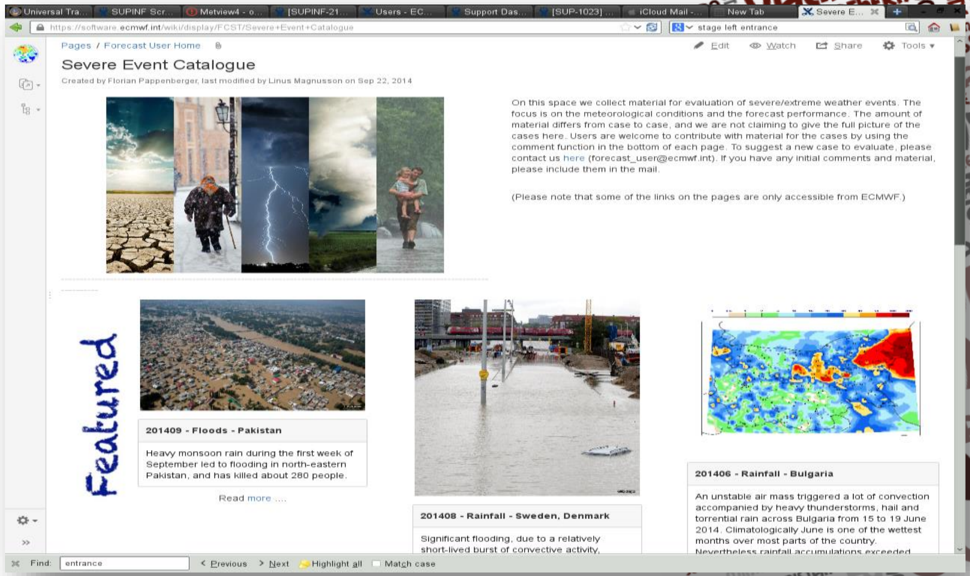
Is there a link to the interaction of the atmospheric circulation with the Himalayas, or to the MJO?

Possible influence on North Pacific storm track and downstream predictability.

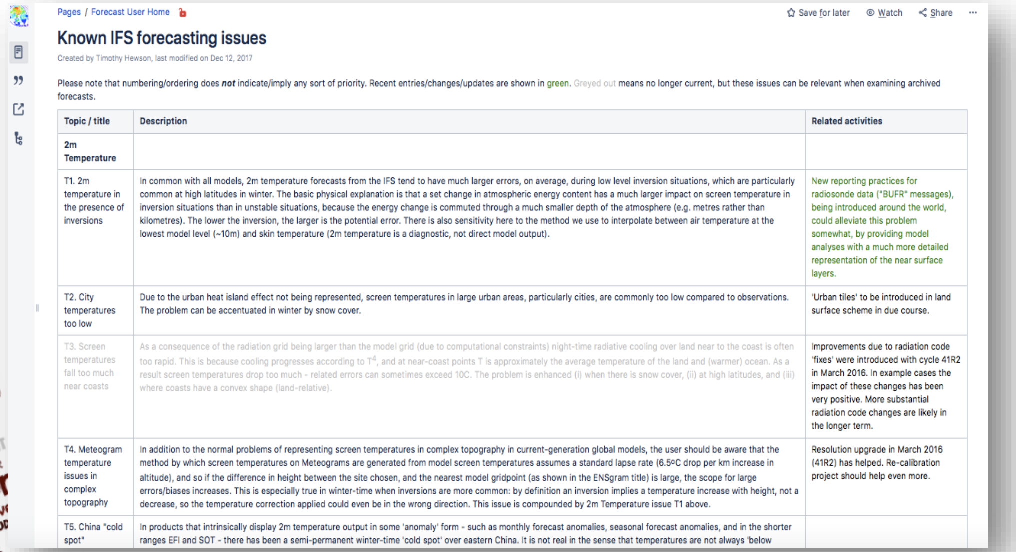
Impact on the regional hydrology.

Outreach in focus

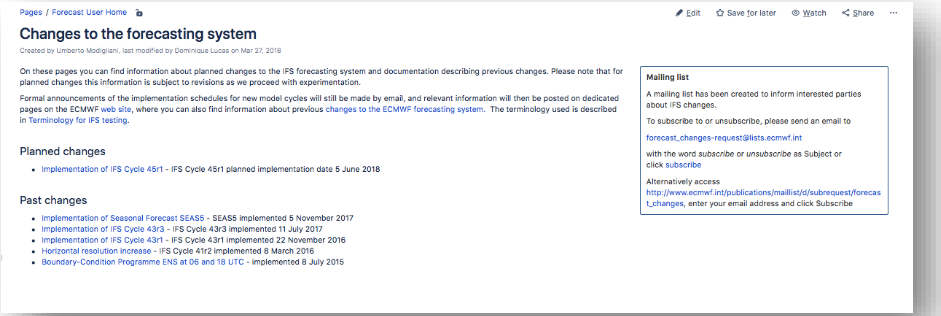
Severe event catalogue



Forecasting issues



Changes to forecasting system



Twitter handle: #newfcsystem @ECMWF

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

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

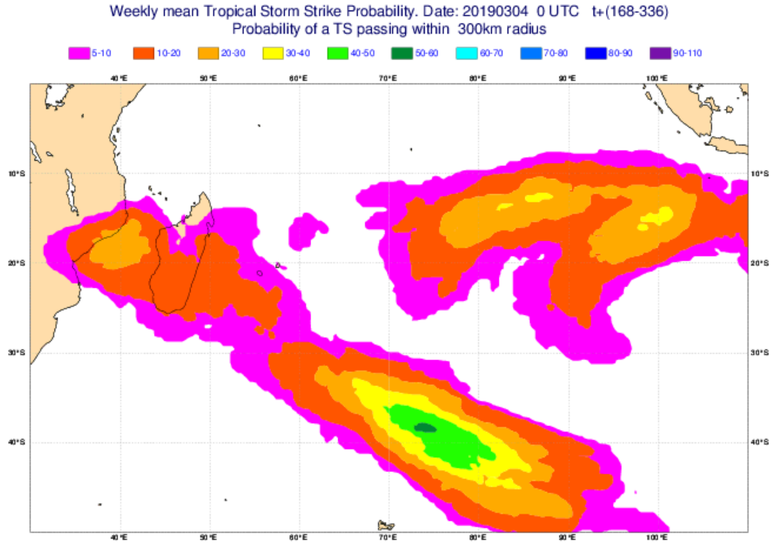
Merged version of articles in 139-158:
https://www.ecmwf.int/sites/default/files/medialibrary/2019-04/ecmwf_nl_severe.pdf

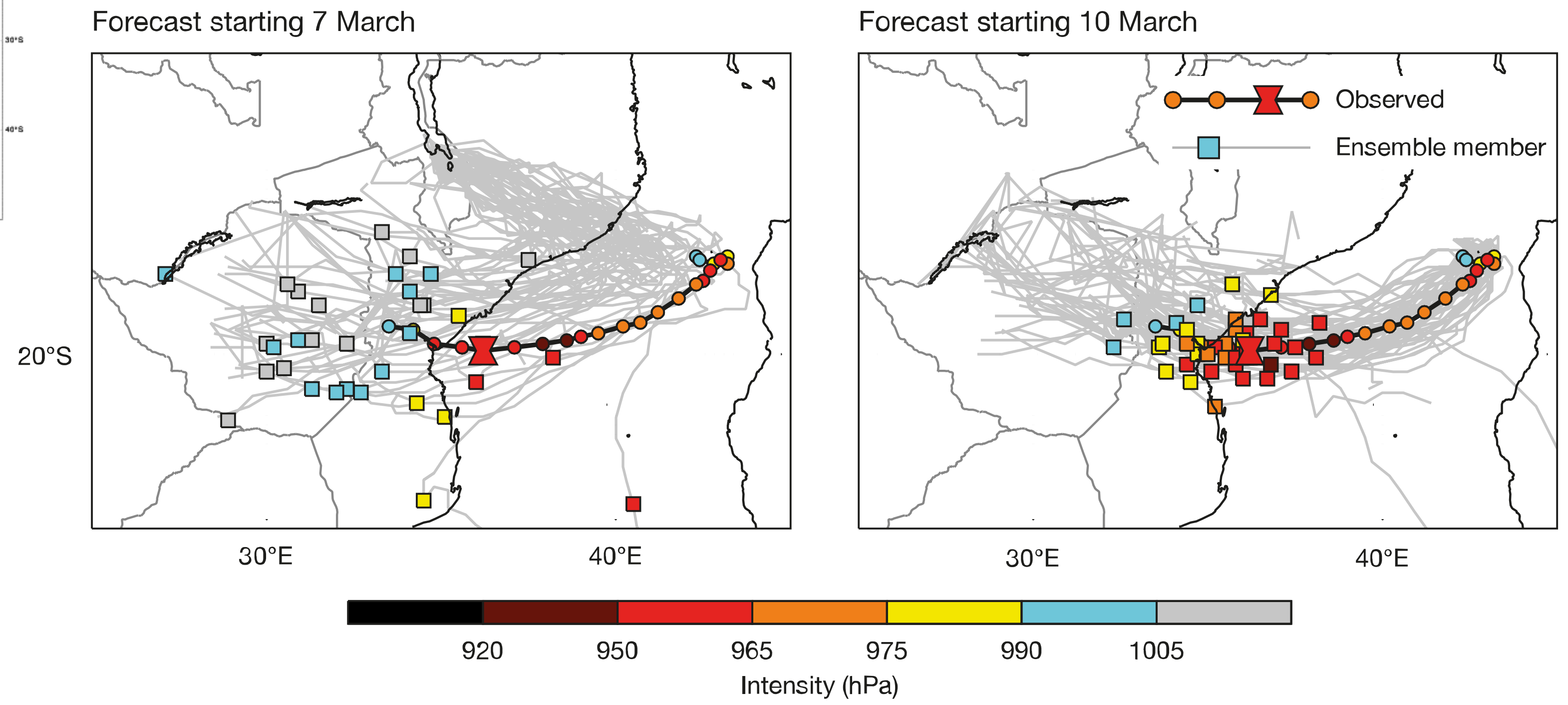
Example of cases in Asia from the catalogue:

- 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





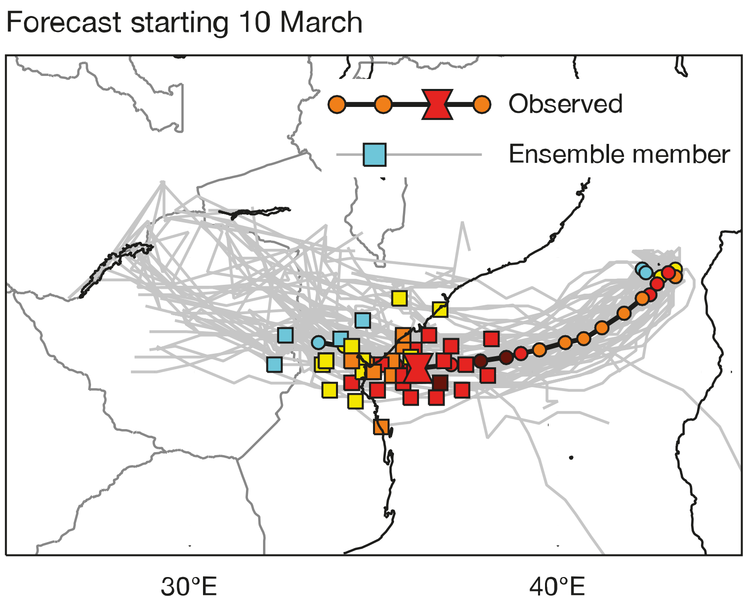
https://www.ecmwf.int/en/newsletter/160/news/ecmwf-works-universities-support-response-tropical-cyclone-idai

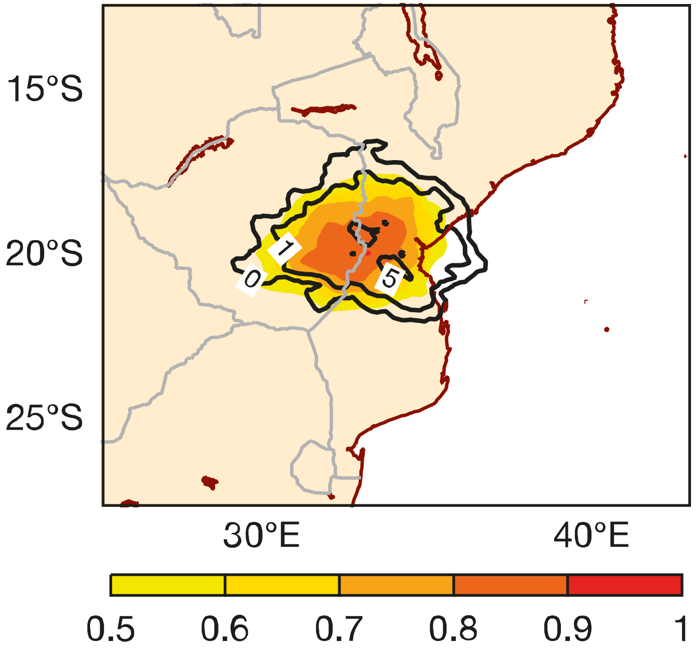
Forecast value chain

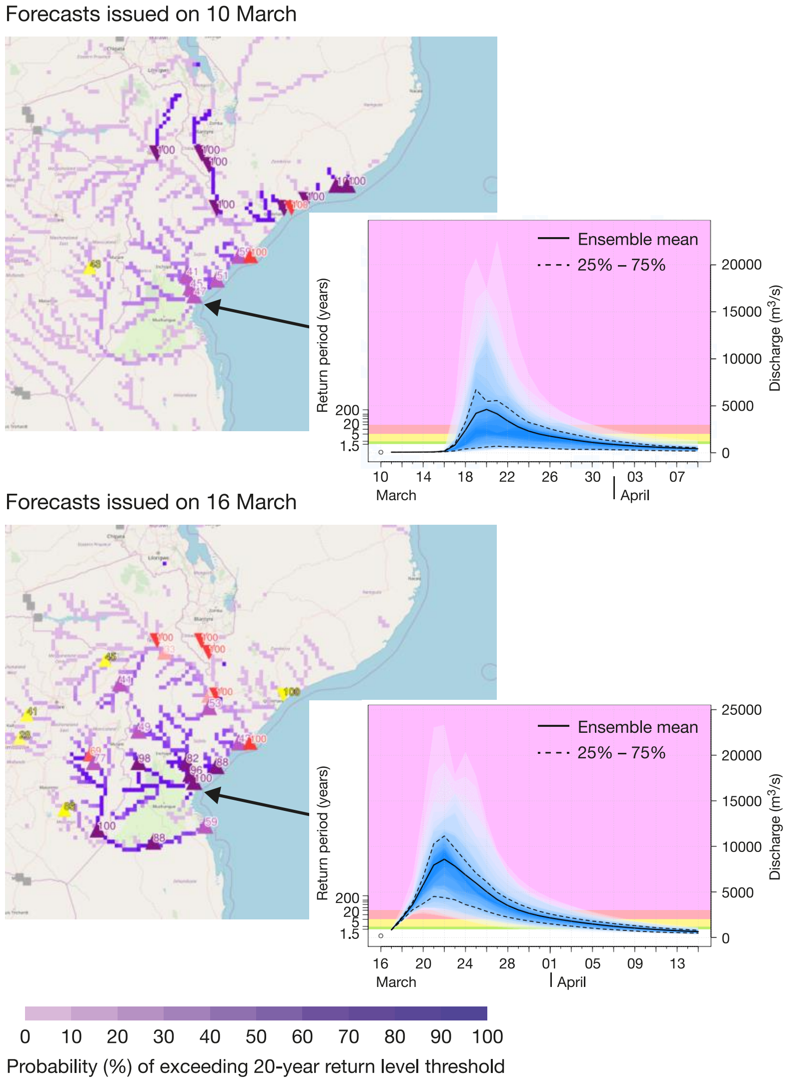
Flood forecast from GLOFAS
globalfloods.eu

Tropical cyclone tracks

Extreme forecast index for precipitation



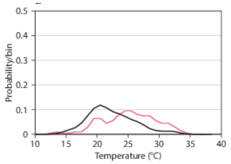


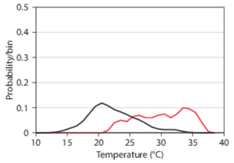


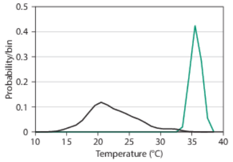
Emerton et al. https://www.sciencedirect.com/science/article/pii/S2212420920313133

Lessons learn 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