

ECMWF forecast system upgrade – 47r1

Florian Pappenberger

Director of Forecasts

@FPappenberger

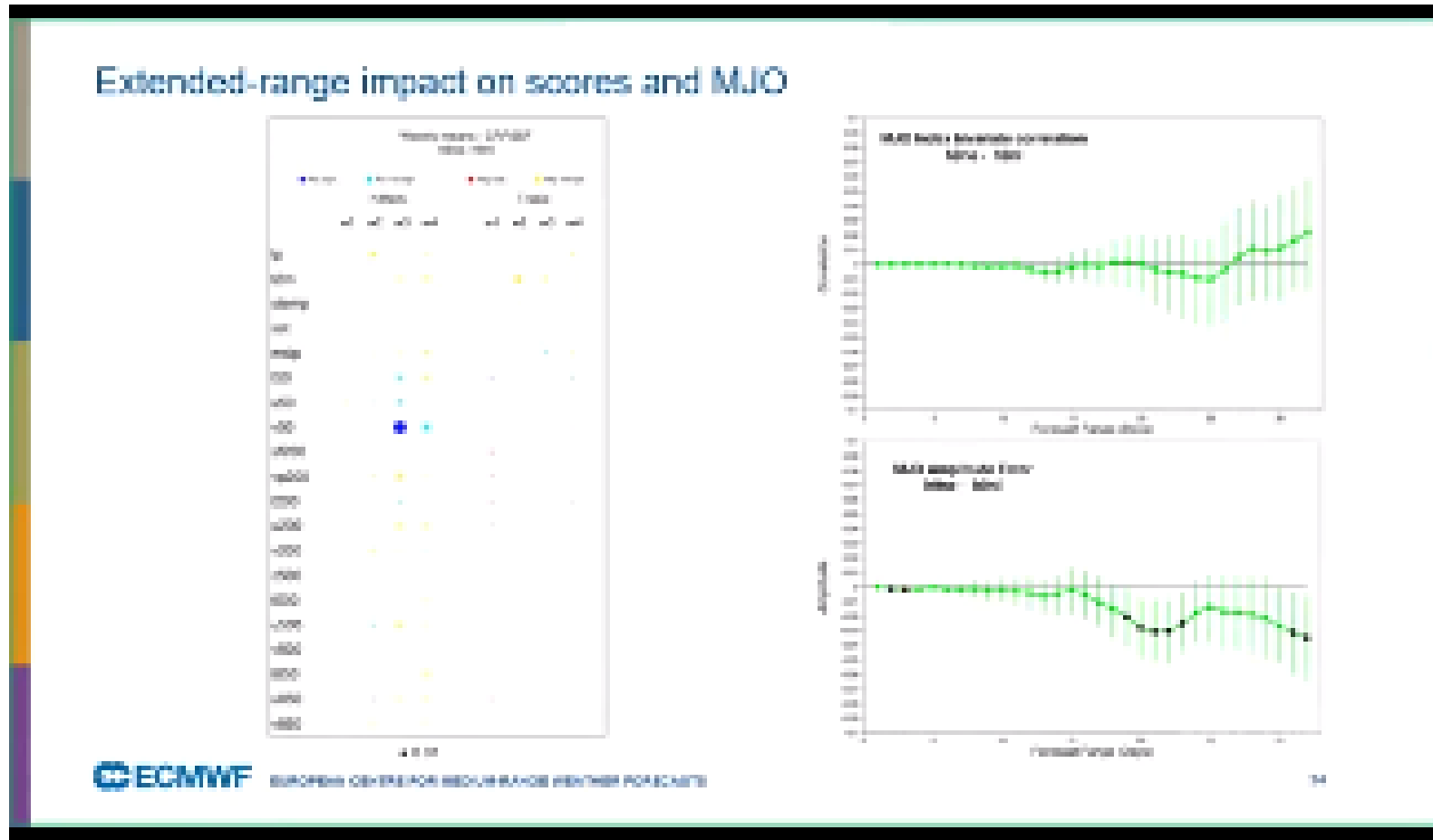


#IFS47r1 #newfcsystem @ECMWF



Keep up to date with the implementation steps – on this side

Webinar on 'Cycle 47r1 overview'



Prof. Andy Brown
Director of Research
30mins

The webinar slides are available to download.



#IFS47r1 #newfcsystem @ECMWF²

USE THE CHAT

&

Questions????

Your questions will be answered immediately



David Richardson



Iain Russell



Andy Brown



Anna Ghelli



Ivan Tsonevsky



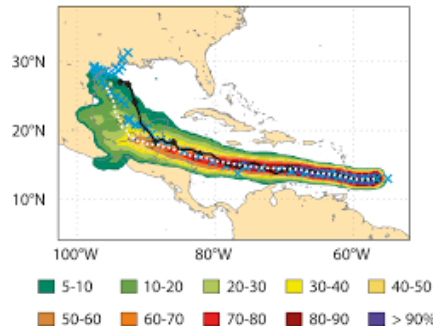
Tim Hewson



Irina Sandu



Thomas Haiden



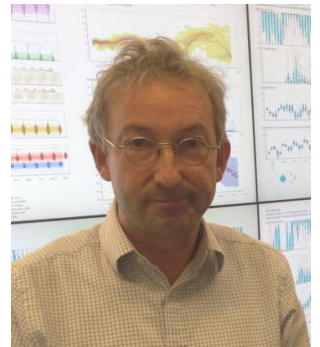
Fernando Prates



Staff @ECMWF



Martin Leutbecher

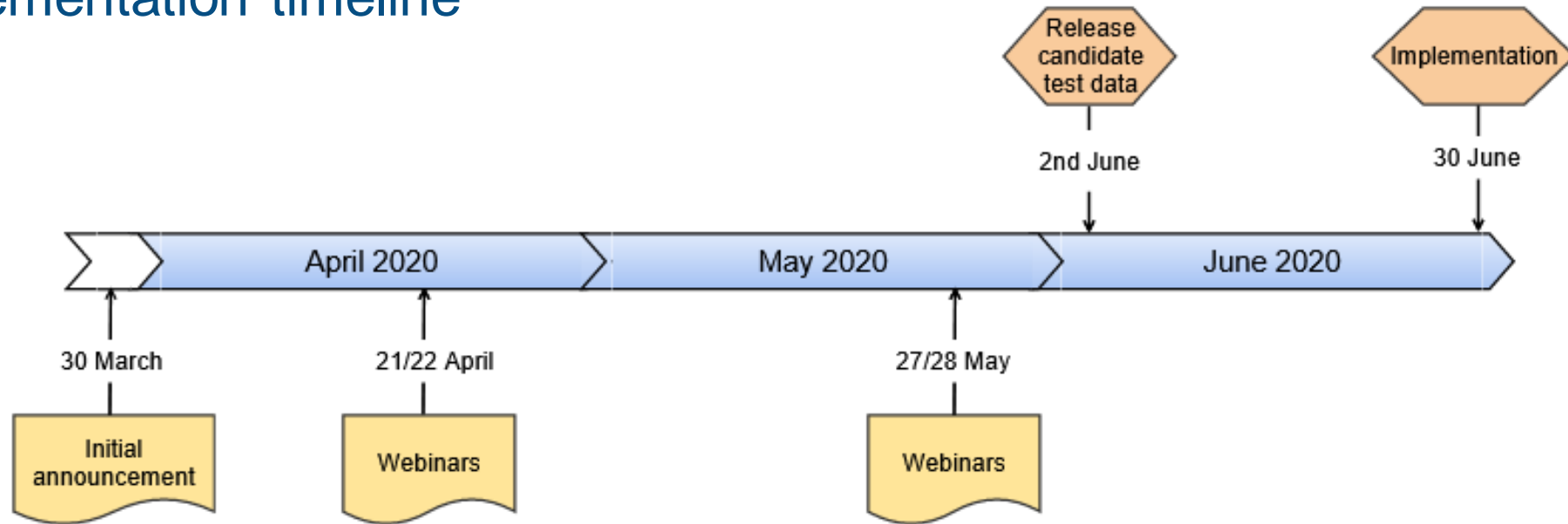


Carsten Maass



#IFS47r1 #newfcsystem @ECMWF

Implementation timeline



On the 2nd June

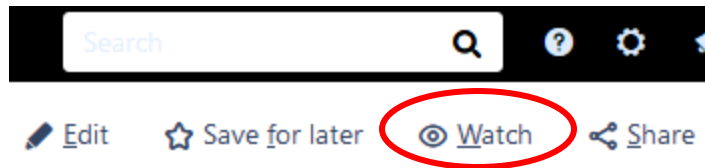
- A full set of product services (e.g. dissemination of test data, ecCharts) will be offered until the operational implementation of the new cycle.
- The test products will be generated daily, shortly behind real-time from the high resolution and ensemble runs and based on the operational dissemination requirements.
- Graphical display of IFS cycle 47r1 test data using ecCharts will become available
- Implementation of new cycle will be on 30 June 06UTC

Keep up to date with the implementation steps

<https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+47r1>

Contains all details on upgrade.

Please *watch* the page



A screenshot of a Confluence page titled 'Implementation of IFS Cycle 47r1'. The page is part of the 'Forecast User Portal' and was updated on 20 May 2020. It contains a 'Description of the upgrade' section detailing changes in observations, data assimilation, and model improvements. A 'NEWS!' section lists recent updates, including the availability of near real-time release candidate test data and new metrics for tropical cyclones. The page also features a 'Implementation timeline' section with two milestones: 'Release candidate test data' and 'Implementation'. The left sidebar shows a navigation menu with categories like 'Pages', 'Blog', and 'SPACE SHORTCUTS', with the current page highlighted under 'Implementation of IFS Cycle'.

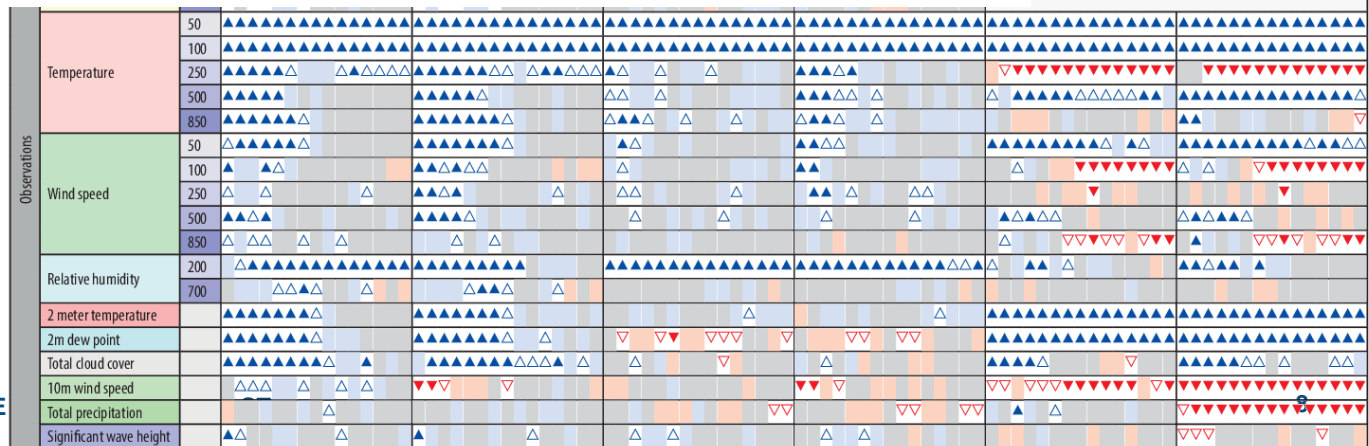
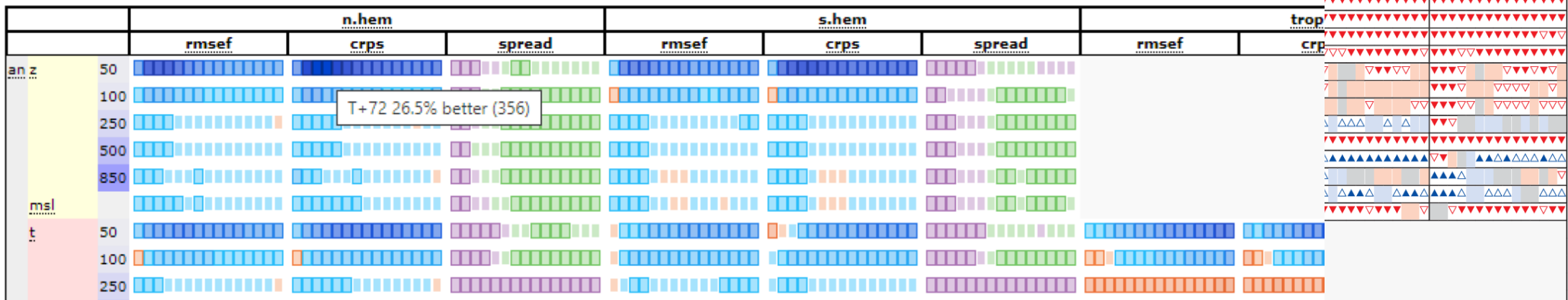
47r1 performance – ENS scorecard

based on ~350 model runs

Parameter	Level (hPa)	Northern hemisphere						Southern hemisphere						Tropics																																
		RMS error			CRPS			RMS error			CRPS			RMS error			CRPS																													
		Forecast day						Forecast day						Forecast day																																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50	50	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲															

47r1 ENS scorecard

- rmsef crps spread
- n.hem s.hem tropics europe n.atl n.amer n.pac e.asia arctic antarctic (all)
- boxes significance triangles



47r1 performance - highlights

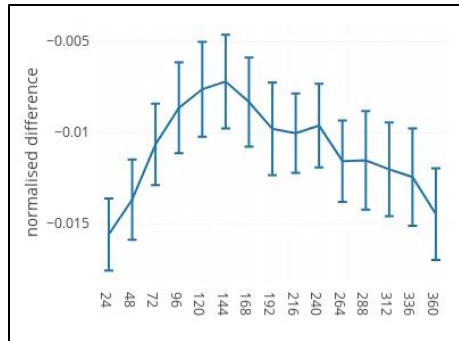
based on ~350 model runs

Apparent degradations against own analysis

Extratropics: mainly short range

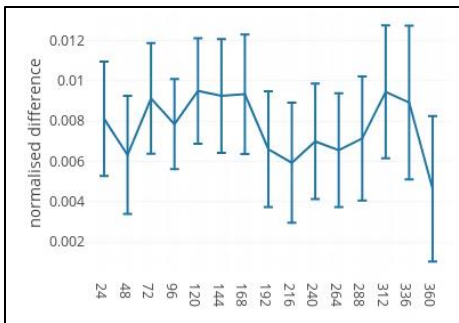
Tropics: throughout forecast range

- Due to use of 1st guess from early delivery in long-window DA
- Leads to better fit to observations



1-1.5% degradation against analysis

T500 in the Tropics



0.5-1% improvement against obs

Parameter	Level (hPa)	Northern hemisphere															Southern hemisphere															Tropics															
		RMS error					CRPS					RMS error					CRPS					RMS error					CRPS																				
		Forecast day					Forecast day					Forecast day					Forecast day					Forecast day					Forecast day																				
Analysis	Geopotential	50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		100	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		250	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		500	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
	Mean sea level pressure	850	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		100	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		250	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
	Temperature	500	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		850	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		100	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
Wind speed	250	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
	500	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
	850	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
	50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Relative humidity	200	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
	700	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
2 meter temperature		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
10 m wind at sea		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Significant wave height		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Mean wave period		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Observations	Geopotential	50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		100	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		250	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		500	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
	Temperature	850	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		100	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		250	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
	Wind speed	500	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		850	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		50	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
		100	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲														
Relative humidity	200	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
	700	▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
2 meter temperature		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
2m dew point		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Total cloud cover		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
10m wind speed		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Total precipitation		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															
Significant wave height		▲▲▲▲▲															▲▲▲▲▲															▲▲▲▲▲															

47r1 performance – HRES scorecard

Qualitatively similar to ENS scorecard:

- Apparent degradations against own analysis
- Mostly neutral to positive against observations

based on ~630 model runs

Parameter	Level (hPa)	Northern hemisphere										Southern hemisphere										Tropics																													
		Anomaly correlation/ SEEPS					RMS error/ Std. dev. of error					Anomaly correlation/ SEEPS					RMS error/ Std. dev. of error					Anomaly correlation/ SEEPS					RMS error/ Std. dev. of error																								
		Forecast day					Forecast day					Forecast day					Forecast day					Forecast day					Forecast day																								
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Geopotential	50	▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																																		
	100	▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																																		
	250	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
	500	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
	850	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
Mean sea level pressure		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
Temperature	50	▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	100	▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	250	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	500	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	850	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
2 m temperature		▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
Vector wind	50	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	100	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	250	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	500	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	850	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
10 m wind speed		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																								
Relative humidity	250	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
700	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																									
10 m wind at sea		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																								
Significant wave height		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																								
Mean wave period		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																								
Geopotential	50	▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																																		
	100	▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																																		
	250	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
	500	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
	850	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																																		
Temperature	50	▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	100	▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	250	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	500	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
	850	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
2 m temperature		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲▲▲▲▲▲																								
Vector wind	50	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
	100	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
	250	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
	500	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
	850	▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
10 m wind speed		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
Relative humidity	250	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																								
700	▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲					▼▼▼▼▼					▲▲▲▲▲▲▲▲▲▲																									
2m dew point		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
Total cloud cover		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
Total precipitation		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								
Significant wave height		▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲					▲▲▲▲▲																								

USE THE CHAT

&

Questions????

Your questions will be answered immediately



David Richardson



Iain Russell



Andy Brown



Anna Ghelli



Ivan Tsonevsky



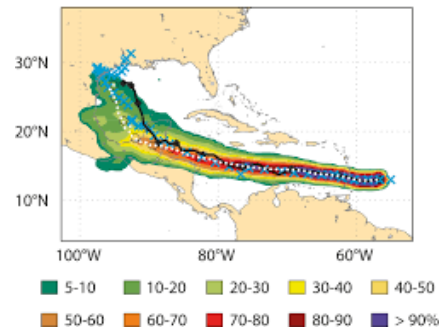
Tim Hewson



Irina Sandu



Thomas Haiden



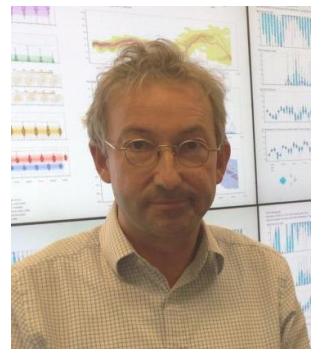
Fernando Prates



Staff @ECMWF



Martin Leutbecher

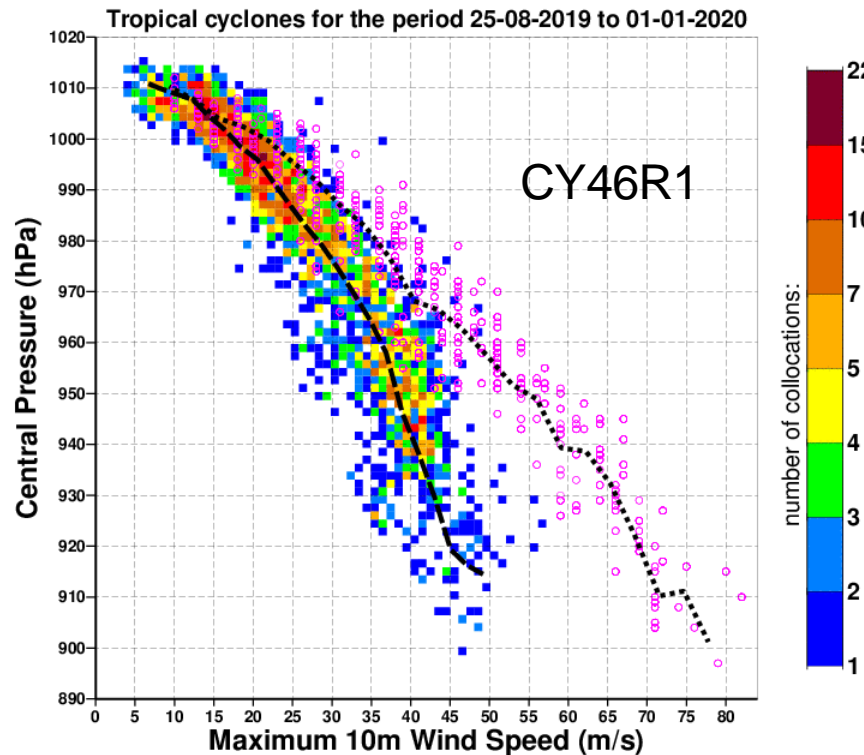


Carsten Maass

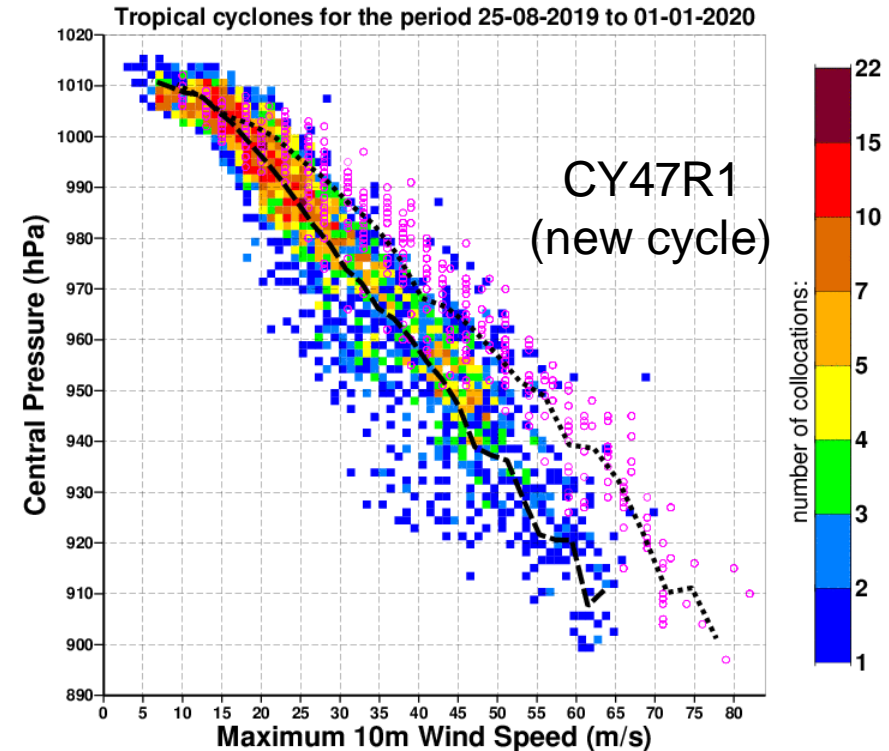


#IFS47r1 #newfcsystem @ECMWF

Tropical cyclone max wind - min pressure relationship



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



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

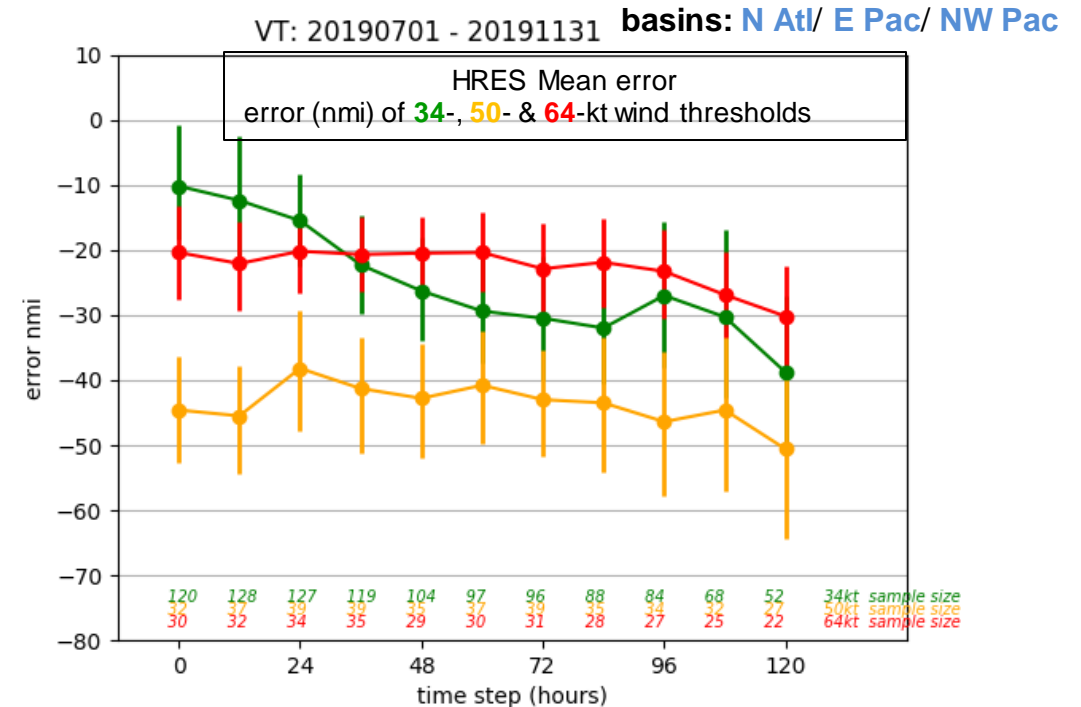
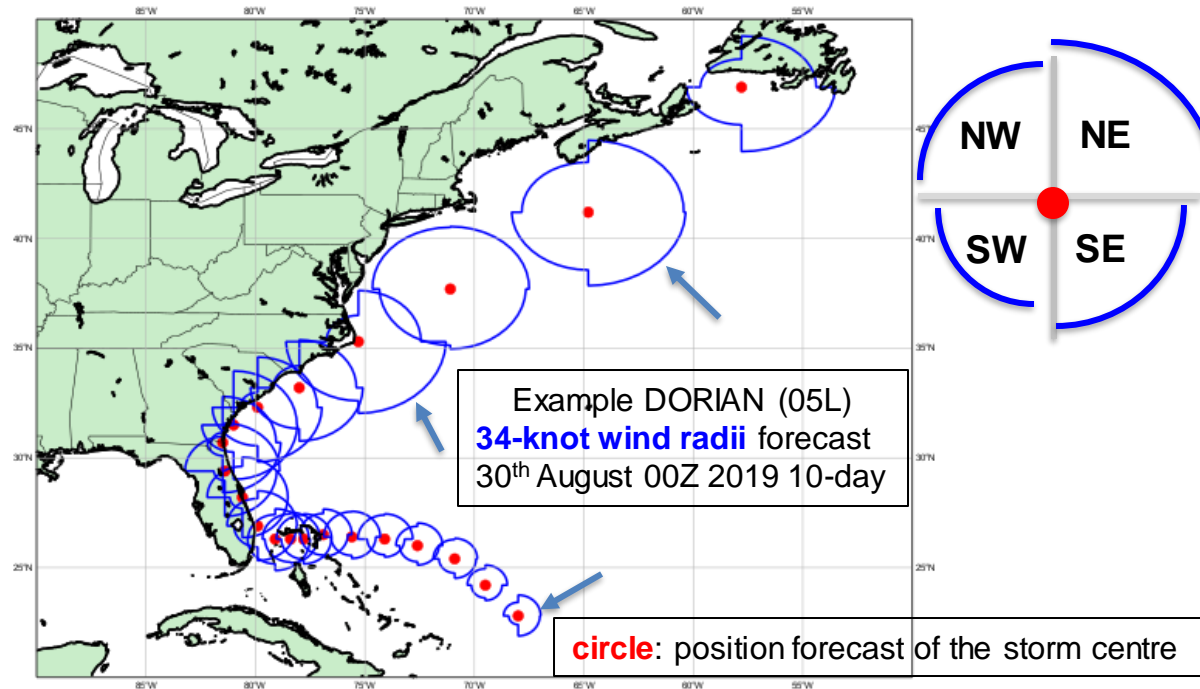
Tco1279 forecasts from 0 UTC for period 25-08-2019 to 01-01-2020 (coloured shading and dotted line).

Reported values (pink symbols and dotted line) for tropical cyclones:

Ambali, Belna, Bualoi, Calvinia, Dorian, Faxai, Fengshen, Hagibis, Halong, Humberto, Kammuri, Kyarr, Lingling, Lorenzo, Maha, Matmo, Nakri, Phanfone, Sarai, Sebastien

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)

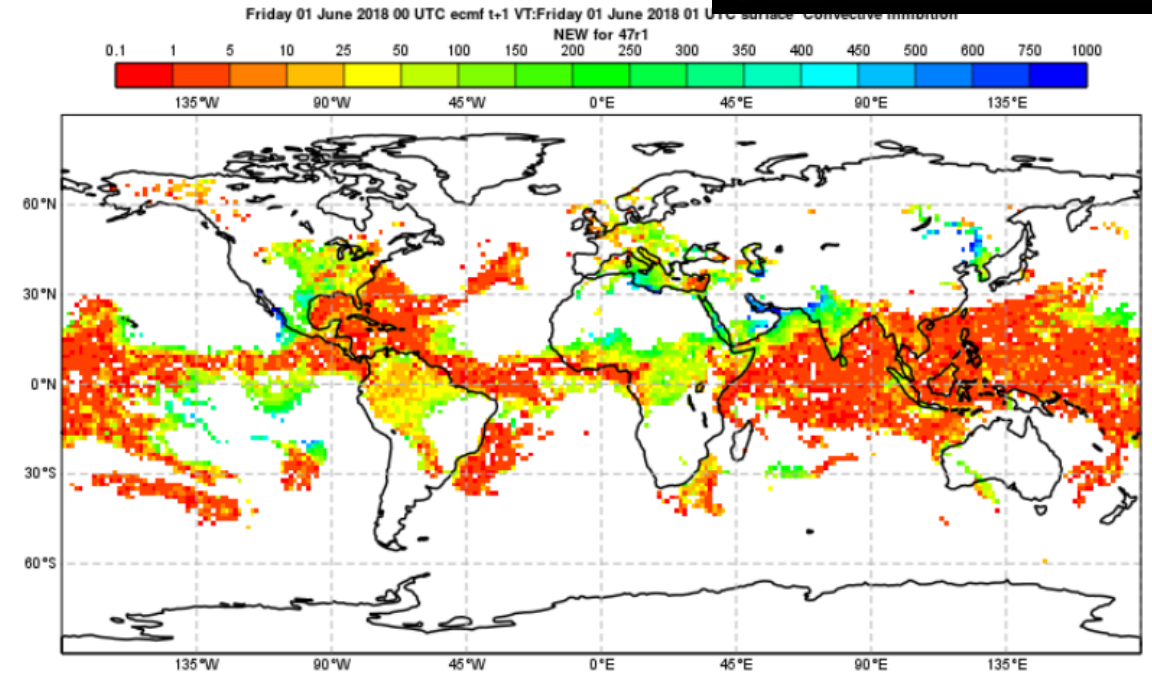
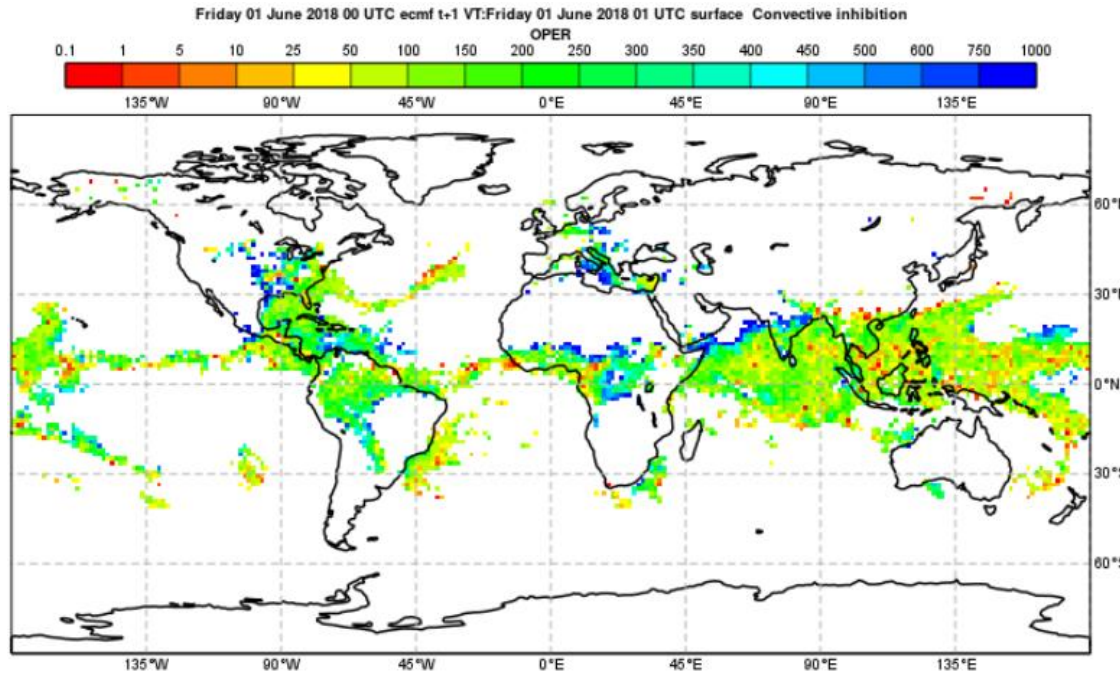
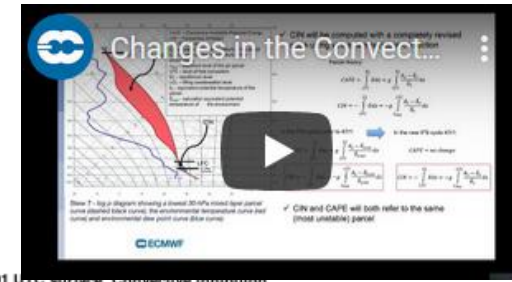


- Product available for the HRES and ENS (all TCs in analysis and those that develop during the forecast –'genesis')
- Can be helpful to 1) identifying coastal areas potentially affected by winds of TS strength or higher; 2) ship routing forecast
- More information in <https://confluence.ecmwf.int/display/FCST/New+Tropical+Cyclone+Wind+Radii+product>

Convective inhibition diagnostic (CIN)

46r1

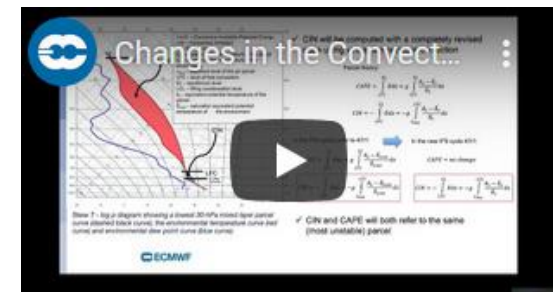
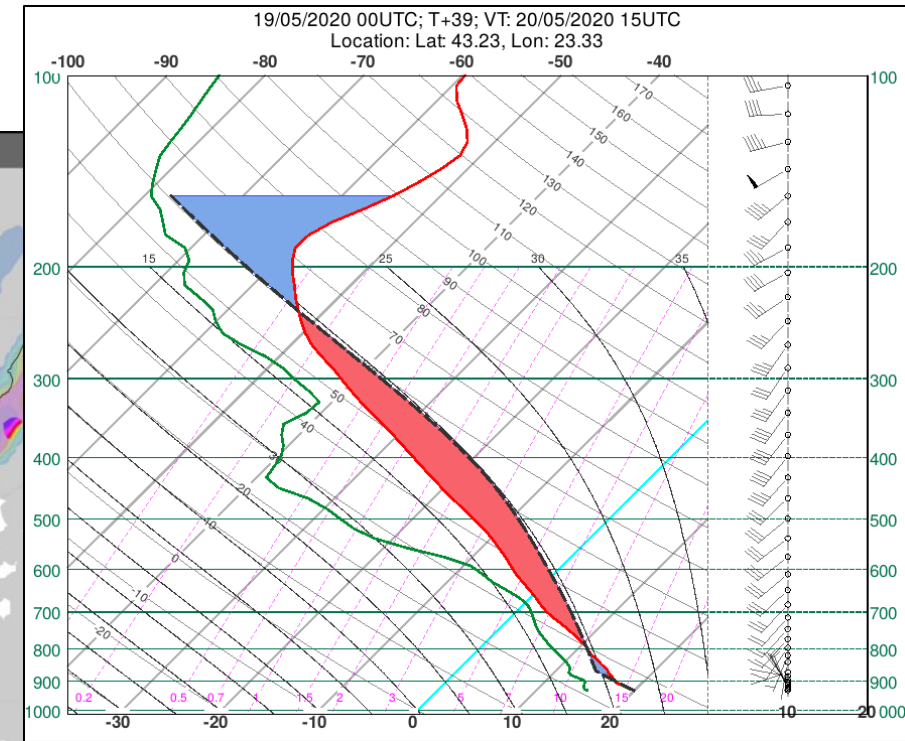
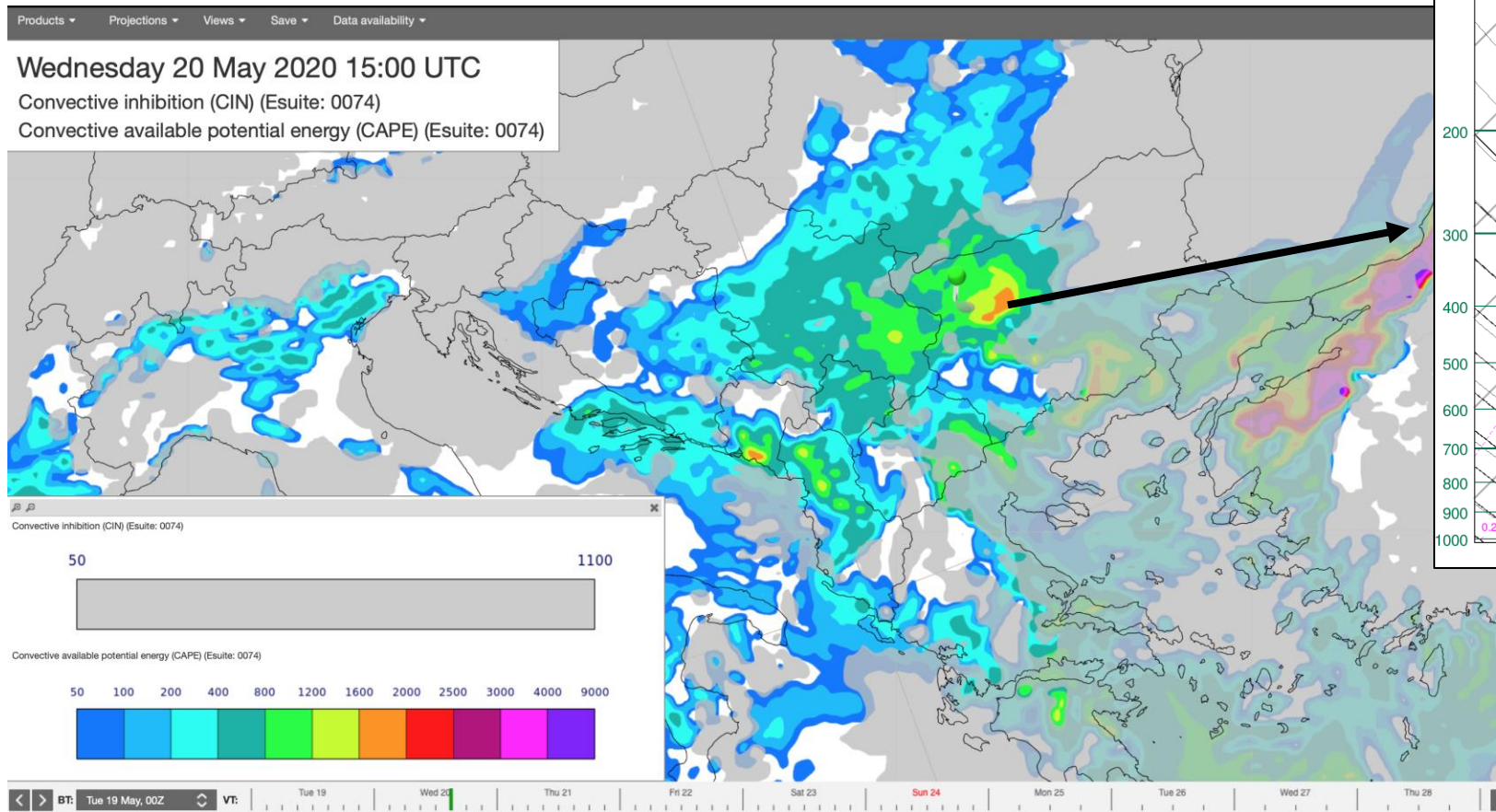
47r1



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



Severe thunderstorms and new CIN computation

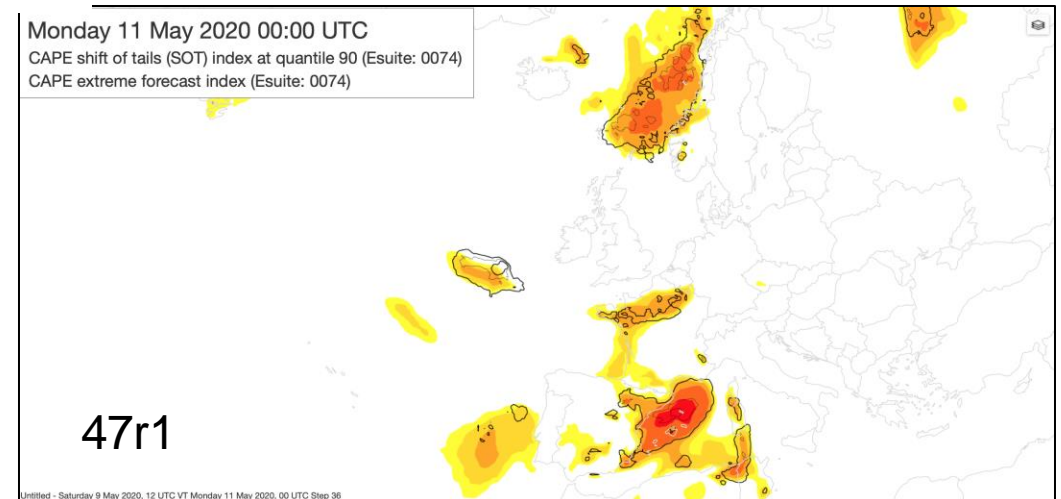
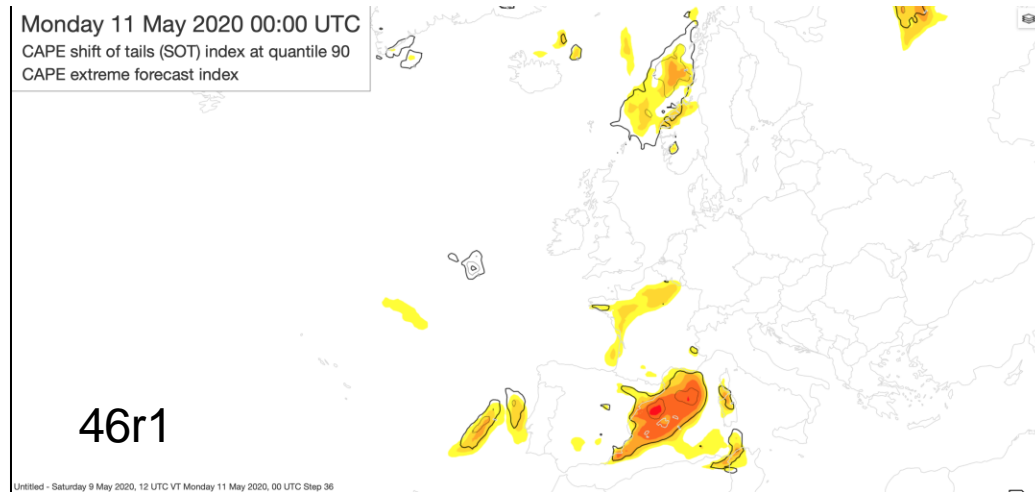
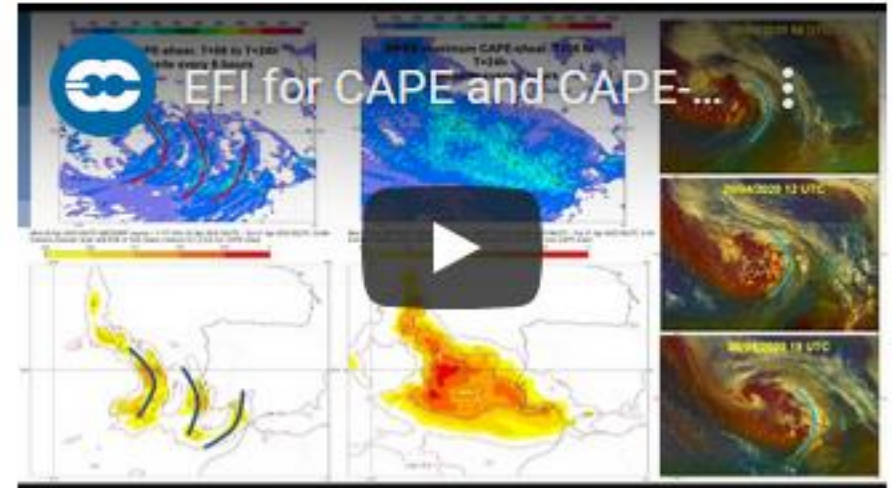


Severe thunderstorms developed over NW Bulgaria in the evening hours on 20 May 2020 producing very large hail.

The new improved computation of CIN and the fact that now CAPE and CIN represent the same air parcel considerably improve CIN for diagnosing deep, moist convection.

Changes in EFI for CAPE and CAPE-shear

Improve the representation of 24-hour maxima by better sampling (maximum of hourly over previous 6 hrs)



47r1 – new parameters

Surface parameters added to the HRES analysis

Param ID	Short name	Name	Units
229 / 230	lews / inss	Instantaneous eastward/northward turbulent surface stress	N m ⁻²
210186	Aluvpi	UV visible albedo for direct radiation, isotropic component	(0 - 1)
210187	aluvpv	UV visible albedo for direct radiation, volumetric component	(0 - 1)
210188	Aluvpg	UV visible albedo for direct radiation, geometric component	(0 - 1)
210189	alnipi	Near IR albedo for direct radiation, isotropic component	(0 - 1)
...	

Changes in parameters formats

Technical change to GRIB headers of Event Probabilities (type EP) for tropical storms

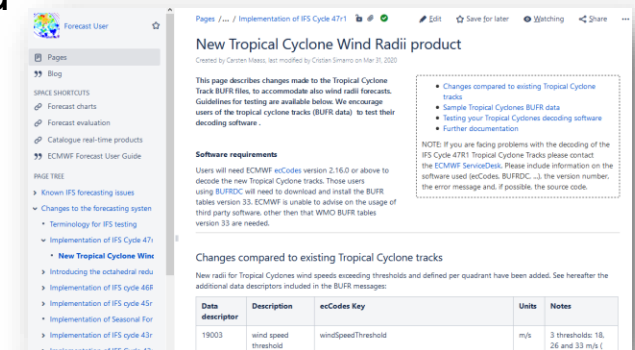
Param ID	Short name	Name	Units
131089	pts	Probability of a tropical storm	%
131090	ph	Probability of a hurricane	%
131091	ptd	Probability of a tropical cyclone	%

Technical change to BUFR messages of Tropical Cyclone Tracks in HRES and ENS

Obstype	Name	BUFR edition
32	Tropical Cyclone track	3/4

For details see

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



47r1 – recommended software versions

ECMWF will update the default versions of its software packages and libraries **across all user platforms** on Wednesday 3 June 2020

The new default versions, including

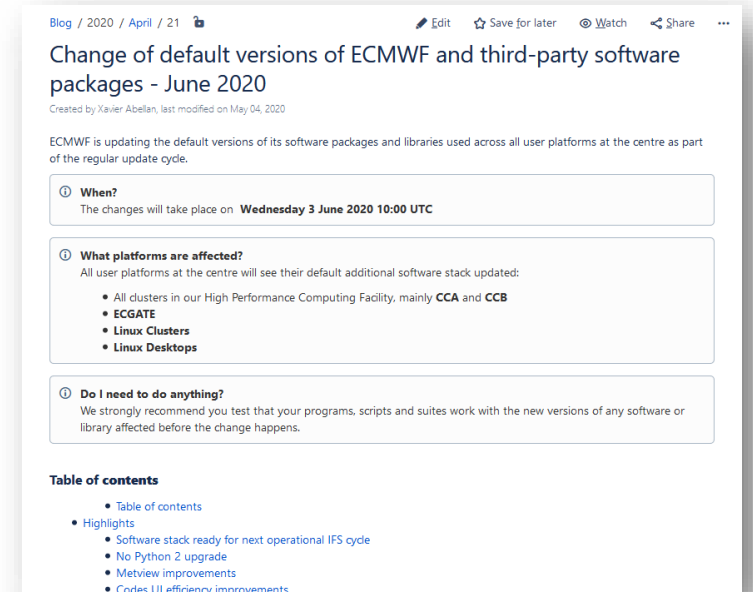
ecCodes 2.17.1

Magics 4.3.3

Metview 5.8.3

are ready to handle the data produced, including all new parameters introduced with 47r1

Users are strongly encouraged to test their software applications and data processing chain with the new versions of the various software packages.



The screenshot shows a blog post from ECMWF dated April 21, 2020. The title is "Change of default versions of ECMWF and third-party software packages - June 2020". The post is created by Xavier Abellan and last modified on May 04, 2020. The main text states: "ECMWF is updating the default versions of its software packages and libraries used across all user platforms at the centre as part of the regular update cycle." The post is structured with three main sections:

- When?** The changes will take place on **Wednesday 3 June 2020 10:00 UTC**.
- What platforms are affected?** All user platforms at the centre will see their default additional software stack updated:
 - All clusters in our High Performance Computing Facility, mainly **CCA** and **CCB**
 - ECGATE**
 - Linux Clusters**
 - Linux Desktops**
- Do I need to do anything?** We strongly recommend you test that your programs, scripts and suites work with the new versions of any software or library affected before the change happens.

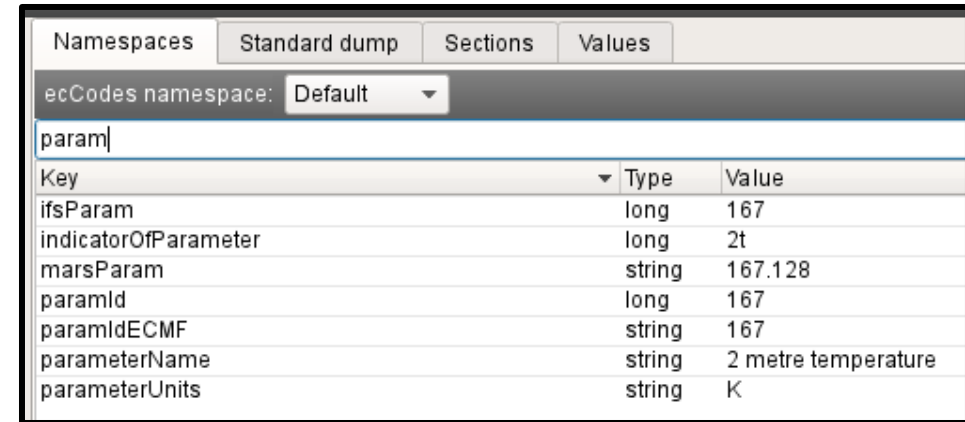
At the bottom, there is a "Table of contents" section with the following links:

- Table of contents
- Highlights
 - Software stack ready for next operational IFS cycle
 - No Python 2 upgrade
 - Metview improvements
 - Codes UI efficiency improvements

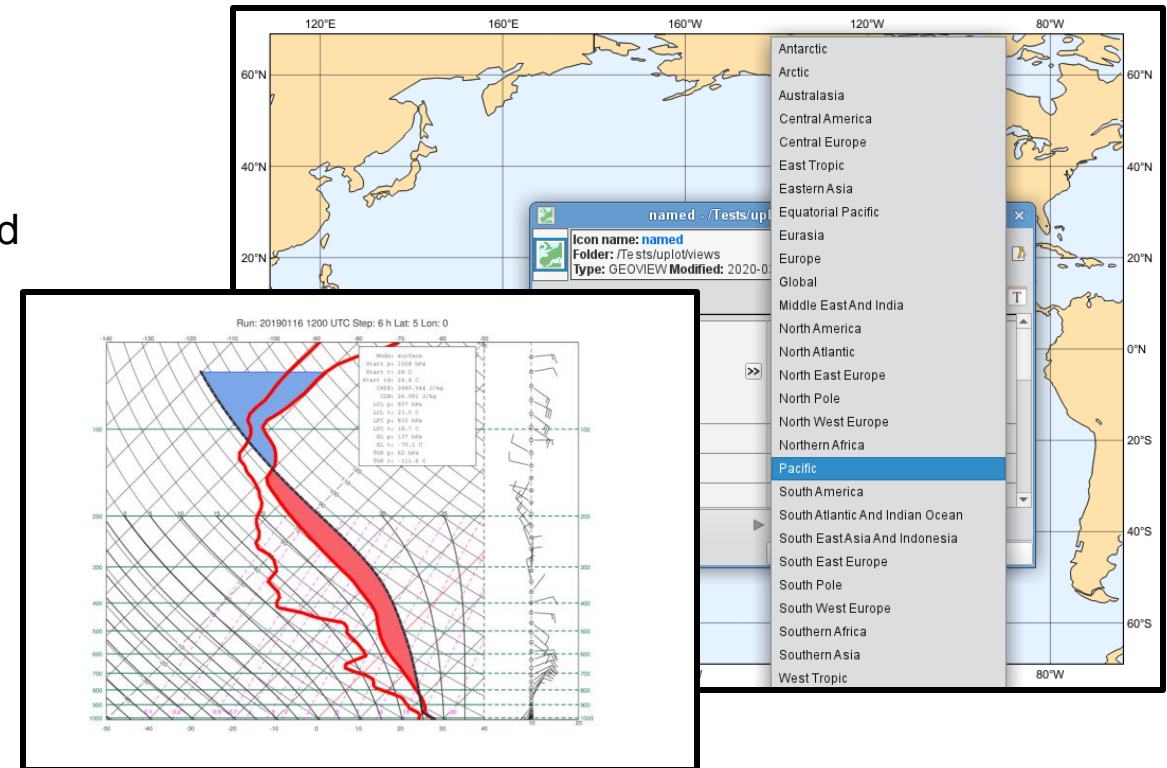
Recent software updates

Our software packages are now available on conda with Python 3 interfaces on PyPi

- ecCodes:
 - Many performance improvements
 - Improved support for Windows
- CodesUI improvements:
 - Easier location of keys with new filter on the standard namespace dump
- Metview improvements:
 - New set of pre-defined areas available
 - New/improved set of thermodynamic functions available



Key	Type	Value
ifsParam	long	167
indicatorOfParameter	long	2t
marsParam	string	167.128
paramId	long	167
paramIdECMF	string	167
parameterName	string	2 metre temperature
parameterUnits	string	K



Next steps

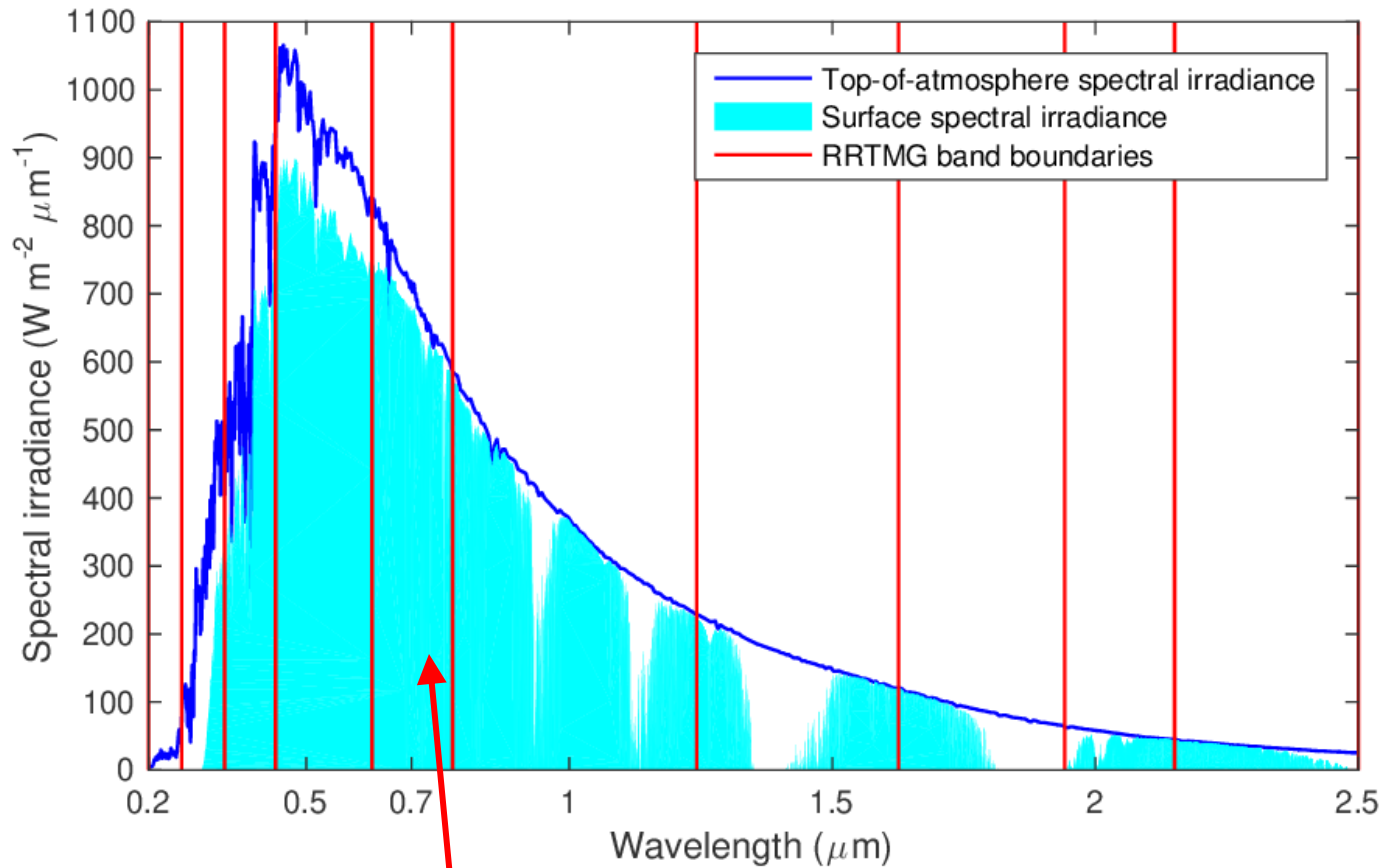
- Start of release candidate test phase with 00 Z run on 2 June 2020
- Implementation planned for June 30th
- Please do 'watch' the cycle 47r1 implementation wiki page to keep in touch with the latest news

<https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+47r1>



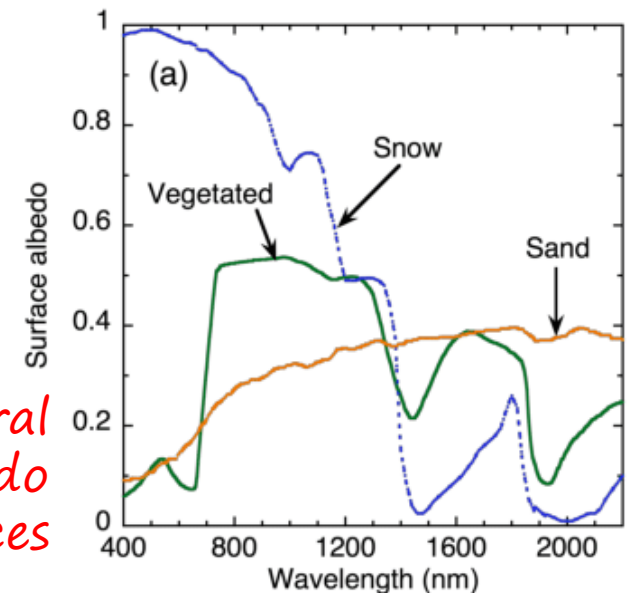
THANK YOU

Changes to surface albedo: 1. spectrum



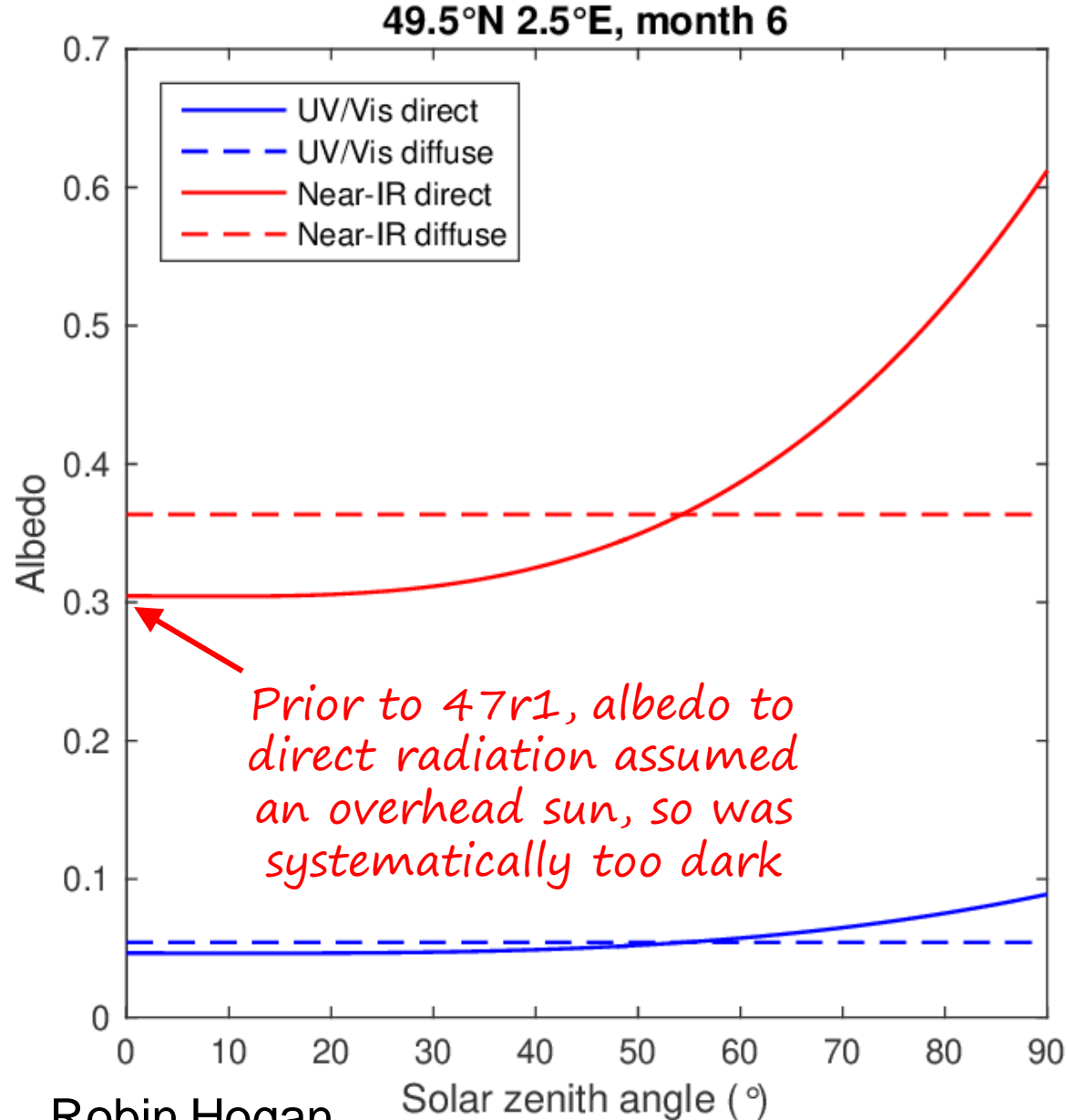
This band contains around 20% of the surface solar energy

- The MODIS albedo climatology is available for the UV/Vis and Near-IR spectral regions, the split being at 0.7 μm
- This lies in the middle of an RRTMG band, and previously the entire band was assigned to the Near-IR region, effectively putting the split at 0.625 μm
- *In 47r1 we carefully average the albedos in this band, which tends to make snow and ice surfaces brighter overall, and vegetated and desert surfaces darker (hence slightly warmer)*



Typical spectral variation of the albedo of different surfaces

Changes to surface albedo: 2. solar zenith angle dependence



- The MODIS climatology provides maps of **three coefficients** in the two spectral ranges (six components in total) and the albedos are computed as follows (Schaaf et al. 2002):

$$\alpha_{direct}(\theta) = A_{iso} + A_{vol}(-0.008 - 0.071\theta^2 + 0.308\theta^3) + A_{geo}(-1.285 - 0.166\theta^2 + 0.042\theta^3)$$

$$\alpha_{diffuse} = A_{iso} + 0.189A_{vol} - 1.378A_{geo}$$

where θ is solar zenith angle in radians

- Before 47r1, the albedo to diffuse radiation, $\alpha_{diffuse}$, was computed offline for fixed overhead sun ($\theta = 0$) so was systematically underestimated
- In 47r1 the solar zenith angle dependence is correctly represented via the explicit use of the six components