ECMWF progress in tropical cyclone forecasts

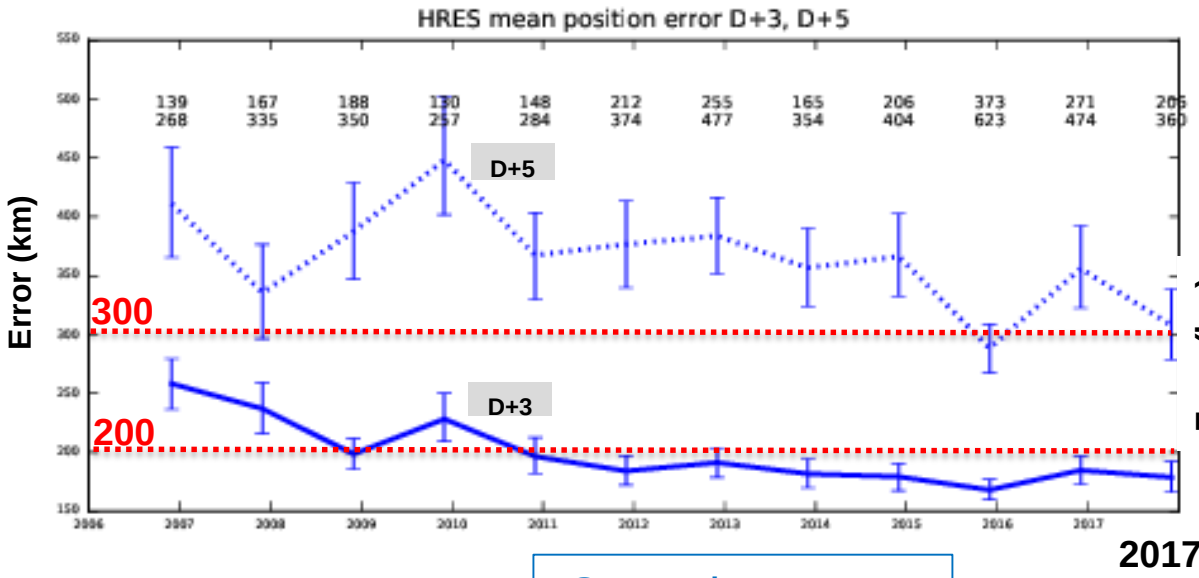
Fernando Prates
Evaluation, Forecast Department, ECMWF
fernando.prates@ecmwf.int

…and colleagues

ECMWF

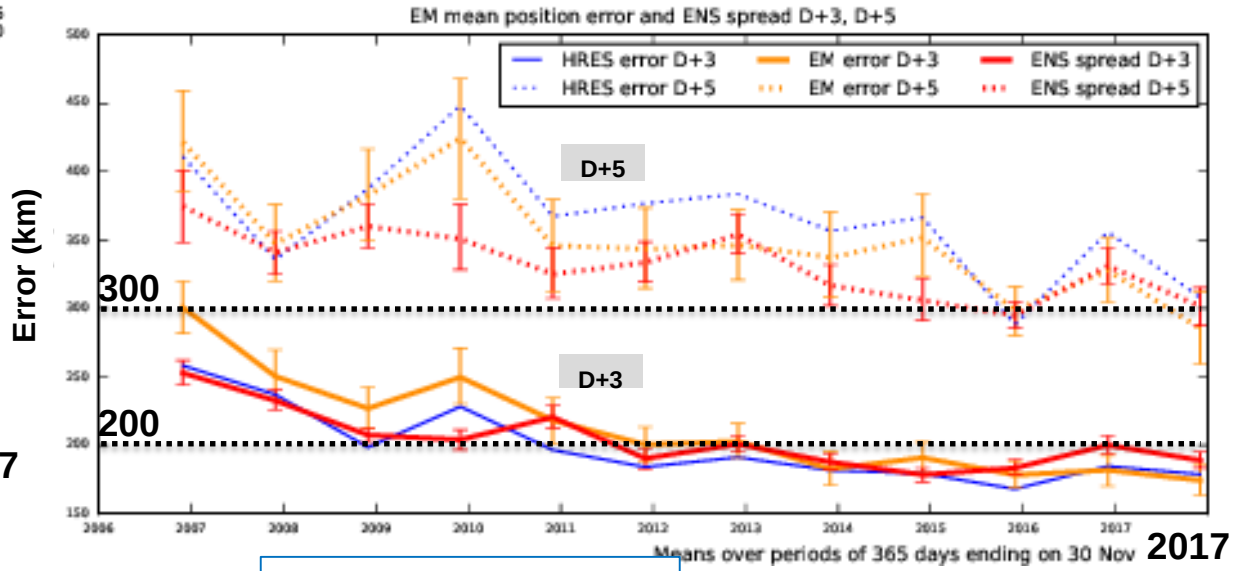
TC Forecast Performance [All Basins, 1-year period ending in 30 Nov]

Position (HRES)

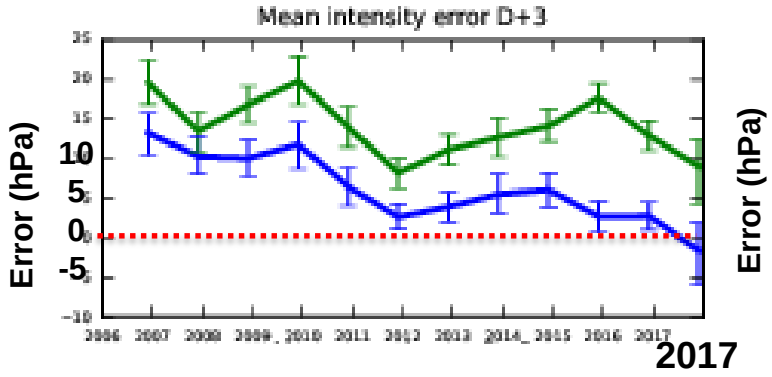


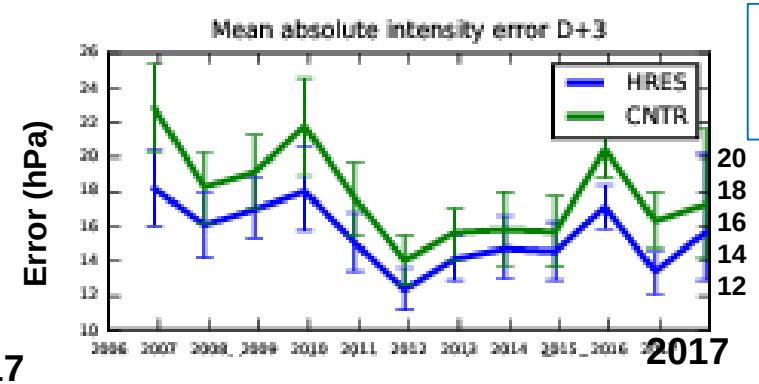
95% confidence interval (whiskers)

Position (ENS)



Central pressure





Current Operational IFS:
HRES T_{Co}1279 (~9km)
CNTR T_{Co}639 (~18 km)

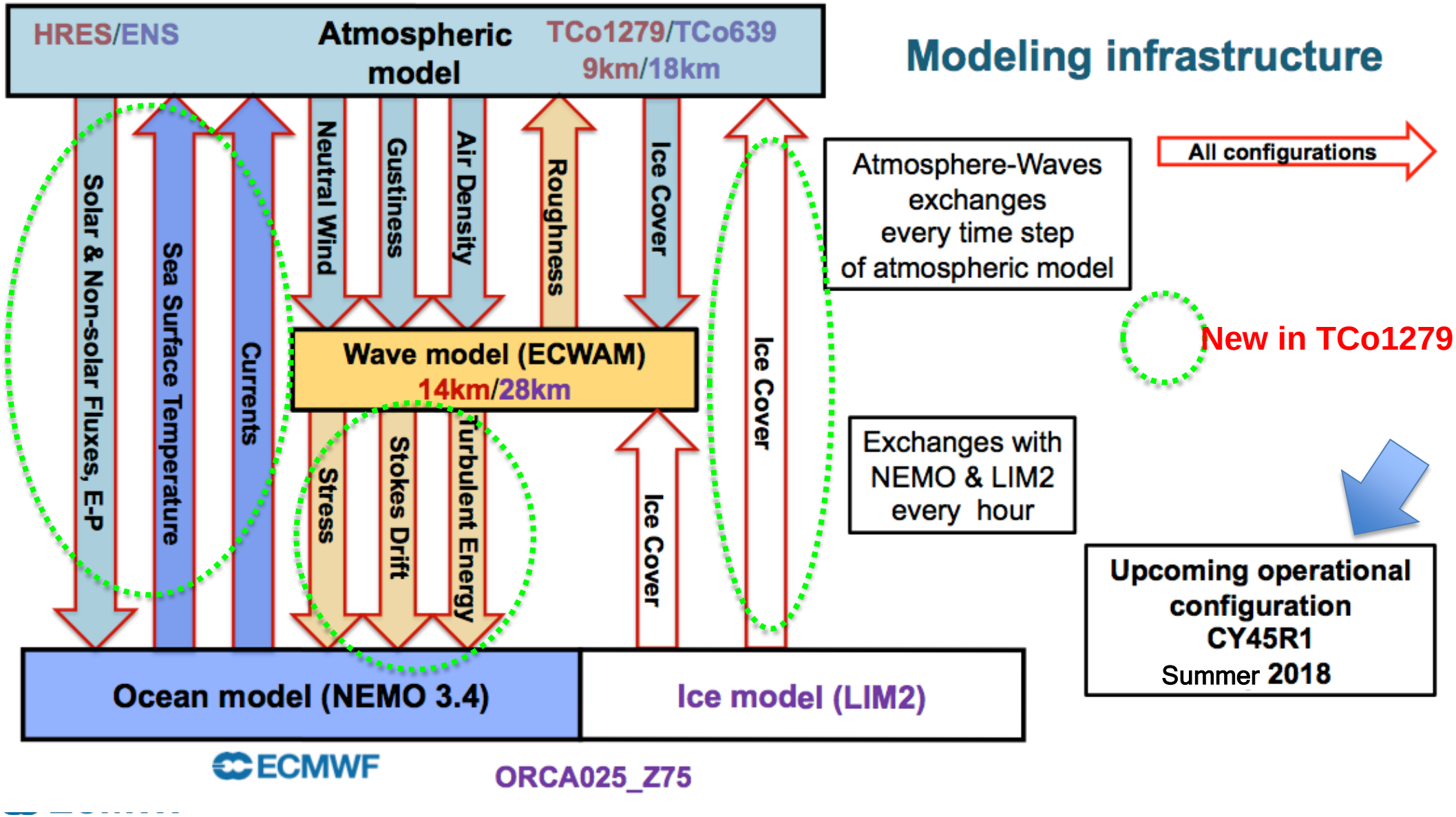
Recent Changes in IFS model:
11-07-2017 cycle 43r3 (current)
22-11-2016 cycle 43r1
08-03-2016 cycle 41r2 (resolution increase)
12-05-2015 cycle 41r1

Last model upgrade/Next model upgrade [Highlights]

Planned model changes can be found at: https://software.ecmwf.int/wiki/display/FCST/Changes+to+the+forecasting+system

IFS 43r3 (11Jul2017)	IFS 45r1 (this Summer)
Assimilation • Bug fix in the first soil layer temperature analysis • Wavelet filter for EDA humidity variances	**Assimilation** • Update radiative transfer model from RTTOV-11 to RTTOV-12 • Use OCEAN5 sea ice instead of OSTIA sea ice • Stochastic representation of model uncertainty in EDA revised so that it is consistent with ENS
Observation • QC for GPS-RO • Consolidate use of microwave sounder channels over land and sea ice • Code for Constrained Variational Bias Correction for radiances	**Observation** • ***Assimilation of upper tropospheric and stratospheric peaking IR channels over land*** • Assimilation of all sky MW sounding channels over coasts • Accounting for radiosonde drift • Assimilation of BUFR SYNOP data into the surface analysis • Assimilation of JASON-3 and Sentinel-3A altimeters
Model Changes • New radiation scheme • New aerosol climatology (CAMS) • Mixed-phase convection allowing super cooled water in the convection scheme	**Model Changes** • ***Coupled ocean/sea-ice in HRES with "partial" coupling in the Extra-Tropics*** • Improvements to the numerics of warm-rain microphysics • **Lightning parametrization activated with new output parameters for total lightning flash density** • Increased (improved) water vapour due to methane oxidation in the stratosphere • Revised non-orographic GWD for L91
Medium Range ENS • No major upgrade	**Medium Range ENS** • Revision of SPPT: perturbations to clear-skies heating rates are removed; tapering modified and random pattern variance reduced • SKEB deactivated • ***Reduced amplitude of singular vector initial perturbations for tropical cyclones***

Seamless coupled ocean-atmosphere forecast system (HRES & ENS)

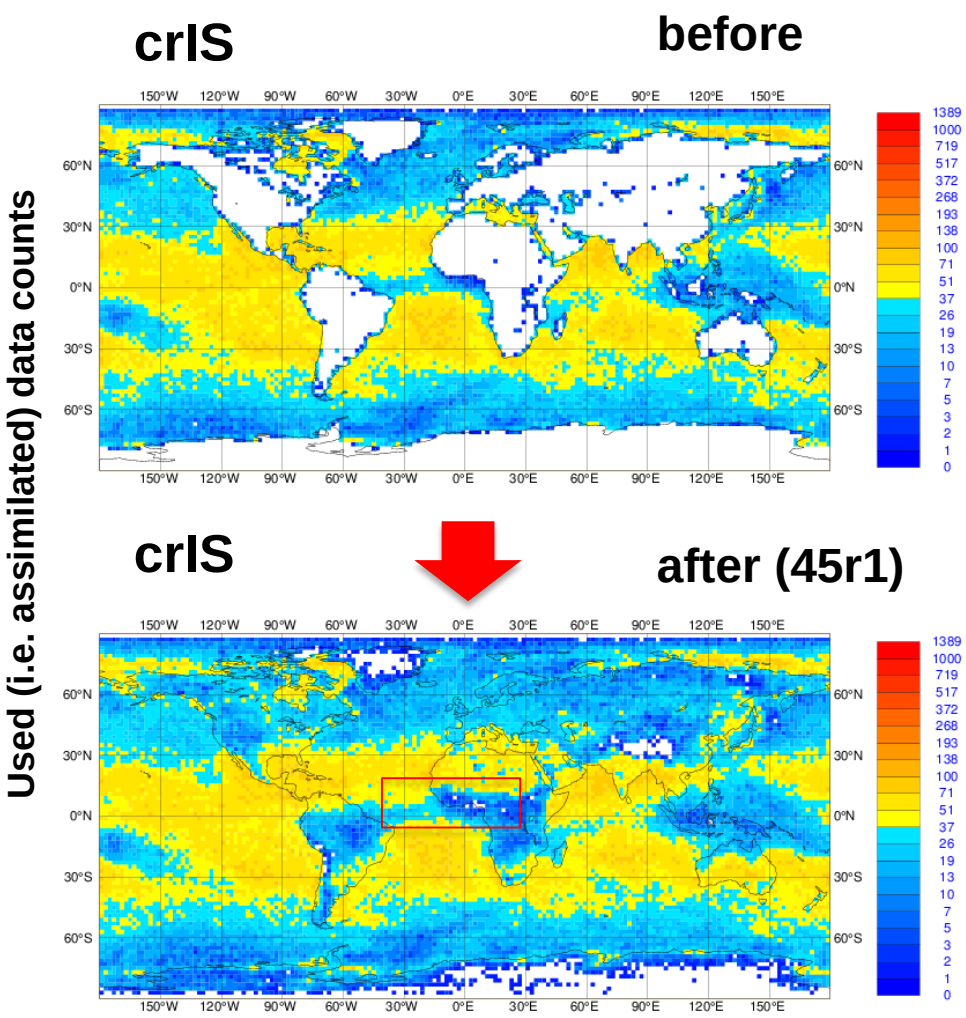


Increased used of hyperspectral infrared sounders over land (AIRS-crIS-AISI)

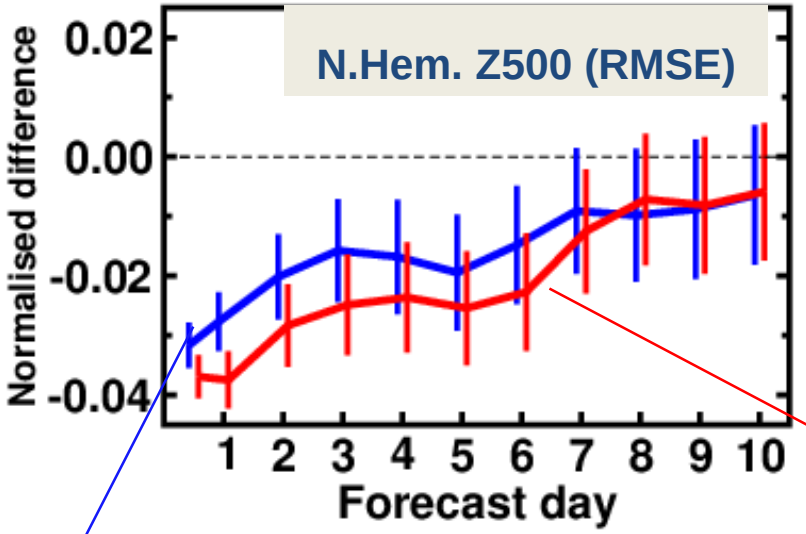
Limited use of IR radiances over land until now

— Poor description of surface emission is to blame

New: reject surface-sensitive channels on a case-by-case basis



Impact from IR radiances



Control run = without IR radiances

*Add IR radiances as in **IFS Cycle 43r3***

*Add IR radiances as in **IFS Cycle 45r1***

Courtesy of Reima Eresmaa

Score Card: 45r1 versus Operations

Verification against own analysis
NDJF (2016-17) JJAS (217)

Region: Tropics
Score: RMSE

Symbol legend: for a given forecast step...

▲ experiment **better** than control statistically **significant with 99.7% confidence**

△ experiment **better** than control statistically **significant with 95% confidence**

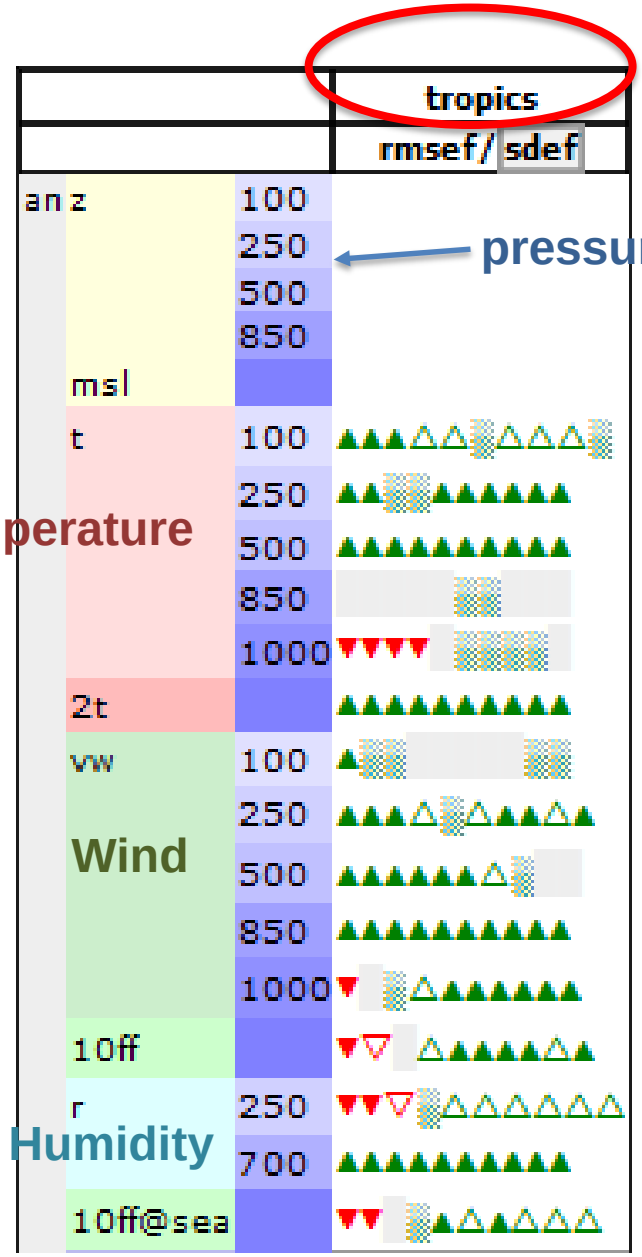
▒ experiment better than control statistically **significant with 68% confidence**

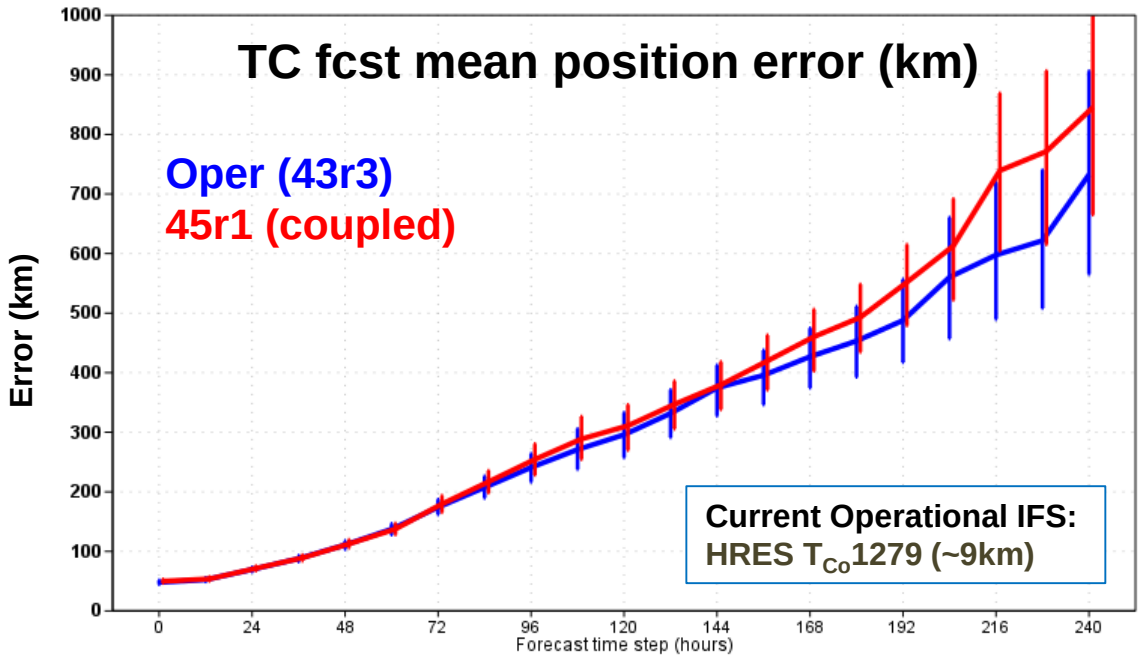
not really any difference between control and experiment

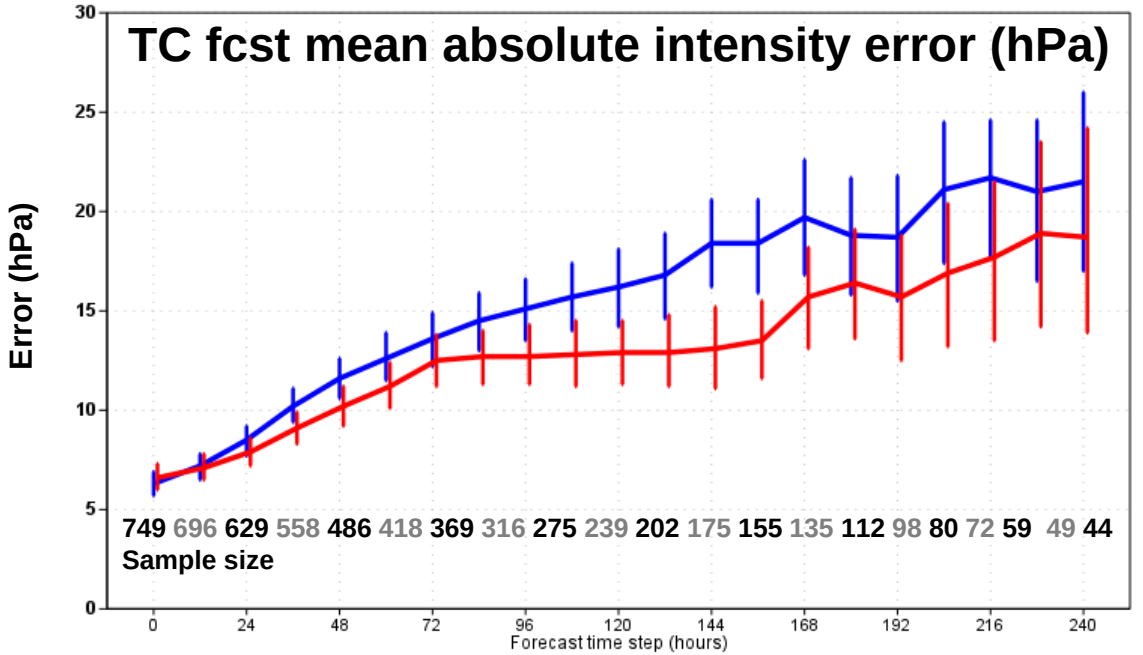
▒ experiment worse than control statistically **significant with 68% confidence**

▽ experiment **worse** than control statistically **significant with 95% confidence**

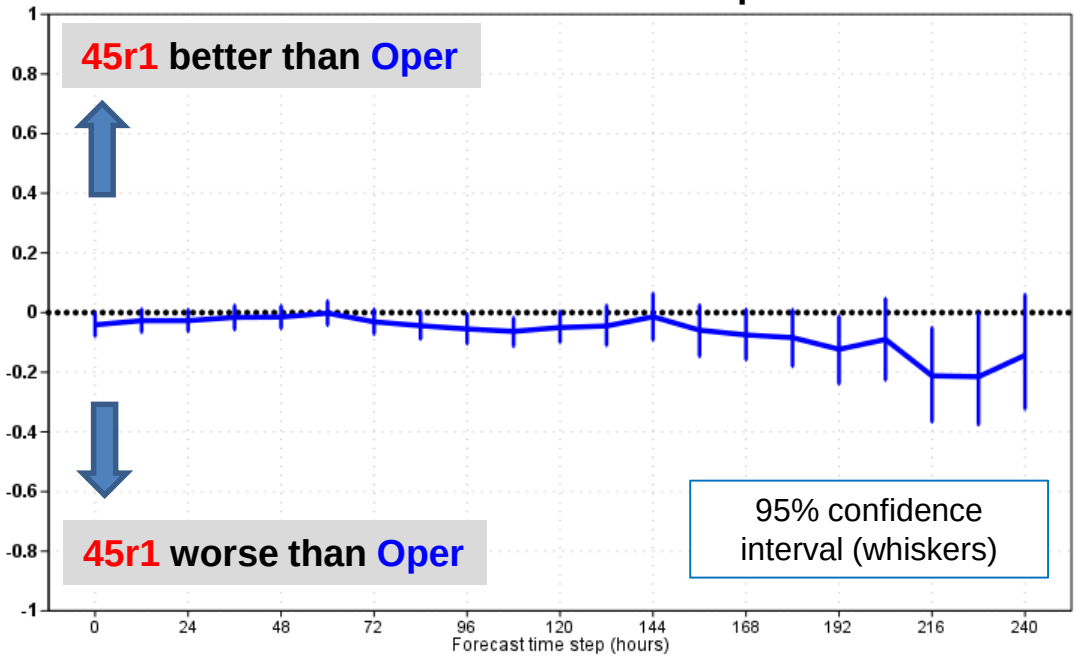
▼ experiment **worse** than control statistically **significant with 99.7% confidence**



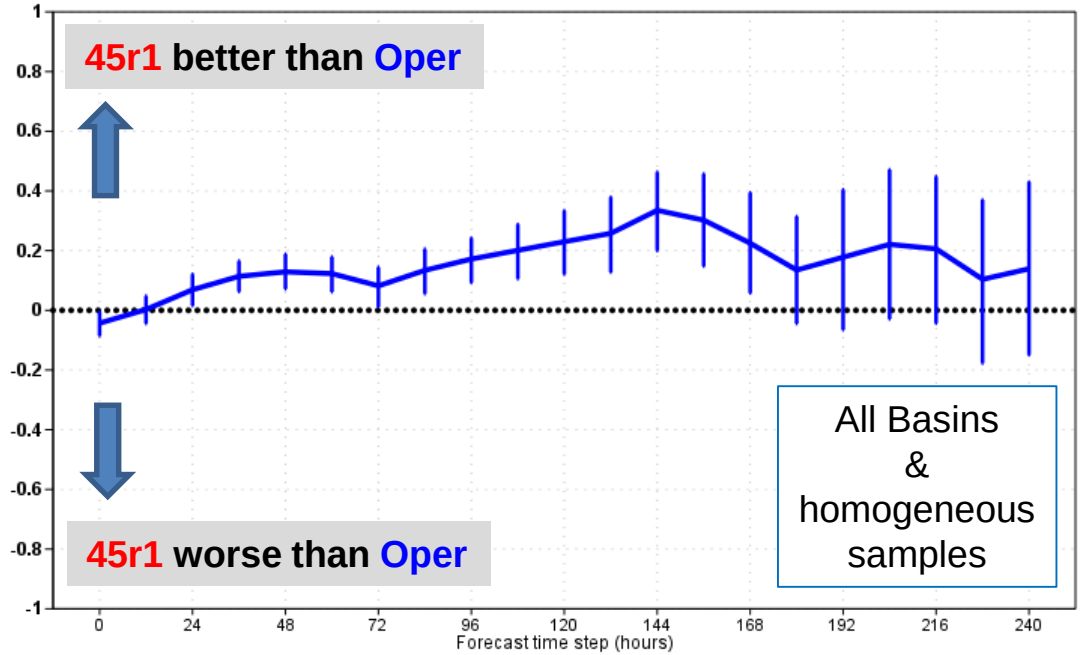




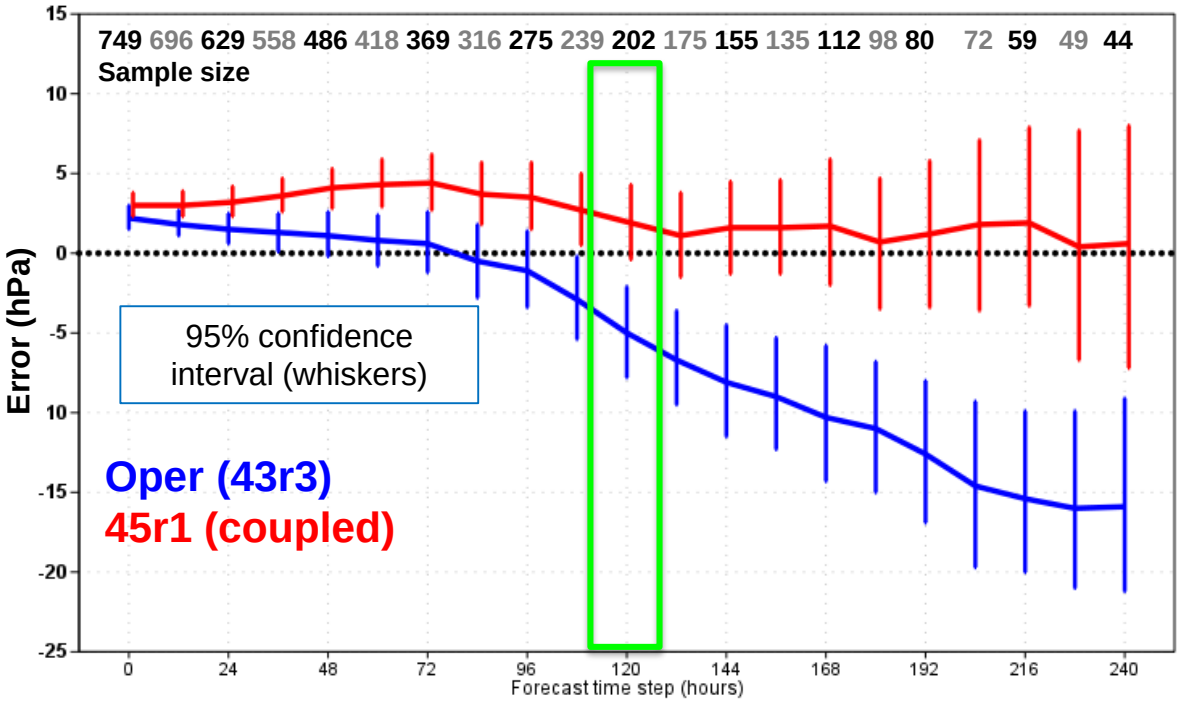
Normalized difference of the TC mean position error

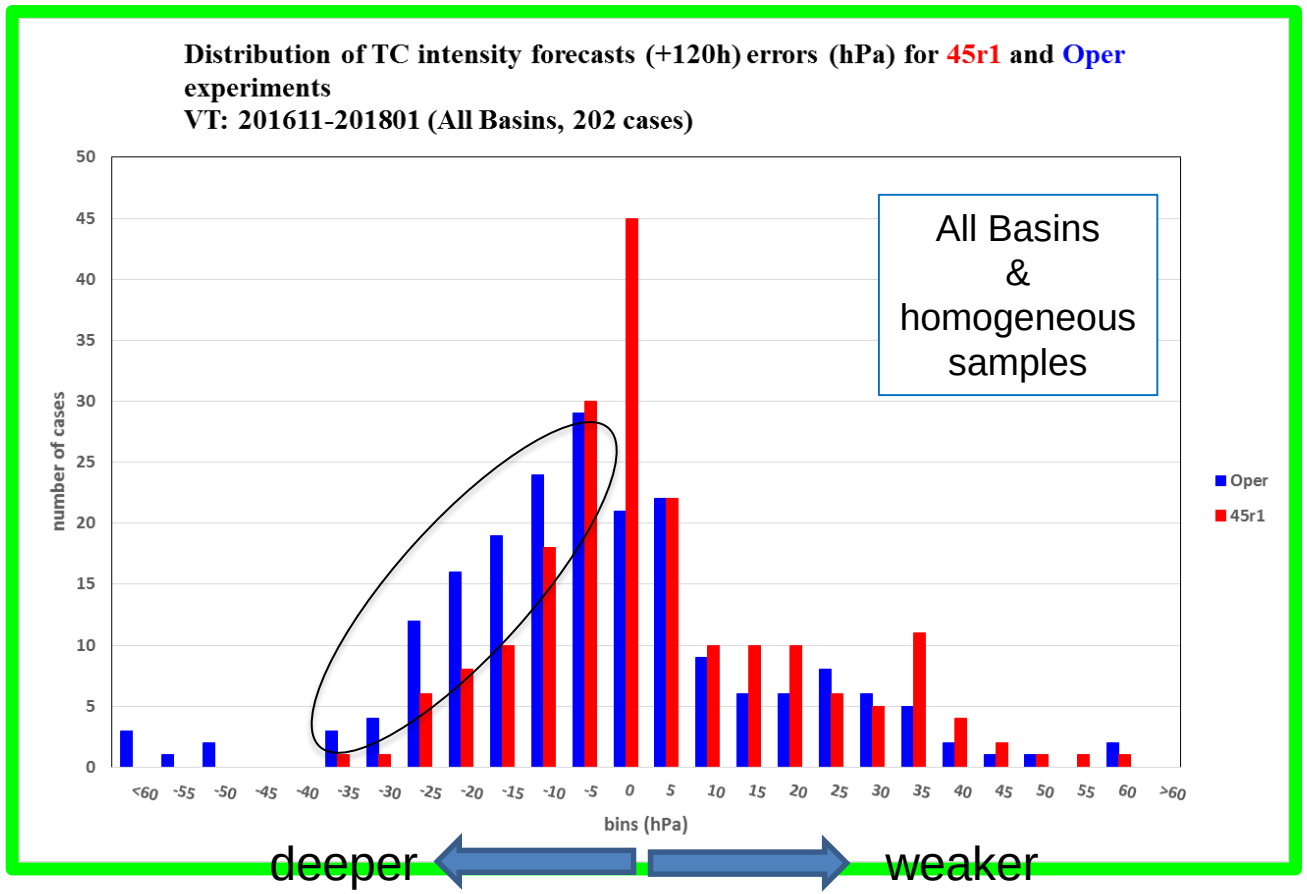


Normalized difference of the TC mean absolute intensity error



TC fcst mean intensity error (hPa)

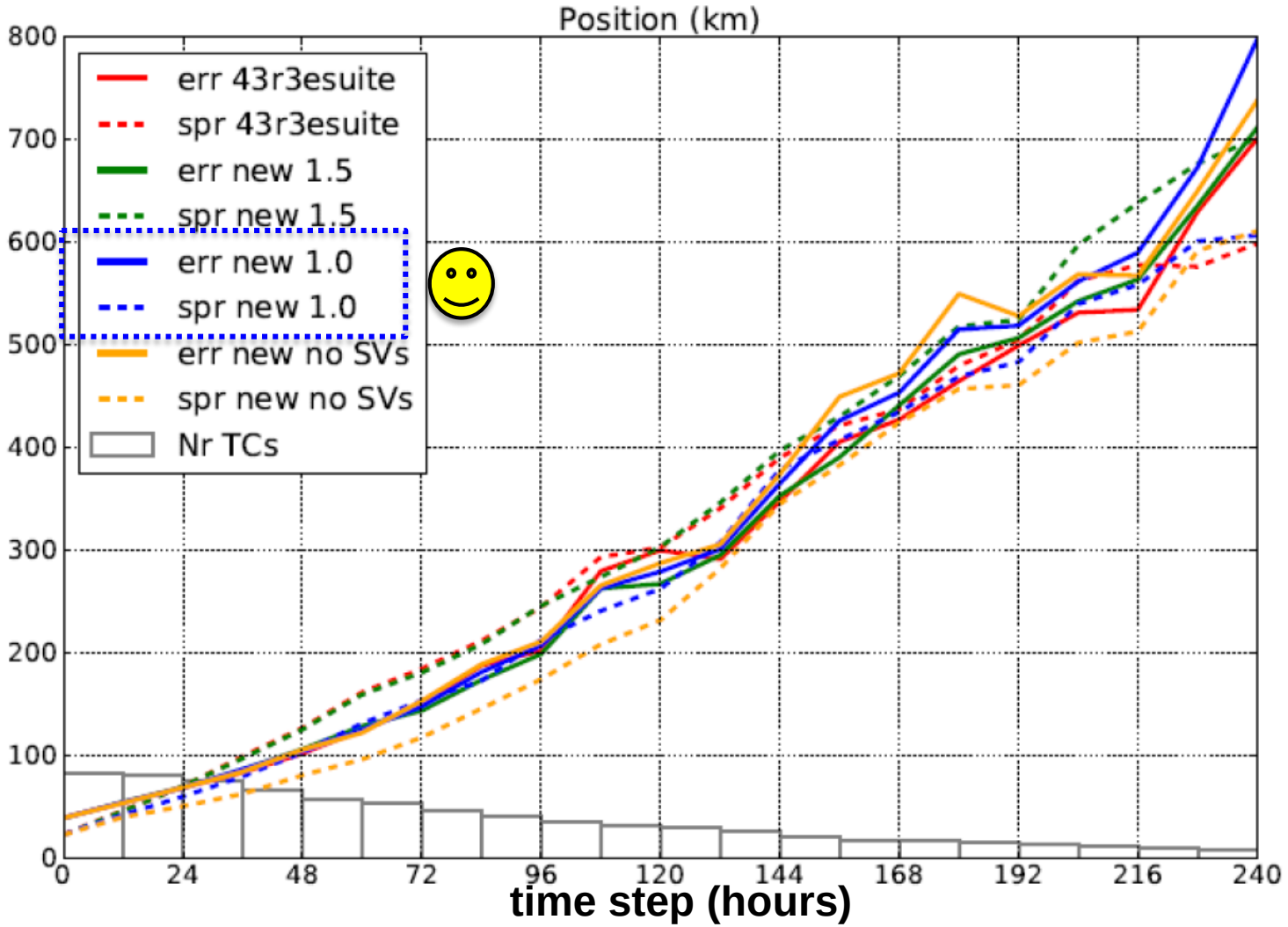




VT period: Nov 2016 –Feb 2017
Jun-Sep 2017
Oct-Dec 2017

Ensemble spread & mean error position

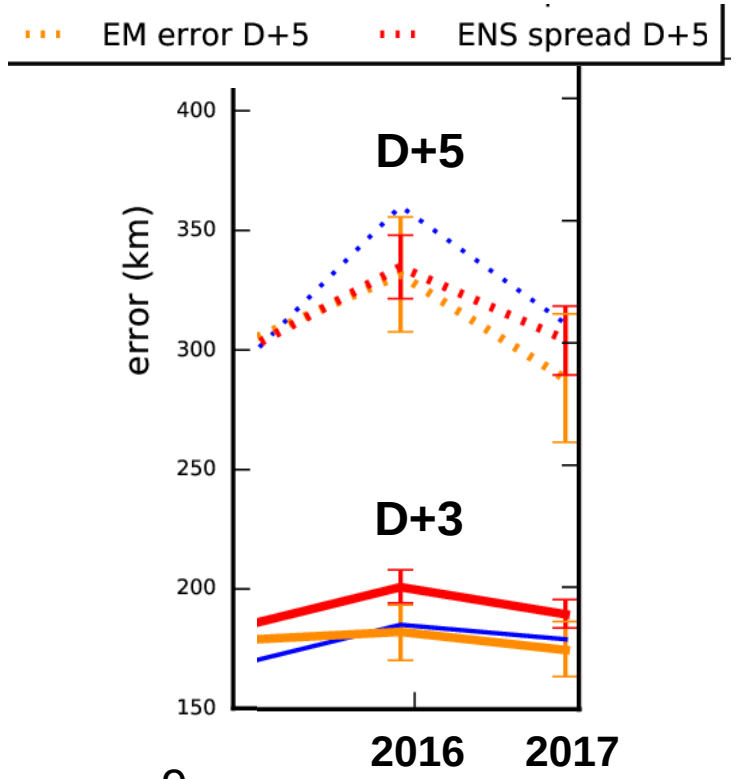
(Inflation of TC-SVs relative to Extra-Tropical-SVs)



Courtesy of Simon Lang

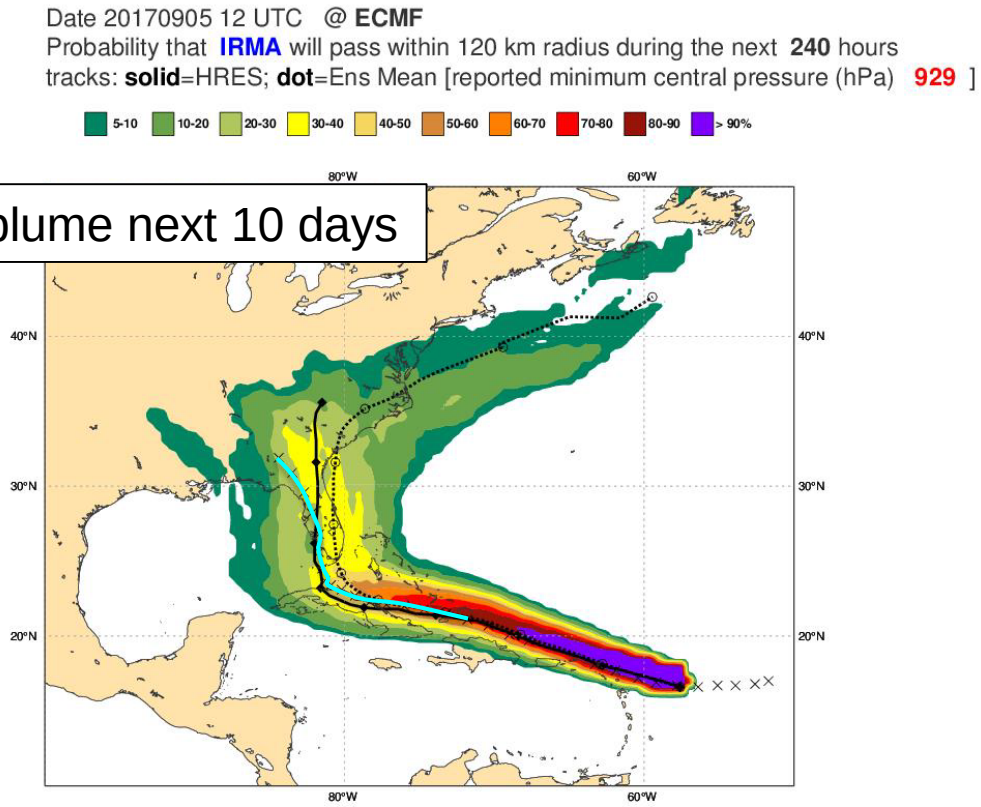
Comparison of different ENS configurations
VT: 20160603-20160830 (every other day)

A reduction of the amplitude of SV in tropics (consistent with extra-tropics SVs) improves spread-mean error relationship
To be implemented in cycle 45r1



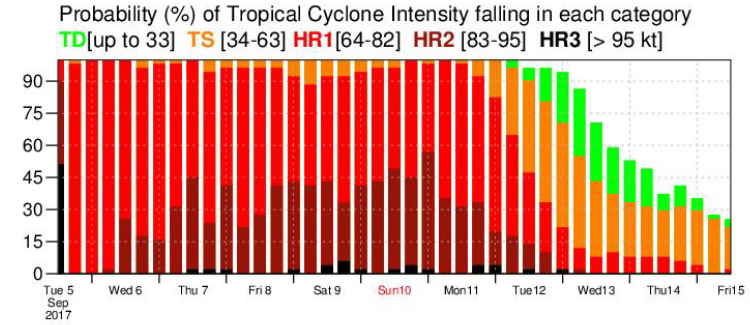
Resolution matters: current operational ENS (18km)

Strike probability plume next 10 days

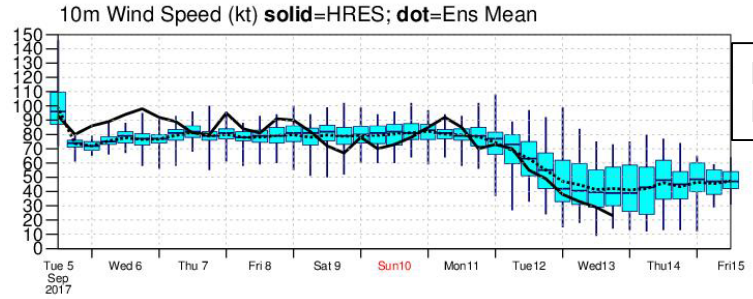


X IRMA BT positions

BT min central pressure

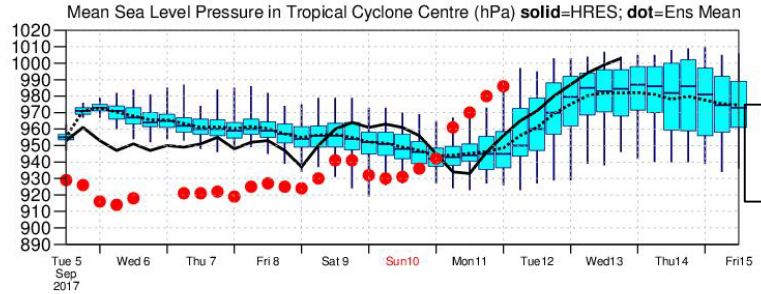


Prob (%) of each TC category



Max wind speed (kt) Meteogram

hPa

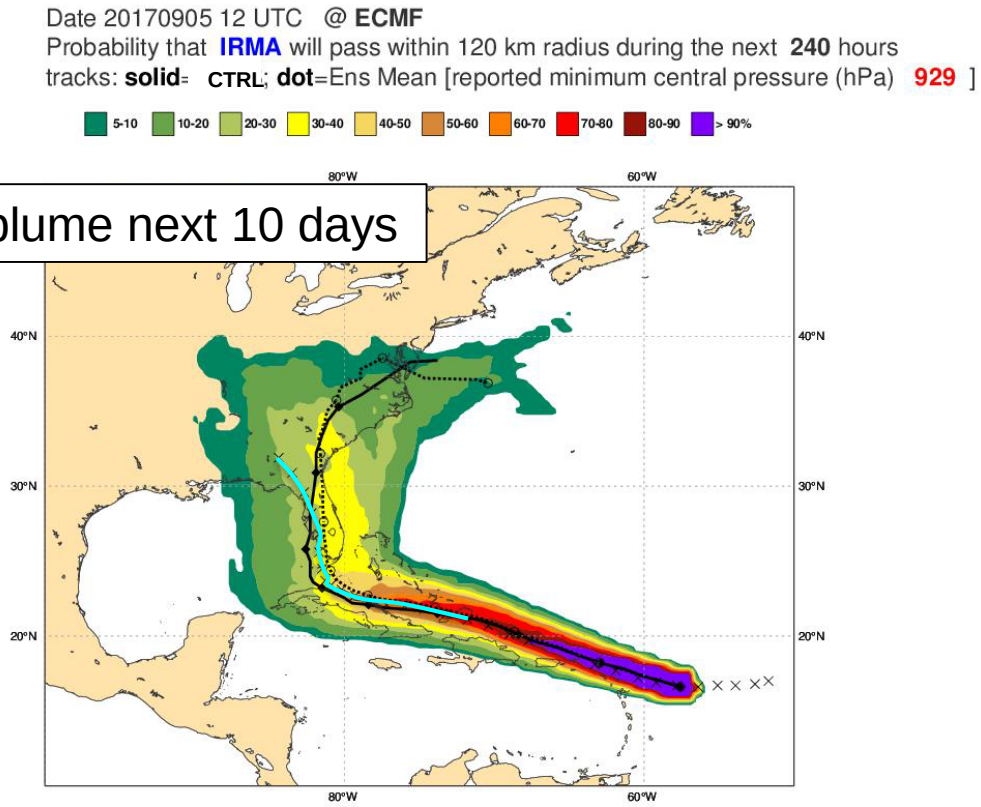


Min surface pressure Meteogram

Resolution matters: the (far) future 5km ENS!!

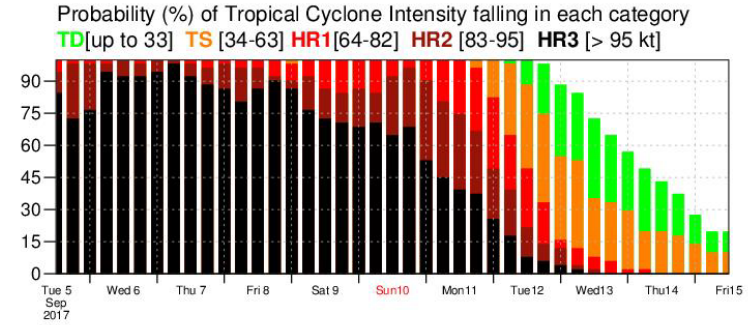
NOT 45r1!

Strike probability plume next 10 days

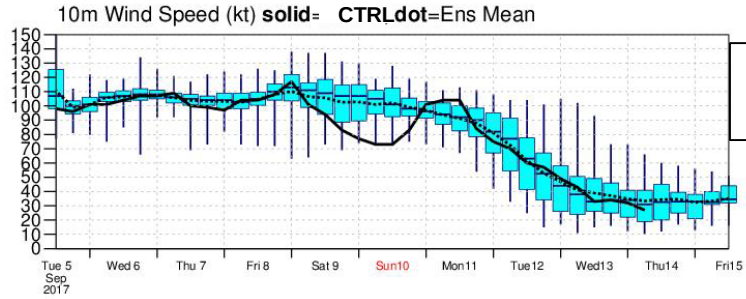


X IRMA BT positions

BT min central pressure

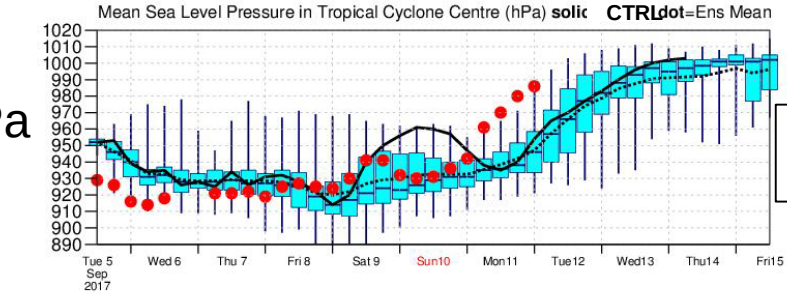


Prob (%) of each TC category



Max wind speed (kt) Meteogram

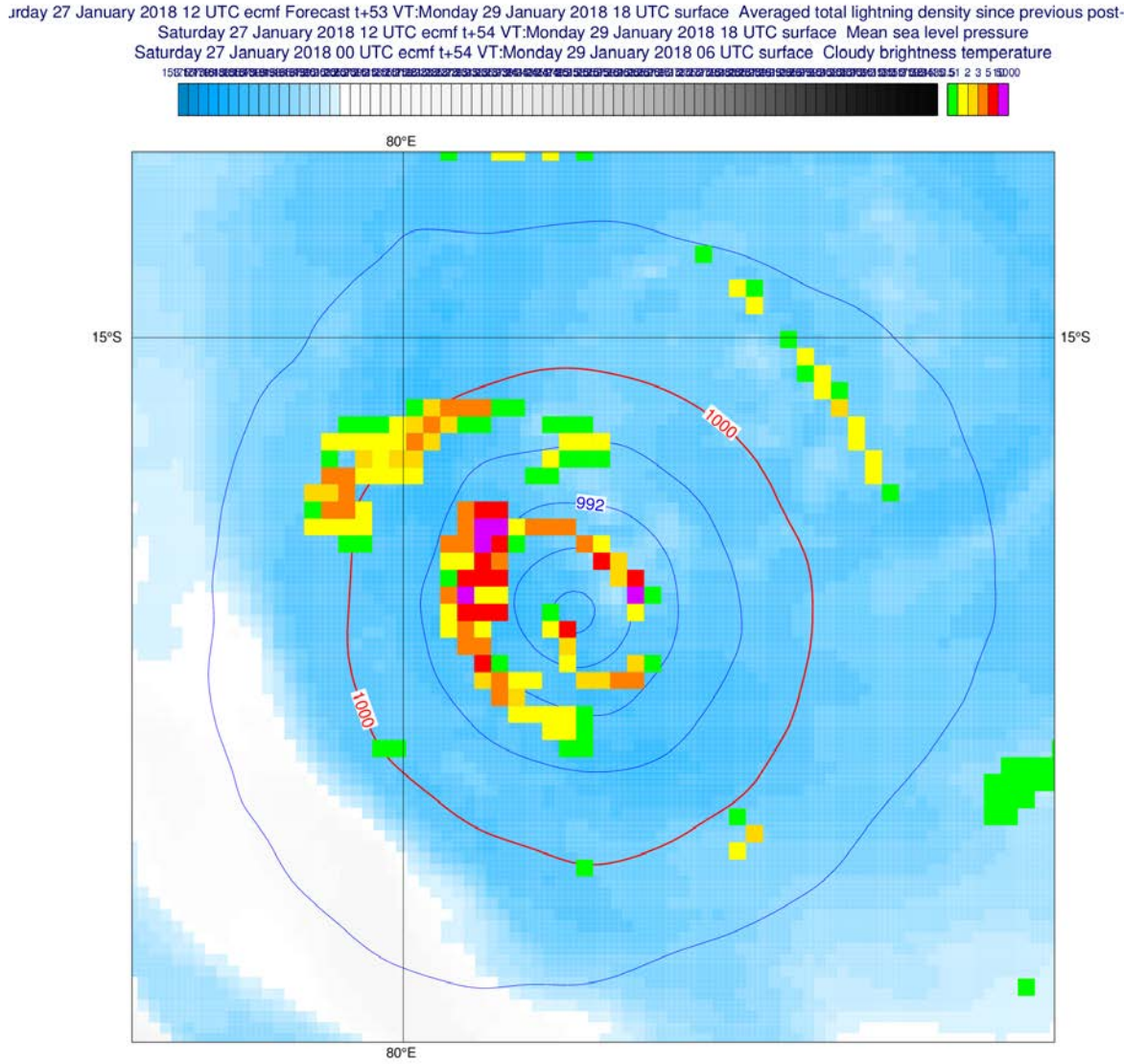
hPa



Min surface pressure Meteogram

New Product (45r1 this Summer)
Lightning Flashes density

- Tropical Cyclone CEBILE
- Run started 27@12 HRES (~9km)
- Cloudy Brightness Temperature (cyan+white background)
- Surface pressure (contours every 4 hPa)
- Avg total lightning density (flashes $km^{-2}day^{-1}$; cell shading)
- t+53h VT: 29 January 18UTC



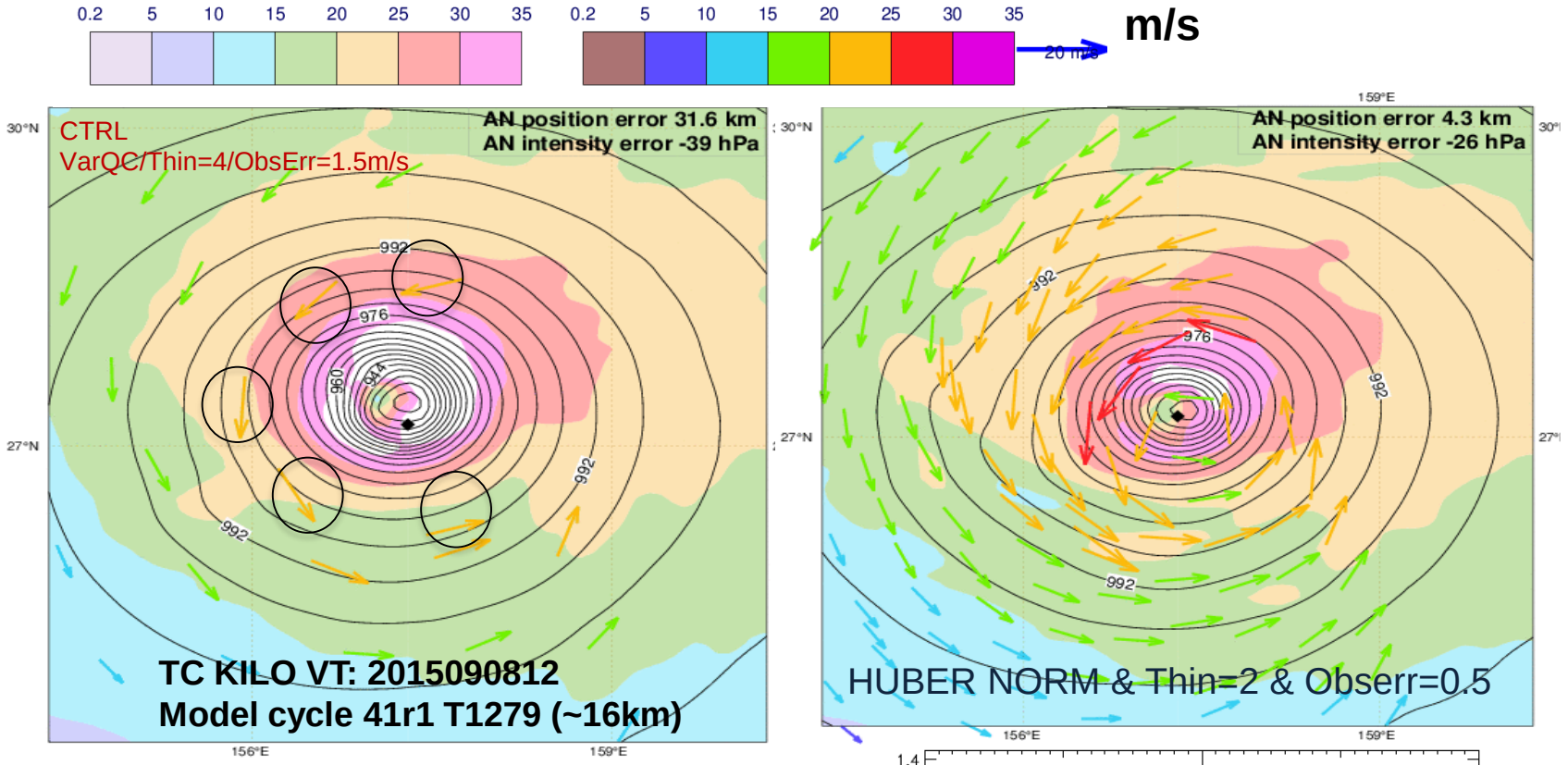
On going work ….ASCAT-A & -B winds assimilation

Operational configuration:

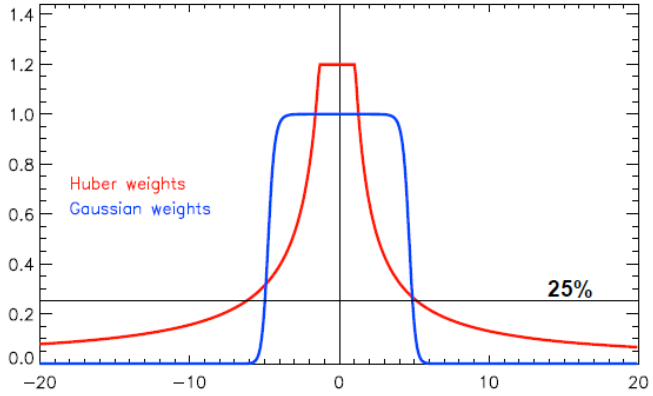
- Sea-ice/speed > 35m/s → Rejected
- Thinned & one out of four is assimilated (~100km)
- Background check/VarQC
- Sigma=1.5 m/s both wind components
- 2 solutions provided: most appropriate solution dynamically determined by comparison with background model winds

Legend:

- BT position of KILO
  model wind speed (shades)
  scatterometer winds (used) arrows
  model mslp (contours)



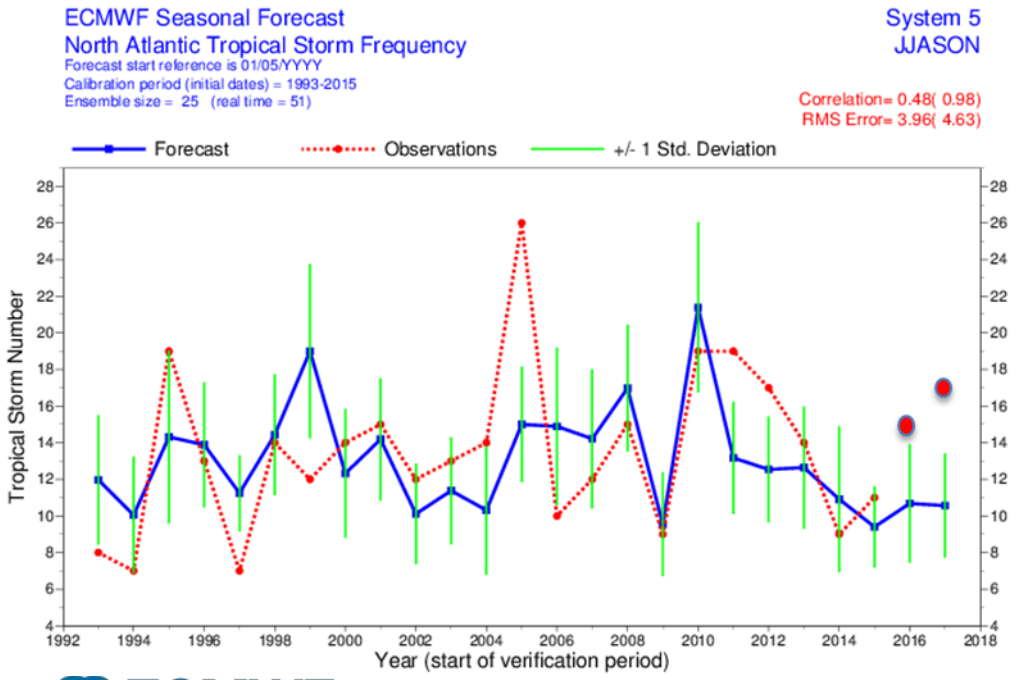
Observation weight after applying the VarQC



Courtesy of Giovanna Chiara

Seasonal Forecast SEAS5

- SEAS5 was successfully implemented in operations on 5.11.2017
- The configuration of the IFS used in SEAS5 is almost identical to that used in ENS
- SEAS5 meteorological impact:
  - substantial improvements in SST bias in the tropical Pacific, with consequent improvements in ENSO forecast skill.



Newsletter article**: ECMWF's new long-range forecasting system SEAS5.** doi:10.21957/tsb6n1

	System 4	SEAS5
Sea ice model	Sampled climatology	LIM2
Re-forecast years	30 (1981-2010)	36 (1981-2016)
Re-forecast ensemble size	15 (0-7m) 15 (8-13m)	25 (0-7m) 15 (8-13m)
Products Release Date	The 8th of each month at 12UTC	The 5th of each month at 12UTC
Ocean vertical resolution	L42	L75
Ocean model	NEMO v3.0	NEMO v3.4
Ocean initialization	ORA-S4	ORS-S5
Ocean horizontal resolution	ORCA 1.0	ORCA 0.25
Land Initialization (Re-forecast/Forecast)	ERA-Interim land (36r4)/Operations	ERA-Interim land (43r1)/Operations
IFS vertical resolution (TOA)	L91 (0.01 hPa)	L91 (0.01 hPa)
IFS model stochastic physics	3-lev SPPT and SPBS	3-lev SPPT and SPBS
IFS horizontal resolution	T_L255	$T_{CO}319$
IFS Gaussian grid	N128 (80 km)	O320 (35 km)
IFS Cycle	36r4	43r1
Forecast ensemble size	51 (0-7m) 15 (8-13m)	51 (0-7m) 15 (8-13m)
Calibration period	1981-2010	1993-2016
Atmosphere initialization (Re-forecast/Forecast)	ERA-Interim/Operations	ERA-Interim/Operations

Summary

- Small reduction of position errors at D+3 & D+5 last year compared with the previous year

- On average the HRES (~9km) TC forecasts are too intense at D+3 (& onwards)

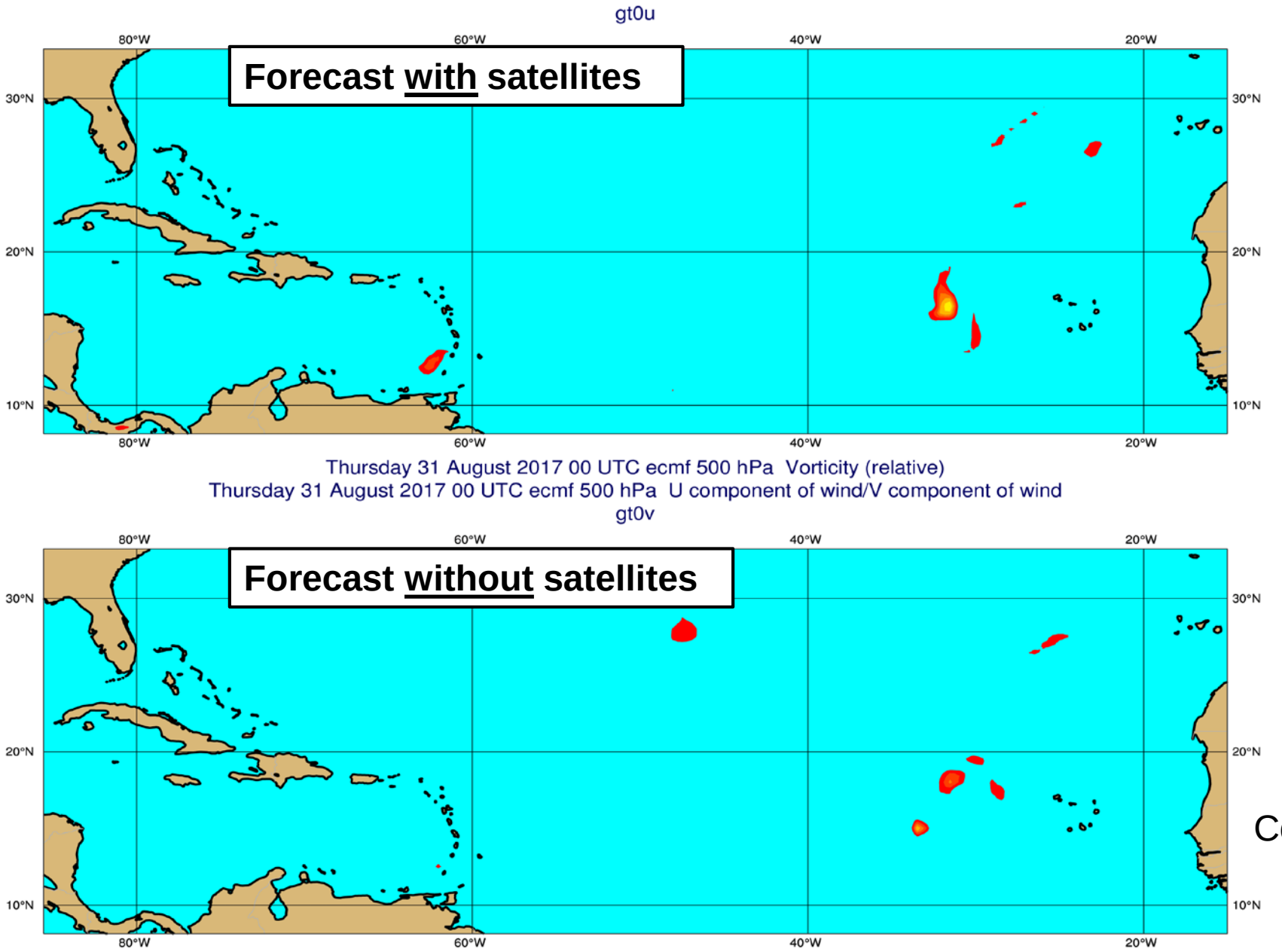
- Significant improvement of TC intensity forecast errors when the HRES (~9km) is coupled with the ocean model. This configuration (45r1) should be in operations by this summer.

- Last year, on average, the TC ENS spread (position) on was too large (compared with the ENS mean error). Reduced amplitude of Singular Vectors initial perturbations seems to improve the spread-mean error relationship of the ENS and is expected to enter cycle 45r1

- Ongoing work to improve the scatterometer winds assimilation in particular around TCs.

- Seasonal Forecast System 5 (SEAS5) was successfully implemented last November.

IRMA with / and without satellites



Courtesy of Tony McNally