Forecasting Tropical Cyclones in the Medium Range

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Evaluation Section

ECMWF

Objectives

➢ Have a better understanding of the Tropical Cyclone Products generated at ECMWF

➢ Learn the recent developments in the forecast system and its impact on the Tropical Cyclone forecast

➢ Learn about the skill of TC forecasts in recent years

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Why is so important to forecast Tropical Cyclones?

➢ Tropical cyclone can cause massive loss of life in highly dense populated areas; STY Hayan in Philippines (2013); TC Nargis in Myanmar (2008), …

  ▪ Fact: Storm surge is the main cause of human fatalities

    · typhoon Haiyan: https://www.youtube.com/watch?v=rS0gv4Xbw7w

➢ They can cause major disruptions on economic activities

  ▪ Off shore oil rigs

  ▪ Ship routing

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Why TC forecasts have improved in recent years?

Due to the continuous upgrades of the forecast system at ECMWF,

- Increase of model horizontal and vertical resolution

- Massive use of Satellite data in Data Assimilation (DA)

- Improvements of the physical processes (parametrization of convection, new cloud microphysics,…)

- Methods for Global Ensemble Prediction : ENS evolved SVs , stochastic physics and perturbations target at observed TCs and **more recently** the implementation of Ensemble Data Assimilation

- Since November 2013:

  - *The atmosphere-ocean coupling of the ENS is active from initial time of the forecast using a new version of the NEMO ocean model (cy40r1)*

….. At ECMWF there is no artificial bogus vortex scheme for TCs. We allow the observations to do their job …..
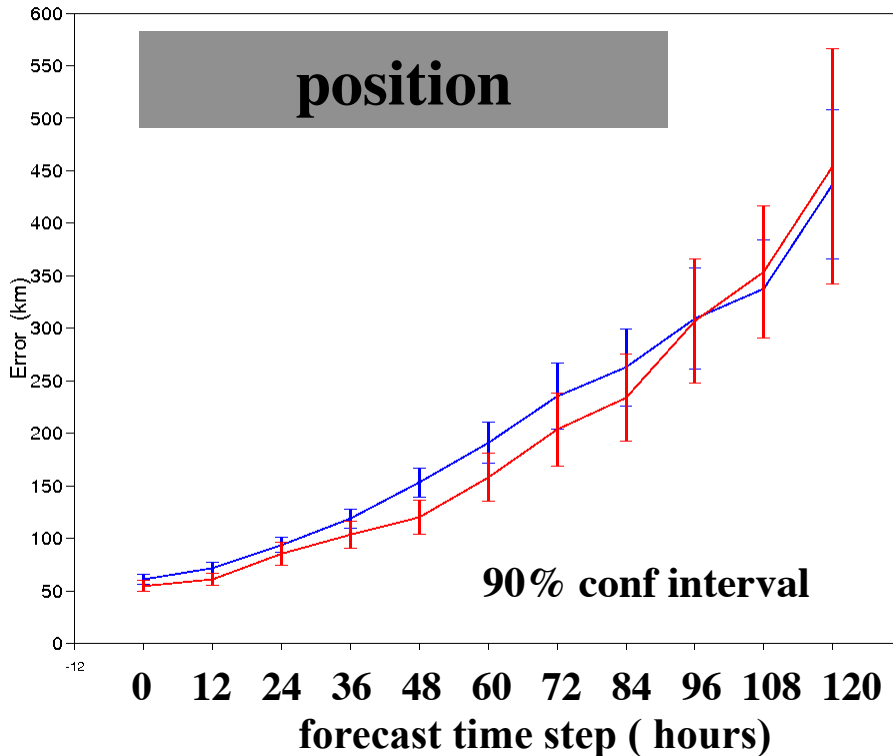
Click me to jump to the next slide

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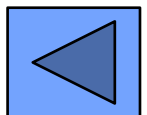# TC forecast performance T799 v T1279
(~25 km) (~16 km)

Tropical cyclone mean position error
fc period [20091004 to 20100121]

Tropical cyclone mean intensity error
fc period [20091004 to 20100121]

position

90% conf interval

intensity

sample size

(270)	(224)	(192)	(164)	(144)	(127)	(113)	(98)	(86)	(72)	(62)
(157)	(129)	(111)	(92)	(83)	(76)	(68)	(58)	(55)	(53)	(42)

forecast time step (hours)

forecast time step (hours)

Error = Forecast – Obs
Obs from the best track reports

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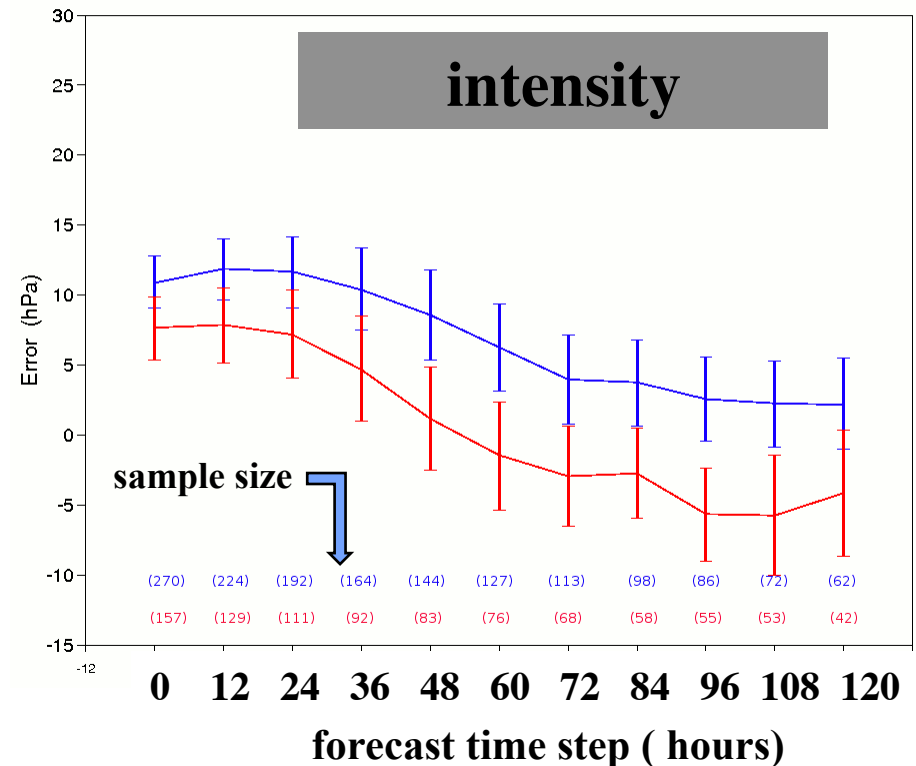
Model resolution impact – Super Typhoon Haiyan

T1279 – min 943 hPa   **T+48h**   **T2047 – min 922 hPa**

2013-11-06 00:00:00 0z +48, Min pres: 943 (Obs: 895 hPa)   2013-11-06 00:00:00 0z +48, Min pres: 922 (Obs: 895 hPa)
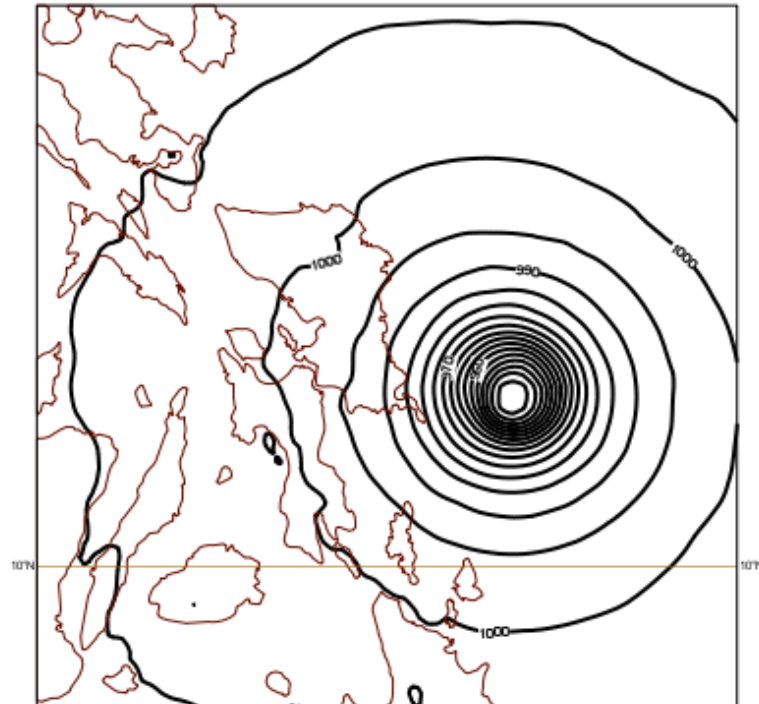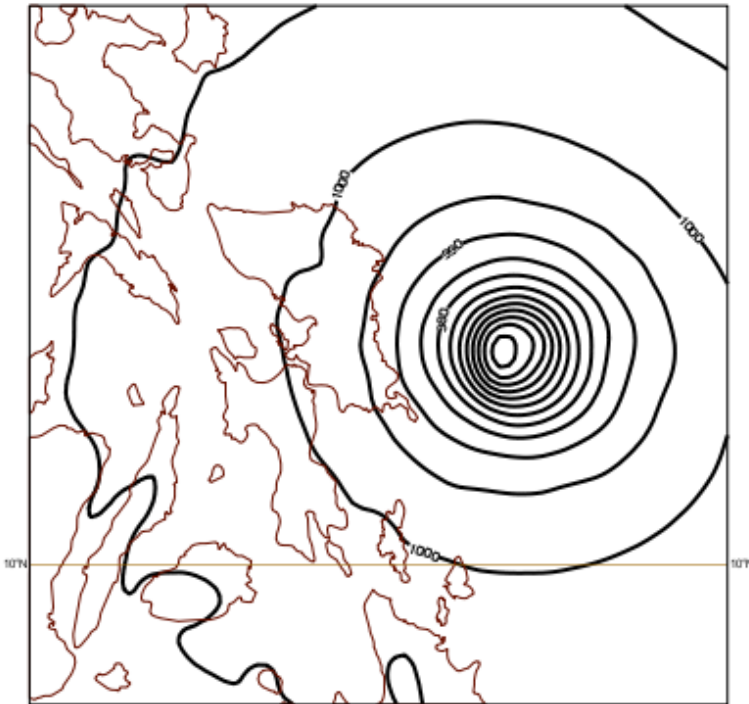
5°≈500 km

Courtesy of Linus Magnusson

ECMWF

Why is important to have an operational tracking scheme running at the Centre?

➢ **In operational environments, when the forecaster has to look at different NWP model outputs, the analysis of TC forecast is possible only when the information (position/intensity) is delivered (displayed) in a compact format (post-processing)**

➢ **It makes possible to verify objectively the TC forecasts. Can be used for comparing different model versions (model upgrades)**

➢ **At ECMWF:**

  ▪ **Operational tracking scheme since 2003. The switch from the current to the <u>new tracker</u> was successfully implemented on 2nd December 2013.**

  ▪ The algorithm runs twice a day (00 & 12 UTC) for high HRES model and ENS (51 perturbed members & control)

  ▪ **generates a track which is nothing more, nothing less than a sequence of locations of minimum (maximum) in MSLP (10m speed) every 6 hours.**

  ▪ **NEW: TC tracks are produced up to 240h (previously 120h) & extra web products.**

ECMWF

What model fields are used in the tracking scheme?

- **Surface fields**

  - Mean sea level pressure

  - Wind at 10 m

- **Upper level fields**

  - Vorticity (850 hPa)

  - Wind (multi-levels) for steering wind

  - Temperature (multi-levels) for warm core detection

The tracker is applied to NWP output every 6 hours and allows a tropical cyclone to 'disappear' for 24 hours (a tropical cyclone may weaken for a short period of time when crossing an island for instance).

For more details see ECMWF Newsletter No 130:

http://www.ecmwf.int/publications/newsletters/

ECMWF

ECMWF TC Tracker – How it works

vort 850hPa

warm core 500-200 hPa

V 850,700,500,200 hPa
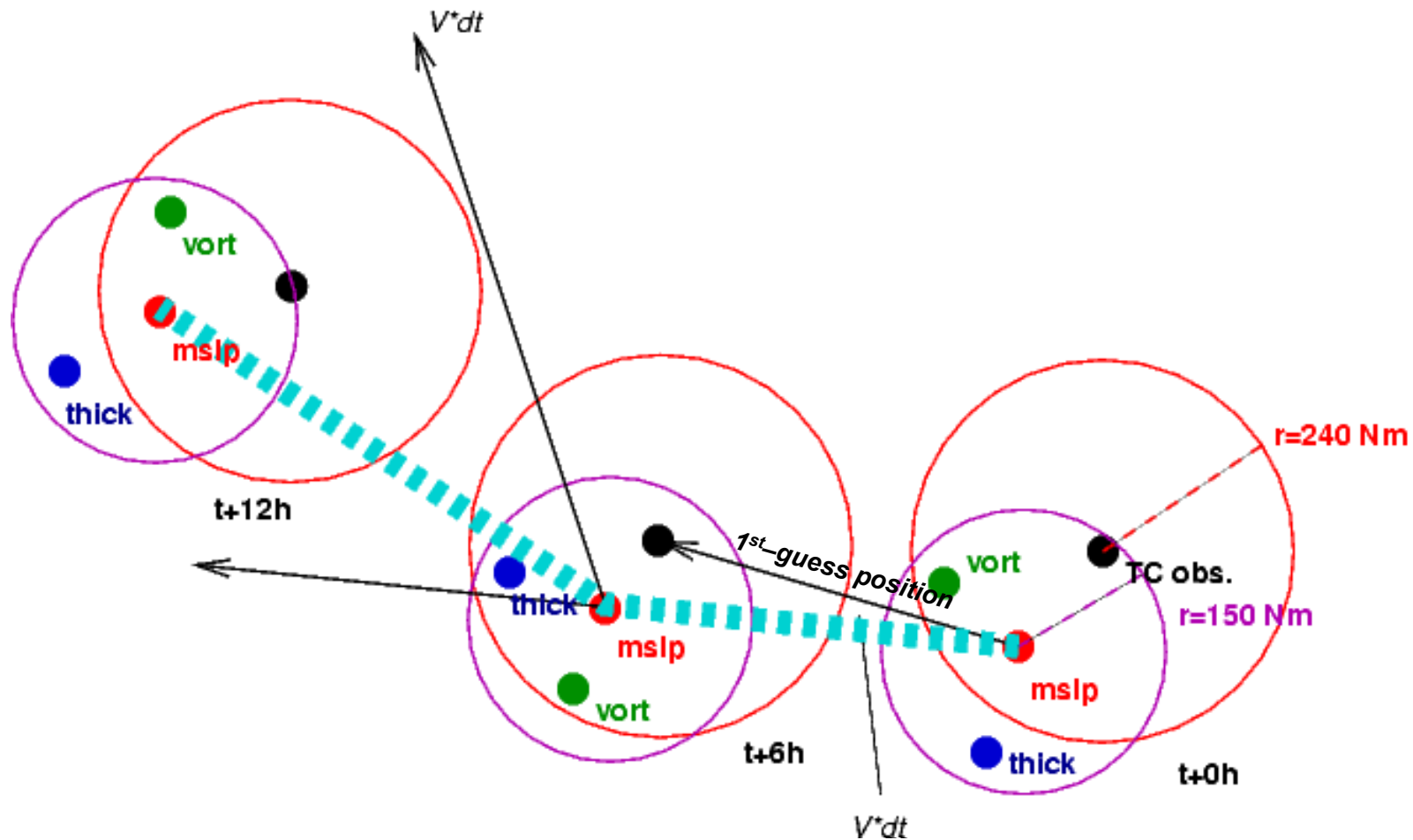
Tracker output (ALSO available in BUFR format)

Lat	Lon	ENS member (1, ...,51)	fc date	hour	mslp
36.94	-38.96	1	20121001	0	988
36.13	-39.4	1	20121001	600	997.6
35.4	-38.89	1	20121002	1200	999.7
35.09	-38.54	1	20121002	1800	999.6
34.52	-37.83	1	20121003	0	1005.6
33.99	-36.13	1	20121003	0600	1006.1
34.75	-33.02	1	20121004	1200	1003.6
37.2	-29.58	1	20121004	1800	995
36.8	-38.7	2	20121001	0	989

....

36.93	-38.96	52	20121001	0	987.9
36.52	-39.09	52	20121001	600	986.9
36.02	-39.12	52	20121001	1200	992.6
35.61	-38.91	52	20121001	1800	993.6
35.37	-38.45	52	20121002	0	994.6

HRES model

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Where can I find the web products?

➢ Whenever a Tropical Cyclone is observed

at the start of a forecast

http://www.ecmwf.int/products/forecasts/d/tccurrent

➢ Whenever there is Tropical Cyclone activity in the forecast

http://**www.ecmwf.int/products/forecasts/d/charts/medium/eps/genesis/ta_genesis**/

➢ **New Web page coming soon!**
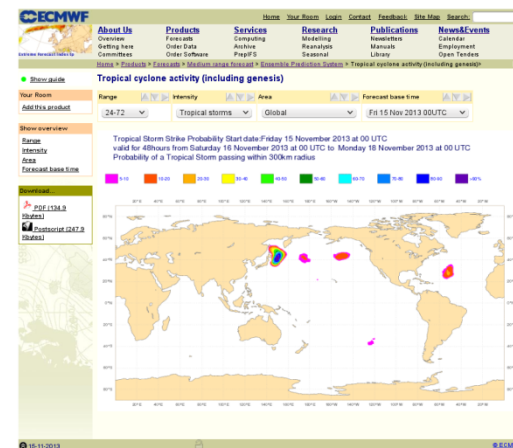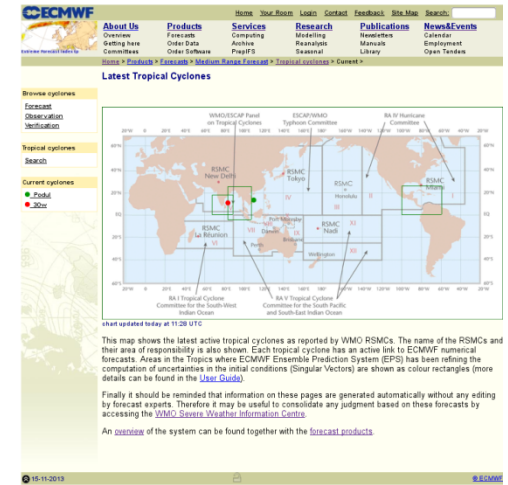
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TC Products – Part I

Date 20120831 00 UTC @ECMWF
Probability that **LESLIE** will pass within 120 km radius during the next **240** hours
tracks: **solid**=OPER; **dot**=Ens Mean [reported minimum central pressure (hPa) **1002**]

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

Tracks are plotted for the HRES (solid) and ENS mean (dot). Symbols are placed at 24-hour intervals.

Meteograms representing the distribution of the ENS for the 10-m wind (kt) and sea level pressure (hPa) at TC centre. Time series are plotted for the EM mean (dot) and HRES (solid).

"Observed" TC position (cross) & minimum central pressure (**red**), when available.

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

Snapshot of ENS members (numbers) tracking the storm together with intensity (colours), at 24-hours intervals. HRES and Control models are labelled 'hr' and 'ct' respectively.

Intensity probability is the fraction of the number of ENS members (relative to the total number of ENS members which held the feature) falling into each of the 5 intensity categories, at 6-hours interval up to 10 days.
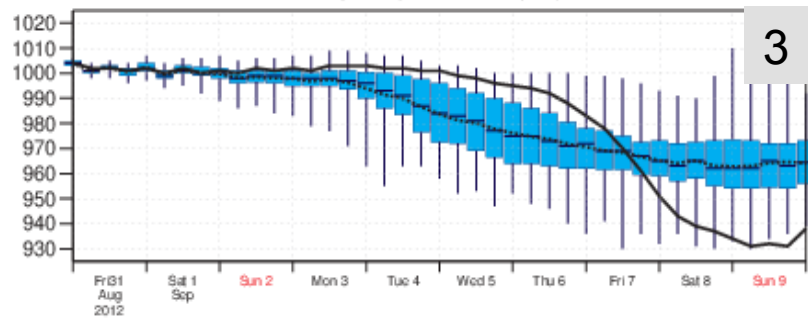
Probability (%) of Tropical Cyclone Intensity falling in each category
TD[up to 33] **TS** [34-63] **HR1**[64-82] **HR2** [83-95] **HR3** [> 95 kt]

10m Wind Speed (kt) **solid**=OPER; **dot**=Ens Mean
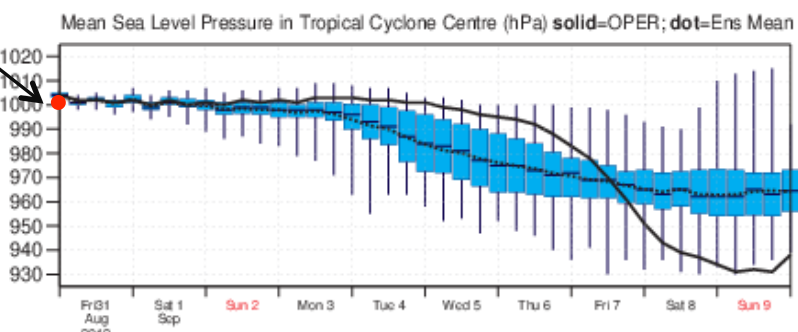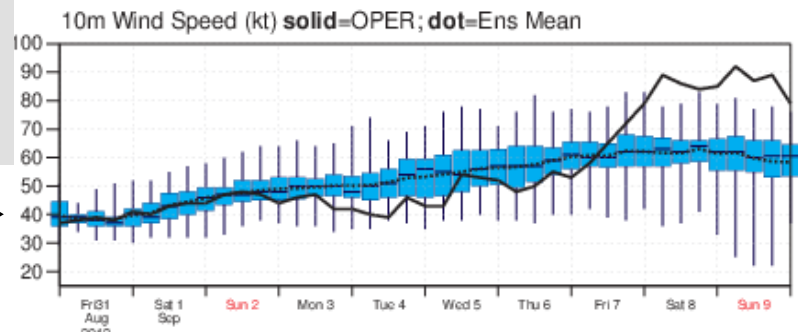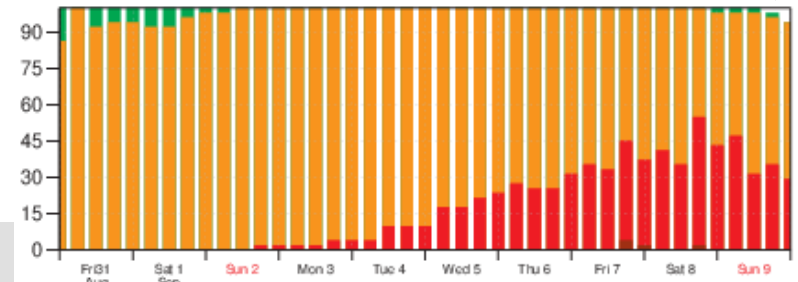
Mean Sea Level Pressure in Tropical Cyclone Centre (hPa) **solid**=OPER; **dot**=Ens Mean
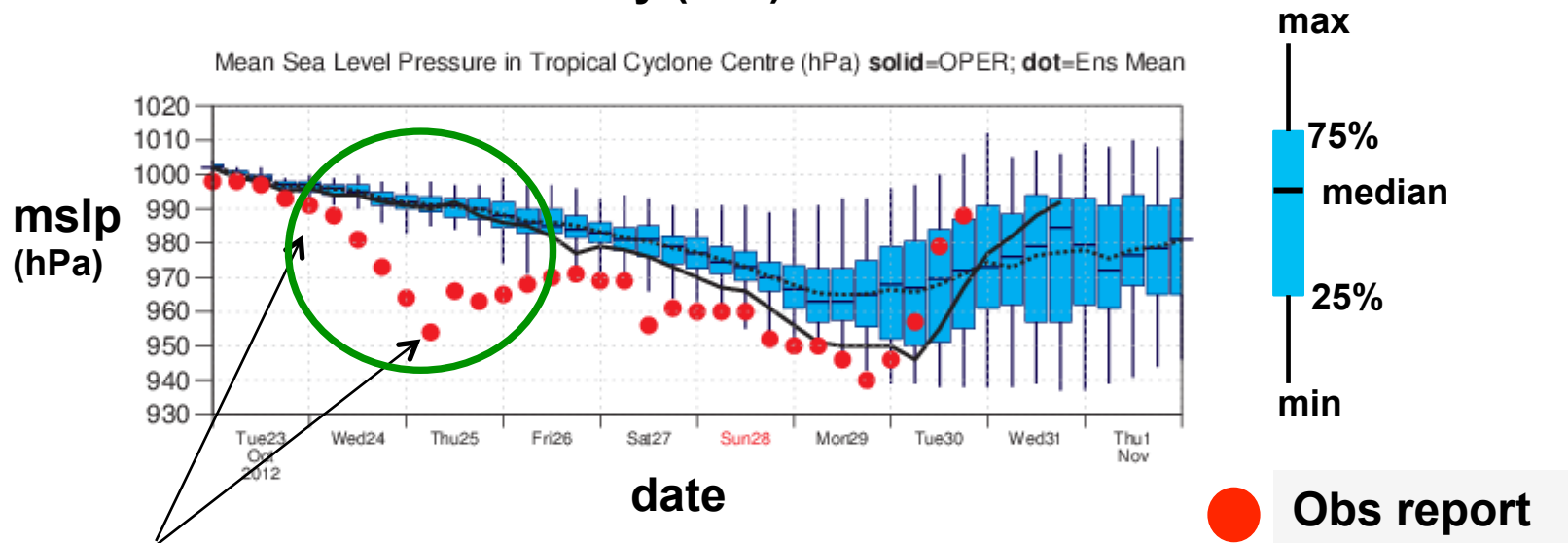
box-and-whiskers plot representing the 5 quantiles of the ENS distribution

max
75%
median
25%
min

Date 20120831 00 UTC @ECMWF
Individual trajectories for **LESLIE** during the next **240** hours
tracks: **thick solid**=OPER; **thick dot**=CTRL; **thin solid**=EPS members [coloured]
0-24h 24-48h 48-72h 72-96h 96-120h 120-144h 144-168h 168-192h 192-216h 216-240h

+48h
+24h
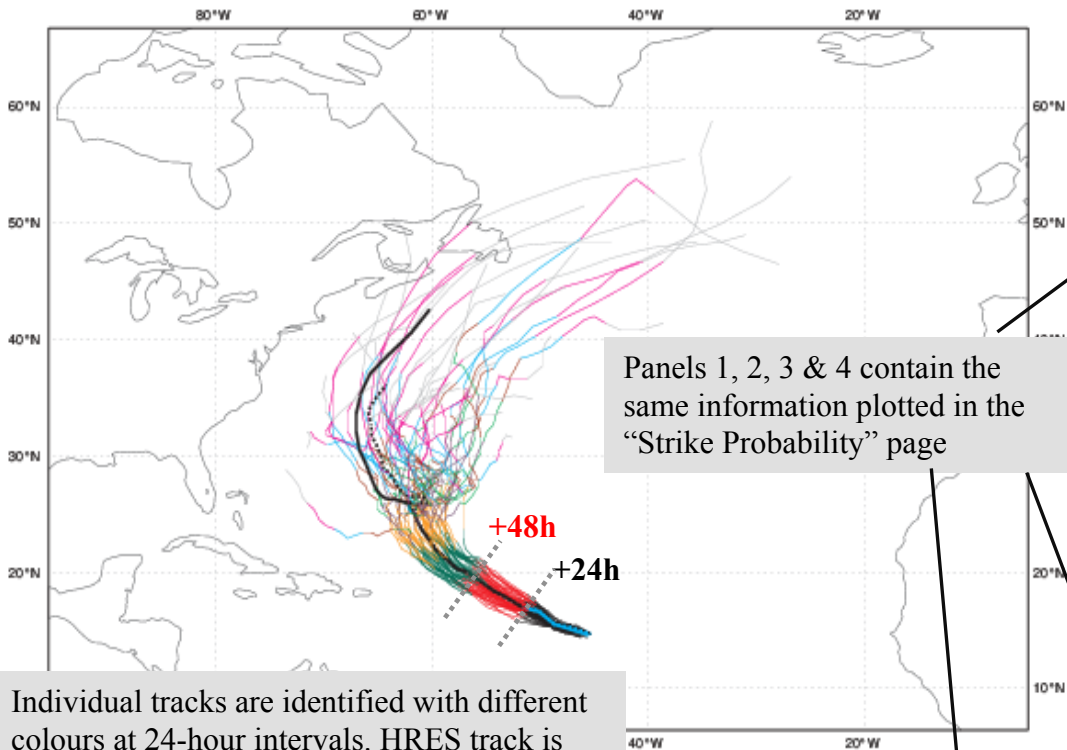
Panels 1, 2, 3 & 4 contain the same information plotted in the "Strike Probability" page

Individual tracks are identified with different colours at 24-hour intervals. HRES track is plotted with thick black line, except in the first 24-hours forecast (cyan).

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

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

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

TC intensity forecast – on going problem

➢ In general , rapid intensification of TCs is still poorly handled by the current global models

HR Sandy (18L)

Rapid intensification
~40 hPa in 30 hrs

Haiyan 2 days before landfall

Too intense TC (12L Leslie) analysis and forecast due to no coupling ocean-atmosphere model

Run 05@00 ● reported obs Run 06@00

0-24h 24-48h 48-72h 72-96h 96-120h 120-144h

•••••••• Ctrl ——— HiRES
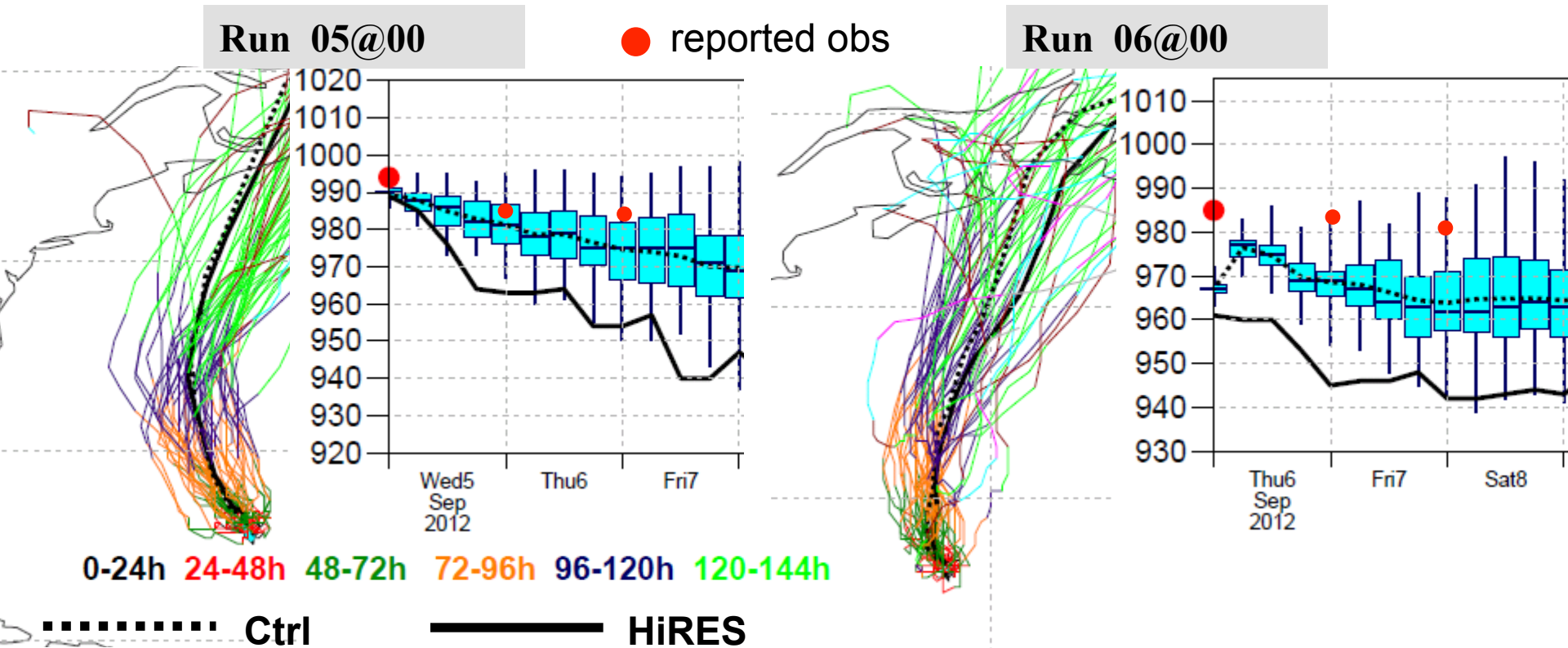
Each line represents an individual TC track ENS member (colours change every 24h interval)
The individual tracks suggest a slow moving storm during the first days
The HiRes analysis shows a too deep storm between 6 and 8th September

Coupled ocean and atmosphere (cont...)
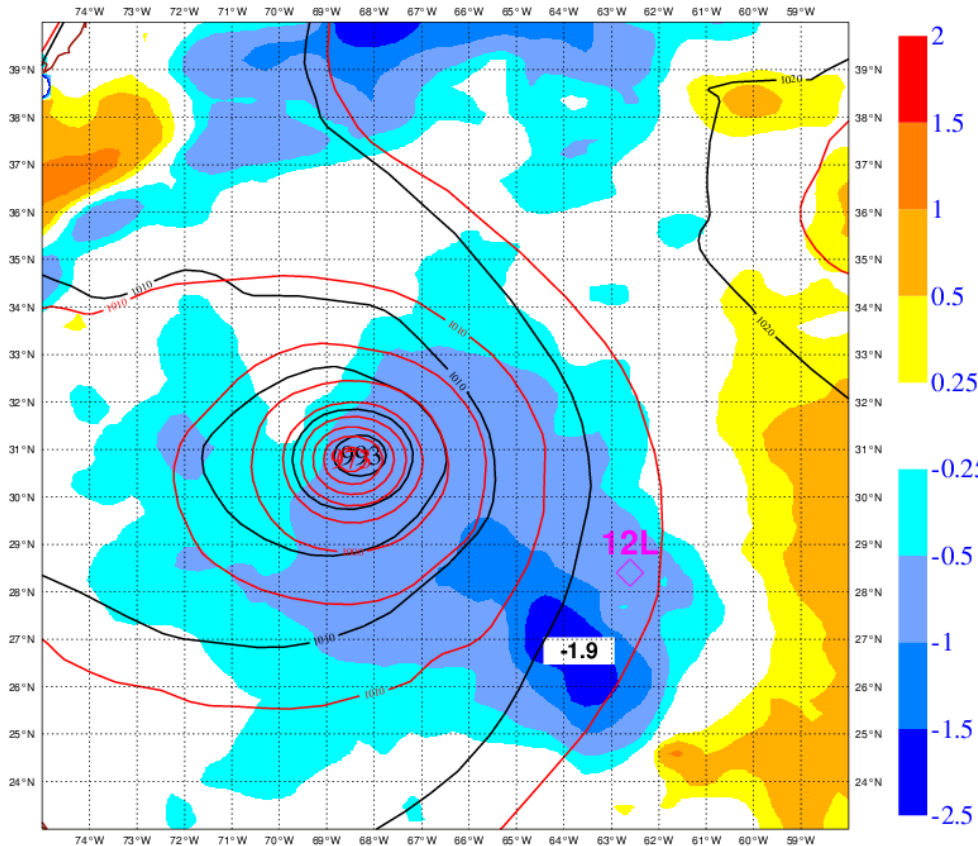
Control: operational T639 (constant SST anomaly)

Experiment: coupled ocean-atmosphere model

contours: MSLP (hPa)
shaded: SST (K) difference (Exper-**Ctrl**)

Minimum Central Pressure:
993 hPa (Experiment)
973 hPa (Control)
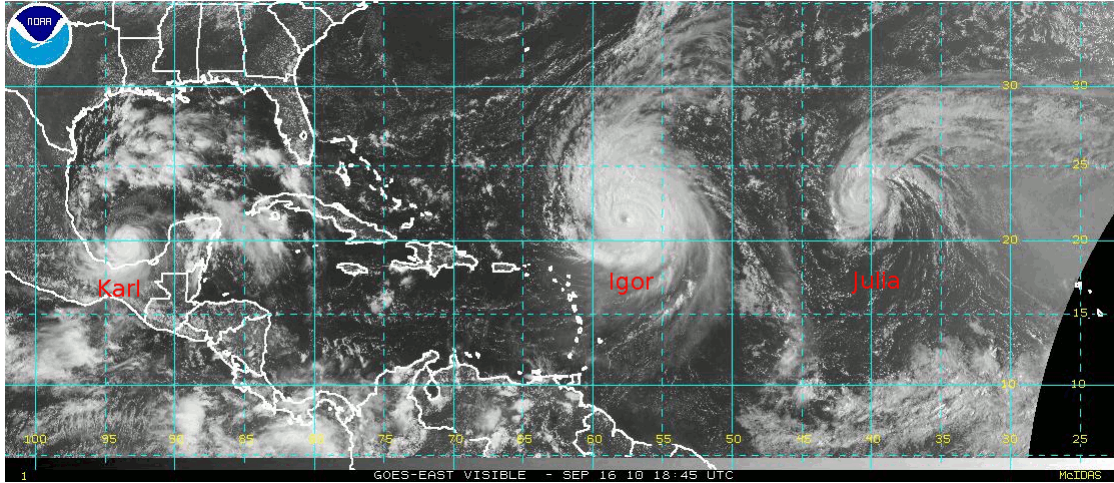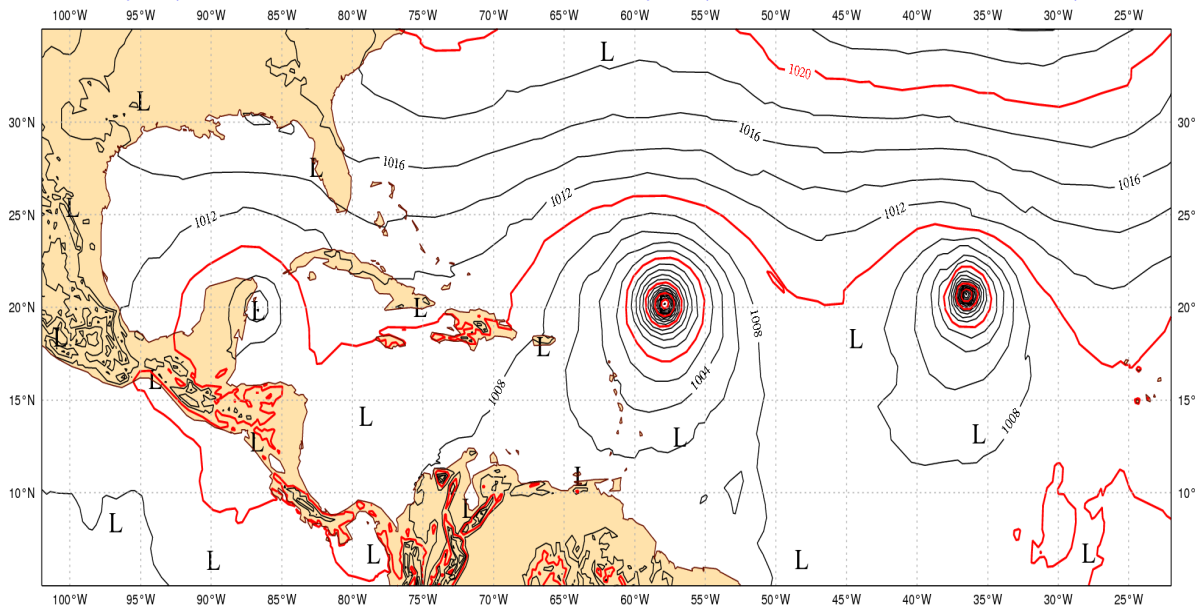
03 Sep 12 UTC   +120h VT: 08 Sep 12 UTC

⊂⊂⊂ECMWF

Forecast period of enhanced Hurricane Activity, 9 days ahead

Goes-East visible image
16 September 18 UTC

Wednesday 8 September 2010 00UTC ECMWF Forecast t+210 VT: Thursday 16 September 2010 18UTC Surface: Mean sea level pressure

T+210 h T1279
Forecast MSLP

Tropical Cyclone activity: Medium Range EPS

Selected forecast steps covering the next 12 days

Maps: global view and 7 additional TC basins

A short explanation about the products is available here by clicking in the show guide

Strike probability for TC/TS/HR

Forecast runs covering the last 10 days
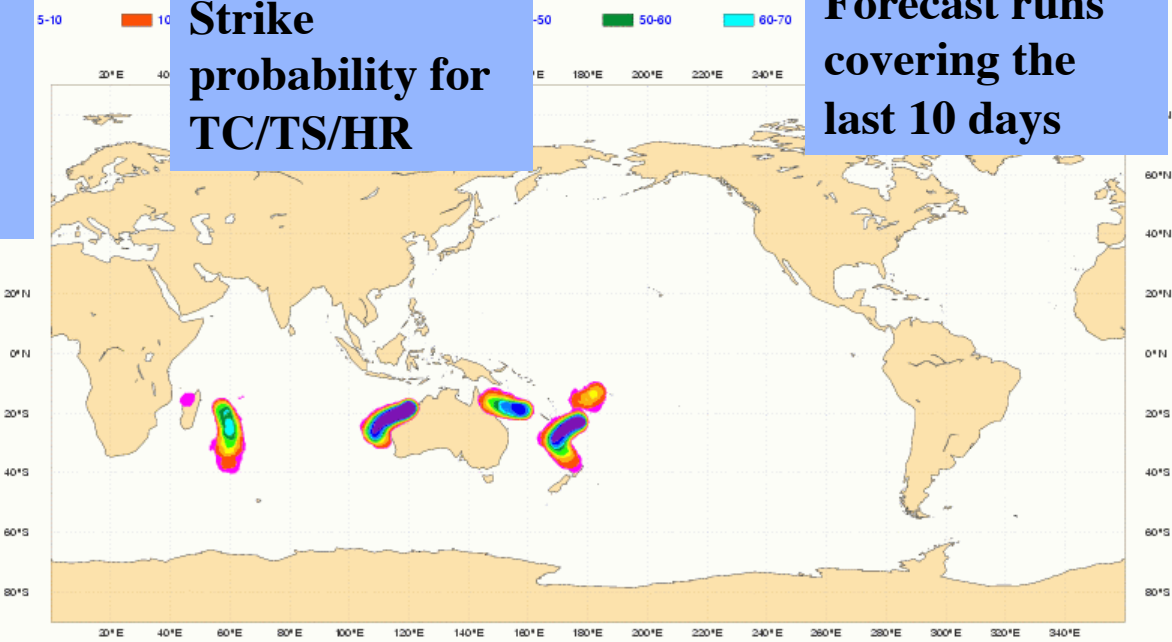
Forecast performance

The forecast performance for TCs is checked regularly and compared with the previous years for the Global HRES model and ENS. The results are reported to the Technical Advisory Committee★ every year.

➤ Mean position error for HRES, Control models and ENS mean

➤ Mean intensity error (ME)

➤ Mean speed error (ME) for HRES

➤ Reliability and ROC for the Strike Probability Products

➤ ENS Spread & EM Error
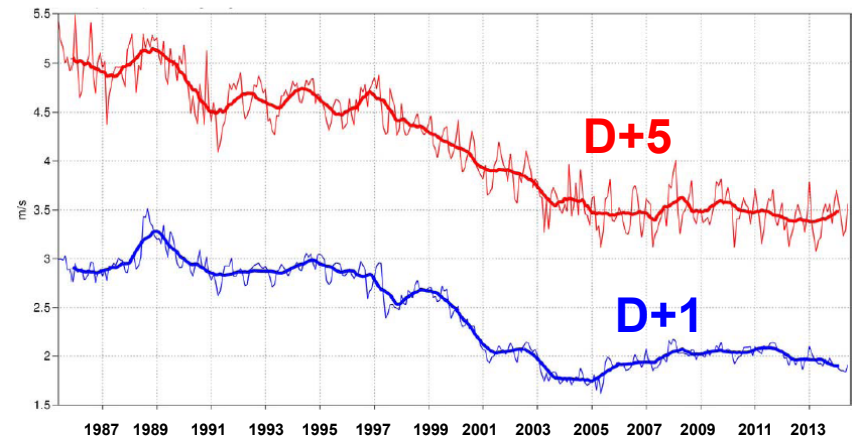
★also available in technical memoranda document

http://www.ecmwf.int/publications/library/do/references/list/14

ECMWF

How accurate are the TC forecasts from ECMWF (Part I)?
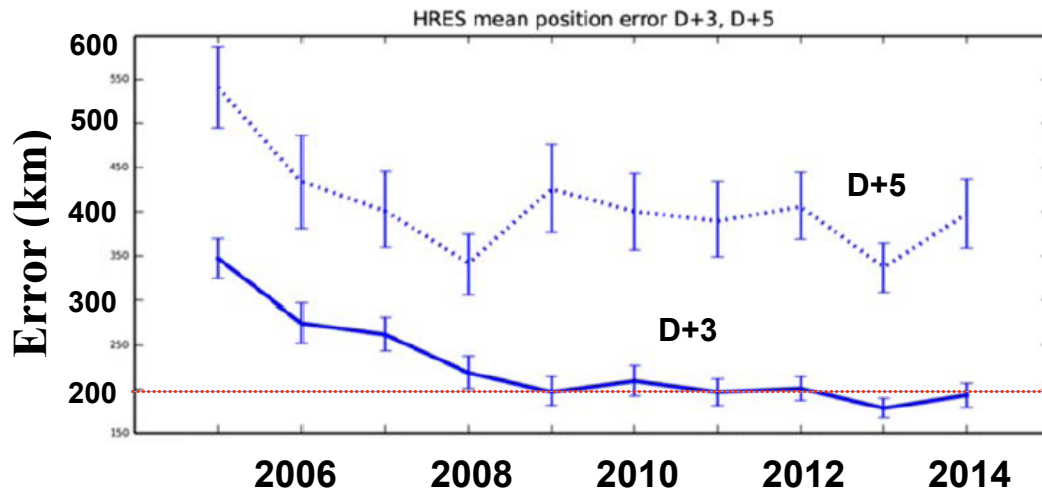
RMS VECTOR WIND at 200 hPa
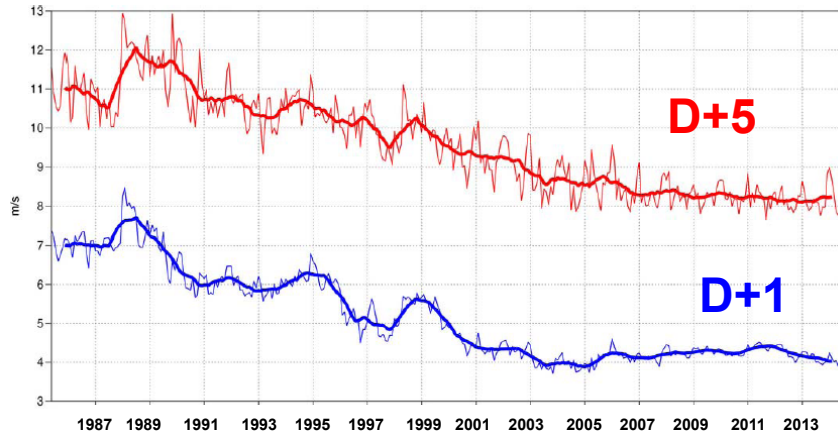
RMS VECTOR WIND at 850 hPa

ECMWF

How accurate are the TC Fcs from ECMWF (Part II) ?
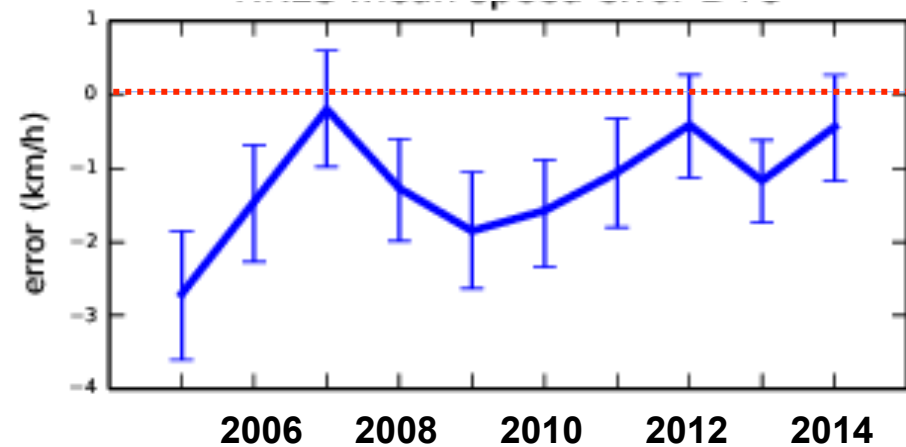## HRES verification (12 month means ending on 30 June)

HRES mean position error D+3, D+5

position

Error (km)

D+5

D+3

2006   2008   2010   2012   2014

intensity

Mean intensity error D+3

Error (hPa)

CNTR
HRES

2006   2008   2010   2012   2014

Error = Forecast – Obs
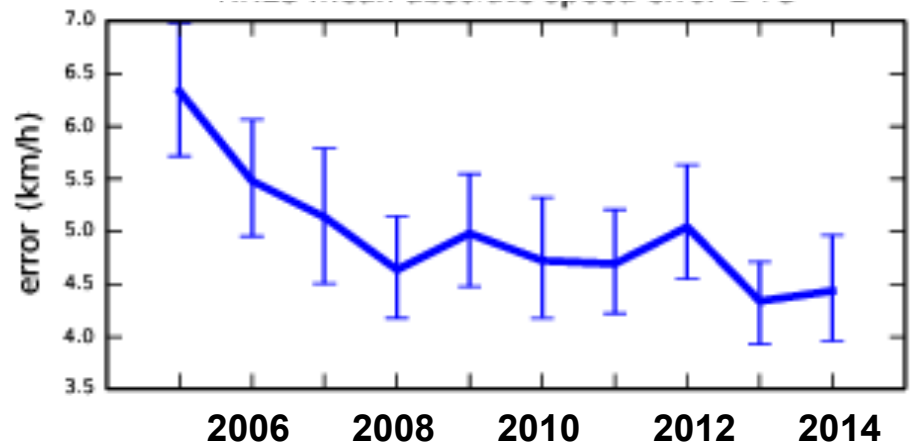*Obs from the best track reports*
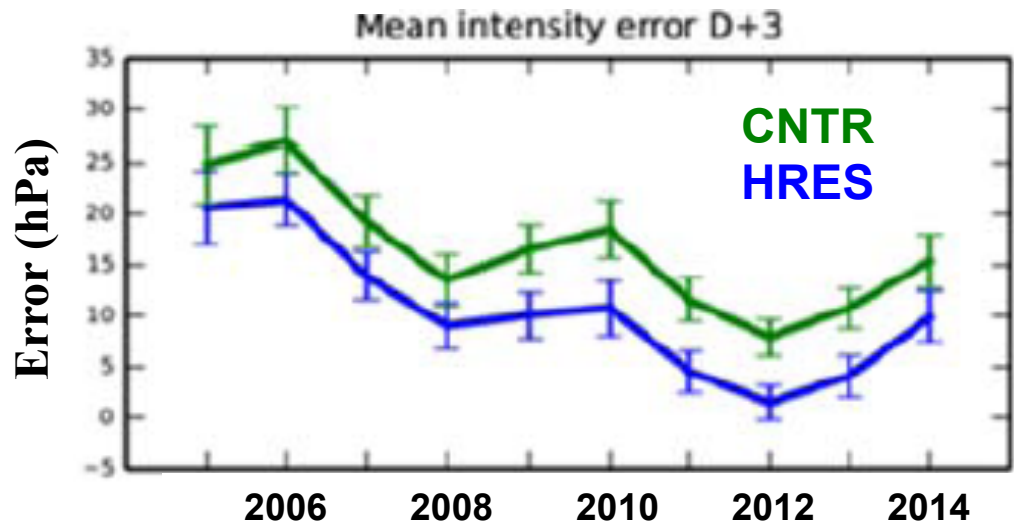
On average TCs move slower in the model (Part III)

HRES Mean Speed Error D+3

HRES Mean Absolute Speed Error D+3

ECMWF

How do we performed against the other NWP Centres (Part IV)? source: Hong Kong observatory

➢ **2011 verification results**

➢ **ECMWF is clearly best model**

➢ **ECMWF is comparable to or better than the multi-centre ensemble mean ("NWP ensemble")**
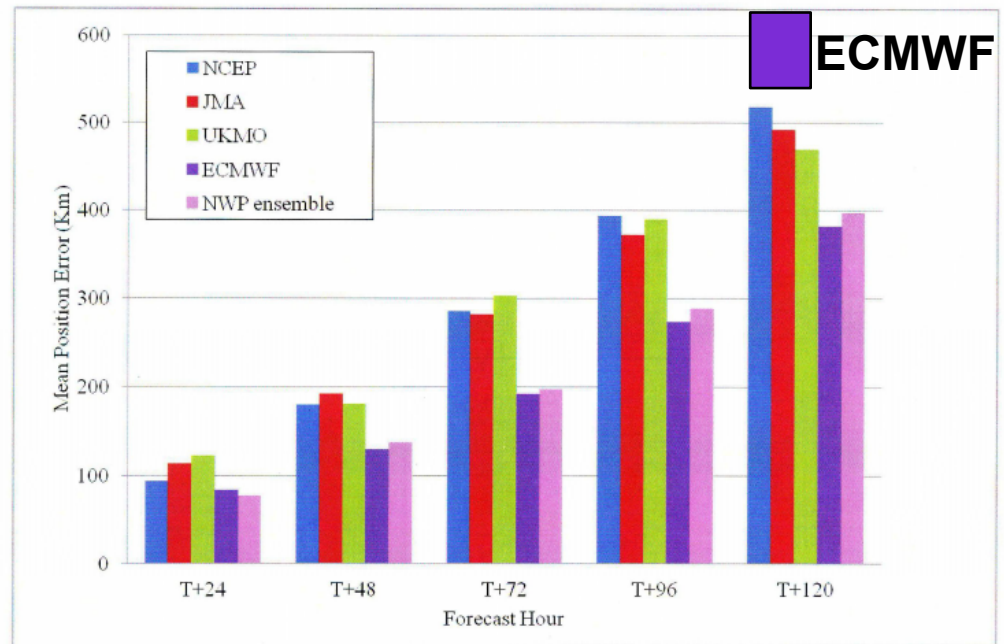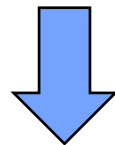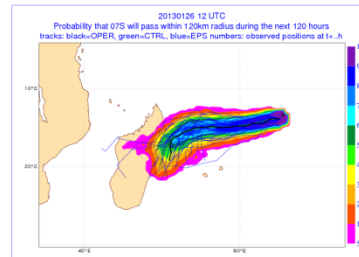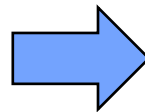

ECMWF

Figure 7. Mean position errors of forecasts from the NWP ensemble and the respective member models for T+24 to T+120 in 2011.
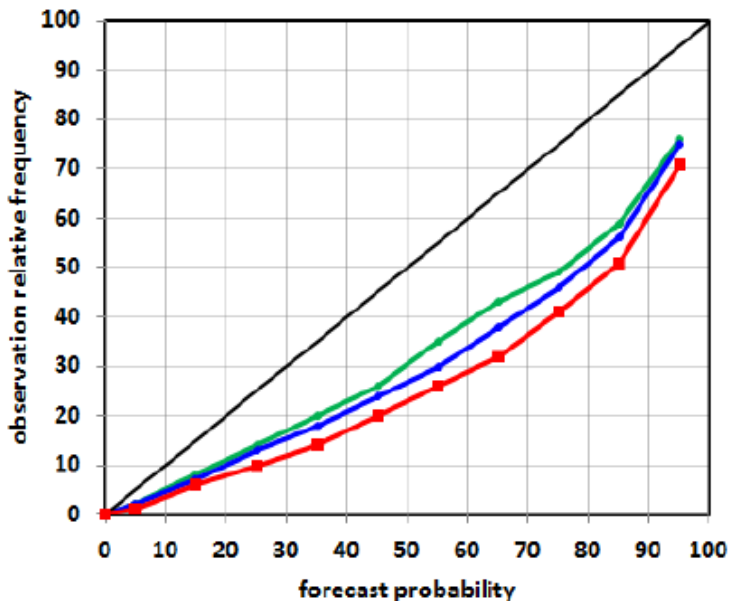
14

ECMWF

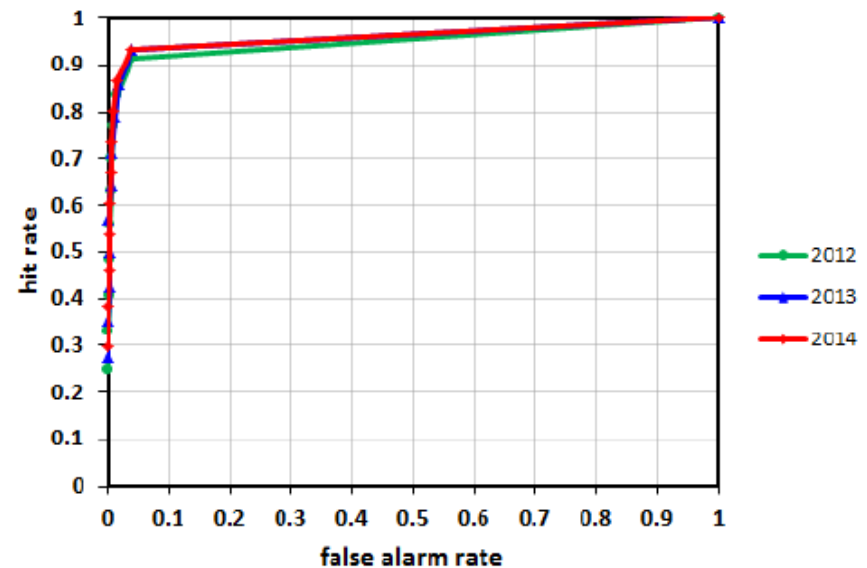# Verification of the ENS Strike Probability product (Part V)

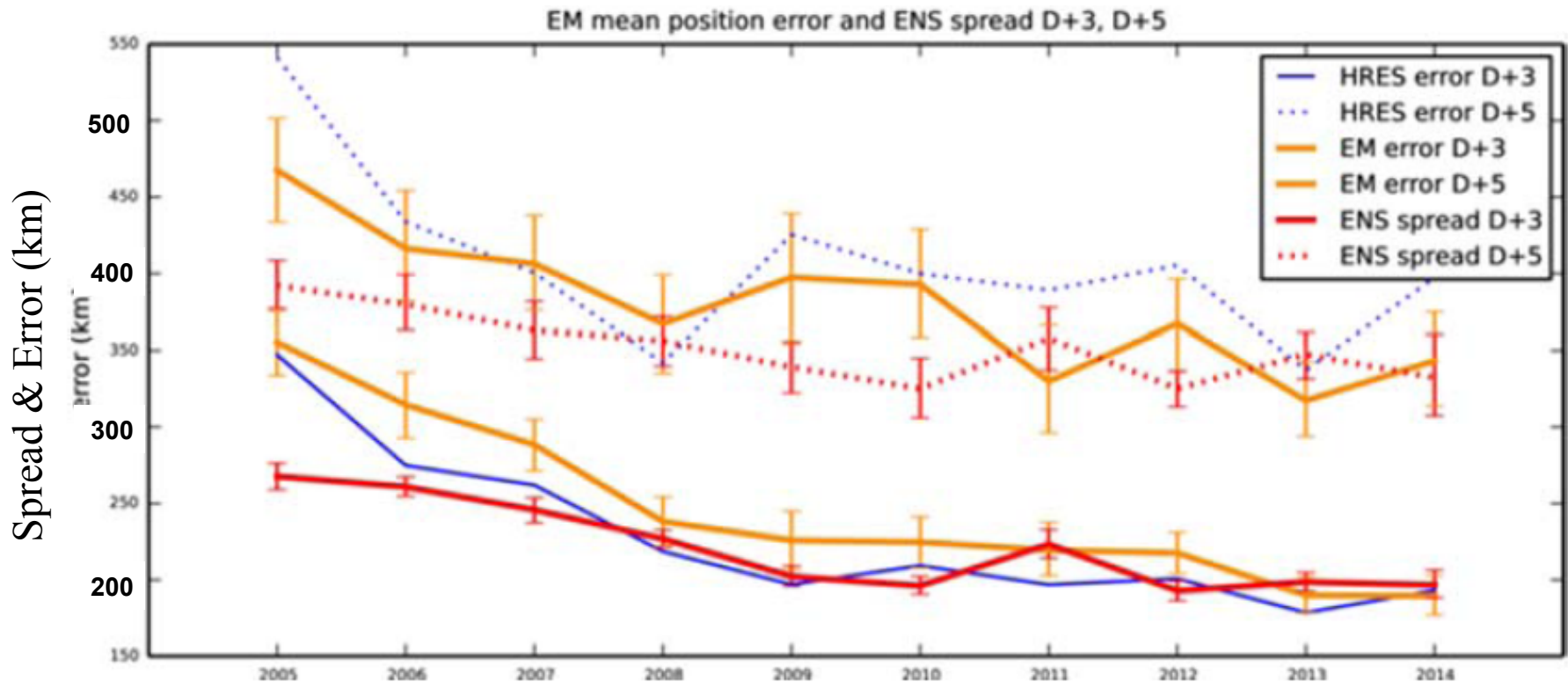Strike probability of TC within 120 km in the next five days

Reliability of TC strike probability (+120h)
(one year ending on 30th Jun)

ROC of TC strike probability (+120h)
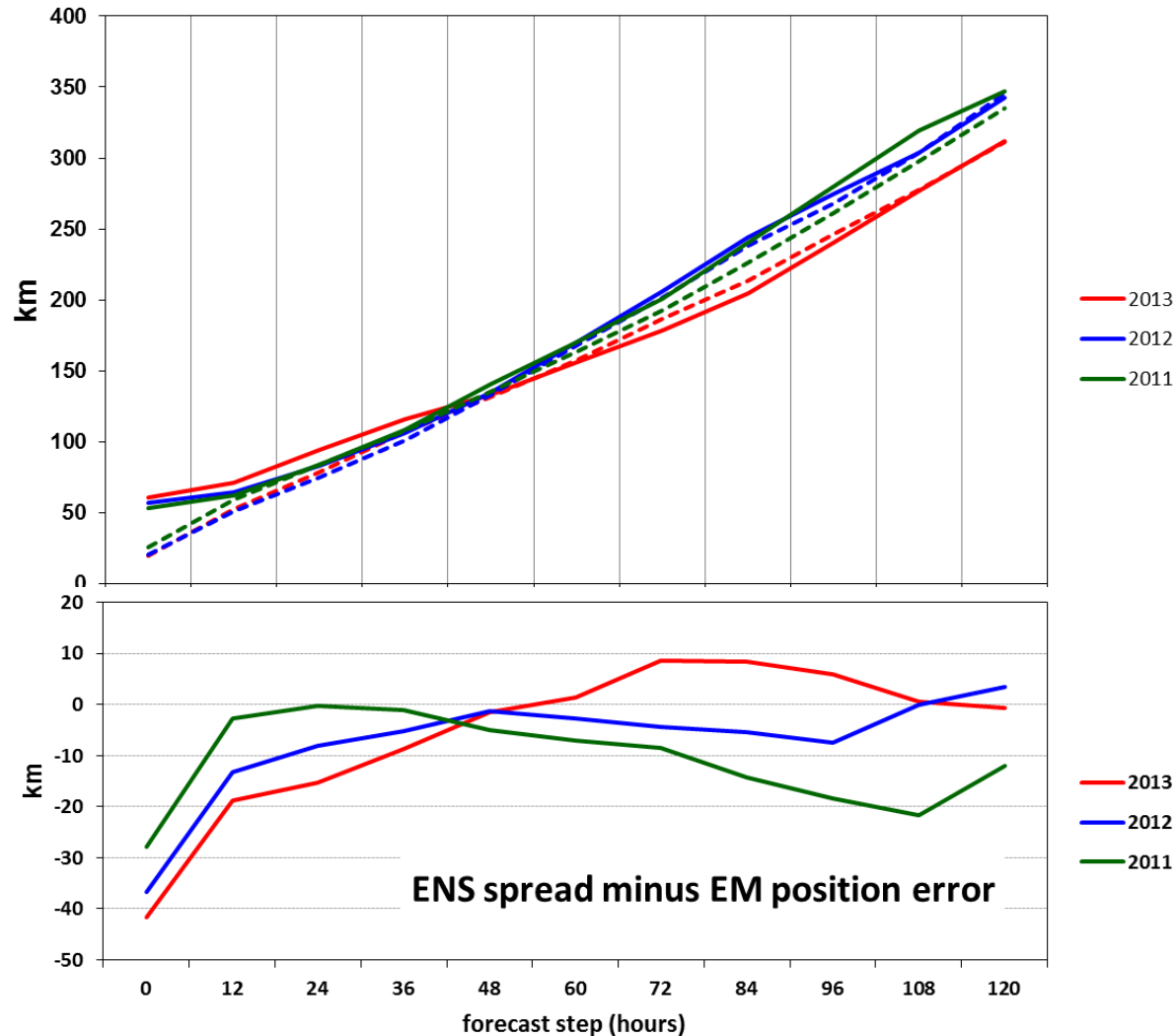(one year ending on 30th Jun)
ROCA: 0.914/0.925/0.930

ECMWF

ENS SPREAD & EM ERROR (Part VI)

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

A calibrated ENS should provide consistency between the EM error and spread.

ENS SPREAD & EM ERROR (Part VII)

EM position error (solid) and ENS spread (dash)

(annual mean ending 30th November)

QUESTIONS?

ECMWF