

Objectives

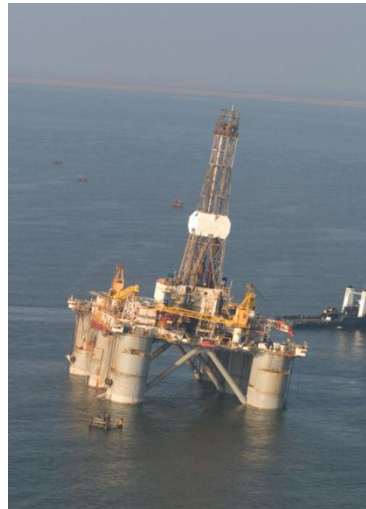
- Have a better understanding of the Tropical Cyclone Products generated at ECMWF
- Learn about the recent developments in the forecast system and its impact on the Tropical Cyclone forecast
- Learn about the skill of TC forecasts in recent years

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Evaluation Section
ECMWF



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
- They can cause major disruptions on economic activities
 - Off shore oil rigs
 - Ship routing



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
- Soon:
 - *The atmosphere-ocean coupling of the ENS will be 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

What are the advantages of running a operational tracking scheme?

- 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 since 2003. The switch from the current to the new tracker will be 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.

What 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:

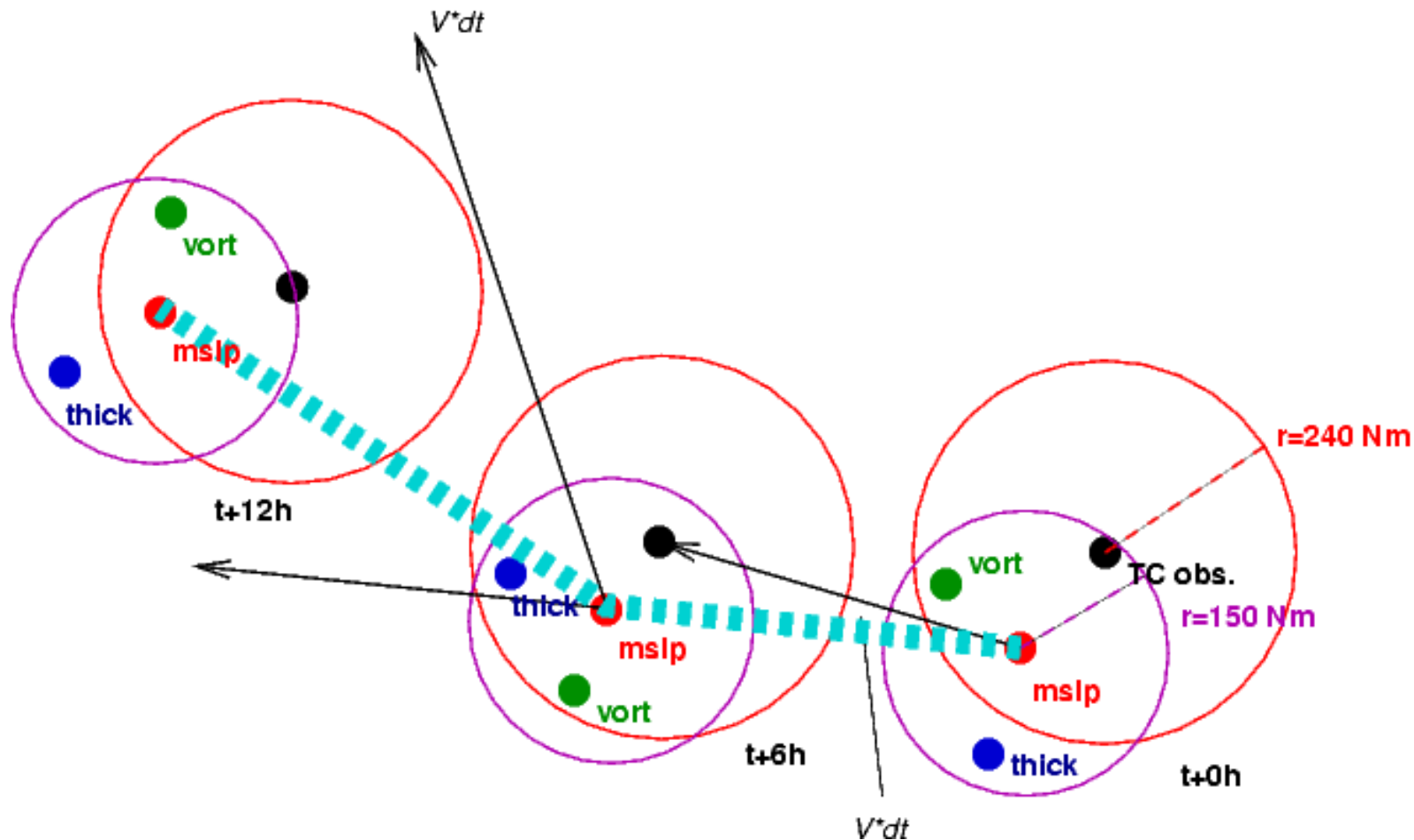
<http://www.ecmwf.int/publications/newsletters/>

ECMWF TC Tracker – How it works

vort 850hPa

V 850,700,500,200 hPa

warm core 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

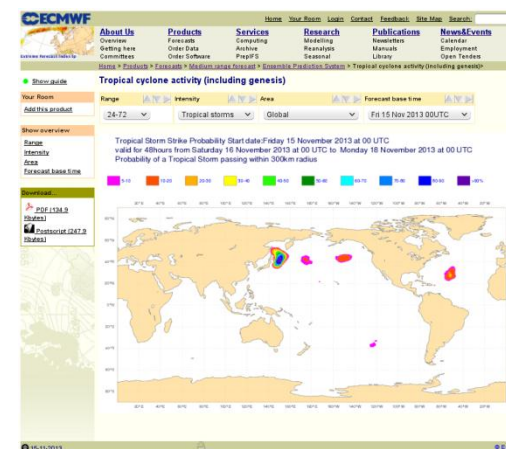
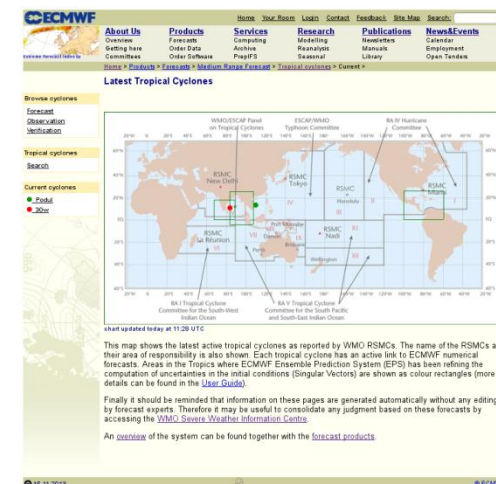
Where can I find the web products?

- 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/



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.

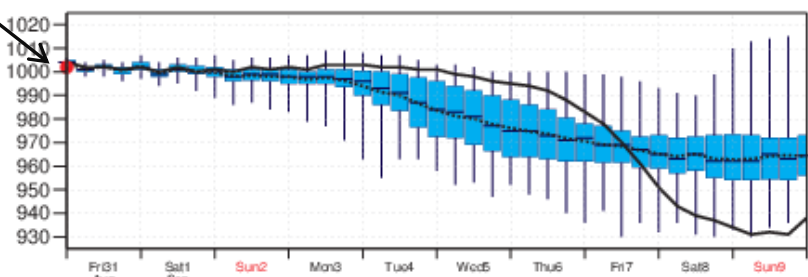
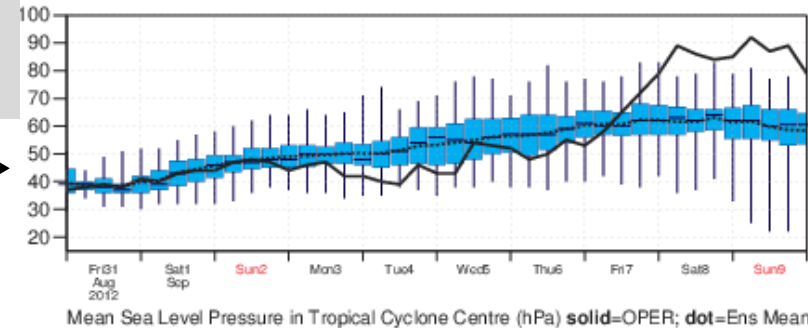
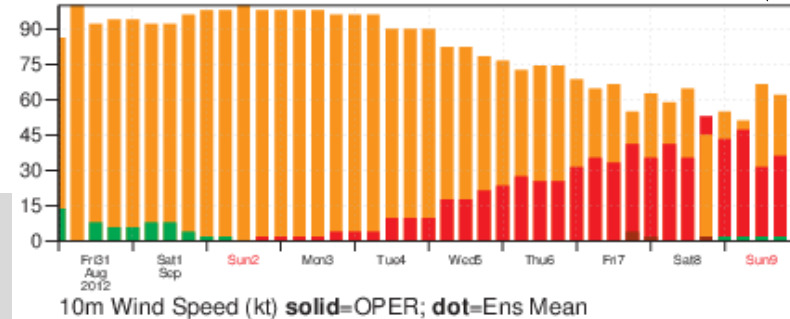
List of ensemble members numbers forecast Tropical Cyclone
Intensity category in colours: **TD**[up to 33] **TS**[34-63] **HR1**[64-82] **HR2**[83-95] **HR3**[>95 kt]

+024 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
+048 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
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+096 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
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+168 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
+192 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
+216 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
+240 h: hr ct 01 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 29 30 31 32 33 34 35 36 37 38 40 41 42 43 44 45 46 47 48 49 50

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’

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]



max
75%
median
25%
min

box-and-whiskers plot representing the 5 quantiles of the ENS distribution

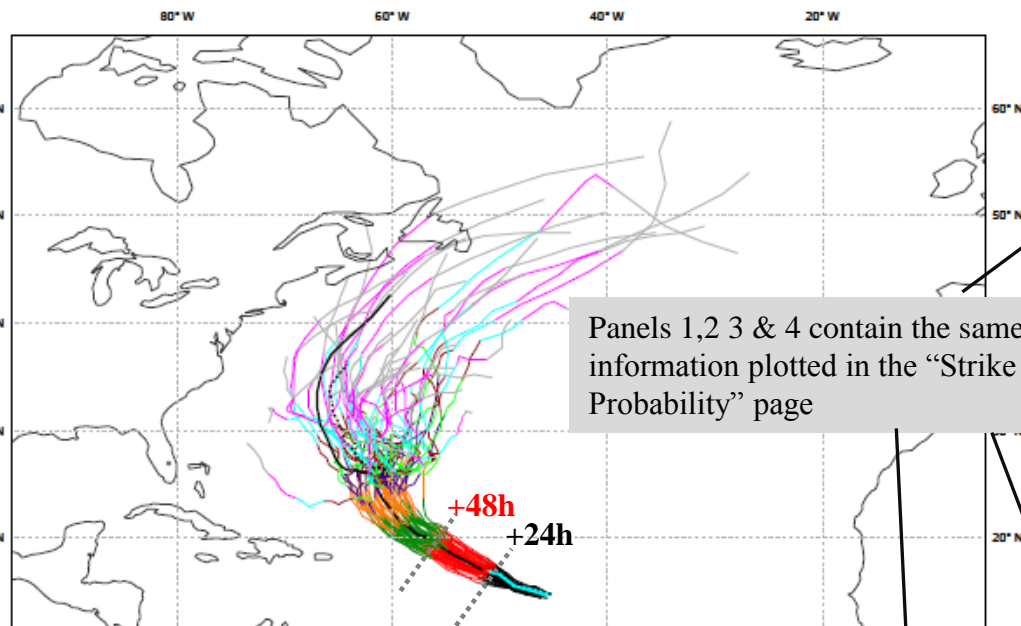
TC Products – Part II

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



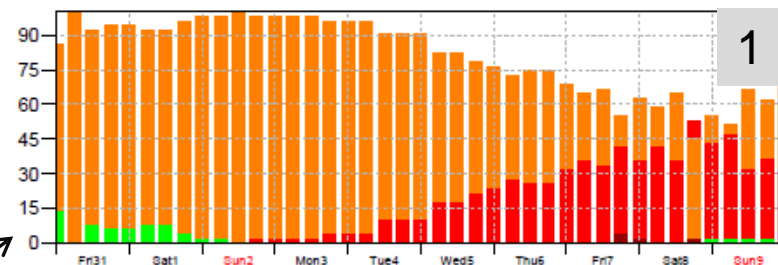
Panels 1,2 3 & 4 contain the same information plotted in the "Strike Probability" page

+48h
+24h

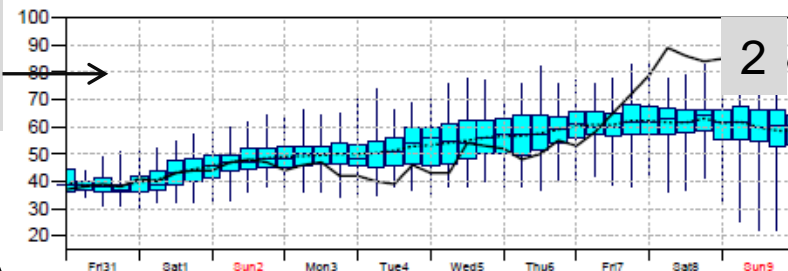
Individual tracks are identified with different colours at 24-hour intervals. HRES track is plotted with thick black line, except in the first 24-hours forecast (cyan).

072 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
 +096 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
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 +144 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
 +168 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
 +192 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
 +216 h: hr ct 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
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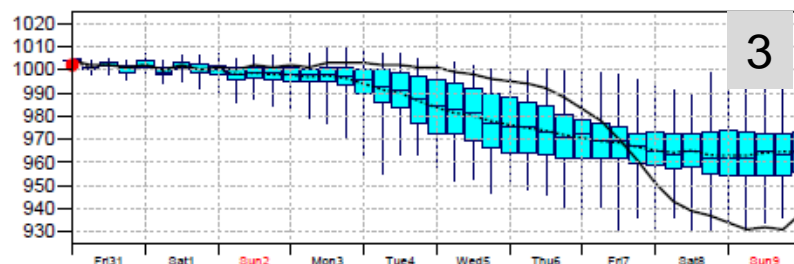
Probability (%) of Tropical Cyclone Intensity falling in each category
 TD[up to 33] TS [34-63] HR1[64-82] HR2 [83-95] HR3 [> 95 kt]



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



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

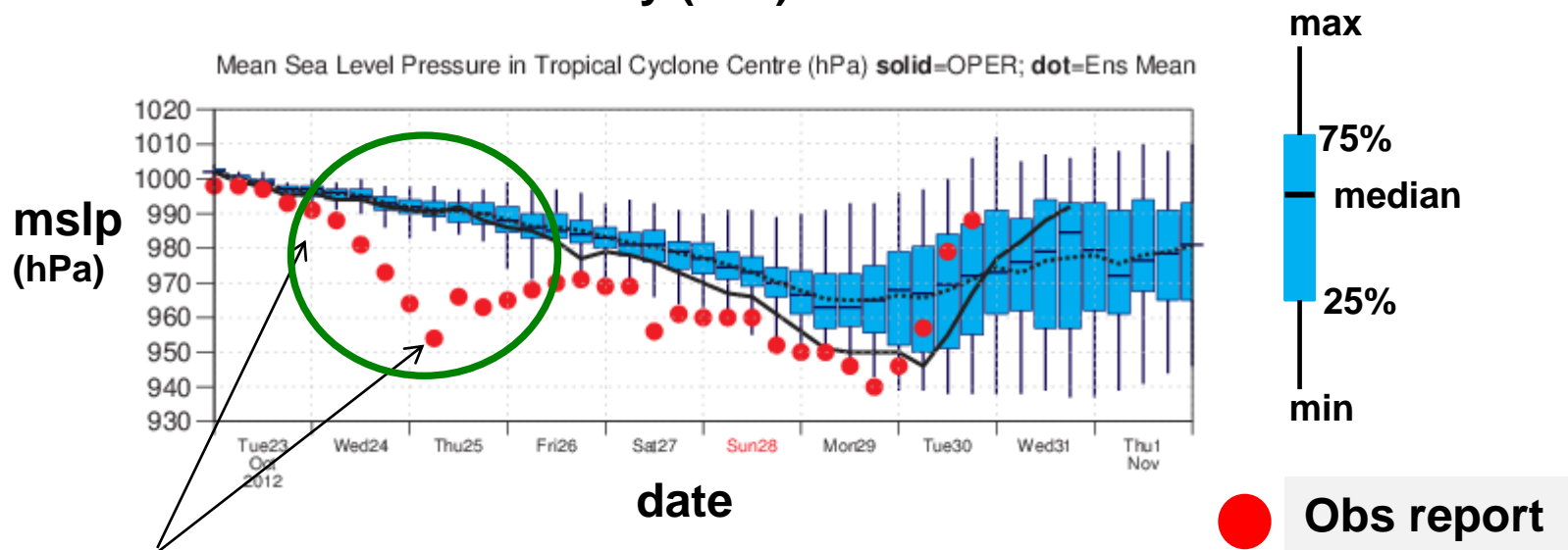


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TC intensity forecast – on going problem

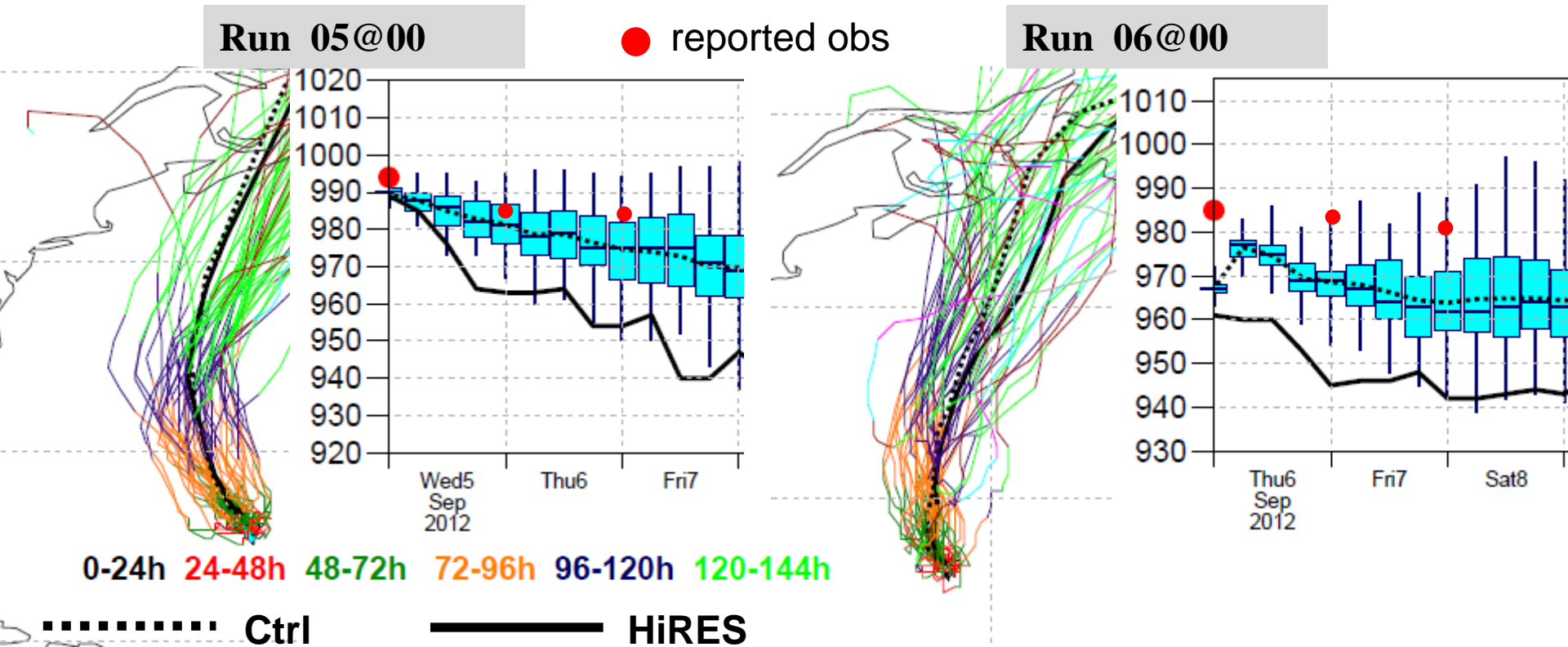
- In general , rapid intensification of TCs is still poorly handled by the current global models

HR Sandy (18L)



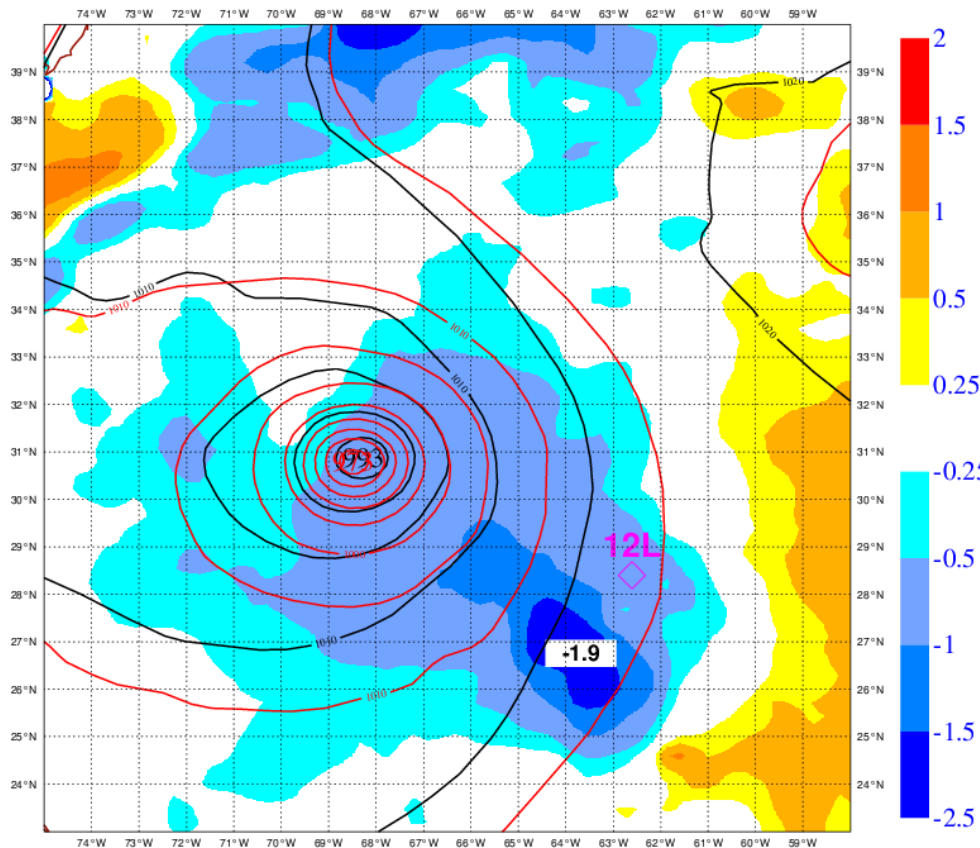
Rapid intensification
~40 hPa in 30 hrs

Too intense TC (12L Leslie) analysis and forecast due to non couple ocean-atmosphere model



Each line represents an individual TC track ENS member (colours change every 24h forecast)
The individual tracks suggest a very 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**)**

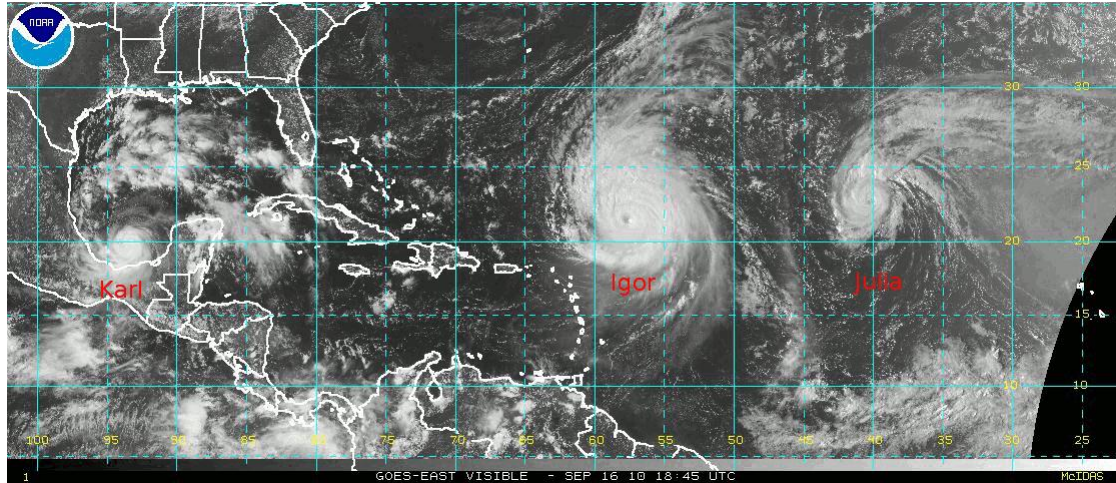
Minimum Central Pressure:

993 hPa (Experiment)

973 hPa (Control)

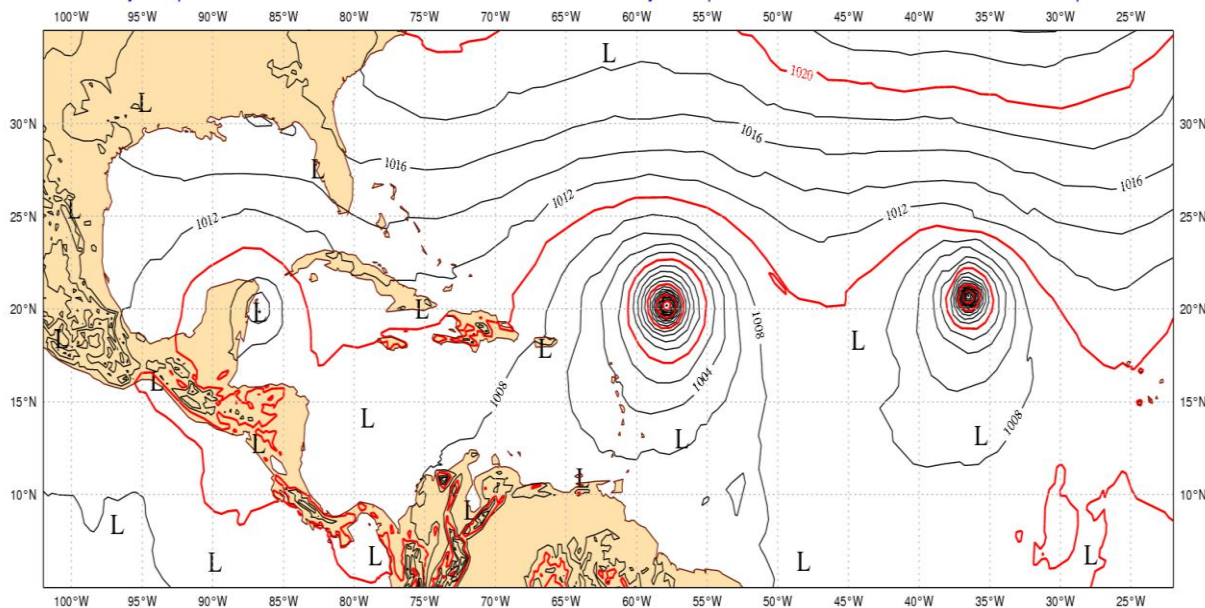
03 Sep 12 UTC +120h VT: 08 Sep 12 UTC

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

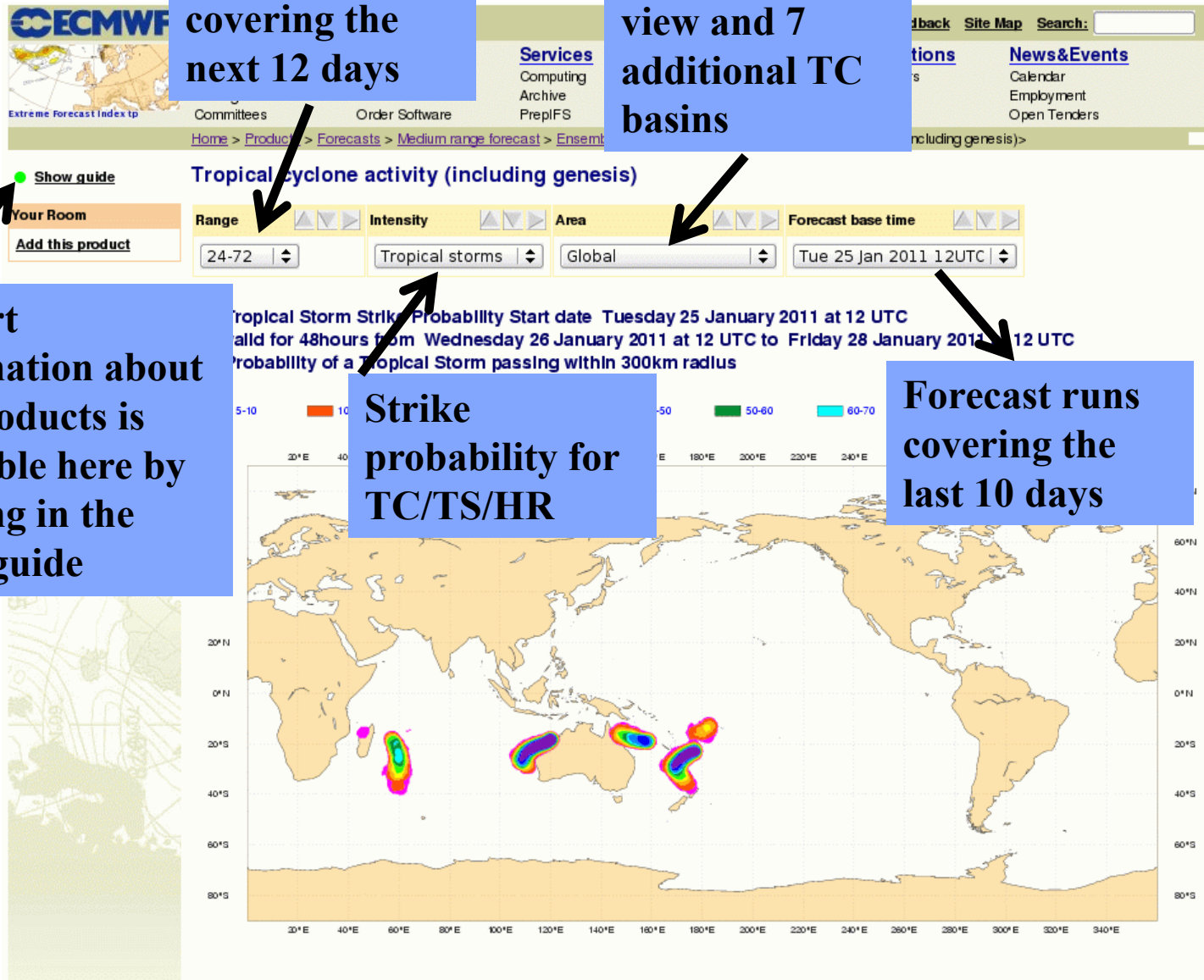
Selected forecast steps covering the next 12 days

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>

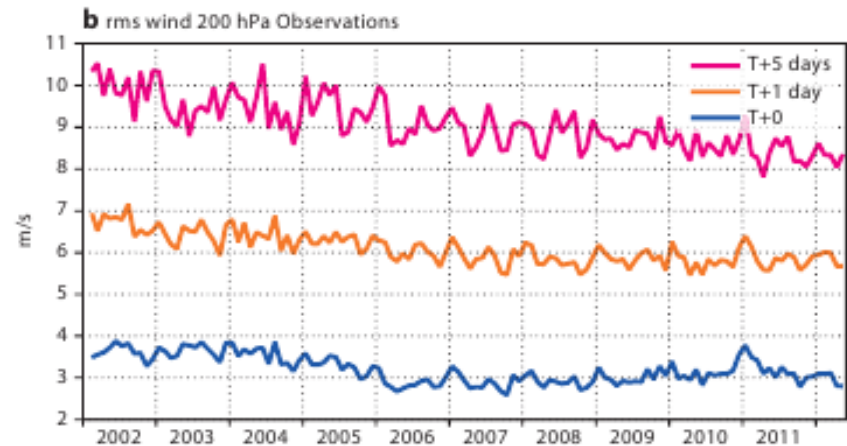
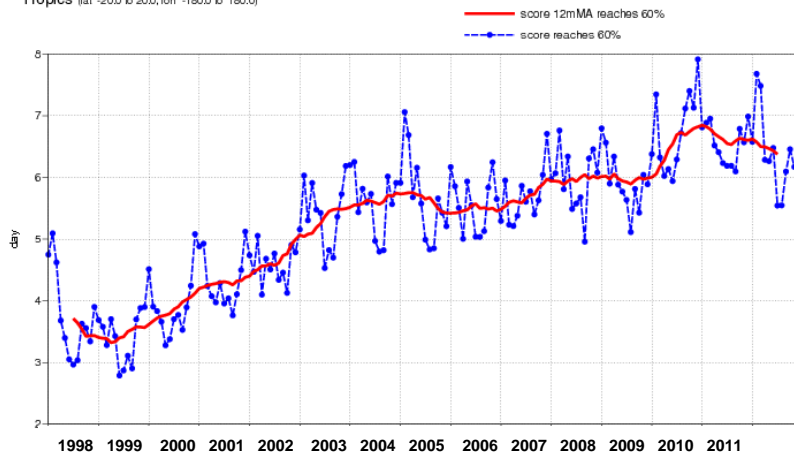
How accurate are the TC forecasts from ECMWF (Part I)?

ECMWF deterministic 00,12UTC forecast skill

850hPa vector wind

Lead time of Anomaly correlation reaching 60%

Tropics (lat -20.0 to 20.0, lon -180.0 to 180.0)



Lead Time of ACC 60% winds 850 hPa

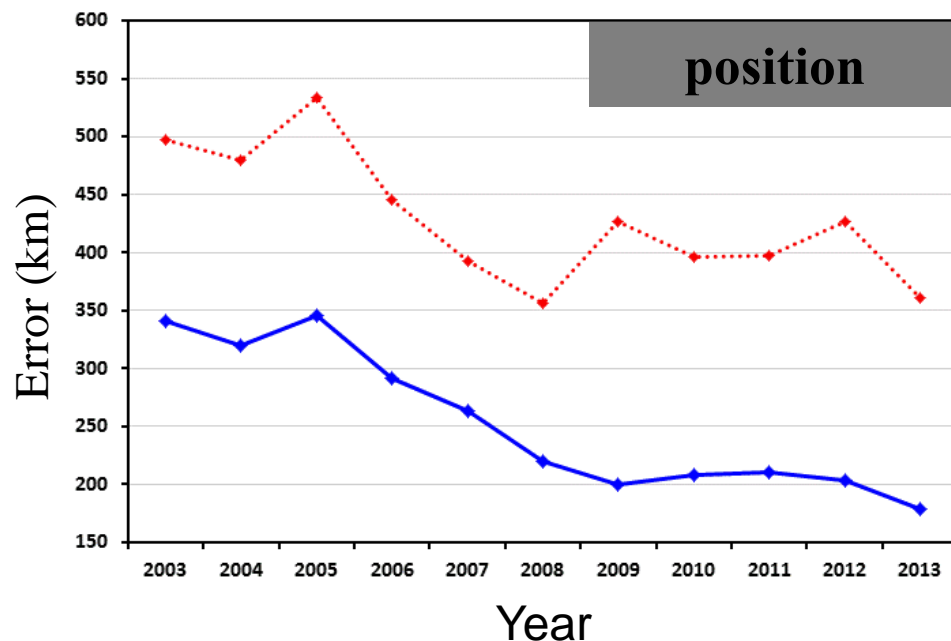
RMS winds 200 hPa (against observations)

A performance gain of ~2.5 days since early 2000 for winds at 850 hPa

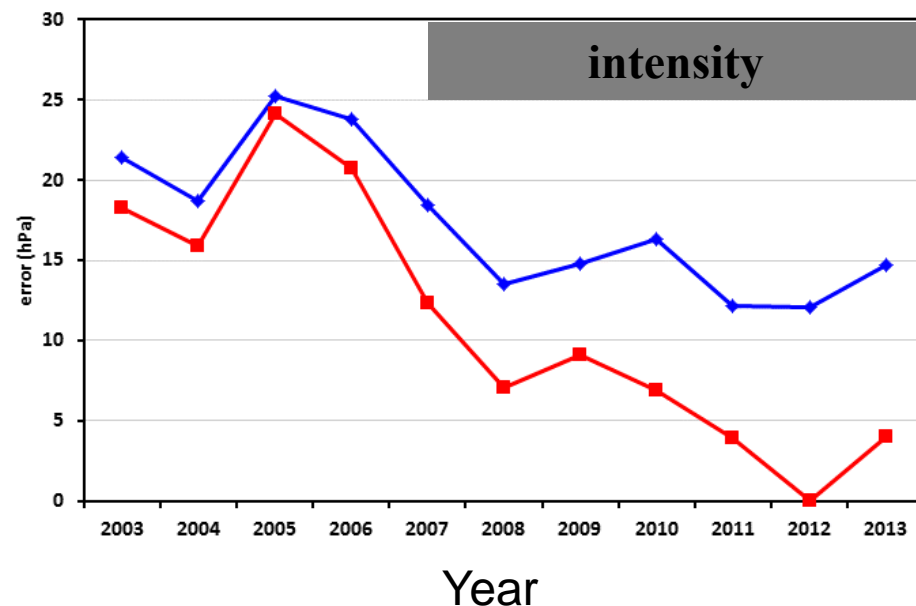
How accurate are the TC Fcs from ECMWF (Part II) ?

HRES verification (12 month means ending on 30 November)

Mean position error D+5 & D+3 Deterministic model
(annual mean ending on 30th June)



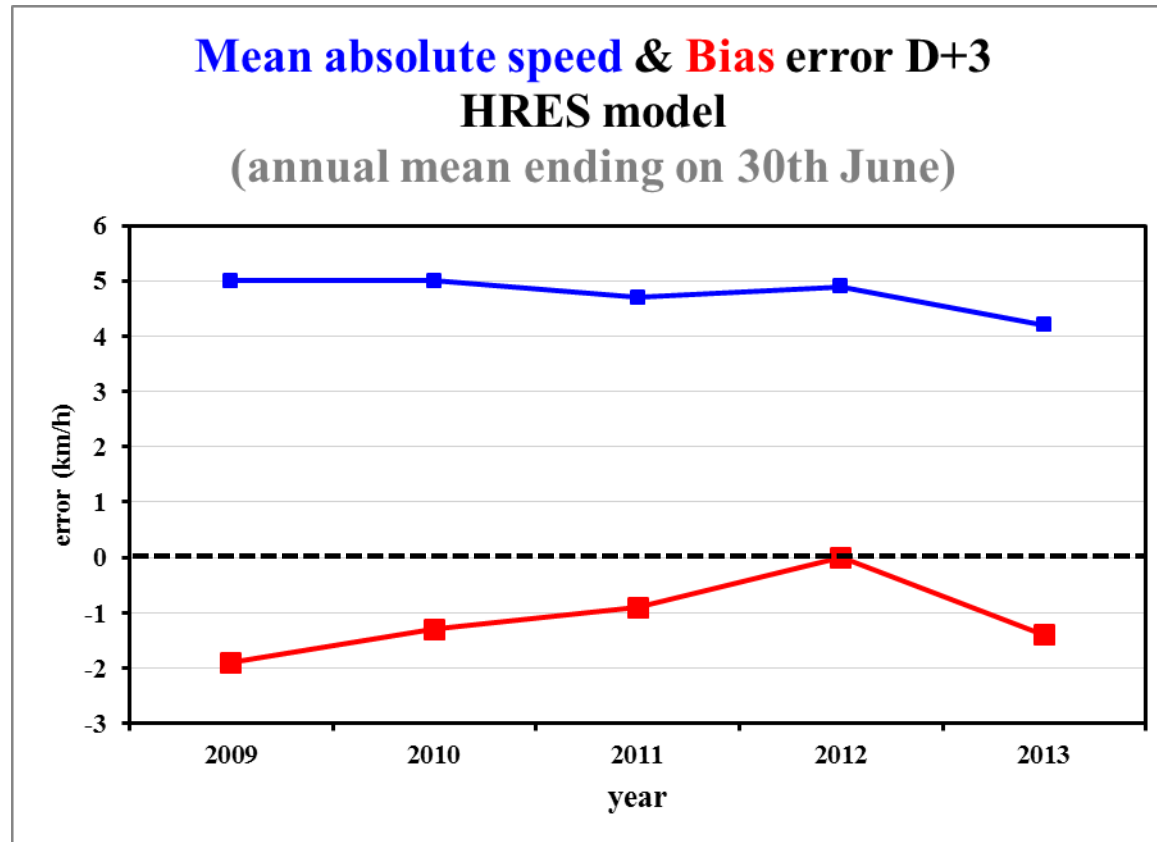
Mean absolute intensity & Bias error D+3
Deterministic model
(annual mean ending on 30th June)



$Error = Forecast - Obs$

Obs from the best track reports

On average TCs move slower in the model (Part III)



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”)

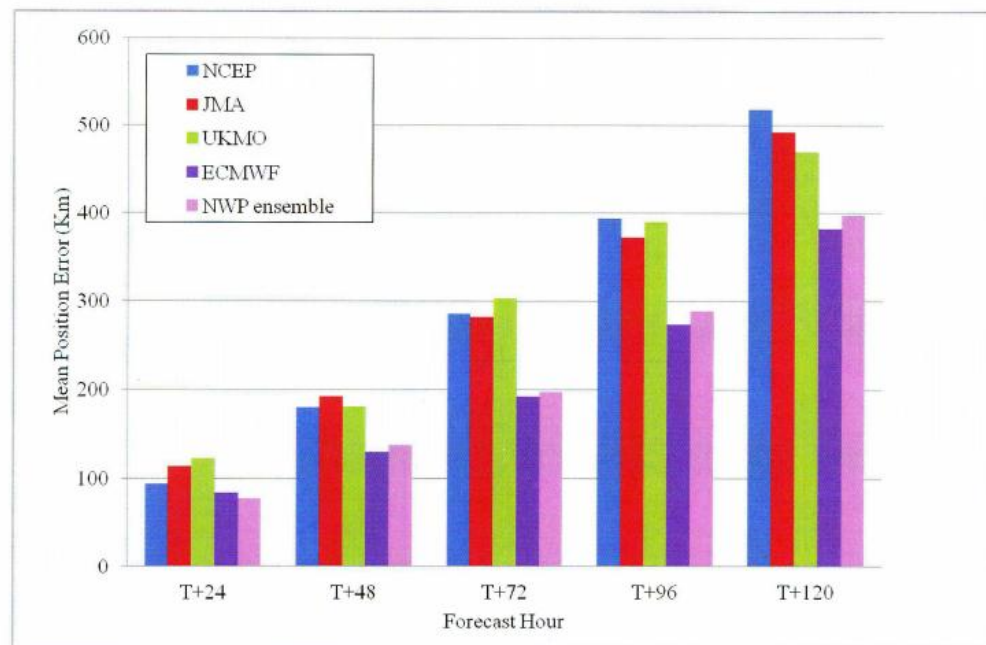
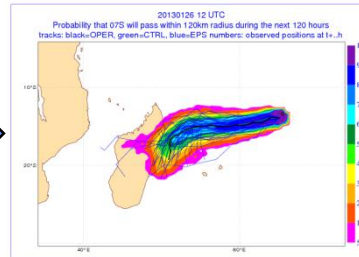


Figure 7. Mean position errors of forecasts from the NWP ensemble and the respective member models for T+24 to T+120 in 2011.

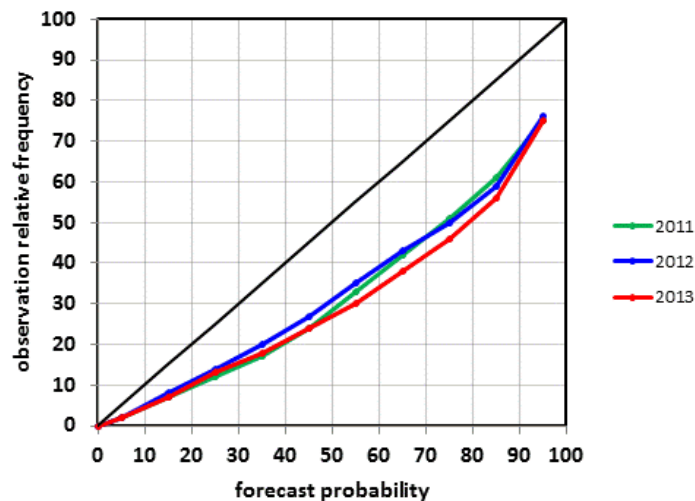
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Verification of the ENS Strike Probability product (Part V)

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



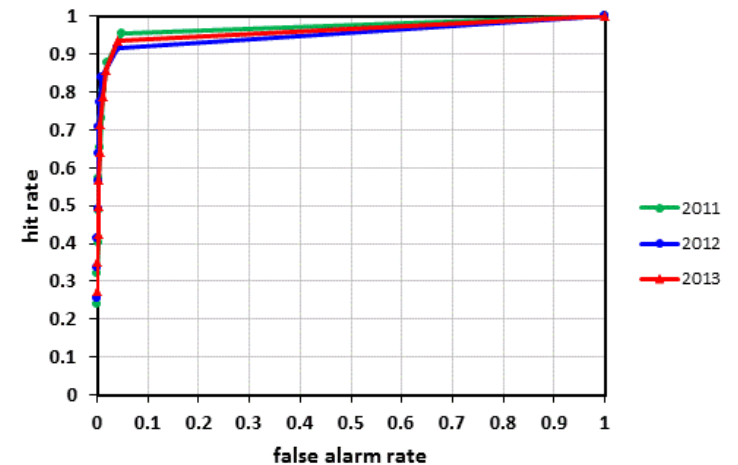
Reliability of TC strike probability
(one year ending on 30th June)



ROC of TC strike probability

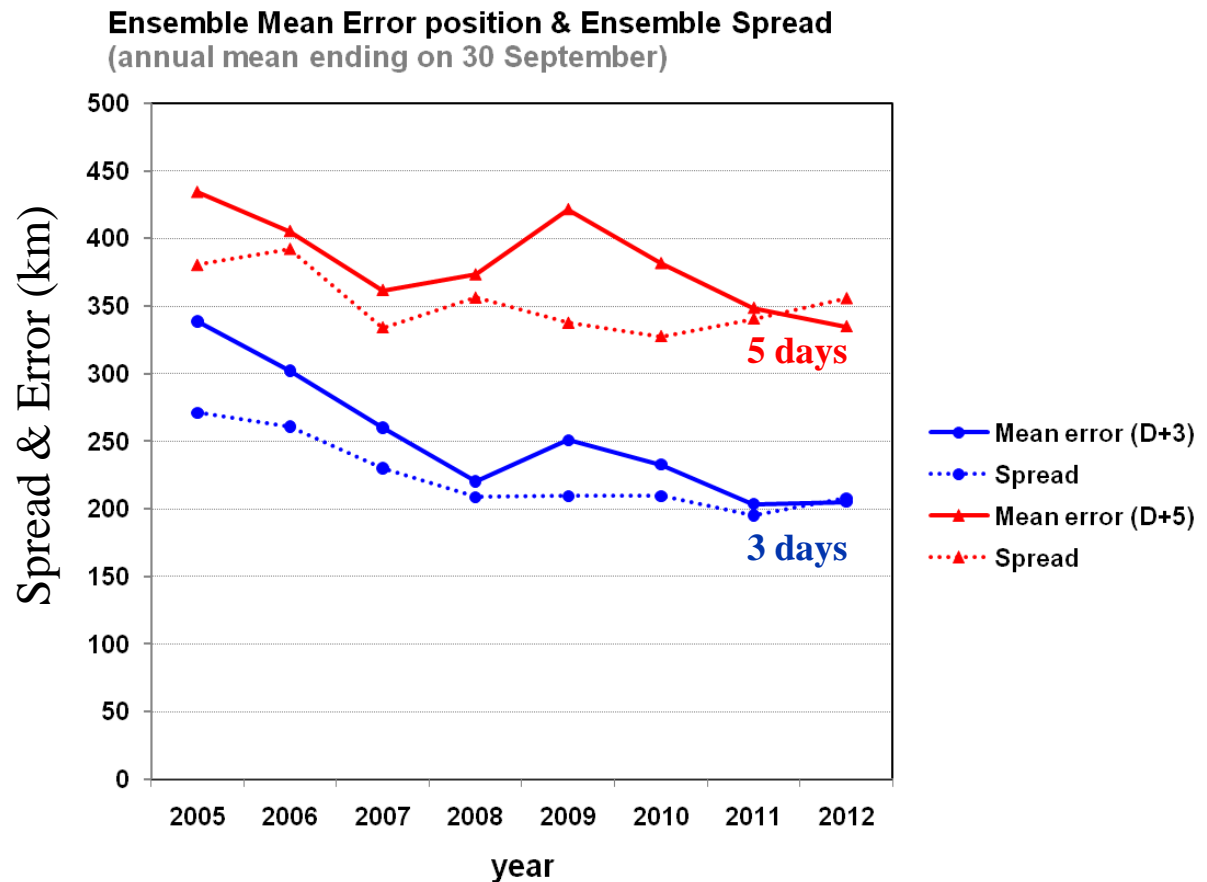
(one year ending on 30th June)

ROCA: 0.933/0.911/0.925



ENS SPREAD & EM ERROR (Part VI)

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



QUESTIONS?