Assimilation of satellite ocean surface winds at ECMWF

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Acknowledgements:
Massimo Bonavita, Patrick Laloyaux, Jean Bidlot, Mohamed Dahoui, Wenming Lin (ICM)

Outline

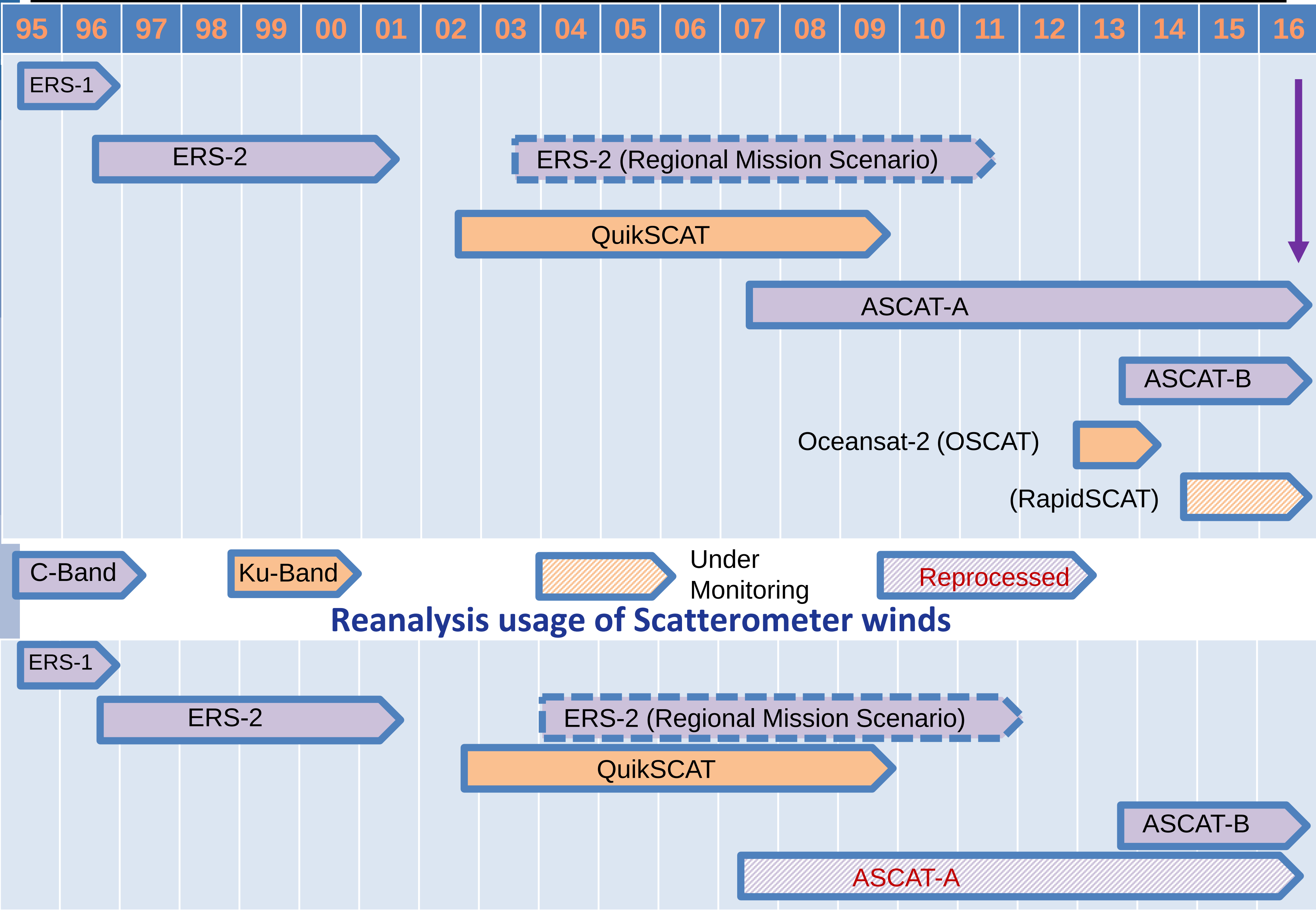
Scatterometer Winds

- ✓ Use of Scatterometer winds at ECMWF
- ✓ Assimilation strategy & QC
- ✓ Impact in the Tropics
- ✓ Research activities

SMOS Winds

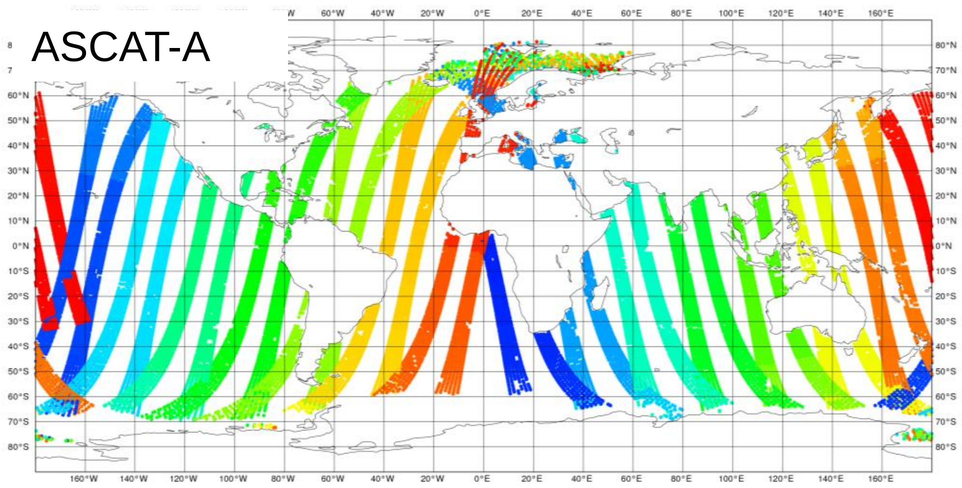
- ✓ Data description
- ✓ Preliminary assessment

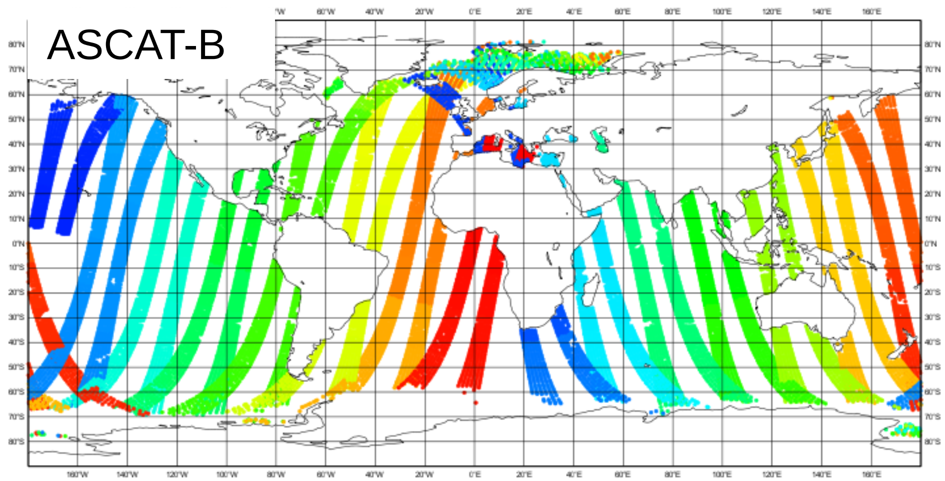
Operational usage of Scatterometer winds



Scatterometer Temporal Coverage

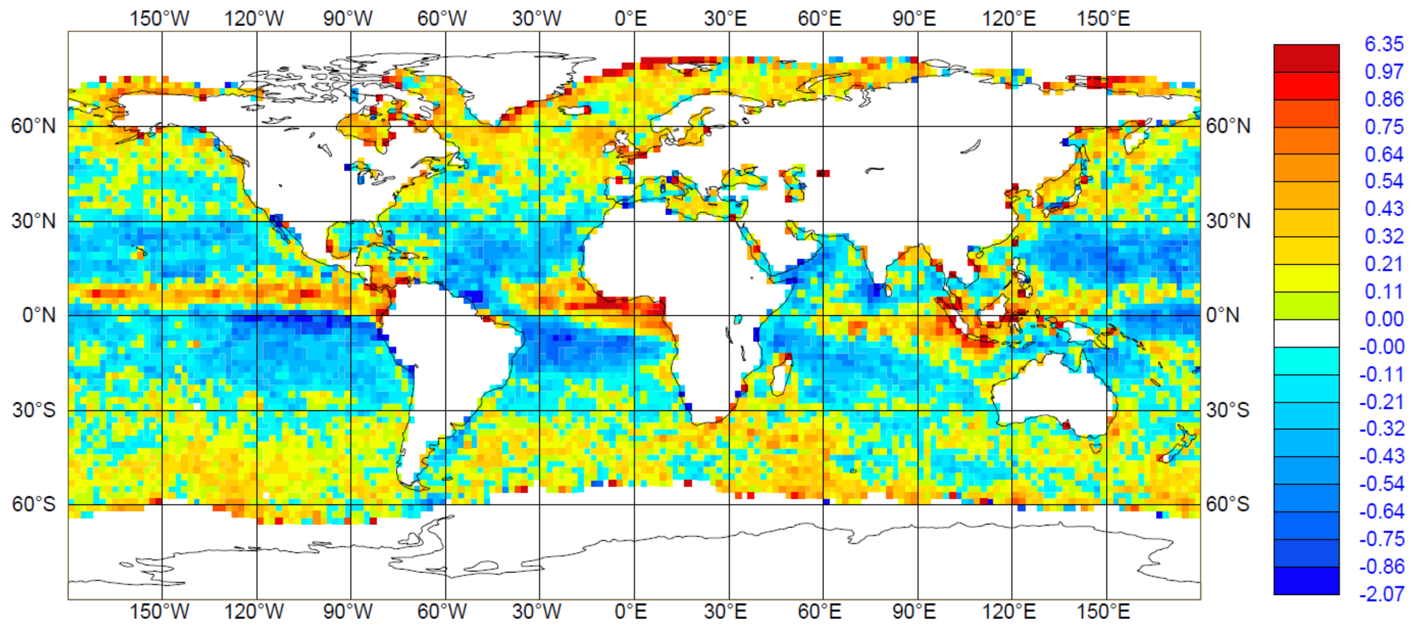
Assimilation Window: 09 – 21 UTC





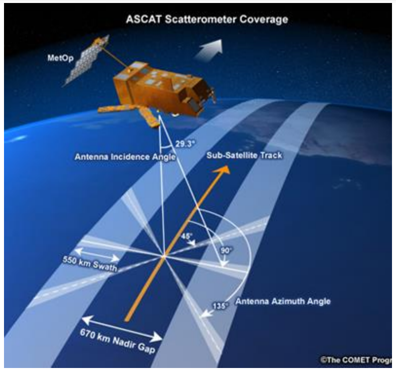
Background Departure

ASCAT-A Wind speed O-B (Oct ‘16)



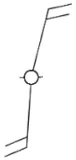
Wind speed bias in the Tropics: also due to Ocean Current?

ASCAT-A & ASCAT-B assimilation strategy



ASCAT (25km) from EUMETSAT

- ✓ Wind inversion is performed in-house using the CMOD5.N (10m equivalent neutral winds)



- ✓ 2 wind solutions are provided
- ✓ The best solution is dynamically chosen during the minimization

- ✓ Quality control, thinning:
  - Screening: sea ice check based on SST and sea ice data
  - Threshold: 35 m/s
  - Thinning: 1 out of 4 → 100 km
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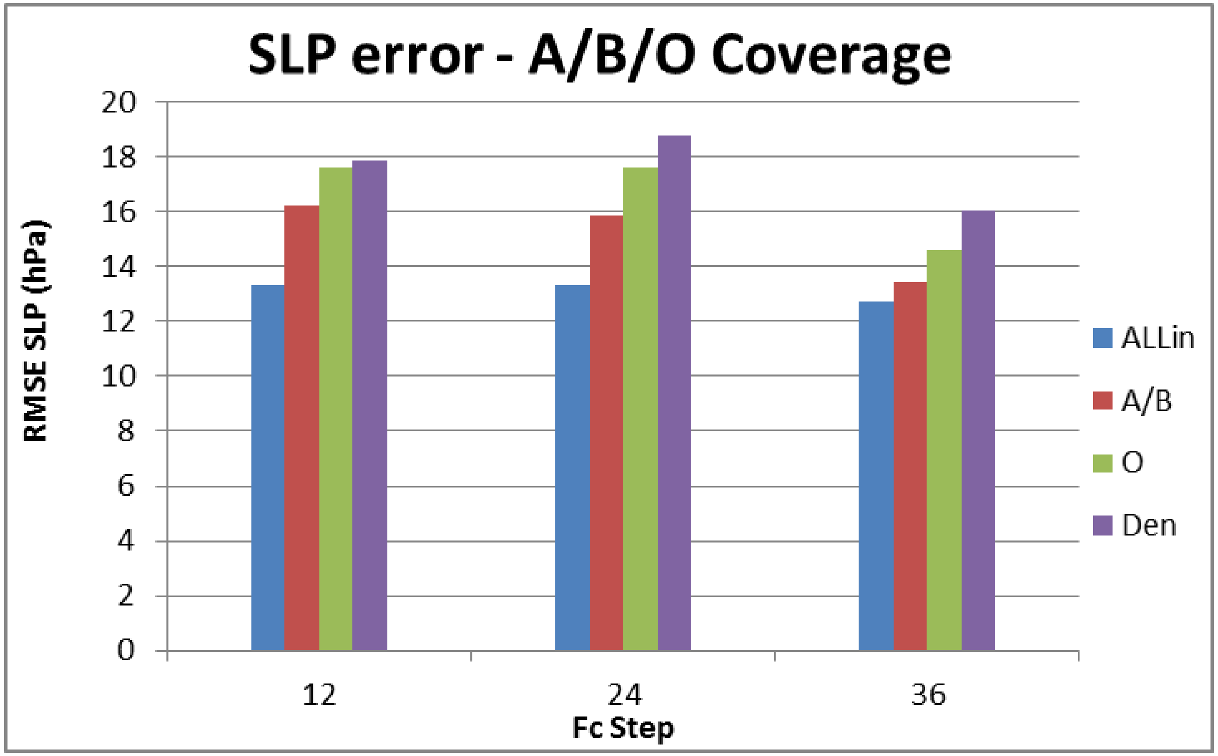
Impact on Tropical Cyclone FC

- ✓ For each storm the min SLP have been detected from the ECMWF model fields
- ✓ SLP have been compared to observation values (from NHC and JMA)

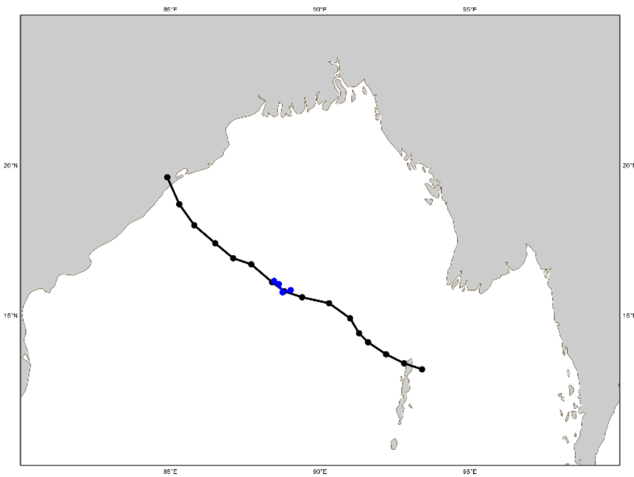


Statistics based only on cases where ASCAT-A, ASCAT-B and OSCAT passes were available Dec 2012/ Feb 2013

G. De Chiara, S. English, P. Janssen and J.-R. Bidlot, “ASCAT ocean surface wind assessment” ECMWF Technical Memorandum 776, 2016.

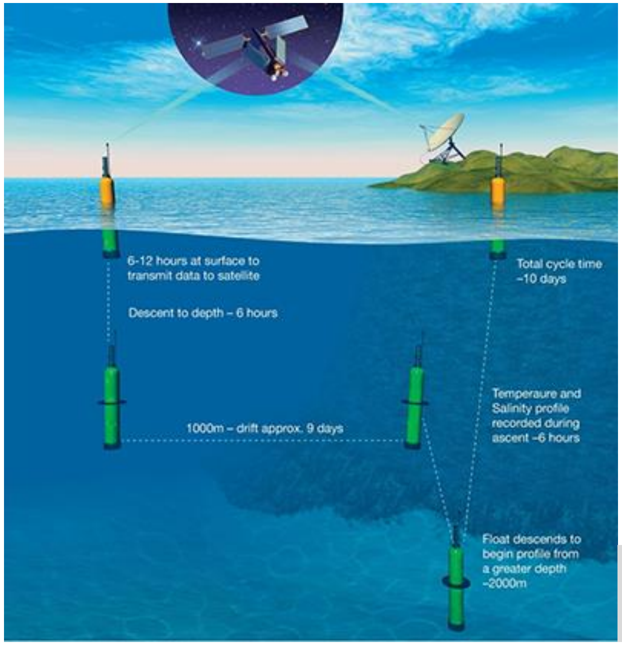
Impact on the coupled system

Impact of scatterometer data in the CERA and UNCPL systems

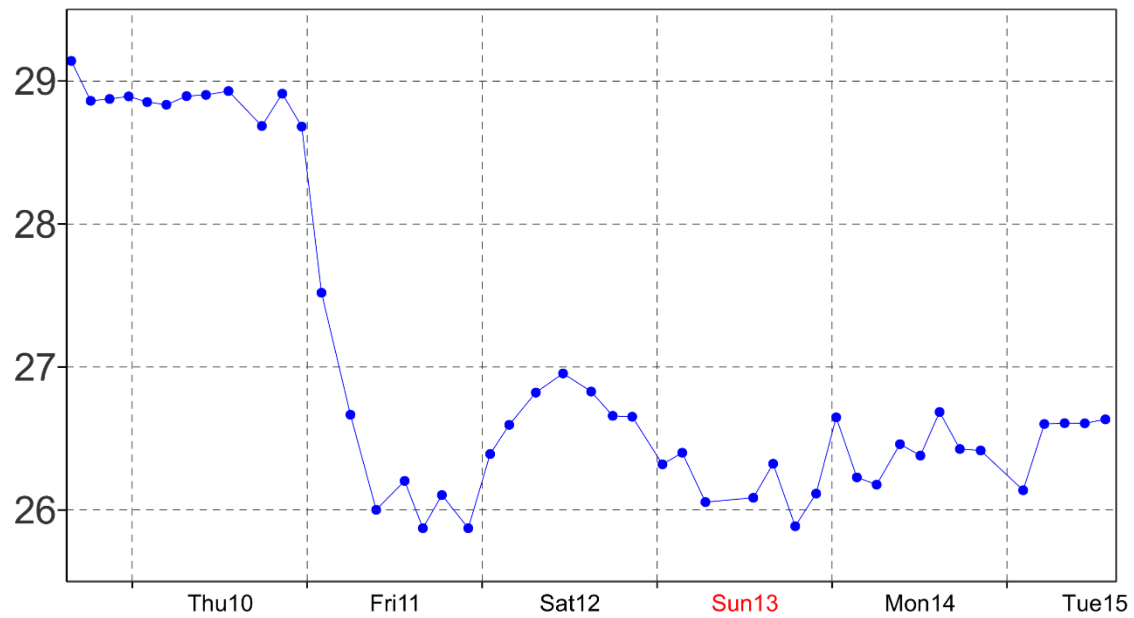


Focus on a specific weather event:

- TC Phailin
- Bay of Bengal
- formed on the 4th October 2013
- Argo probe with high-frequency measurements



Temperature measurements at 40-meter depth

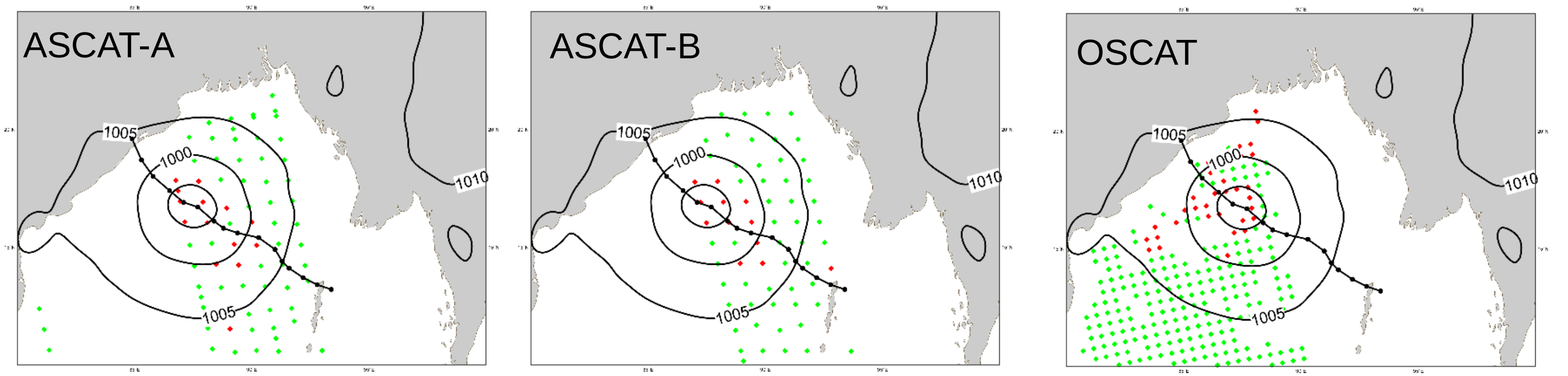


Impact of scatterometer surface wind data in the ECMWF coupled assimilation system
P. Laloyaux, J-N Thépaut and D. Dee. MWR, 2016

Impact on the coupled system

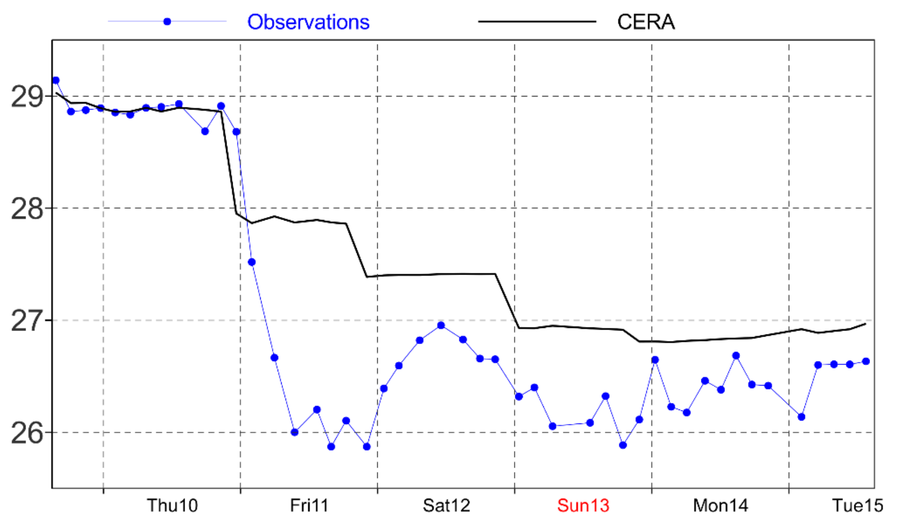
TC Phailin

Wind measurements from scatterometers (ascending pass, 11 October 2013)

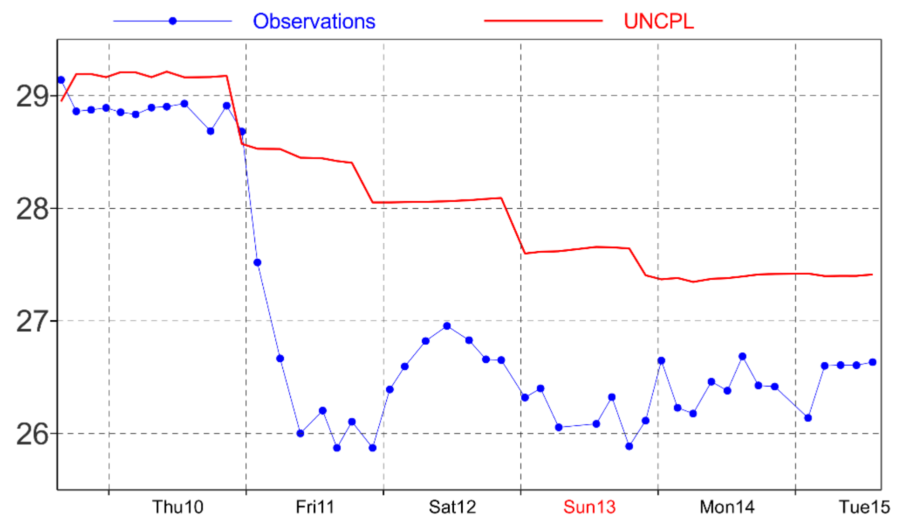


Ocean temperature analysis at 40-meter depth (scatterometer data are assimilated)

CERA



UNCPL

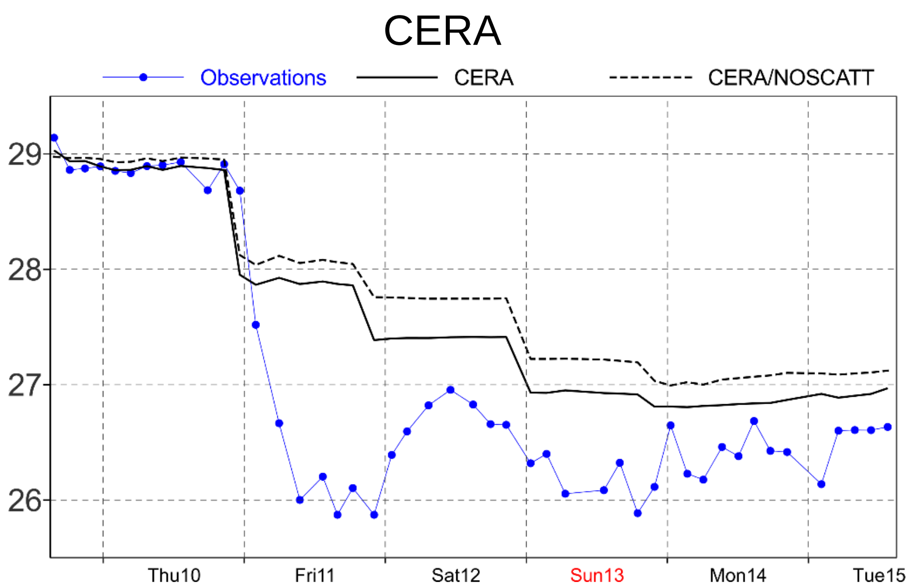


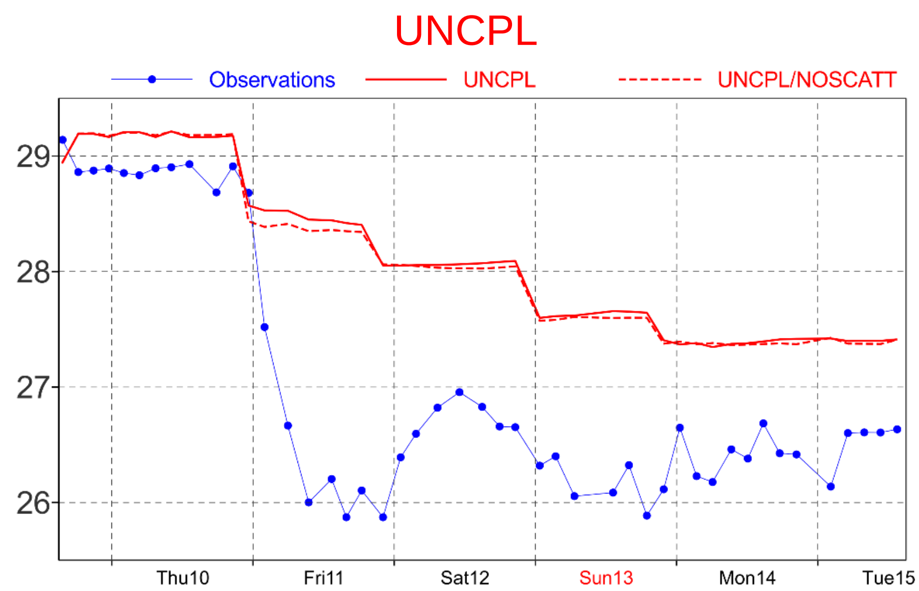
Coupled analysis is closer to the observations with a stronger cold wake

Impact on the coupled system

TC Phailin

Ocean temperature analysis at 40-meter depth (no scatterometer data in dashed)





Crucial role of scatterometer data to estimate the ocean state in coupled assimilation
Atmospheric observations have the potential to improve ocean analysis
Fit to observations is not perfect (vertical resolution, nudge to a daily SST product)

Outline

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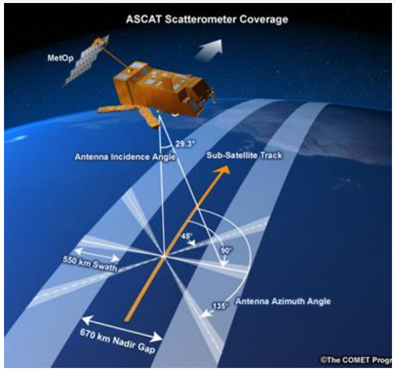
ASCAT-A & ASCAT-B assimilation strategy



ASCAT (25km) from EUMETSAT

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- ✓ 2 wind solutions are provided
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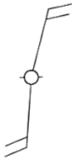

- ✓ Quality control, thinning:
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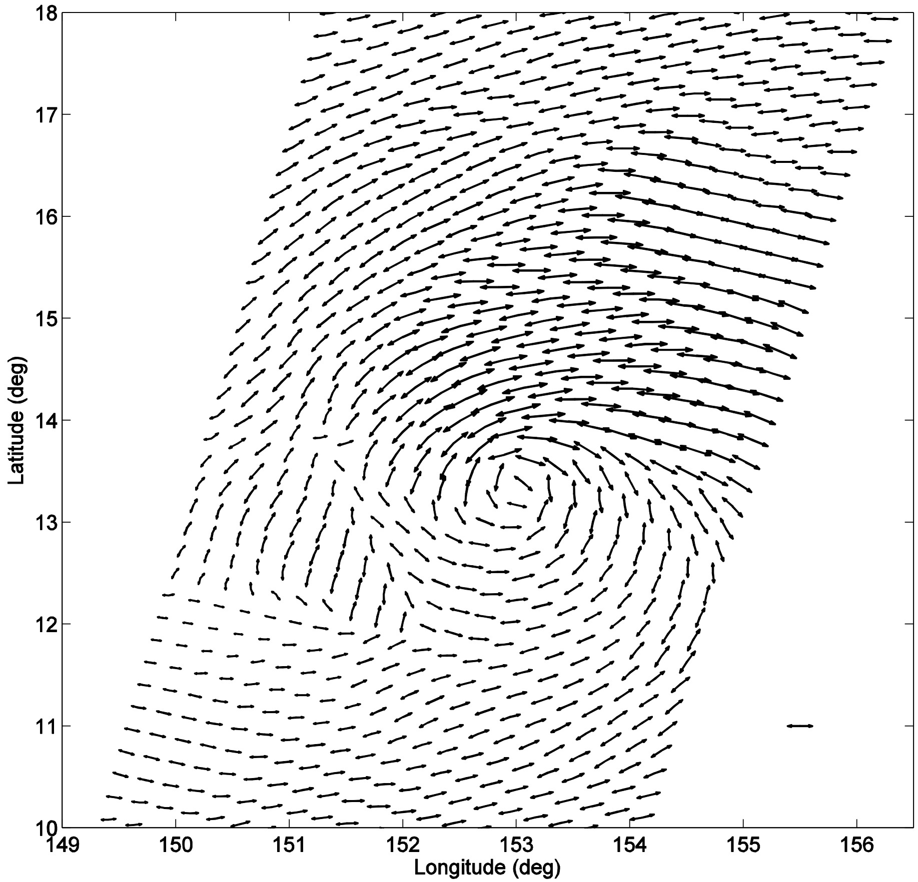
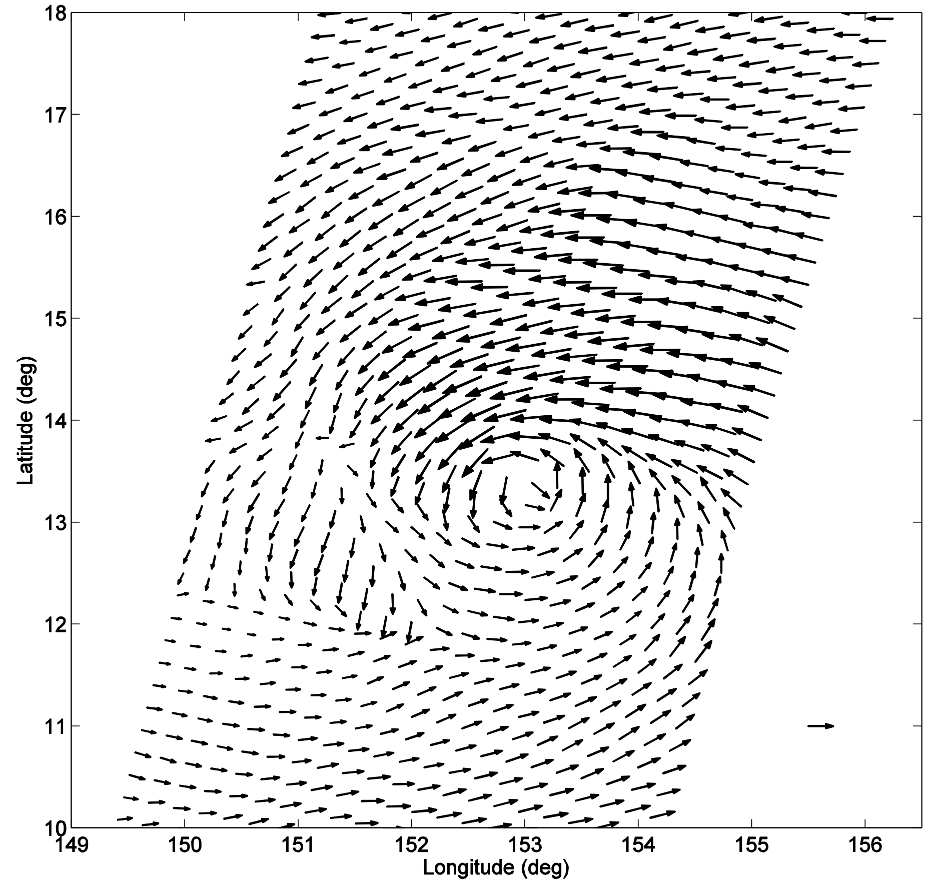
Ambiguity removal

Wind Direction Ambiguity removal:

- ✓ We provide 2 solutions (almost same wind speed, opposite directions)
- ✓ At each minimization the solutions are compared to the background



Ambiguities provided

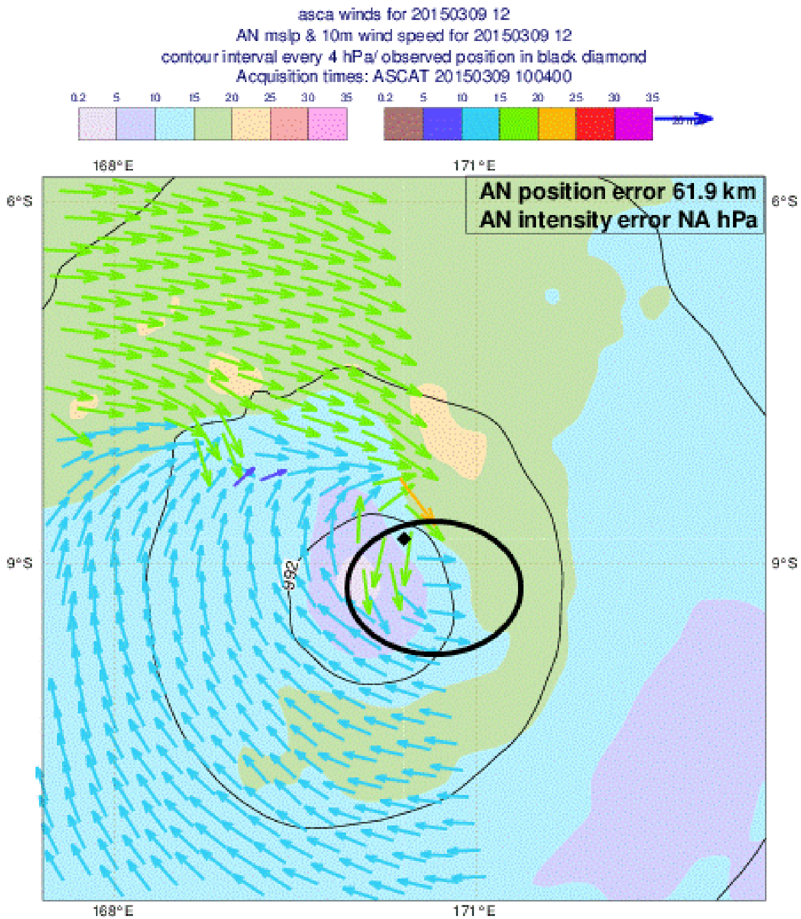


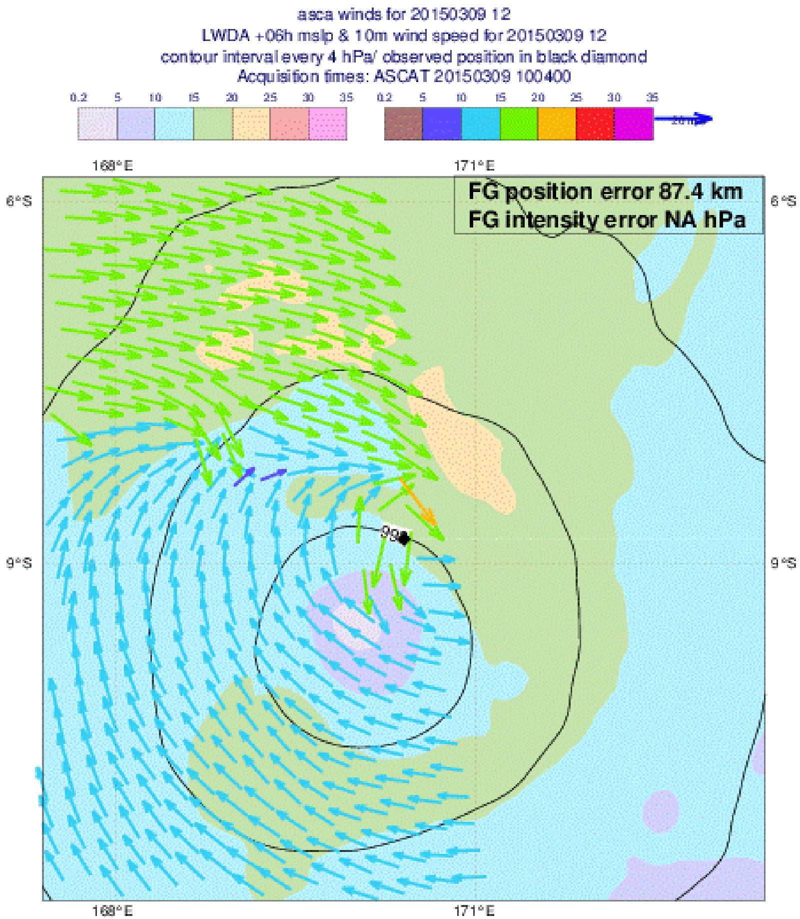
Ambiguities selected

[by Wenming Lin]

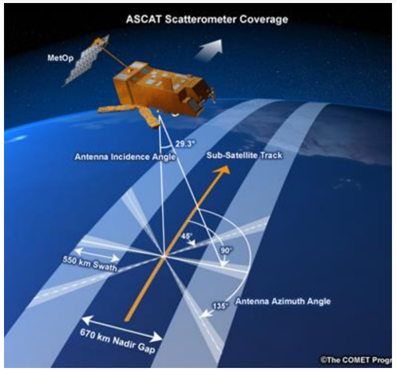
Ambiguity removal

TC Pam – 9 March 2015 12 UTC





ASCAT-A & ASCAT-B assimilation strategy



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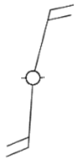

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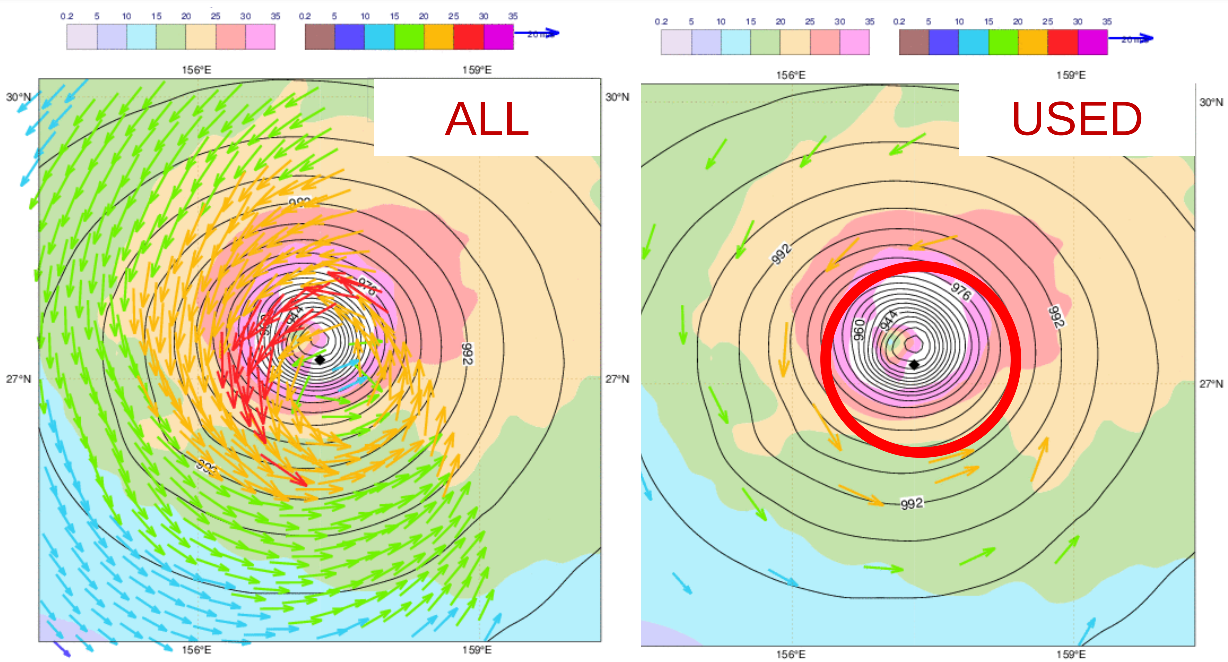
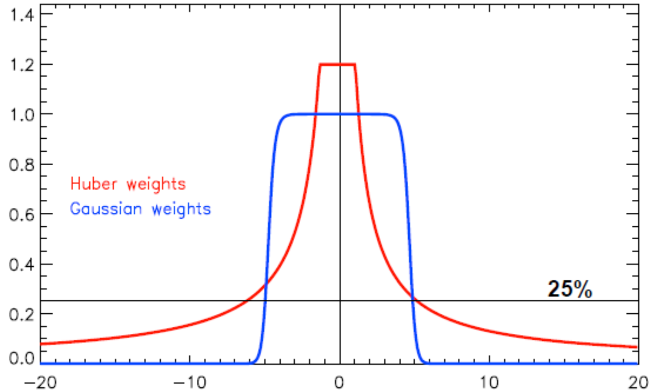
Thinning and QC issues



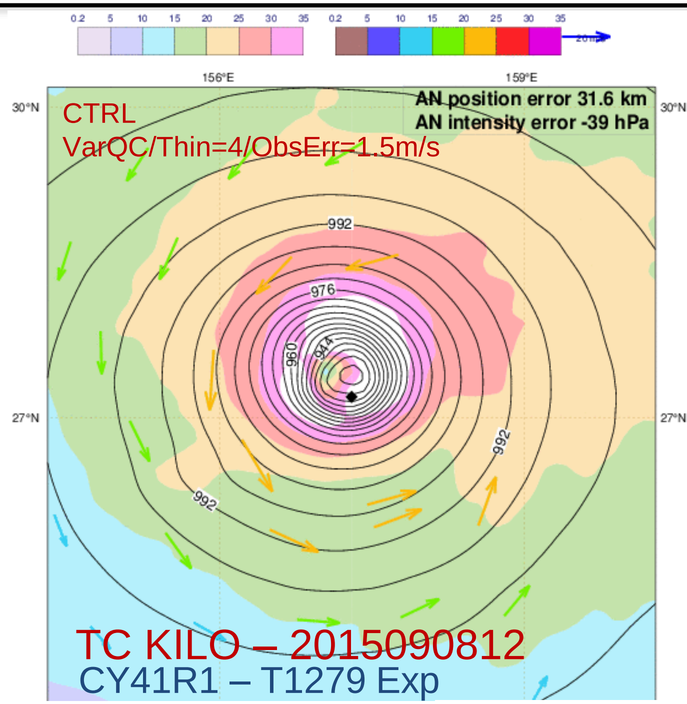
Comparing Observation weights:

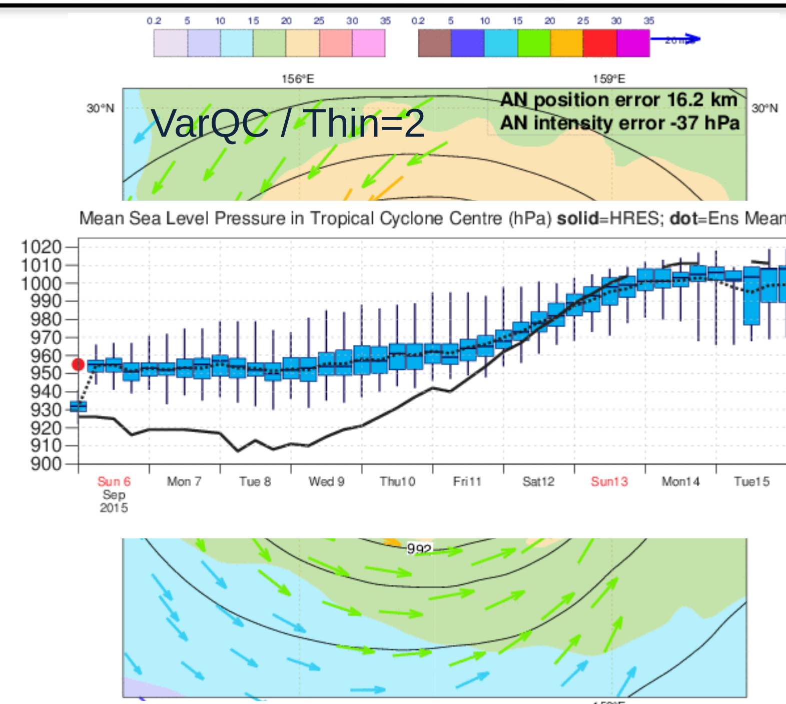
Gaussian + flat (VarQC): more weight in the middle of the distribution

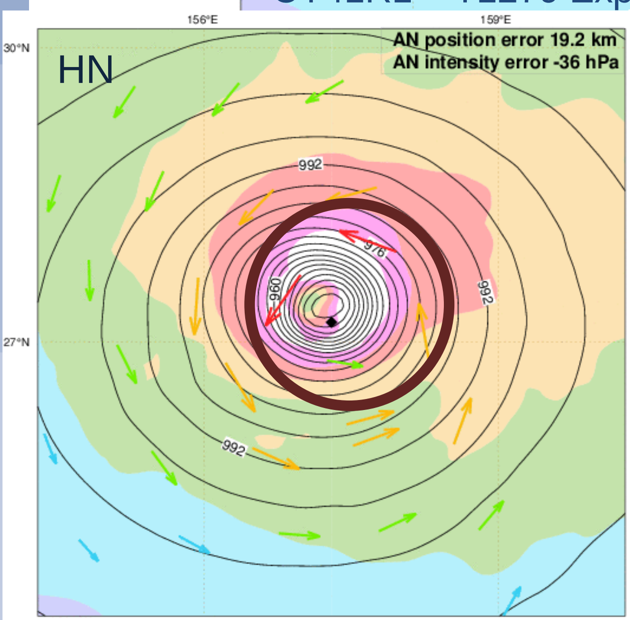
Huber Norm: more weight on the edges (to data with large departure)

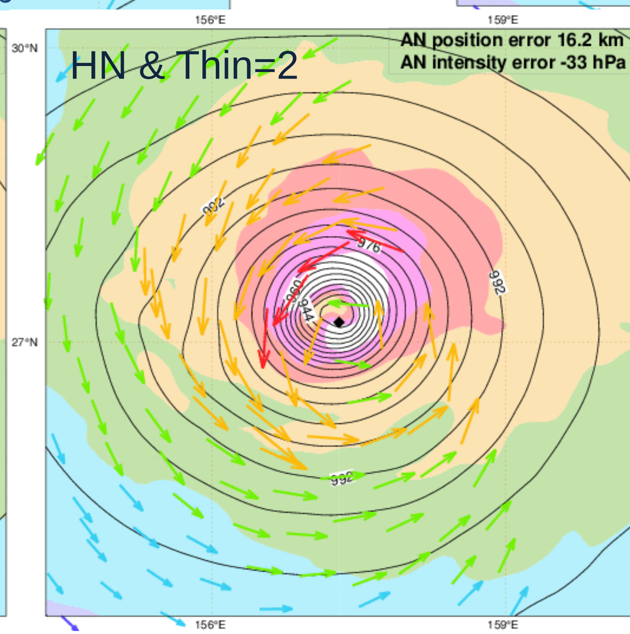


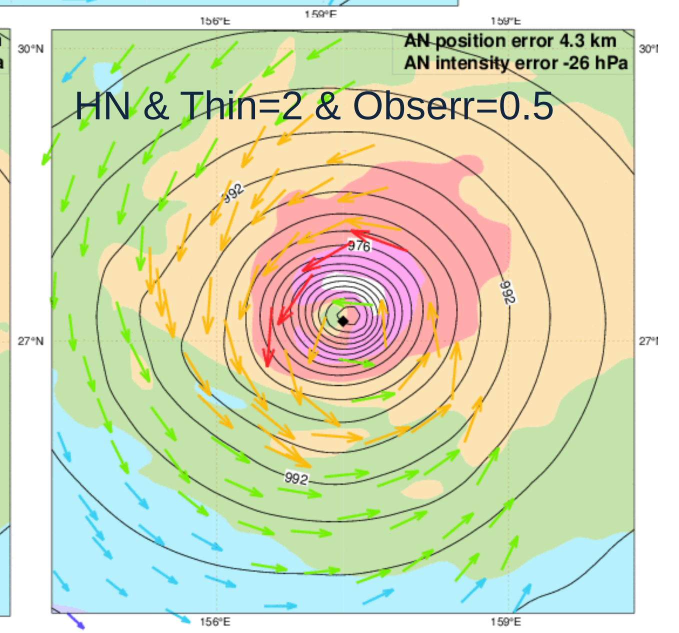
TC QC issues


AN position error 31.6 km
AN intensity error -39 hPa
CTRL
VarQC/Thin=4/ObsErr=1.5m/s
TC KILO – 2015090812
CY41R1 – T1279 Exp
156°E
159°E
30°N
27°N
992
976
960
944


AN position error 16.2 km
AN intensity error -37 hPa
VarQC / Thin=2
Mean Sea Level Pressure in Tropical Cyclone Centre (hPa) solid=HRES; dot=Ens Mean
1020
1010
1000
990
980
970
960
950
940
930
920
910
900
Sun 6 Sep 2015
Mon 7
Tue 8
Wed 9
Thu10
Fri11
Sat12
Sun13
Mon14
Tue15
992


AN position error 19.2 km
AN intensity error -36 hPa
HN
156°E
159°E
30°N
27°N
992
976
960

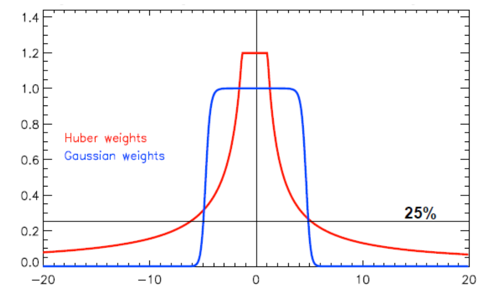

AN position error 16.2 km
AN intensity error -33 hPa
HN & Thin=2
156°E
159°E
30°N
27°N
992
976
960
944


AN position error 4.3 km
AN intensity error -26 hPa
HN & Thin=2 & Obserr=0.5
156°E
159°E
30°N
27°N
992
976

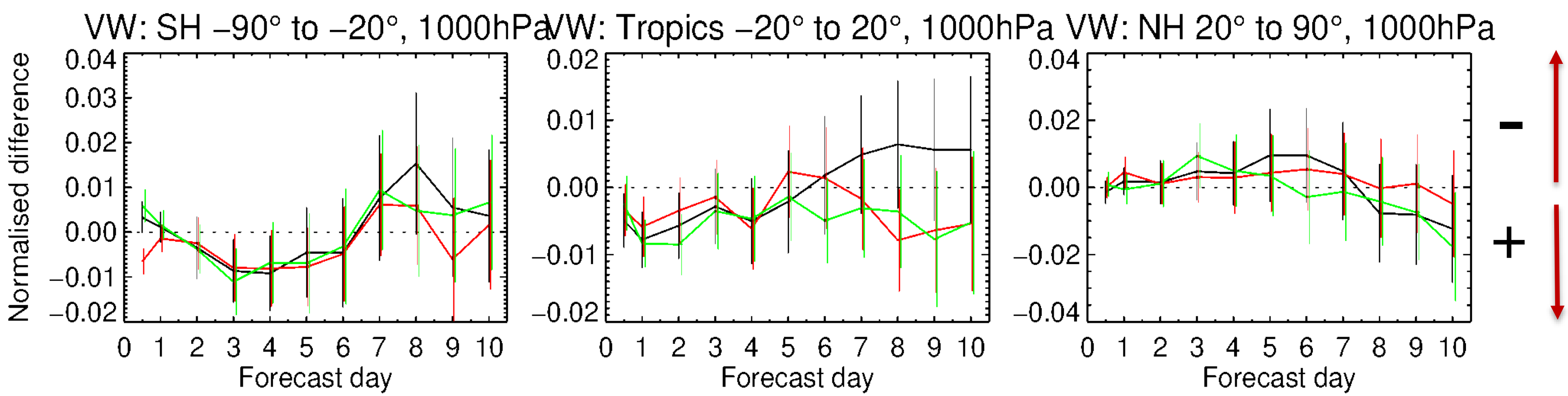
Huber Norm

Cy41R1 TL639 Sep-Nov 2013

- CTRL: VarQC
- HN Left/Right = 1
- HN Left/Right = 1 & No Upper Wind Speed threshold
- HN Left/Right = 3



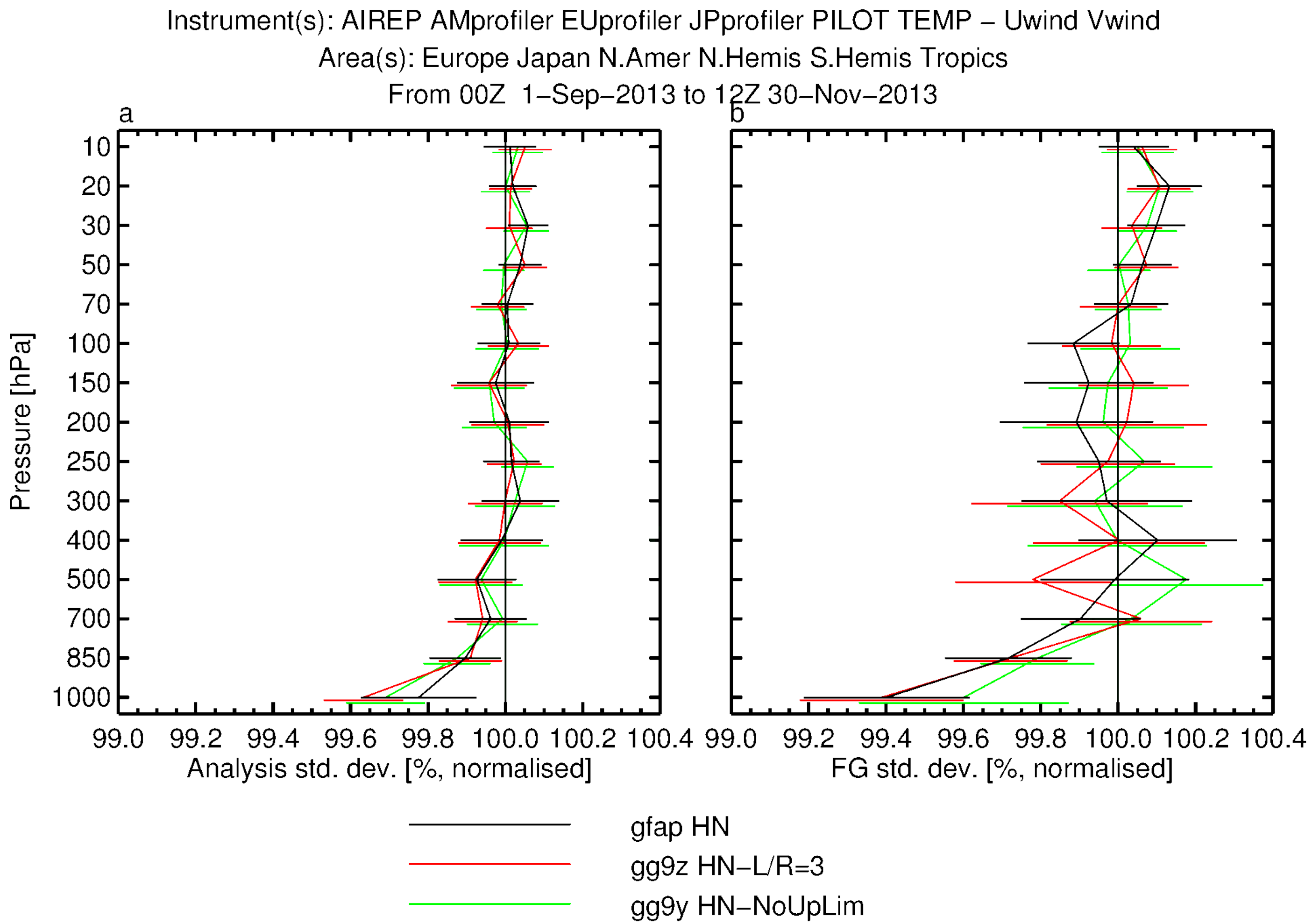
VW RMS Forecast Error Differences



HN L/R=1 - CTRL
HN L/R=3 - CTRL
HN NoUpLim - CTRL

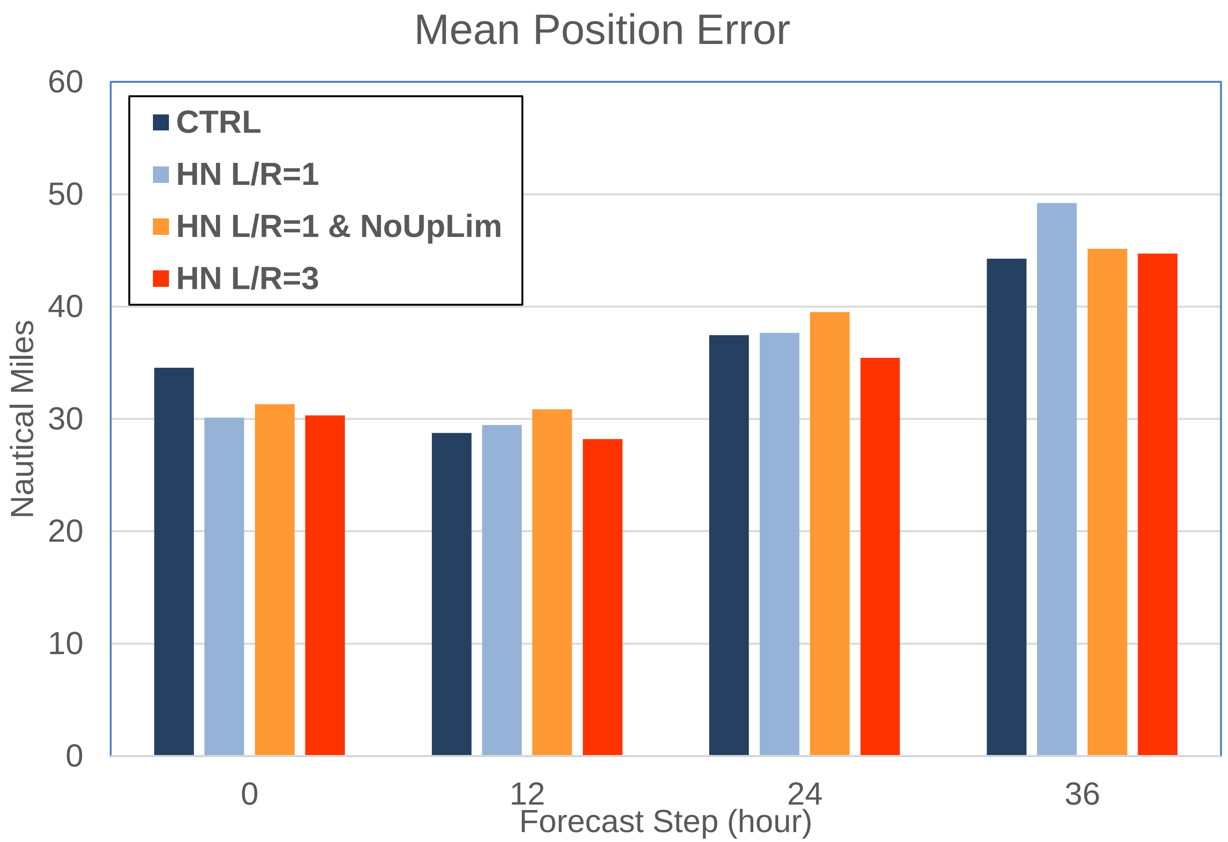
Huber Norm

Fit to observations - U&V statistics



Huber Norm

Impact on TC Analysis and Forecast



N.Obs: ~	*150*	*130*	*110*	*90*

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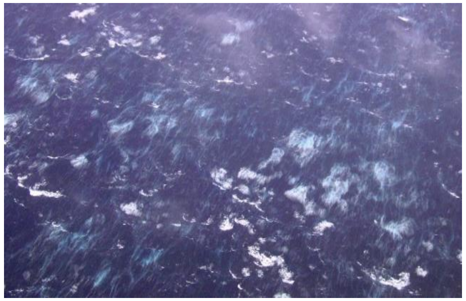
SMOS wind data

- Soil Moisture and Ocean Salinity (SMOS) mission provides multi-angular L-band (1.4 GHz) brightness temperature (resolution range 30/80 km)

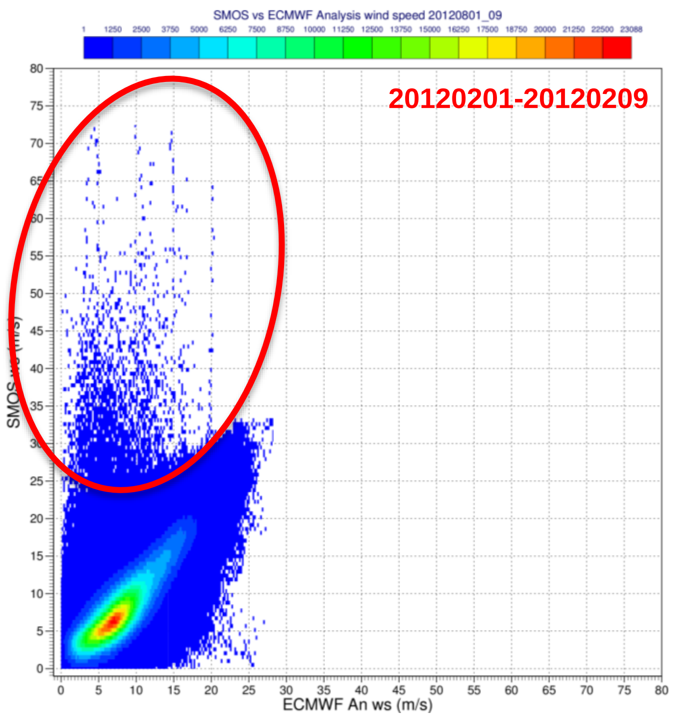


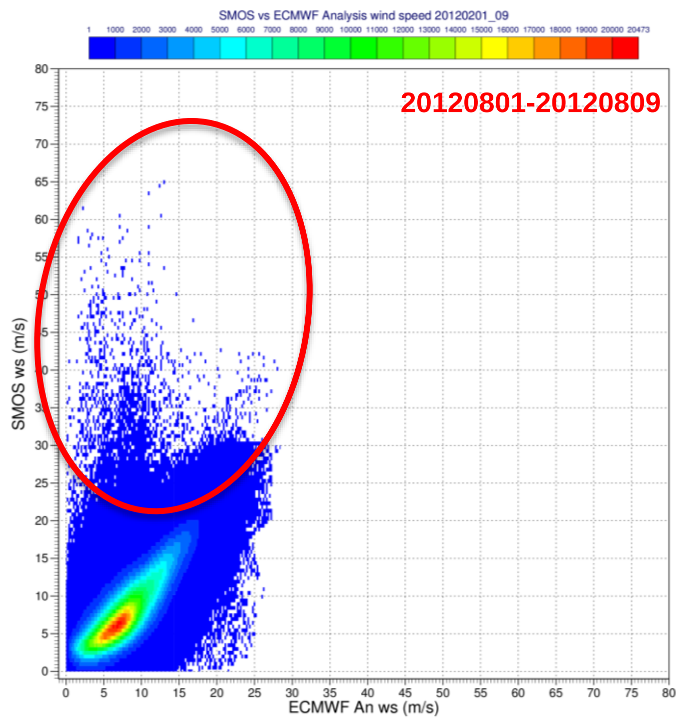
- L-band is less affected by rain, spray and atmospheric effects than higher mw frequencies (C-band, Ku-band)
- There is no saturation at high wind speed like for radars
- Sea foam, generated by breaking waves which mainly depends on surface wind strength and sea state development, increases the microwave ocean emissivity
- In the framework of the SMOS+STORM project, Ifremer developed a SMOS wind speed GMF based on Hwind products in IGOR hurricane

***Reul, N., J. Tenerelli, B. Chapron, D. Vandemark, Y. Quilfen, and Y. Kerr (2012), SMOS satellite L-band radiometer: A new capability for ocean surface remote sensing in hurricanes, J. Geophys. Res., 117, C02006, doi:10.1029/2011JC007474.*

SMOS wind data

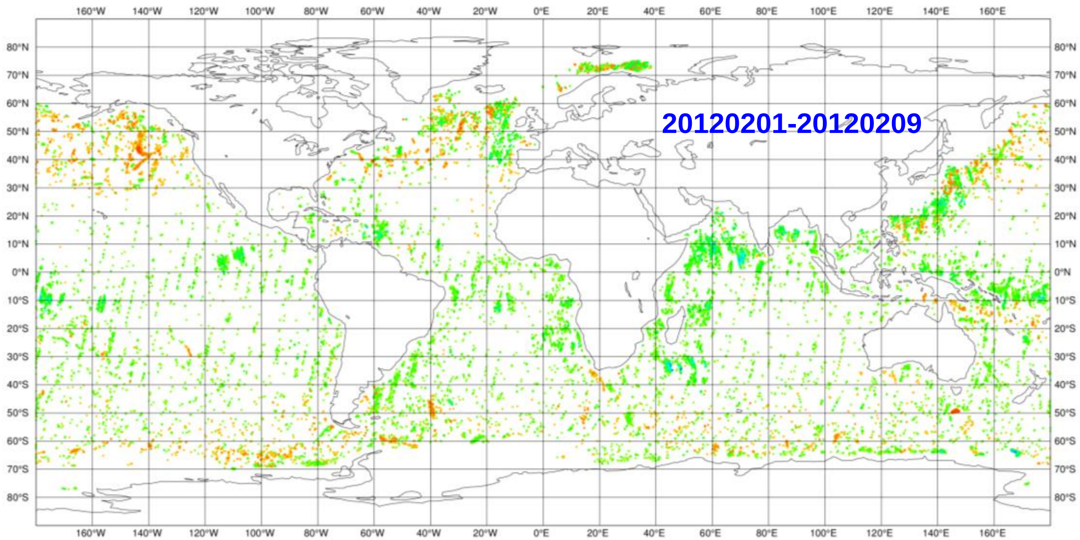
- ✓ Two sets of nine days were filtered (QC) and processed: 1-9 February 2012 & 1-9 August 2012
- ✓ An ECMWF tool developed to process ODB data was adapted and used to compute the analysis departure



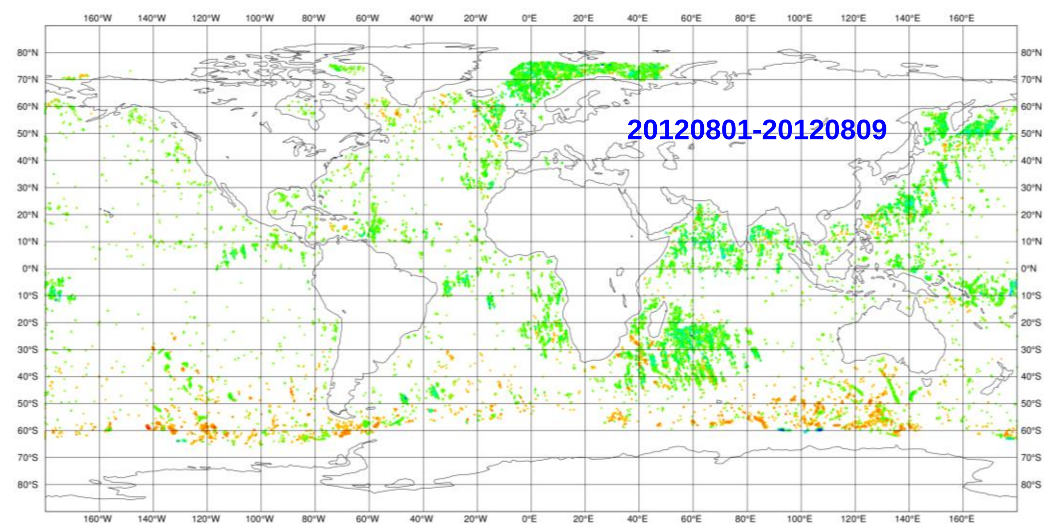


SMOS wind data

SMOS vs ECMWF AN wind speed



an departure > 10 m/s



Further investigations needed

Summary

- ✓ Scatterometer winds are widely used in NWP and have shown to have positive impact on analysis and the forecast:
  - Beneficial impact on atmospheric, wave and ocean models
  - On global scale and extreme events
  - Important for TC analysis and forecast
- ✓ Work to improve the QC and wind sampling, in particular for TC, is ongoing
- ✓ It is important to better investigate the sensitivity of the system to different resolutions
- ✓ Assimilation of as many good datasets as possible

- ✓ Overall SMOS winds look promising
- ✓ More investigations needed to better characterize the data

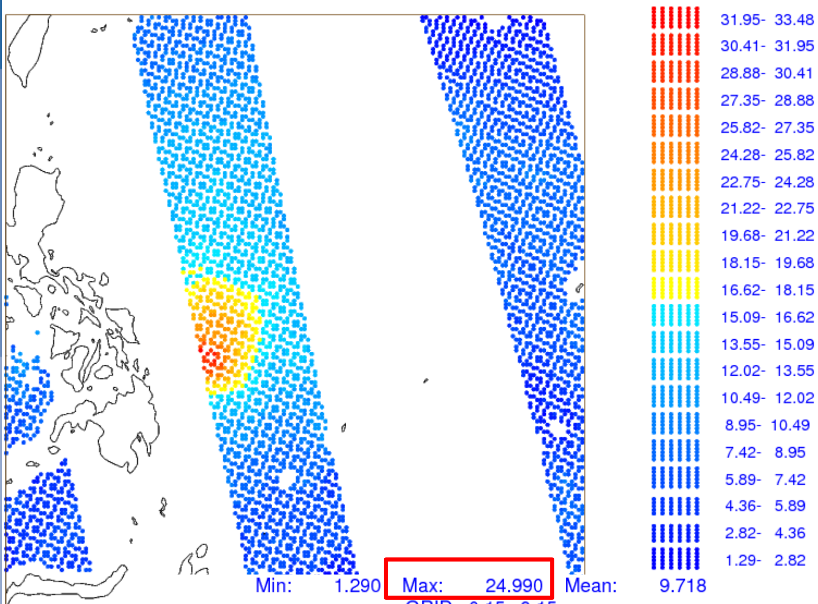
Typhoon Haiyan

10m ASCAT-A wind speed

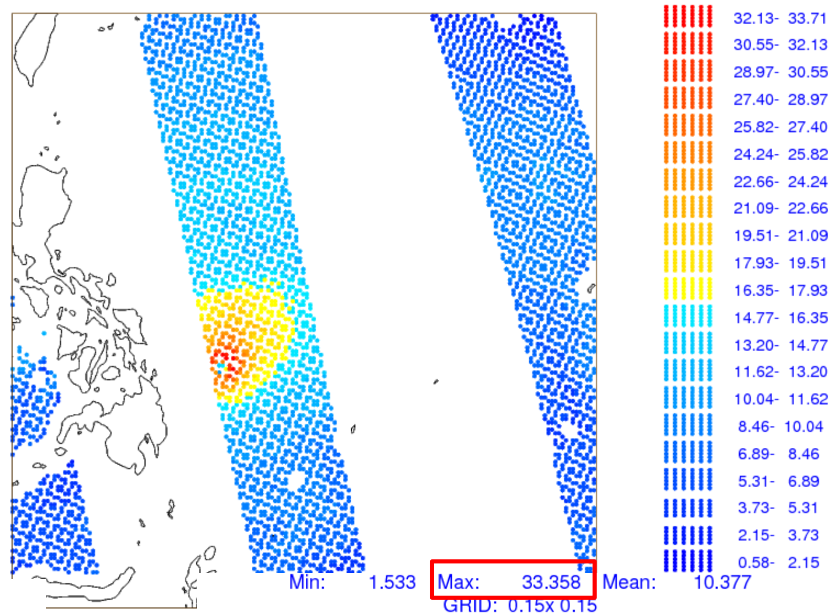
All observations

10m FG wind speed

Min: 1.290 Max: 33.480 Mean: 9.296
GRID: 0.15x 0.15

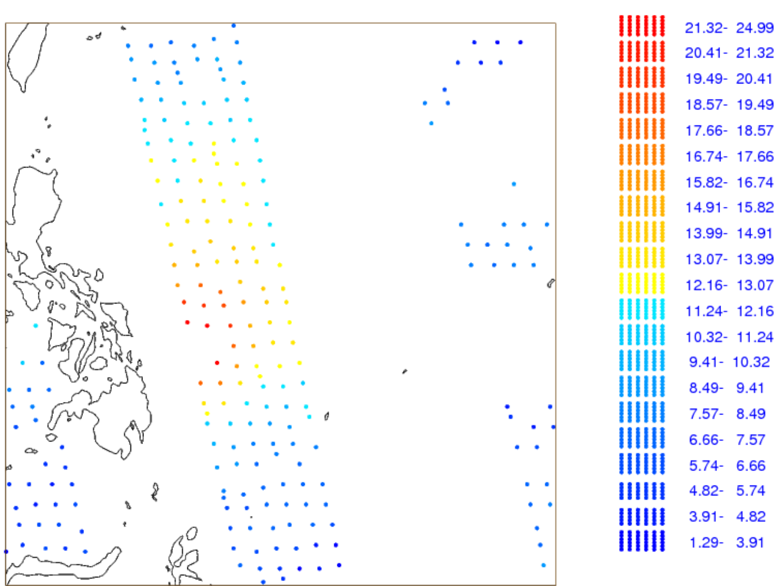


Min: 0.575 Max: 33.708 Mean: 9.929
GRID: 0.15x 0.15

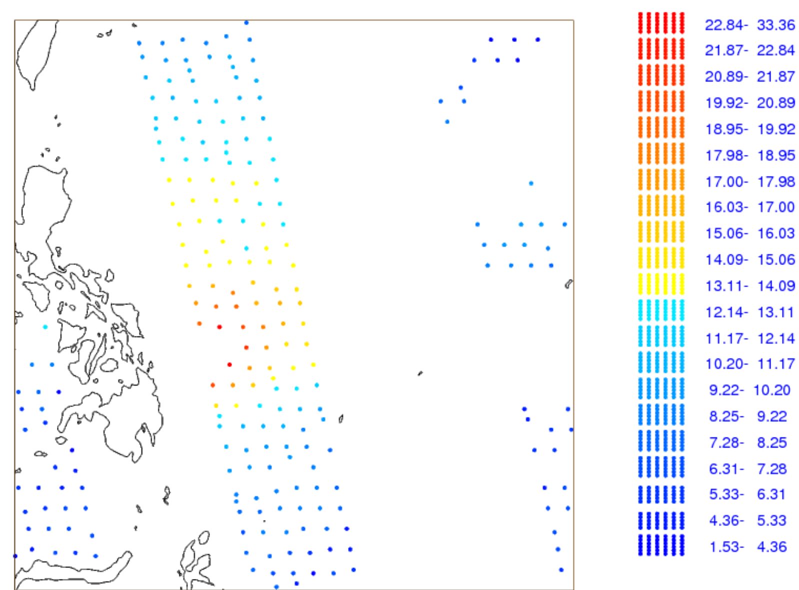


Min: 1.290 Max: 24.990 Mean: 9.718
GRID: 0.15x 0.15

Min: 1.533 Max: 33.358 Mean: 10.377
GRID: 0.15x 0.15

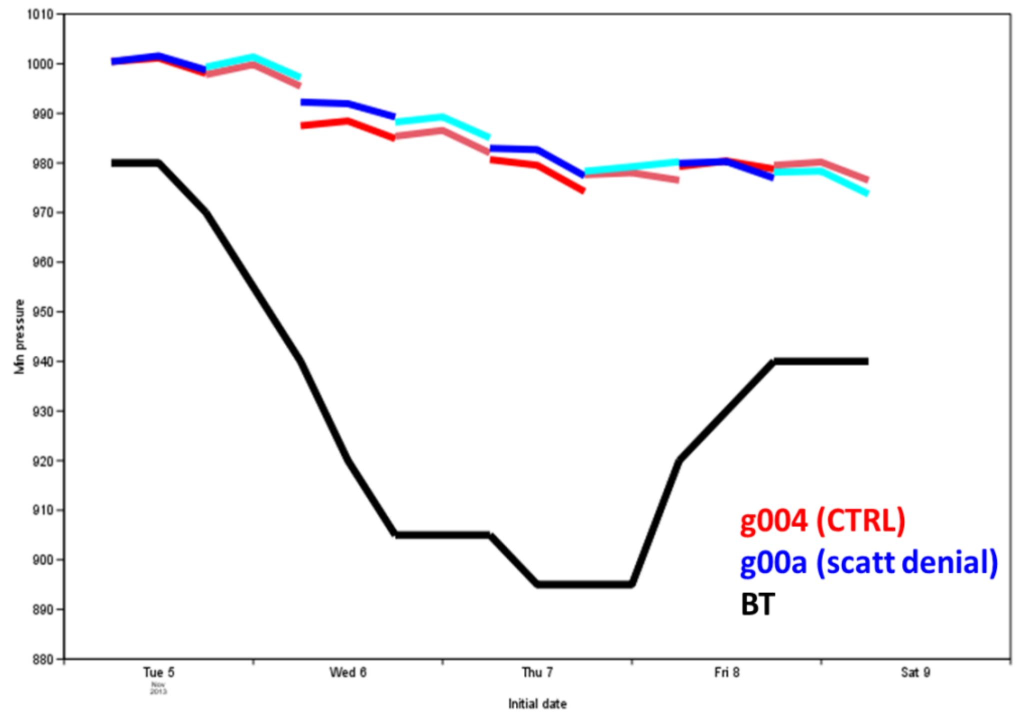


Used

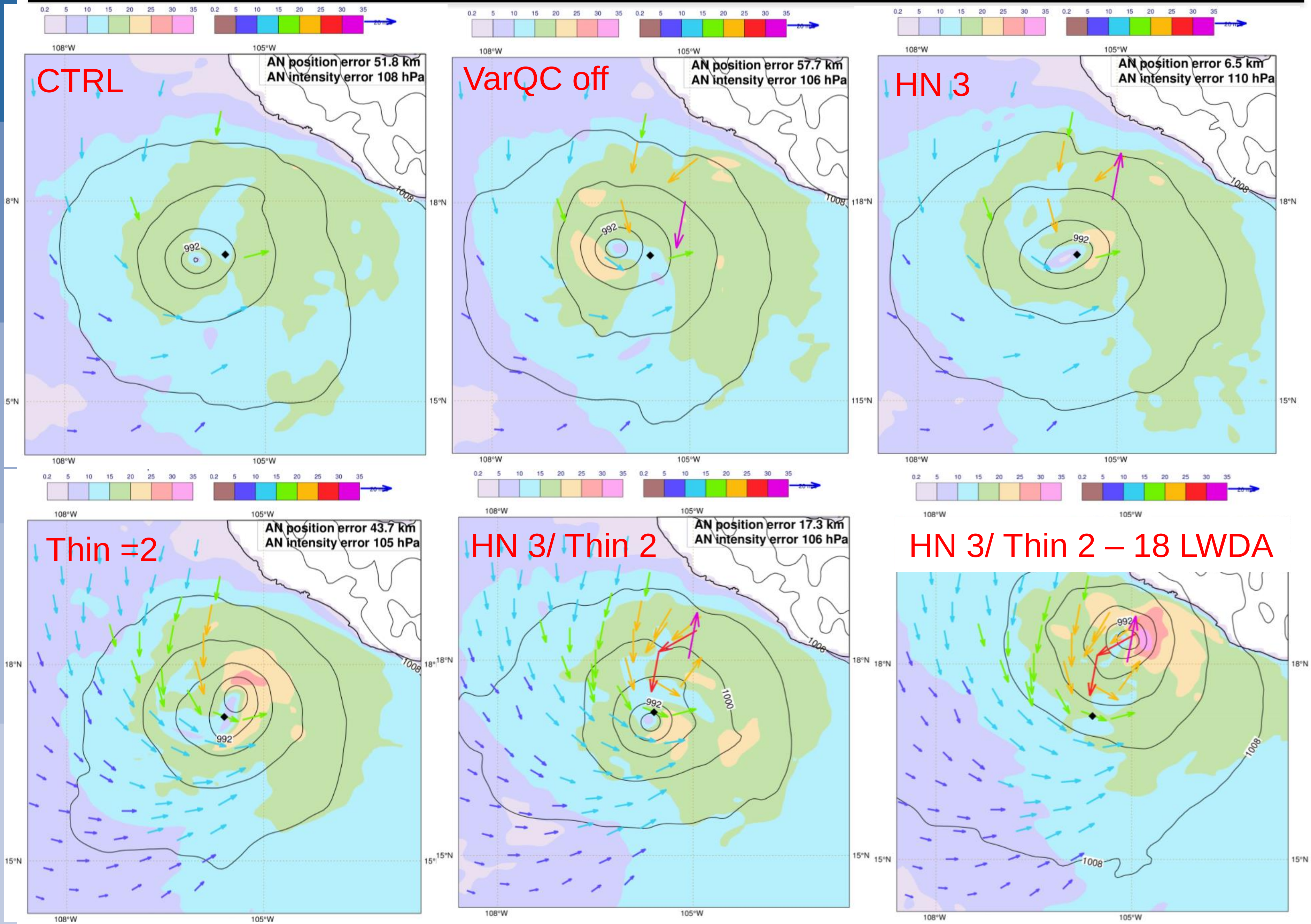


Typhoon Haiyan

Experiments Configuration
T511 (~ 40km)
g004: CTRL
g00a: Scatterometer Denial

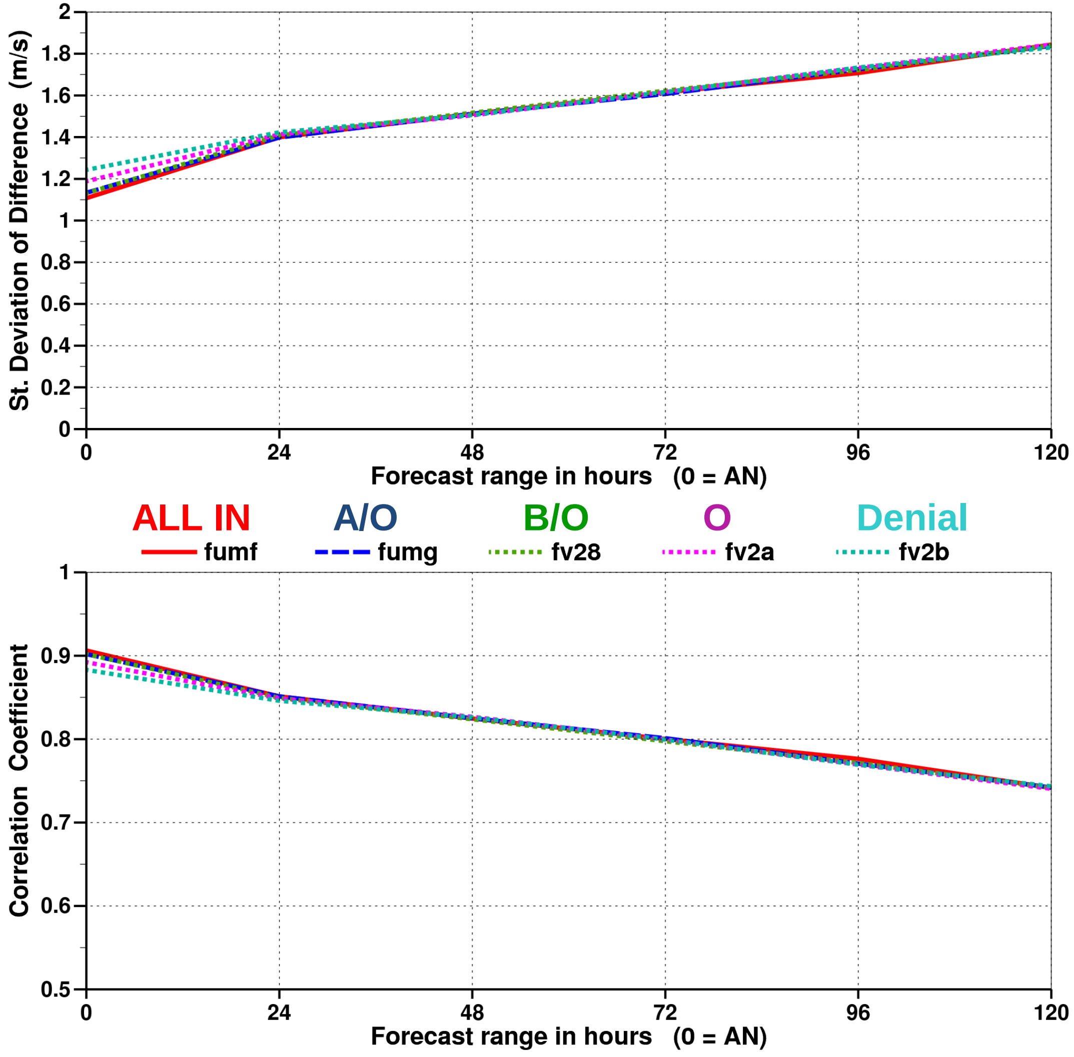


TC Patricia: DA 2015102312 UTC - ASCAT @ 17.11



Ascat Impact studies

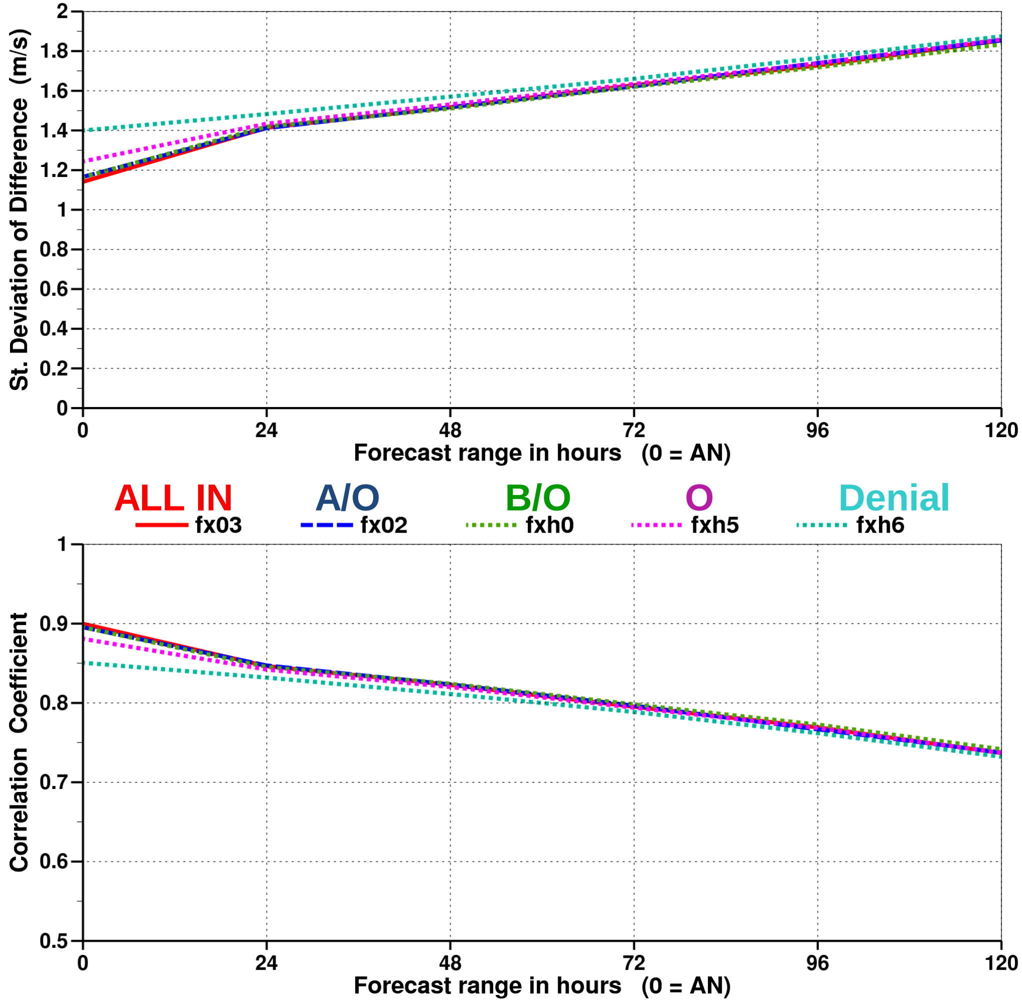
Verification vs Altimeter winds (JASON-1) – Full System - Tropics



G. De Chiara, S. English, P. Janssen and J.-R. Bidlot, “ASCAT ocean surface wind assessment” ECMWF Technical Memorandum 776, 2016.

Ascat Impact studies

Verification vs Altimeter winds (JASON-1) – Starved+ System - Tropics



Optimum wind sampling

- ✓ For spatially correlated observations the thinning is used to reduce their error-correlation. It is important to find the best balance between thinning and the observation error
- ✓ Current ASCAT configuration:
  - 25 sampling km products
  - Thinning = 1 out of 4 (100 km)
  - Observation Error (σ)= 1.5 m/s
  - Wind speed threshold = 35 m/s
- ✓ Testing several options of thinning and Observation Error

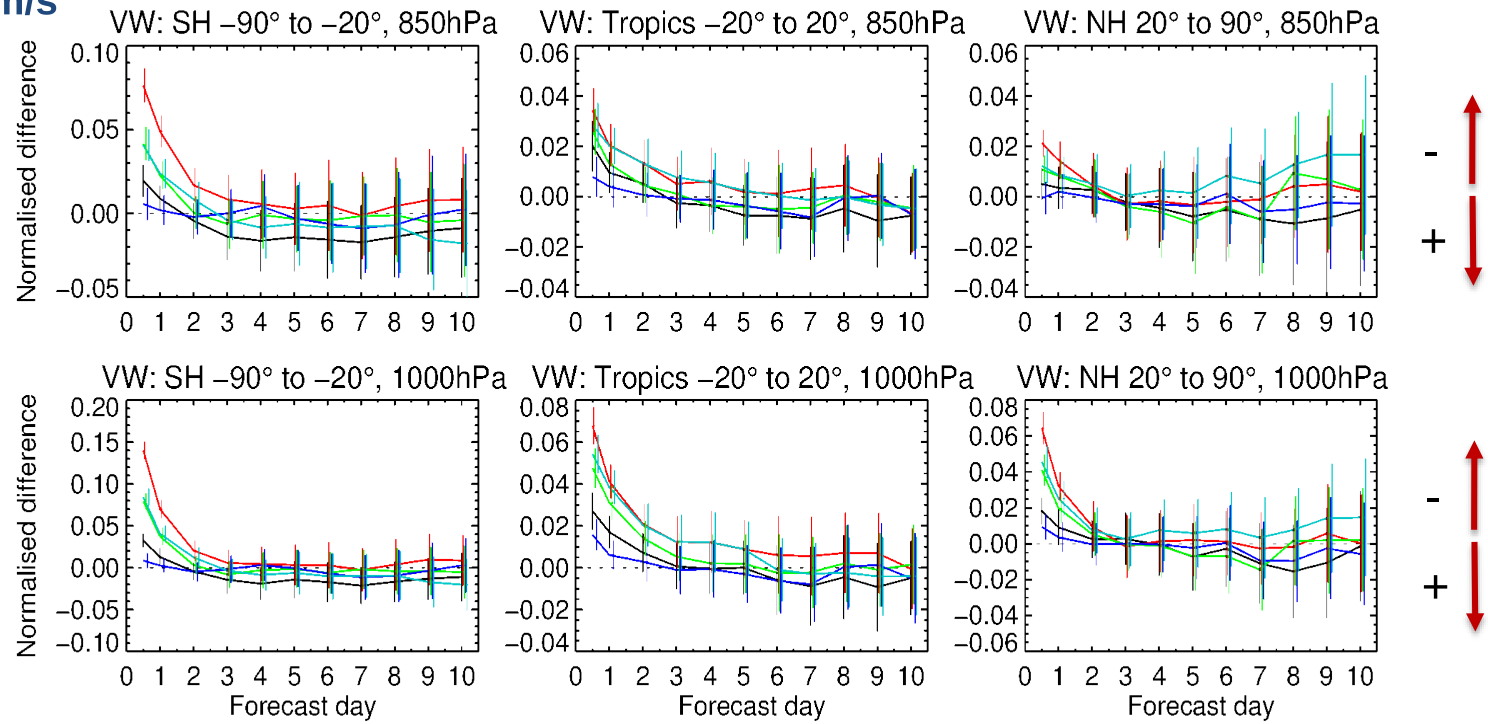
	Thinning	Obs Err (σ=1.5)	Obs. Error (m/s)
CTRL	4	σ	1.5
Th2 / OE1σ	2	σ	1.5
Th2 / OE1.25σ	2	1.25σ	1.875
Th2 / OE1.5σ	2	1.5 σ	2.25
Th2 / OE1.75σ	2	1.75 σ	2.625
Th2 / OE2σ	2	2 σ	3
Th4/OE0.67σ	4	0.67σ	1

Huber norm & wind sampling

Cy41R2 TCO639 Dec 2015-Feb 2016

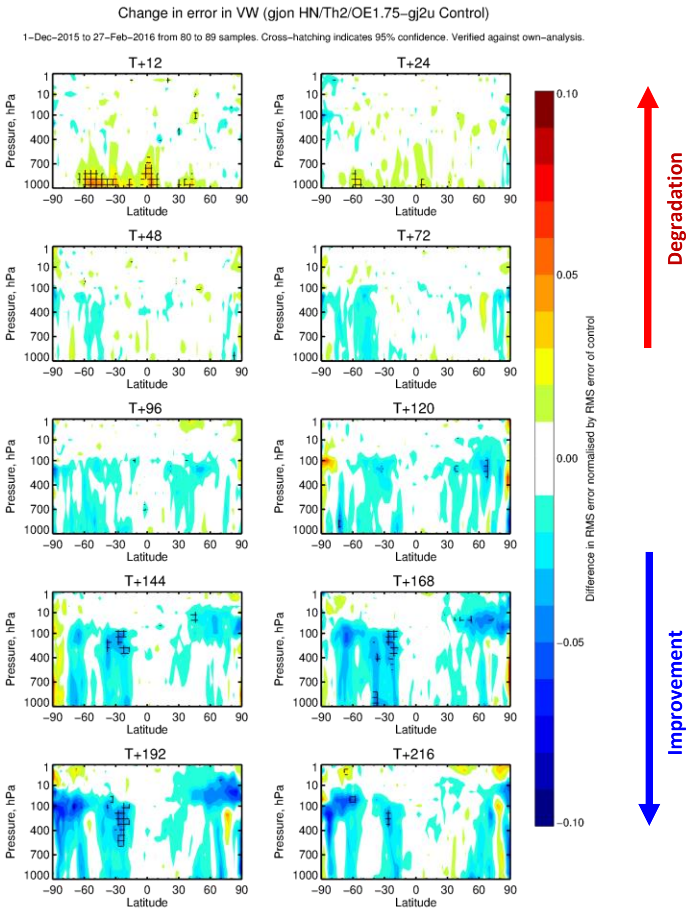
CTRL: VarQC & Thin=4 & σ=1.5 m/s

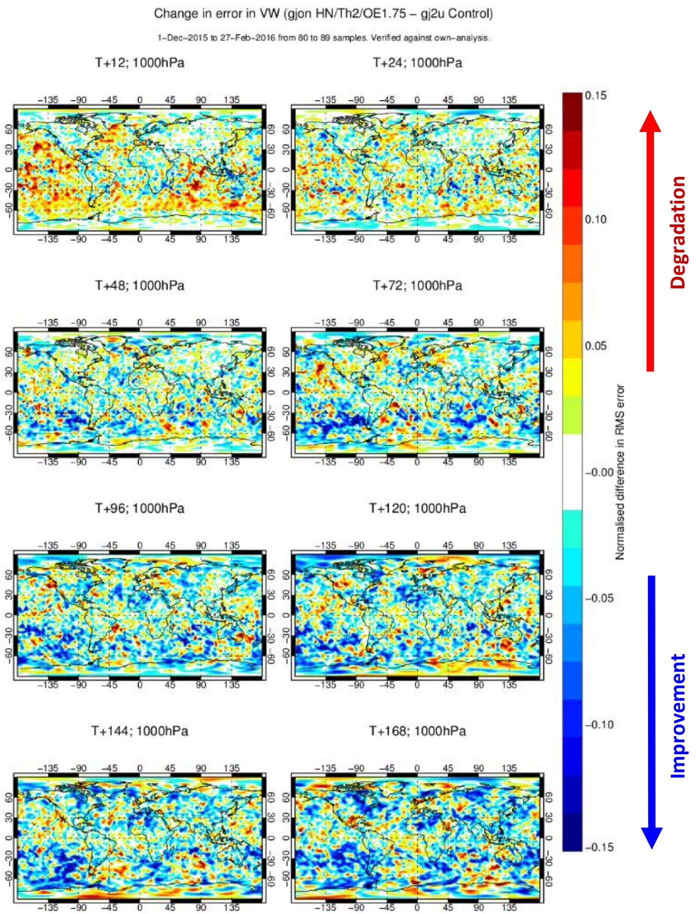
Thin 2/ ObsErr 1.5σ - CTRL
HN3 - CTRL
HN3 / Thin 2 / ObsErr 1.75σ - CTRL
HN1 / Thin 2/ ObsErr 1.5 σ - CTRL
HN3 / Thin 2 / ObsErr 1.5 σ - CTRL



Huber norm & wind sampling

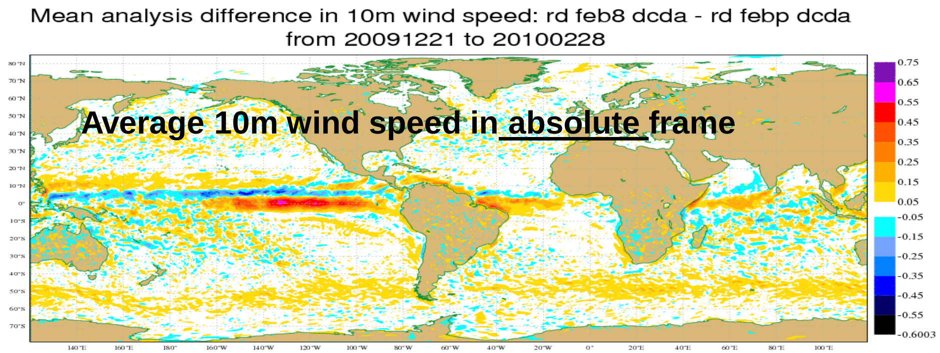
HN3 / Thin 2 / ObsErr 1.75σ - CTRL

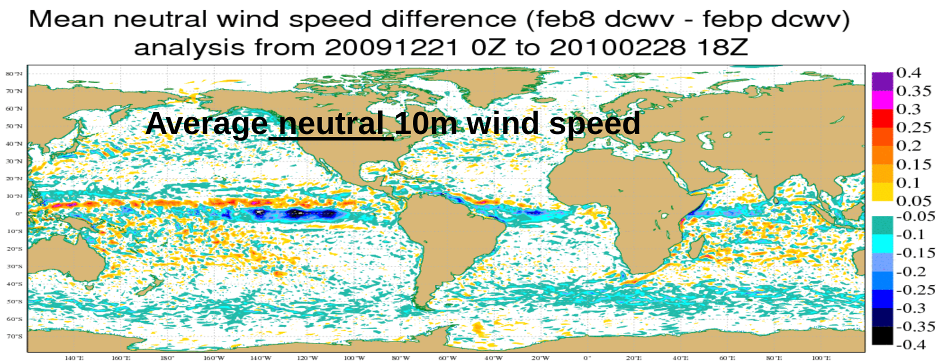




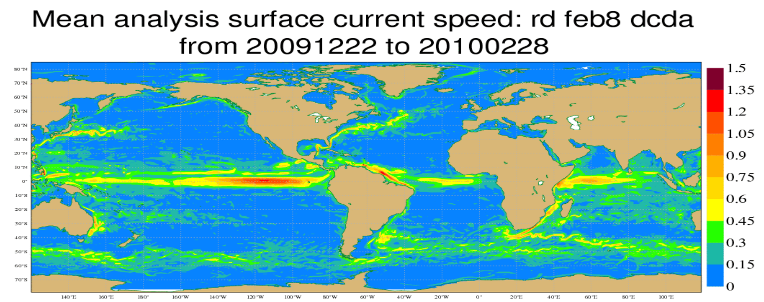
ECMWF

Surface current feedback on atmosphere





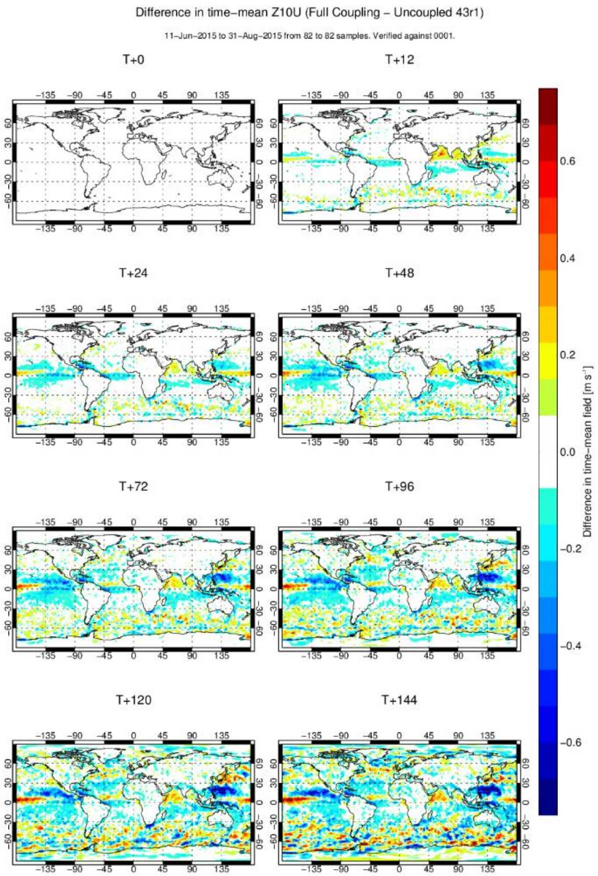
Currents – no currents

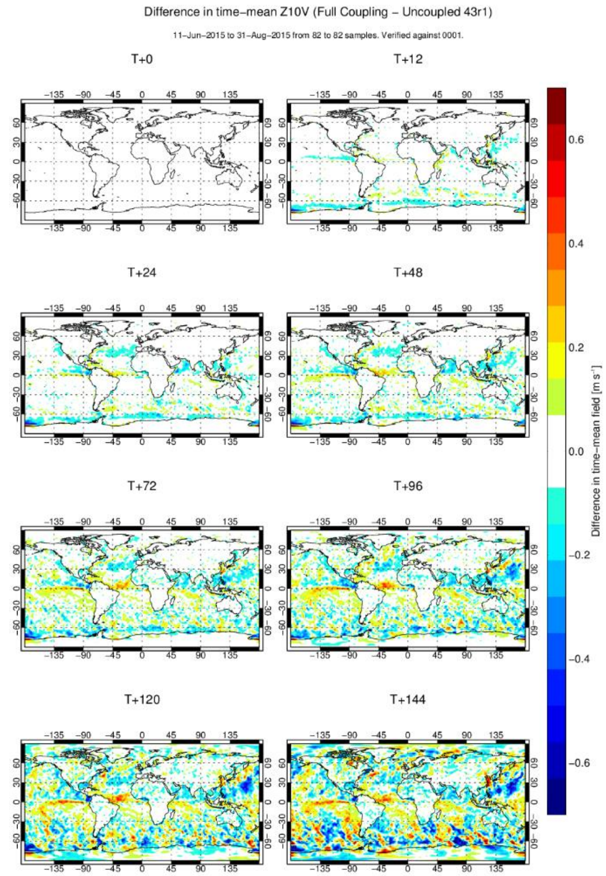


- **Absolute winds receive about 50% from ocean currents**

Sensitivity study: coupling v no coupling to NEMO

U10





V10

summer