



# WGNE intercomparison of Tropical Cyclone Track forecast 2016

# STANDARD VERIFICATION

Verification of Global Models

# History of the Project

- 1991 : Commencement with 3 centres: ECMWF, UKMO and JMA.  
The verification area was only western North Pacific (WNP).
- 1994 : CMC joined.
- 1999 : Verification for North Atlantic (NAT) started.
- 2000 : DWD joined. Verification for eastern North Pacific (ENP) started.
- 2002 : Verification for 2 regions in the Southern Hemisphere (SIO and AUR),  
North Indian Ocean (NIO) and central North Pacific (CPC) started.
- 2003 : NCEP and BoM joined. A website for this project was launched.
- 2004 : Meteo-France (FRN) and CMA joined.
- 2006 : CPTEC and NRL joined.
- 2011 : KMA joined.
- 2017 : 11 NWP centres (BoM, CMA, CMC, DWD, ECMWF, FRN, JMA, KMA,  
NCEP, NRL, UKMO) are now involved in the project.

# Data Specifications in 2016

NWP centre	Year of verification commencement	Horizontal resolution of provided data (degrees in longitude and latitude)	Model resolution as of 2016
BoM	2003	0.5625 x 0.3750 (~Mar. 15) 0.3516 x 0.2344 (Mar. 16~)	40kmL70 (~Mar. 15) 25kmL70 (Mar. 16)
CMA	2004	0.2813 x 0.2813	T <sub>L</sub> 639L60
CMC	1994	1.0 x 1.0	25km L80
DWD	2000	0.25 x 0.25	13kmL90
ECMWF	1991	0.125 x 0.125	T <sub>L</sub> 1279L137 (~Mar. 7) 01280L137 (Mar. 8~)
FRN	2004	0.5 x 0.5	T <sub>L</sub> 1198C2.2L105
JMA	1991	0.25 x 0.25	T <sub>L</sub> 959L100
KMA	2010	0.3516 x 0.2344 (~Jun. 30) 0.2344 x 0.1563 (Jul. 1~)	25kmL70 (~Jun. 30) 17kmL70 (Jul. 1~)
NCEP	2003	0.5 x 0.5	T1534L64
NRL	2006	0.5 x 0.5	T425L60
UKMO	1991	0.2344 x 0.1563	17kmL70

[Data missing] CMA : 11/14 - 12/31

# Verification Method using MSLP

## Target TCs

TC best track data provided by individual RSMCs are used in verification, with focus on cyclones reaching **tropical storm (TS)** intensity with maximum sustained winds of **34 knots or stronger**. The tropical depression (TD) stage of targeted TCs is also included in this verification, and TCs remaining at TD level throughout their lifespan are excluded.

## Tracking Method

TCs are tracked using **mean sea level pressure** data provided by participating NWP centres. Under this method, the minimum pressure point is identified as the initial or predicted TC position.

- 1) **First position (FT+0hr)** is searched within a 500 km radius of a best track position.
- 2) **Second position (FT+6hr)** is searched within a 500 km radius of the first position.
- 3) **Subsequently (FT+12hr~)**, a TC position within a 500 km radius of a reference point determined from linearly extrapolation of the latest two positions is identified.

Tracking ends when no appropriate minimum pressure point is found.

# Definitions

- **Position Error [km]** :

distance between the best track (analyzed) position and the forecast position

- **Along Track – Cross Track bias**

AT (along-track) bias : bias in the direction of TC movement

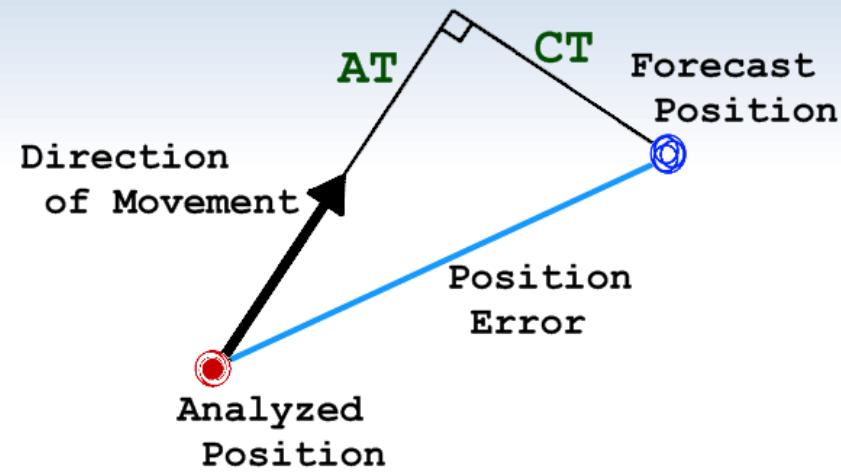
CT (cross-track) bias : bias in the direction perpendicular to TC movement

- **Detection Rate**

**Detection Rate (t)** =  $A(t)/ B(t)$  , where:

$A(t)$  : number of events in which a TC is analyzed at time t with the condition that the NWP model successively expresses the TC until time t

$B(t)$  : number of events in which a TC is analyzed at time t.



# TCs in 2016

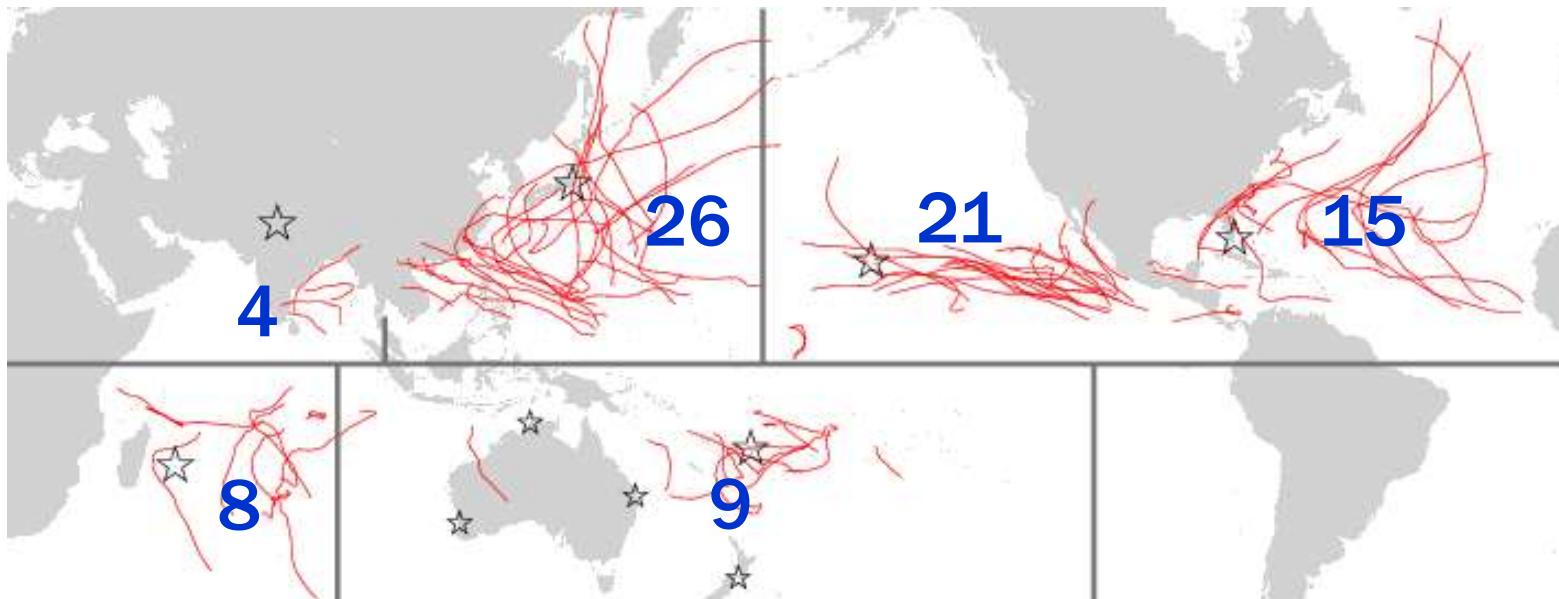
## TC season

Northern Hemisphere : 1 January 2016 to 31 December 2016

Southern Hemisphere : 1 September 2015 to 31 August 2016

## Number of TCs [best track data provider]

- 26 Western North Pacific [RSMC Tokyo]
- 21 Eastern North Pacific (including Central North Pacific) [RSMC Miami, Honolulu]
- 15 North Atlantic [RSMC Miami]
- 4 North Indian Ocean [RSMC New Delhi]
- 8 South Indian Ocean [RSMC La Reunion]
- 9 Around Australia [RSMC Nadi and 4 TCWCs ]



# Improvement of models for each centres in 2016

## BOM

- 2016.03.16 improve horizontal resolution(40km => 25km)

## DWD

- 2016.04.13 improve physical process(convective, radiation)
- 2016.09.28 improve physical process(cloud)
- 2016.11.30 improve data assimilation method

## ECMWF

- 2016.03.08 improve horizontal resolution(16km => 9km: Octahedral grid), convection scheme, etc (Cycle 41r2)
- 2016.11.22 improve data assimilation method, method of using observation data, and physical process (Cycle 43r1)

## JMA

- 2016.03.17 start to use Himawari-8 AMV, CSR data
- 2016.03.24 improve physical process and start to use GPM microwave imager data
- 2016.09.28 improve tropical cyclone bogus data

## KMA

- 2016.07.01 improve horizontal resolution(25km => 17km)

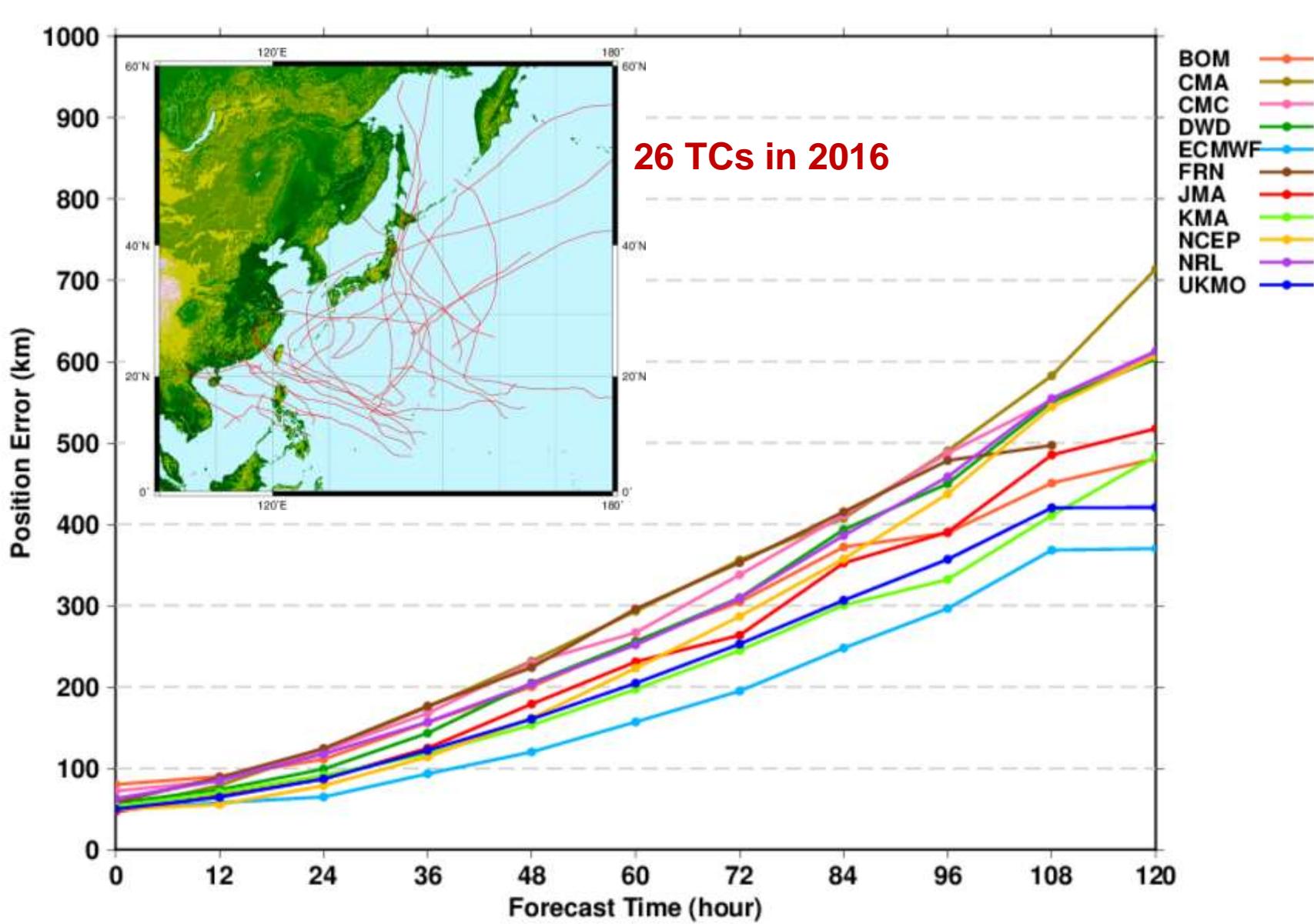
## NRL

- 2016.10 model update

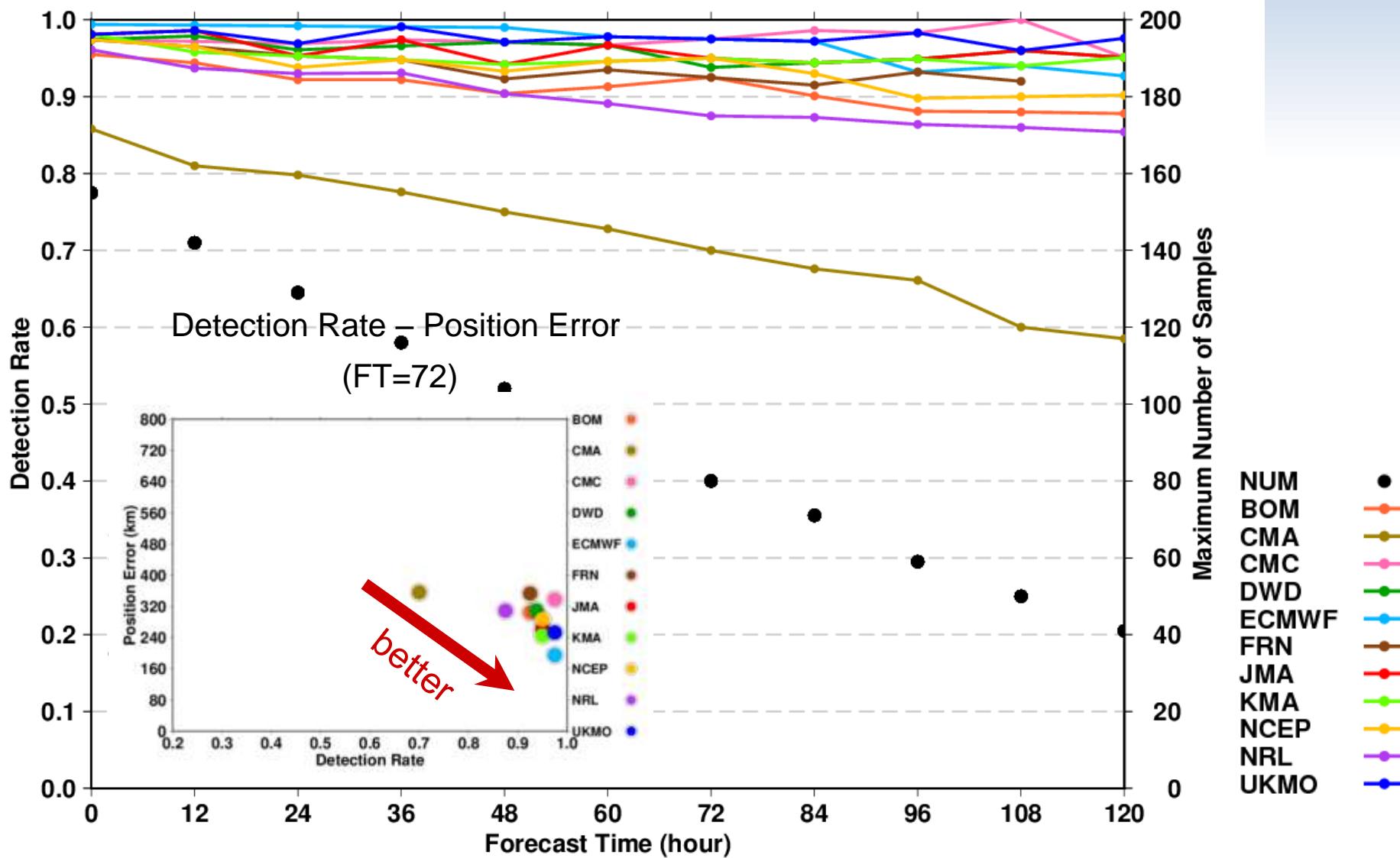
## UKMO

- 2016.03.15 implement bias correlation of variational method for satellite observation data

# (a) Western North Pacific (WNP) Position Error



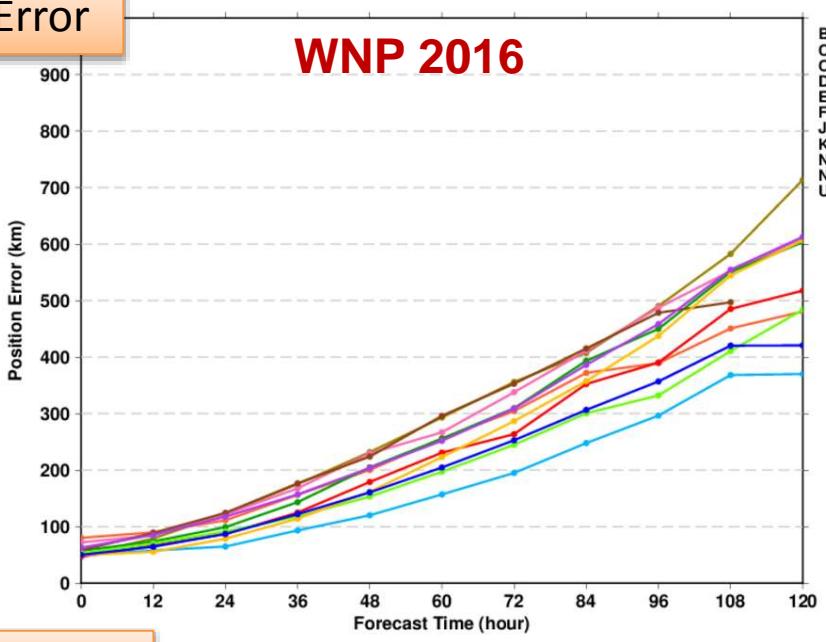
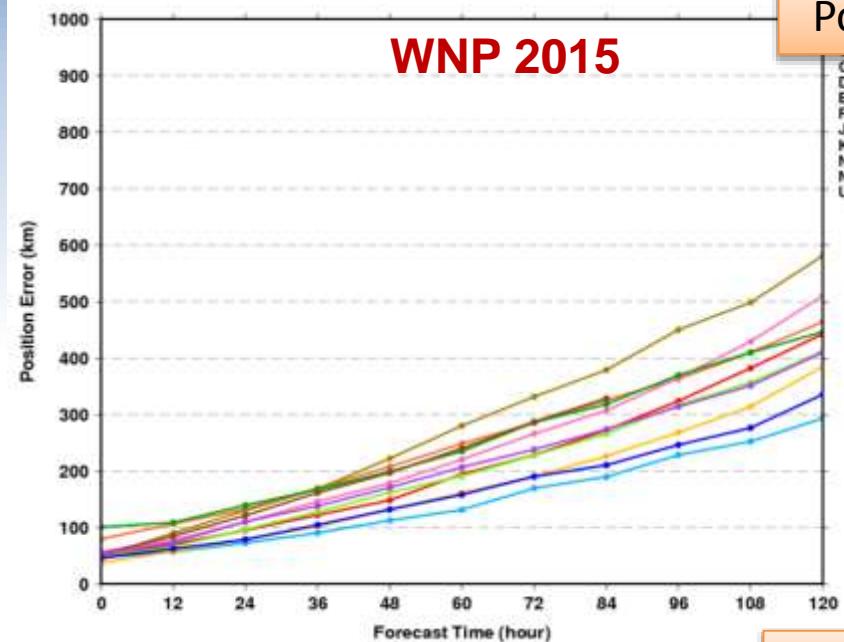
# (a) WNP Detection Rate



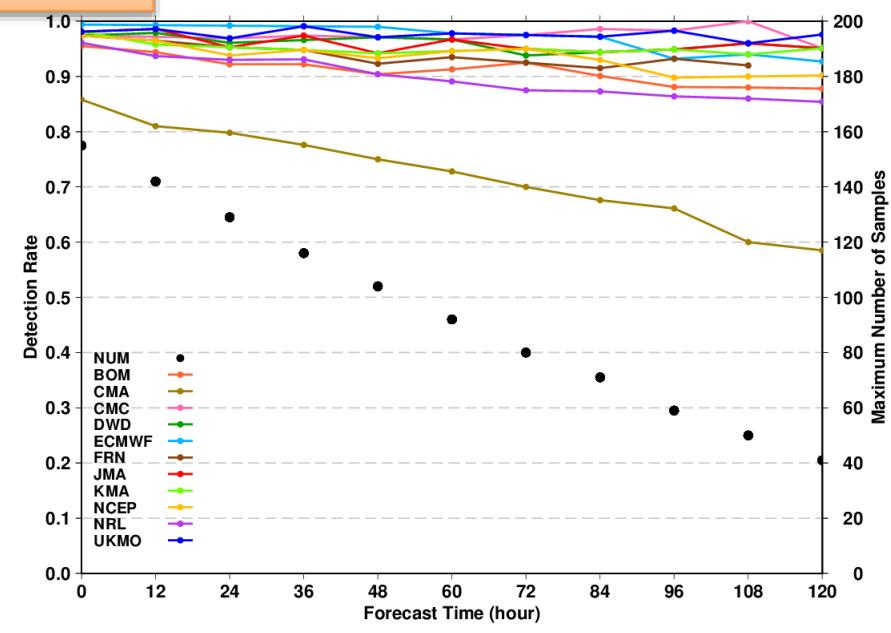
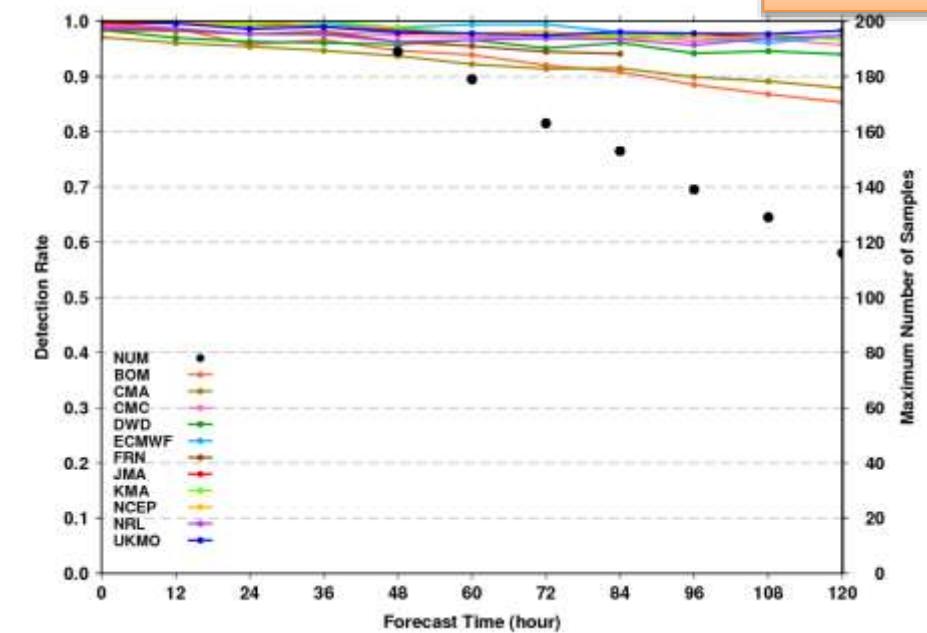
## Position Error

**WNP 2015**

**WNP 2016**

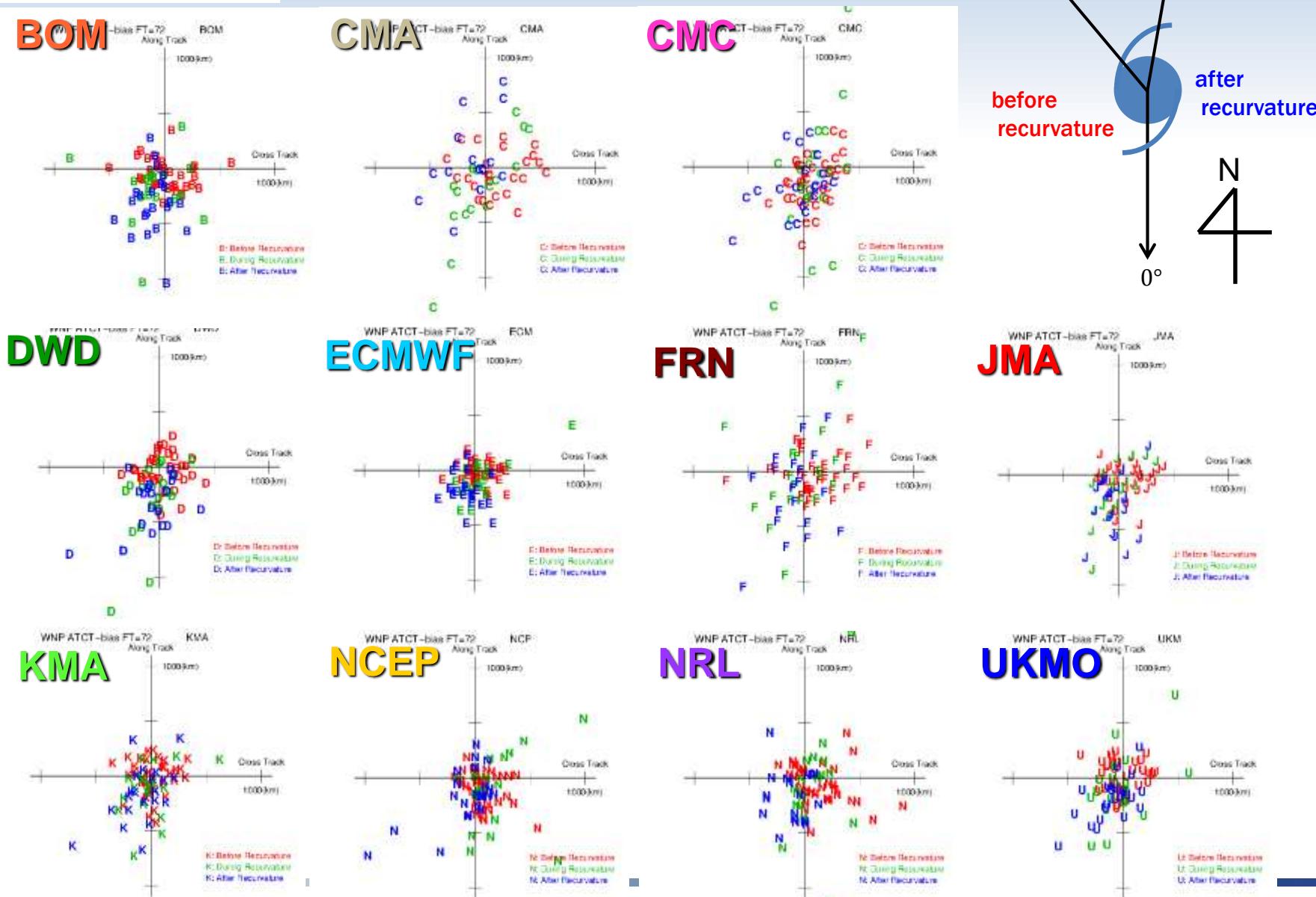


## Detection Rate

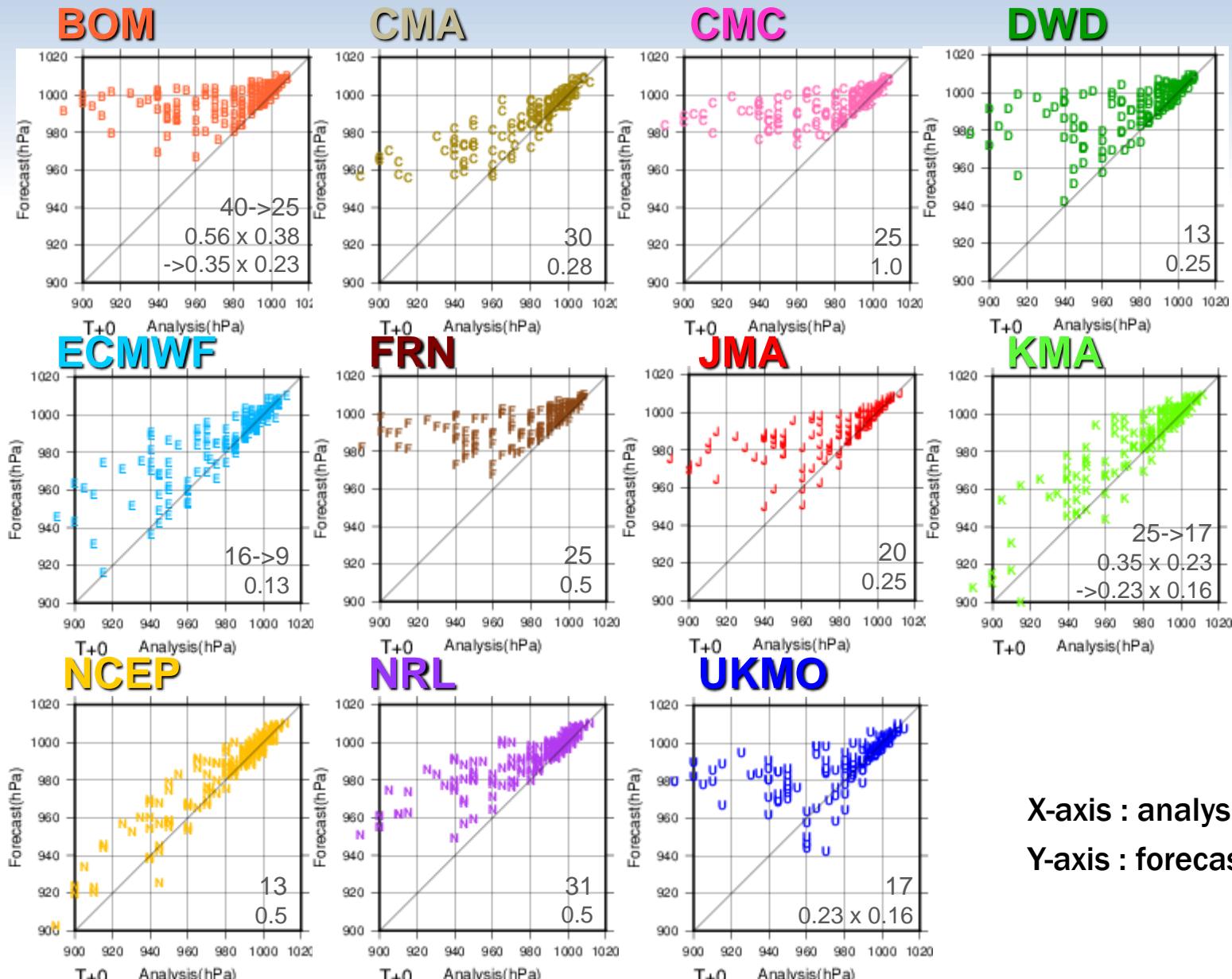


Y-axis : position errors (km)  
in the along track direction  
X-axis : position errors (km)  
in the cross track direction

# (a) WNP AT-CT Bias (FT=72)

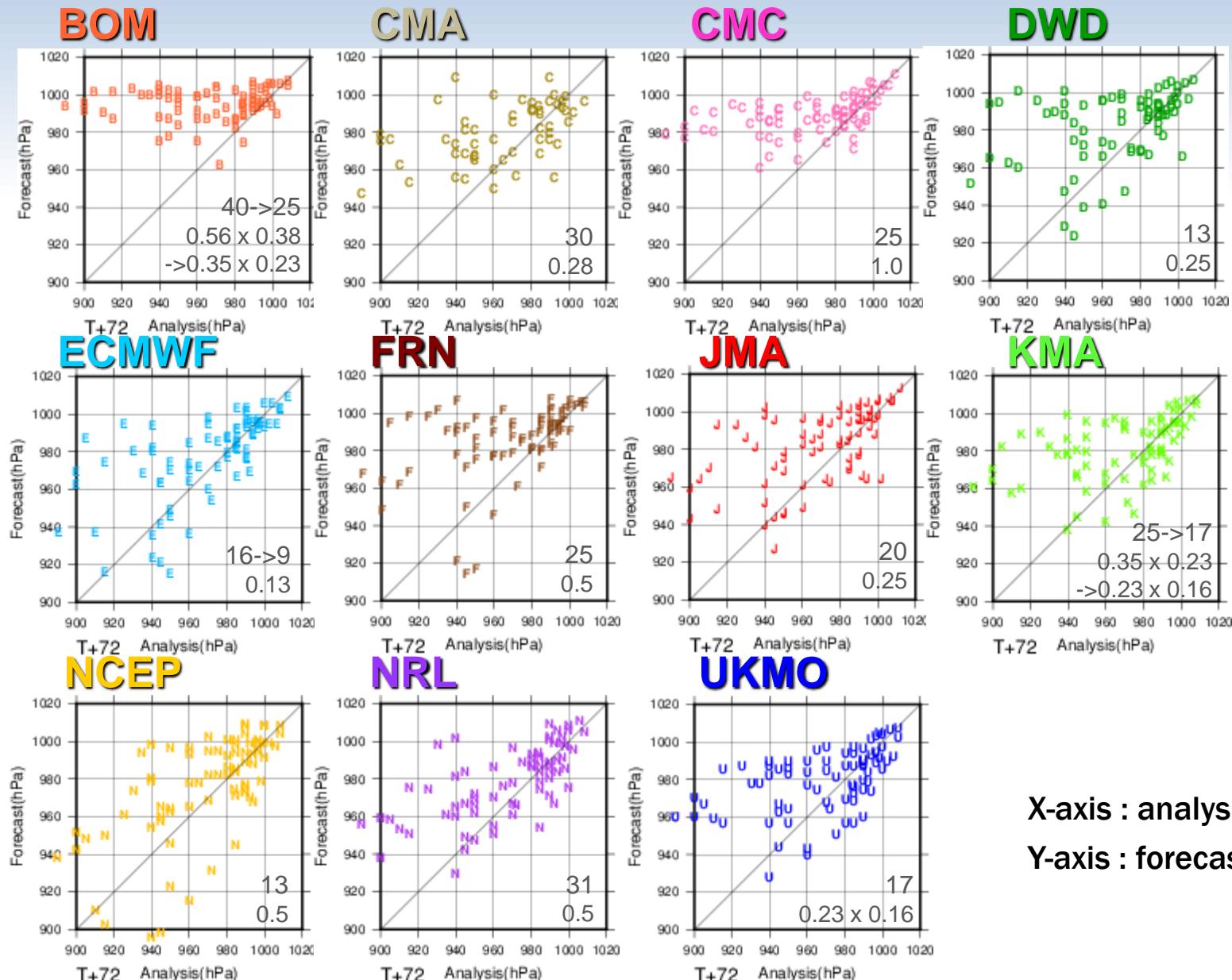


## (a) WNP Central Pressure Scatter Diagram (FT=0)

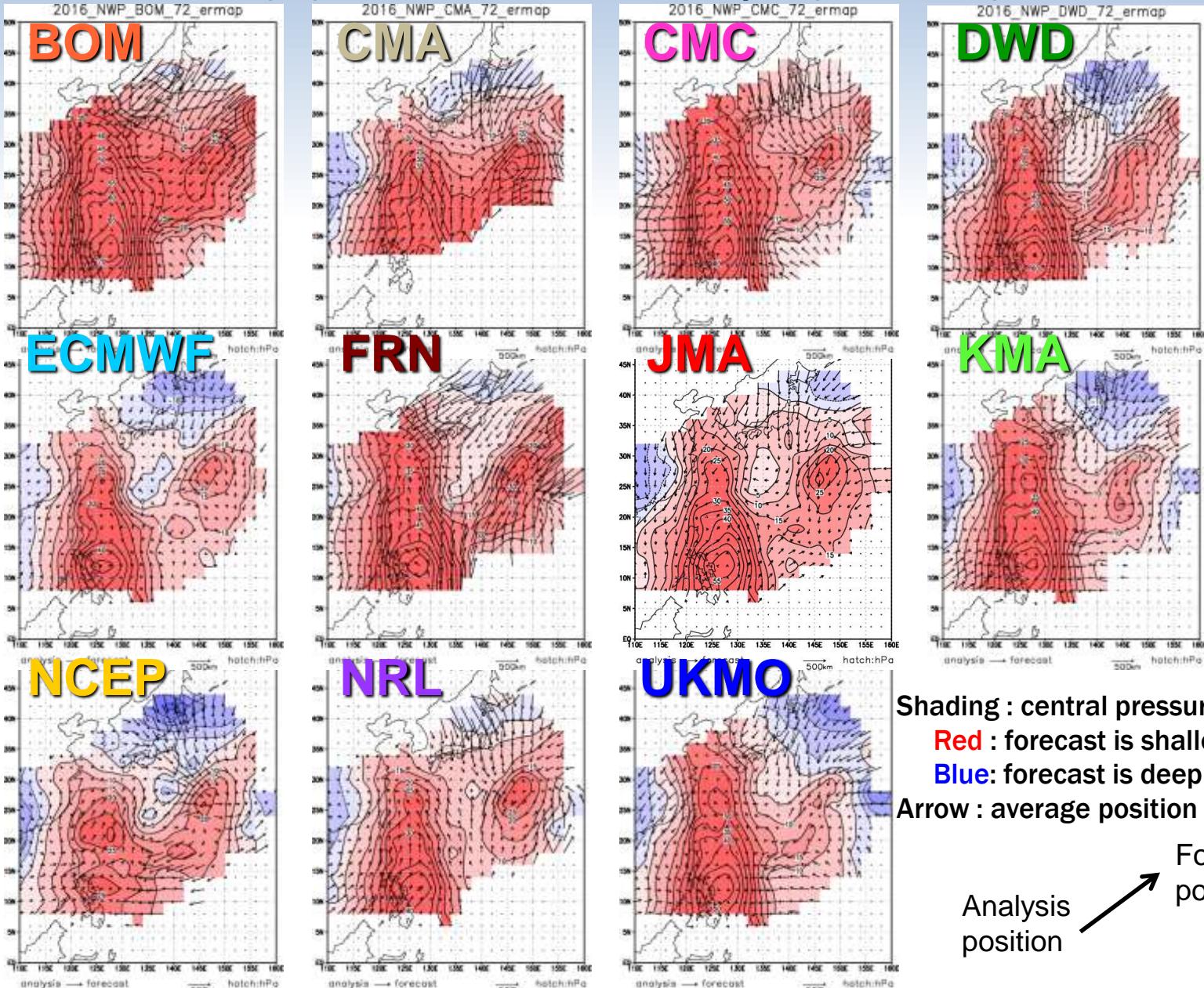


X-axis : analysis  
Y-axis : forecast

# (a) WNP Central Pressure Scatter Diagram (FT=72)



# (a) WNP Error Map (FT=72)



Shading : central pressure error (hPa)

Red : forecast is shallow

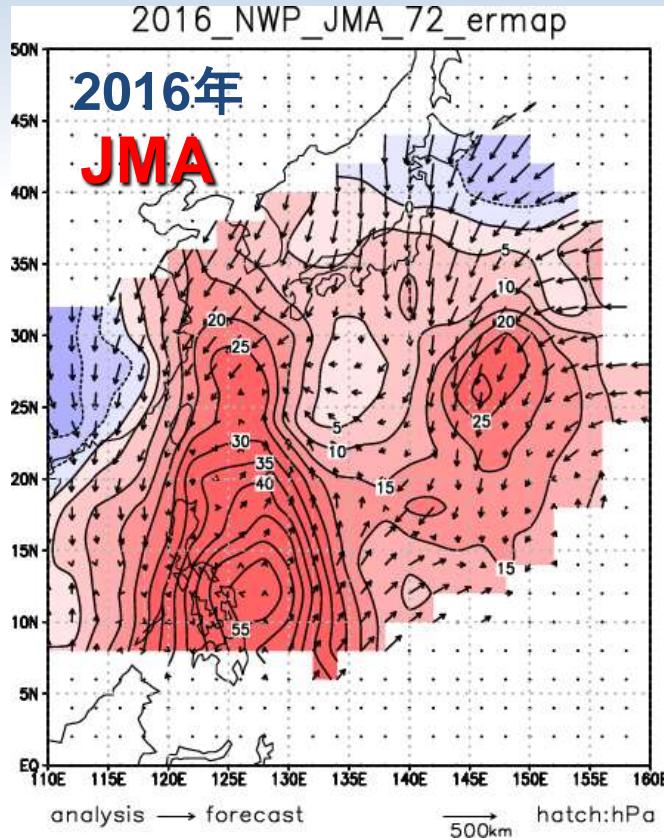
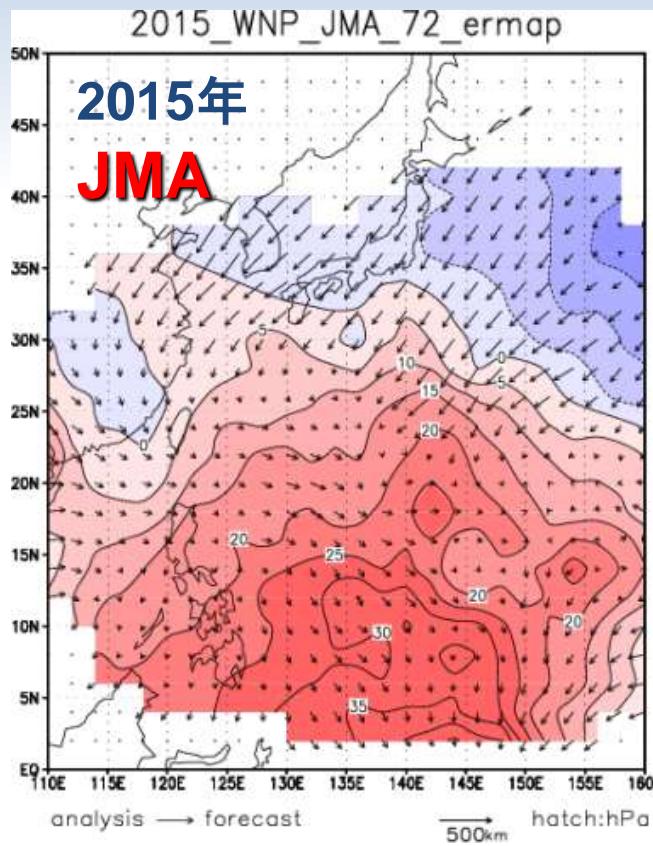
Blue: forecast is deep

Arrow : average position error

Forecast  
position

Analysis  
position

# (a) WNP Error Map (FT=72)



Shading : central pressure error (hPa)

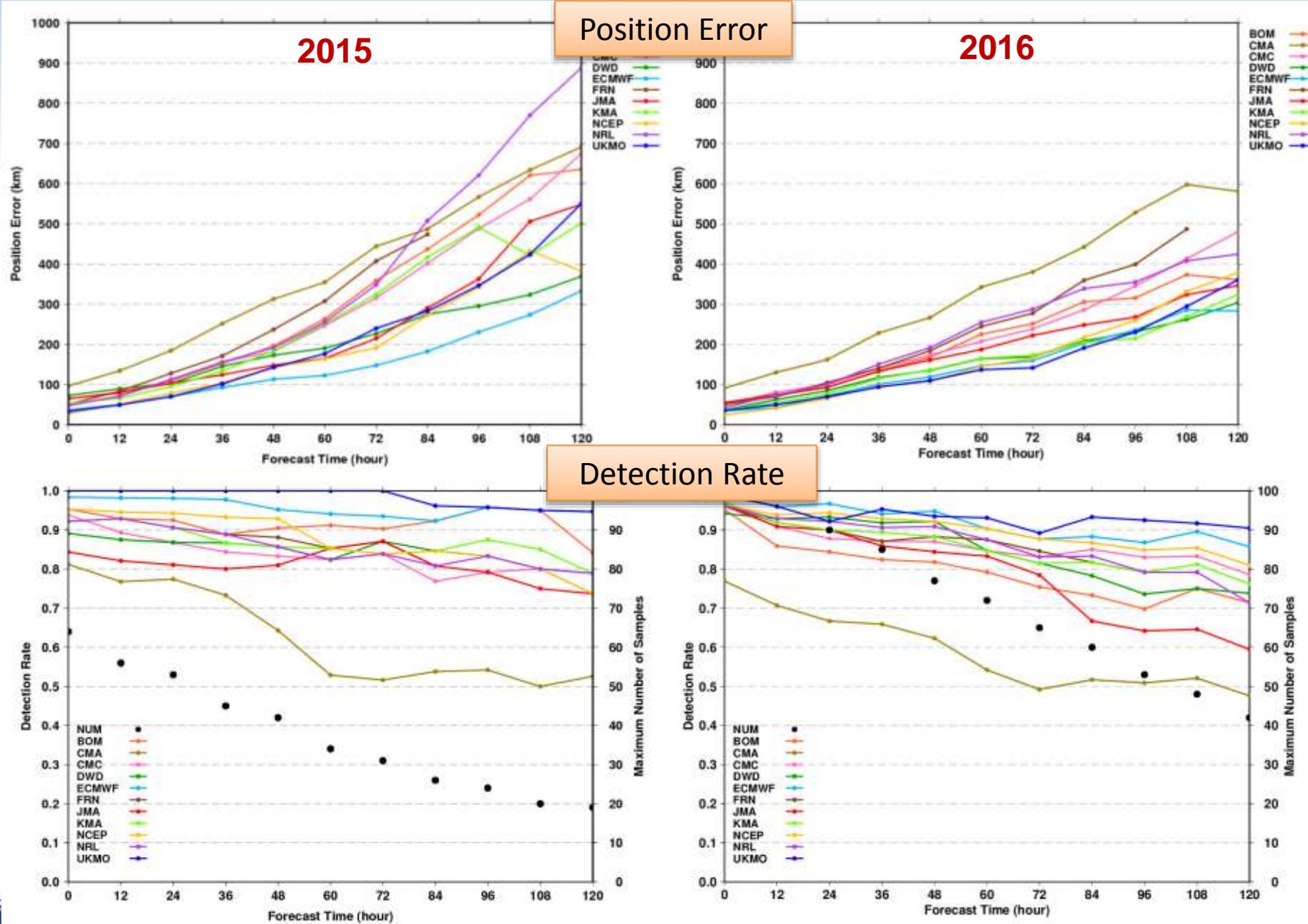
Red : forecast is shallow

Blue: forecast is deep

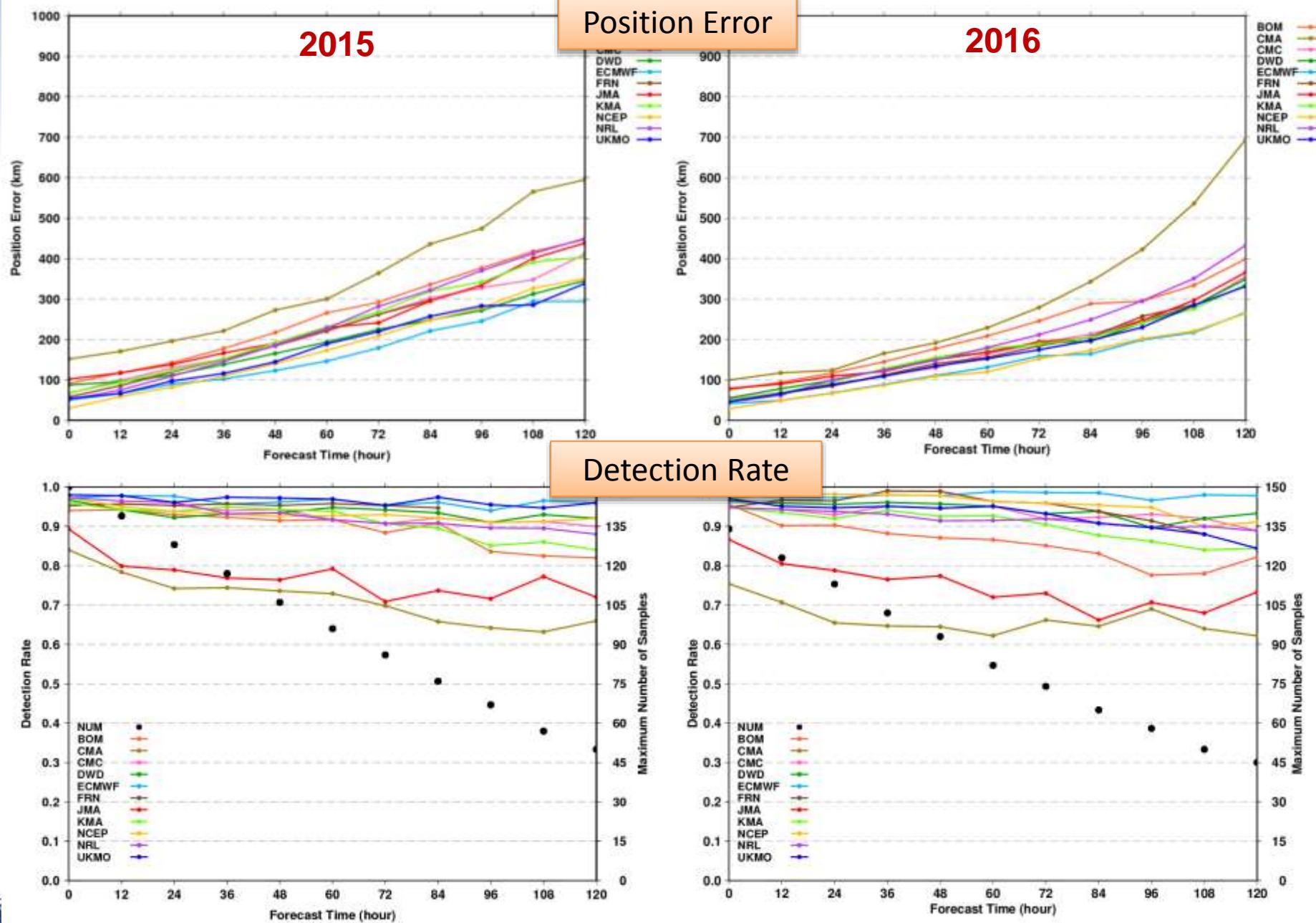
Arrow : average position error

Forecast position  
Analysis position

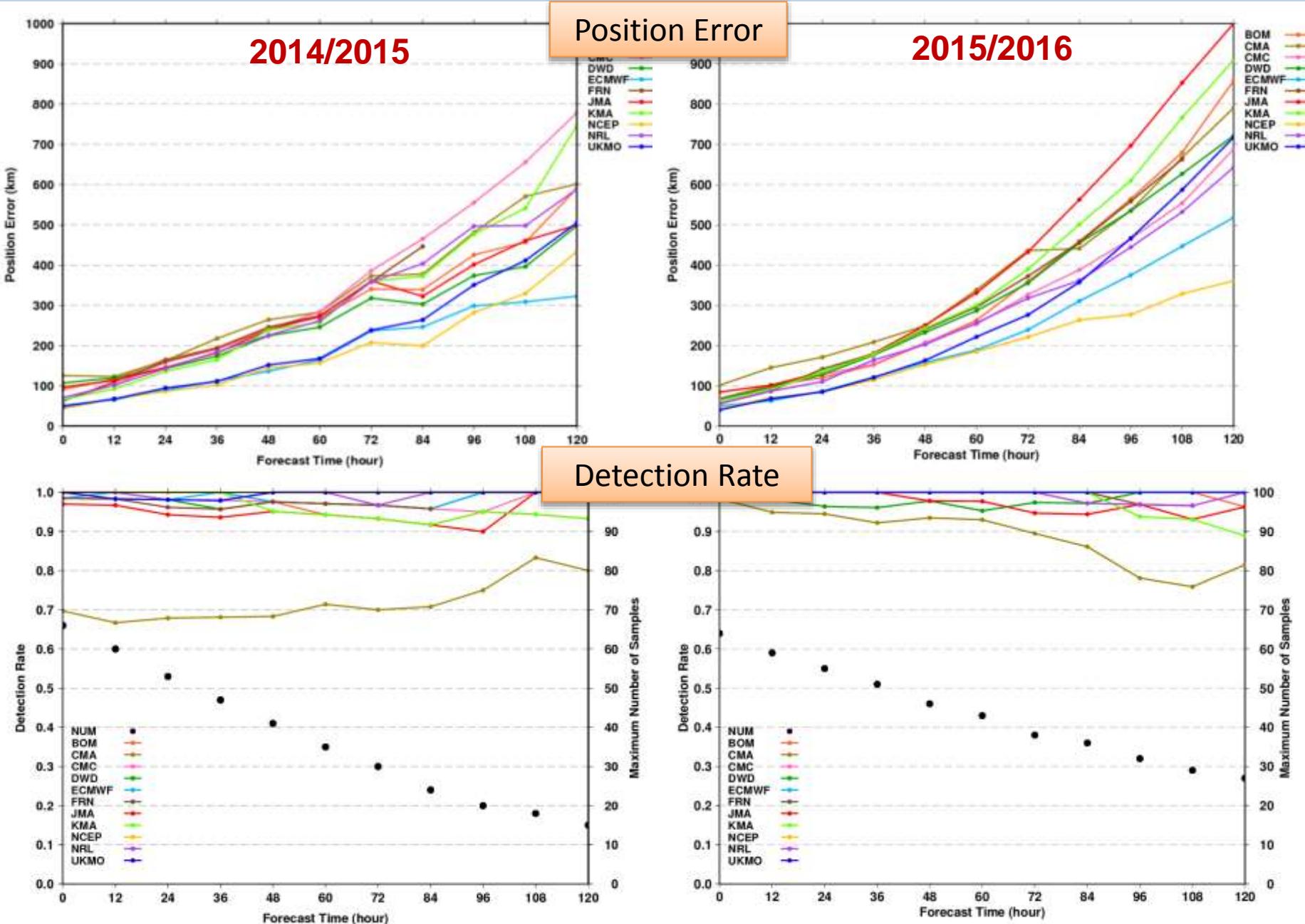
# (b) North Atlantic (NAT)



# (c) Eastern North Pacific (ENP)



# (d) “around Australia” (AUR)

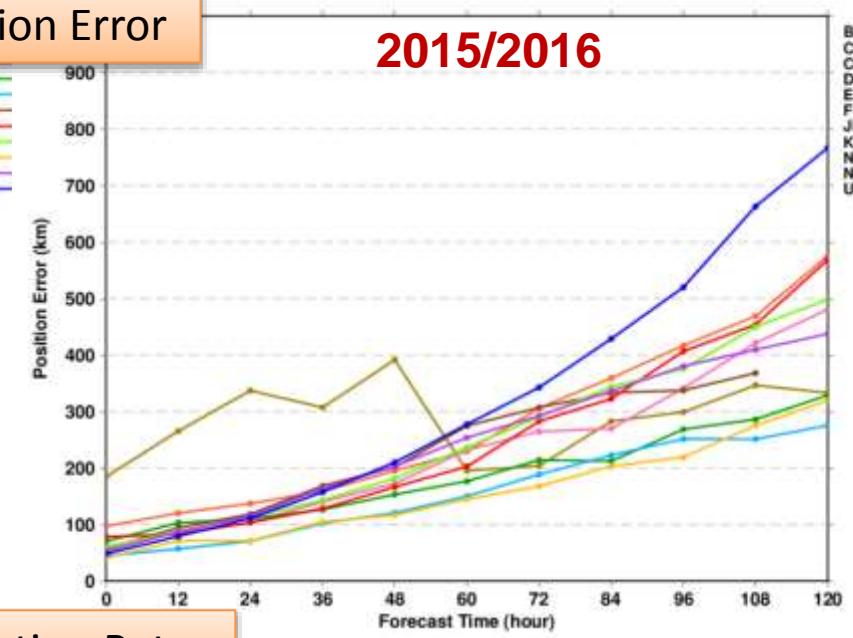
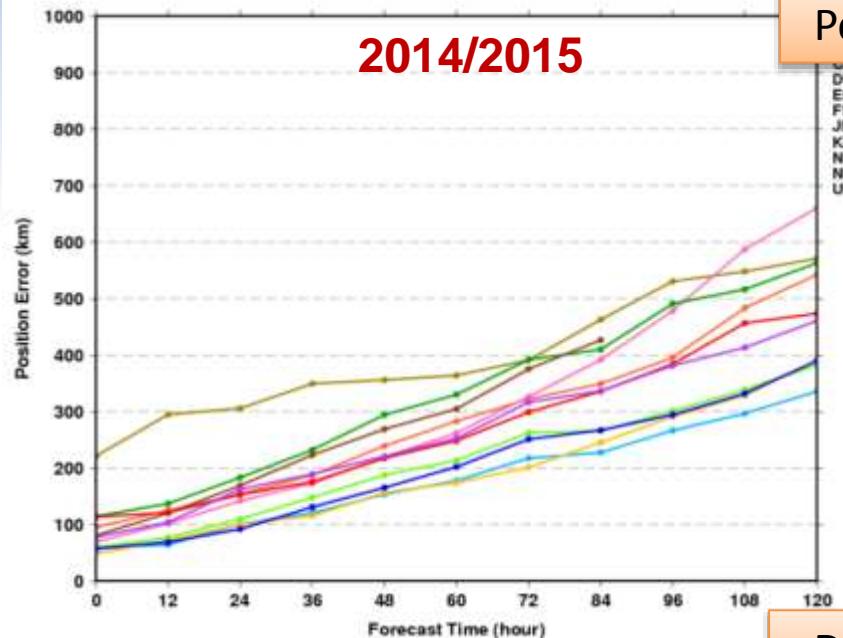


# (e) South Indian Ocean (SIO)

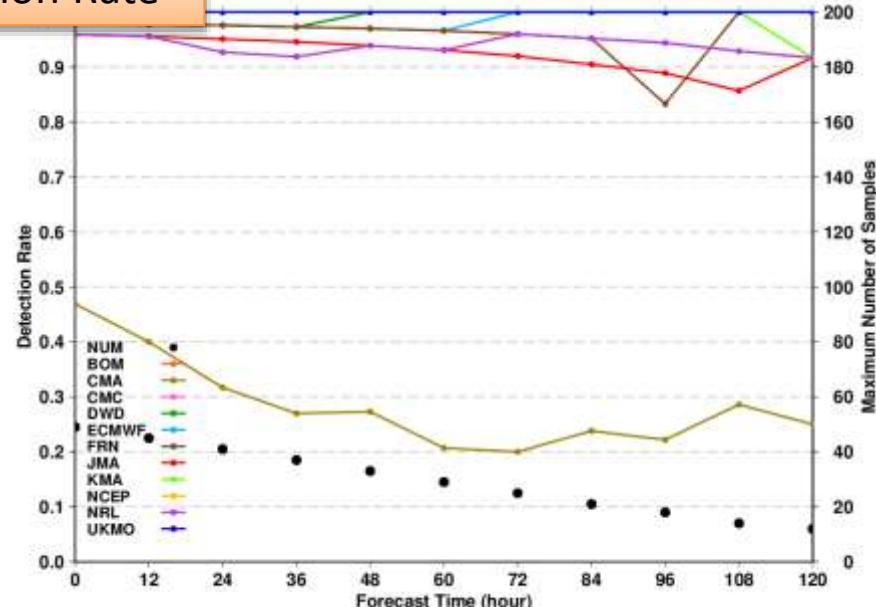
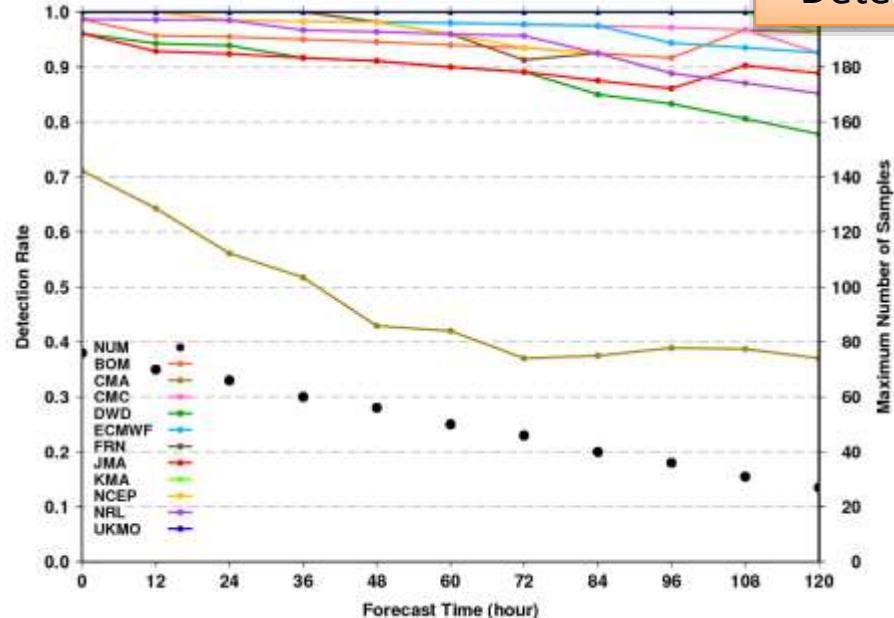
2014/2015

Position Error

2015/2016

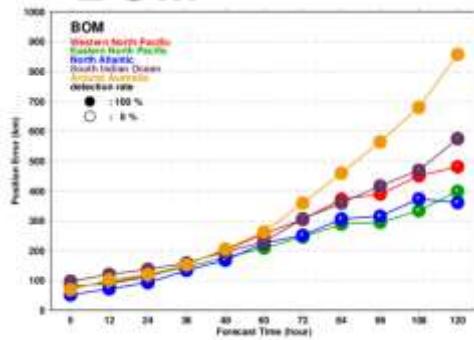


Detection Rate

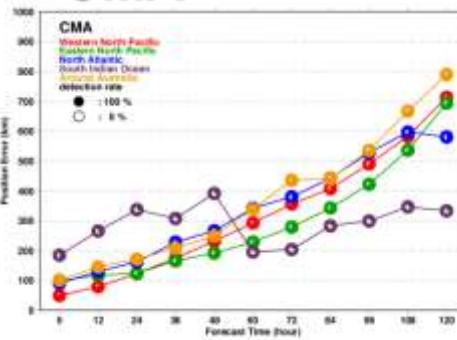


# Visualization with “Pie-chart”

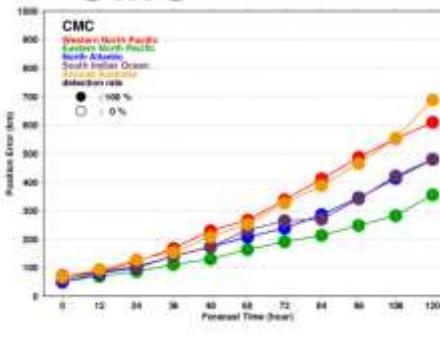
# BOM



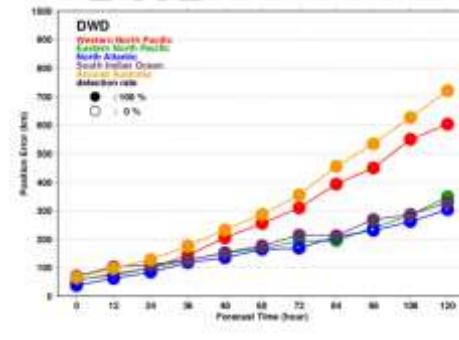
CMA



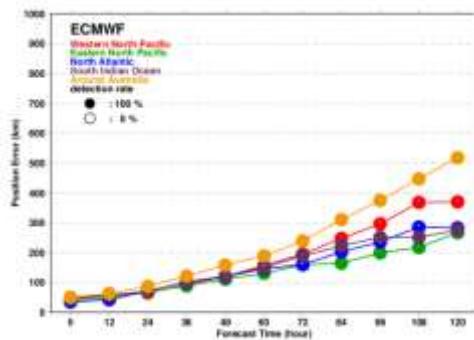
**CMC**



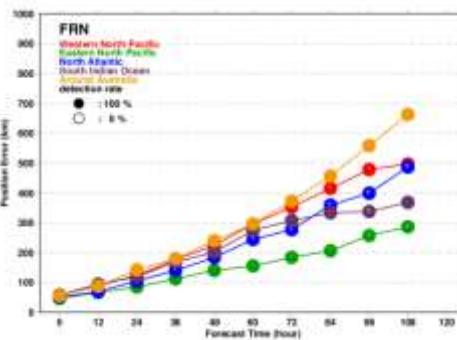
DWD



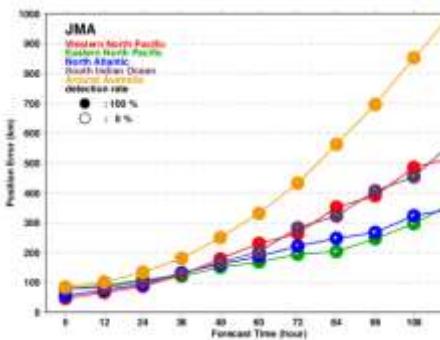
ECMWF



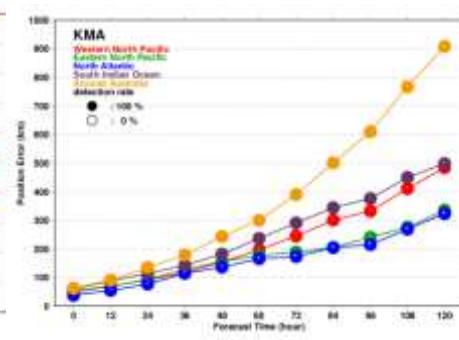
FRN



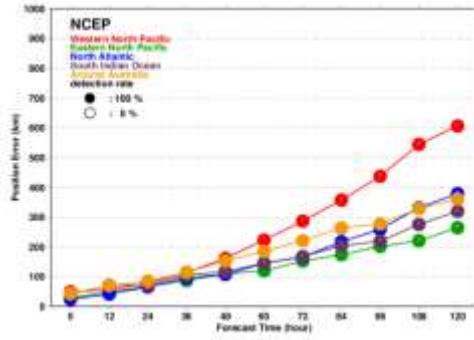
JMA



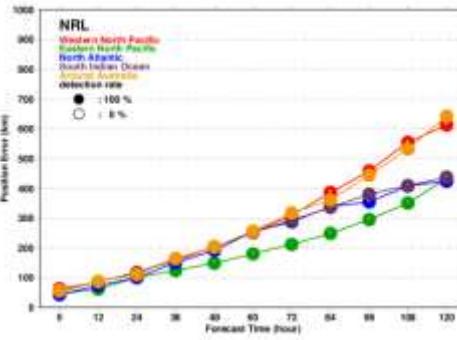
KMA



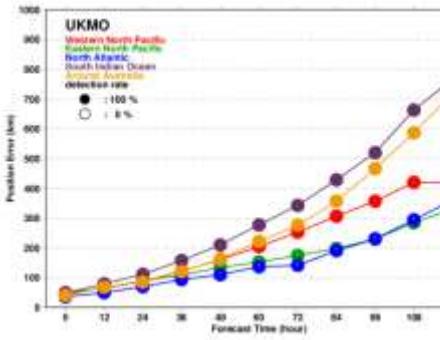
NCEP



NRL



UKMO

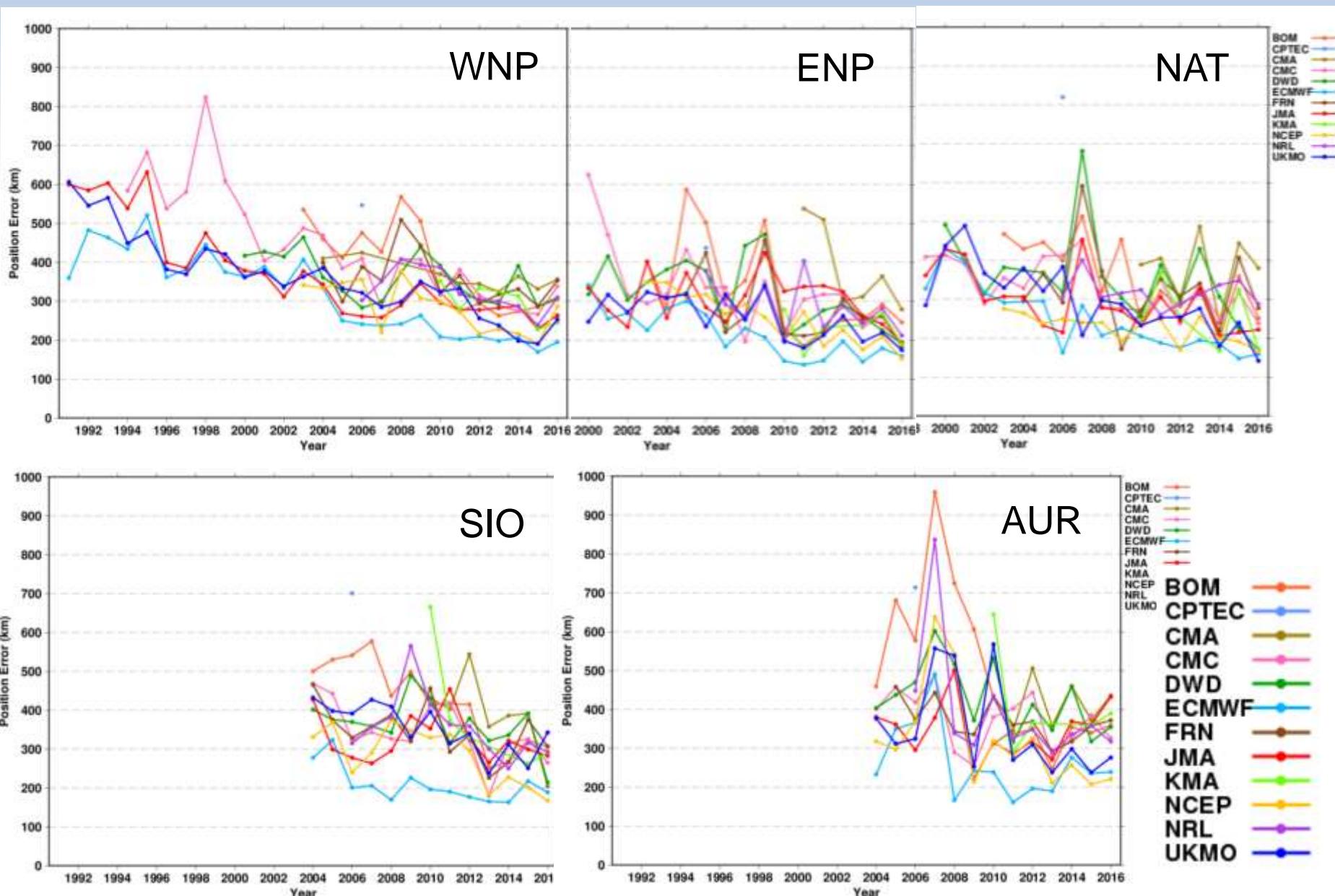


**Western North Pacific**  
**Eastern North Pacific**  
**North Atlantic**  
**South Indian Ocean**  
**Around Australia**  
**detection rate**

- : 100 %  
○ : 0 %



# Transition of FT=72 Position Error over Decade(s)



# TC intercomparison website will be available soon!

**WGNE Intercomparison of Tropical Cyclone Track Forecasts Using Operational Global Models**

Updated: 28 August 2018

[Forecast](#) [Verification](#) [Verification \(regional\)](#) [Introduction](#) [Read Me](#) [Data](#) [Data \(regional\)](#) [Contact](#) [Link](#)

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**Verification Result**

Click on a region of the map to show a pop-up verification.

<[http://nwp-verif.kishou.go.jp/wgne\\_tc/index.html](http://nwp-verif.kishou.go.jp/wgne_tc/index.html)>

Login ID: verif

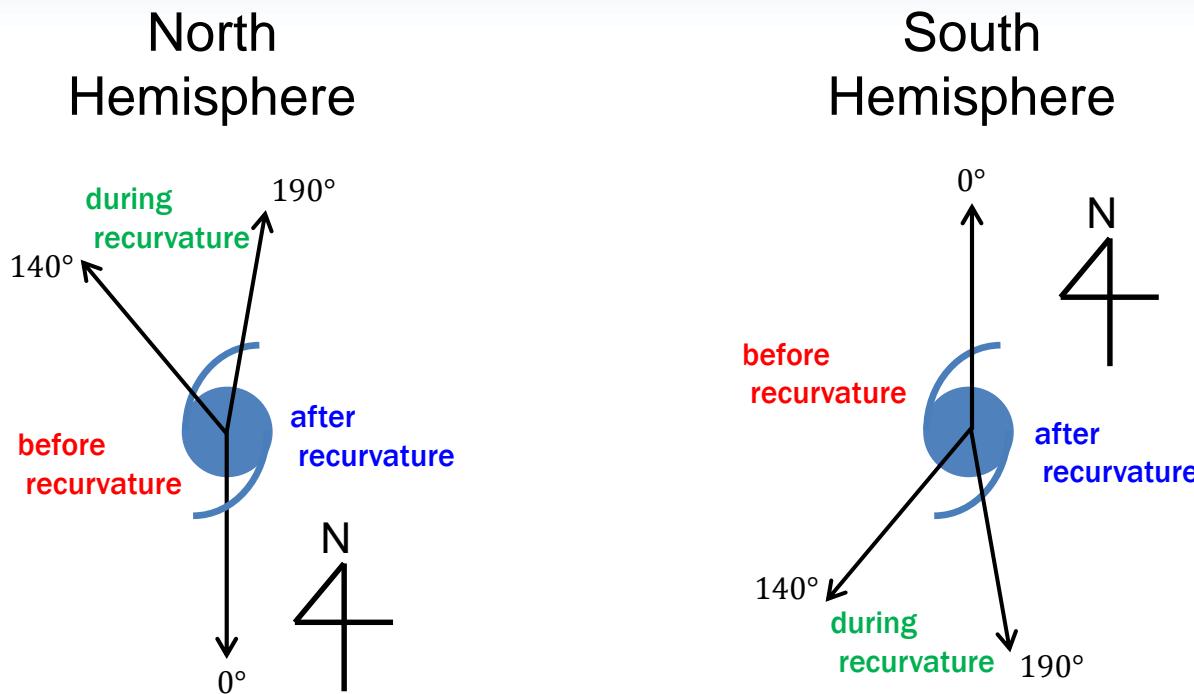
Password: wgne2018 (beyond 15 October 2018)

Contact: [globalnwp@naps.kishou.go.jp](mailto:globalnwp@naps.kishou.go.jp)

# PRELIMINARY SLIDE

# AT-CT Bias

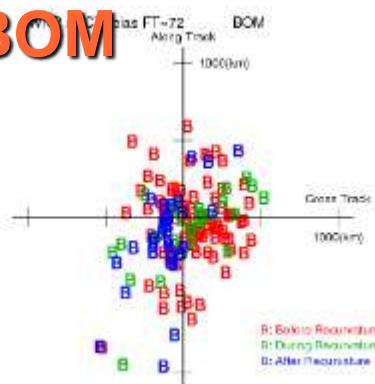
# [Before, During, After] Recurvature



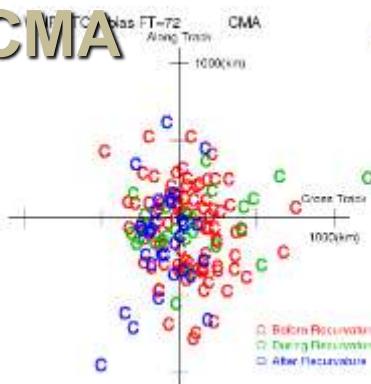
# (a) WNP AT-CT Bias (FT +72)

In 2015

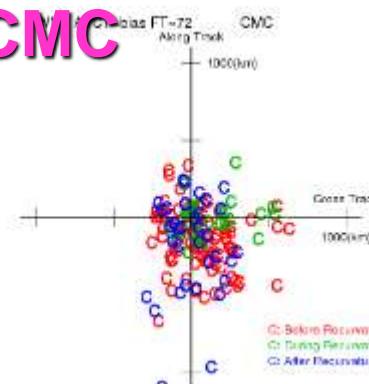
**BOM**



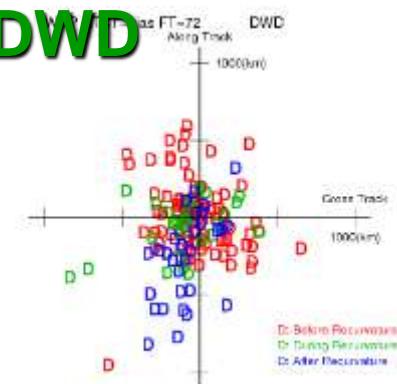
**CMA**



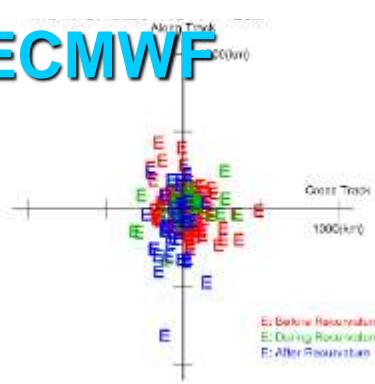
**CMC**



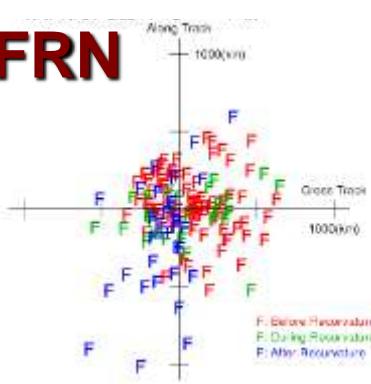
**DWD**



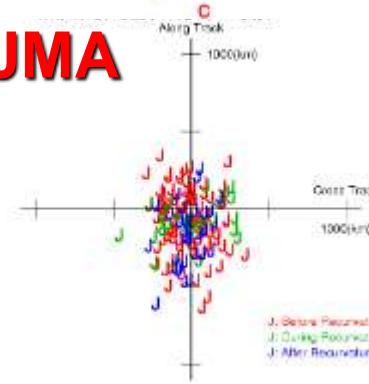
**ECMWF**



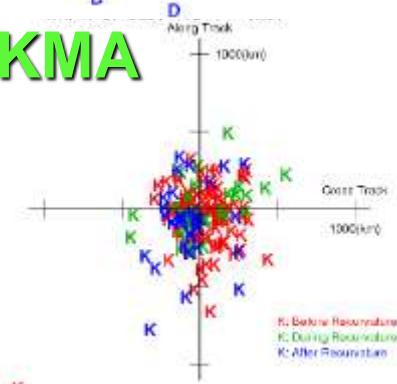
**FRN**



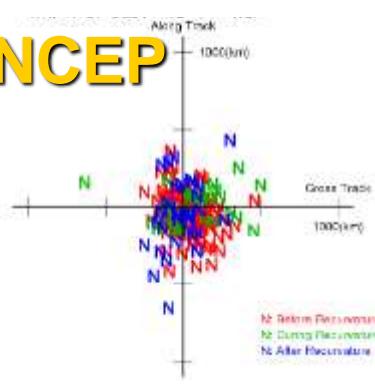
**JMA**



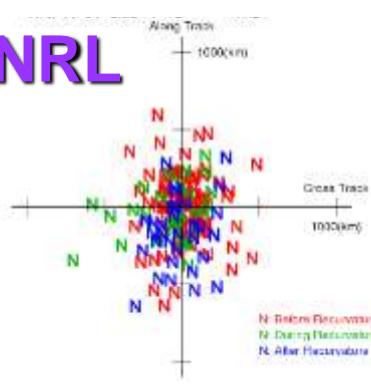
**KMA**



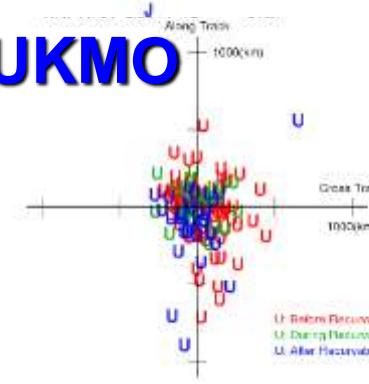
**NCEP**



**NRL**



**UKMO**



Red : before recurvature  
Green : during recurvature  
Blue : after recurvature

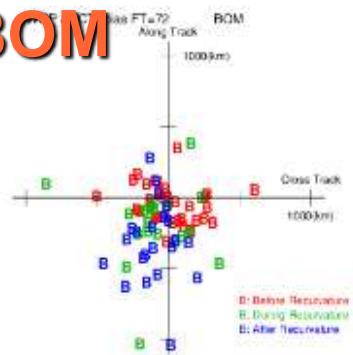
Y-axis : position errors (km)  
in the along track direction

X-axis : position errors (km)  
in the cross track direction

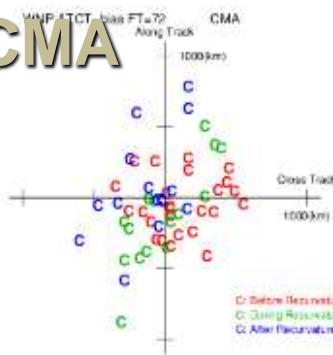


# (a) WNP AT-CT Bias (FT=72)

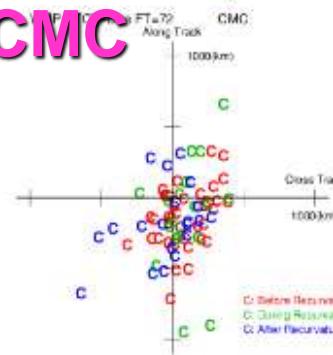
**BOM**



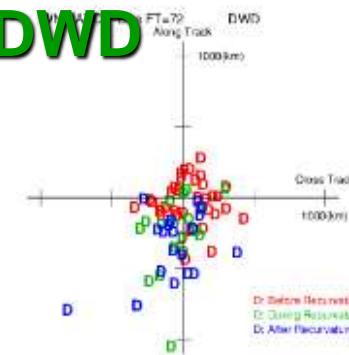
**CMA**



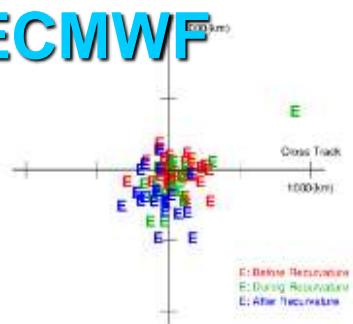
**CMC**



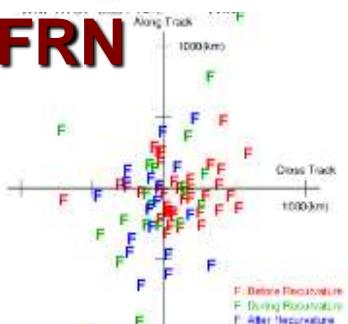
**DWD**



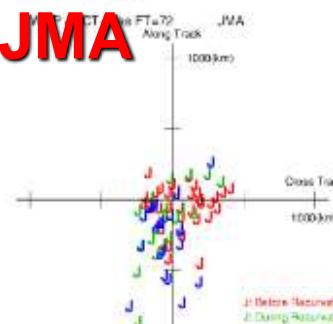
**ECMWF**



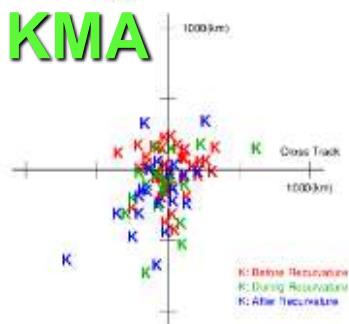
**FRN**



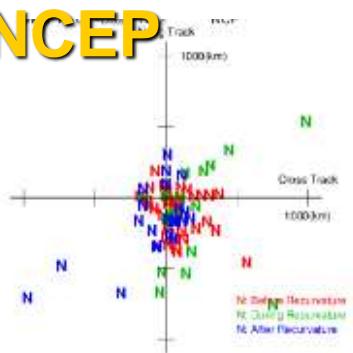
**JMA**



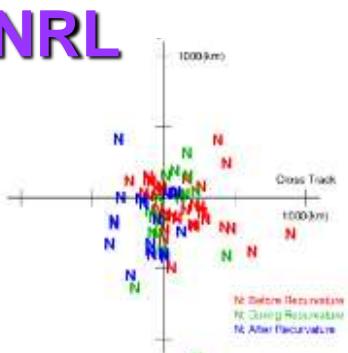
**KMA**



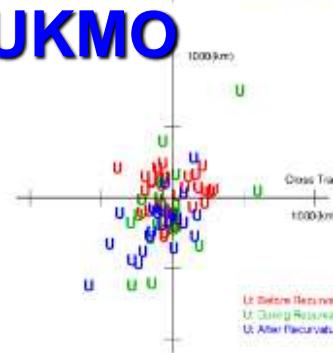
**NCEP**



**NRL**



**UKMO**



Red : before recurvature  
Green : during recurvature  
Blue : after recurvature

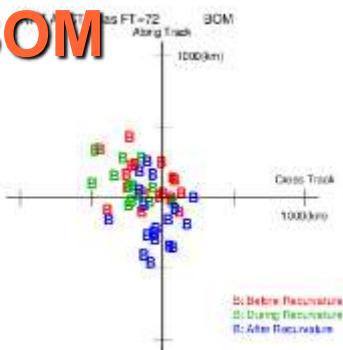
Y-axis : position errors (km)  
in the along track direction

X-axis : position errors (km)  
in the cross track direction

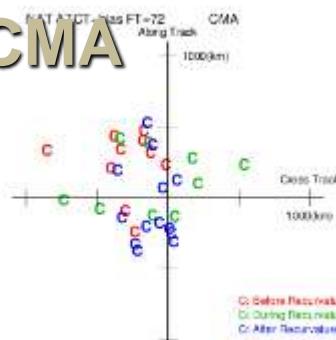


## (b) NAT AT-CT Bias (FT=72)

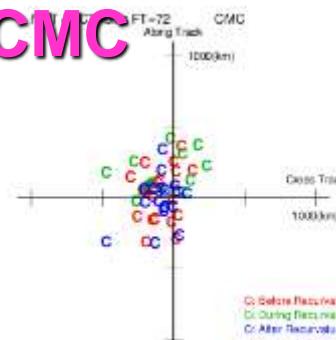
**BOM**



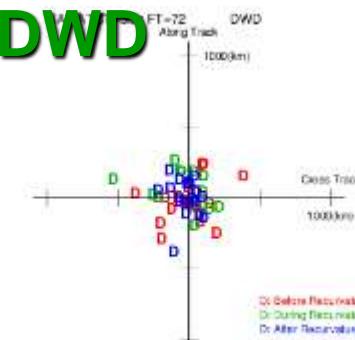
**CMA**



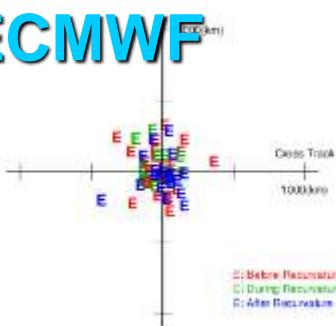
**CMC**



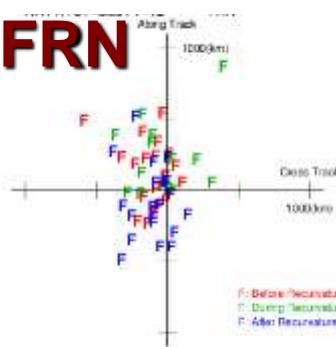
**DWD**



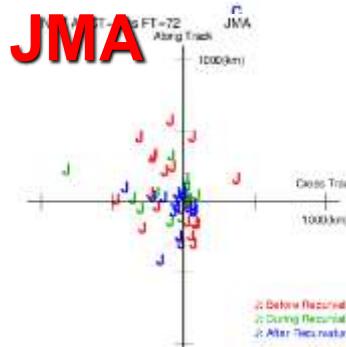
**ECMWF**



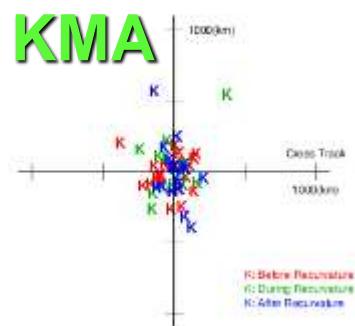
**FRN**



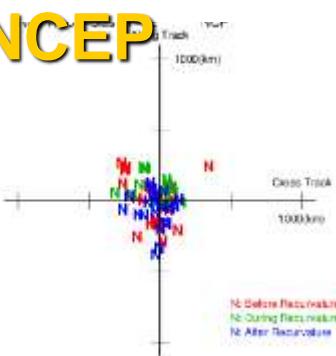
**JMA**



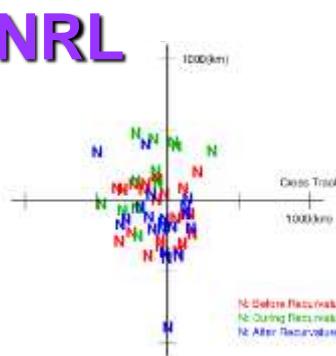
**KMA**



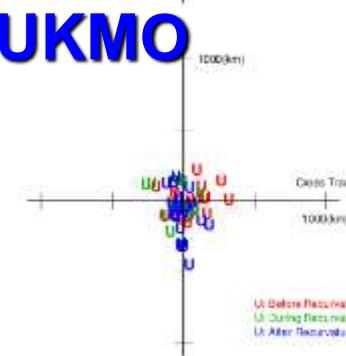
**NCEP**



**NRL**



**UKMO**



Red : before recurvature  
Green : during recurvature  
Blue : after recurvature

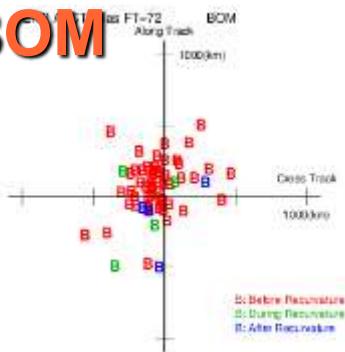
Y-axis : position errors (km)  
in the along track direction

X-axis : position errors (km)  
in the cross track direction

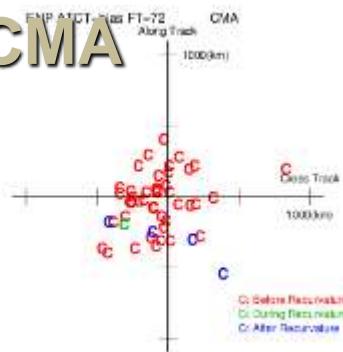


# (c) ENP AT-CT Bias (FT=72)

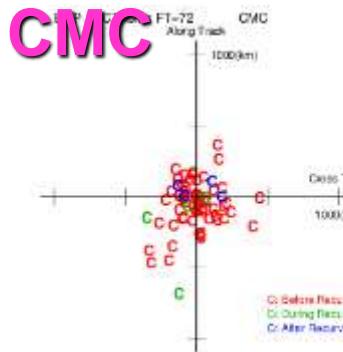
**BOM**



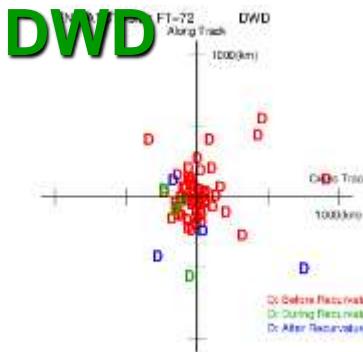
**CMA**



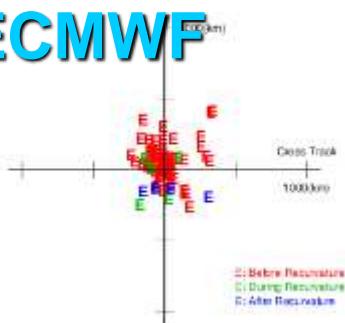
**CMC**



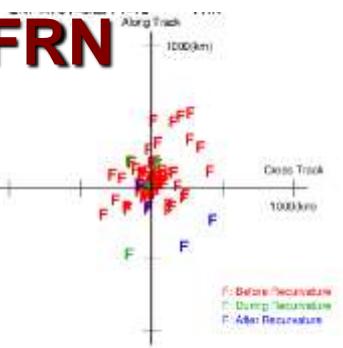
**DWD**



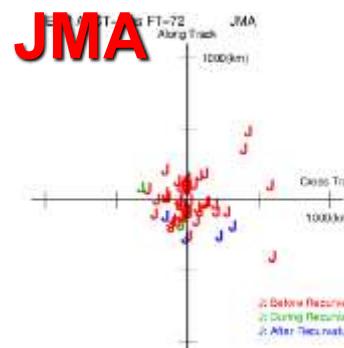
**ECMWF**



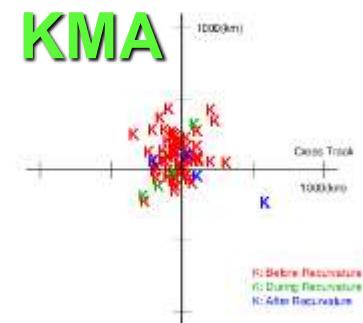
**FRN**



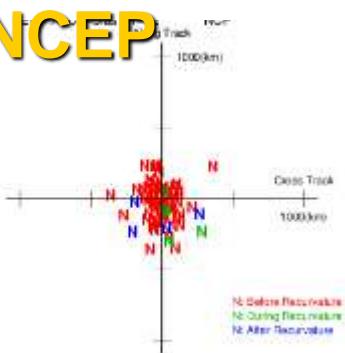
**JMA**



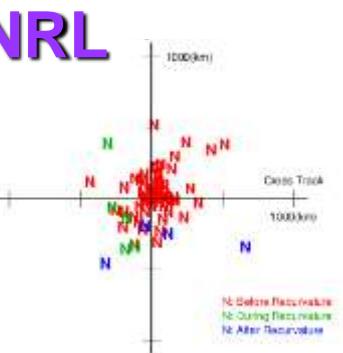
**KMA**



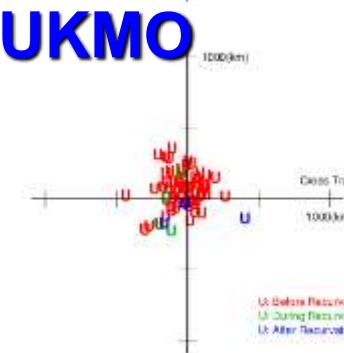
**NCEP**



**NRL**



**UKMO**



Red : before recurvature  
Green : during recurvature  
Blue : after recurvature

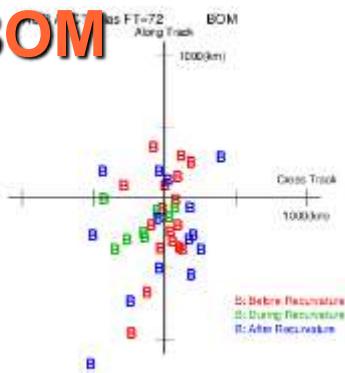
Y-axis : position errors (km)  
in the along track direction

X-axis : position errors (km)  
in the cross track direction

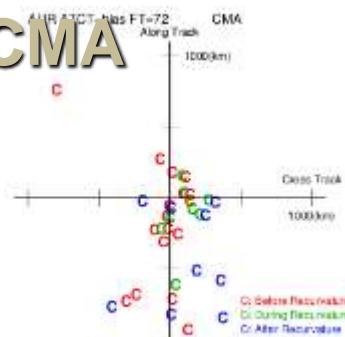


# (d) AUR AT-CT Bias (FT=72)

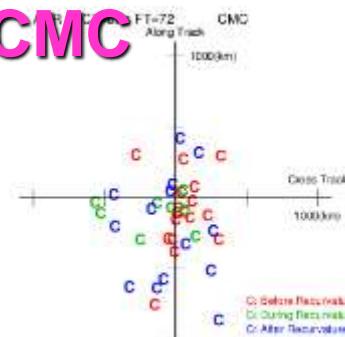
**BOM**



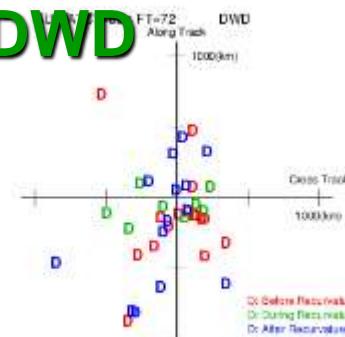
**CMA**



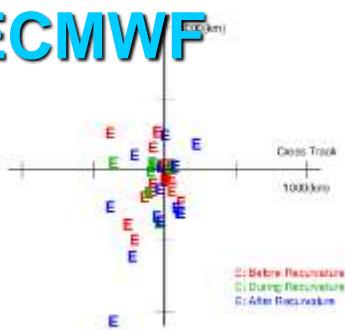
**CMC**



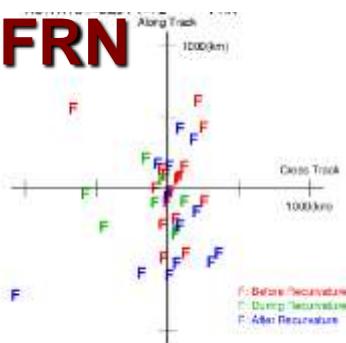
**DWD**



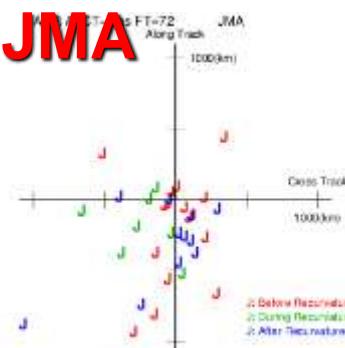
**ECMWF**



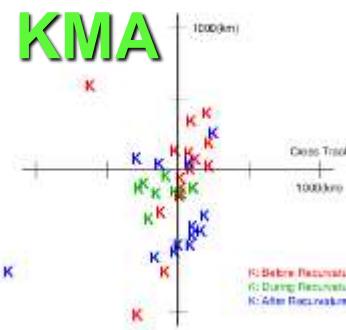
**FRN**



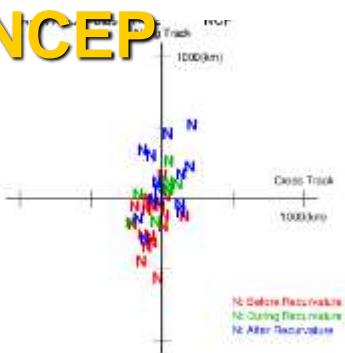
**JMA**



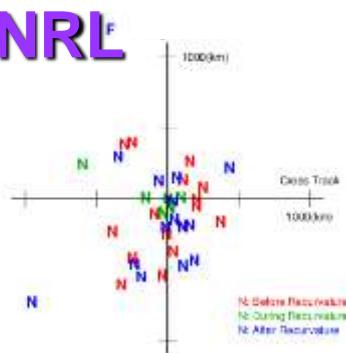
**KMA**



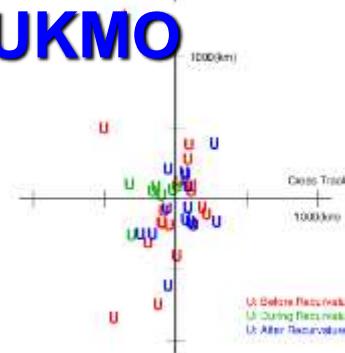
**NCEP**



**NRL**



**UKMO**



Red : before recurvature  
 Green : during recurvature  
 Blue : after recurvature

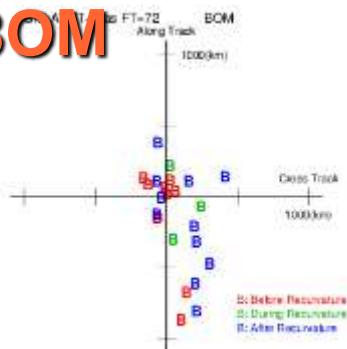
Y-axis : position errors (km)  
 in the along track direction

X-axis : position errors (km)  
 in the cross track direction

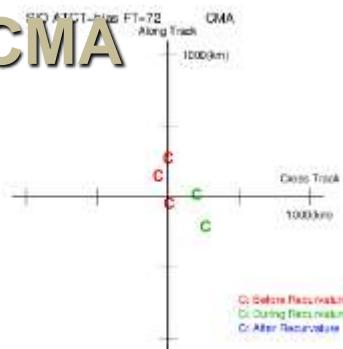


# (e) SIO AT-CT Bias (FT=72)

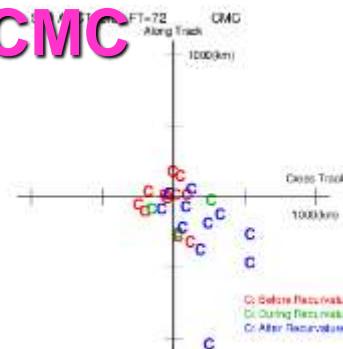
**BOM**



**CMA**



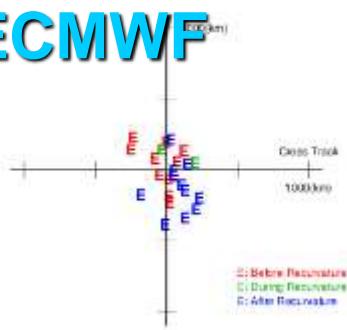
**CMC**



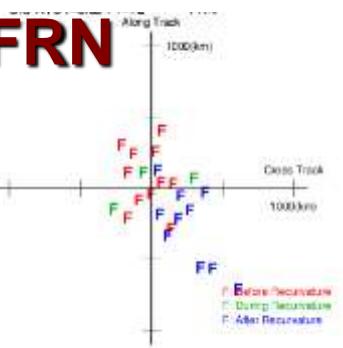
**DWD**



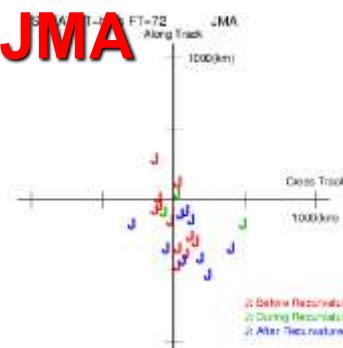
**ECMWF**



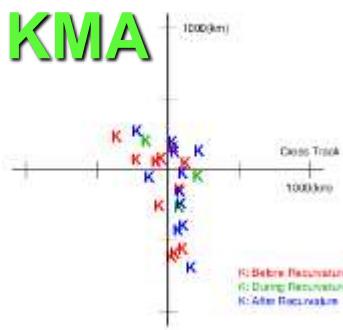
**FRN**



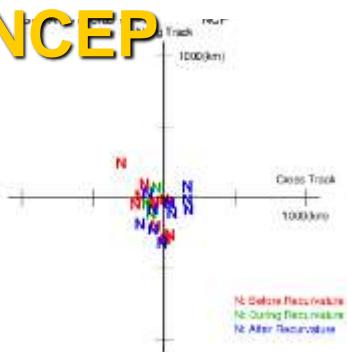
**JMA**



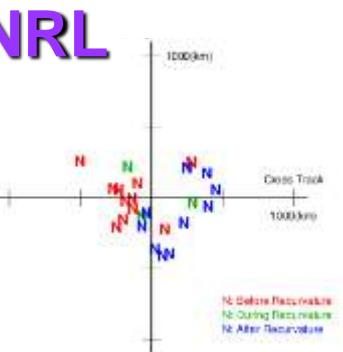
**KMA**



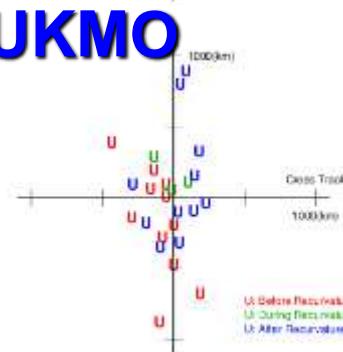
**NCEP**



**NRL**



**UKMO**



Red : before recurvature  
Green : during recurvature  
Blue : after recurvature

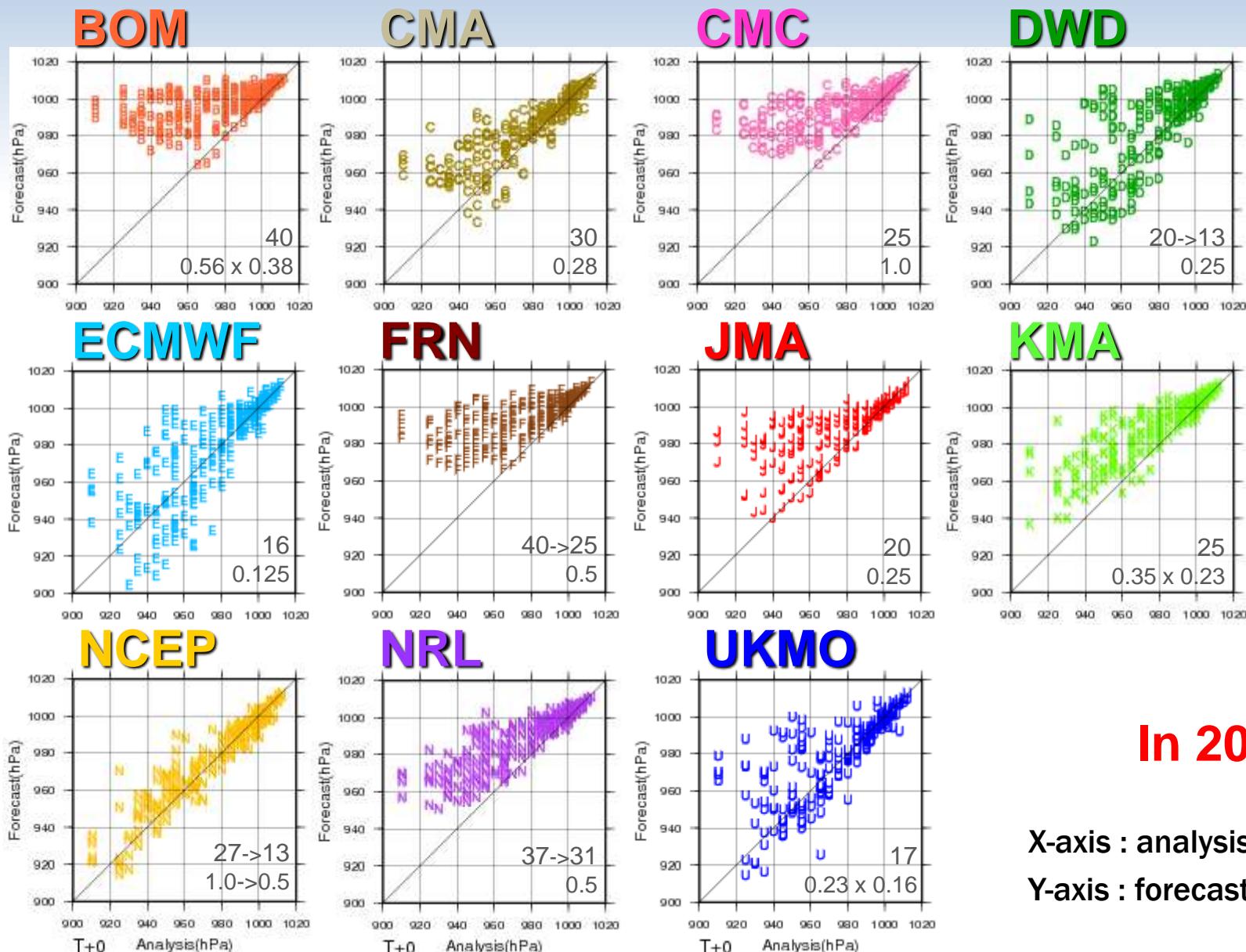
Y-axis : position errors (km)  
in the along track direction

X-axis : position errors (km)  
in the cross track direction

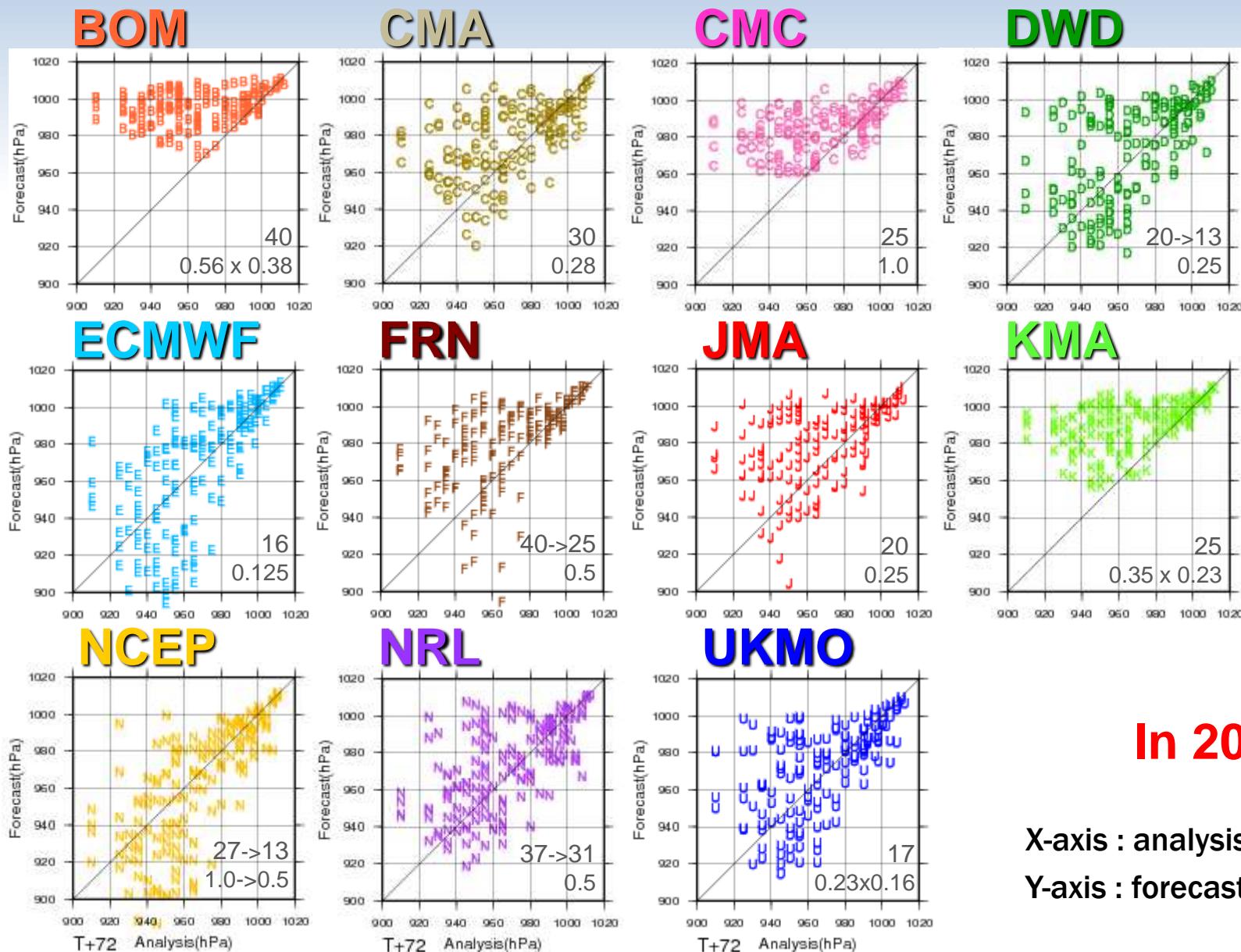


# Central Pressure Scatter Diagram

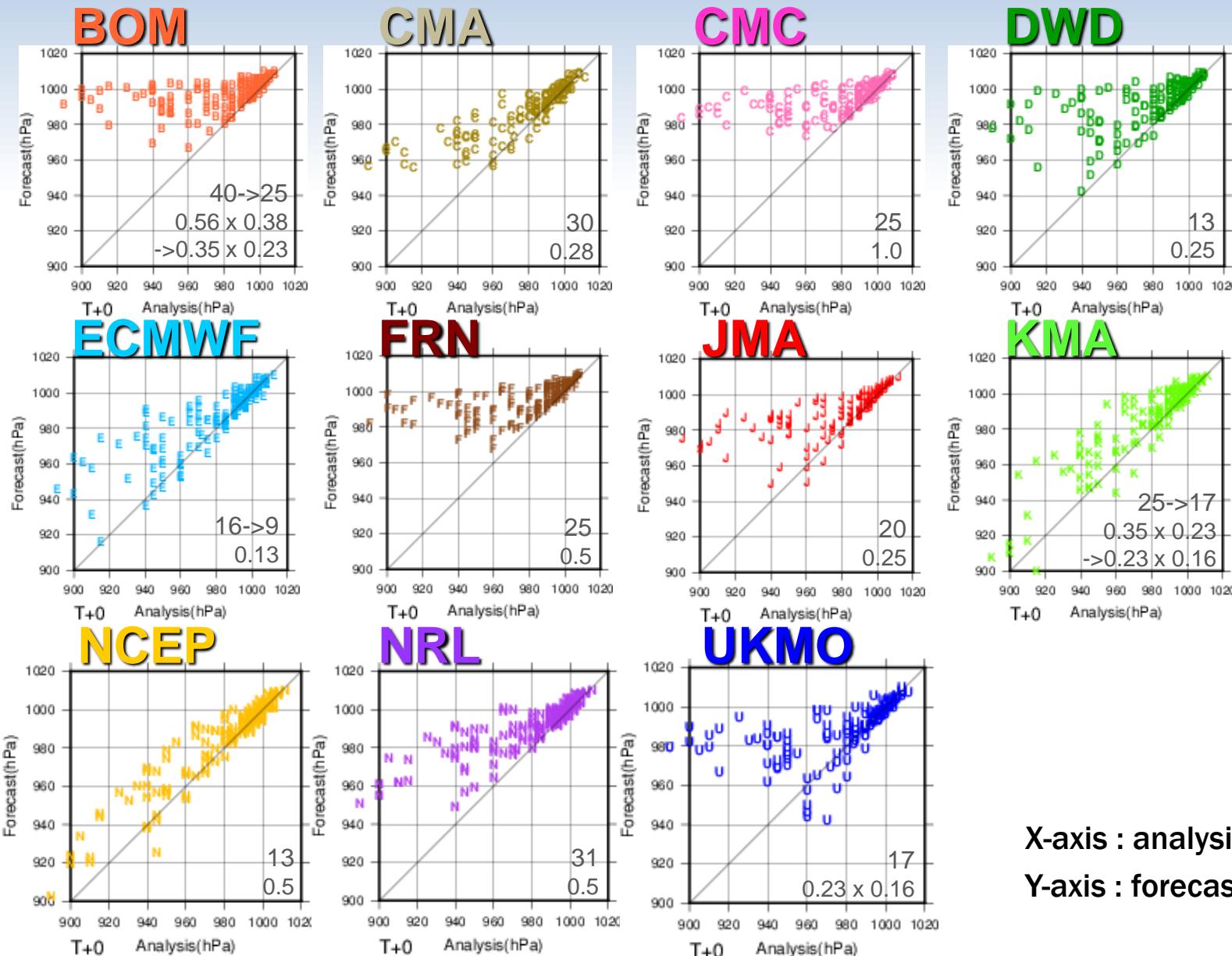
# (a) WNP Central Pressure Scatter Diagram (FT +0)



# (a) WNP Central Pressure Scatter Diagram (FT +72)



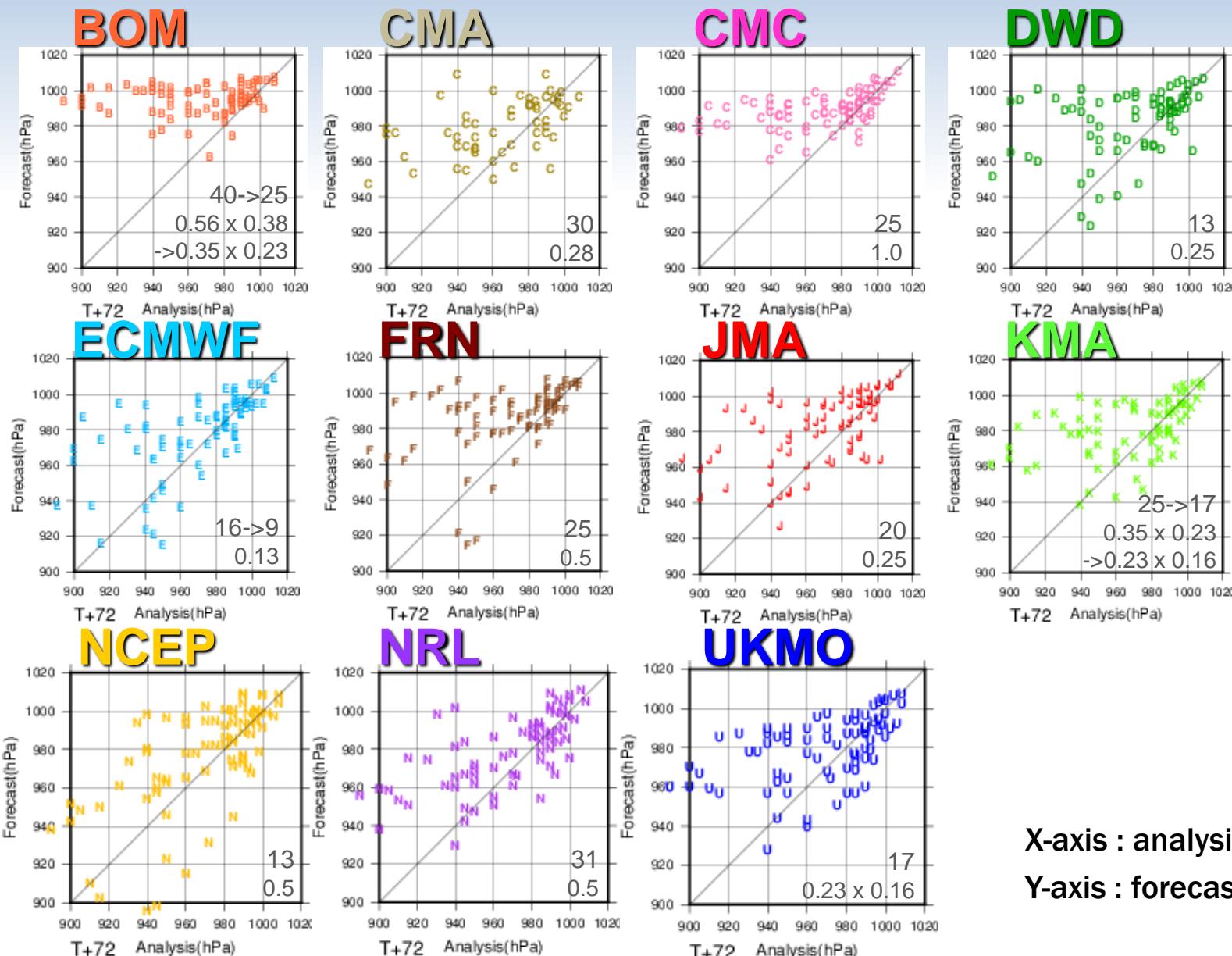
# (a) WNP Central Pressure Scatter Diagram (FT +0)



Resolution  
Model (km)  
Data (deg)

X-axis : analysis  
Y-axis : forecast

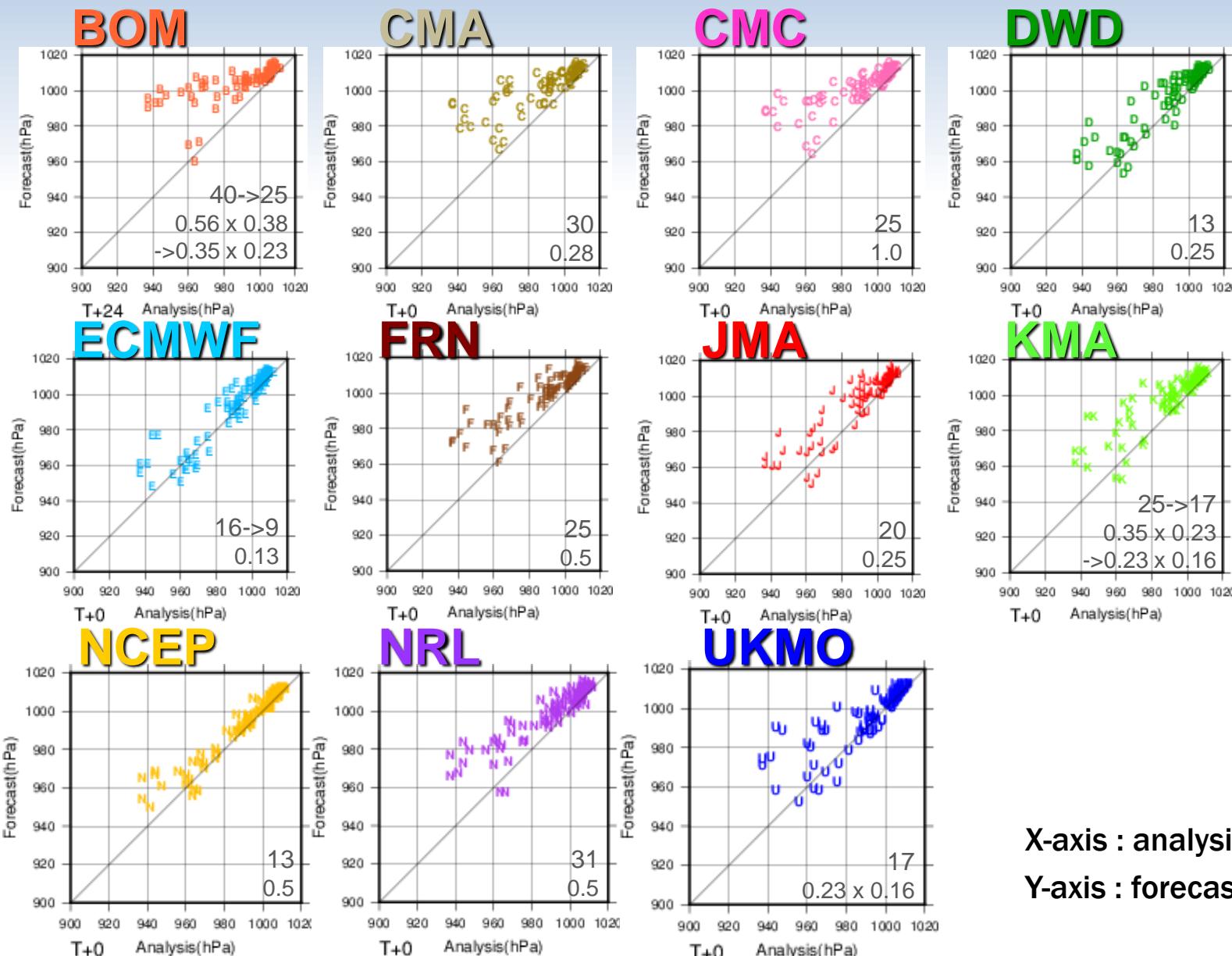
# (a) WNP Central Pressure Scatter Diagram (FT +72)



Resolution  
Model (km)  
Data (deg)

X-axis : analysis  
Y-axis : forecast

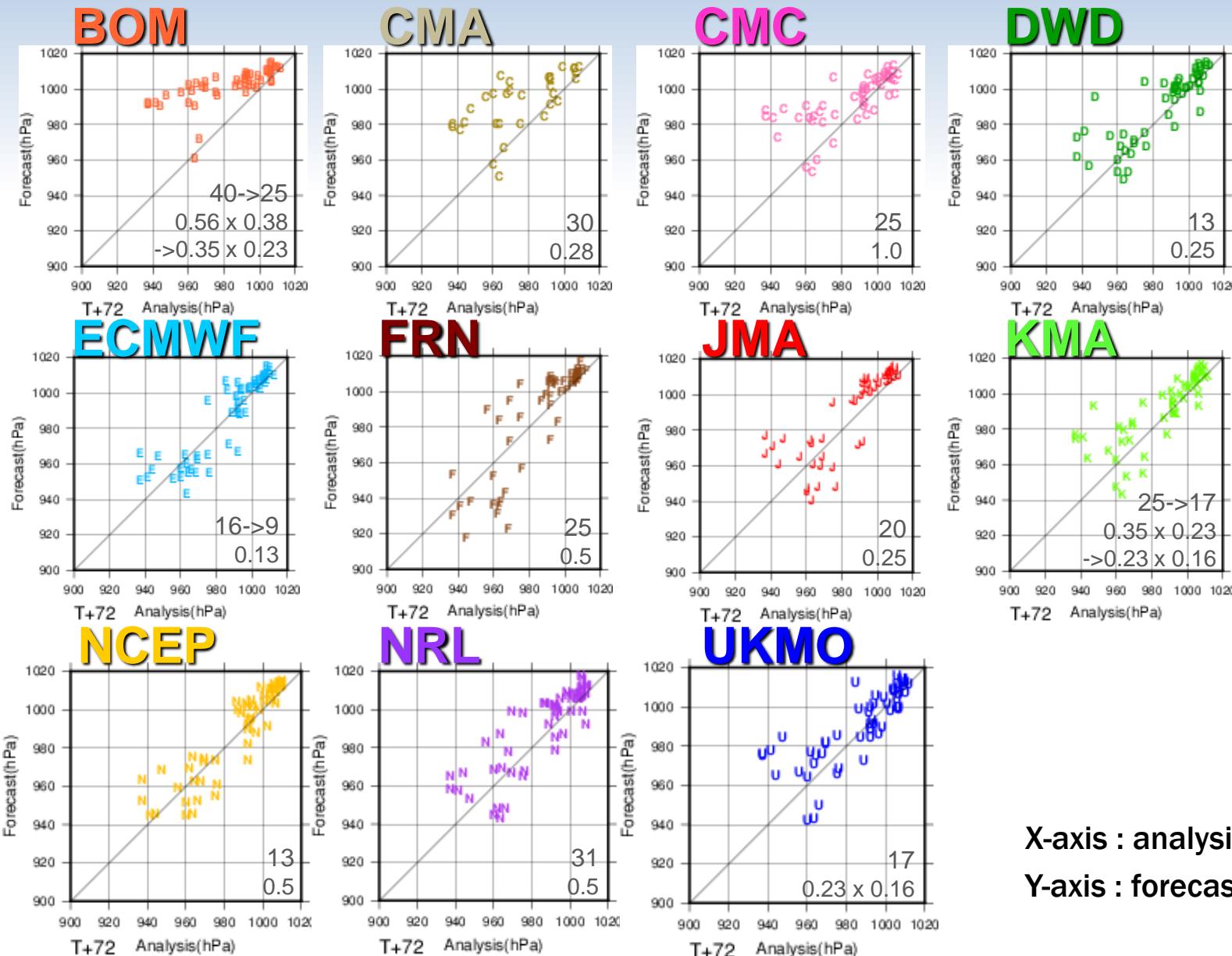
# (b) NAT Central Pressure Scatter Diagram (FT +0)



Resolution  
Model (km)  
Data (deg)

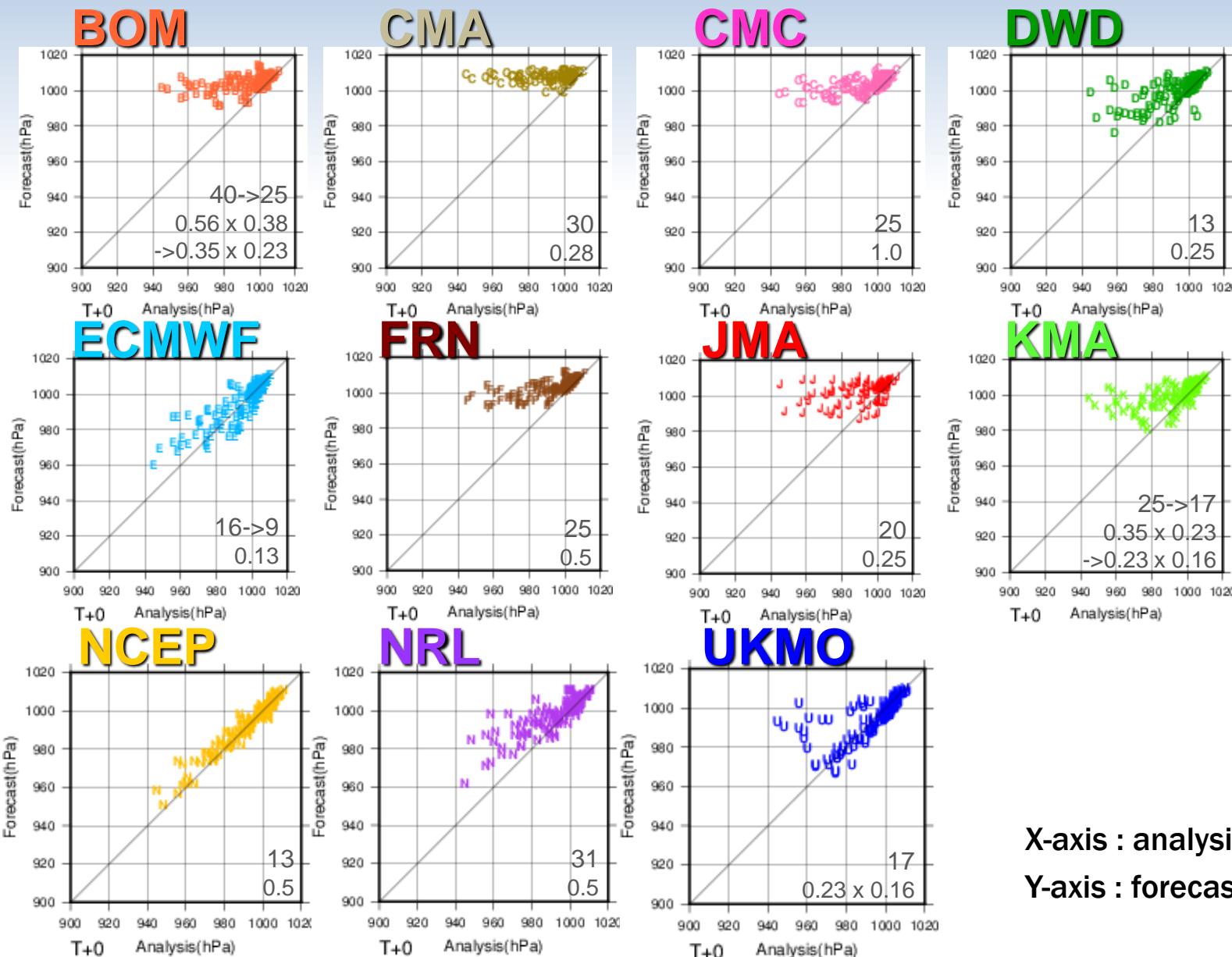
X-axis : analysis  
Y-axis : forecast

# (b) NAT Central Pressure Scatter Diagram (FT +72)

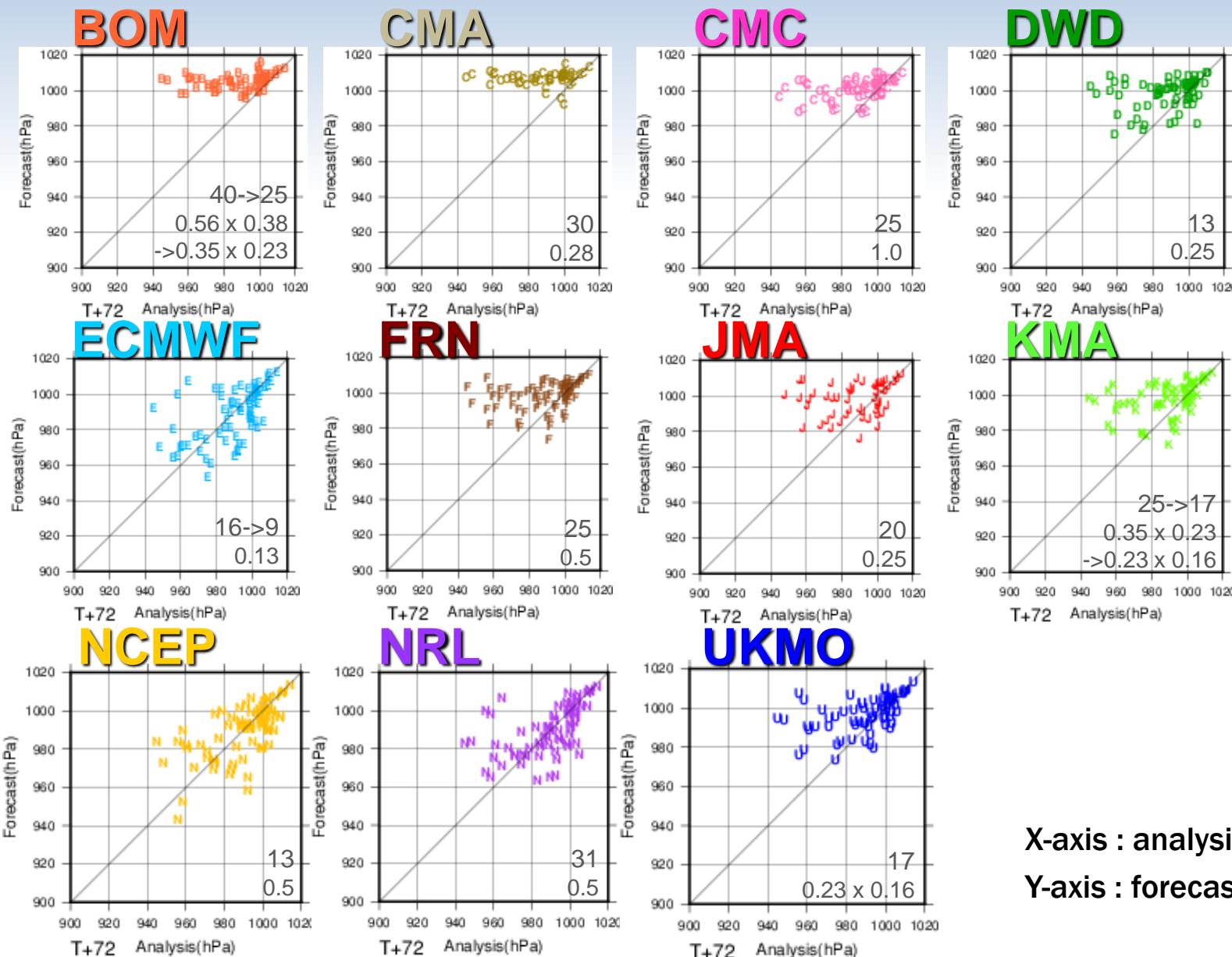


X-axis : analysis  
Y-axis : forecast

# (c) ENP Central Pressure Scatter Diagram (FT +0)



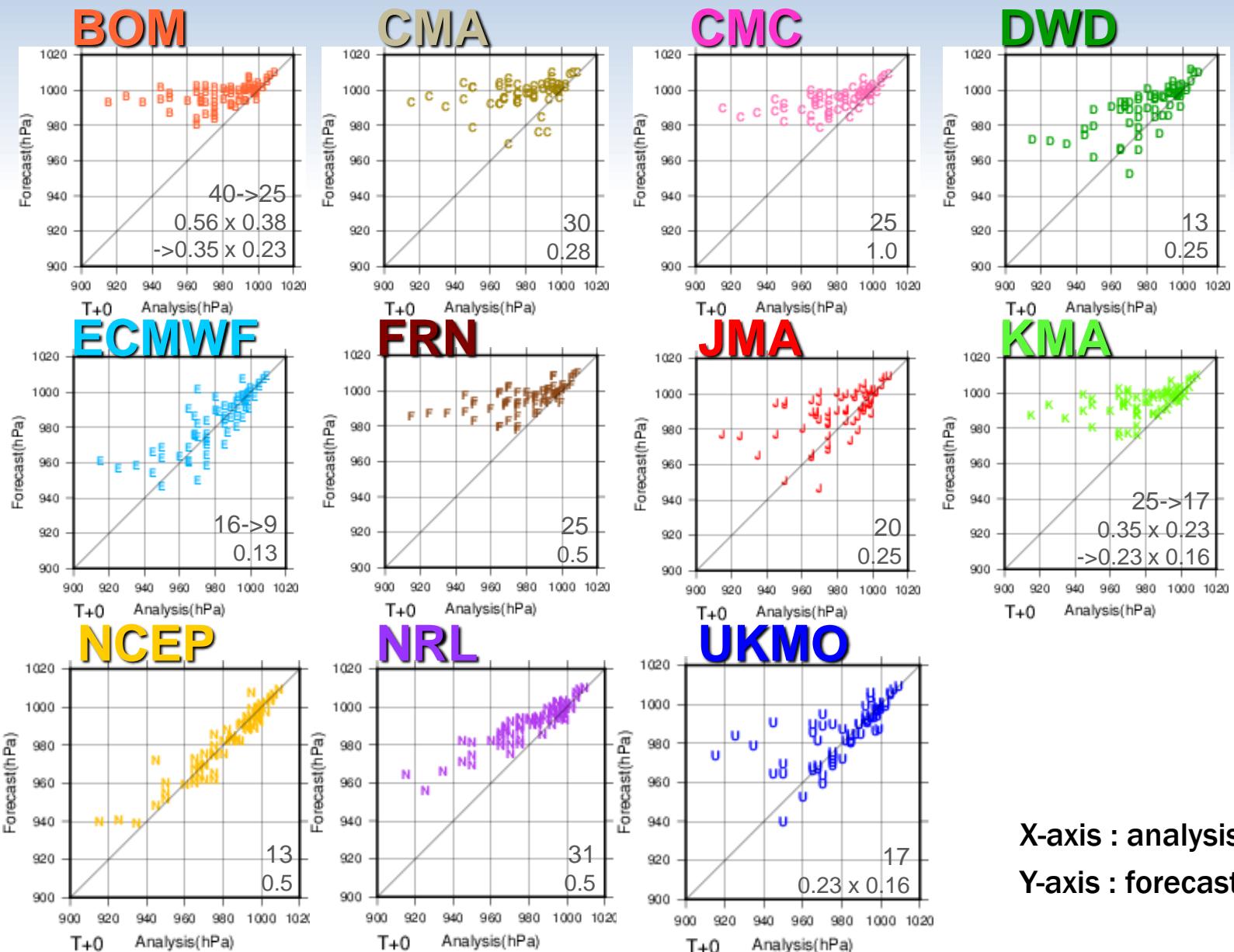
# (c) ENP Central Pressure Scatter Diagram (FT +72)



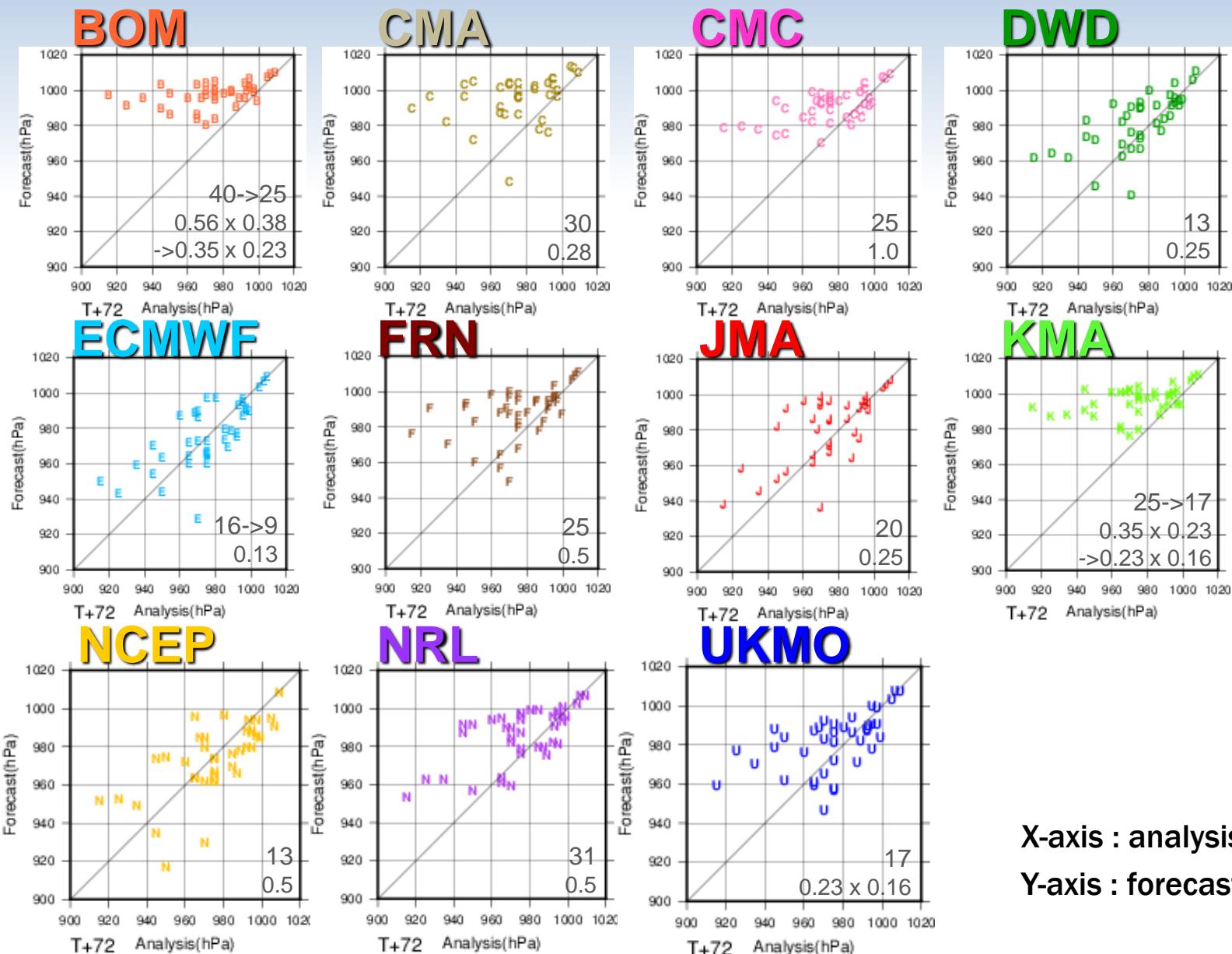
Resolution  
Model (km)  
Data (deg)

X-axis : analysis  
Y-axis : forecast

# (d) AUR Central Pressure Scatter Diagram (FT +0)

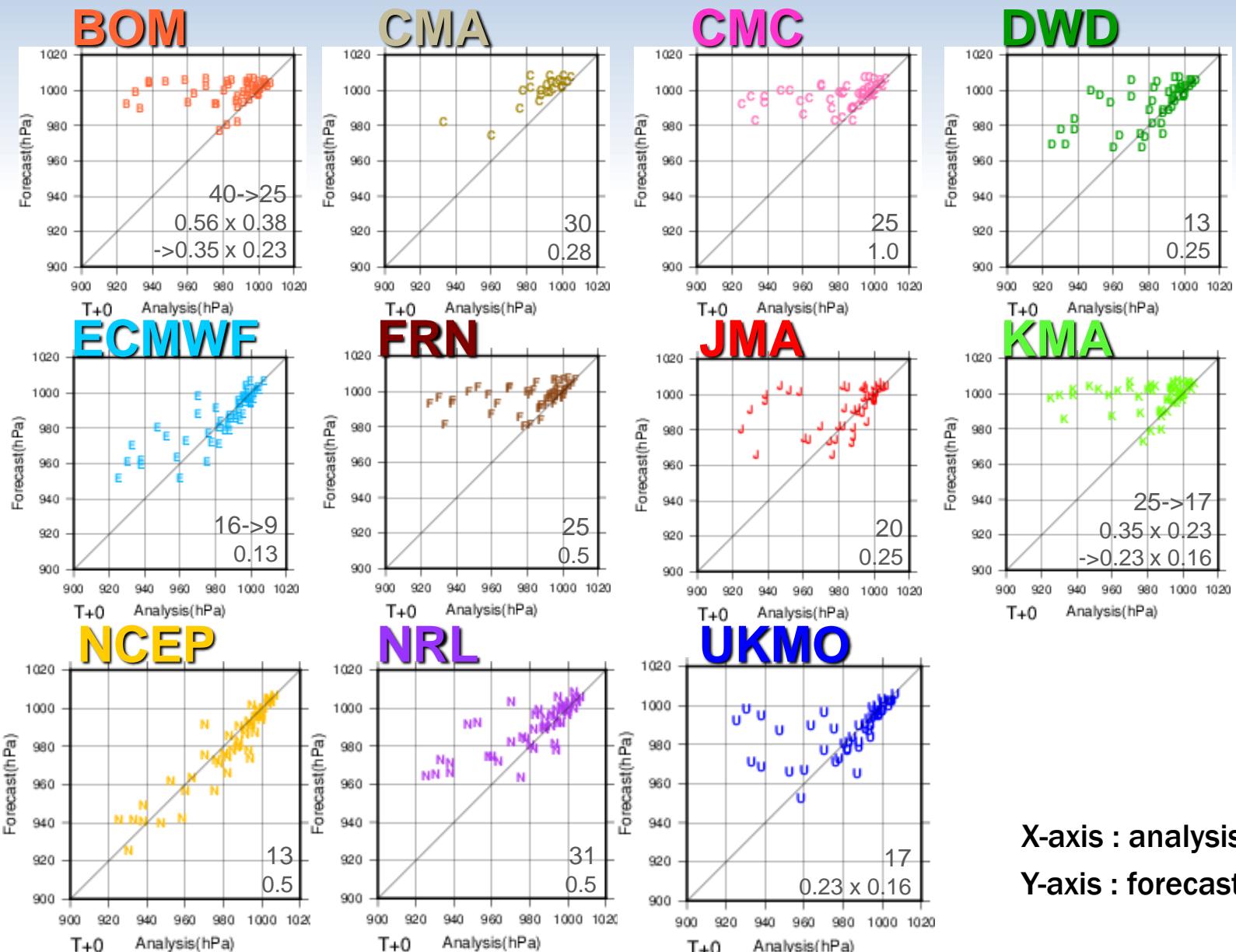


# (d) AUR Central Pressure Scatter Diagram (FT +72)

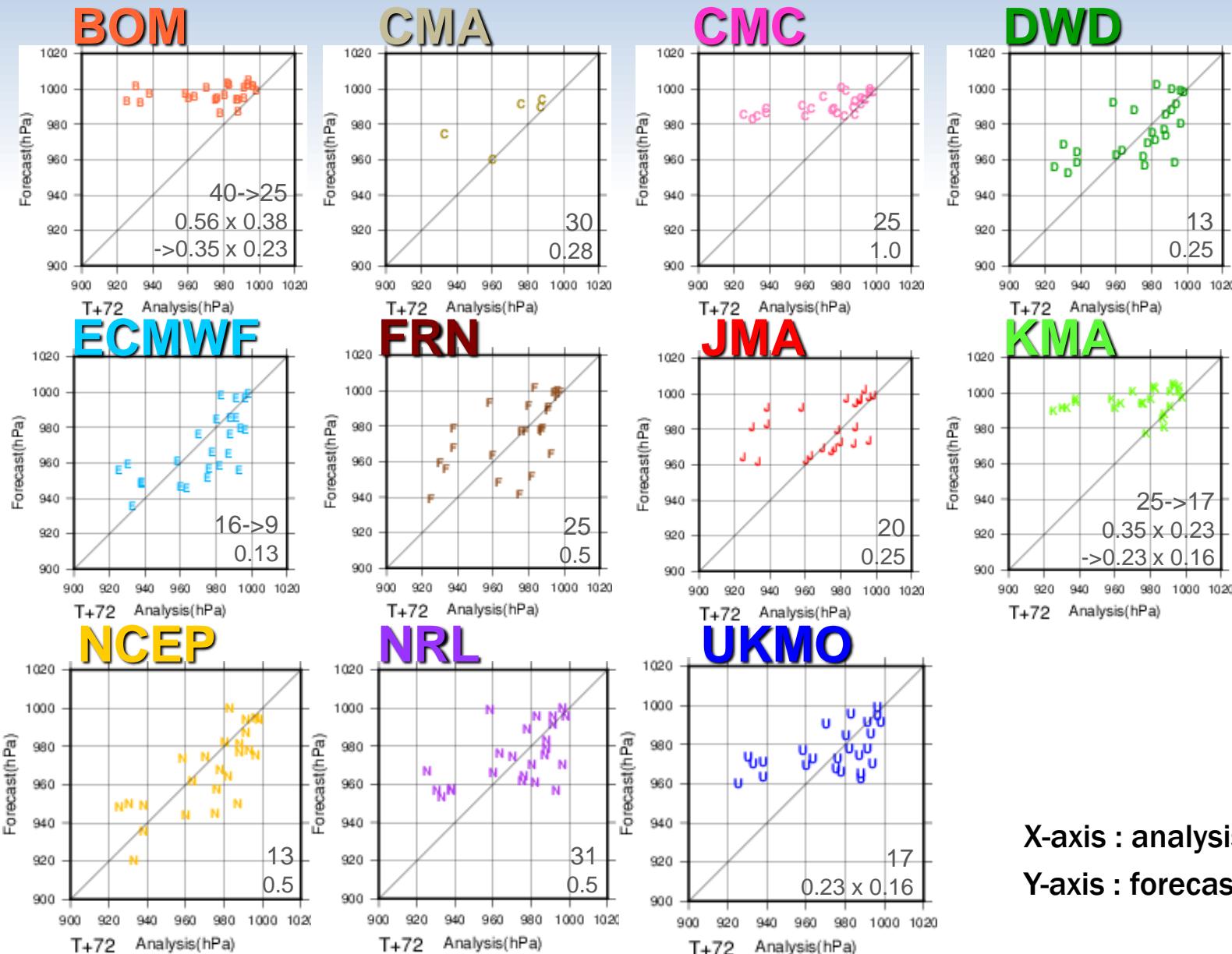


X-axis : analysis  
Y-axis : forecast

# (e) SIO Central Pressure Scatter Diagram (FT +0)

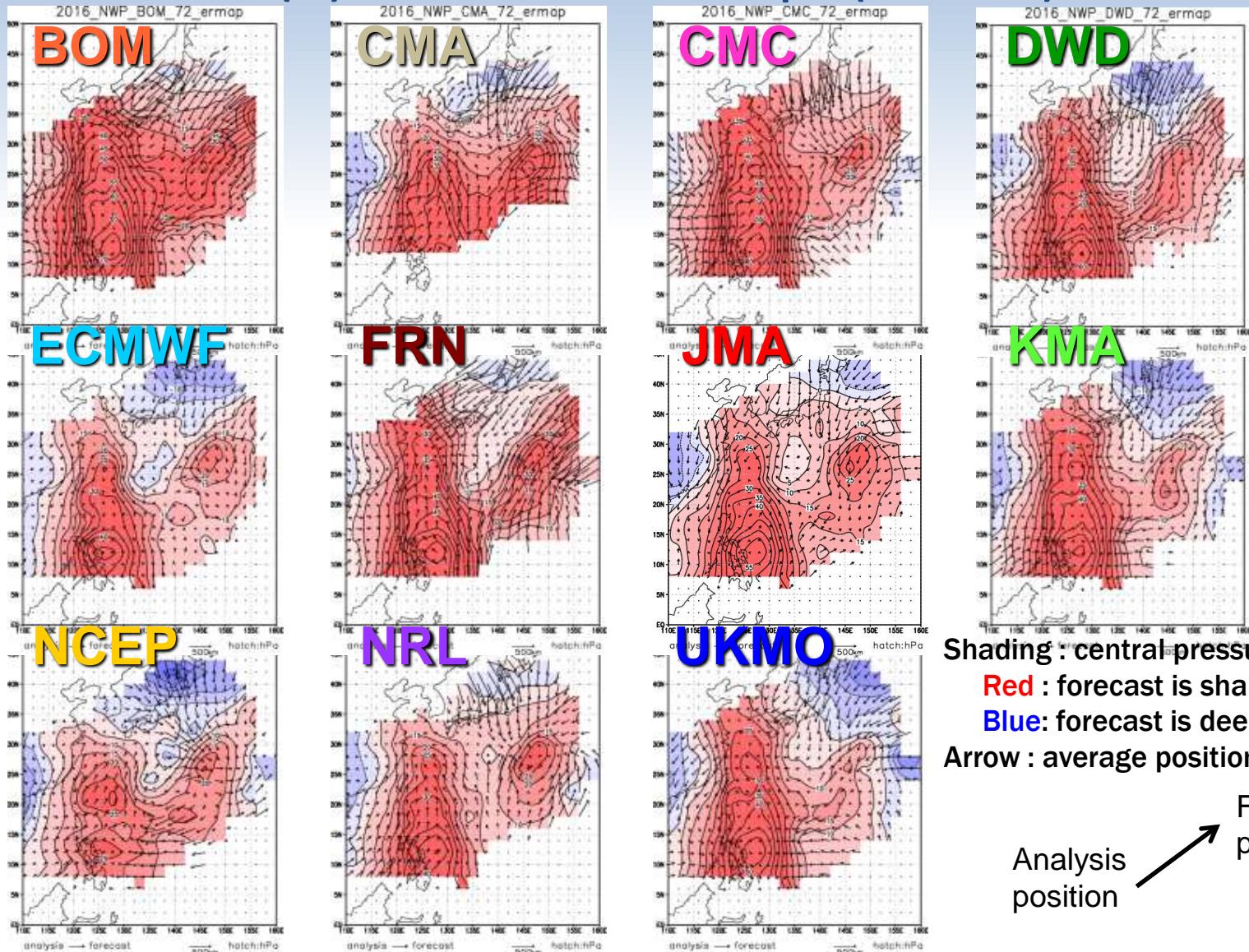


# (e) SIO Central Pressure Scatter Diagram (FT +72)



# Error Map

# (a) WNP Error Map (FT=72)



Shading : central pressure error (hPa)

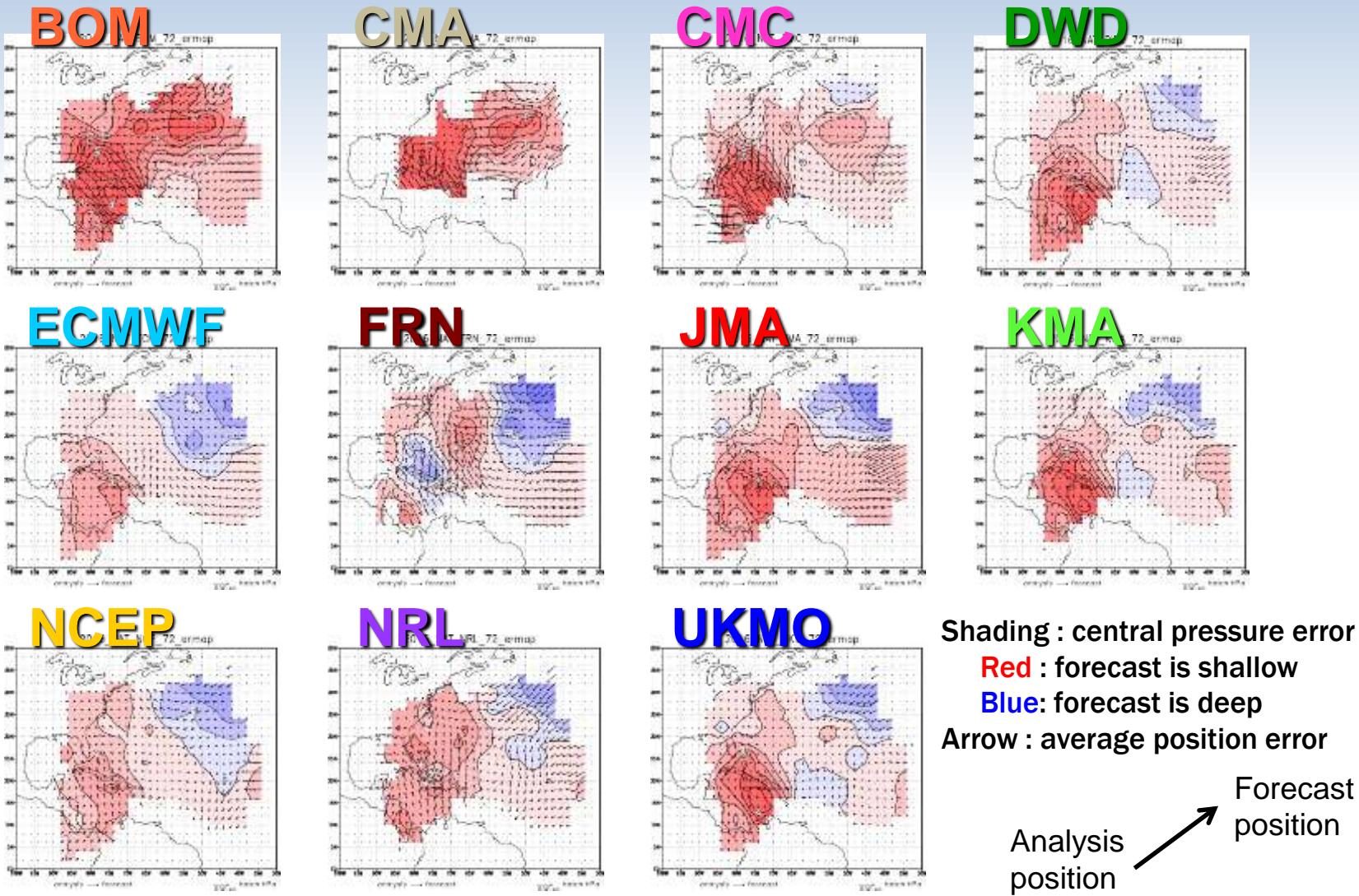
Red : forecast is shallow

Blue: forecast is deep

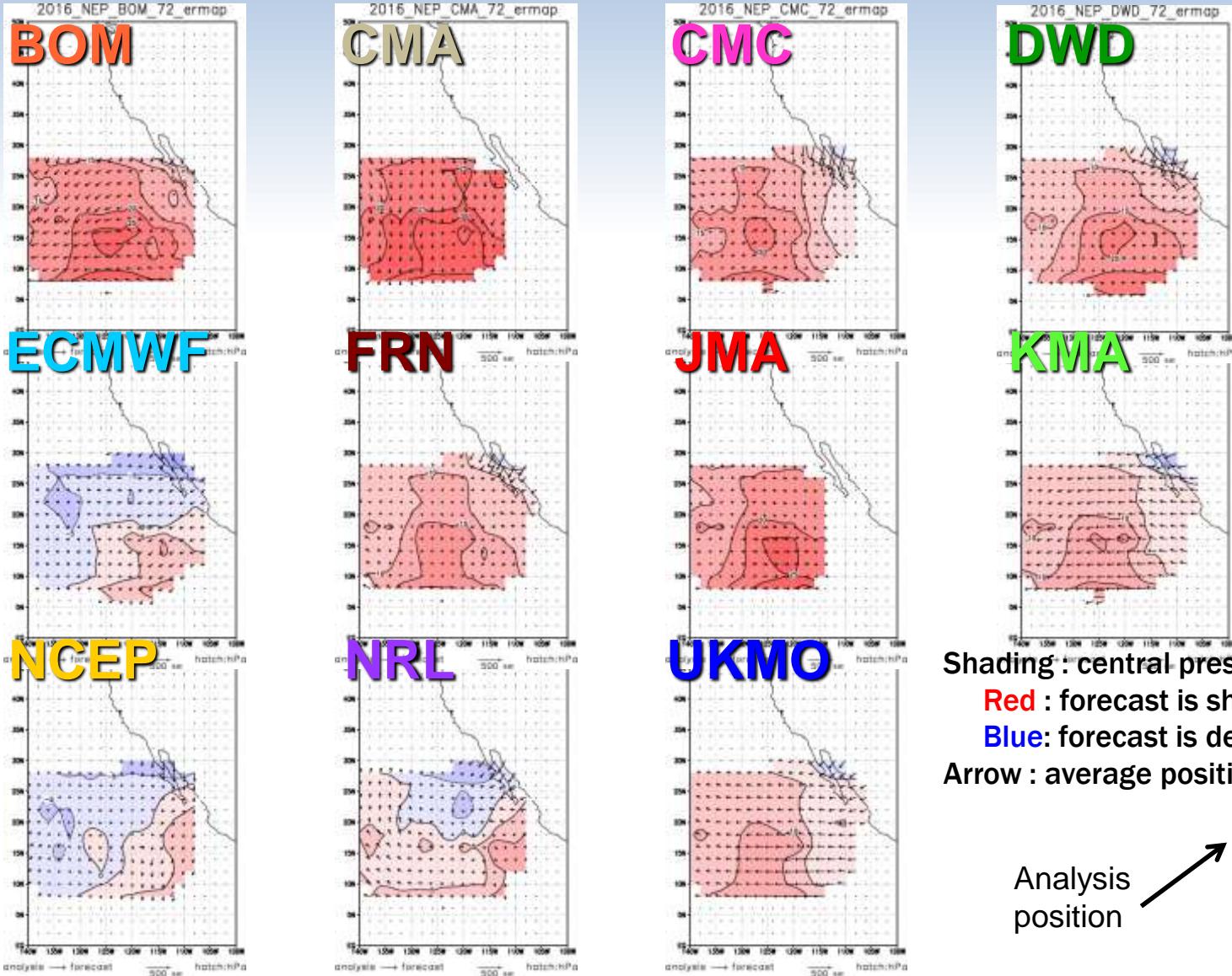
Arrow : average position error

Forecast position  
Analysis position

## (b) NAT Error Map (FT=72)



# (c) ENP Error Map (FT=72)



Shading : central pressure error (hPa)

Red : forecast is shallow

Blue: forecast is deep

Arrow : average position error

Forecast  
position

Analysis  
position

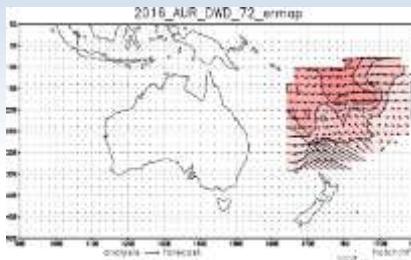
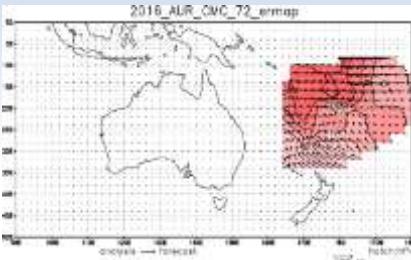
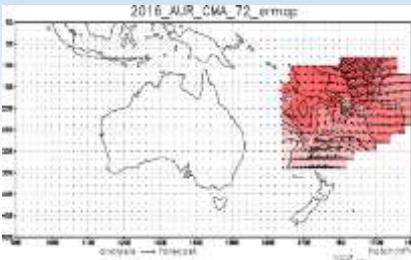
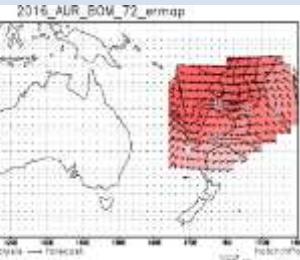
# (d) AUR Error Map (FT=72)

**BOM**

**CMA**

**CMC**

**DWD**

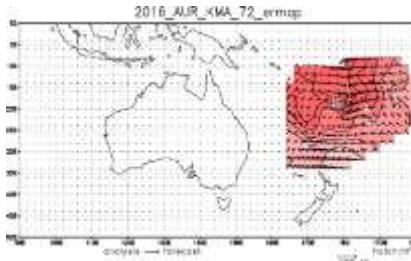
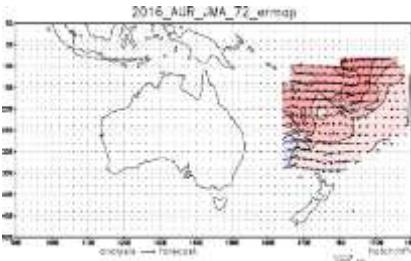
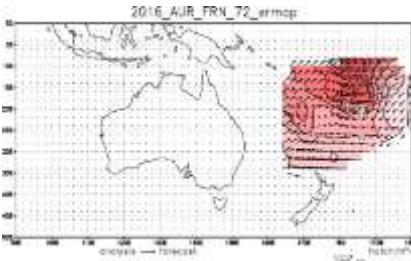
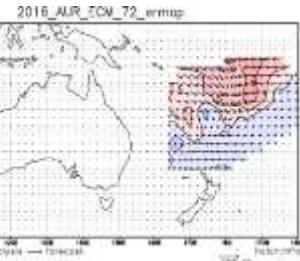


**ECMWF**

**FRN**

**JMA**

**KMA**



**NCEP**

**NRL**

**UKMO**

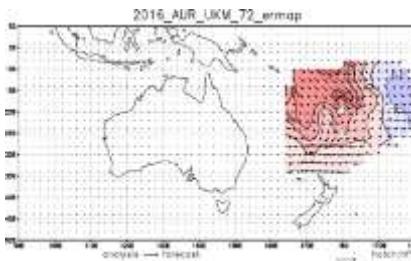
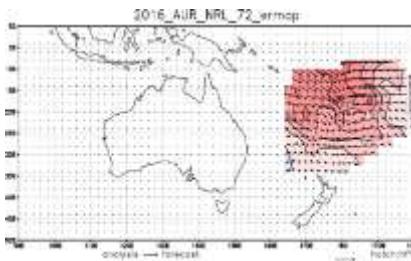
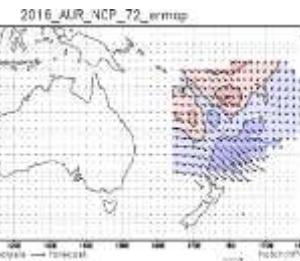
Shading : central pressure error (hPa)

Red : forecast is shallow

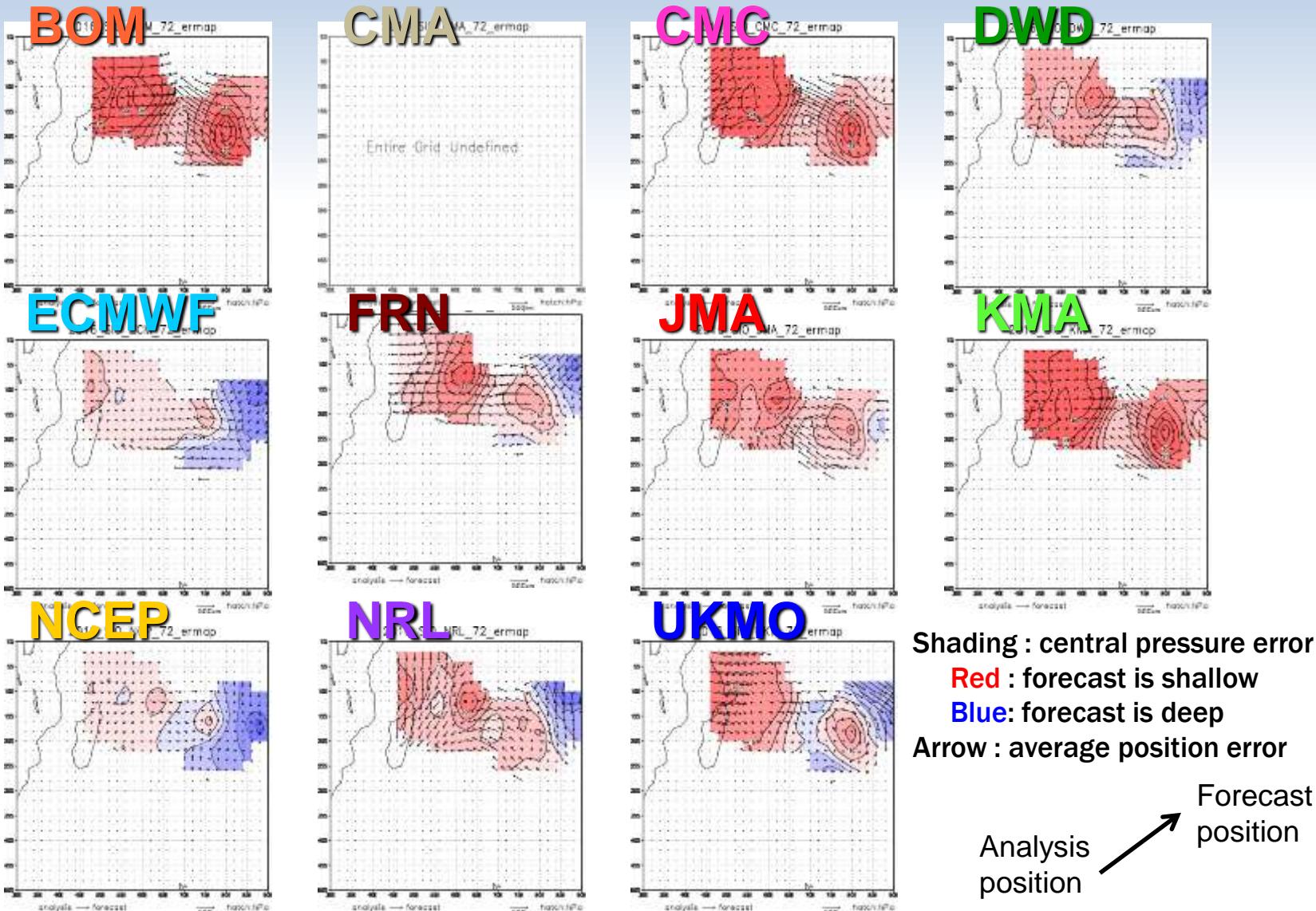
Blue: forecast is deep

Arrow : average position error

Forecast position  
Analysis position



# (e) SIO Error Map (FT=72)



Shading : central pressure error (hPa)

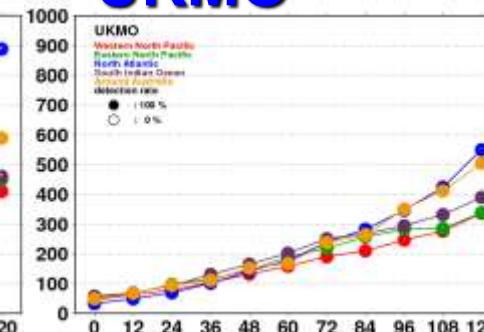
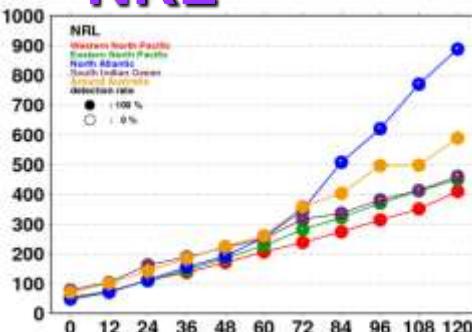
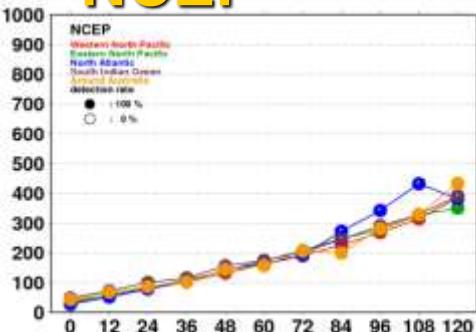
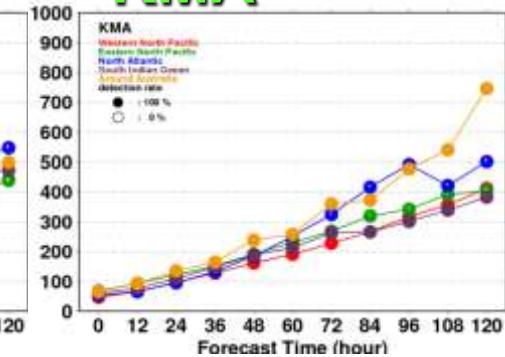
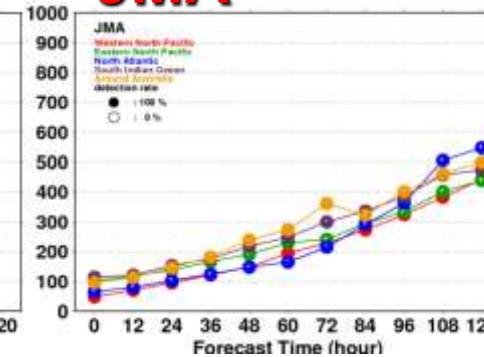
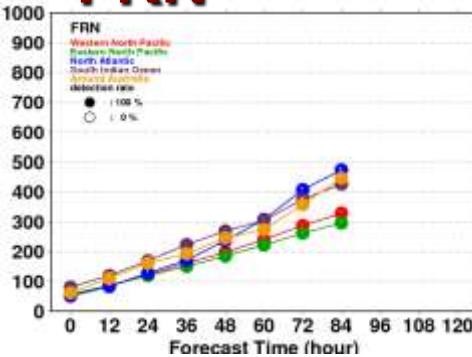
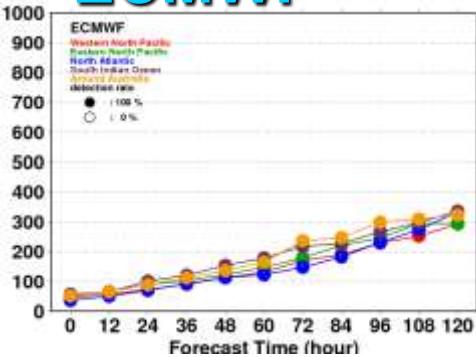
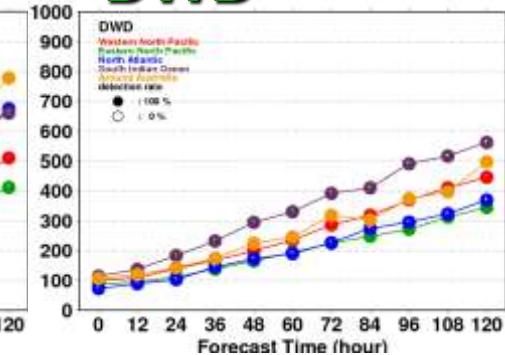
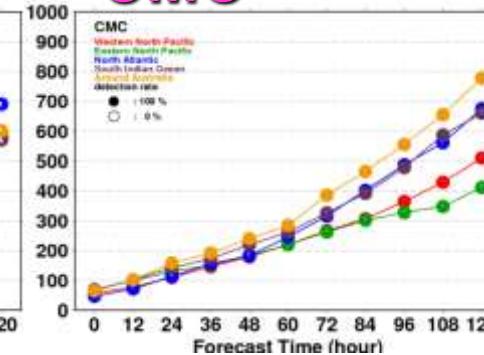
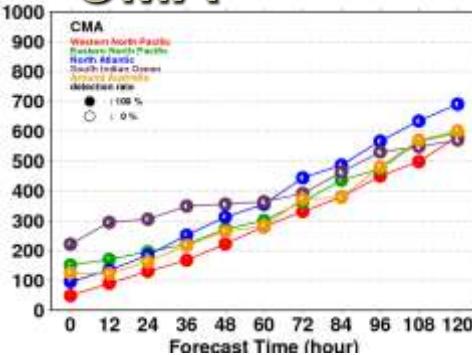
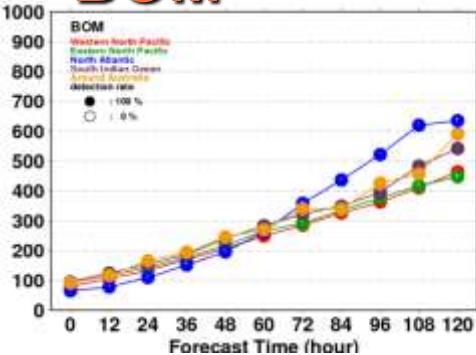
Red : forecast is shallow

Blue: forecast is deep

Arrow : average position error

Forecast position  
Analysis position

# Visualization with “Pie-chart” in 2015



**Western North Pacific**  
**Eastern North Pacific**  
**North Atlantic**  
**South Indian Ocean**  
**Around Australia**  
**detection rate**

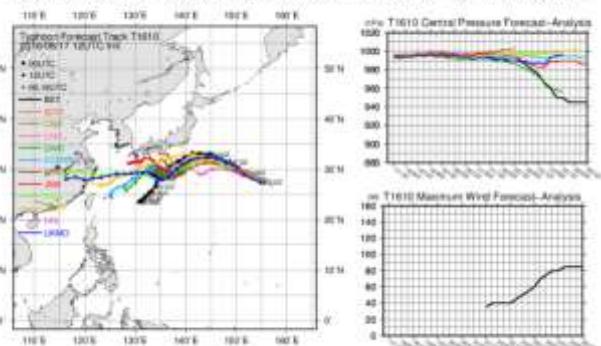
- : 100 %  
○ : 0 %

ECMWF, NCEP, UKMOは各領域で精度が良い(UKMOはFT=120ではNAT,AURで誤差やや大)。JMAはWNP以外で予測初期の誤差が大きめ。

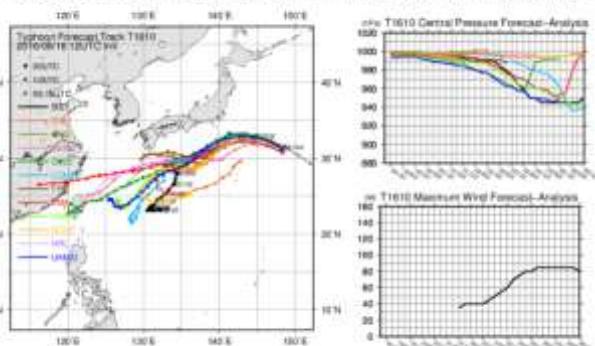
# (a) TCtrack (WNP) TC1610(LIONROCK)

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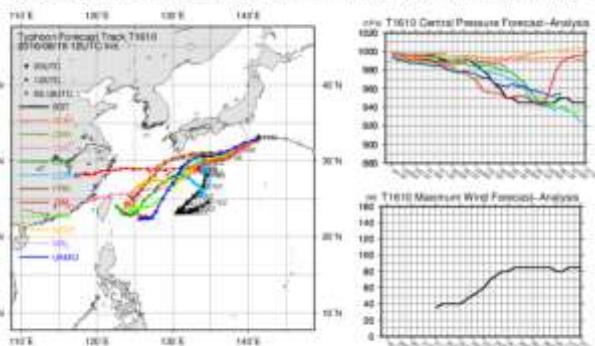
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/17 12UTC —



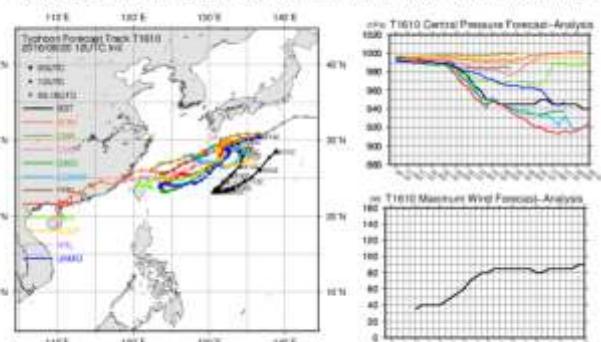
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/18 12UTC —



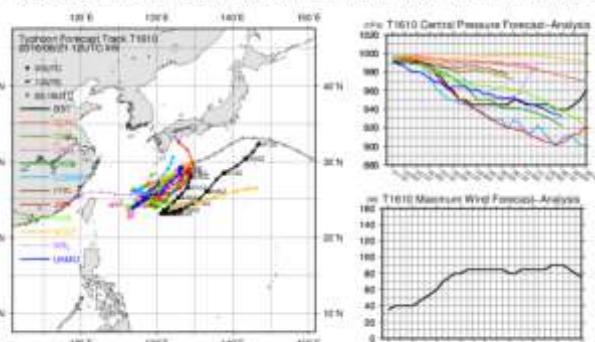
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/19 12UTC —



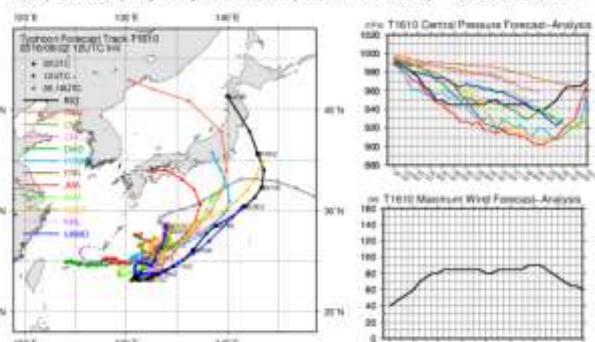
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/20 12UTC —



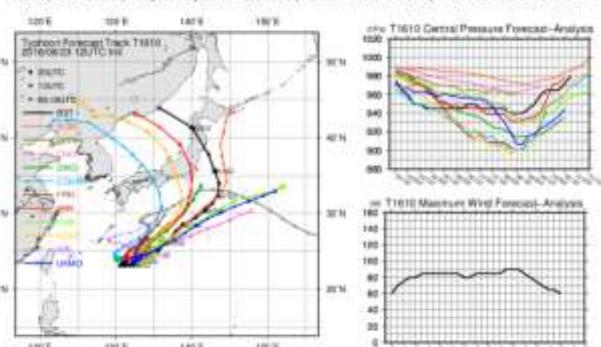
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/21 12UTC —



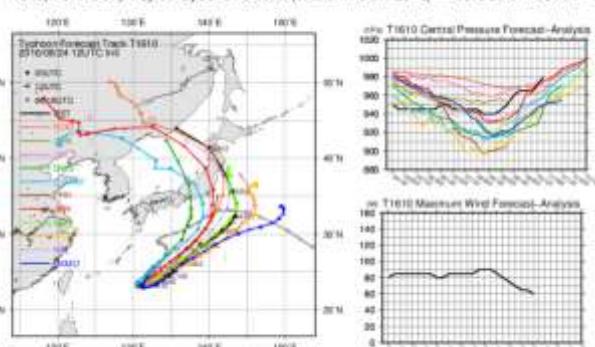
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/22 12UTC —



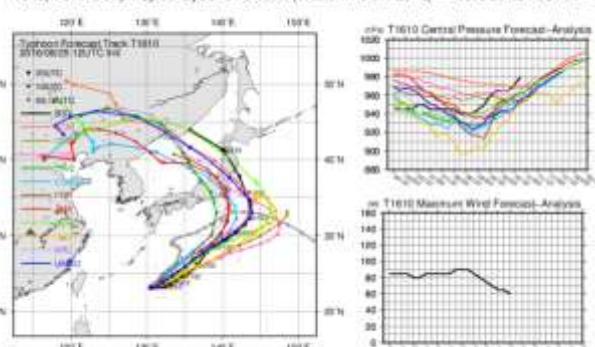
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/23 12UTC —



1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/24 12UTC —

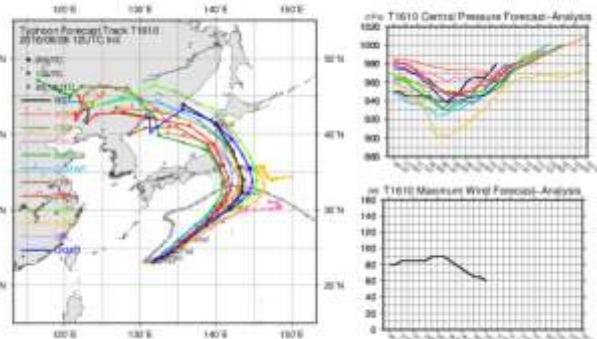


1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/25 12UTC —

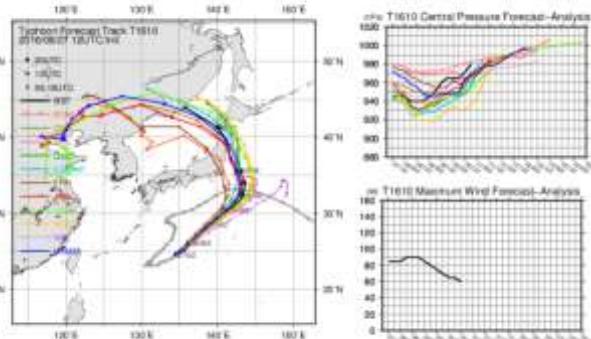


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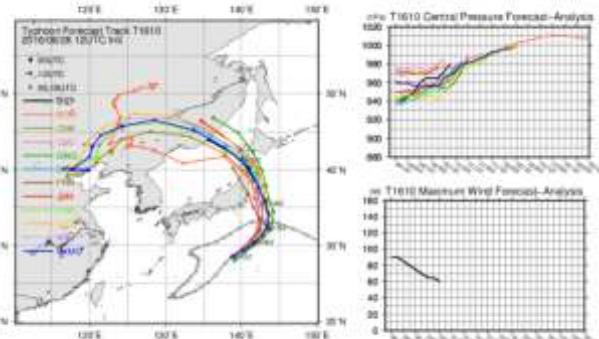
1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/26 12UTC —



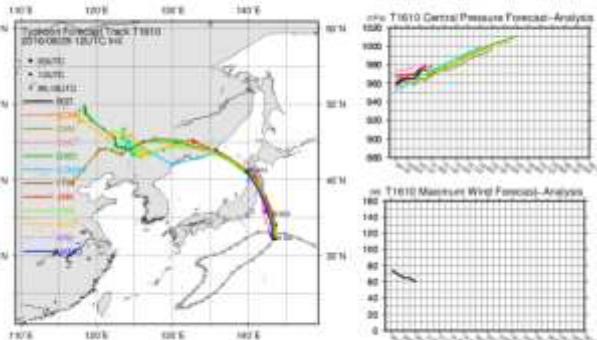
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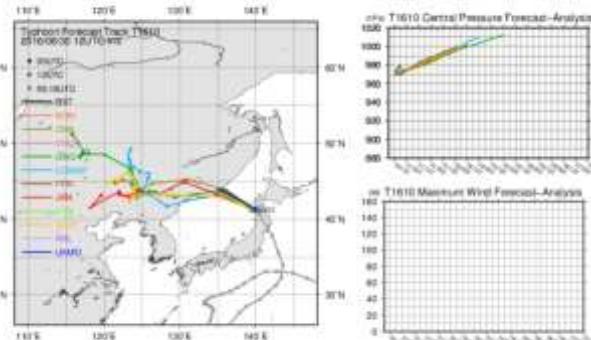
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1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/29 12UTC —

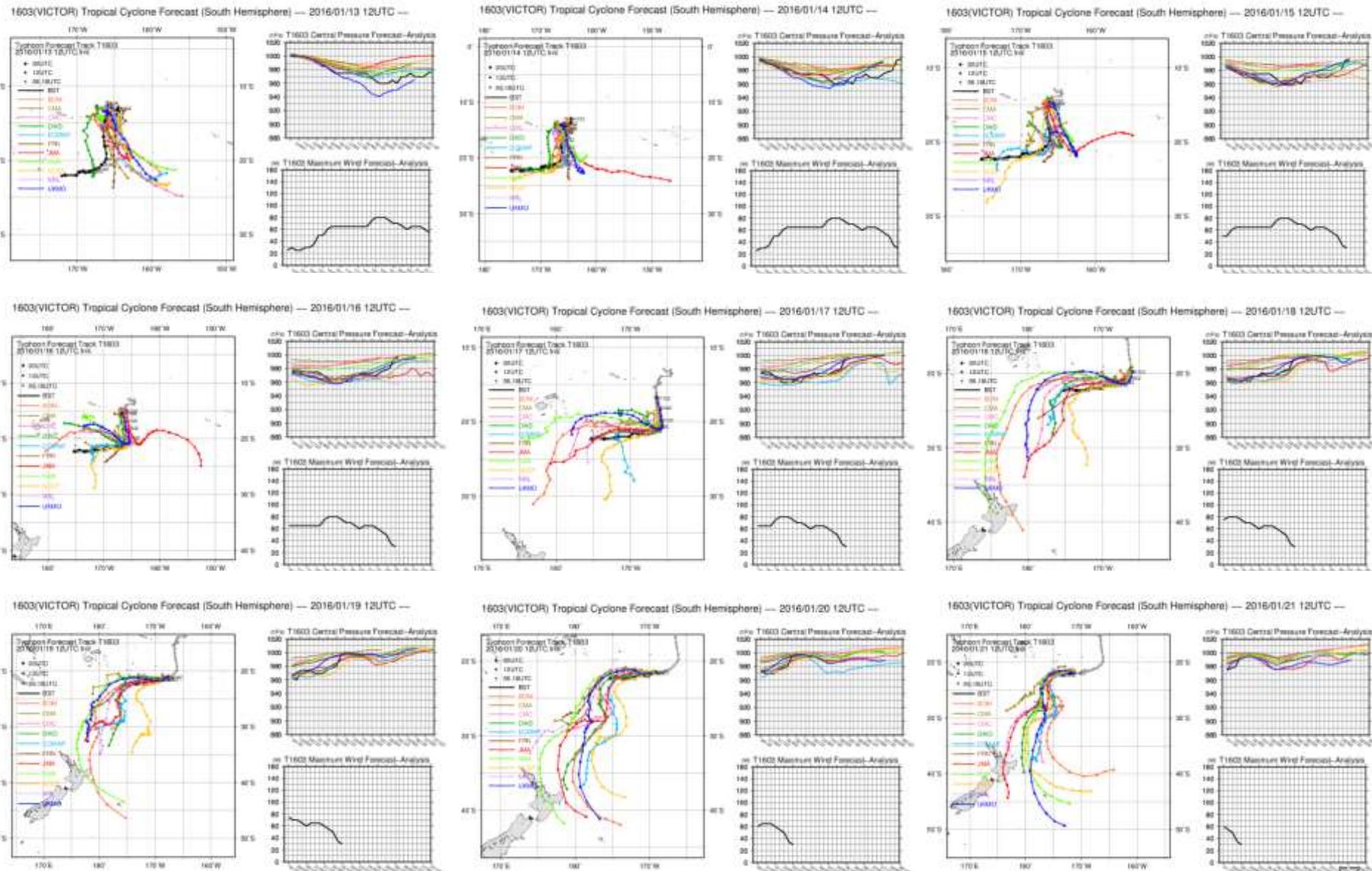


1610(LIONROCK) Tropical Cyclone Forecast (Western north Pacific) — 2016/08/30 12UTC —



## (d) TCtrack (AUR) TC1603(VICTOR)

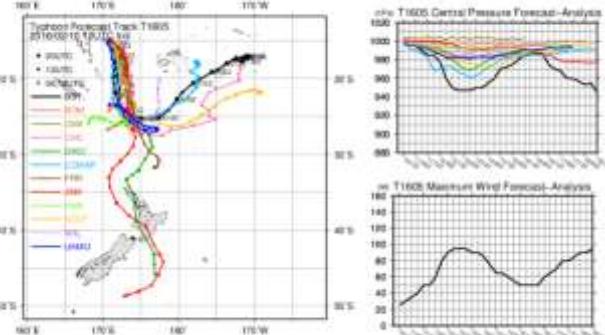
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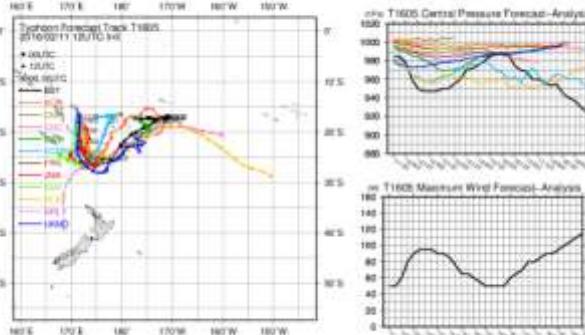
## (d) TCtrack (AUR) TC1605(WINSTON)

# (d) TCtrack (AUR) TC1605(WINSTON)

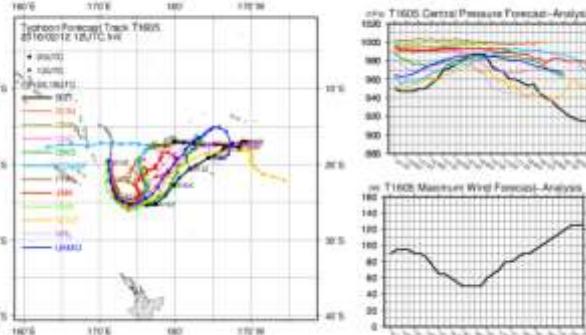
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/10 12UTC —



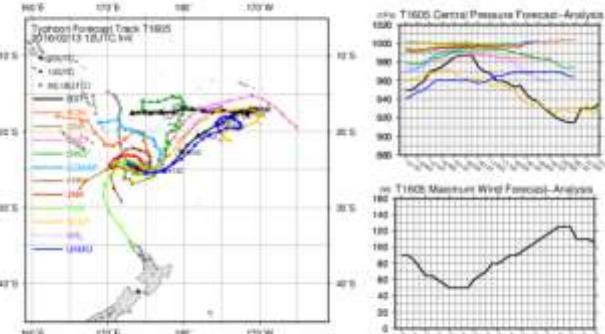
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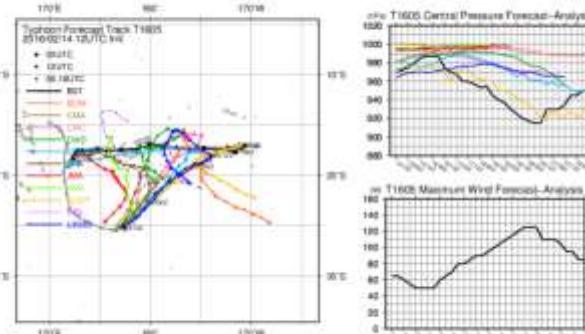
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/12 12UTC —



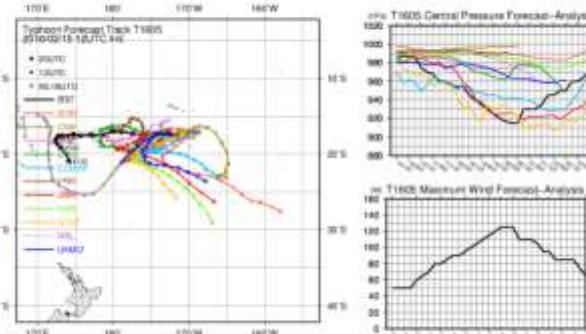
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/13 12UTC —



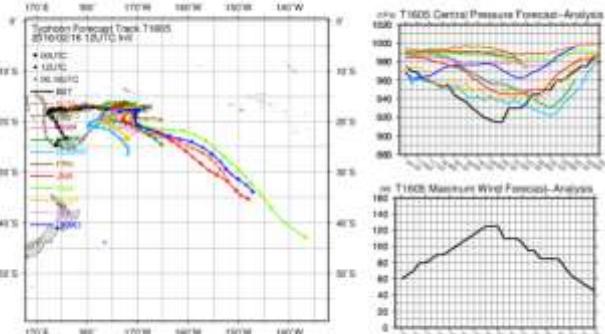
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/14 12UTC —



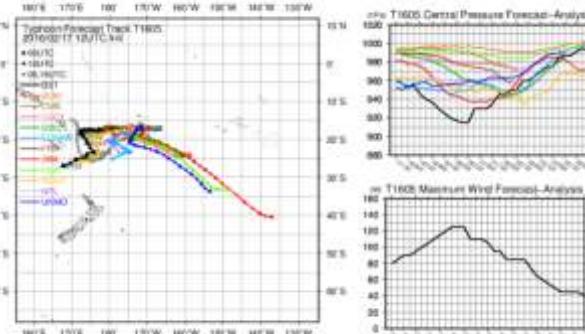
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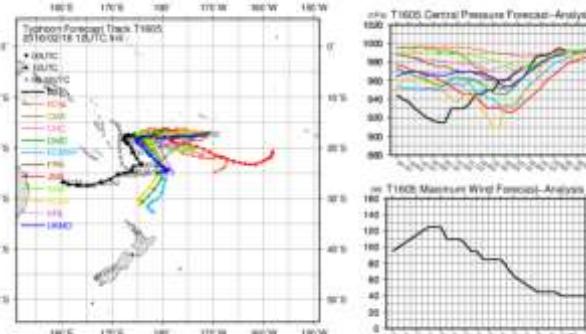
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/16 12UTC —



1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/17 12UTC —

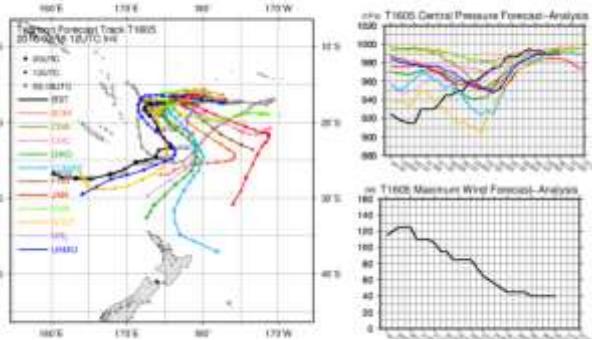


1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/18 12UTC —

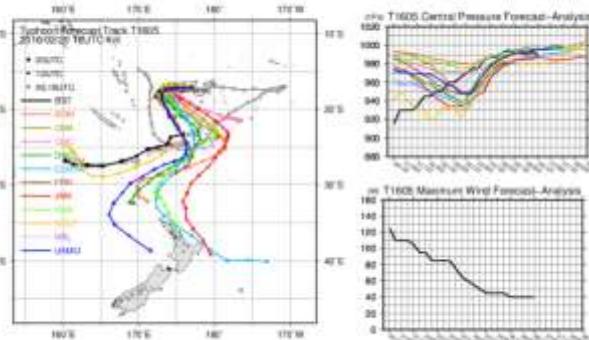


# (d) TCtrack (AUR) TC1605(WINSTON)

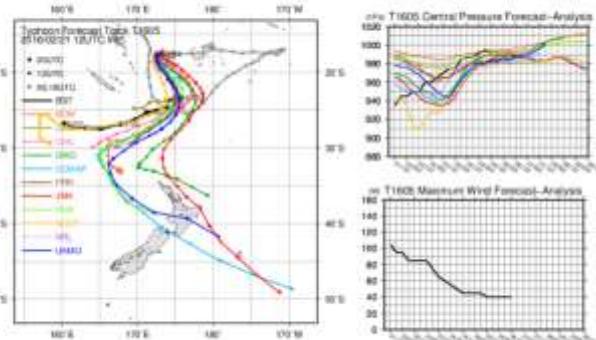
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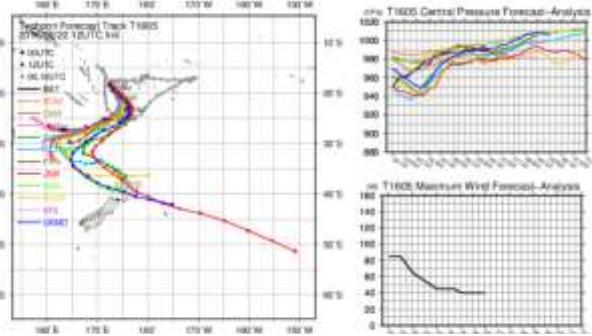
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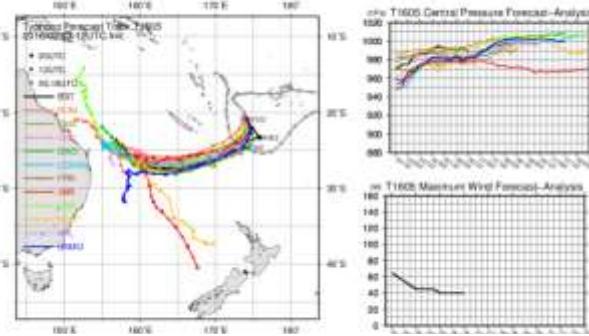
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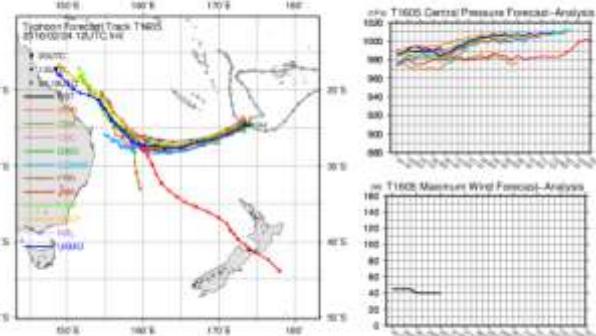
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/22 12UTC —



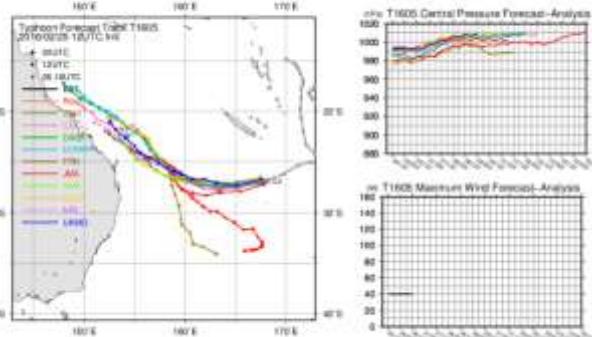
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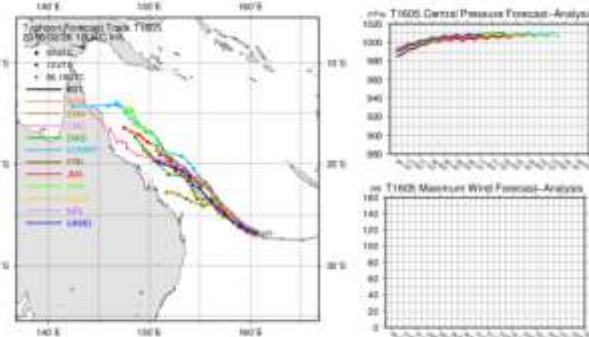
1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/24 12UTC —



1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/25 12UTC —

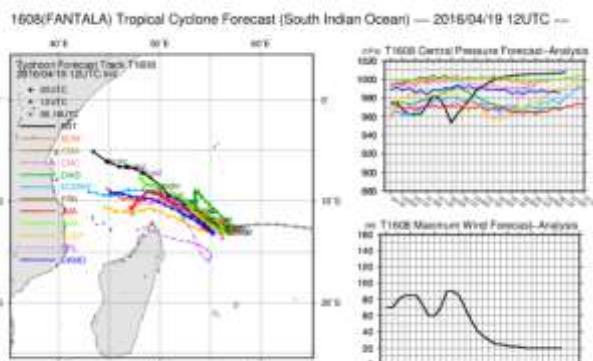
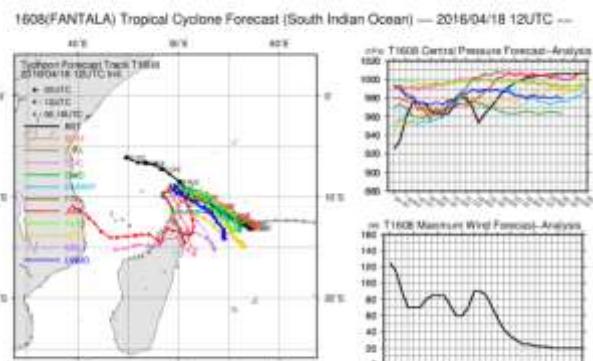
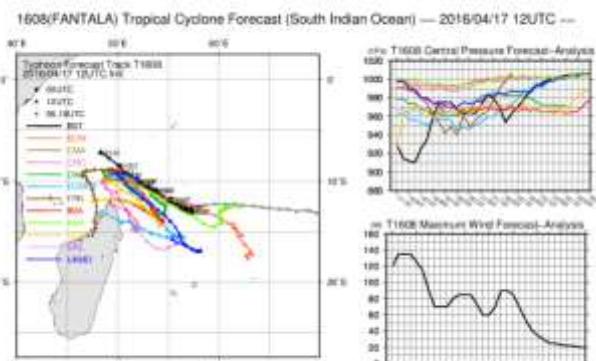
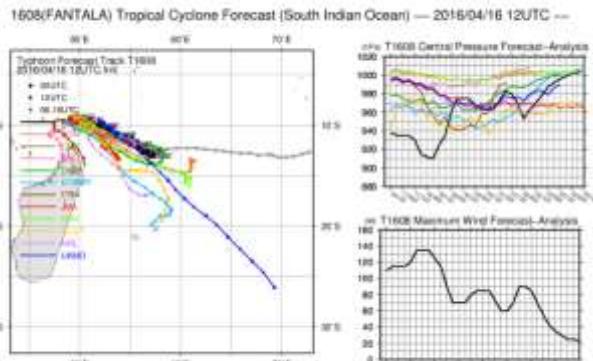
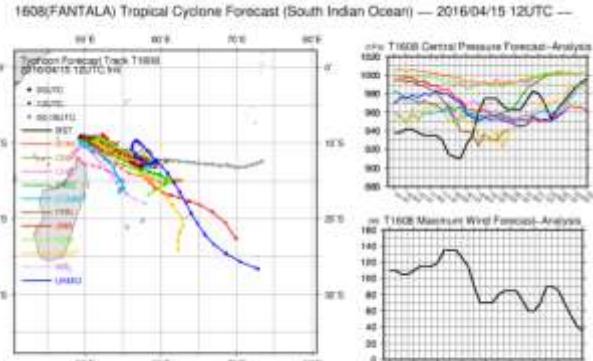
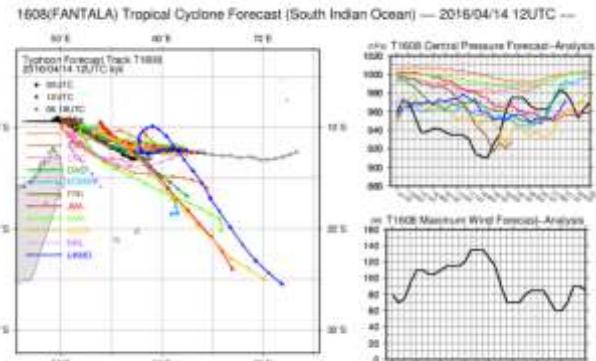
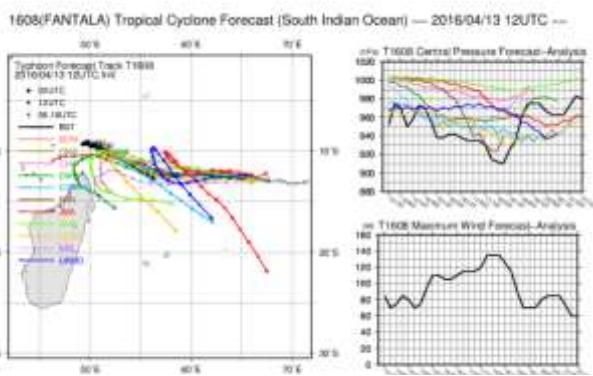
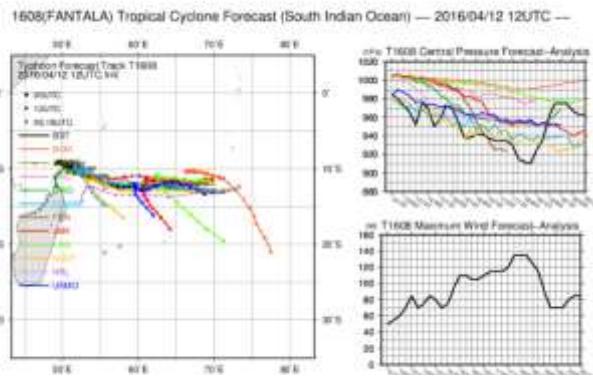
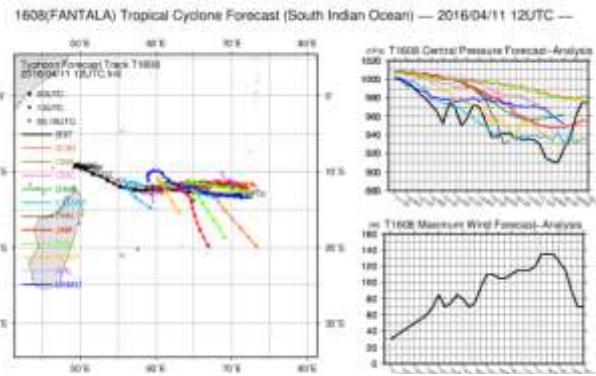


1605(WINSTON) Tropical Cyclone Forecast (South Hemisphere) — 2016/02/26 12UTC —



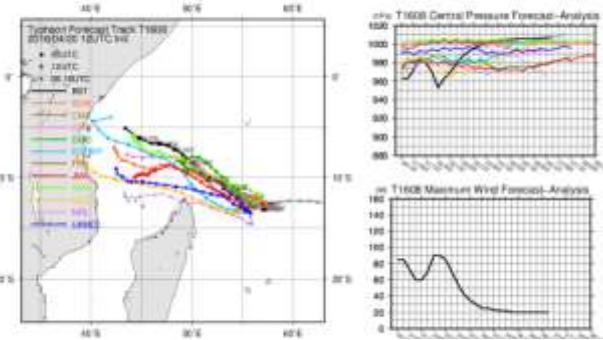
## (e) TCtrack (SIO) TC1608(FANTALA)

(e) TCtrack (SIO) TC1608(FANTALA)

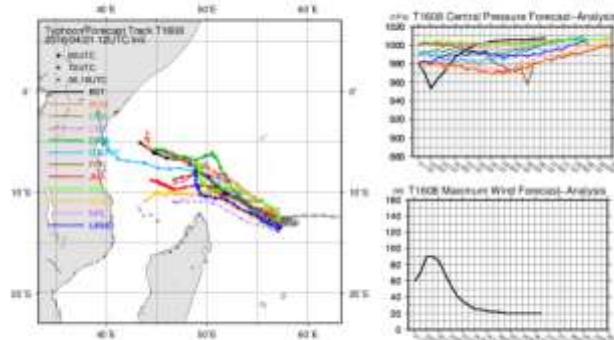


# (e) TCtrack (SIO) TC1608(FANTALA)

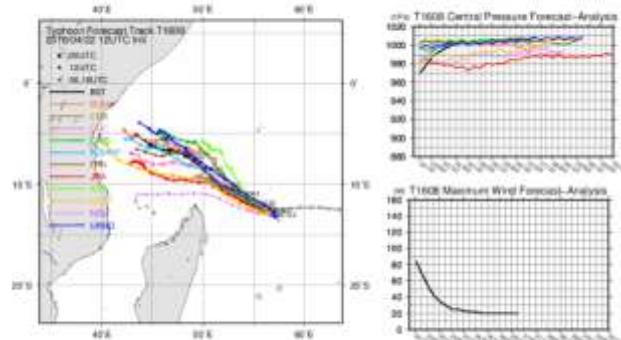
1608(FANTALA) Tropical Cyclone Forecast (South Indian Ocean) — 2016/04/20 12UTC --



1608(FANTALA) Tropical Cyclone Forecast (South Indian Ocean) — 2016/04/21 12UTC --



1608(FANTALA) Tropical Cyclone Forecast (South Indian Ocean) — 2016/04/22 12UTC --



1608(FANTALA) Tropical Cyclone Forecast (South Indian Ocean) — 2016/04/23 12UTC --

