Typhoon Predictions with GNSS RO Data Assimilation in the MPAS-GSI System

Shu-Ya Chen[1], Cheng-Peng Shih[2], Ching-Yuang Huang[2],

Hsiu-Wen Li[1], Zhiquan Liu[3], and Wen-Hsin Teng[2,4]

[1]*GPS Science and Application Research Center, National Central University, Taoyuan, Taiwan*

[2]*Department of Atmospheric Sciences, National Central University, Taoyuan, Taiwan*

[3]*Mesoscale and Microscale Meteorology Laboratory, National Center for Atmospheric Research, CO. U.S.A.*

[4] *Central Weather Bureau, Taipei, Taiwan*

國立中央大學全球定位科學與應用研究中心

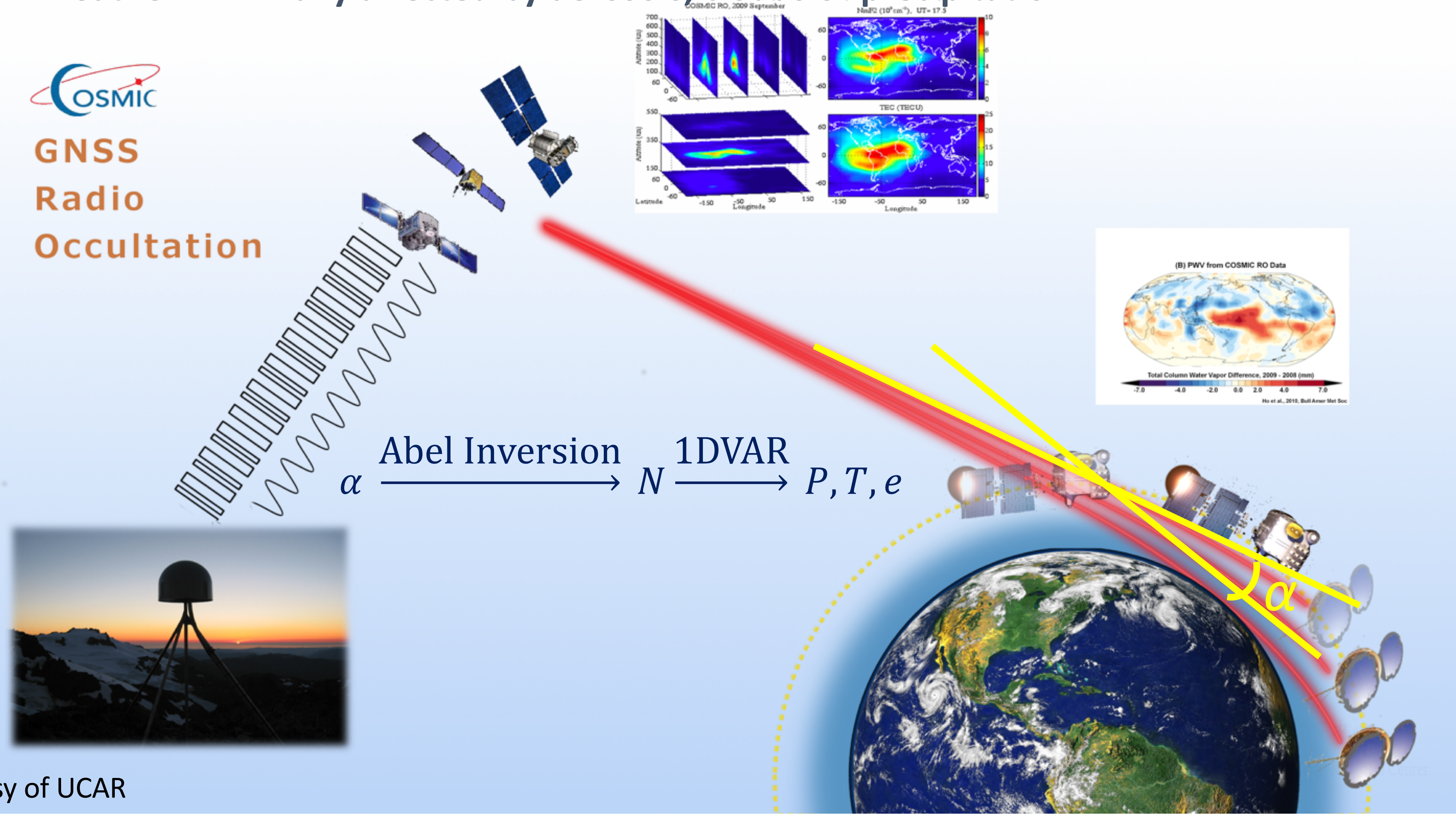
GPSARC GPS Science and Application Research Center

Introduction

- To improve a typhoon prediction, an accurate representation of the atmospheric environment would be much helpful. However, sparse observations are available over the ocean.
- The accurate and abundant observations over ocean could be helpful for the NWP, e.g., FORMOSAT-7 data over the tropical region.
- With the global MPAS-GSI system, we conduct data assimilation to assess the RO data impact on the prediction of typhoon events. A preliminary result for two typhoon cases, i.e., Typhoon Nepartak (2016) and Typhoon Lekima (2019), will be shown.

GNSS Radio Occultation

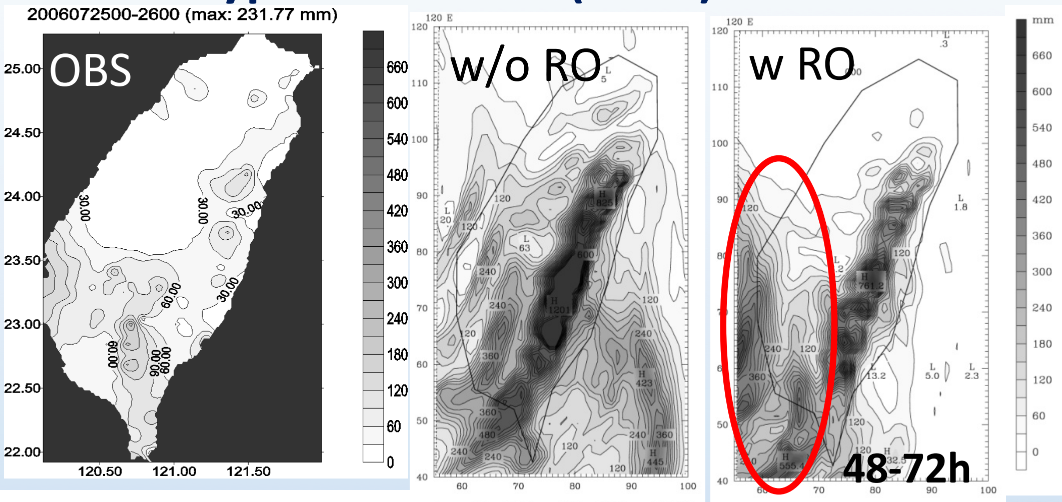
- GNSS (Global Navigation Satellite System)
- Global coverage
- High accuracy and high vertical resolution
- All weather-minimally affected by aerosols, clouds or precipitation



Courtesy of UCAR

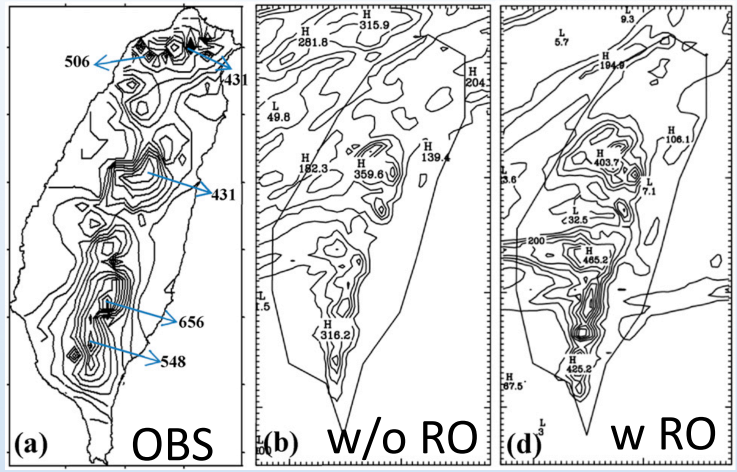
Paper review

Typhoon Kaemi (2006)



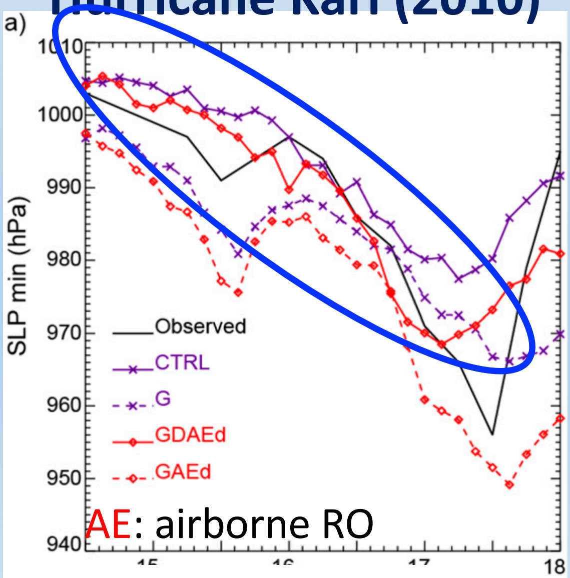
Chen et al. (2009)

2012/06 Mei-yu front



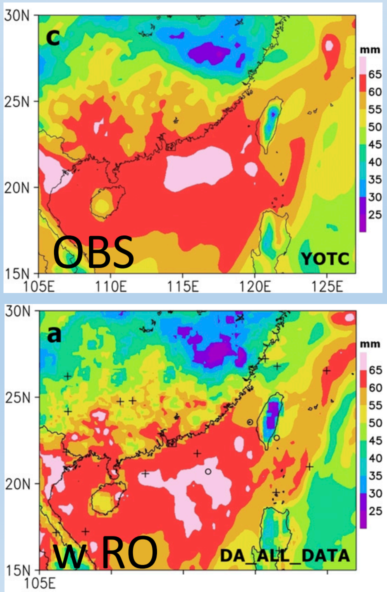
Huang et al. (2016)

Hurricane Karl (2010)



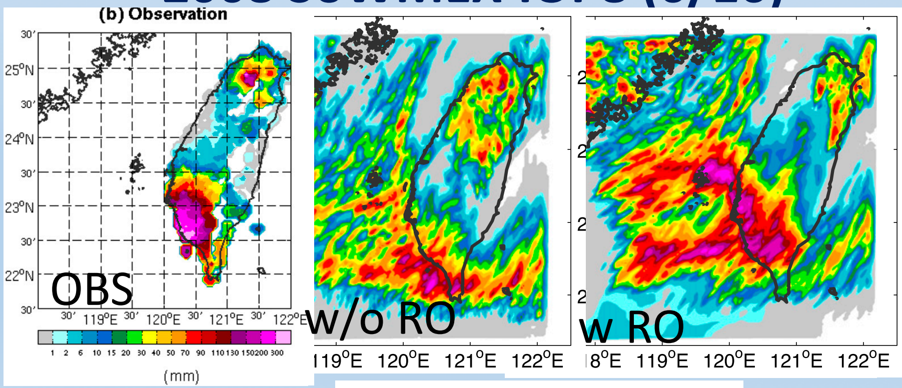
Chen et al. (2018)

2008 SoWMEX-IOP8 (6/15)



Tu et al. (2017)

2008 SoWMEX-IOP8 (6/16)

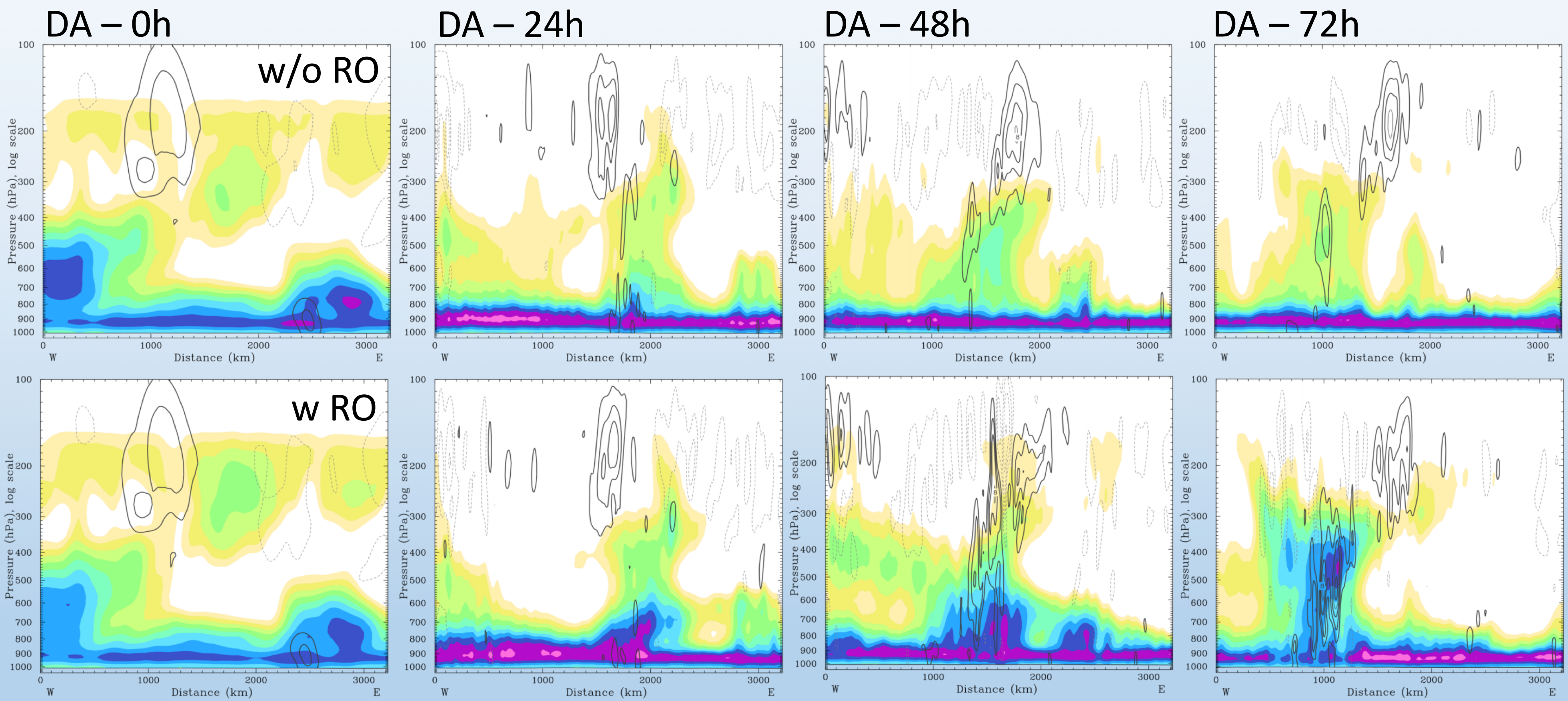


Yang et al. (2014)

國立中央大學全球定位科學與應用研究中心
GPSARC GPS Science and Application Research Center

cyclogenesis of typhoon Nuri (2008)

Vertical Cross Section of Vorticity and RH



600-km averaged cross section

Cyclogenesis after two-day forecast

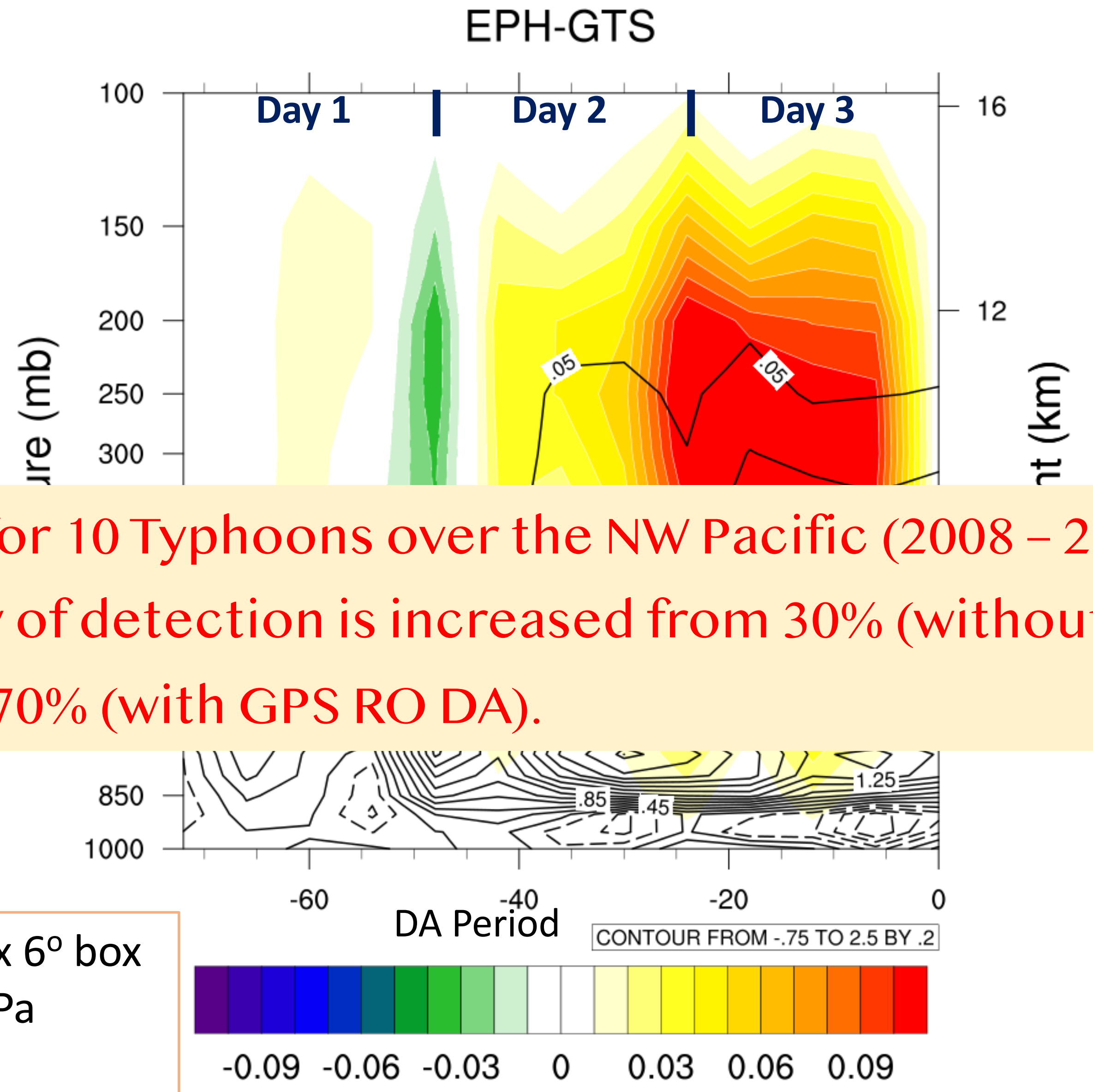
ChenKuoHuang (2019) has been submitted to Mon. Wea. Rev.

Vor: $2 \times 10^{-5} s^{-1}$
RH: %

國立中央大學全球定位科學與應用研究中心
GPSARC GPS Science and Application Research Center

Vertical Motion and Water Vapor Mixing Ratio

W (m s^{-1})
Q (g kg^{-1})



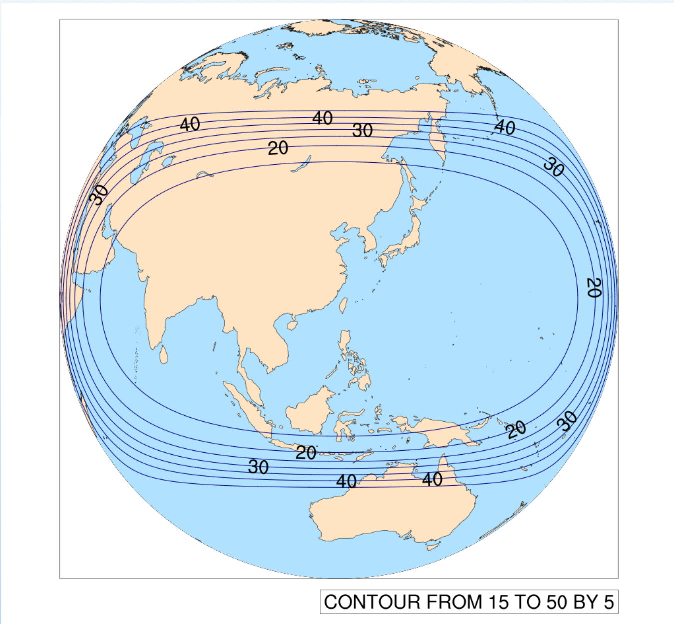
Statistics for 10 Typhoons over the NW Pacific (2008 – 2010): Probability of detection is increased from 30% (without GPS RO DA) to 70% (with GPS RO DA).

Averaged over a 6° x 6° box following the 500 hPa vorticity center

Introduction

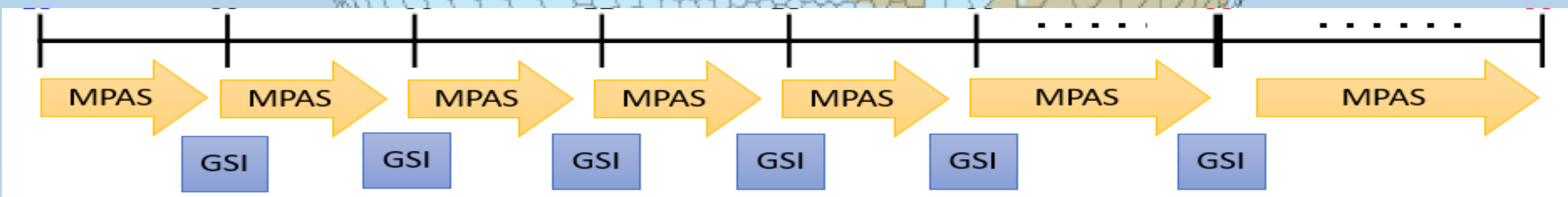
- To improve a typhoon prediction, an accurate representation of the atmospheric environment would be much helpful. However, sparse observations are available over the ocean.
- With the **global MPAS-GSI system**, we conduct data assimilation to assess the RO data impact on the prediction of typhoon events.
- A preliminary result for two typhoon cases, i.e., **Typhoon Nepartak (2016) and Typhoon Lekima (2019)**, will be shown.
- The accurate and abundant observations over ocean could be helpful for the NWP, e.g., **FORMOSAT-7/COSMIC-2 data over the tropical region.**

MPAS Model Configuration



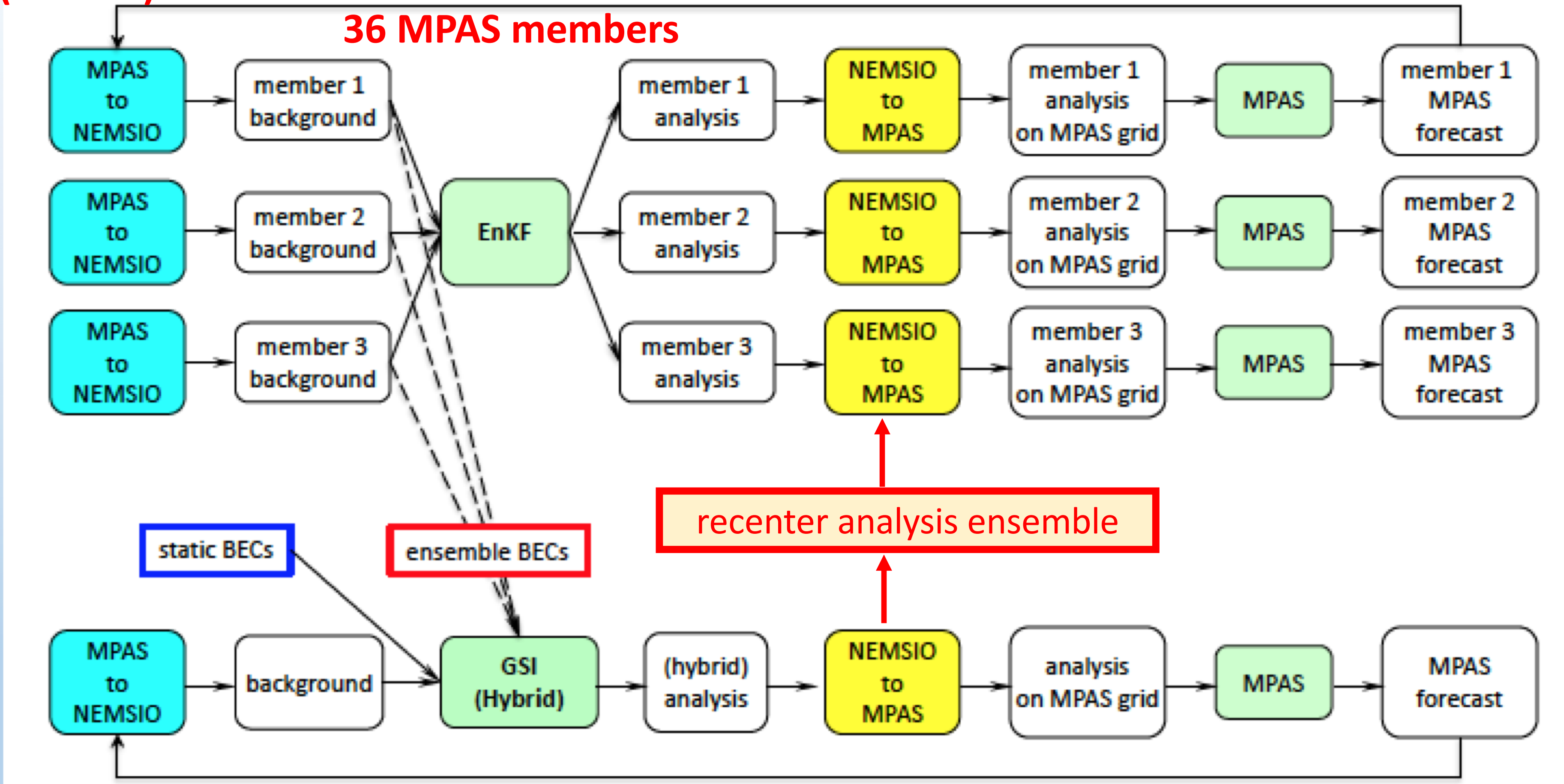
- **Model configuration:**
- **Variable reso. meshes: 60-15 km**
  Vertical levels of 41 and model top of 30 km
- **Physics suites : mesoscale reference**
  Convection: Tiedtke ; Microphysics: WSM6 ; Land surface: Noah ; Boundary layer: YSU ; Surface layer: Monin-Obukhovi ; Radiation, LW/SW: RRTMG

Cycling DA example:



MPAS-GSI system

Low resolution (120 km)

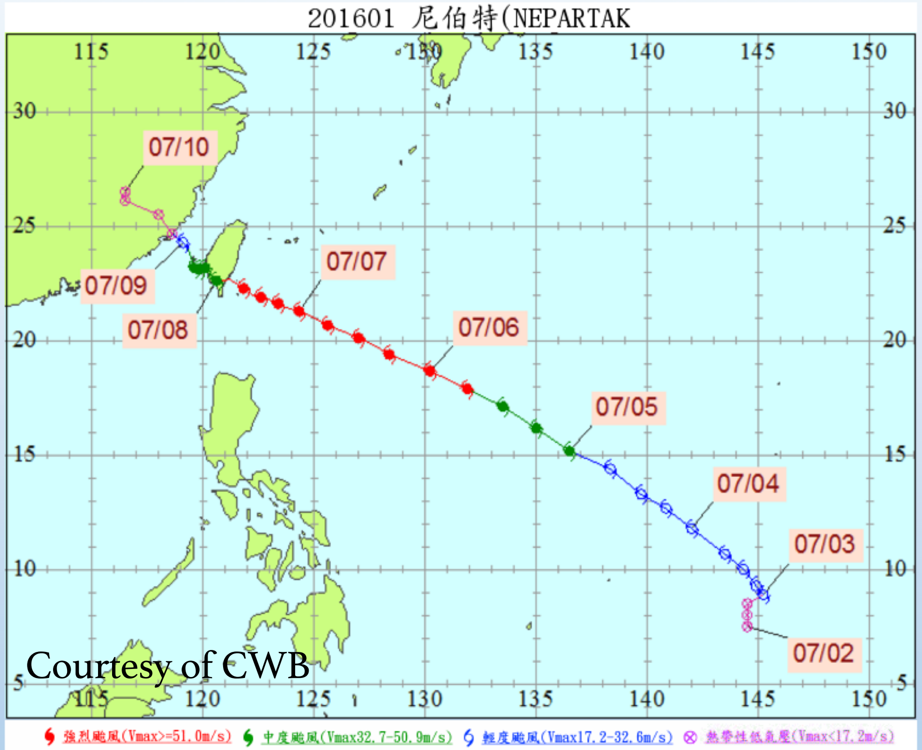


High resolution (60-15 km)

1. Dual resolution
2. Recenter process

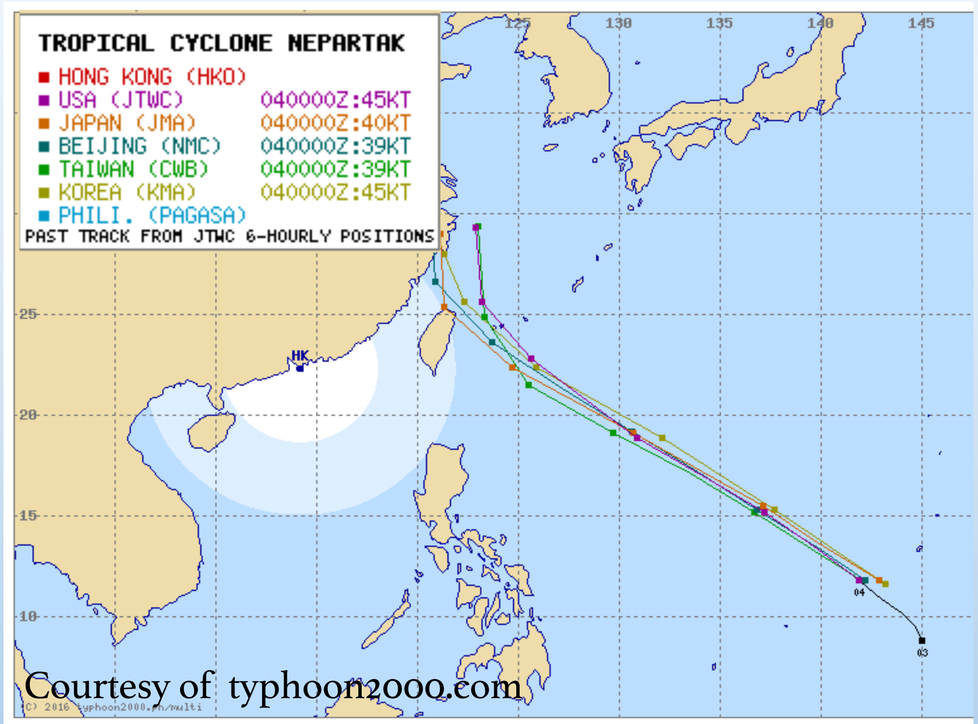
(extracted from Bresch et al. 2015)

Typhoon Nepartak (2016)



Courtesy of CWB

Multi-Agency Tropical Cyclone Forecast



Courtesy of typhoon2000.com

JTWC:

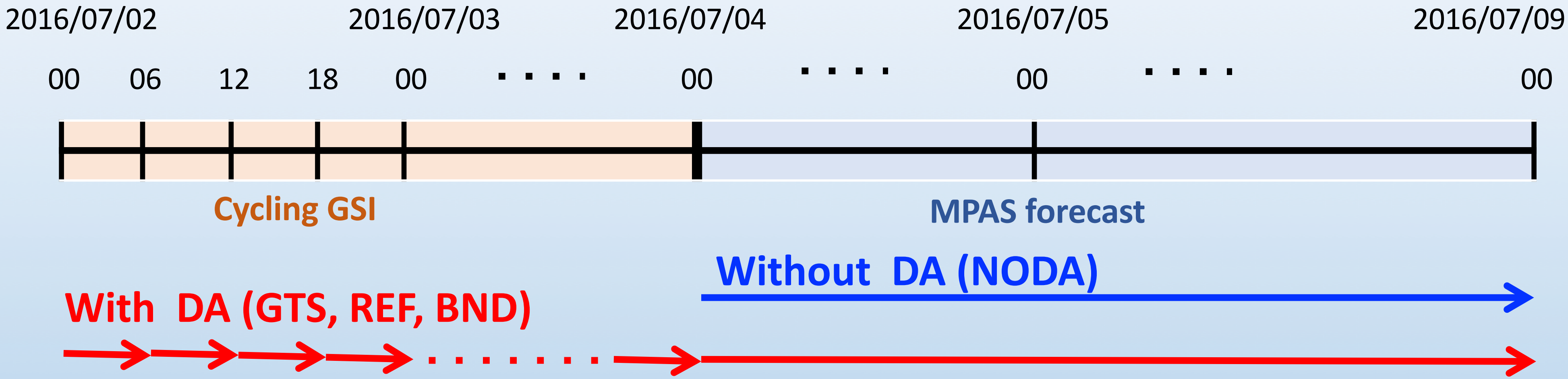
2016/07/03 00UTC: Tropical depression

2016/07/03 12UTC: Tropical storm

2016/07/04 18UTC: Typhoon

Experimental design

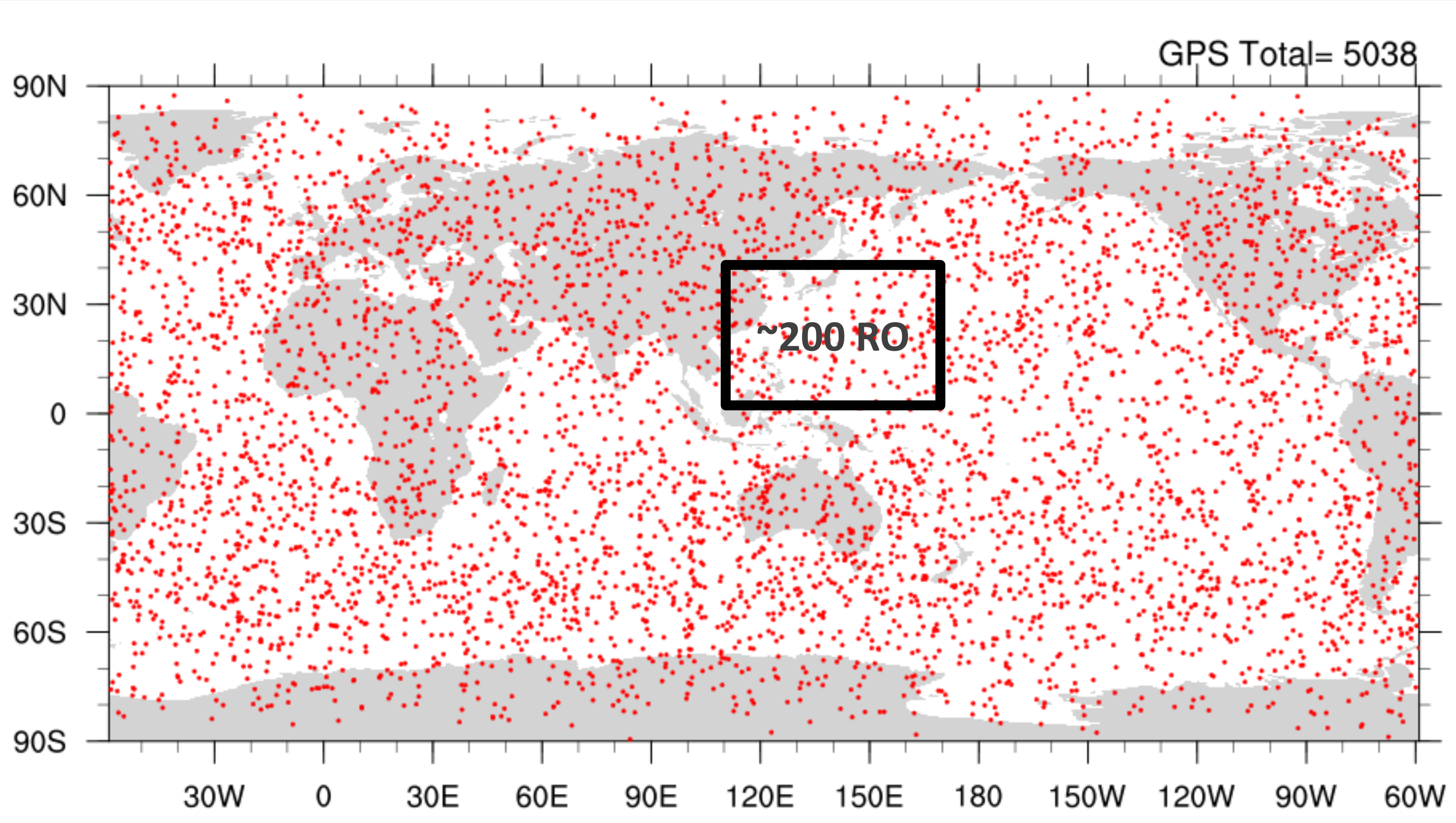
TY Nepartak (2016)



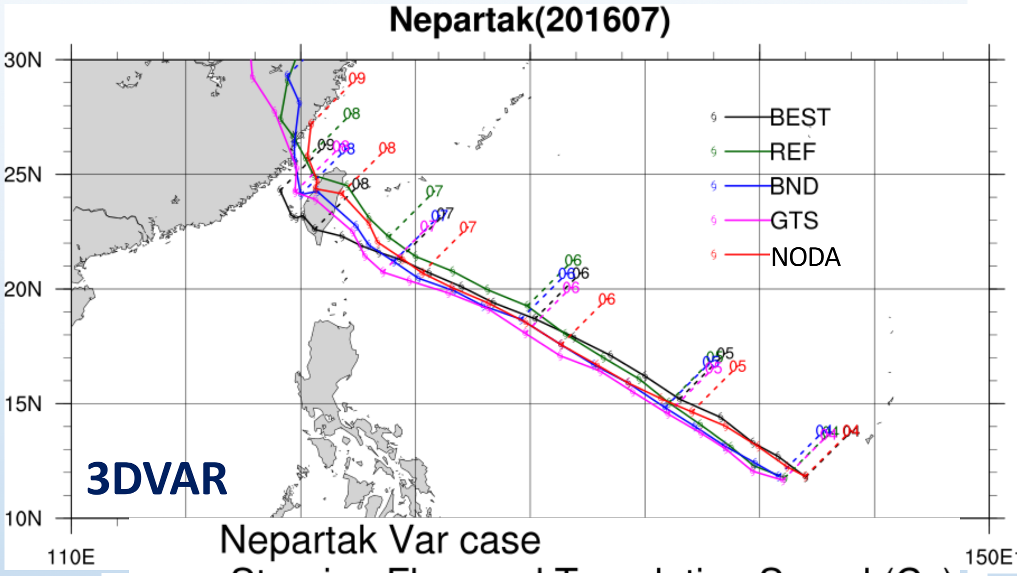
CASE	DA obs.	GPS variable	DA strategy
NODA	X	X	X
GTS	GTS	X	**3DVAR / Hybrid**
REF	GTS + GPSRO	Refractivity	**3DVAR / Hybrid**
BND	GTS + GPSRO	Bending angle	**3DVAR / Hybrid**

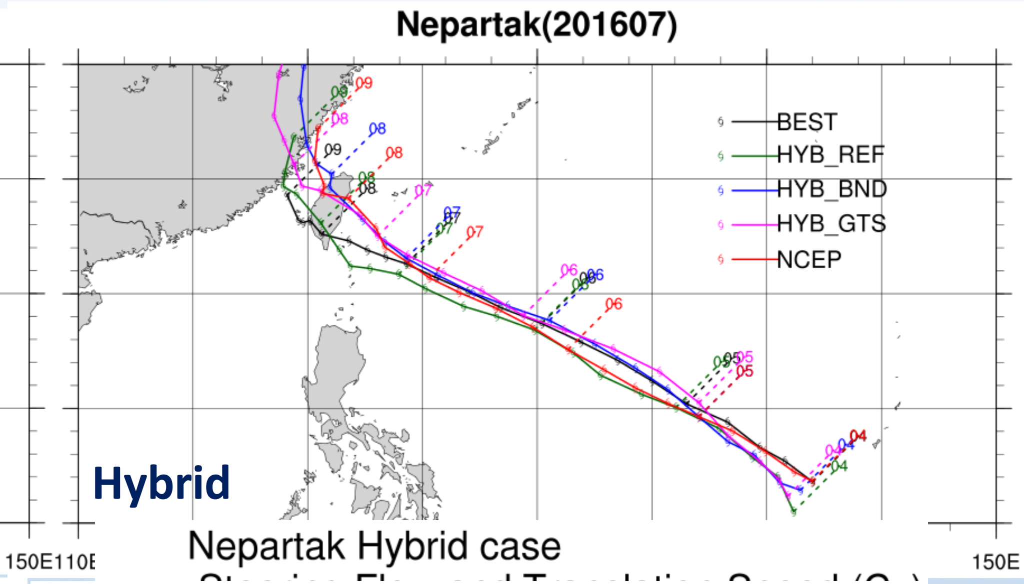
GNSS RO Data

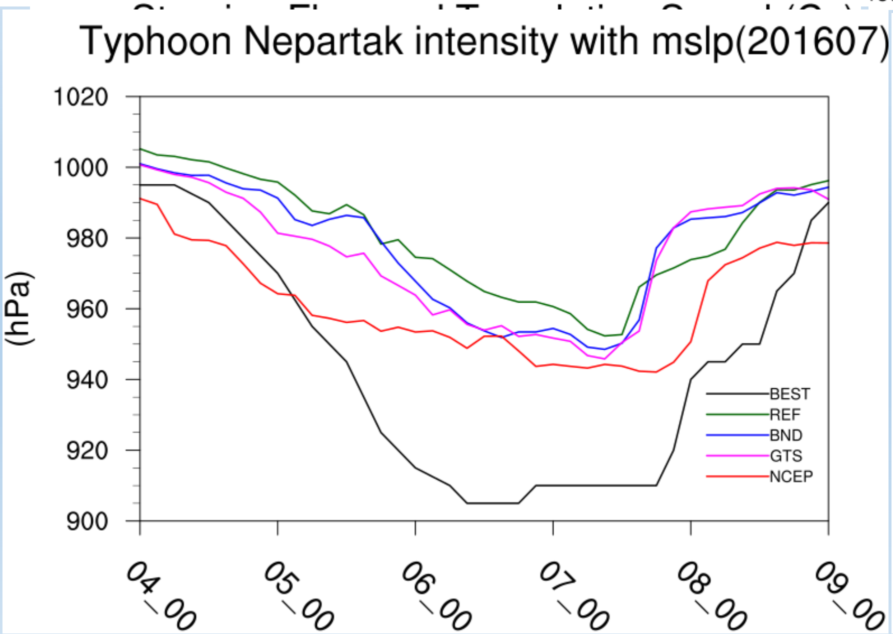
2016/07/02 0000 UTC ~ 2016/07/04 0000 UTC

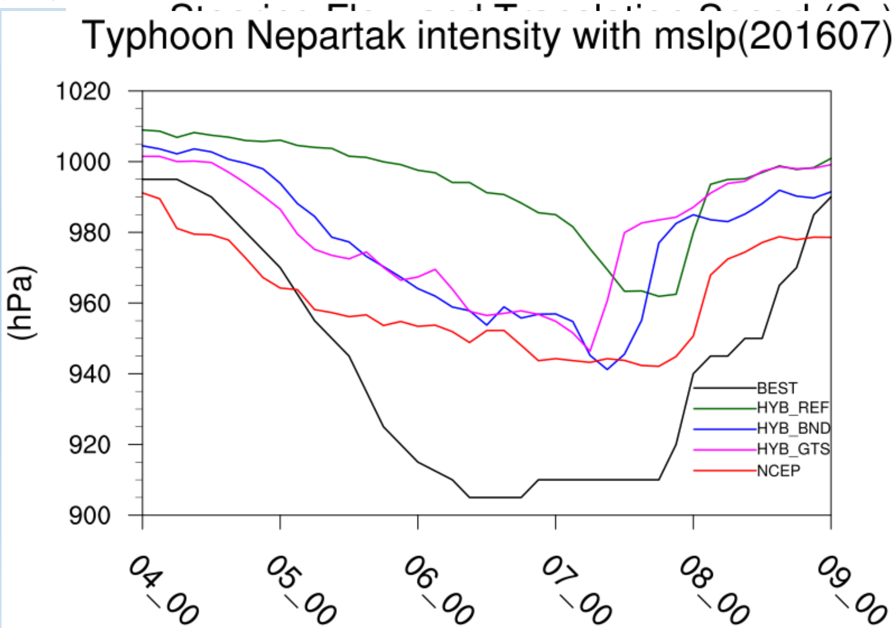


Simulated Track and Intensity

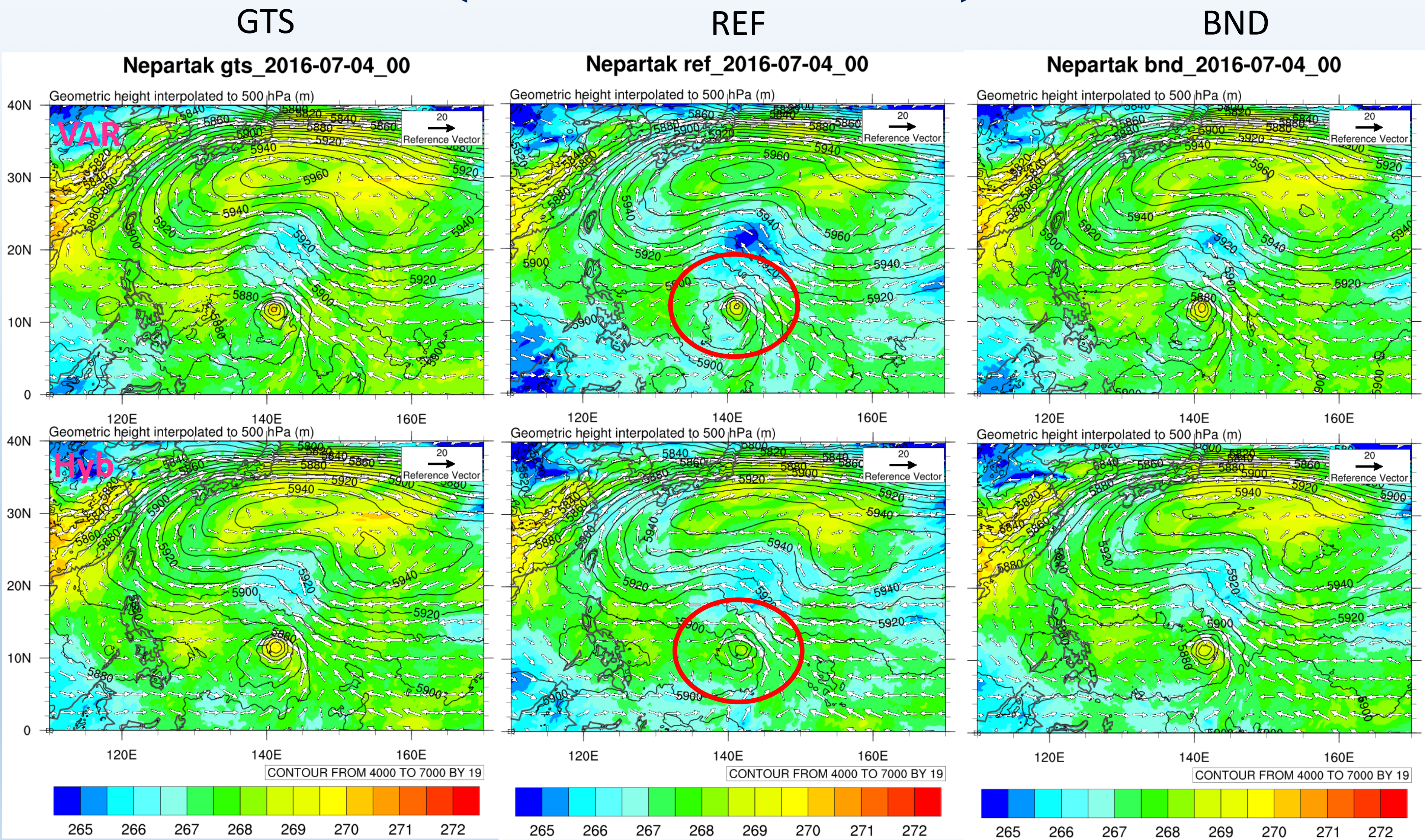






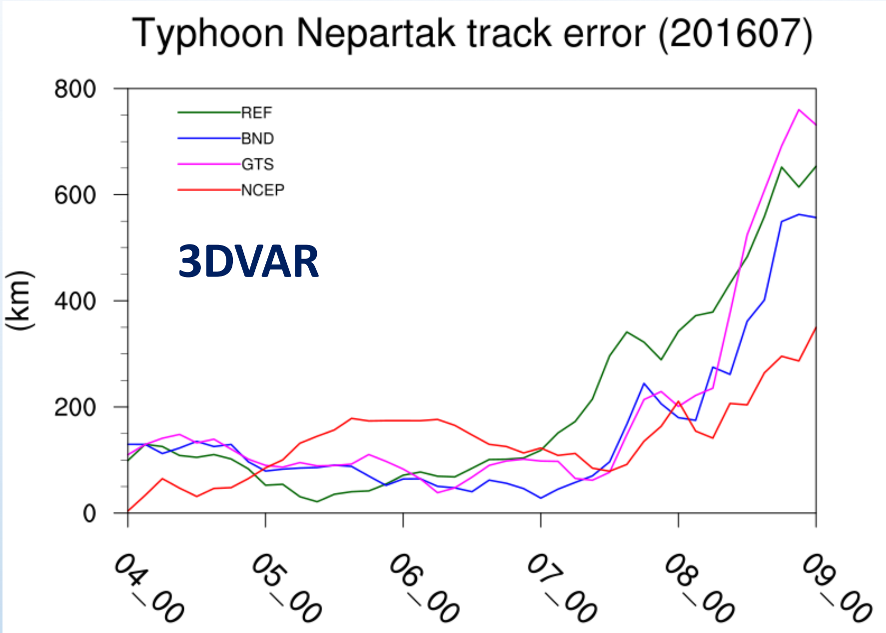


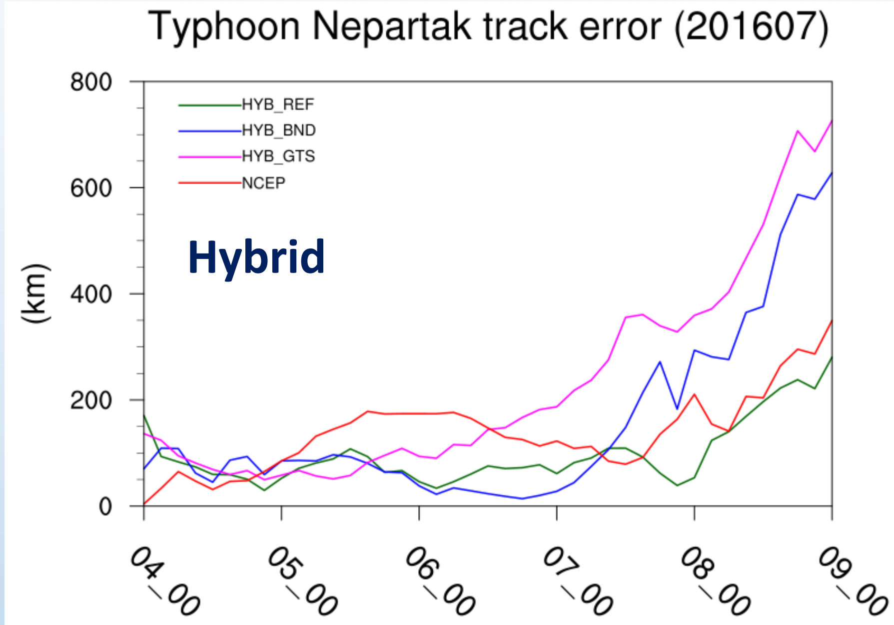
After two-day cycling DA (T, Z, and Wind)



GPSARC GPS Science and Application Research Center

Track Error

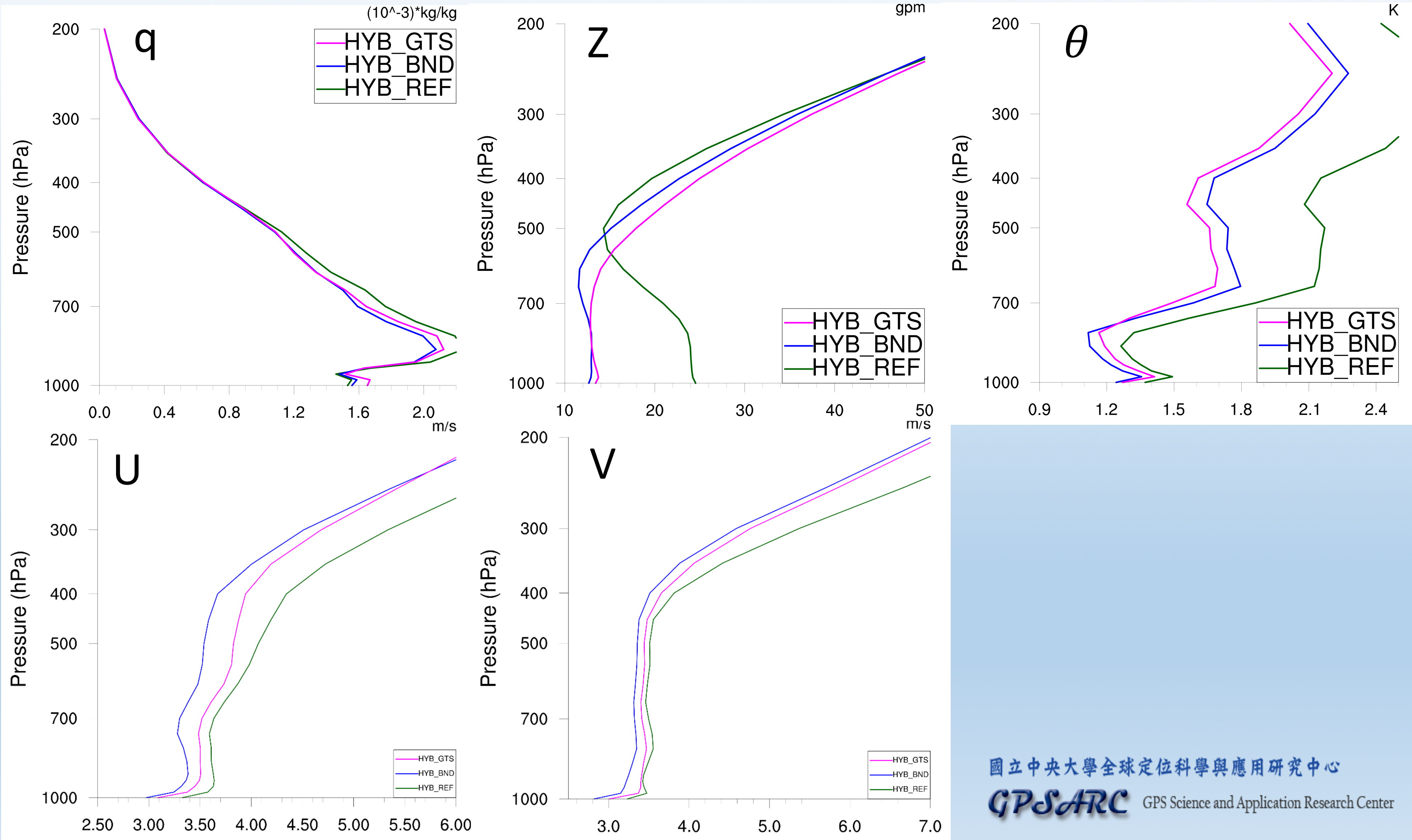




	AVE. TRACK ERROR (07/04-07/07)	
EXP	3DVAR DA	Hybrid DA
NODA	112.5	112.5
GTS	98.4	100.0
REF	79.5	71.5
BND	83.0	60.5

Before landfall

Verification against ERA-Interim (RMSE) [averaged of 5-day fcst.]



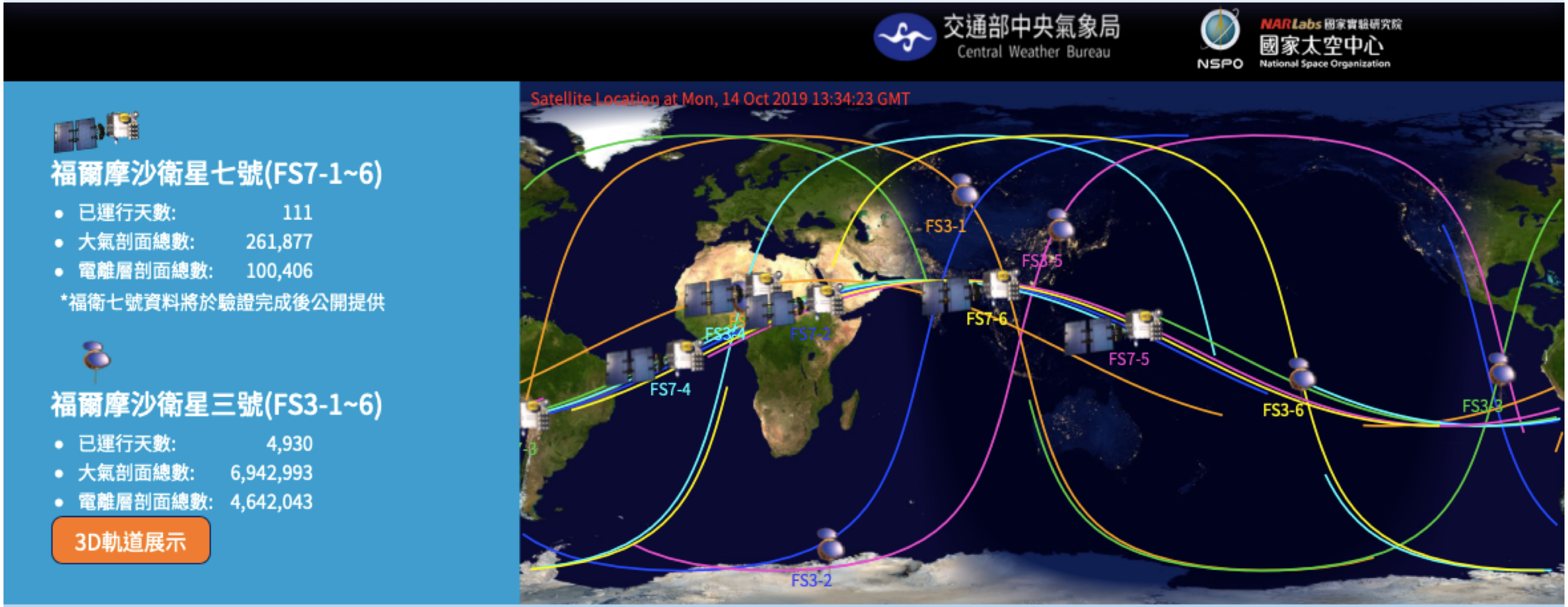
國立中央大學全球定位科學與應用研究中心

GPSARC GPS Science and Application Research Center

FORMOSAT-7/COSMIC-2

FORMOSAT-7/COSMIC-2 satellites were launched successful on 25 June 2019.

The first RO profile (2019/07/16 11:44 TST)



http://tacc.cwb.gov.tw

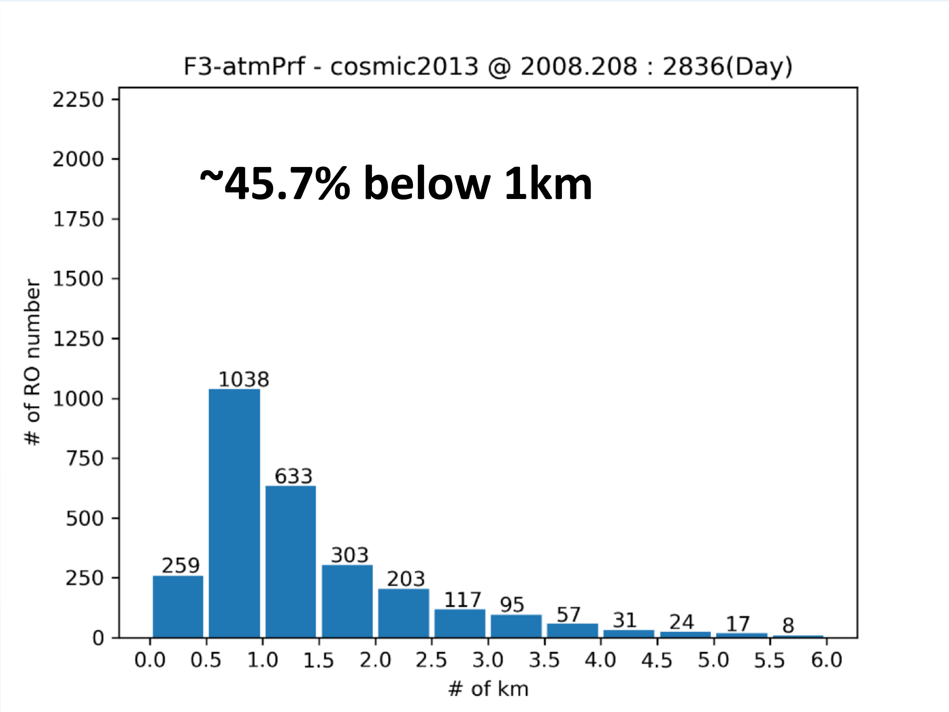
國立中央大學全球定位科學與應用研究中心

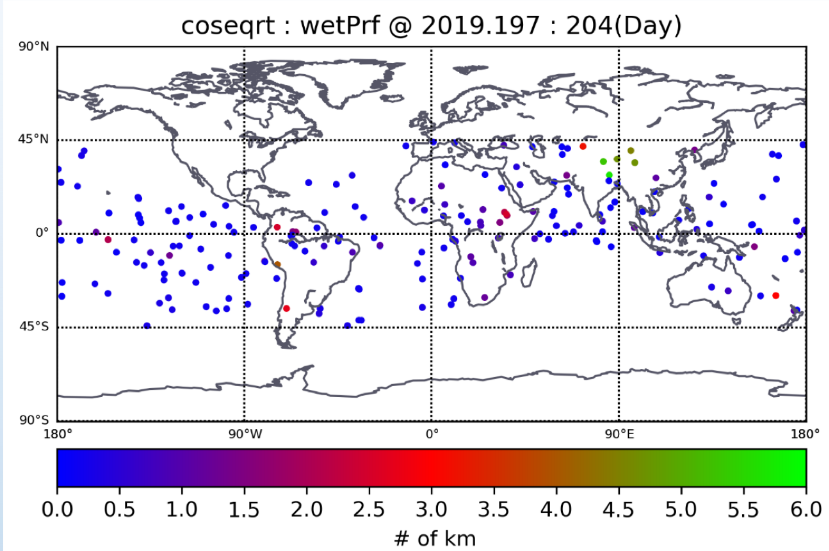
GPSARC GPS Science and Application Research Center

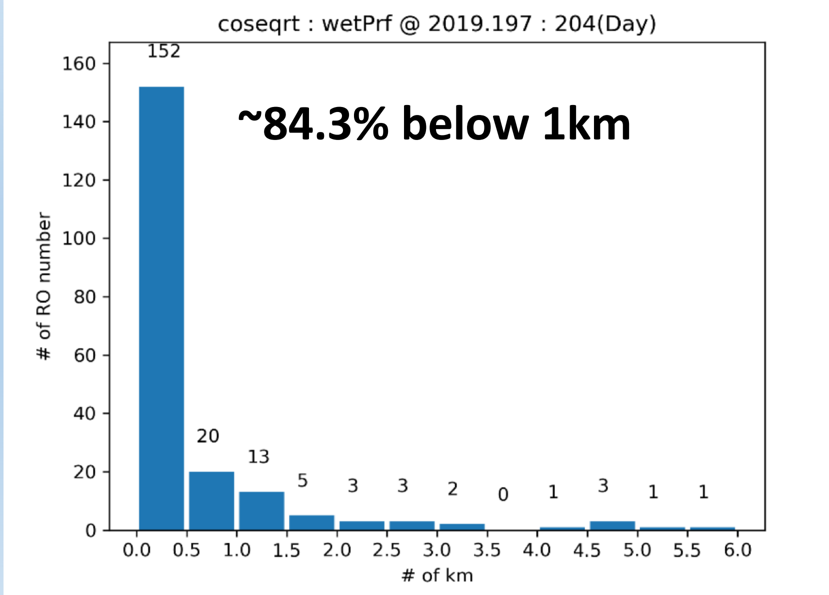
Data Penetration

FS7/C2 Data @ 2019/07/16 (first day)

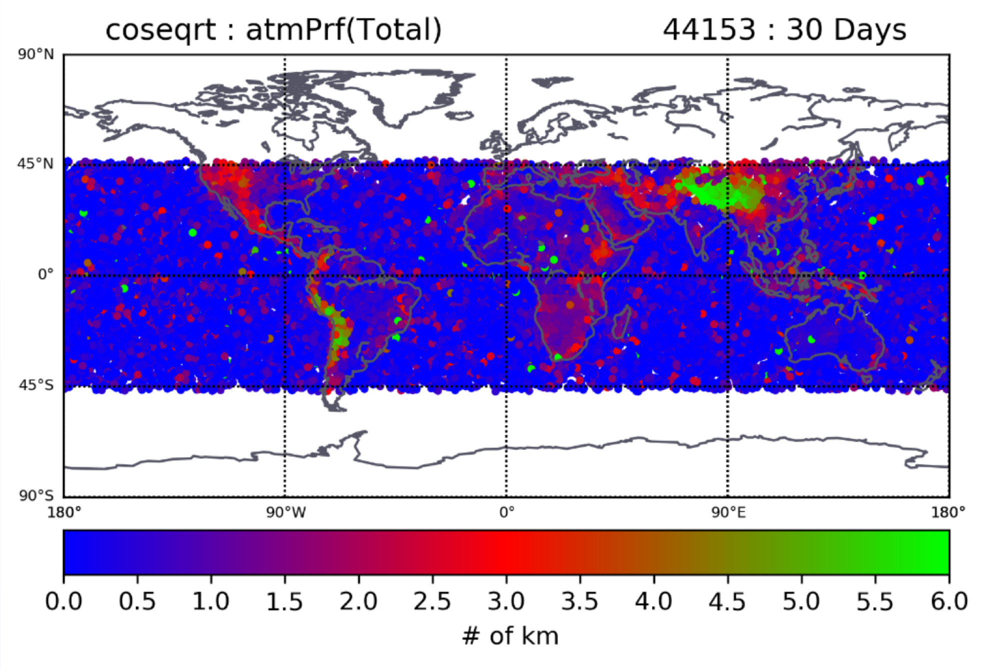
FS3/C1 (one day data)

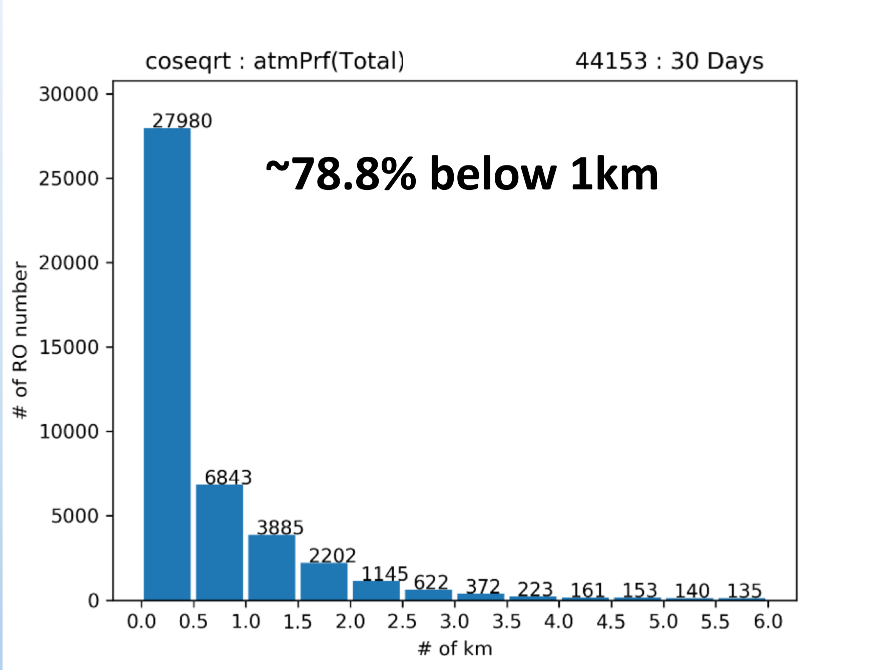






FS7/C2 NRT Data (30 days)

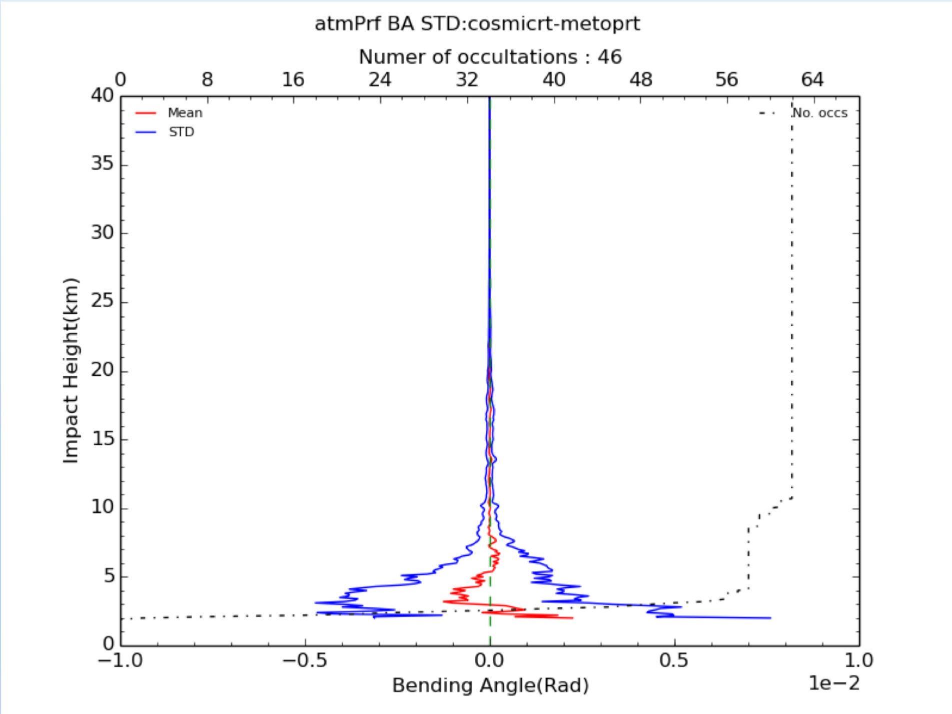




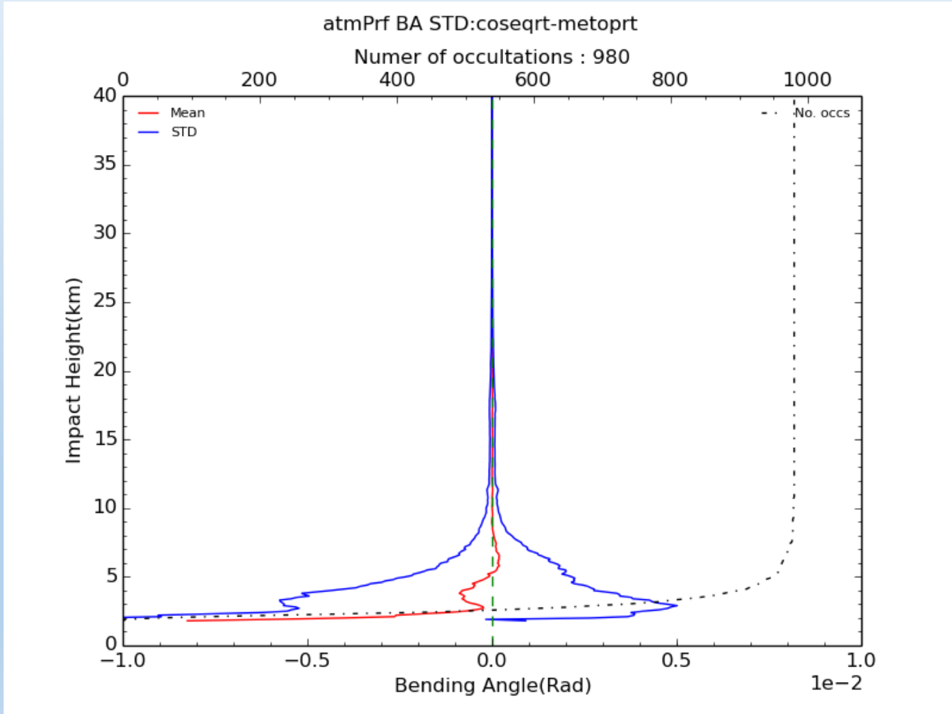
Verification against MetOP (30 days)

atmPrf (Bending Angle)

FORMOSAT-3 (±45°)
2018/08/01-2018/08/31



FORMOSAT-7
2019/07/26-2019/08/25

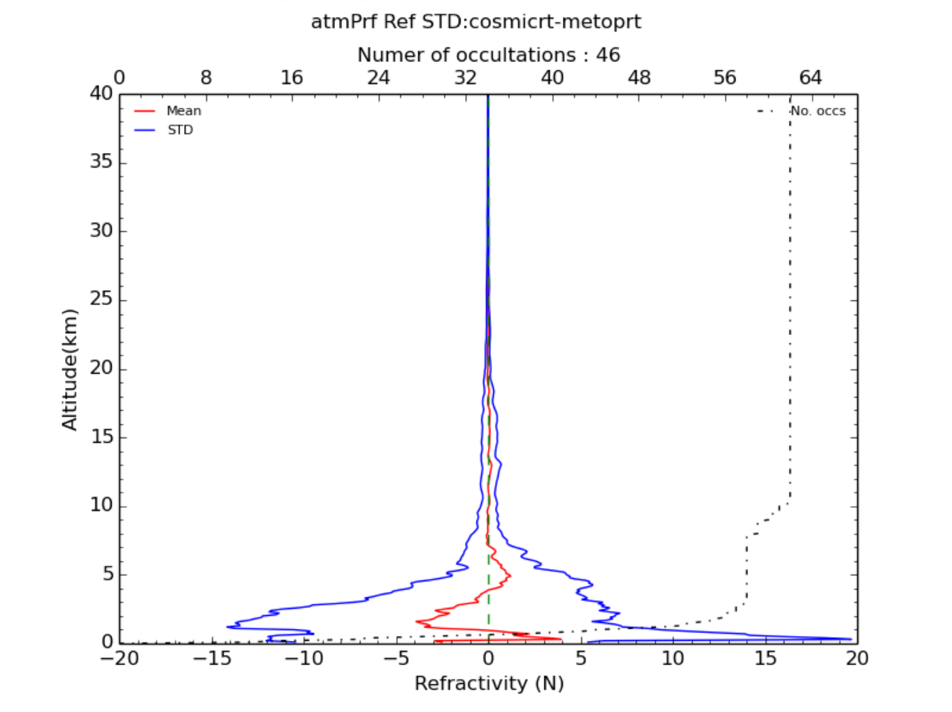


courtesy of TACC

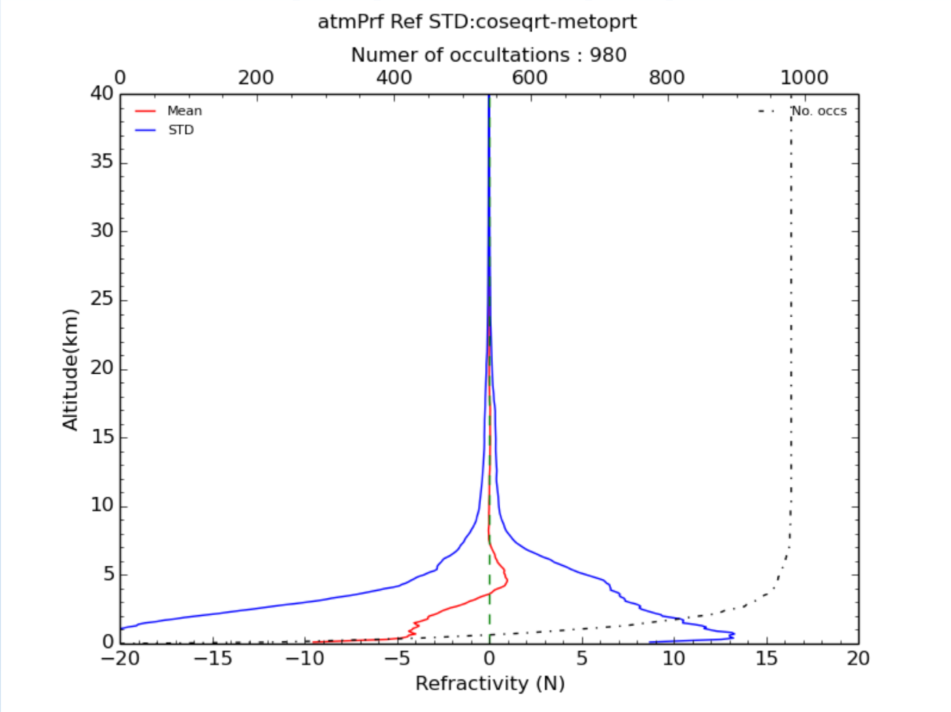
Verification against MetOP (30 days)

atmPrf (Refractivity)

FORMOSAT-3 (±45°)
2018/08/01-2018/08/31



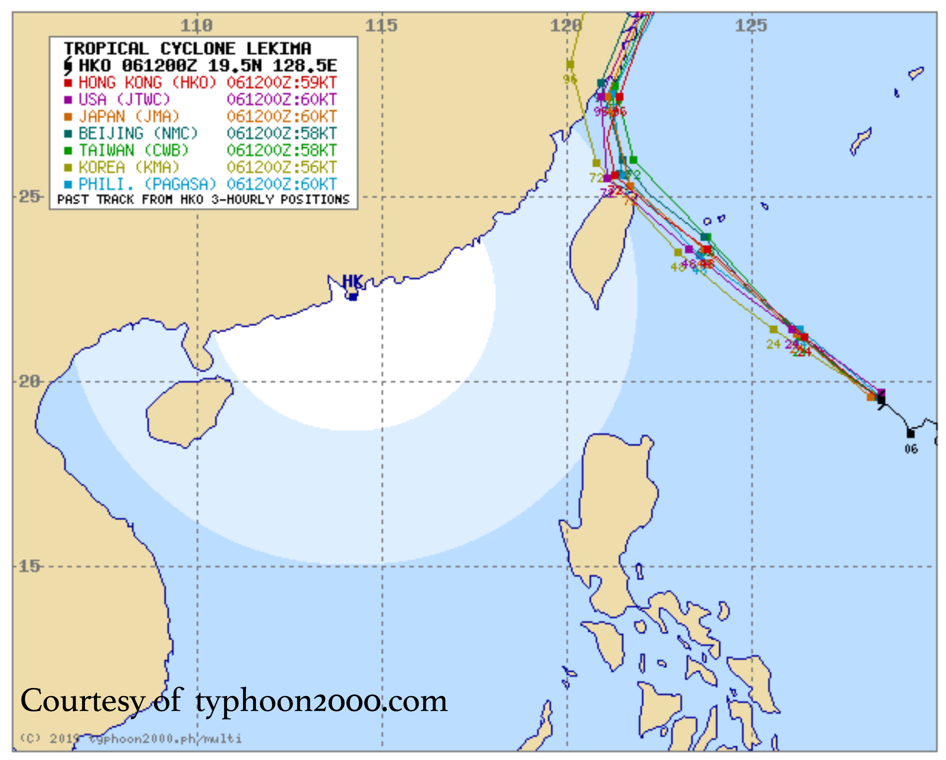
FORMOSAT-7
2019/07/26-2019/08/25

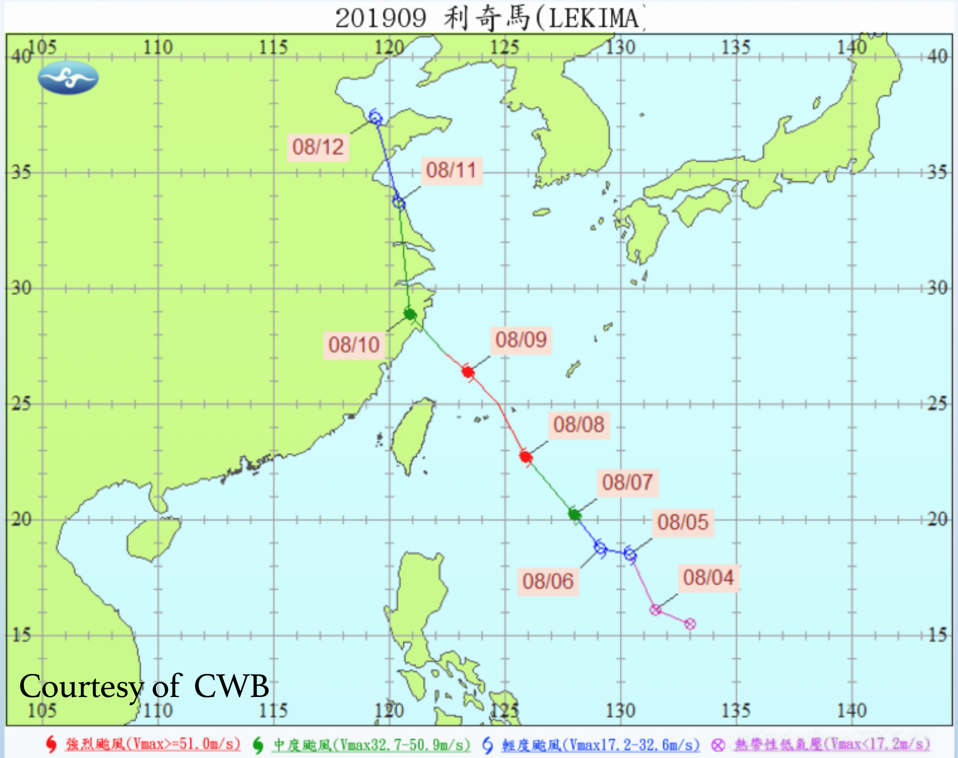


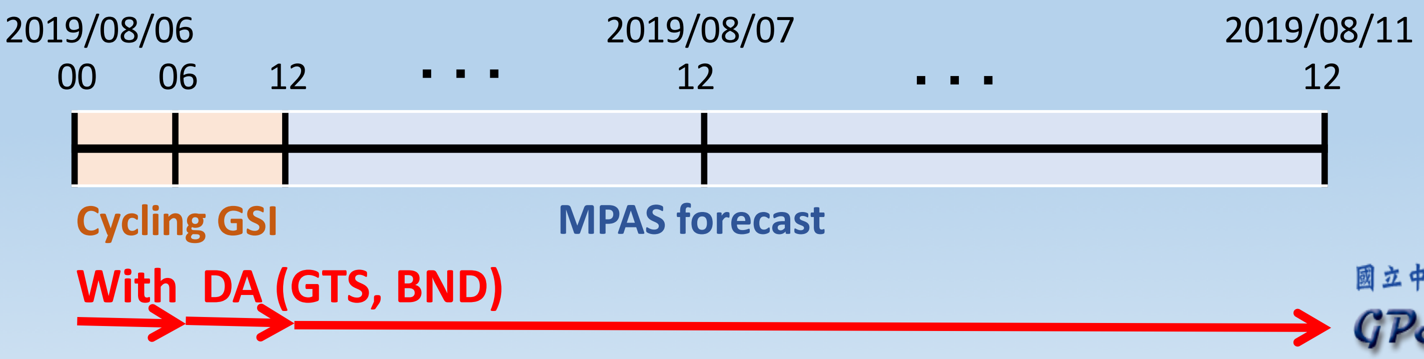
courtesy of TACC

國立中央大學全球定位科學與應用研究中心
GPSARC GPS Science and Application Research Center

Typhoon Lekima (2019)



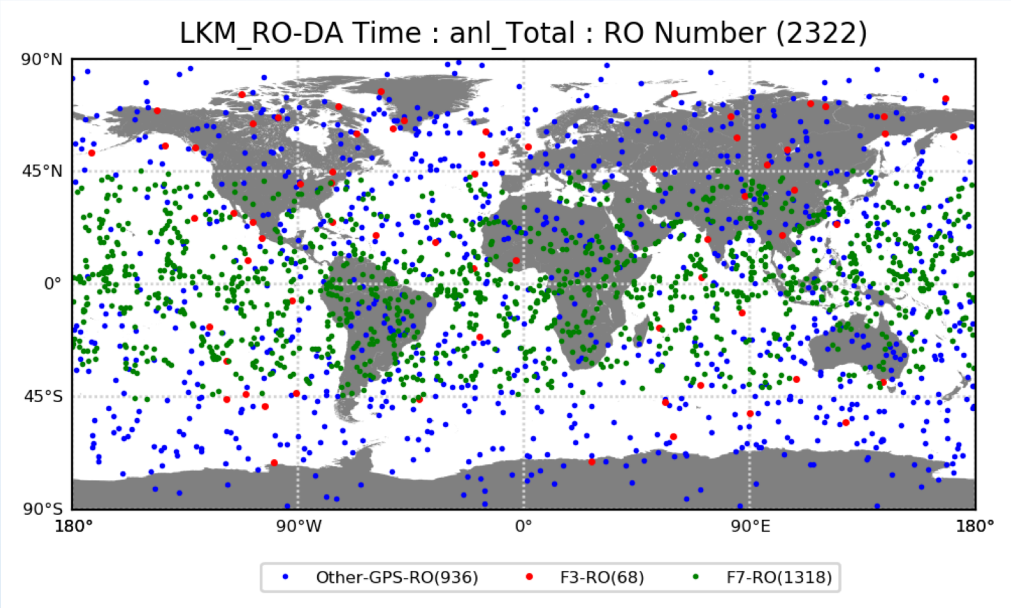




國立中央大學全球定位科學與應用研究中心

GPSARC GPS Science and Application Research Center

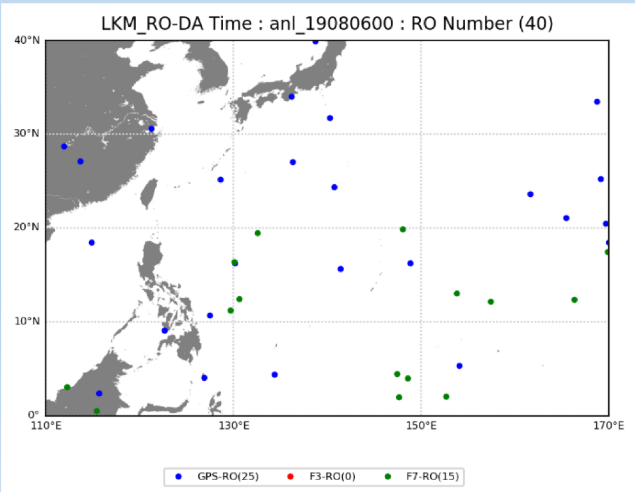
GNSS RO distribution



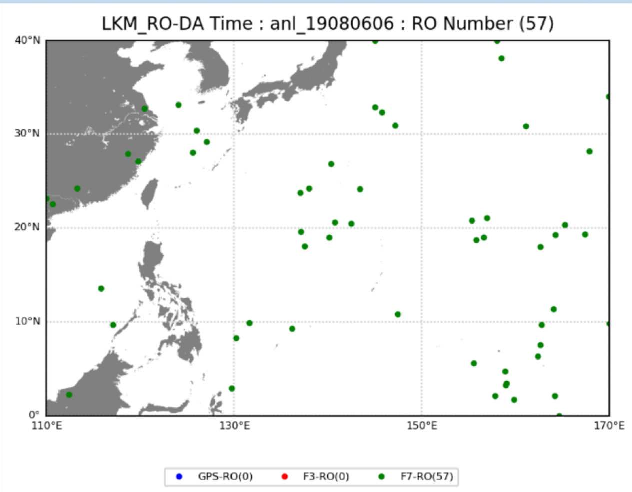
FS3
FS7
Others

More than 50% come from FS7

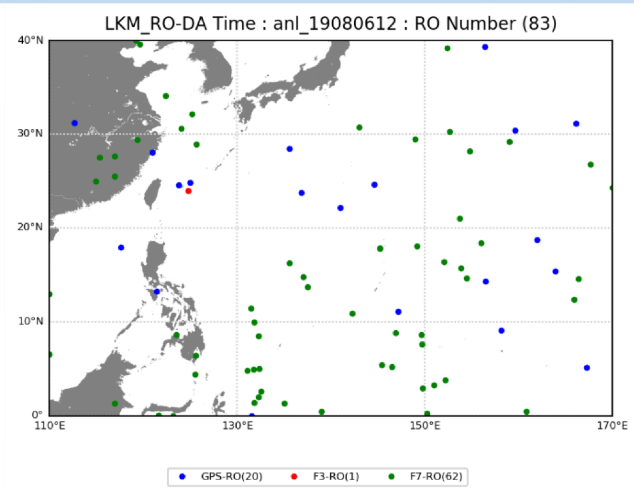
2019/08/06 0000UTC



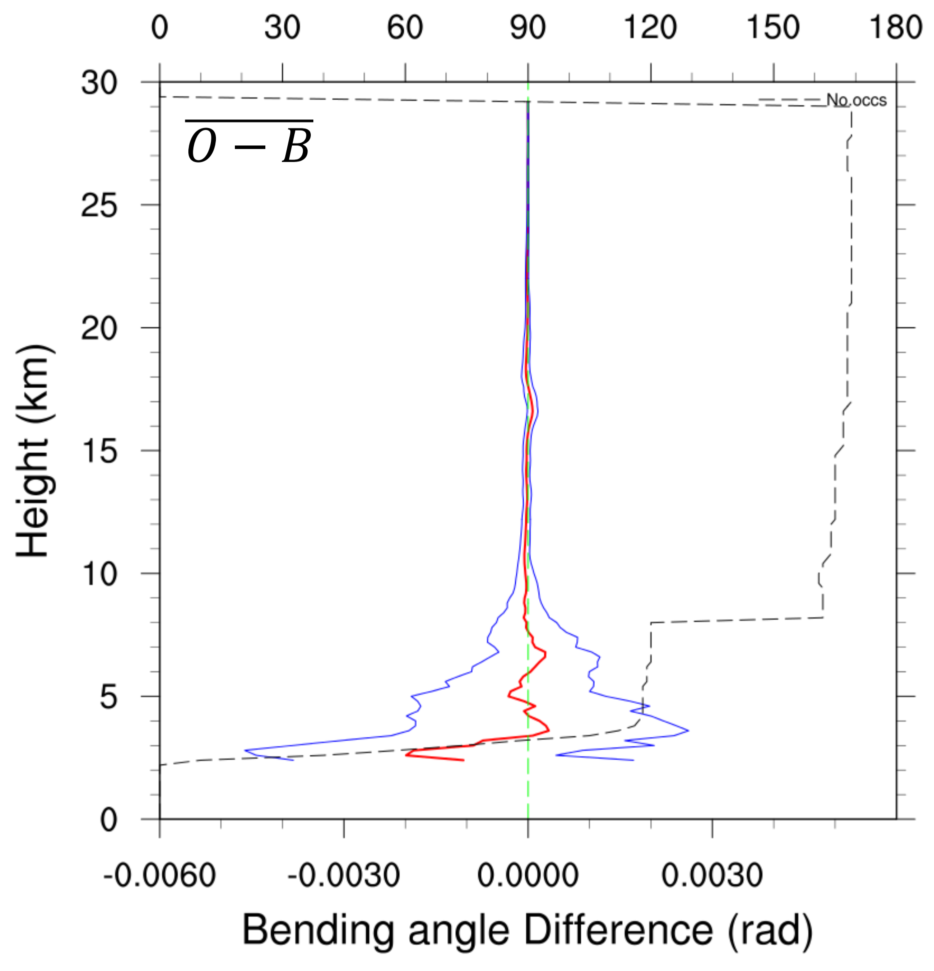
2019/08/06 0600UTC

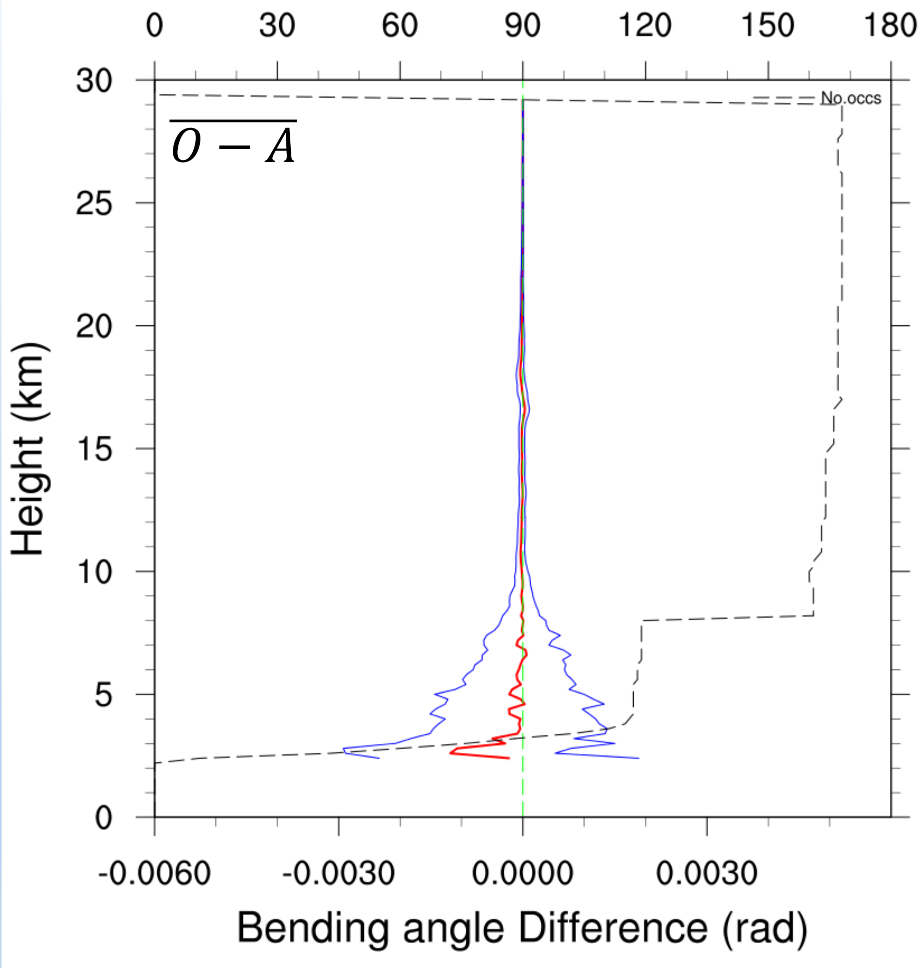


2019/08/06 1200UTC

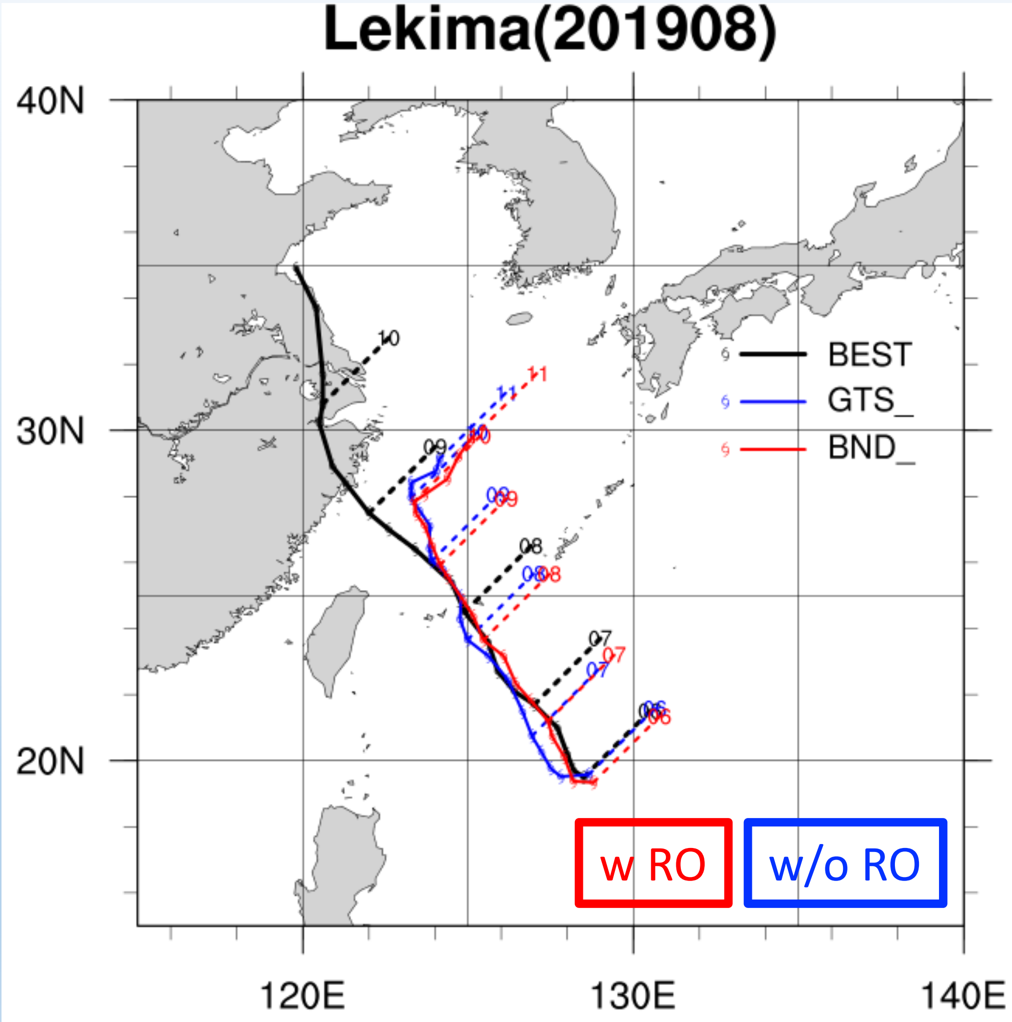


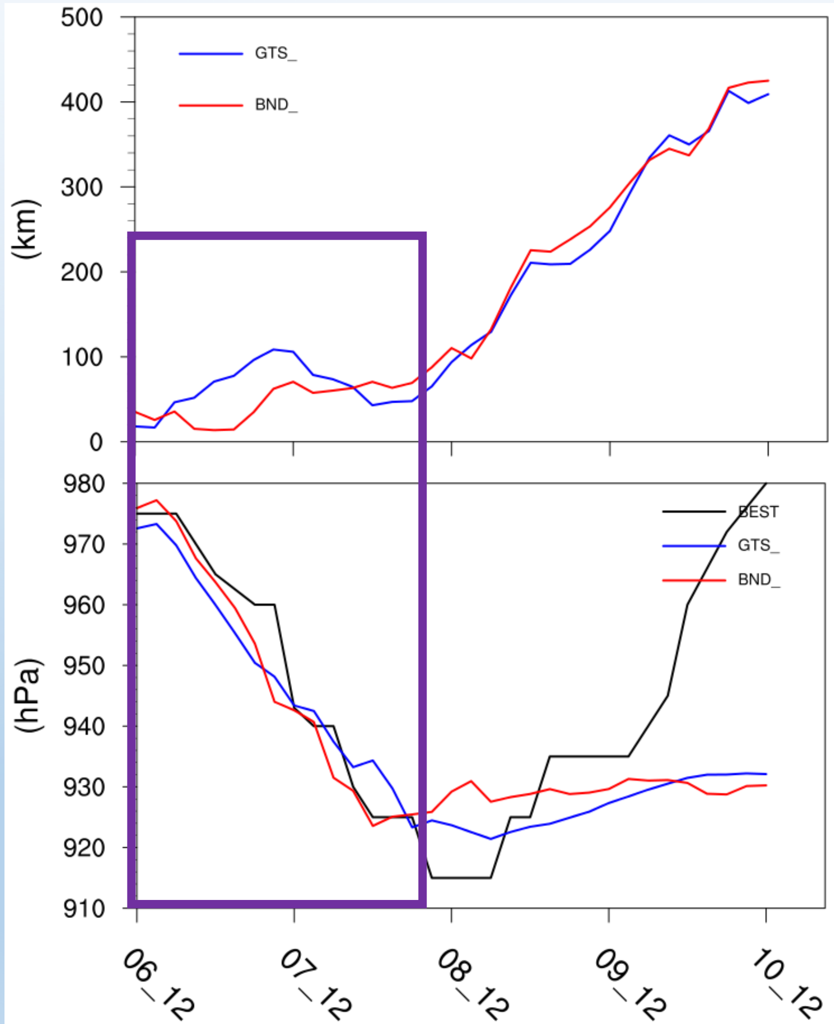
Statistic (bending angle)





EXP	GTS	BND
Ave. track error (3 days)	68	45





Summary

- In this study, the simulations with GNSS-RO data assimilation have better predictions in typhoon tracks for both assimilation strategies (3DVAR or Hybrid).
- Further, the assimilation with RO bending angle has a better performance than the others (GTS and REF).
- From the preliminary comparison, the data quality of FS7 is comparable with FS3, but the FS7 has more data available and further penetrate into the lower troposphere.
- With GNSS RO DA (inc. FS7), the simulated track and intensity show a slightly improvement in the early forecast of typhoon Lekima (2019).
- Further investigation and more experiments will be conducted in the future.

Thank you ~

國立中央大學全球定位科學與應用研究中心

GPSARC GPS Science and Application Research Center