Measuring Prediction Skill of Upgraded GRAPES-TCM and Modeling Activities in STI

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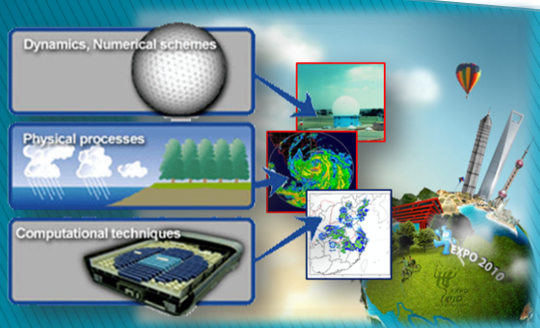
Shanghai Typhoon Institute, CMA



Acknowledgments: Drs. Vijay Tallapragada, Qingfu Liu, Jian-Wen Bao, Jimy Dudhia, John Michalakes and the others from WRF and HWRF team for their invaluable help and support, Also X Zhang, W. Huang, Li Hong etc. from STI NWP group and Xueshun Shen etc. from CMA

Outline

- Introduction/background (overview of Modeling activities in STI)
- A brief description of the upgraded GRAPES-TCM
- Validation and comparison
- Works related to impact-based forecasts and risk-based warning

Missions of STI's Modeling Work

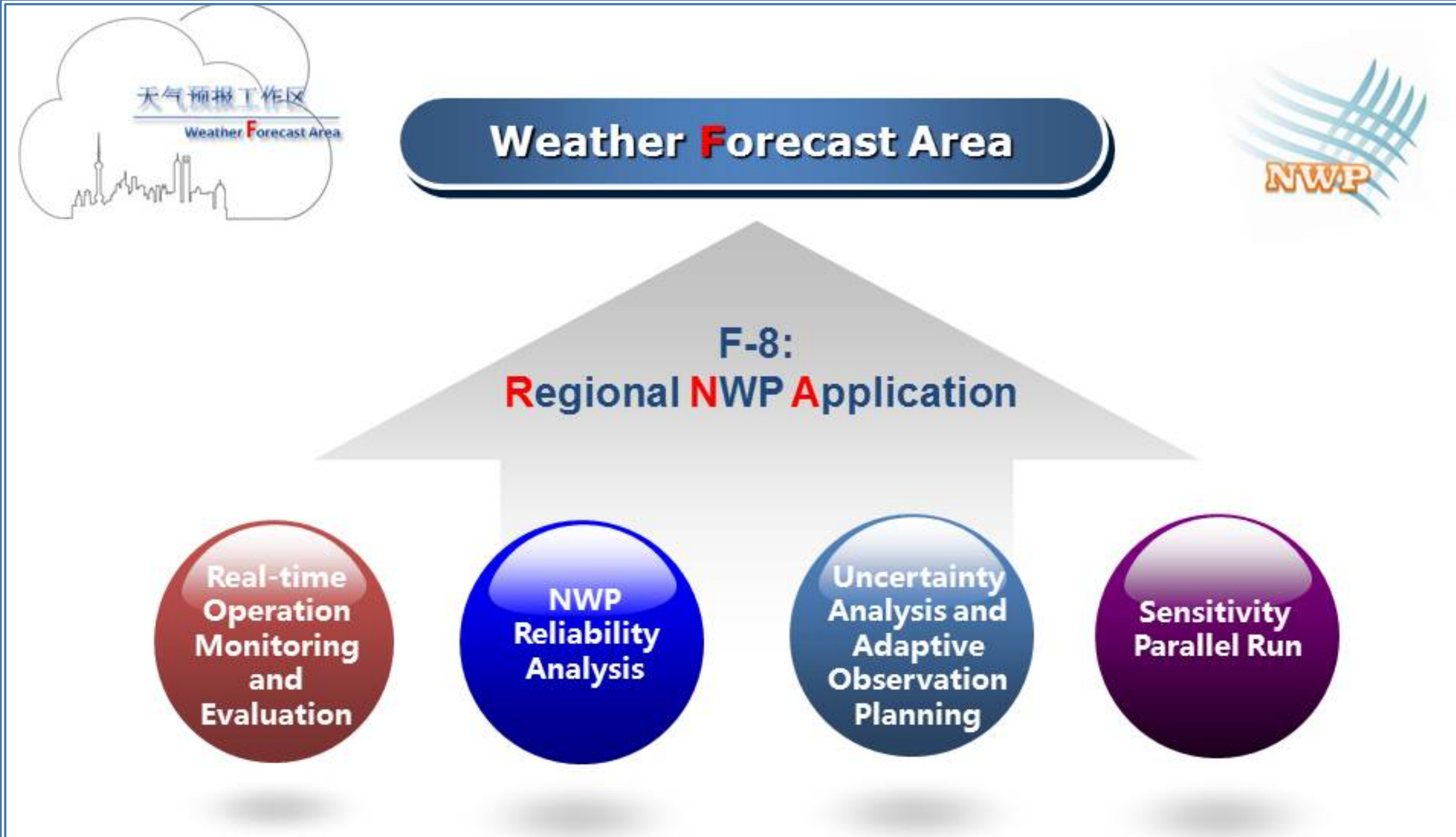
Innovative research of numerical modeling associated with TC , advanced technology implementation (R2O application), young scientists training, providing technical support and model prototype for operational NWP system upgrade.

The research areas include: observation analysis and regional data assimilation, tropical cyclone vortex initialization techniques, atmospheric dynamics and model dynamical core, physical & chemical processes and their parameterizations, model verification and evaluation

Specifically, two missions:

- Supporting SMB: Operational meso-scale Numerical Weather Forecast
- Supporting CMA: Operation and Research on TC NWP

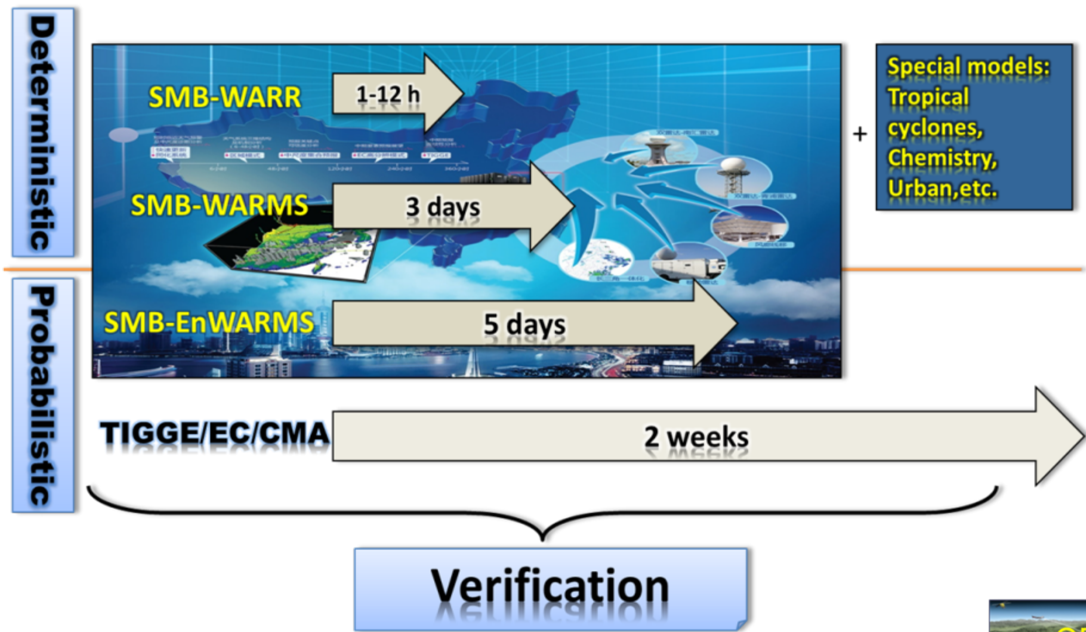
Supporting SMS's mission: Operational Numerical Weather Forecast

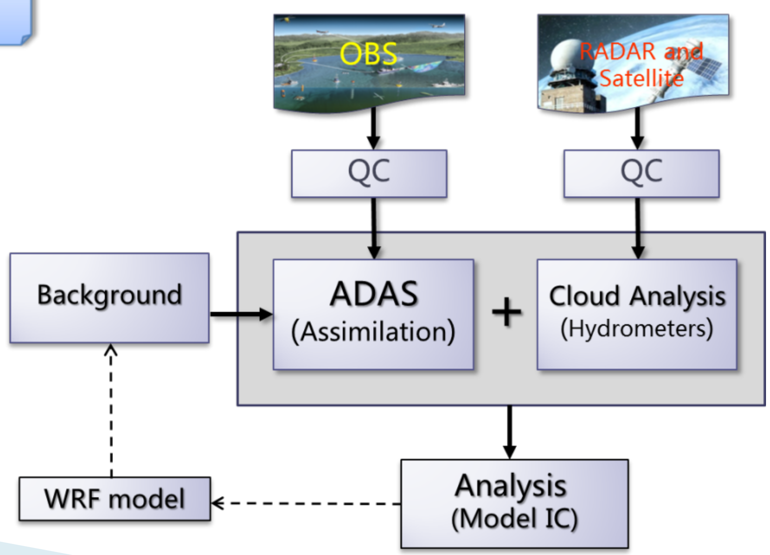


- To build up a NWP supporting platform
- To provide multi-scale NWP products
- To provide forecast uncertainty, reliability information

Supporting SMS's mission: Operational Numerical Weather Forecast

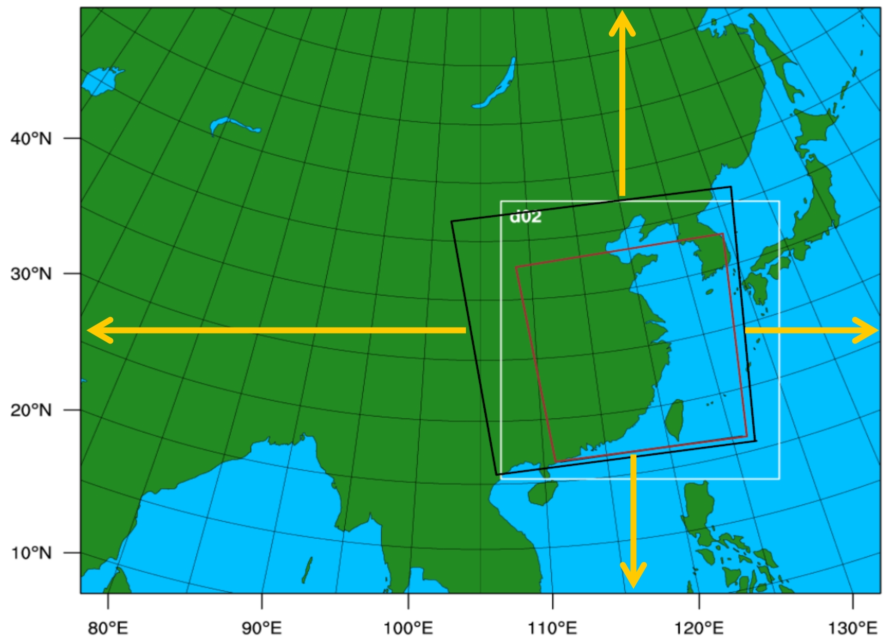
Framework of SMS Regional Modeling System





ADAS: ARPS Data Analysis System

STI-WARMS (WRF-ADAS REALTIME MODELING SYSTEM)

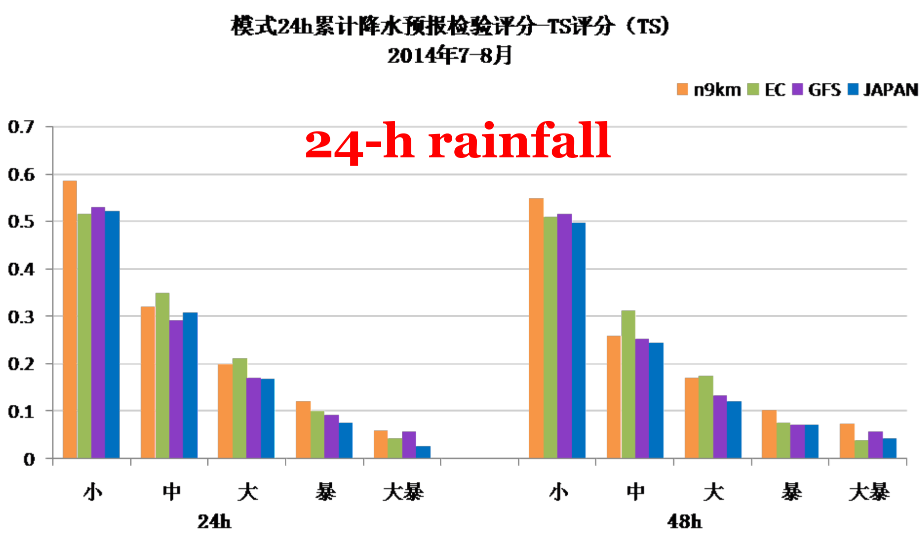


Resolution : 9km, 760X600 grid points, 51 levels
STI-WRF 3.5.1
STI-ADAS 5.5.3

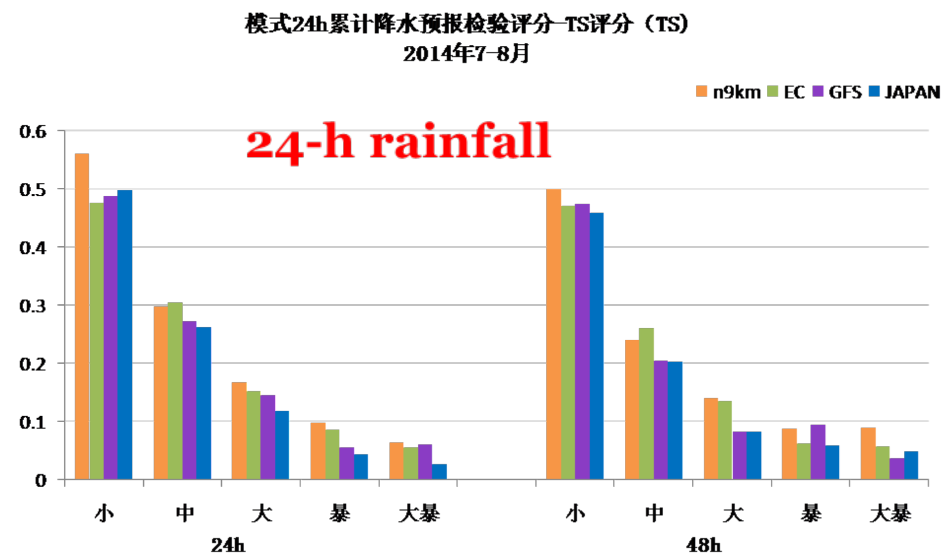
观测资料类型	简 称	获取频率
常规地面观测	SYNOP	1h (10min)
机场地面	METAR	1h
船舶观测	SHIP	1h
浮标	BUOY	1h
自动站	AWS	1h (5min)
飞机观测	AMDAR	1h
探空	RAOB	12h
小球测风	PILOT	12h
雷达（反射率）	RADAR	1h (6min)
FY2E红外和可见光（辐射率）	FY2E	1h (30 min)

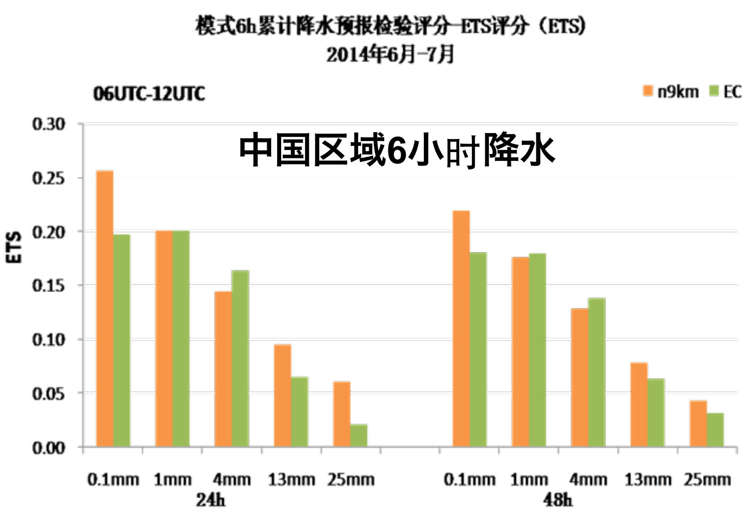
Interactive NWP verification Platform

Domain

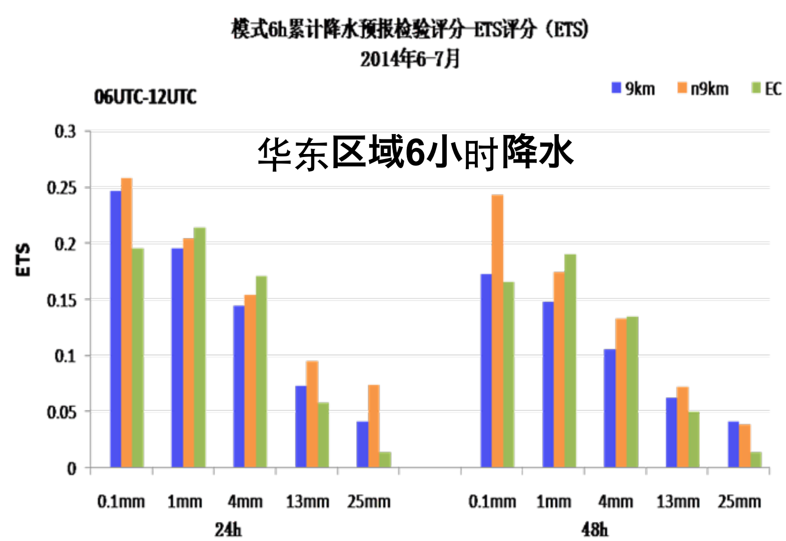


Eastern China



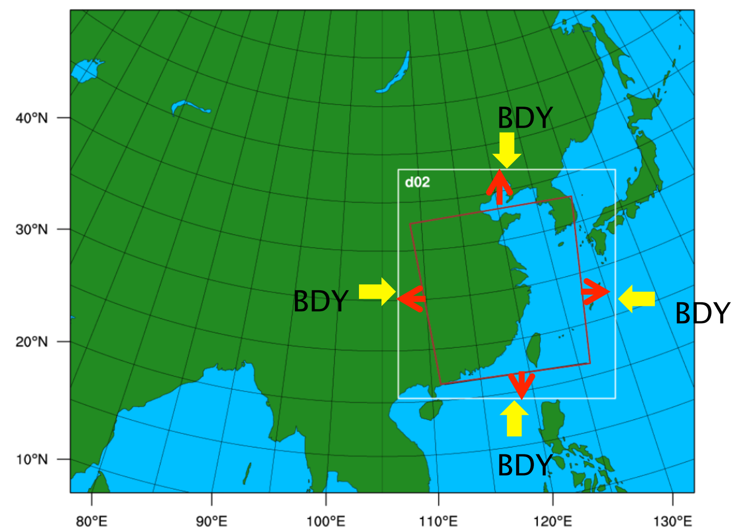


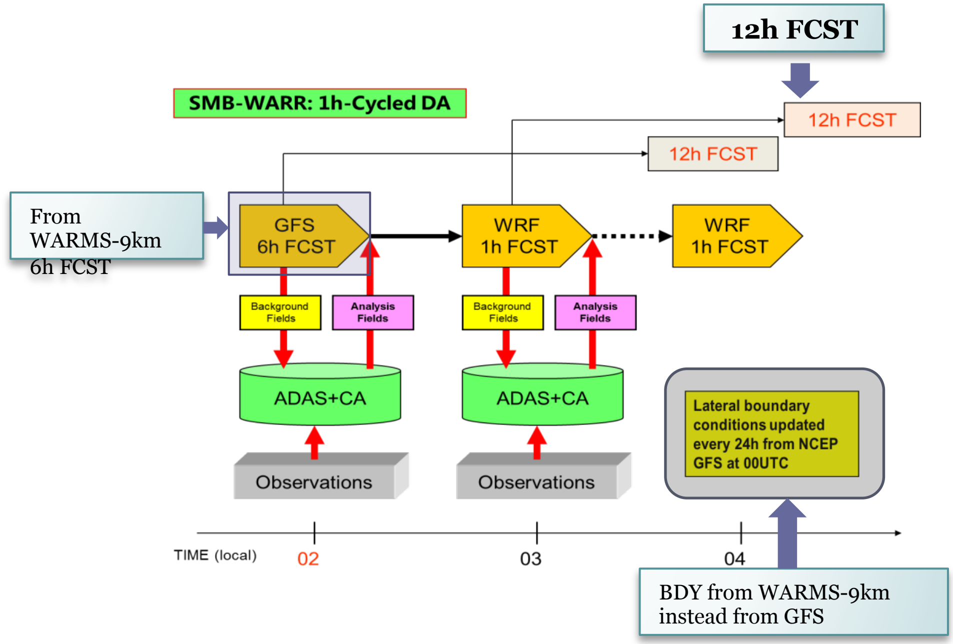
6-h



STI-WARR : WRF_ADAS Rapid Refresh System

Cool Start from WARMS-9km





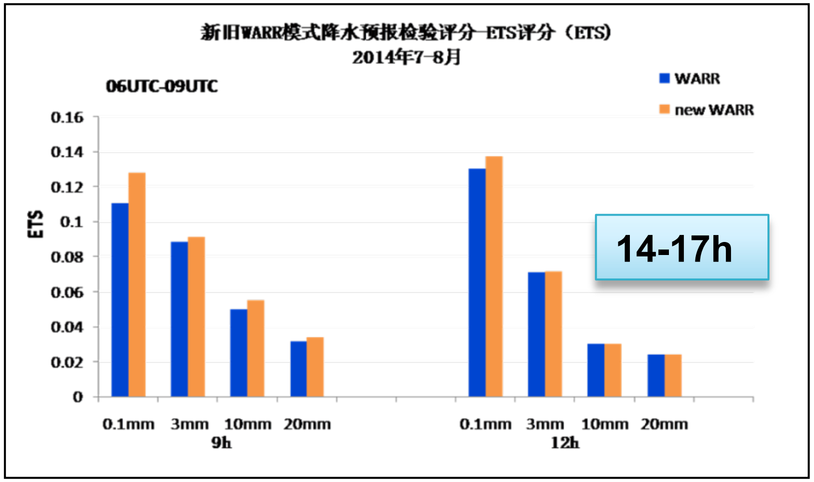
Key Techniques in Rapid Refresh Assimilation and Forecast

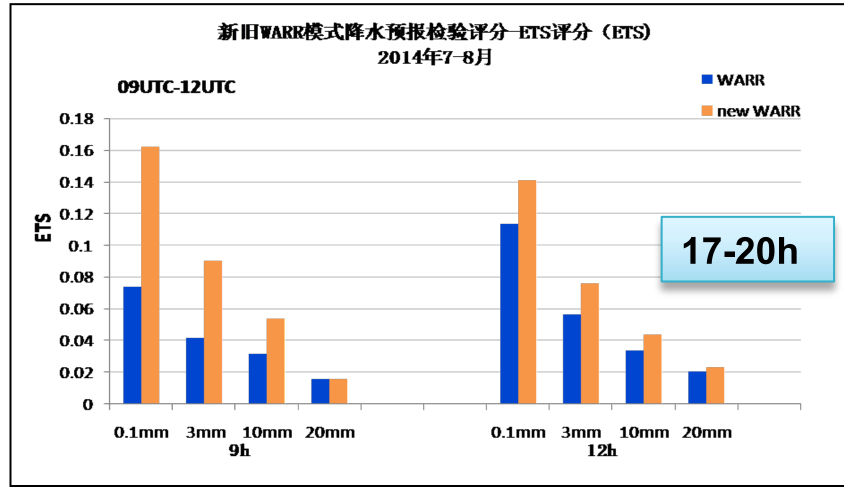
- 绝热与非绝热数字滤波初始化技术
- 冷启动（Cold Start）、暖启动（Warm Start）和热启动（Hot Start）技术
- 循环同化设计（如何配置不同的启动）
- 云分析技术（雷达、闪电、卫星资料应用）
- 近地面资料同化技术
- 同化频率与资料空间分辨率

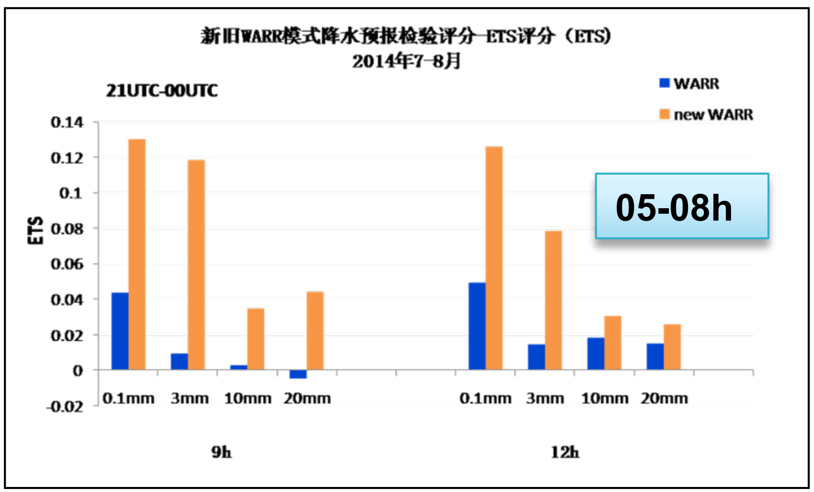
3km Resolution, 51 level
Cooling start at 02 am (BT)
Data assimilation every hour,
12-hour prediction

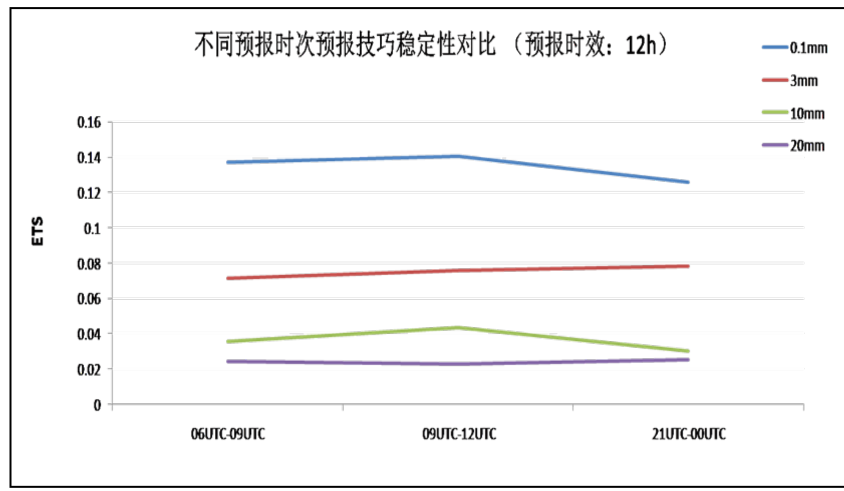
[1] 陈葆德、王晓峰、李泓和张 蕾：《快速更新同化预报的关键技术综述》
Advances in Meteorological Science and Technology 气象科技进展 3（2）- 2013

3h accumulated rainfall verification









New-WARR各个量级预报ETS评分都远高于原来的模式 (much better than its predecessor)

NWP for Nowcasting : from some kind of reference to practical use in daily operation

GRAPES-TCM

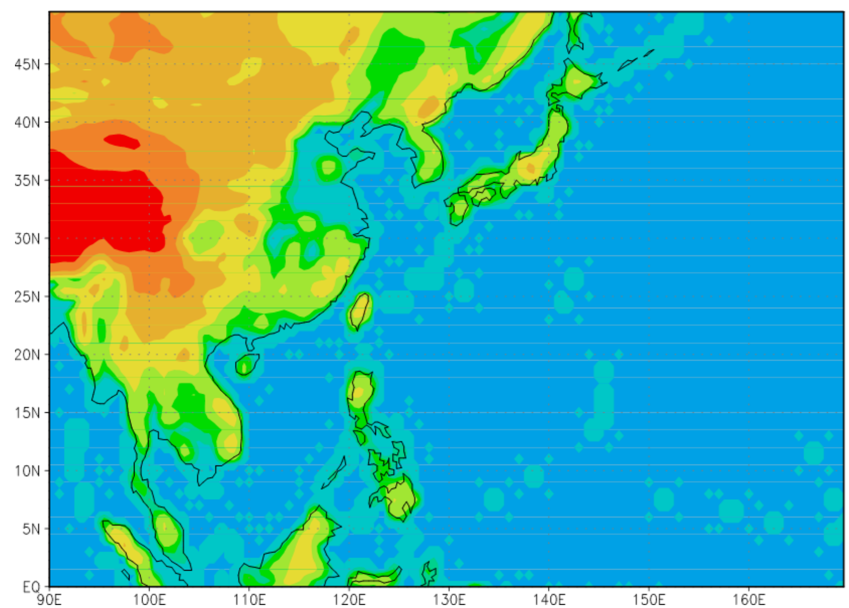
The **GRAPES** (a short form of **G**lobal/**R**egional **A**ssimilation and **P**r**E**diction **S**ystem) was developed during 2003-2008 by China Meteorological Administration (CMA), which includes variational data assimilation (3DVAR), full compressible non-hydrostatical dynamical core with semi-implicit and semi-Lagrangian discretization scheme; modularized model physics package (most from the WRF); global and regional versions.

STI implemented a BDA scheme into the GRAPES, known as GRAPES-TCM (GRAPES-Typhoon Cyclone Model), and put into operational forecast since 2007

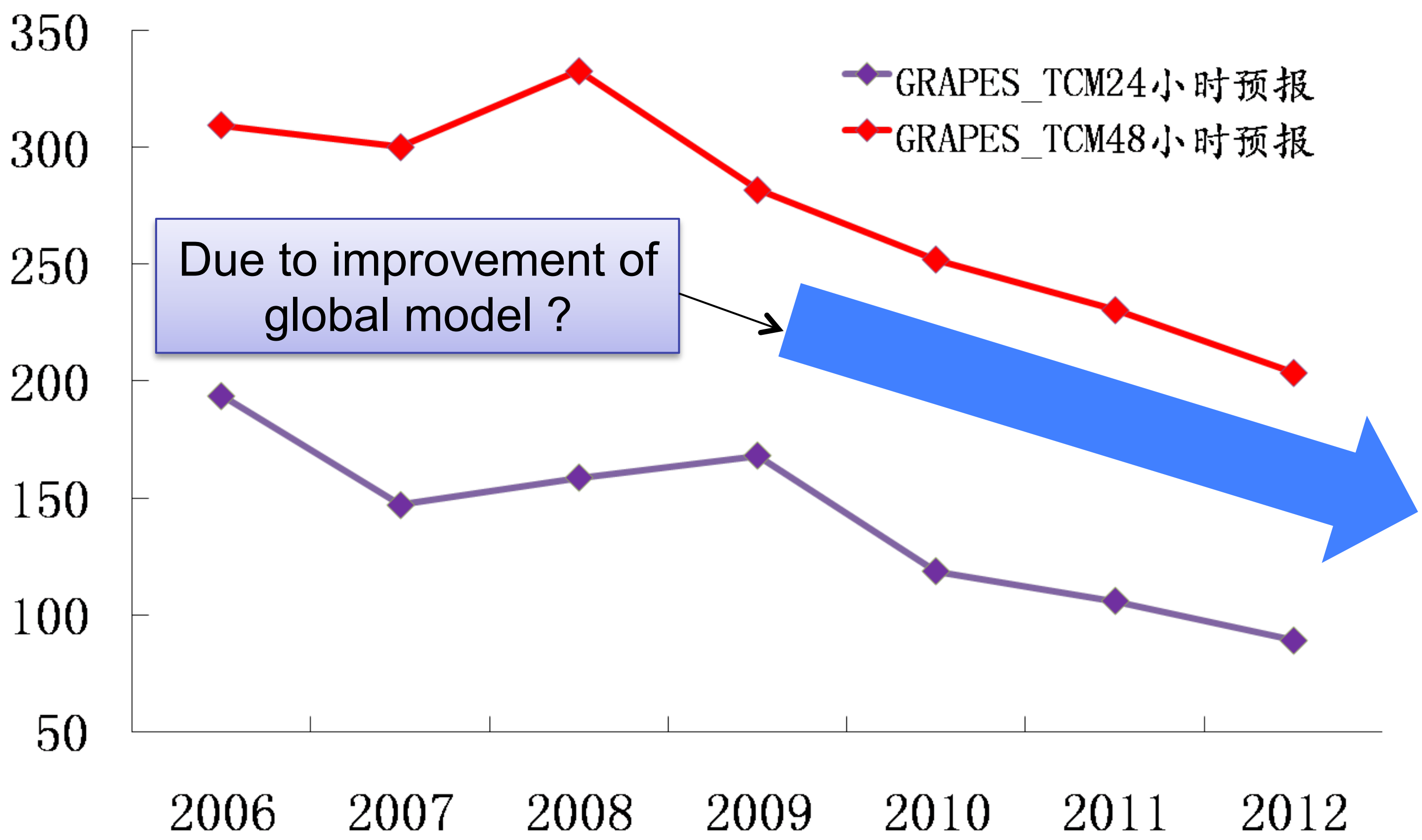
- Configuration
  - Domain: E90°~E170°,N0°~N50°
  - Hor. Res.: 0.25°x0.25°
  - Grids: 321x201
  - V. res.: 31(ztop: 35000m)

- Physics
  - Cumulus: KF-eta
  - PBL: YSU
  - Micro: NCEP cloud3
  - LSM: SLAB scheme
  - Radia.: RRTM scheme

Domain of operational GRAPES_TCM

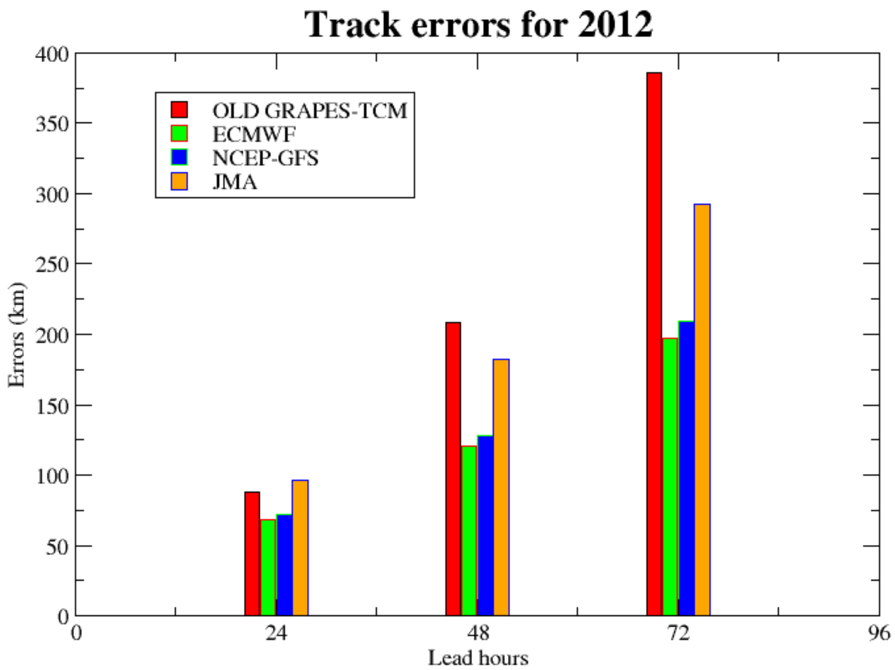


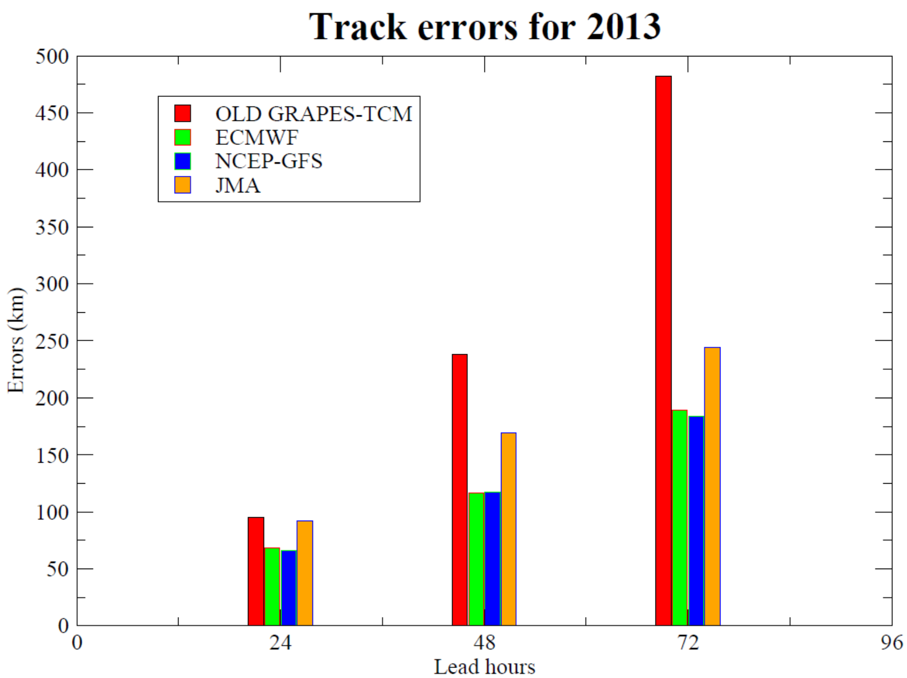
Evolution of yearly mean track errors



(From Wang et al., 2012)

Compared with other models:





Prediction Skill: downgrading too much and too quick as the lead time increasing !

Reflecting deficiency not only in the physics but also in the dynamics

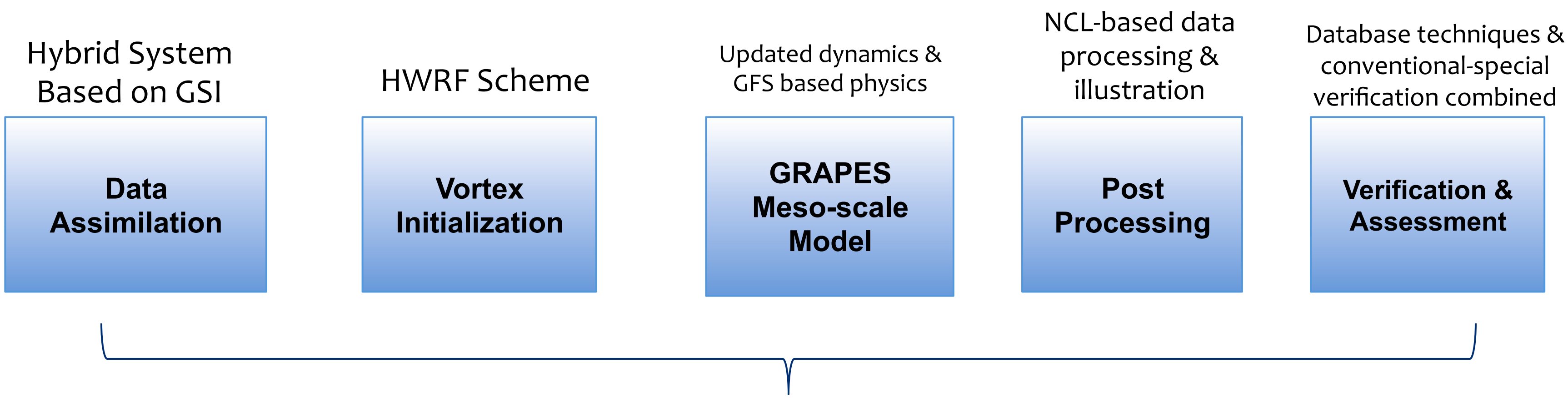
A 3-year project of 'Development and Implementation of Critical Technologies in High-resolution Modeling of Tropical Cyclones' supported by 'China Special Fund for Meteorological Research in the Public Interest' from Ministry of Finance of China.

OBJECTIVE: Based on CMA's GRAPES, to develop a new regional modeling system for tropical cyclone forecast, to achieve 10% reduction of track error w.r.t the operational GRAPES-TCM's track error in 2010 (116km/24h) and 5% increase of intensity accuracy .

The establishment of the Key Laboratory of Numerical Modeling for Tropical Cyclones of CMA

Scientific Steering Committee:
Chair: Jimy Dudhia
Member: Jian-wen Bao, Geoge Grell, Songyou Hong, Haraldur Olafsson, Vijay Tallapragada, X. Lei, Xueshun Shen, H. Yang, G. Wu, Y. Yang

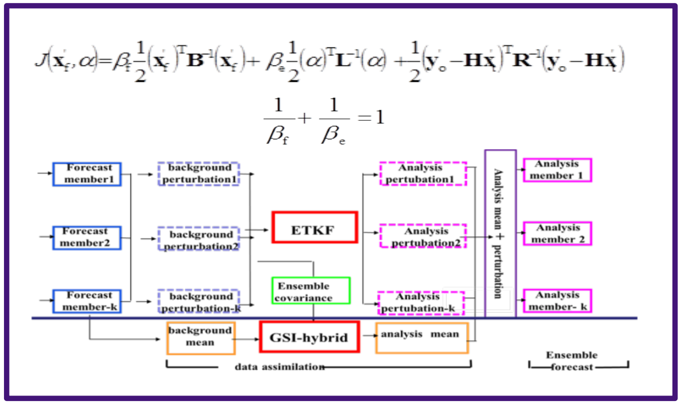
Upgraded GRAPES-TCM



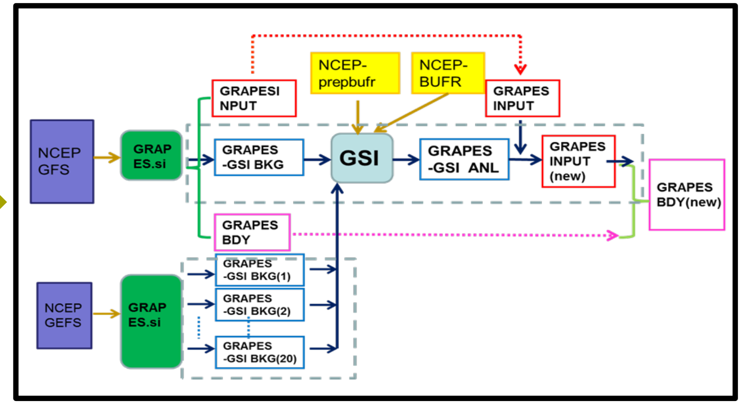
To be consolidated into a single package

Data Assimilation and Vortex Initialization

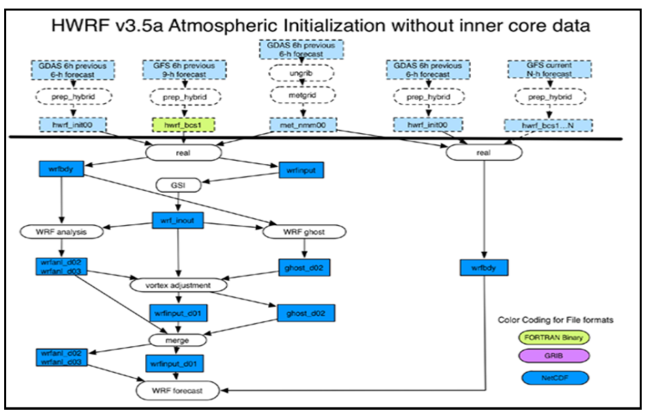
WRF GSI-Hybrid



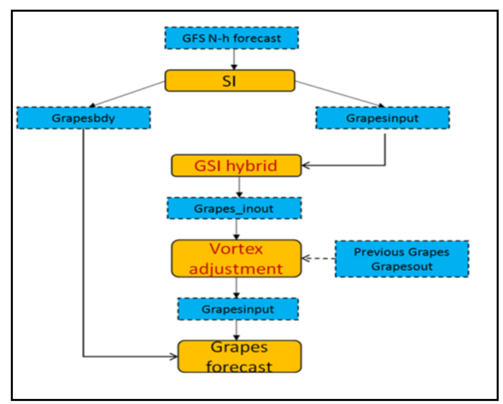
GRAPE GSI-Hybrid



GFS-HWRF Vortex Initialization



GRAPES Vortex Initialization



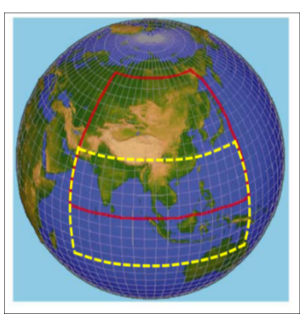
GRAPES-TCM Dynamical Core

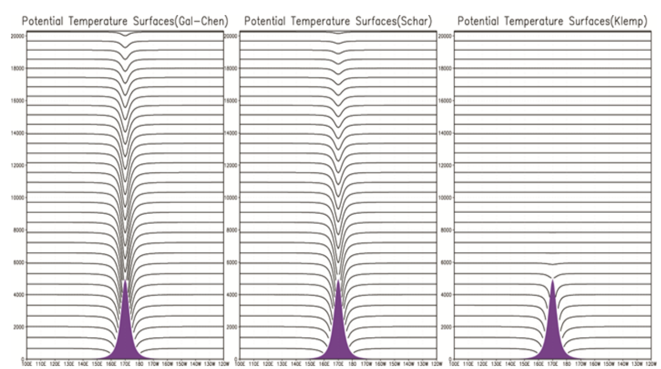
Full compressible non-hydrostatical model, height terrain-following vertical coordinate, Arakawa C-grid, Charney-Phillips vertical grid, and semi-implicit and semi-Lagrangian time integration scheme, prognostic variables: u, v, w, θ, Π and q

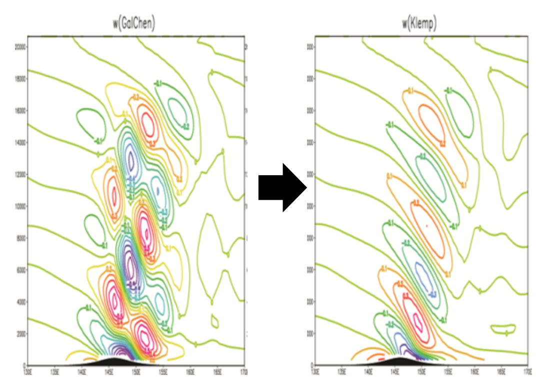
Finished | Nearly finished | On-going

Upgrading：

- **Rotated coordinate；**
- **New terrain-following vertical coordinate;**
- **Implicit Rayleigh damping for the vertical velocity ；**
- **New scheme for pressure gradient calculation；**
- **Stable Extrapolation Two-Time-Level Scheme (SETTLS) for semi-Lagrangian time integration and trajectory calculation, centering linear terms;**
- **RSL-LITE, new algorithm to build up coefficient matrix of pressure elliptic equation (addressing scheme), new pressure elliptic solvers (PETSC and HYPE based);**
- **New Positive definite trace advection scheme;**
- **New discretization scheme for elliptic equation (7-point stencil Helmholtz equation);**

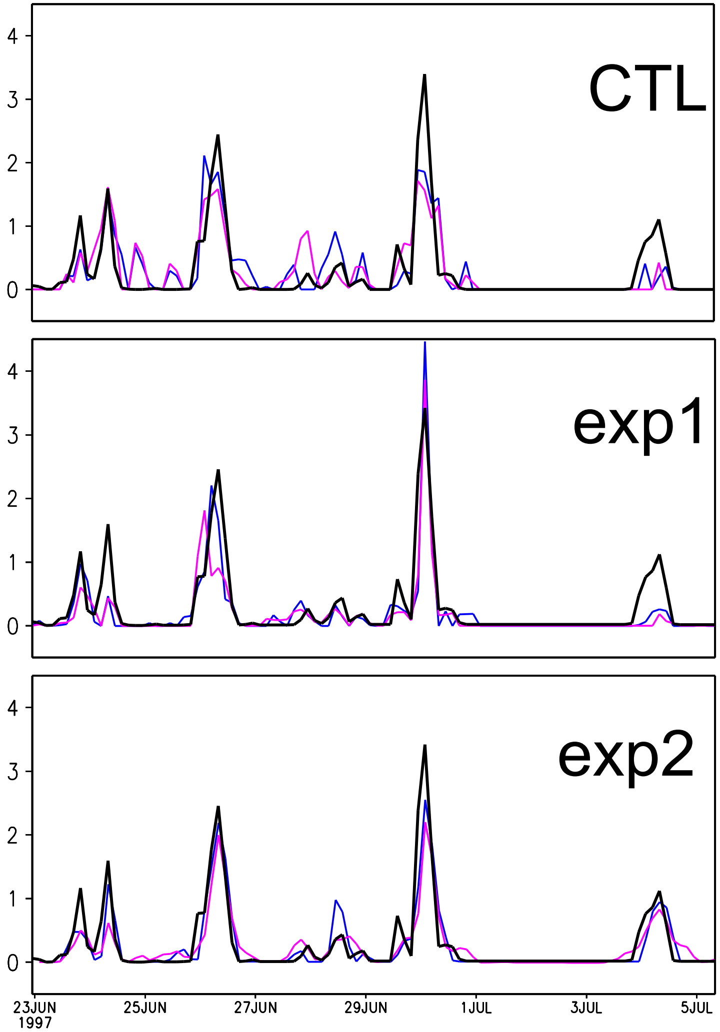






Single Column Model Test

1-hour precipitation



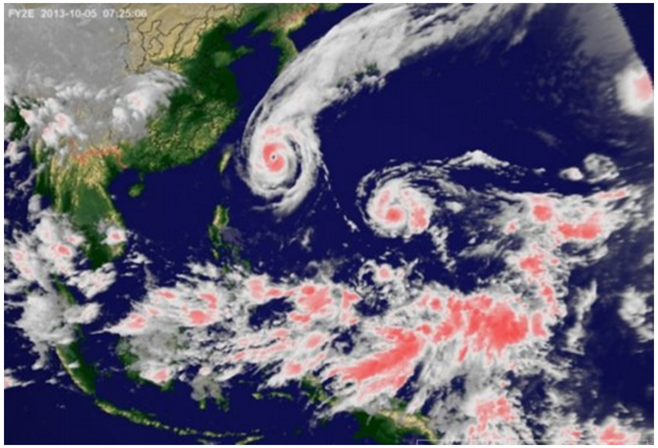
Current Physics

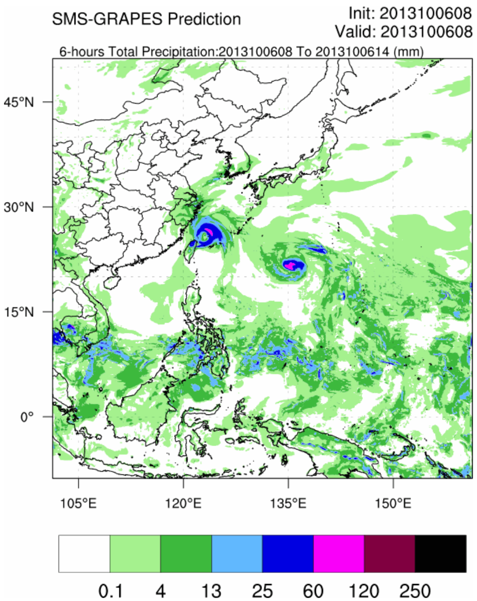
Combination of HWRF physics

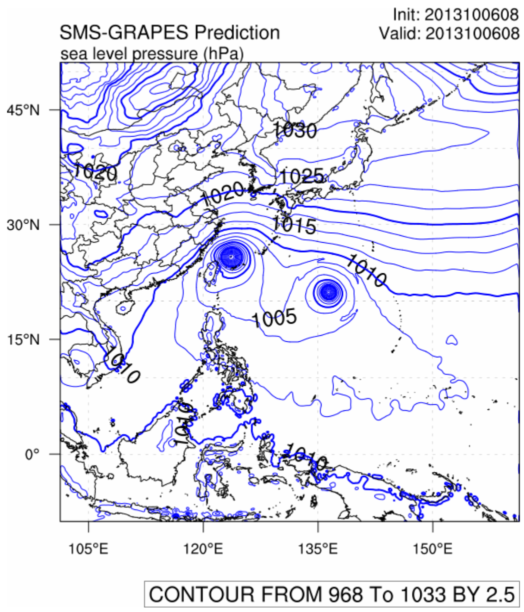
Whole Package of GFS physics

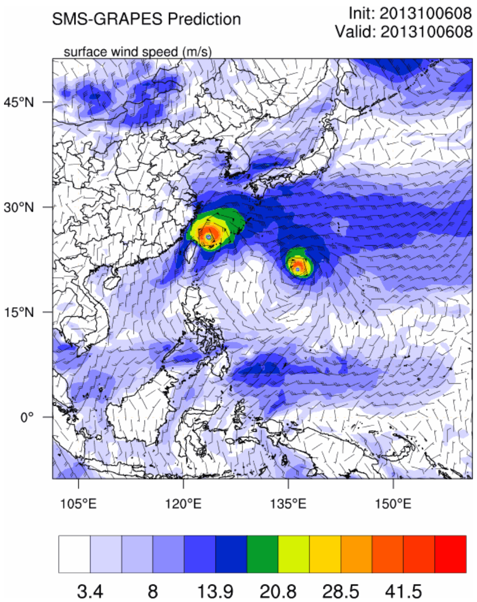
Coupling of physics components is very important !

Post-processing Package based on NCL



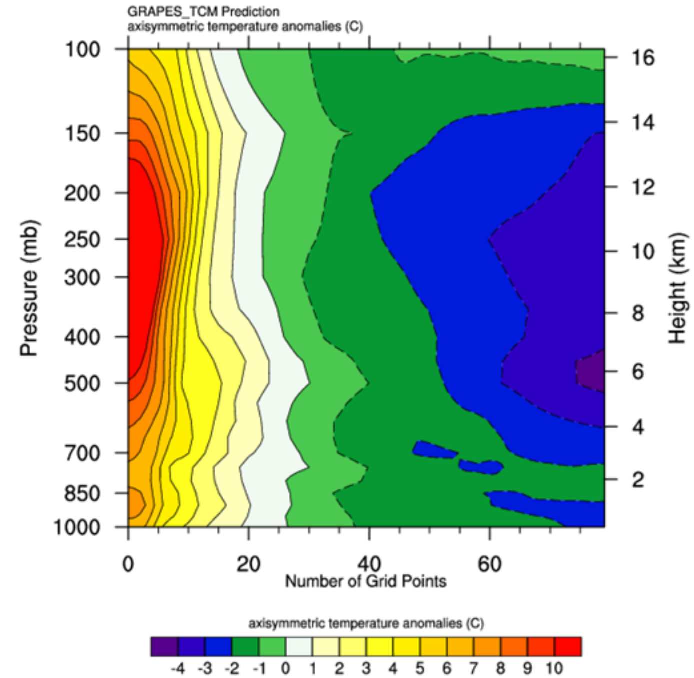


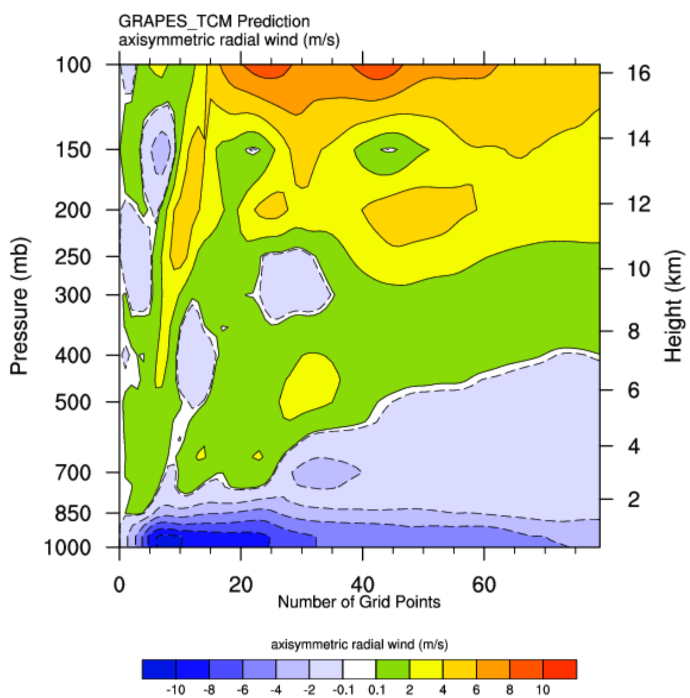


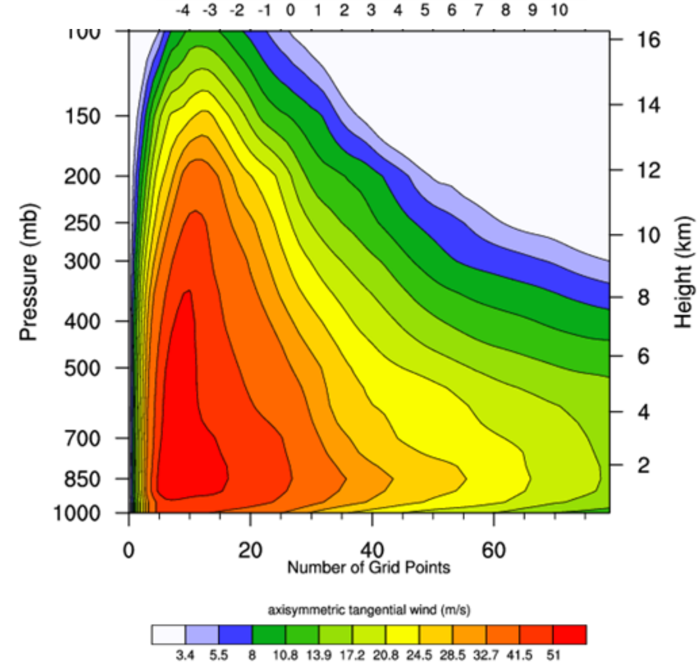


Post-processing Package based on NCL

Storm Structure:
Axis Symmetric Plots

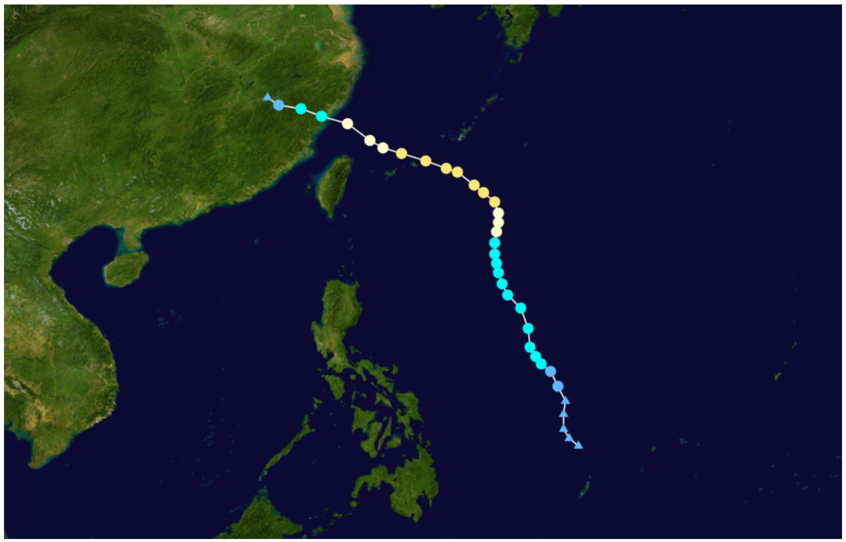


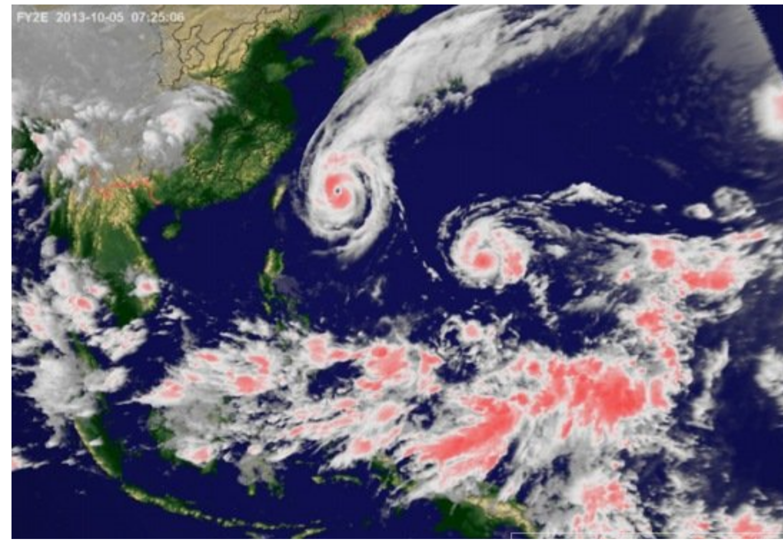




Quick-look type test

Typhoon Fitow was the strongest typhoon to make landfall in Mainland China during October since 1949.





Track map of Severe Tropical Storm Fitow of the 2013 Pacific typhoon season. The points show the location of the storm at 6-hour intervals. (from en.wikipedia.org/wiki/Typhoon_Fitow)

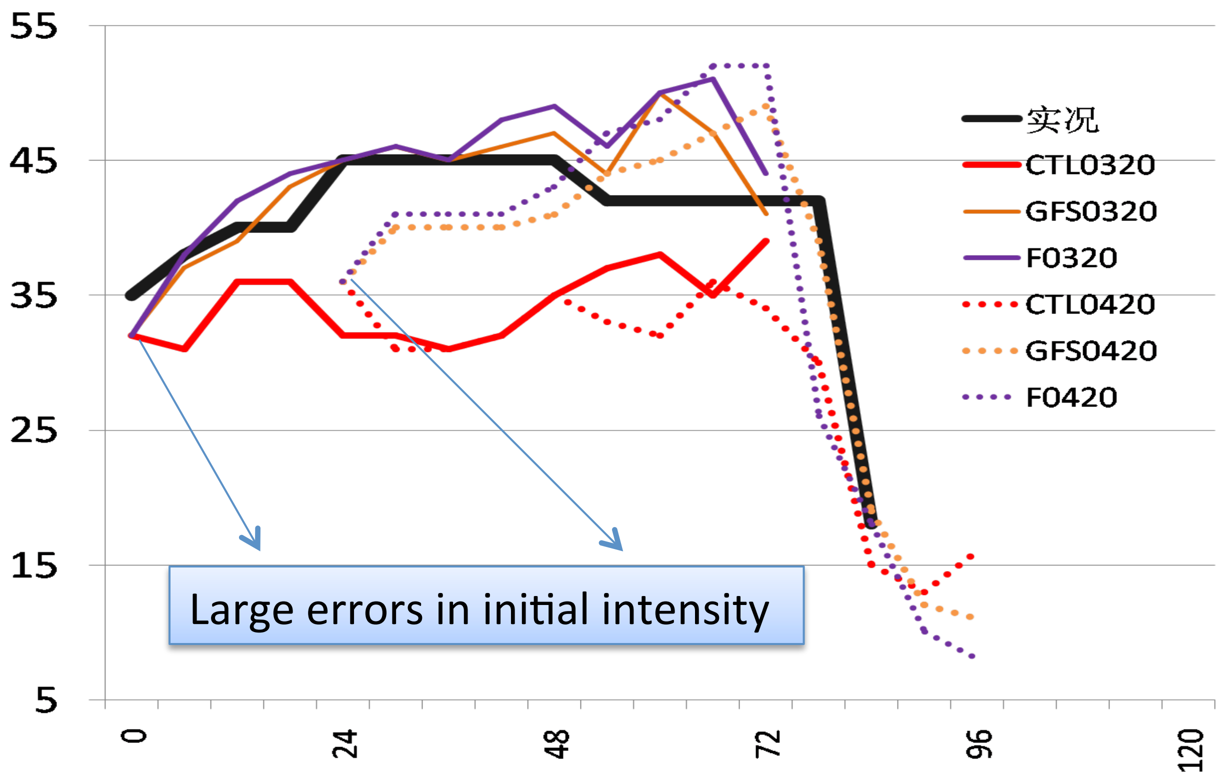
FY2E 2013-10-05 12:00 UTC

Saffir-Simpson Hurricane Scale

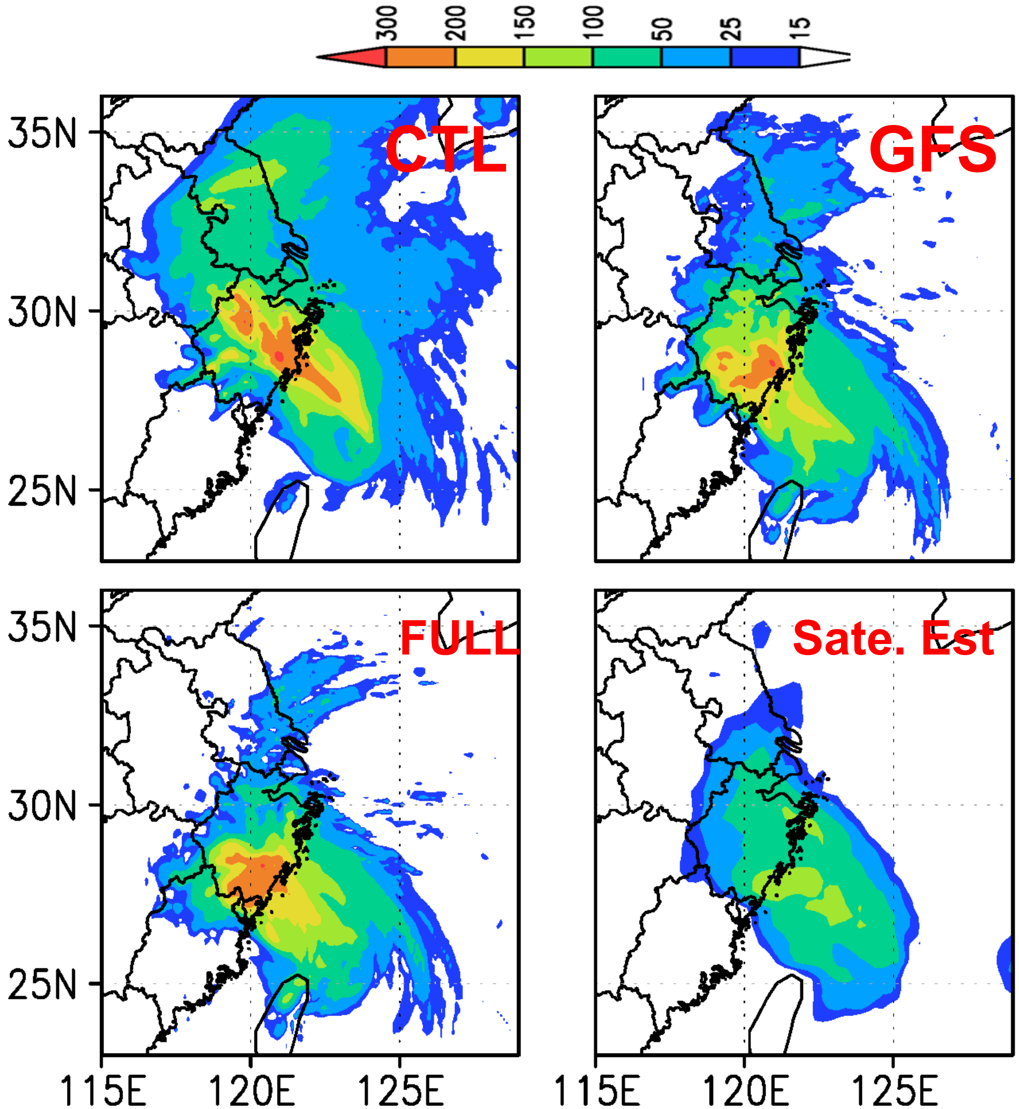
Tropical depression	<39 mph	<63 km/h	Category 3	111–129 mph	178–208 km/h
Tropical storm	39–73 mph	63–117 km/h	Category 4	130–156 mph	209–251 km/h
Category 1	74–95 mph	119–153 km/h	Category 5	>156 mph	>251 km/h
Category 2	96–110 mph	154–177 km/h	Unknown		

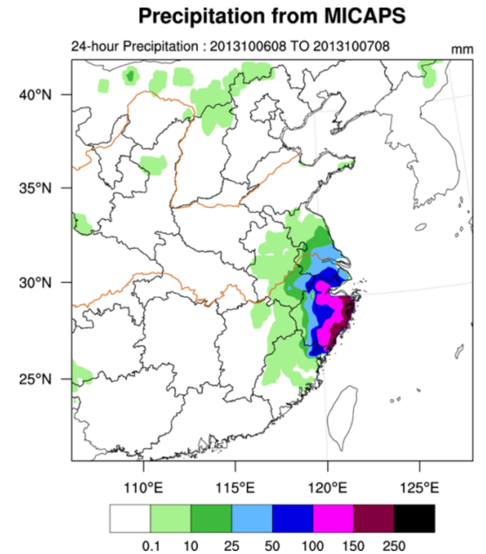
‘Fitow’ intensity forecasts

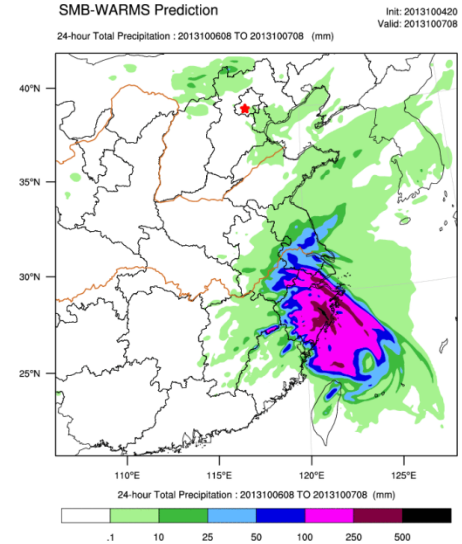
Control experiment (CTL): w/o any upgrades
GFS: only physics
FULL: both upgraded dynamics and physics
Initialized at 2013-10-03 12:00(UTC) and 2013-10-04 12:00 (UTC)



Forecasts for 24-hour rainfall



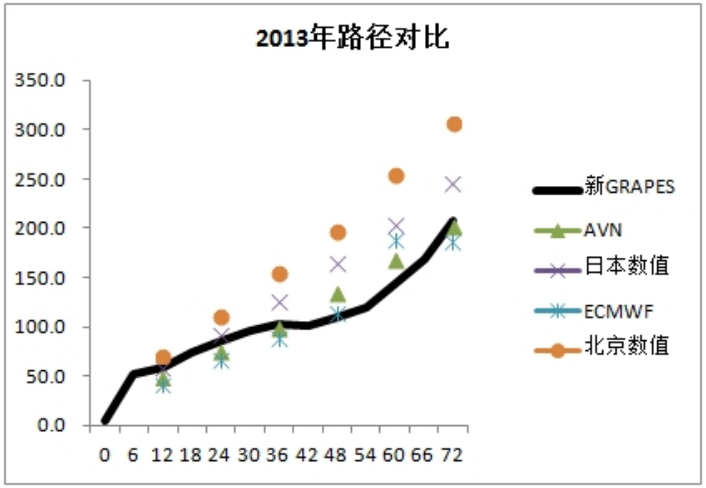


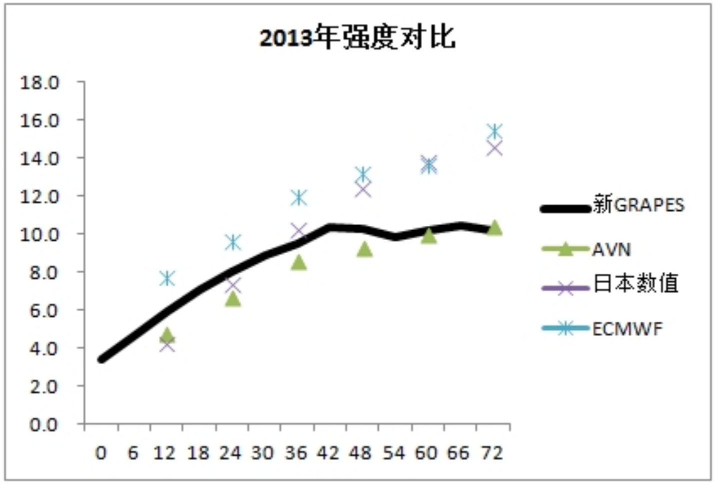


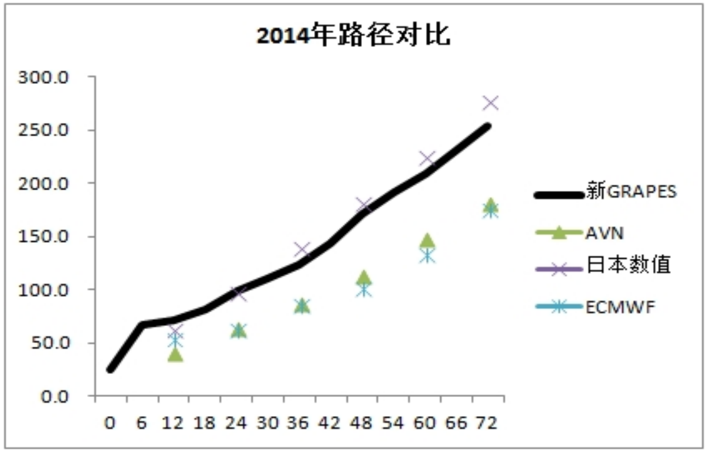
Please be noticed:

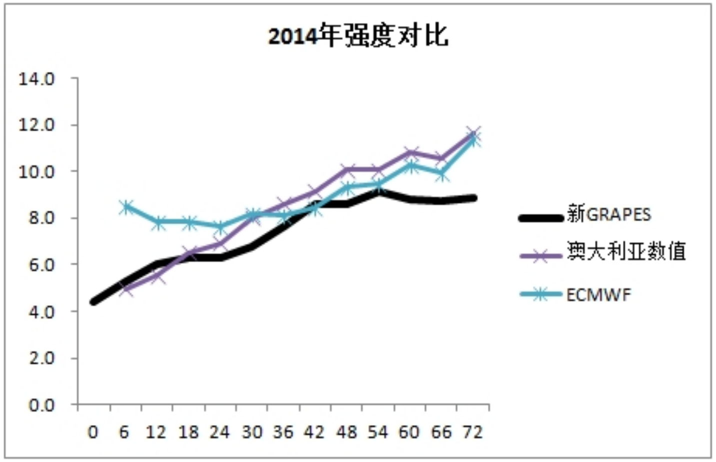
Quick-look verification (i.e., no robust and homogeneous consideration)

No any turning and cross check for the model (just a version from SVN repository)



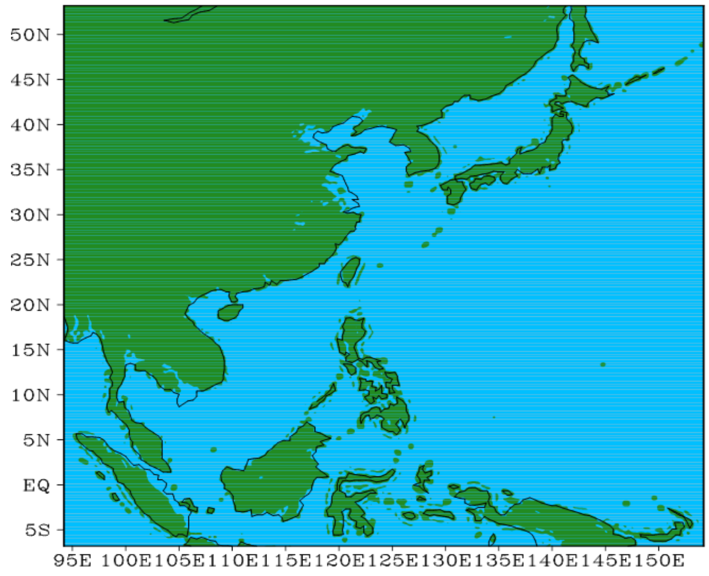






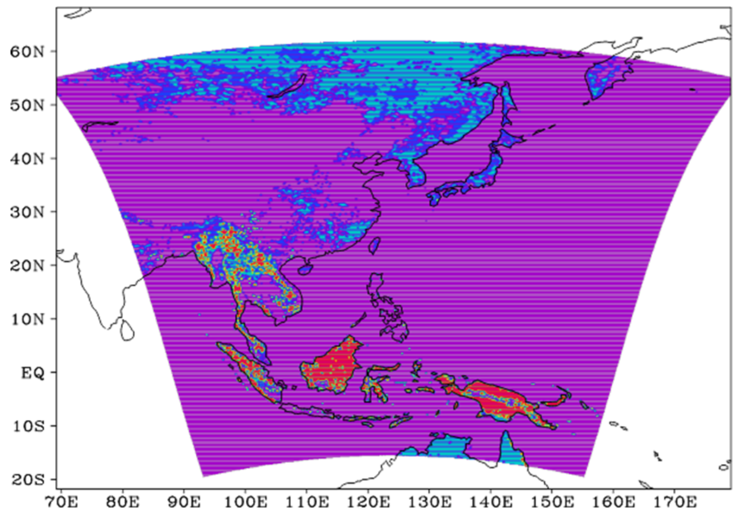
Message taken： **We are in correct direction and in a good shape !** More improvement could be achieved by turning and more detailed adjustment.

Case comparison with HWRF



W/ Vortex Initialization

GRAPES-TCM
Resolution: 0.1°X0.1°
Vertical Level : 51
Atmosphere Top: 35km
GFS physics Package

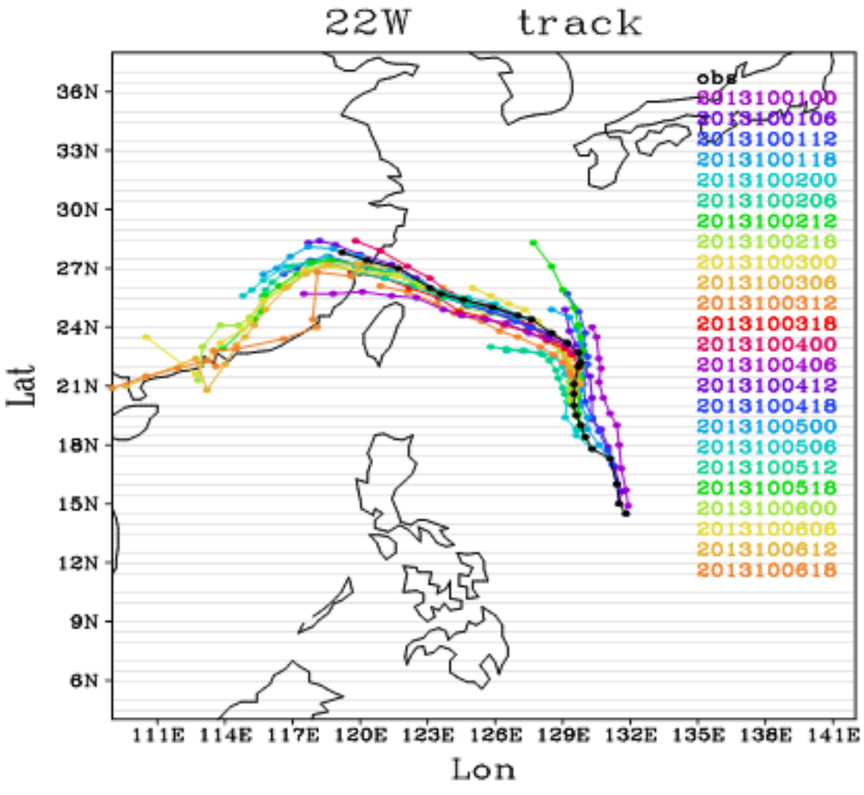


HWRF (v3.5a, public release)
Horizontal resolution : 27/9/3 km
Vertical level: 43
Grid size： outer 216*432; middle 88*170;inner 180*324

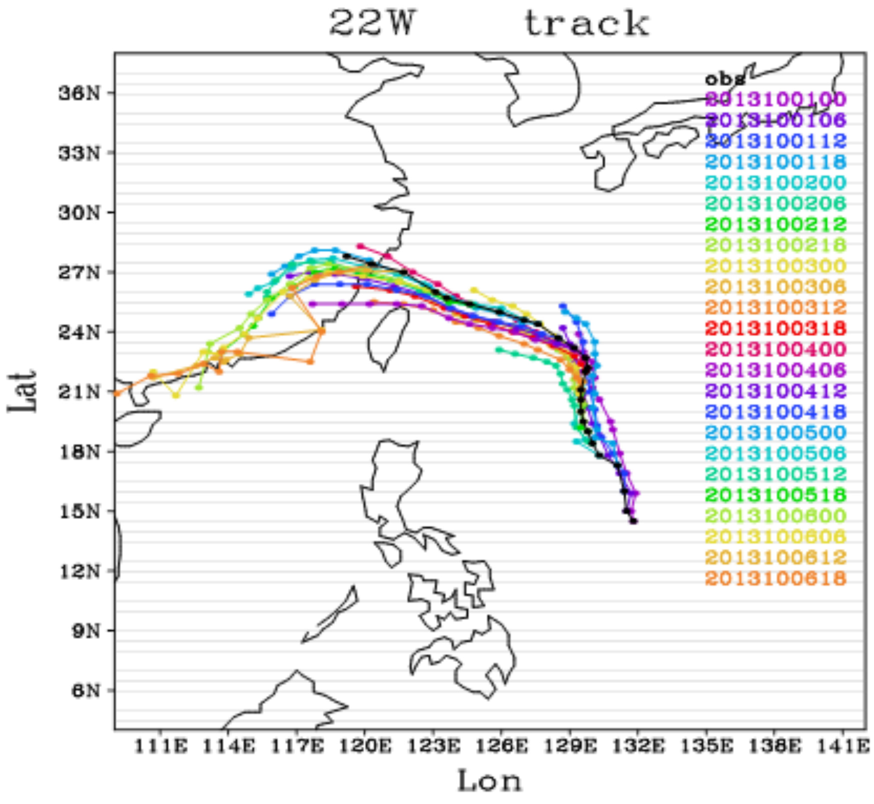
TRACK

GRAPES-TCM

w/o Vortex Initialization



w/ Vortex Initialization

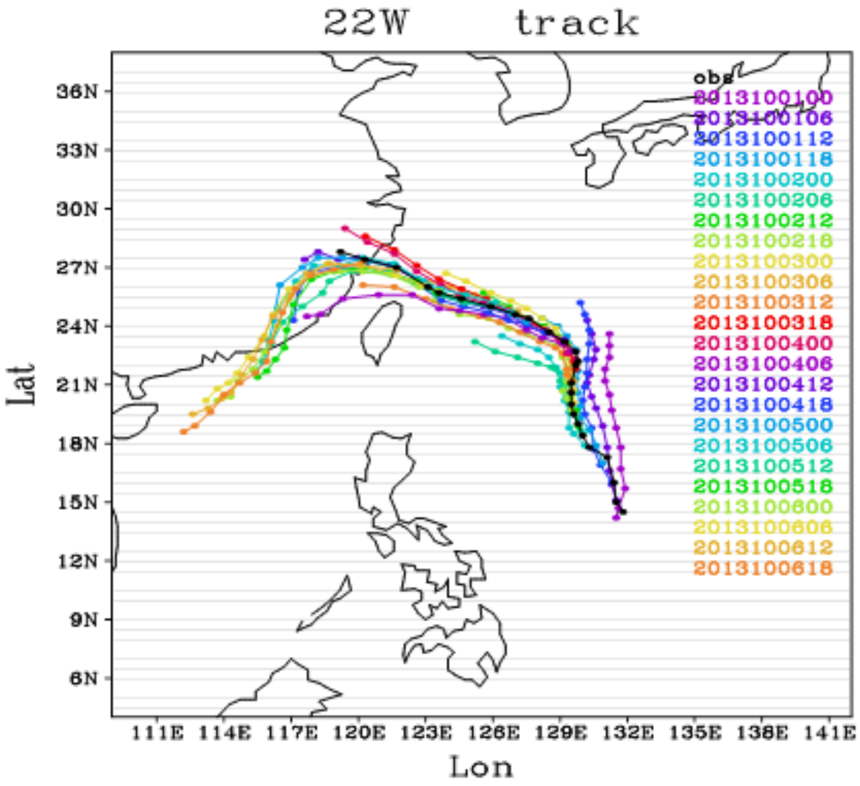


OBS used : JTWC

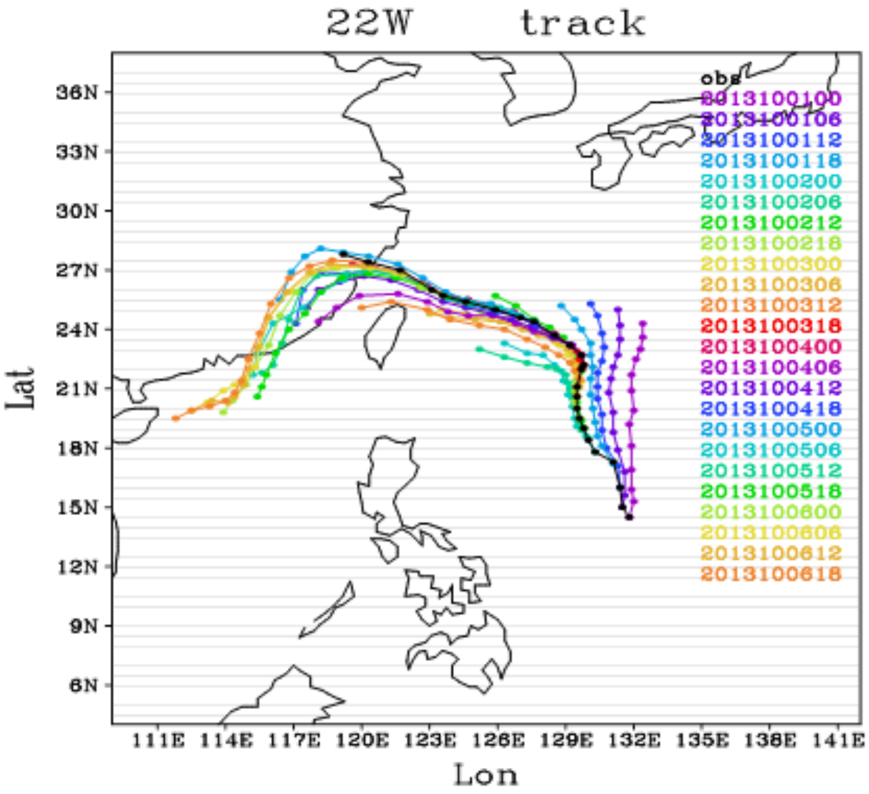
TRACK

HWRF

w/o Vortex Initialization



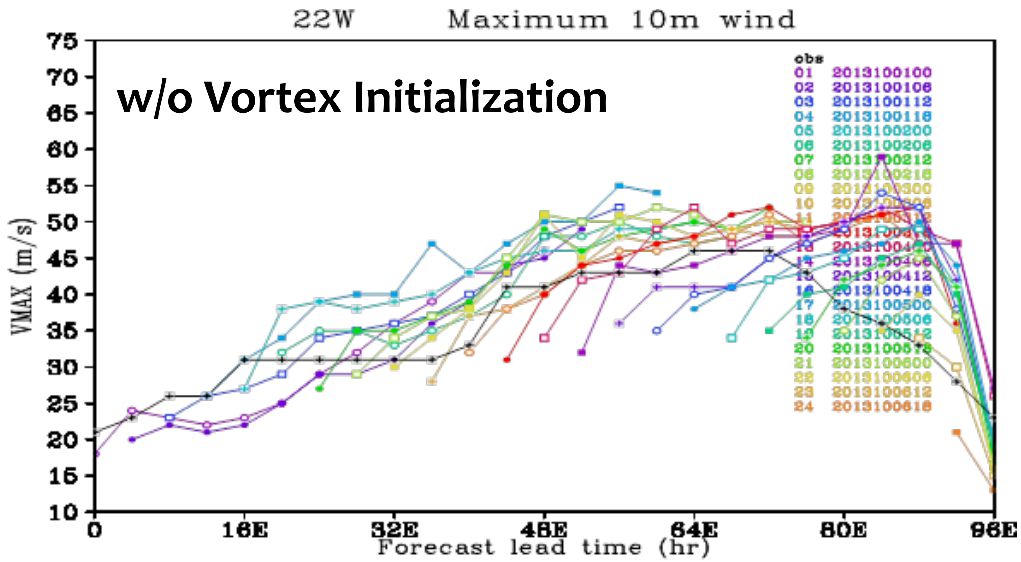
w/ Vortex Initialization

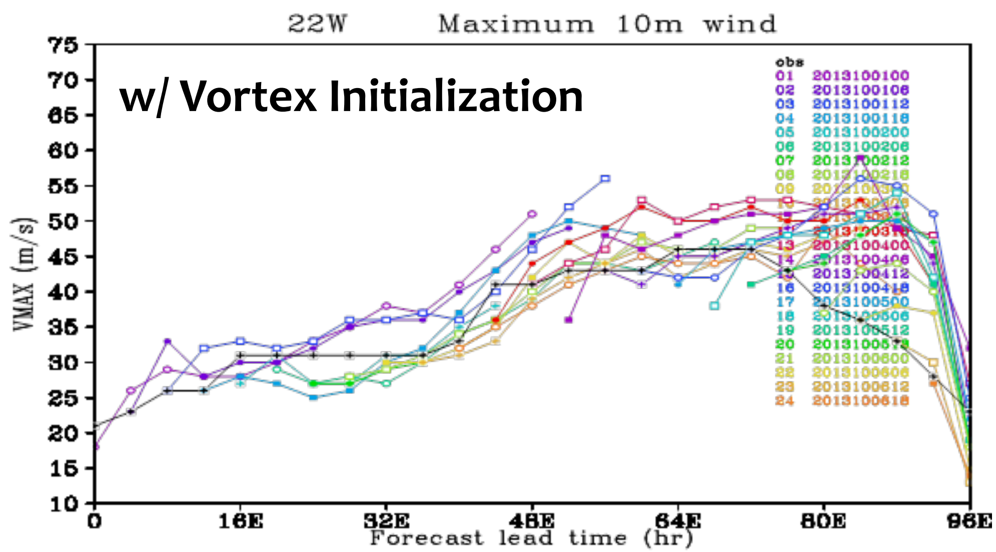


GRAPES-TCM

OBS: JTWC

Intensity

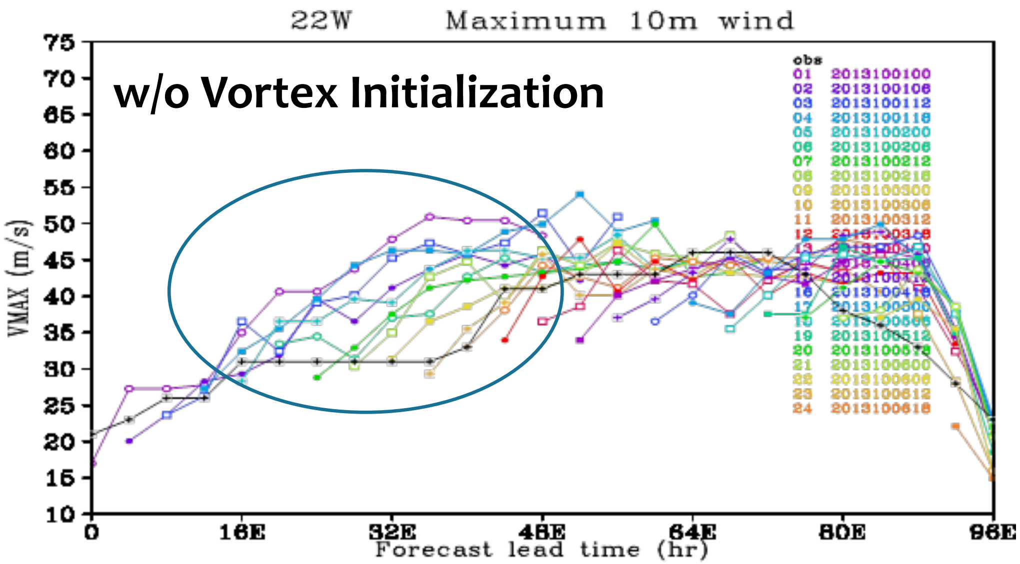


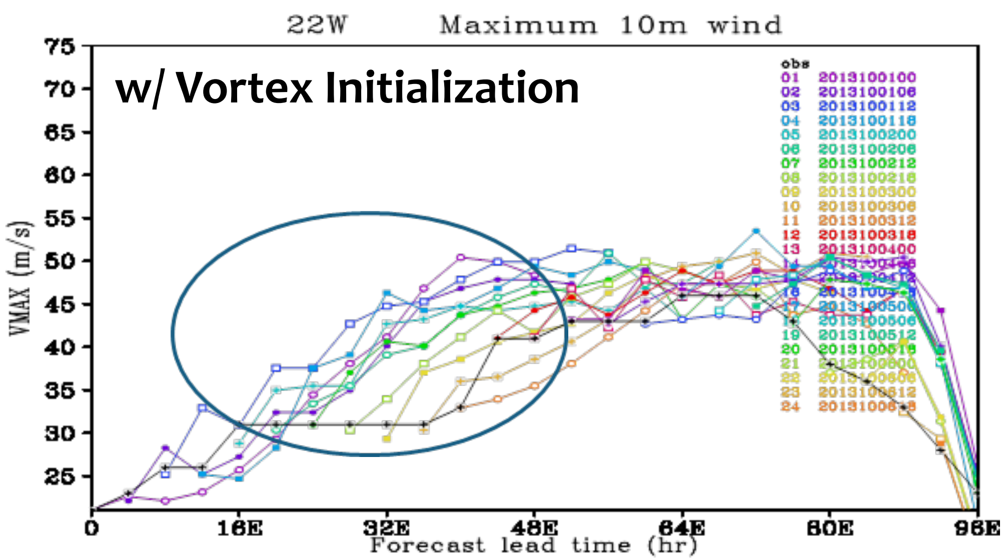


Intensity

HWRF

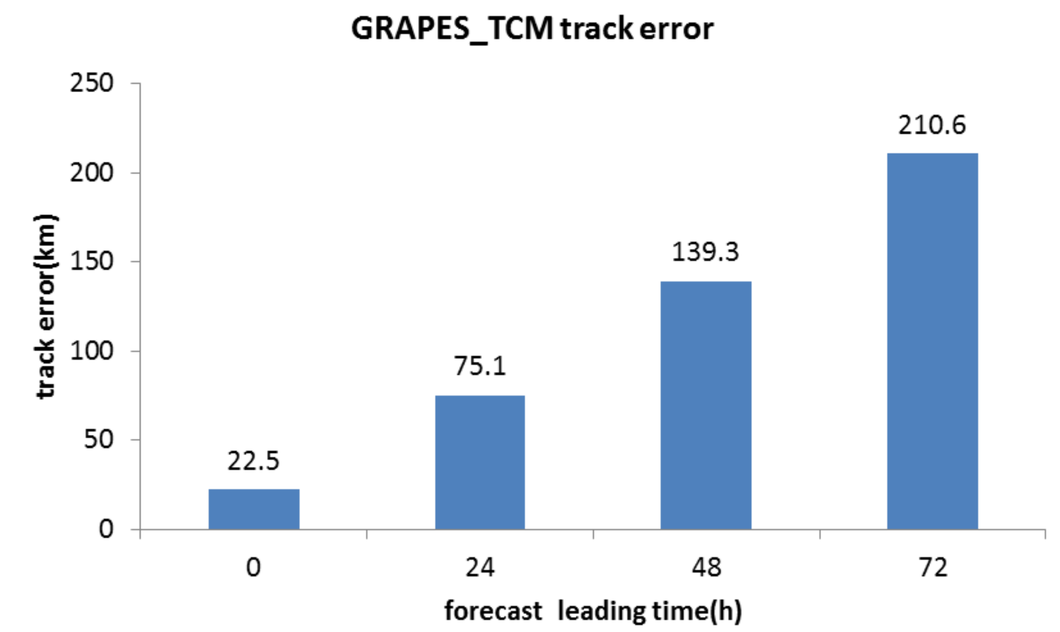
OBS: JTWC

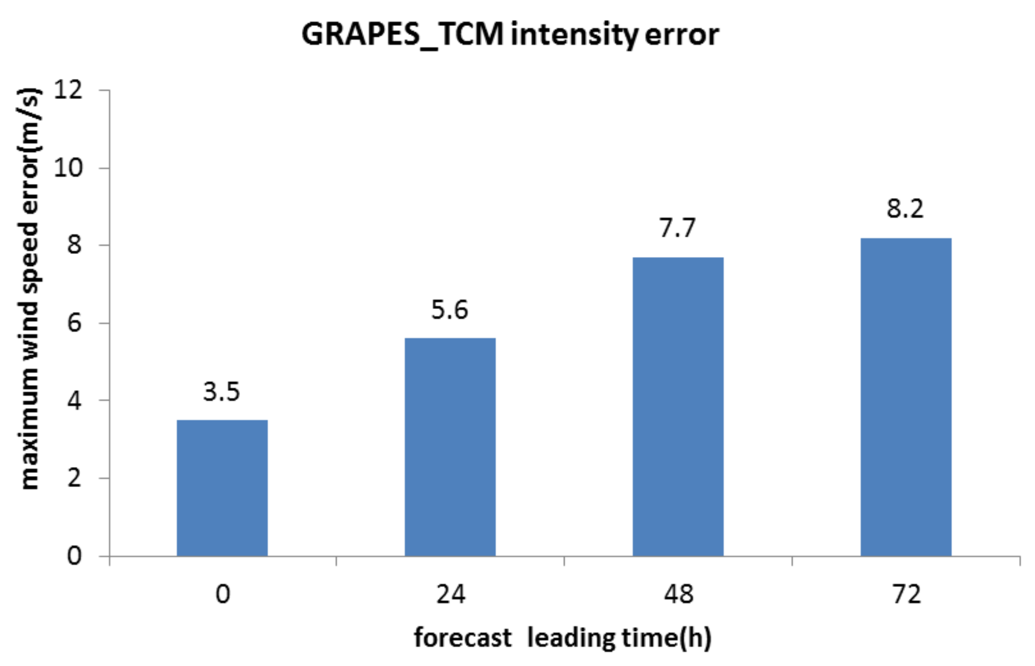




Verification

(2014. 7-10)





Works related to impact-based forecasts and risk-based warning

Translating weather forecasts (Ensemble forecast information) into impact-relevant information

Background & Introduction

- **National Meteorological and Hydrological Services (primary responsibility)**: to provide timely and accurate forecasts and warnings of hydrometeorological hazards and events.
- **Governments and Public:** to use forecasting and warning information and take effective action.

BUT even good forecasts are not always well used because they do not respond to the requirements of the users (e.g., emergency managers) in way that they can be of real use in decision-making and actions.

Why do good weather forecasts result in a poor response?

Example 1

Tropical Cyclone **Haiyan (Yolanda),** which struck the Philippines as a Category 5 storm on November 7 2013, as of 14 January 2014:

- 6,201 dead, 28,626 injured and 1,785 missing.
- More than sixteen million affected and more than US$827 million estimated for the damage of infrastructure and agriculture (NDRRMC 2014).

1. Accurate warnings were issued by the meteorological agency – PAGASA – for heavy rain and winds in time.
2. The government deployed planes and helicopters to the regions most likely to be affected.

Many of the deaths were caused by the storm surge that resulted from the wind, which reached a maximum ten-minute sustained velocity of 275 km per hour.

- Accurate warnings issued
- Good indication of storm surge

Not enough knowledge of storm surge impacts

Why do good weather forecasts result in a poor response?

Example 2

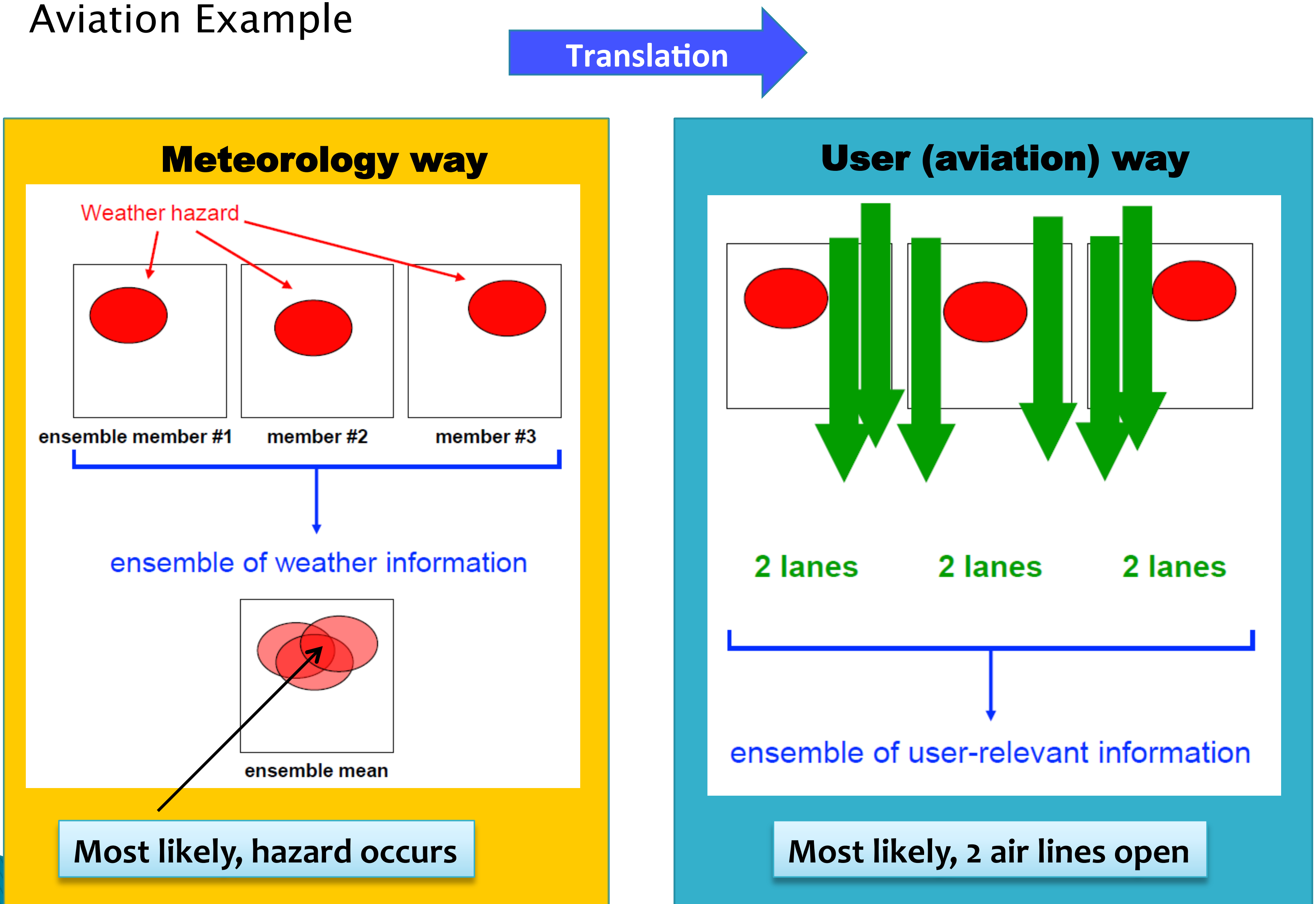
Tropical cyclone Fitow: Shanghai, China
Many roads and communities flooded, rivers overflowed, 1.2 million people directly impacted, direct economic loss 890 million RMB (app. US$ 150 million), one death

- Good weather forecasts of TC
- Highly developed multi hazard warning system
- Well prepared emergency management and first responders
- Good public communication using multiple channels
- Good rules and regulations for warnings and response
- Good standard operating procedures
- Over 18 million people alerted

But, gridlock and many people exposed to the hazard; flooded cars, buses, etc.
1,240,000 people directly affected

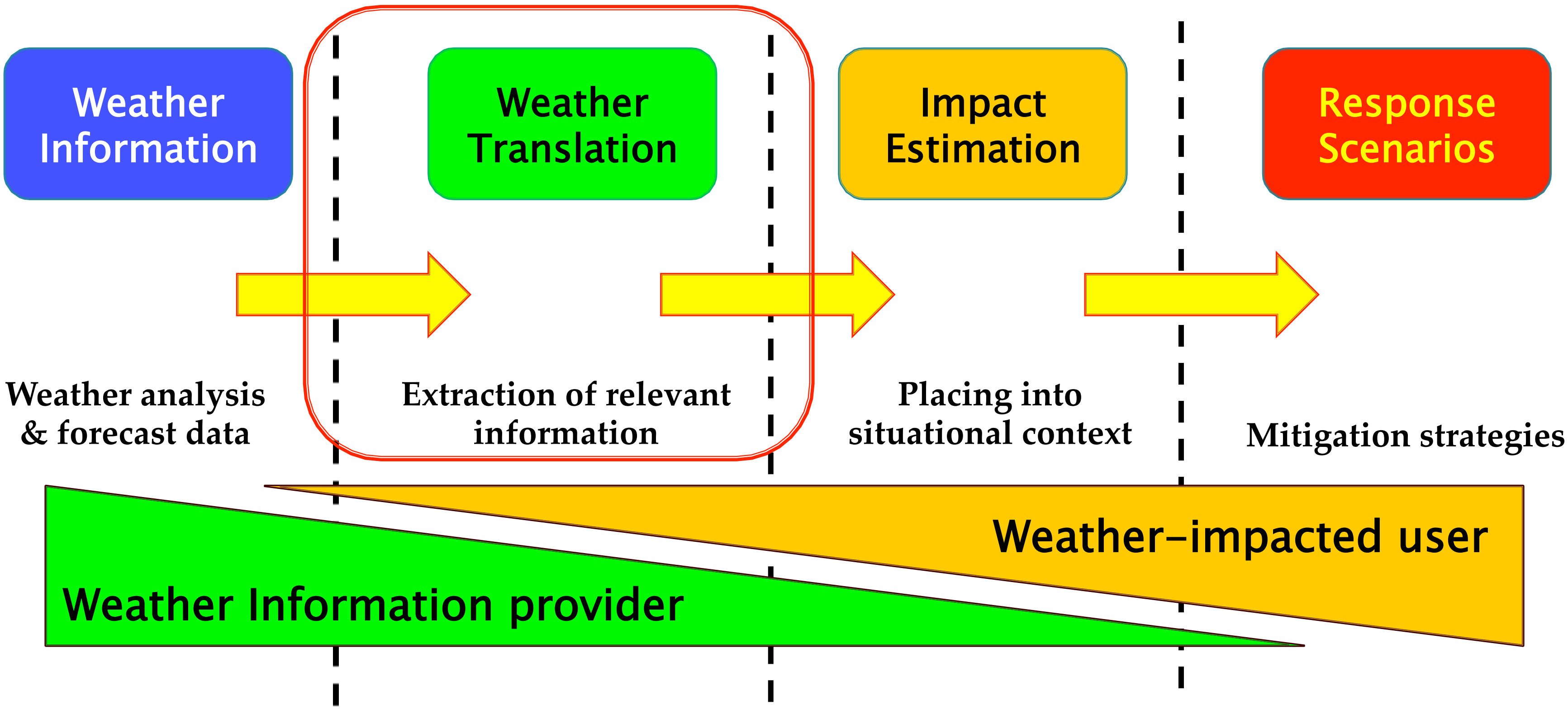
1. The actions recommended to take are usually quite general and do not provide specific guidance for a particular circumstance.
2. The forecaster does not usually consider the vulnerability and exposure of the population to the hazard.
3. The highest level of warning was not issued until well into the morning rush hour when the appropriate meteorological thresholds were exceeded.

Aviation Example



Curtesy of Dr. Matthias Steiner of NCAR

Weather Translation & Integration Concept



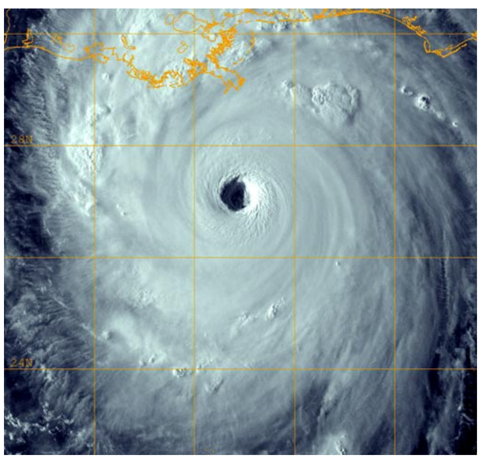
Some examples:

Airport operation	Ceiling & visibility (flight categories)	Reduced capacity (arrival rates)	Ground delay programs
Dam operation	Precipitation & runoff (water level)	Overflow or breaking, minimal discharge	Controlled release of water
Power plant operation	Winds below/above critical thresholds	Reduced power generation	Balancing grid with other power sources

Curtesy of Dr. Matthias Steiner of NCAR

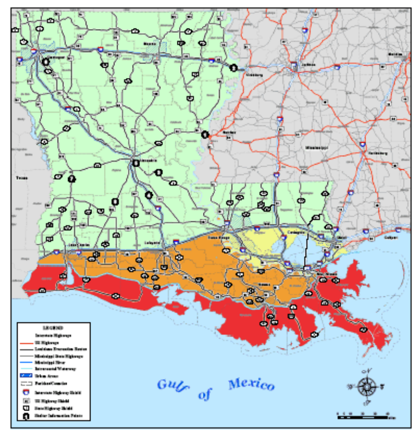
Hurricanes/Typhoons

Weather Information	Weather Translation	Impact Estimation	Response Scenarios
Weather analyses & forecast data	Extraction of relevant information	Placing into situational context	Mitigation strategies



Hurricane track, size, & intensity

Storm surge, flooding, inundated areas



Affected population & infrastructure, disruption of services, damages due to wind & water, etc.

Implementation of evacuation & recovery plans

Operation Shifts needed

Phenomenon-Based Forecasts	→	Impact-Based Forecasts
Products-Based Services	→	Decision Support Services
Meteorological Threshold–Based Warning	→	Impact Threshold–Based Warning (Risk based warning)

Deterministic (best forecast) → Probabilistic (uncertainty range)

underway

Thank you for your attentions

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