Advances in the Typhoon Rapid Refresh Analysis and Nowcasting Systems (TRANSv1.0)

TRANS Research and Development Team

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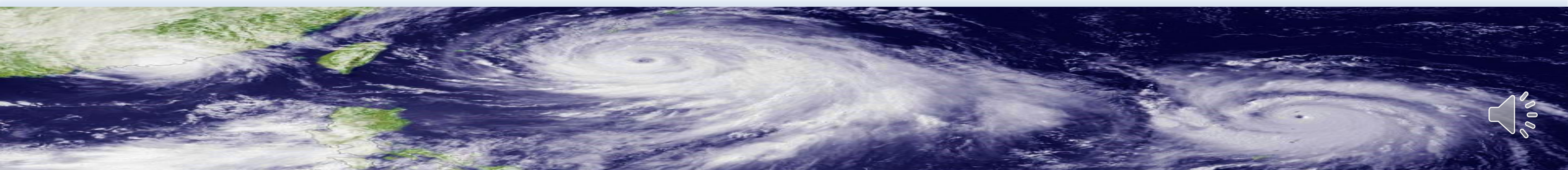

Outlines

- Motivation and background
- Introduction to TRANS
- Performance and application of TRANS
- Conclusion and future plan

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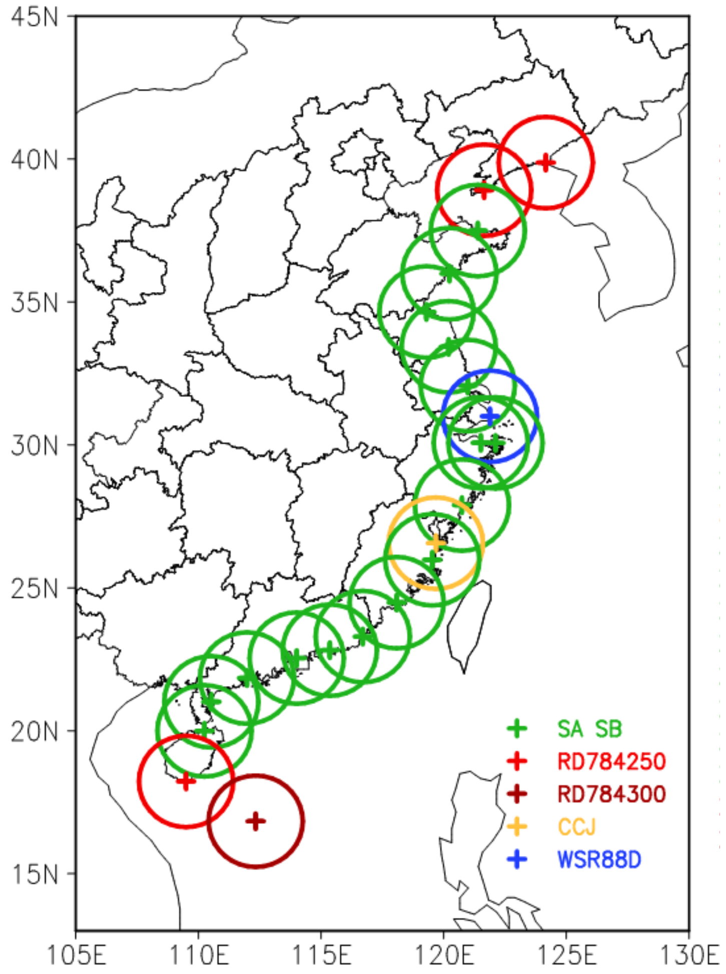
Motivation and background

TC Rumbia (2018)

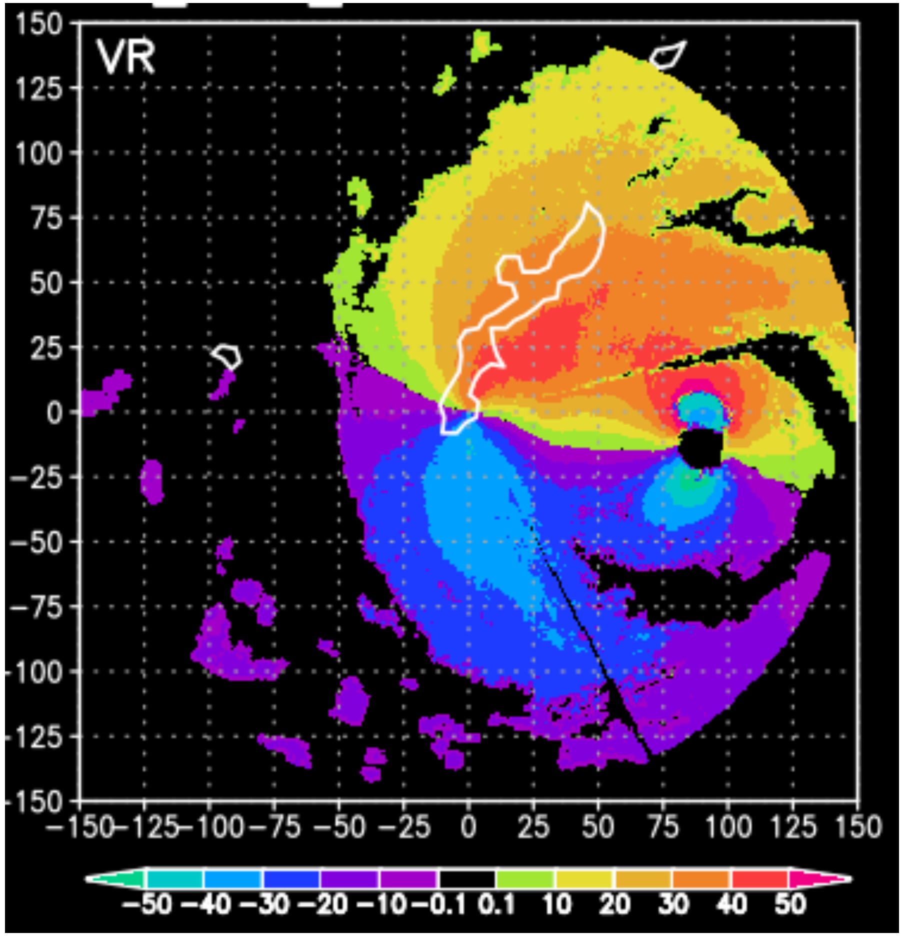
TC Lekima (2019)

Landfalling TC caused direct economic loss of 59 billion CNY in 2019 and 74 deaths.

Coastal radar distribution in China

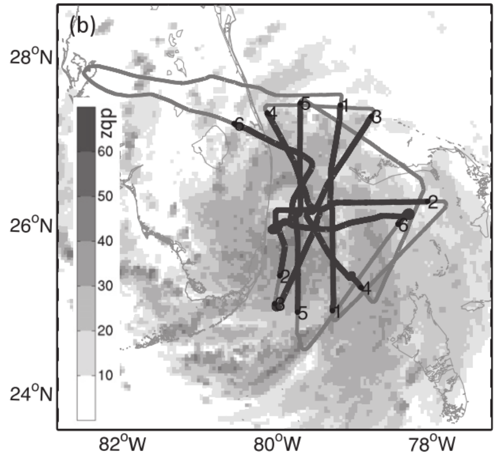


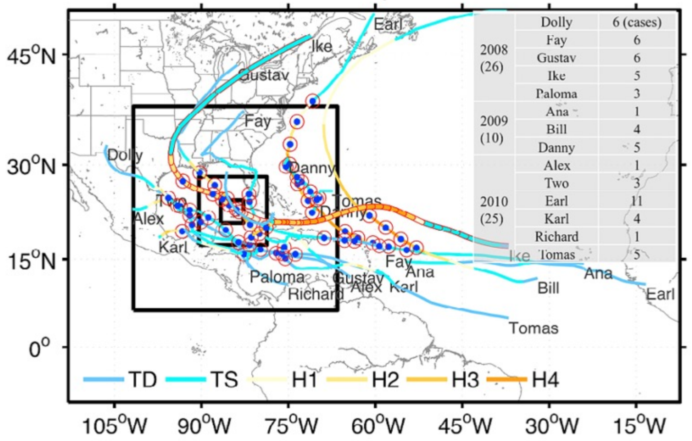
Radar radial wind observation

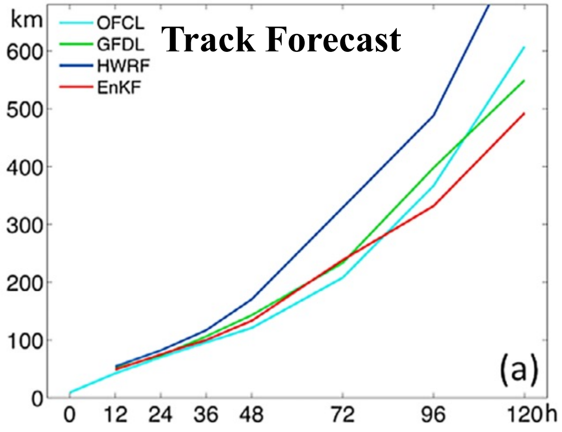


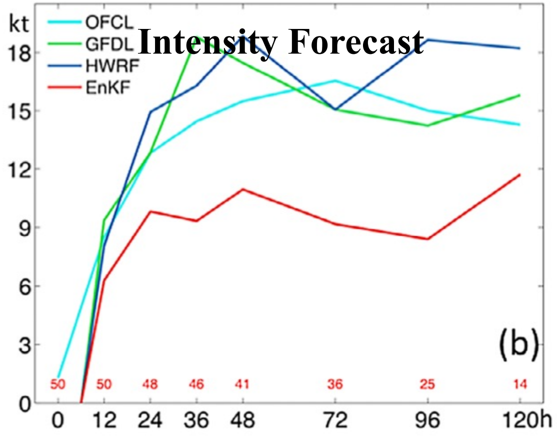
USA：airborne Doppler radar radial wind assimilation

Mean absolute error over 61 Airborne Doppler Observing Missions During 2008–2010 for 14 TCs







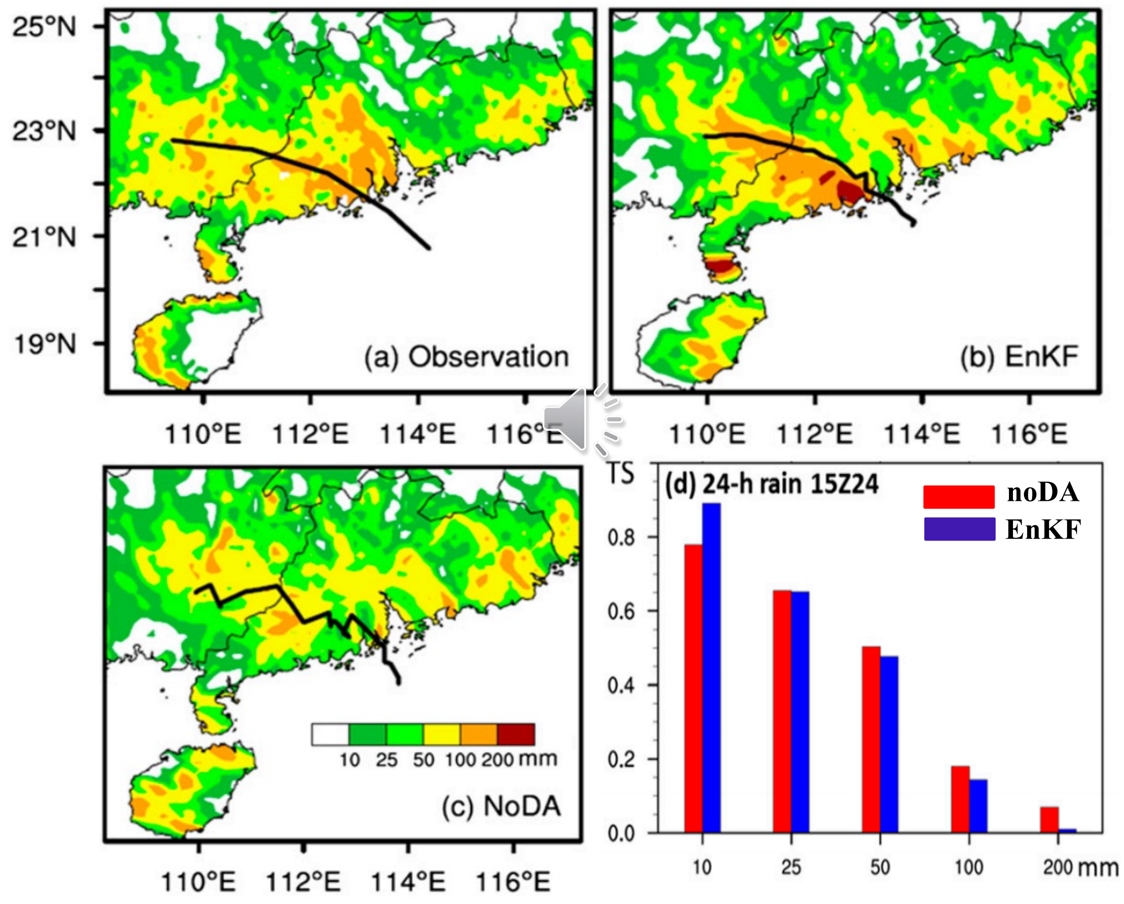


Intensity error of PSU WRF-EnKF is 5kt lower than official forecast for the 48-h leading time.

（ Weng et al, 2011,2012；Zhang et al, 2011；Munsell et al, 2013； Zhang and Weng, 2015；Zhang et al.2016 ）

Motivation and background

China：case studies of ground-based radar data assimilation



Observations of the radar in Chinese mainland(Zhu et al., 2015) TC Vicente（2012）

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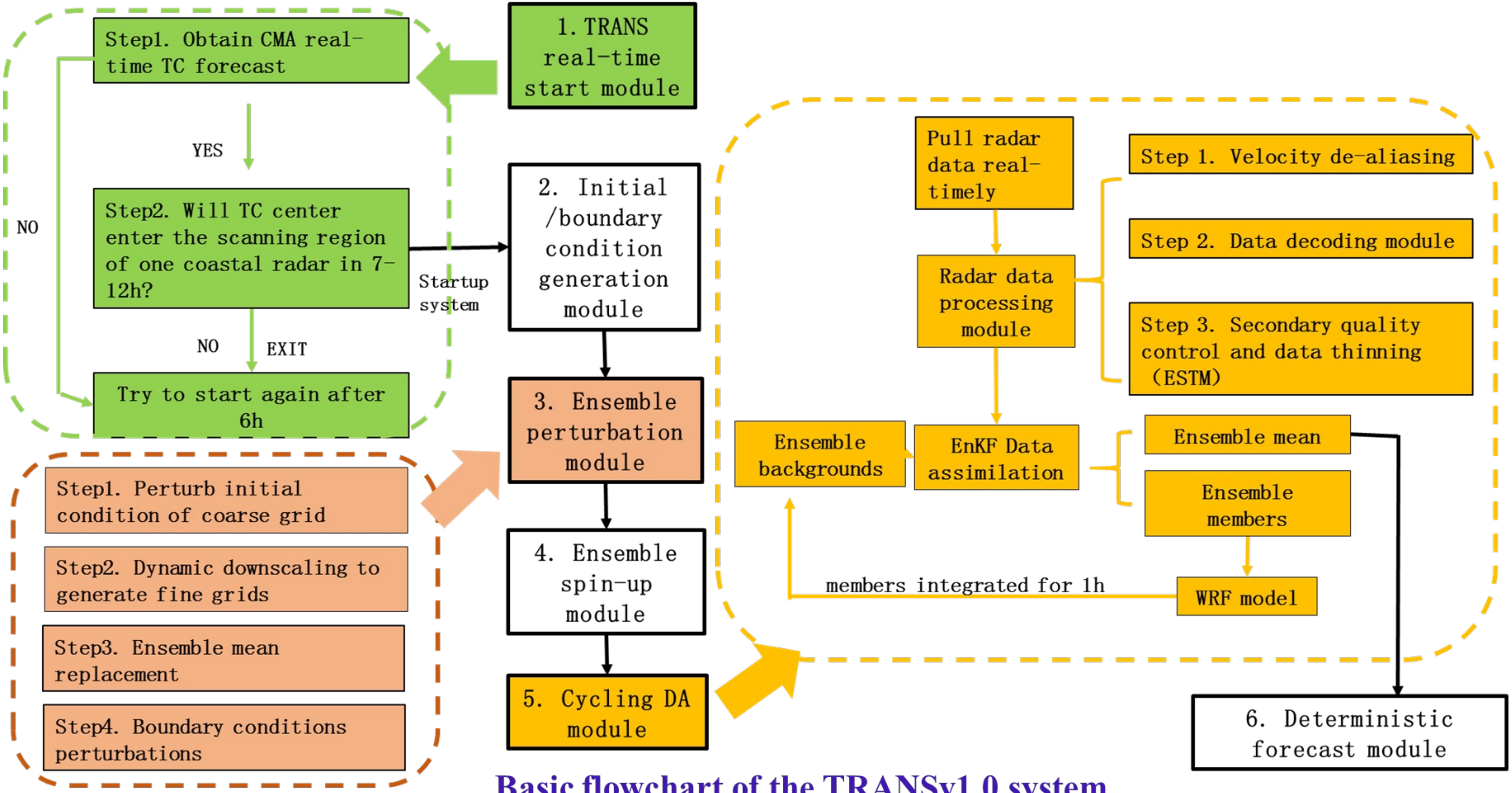
➢Introduction to TRANS



Basic flowchart of the TRANSv1.0 system

Forecast Model	WRFV3.8.1		
Resolution (km)	40.5	13.5	4.5
grid domain	120×100	151×151	169×169
Moving nest	No	yes	
Vertical level	43		
Model top (hPa)	50		
Ensemble number	60		
Cumulus parameterization scheme	KF (new Eta)	no	
Microphysical parameterization scheme	WSM6		
PBL parameterization scheme	YSU		
Surface layer parameterization scheme	Revised MM5 M-O		
Radiation scheme	RRTMG/RRTMG		
Land surface scheme	5-layer thermal diffusion		

➢Introduction to TRANS

60 members

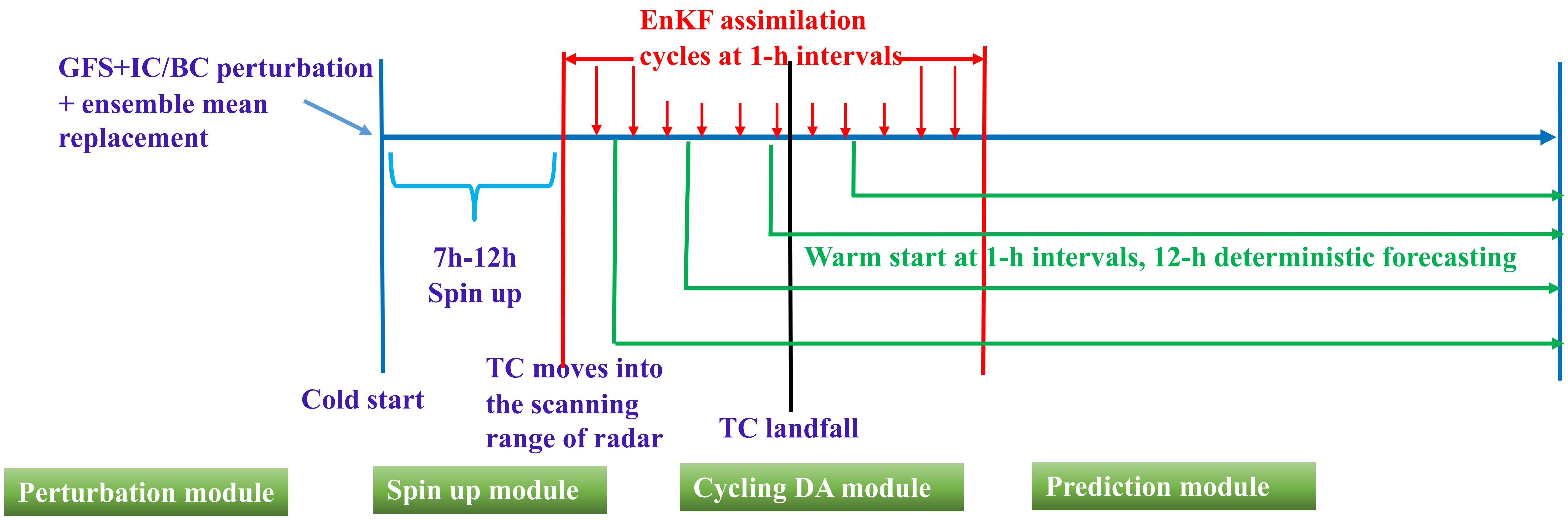


Fig. Schematic flowchart for the EnKF rapid refresh cycling assimilation.
The red arrows show radar data EnKF assimilation cycles at 1-h intervals.
The green arrows present forecasts with the ensemble mean of EnKF.
The black line represents the time of TC landfall.

➢Introduction to TRANS

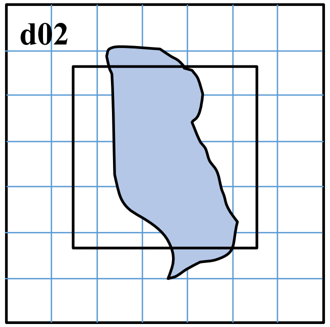
A. Inflation of background error covariance

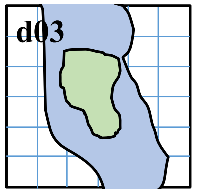
- Maintain ensemble spread

$(x^a_{new})' = (1-\alpha)(x^a)' + \alpha(x^f)'$, α=0.5

B. Muti-scale data assimilation technique

- Assimilate 20% in d02; interpolate the innovation into d03; assimilate the left 80% in d03
- Keep balance between multi domains; Reduce assimilation computing cost



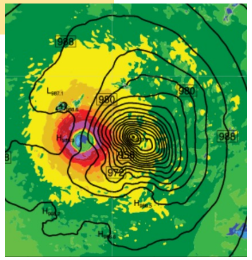


Ensemble Kalman Filter

Observation Operator: Vr=u sinθ cosφ+v cosθ sinφ

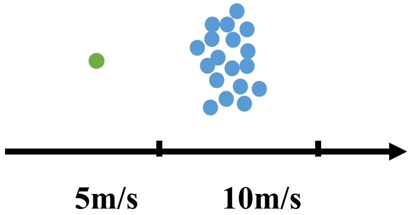
D. Data selection

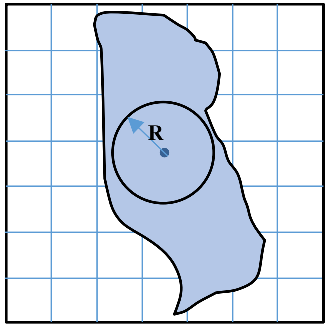
- Keep model balance
- Reduce assimilation computing cost



1. Reject the observation if its O-B>10m/s

2. Reject the observation if its Std(members)<0.1 ,

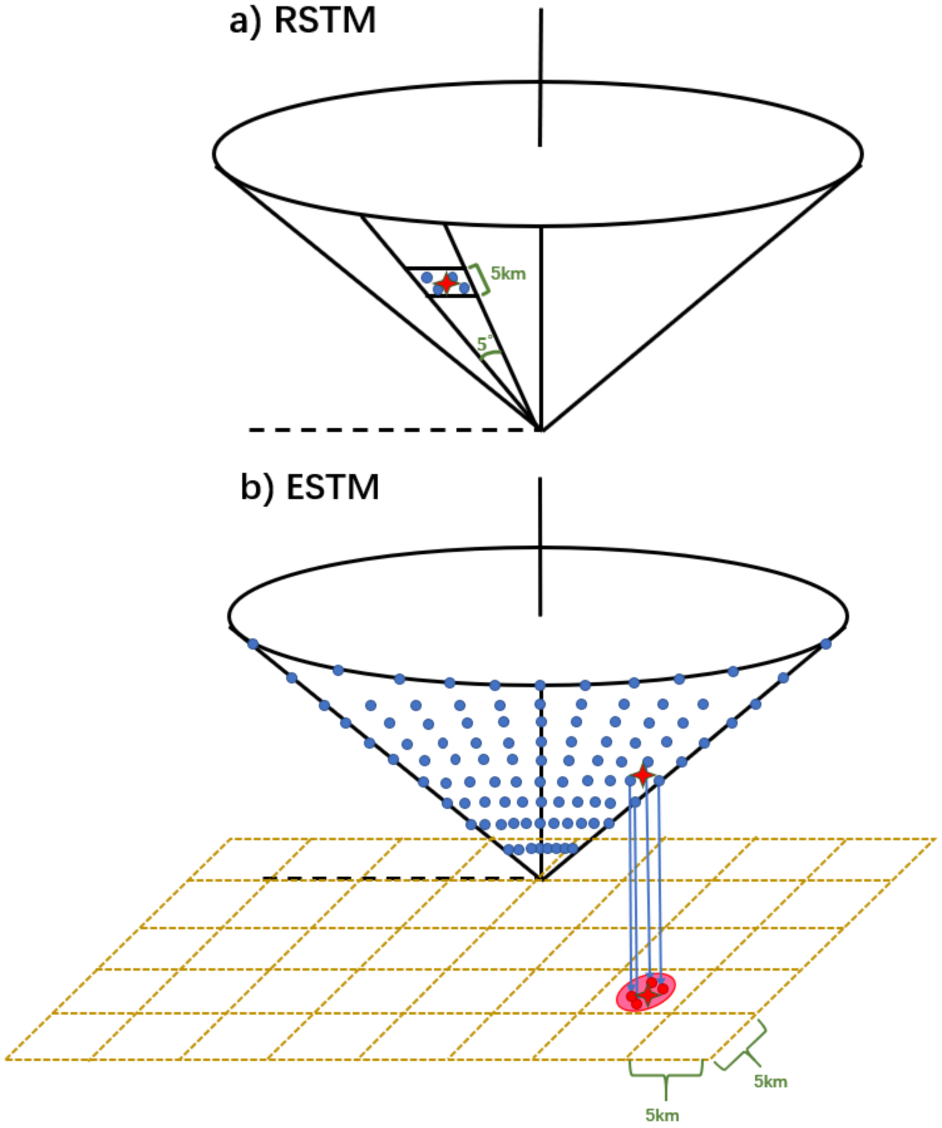




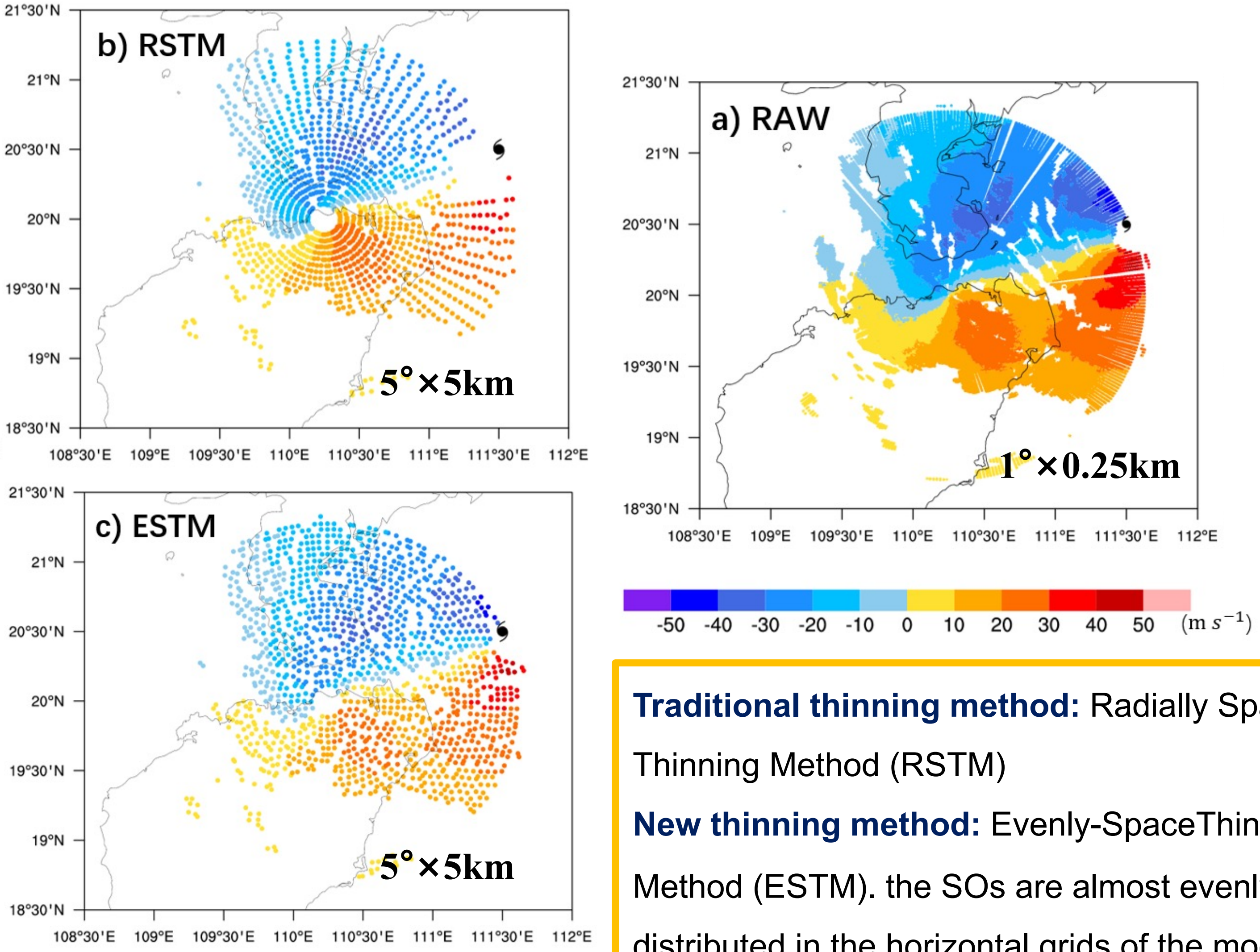
C. Localization

- Restrain sampling error due to limited ensemble size
- Reduce assimilation computing cost

Horizontal R=150km（d03）, 450km（d02）
Vertical influent over all model layers

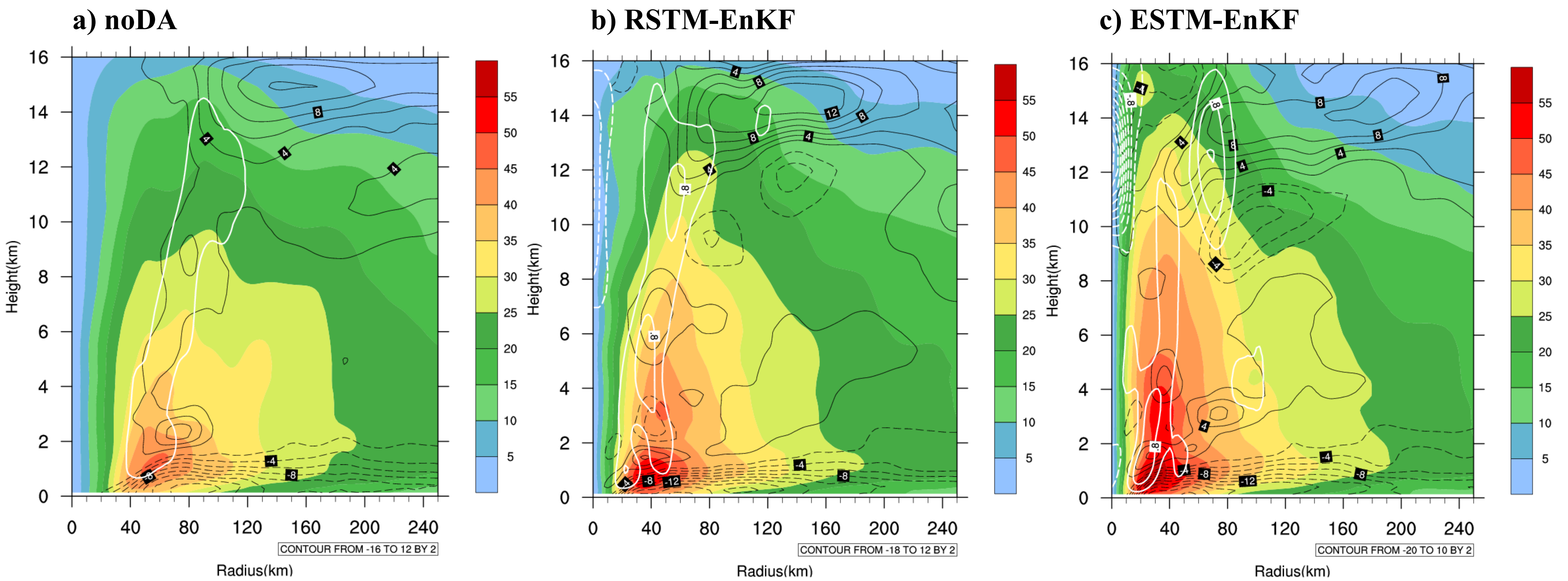


(Feng et al., 2020, WAF)



Traditional thinning method: Radially Spaced Thinning Method (RSTM)

New thinning method: Evenly-SpaceThinning Method (ESTM). the SOs are almost evenly distributed in the horizontal grids of the model background, resulting in more observations located in the TC inner-core region being involved in SOs.

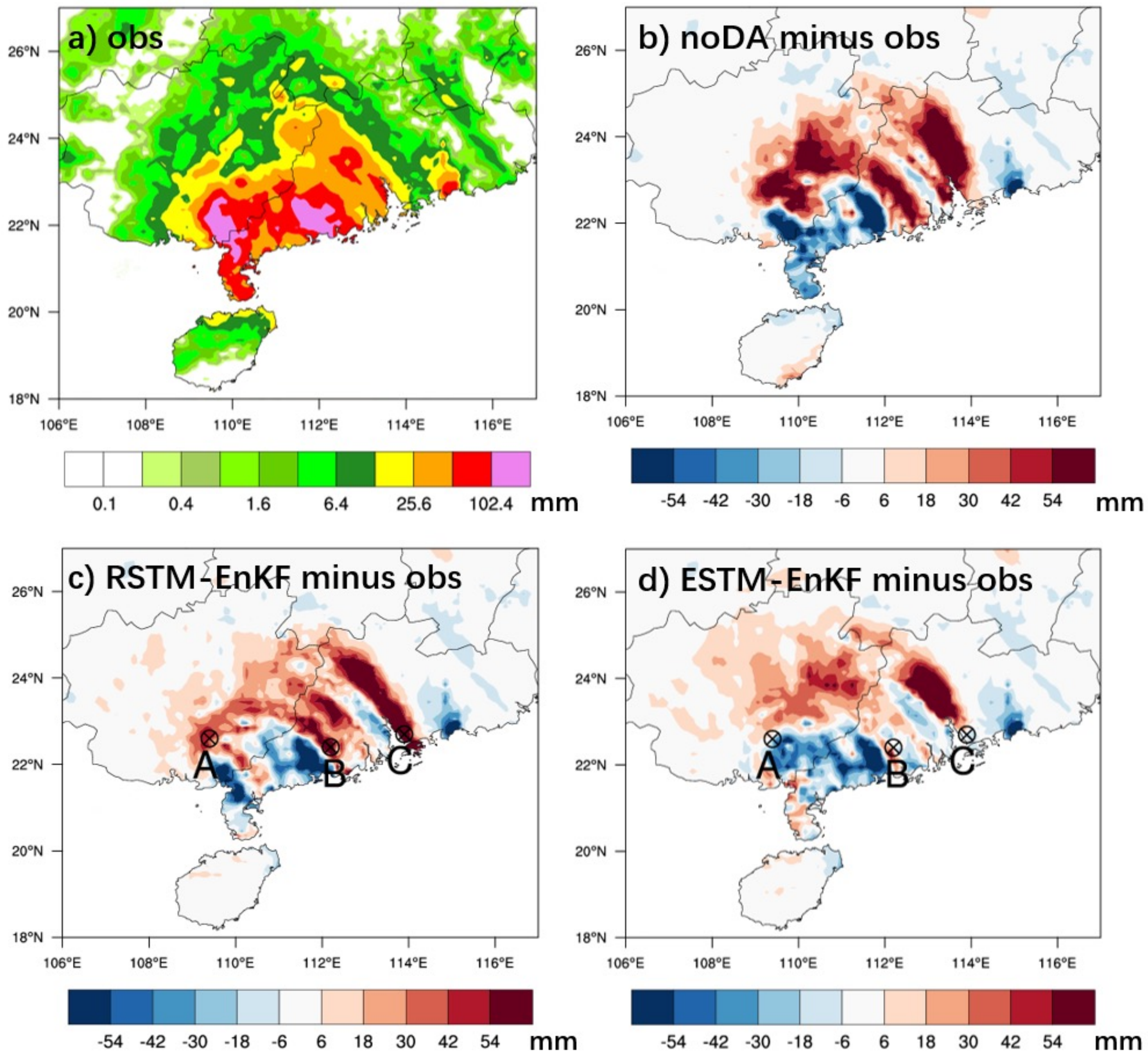


shading：mean tangential wind; black contour：mean inflow/outflow; white contour ：updraft/downdraft

(Feng et al., 2020, WAF)

➢Introduction to TRANS

9-h accumulated rainfall(0500UTC to 14UTC 04 Oct, 2015)

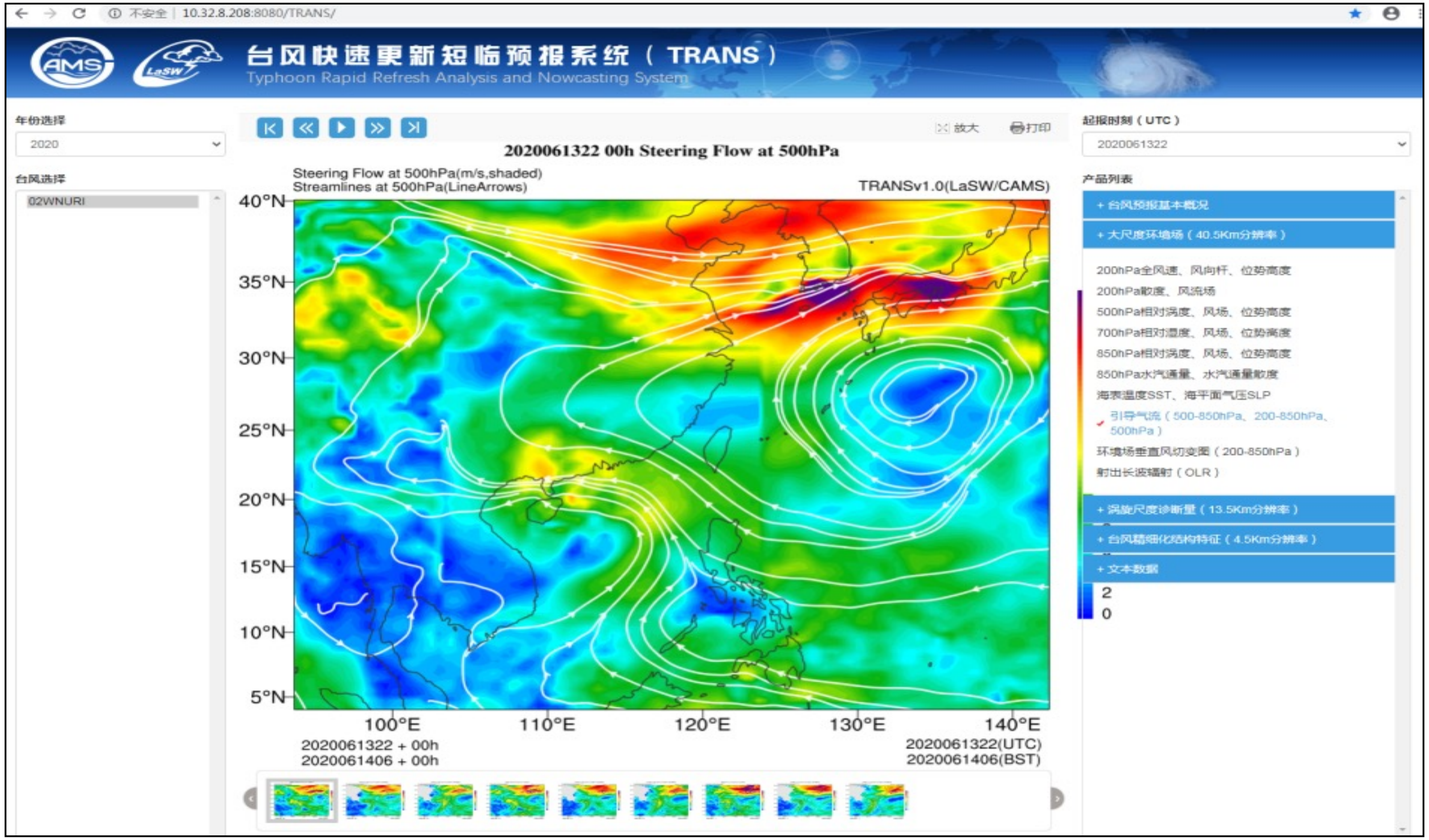


Spatial correlation coefficient between forecast and observation

exp	coefficient
noDA	0.5903
RSTM-EnKF	0.7102
ESTM-EnKF	0.7691

(Feng et al., 2020, WAF)

➢Introduction to TRANS



1. Annex 1: List of TRANSv1.0 real-time forecast products.

a) Basic overview of typhoon forecast.

i. Track forecast; Track
ii. Intensity forecast; Intensity
iii. Gale (hourly fine gale, mean gale, gusty gale, cumulative gale); Wind
iv. Precipitation (hourly precipitation, accumulated precipitation in the process); Rain

b) Large-scale environmental field.

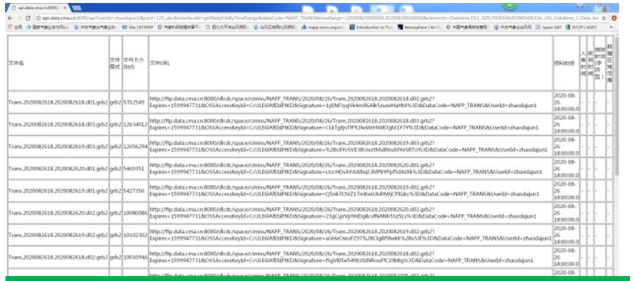
i. Superposition diagram of total wind speed, wind-directing posts and geopotential height at 200hPa; 200-wind-hgt
ii. Superposition diagram of divergence and airflow field at 200hPa; 200-wind-div
iii. Superposition diagram of relative vorticity, wind field and geopotential height at 500hPa; 500-vor-wind-hgt
iv. Superposition diagram of relative humidity, wind field and geopotential height at 700hPa; 500-rh-wind-hgt
v. Superposition diagram of relative vorticity, wind field and geopotential height at 850hPa; 850-vor-wind-hgt
vi. Superposition diagram of water vapor flux and water vapor flux divergence of 850hPa; 850-wtrflx-div
vii. Overlay of SST and SLP; SST-SLP
viii. Steering flow(500-850hPa, 200-850hPa, 500hPa); Steer-flow-500-850, Steer-flow-200-850, Steer-flow-500
ix. Vertical wind shear chart of environmental field (200-850hPa); VWS-200-850
x. Simulated cloud image. d01-Cloud-simulation. d01-Cloud-simulation

c) Diagnostic quantity of vortex scale

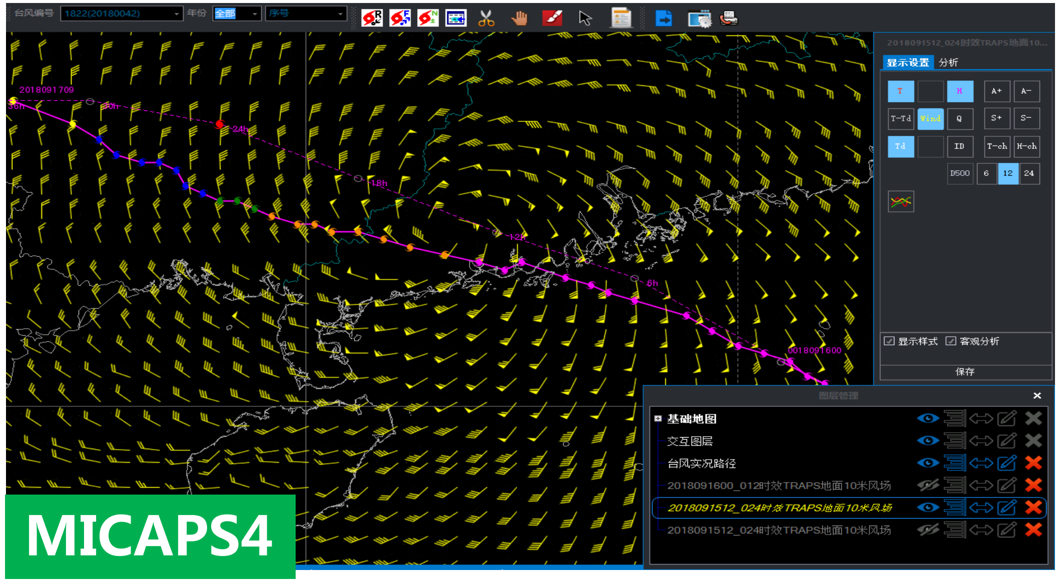
i. Superposition diagram of sea level pressure, large wind circle of 10m wind field and wind-directing posts of 10m wind field; d02-SLP-10mwind-circle-barb
ii. Combined reflectivity; d02-Radar-dbz
iii. Simulated cloud image; d02-Cloud-simulation
iv. Superposition diagram of temperature anomaly, wind field and geopotential height at 200hPa; d02-200-Tabnormal-wind-hgt
v. Superposition diagram of relative humidity, wind field and geopotential height 700hPa; d02-700-rh-wind-hgt
vi. Superposition diagram of 850hPa relative vorticity, wind field and geopotential height; d02-vor-wind-hgt

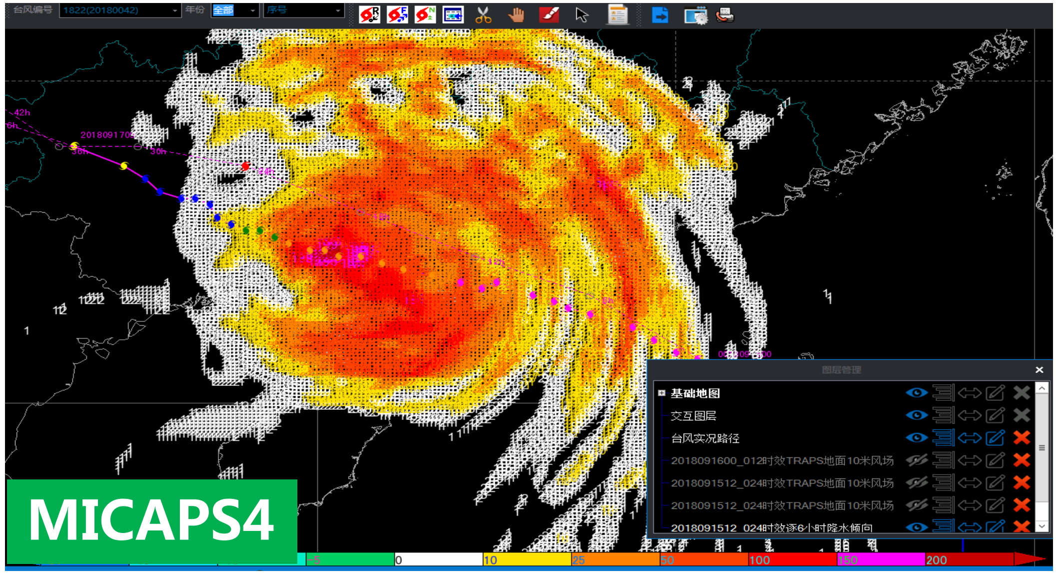
- ✓ **TRANS also includes its own post-processing module**
- ✓ **3 types of 20 products are generated in real time**

➢Introduction to TRANS



http://data.cma.cn





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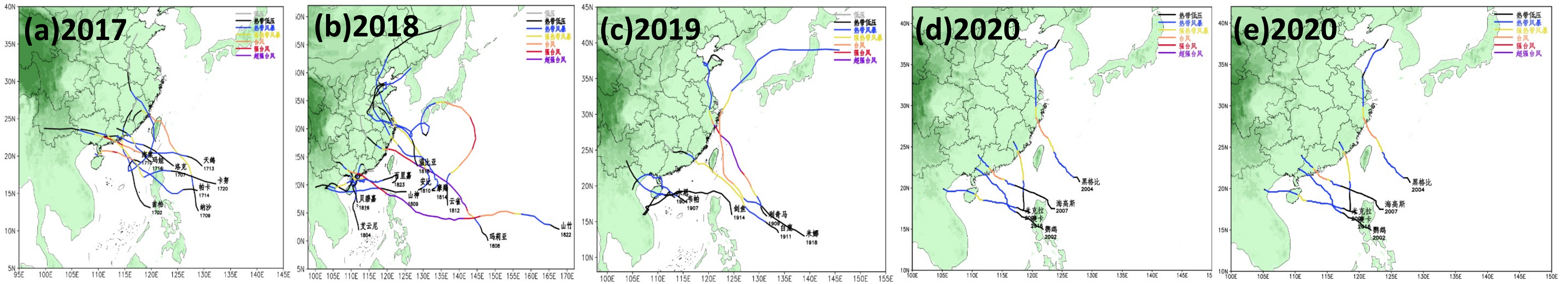
Performance and application of TRANS



Landfalling TCs from 2017 to 2021, 36 cases

2017（8cases）：1702 Merbok、1707 Roke、1709 Nesat、1710 Haitang、1713 Hato、1714 Pakhar、1716 Mawar、1720 Khanun

2018（10cases）：1804 Ewiniar、1808 Maria 、1809 Son-Tinh 、1810 Ampil 、1812 Jongdari 、1814 Yagi 、1816 Bebinca 、1818 Rumbia 、1822 Mangkhut 、1823 Trami

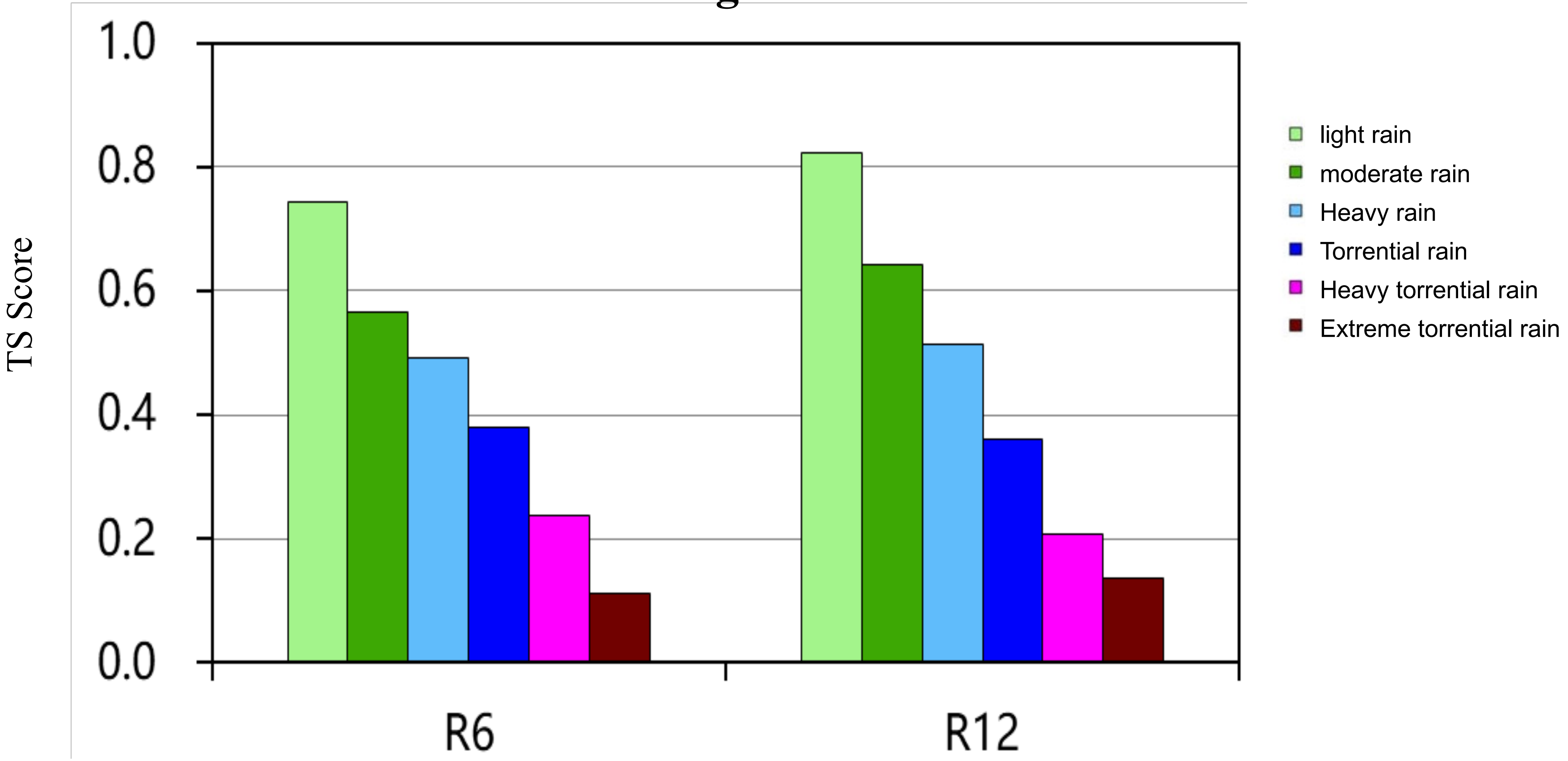
2019（6cases）：1904 Mun、1907 Wipha、1909 Lekima、1911 Bailu、1914 Kajiki、1918 Mitag

2020（6cases）： 2002Nuri 、 2004 Hagupit 、 2006 Mekkhala 、 2007 Higos 、 2008 Bavi 、 2009 Nangka

2021（6cases）： 2106 Infa 、 2107 Cempaka 、2109 Lupit 、 2114 Chanthu 、 2117 Loonrock 、 2118 Kompasu

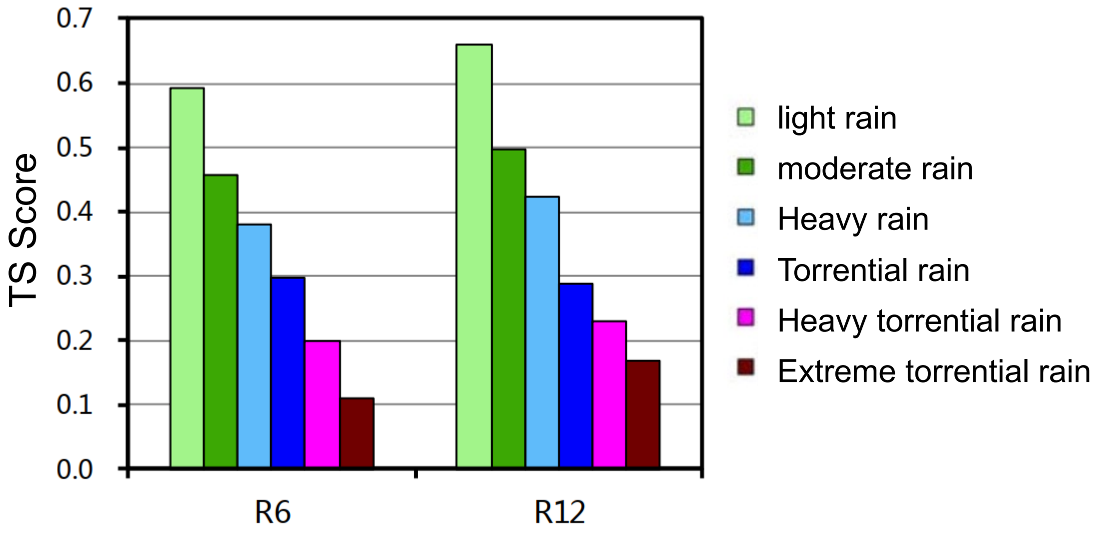
Performance and application of TRANS

Mean TS of TRANS during 2017-2019 hindcast

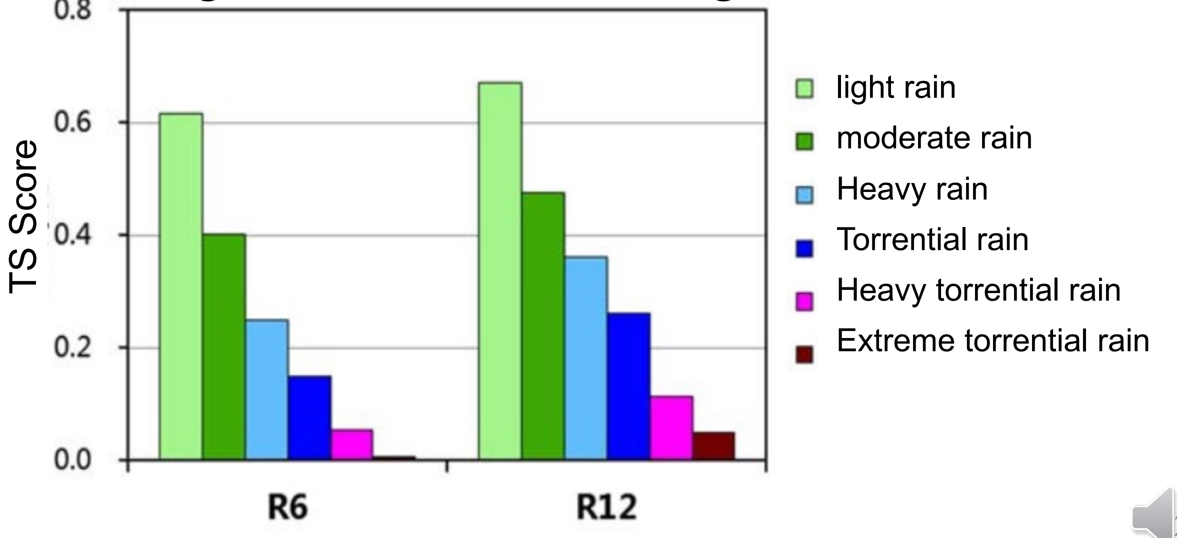


Performance and application of TRANS

Average TS of real-time forecasting in 2020

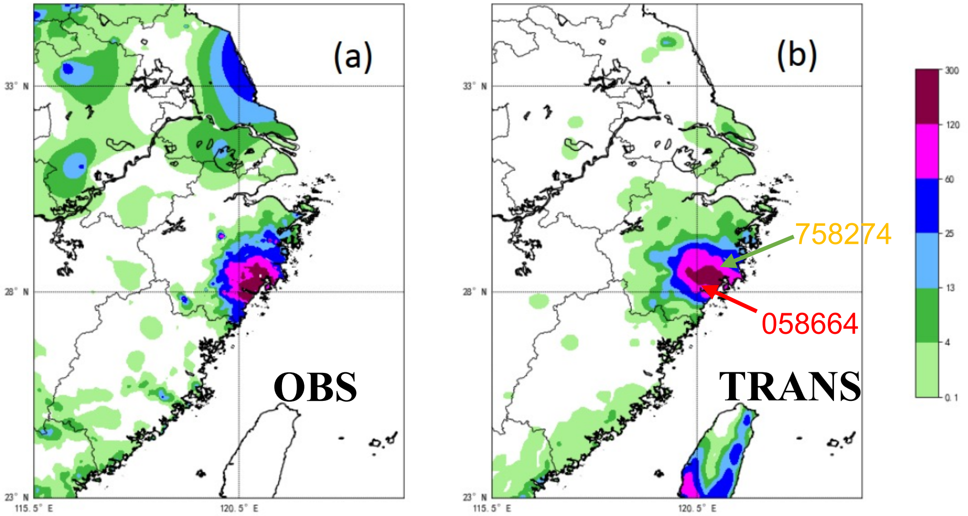


Average TS of real-time forecasting in 2021

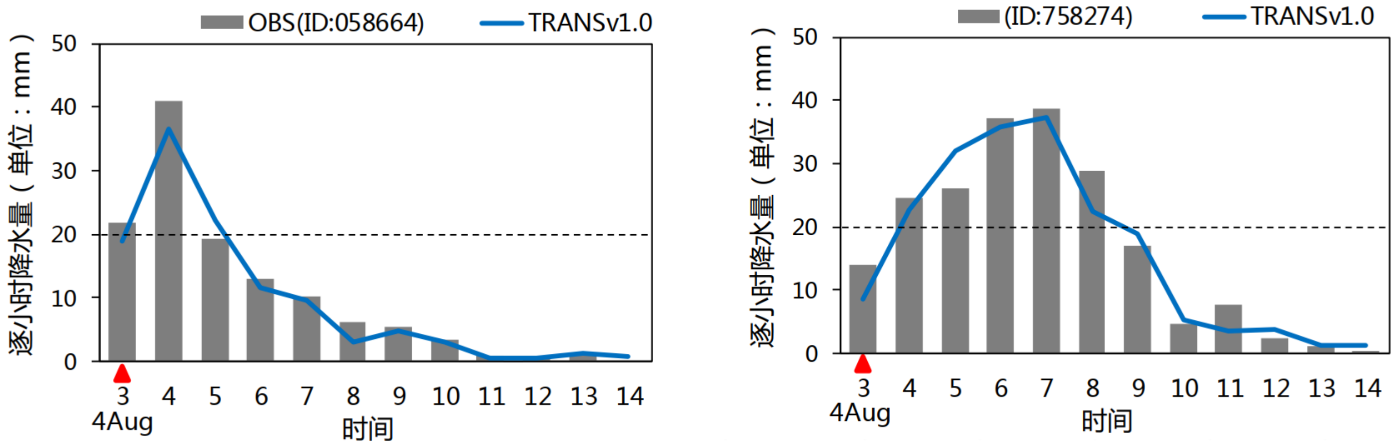


Performance and application of TRANS

2020Hagupit, R12, Initial time:2020080312（UTC）



Predicted hourly rainfall evolution from two typical site



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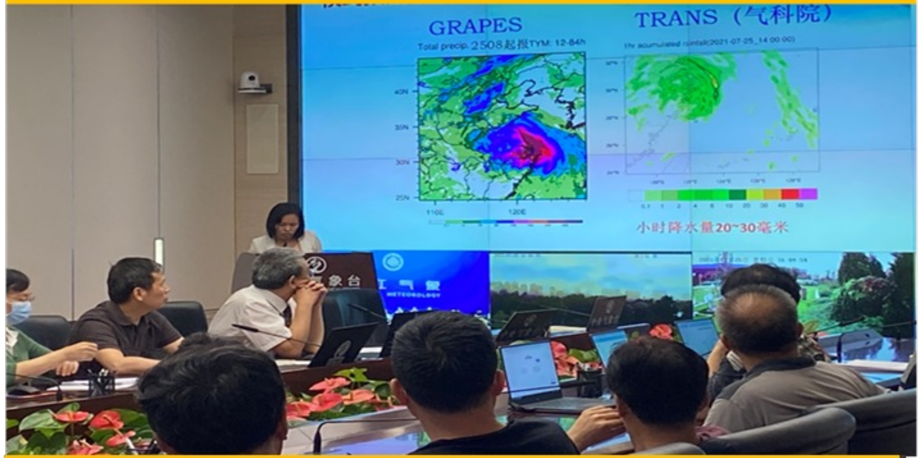
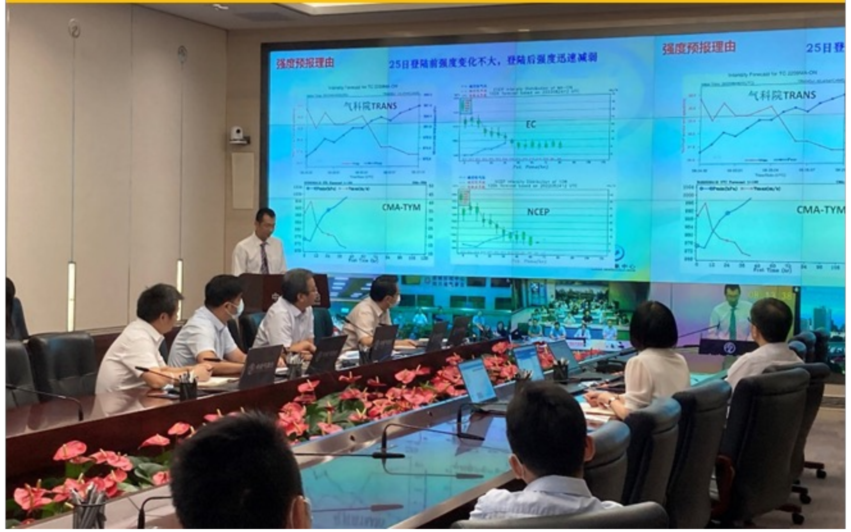
Performance and application of TRANS

2020 TC Hagupit

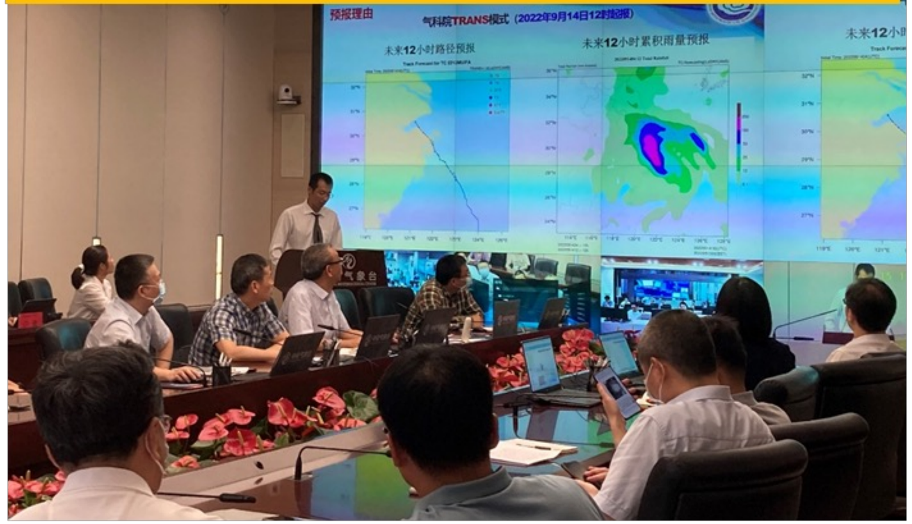
2021 TC Infa



2022 TC MA-ON



2022 TC Muifa



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Conclusion and future plan

- A rapid refresh cycling data assimilation system with EnKF is developed, in which radar radial winds are proper absorbed to enhance the skill of landfalling TC forecasts.
- A new SO processing named Evenly Spaced Thinning Method is developed to increase the utilization factor of TC inner-core region. It shows that ESTM could significantly improve intensity, and heavy rainfall forecast.
- The result of three-year real-time forecast shows that the TS of heavy rainfall(100mm/12 hour) is above 0.2, TRANS have provided accurate real-time guidance to the official TC forecast in CMA.

Conclusion and future plan

- Basic model configurations are in continuous tuning and optimization, explore higher resolution for both horizontal and vertical, etc;
- Assimilate radar reflectivity data, and assimilate multiple radar data simultaneously;
- Further improve parameterization schemes, an improved two-moment bulk microphysical scheme developed by CAMS and turbulence kinetic energy (E)-TKE dissipation rate (ε) PBL scheme will be integrated in the near future.

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Thank you for your attention !

References:
Feng, J., Y. Duan, Q. Wan, H. Hu, and Z. Pu, Improved Prediction of Landfalling Tropical Cyclone in China Based on Assimilation of Radar Radial Winds with New Super-Observation Processing. *Wea. Forecasting*, doi: https://doi.org/10.1175/WAF-D-20-0002.1
Duan, Y., Q. Wan, J. Huang, K. Zhao, H. Yu, Y. Wang, D. Zhao, J. Feng, J. Tang, P. Chen, X. Lu, Y. Wang, J. Liang, L. Wu, X. Cui, J. Xu, and P. Chan, *2019*: Landfalling Tropical Cyclone Research Project (LTCRP) in China. Bull. Amer. Meteor. Soc., 100, ES447–ES472, https://doi.org/10.1175/BAMS-D-18-0241.1