FV3GFS 全球模式之資料同化於氣象局之建置與初步評估

Development and preliminary evaluation of the data assimilation for the FV3GFS global model at CWB

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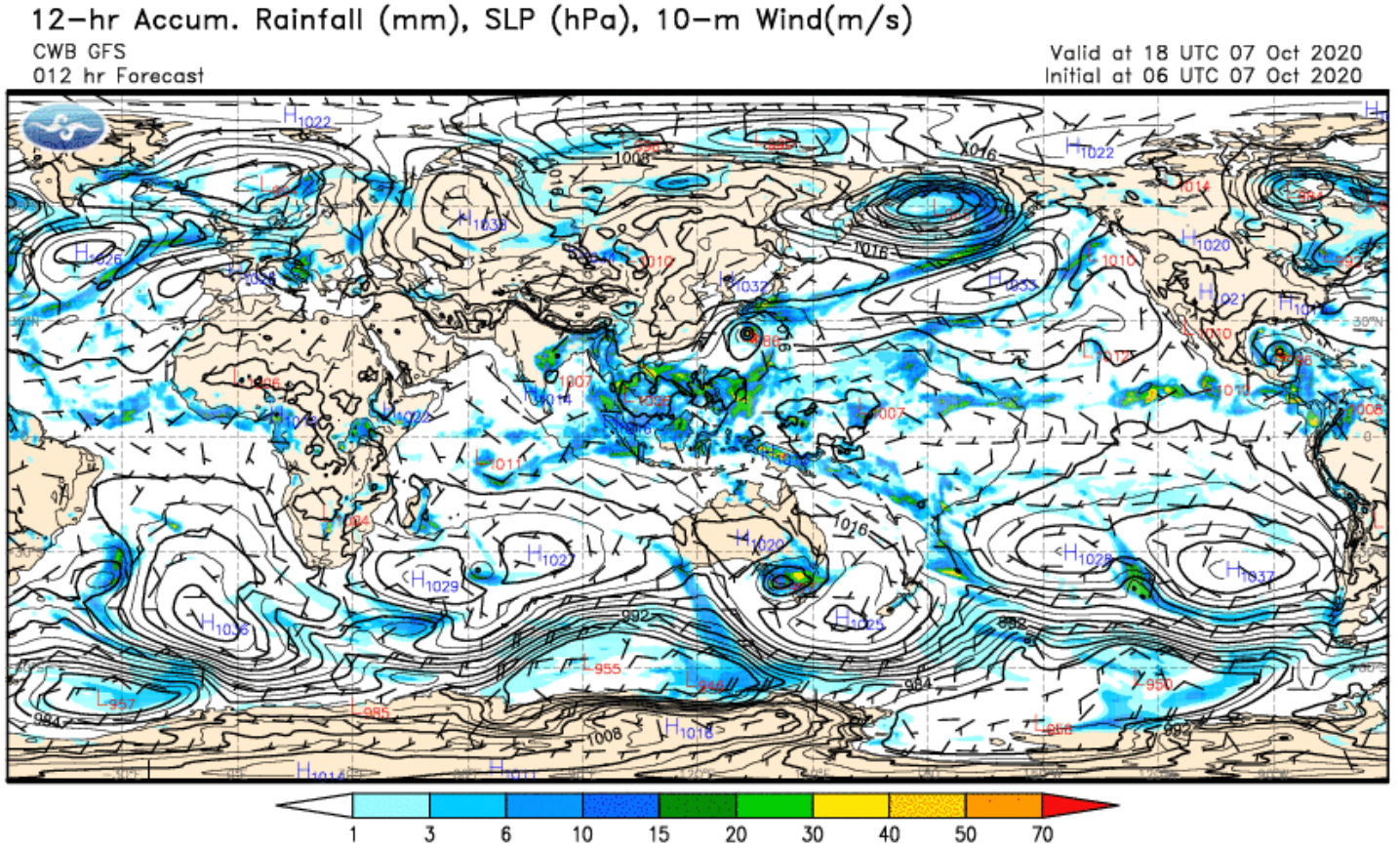
交通部中央氣象局 Central Weather Bureau

2020/10/13

109 年天氣分析與預報研討會

CWB Global Forecast System (CWBGFS)



2002 T119L30

2003 SSI 3DVar

2004 T179L30

2007 T239L30

2010 GSI 3DVar

2011 T319L40 (~40 km)

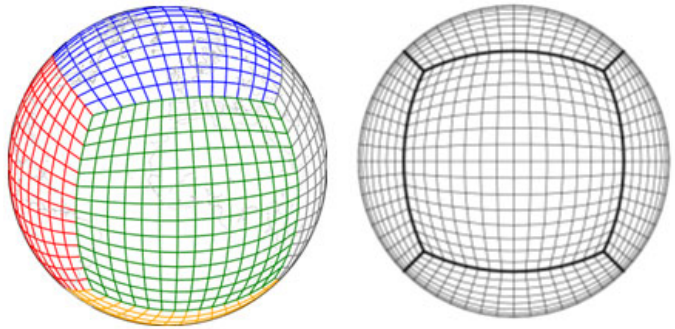
2014 GSI hybrid 3DEnVar

2016 T511L60 (~25 km)

2020 TCo639L72 (~15 km)

NCEP FV3GFS

- Originally developed by GFDL (Lin and Rood 1997; Lin 2004)
- Finite volume (FV) method
- Non-hydrostatic
- Cubed-sphere grid (FV3)
- Local grid refinement: Nested tile (Harris and Lin 2013)



https://www.gfdl.noaa.gov/fv3/fv3-grids/

2016 NGGPS

2018/03 1st public release

2019/06 GFS v15 (based on FV3GFS)

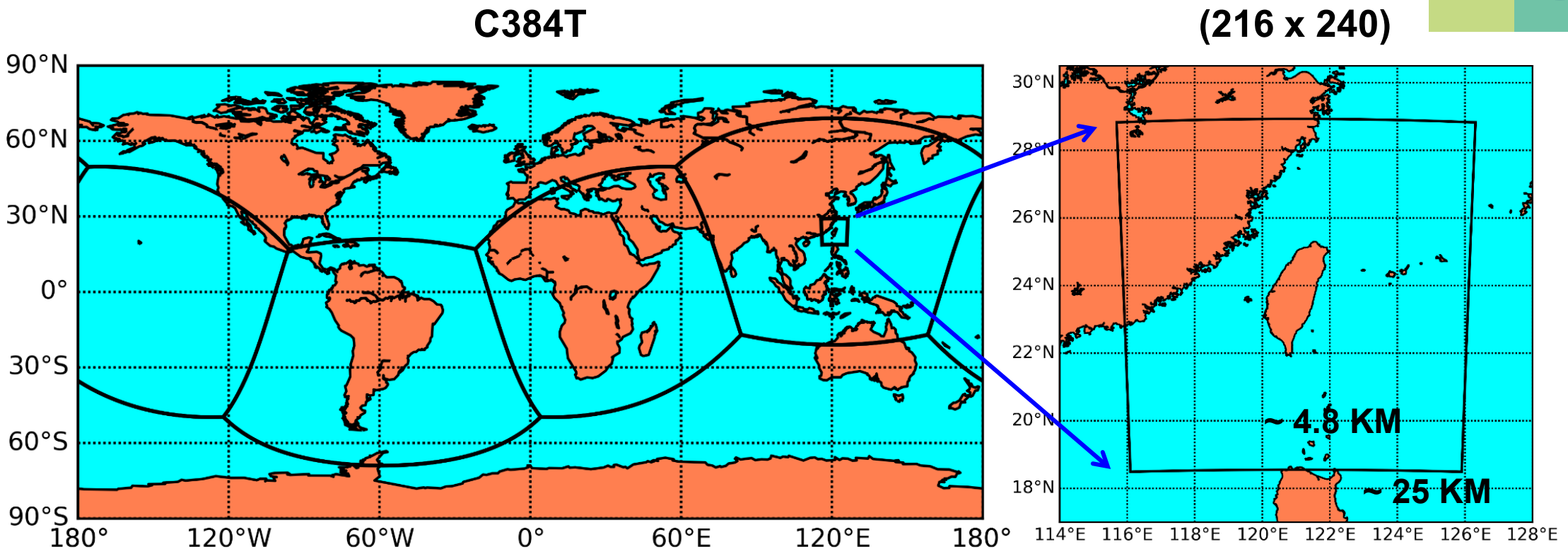
2020/03 UFS v1.0 (everything becomes open-source)

2020 Q4 2nd public release

CWB's goals:

- Build a flexible global NWP and DA system for both operation and research in Taiwan's community
  - Fit to CWB's operational environment (hardware, software)
  - Easy use for research
- Joint the world-wide community development (feedback to NCEP)

FV3GFS grid configuration at CWB



Grid settings for the initial operation:

C384T (~25 km) with an online-nested tile for the Taiwan area (~4.8 km)

cf. NCEP: C768 (~13 km)

All data assimilation work so far is limited to the global tiles only.

Current status of the FV3GFS at CWB

- Completed porting of FV3GFS and GSI code, and workflow scripts onto CWB's HPC
- Added capability of assimilation CWB FGGE-format observation data
- Tested the following configurations:
  - C384T (~25 km) deterministic forecast resolution;
    C192T (~50 km) ensemble resolution
  - Various DA methods:
    - 3DVar
    - Ensemble Kalman filter (EnKF)
    - Hybrid 3D/4DEnVar
  - Operational Early (Major)—Post analysis workflow
- A number of development work described later

First one-month experiment

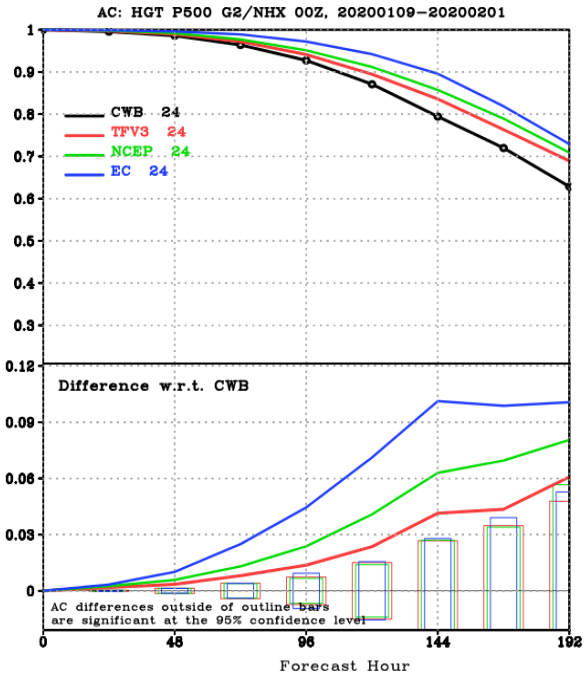
		CWBGFS–GSI operation	FV3GFS–GSI test
Experimental period		2020/01/01 – 02/01 (one month)	
Deterministic forecast system	**Resolution**	**T511 L60 (25 km)**	**C384T L64 (25 km)**
	Data assimilation method	3DEnVar	**4DEnVar**
Ensemble system	**Resolution**	T319L60 (40 km)	C192L64 (50 km)
	Ensemble size	**36 + 36 lag-ensemble**	32
Observations assimilated	**EC bogus**	**V**	**–**
	Typhoon bogus	V	–
	Near Sea Surface Temperature (NSST) analysis	No (replaced with external data)	V
	Ozone analysis	No (replaced with external data)	V

First one-month experiment

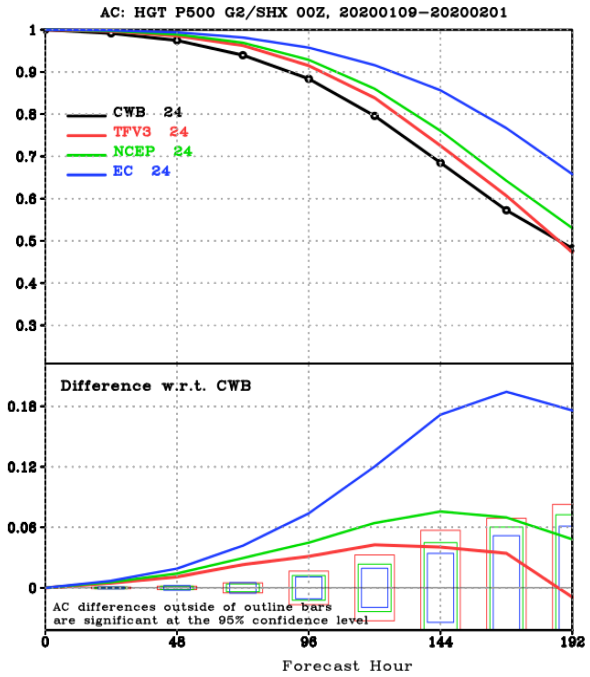
▲▼ 99.9% significance level
▲ ▼ 99% significance level
95% significance level
Not statistically significant

500-hPa height anomaly correlation

NH (20-80N)



SH (20-80S)

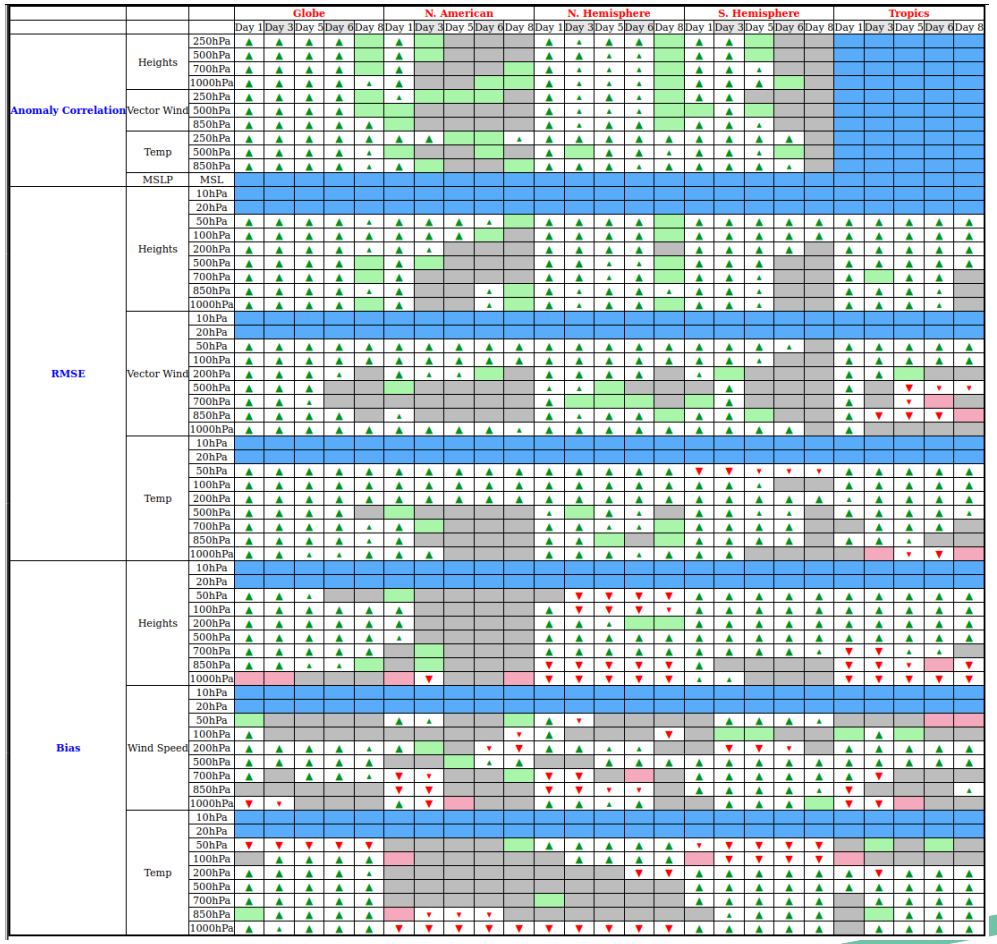


CWBGFS (OP)
CWB FV3GFS (C384T)
NCEP FV3GFS (C768)
ECMWF IFS

Differences between CWB FV3GFS and NCEP FV3GFS:
1. Lower resolution (25 km vs. 13 km)
2. Smaller ensemble (32 vs. 80)
3. Fewer satellite data assimilated

Scorecard – Green/Red :
CWB FV3GFS is better/worse than CWBGFS(OP)

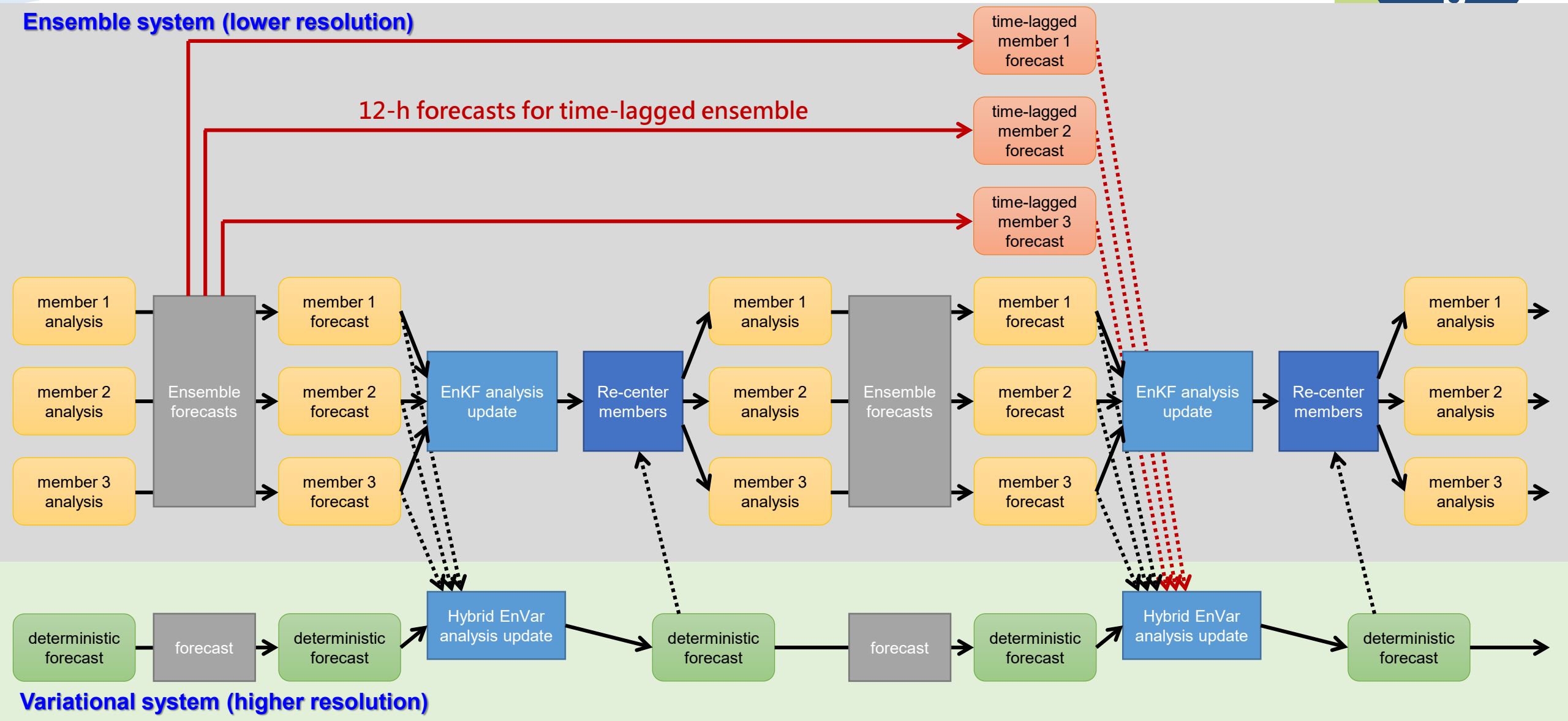
(2020/01/09 – 02/01)



Development and testing work on FV3GFS DA

- Testing on the sea ice and snow depth analysis procedures (黃子茂)
- Time-lagged ensemble (趙子瑩) **[Talk A2-14]**
- TC vital assimilation (鄧雯心)
- LETKF testing (鄧雯心)
- FORMOSAT-7 RO bending angle assimilation (黃子茂、林宗翰)
- Himawari-8 IR radiance assimilation (林宗翰、周鑑本)

Hybrid EnVar with time-lagged ensemble



Results with time-lagged ensemble

Significant improvement by employing the time-lagged ensemble (32+32 members)

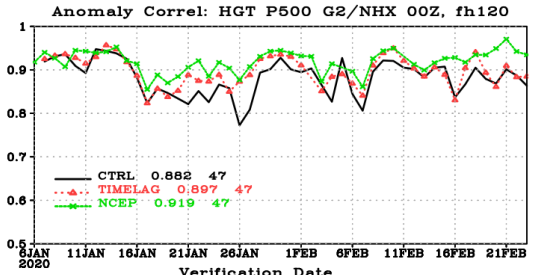
2020/01/01 00Z ~ 02/18 00Z

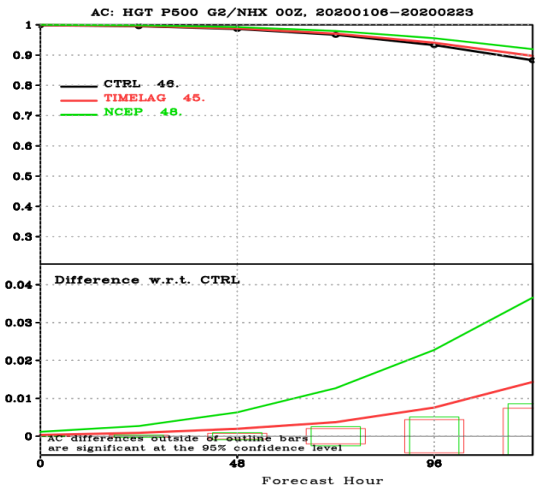
▲▼ 99.9% significance level
▲ ▼ 99% significance level
95% significance level
Not statistically significant

500-hPa height anomaly correlation

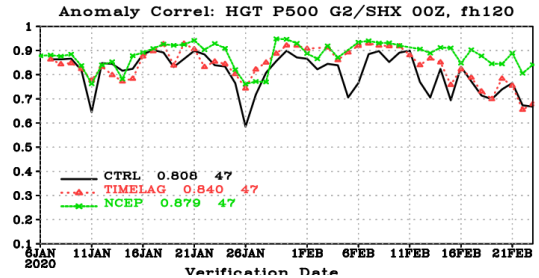
FV3GFS CTRL (32mem)
FV3GFS TIMELAG (32+32mem)
NCEP GFS (C768 / 80mem)

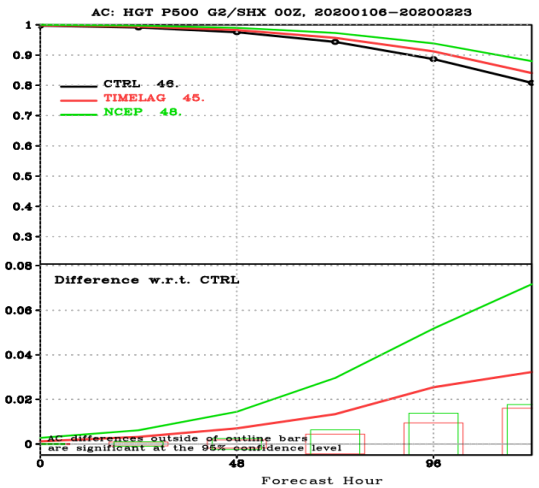
NH (20-80N)



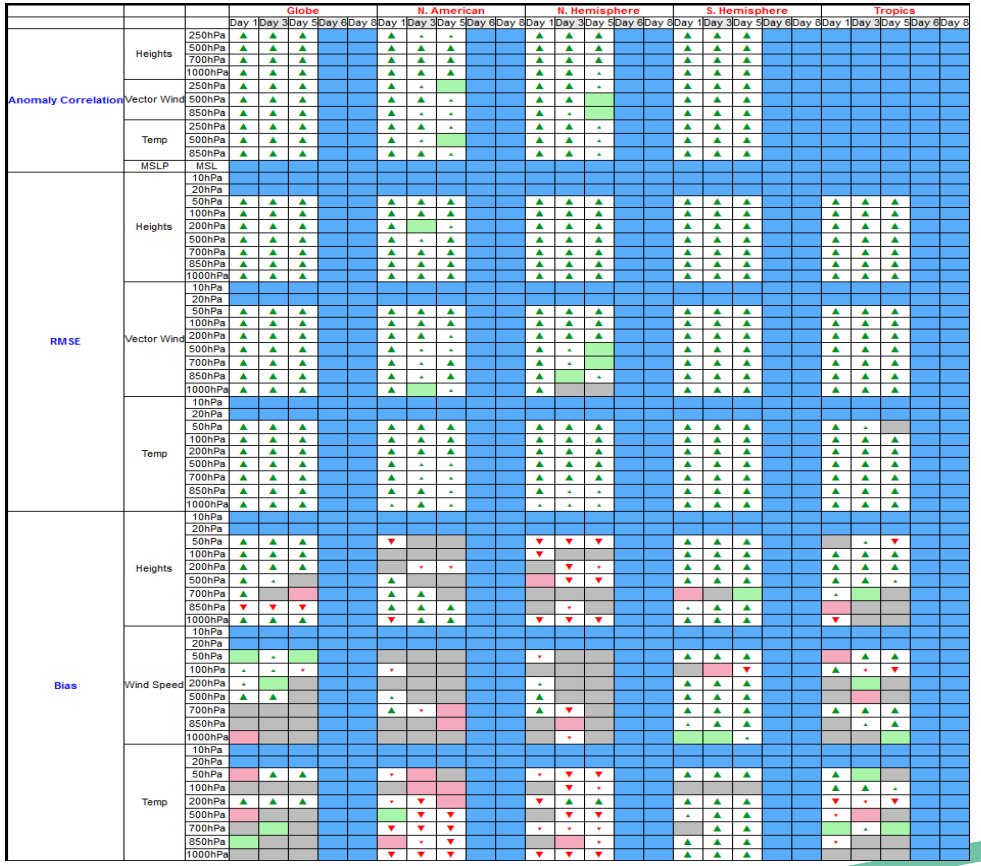


SH (20-80S)





Scorecard – Green/Red : TIMELAG is better/worse than CTRL



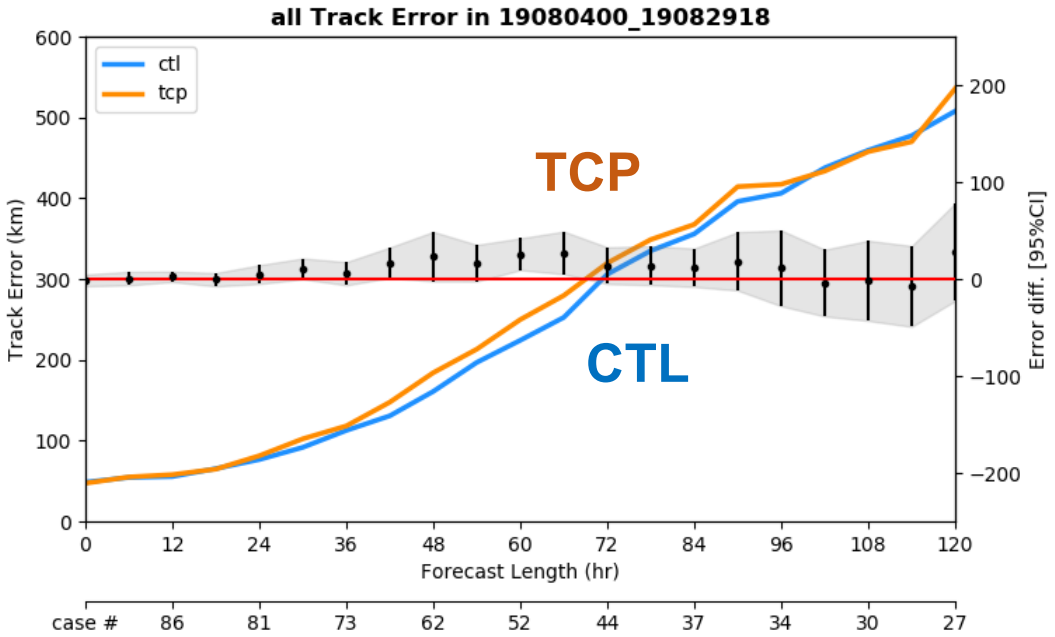
TC vital (MinSLP) assimilation

- **Special procedures/bogus data for TC initialization:**
  - NCEP: TC vital (i.e., MinSLP) assimilation (Daryl 2011)
  - ECMWF: **None (never)**
  - CWBGFS: TC bogus data + Relocation
  - CWB FV3GFS: ??

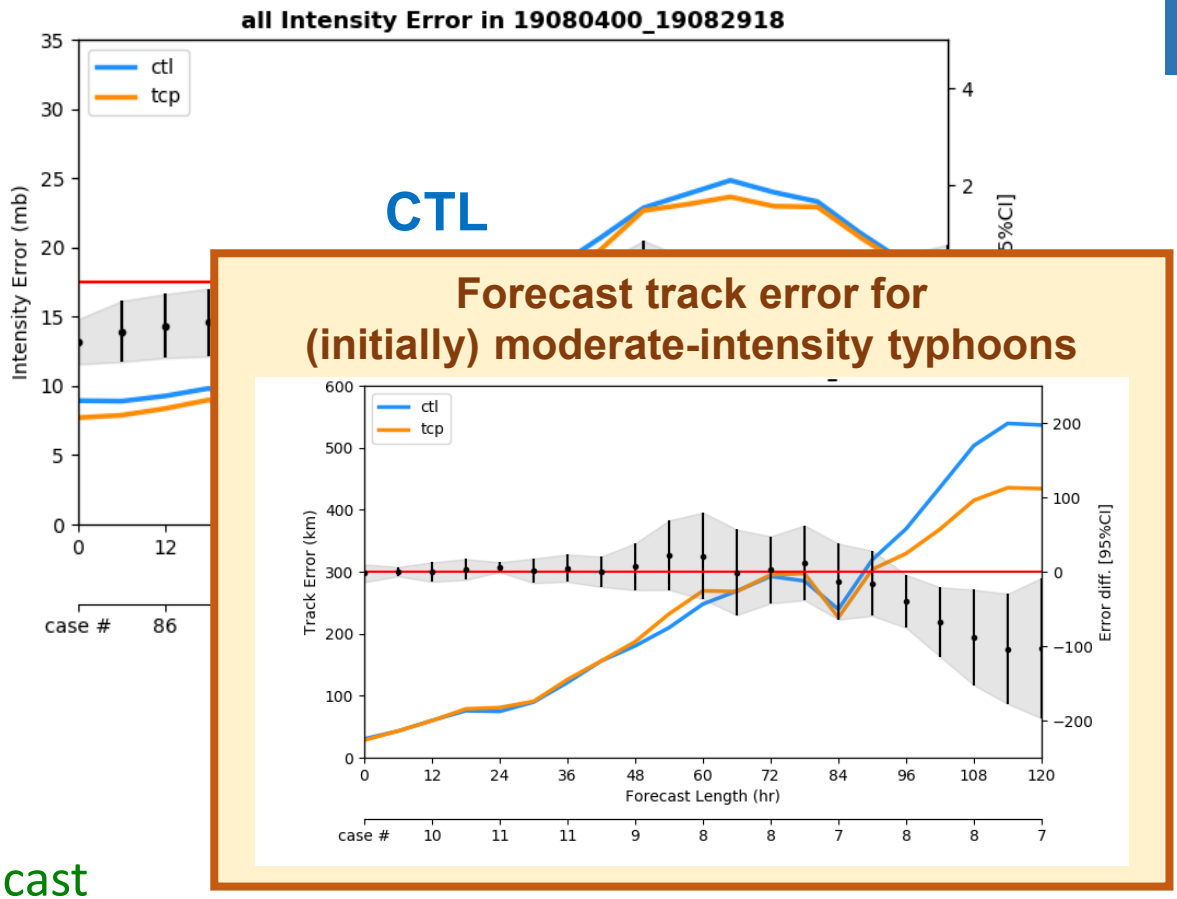
- **Experiments:**
  - **CTL**: Assimilate operational observations
  - **TCP**: Assimilate operational observations + TC Vital
  - 5 typhoons: FRANCISCO, LEKIMA, KROSA, BAILU, PODUL (2019/08/04 00Z – 08/29 18Z)

TC vital (MinSLP) assimilation

0-120h Forecast **track error**



0-120h Forecast **intensity error**



Forecast track error for (initially) moderate-intensity typhoons

- No improvement on initial typhoon position
- No improvement on track forecast
- Slight improvement on intensity analysis and forecast
- Still no clear signals even if stratified by the “initial position errors” or “initial observed intensity”

LETKF testing and comparison with EnSRF

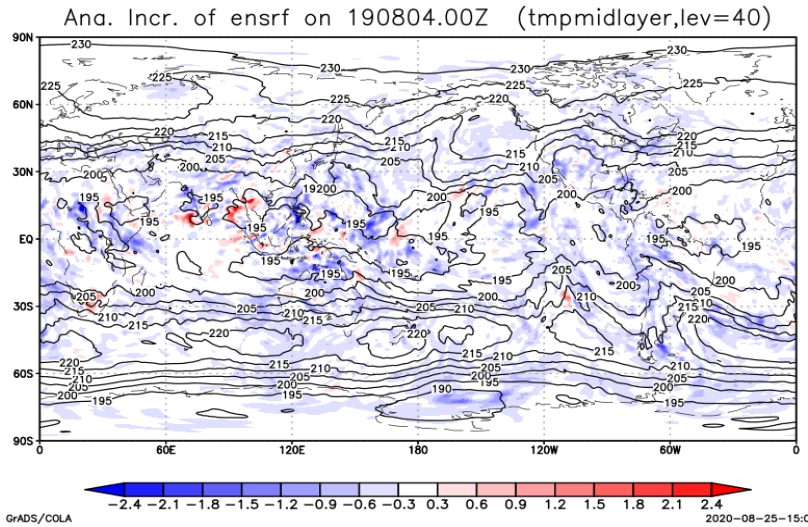
- In the ensemble subsystem of NCEP GSI, it uses a serial Ensemble Square-Root Filter (EnSRF; Whitaker and Hamill 2002) for the EnKF data assimilation.
- NCEP GSI also has a function to perform Local Ensemble Transform Kalman Filter (Hunt et al. 2007) analysis, but it has not yet been used in any operation.

- We have a plan to use LETKF for the ensemble component of the hybrid EnVar data assimilation, replacing the current EnSRF.
  - The first step is to compare the EnSRF and LETKF performance.
  - However, it is found that a tuning parameter **"paoverpb_thresh"** (threshold of ratio of predicted analysis error variance over background error variance) is critical to this EnSRF vs. LETKF comparison.

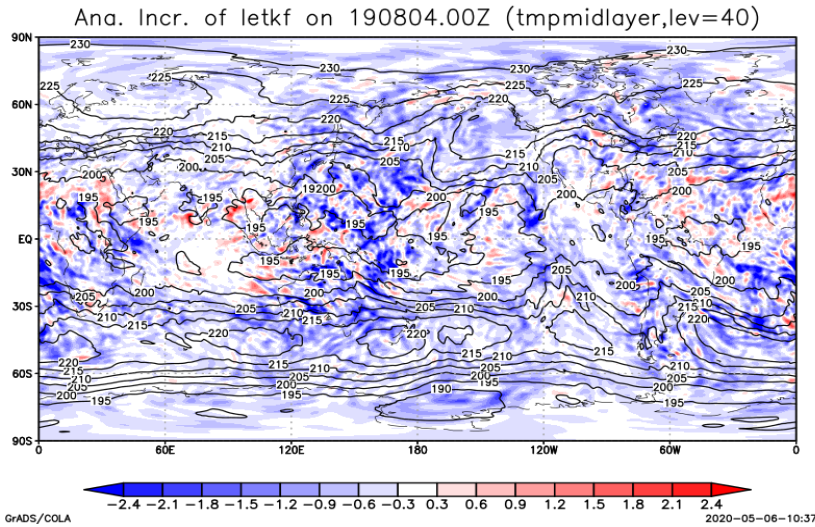
LETKF testing and comparison with EnSRF

Analysis increment in one cycle (temperature at model level #40)

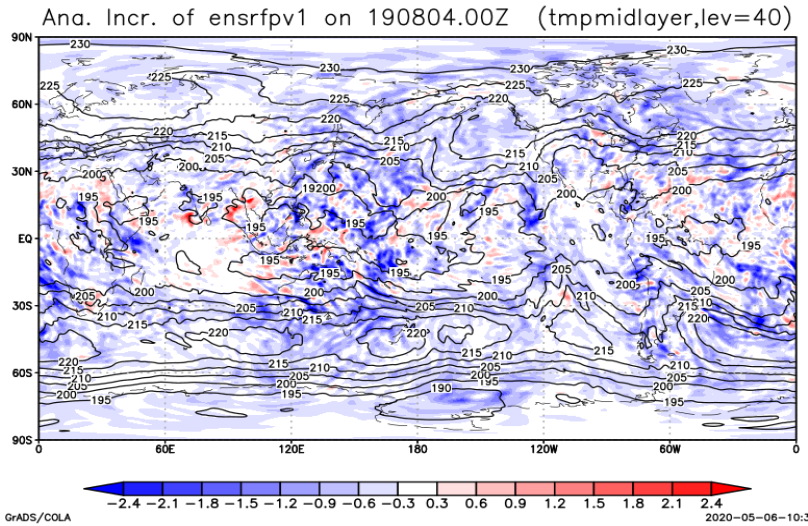
EnSRF [pa/pb <= 0.98]



LETKF

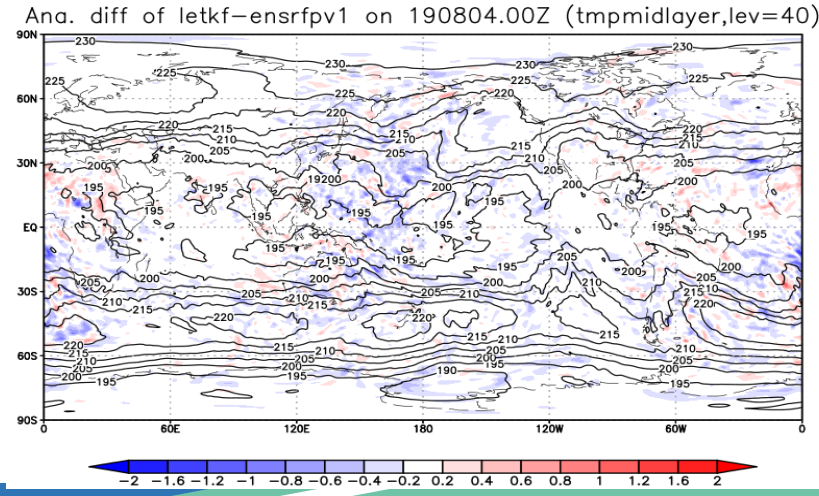


EnSRF [pa/pb <= 1]



The default setting of “paoverpb_thresh” in GSI is 0.98,
which causes about 78% observations to be discarded
(72%, 56%, 85% for conventional, RO, radiance data, respectively).

LETKF – EnSRF [pa/pb <= 1]

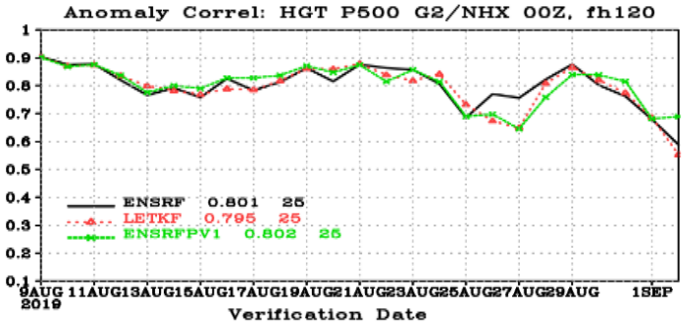


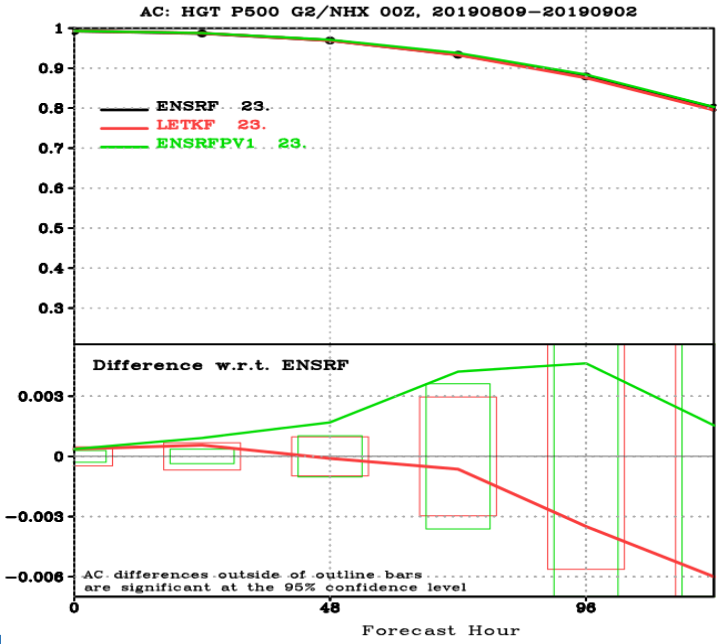
LETKF testing and comparison with EnSRF

500-hPa height anomaly correlation

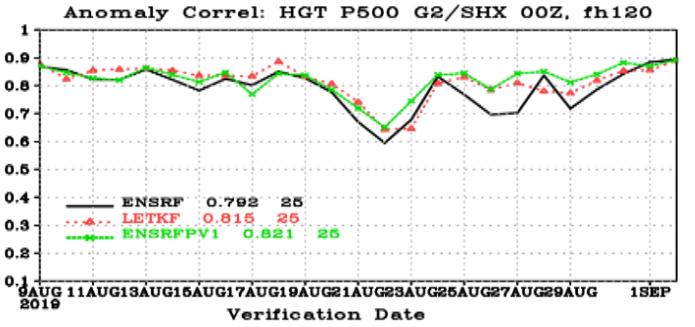
(deterministic forecast from ensemble mean analysis)

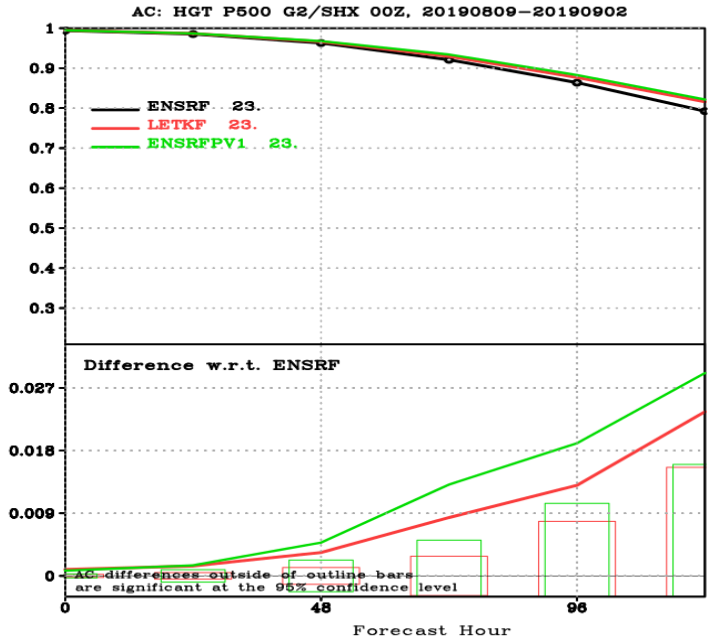
NH (20-80N)





SH (20-80S)





EnSRF [pa/pb <= 0.98]
(GSI default)

LETKF

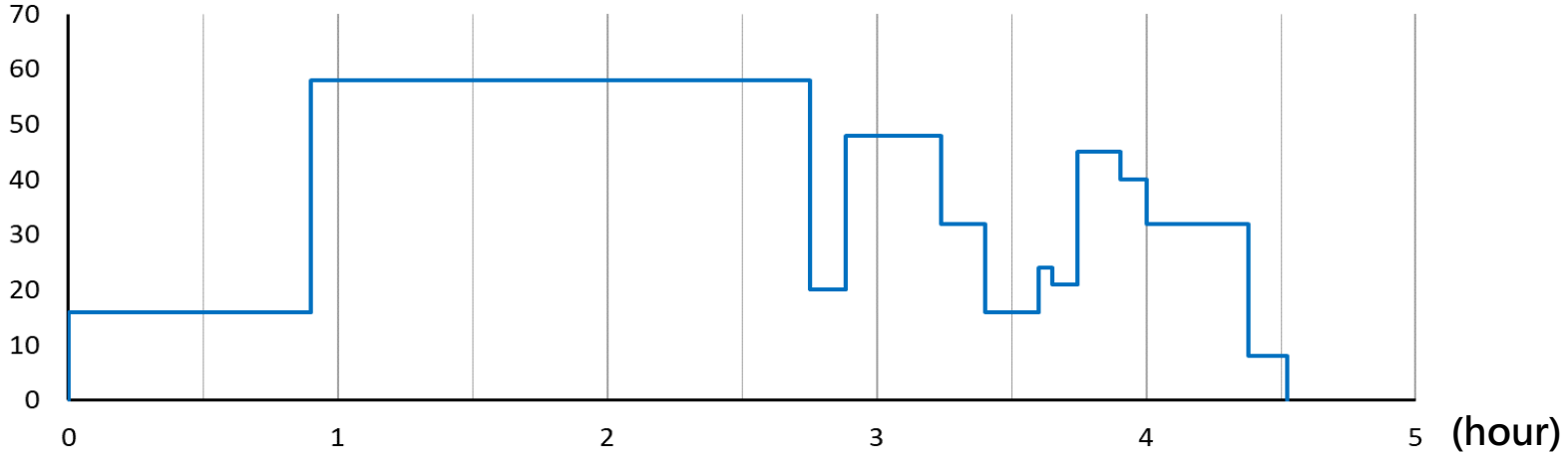
EnSRF [pa/pb <= 1]

Computational cost estimation

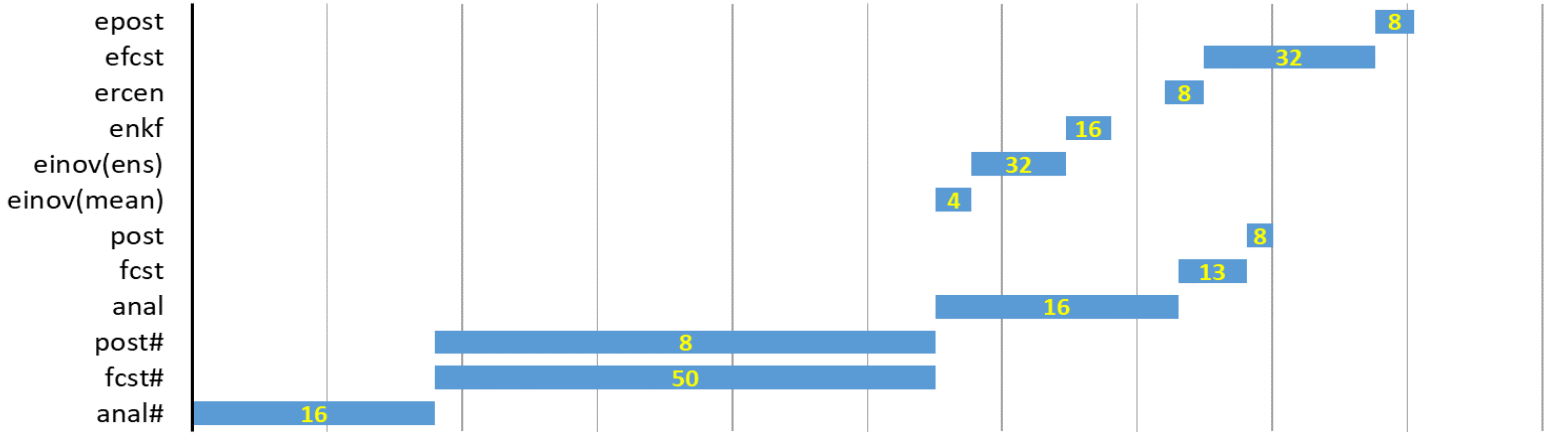
Average resource usage for a single forecast-analysis cycle

(with early/post operational workflow and time-lagged ensemble)

Total FX100 nodes used with respect to real time



Schedule of each job and its number of nodes



Less than the current CWBGFS resource usage!

Operational schedule

2018/12
Near-realtime forecast from NCEP analysis
(5-day with a nested tile)

2020 Q4
Near-realtime cycled data assimilation and forecast
(10-day+)

2021 Q2–Q3?
Start operational implementation on the new HPC

2021 Q4?
Operation on the new HPC
(replacing CWBGFS)

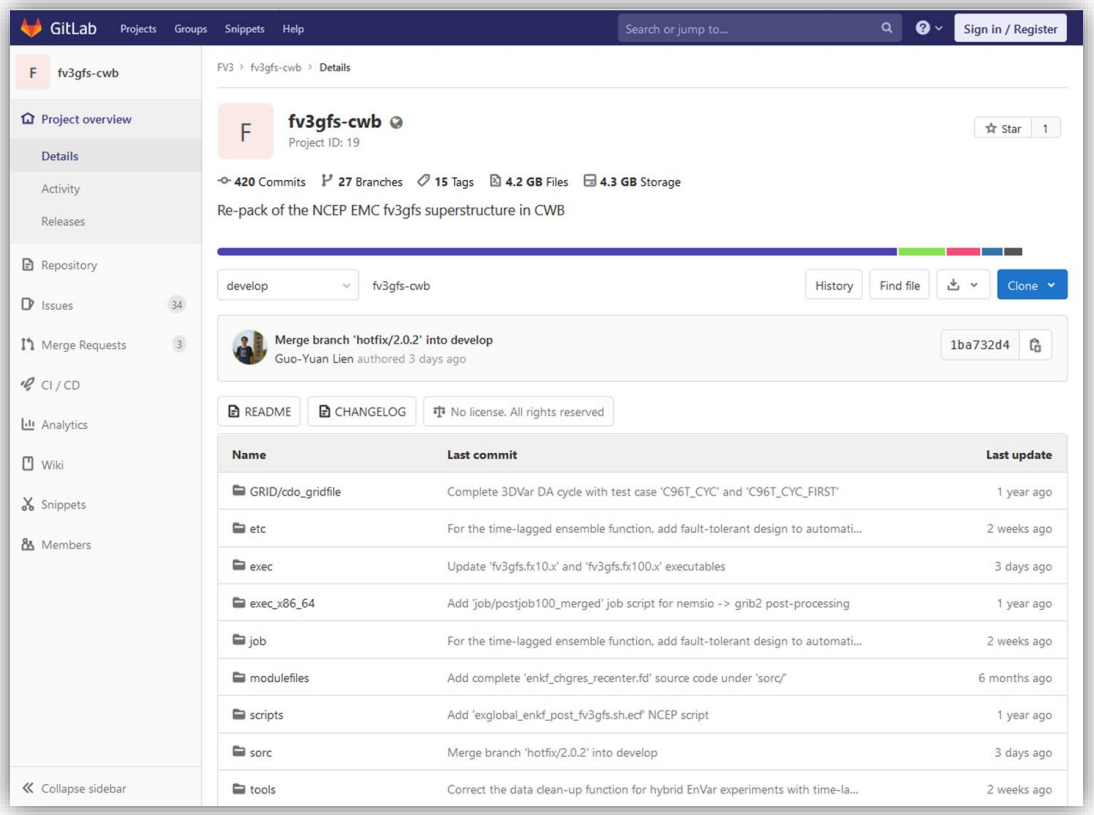
Self-maintained by the research team

Work with operational team

Maintained by the operational team

Collaboration with research community

- Maintain a code repository (CWB-localized FV3GFS, with DA) which is easy to use for research



("fv3gfs-cwb" project on CWB internal GitLab website)

Ongoing collaborations:

- RCEC (Academia Sinica) (許晃雄、杜佳穎): Unified model for weather-to-climate simulation
- NCU (黃清勇、楊舒芝、陳舒雅): Typhoon simulation and data assimilation studies

Future plan on FV3GFS data assimilation

- Improvement of LETKF core (computational efficiency, localization, …)
- Improvement of satellite DA in LETKF
- Implementation and evaluation of hybrid gain DA method
- Ensemble Forecast Sensitivity to Observation Impact (EFSOI)
- FORMOSAT-7 RO data assimilation
- Himawari-8 IR radiance assimilation
- (Far future?) Nested-domain DA

Summary

- CWB has mostly completed porting and localization of the NCEP FV3GFS–GSI global NWP system, for operation and research.
- An early test has shown significantly better synoptic forecast skills than the current CWBGFS operational system.
- A number of research and development work is going on, such as time-lagged ensemble, LETKF testing, … etc.
- Operation schedule:
  - 2020 Q4 : Self-maintained near-realtime cycled data assimilation and forecast
  - 2021 Q4(?) : Operation on the new HPC (replacing CWBGFS)
- Several collaborations with Taiwan's research community have been initiated, and hope to see more in the future.