Current status of
the use of FV3GFS at CWB

Guo-Yuan Lien, Jen-Her Chen, Ling-Feng Hsiao, and many other colleagues

May 21, 2019

交通部中央氣象局
Central Weather Bureau

CWB's current operational global NWP system

- **Model: CWB Global Forecast System (CWBGFS)**
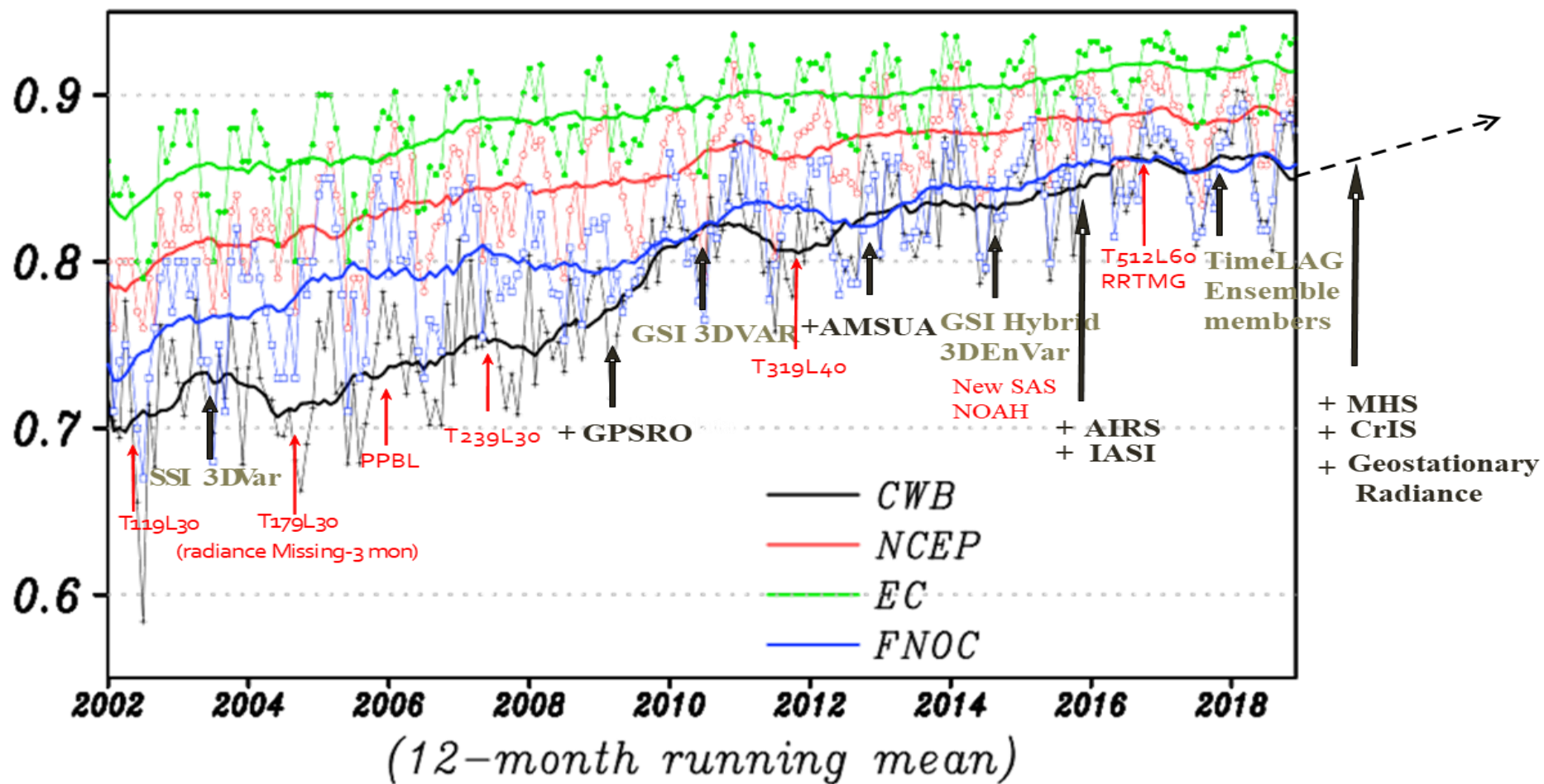 - Self-developed dynamic core
  - Physics parameterizations mostly (not all) adapted from the NCEP GFS
  - T511L60 (~25 km ; 2016~)
  - 384-h deterministic forecast

- **Data assimilation**
  - Modified GSI for CWBGFS
  - 6-h update cycle
  - Hybrid 3DEnVar:
    - EnSRF; T319L60;
      36 members (6-h fcst) + 36 time-lag members (12-h fcst) = 72 members
    - Hybrid 4DEnVar under testing
  - Conventional observations mostly from the GTS;
    Satellite observations mostly from the NCEP server

CWB operational global NWP system: 5-day forecast skill
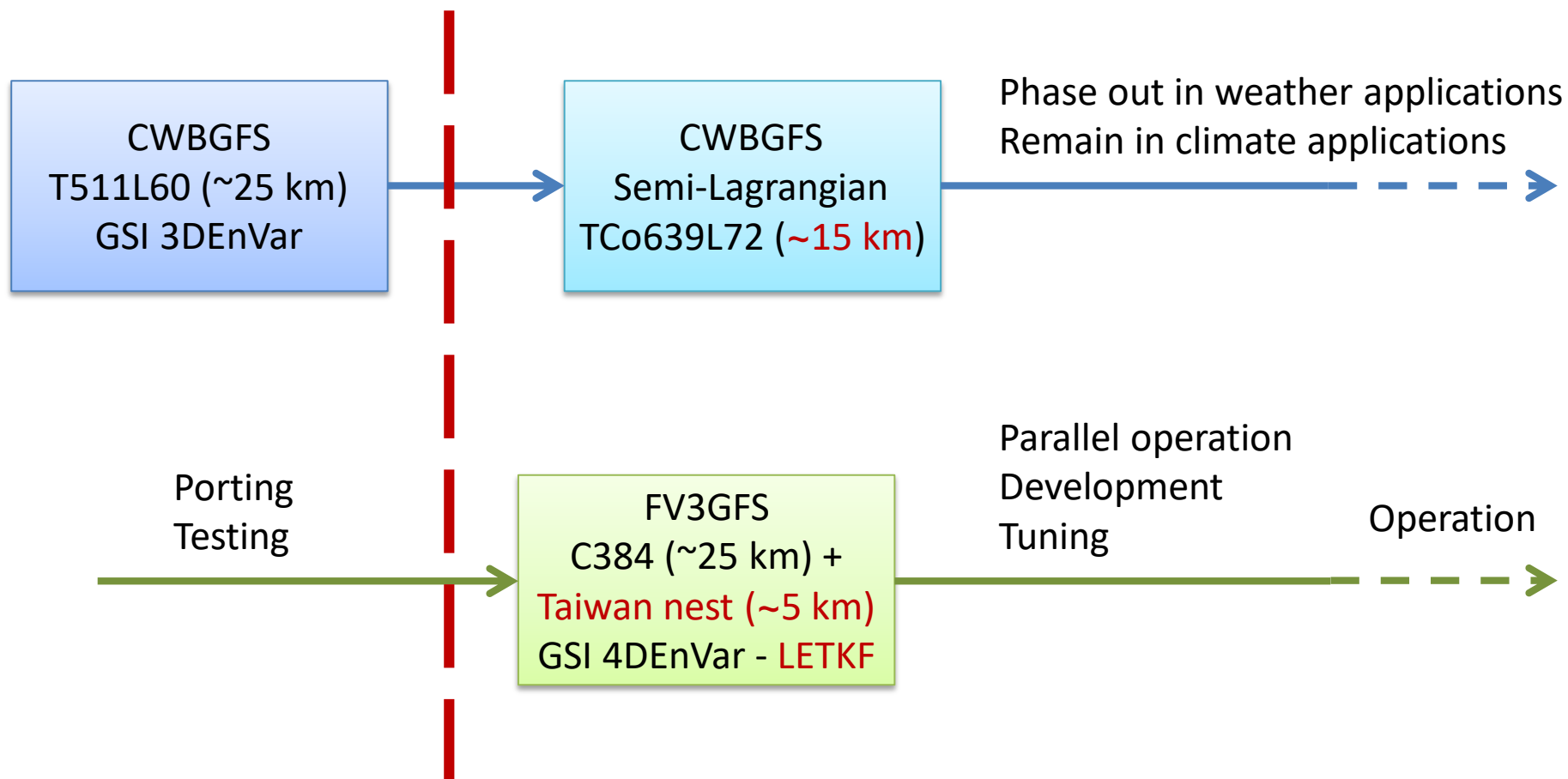

day 5 forecast, 500hPa H AC − N.Hemis.

(12−month running mean)

— CWB
— NCEP
— EC
— FNOC

GSI 3DVAR   +AMSUA   GSI Hybrid 3DEnVar   T512L60 RRTMG   TimeLAG Ensemble members

T319L40   New SAS NOAH

T239L30   + GPSRO   + AIRS + IASI   + MHS + CrIS + Geostationary Radiance

PPBL

SSI 3DVar

T119L30   T179L30

(radiance Missing-3 mon)

Courtesy of Deng-Shun Chen

Plan of global NWP at CWB

CWB has decided to use the NCEP FV3-based system for global NWP.
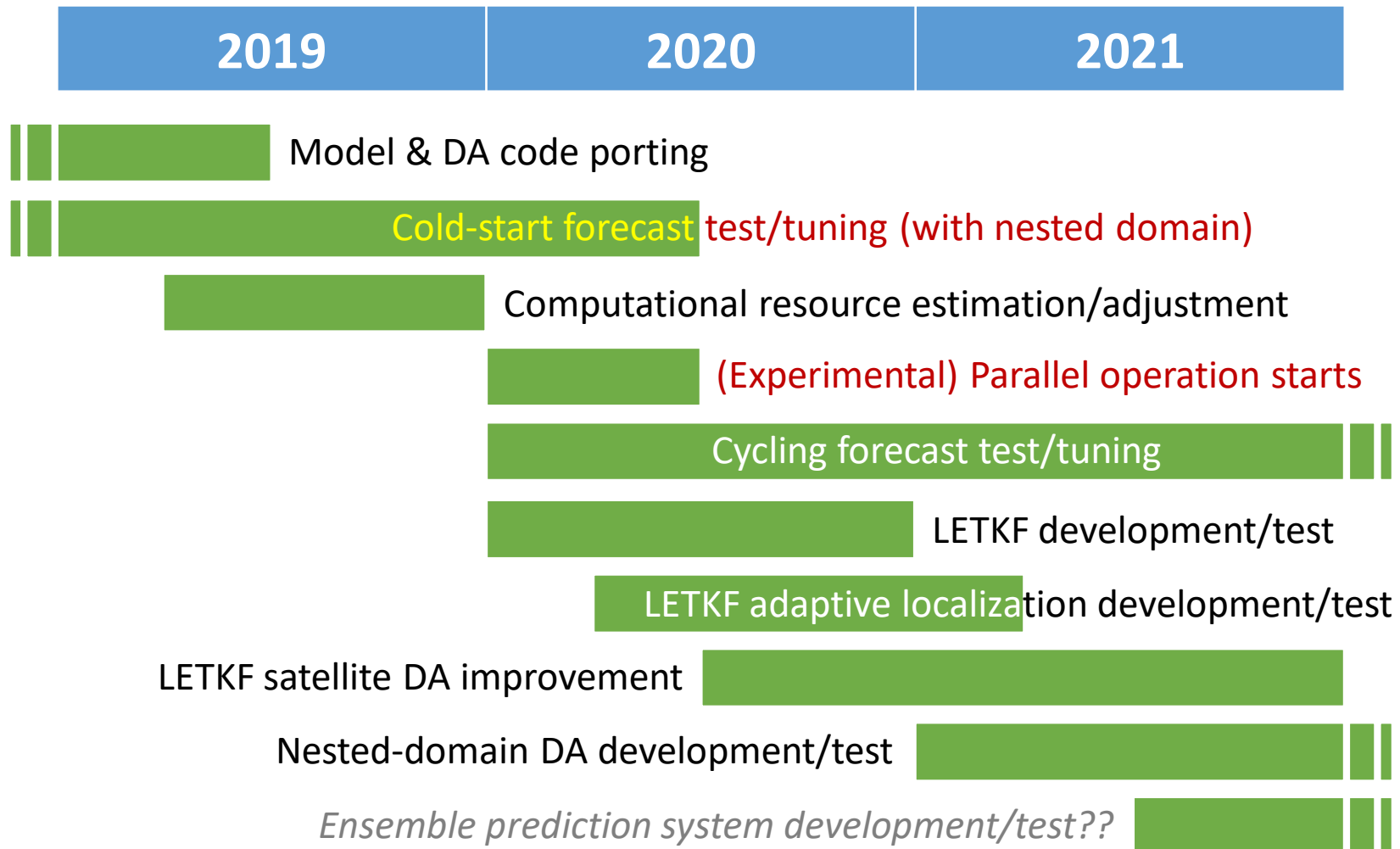
- Model: **NCEP FV3GFS**
    - Online nested regional tile will be enabled.
    - Local tuning and development:
        - *Nested domain tuning*
        - *… ?*

- Data assimilation: **NCEP GSI 4DEnVar**
    - Same observation data stream as used in the current CWBGFS system
      → Need to be improved
    - Local tuning and development:
        - *LETKF in the hybrid system*
        - *Separate DA for nested domains… ?*
        - *… ?*

Plan of global NWP at CWB

Plan of FV3GFS model and DA work at CWB

2019	2020	2021

Model & DA code porting

Cold-start forecast test/tuning (with nested domain)

Computational resource estimation/adjustment

(Experimental) Parallel operation starts

Cycling forecast test/tuning

LETKF development/test

LETKF adaptive localization development/test

LETKF satellite DA improvement

Nested-domain DA development/test

Ensemble prediction system development/test??

Progress summary

✔ **Code porting**

- NCEP FV3GFS model: Successfully ported to the CWB HPC.
  - Porting ESMF caused a big headache… but finally solved.
- GSI for FV3GFS: Ongoing

✔ **Cold-start forecast test/tuning**

- Workflow for cold-start forecast using initial conditions from several models (NCEP GFS, CWBGFS) has been set up.
- With NCEP GFS initial conditions, lots of experiments have been conducted:
  - Retrospective cases
  - Near-real-time run
- Verification has been performed using the existing verification systems:
  - **GVER**   (for global verification)
  - **CWB QPF system** (for Taiwan precipitation verification)

✔ **Computational resource estimation/adjustment** (ongoing)

FV3GFS tile settings at CWB (old)

C384

(216 x 240)

~ 4.4 KM
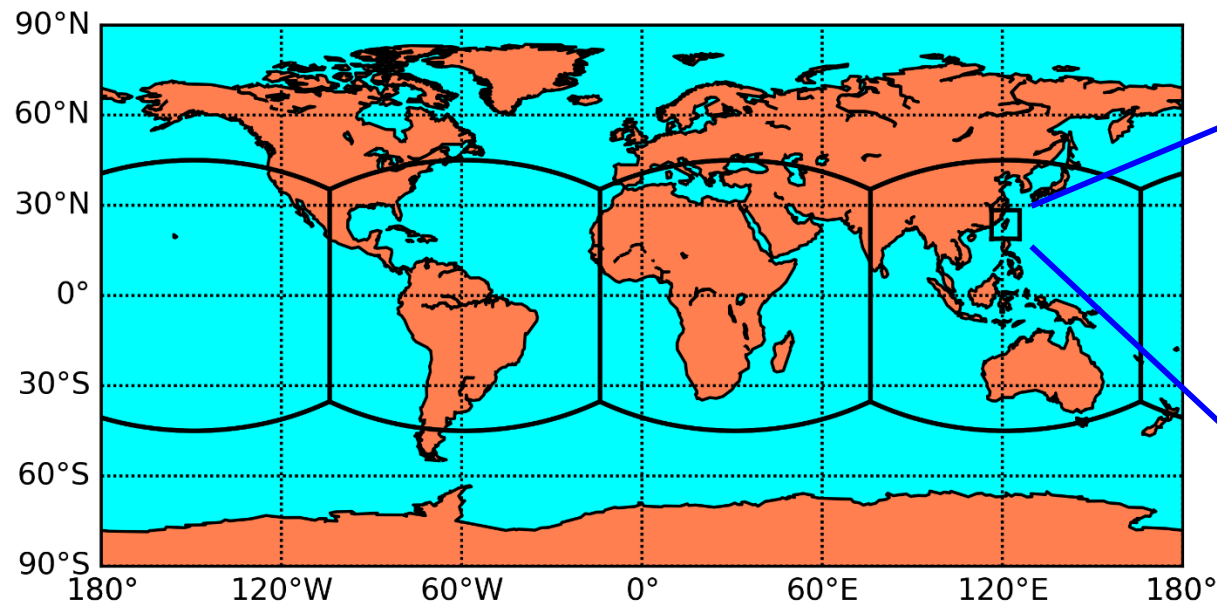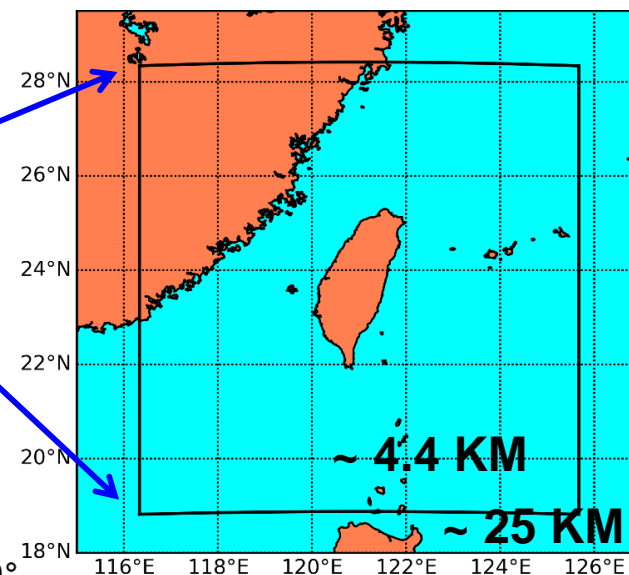
~ 25 KM

(Yu-Han Chen)

FV3GFS tile settings at CWB

C384T   **(216 x 240)**
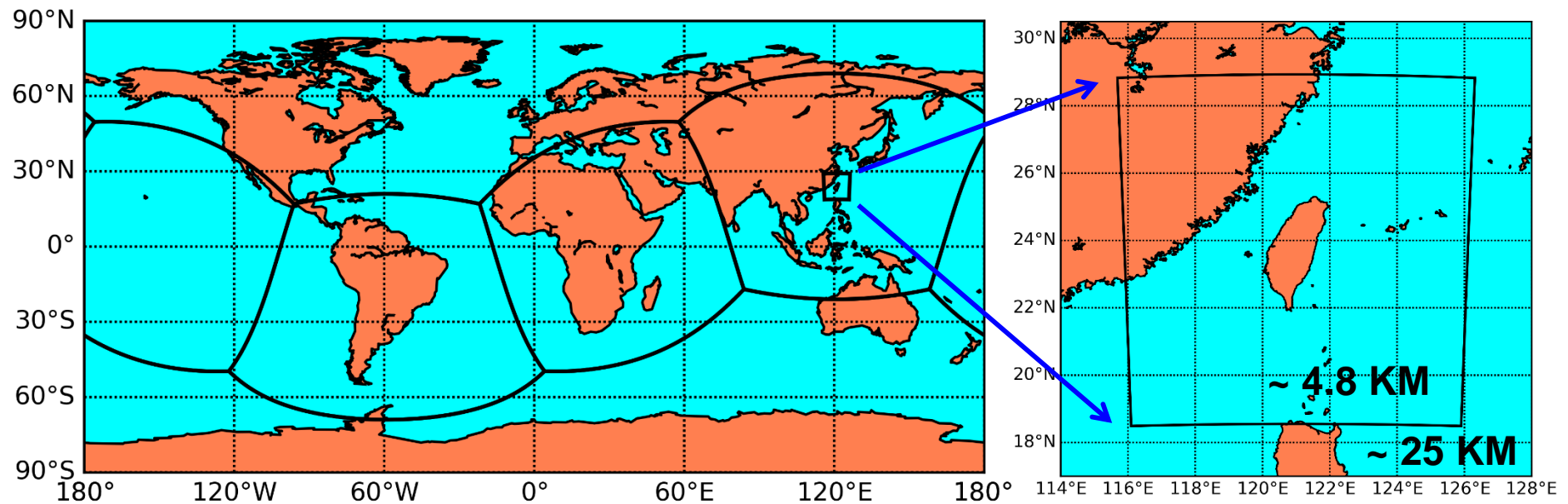
- No distinct differences to the previous zonal tile setting.

- Tentative target for the initial operation:
  C384T (~25 km) with a nested tile for Taiwan area (~4.8 km) , two-way feedback.
  c.f. NCEP: C768 (~13 km)

(Yu-Han Chen)

Verification of the cold-start forecasts

- Global verification:
  - Standard AC, RMSE, bias, … etc.

- Taiwan area verification:
  - So far, precipitation only: TS, ETS, … etc.
  - Link to CWB's integrated QPF system to make it easy for model intercomparison.

5-day forecast 500-hPa AC

NCEP :   NCEP GFS (NCEP IC)
FV3_C384T_NCEP :   FV3GFS / NCEP IC
FV3_C384T_CWB :   FV3GFS / CWB IC
CWB :   CWBGFS (CWB IC)
EC :   ECMWF IFS (EC IC)

Global

Anomaly Correl: HGT P500 G2 00Z, fh120

FV3_C384T_CWB   0.858   31
FV3_C384T_NCEP   0.867   31
NCEP   0.862   31
CWB   0.832   31
EC   0.909   30
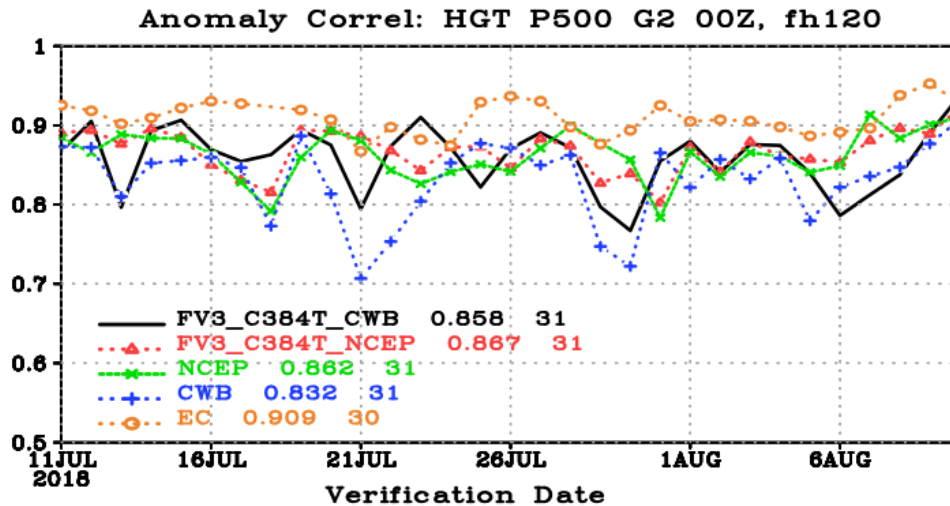
Global 5-day fcst 500-hPa AC

NH

Anomaly Correl: HGT P500 G2/NHX 00Z, fh120

FV3_C384T_CWB   0.846   31
FV3_C384T_NCEP   0.859   31
NCEP   0.857   31
CWB   0.827   31
EC   0.897   30

NH 5-day fcst 500-hPa AC
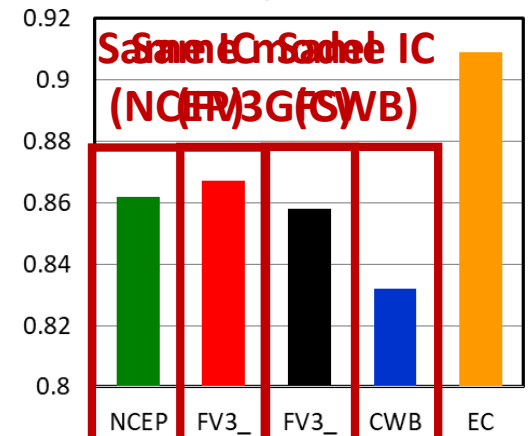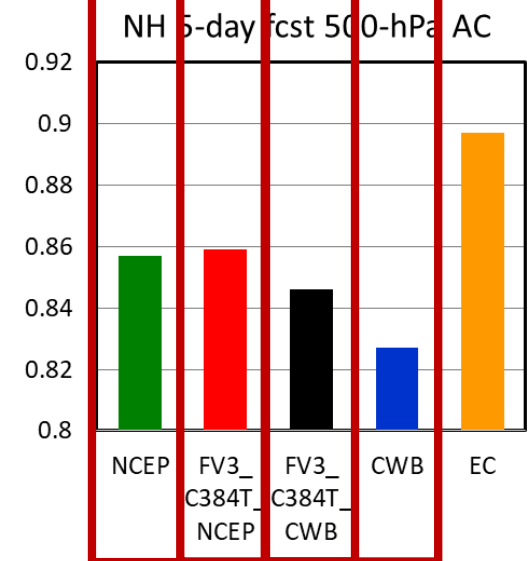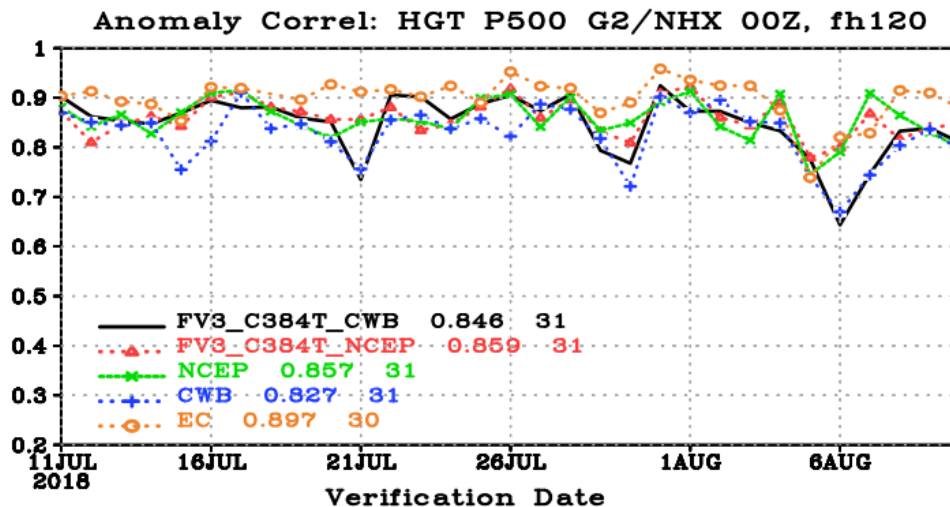
Taiwan QPF verification

-- A winter rainfall case [2019/01/15 00Z; 12-24h forecast]
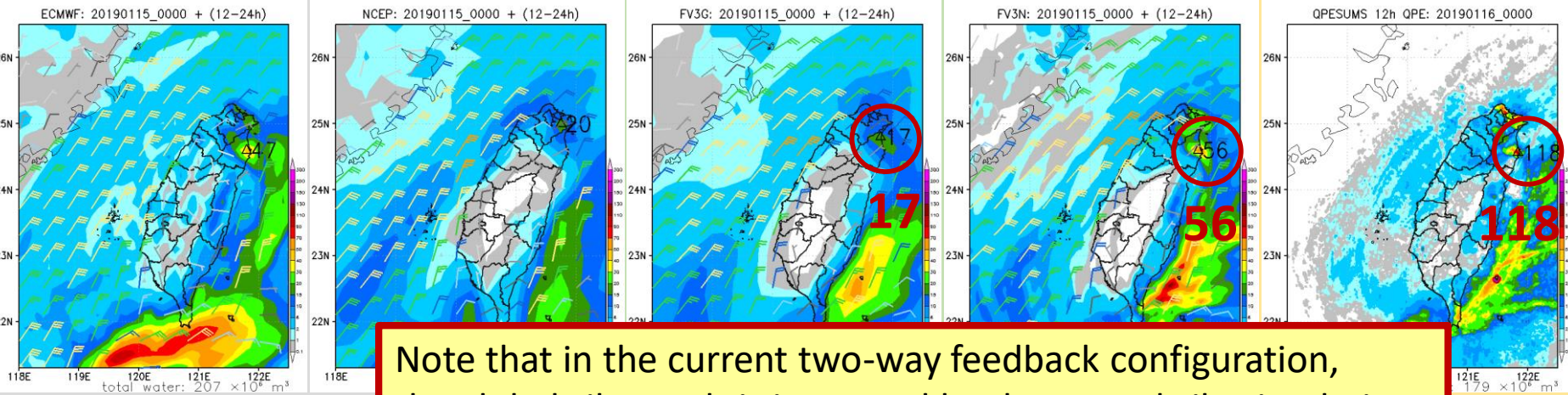
Note that in the current two-way feedback configuration,
the global-tile result is improved by the nested-tile simulation.
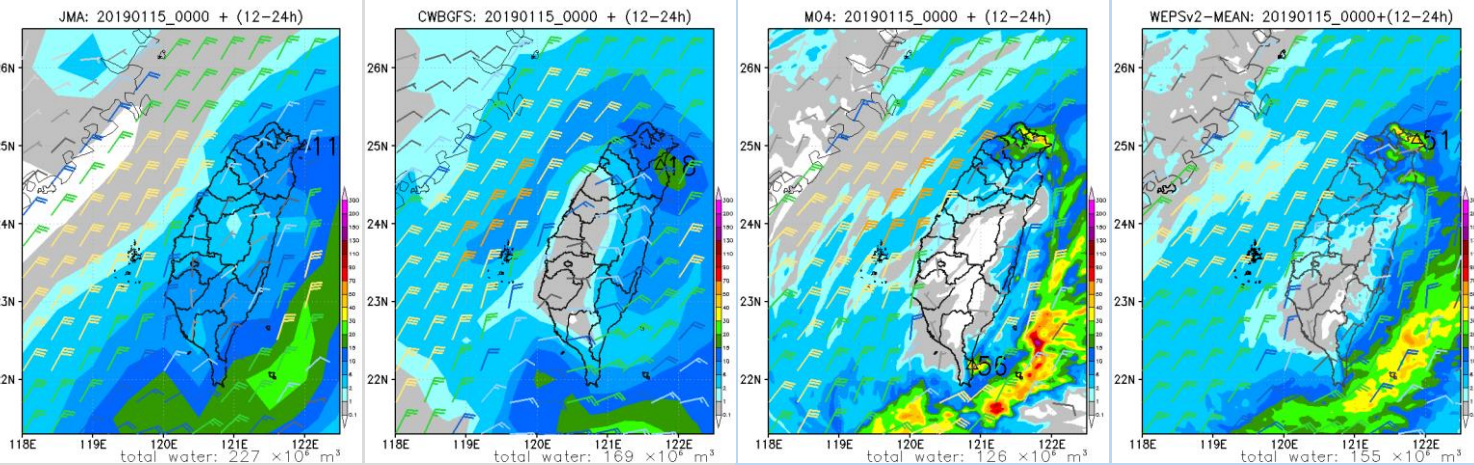
Taiwan QPF verification
 -- A TC heavy rainfall case [2018/08/22 12Z; 12-24h forecast]
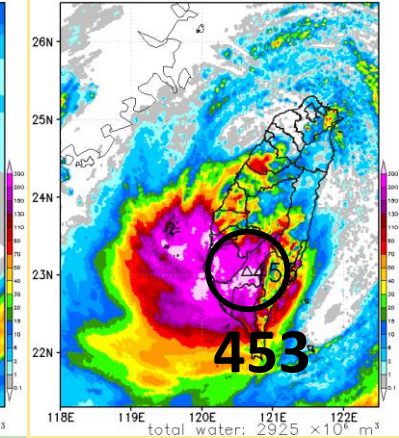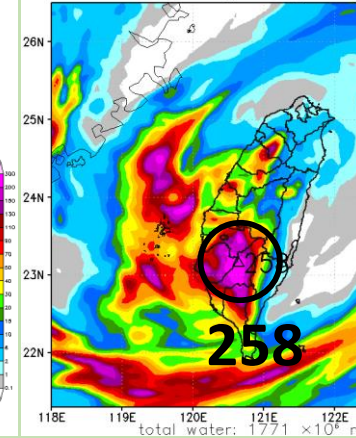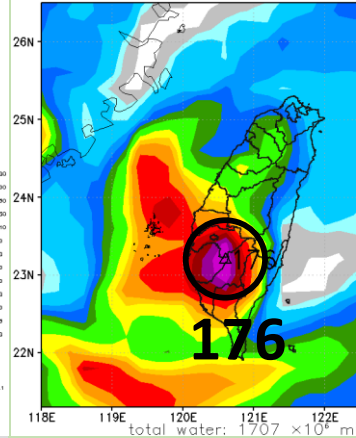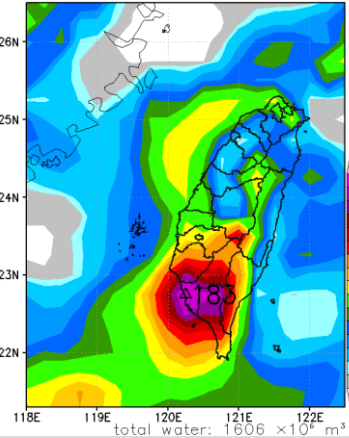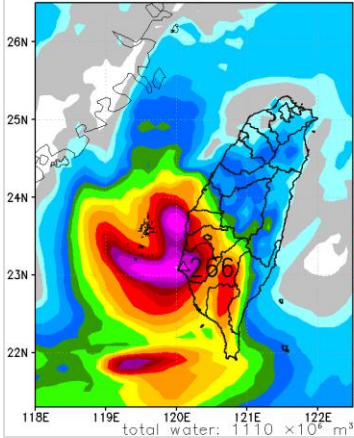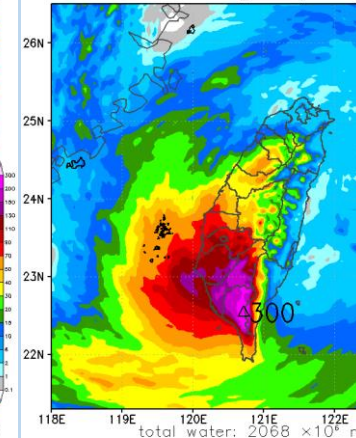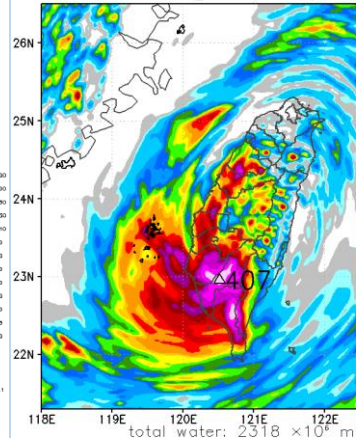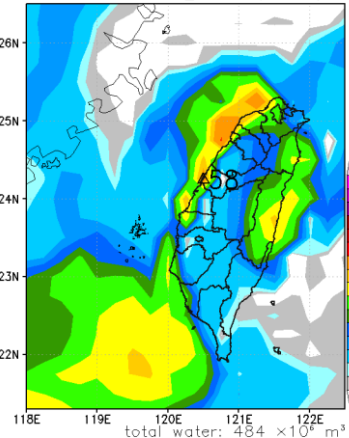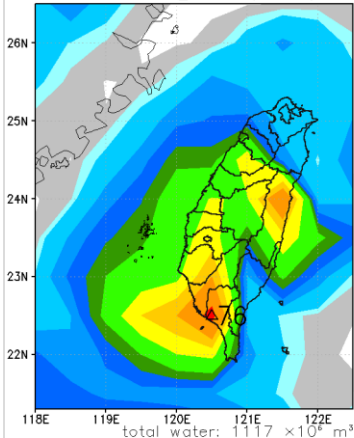
Taiwan QPF verification
-- A spring frontal rainfall case [2019/05/19 12Z; 12-24h forecast]
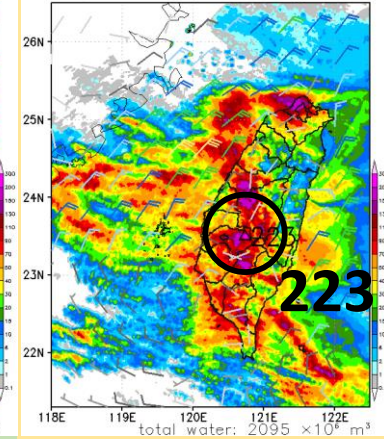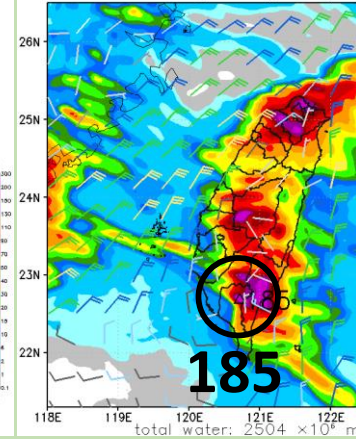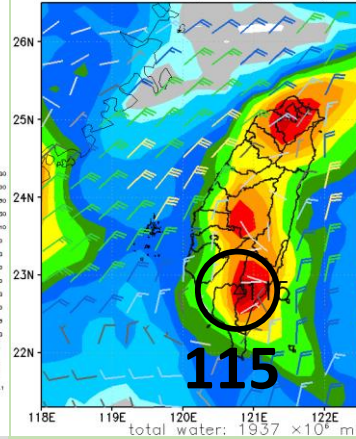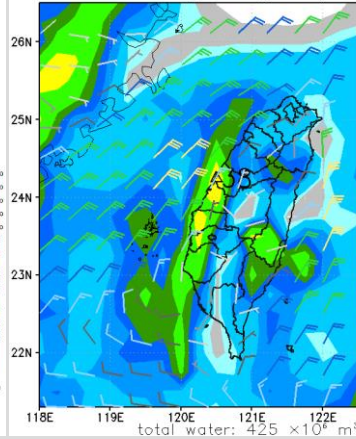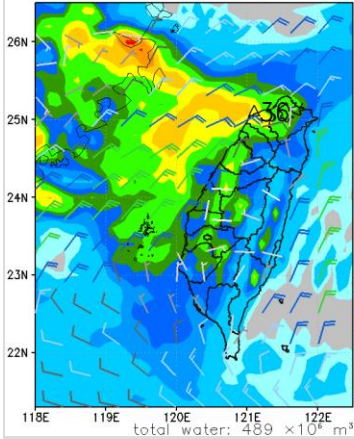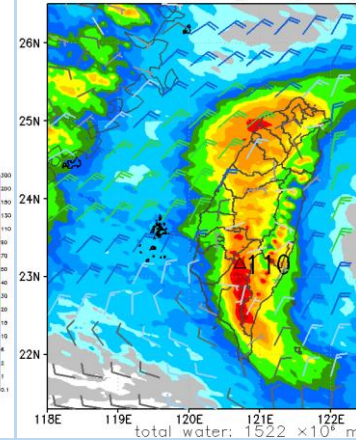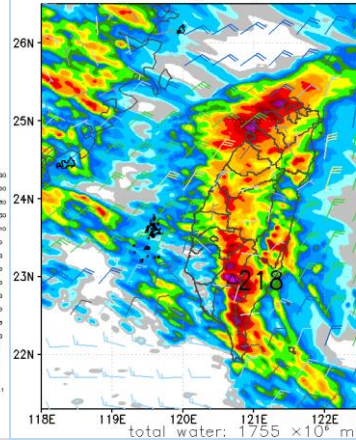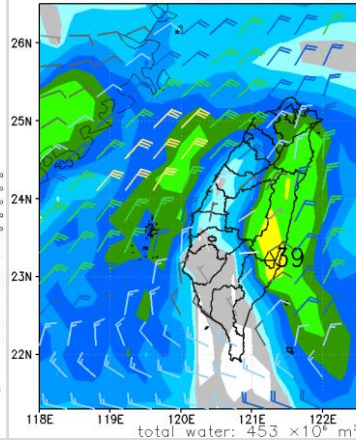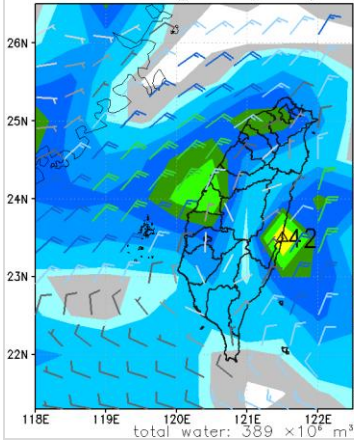
Taiwan rainfall verification – Winter period

12 – 24 h forecast
2019/12/31 12Z ~ 2019/02/19 00Z
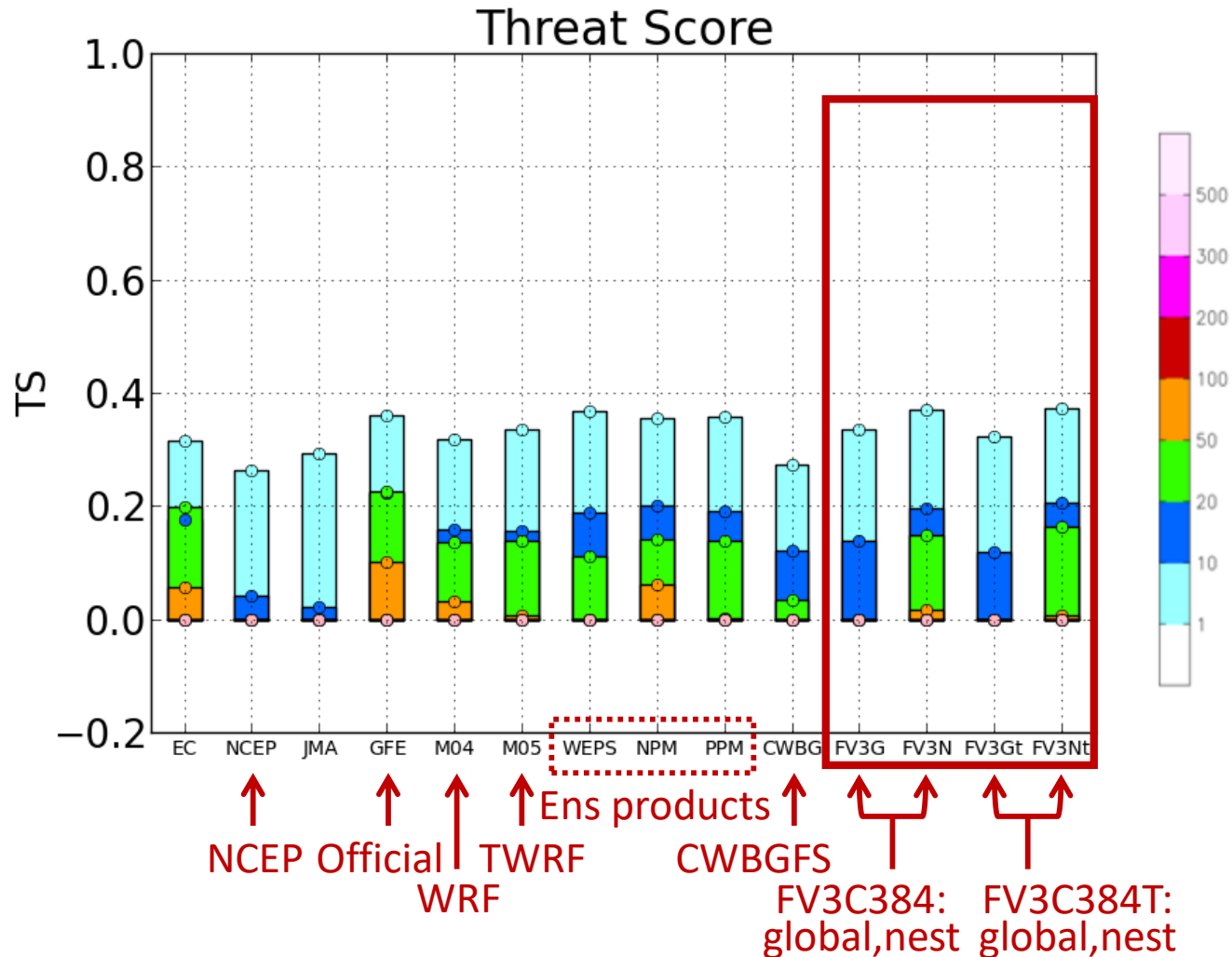
Taiwan rainfall verification – Winter period

0 – 72 h forecast
2019/12/31 12Z ~ 2019/02/19 00Z

Threat score (TS)

Bias score (BS)
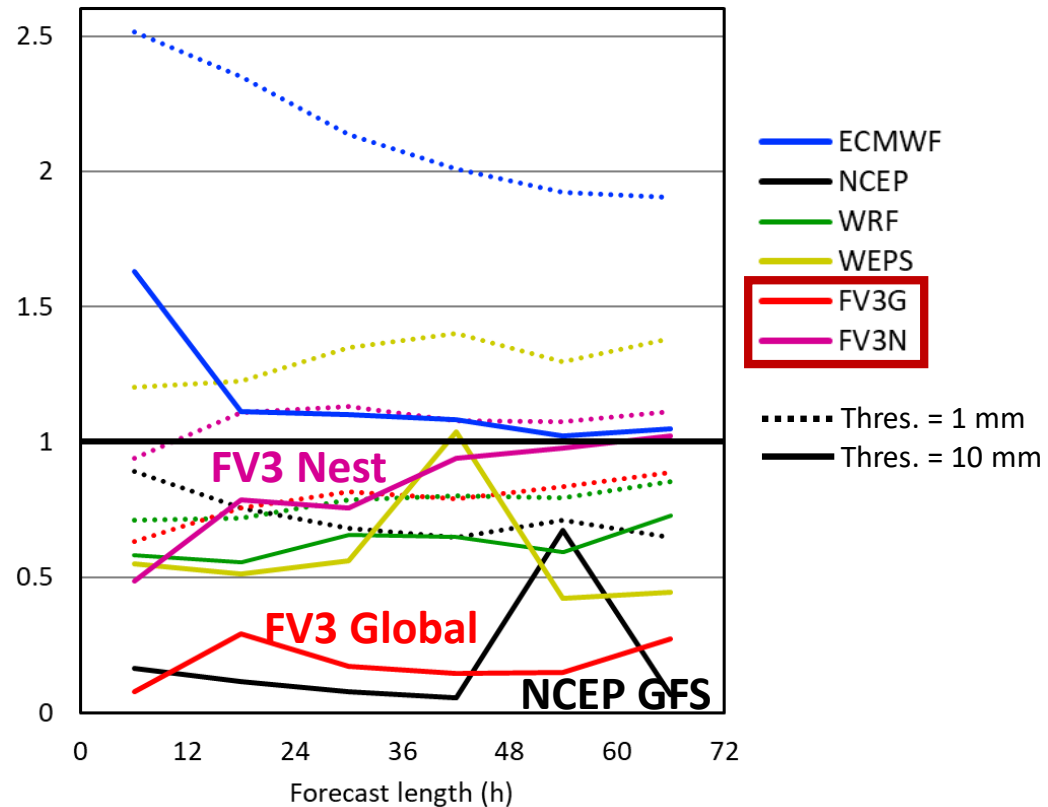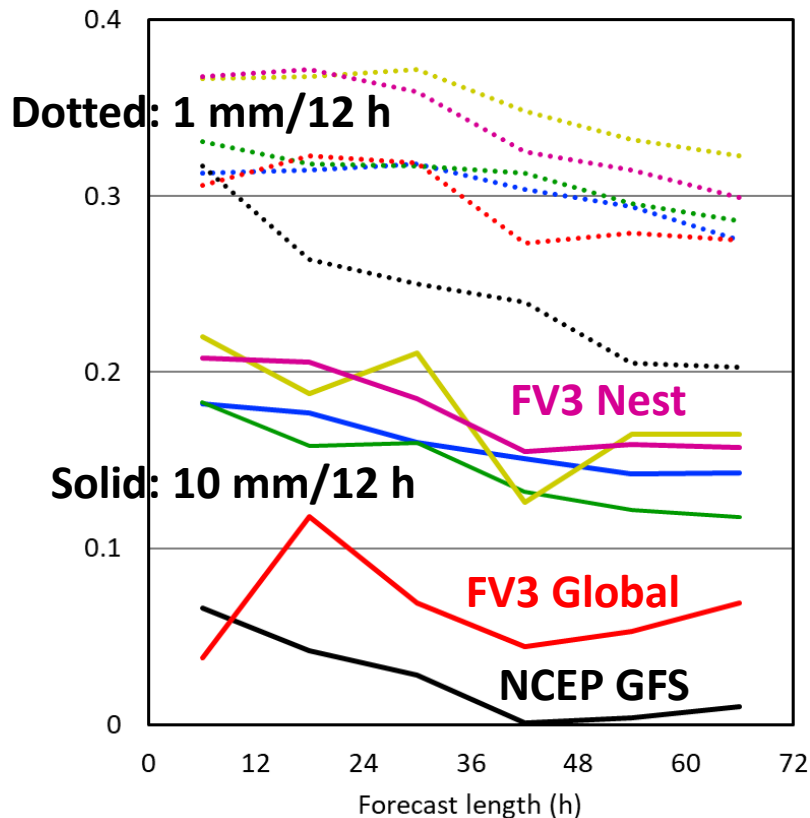
Taiwan rainfall verification – Summer period

12 – 24 h forecast
2018/08/01 00Z ~ 2018/09/30 12Z
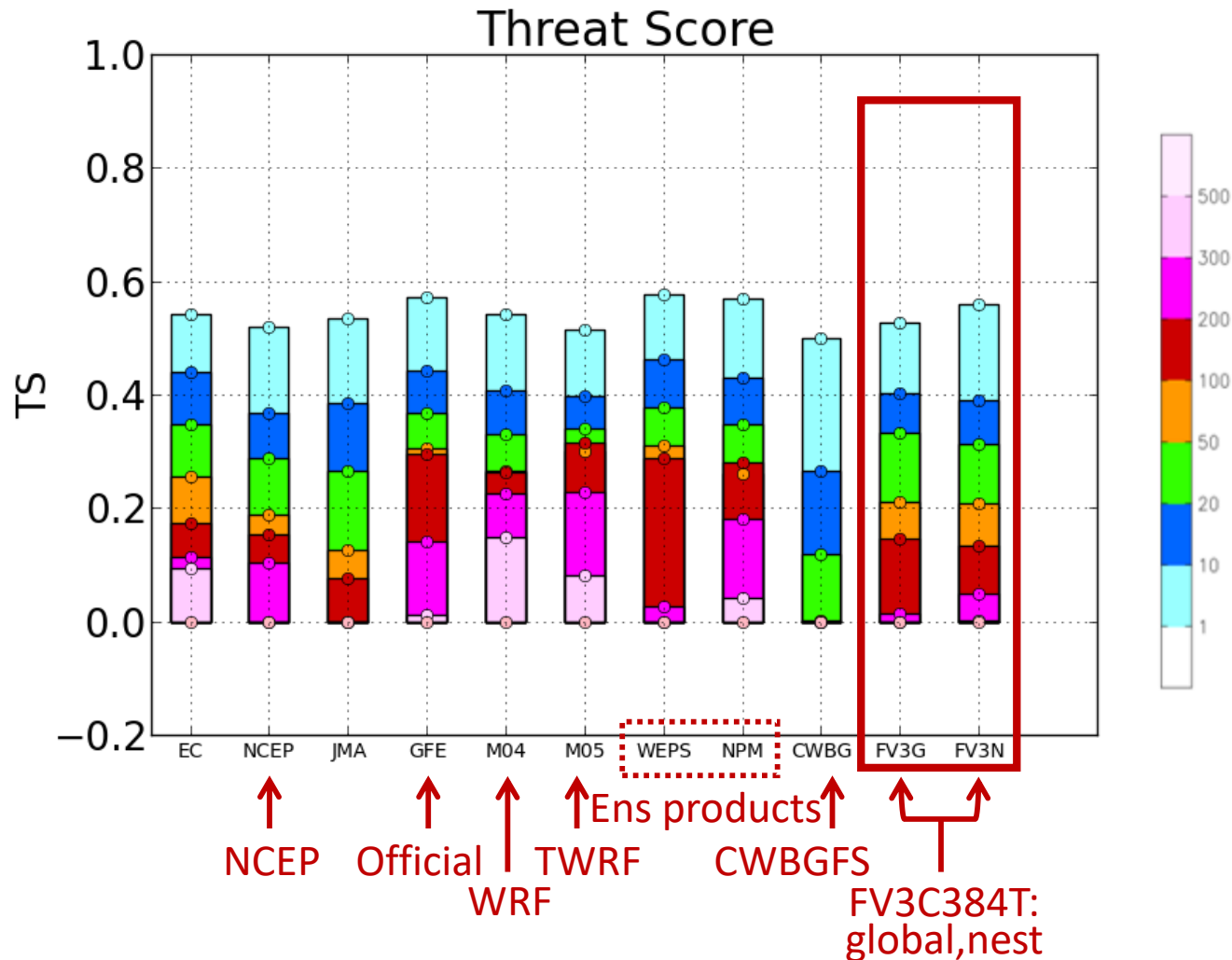
Taiwan rainfall verification – Summer period

0 – 72 h forecast
2018/08/01 00Z ~ 2018/09/30 12Z

Threat score (TS)

TS – 0-72 h precip fcst (12-h accu precip)

Solid: 10 mm/12 h

FV3 Global

FV3 Nest

NCEP GFS

Dashed: 100 mm/12 h

Forecast length (h)

Bias score (BS)

BS – 0-72 h precip fcst (12-h accu precip)

FV3 Global

FV3 Nest

NCEP GFS

Forecast length (h)

Legend:
- ECMWF
- NCEP
- WRF
- WEPS
- FV3G
- FV3N
- Thres. = 10 mm
- Thres. = 100 mm

FV3GFS post-processing workflow

Fix data

GFS_INPUT.tar
(gfs_data / sfc_data)
[6-tile NetCDF]

fv3gfs

Vertical interp/extrap   Not good

Horizontal interp

quilting
= .false.

– OR –

quilting
= .true.

Model history files
(model grid; pres-
sure/model level)
[6-tile NetCDF]

Model history files
(Gaussian lat-lon grid;
model level only)
[global NetCDF/Nemsio]

Model restart files
[6-tile NETCDF]

fregrid: **Horizontal interp**

UPP: **Vertical interp/extrap**

Model history files
(lat-lon grid)
[global NetCDF]

Model history files
(pressure level)
[Grib2]

Global bias and RMSE of temperature forecasts
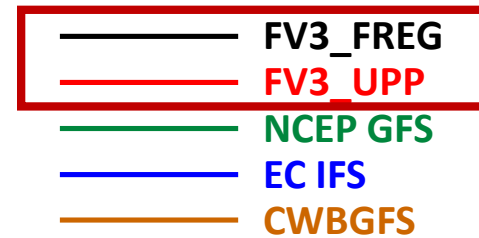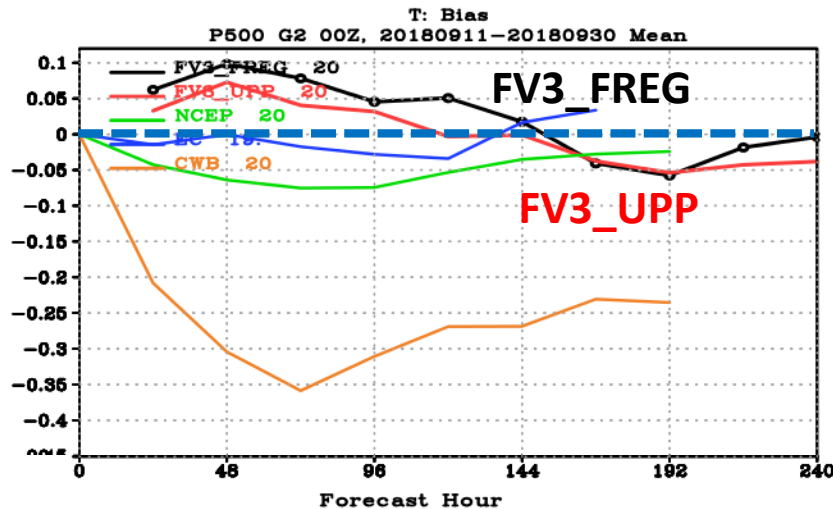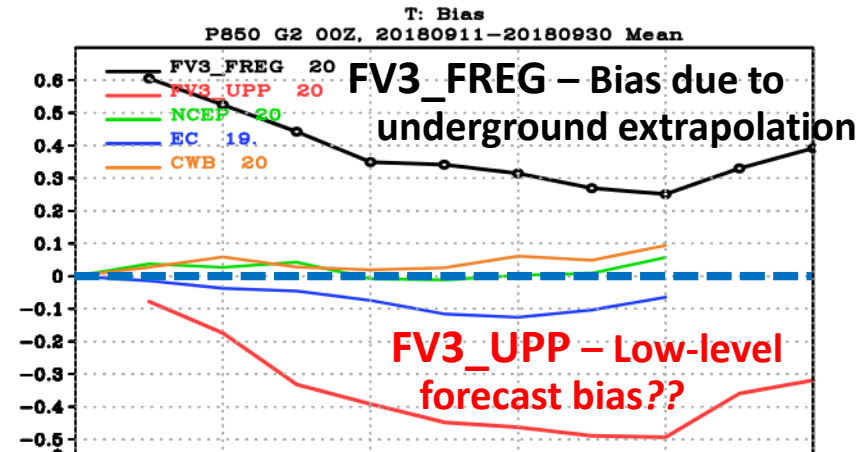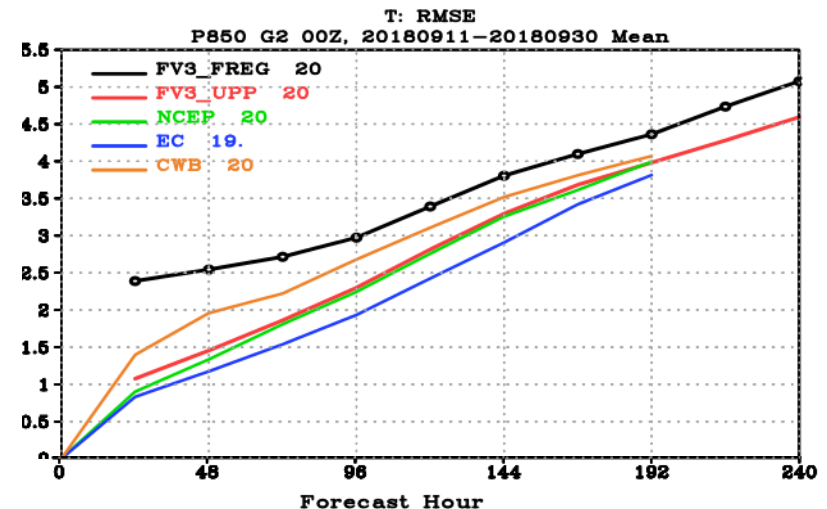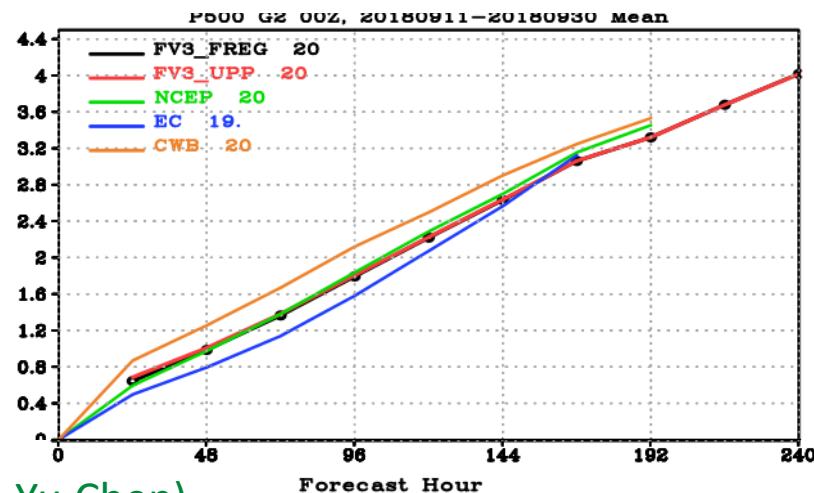
(Cheng-Yu Chen)

Comparison of two post-processing approaches

quilting (in model_configure)	.false.	.true.
Native-grid output	Yes	(Yes)
Globally merged Gaussian-grid (lat-lon) output	No	Yes
Pressure-level field output	Yes (poor underground extrapolation)	No
Multiple times in a single history file	Yes	No
Use different time intervals in different output files	Yes	No
FT = 0 output	No	Yes
Support nest domains	Yes	No??

Potential directions for global NWP at CWB

- The regional high-resolution NWP (WRF, TWRF) systems have played a very important role in CWB's routine weather forecast procedure.
    - In particular, the gridded forecast heavily relies on the high-resolution WRF forecasts.
- The global NWP work at CWB has struggled with the fact that *there are "better alternatives"… (e.g., NCEP, EC)*

To add value to the global NWP at CWB, we consider two potential directions:

- Provide useful initial/boundary conditions to the regional NWP systems:
    - Should focus on the analysis and forecast skill over the East Asia/ western North Pacific region (i.e., the regional NWP domains)
- Run and improve the online-nested tile in FV3GFS:
    - Has been setup, but has not been well tuned.
    - Separate DA for nested domains… *??* (probably not easy)
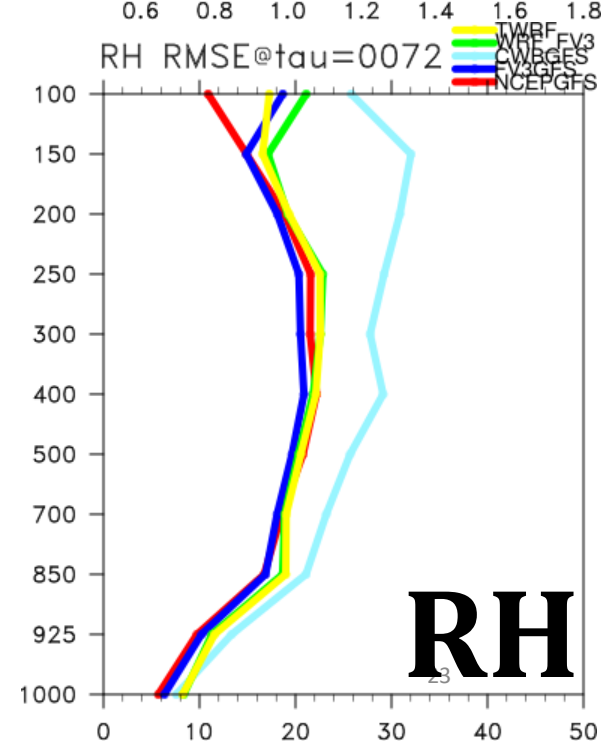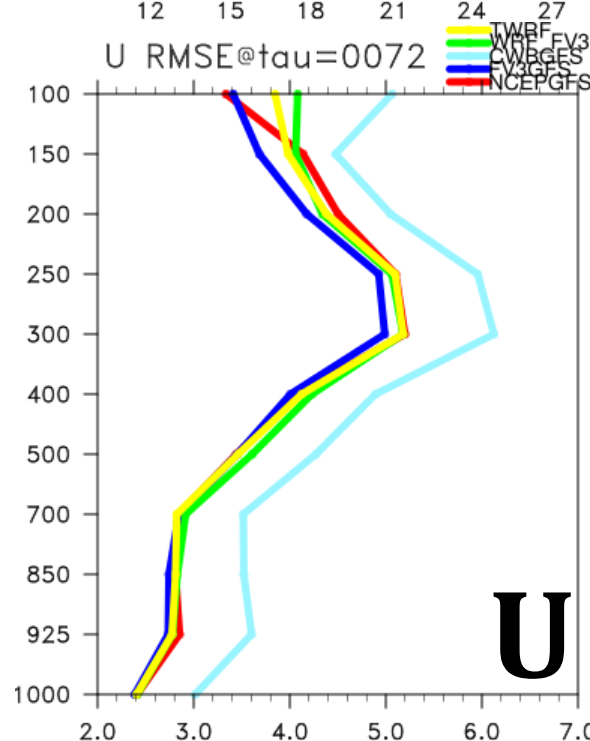
Verification over the CWB WRF domain

RMSE

72h forecast verified against NCEP GFS

— NCEP GFS
— NCEP FV3GFS (parallel run)
— CWBGFS

— TWRF driven by NCEP GFS
— WRF driven by NCEP FV3GFS

(Ling-Feng Hsiao)

H RMSE@tau=0072

T RMSE@tau=0072

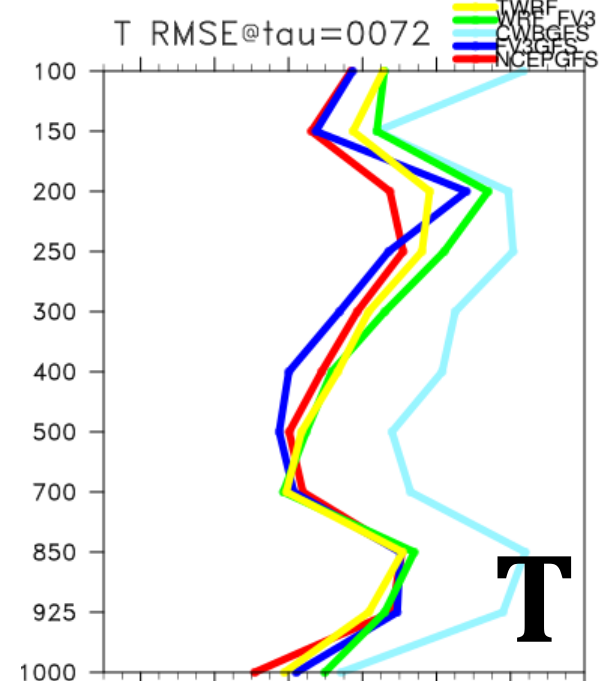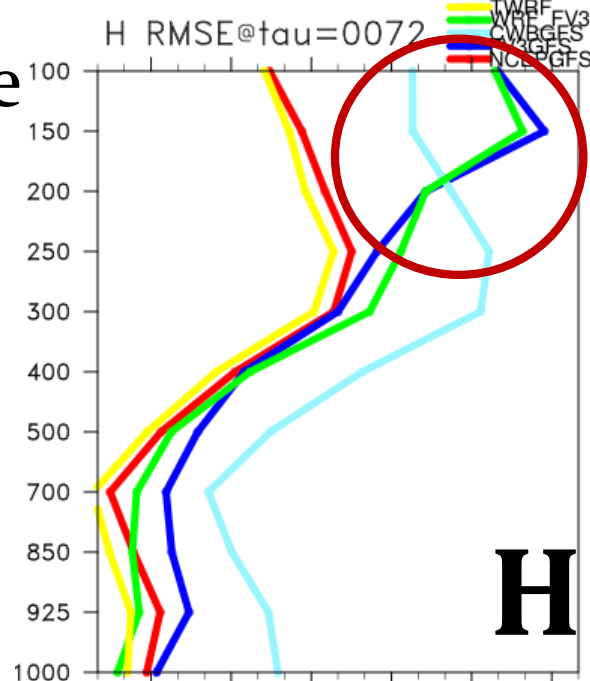U RMSE@tau=0072

RH RMSE@tau=0072

Verification over the CWB WRF domain

Bias

72h forecast verified against NCEP GFS

—— NCEP GFS

—— NCEP FV3GFS (parallel run)

—— CWBGFS

—— TWRF driven by NCEP GFS

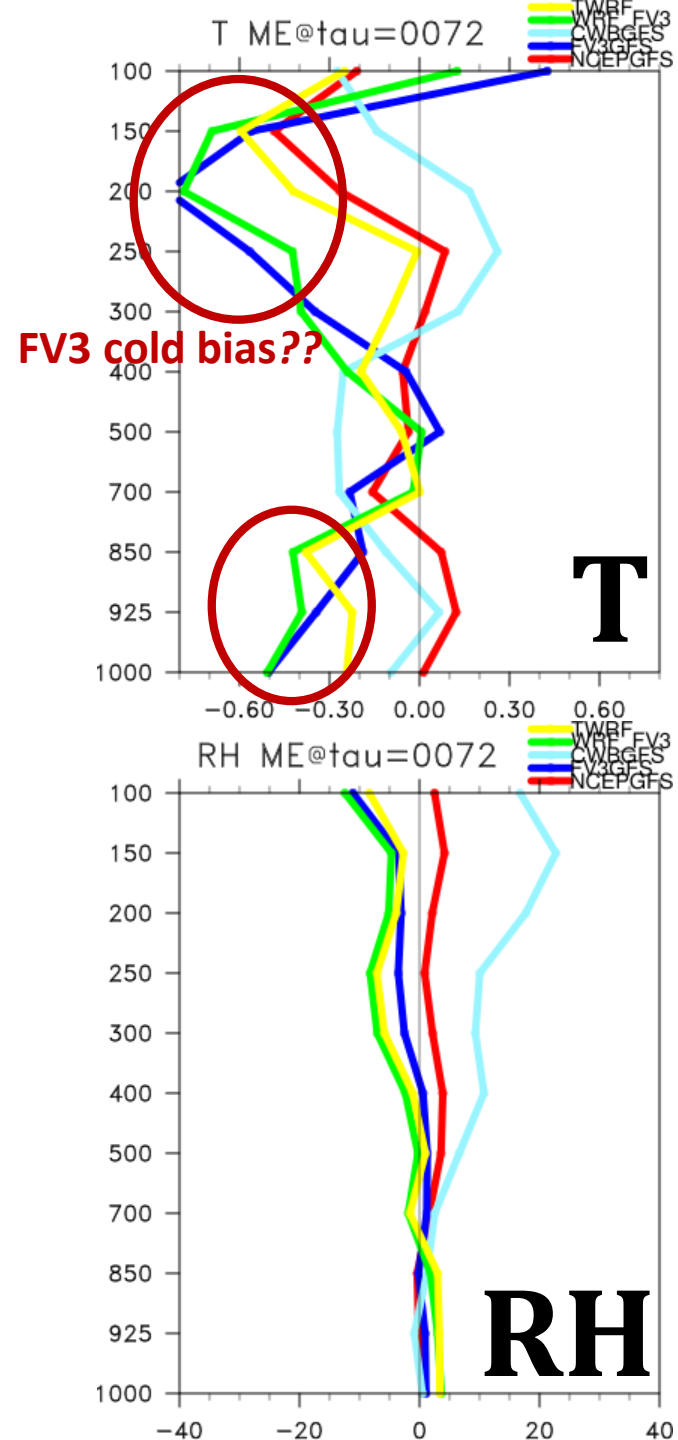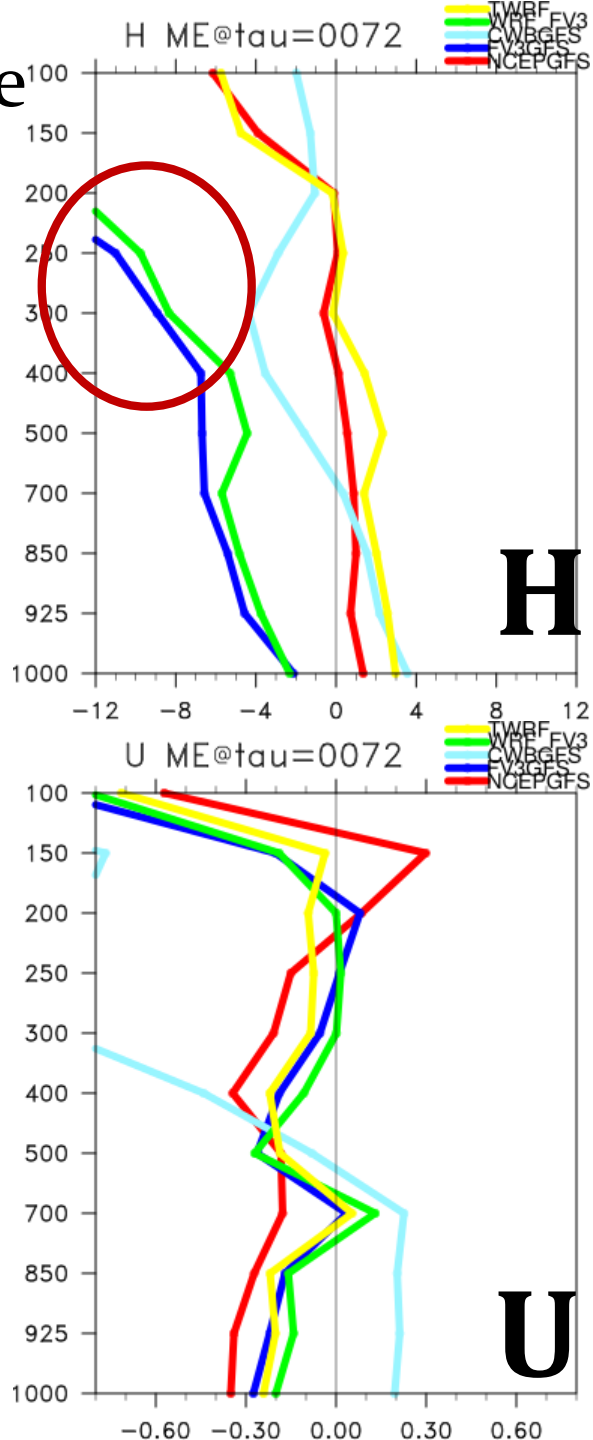—— WRF driven by NCEP FV3GFS

(Ling-Feng Hsiao)

H ME@tau=0072

T ME@tau=0072

FV3 cold bias??

U ME@tau=0072

RH ME@tau=0072

Differences in namelist settings between global and nested tiles

Section	Variable	Global tiles	Nest tiles
&fv_core_nml	n_sponge	15	8
	n_split	6	6
	k_split	1	5
	consv_te	1	0
	do_schmidt	True	---
	nestupdate	---	7
	full_zs_filter	---	True
&surf_map_nml	zero_ocean	---	False
	cd4	---	0.15
	cd2	---	-1
	n_del2_strong	---	0
	n_del2_weak	---	12
	n_del4	---	1
	max_slope	---	0.12
	peak_fac	---	1
&gfs_physics_nml	do_deep	True	False
	shal_cnv	True	True
	imfdeepcnv	2	-1
&gfdl_cloud_microphysics_nml	tau_l2v	225	45
	tau_v2l	150	45
	tau_g2v	900	180
	tau_i2s	1000	180
	mp_time	150	45

NCEP's experience in FV3-SAR should greatly help our nested-tile settings!
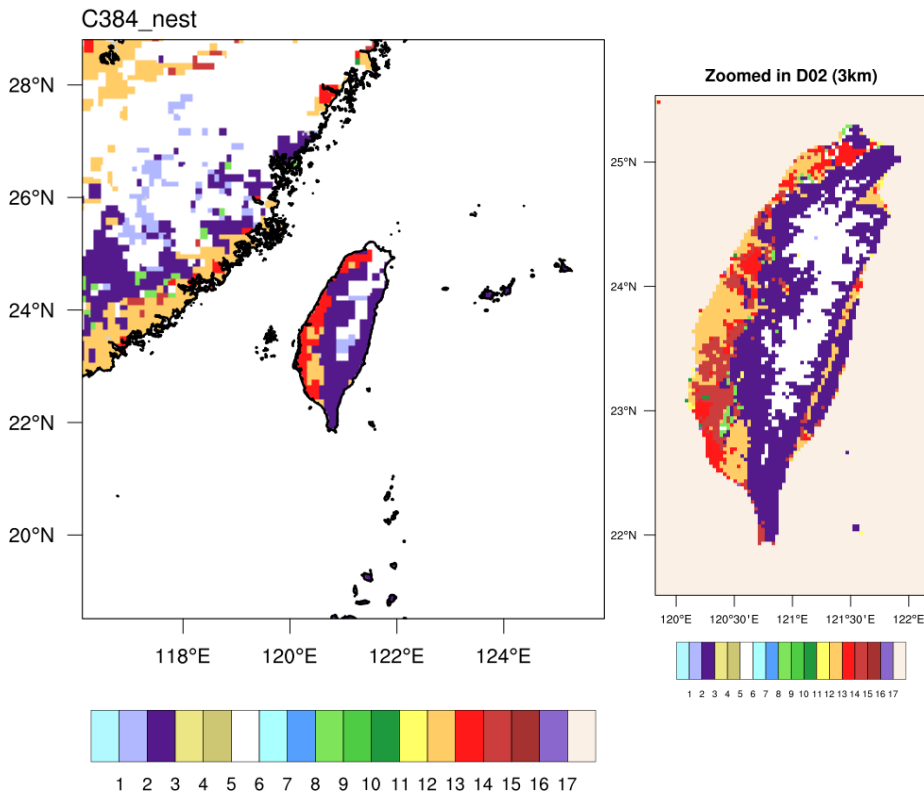
Landuse and soil type data for the nested tile

Landuse

FV3GFS Taiwan nest (~4.8 km)
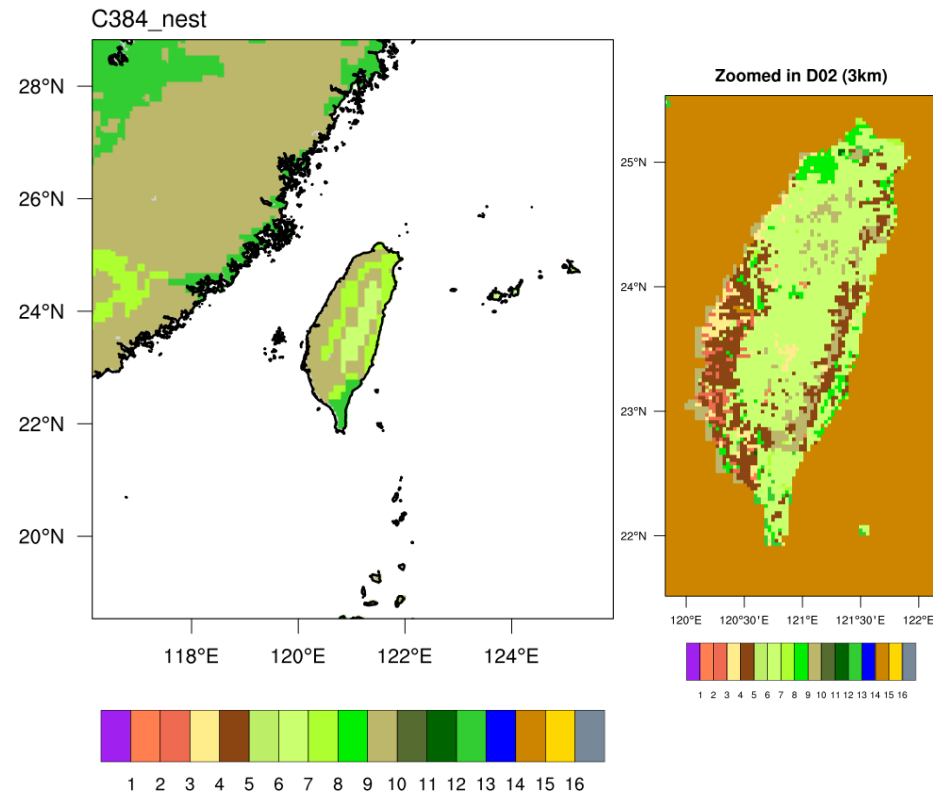
CWB WRF D2 (3 km)

Soil type

### FV3GFS Taiwan nest (~4.8 km)

CWB WRF D2 (3 km)

(Ling-Feng Hsiao)

DA development with CWBGFS & Other things

- Improve observation usage in CWBGFS (Chung-Han Lin)

- Explore new observations:
    - COSMIC-2 and other GNSS-RO data
      (Zih-Mao Huang, Chung-Han Lin)
    - Himawari-8 AHI radiance (Jian-ben Jou, Chung-Han Lin)

- EFSOI in CWBGFS (Wen-Hsin Teng)

- Migrate to using Git version control system

GNSS-RO observation errors diagnosed by Desroziers' method

GPSRO BND Observation Error

sat: ALL   count: 105637
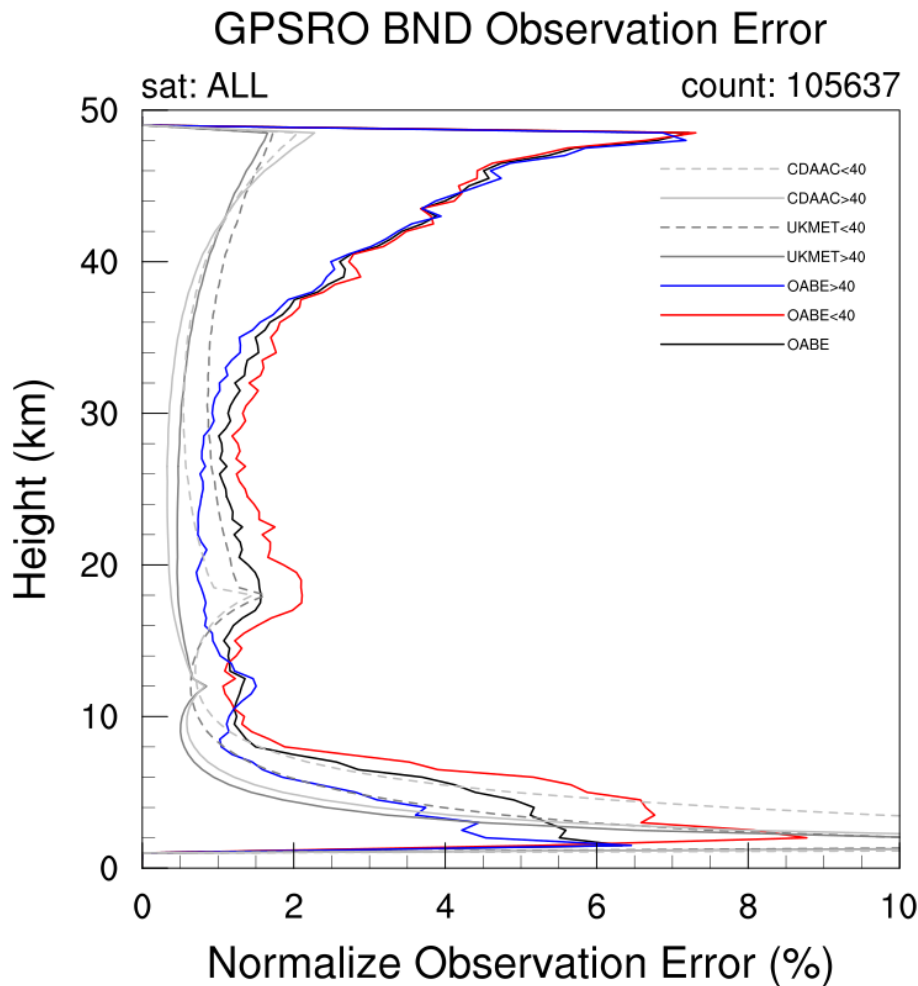
Gray lines (4 lines):
GSI hardcoded observation errors for GNSS RO data
2 latitudinal bands (40S-40N, 40-90S/N) X
2 observation classifications (CDAAC, UKMET)

Colored lines:
Diagnosed by Desroziers' method in CWBGFS
40S-40N
40-90S/N
ALL

$$E\left[[y^o - H(x^a)][y^o - H(x^b)]^T \right] = R$$

(Zih-Mao Huang)
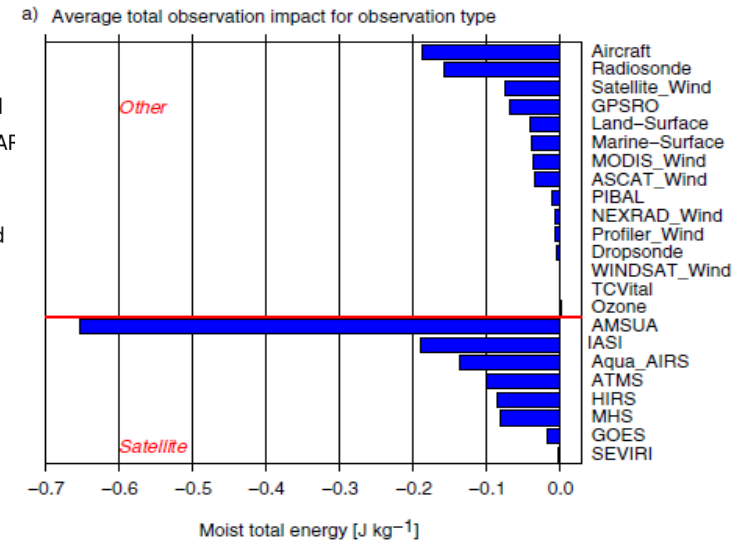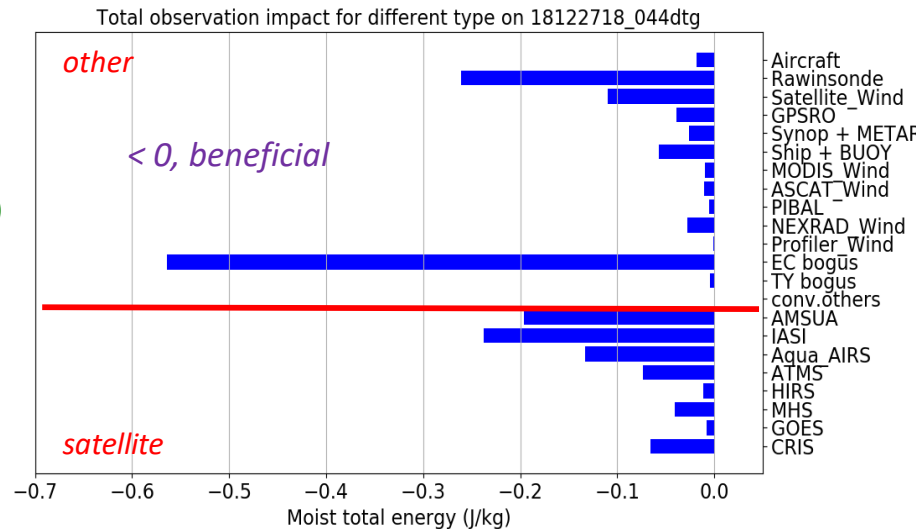
EFSOI in CWBGFS

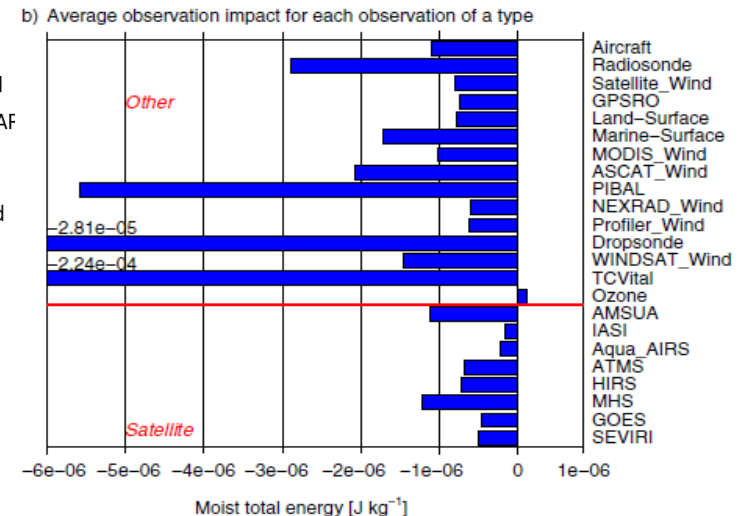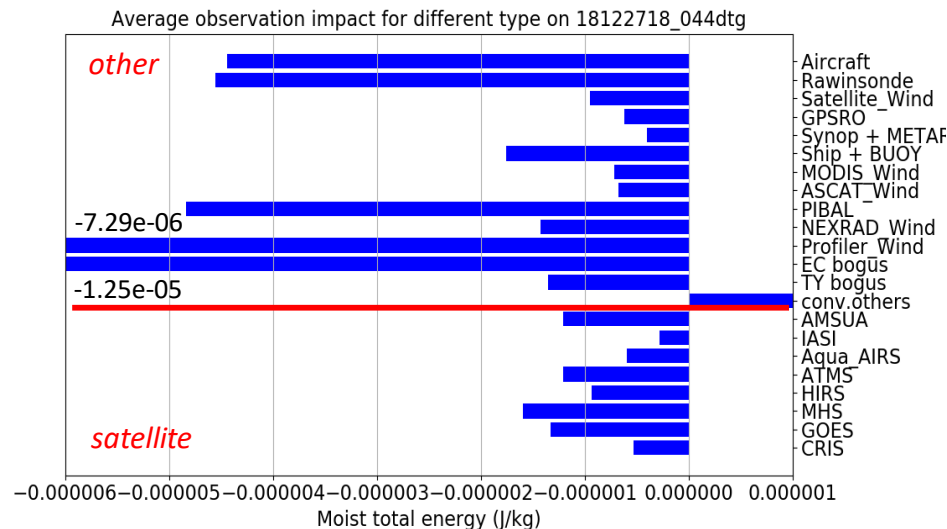**Moist total energy norm**

(Wen-Hsin Teng)

CWBGFS

NCEP system by Ota et al. (2013)

Total EFSO (per cycle)

Per-obs EFSO

Summary

- CWB has started researching on FV3GFS:
  - Retrospective cases and near-real-time run (mainly using NCEP IC) have been conducted.
  - Sensitivity to tile settings has been studied.
  - Verification workflow at CWB has been set up.
- Potential directions to add value to the global NWP at CWB:
  - Provide useful initial/boundary conditions to the regional NWP systems.
  - Run and improve the online-nested tile in FV3GFS.

Ongoing/Future work

- Model:
  - Physical parameterization tuning for the nested tile.
  - Refine the landuse, soil type, and topography data for the nested tile.
  - More evaluation focusing on the East Asia area.
  - Case studies.
  - Implement/test new physics parameterization schemes*??*

- Data assimilation:
  - Port the GSI for FV3GFS and set up the cycling DA workflow on CWB HPC (with the CWB observation data stream)
  - Tuning the DA system
  - Implement/test a LETKF component in the hybrid DA system.

- Hope to start experimental parallel operation as soon as possible.