APCS 2015
2-4 November, Manila, Philippines

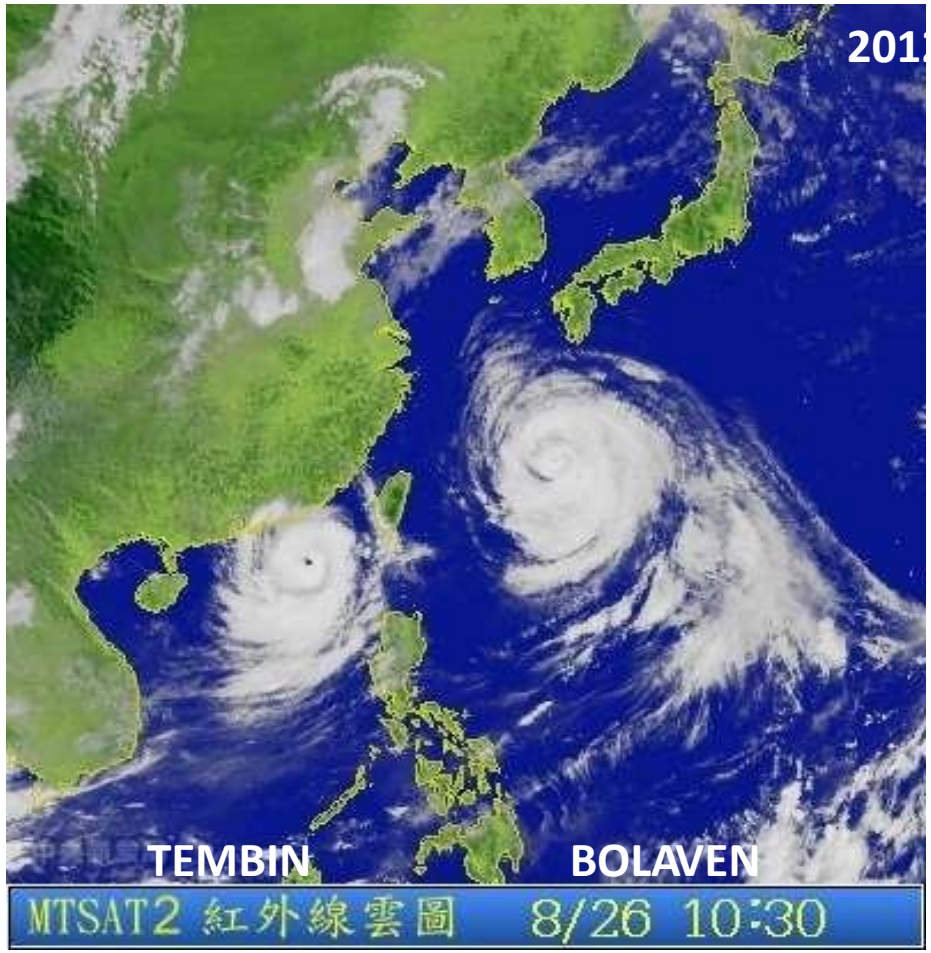
Recent Progresses of the Operational Prediction on Typhoon and Heavy Rainfall in Chinese Taipei

T.-C. Yeh, D.-S. Chen, J.-S. Hong, T.-S. Huang, W.-P. Huang, and colleaques

Central Weather Bureau, Chinese Taipei

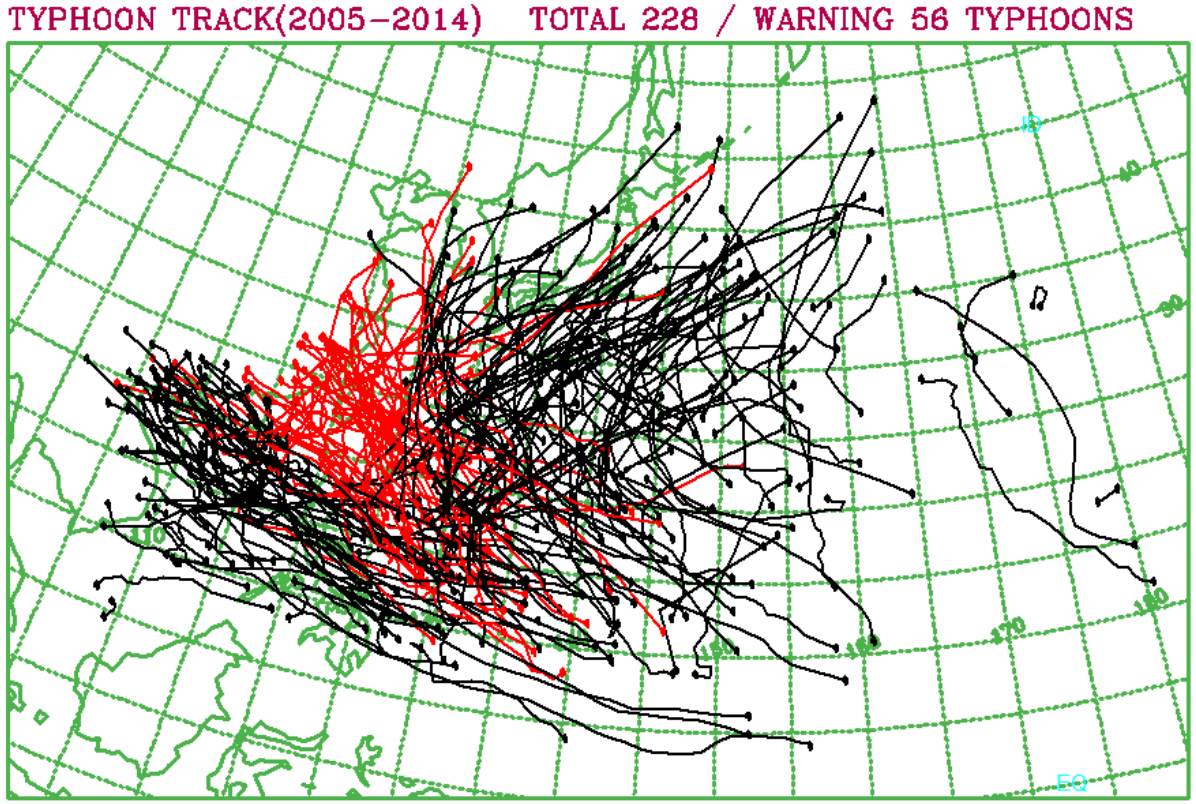
Background

Background



- **Size**
  - ~350km x 15 km 36,000km^2
- **Topography**
  - 32% mountain area > 1000m
  - over 200 peaks > 3000m
  - strong orographic forcing
- **Sever weather phenomena**
  - spring : MeiYu
  - summer : Typhoon, sounder storm
  - winter : cold surge
- **Forecast Challenges**
  - Typhoon
  - Heavy rainfall
  - Drought

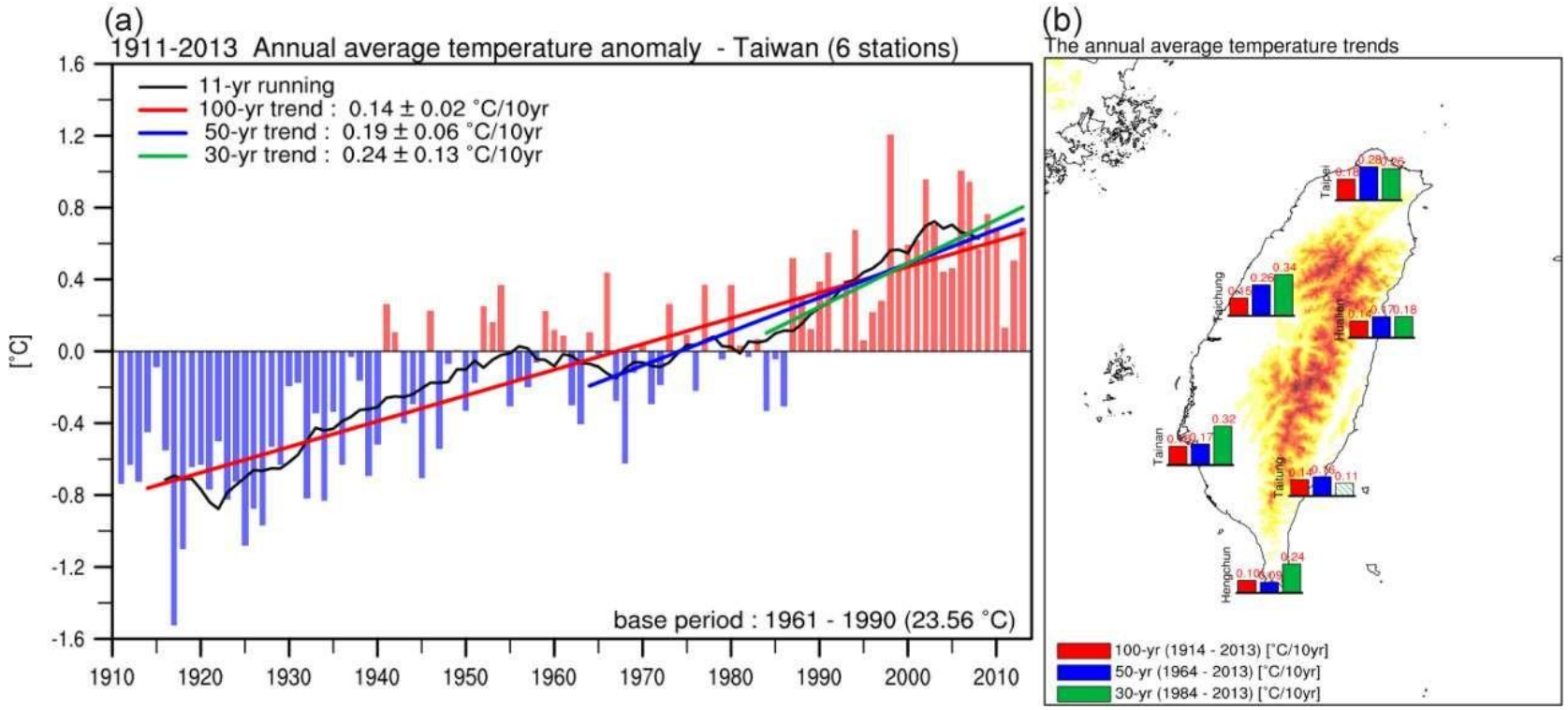
Background



56 of the 228 Tropical Cyclones in WNP, the CWB issued warnings in 2005-2014
21 of the TCs the center made landfall

From K.-L. Huang

Background

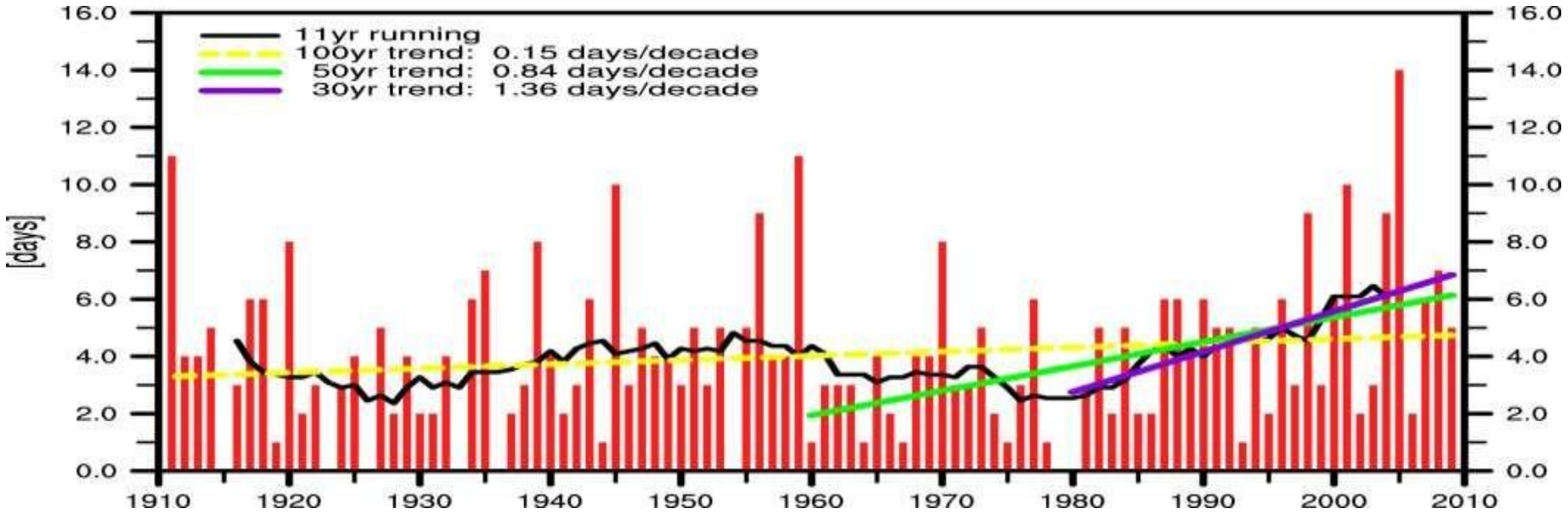


100-year surface temperature trend from 6 climate stations

from M.-M. Lu, M.-S. Chen, et al.

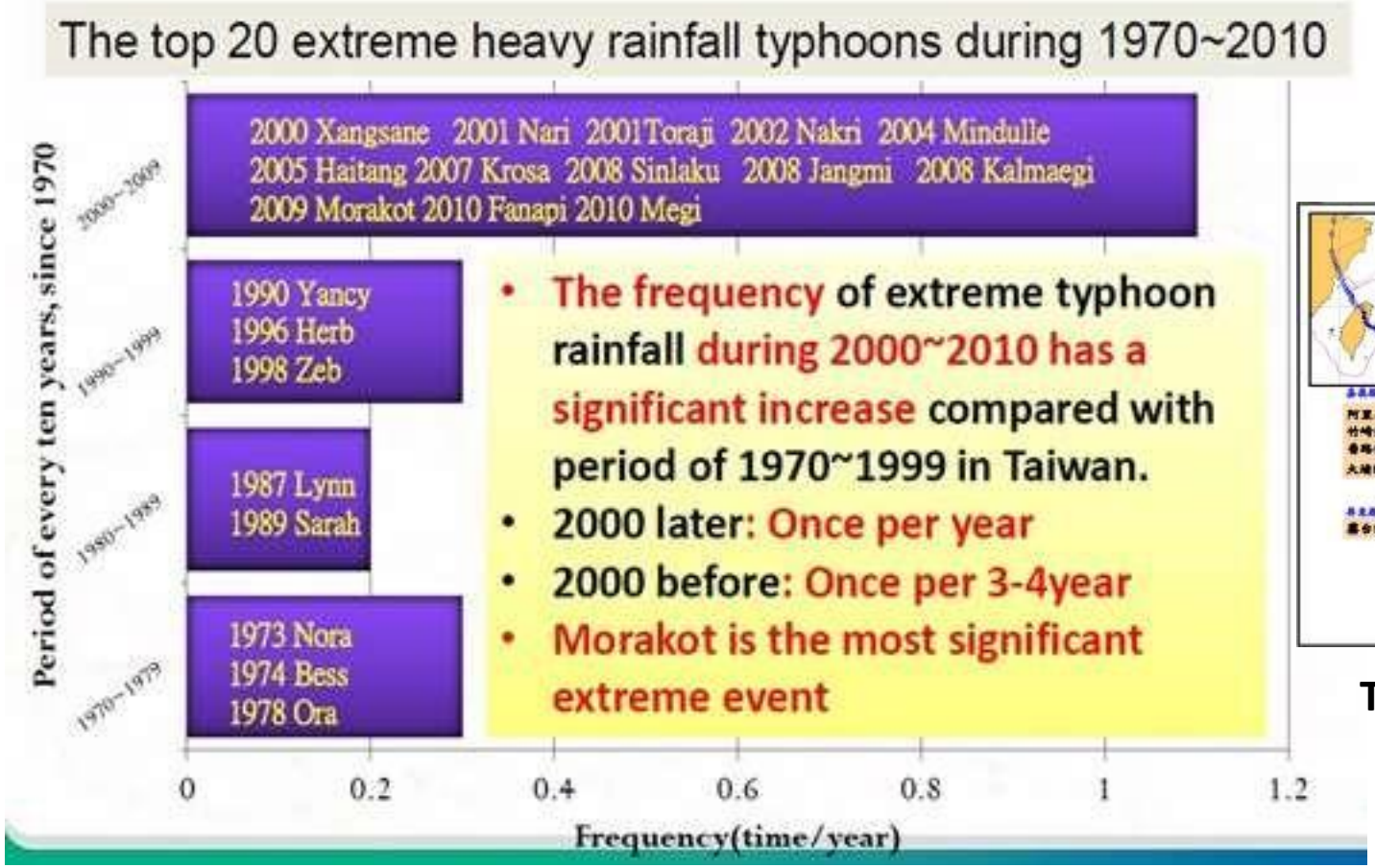
Background

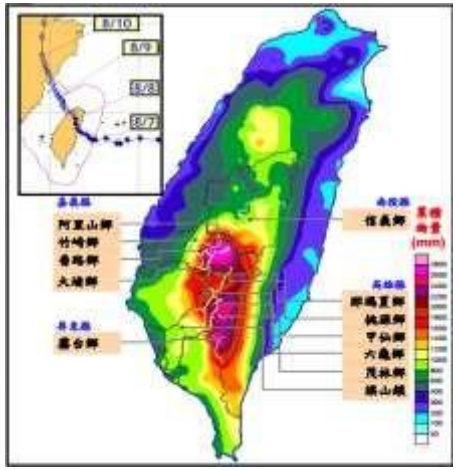
Torrential Rain Days anomaly
(Precip. > 200 mm/day)



M.-M. Lu, M.-S. Chen, et al.

Background

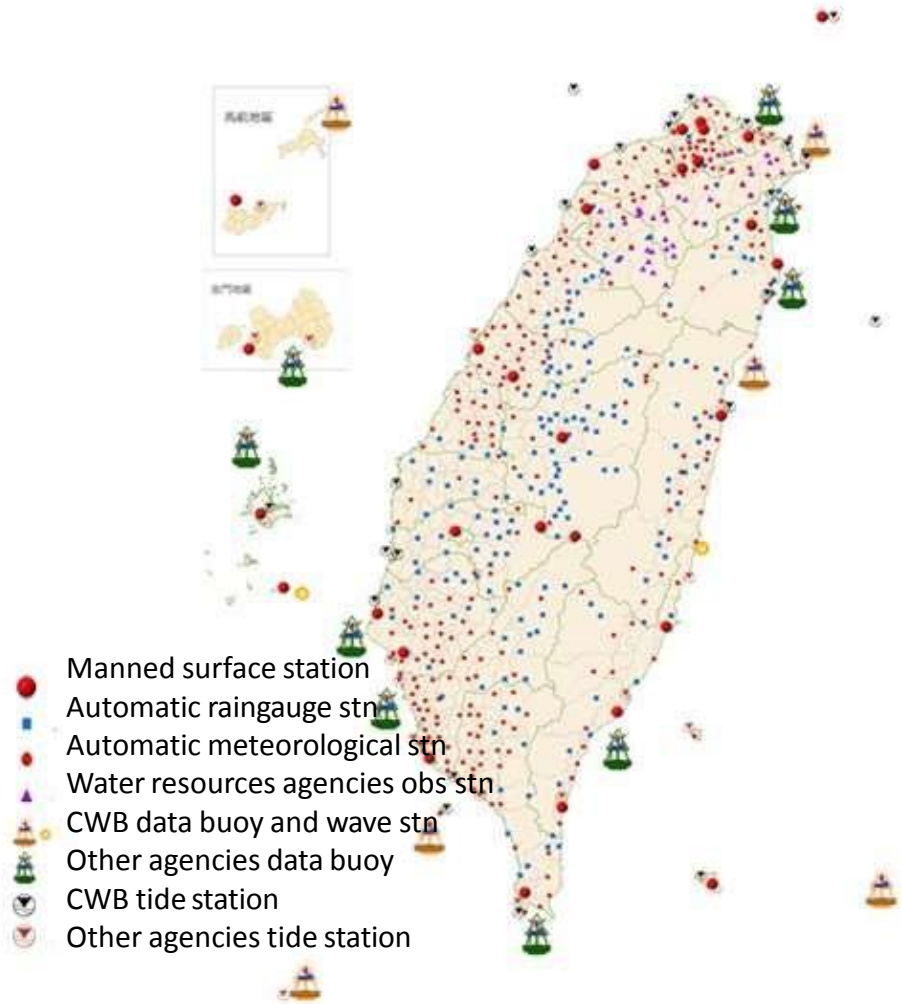




TY Morakot (2009)

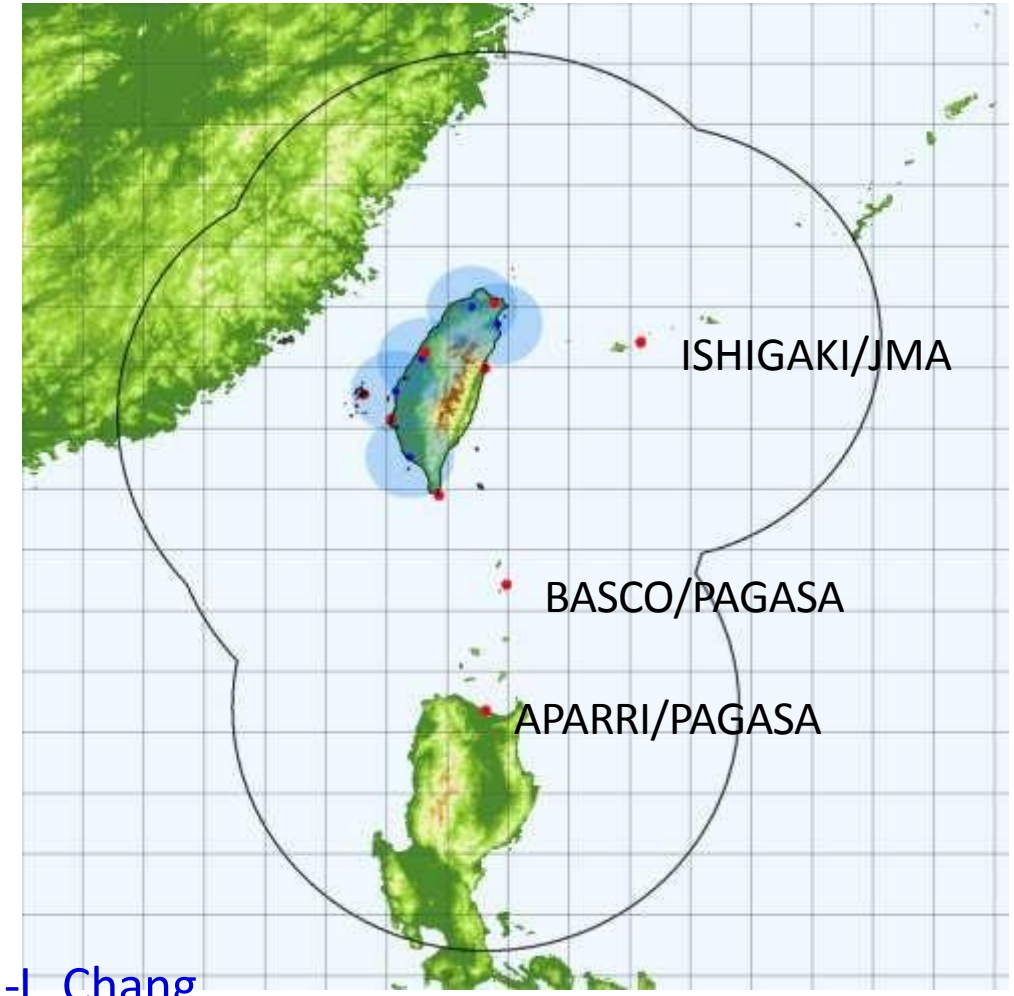
Observation

- surface observation facilities
  - synoptic stations:42
  - upper-air: 3
  - AWS: 469
  - tide stations: 23
  - wave stations & buoys: 9



Observation

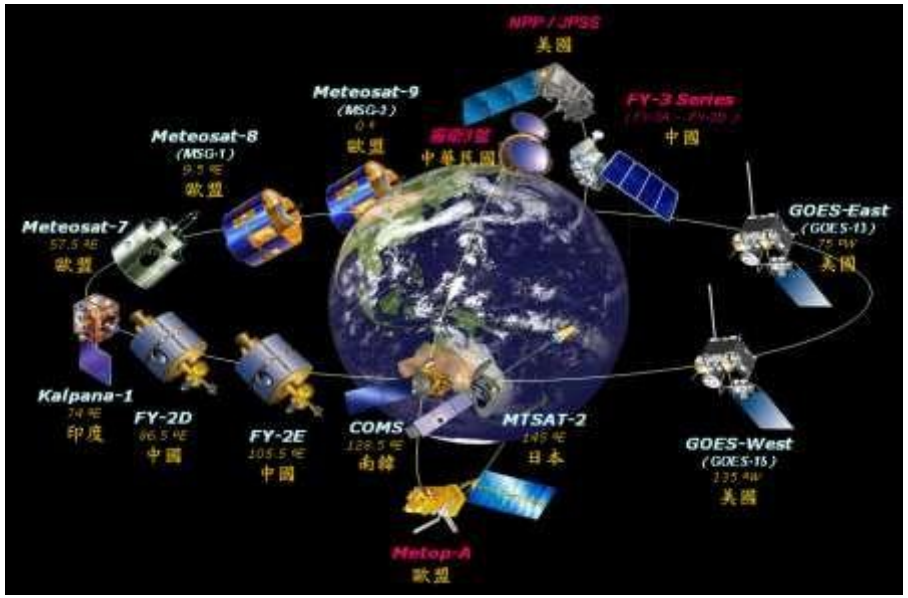
- Radar network
  - weather radar:6 +3
  - rain radar: 5 (in progress)



From P.-L. Chang

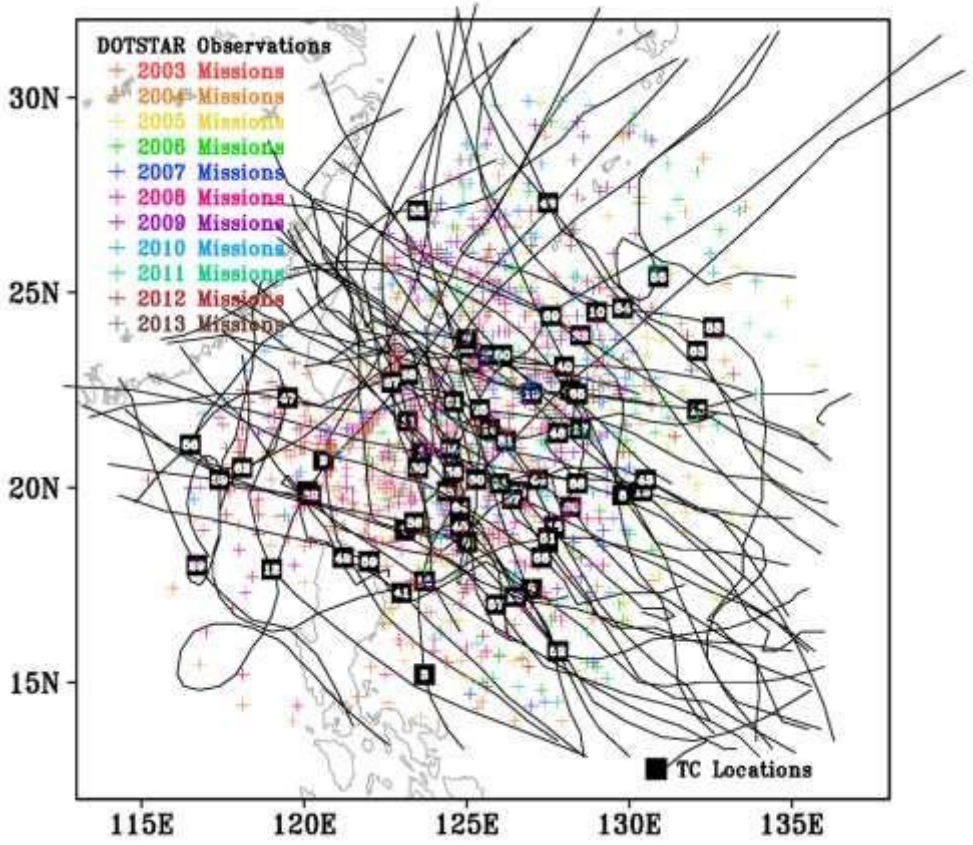
Observation

- Satellite data receiving and processing
  - geostationary:
    - HIMAWARI 8 (Japan)
    - COMS (Korea)
    - FY-2D,FY-2E,FY-2F (Mainland China)
  - polar orbiting:
    - NOAA-15,16,18,19 EOS-Terra, Aqua Suomi NPP (US)
    - Metop-A, B (EU)
  - others:
    - FORMOSA/COSMIC (Chinses Taipei)

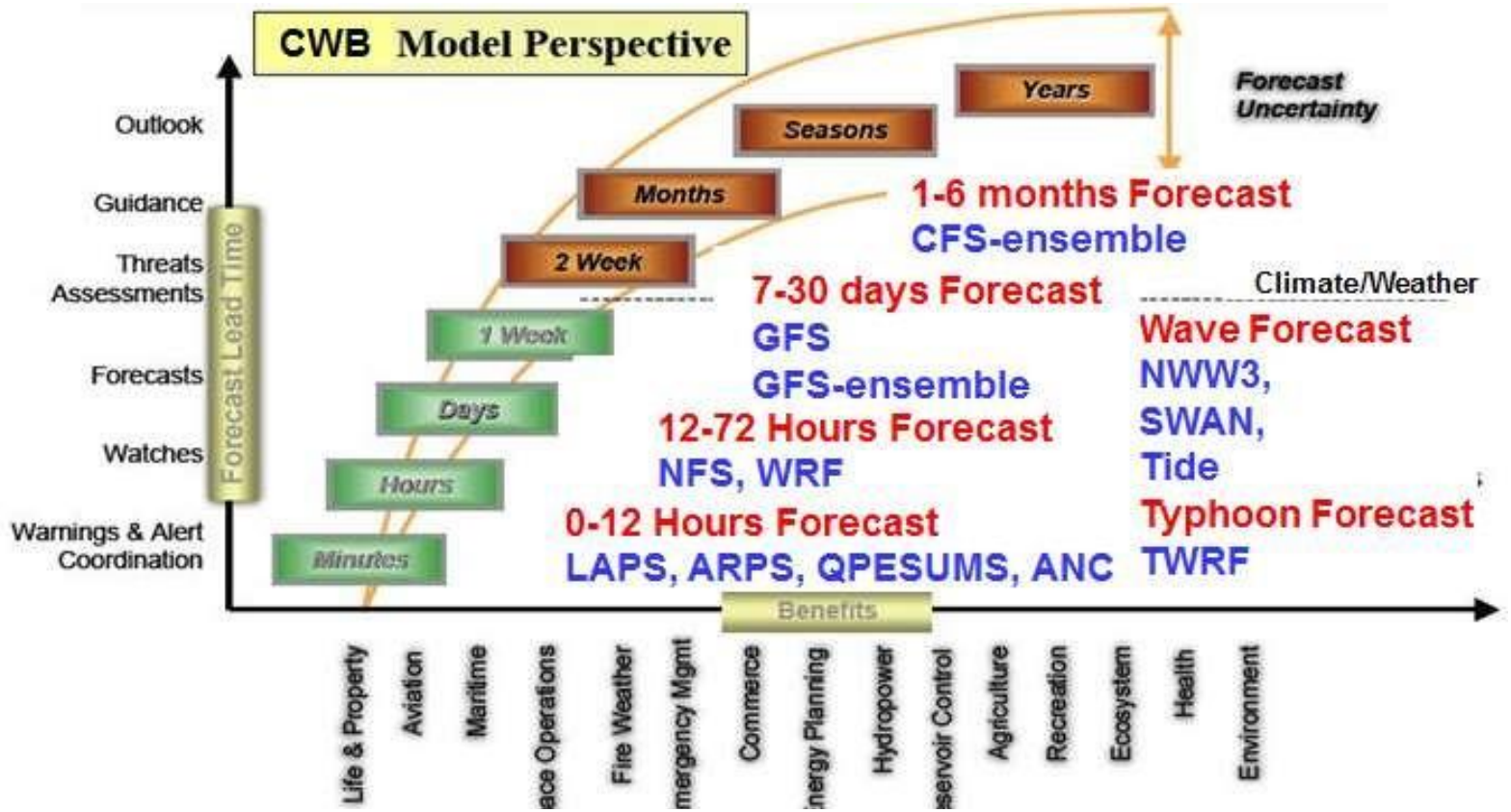


Observation

- Typhoon surveillance dropsonde



Numerical Forecast Models

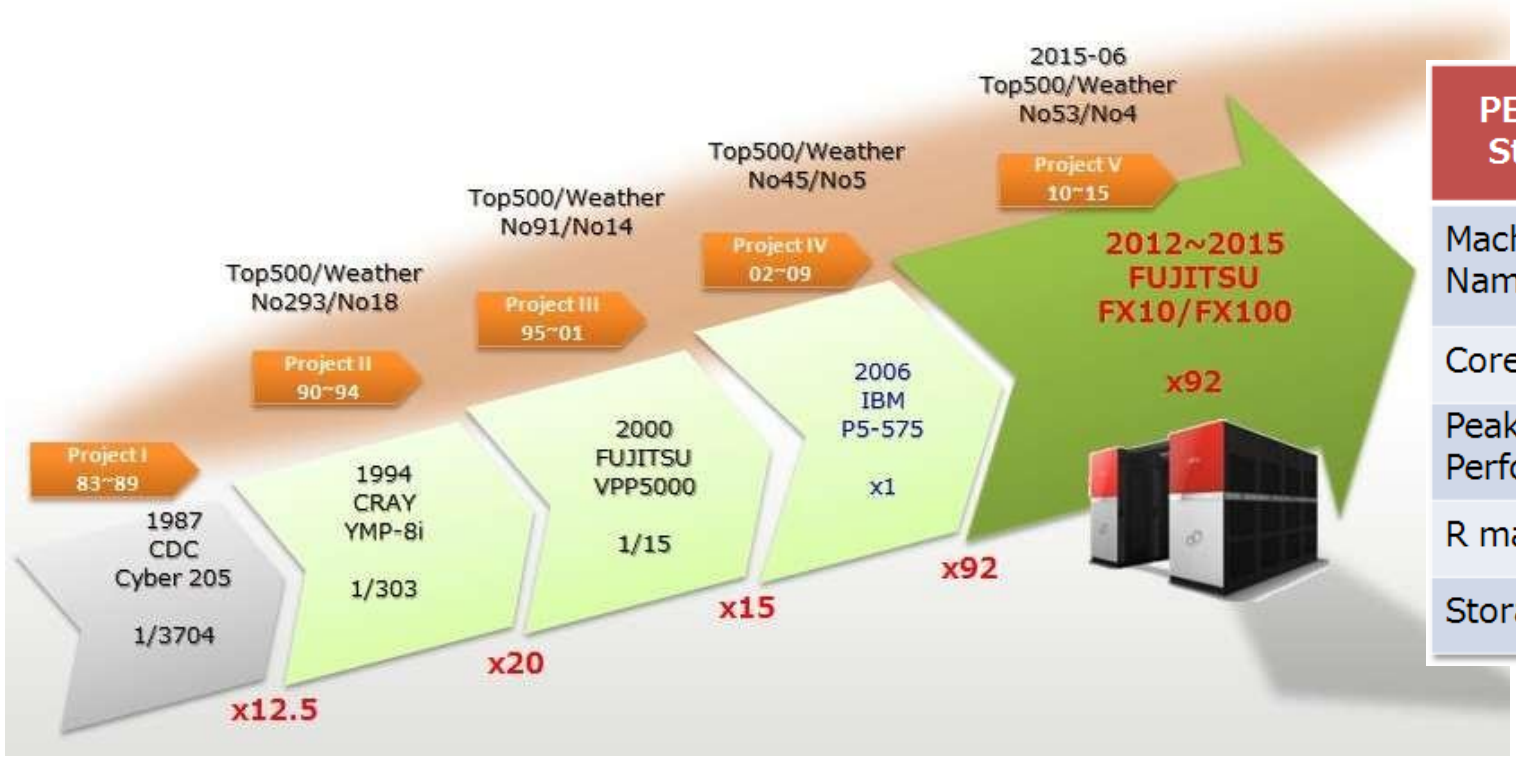


Based on the slide from

Dr. Louis W. Uccellini NWS/USA Mar. 24,2008 NCEP's Climate Forecast System as a national model

Computing Facilities

Upgrade High Performance Computer



PEAK: >1.3 P Flops Storage: 1.2 P Byte	
Machine Name	PRIMEHPC FX10 / FX100
Cores	46,848
Peak Performance	>1.3 PF
R max	1.2 PF
Storage size	1.221 PB

Large Scale Forecast

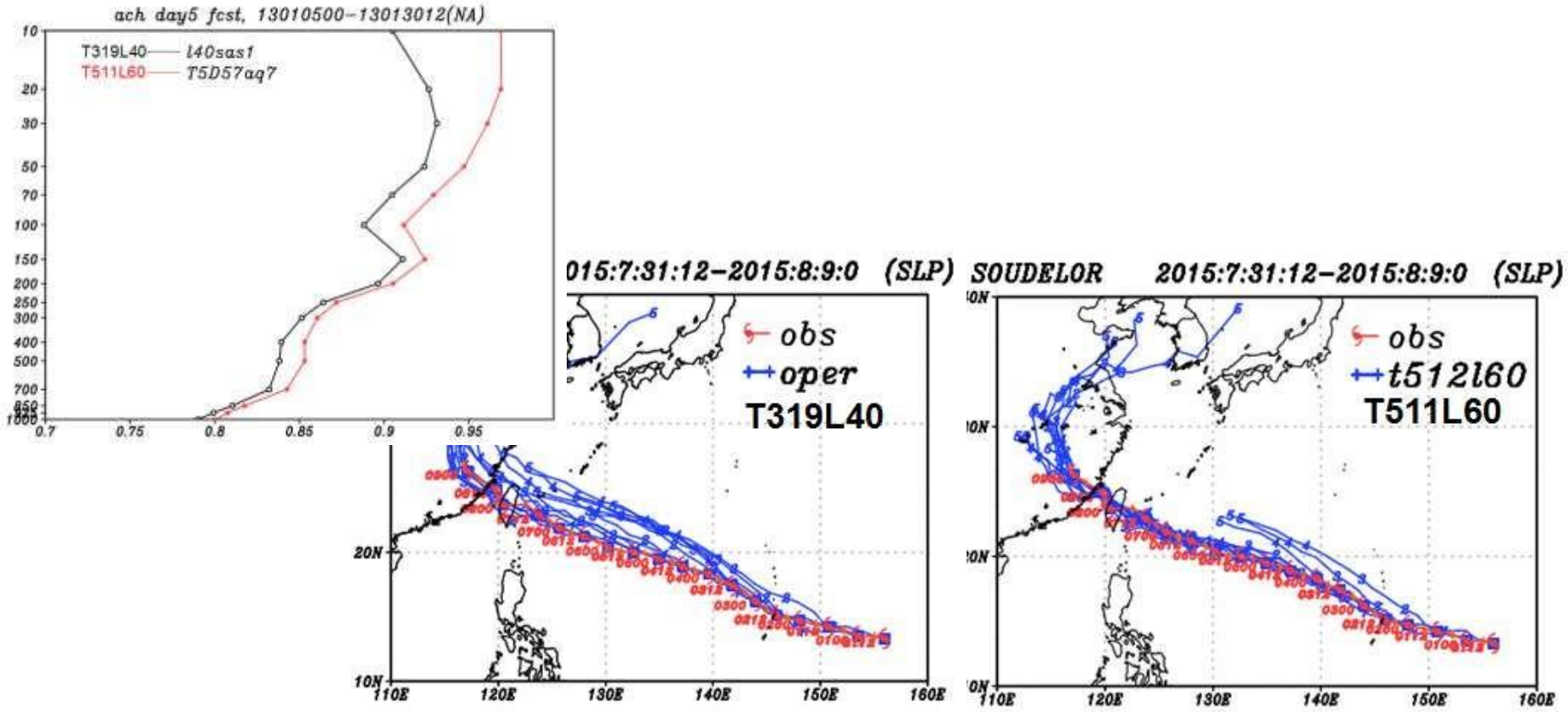
Improvement of Global Forecast Model

	T511L60 (2016 operational)	T319L40 (operational)
DA	Hybrid GSI	Hybrid GSI
Model dynamic (Eulerian spectrum)	model top:0.1MB Vertical Coord. : S-P hybrid 60 layers Horizontal Coord. : reduced gaussian grid (~25KM)	model top:1MB Vertical Coord. : Sigma 40 layers Horizontal Coord. : regular gaussian grid (~40KM)
Model physics	**Soil model** : Noah Land Surface model **Vertical turbulence** : Hong and Pan (2011) **Cumulus convection** : **NSAS** Han and Pan(2011) **Grid scale precipitation:** Zhao and Carr (1997) **Shallow convection:** Han and Pan(2011) **Topographic gravity wave drag:** palmer (1986) **Radiation** : Fu et.al. (1997) 、Fu an Liou（1992；1993） **nonorographic gravity wave drag:** Scinocca (2003)	**Soil model** : Noah Land Surface model **Vertical turbulence:** Mahrt and Pan (1984) **Cumulus convection** : **NSAS** Han and Pan (2011) **Grid scale precipitation:** Zhao and Carr (1997) **Shallow convection:** Li and Wang (2000) **Topographic gravity wave drag:** palmer (1986) **Radiation** : Fu et.al. (1997) 、Fu an Liou（1992；1993）

From J.-H. Chen

Large Scale Forecast

Improvement of Global Forecast Model



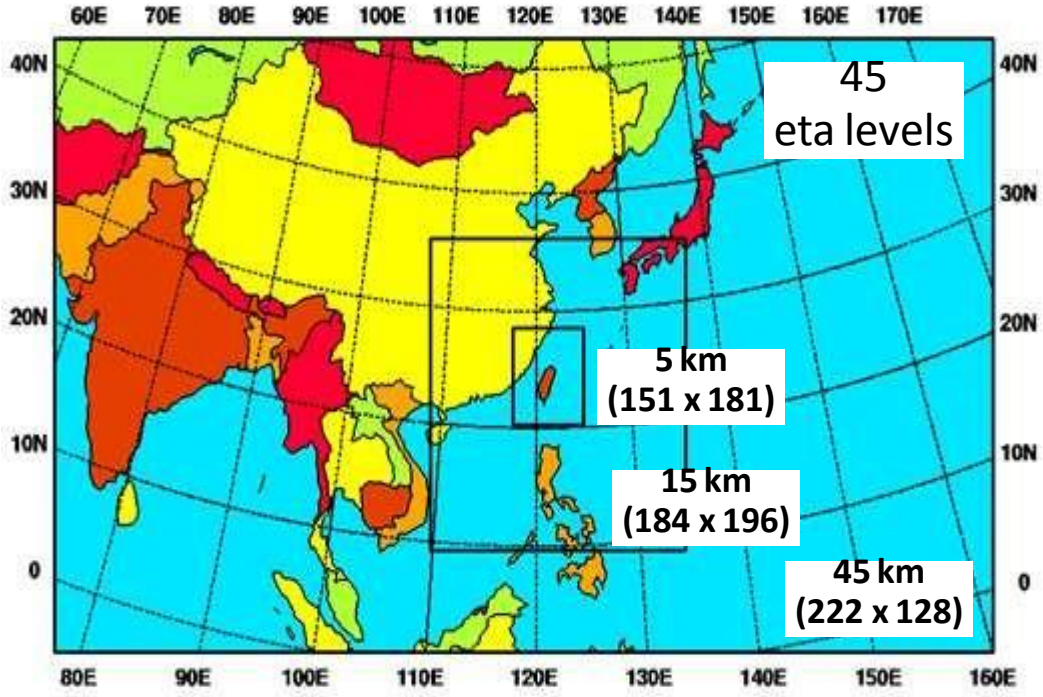
From J.-H. Chen

Regional/Mesoscale Forecast

An ARW-WRF based system CWB WRF was installed for operation since Nov 2007

Deterministic forecast, 4 times per day

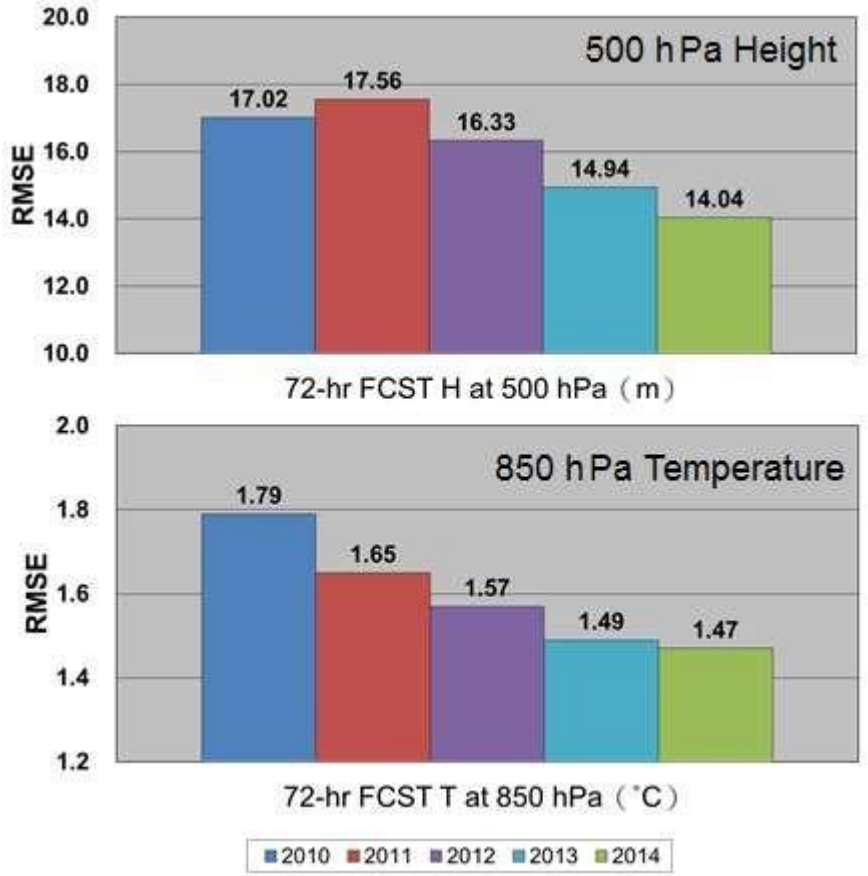
20 members Ensemble prediction, 4 times per day



- Microphysics: Goddard MPS
- Cumulus: Kain-Fritch scheme with new trigger function
- PBL: YSU scheme
- Surface layer: Monin-Obukhov scheme
- Land process: NOAH
- Long wave and short wave radiation: RRTMG
- Gravity drag parameterization

Regional/Mesoscale Forecast

Improvement of CWBWRF from 2010-2014



Regional/Mesoscale Forecast

Toward a better CWBWRF

Adopt from the community, Collaboration with NCAR/US, In-house development

Model Physics

- Migrate to RRTMG Rad scheme
- Tuning of the GWDO scheme
- Modify the trigger function in K-F Cumulus Scheme
- Modify the surface roughness
- Develop the MODIS based vegetation fraction
- Update the land-use table and the soil texture

Initialization process

- Digital Filter initialization
- Two-way nesting
- Modify the calculation of the geo-potential height
- Develop the blending scheme
- Develop the typhoon bogus and re-location scheme
- Improve the vertical interpolation scheme

Bug fixing

- Many bugs in WRFDA
- Mismatching of the global SST

Data assimilation

- The Hybrid ensemble-variational scheme and Ensemble adjustment Kalman filter
- High Resolution Land Data Assimilation System
- Assimilation of the COSMIC and ground base ZTD observation
- Develop the outer loop process in 3DVAR
- Re-center the EAKF using the blending scheme
- Fine tune the background error covariance and the use of the observation
- Design the partial cycle strategy

Regional/Mesoscale Forecast

CWBWRF Ensemble System

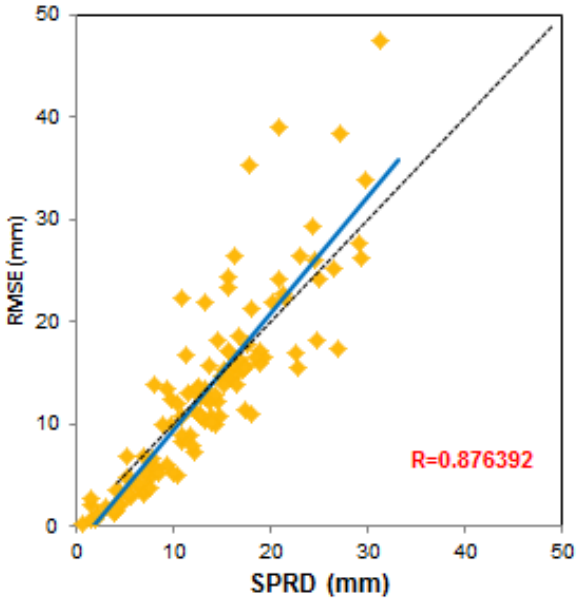
4 times per day
20 members

Control run from the deterministic analysis

Initial random perturbation from WRF 3DVAR

Lateral Boundary perturbation from the NCEP ensemble GFS

Model physic perturbation from 20-physics suite



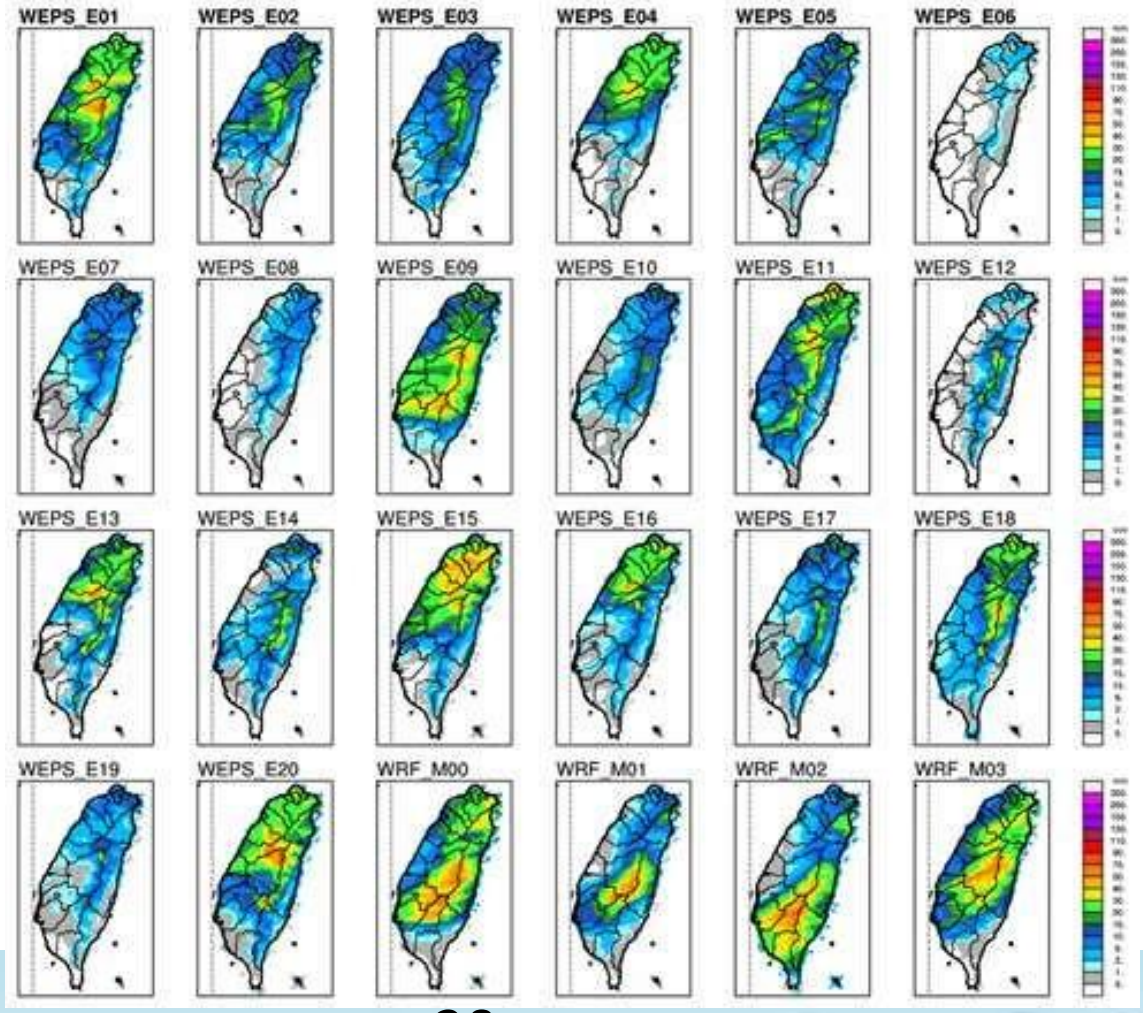
Dispersion Relation
CWB WRF EPS

C.-H. Li, and C.-Y. Tzeng

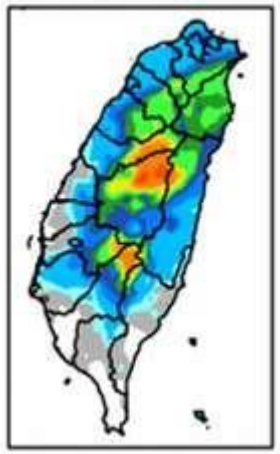
Regional/Mesoscale Forecast

Application to Quantitative Precipitation Forecast

initail at 0000 UTC 06 May 2014
00~12hr fcst Accumulated rainfall
Ensemble QPF

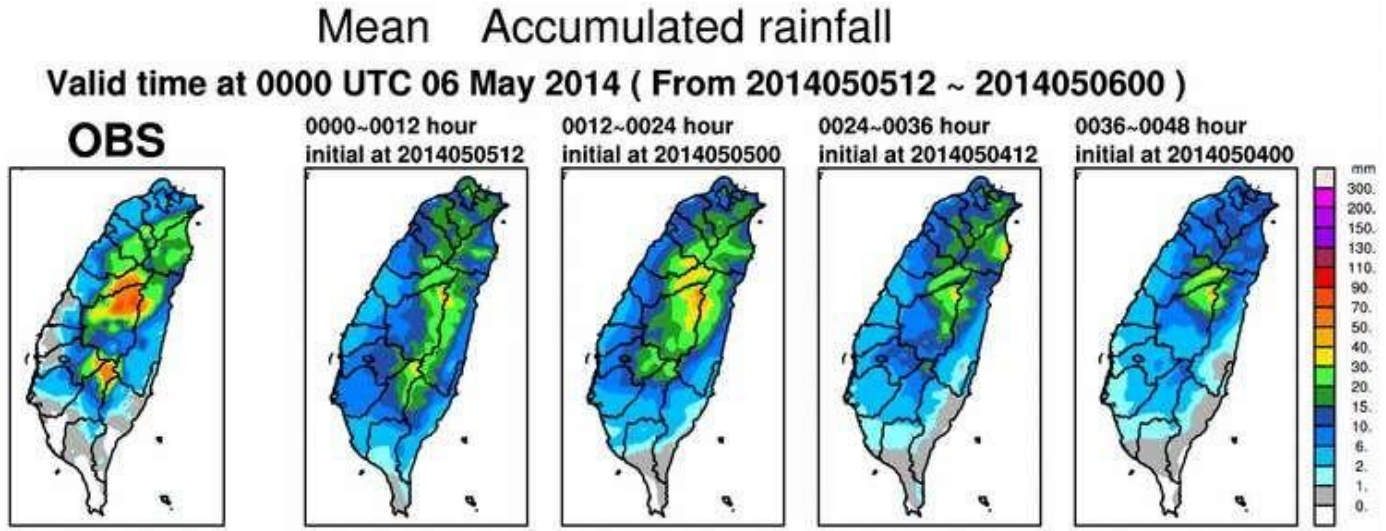


OBS

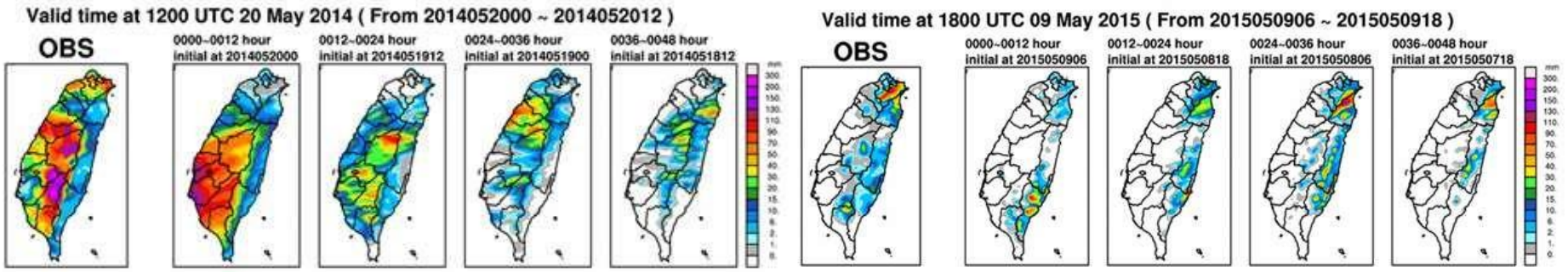


Regional/Mesoscale Forecast

Application to Quantitative Precipitation Forecast



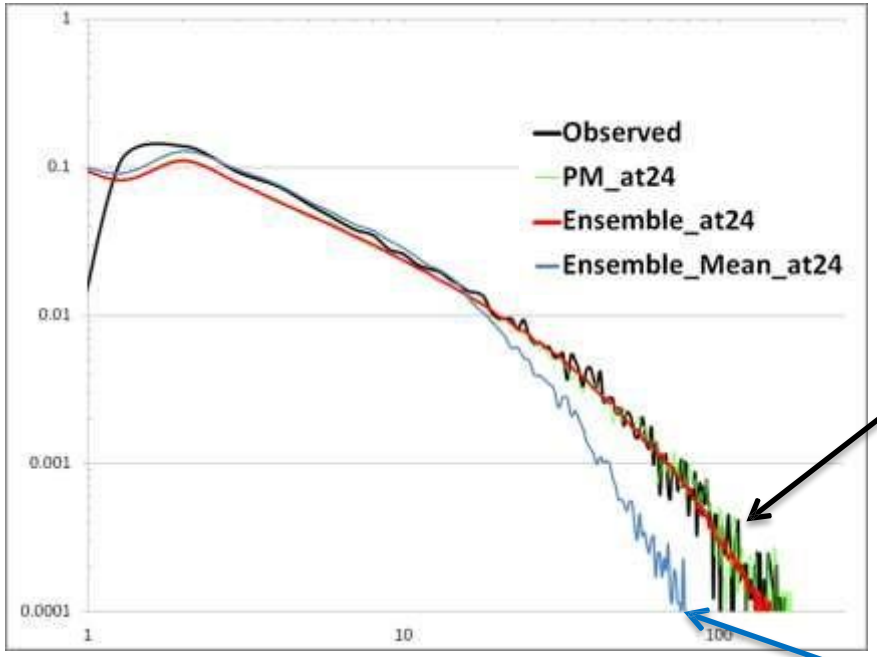
Simple mean smooth out the rainfall extremes due to the averaging process



Regional/Mesoscale Forecast

Deficiency of EPS rainfall prediction mean

Occurrence Probability



12-h accumulation rainfall (mm)

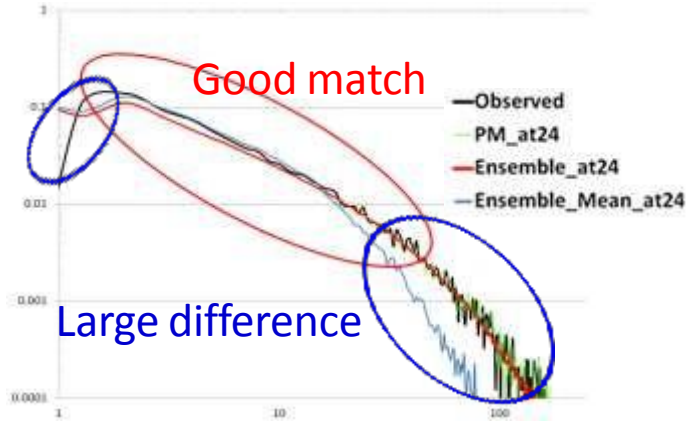
Data Period:
May and June 2015

observation

Mean of EPS

Regional/Mesoscale Forecast

Apply Probability Matching



- Step 1: Sorting according to EPS mean (for all forecast points , e.g., N points).
- Step 2: Sorting of all the predictions from EPS, and select t median value for N sub-groups.
- Step 3: Replace the mean values of the N points by median of the N subgroups, in

Model 1		
0 mm	0 mm	1 mm
0 mm	2 mm	9 mm
0 mm	5 mm	50 mm

Model 2		
7 mm	21 mm	15 mm
17 mm	60 mm	20 mm
12 mm	10 mm	8 mm

Model 3		
0 mm	1 mm	5 mm
0 mm	5 mm	40 mm
0 mm	1 mm	7 mm

2.3 mm 9	7.3 mm 4	7 mm 5
5.7 mm 6	22.3 mm 2	23 mm 1
4 mm 8	5.3 mm 7	21.[illegible] mm 3

Rank	1	2	3	4	5	6	7	8	9
Forecast	60 mm	50 mm	40 mm	21 mm	20 mm	17 mm	15 mm	12 mm	10 mm
組別	1			2			3		

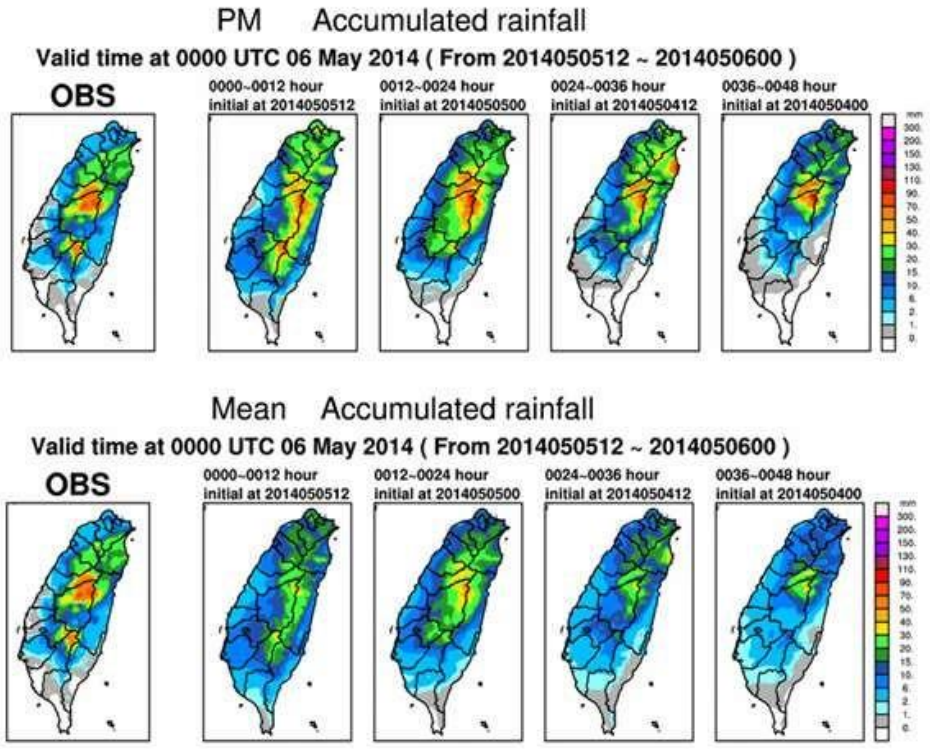
Rank	10	11	12	13	14	15	16	17	18
Forecast	9 mm	8 mm	7 mm	7 mm	5 mm	5 mm	5 mm	2 mm	1 mm
組別	4			5			6		

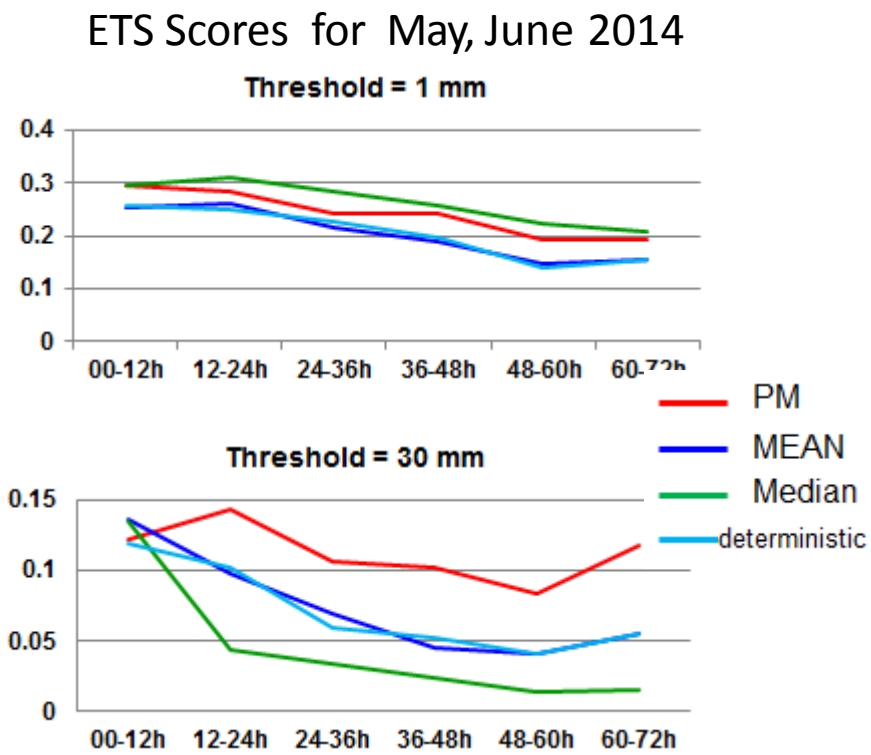
Rank	19	20	21	22	23	24	25	26	27
Forecast	1 mm	1 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
組別	7			8			9		

C.-H. Li, and C.-Y. Tzeng

Regional/Mesoscale Forecast

Improvement of EPS QPF by Applying Probability Matching

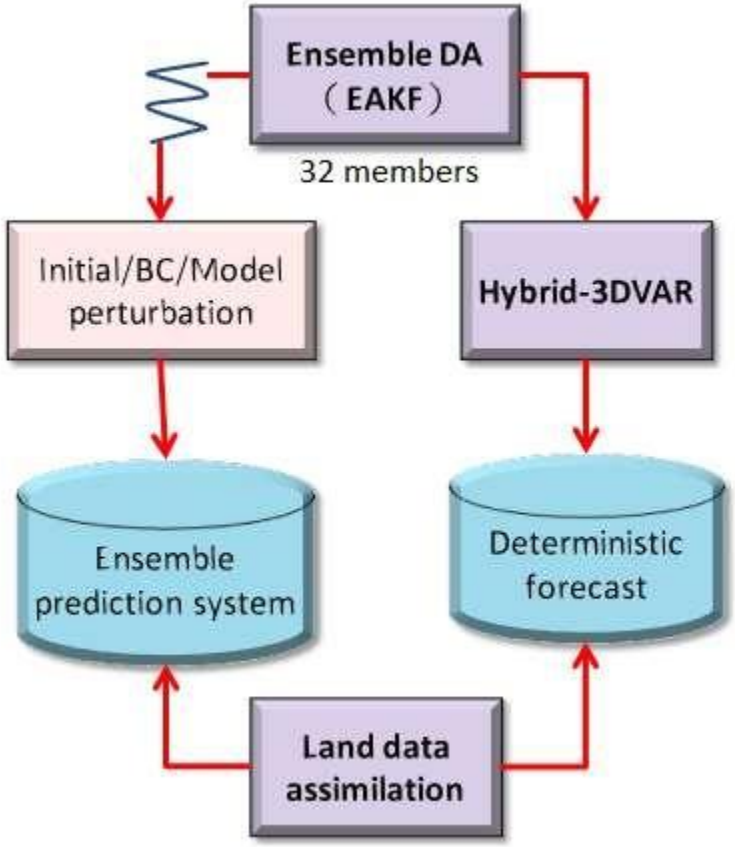




C.-H. Li, and C.-Y. Tzeng

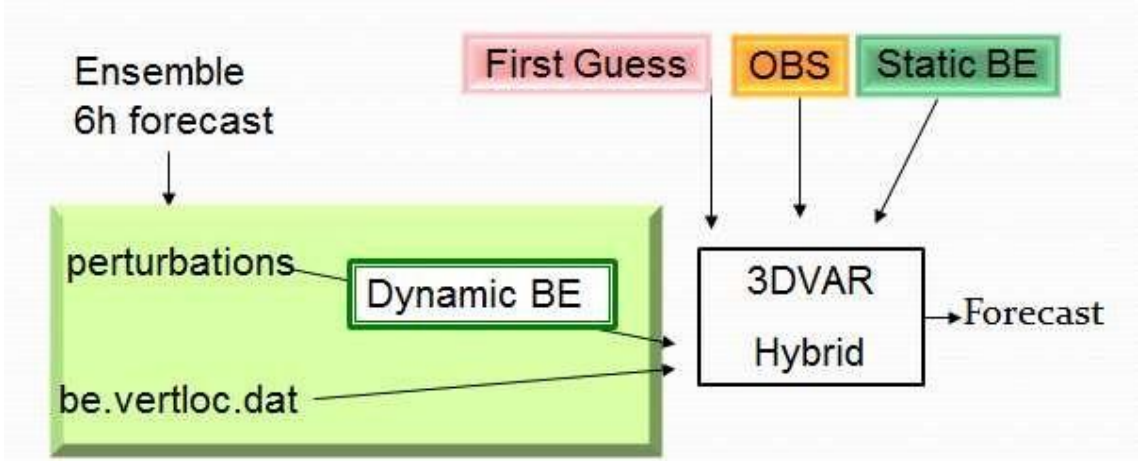
Regional/Mesoscale Forecast

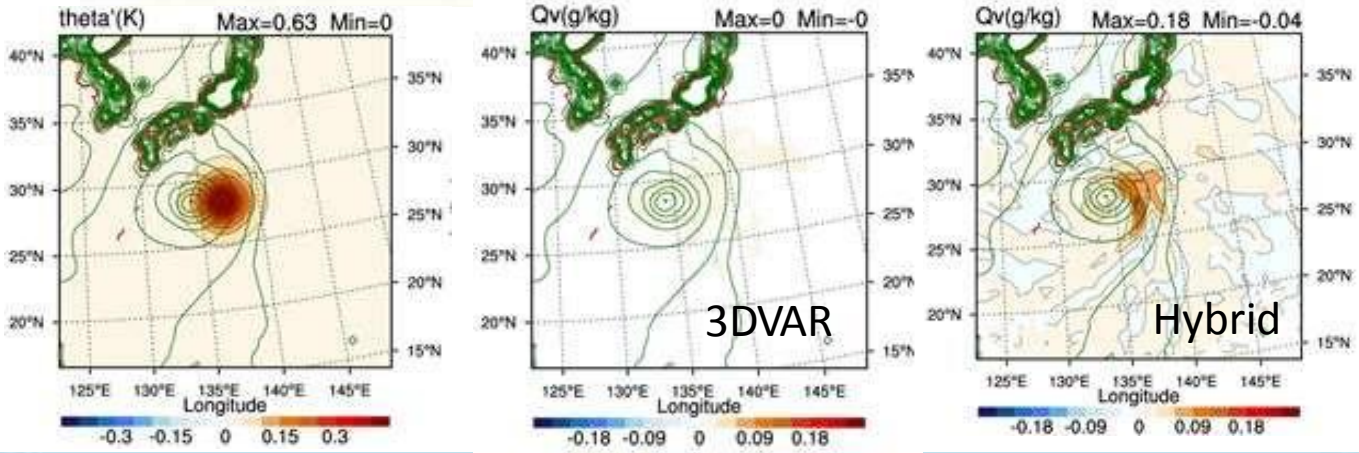
Conceptual Diagram of CWBWRF Data Assimilation System



Data Assimilation

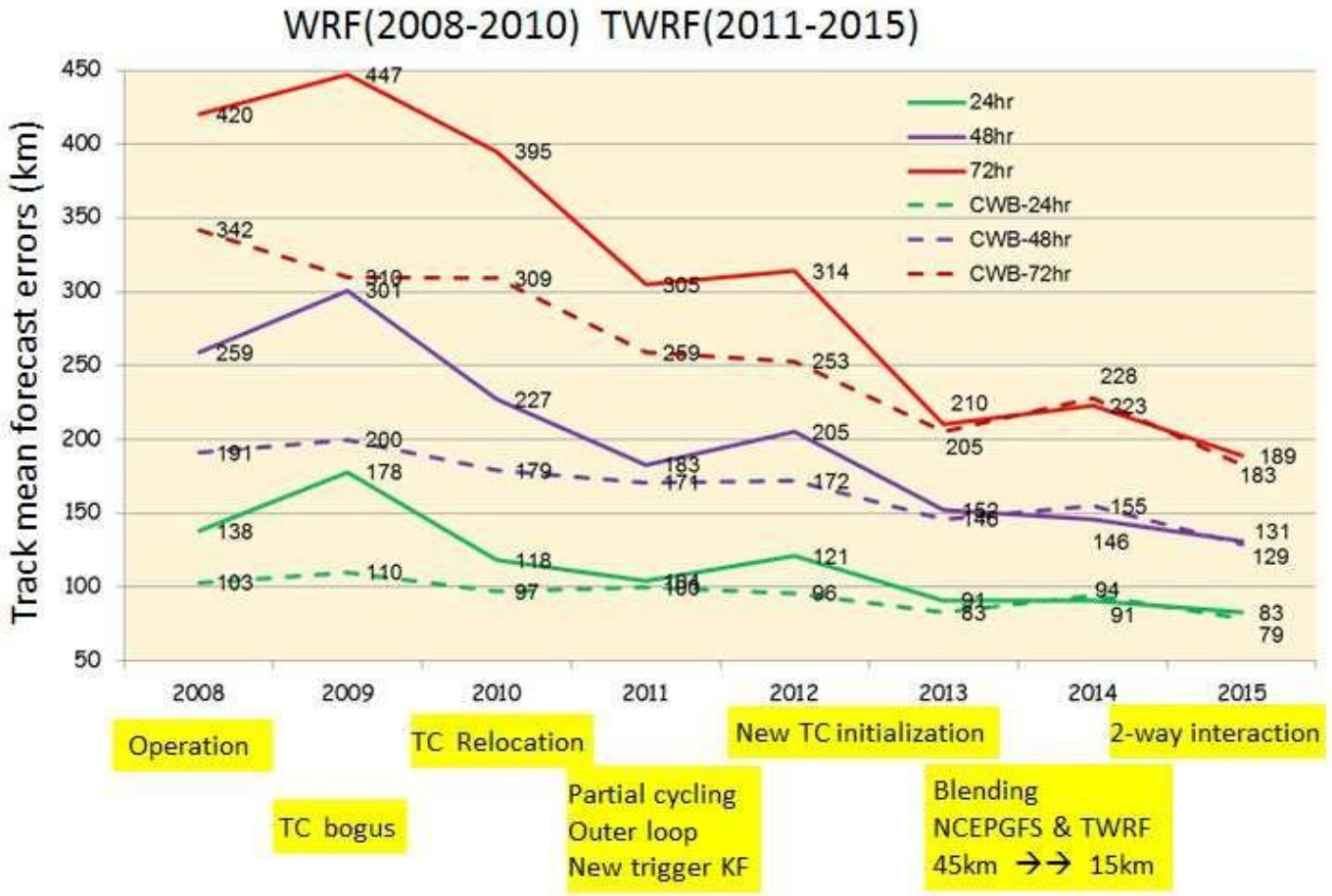
Hybrid-3DVAR Data Assimilation





Tropical Cyclone Track Forecast

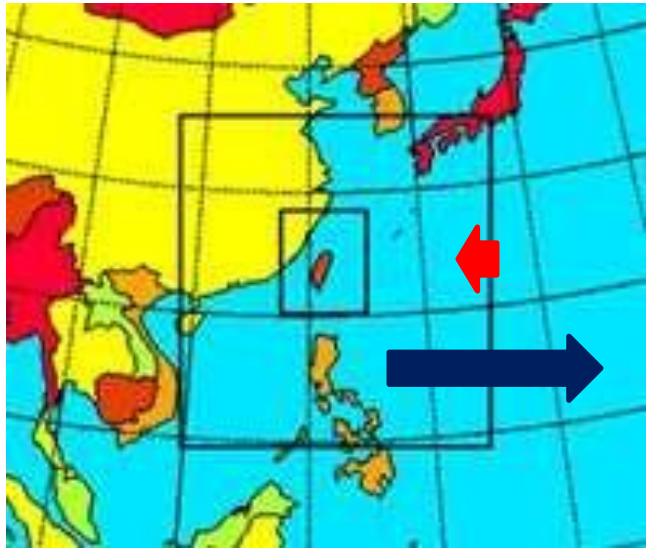
Improvement of CWB TWRF on TC Track Forecast



Tropical Cyclone Track Forecast

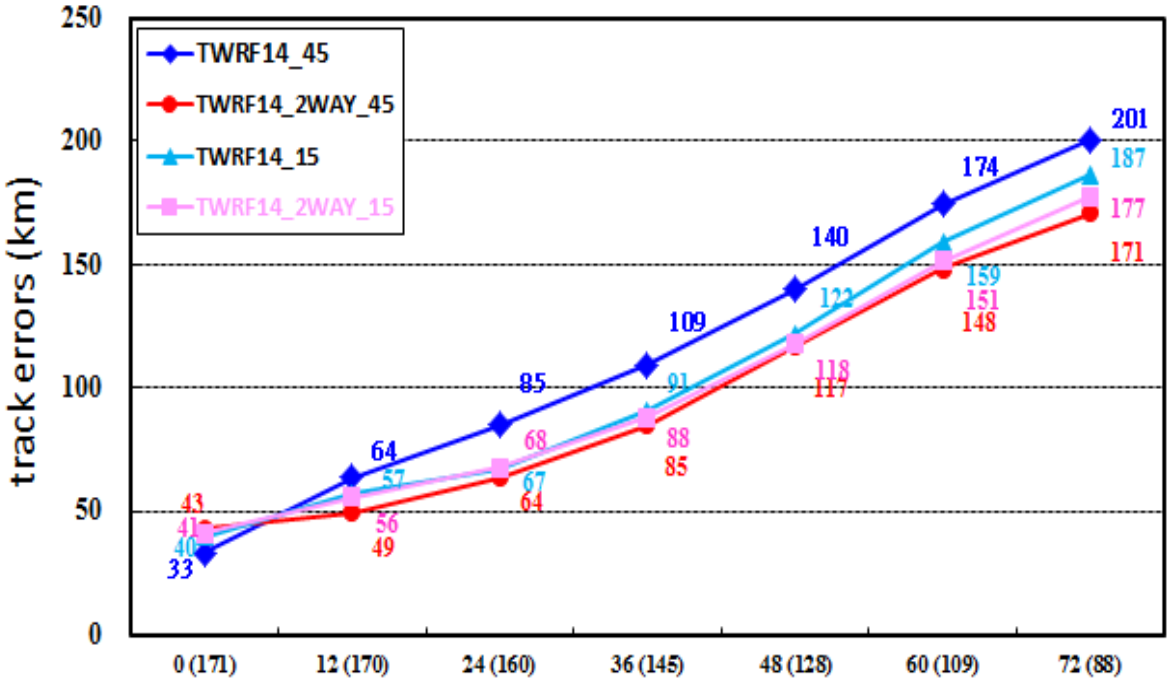
2-way nesting

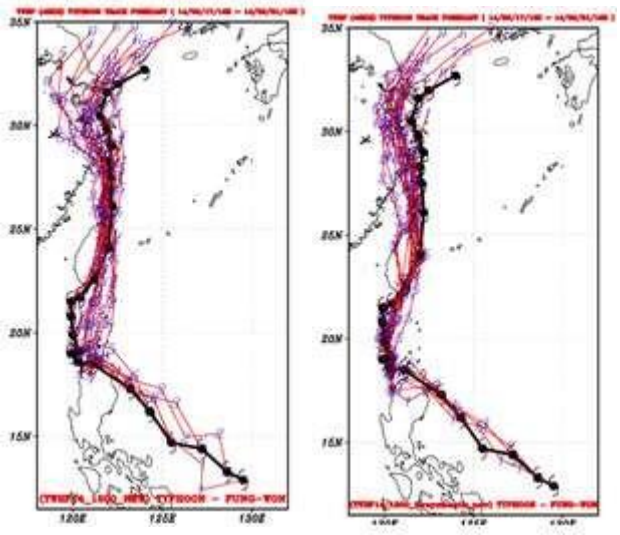
1. 2-WAY nesting: pass better forecast information from nest domain to mother domain and improve the performance of mother domain
2. Mother domain can provide better lateral boundary condition for nest domain



Tropical Cyclone Track Forecast

Improvement of TWRF



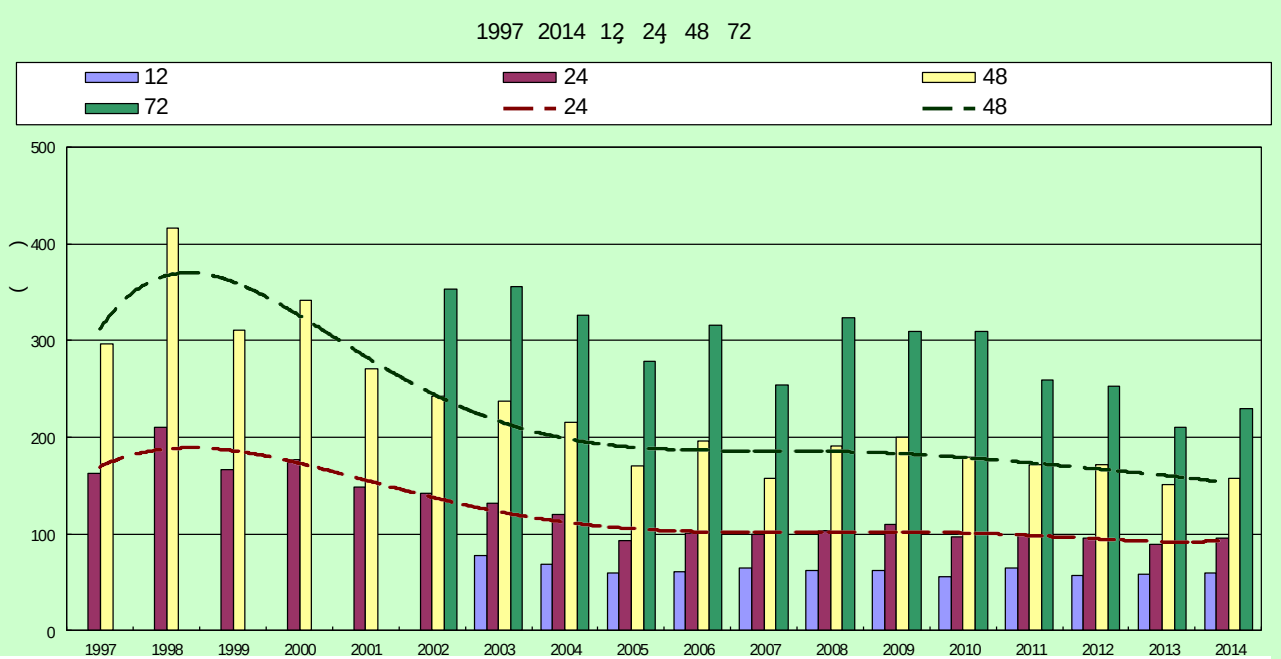


TC FUNG-WONG
(2014/09/17/18 ~ 2014/09/21/18)

2-Way nesting experiments for 2014 11 TCs (171 cases)

Tropical Cyclone Track Forecast

Official TC Track Forecast



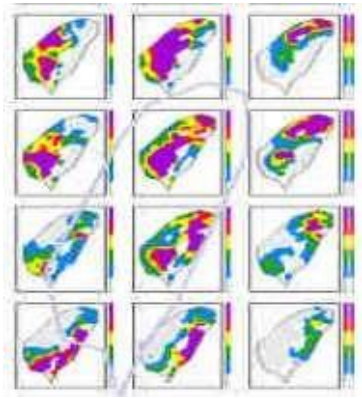
Average Track Forecast Error 2005~2014

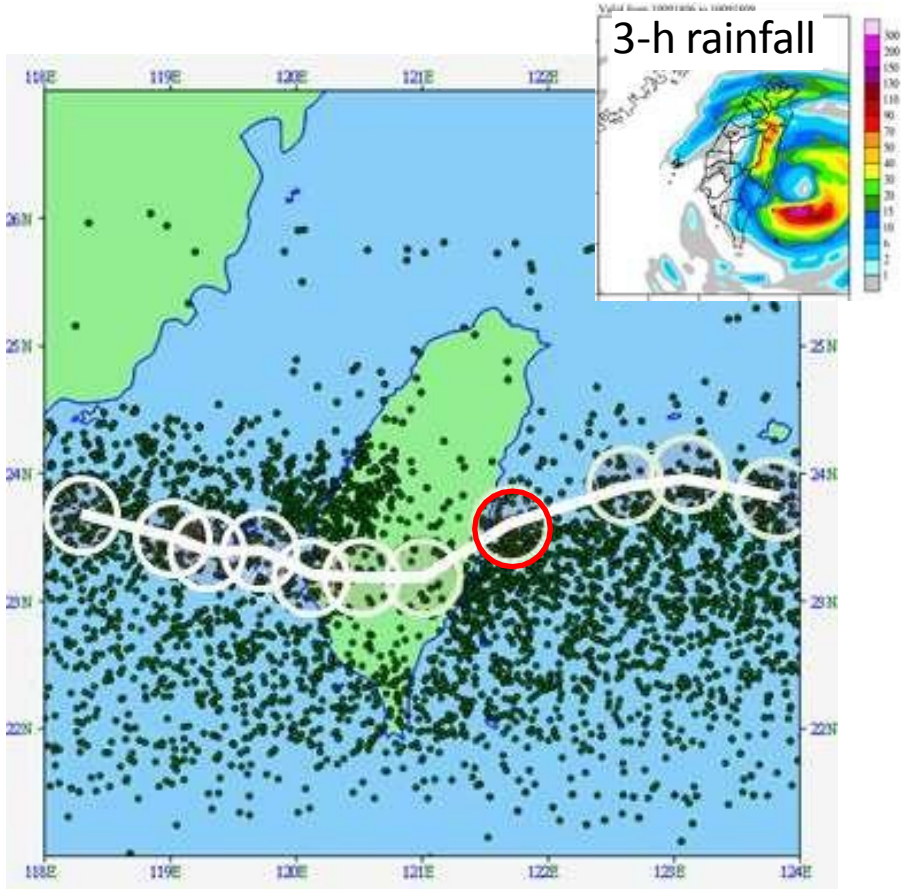
	24 H	48 H	72 H	96 H	120 H
CWB	**97**	**173**	**268**	**350**	**473**

P.-S. Chang

Tropical Cyclone Rainfall Forecast

EPS application on TC rainfall prediction (ETQPF)

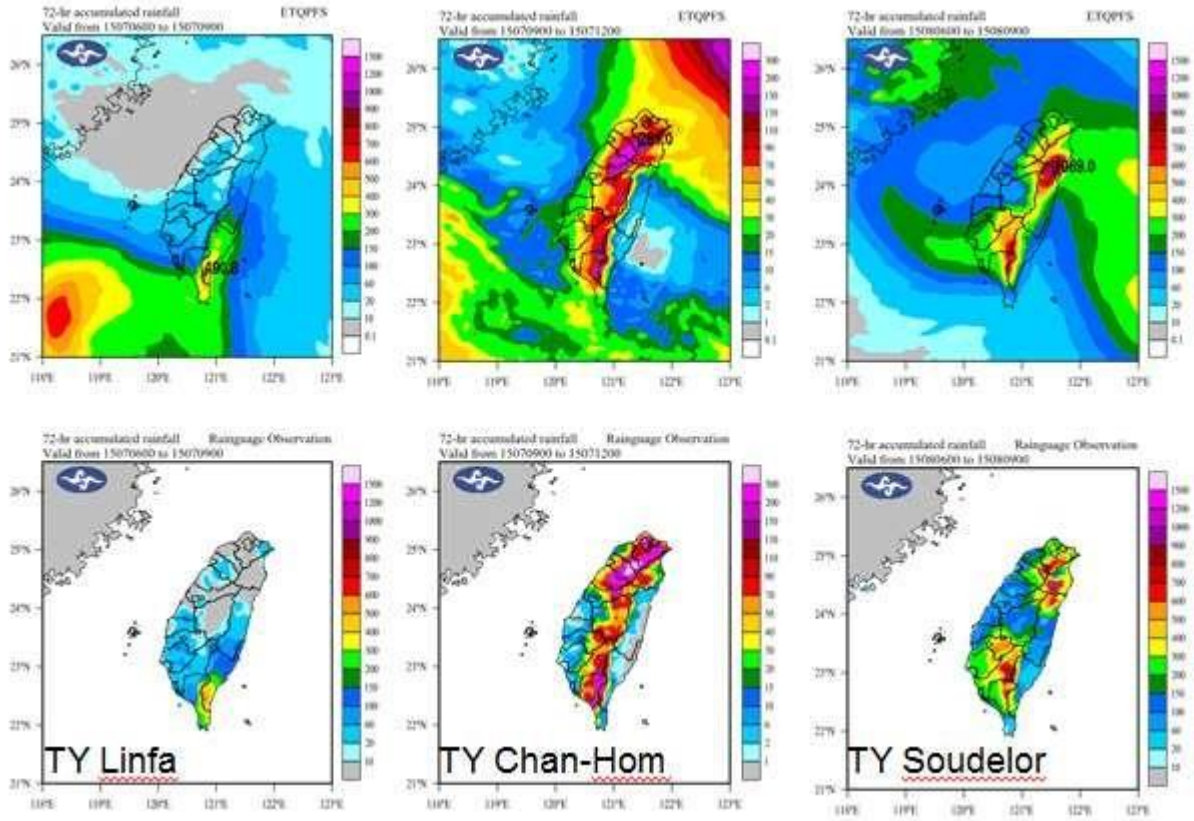




- Statistics show the TC rainfall distribution over Taiwan depends strongly on the TC center location.
- Model track forecast error will induce large rainfall forecast error.
- ETQPF use the mean of the EPS cases those forecast TC center near the select location (official forecast track).

Tropical Cyclone Rainfall Forecast

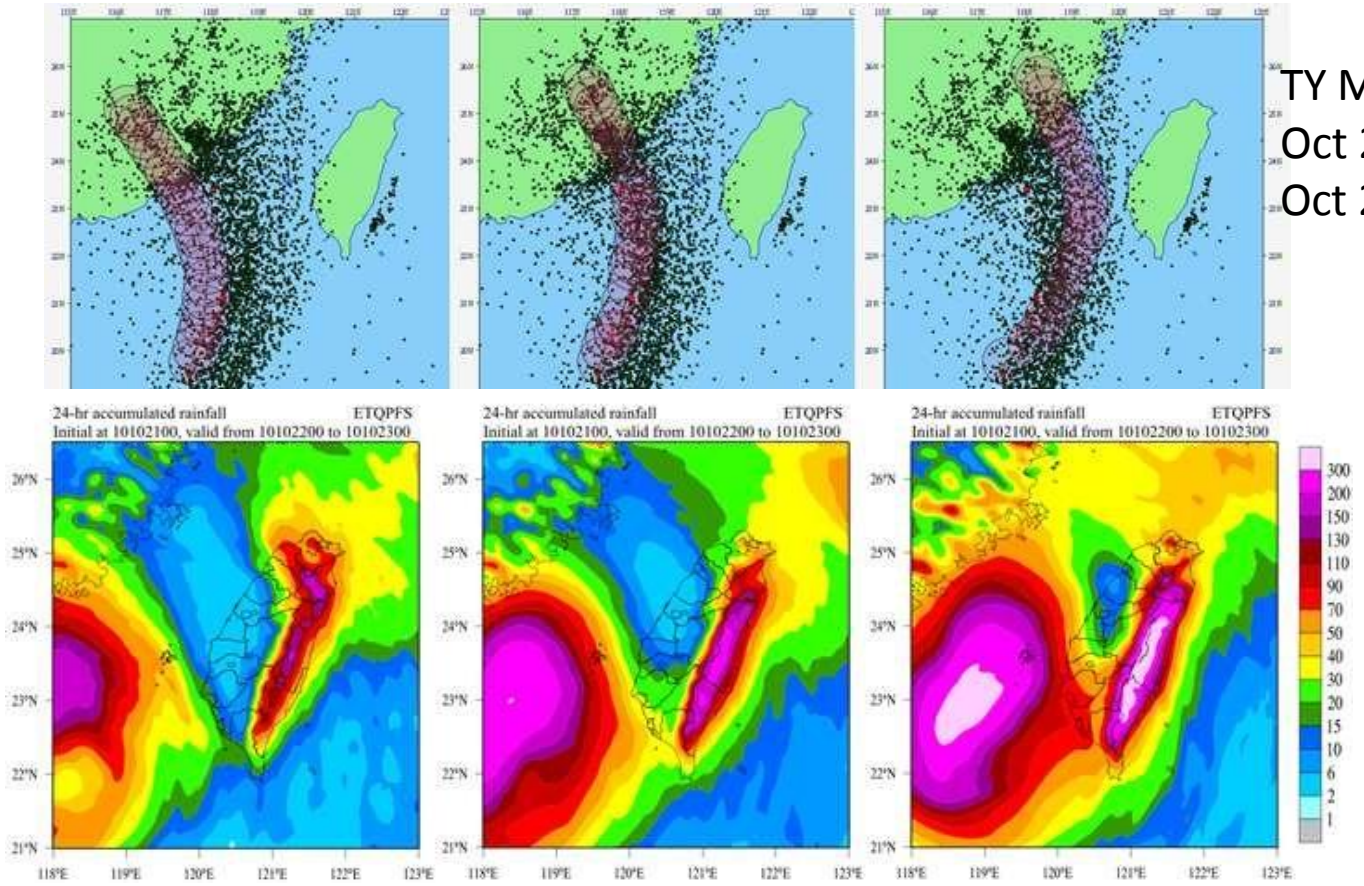
EPS application on TC rainfall prediction (ETQPF)



The ETQPF forecast for the typhoons affected Taiwan in 2015

Tropical Cyclone Rainfall Forecast

ETQPF helps to assess the uncertainty of rainfall with different tracks

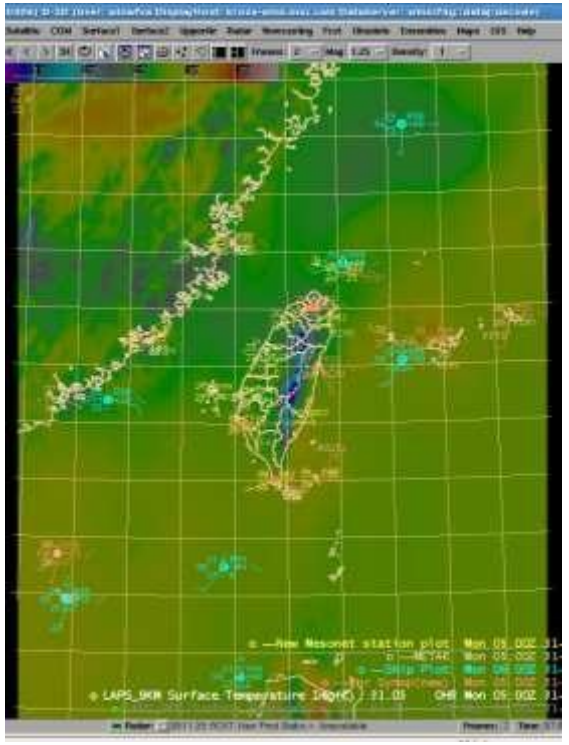


TY Megi (2010-13)
Oct 22 00UCT-
Oct 23 00UTC

Short Range Forecast

For 0-12 Hours Forecast

- CWB introduced LAPS from GSD/ESRL/NOAA/US (formerly FSL) in 2002 to improve short-range forecasts.
  (LAPS: Local Analysis and Prediction System)
- Upgraded LAPS to STMAS in 2011.
  (STMAS: Space and Time Multi-scale Analysis System)

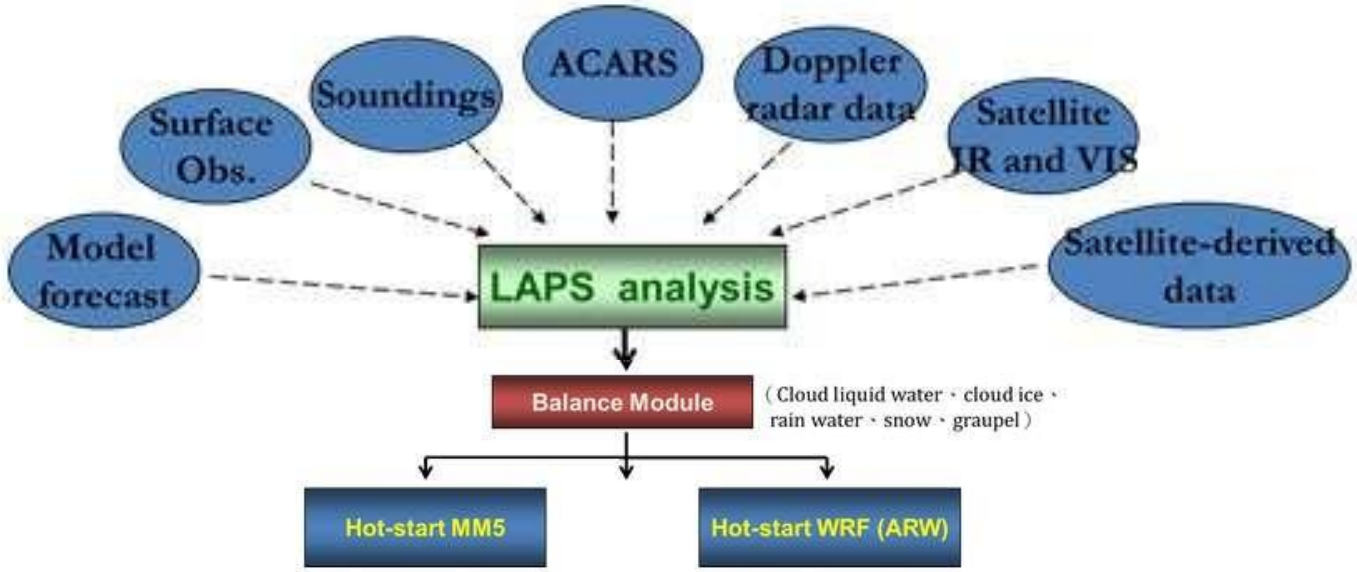


Smaller scale, real time rapid update

P.-L. Chang, W.-H. Wang, H.-L. Chang, Y.-S. Tang, W.-T. Fang, C.-J. Wu

Short Range Forecast

LAPS/STMAS Prediction System

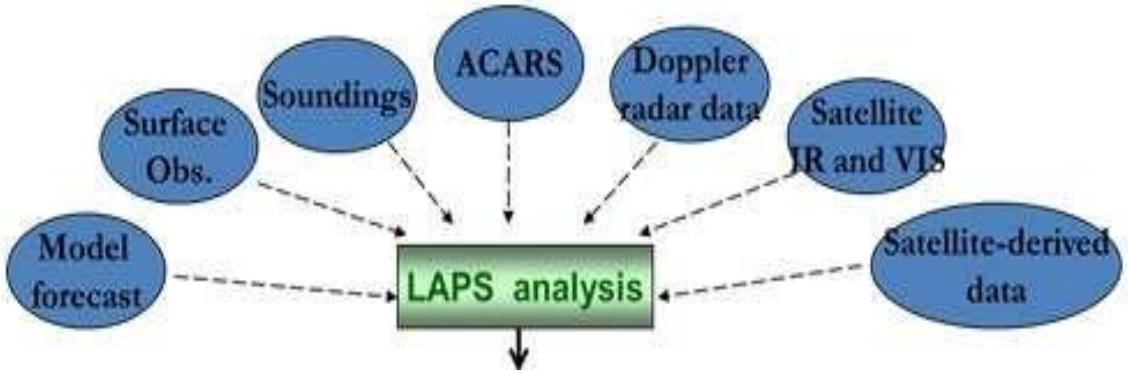


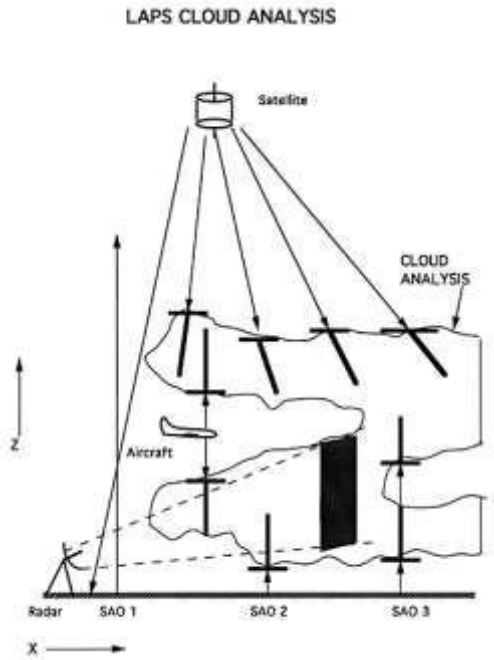
Bring a variety of datasets into the analysis for forecast

P.-L. Chang, W.-H. Wang, H.-L. Chang, Y.-S. Tang, W.-T. Fang, C.-J. Wu

Short Range Forecast

LAPS/STMAS Prediction System





The cloud analysis uses satellite, METARs, radar, aircraft data and model first guess information to produce 3D fields of cloud fraction, cloud liquid, cloud ice, rain, snow, and precipitating ice.

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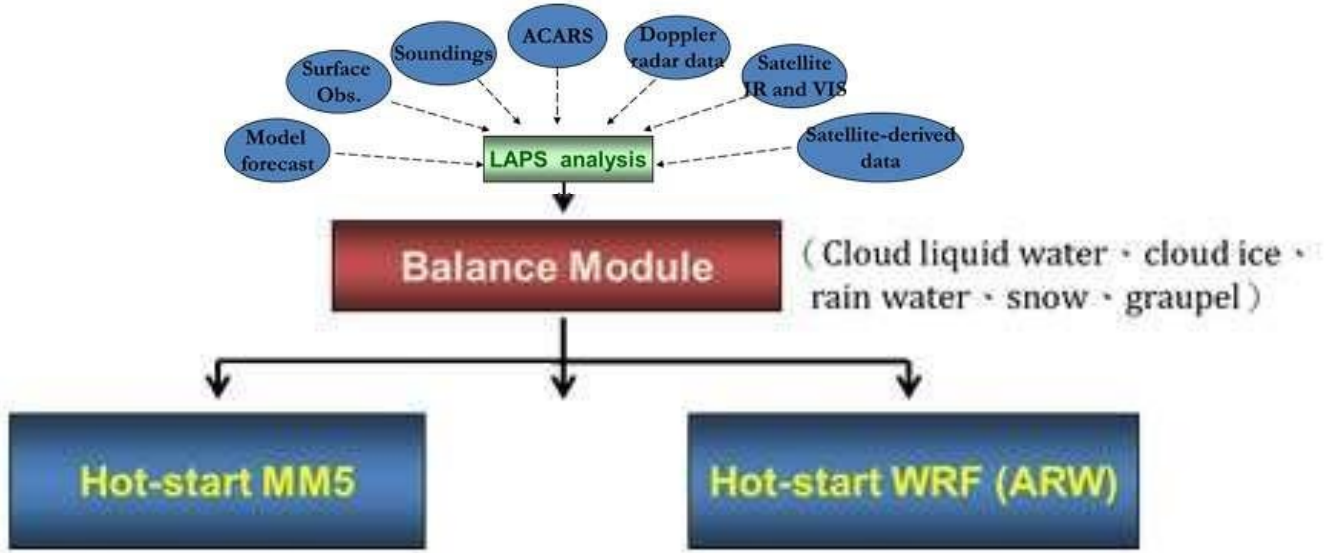
Short Range Forecast

LAPS/STMAS Prediction System



Hot-start (Minimize Spin upProblem)

With complete cloudinformation from cloud analysis,and with balance packageto balancebetween mass andmomentum fields, themodel forecast canminimize the spin-up problem.

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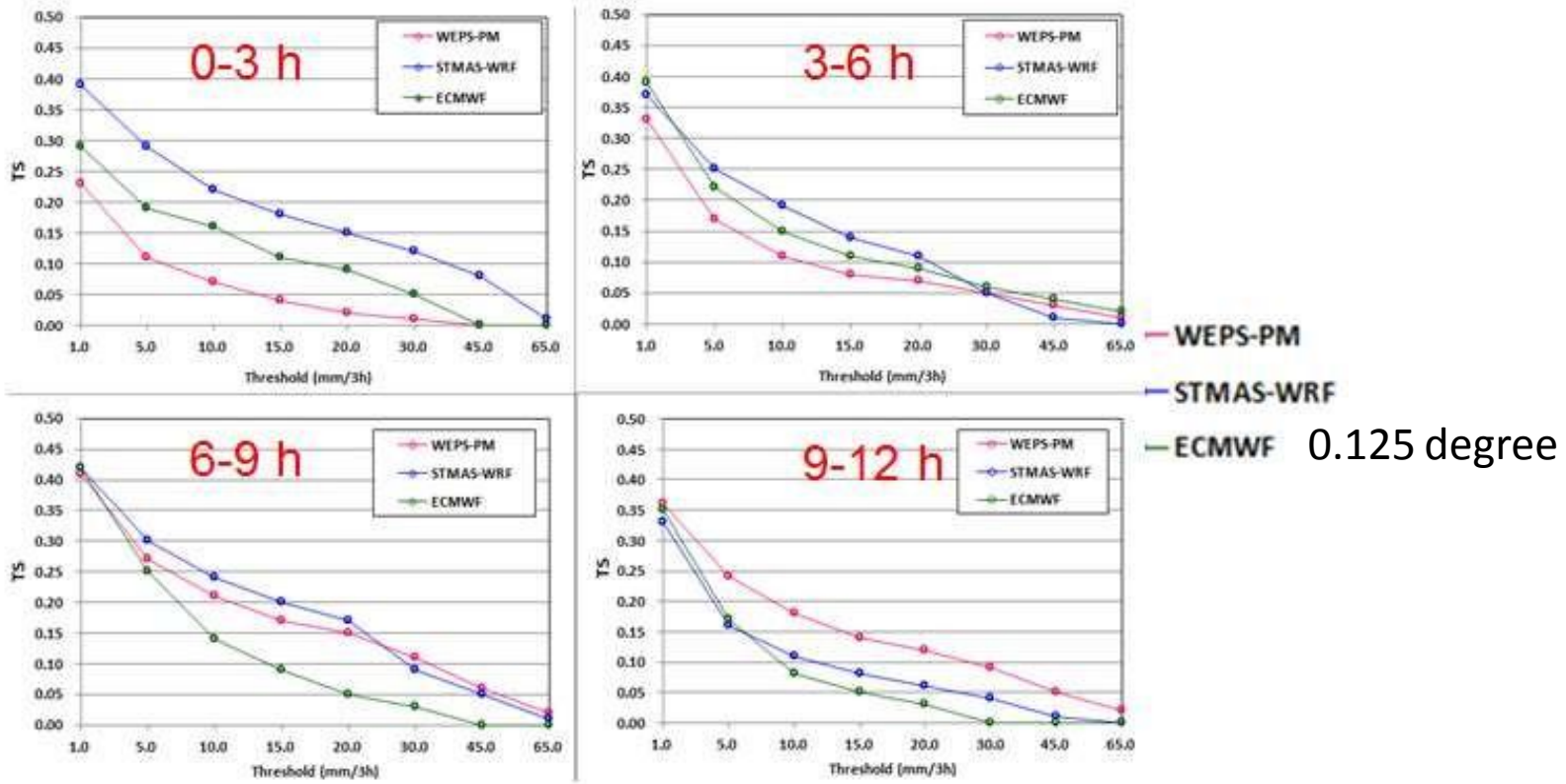
Short Range Forecast

LAPS/STMAS Prediction Scores

May and June 2014 and 2015 (64 cases)



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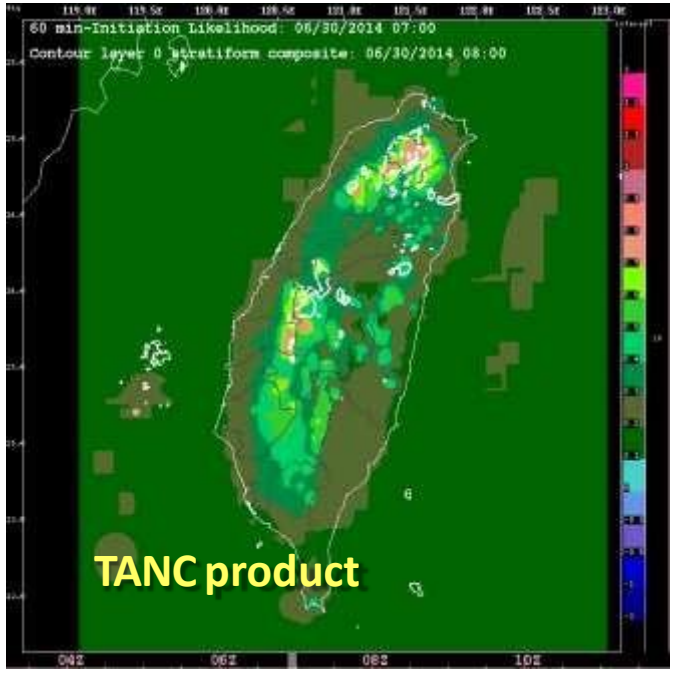
Very Short Range Forecast

Very Short Range Forecast

For 1 Hour Forecast

- CWB introduced the AutoNowCaster developed by NCAR/US in 2010.
- TANC is localized for Taiwan to predict the initiation of the summer thunderstorm (reflectivity > 35 dBz).
- Based on the fuzzy logic concept and considering the factors from the radar, surface observation, and numerical model prediction to produce the nowcast for 0-1 hour.



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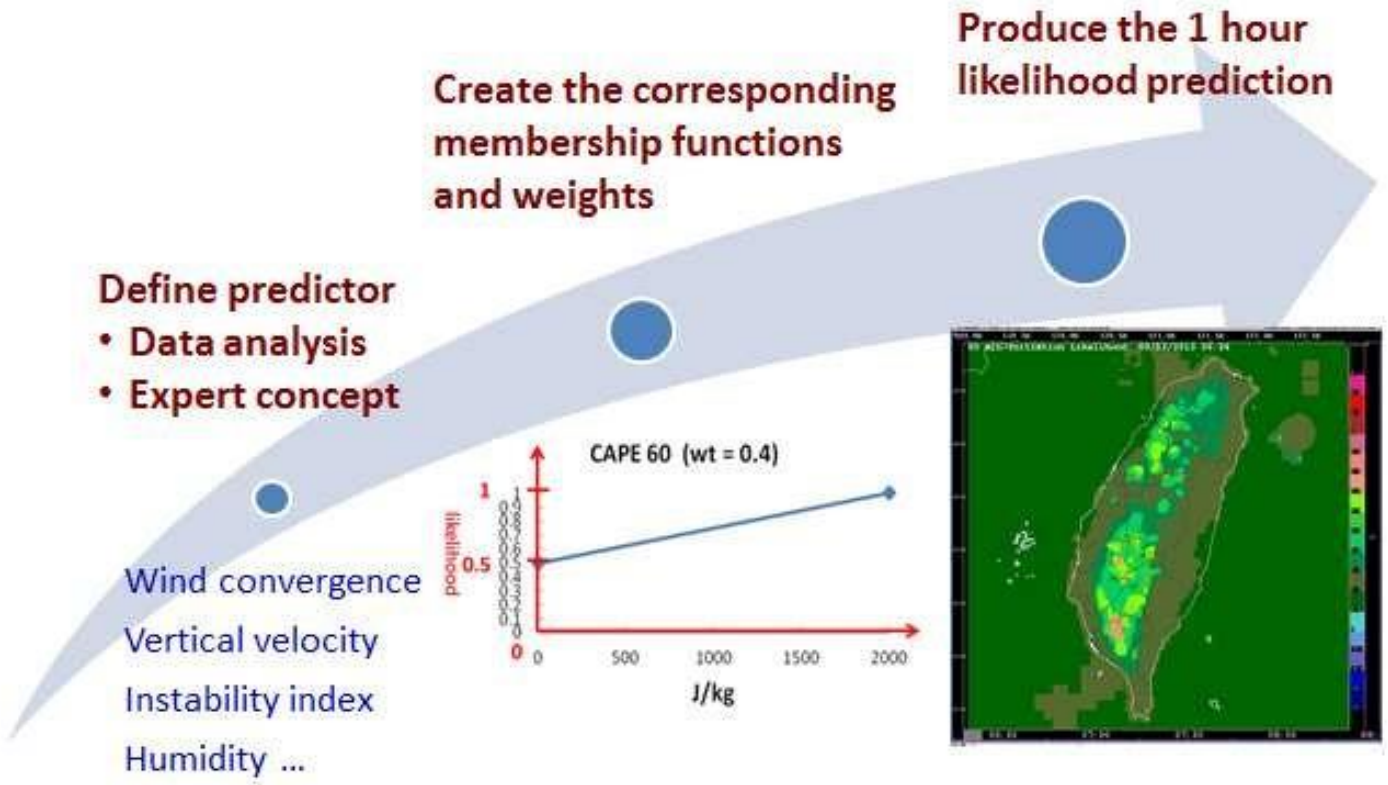
Very Short Range Forecast

TANC Conceptual Diagram



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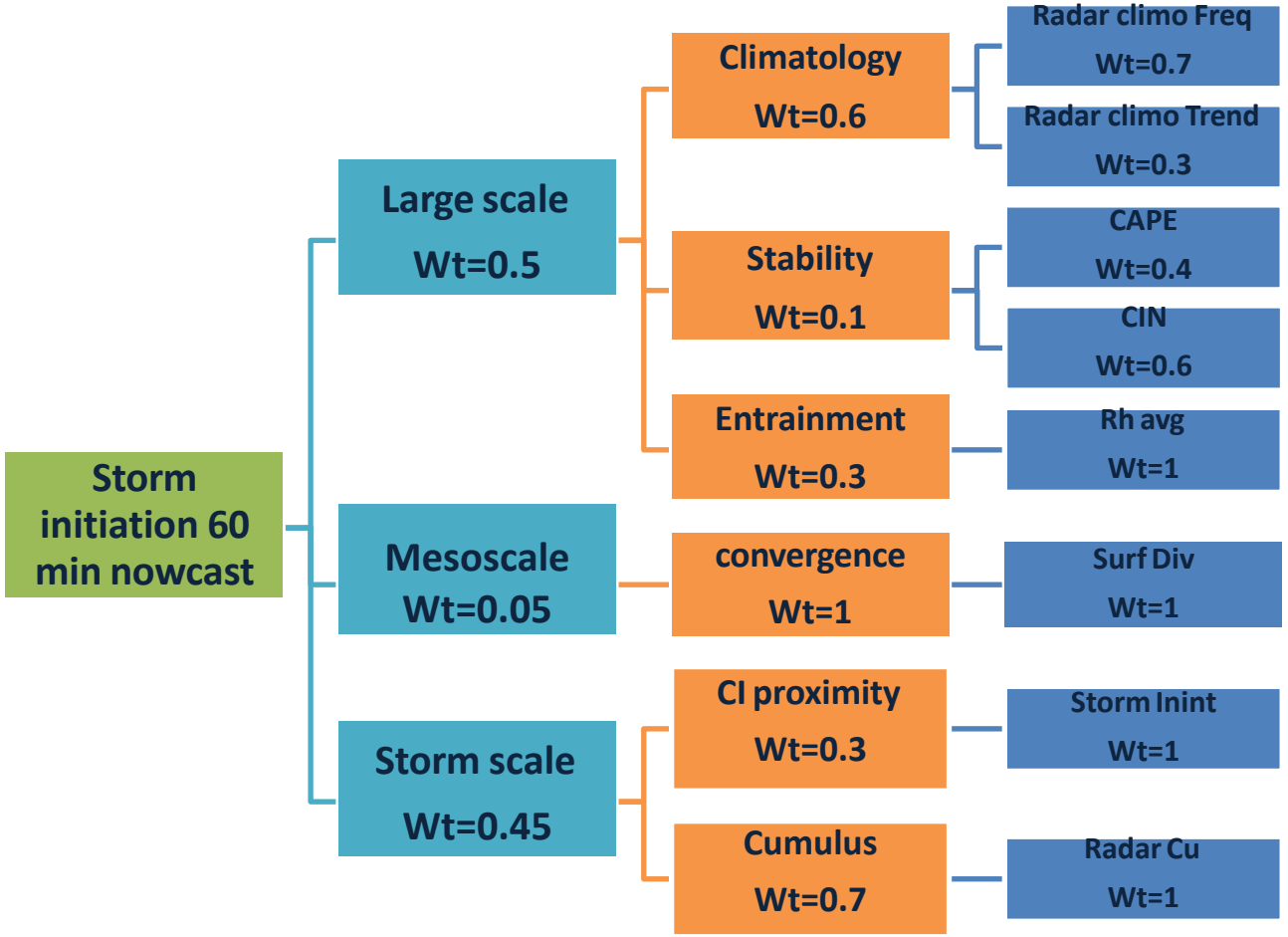
Very Short Range Forecast

TANC Predictors for Thunderstorm in Taiwan



From Climate statistics using Radar data

From model forecast (WRF)

From surface obs.

From real-time radar data

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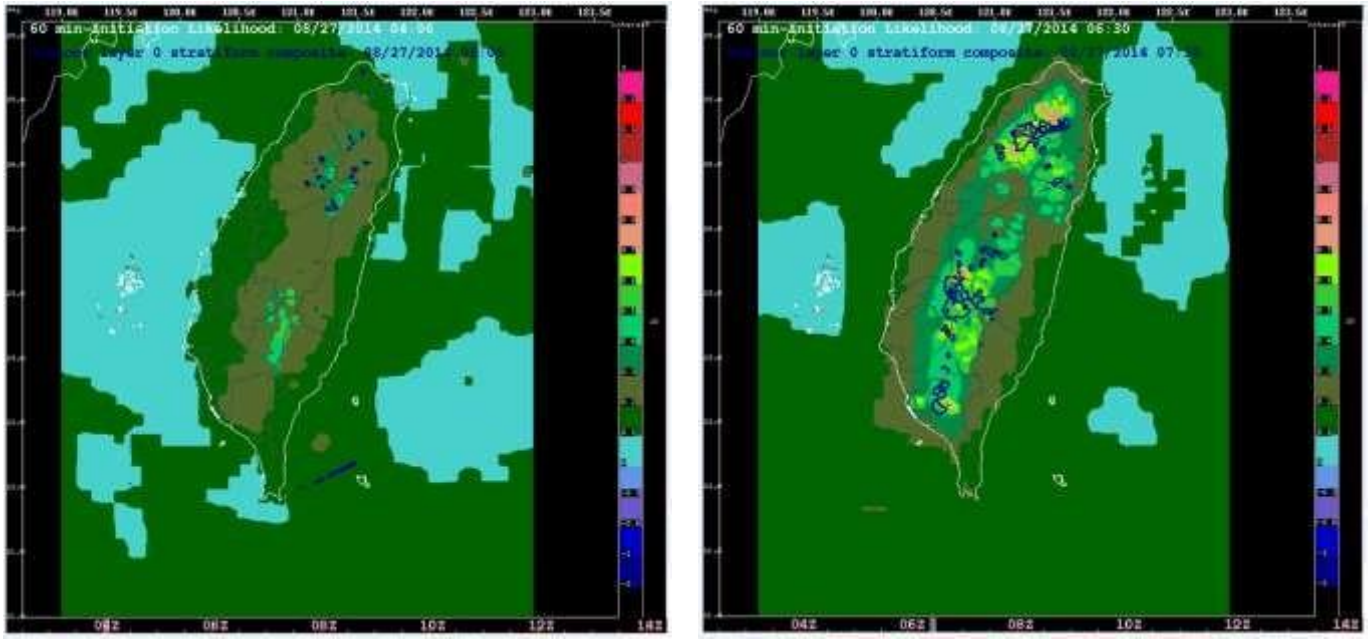
Very Short Range Forecast

TANC Forecast Example

Likelihood of storm initiation Dark blue observed convection



Afternoon thunderstorm case: Aug. 27, 2014

Under weak synoptic forcing, the convection initiation is captured spatially and temporally, with a little bit over-forecast for southern Taiwan.

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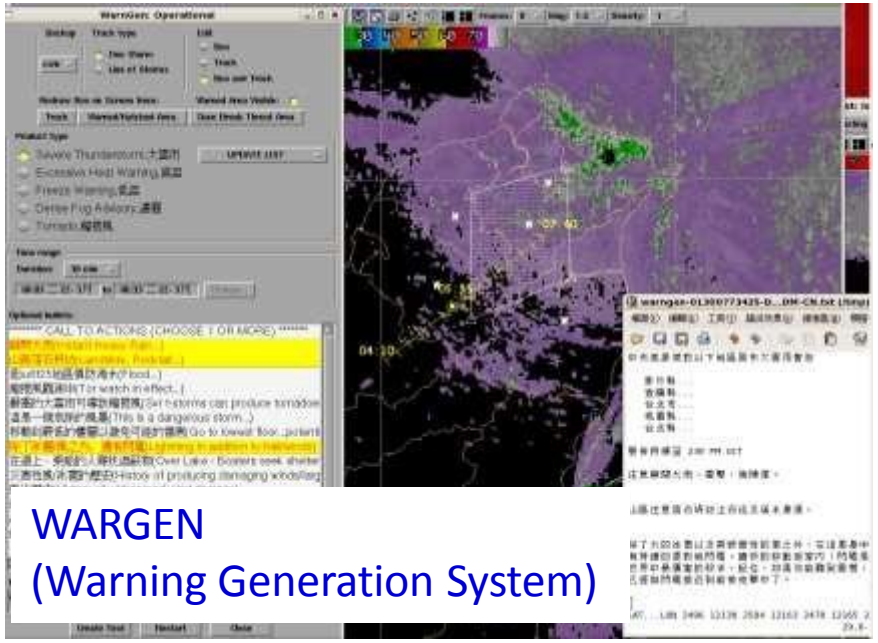
Services

Warnings are Generated and Distributed



WARGEN
(Warning Generation System)

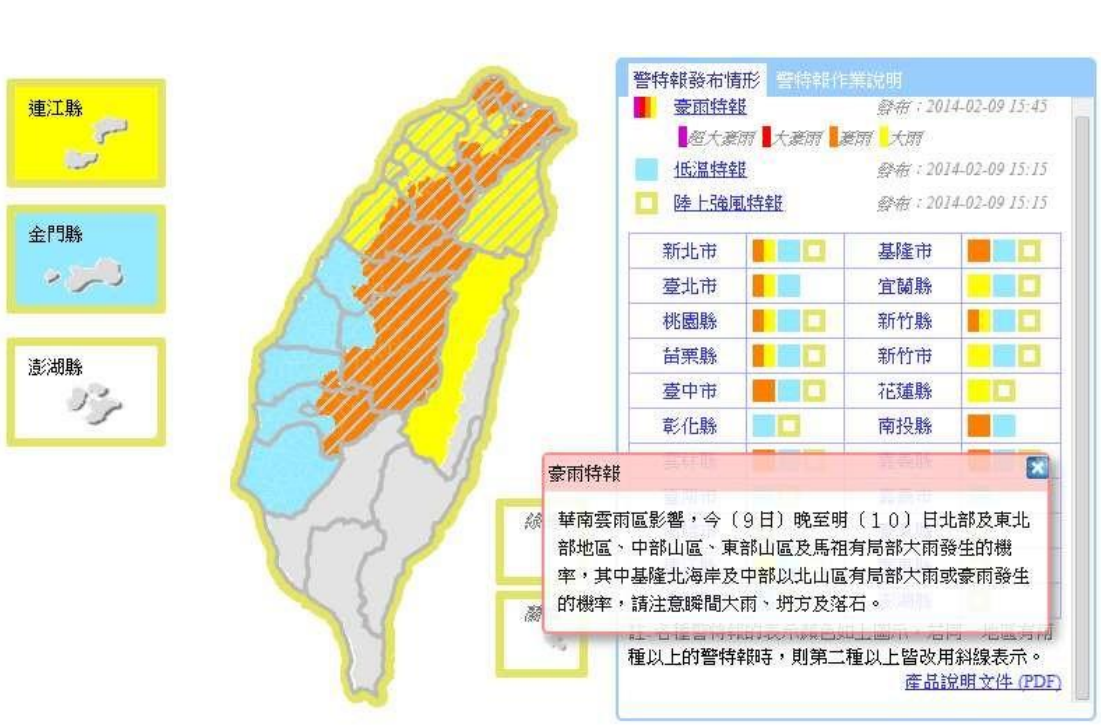
Warnings are distributed through Short Message, Line, CWB app, Facebook, CWB Homepage, Media (TV/Radio/Newspaper), etc

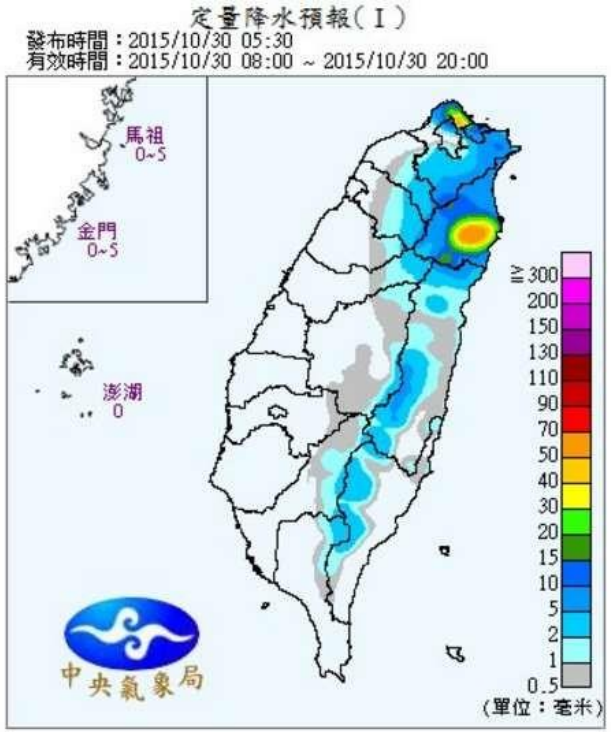
Services

Detail Information are provided on Webpage

http://www.cwb.gov.tw/V7/index_home.htm

http://www.cwb.gov.tw/eng/index.htm





Services

Customized information are provided to related Government Agencies through QPESUMS system

QPESUMS : Quantitative Precipitation Estimation and Segregation Using Multiple Sensor

Generate ALARM when reach given criteria

中華民國交通部公路總局 Directorate General of Highways, MOTC

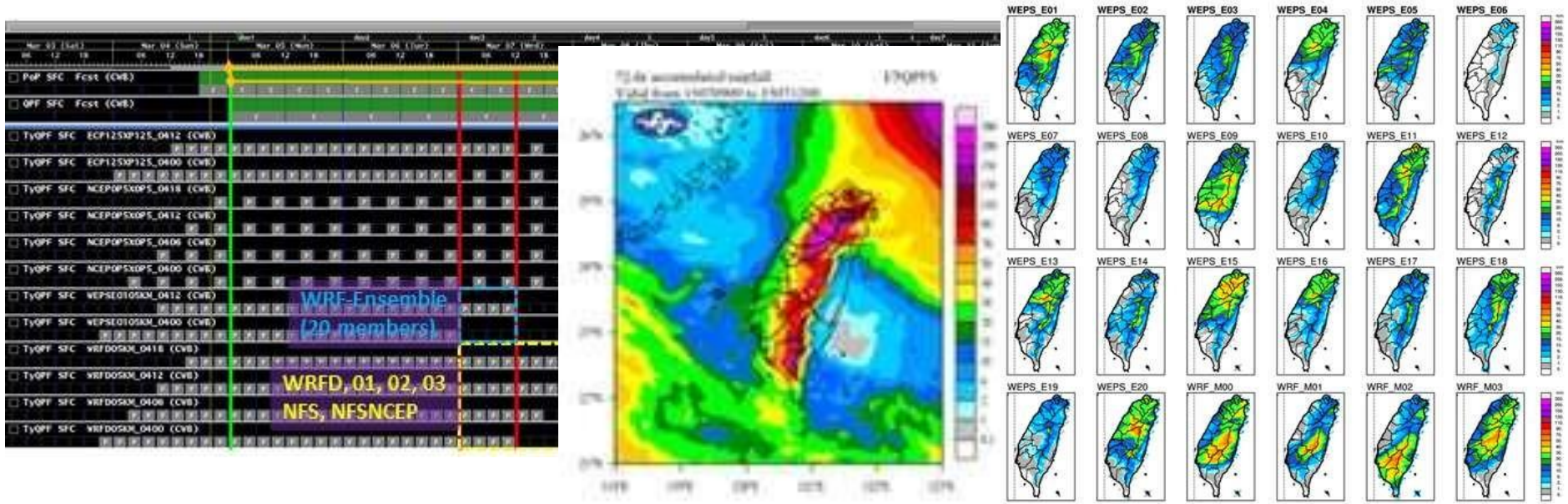
交通部臺灣鐵路管理局 Taiwan Railways Administration

TAIPEI

臺東縣政府 Taitung County Government

Services

Binary data are provided to related Government Agency for Downstream Applications



經濟部水利署 Water resources & flooding

行政院農業委員會水土保持局 Soil and Water Conservation Bureau, Council of Agriculture, Executive Yuan
Landslide and Debris flow

NCDR 國家災害防救科技中心 National Science and Technology Center for Disaster Reduction
National Science and Technology Center for Disaster Reduction

TAIPEI 新北市政府 New Taipei City Government

Future Work

- Data Assimilation
  (4DVAR, hybrid EnKF/4DVar, radar observation)
- Model Improvement
  (resolution, physics, parameterization)
- Better Ensembles
  (global and mesoscale)
- Forecast Verification
- Focus on Application


Thank you for your attention!