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Research on bias correction techniques of quantitative precipitation forecasts

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6th NCEP Ensemble User Workshop, NCEP, Mar 25-27, 2014

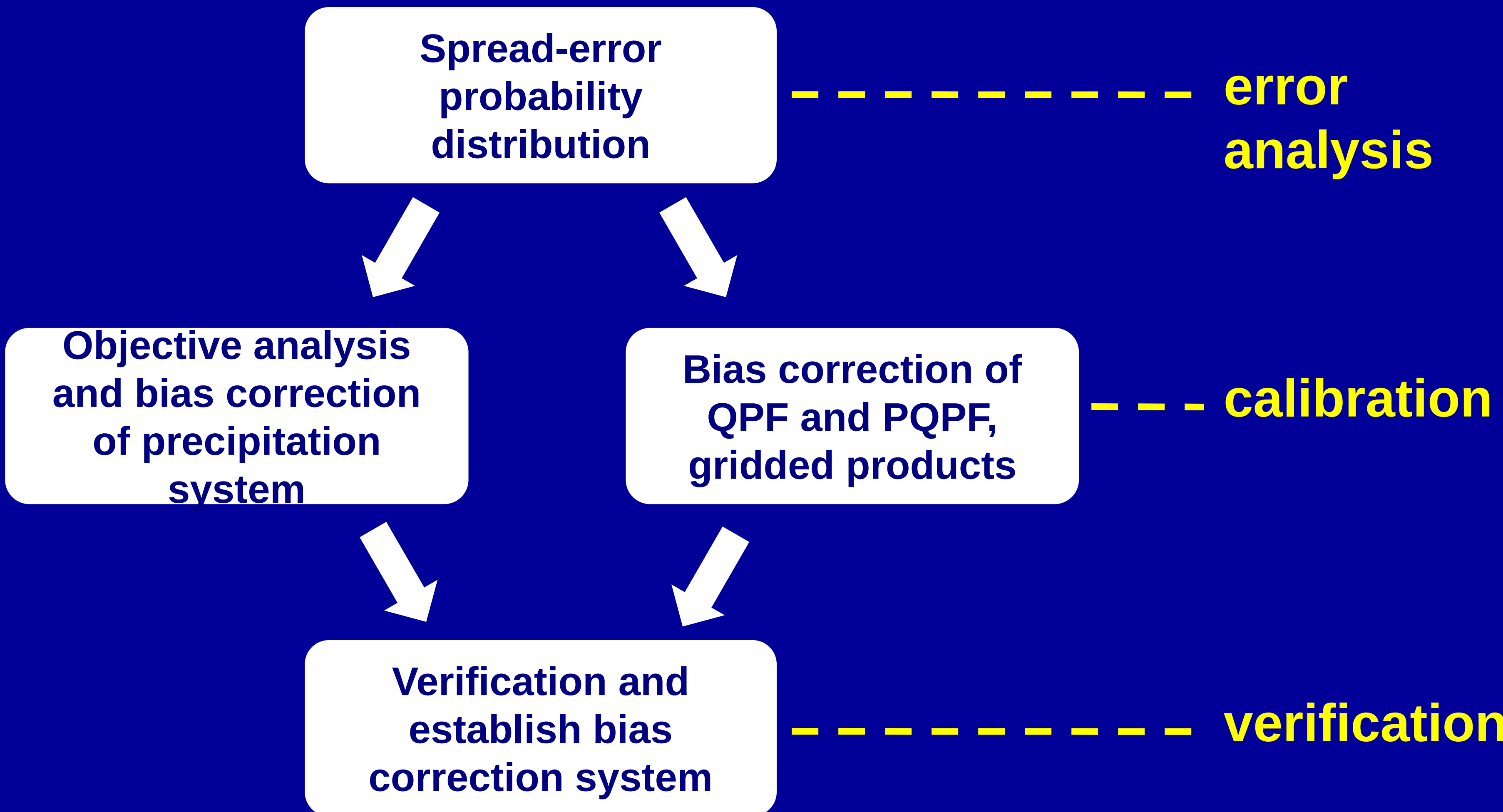
Objectives

- **Based on operational middle-range NWP products used in CMA, study QPF and its predictability.**
- **Correct systemic bias and provide calibrated QPF products.**
- **Objective: accuracy (hit rate, light to heavy rain) increases 3%.**

Key issues

- Factors affecting the error of QPF and PQPF
- Identify the bias of weather systems producing precipitation and the objective bias correction
- Calibration of QPF and PQPF (grid products)

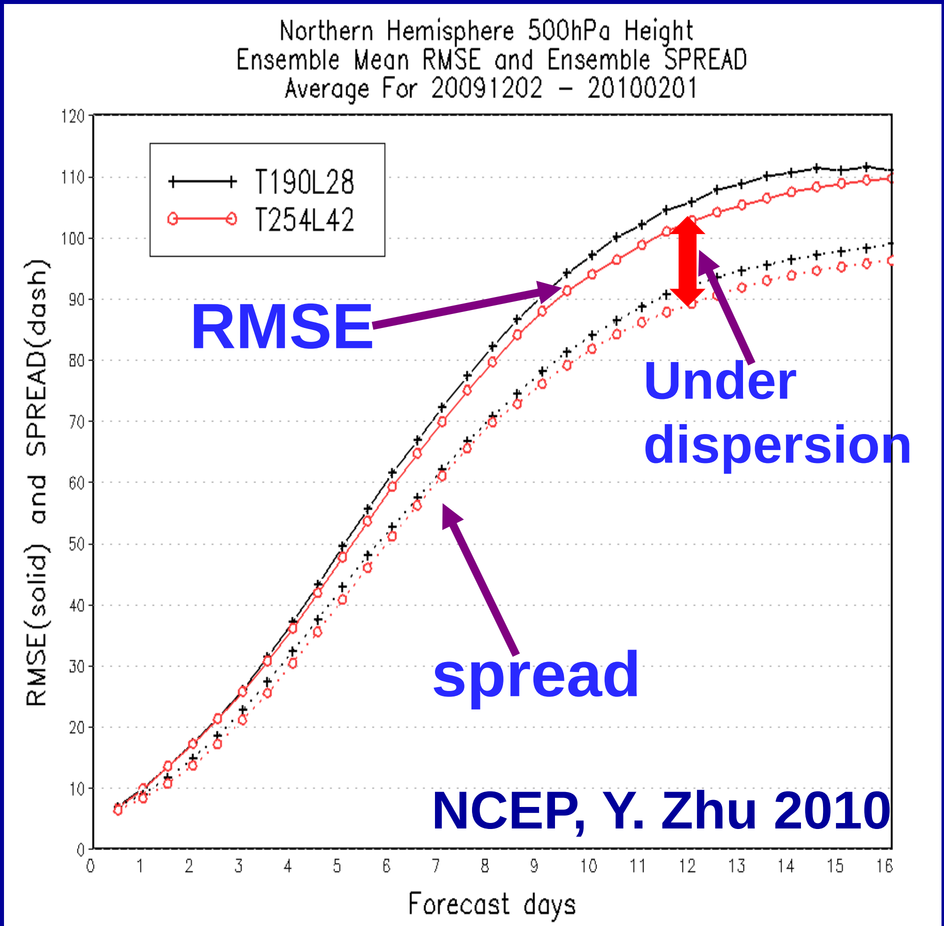
Research plan

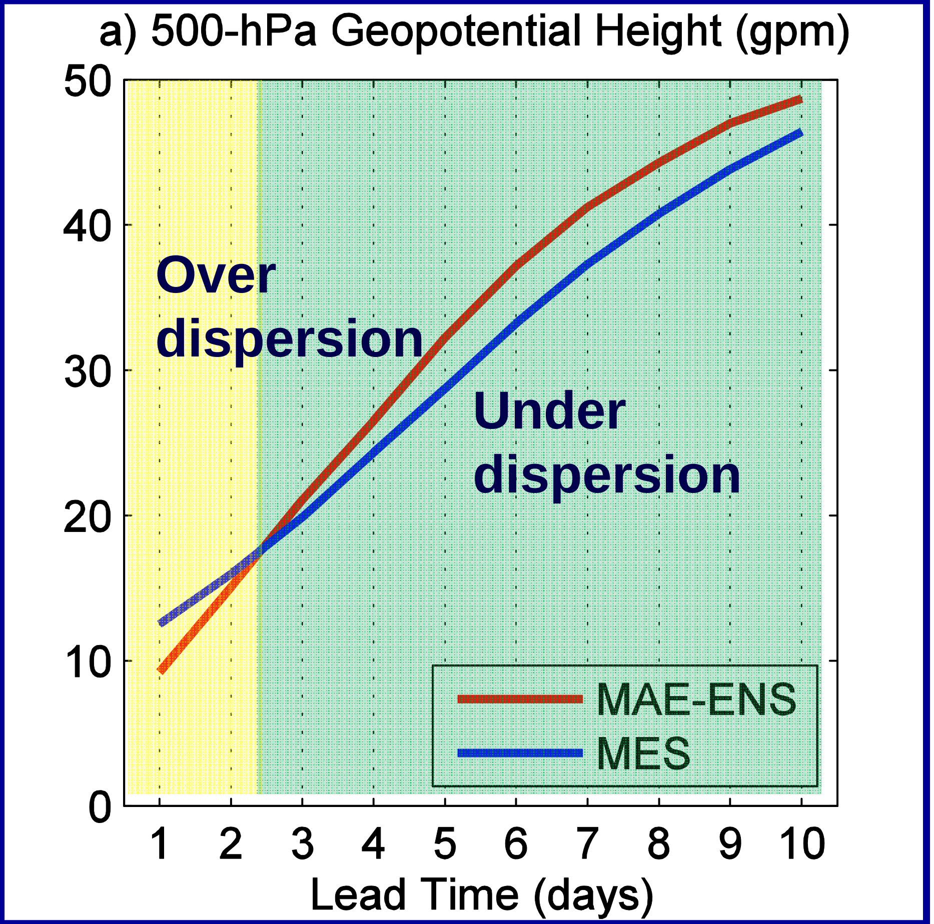


TIGGE ensemble predictions, 10 centers

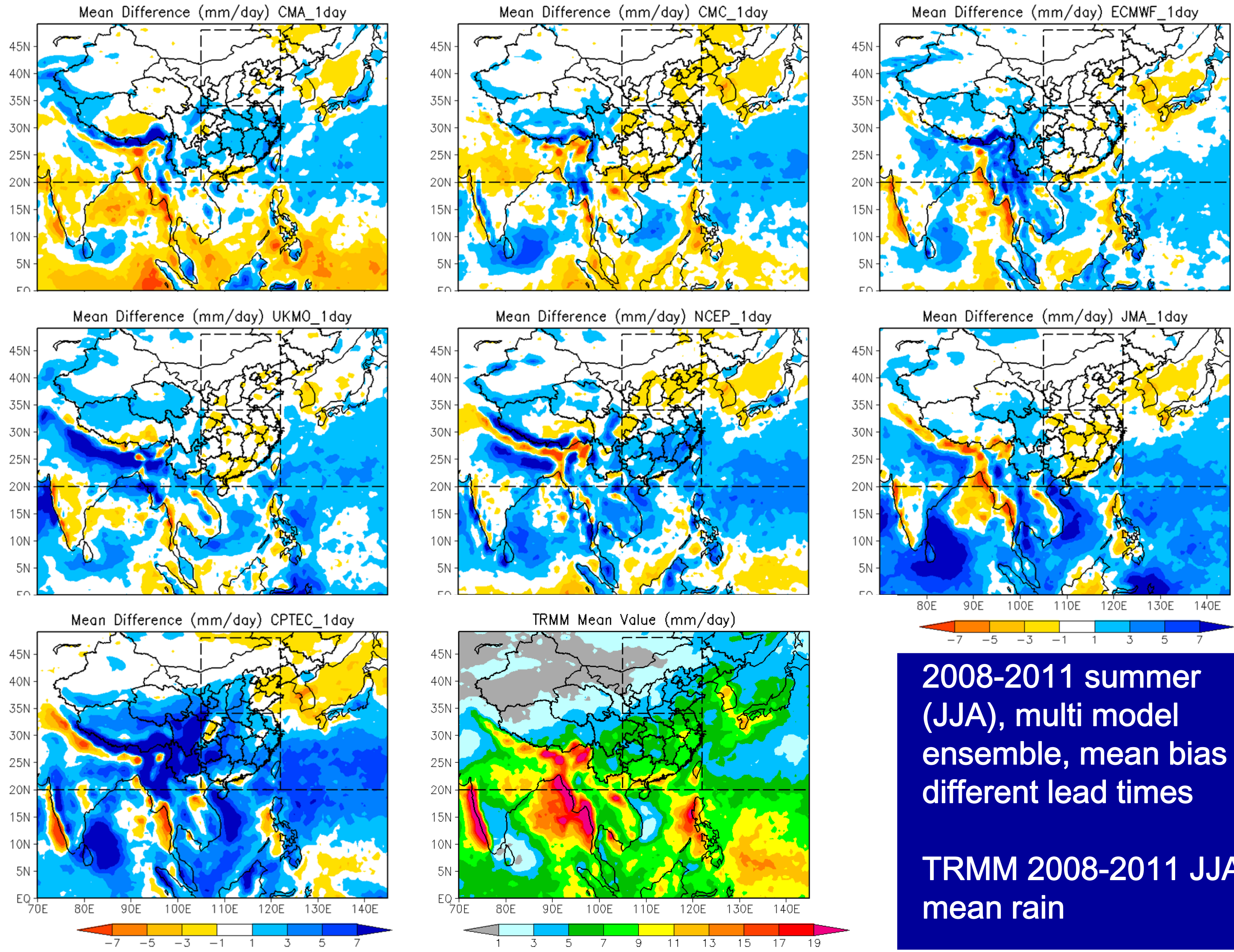
Origin	Owner	Base time	Ensemble number	Resolution	Time step	Date range for precip
BoM	Australia	00,12	32+1	1.5 * 1.5	6 to 240 by 6	2007-9-3 -> 2010-07-20
CMA	China	00,12	14+1	0.56 * 0.56	0 to 240 by 6	2007-5-15 -> today
CMC	Canada	00,12	20+1	1.0 * 1.0	6 to 384 by 6	2007-10-3 -> today
CPTEC	Brazil	00,12	14+1	0.94 * 0.94	6 to 360 by 6	2008-2-1 -> today
ECMWF	Europe	00,12	50+1	N200,N128 (-2010.1.26) N320,N160 (2010.1.27-)	0 to 240 by 6 (0-10day) 240 to 360 by 6 (10-15day)	2006-10-1 -> today
JMA	Japan	12	50+1	1.25 * 1.25	0 to 216 by 6	2006-10-1 -> today
KMA	Korea	00,12	23+1	1.25 * 1.25 (-2010.11.30) 0.56 * 0.38 (2011.8.1-)	0 to 252 by 6	2009-12-18 -> 2010.11.30 2011.8.1 -> today
MeteoFrance	France	06,18	34+1	1.5 * 1.5	6 to 72 by 6 (06) 6 to 108 by 6 (18)	2009-12-8 -> today (06) 2007-10-25 -> today (18)
NCEP	USA	00,06,12,18	20+1	1.0 * 1.0	0 to 384 by 6	2007-3-19 -> today
UKMO	United Kingdom	00,12	23+1	1.25 * 0.83 (-2010.3.8) 0.83 * 0.56 (2010.3.9-)	0 to 360 by 6	2006-10-1 -> today

Spread-skill relationship





CMA（Song, Yuan, et al. 2011）



2008-2011 summer (JJA), multi model ensemble, mean bias different lead times

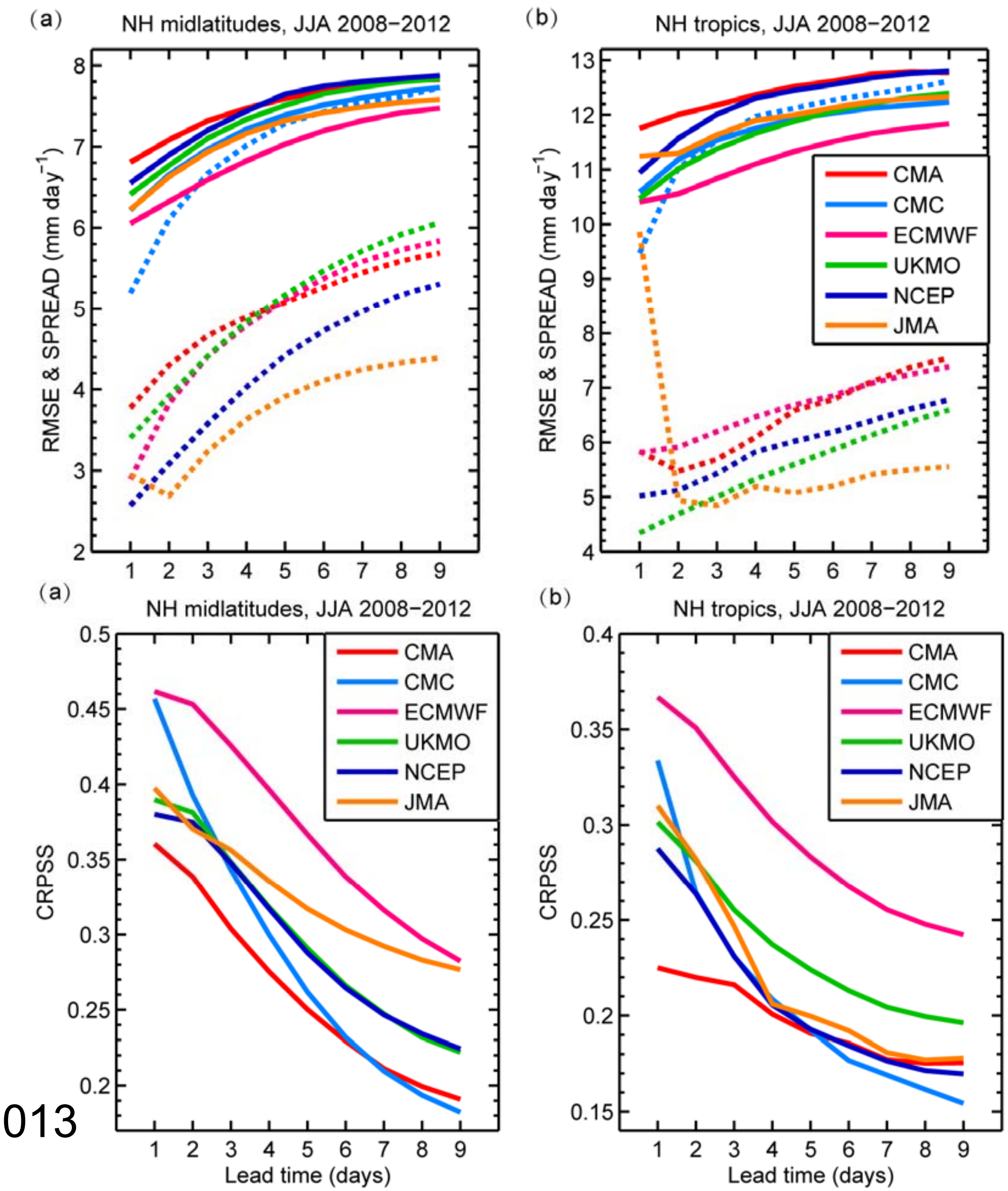
TRMM 2008-2011 JJA , mean rain

Spread-skill relationship and the CRPSS

Spread-skill

JMA has large spread in the NH Tropics for the day +1 fcsts, and low spread for other lead times

All EPSs suffer from deficiency of ensemble spread except CMC



Su, Xiang et al. 2013

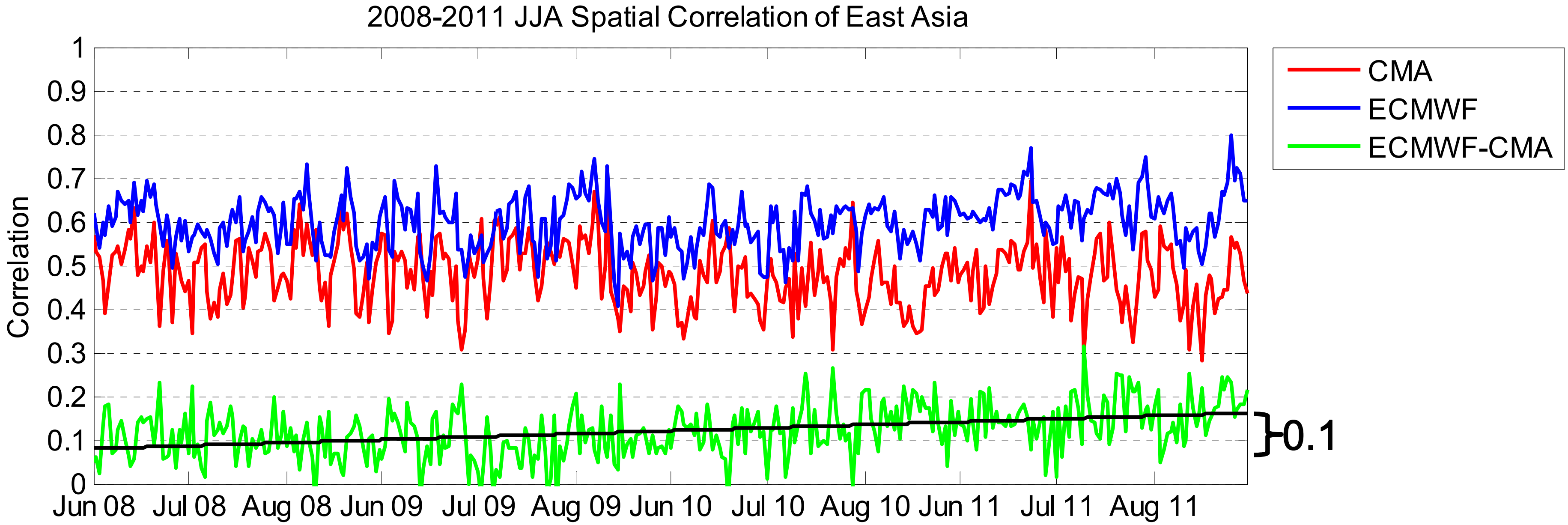
CRPSS

EC best

CMC drops rapidly with the increasing of lead time

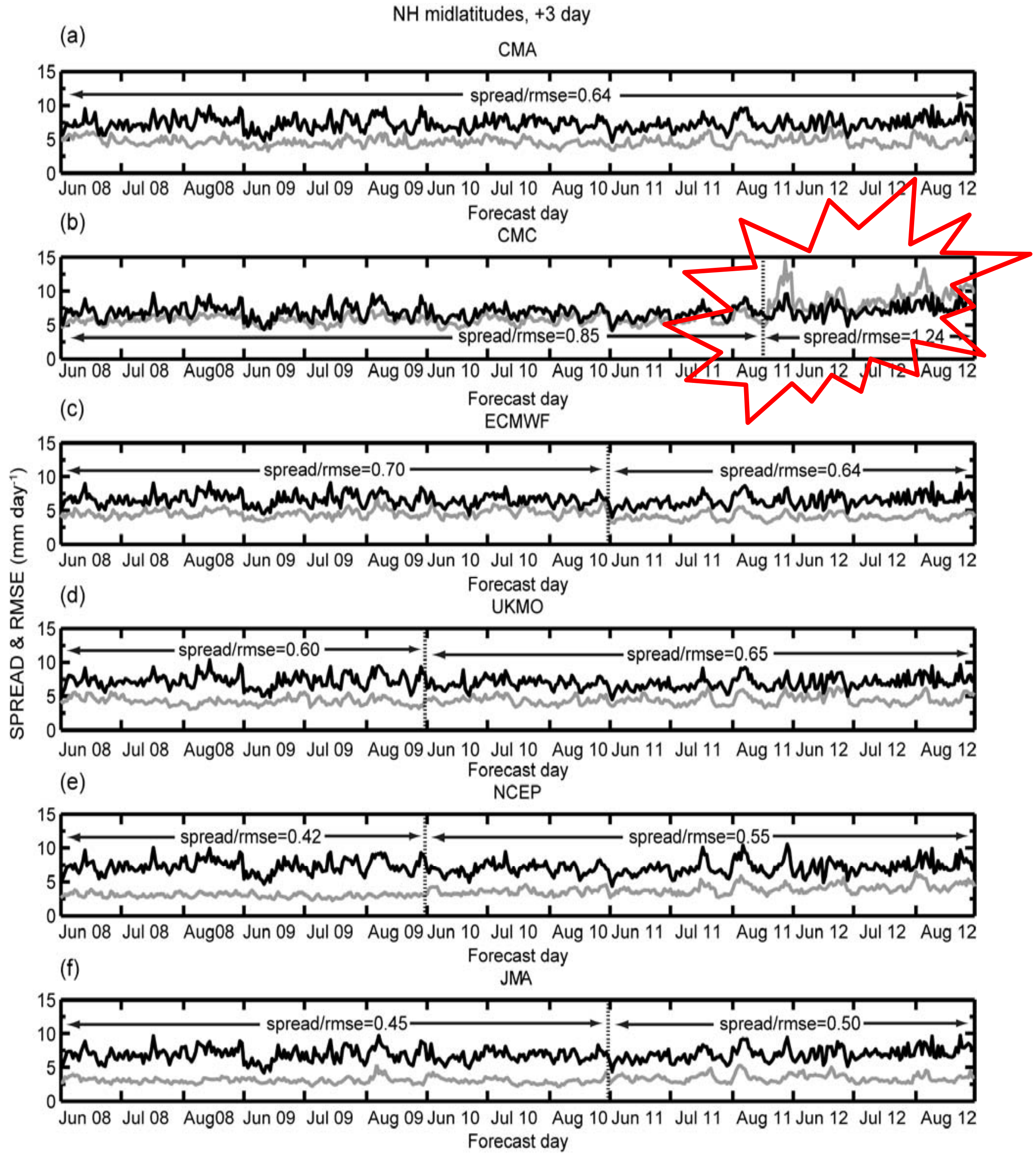
CMA worst in the NH Tropics

Time series of spatial correlation

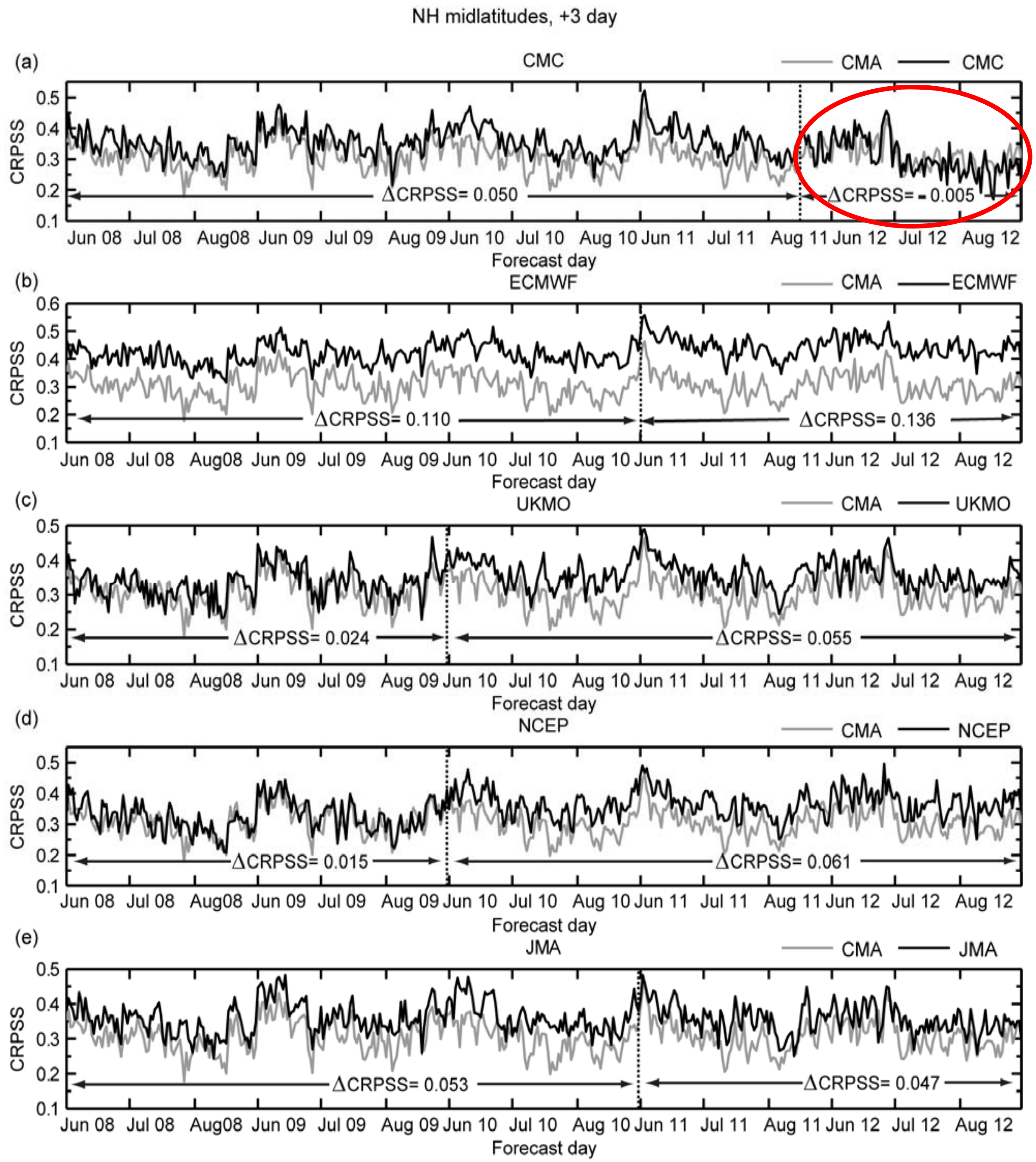


With the upgrade of ECMWF, the difference of skill between ECMWF and CMA increases about 0.1 over 4 years.

Spread/RMSE ratio changes due to model upgrade



CRPSS changes due to model upgrade



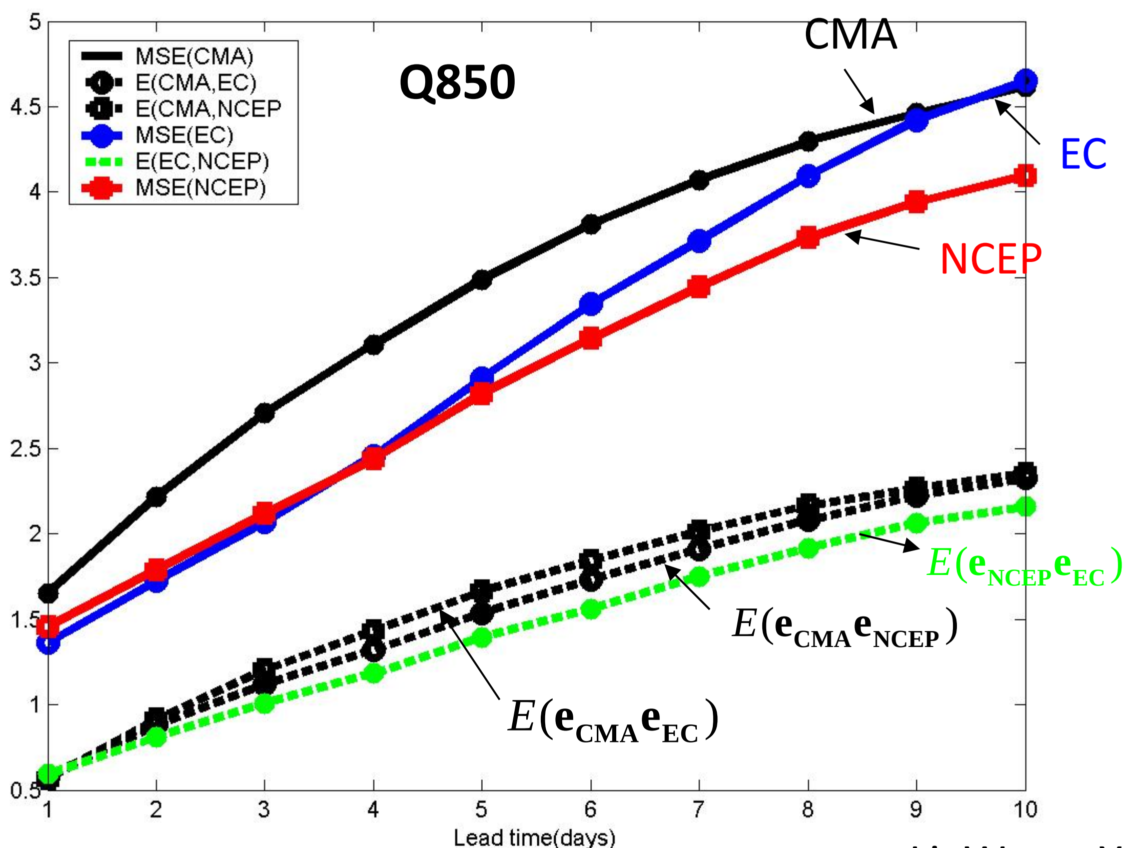
Forecast skill of multi-center ensemble

$$R^{*2} = \frac{1}{9}(R^2_{cma} + R^2_{ec} + R^2_{ncep}) + \frac{2}{9}[E(\mathbf{e}_{\mathbf{cma}}\mathbf{e}_{\mathbf{ec}}) + E(\mathbf{e}_{\mathbf{cma}}\mathbf{e}_{\mathbf{ncep}}) + E(\mathbf{e}_{\mathbf{ec}}\mathbf{e}_{\mathbf{ncep}})]$$

Ensemble mean, MSE

Individual center, MSE

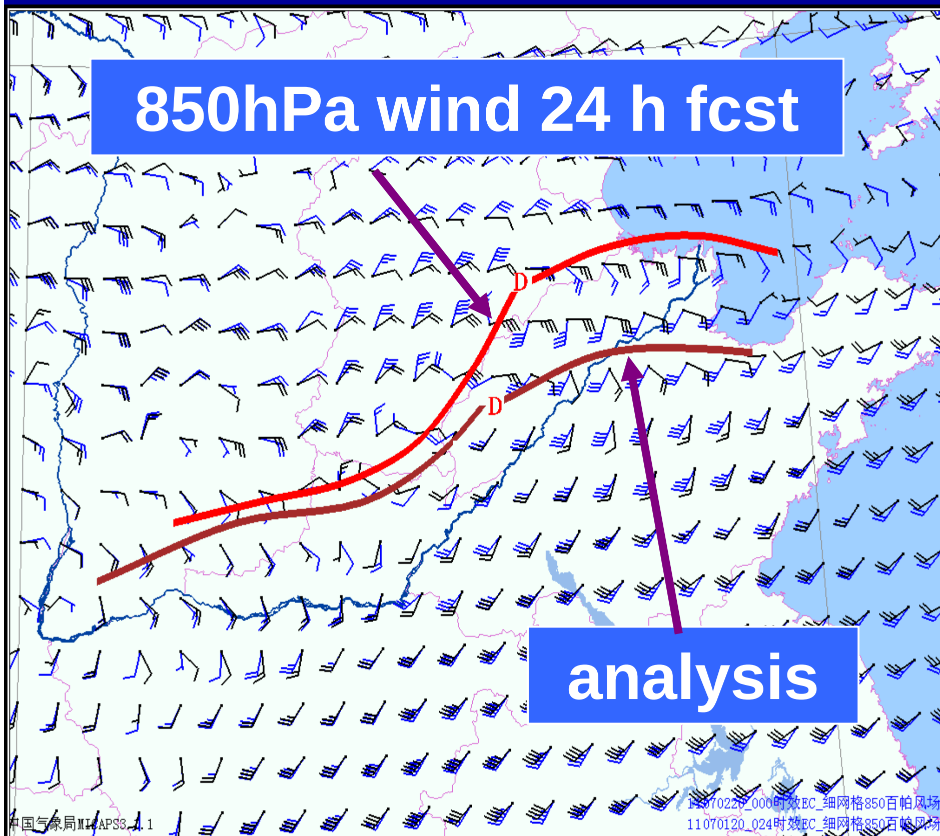
Covariance of two centers

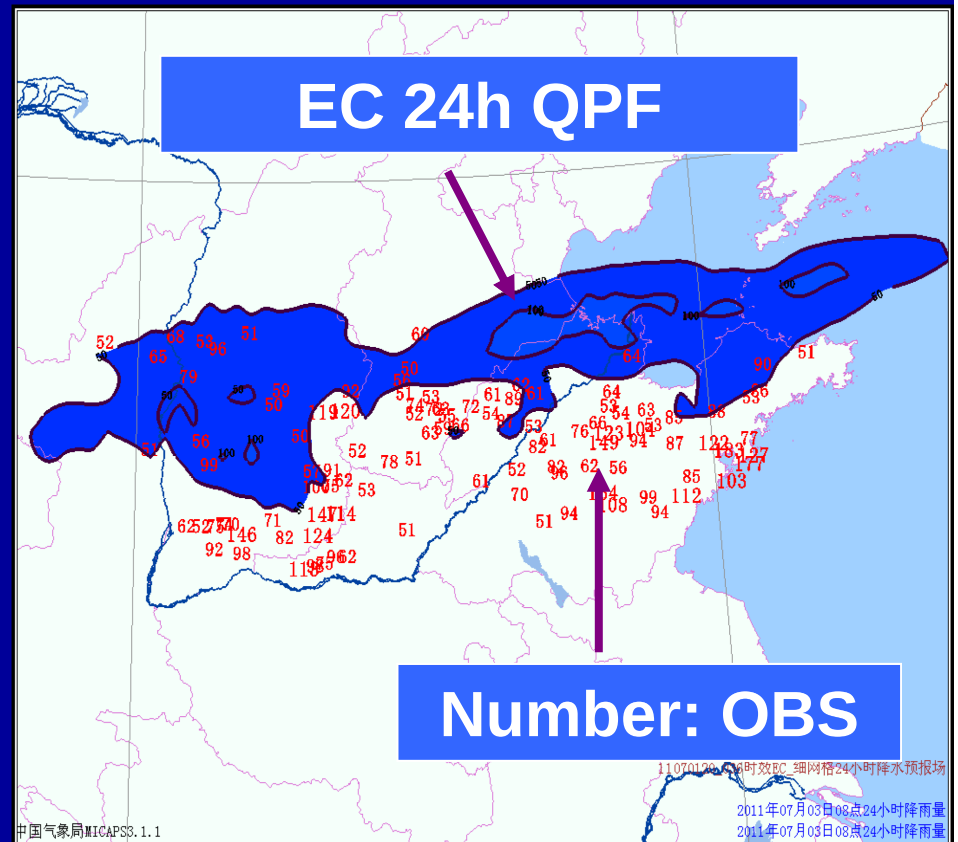


Li, Wang, Yuan 2012

Objective analysis of precipitation systems and bias correction

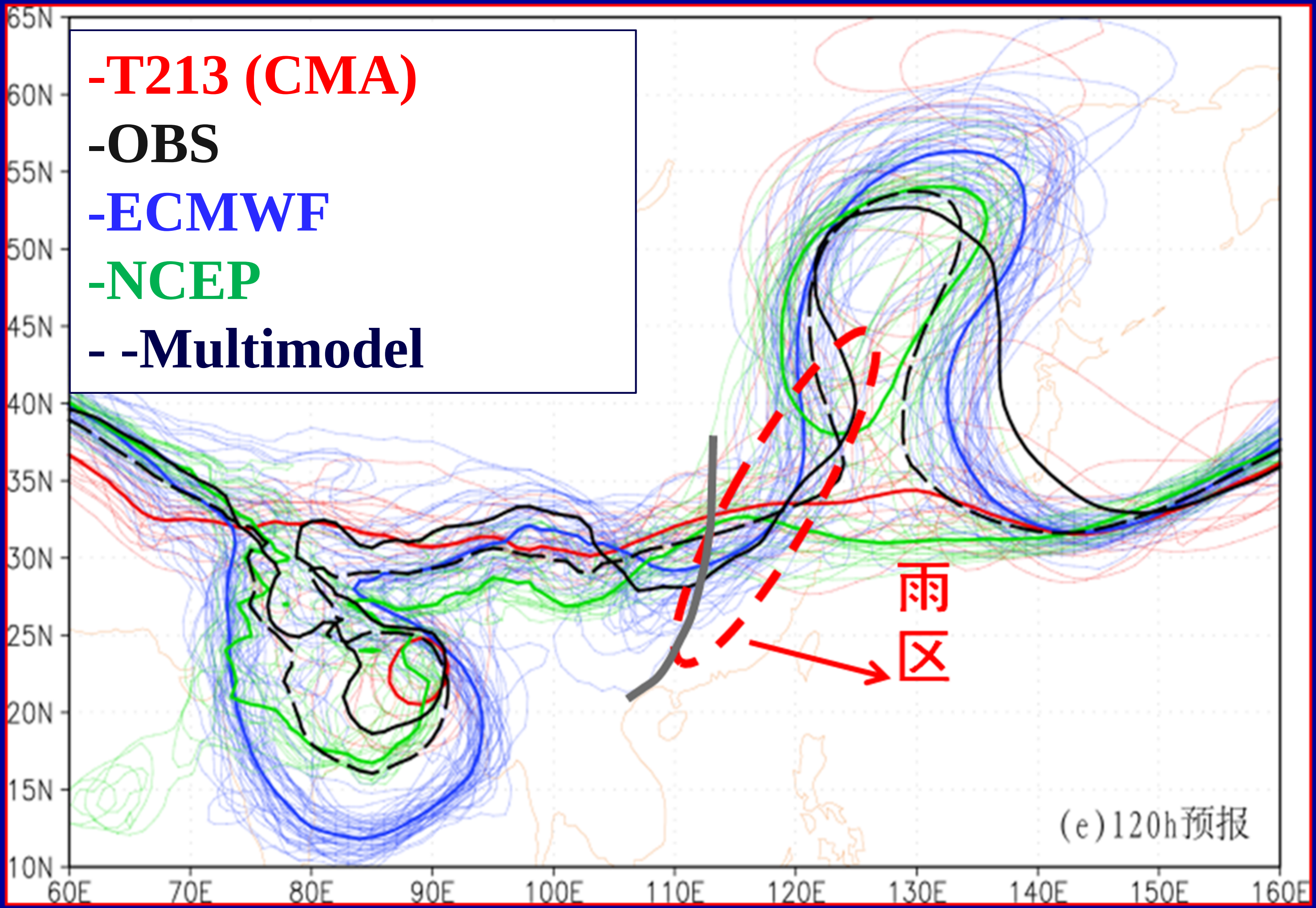
07/03/2011, ECMWF fcst and obs





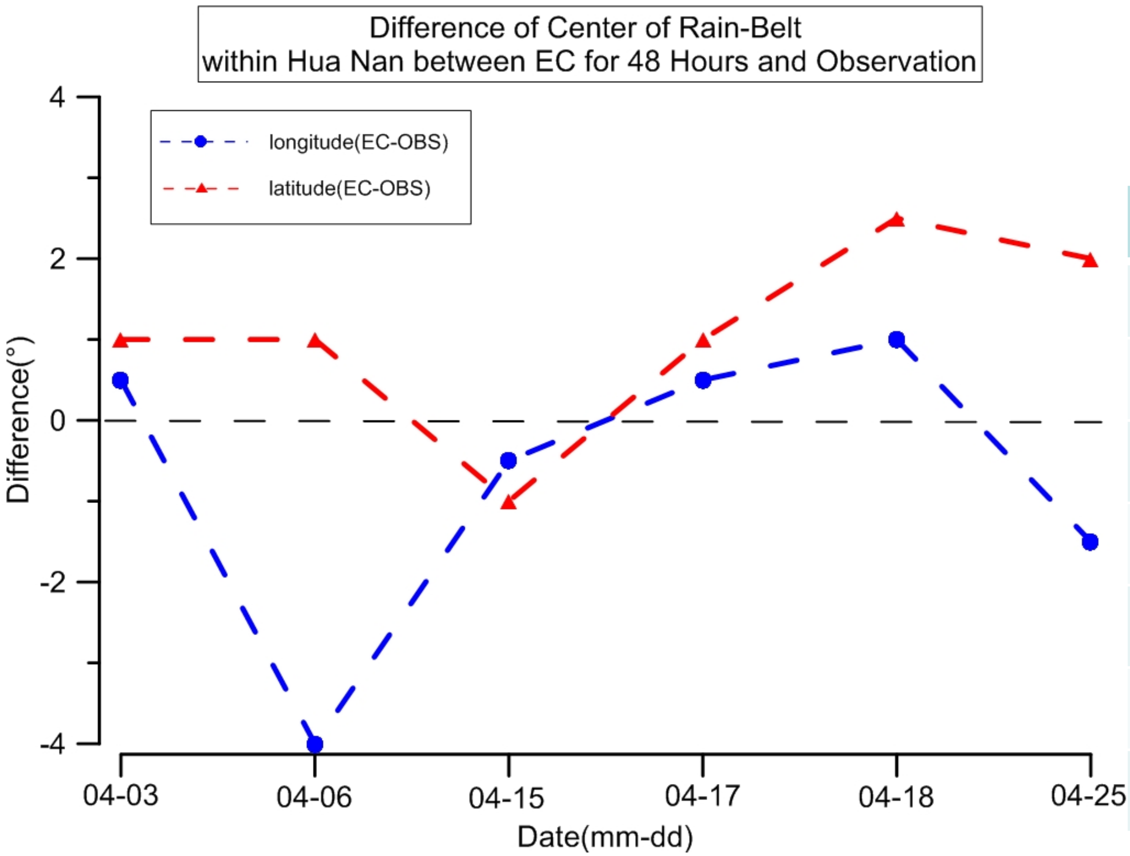
Provided by Huang, Xiaoyu

Predictability of precipitation systems



(Chen, S., H. Yuan et al., 2011)

Displacement errors of large precipitation bands：South China

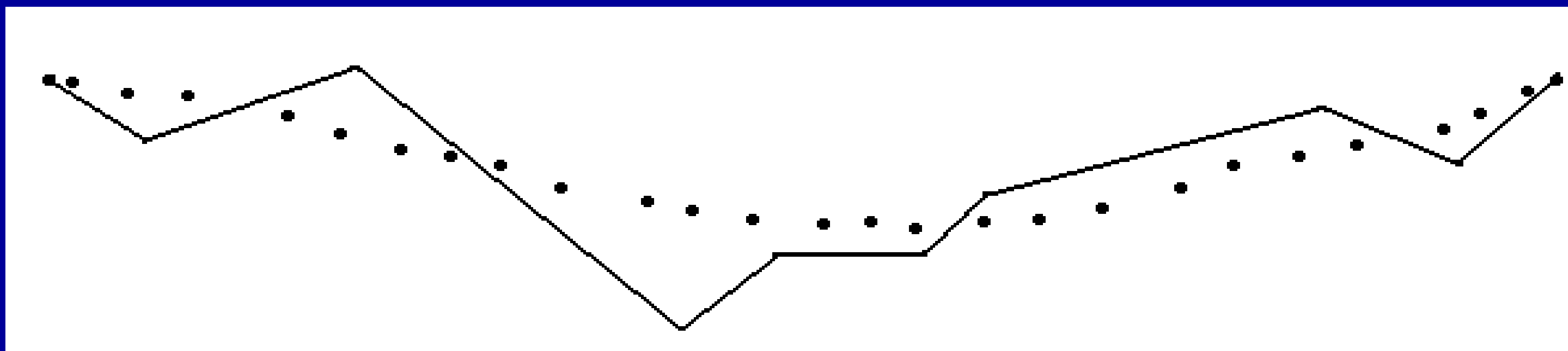


Date	Long	Lat
4月3日	E,0.5	N,1.0
4月6日	W,-4.0	N,1.0
4月15日	W,-0.5	S,-1.0
4月17日	E,0.5	N,1.0
4月18日	E,1.0	N,2.5
4月25日	W,-1.5	N,2.0
Ave	W,-0.7	N,1.1

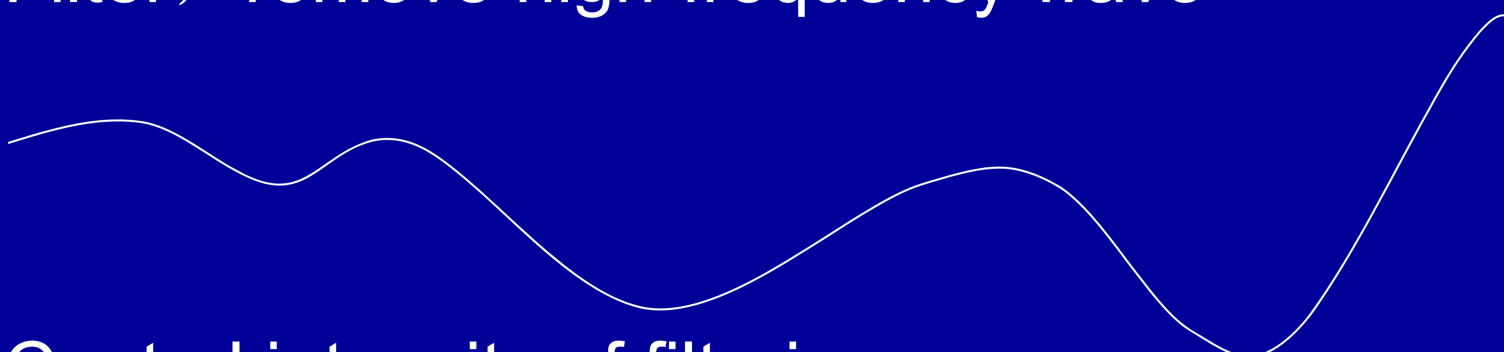
Difference (of longitude or latitude) = EC – OBS

Dai et al. 2013

Example：trough

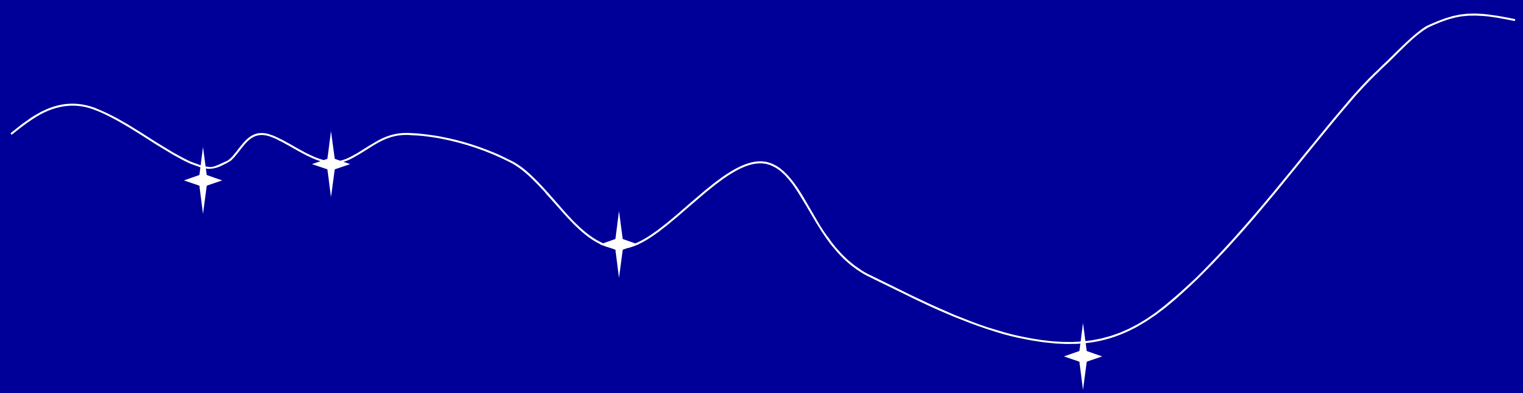


- Filter，remove high-frequency wave



- Control intensity of filtering

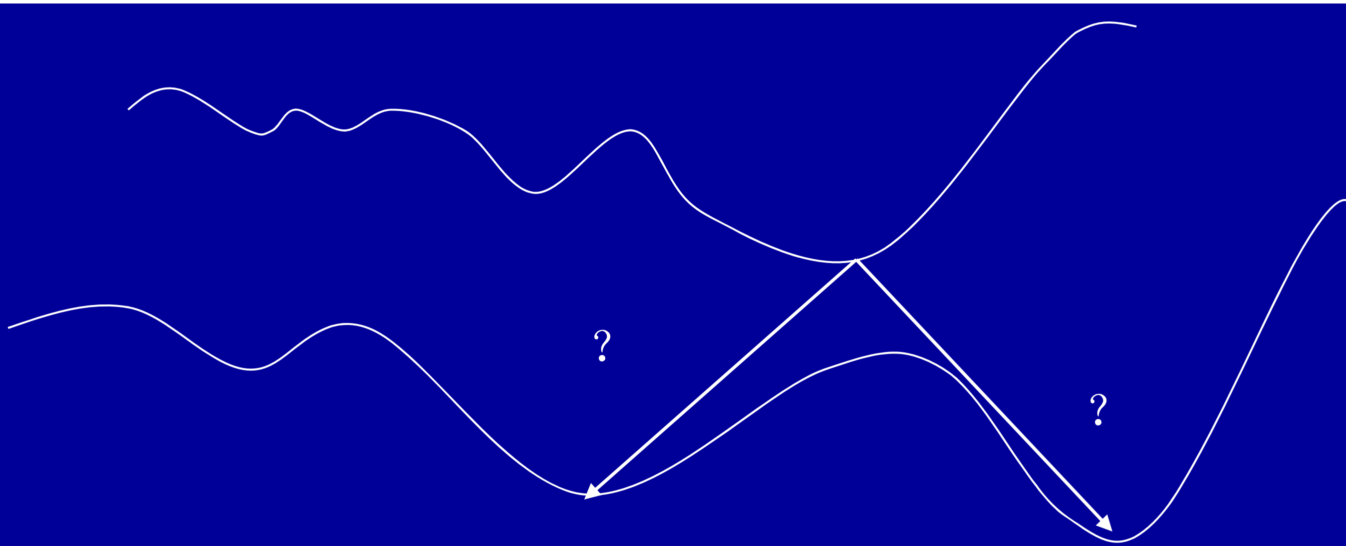
Hu et al. 2013



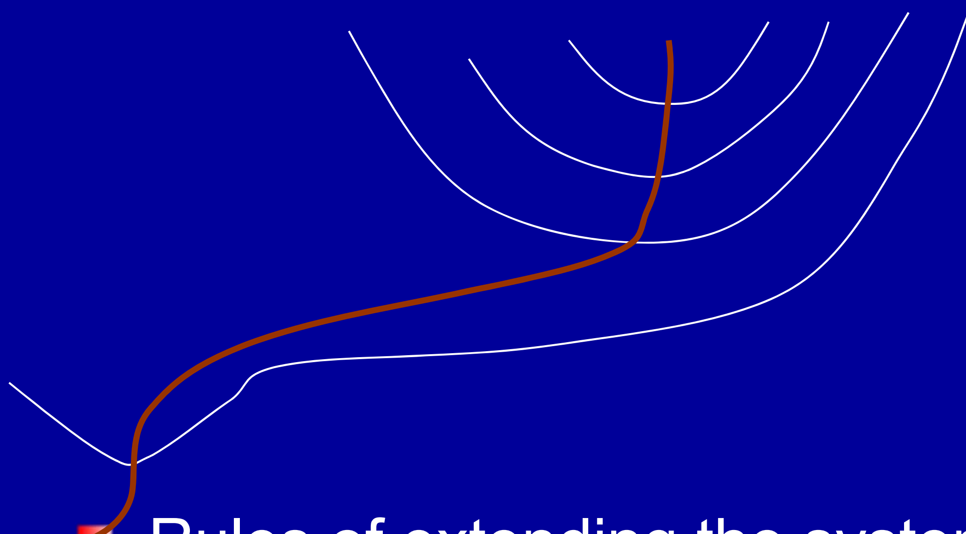
- Obtain a series of nodes

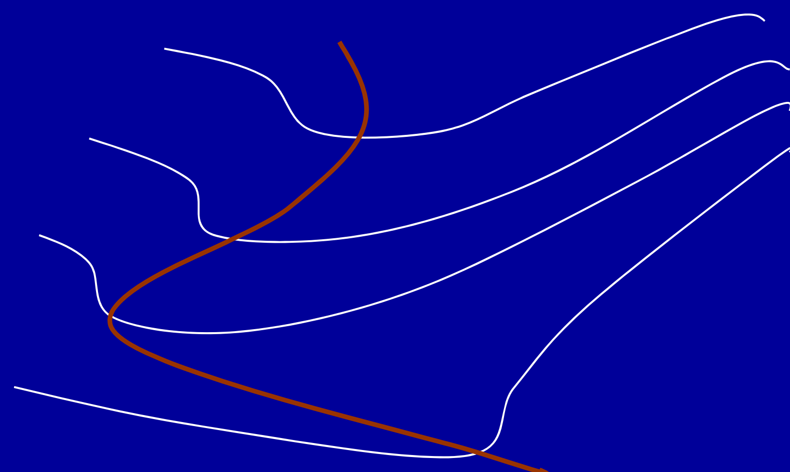
- Identify effective nodes

Hu et al. 2013

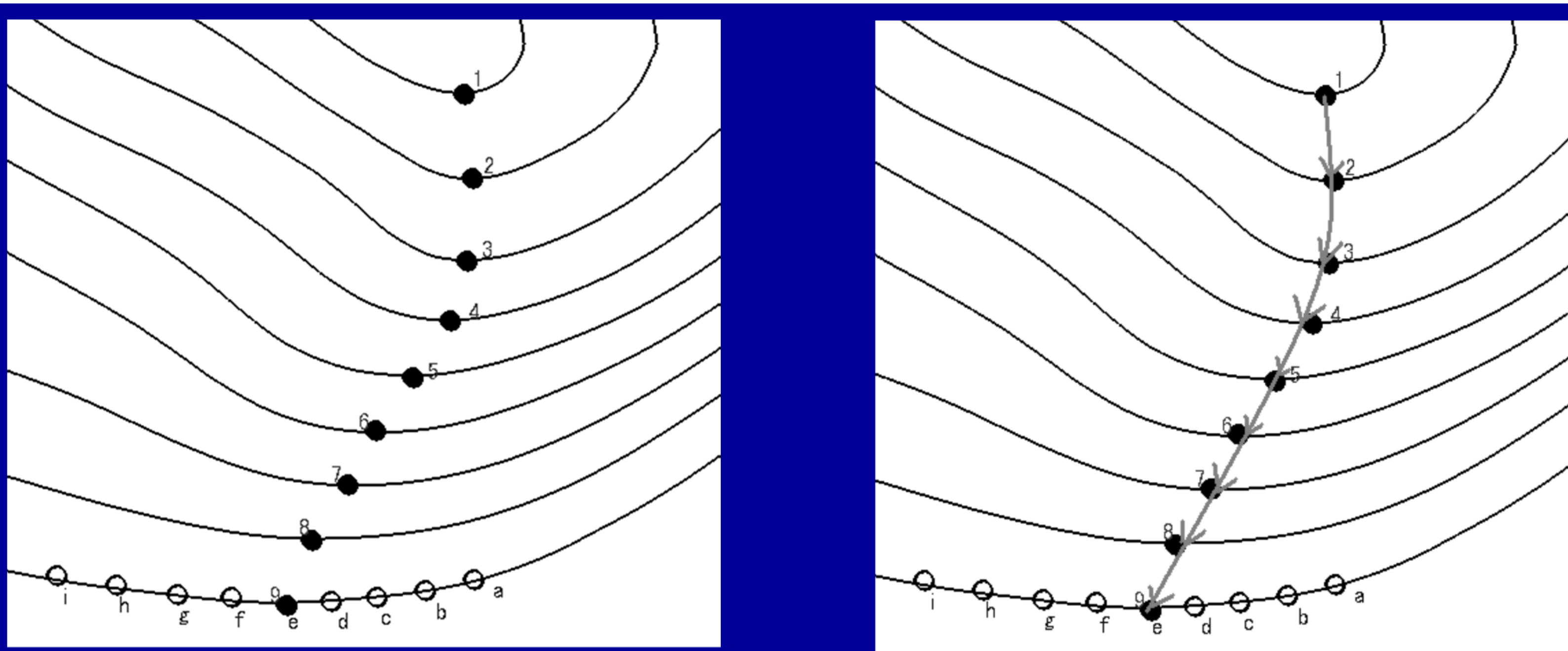


- Scientific organization

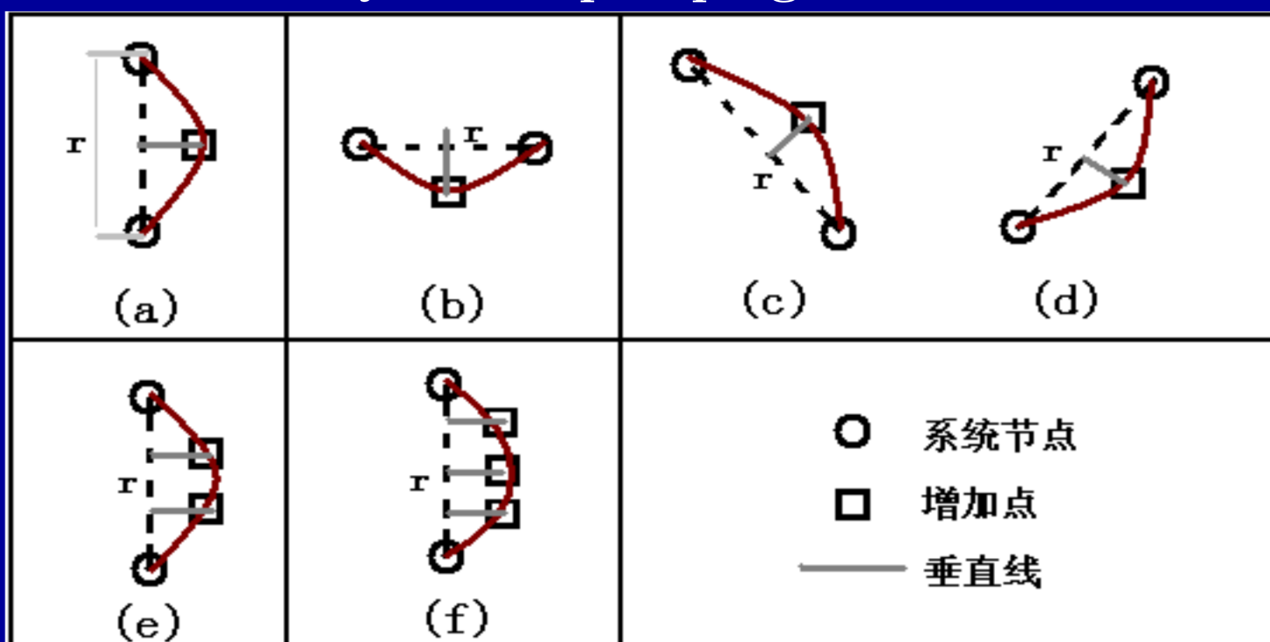




- Rules of extending the system
- Synoptic constrain



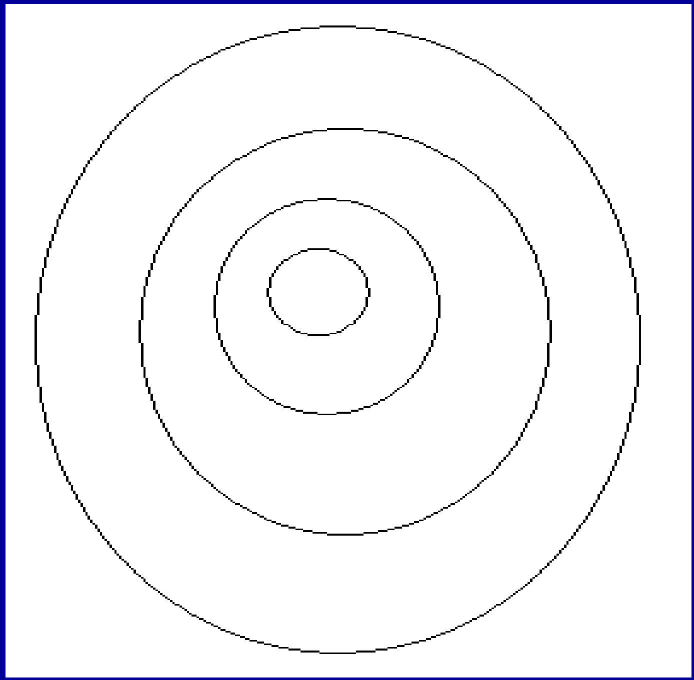
The system propagation

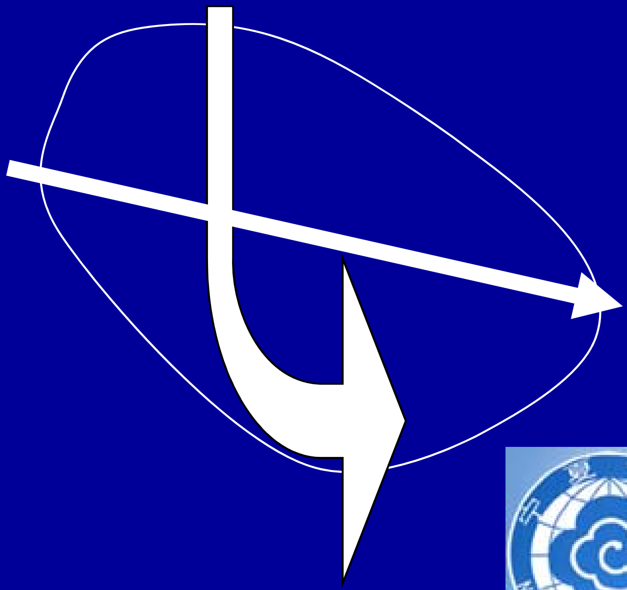


Processing short wave

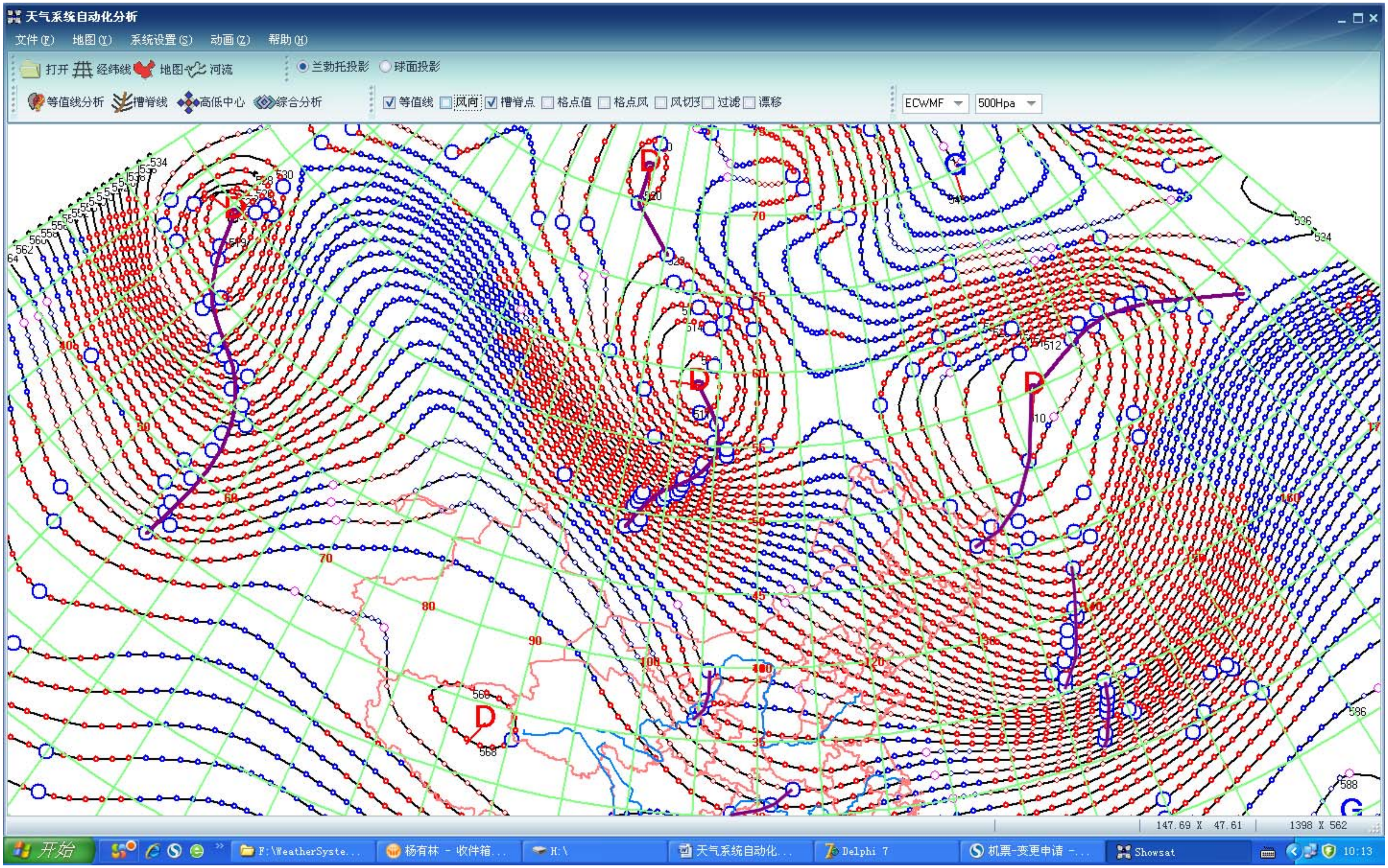
- Closed systems
  - center
  - initial and ending closed zones
  - intensity
  - location
  - speed, direction
- Jet
  - long axis
  - centroid
  - jet stream core
  - area

Hu et al. 2013





Products: Trough, ridge, and nodes, high (G) and low (D) centers（Red: trough region，Blue: ridge region，○: possible nodes）



Calibration Methods of QPF and PQPF

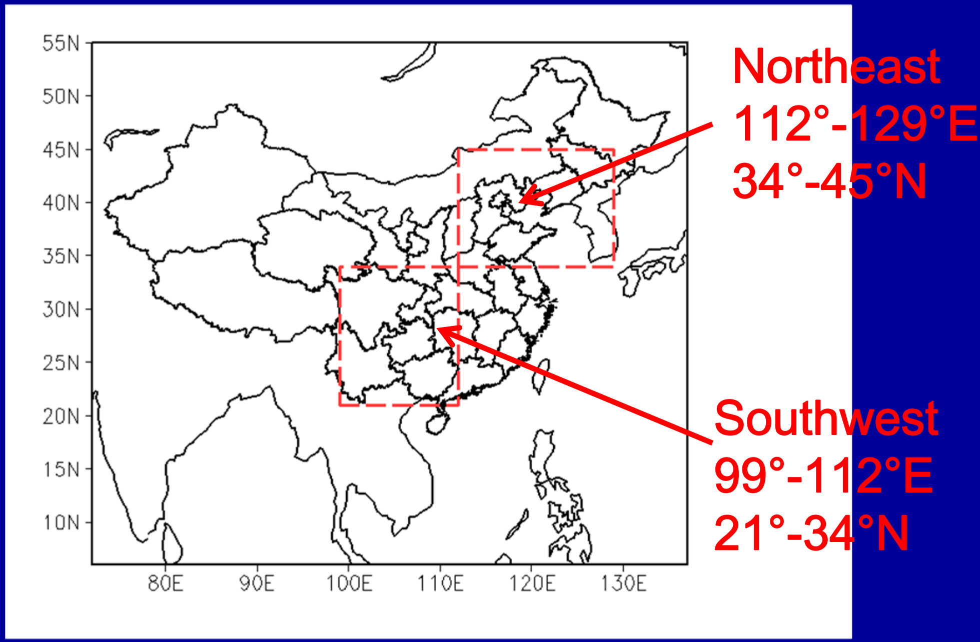
e.g., MOS， Kalman Filter，Frequency matching， Regression， ANN， rank， Analog，Ingredient _based，Bayesian Model Averaging …

Model output:

T639、T213 ensemble、NCEP、ECMWF、JMA and so on

CDF calibration

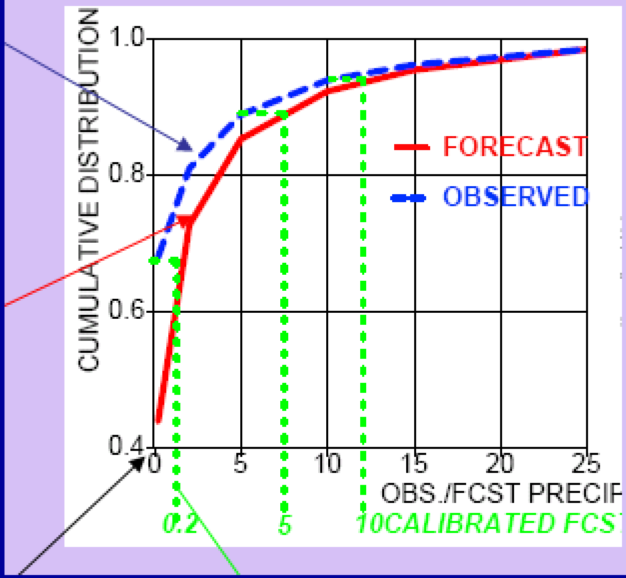
- ECMWF fcsts (0.5° × 0.5°)
- OBS：gauges
- training：2013.07-2013.08
- validation：2013, 9.1-9.26



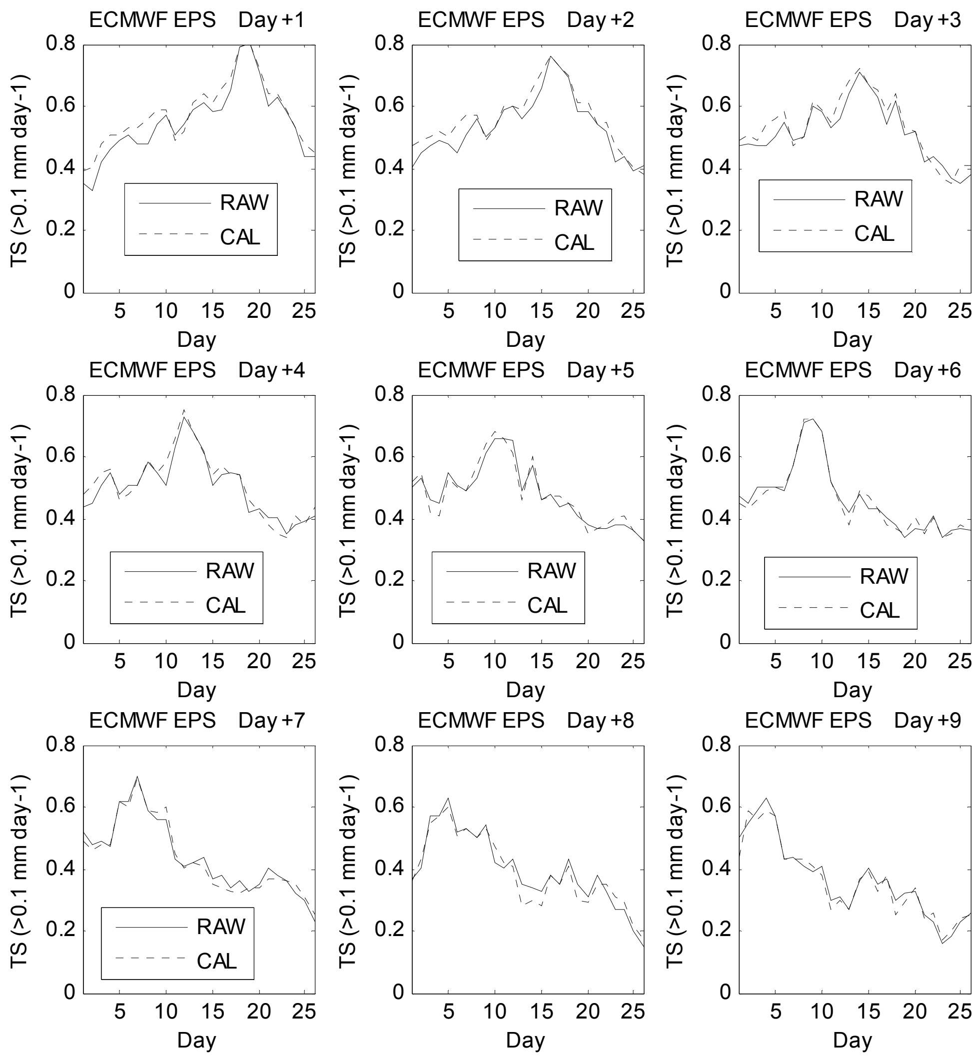
NCEP CDF decaying

$$\overline{CDF}_j = (1-W) * \overline{CDF}_{j-1} + W * CDF_j$$

Frequency match algorithm



Statistical verification for the recent outputs

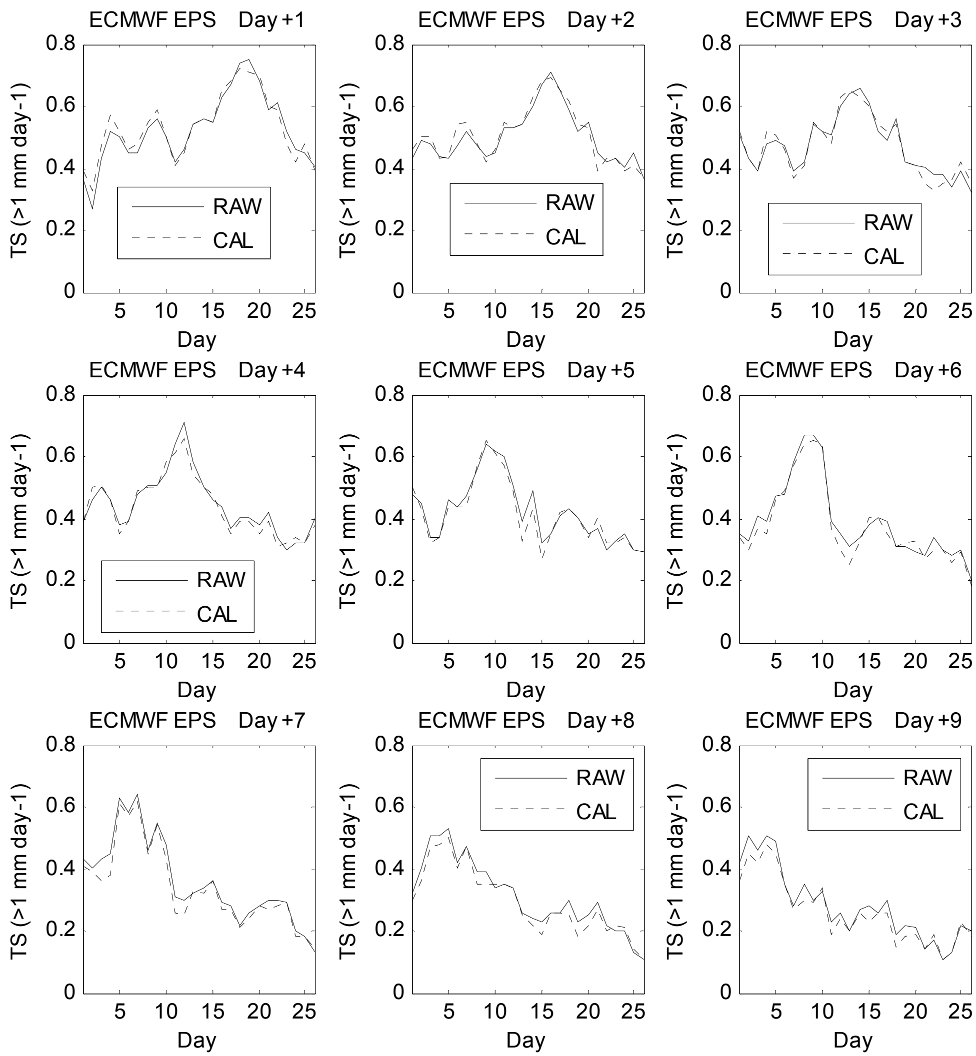


TS (>0.1mm day^{-1})

Lead	RAW	CAL
1	0.55	0.58
2	0.54	0.56
3	0.52	0.54
4	0.50	0.51
5	0.48	0.48
6	0.46	0.46
7	0.44	0.43
8	0.40	0.39
9	0.37	0.36

Su and Yuan, 2013

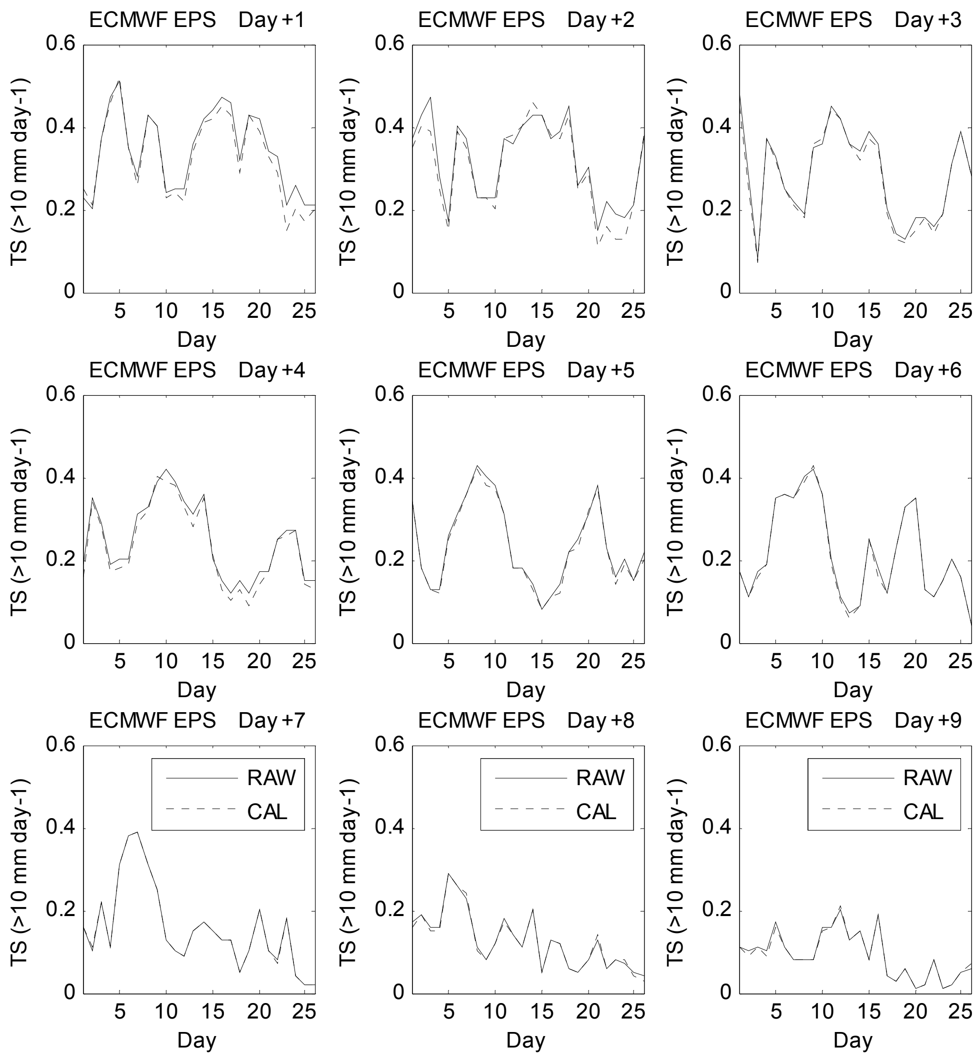
Statistical verification for the recent outputs



TS (>1.0mm day^{-1})

Lead	RAW	CAL
1	0.52	0.53
2	0.50	0.51
3	0.47	0.47
4	0.45	0.44
5	0.42	0.41
6	0.39	0.38
7	0.36	0.34
8	0.31	0.30
9	0.28	0.26

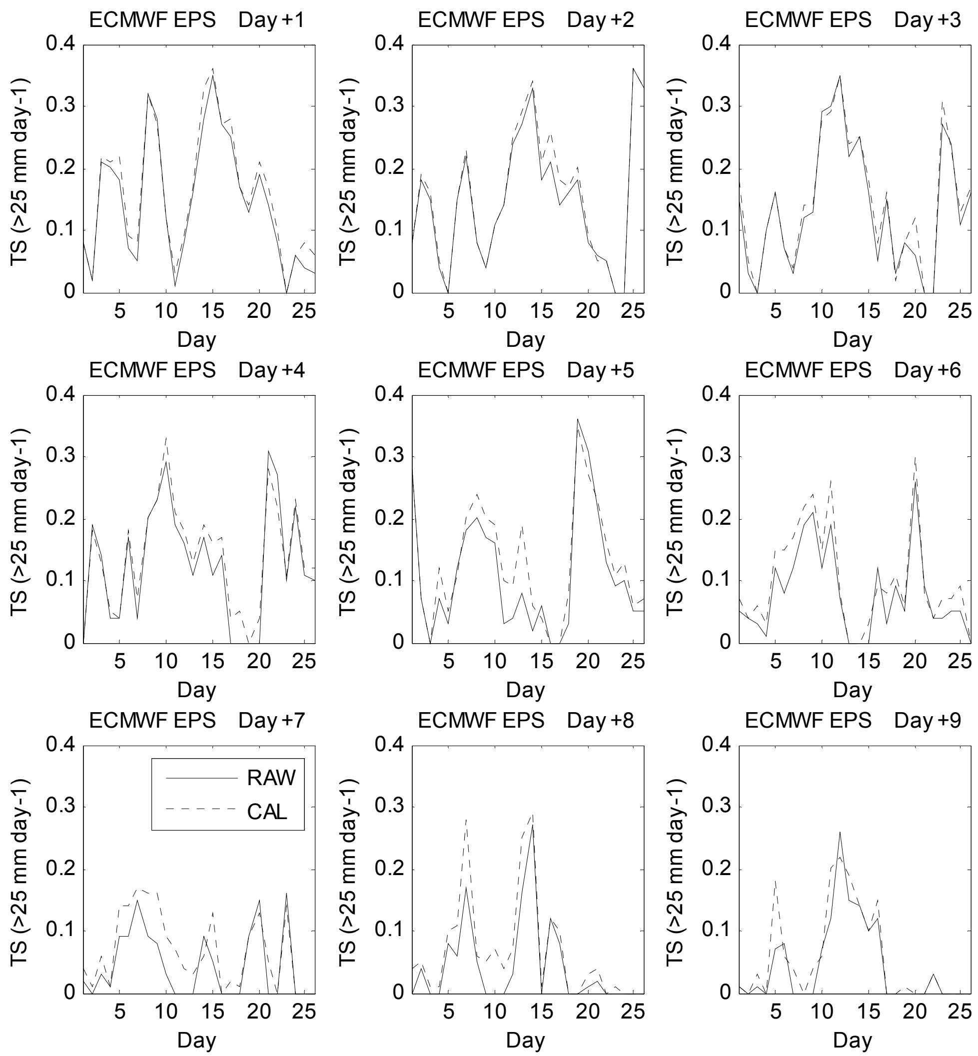
Statistical verification for the recent outputs



TS (>10 mm day^{-1})

Lead	RAW	CAL
1	0.34	0.32
2	0.32	0.30
3	0.28	0.28
4	0.25	0.23
5	0.24	0.23
6	0.22	0.21
7	0.16	0.16
8	0.13	0.13
9	0.09	0.09

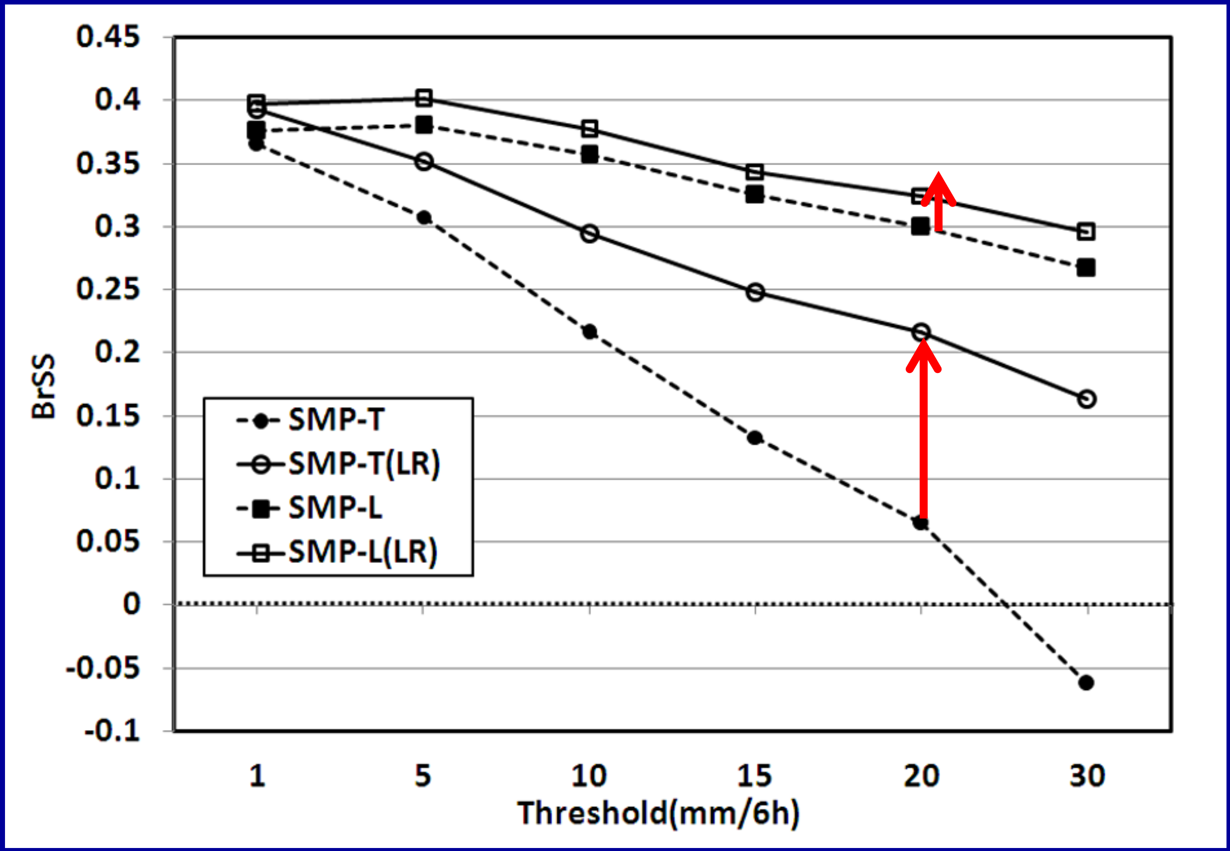
Statistical verification for the recent outputs



TS (>25 mm day^{-1})

Lead	RAW	CAL
1	0.15	0.16
2	0.15	0.16
3	0.14	0.15
4	0.13	0.14
5	0.11	0.13
6	0.08	0.10
7	0.04	0.07
8	0.04	0.07
9	0.04	0.06

Linear regression of PQPF

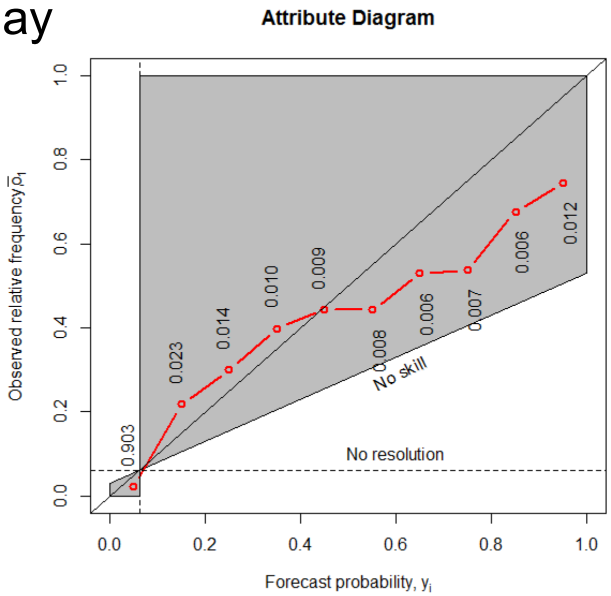


Typhoon cases in Taiwan area

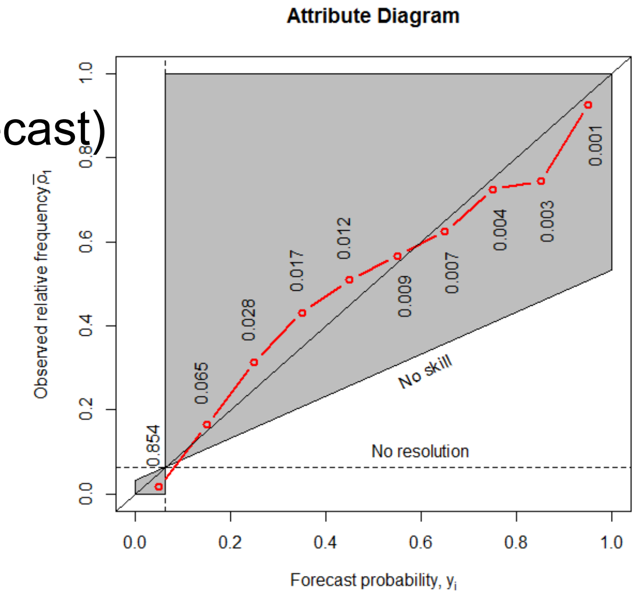
(Chang, Yuan, and Lin 2012, MWR)

Logistic regression

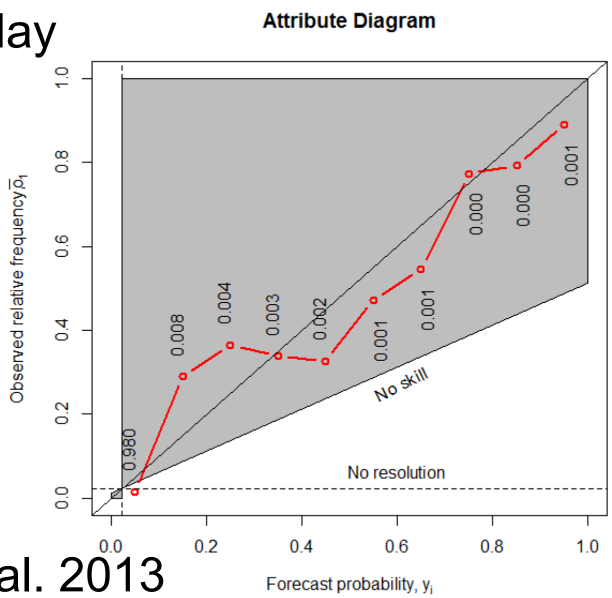
25mm/1day
Original



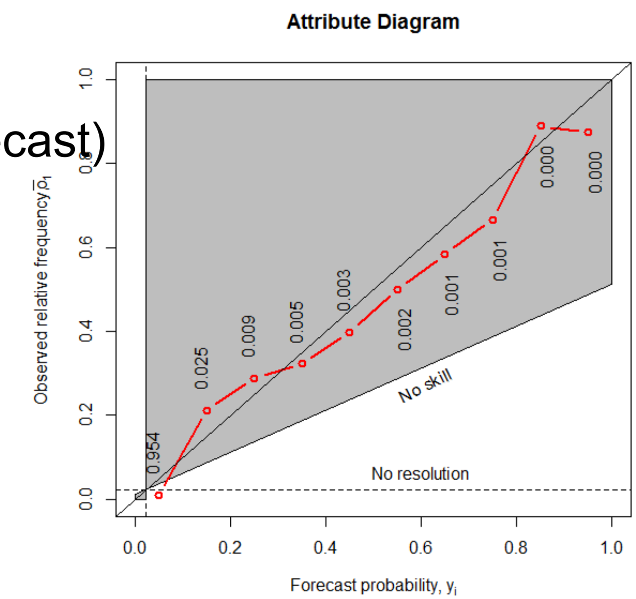
25mm/1day
Calibrated
(history forecast)



50mm/1day
Original



50mm/1day
Calibrated
(history forecast)



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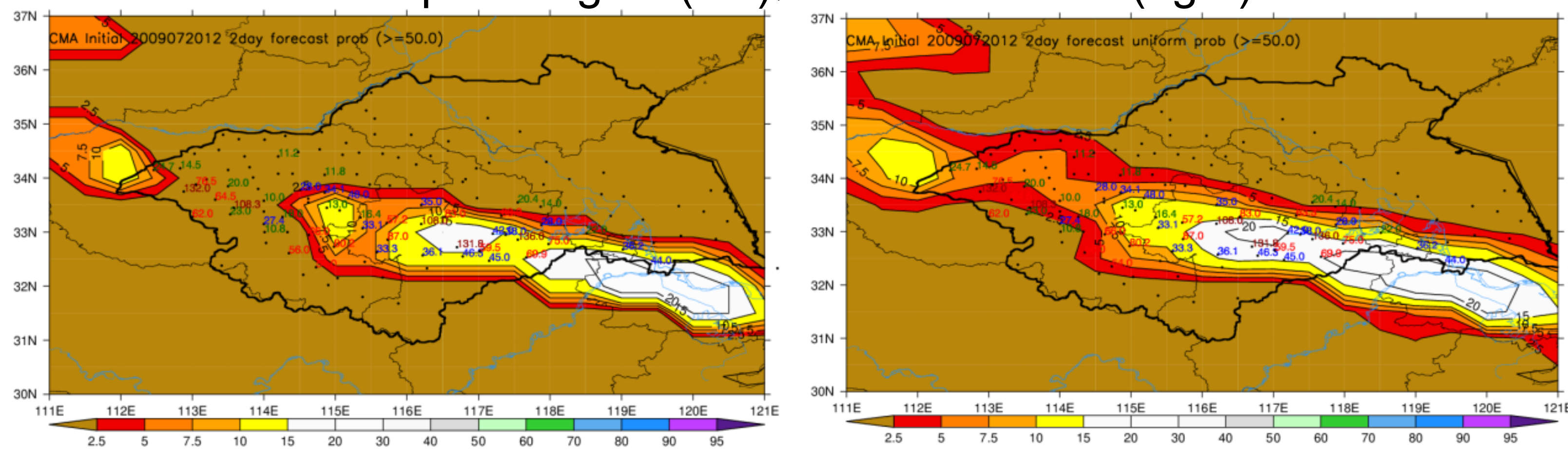
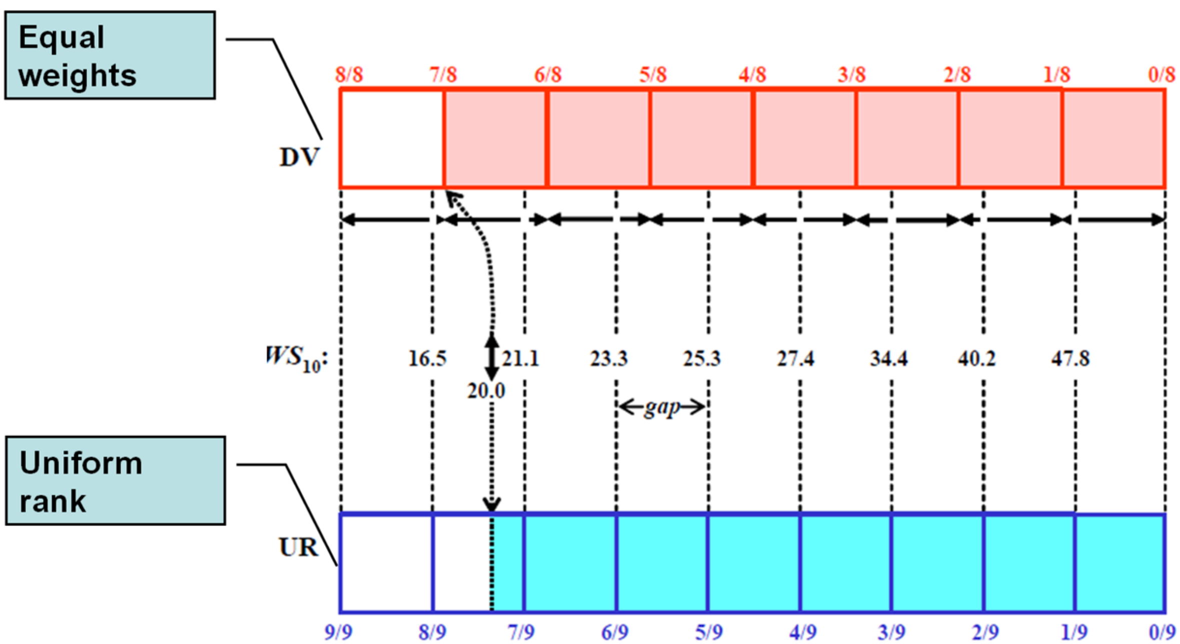
PQPF by Uniform Rank

Equal weights (left)， Uniform Rank (right)





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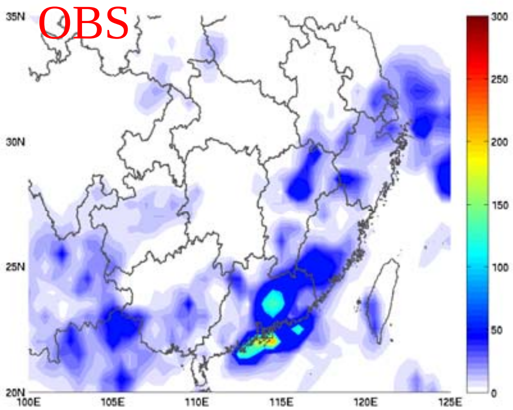
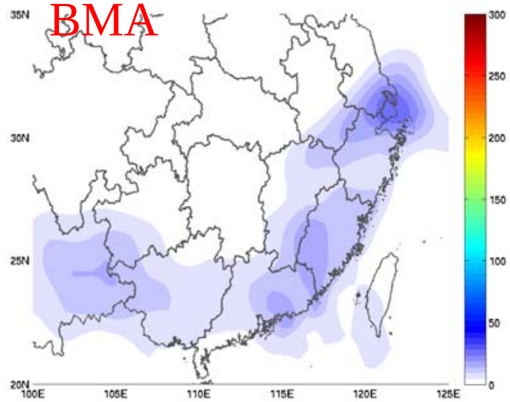
BMA Calibration

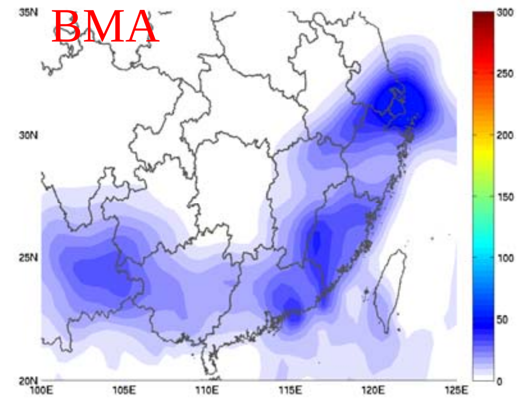
CMA



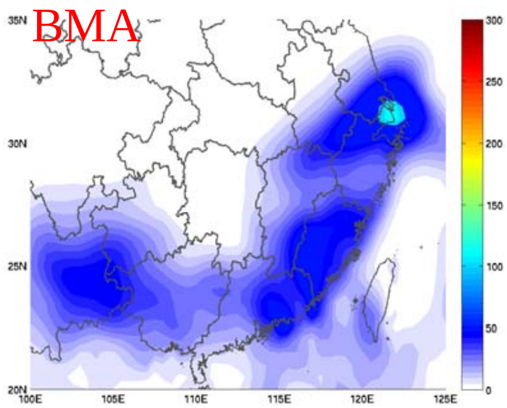
TRMM 20080626 12UTC h mm/24h



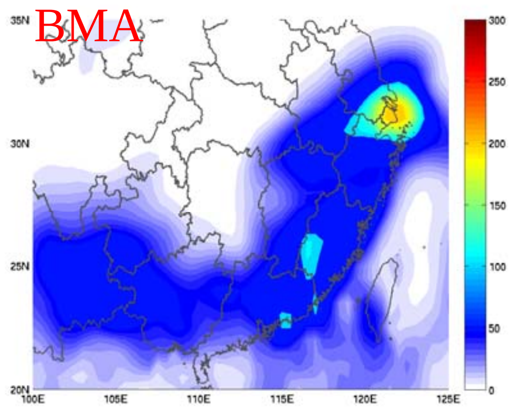
BMA50%CDF，2008062612， 24h



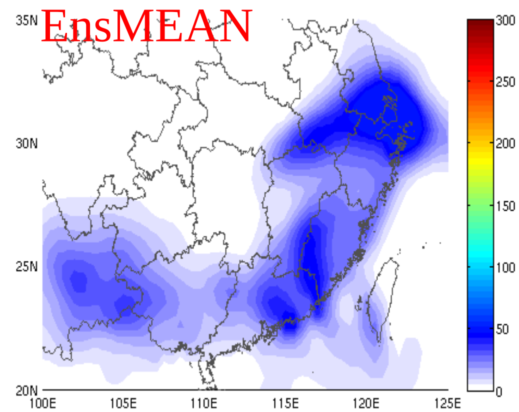
BMA70%CDF，2008062612， 24h



BMA80%CDF，2008062612， 24h



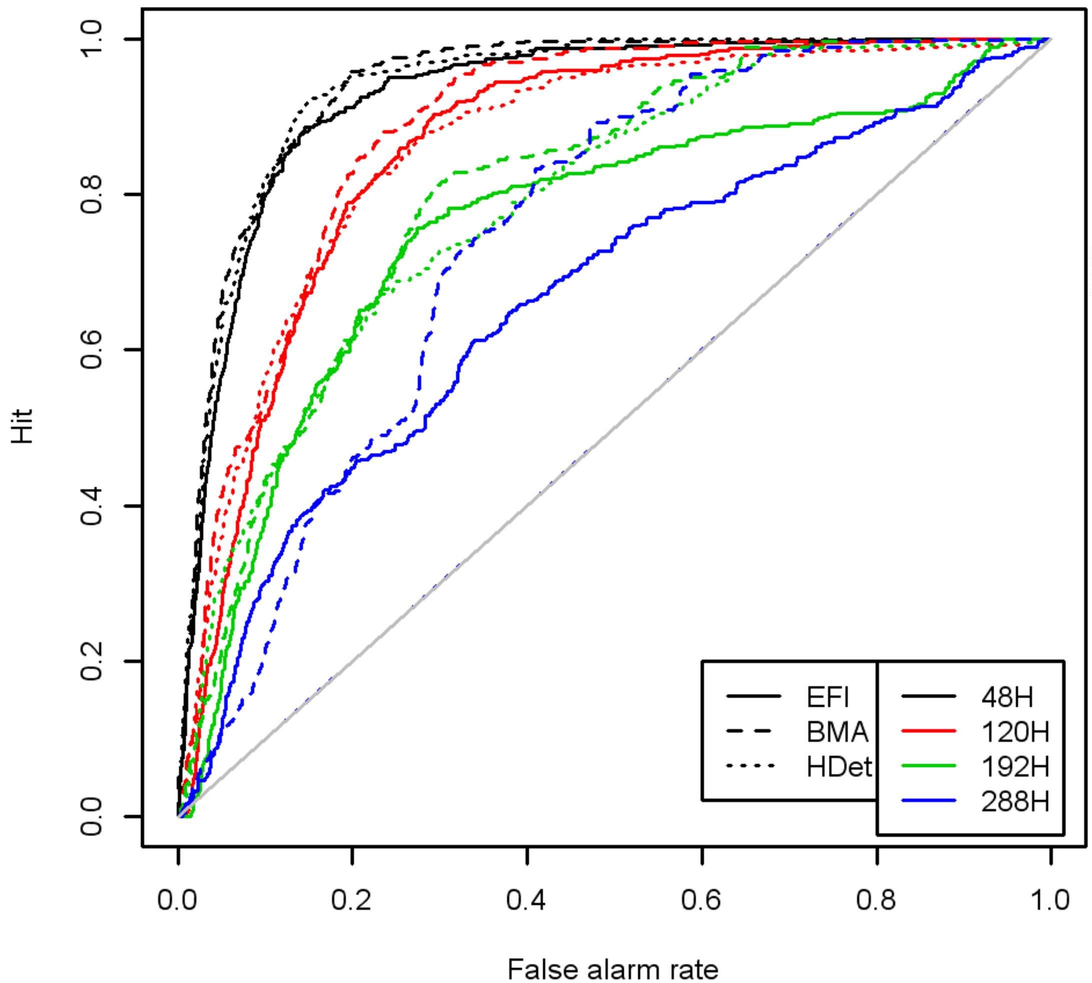
BMA90%CDF，2008062612， 24h

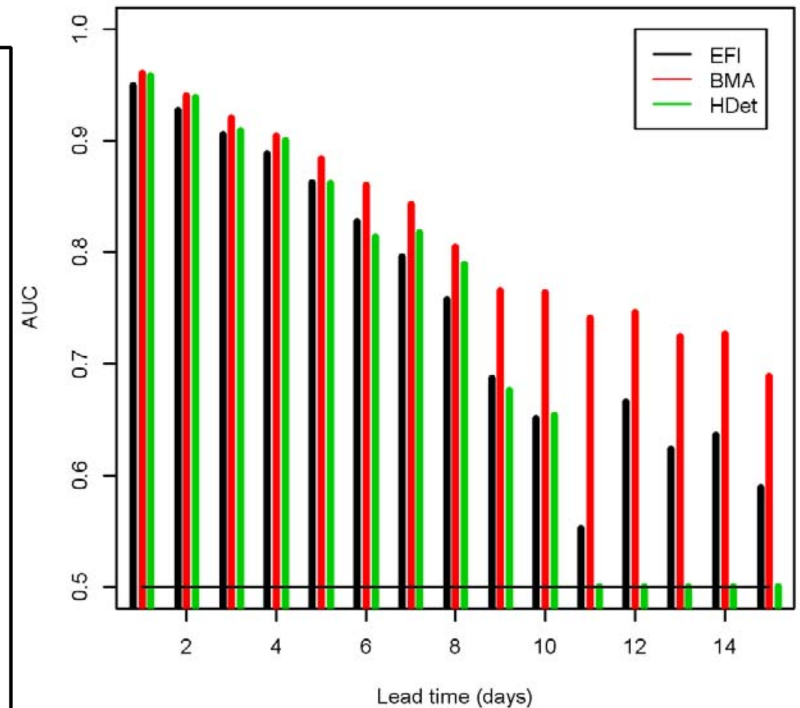


ensemble mean， 2008062612，24h

BMA fcst with larger spread，80%CDF fcst more closes to OBS and improves than EnsMean.

Yang et al. 2013



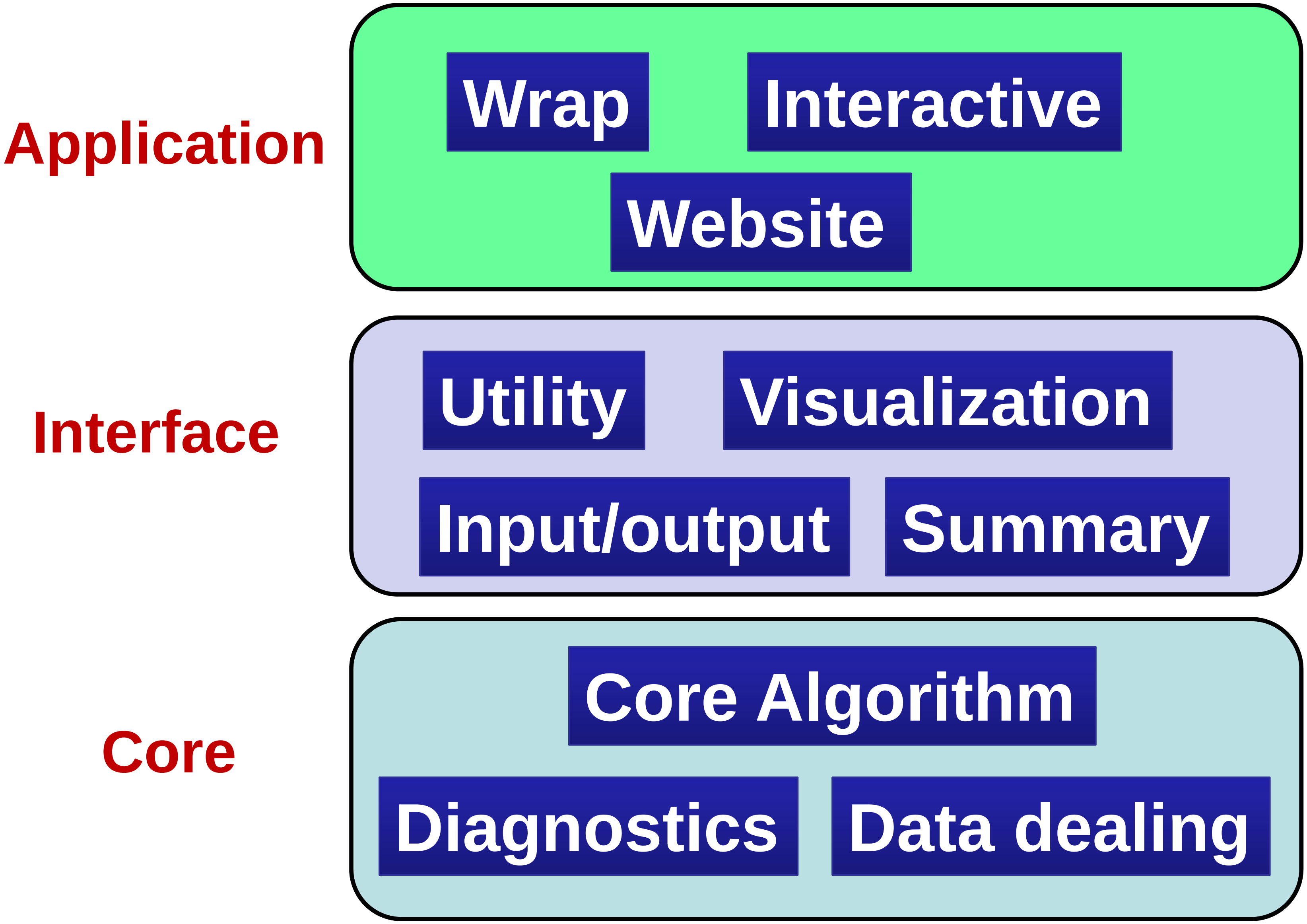


Three products of heavy rainfall over Huaihe basin. ROC（left） and Area under ROC（right）。

- ➢ BMA is best， much better than EFI and high-reso fcst, especially at mid-range and extended range
- ➢ EFI is worst

Dai et al. 2013

Verification framework



Dai et al. 2013

Challenges

- Factors affecting the error of QPF and PQPF
- Identify the bias of precipitation systems
  - Objective analysis and auto identification of the bias
  - Calibration methods
- Calibration of QPF and PQPF (grid products)
  - Methods
  - Training period
  - verification / QPE data


Thank you！