CMA report

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NWPC of CMA

WGNE-30, 23-26 Mar.2015

Outline

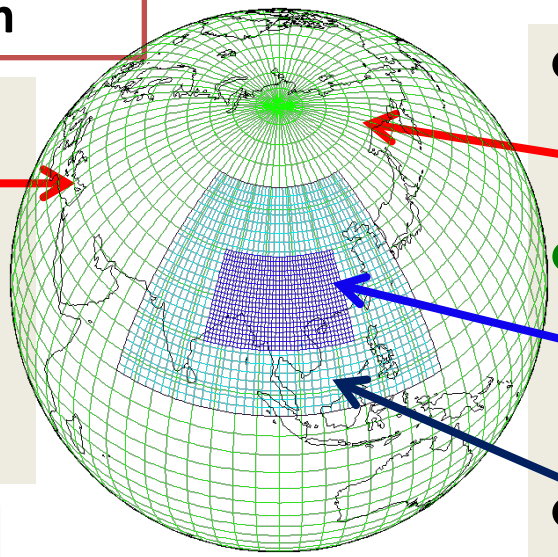
- Production systems
  - Current status
  - GRAPES-GFS operational in 2015
  - FY-3C assimilation
- Research activities
  - 4D-Var
  - New dynamical core
    - MCV
    - GRAPES-YY
- Precipitation verification over China

Current CMA Operational NWP System

Spectral model from ECMWF
Main production system

- GLB 10-day deterministic:
  - T639L60
- Global ensemble forecast:
  - T639L60, M15
- Global Typhoon forecast:
  - T639L60

Data assimilation: GSI



CMA-developed GRAPES

- GLB 10-day deterministic:
  - GRAPES_GFS 50km

Parallel run vs. T639

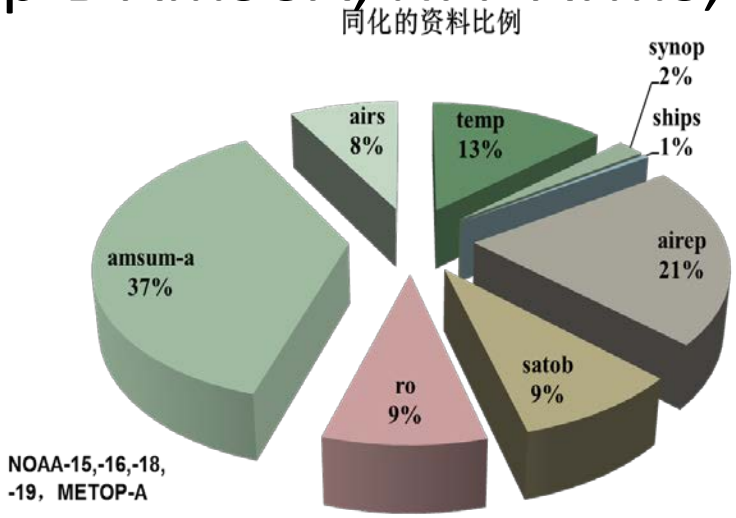
- Meso-scale :
  - GRAPES_Meso 10km
  - **GRAPES_CR 3km**
    - **In flood season**
- Typhoon forecast:
  - GRAPES_TYM 15km
- Rapid update:
  - GRAPES_RAFS 10km

Data assimilation: GRAPES_3DVAR

Green: Upgraded in 2014

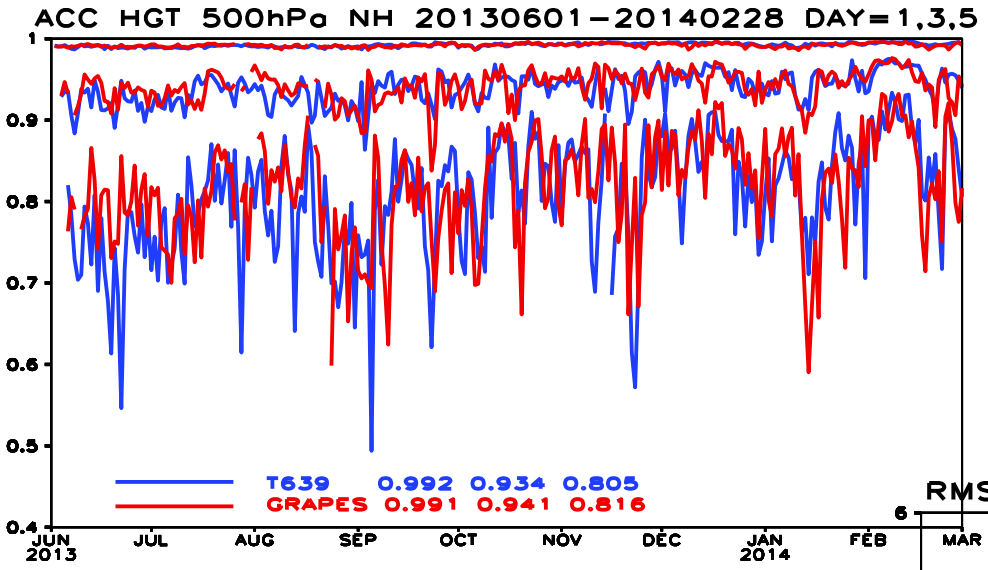
GRAPES-GFS

- Operational in 2015 (research began in 2007)
- 3DVAR + SI-SL MODEL
- 0.25*0.25, L60, model top 37km
- Assimilated OBS
  - IASI, Metop-B AMSUA, NPP ATMS, FY-3C in 2015

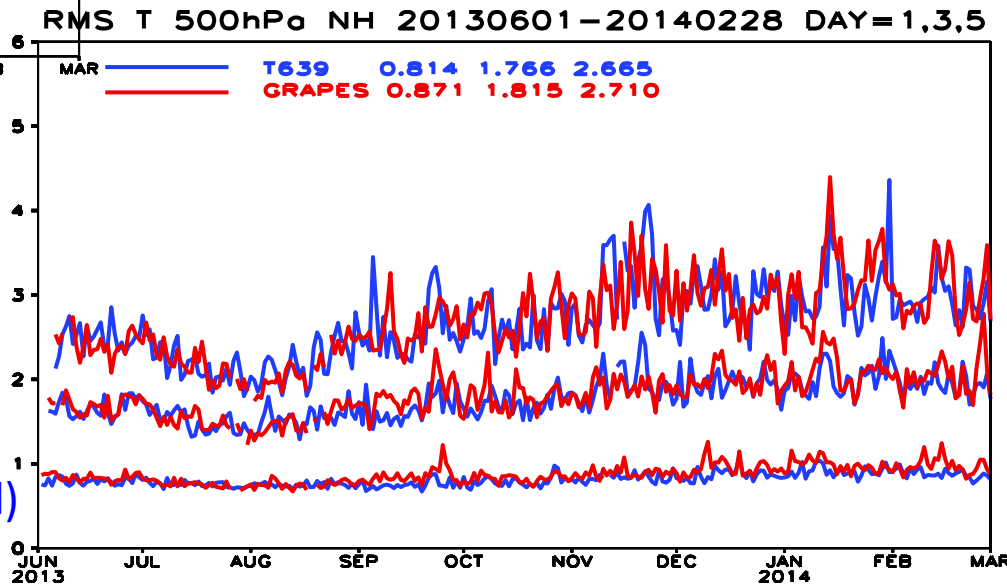


Assimilated OBS in GRAPES-GFS (2014)

Performance of GRAPES-GFS



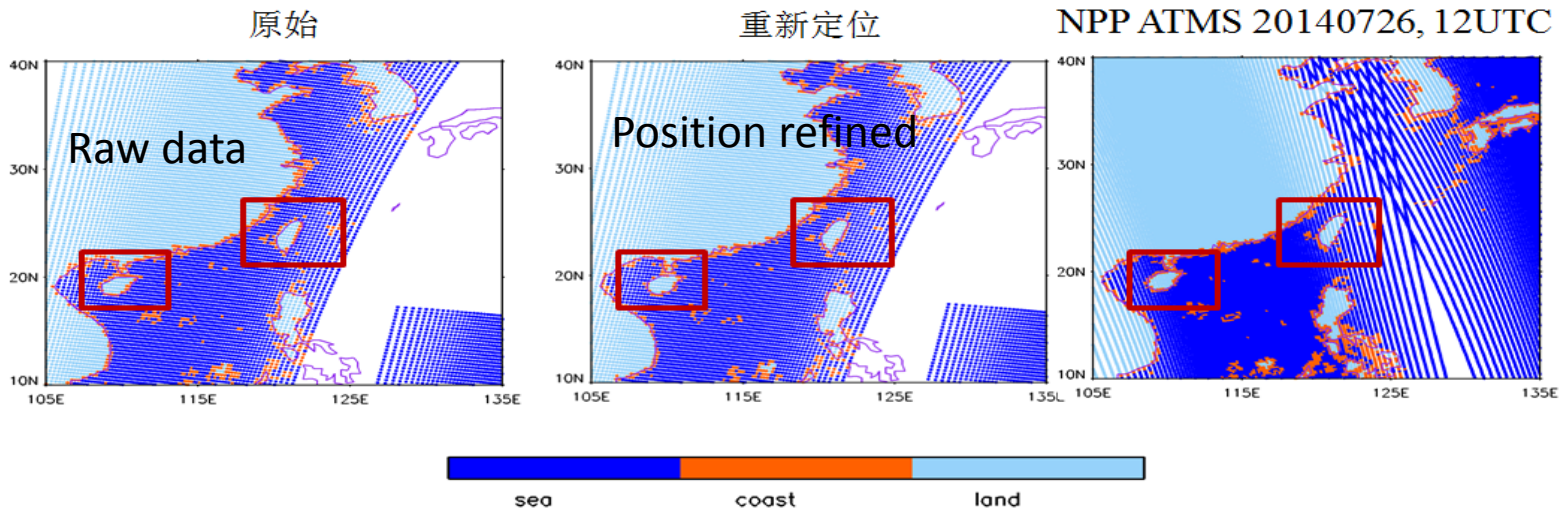
ACC, HGT, 500hPa, NH., 1/3/5d
2013 Jun. – 2014 Mar.
Blue: T639+GSI (Operation Global)
Red: GRAPES-GFS



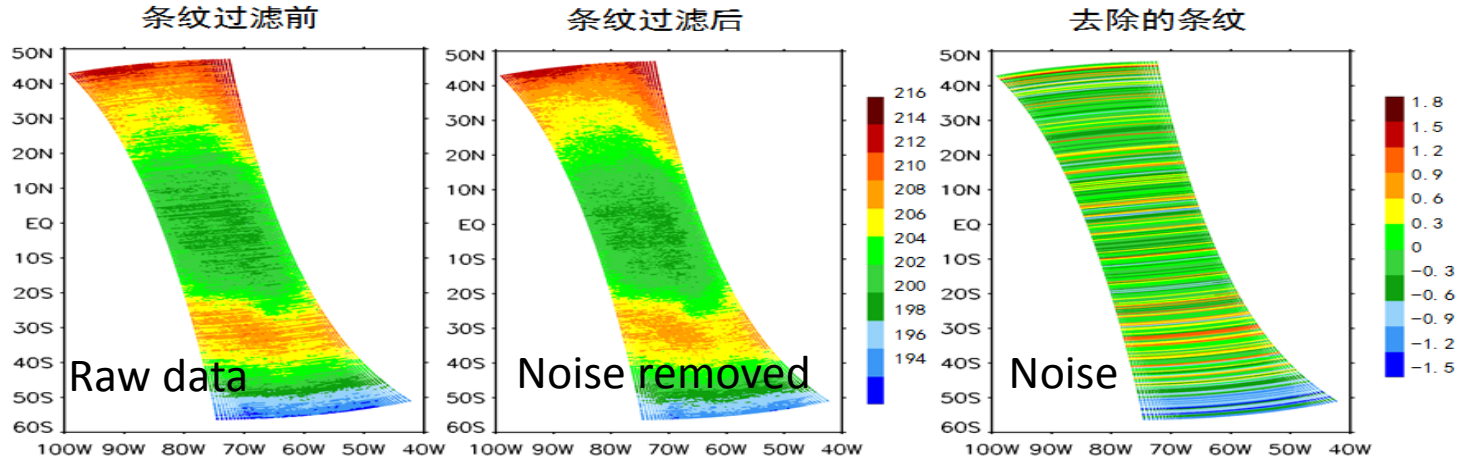
RMSE, T, 500hPa, NH., 1/3/5d
2013 Jun. – 2014 Mar.
Blue: T639+GSI (Operation Global)
Red: GRAPES-GFS

FY-3C MWTS Assimilation

- Position

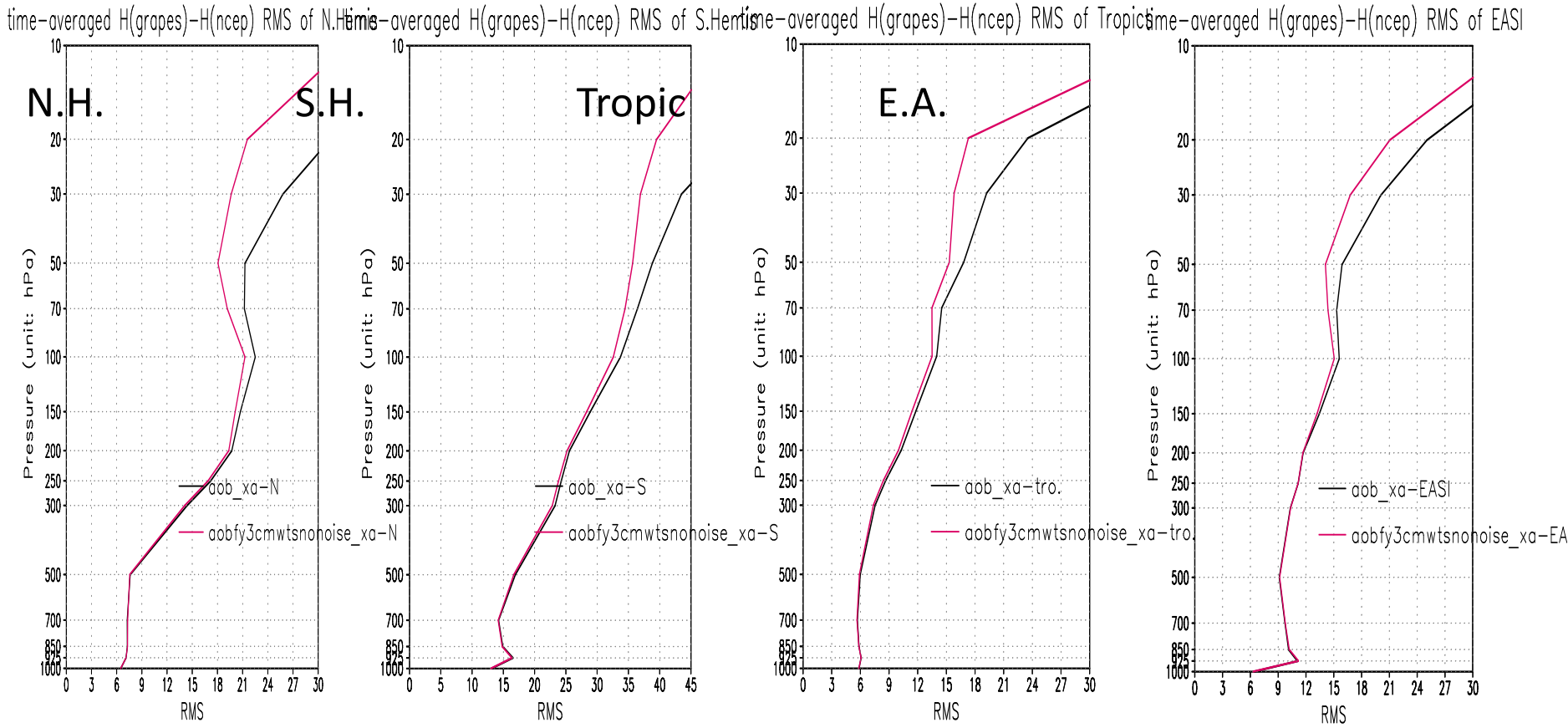


- Noise



FY-3C MWTS Impact experiment

(20140701-20140720)



RMSE, HGT， GRAPES analysis against NCEP analysis

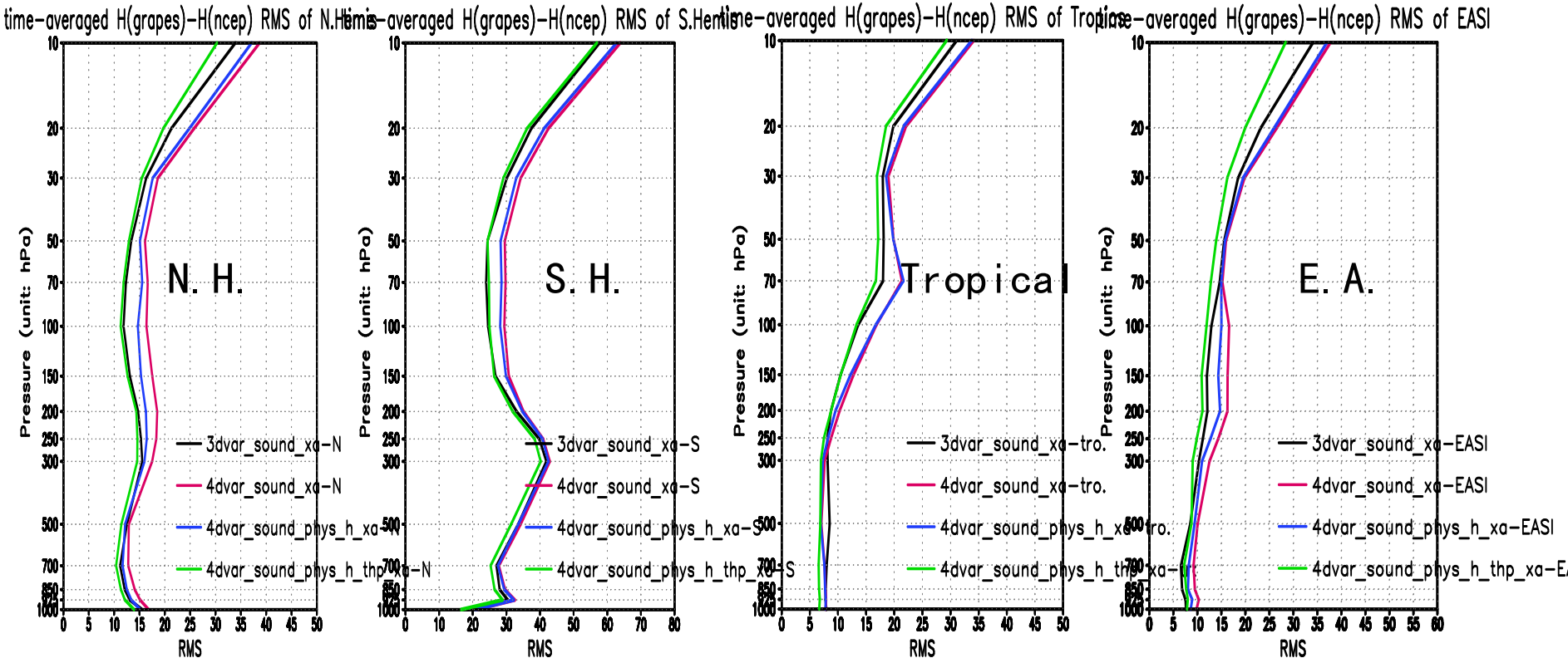
CTL： GTS data

Impact： GTS+FY-3C MWTS-2

NWP research activities

GRAPES Global 4D-Var

RMSE, HGT, against NCEP analysis



Re-write the 4D-Var ajoint and linear model in 2014 (code>40, 000 lines)

Reasonable CPU consuming

With GTS data, 4D-Var is comparable with 3D-Var (even better)

Physics in 2015

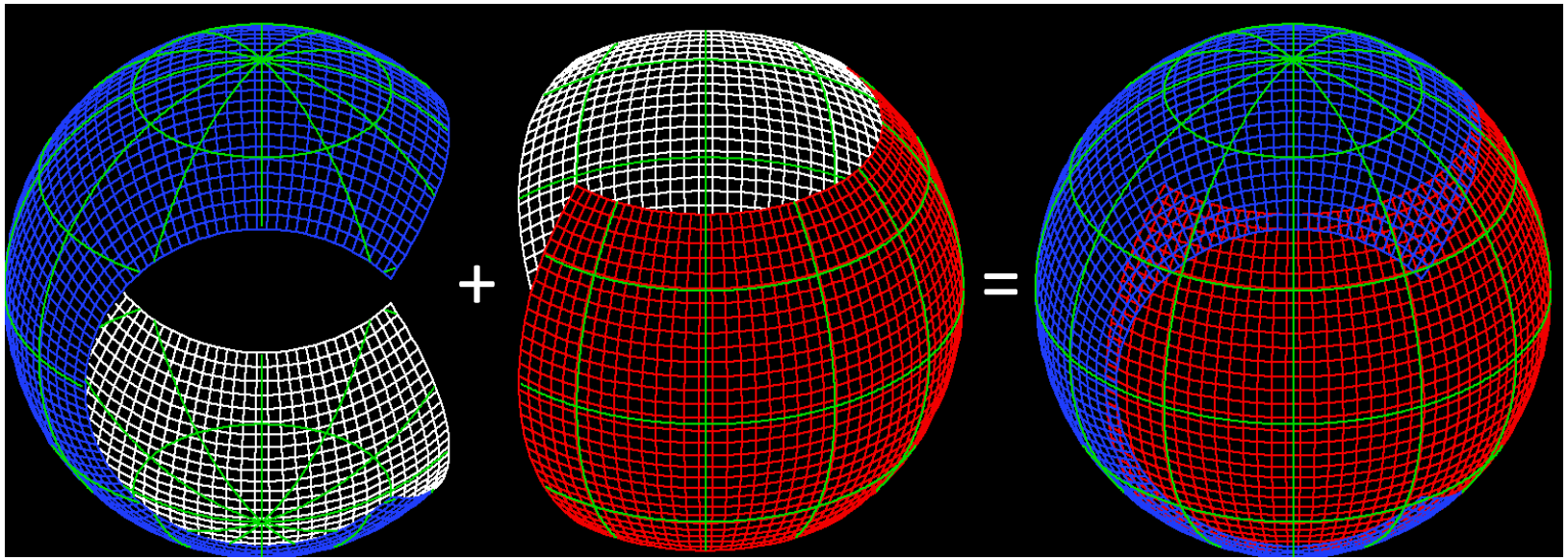
New dynamical core research-1

Non-hydrostatic Dynamic Core on the Yin-Yang Grid

Xindong PENG (pengxd@cams.cma.gov.cn)

About the Yin-Yang grid

- Quasi-uniform, the least proportion being 0.707:1
- Symmetry of the subdomains, identical structure
- Orthogonal lat-lon grid
- No singular point
- Easy for physics and numerical scheme installation
- Suitable for Global/Regional model development

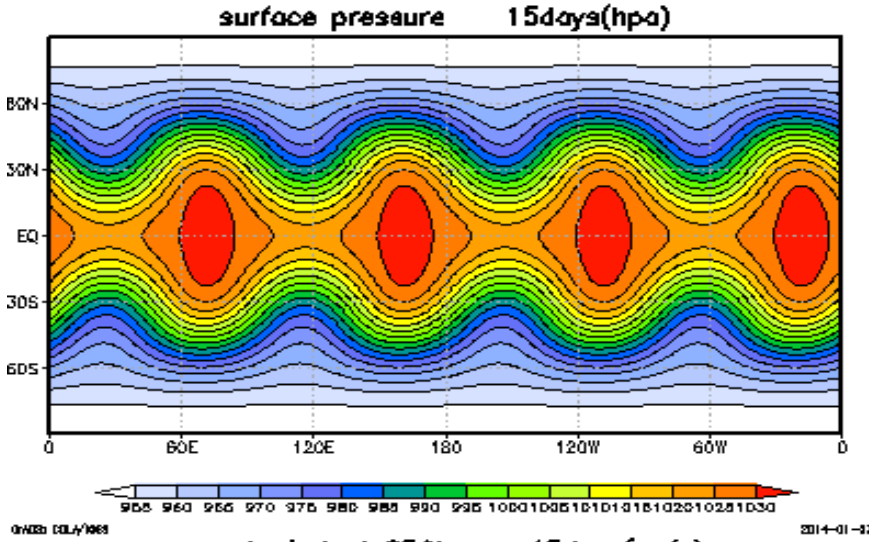


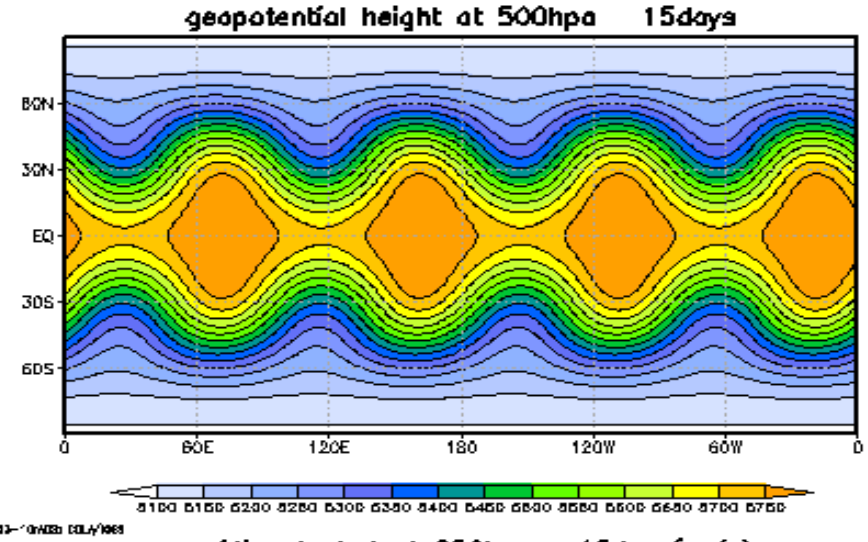
Key issues

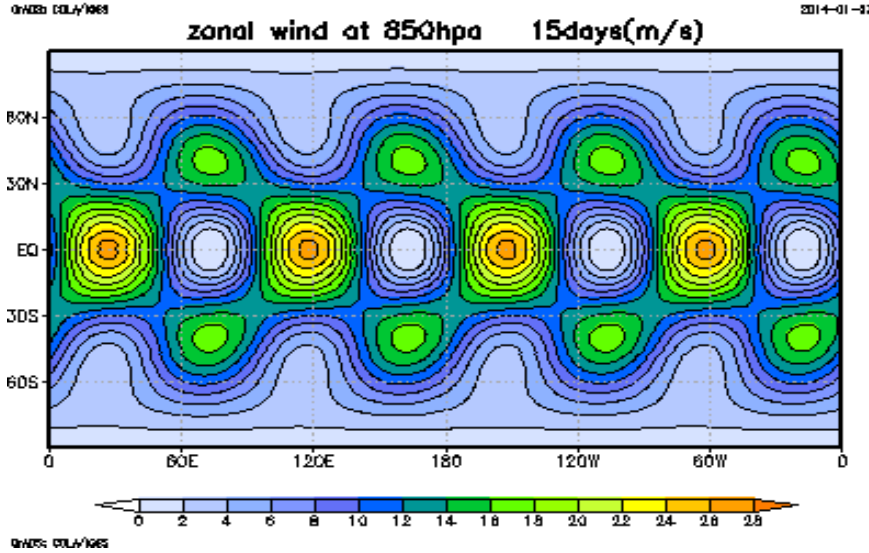
- Establishment of fully compressible GRAPES nonhydrostatic core with **SISL** scheme on the Yin-Yang grid
- Improvement of the dynamic processes
  - **Full 3D Coriolis** forcing
  - Generalization of the **reference state**
- Modification of the SISL scheme and the numerical solution of the elliptical equation
- Idealized standard tests and results

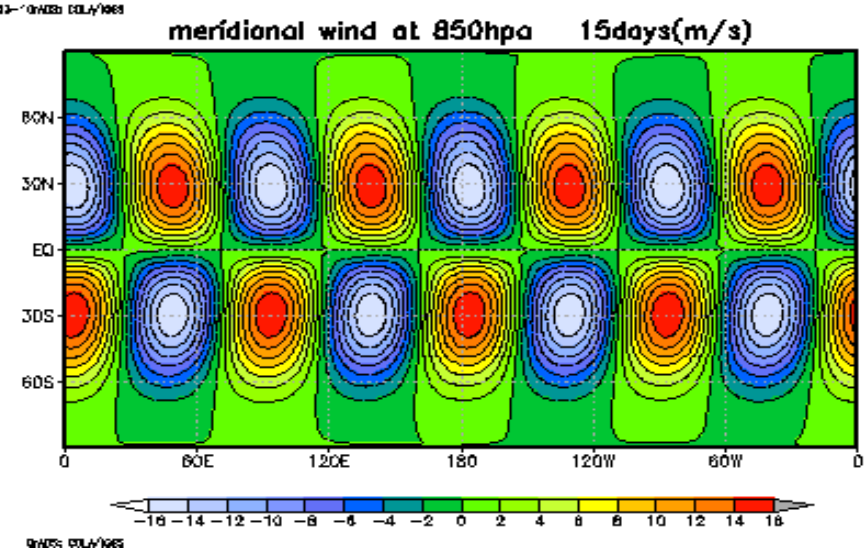
Rossby-Hauwitz

GRAPES_YY 15d

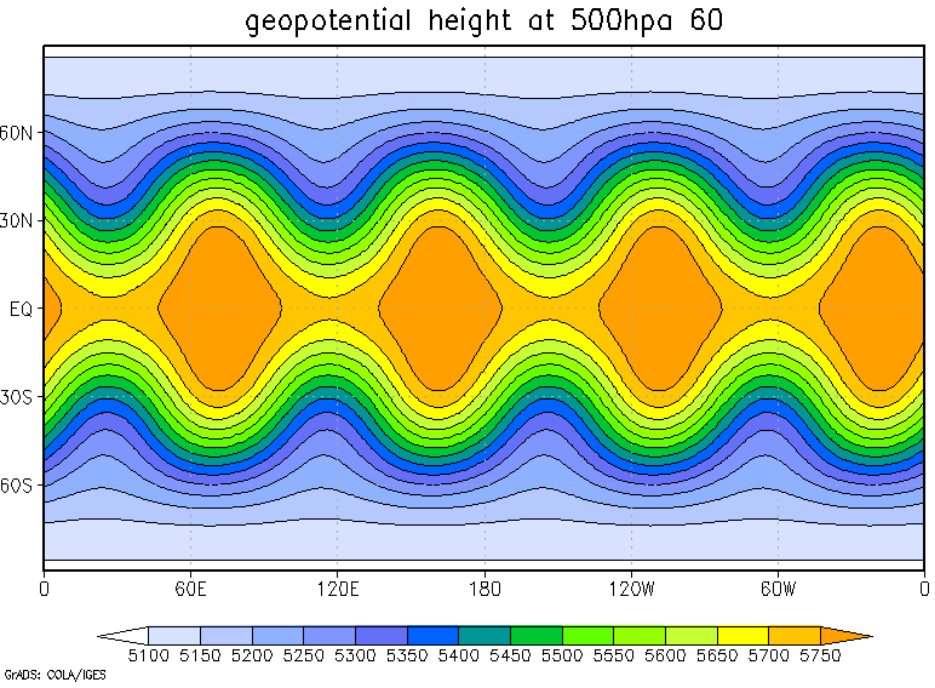




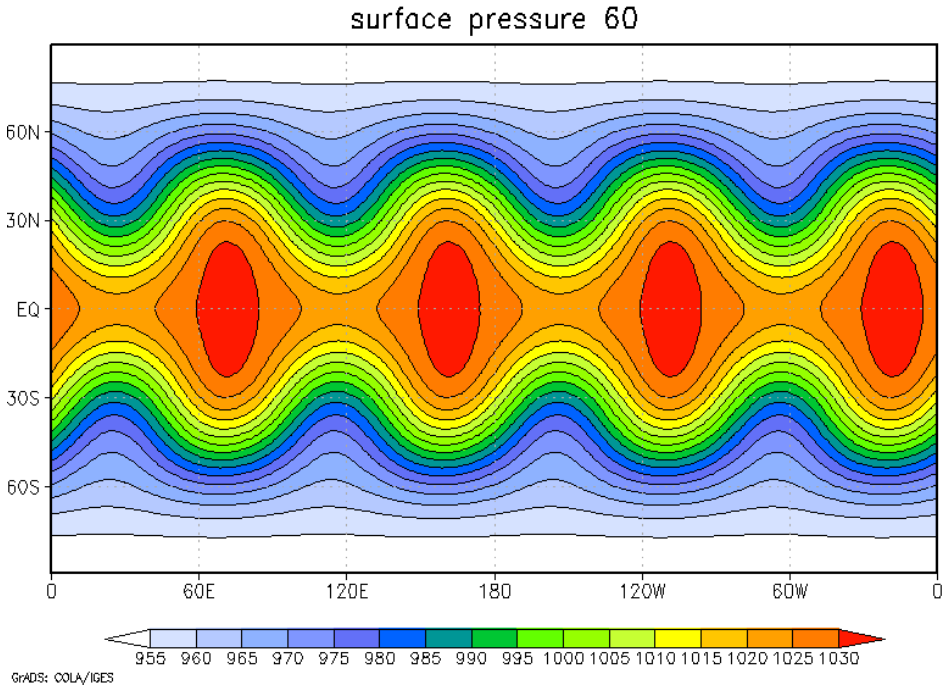




Rossby-Hauwitz

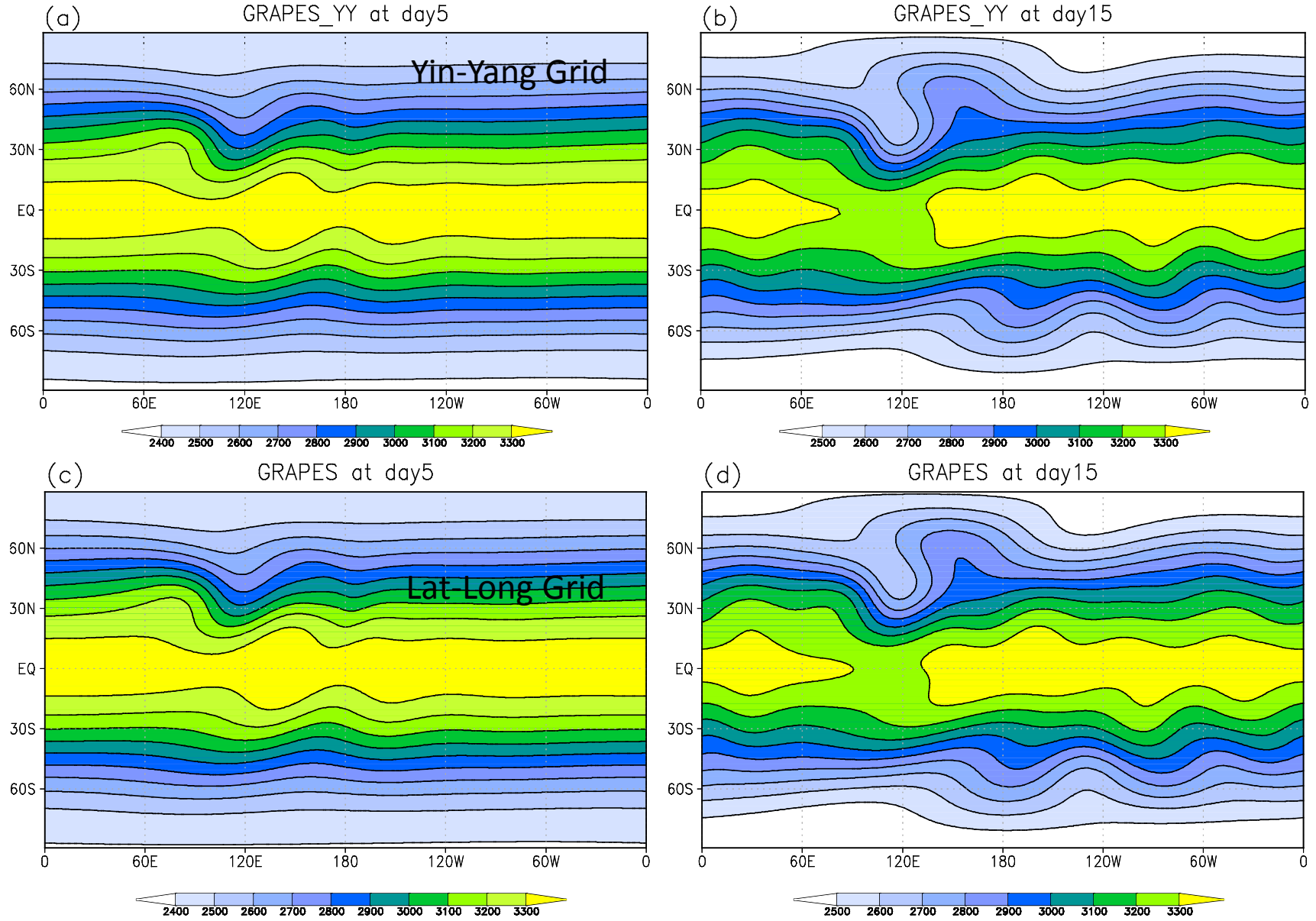


HGT,60d, 500hPa



PS,60d

Mountain induced Rossby wave (1°)



New dynamical core research-2

Based on multi-moment constrained finite volume (MCV) method

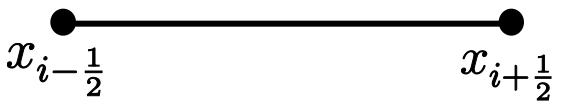
Xinliang LI (lixl@cma.gov.cn), Xueshun SHEN, Feng XIAO

Fundamentals: nodal type conservative formulation based on local high-order reconstruction (li & Xiao,2009)

Conservation law $\dfrac{\partial q}{\partial t} = -\dfrac{\partial f(q)}{\partial x}$

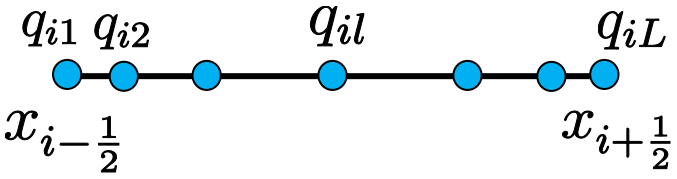
Multi-moments:
- Point values
- Integrated values
- Derivatives

Mesh element



$x \in \Omega_i \equiv [x_{i-\frac{1}{2}}, x_{i+\frac{1}{2}}]$

Define the solution points x_{il}



The solutions q_{il} are point-wisely computed by solving the conservation law in a differential form

$$\frac{\partial q_{il}}{\partial t} = -\frac{\partial \hat{\mathcal{F}}(q_{il})}{\partial x}$$

Reconstruct flux function

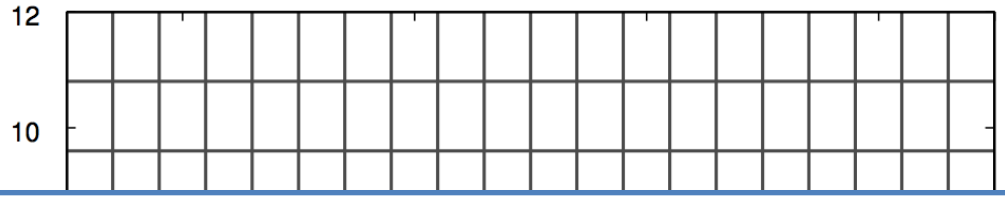
$$\int_{x_{i-\frac{1}{2}}}^{x_{i+\frac{1}{2}}} q_t(x,t)dx = \int_{x_{i-\frac{1}{2}}}^{x_{i+\frac{1}{2}}} \hat{\mathcal{F}}_{xi}(x;q_{il})dx$$

$$\longrightarrow \sum_{l=1}^{L} w_{il}(q_{il})_t = -\left(\hat{\mathcal{F}}_i(x_{i+\frac{1}{2}};q_{il}) - \hat{\mathcal{F}}_i(x_{i-\frac{1}{2}};q_{il})\right)$$

Conserved if the flux function is continuous at cell boundaries.

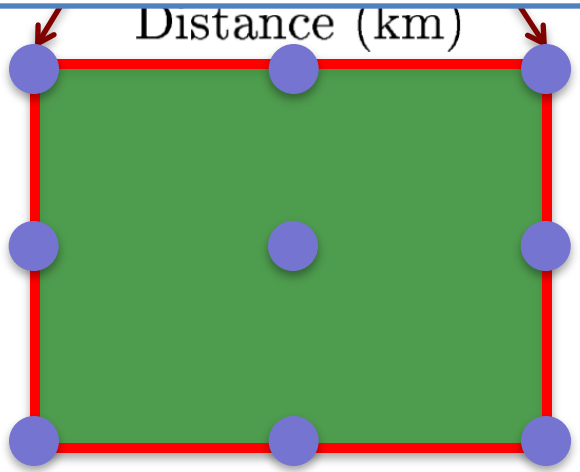
$\hat{\mathcal{F}}_i(x_{i+\frac{1}{2}};q_{il}) = f^{\mathcal{B}}_{i+\frac{1}{2}}$ ← Riemann problem

MCV vs. FV



Merits：

1）Local high-order reconstruction, high accuracy
2）Local numerical methods, no global communication
3）nodal type， easy to implement source term
4）Rigorous conservation
5）Stable and robust
6）Flexible and adaptive



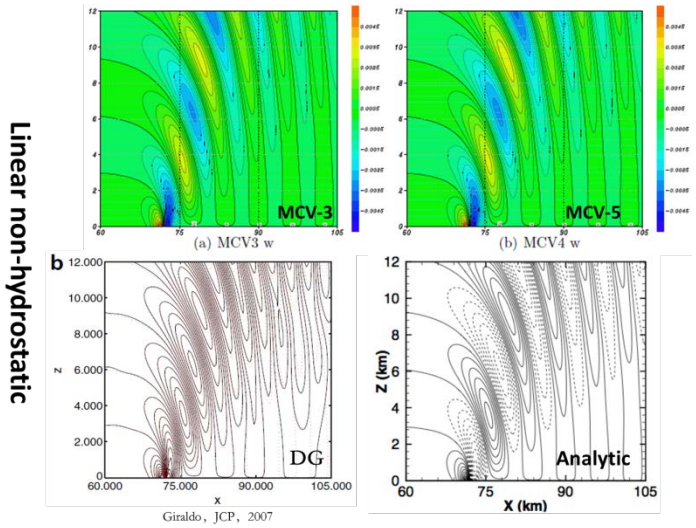
Local definition of DOF

Progresses of MCV dynamical core

- The 2-D compressible non-hydrostatic flow
  - Cold bubble
  - Internal gravity wave
  - Steep mountain model intercomparison project

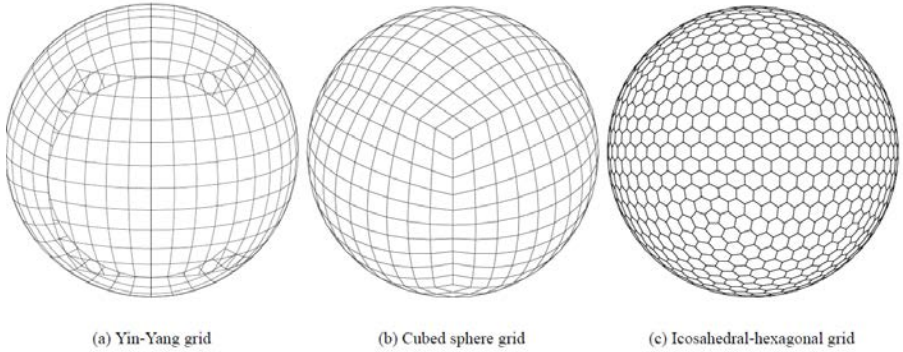
  (Satomura et al, Annuals of Disas. Prev. Res. Inst., Kyoto Univ., No. 46B, 2003)
  - Schär mountain

  Li, Chen, Shen and Xiao, et al (MWR, 2013)
  Li, Shen et al (AAS, 2013)

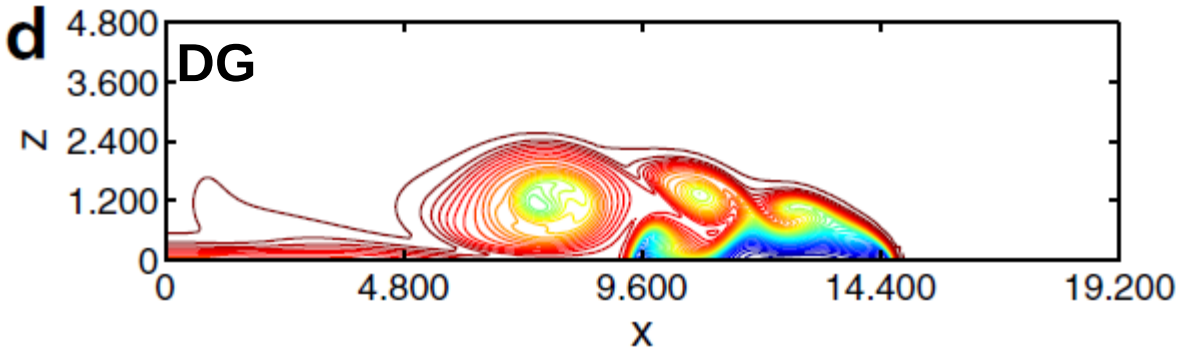


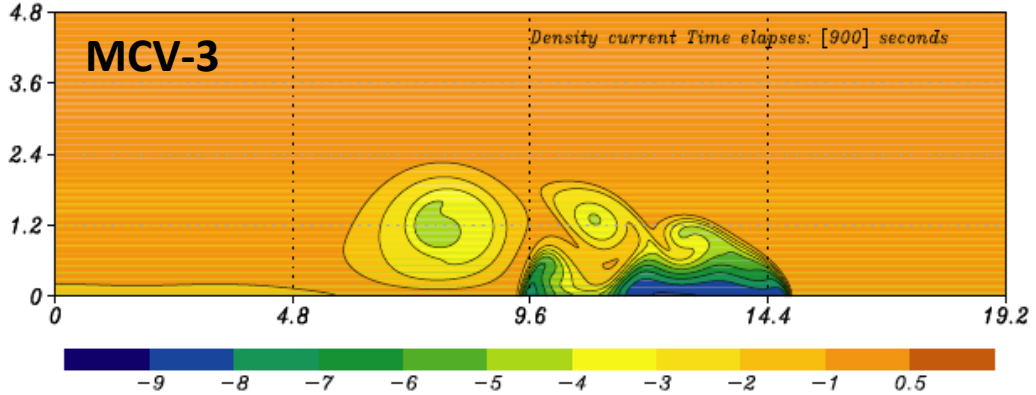
- The global shallow water model at various quasi-uniform spherical grids

  Chen, Li, Shen and Xiao (JCP, 2013)
  Chen, Bin, Xiao, Li and Shen (QJRMS, 2013)

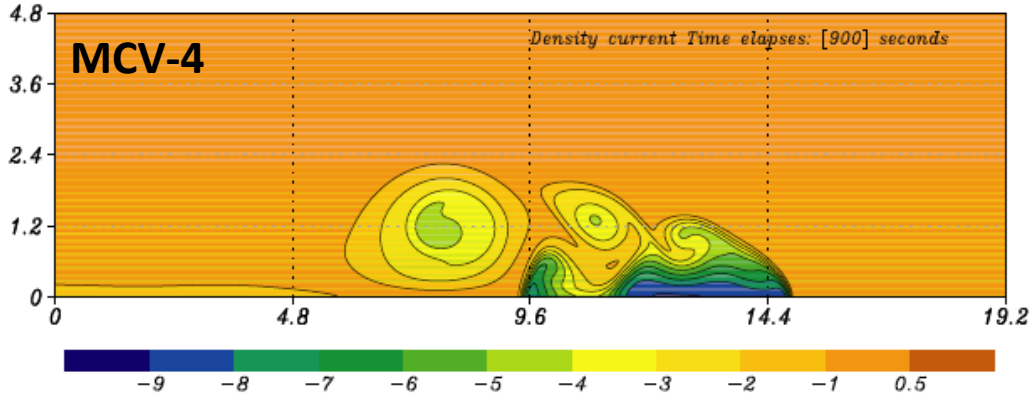


Density current



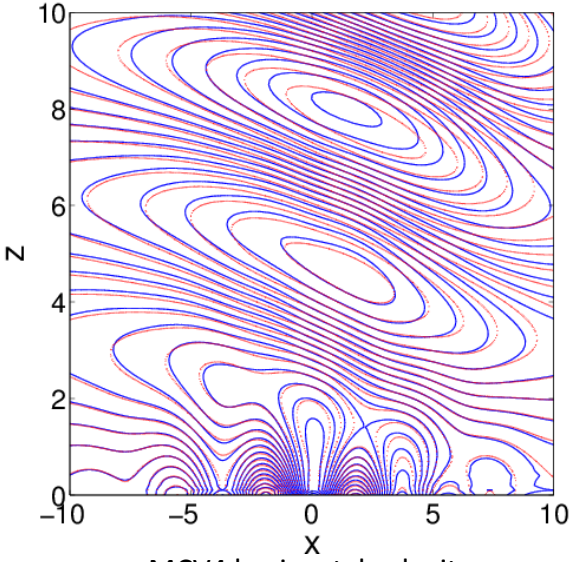


(a) MCV3 $\Delta x = \Delta z = 25$ m

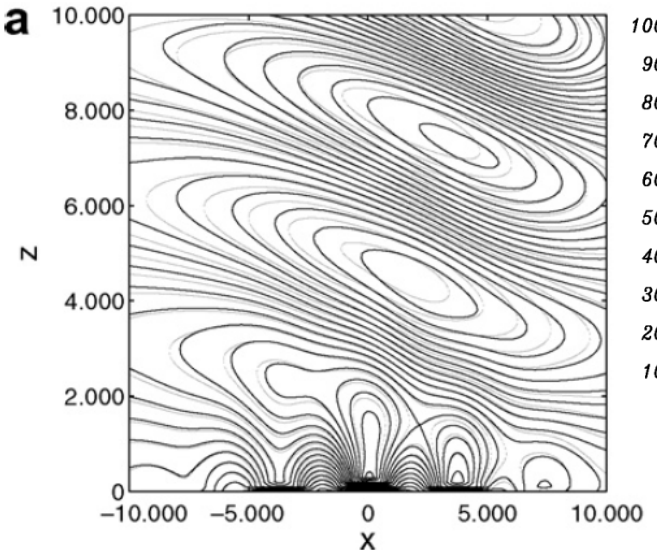


(b) MCV4 $\Delta x = \Delta z = 37.5$ m

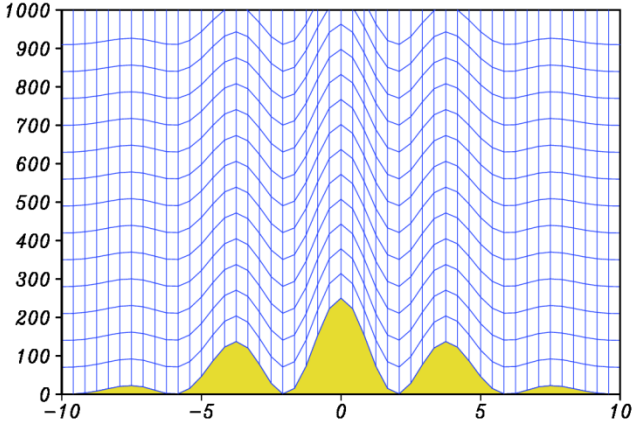
Red lines: analytic solution, blue lines: our results



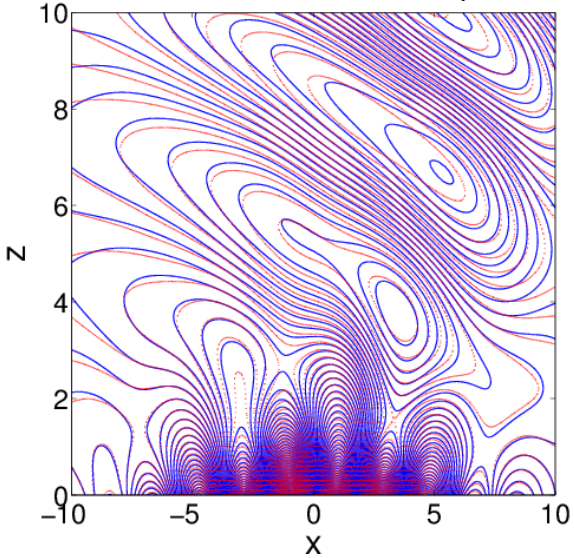
MCV4 horizontal velocity



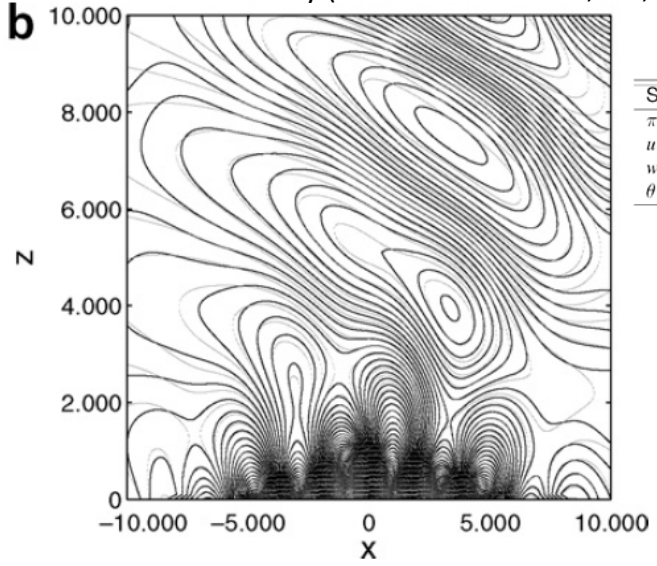
DG horizontal velocity (Giraldo and Restelli, JCP,2008)



Schär mountain (2002)



MCV4 vertical velocity



DG vertical velocity (Giraldo and Restelli, JCP,2008)

Schemes	MCV3	MCV4	SE3	DG3
π	5.25×10^{-6}	5.27×10^{-6}	8.27×10^{-6}	7.36×10^{-6}
u	9.21×10^{-2}	9.24×10^{-2}	2.26×10^{-1}	1.94×10^{-1}
w	2.76×10^{-2}	2.93×10^{-2}	7.66×10^{-2}	7.51×10^{-2}
θ	4.19×10^{-2}	4.39×10^{-2}	6.78×10^{-2}	5.84×10^{-2}

Red frame: our results, blue frame: SE/DG results

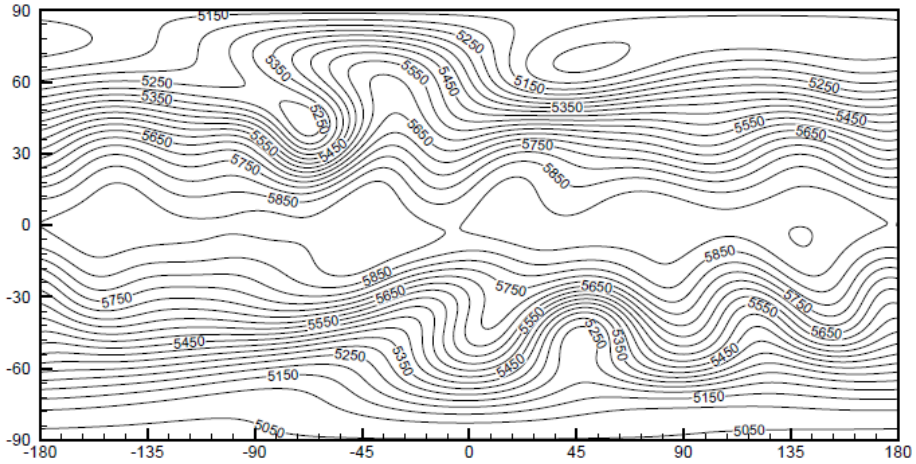
Root-mean-square errors of the schär mountain for different physical fields after 10 hours.

The RMS errors of our results are smaller in this test case

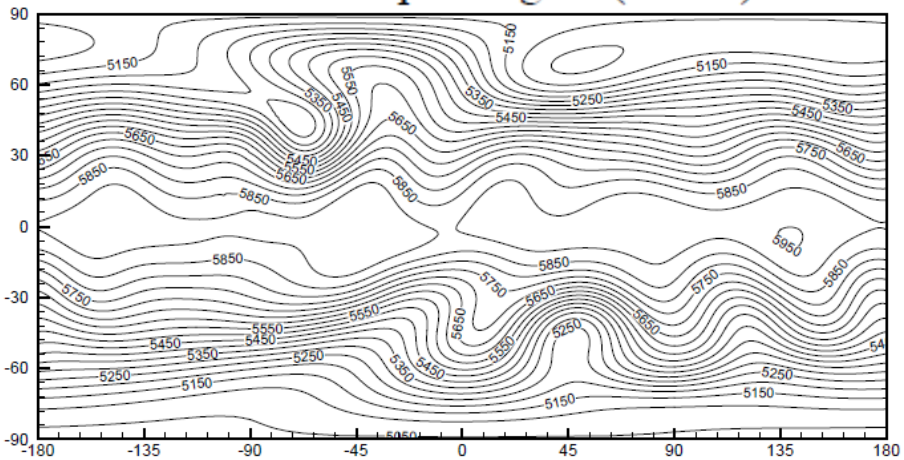
Williamson's test case 5: Mountain wave

Height fields at day 15

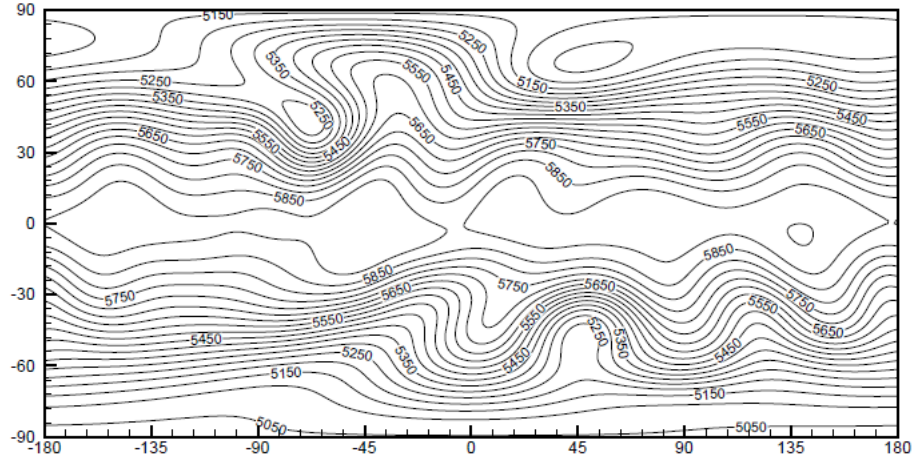
Yin-Yang grid (N=40)



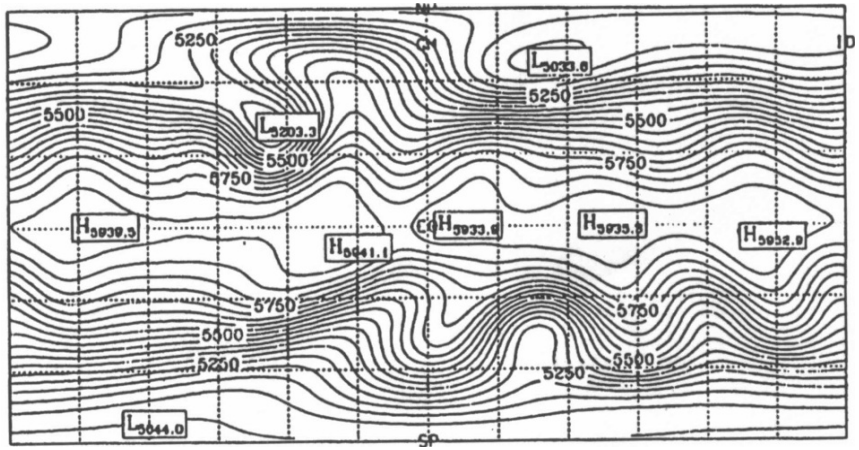
Cubed-sphere grid (N=40)



Icosahedral grid (N=36)



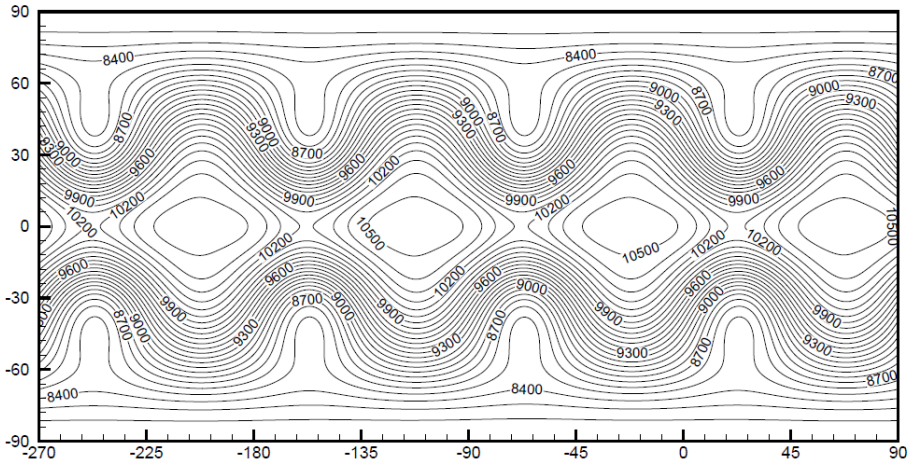
T213 spectrum reference solution



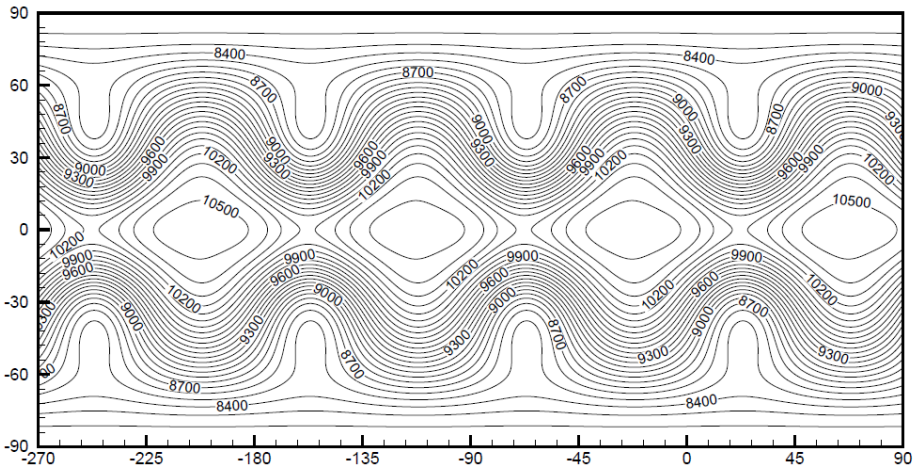
Williamson's test case 6: Rossby-Haurwitz wave

Height fields at day 14

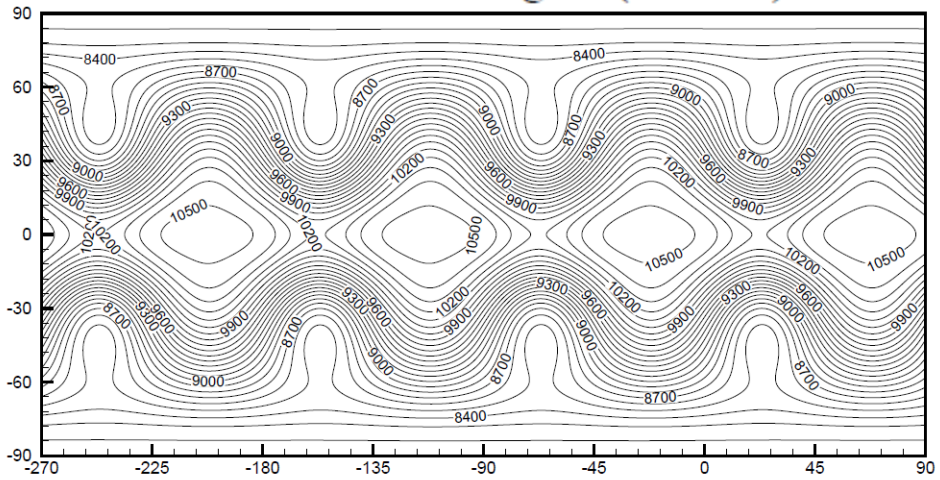
Yin-Yang grid ($N = 108$)



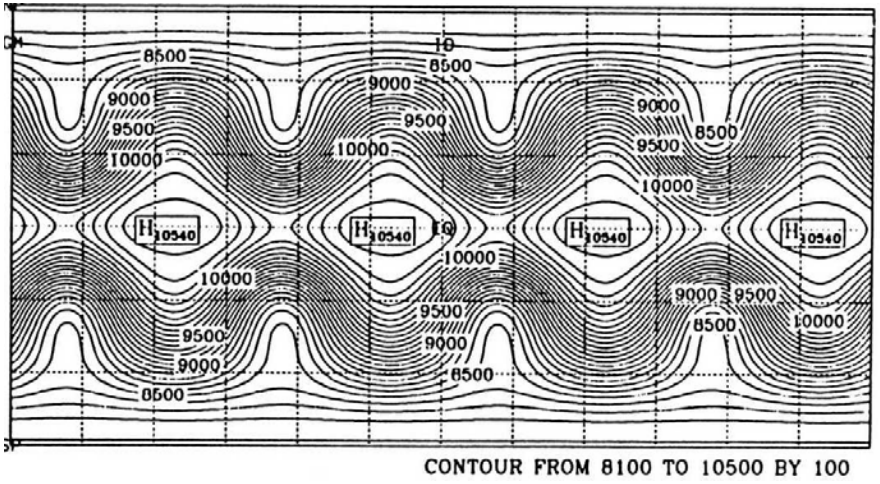
Cubed-sphere grid ($N = 108$)



Icosahedral grid ($N = 96$)



T213 spectrum reference solution



Precipitation verification over China

May 2014 – Sep. 2014(warm season)

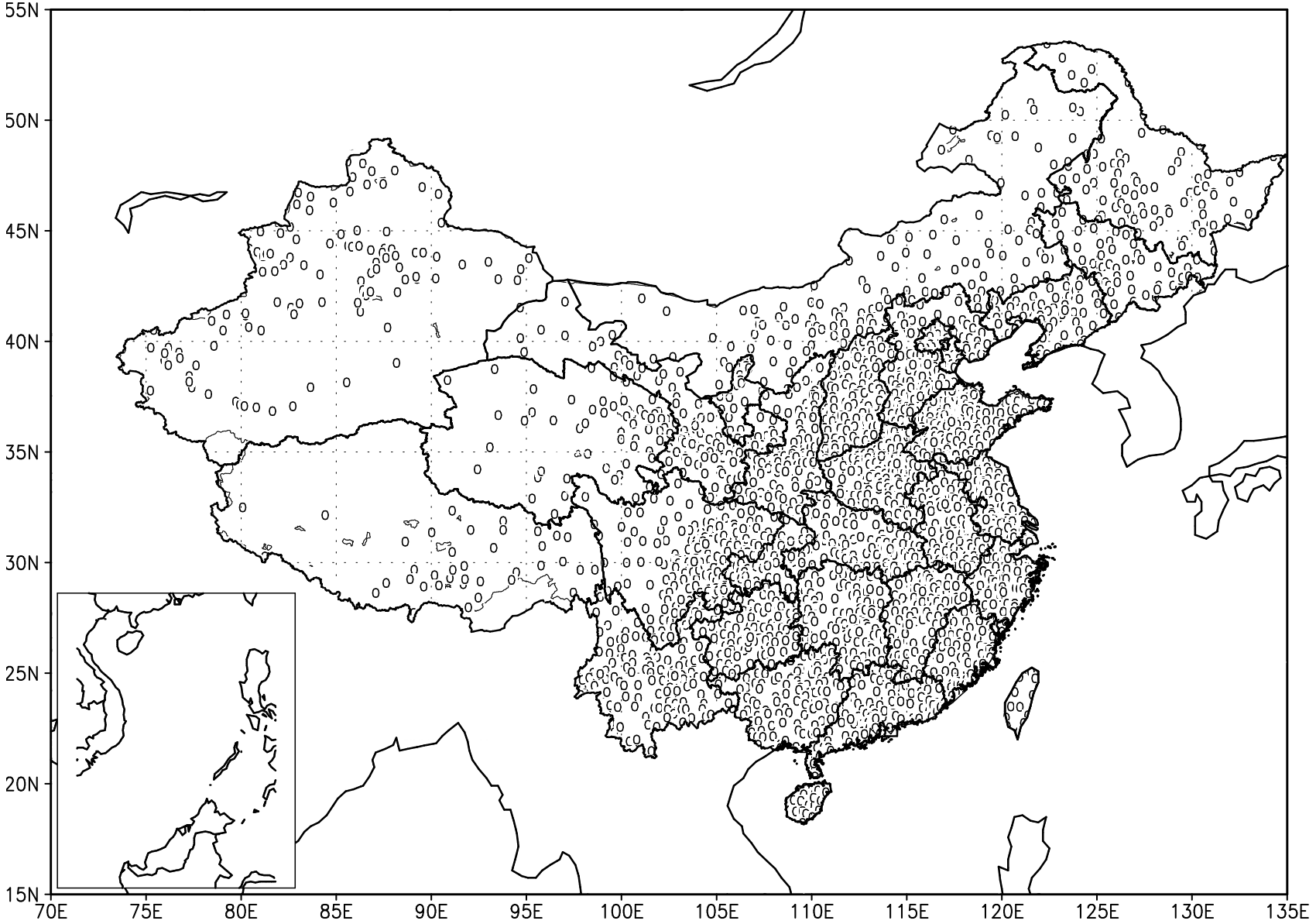
Models included:

- NCEP
- CMC
- ECMWF
- JMA
- UKMO
- CMA

- DWD – Data file broken?

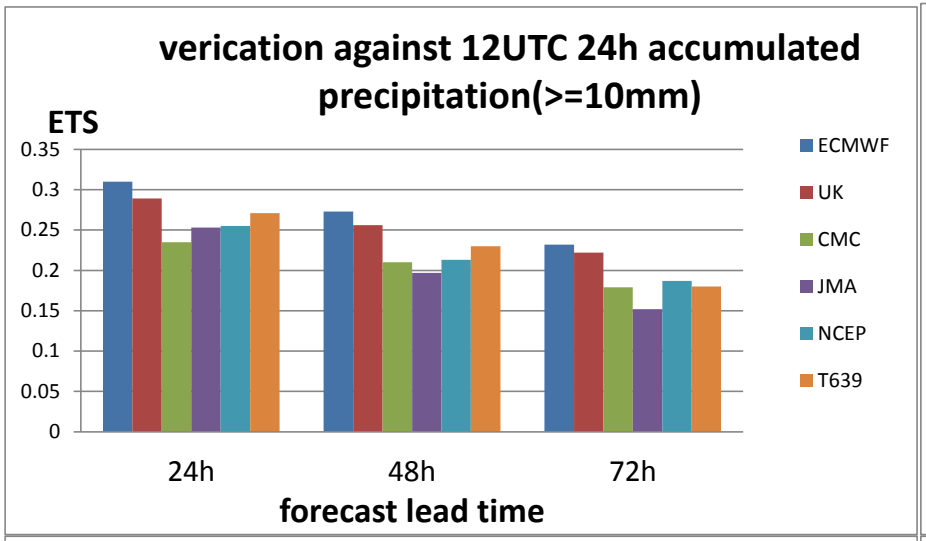
Thanks to the colleagues for uploading these data

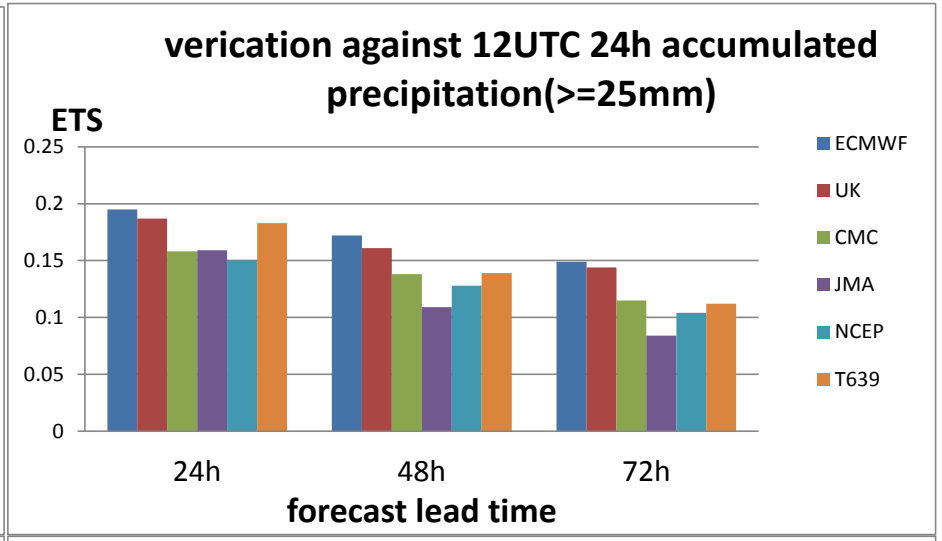
Observation station distribution

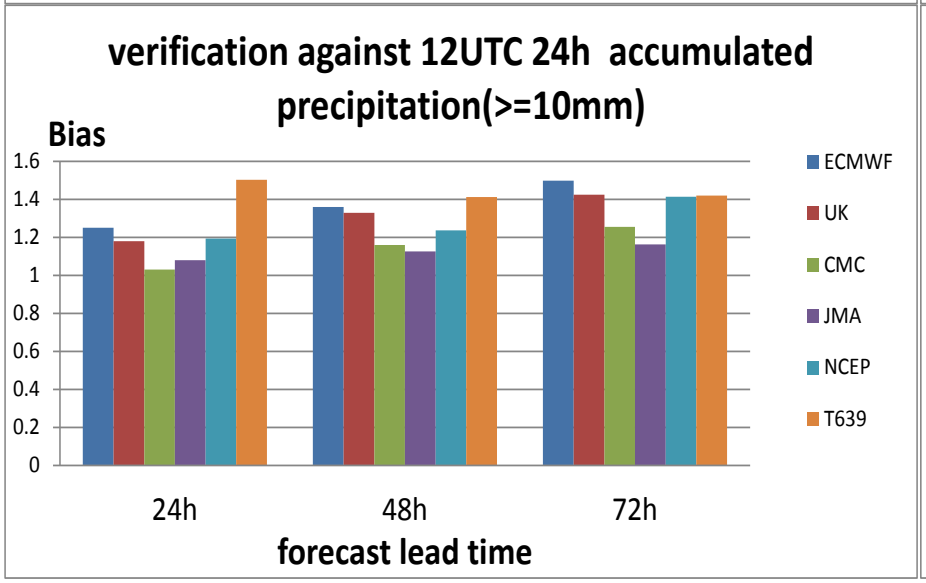


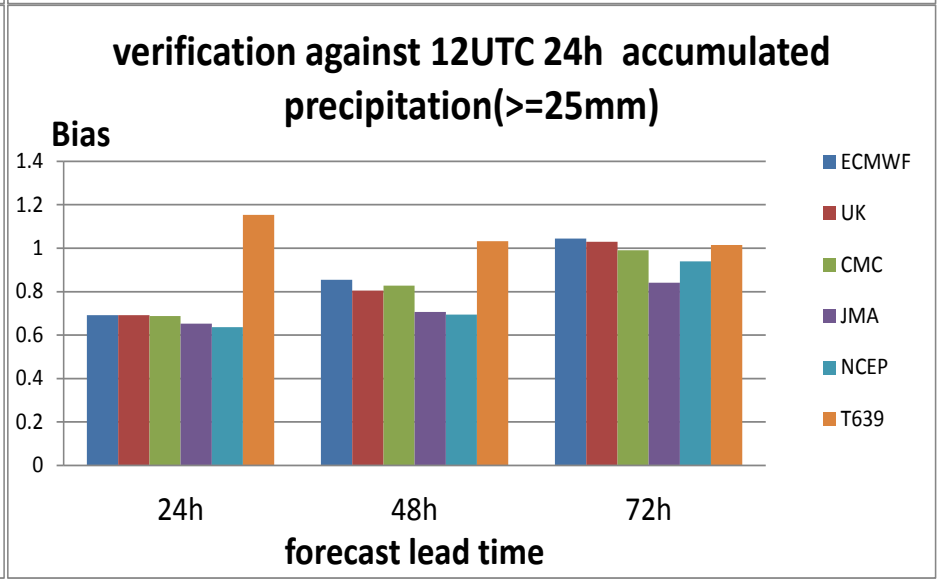
Precipitation forecast ETS and Bias over China

May 2014 – Sep 2014



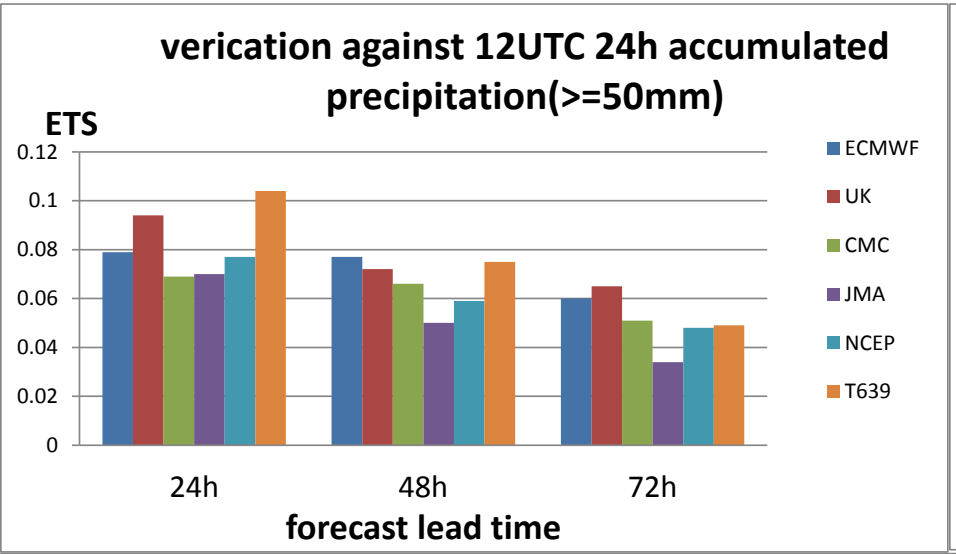


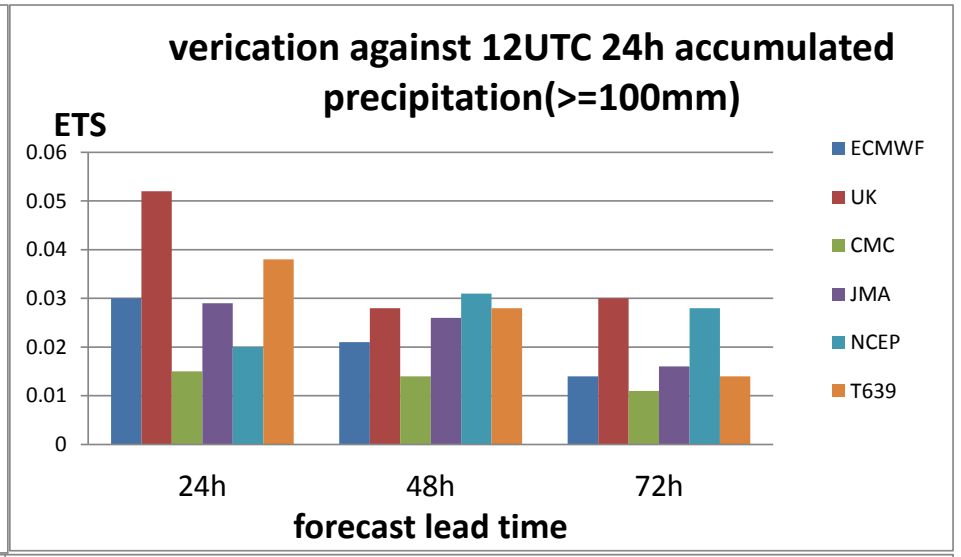


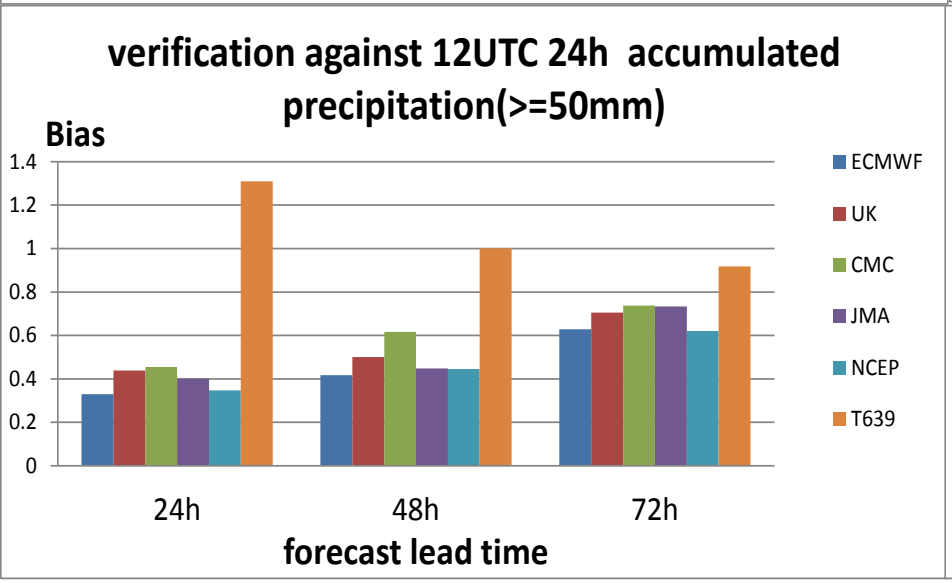


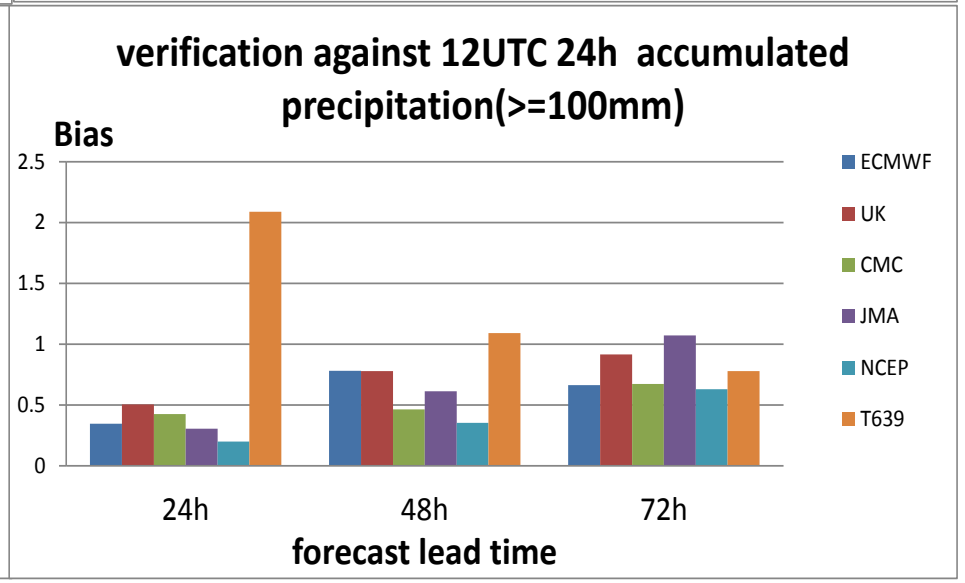
Precipitation forecast ETS and Bias over China

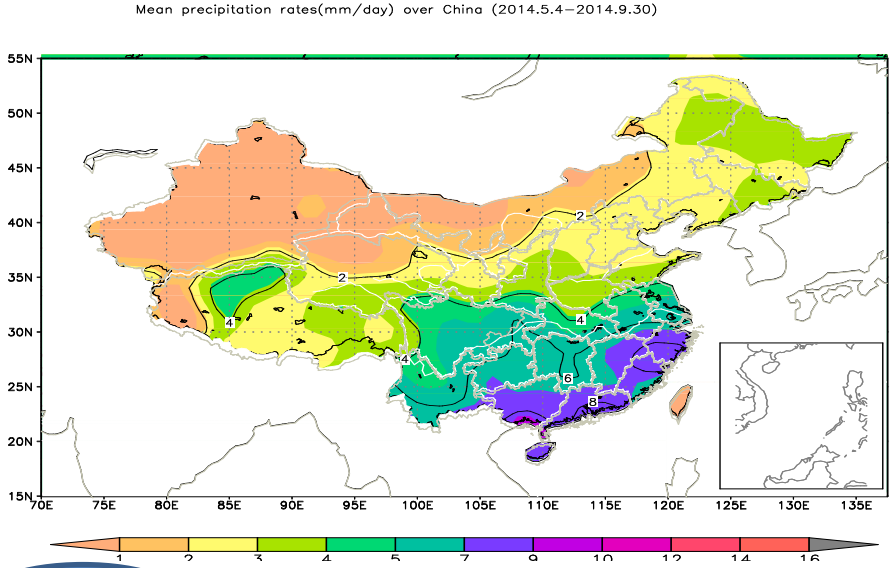
May 2014 – Sep 2014



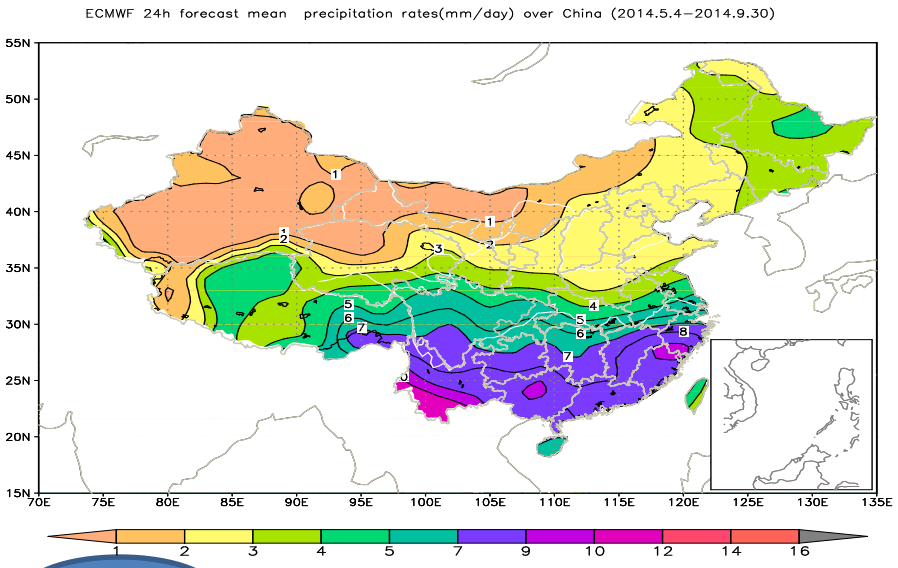






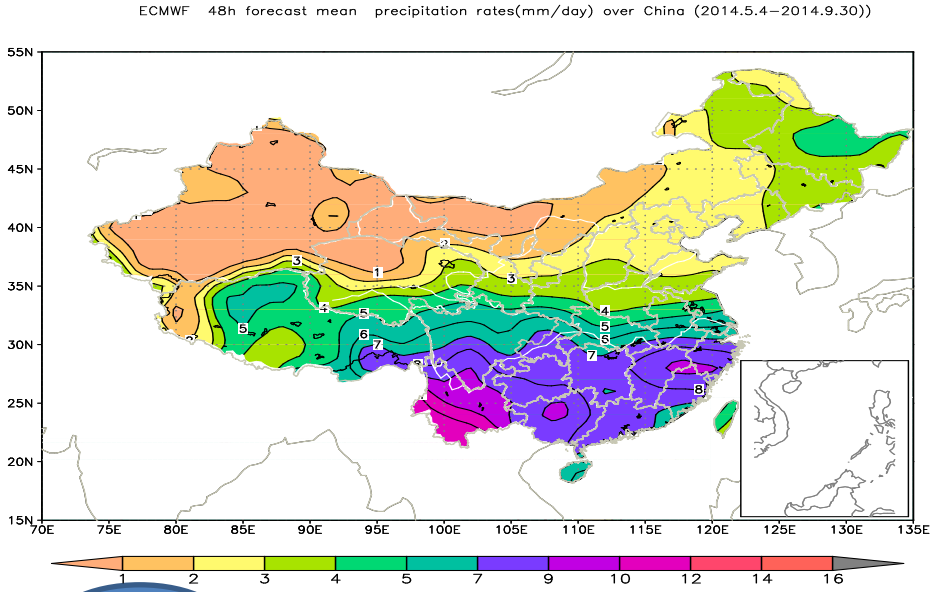


OBS

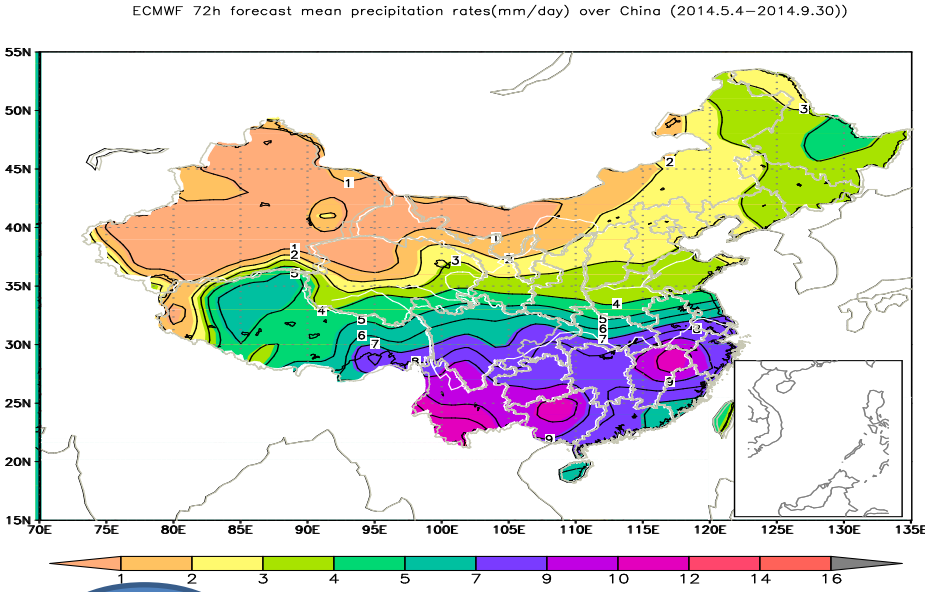


24H

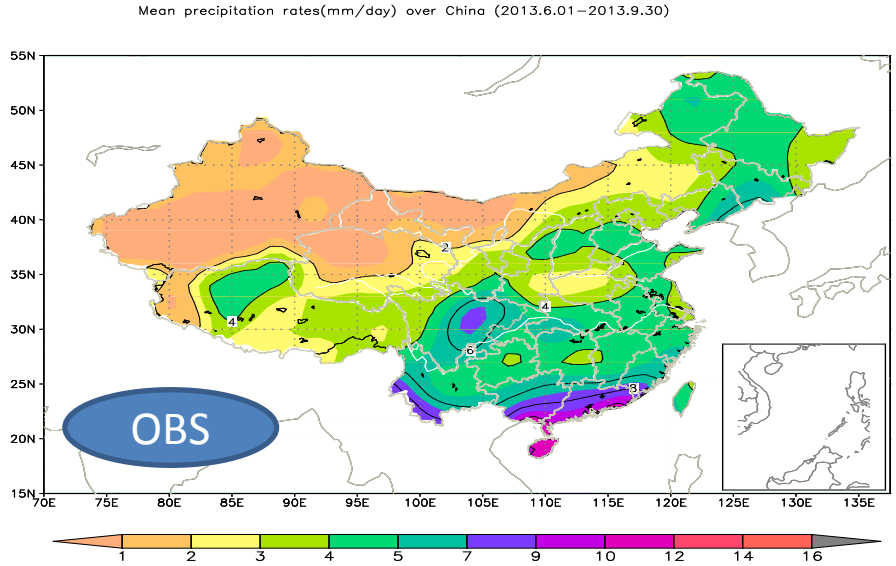
ECMWF 1/2/3day forecast mean precipitation rate distibution

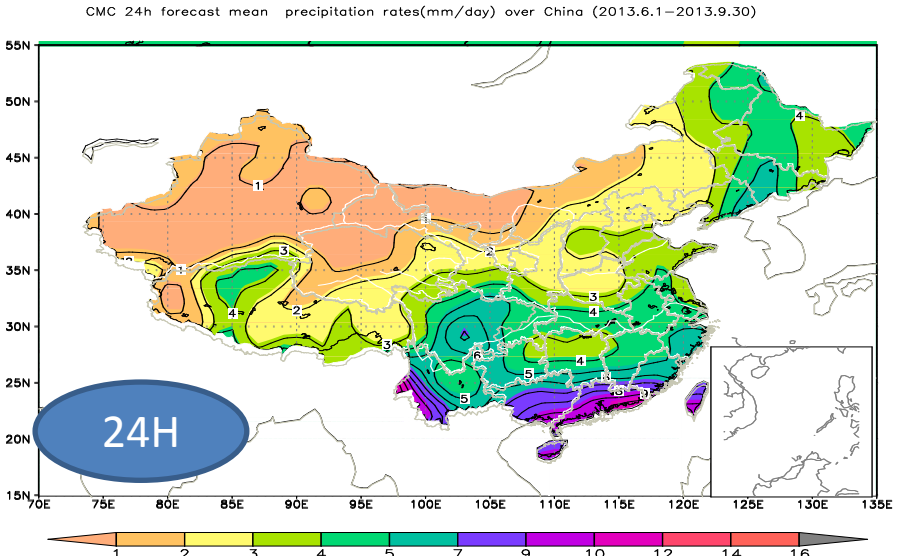


48H

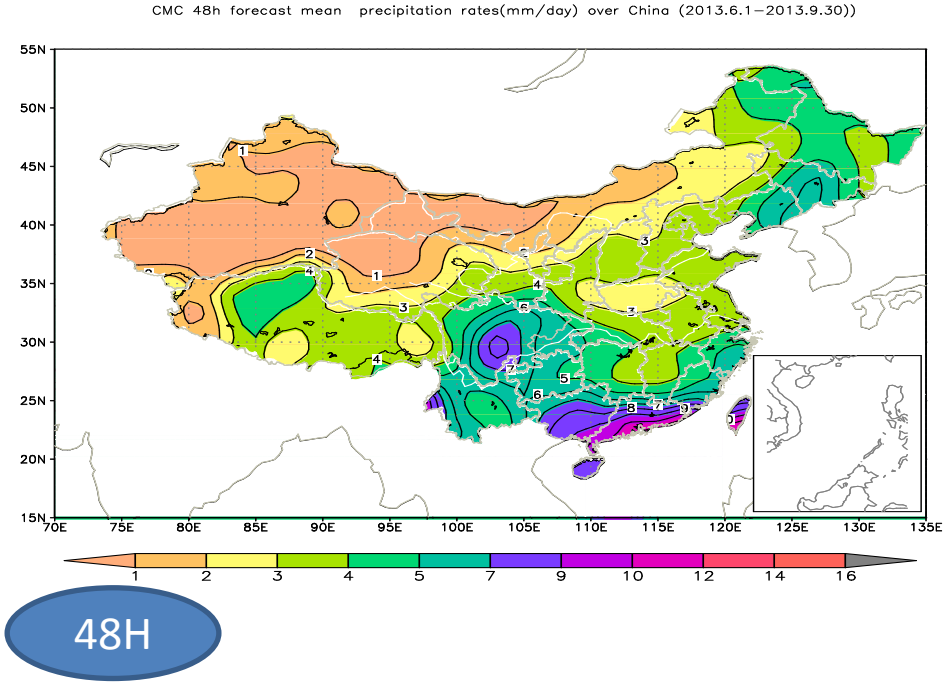


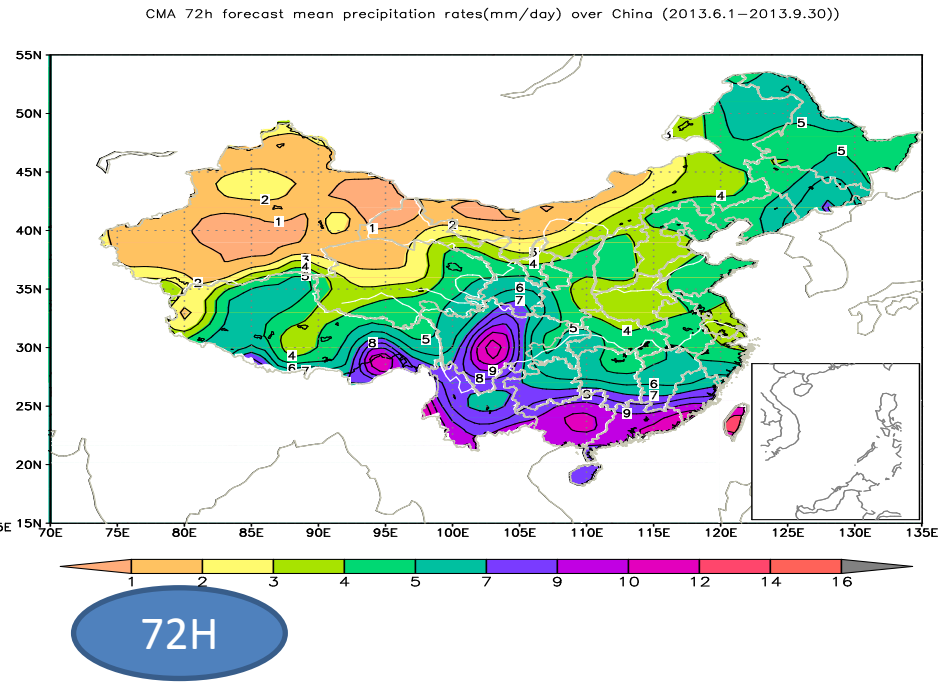
72H



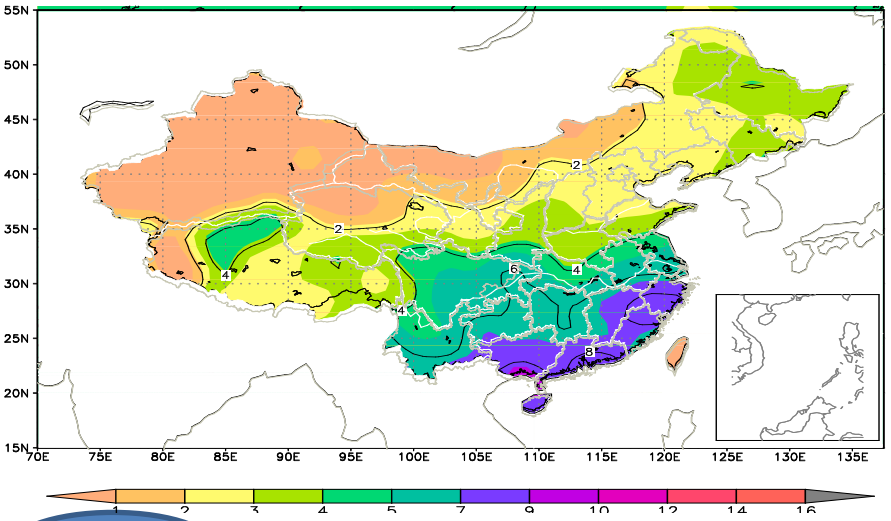


CMC 1/2/3day forecast mean precipitation rate distibution



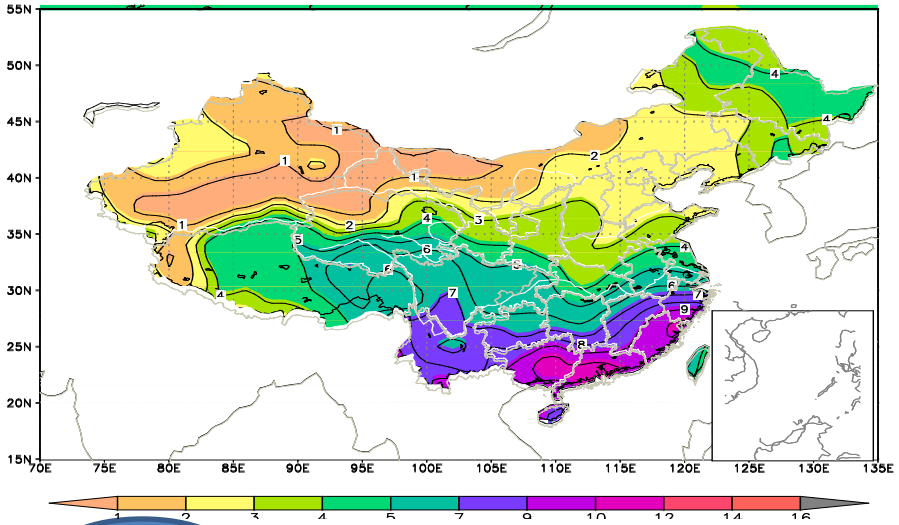


Mean precipitation rates(mm/day) over China (2014.5.4—2014.9.30)



OBS

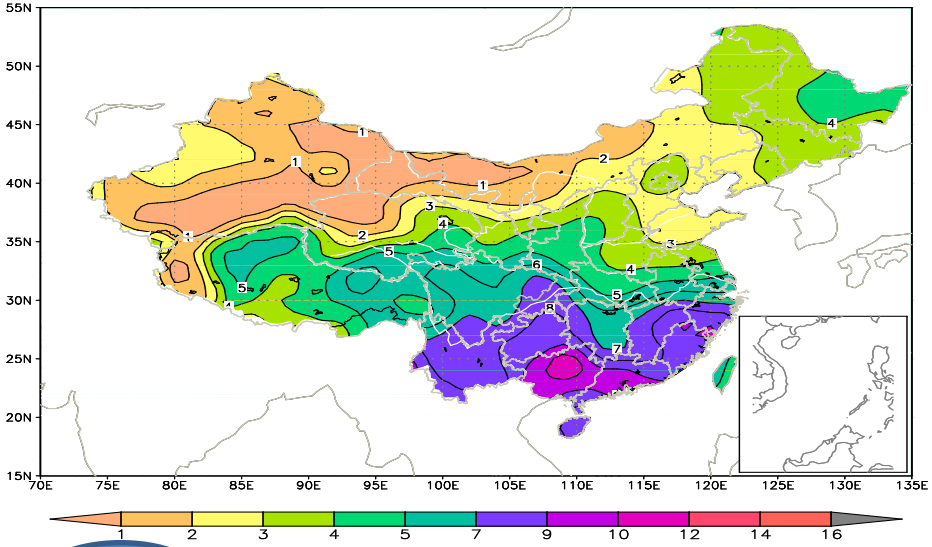
UK 24h forecast mean precipitation rates(mm/day) over China (2014.5.4—2014.9.30)



24H

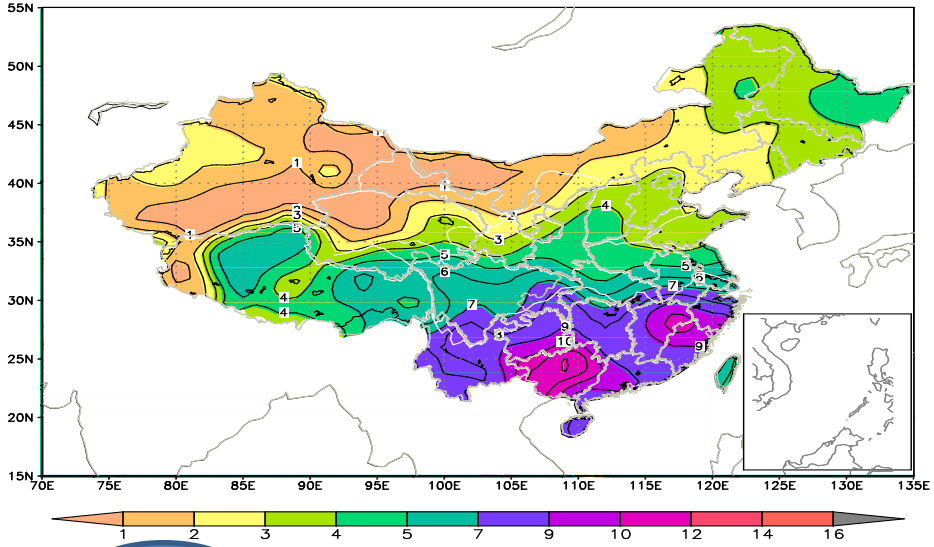
UKMO 1/2/3day forecast mean precipitation rate distibution

UK 48h forecast mean precipitation rates(mm/day) over China (2014.5.4—2014.9.30))

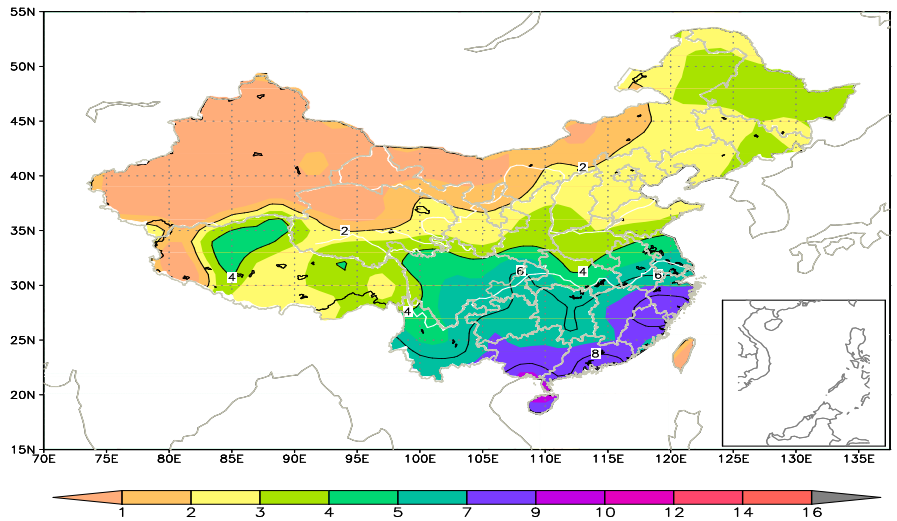


48H

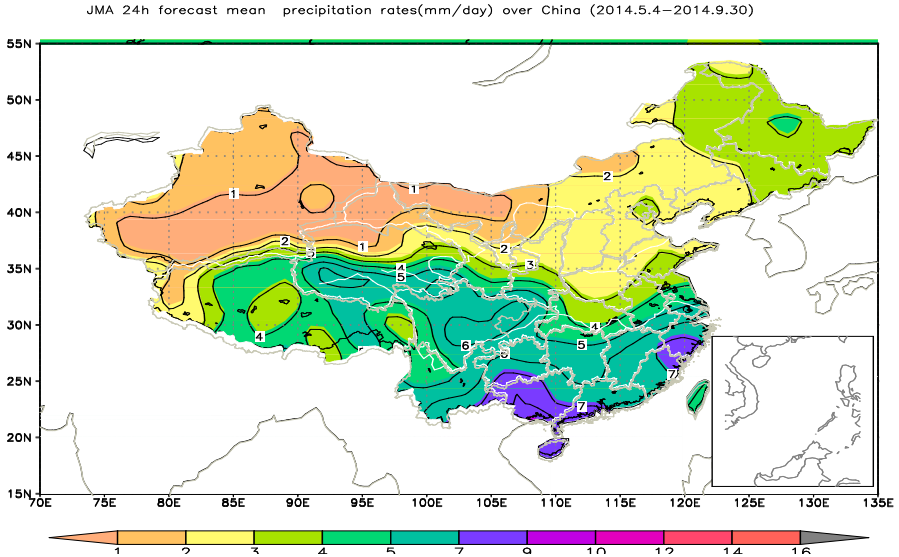
UK 72h forecast mean precipitation rates(mm/day) over China (2014.5.4—2014.9.30))



72H

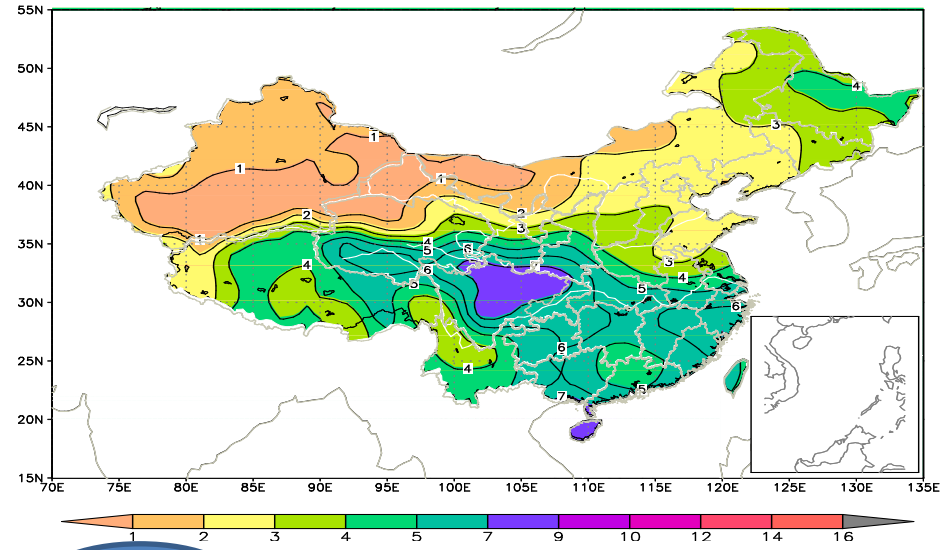


OBS

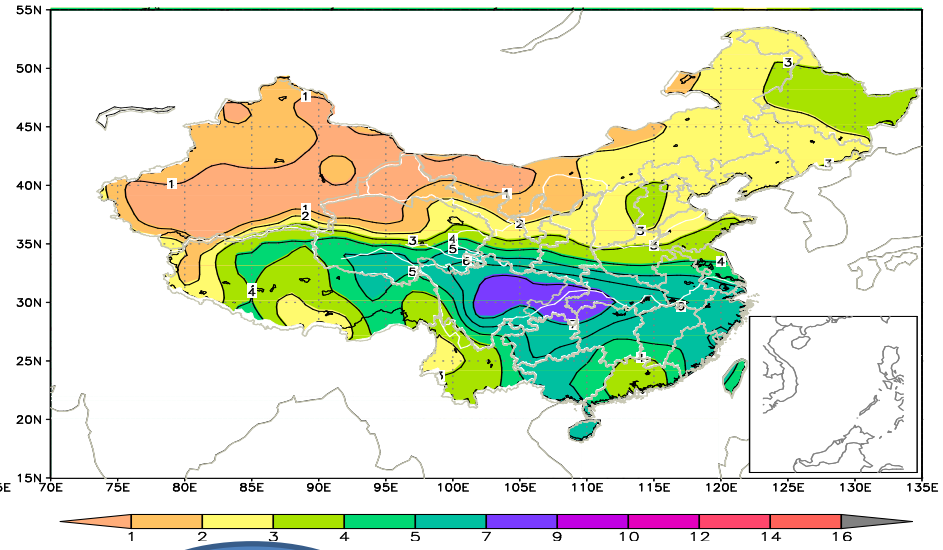


24H

JMA 1/2/3day forecast mean precipitation rate distibution

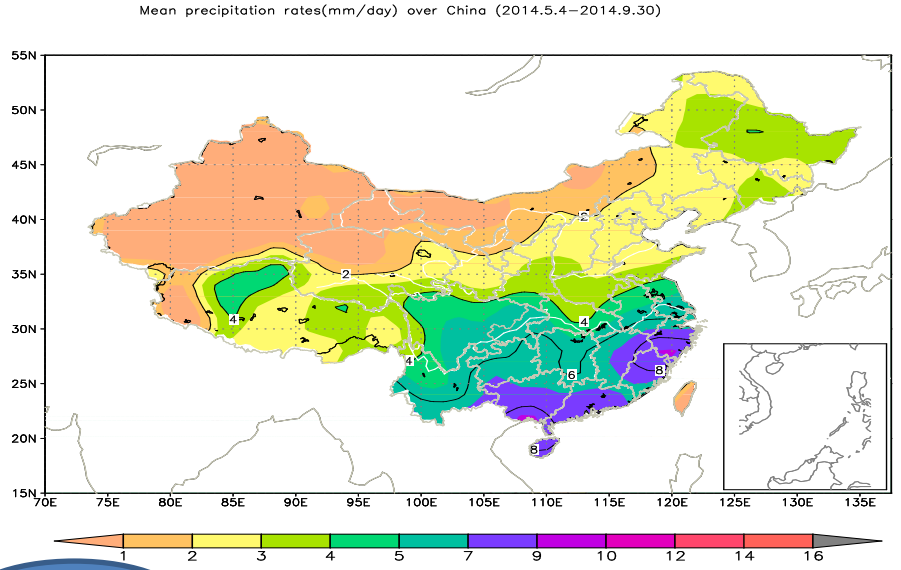


48H

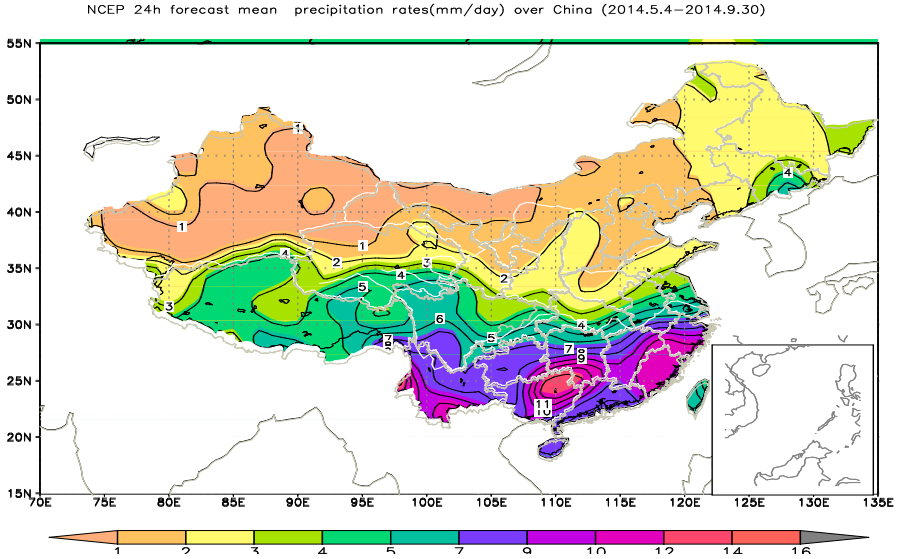


72H

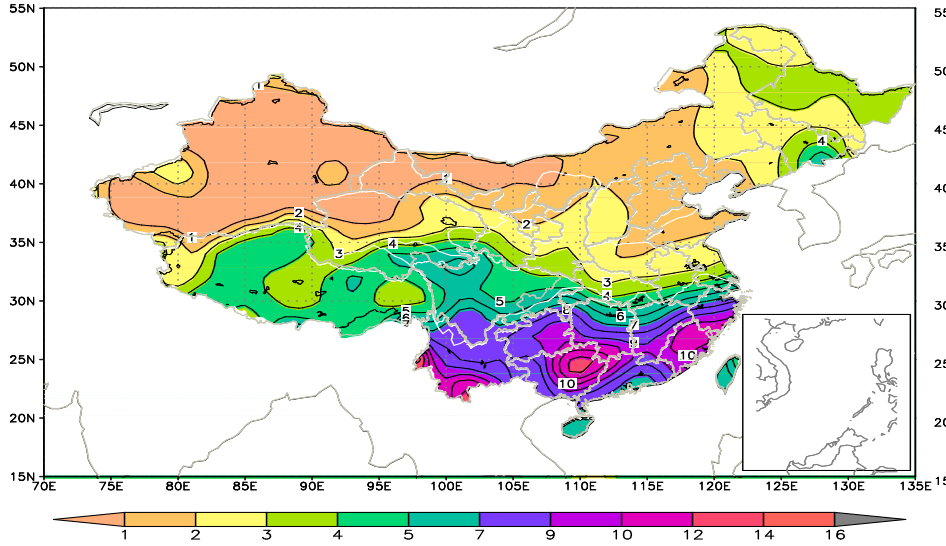
NCEP 1/2/3day forecast mean precipitation rate distibution



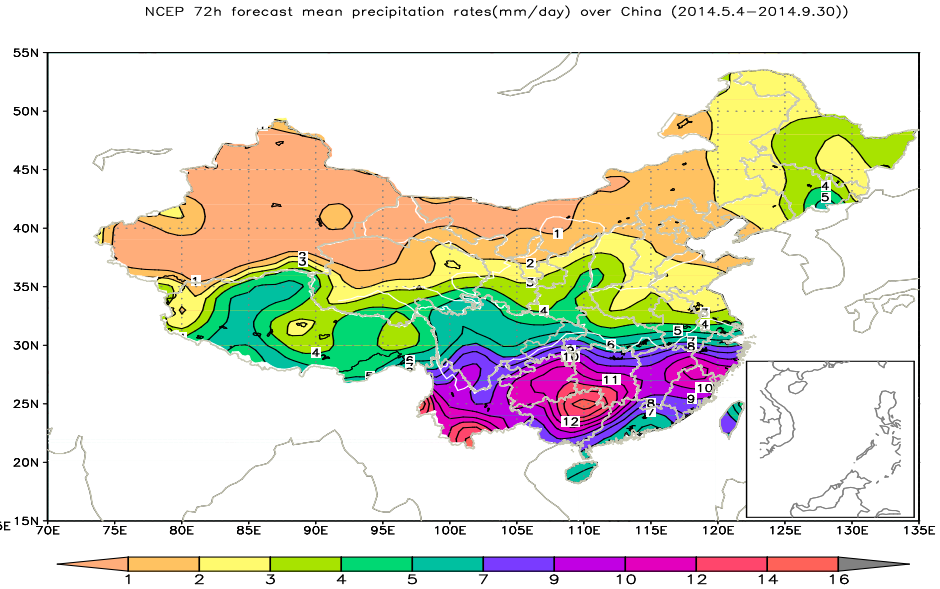
OBS



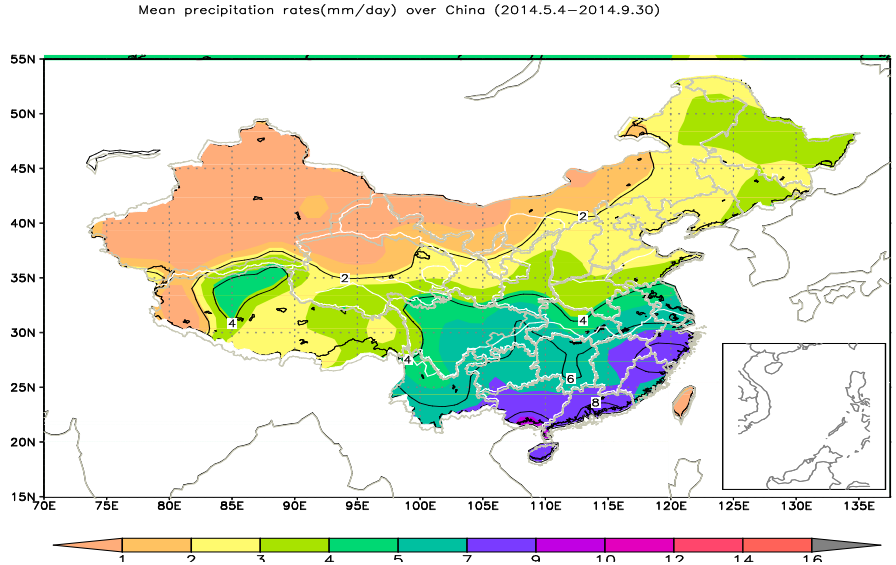
24H



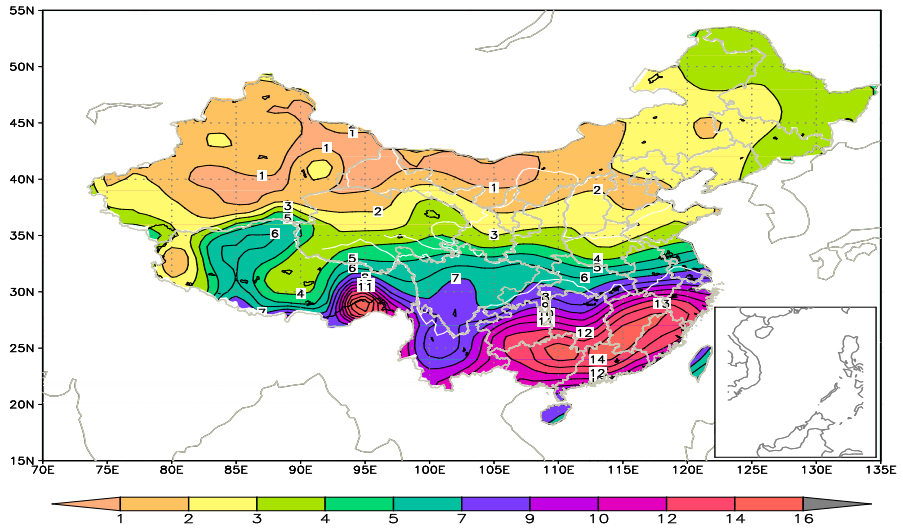
48H



72H

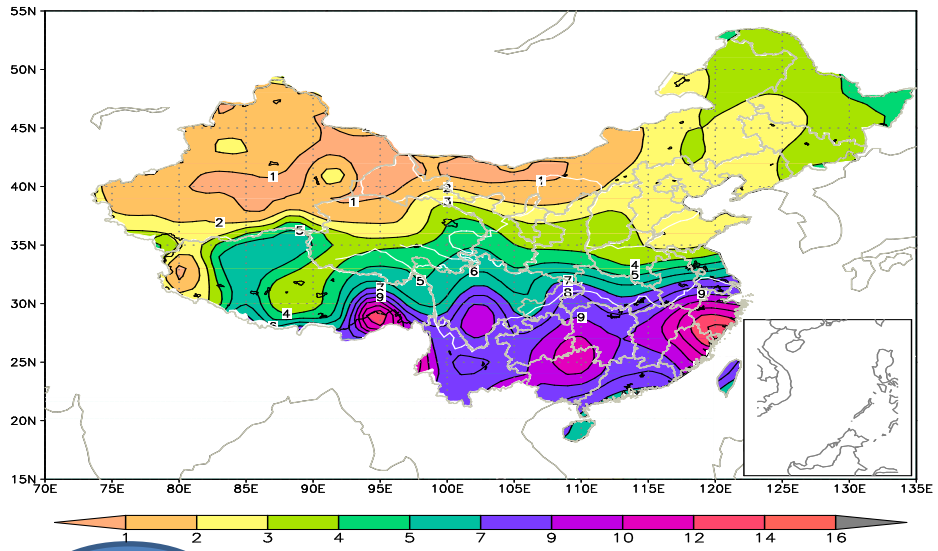


OBS

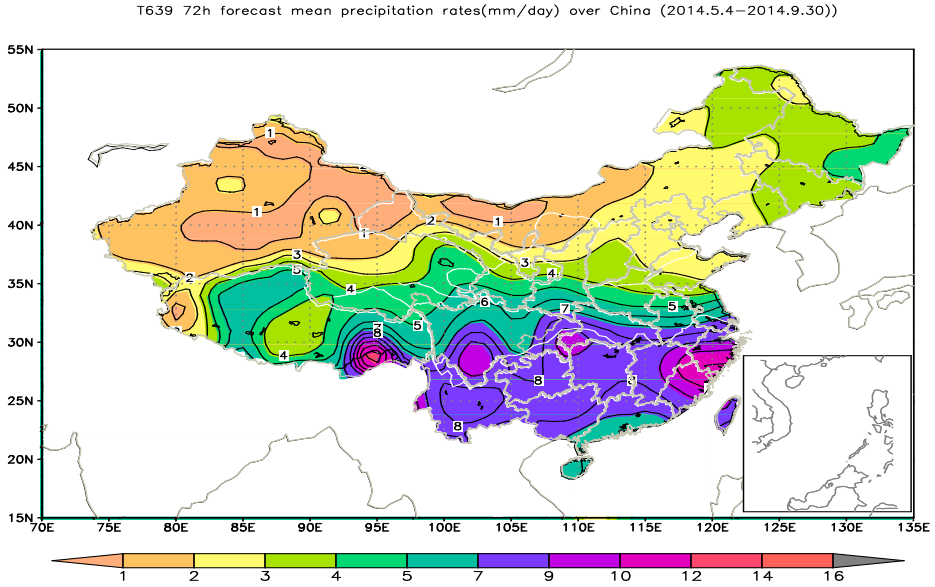


24H

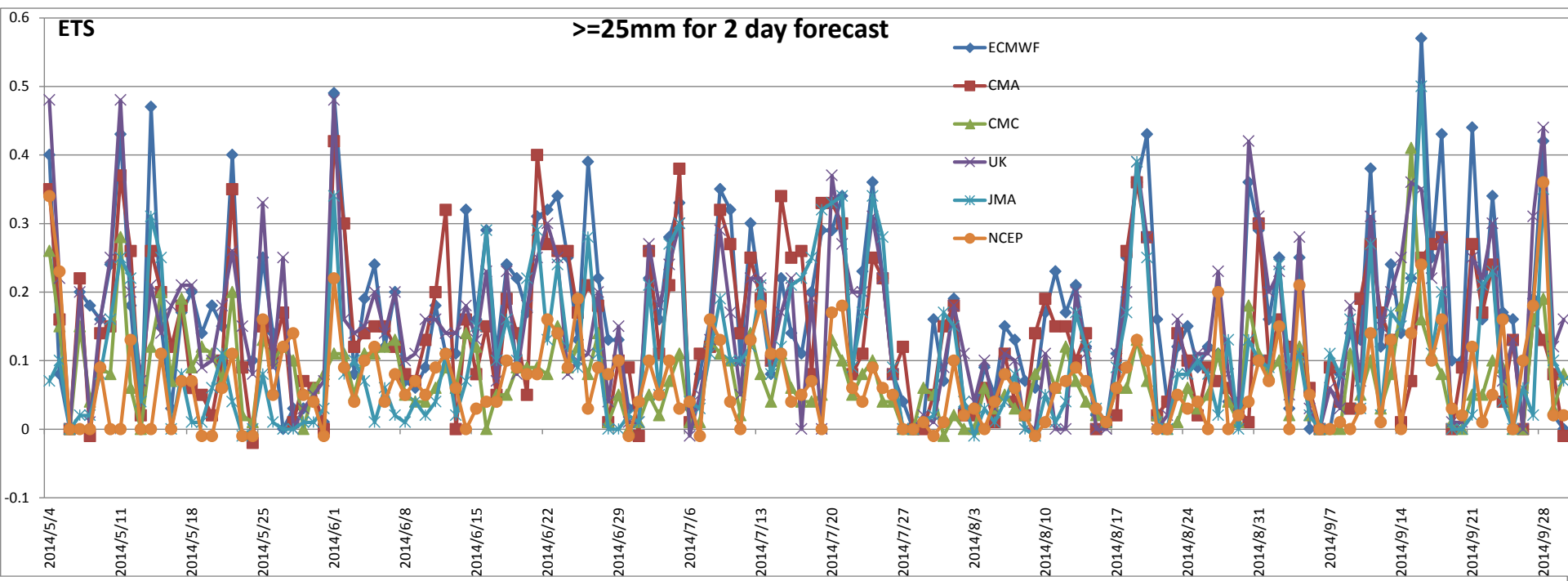
CMA 1/2/3day forecast mean precipitation rate distibution

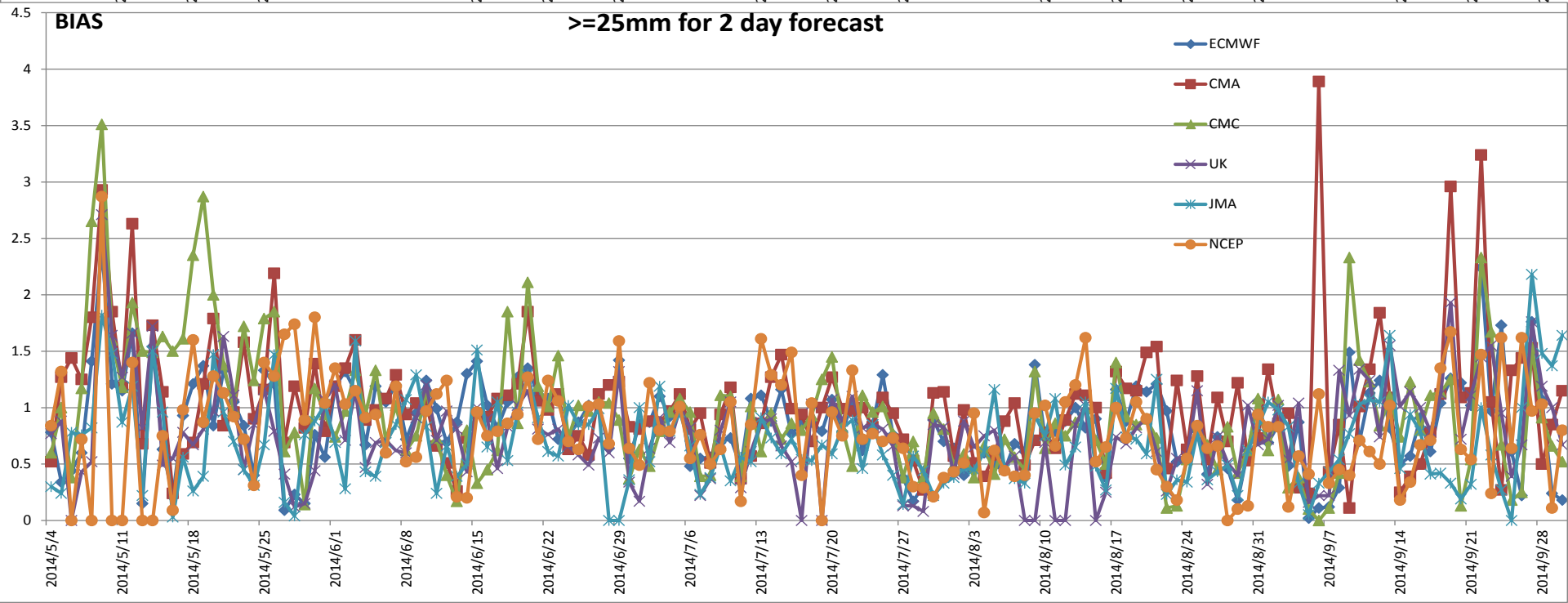


48H



72H


ETS
>=25mm for 2 day forecast
ECMWF
CMA
CMC
UK
JMA
NCEP
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
2014/5/4
2014/5/11
2014/5/18
2014/5/25
2014/6/1
2014/6/8
2014/6/15
2014/6/22
2014/6/29
2014/7/6
2014/7/13
2014/7/20
2014/7/27
2014/8/3
2014/8/10
2014/8/17
2014/8/24
2014/8/31
2014/9/7
2014/9/14
2014/9/21
2014/9/28


BIAS
>=25mm for 2 day forecast
ECMWF
CMA
CMC
UK
JMA
NCEP
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2014/5/4
2014/5/11
2014/5/18
2014/5/25
2014/6/1
2014/6/8
2014/6/15
2014/6/22
2014/6/29
2014/7/6
2014/7/13
2014/7/20
2014/7/27
2014/8/3
2014/8/10
2014/8/17
2014/8/24
2014/8/31
2014/9/7
2014/9/14
2014/9/21
2014/9/28

Thank you for your attention.