SHAtrop: the new tropospheric delay model over China continent

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Content

- **Background**
- **SHAtrop: ZTD Modeling**
- **SHAtrop: ZTD Grid modeling**
- **SHAtrop: Model validation**
- **Summary**

Troposphere modeling

- Slant Propagation Delay

$$SPD(e) = Z_h \bullet MF_h(e) + Z_w \bullet MF_w(e)$$

$$ZTD = Z_h + Z_w, \quad e = 90^\circ$$

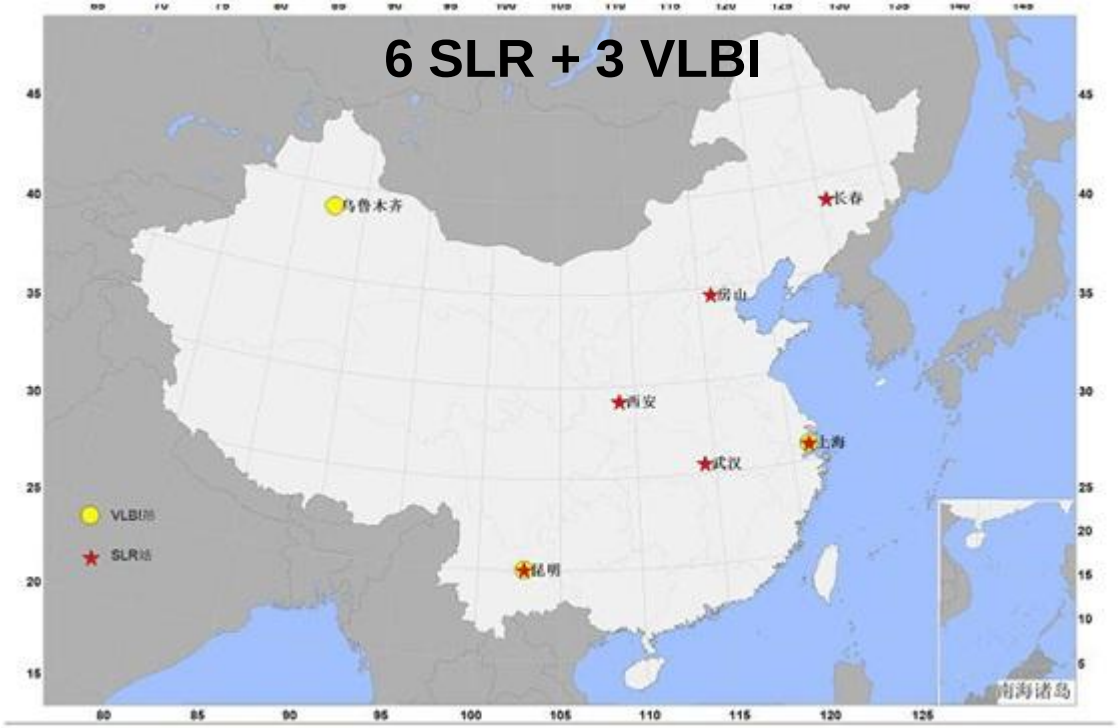
- ZTD:
  - EGNOS/UNB3 et al
  - Saastamoinen/Hopfield et al using :
    - weather data at the site
    - numerical weather model (NWM)
    - empirical pressure/temperature model (GPT2/GPT2w)
  - Ray-traced delays (VMF1/UNB-VMF)
  - Empirical model based on GNSS ZTD

SHAtrop: *overview*

- Empirical regional ZTD model over China continent
- GNSS ZTD estimates (of 223 continuous GNSS sites) at Shanghai Astronomical Observatory
- ZTD is modeled by a function of station height and the ZTD at geoidal surface (ZTD-Geiod).
- Grid model with high spatial resolution (2°×2.5°)
- Without weather data, easy to implement

SHAtrop: *data*

- **CMONOC** (Crustal Movement Observation Network of China)



http://neiscn.org/

SHAtrop: *data*

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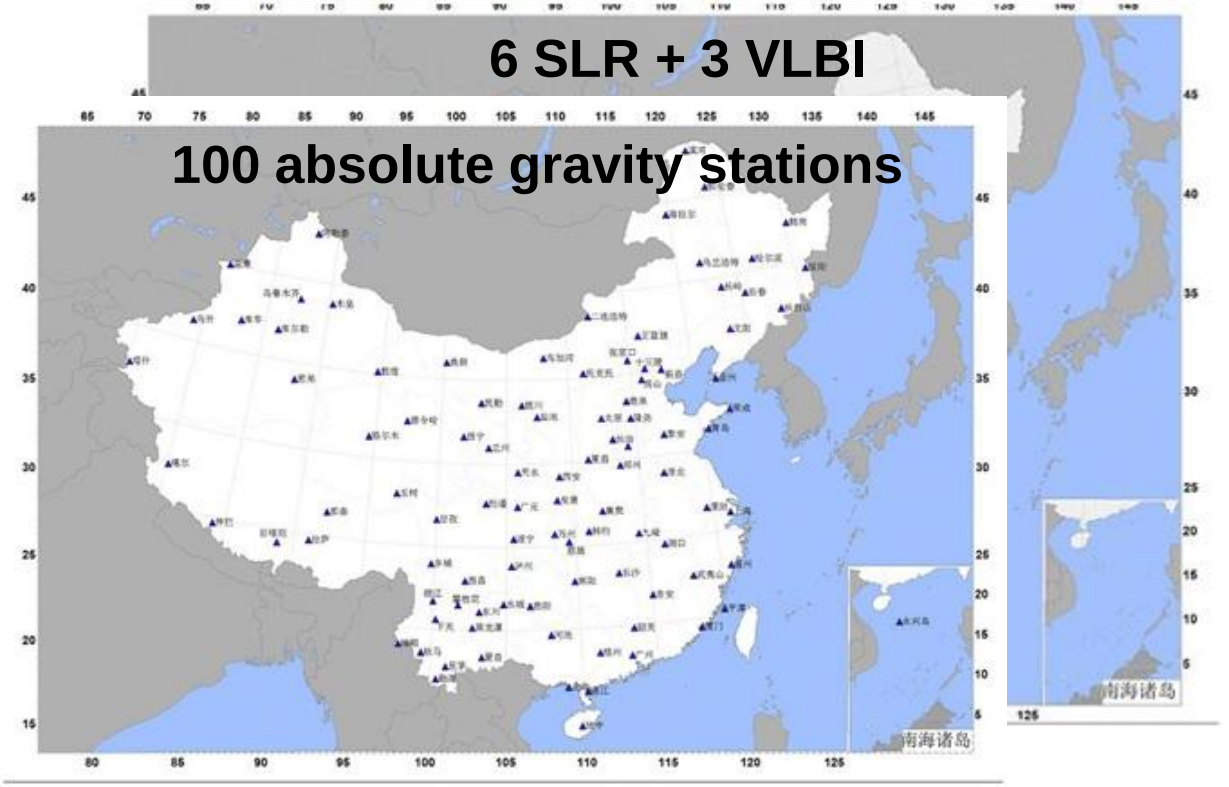

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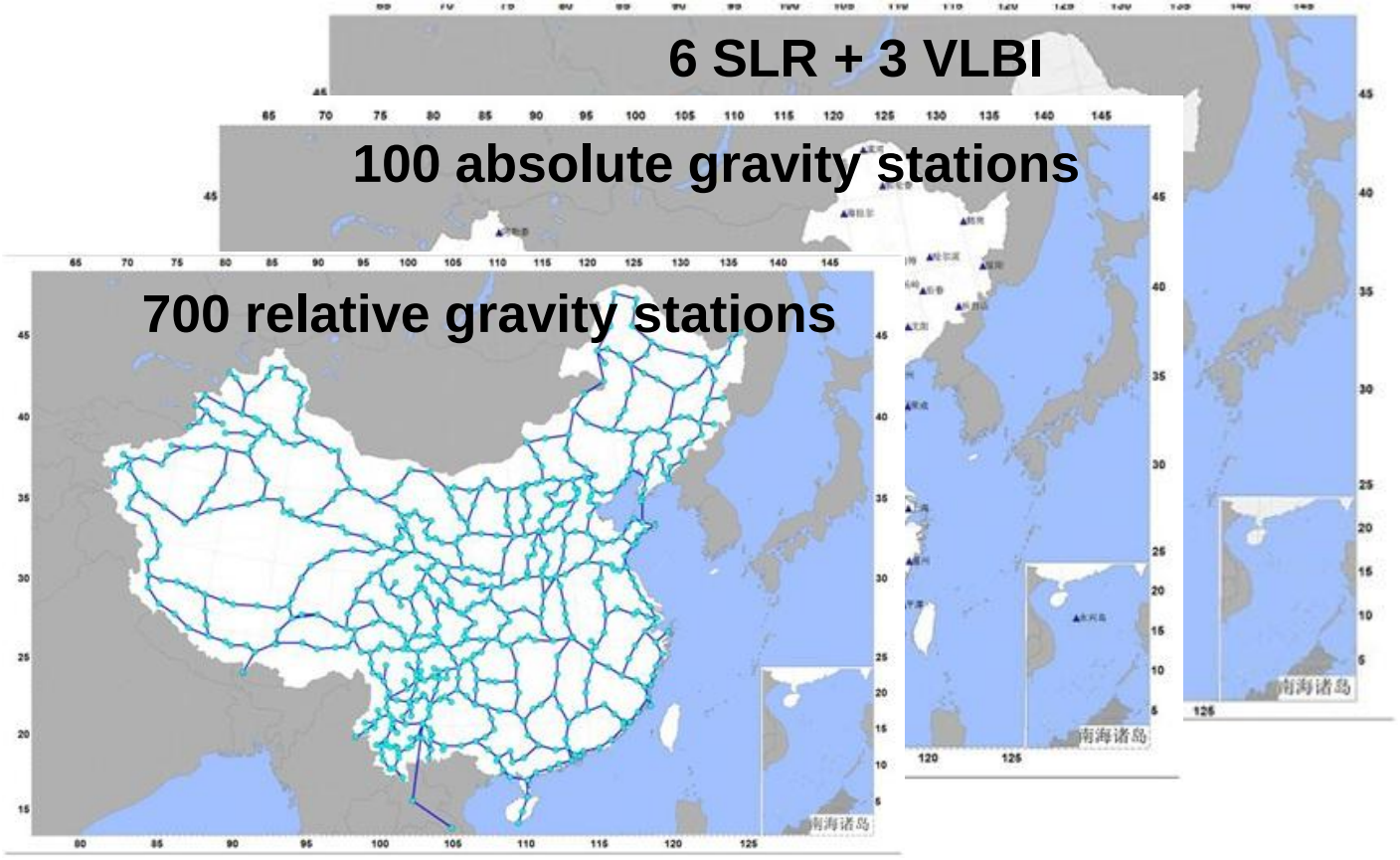

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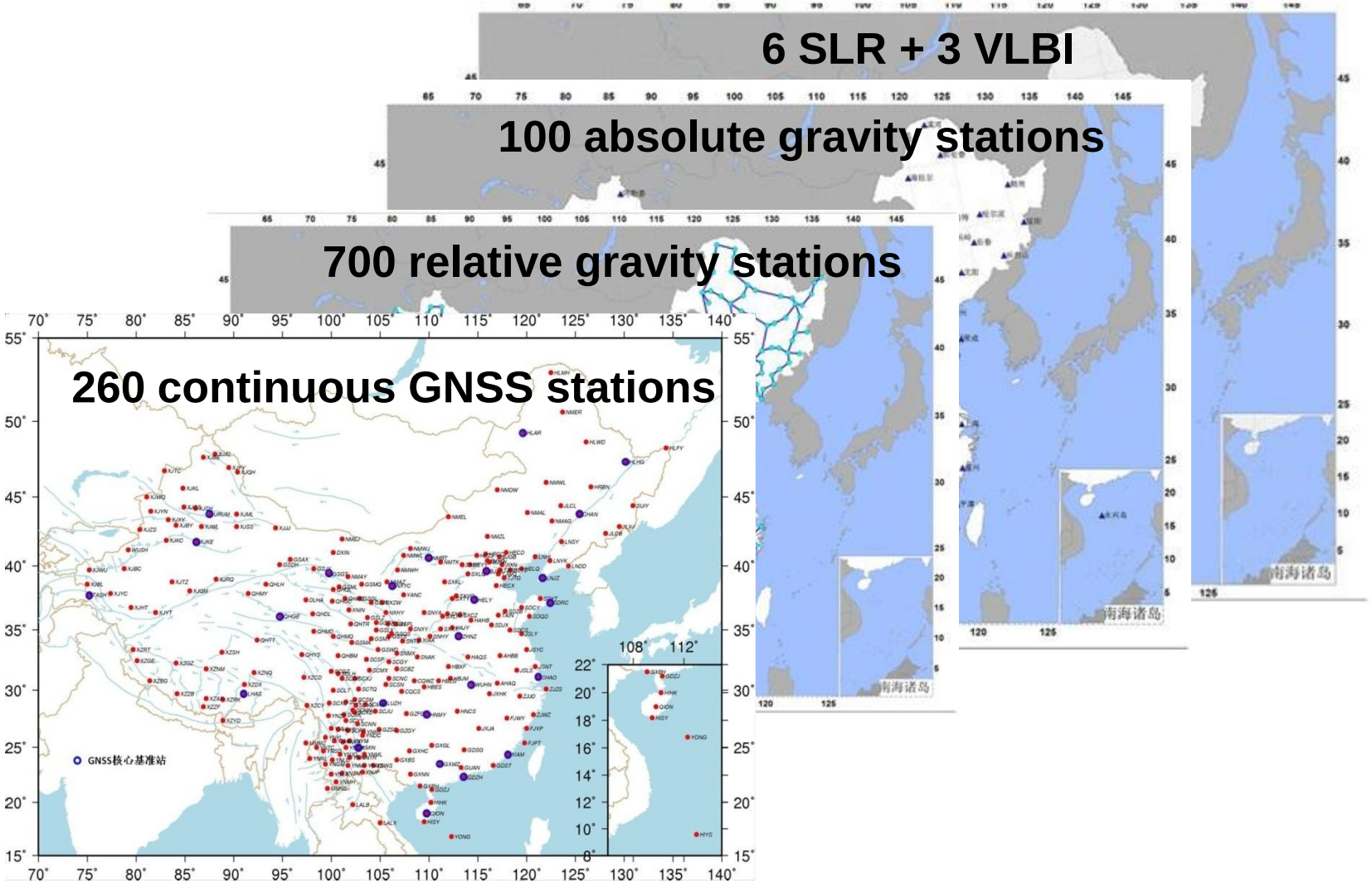

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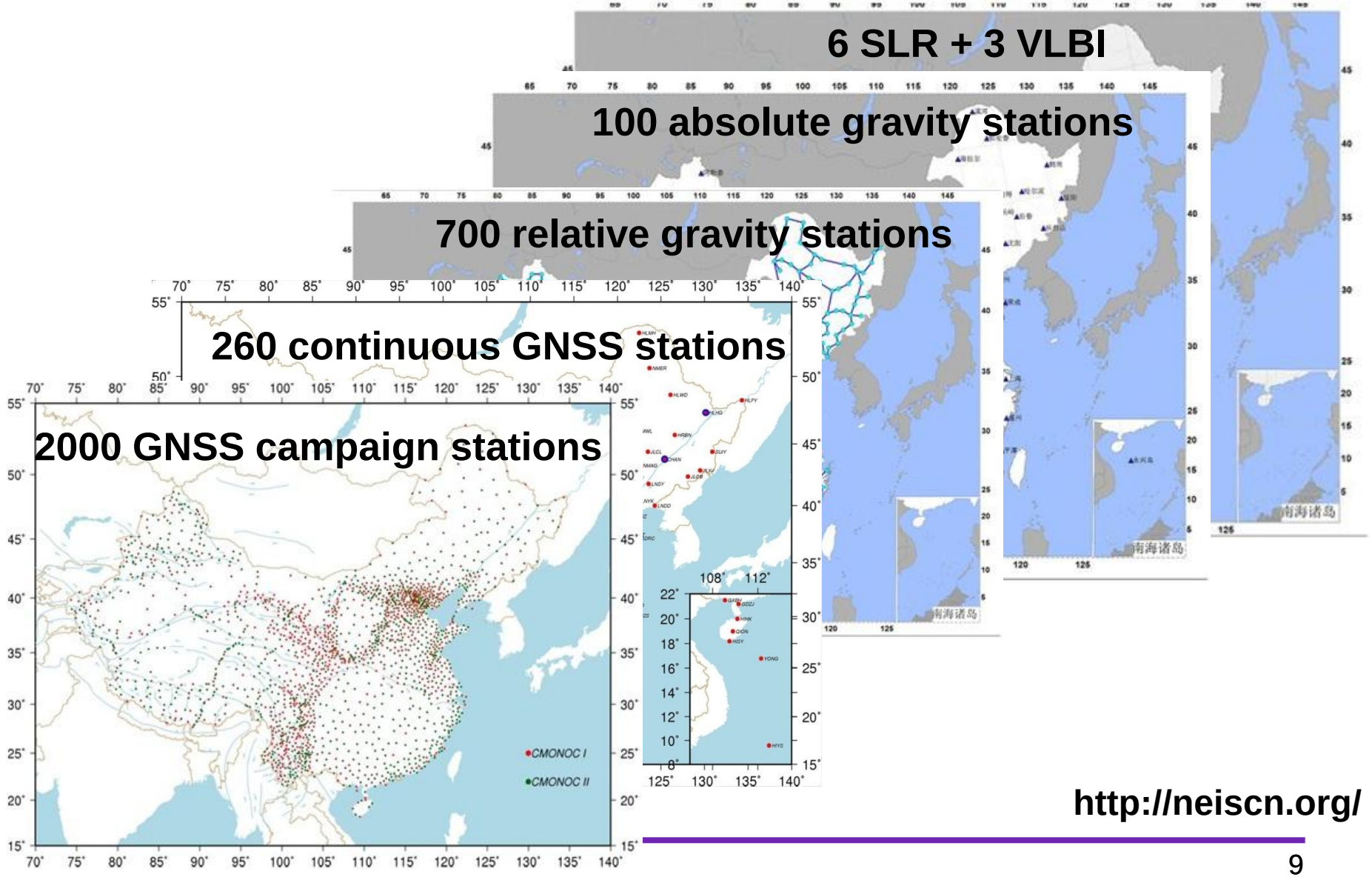
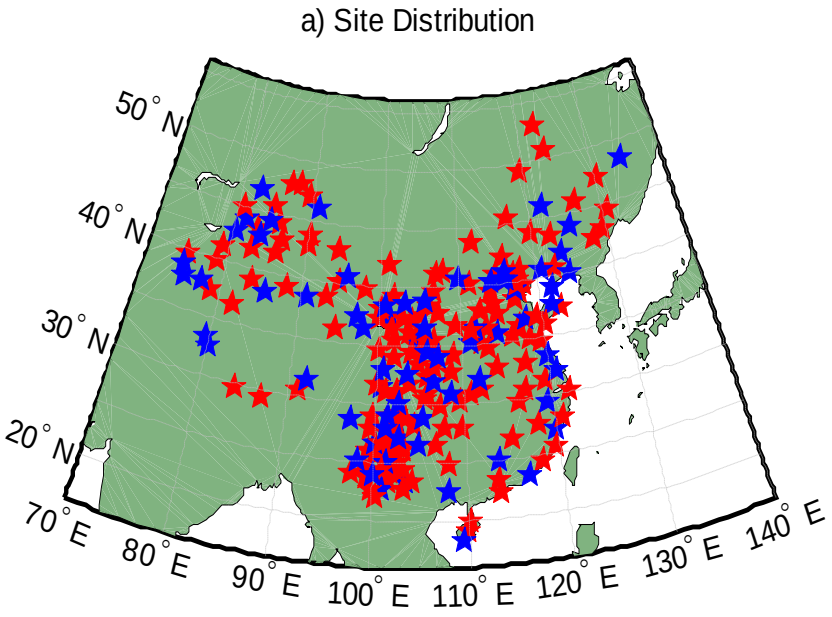
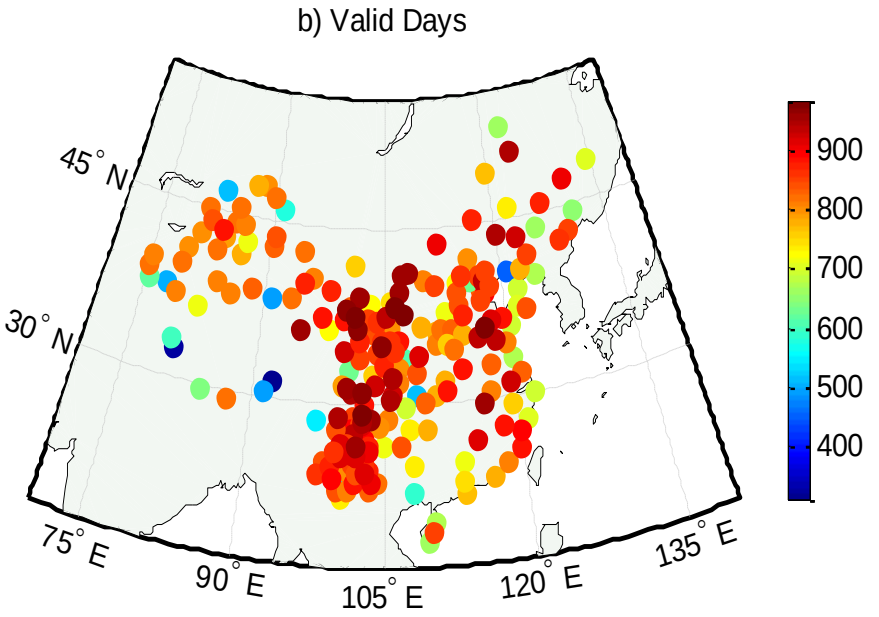


http://neiscn.org/

SHAtrop: *data*

- 4 years' GNSS ZTD estimates (of 223 continuous GNSS sites) at Shanghai Astronomical Observatory;
- Model determination: 152; model validation: 152+71;
- Spanning: 2012-2014





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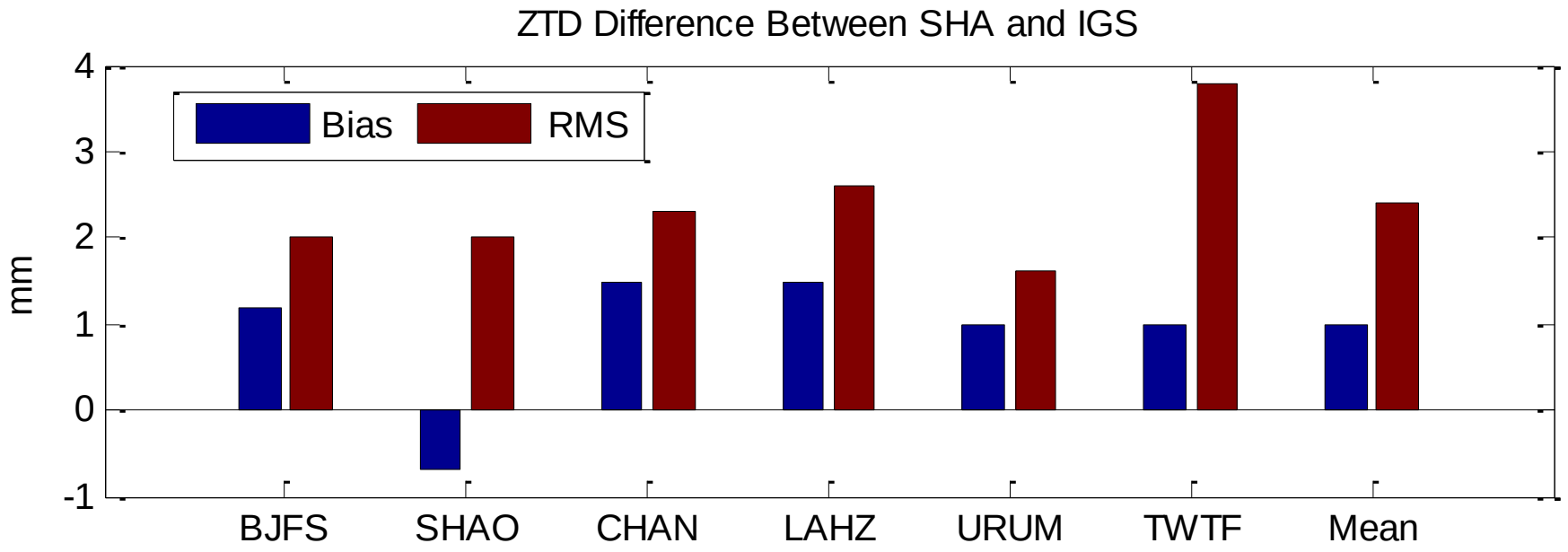
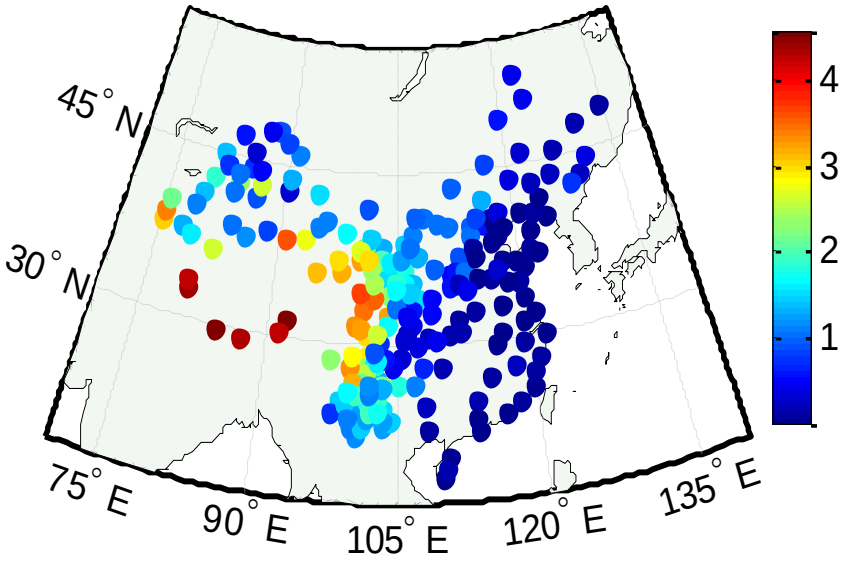


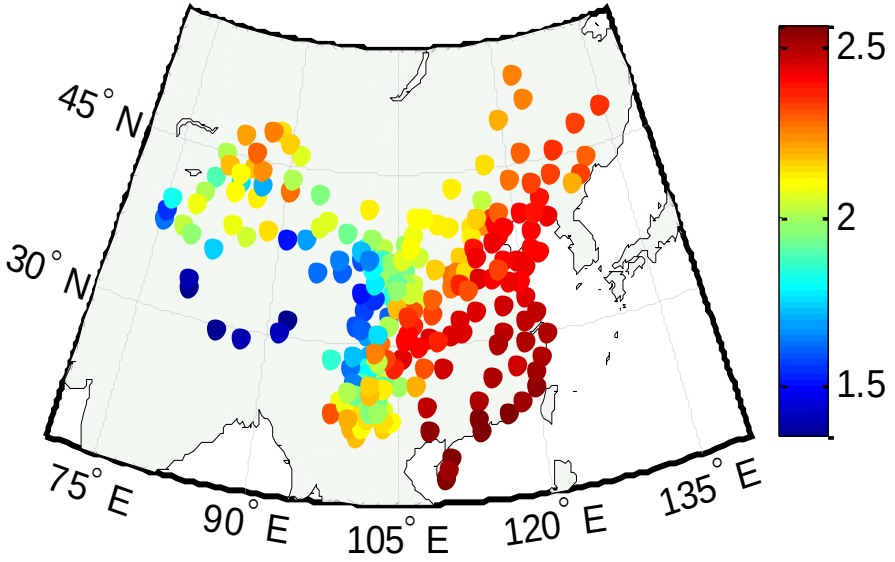
SHAtrop: ZTD v.s. station height

- Mean annual ZTD with respect to station height

a) Site Altitude(km)

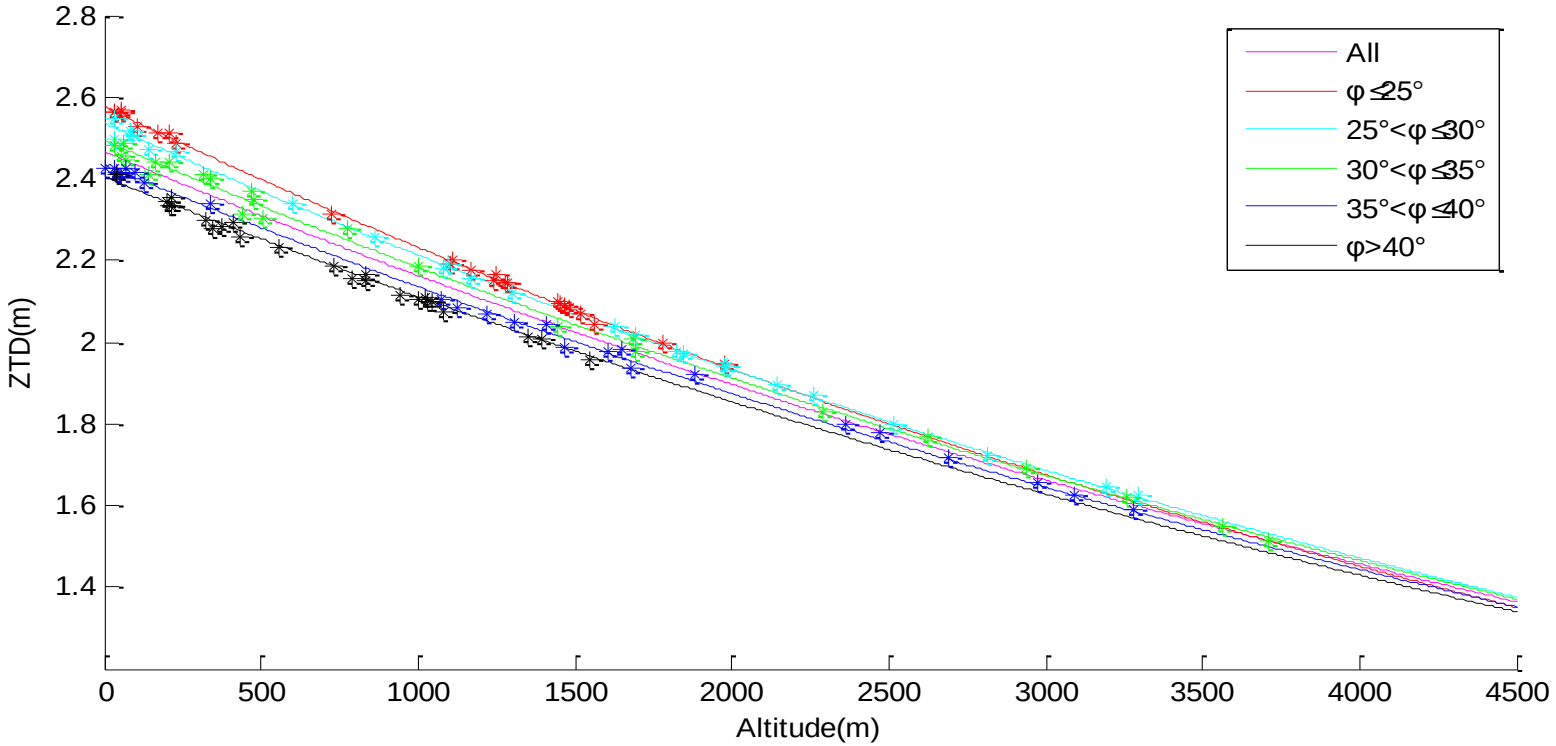


b) Mean ZTD(m)



SHAtrop: ZTD v.s. station height

- Fitting of annual ZTD with respect to station height: β varies with station latitude



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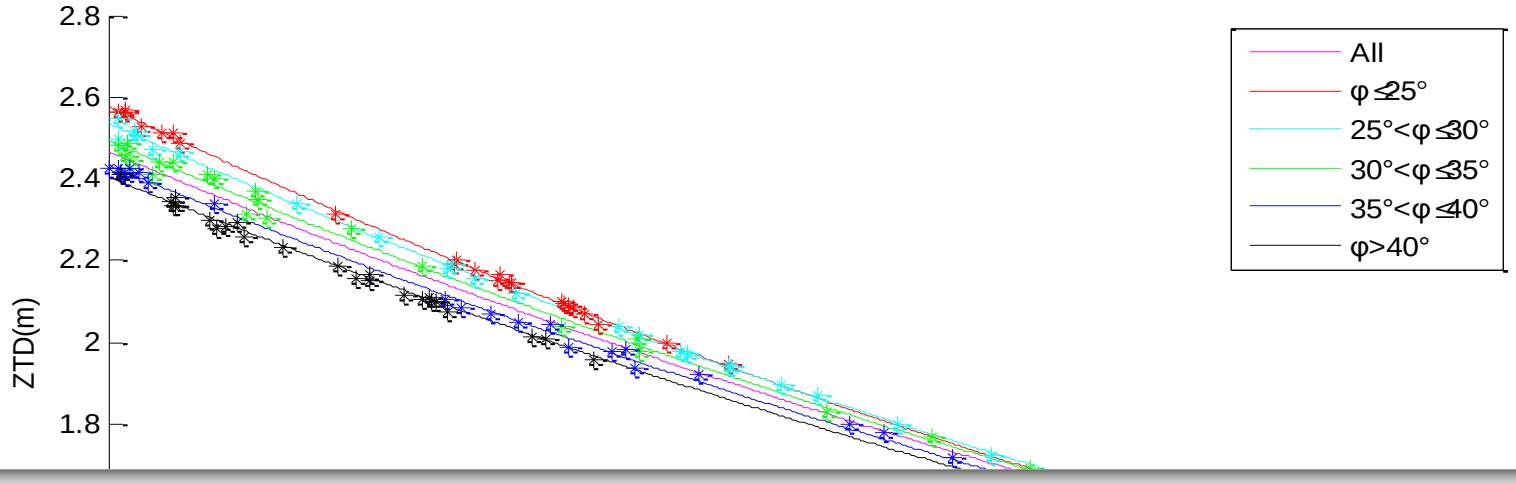
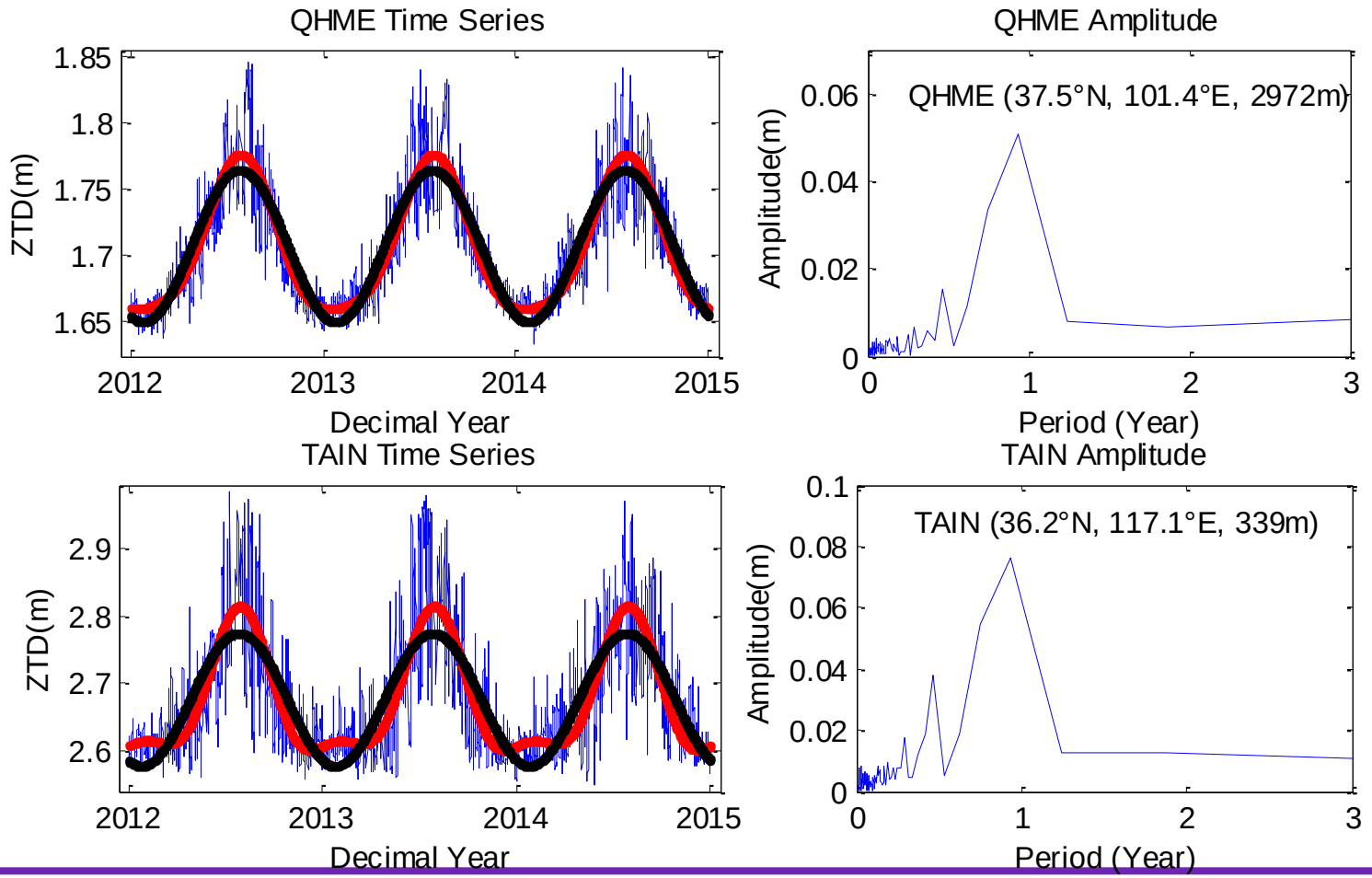


$$ZTD(h) = ZTD_0 \times e^{\beta h}$$

Latitude	<25° N	25° N~30° N	30° N-35° N	35° N-40° N	>40° N
$\beta\ (10^{-3})$	- 0.1435	- 0.1359	- 0.1329	- 0.1306	- 0.1300

SHAtrop: ZTD period term

- ZTD time series fitting with annual and semi-annual terms
- amplitude derived from fast Fourier transform



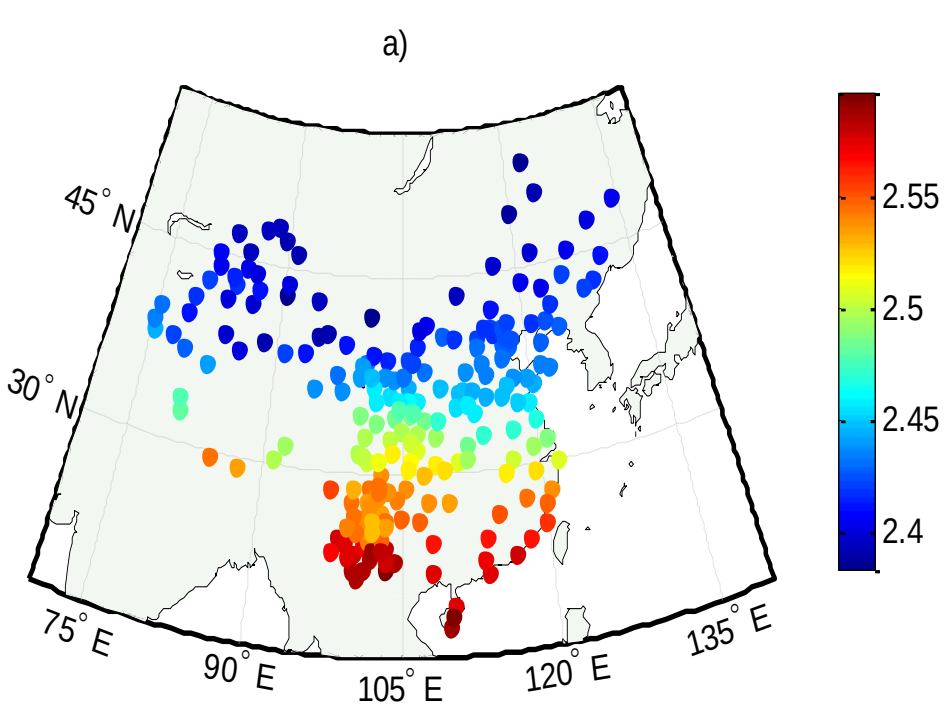
SHAtrop: ZTD model over China continent

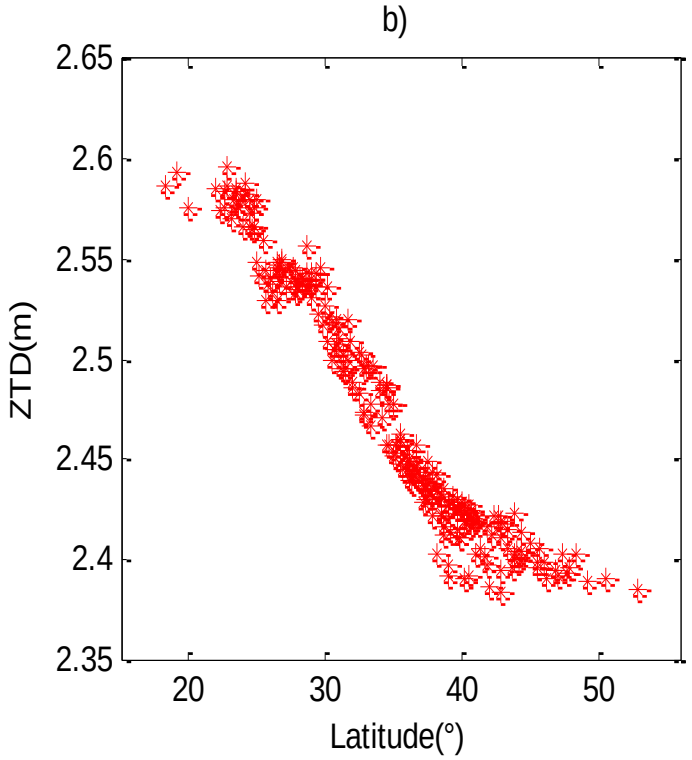
- ZTD modeled with function of station height over Geoid (constant term) and periodical terms

$$ZTD(doy) = ZTD_m + A_1 \cos\left(\frac{2\pi}{365.25}(doy - d_1)\right) + A_2 \cos\left(\frac{4\pi}{365.25}(doy - d_2)\right)$$

SHAtrop: ZTD constant term

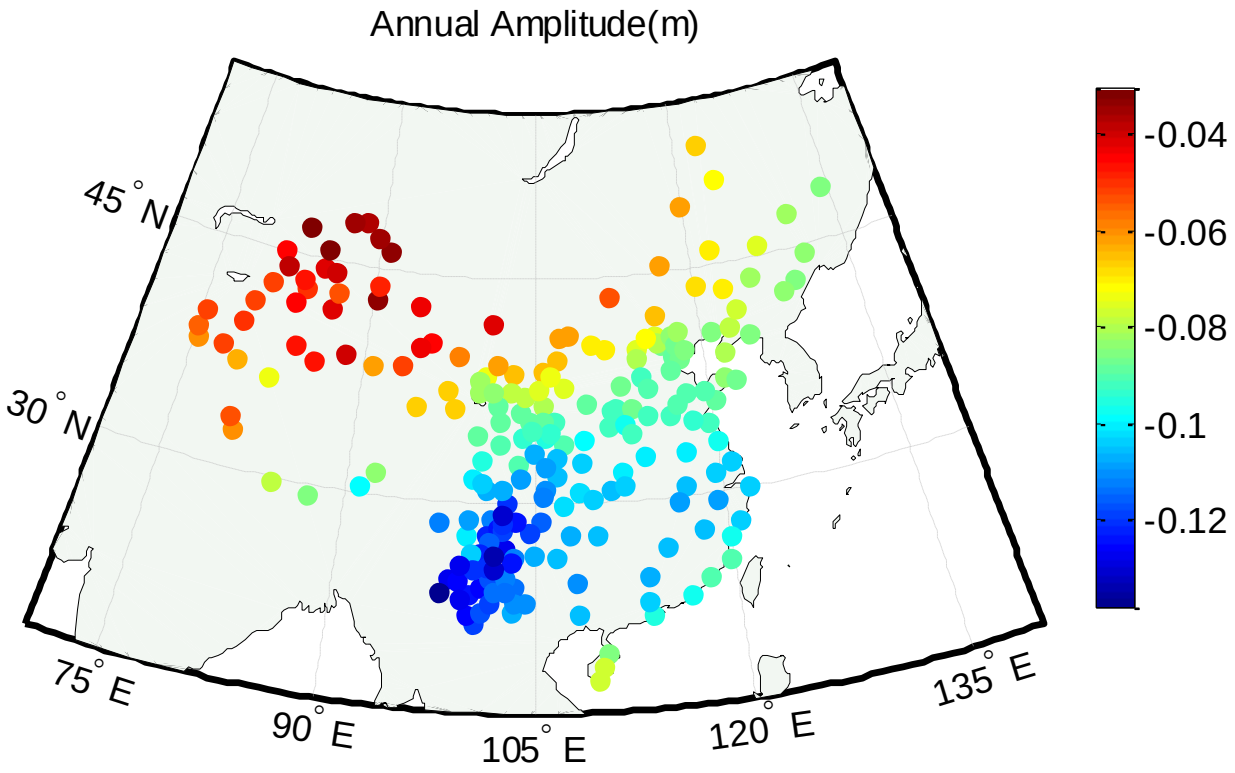
- Constant term of all sites
- Constant term v.s. site latitude





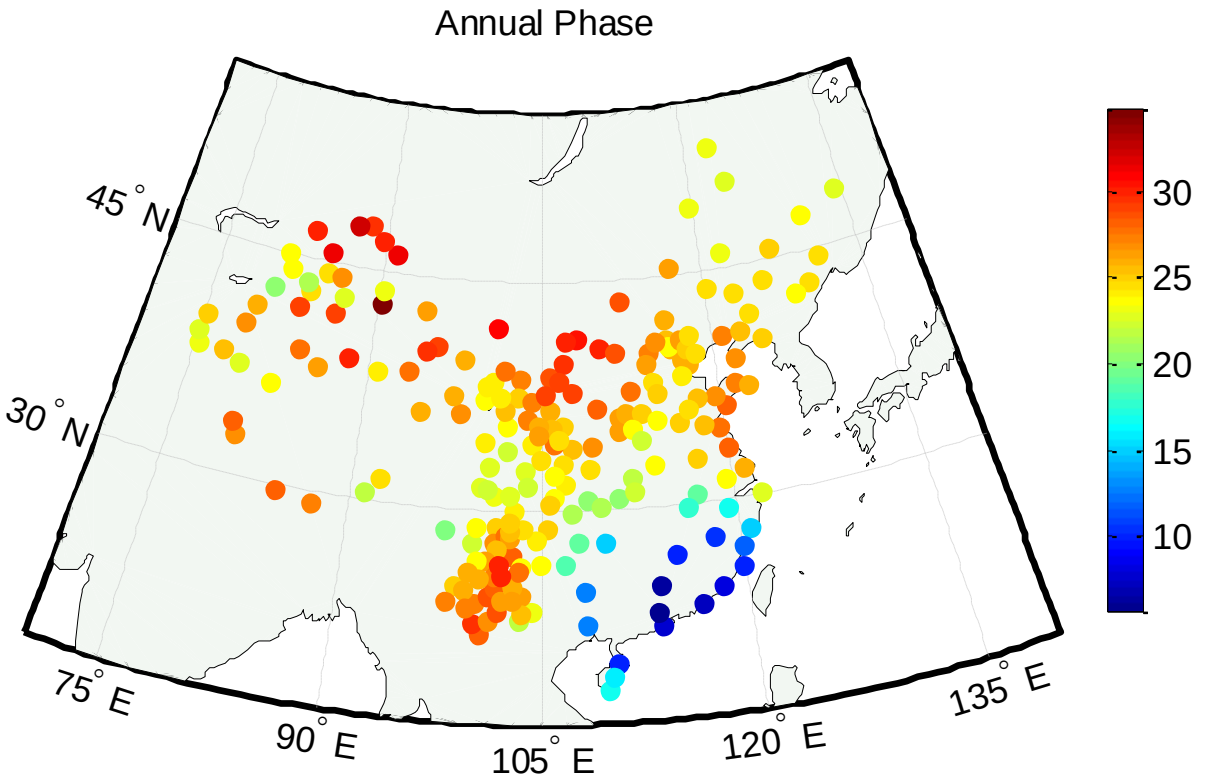
SHAtrop: ZTD annual term

- Annual amplitude



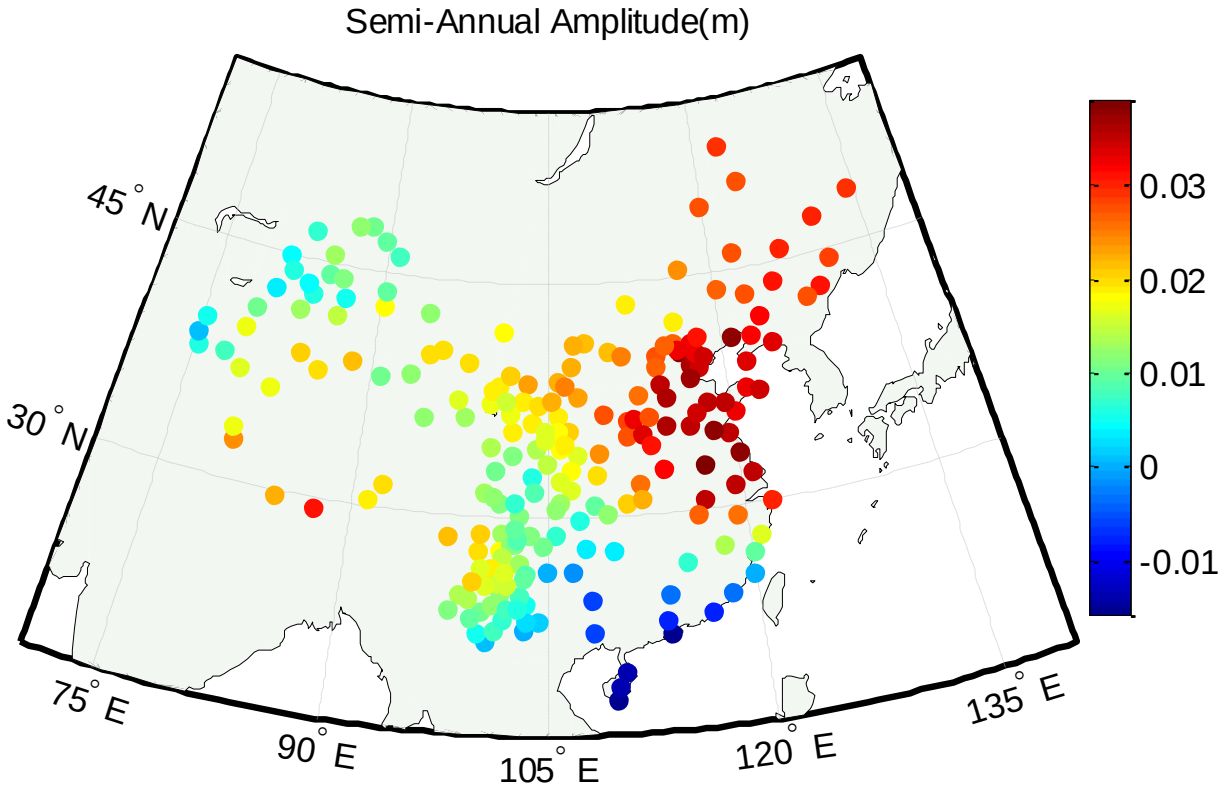
SHAtrop: ZTD annual term

- Annual phase



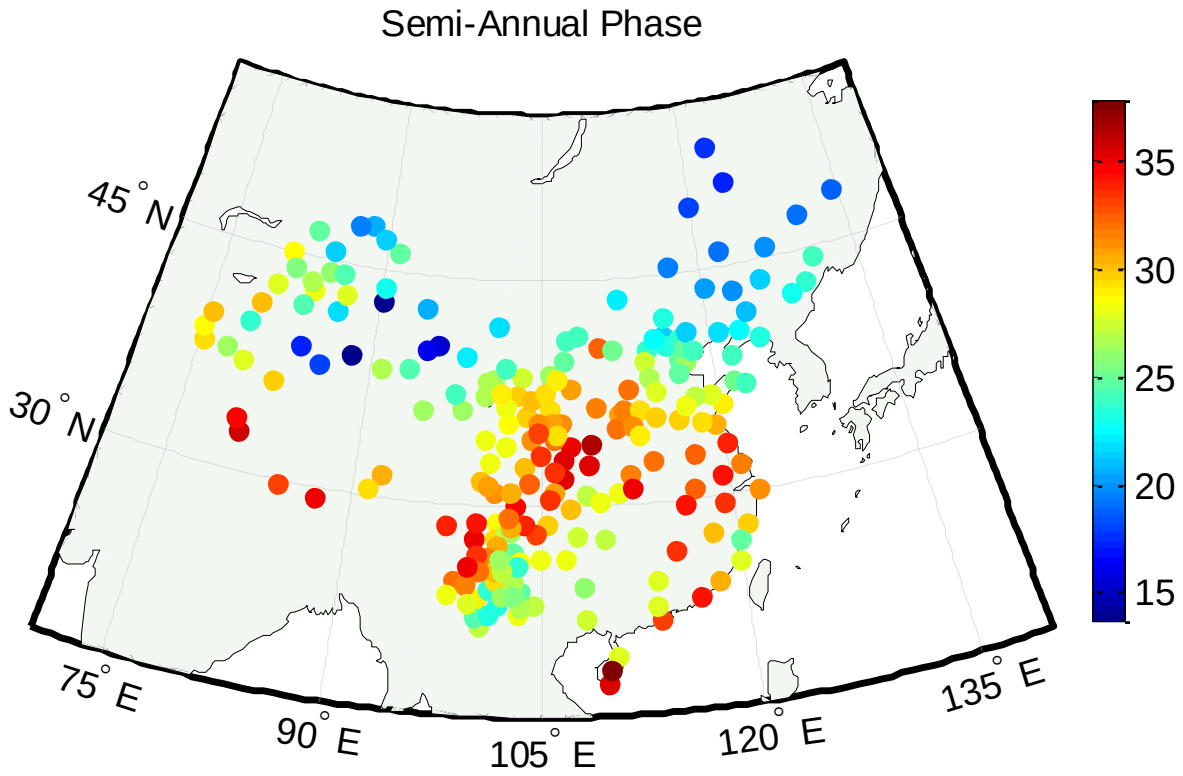
SHAtrop: ZTD semi-annual term

- Semi-annual amplitude



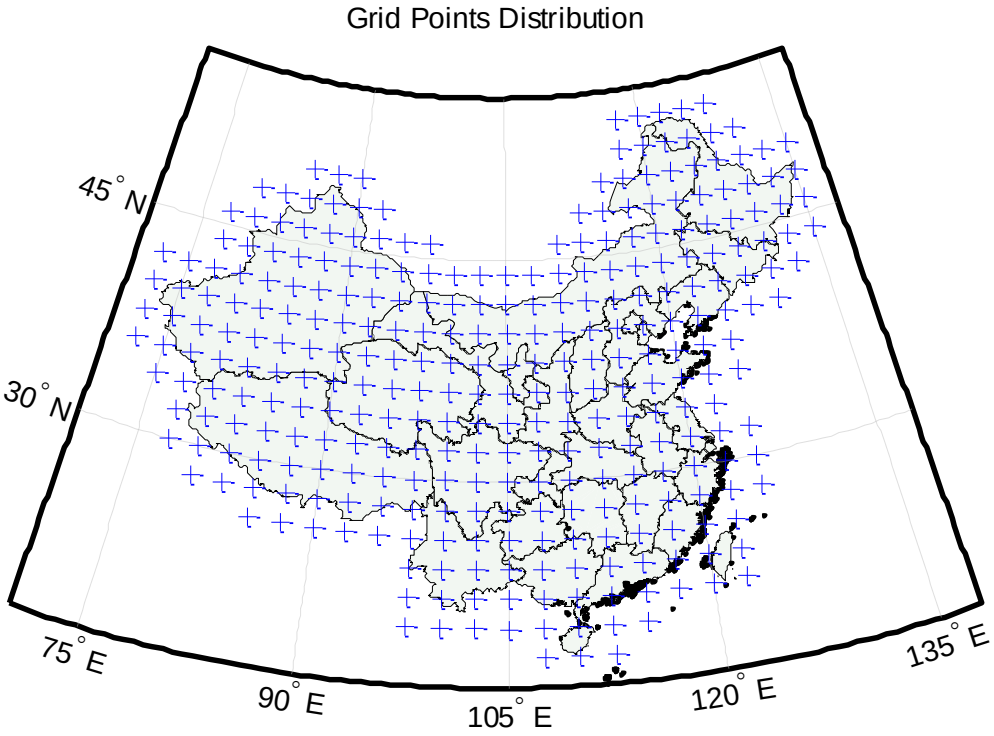
SHAtrop: ZTD semi-annual term

- Semi-annual phase



SHAtrop: ZTD Grid model over China continent

- Parameters of 152 sites
- Latitude-Longitude: 2°× 2.5°grid
- [70°E~135°E, 18°N~54°N]



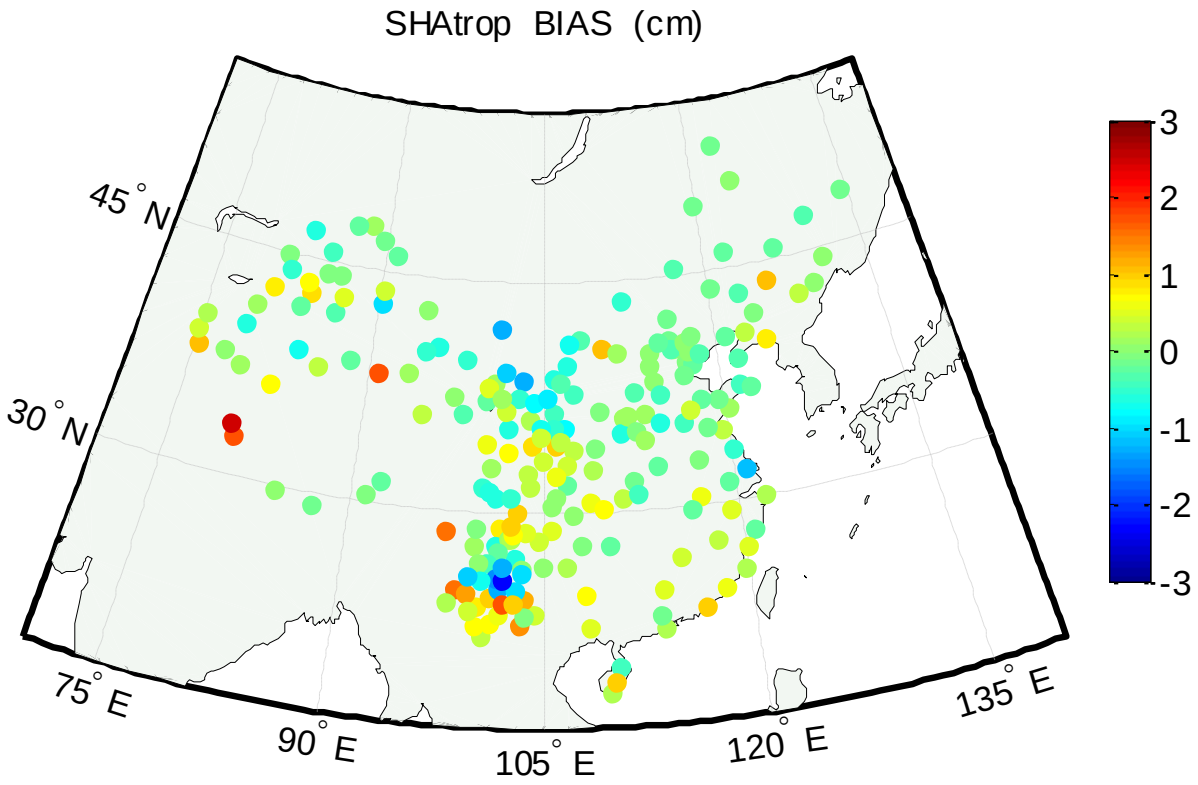
SHAtrop: ZTD calculation for user

- Select four grid points around the site
- Bilinear interpolation (ZTD_m, A_1, d_1, A_2, d_2)
- Reduction to the site height
- ZTD at each grid point is modeled by:

$$ZTD(doy,h) = \left(ZTD_m + A_1 \cos\left(\frac{2\pi}{365.25}(doy - d_1) \right) + A_2 \cos\left(\frac{4\pi}{365.25}(doy - d_2) \right) \right) \times e^{\beta h}$$

SHAtrop: model validation - bias

- Compare to precise ZTD estimates of SHAO



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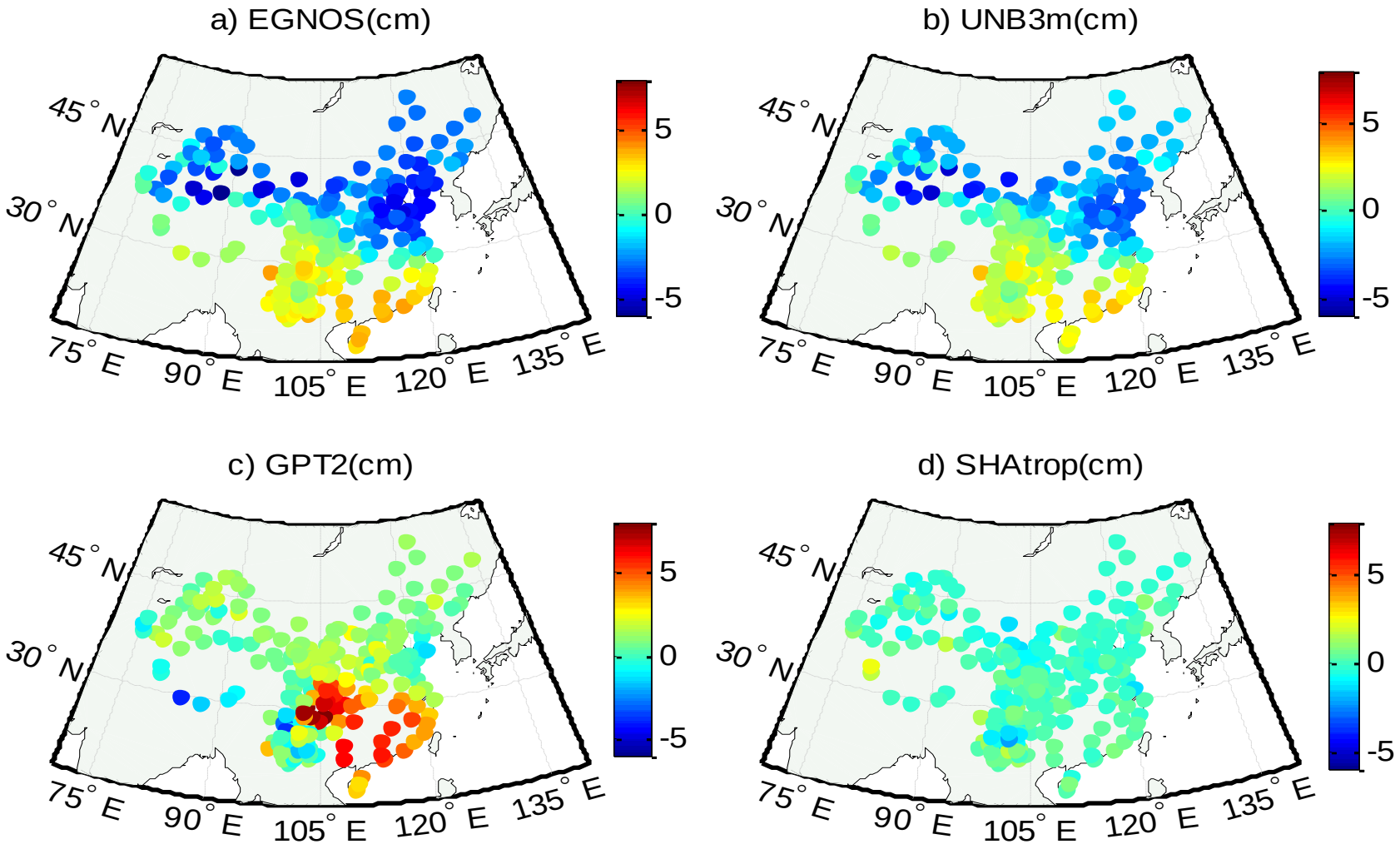
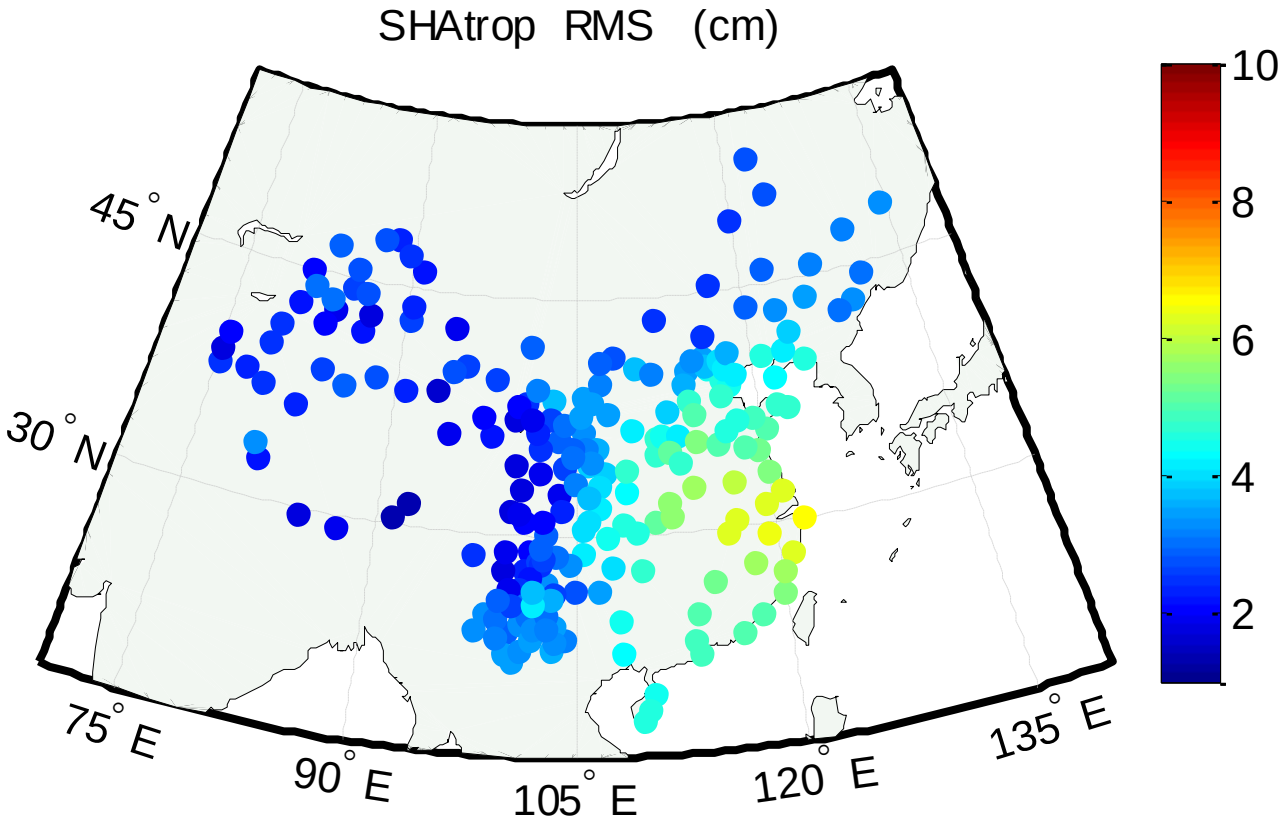


SHAtrop: model validation - rms

- Compare to precise ZTD estimates of SHAO



SHAtrop: model validation - rms

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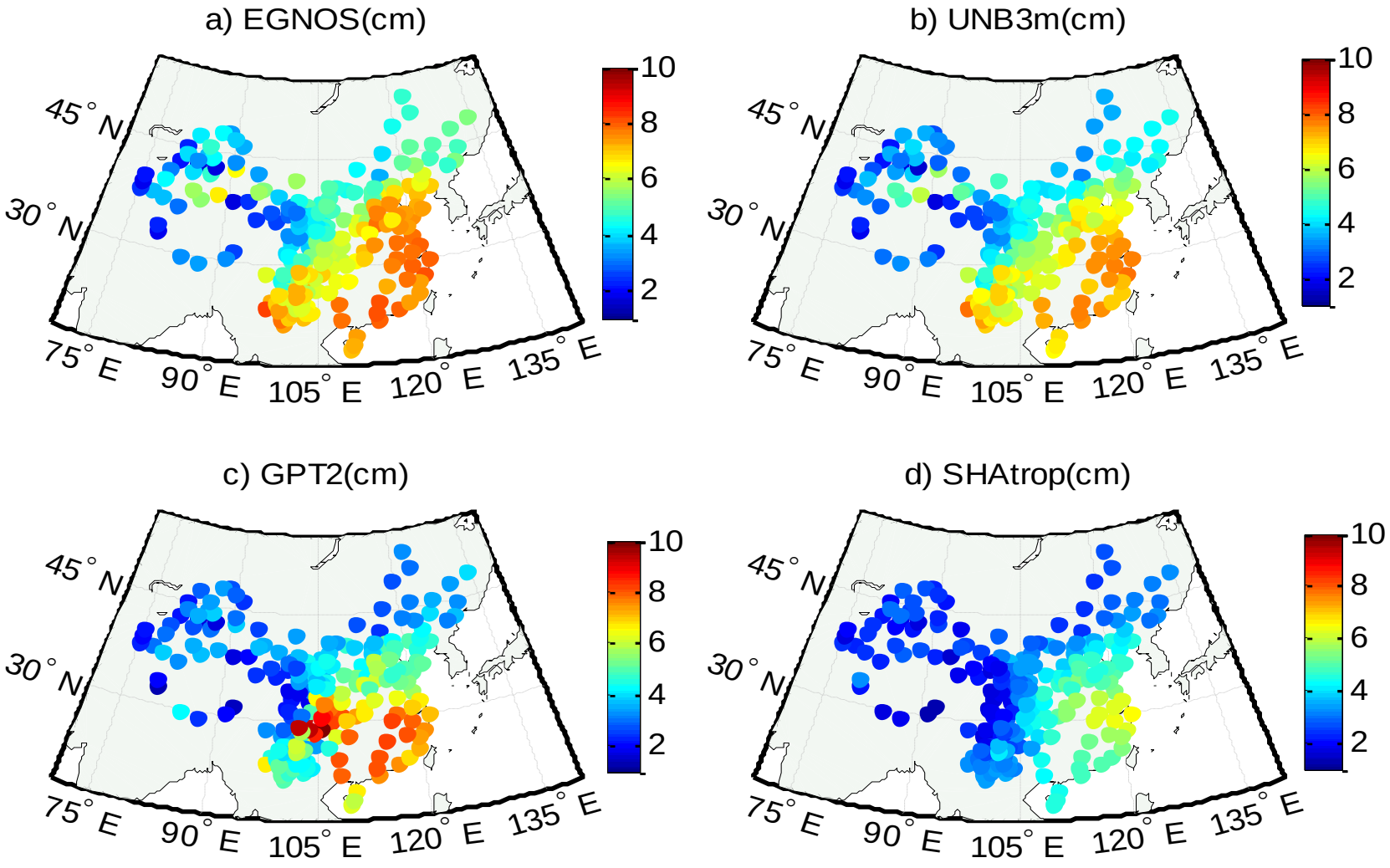


SHAtrop: model validation

- Compare to precise ZTD estimates of SHAO

Internal accuracy using sites included in model determination

	EGNOS	UNB3m	GPT2	SHAtrop
RMS(cm)	5.64(1.77, 8.22)	5.20(1.68,7.81)	4.70(1.55,9.35)	3.45(1.34,6.56)
BIAS(cm)	- 0.58(- 5.87,3.84)	- 0.32(- 5.07,3.23)	1.67(- 3.89,7.53)	- 0.02(- 2.27,1.70)

- Improved by 39%,34%,26% over EGNOS,UNB3,GPT2

SHAtrop: model validation

- Compare to precise ZTD estimates of SHAO

External accuracy using sites not included in model determination

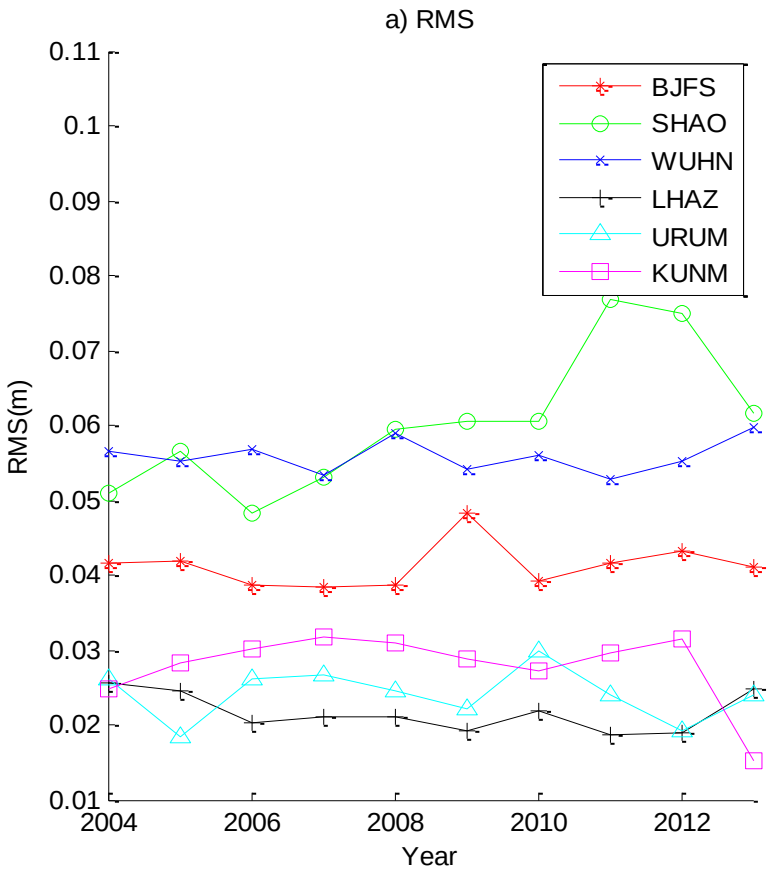
	EGNOS	UNB3m	GPT2	SHAtrop
RMS(cm)	5.45(1.75,7.89)	5.03(1.75,7.89)	4.53(1.41,10.11)	3.48(1.30,6.41)
BIAS(cm)	- 0.32(- 4.18,4.78)	- 0.08(- 3.90,3.59)	1.51(- 3.68,8.33)	0.19(- 1.31,2.51)

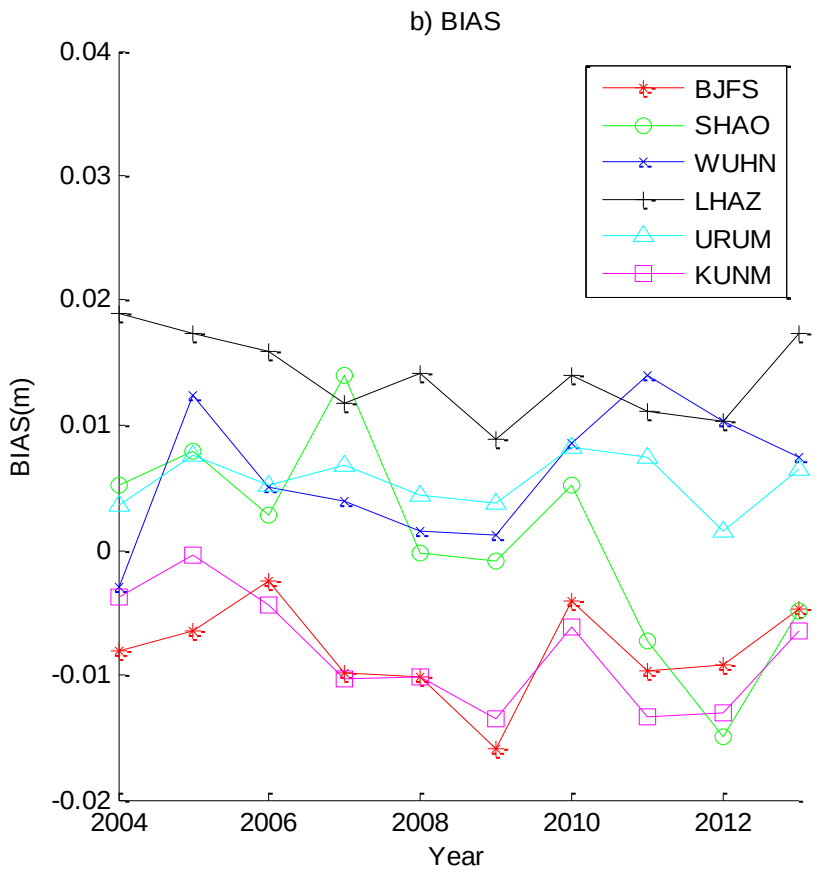
- Improved by 36%,31%,23% over EGNOS,UNB3,GPT2

SHAtrop: model validation

- Compare to precise ZTD estimates of IGS

Long term validation: 6 IGS sites, 10 years(2004-2013)





Summary

- New ZTD model based on precise GNSS ZTD time series
- High spatial resolution
- Better accuracy in China continent than other empirical models

Acknowledgment: 863 projects
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Thank you!