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Tibetan Plateau Surface Air Temperature Estimation and Analysis from Satellite Observations

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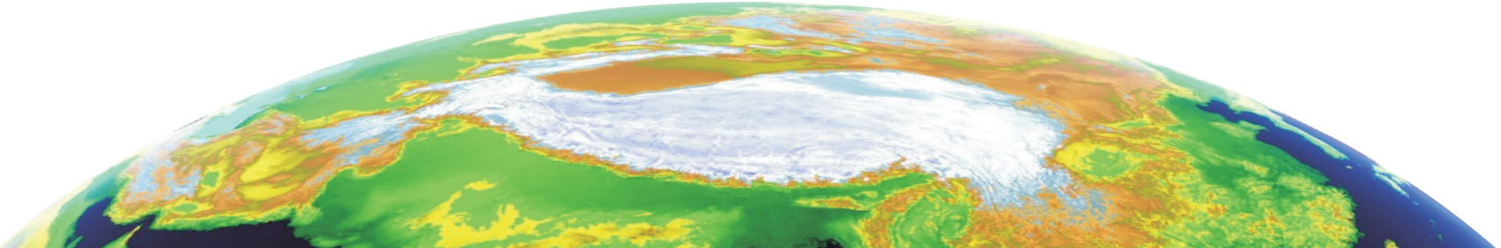


Contents

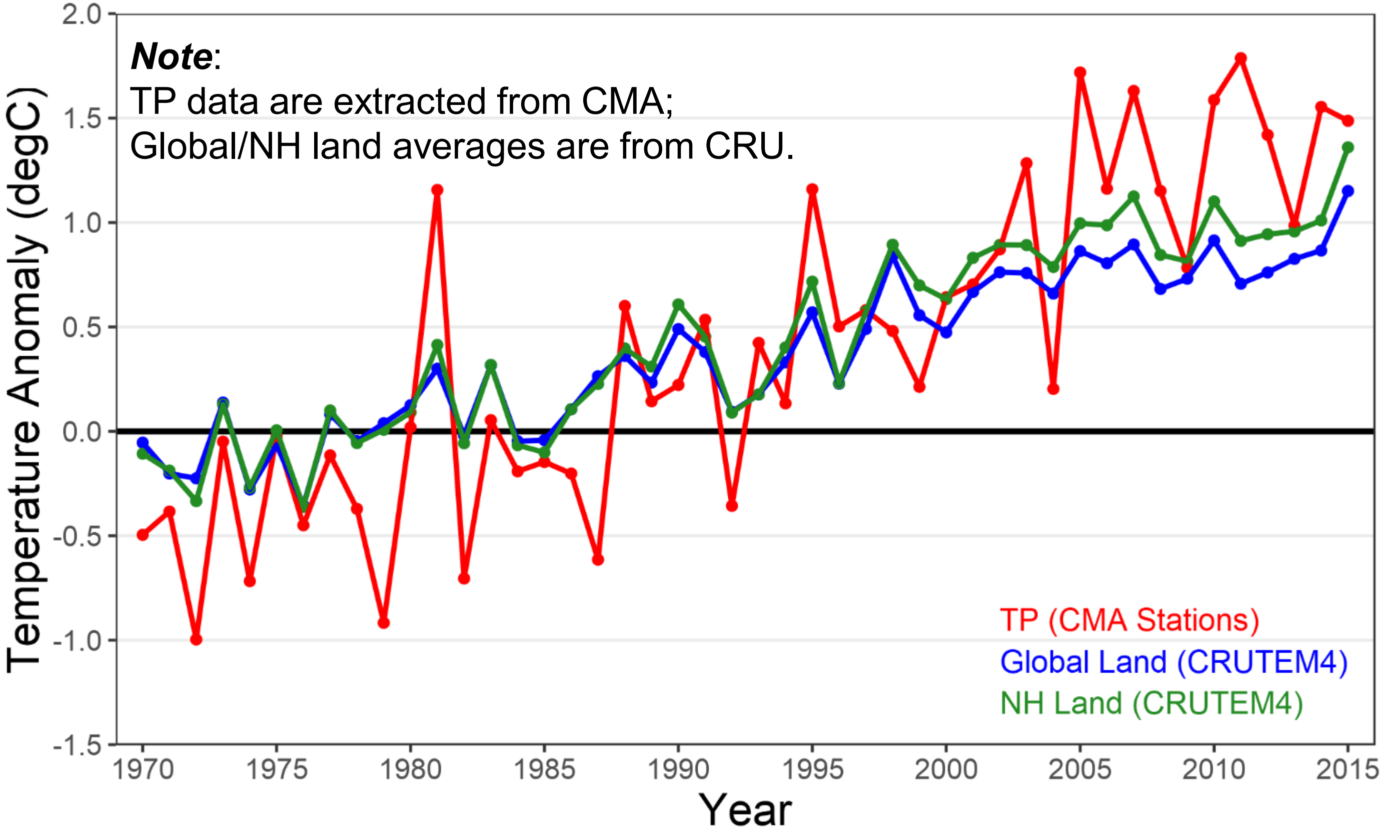
Introduction

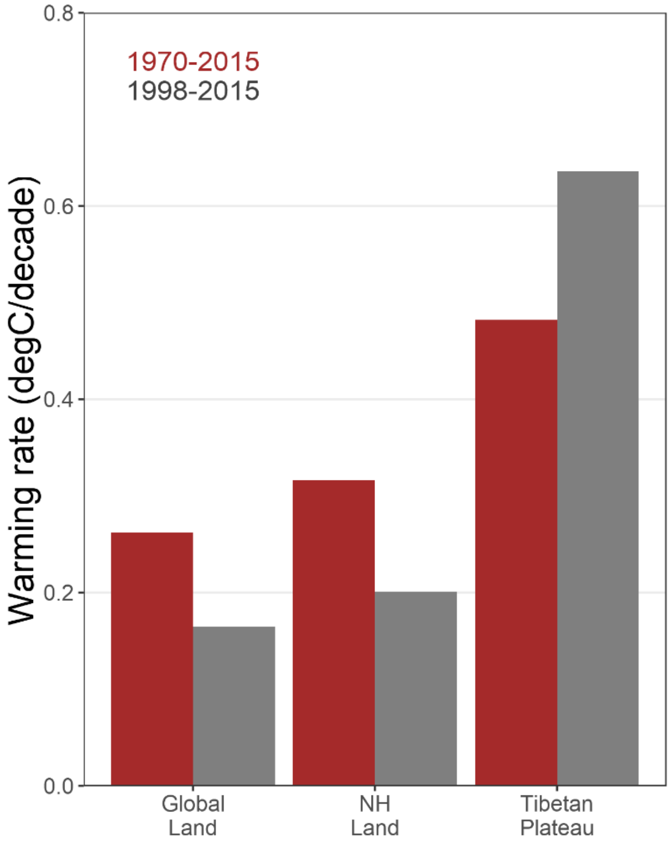
- Surface mean temperature is an important indicator of climate change
- IPCC AR5 estimated (2013) that the global mean surface temperature shows a warming of 0.85 (0.65–1.06) C during 1880–2012
- The warming trend is not uniform cross the globe, and mountainous regions are more sensitive to climate change
- Based on CMA station measurements, the TP has been recently warming at a rate of 0.16 C per decade (Liu and Chen 2000).
- There has been more rapid warming at higher elevations over TP. Yan and Liu (2014) estimated a warming trend of 0.316 C per decade in annual mean temperature over the TP for the period 1961–2012, based on the 73 stations above the elevation of 2000m
- Yan et al. (2016) concluded that the increase in surface net radiation at elevation was responsible for EDW over the TP.

Introduction

- Are these estimates of the warming trends over TP are robust?
- Are the station measurements sufficiently representative over the extremely complex TP ?
- Model simulation may also contain large uncertainties,
- Satellite remote sensing can provide more accurate estimation of the warming rate over TP.

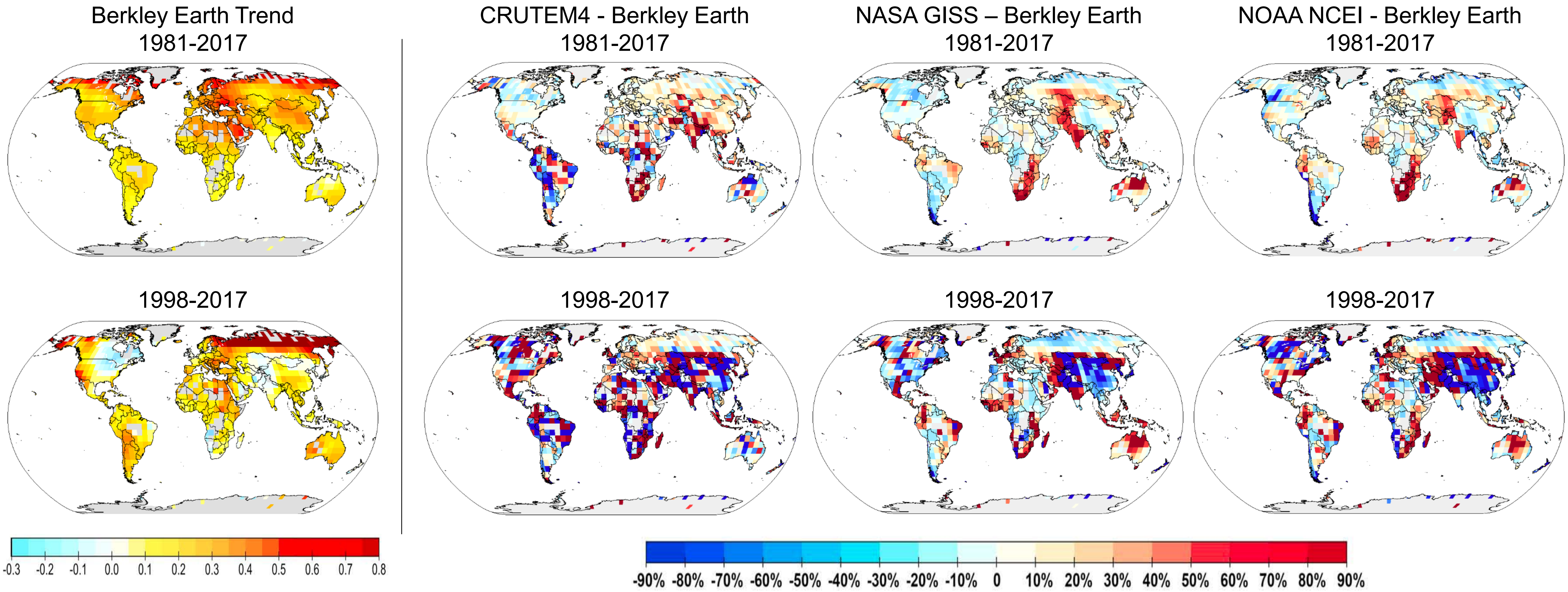
Background: Global and Tibetan Plateau warming





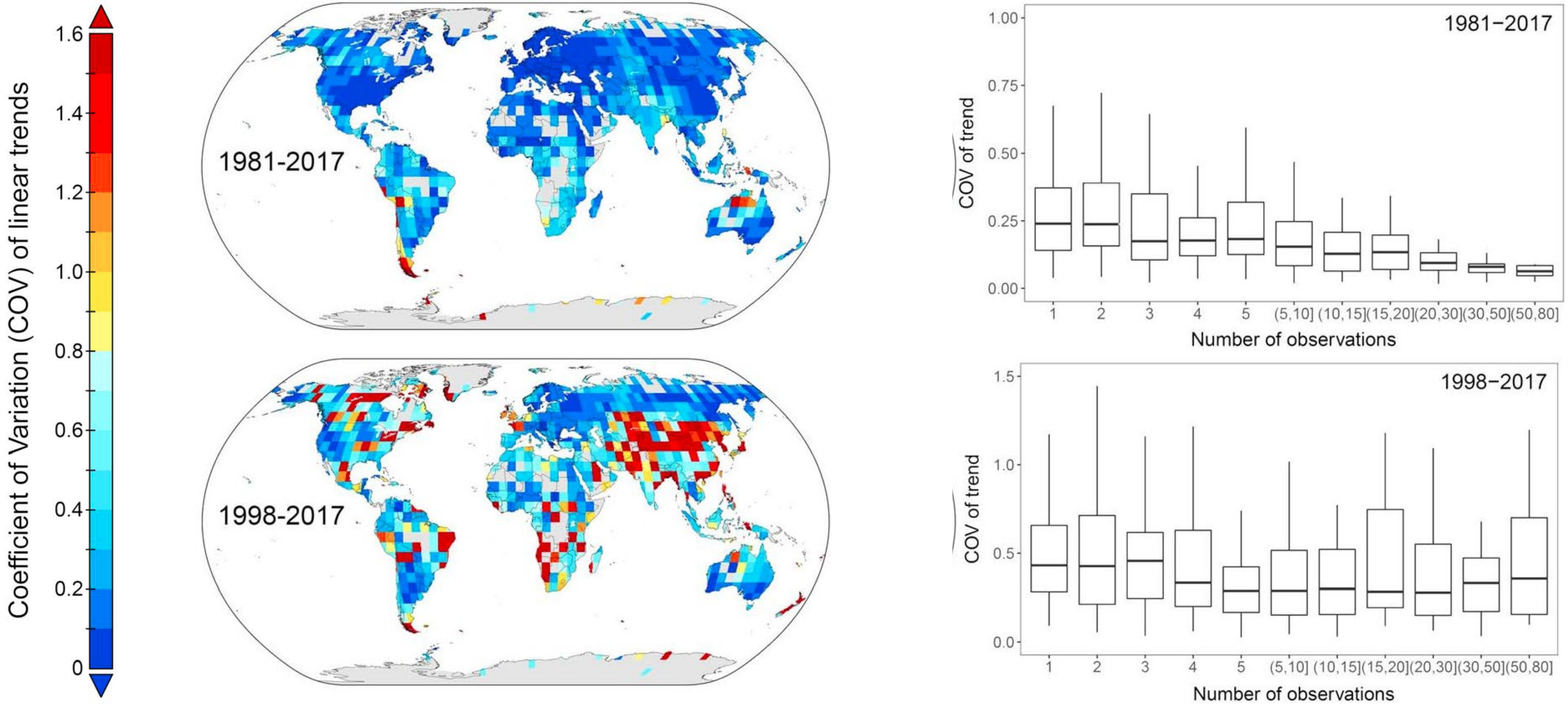
Based on ground observations at 91 sites, Tibetan Plateau (TP) has warmed at a notably faster rate than global and northern hemisphere land surface;

Gridded temperature dataset differences



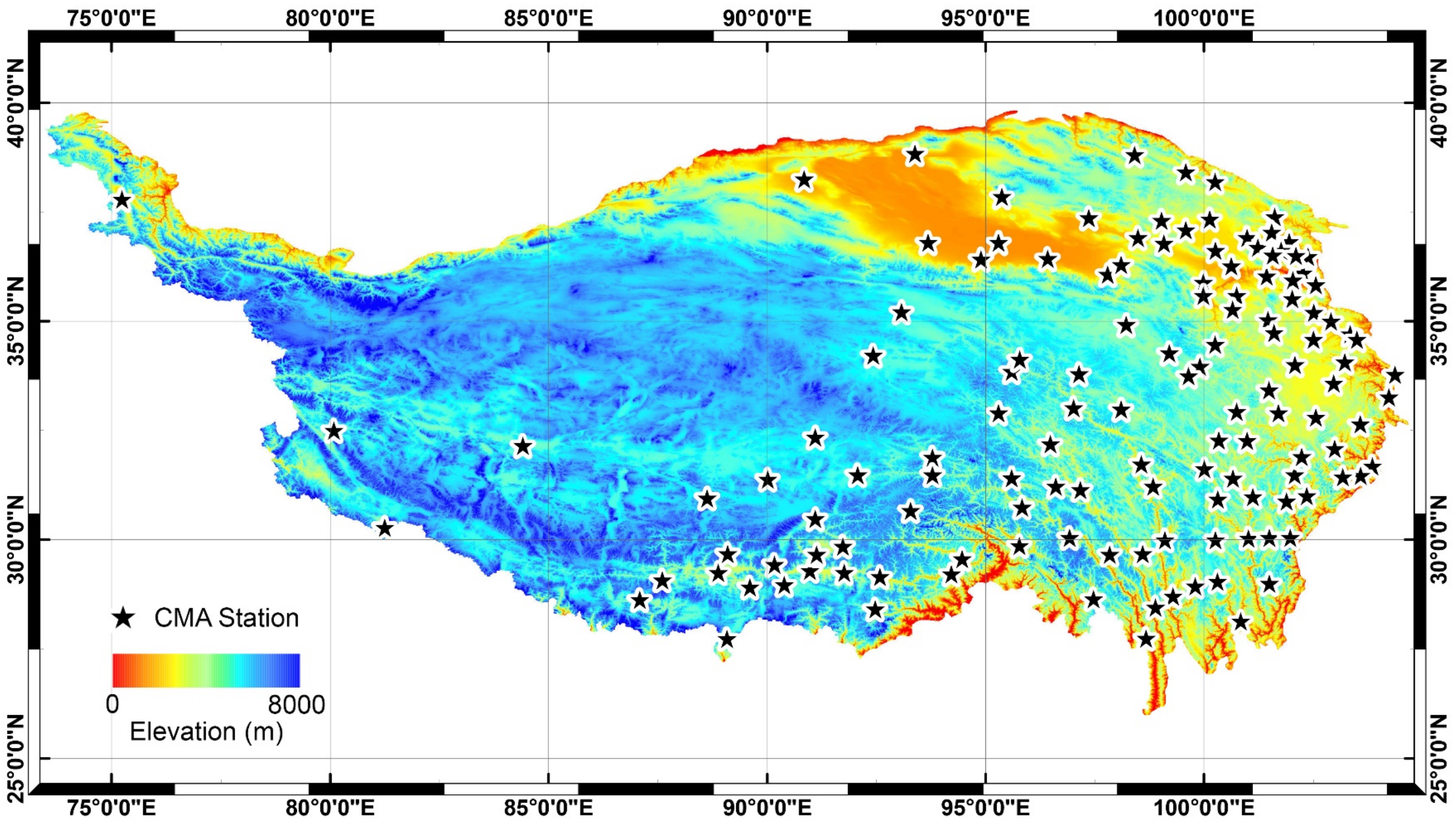
Rao, Y., Liang, S., & Yu, Y. (2018). Land surface air temperature data are considerably different among BEST-LAND, CRU-TEM4v, NASA-GISS, and NOAA-NCEI. Journal of Geophysical Research - Atmosphere, 123, 5881-5900

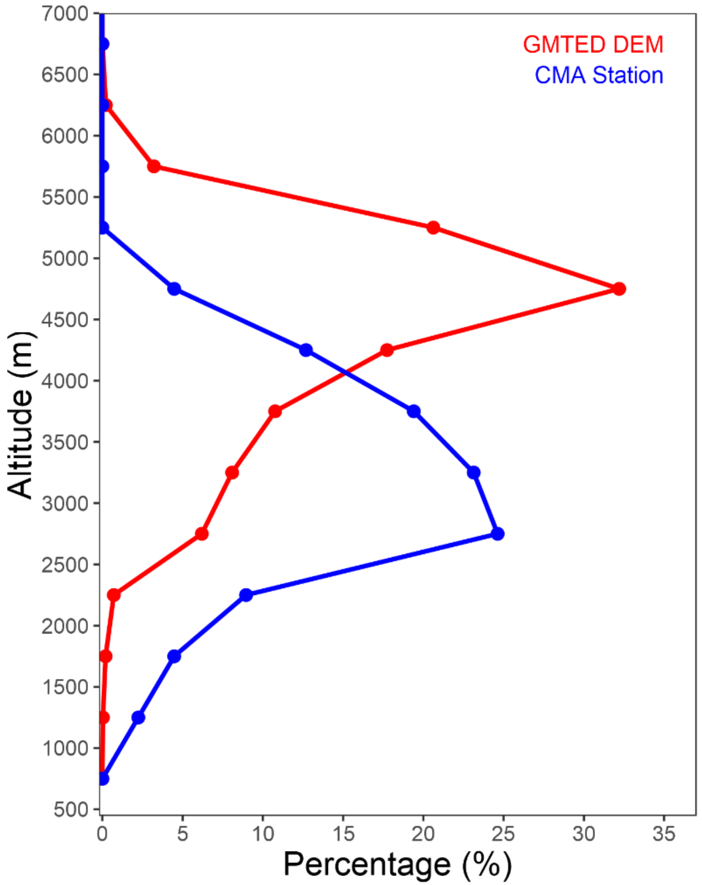
Dependency on station data density



The estimated trend show larger uncertainty over regions with less number of station observations in station based analysis. (Rao et al., 2018)

Few stations at the high elevation of Tibetan Plateau



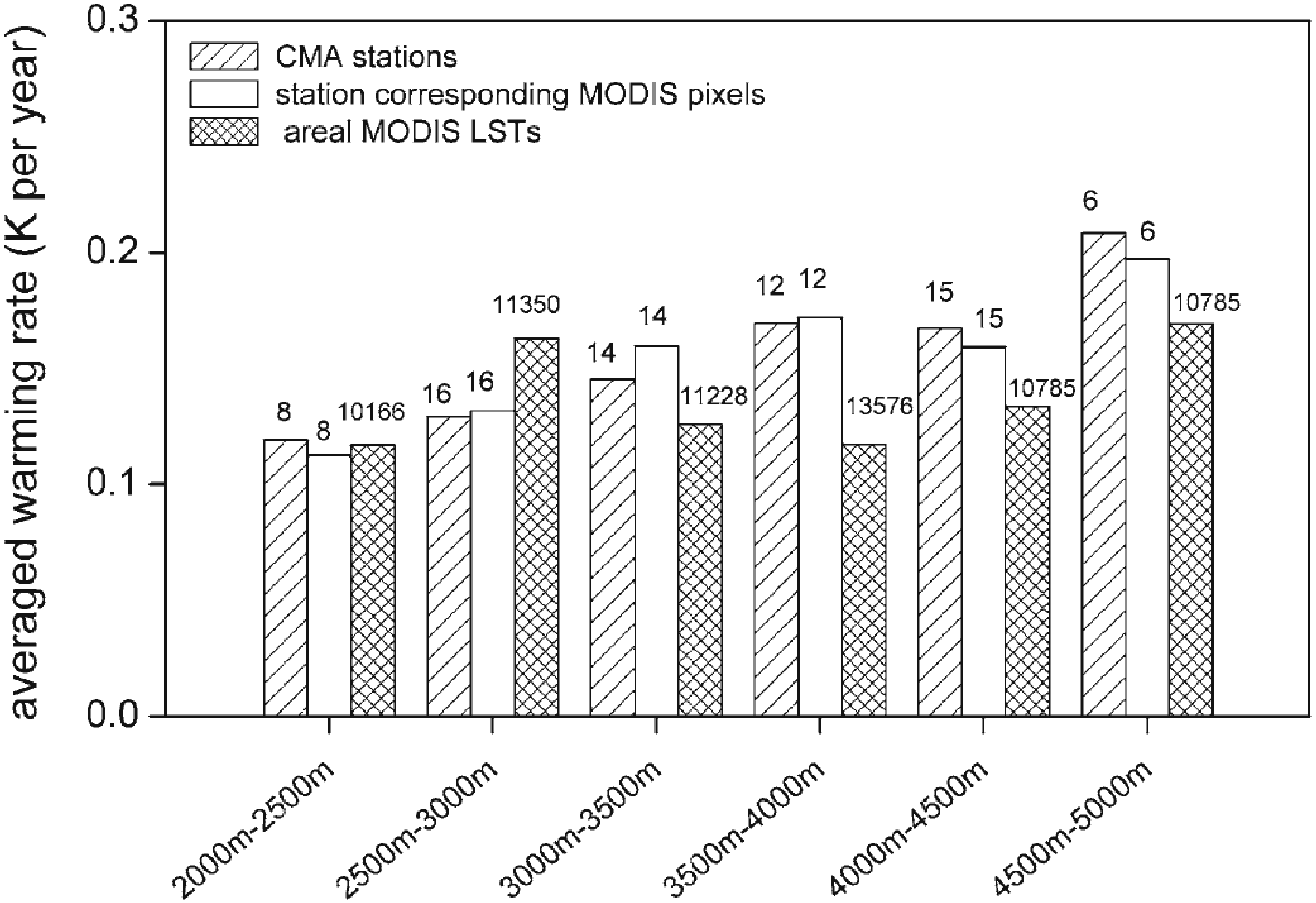


However, current TP studies heavily depended on unevenly distributed CMA station data (lack the representation of high elevation stations above 5 KM);

Representative thermal remote sensing satellite systems

sensors	**Wavebands (μm)**	
AVHRR	3.55 – 3.93 10.30 –12.50	1.1km
MODIS	3.66 – 4.08 8.400 – 13.48	1km
ATSR/ATSR–2/AASTR	3.55 –3.93 10.4 – 12.5	1km
ASTER	8.125 – 11.65	90m
TM/ETM+	10.00 –12.90	120m/60m
MSG–SEVIRI	8.30–13.0	3km at nadir
FY–3	3.7 – 4 9.59 – 13.49	1.1km
GOES	10.2 – 12.5	4km at nadir
GMS(Geostationary Meteorological Satellite)	3.5 – 4.0 10.3 – 12.5	4km at nadir
HJ–1B	3.50 – 3.90 10.5 – 12.5	150m 300m
METOP–IASI	3.2–15.5 (645–2760 cm^{-1})	12km

Elevation-dependent warming over TP from MODIS land surface temperature (LST) product



Qin, J., Yang, K., Liang, S., & Guo, X.F. (2009). The altitudinal dependence of recent rapid warming over the Tibetan Plateau. *Climatic Change*, 97, 321-327

- LST is different from the near surface air temperature (T_{air}) by definition;
- Strong correlation between LST and T_{air} makes it possible to estimate T_{air} using LST;

Linear regression based methods

$$T_{air} = a + b * LST + c * ancillary\_data$$

Machine learning based methods

$$T_{air} = f(LST, ancillary\ data)$$

Typical ancillary data includes:

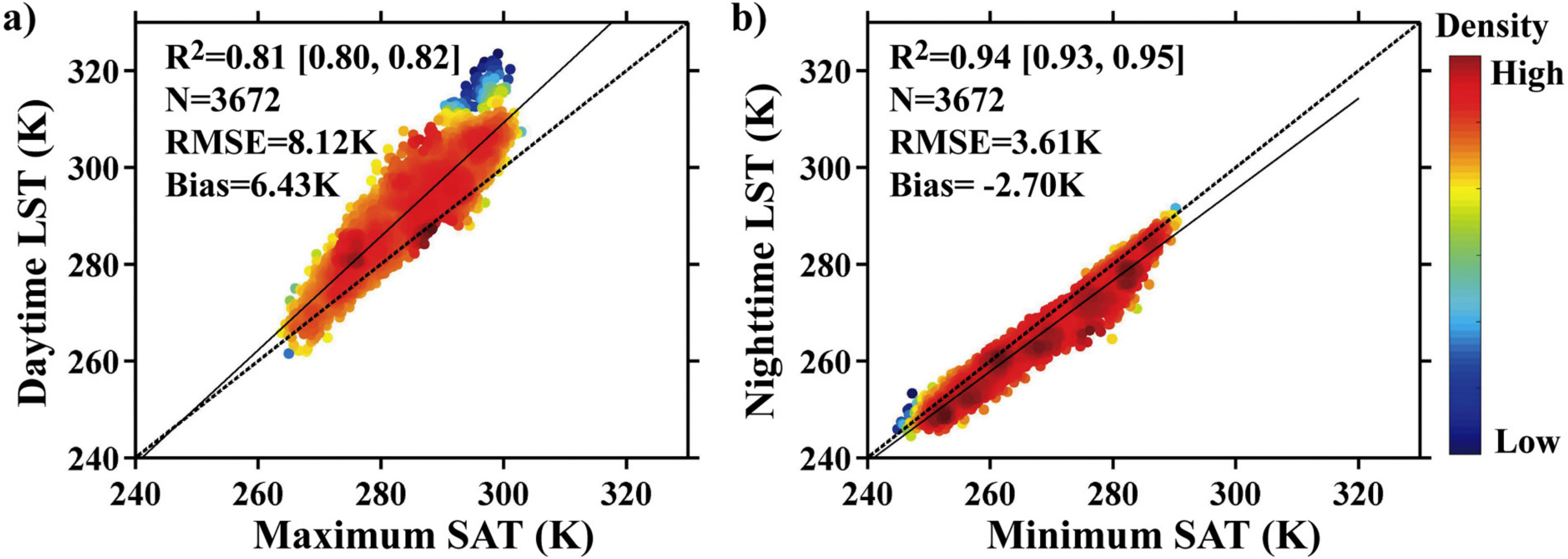
- Vegetation indices
- Land cover information
- Surface radiation
- …

Advantages:

- Nearly spatial complete T_{air} data;
- Providing important spatial details (1-5 km) for warming studies;

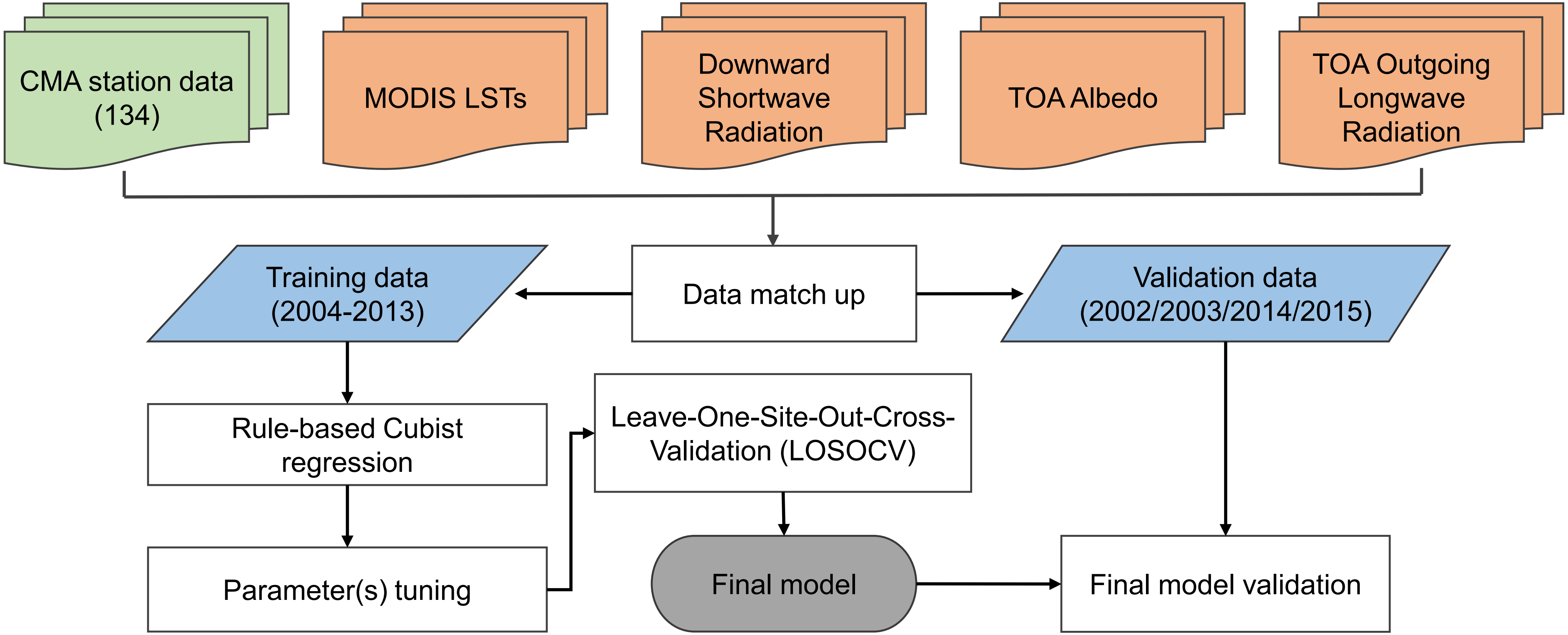
Limitations:

- Clear sky only estimation (due to cloud contamination);
- RMSE: 2~3 K;

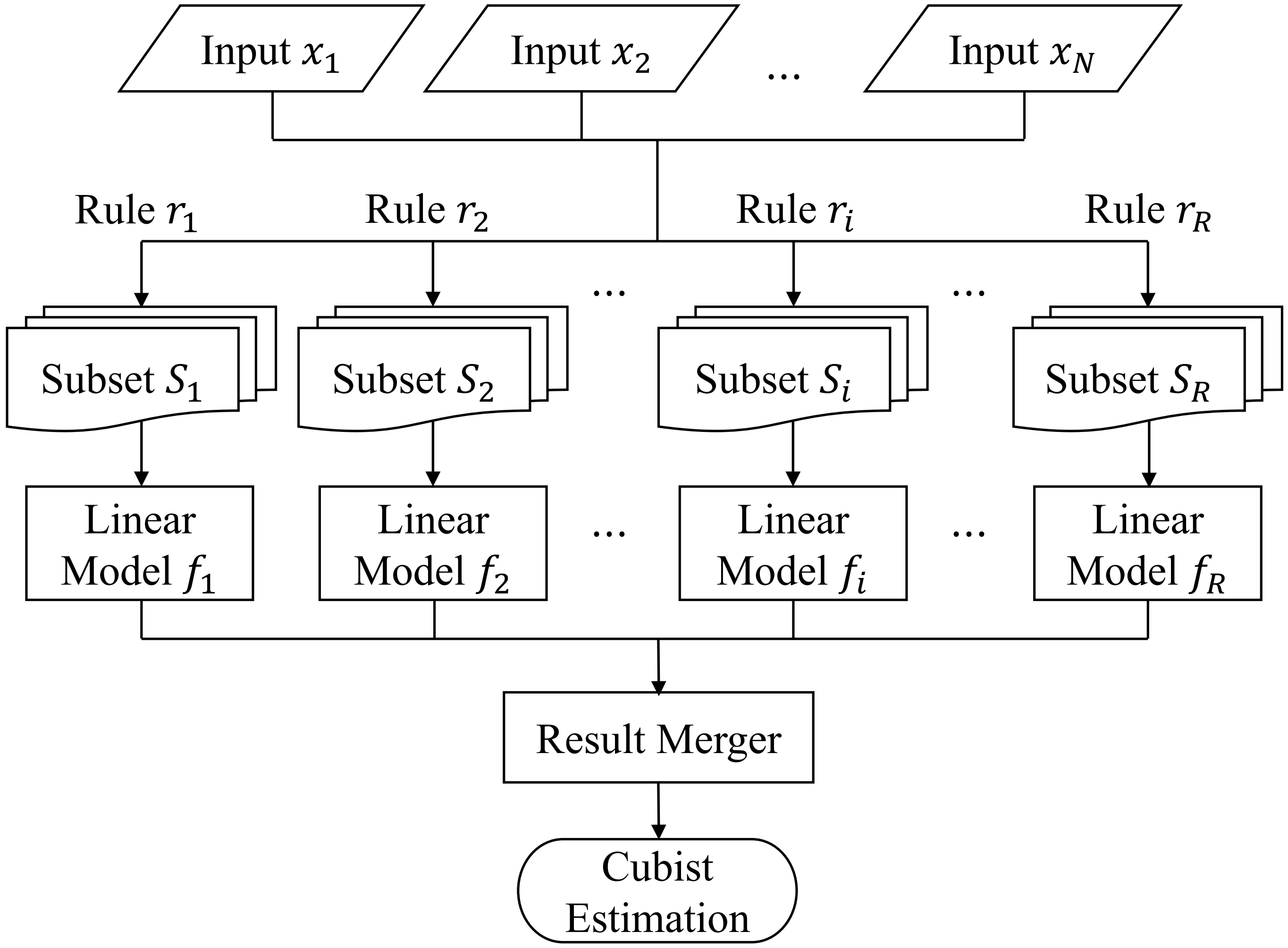


Lu, N., Liang, S., Huang, G., Qin, J., Yao, L., Wang, D., & Yang, K. (2018). Hierarchical Bayesian space-time estimation of monthly maximum and minimum surface air temperature. *Remote Sensing of Environment*, 211, 48-58

A new all-sky model

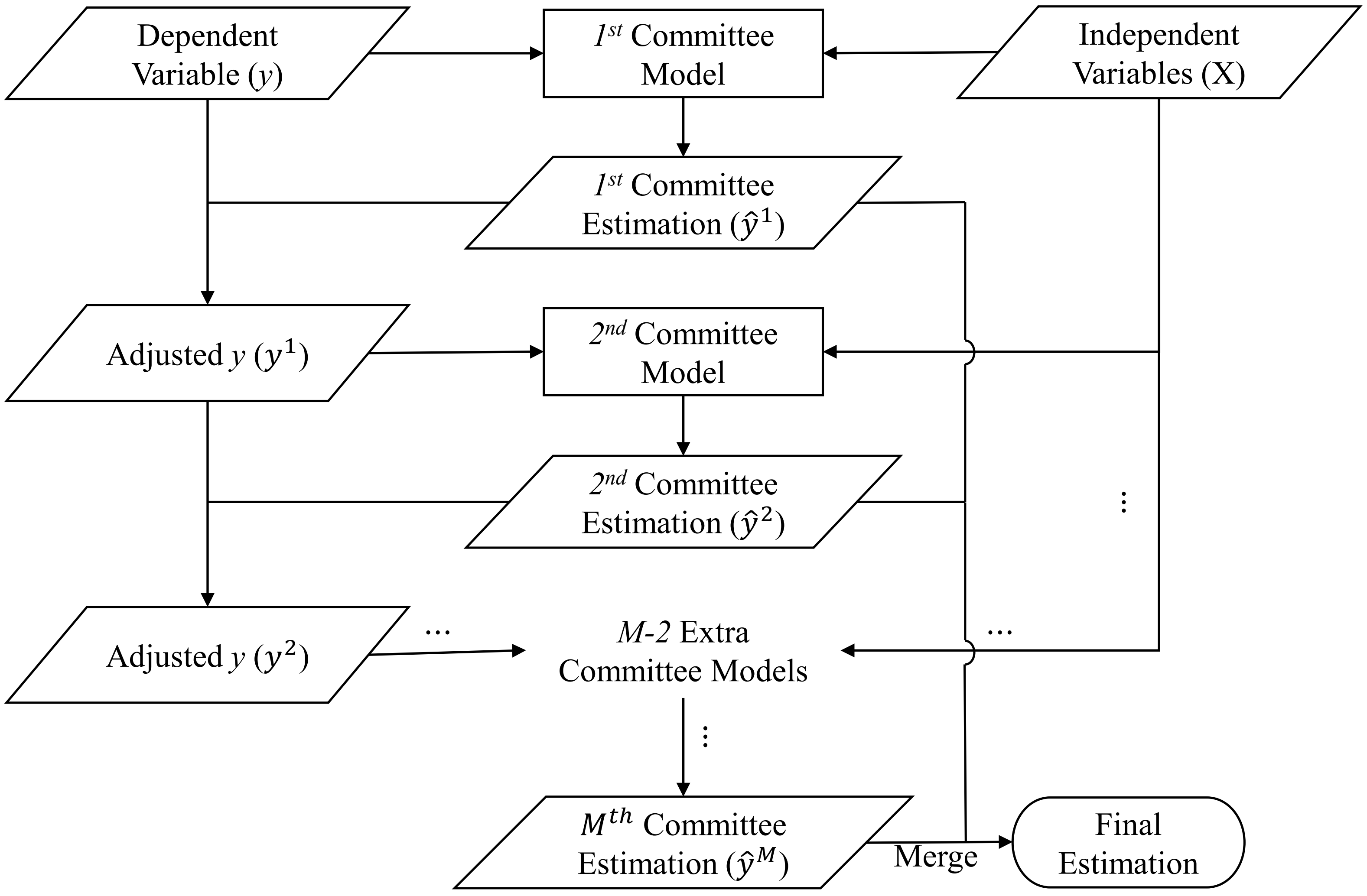


Cubist modeling



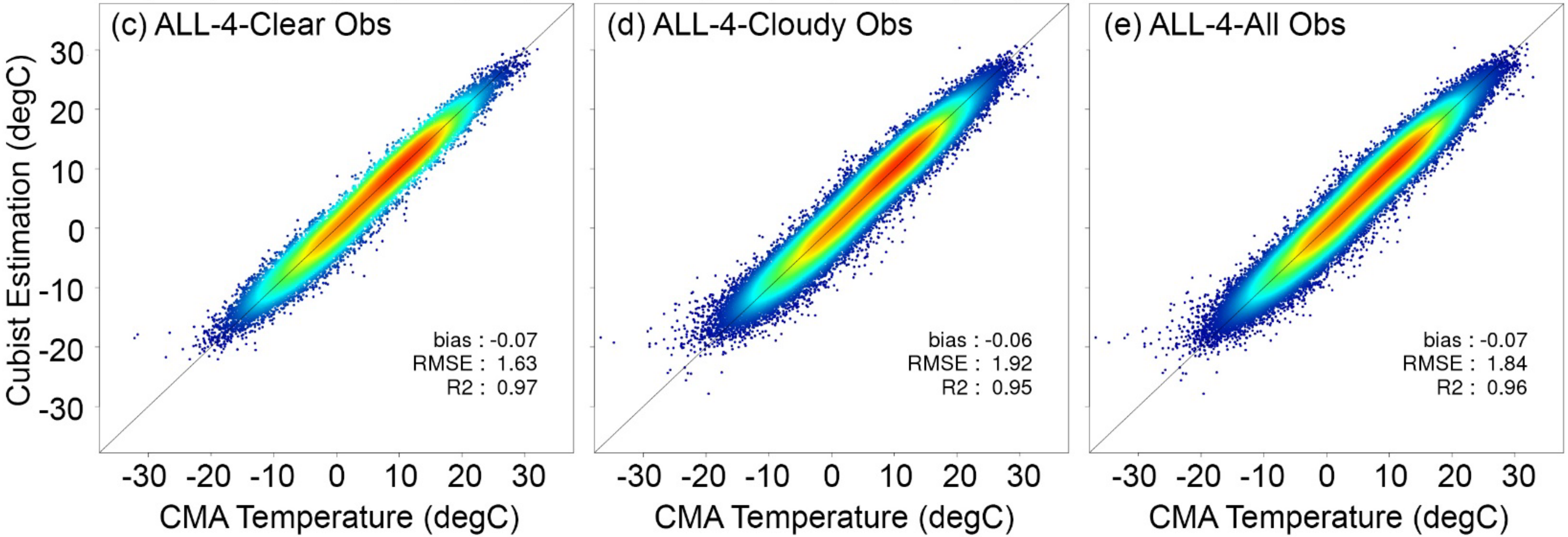
- Cubist regression model is similar to classic regression tree model, which separate data into small subsets to develop linear regression for each subset;
- However, Cubist model allows each data point belong to multiple subsets;

Cubist modeling



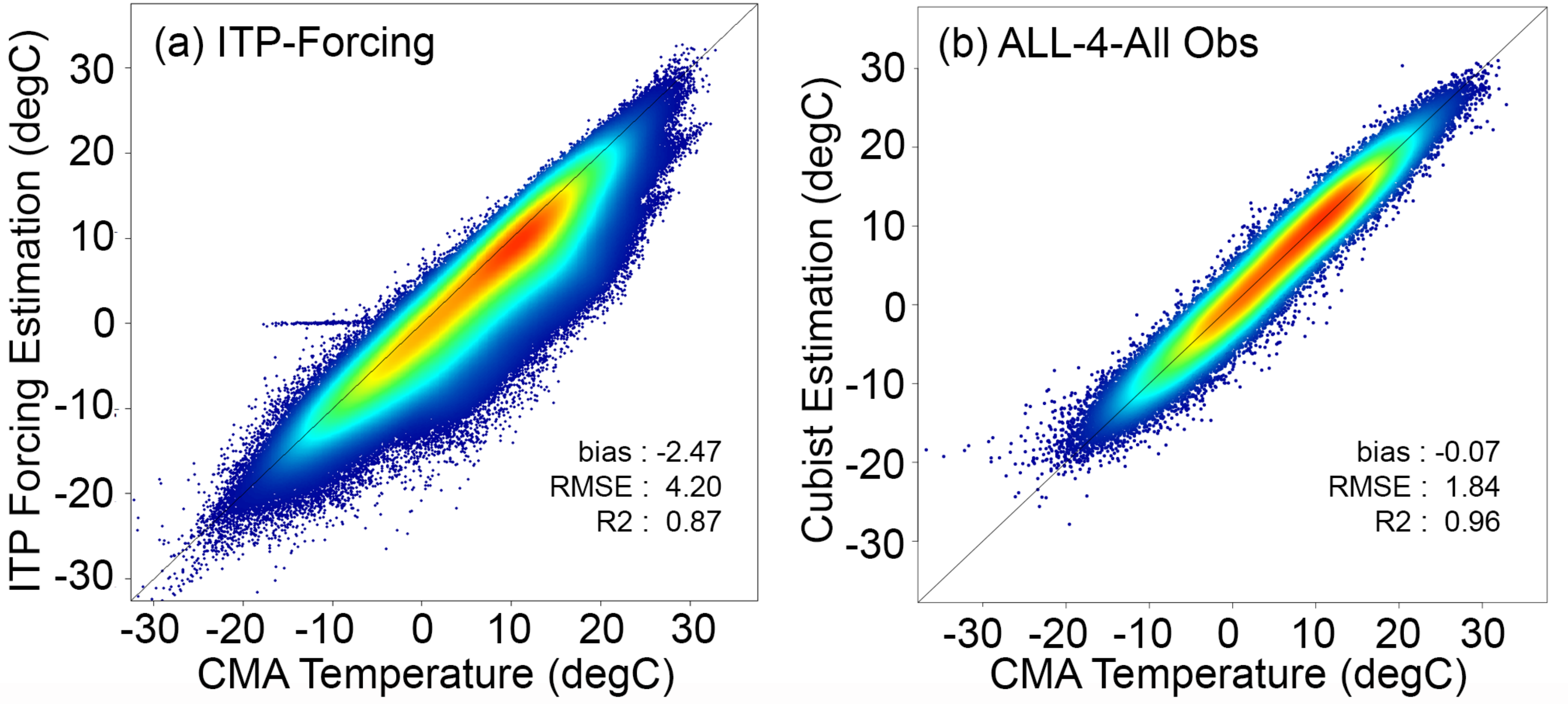
It also allows a committee-based structure to adjust prediction /estimation based to improve the final accuracy.

Model evaluation results



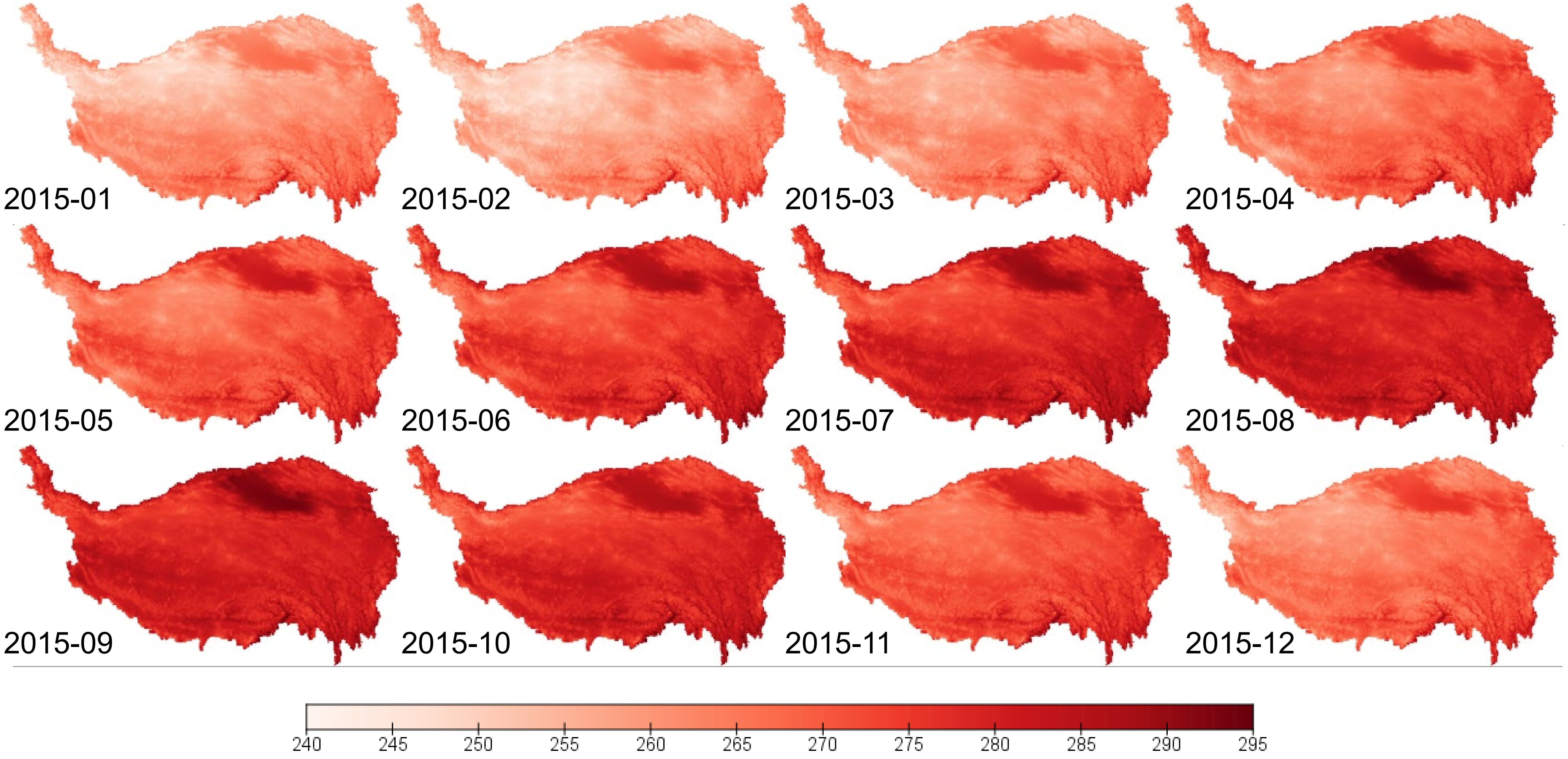
Also, daily T_{air} data availability increases from 27.55% (clear sky) to 99.87% (all sky) during 2000 – 2015 for CMA station pixels over TP.

Model evaluation results

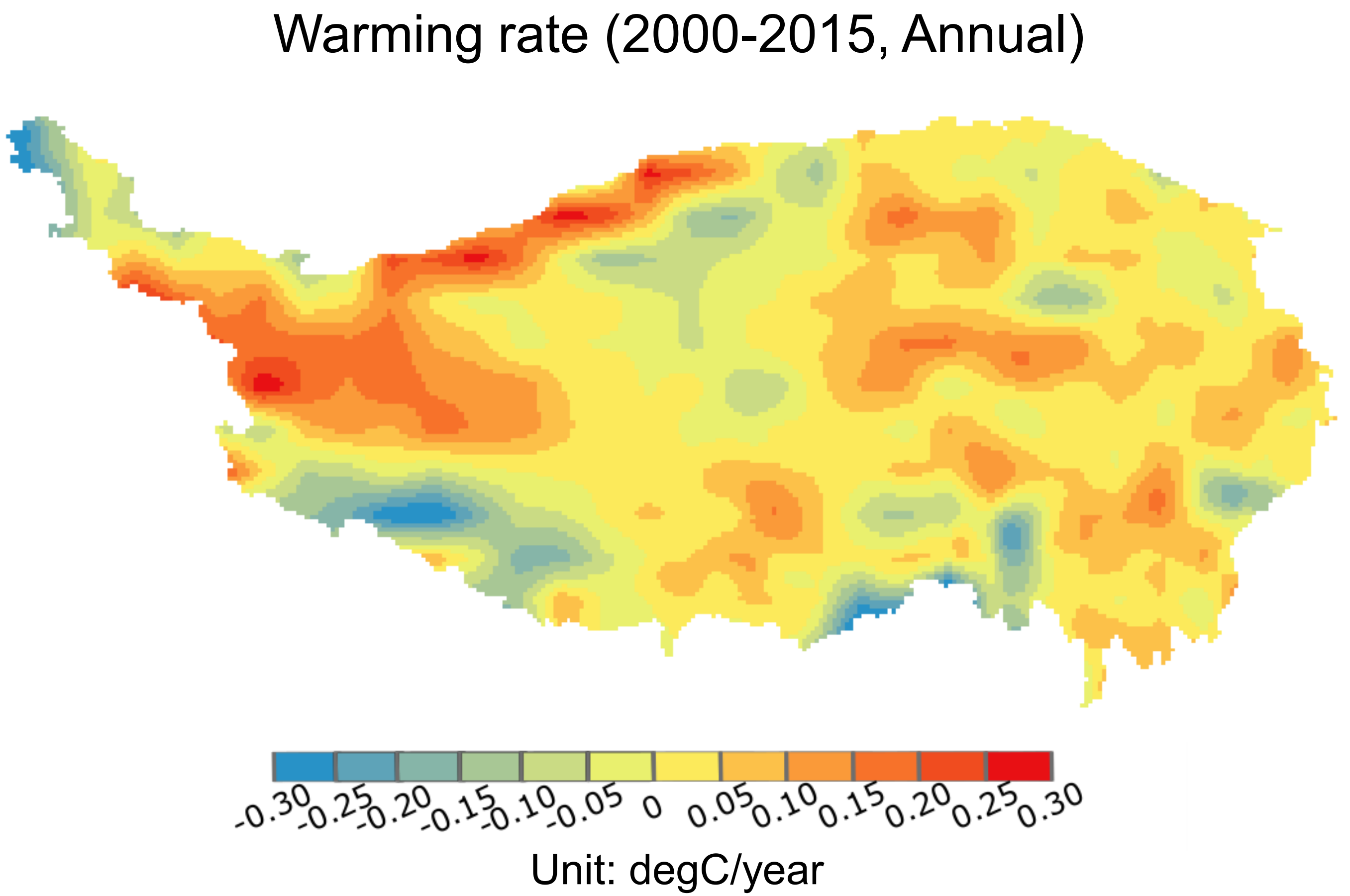


Comparing with ITP meteorological forcing dataset, the model estimation shows significant better performance when validating against CMA station measurements;

Estimated monthly means of 2015



Spatial pattern of TP warming

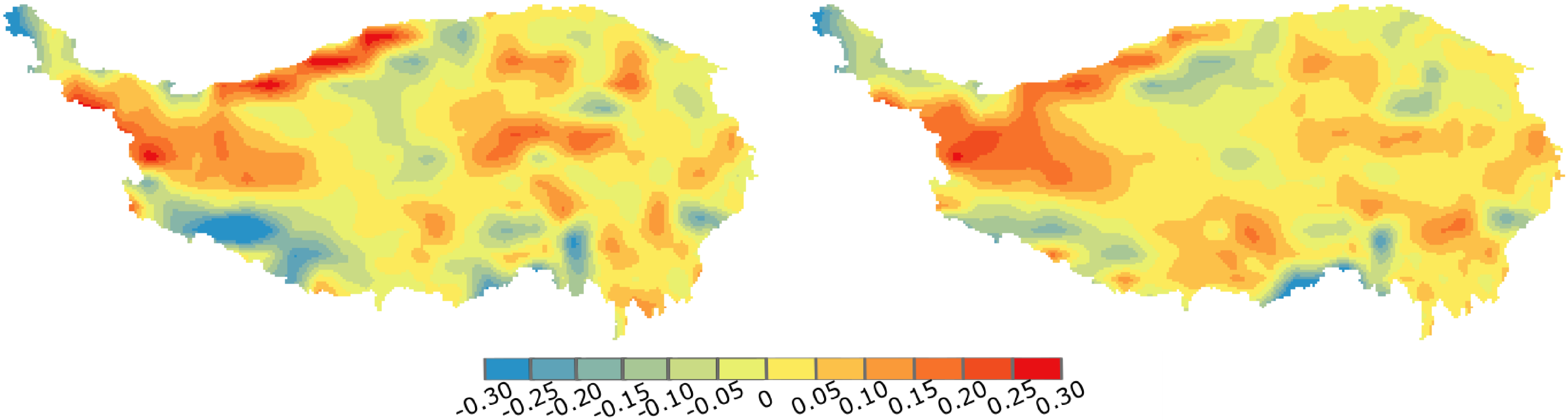


Higher warming rate over the northwestern region of the TP, which is barely sampled by the CMA station network;

Eastern TP (with dense CMA stations) show smaller magnitude of surface T_{air} change;

Spatial pattern of TP warming

Warming rate (2000-2015, DJFMAM)   Warming rate (2000-2015, JJASON)



The high elevation northwestern region appears to have higher warming rate over warm season (JJASON) comparing to cold season (DJFMAM);

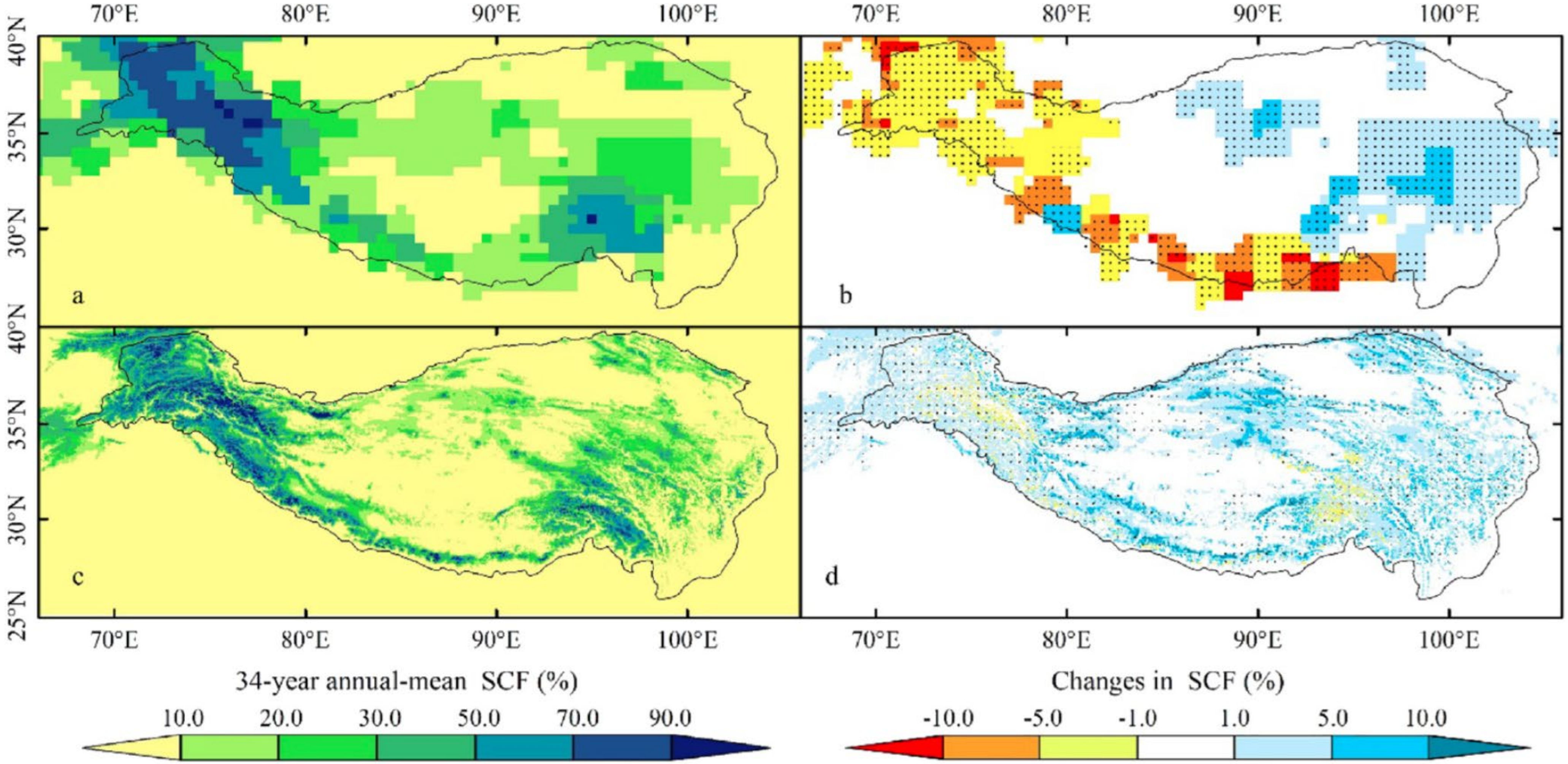
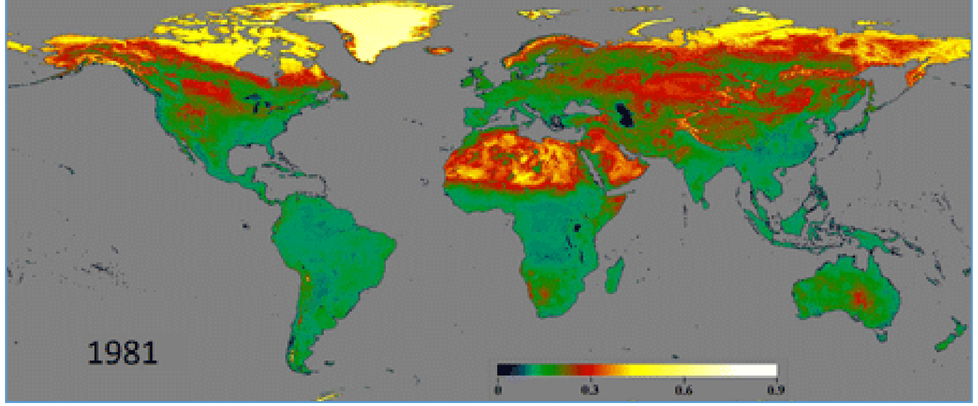
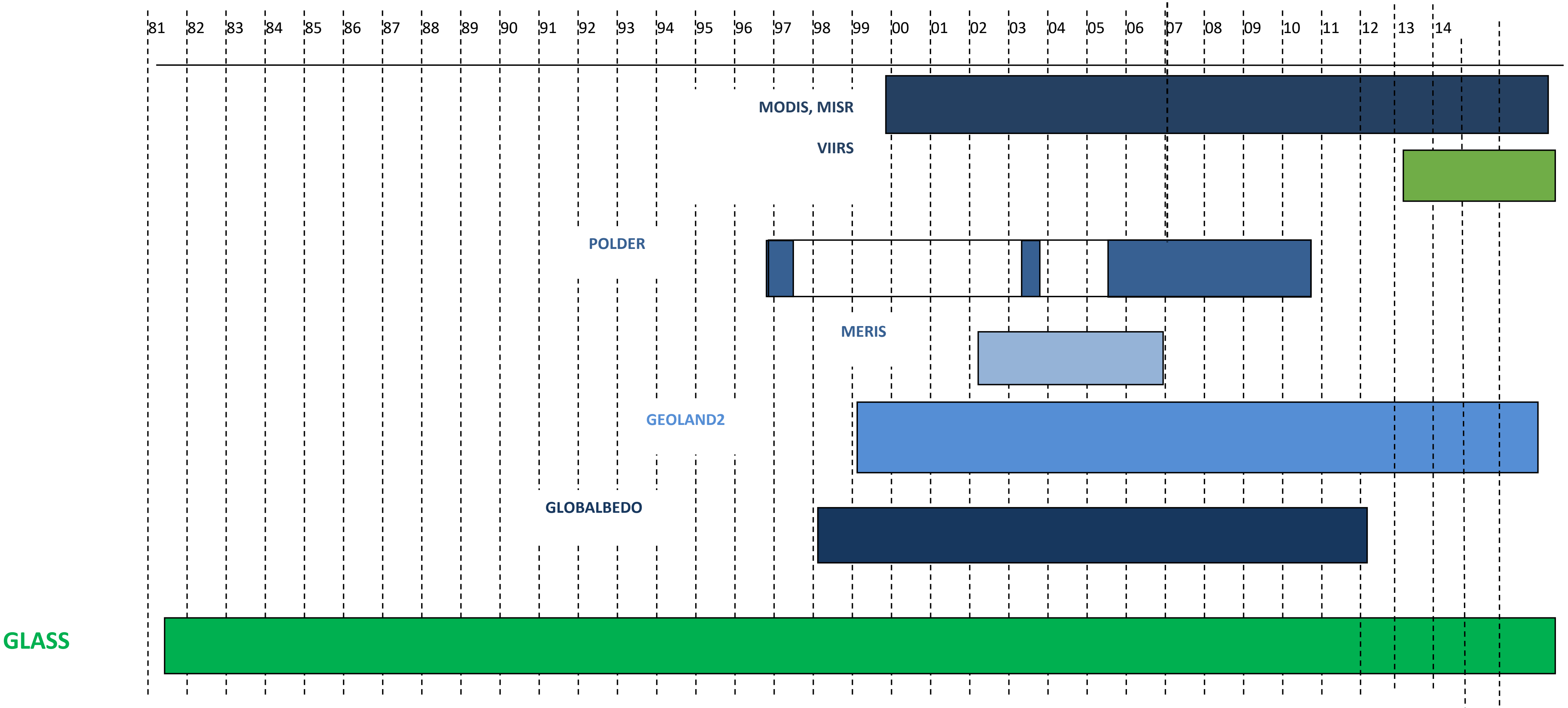


Fig. 12. 34-year climatology of annual-mean SCF (%) across the TP for the period 1982–2015 (excluding 1994), calculated from (a) NHSCE and (c) TPSCE. The 34-year changes in SCF (%) were calculated from (b) NHSCE and (d) TPSCE. Black dots in (b) and (d) indicate changes that are significant at the 95% level.

Chen, X., Long, D., Liang, S., He, L., Zeng, C., Hao, X., & Hong, Y. (2018). Developing a composite daily snow cover extent record over the Tibetan Plateau from 1981 to 2016 using multisource data. Remote Sensing of Environment, 215, 284-299

❑ GLASS albedo product





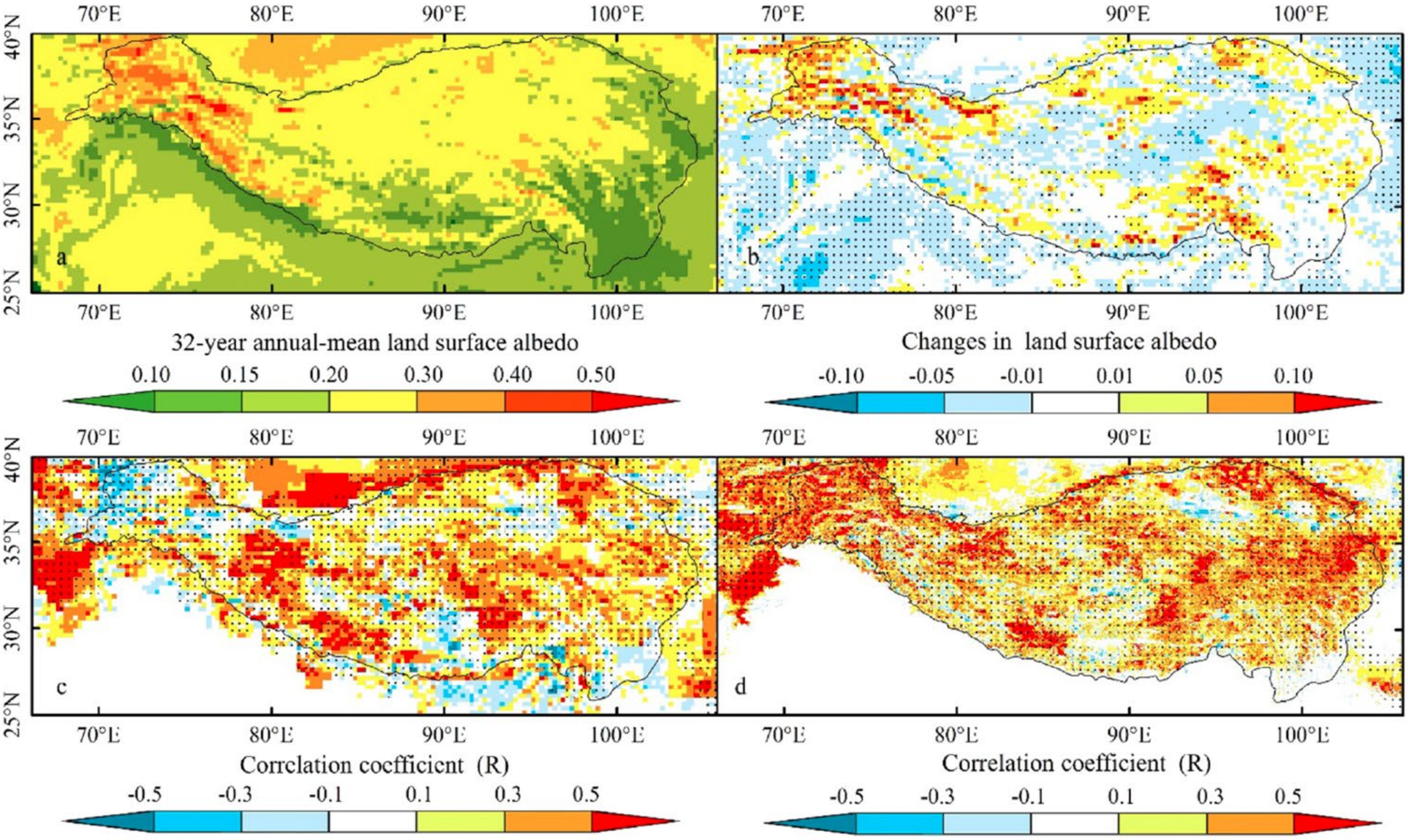
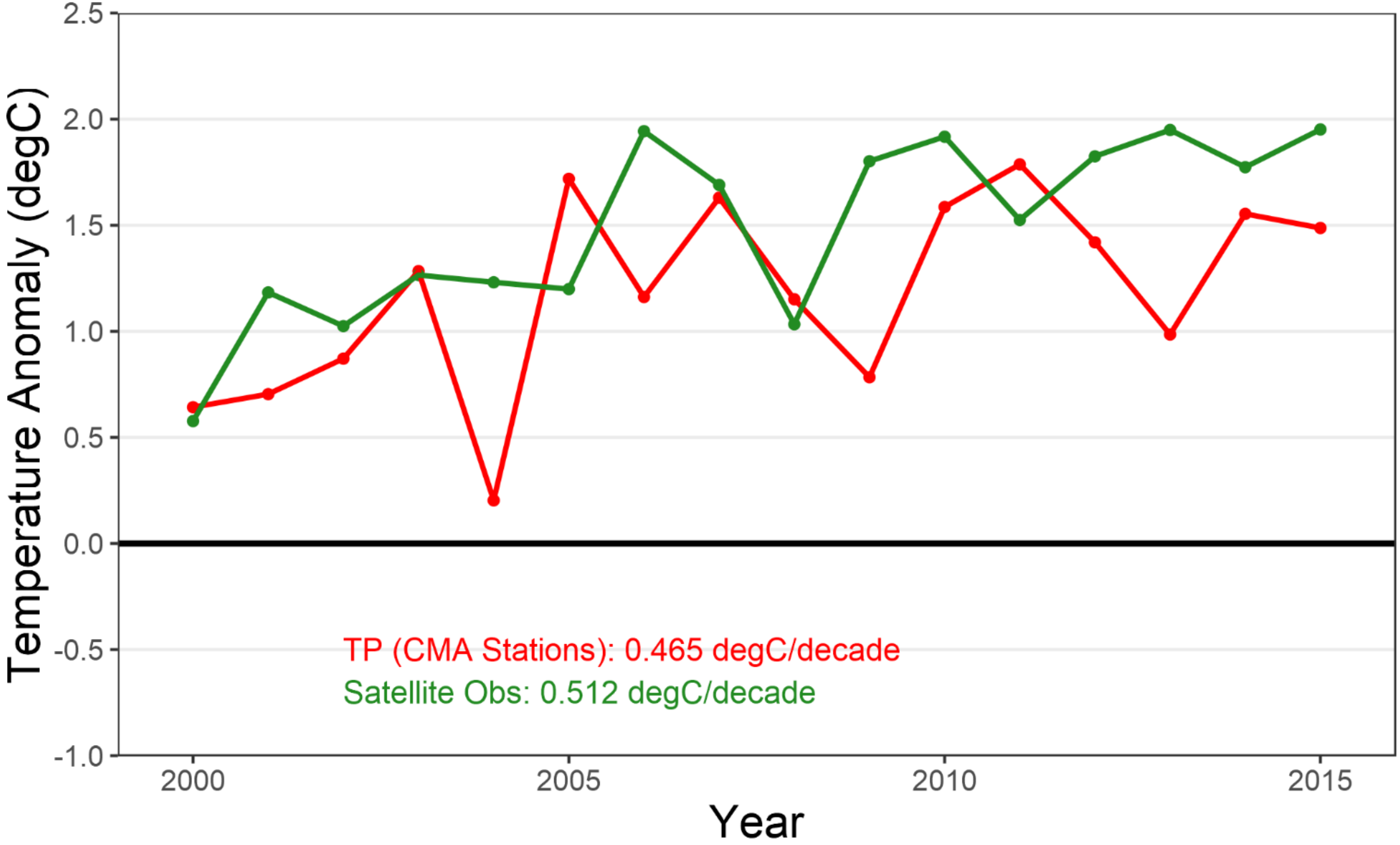


Fig. 15. 32-year (a) climatology of annual-mean land surface albedo and (b) changes across the TP for the period 1982–2015 (excluding 1994). The correlation coefficient (*R*) between land surface albedo and SCF was calculated from (c) NHSCE and (d) TPSCE snow cover products. Black dots in (b) indicate that changes are significant at the 95% level. Black dots in (c) and (d) indicate that the correlation coefficient is statistically significant at the 95% level.



Temperature Anomaly (degC)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
2000
2005
2010
2015
Year
TP (CMA Stations): 0.465 degC/decade
Satellite Obs: 0.512 degC/decade

Summary

- The all-sky model provide accurate daily *Tair* estimation over the TP, which can be adapted to other regions with sparse station observations;
- CMA station-based analysis underrepresented the northwestern TP region which warmed at faster rate than eastern TP (with CMA stations);
- There is notable signal of elevation-dependent warming (EDW) over TP, which is likely linked with the surface albedo change.