Atmospheric heat sinks over the western Tibetan Plateau associated with snow depth in late spring

Zhixiang Xiao[1], Anmin Duan[2], Ziqian Wang[3]
[1]Guangxi Institute of Meteorological Sciences
[2]LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, [3]School of Atmospheric Sciences, Sun Yat-sen University
(**xiaozx_gx@163.com**)

1. Introduction

As a huge, intense, and elevated atmospheric heat source (AHS) approaching the mid-troposphere in spring and summer over the Tibetan Plateau (TP), and it is perceived as an important factor contributing to the formation and variation of the Asian summer monsoon. However, it is difficult to quantitative estimation of the AHS over the TP and large uncertainties still remain in almost all various data sources and methods. On the other hand, AHS is significantly affected by snow, the snow cooling effect is ambiguous over the TP. The intrinsic connection between the AHS and snow depth over the TP are insufficient. Therefore, a critical issue is how and to what extent the TP's snow depth cools the overlying atmosphere.

2. Snow depth and AHS over the TP

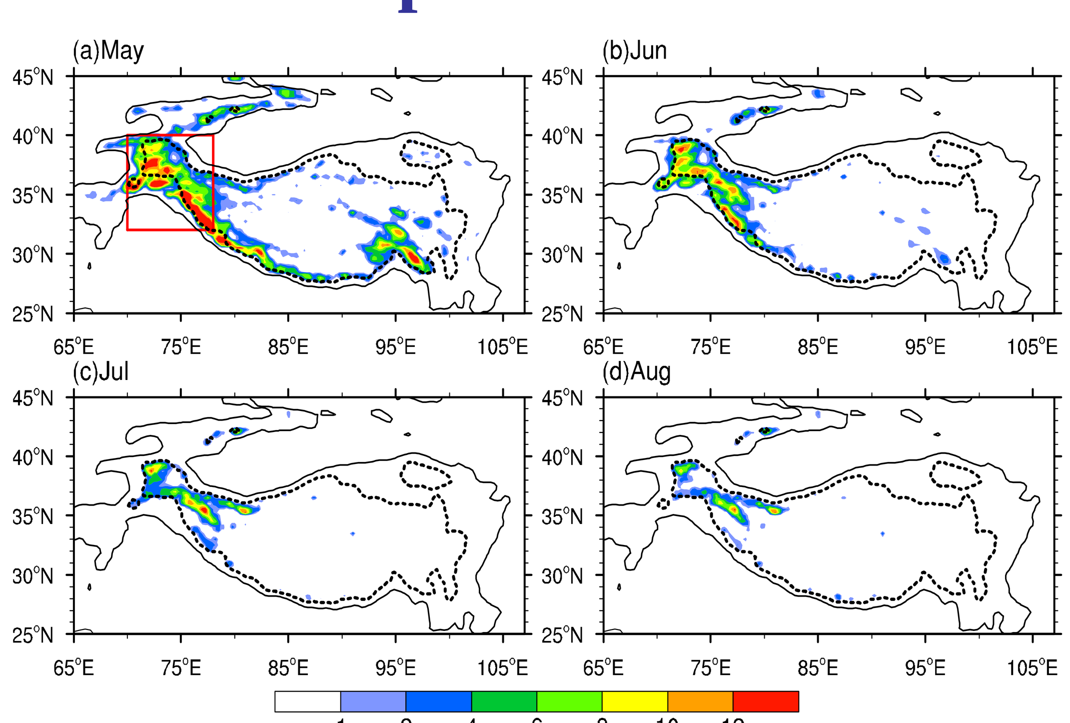

Fig.1 Climatological distributions of snow depth (units: cm) over the TP in (a) May, (b) June, (c) July, and (d) August. Black solid lines and dashed curved lines outline the areas of the TP with an average altitude greater than 2000 m and 4000 m, respectively. The red rectangle in (a) represents the area (32° N–40° N,70° E–78° E), covered by thick snow, over the western TP.

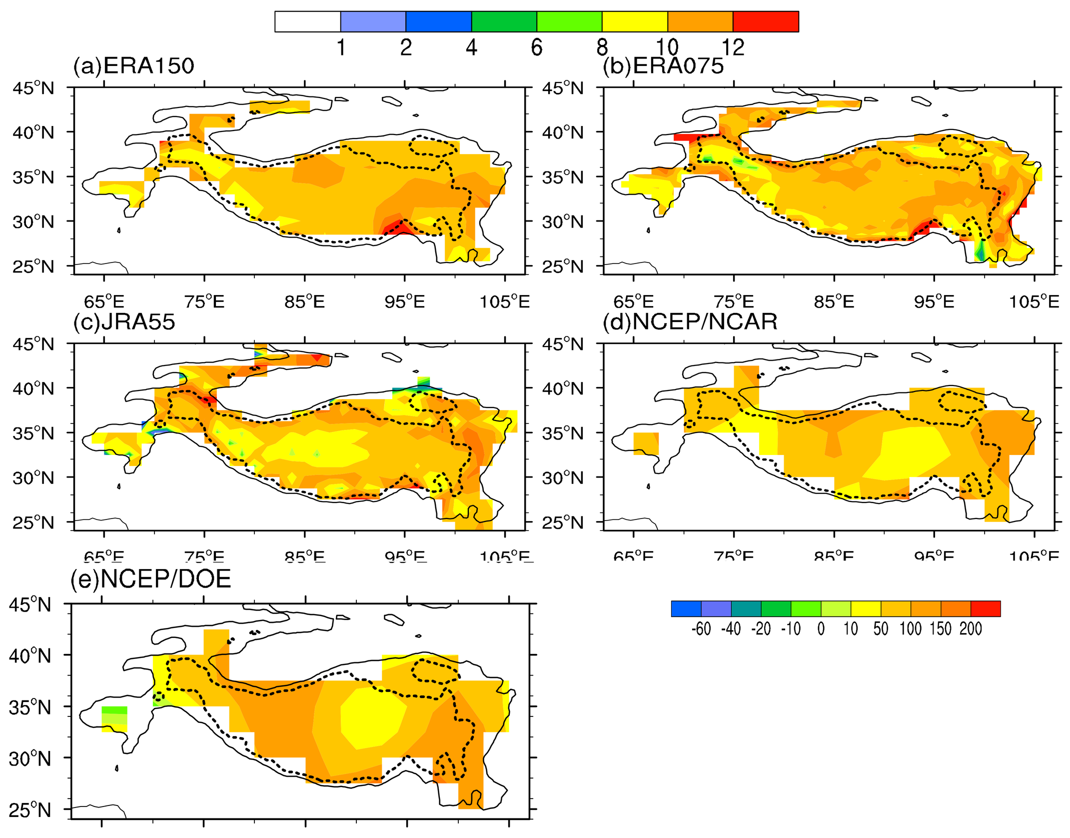

Fig.2 Spatial distributions of the AHS (units: W m^{-2}) in May, averaged over 2011–2016, derived from (a) ERA150, (b) ERA075, (c) JRA-55, (d) NCEP/NCAR, (e) NCEP/DOE

3. AHS reproduced by WRF model

Experimental design: WRF model is reinitialized every 36 h, with each run starting at 12 UTC every day, and the first 12h of each run is discarded as spin up time, while the remaining 24h of the WRF model output data, with intervals at 6h, provides 1 day of output data. There are 6 total months simulated, i.e. starting at 1200UTC 30 April and ending at 0000UTC 1 June for each year from 2011-2016. The AHS in WRF model can be estimated by:

AHS= CU + MP + LW + SW + BL
Cumulus microphysics longwave radiation shortwave radiation planet boundary layer

Table 1 WRF parameters

	Physical package
Land surface	Noah
Boundary Layer	MYJ
Cumulus scheme	Grell-Devenyi
Microphysics scheme	Thompson
Longwave radiation	RRTM
Shortwave radiation	Duhia

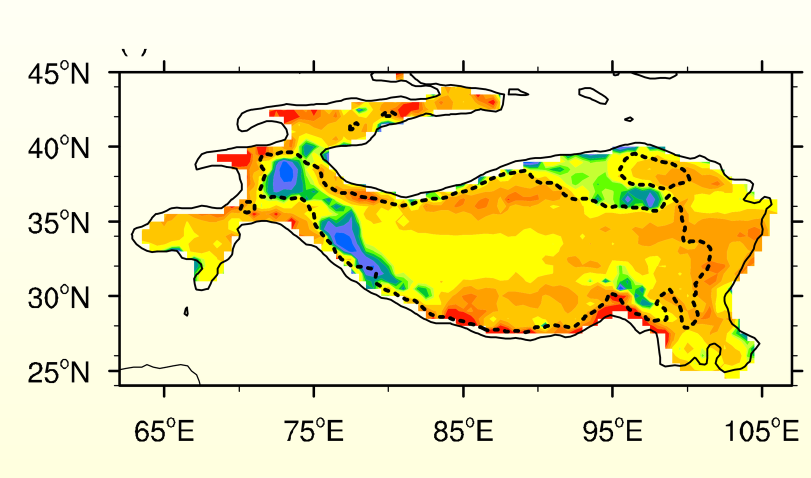

Fig.3 Spatial distributions of the AHS (units: W m^{-2}) in May, averaged over 2011–2016, derived from WRF.

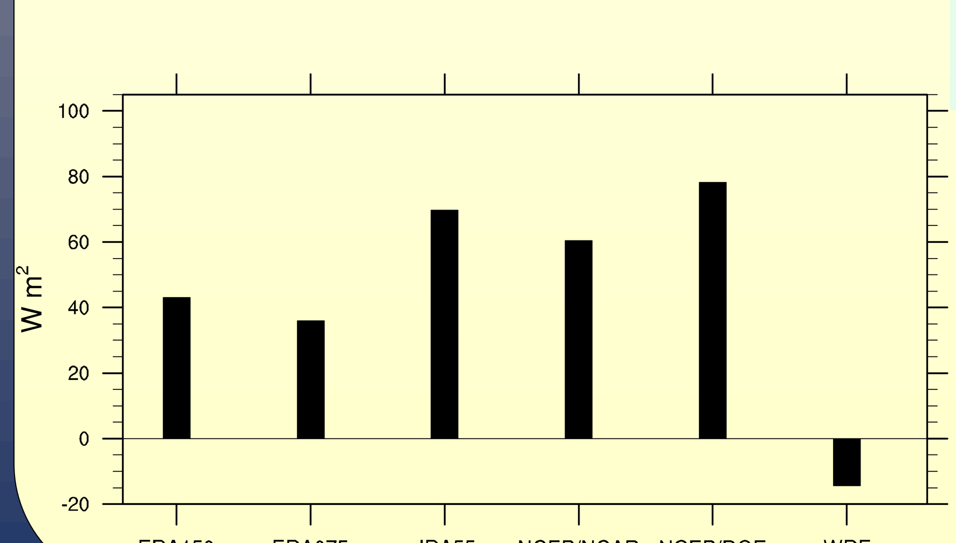

Fig.4 Area-averaged AHS over the western TP (32ºN–40 ºN, 70ºE–78 ºE) in May from 2011–2016. Only values with orography heights greater than 4000 m are counted..

4. Relationship between snow depth and the AHS

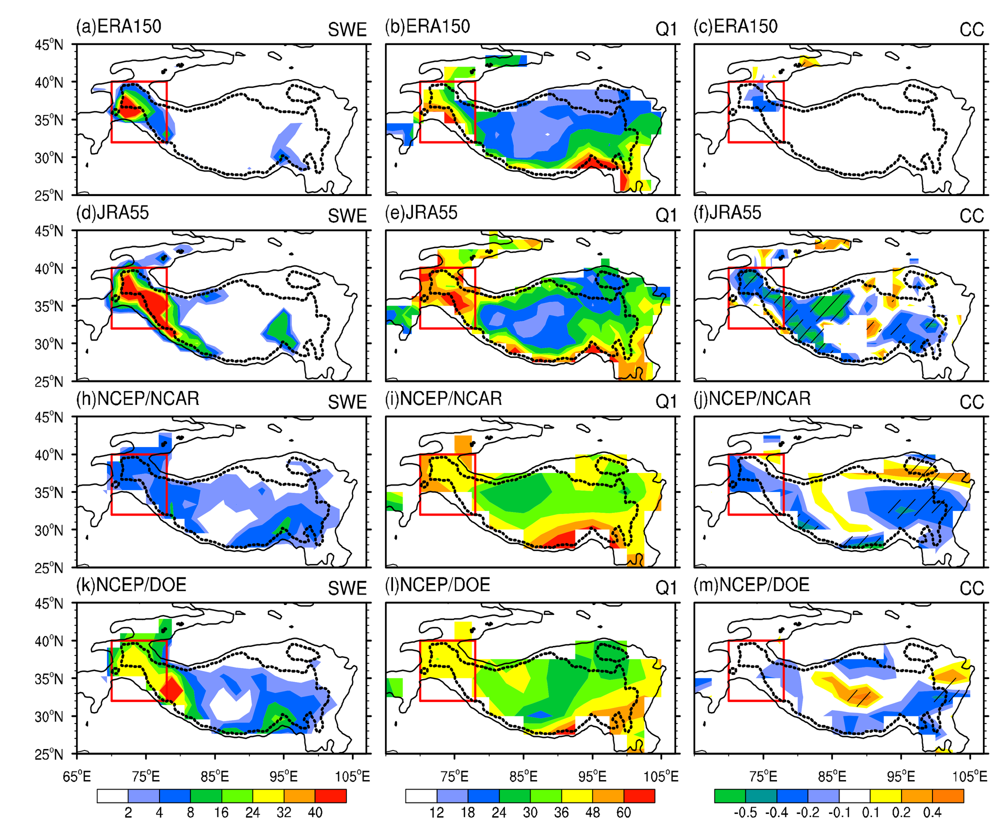

Fig.5 Standard deviations of SWE (units: mm; left-hand column), Q1 (units: W m−2; middle column) and correlation coefficients (right-hand column) between SWE and Q1 over the TP in May, 1979–2016, derived from (a–c) ERA150, (d–f) JRA-55, (h–j) NCEP/NCAR, and (k–m) NCEP/DOE. The hatched regions (right-hand column) denote correlation coefficients significant at the 95% confidence level.

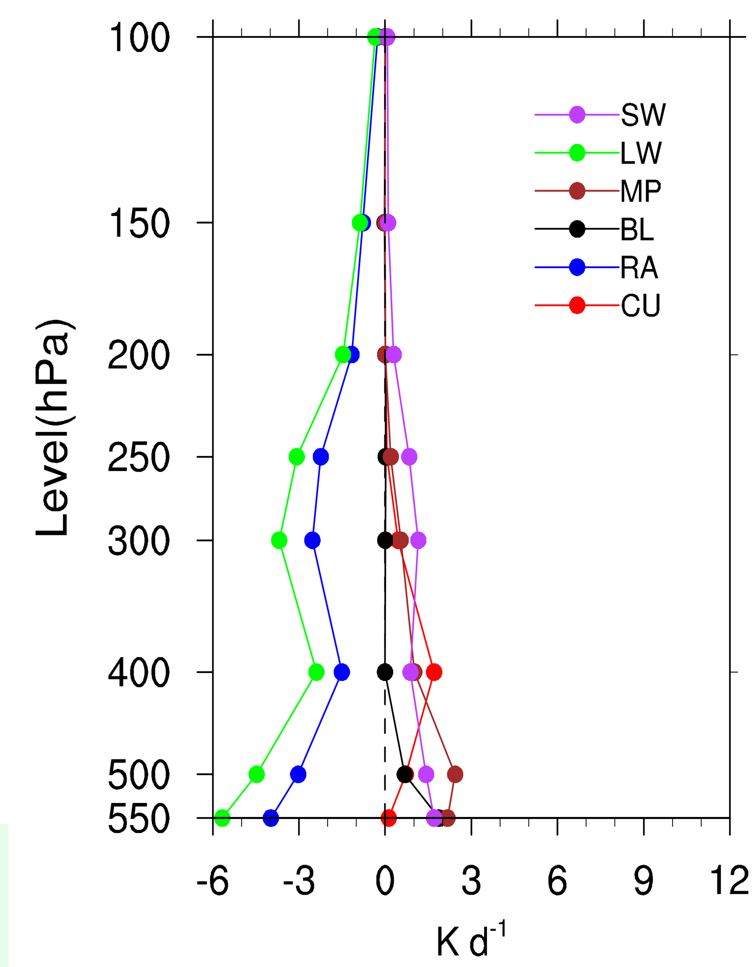

Fig.7 Vertical heating profiles contributed by each physical progress over the western TP (32ºN–40 ºN, 70ºE–78 ºE) from the WRF model. Only values with orography heights greater than 4000 m are counted.

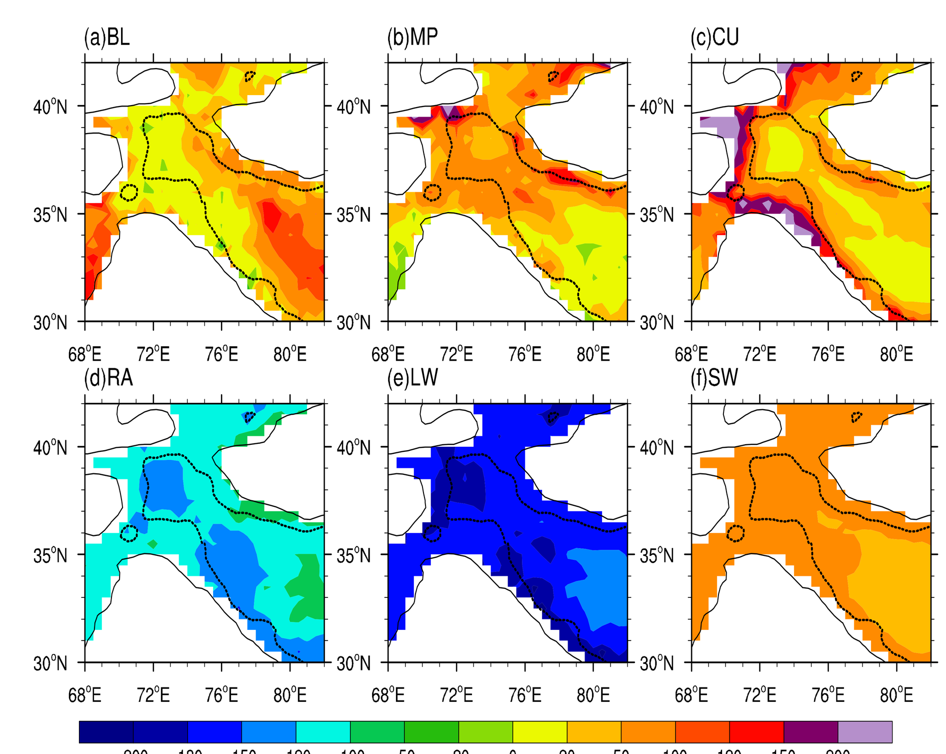

Fig.6 Contributions from each physical scheme to the AHS (units: W m^{-2}) derived by the WRF model in May from 2011–2016. (a) BL, (b) MP, (c) CU, (d) RA, (e) LW, (f) SW

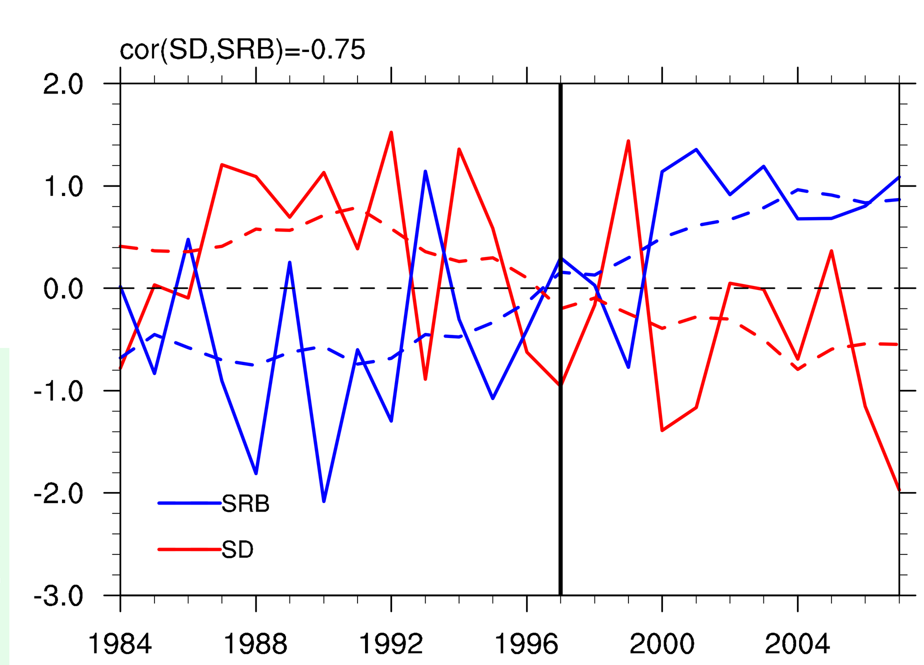

Fig.8 Standardized time series of snow depth (red) and net longwave radiation from SRB (blue) averaged over the western TP (32ºN–40 ºN, 70ºE–78 ºE) in May from 1984–2007. Dashed red and blue lines indicate the corresponding 9-yr running averages. The black thick solid line represents the year 1997. Only values with orography heights greater than 4000 m are counted.

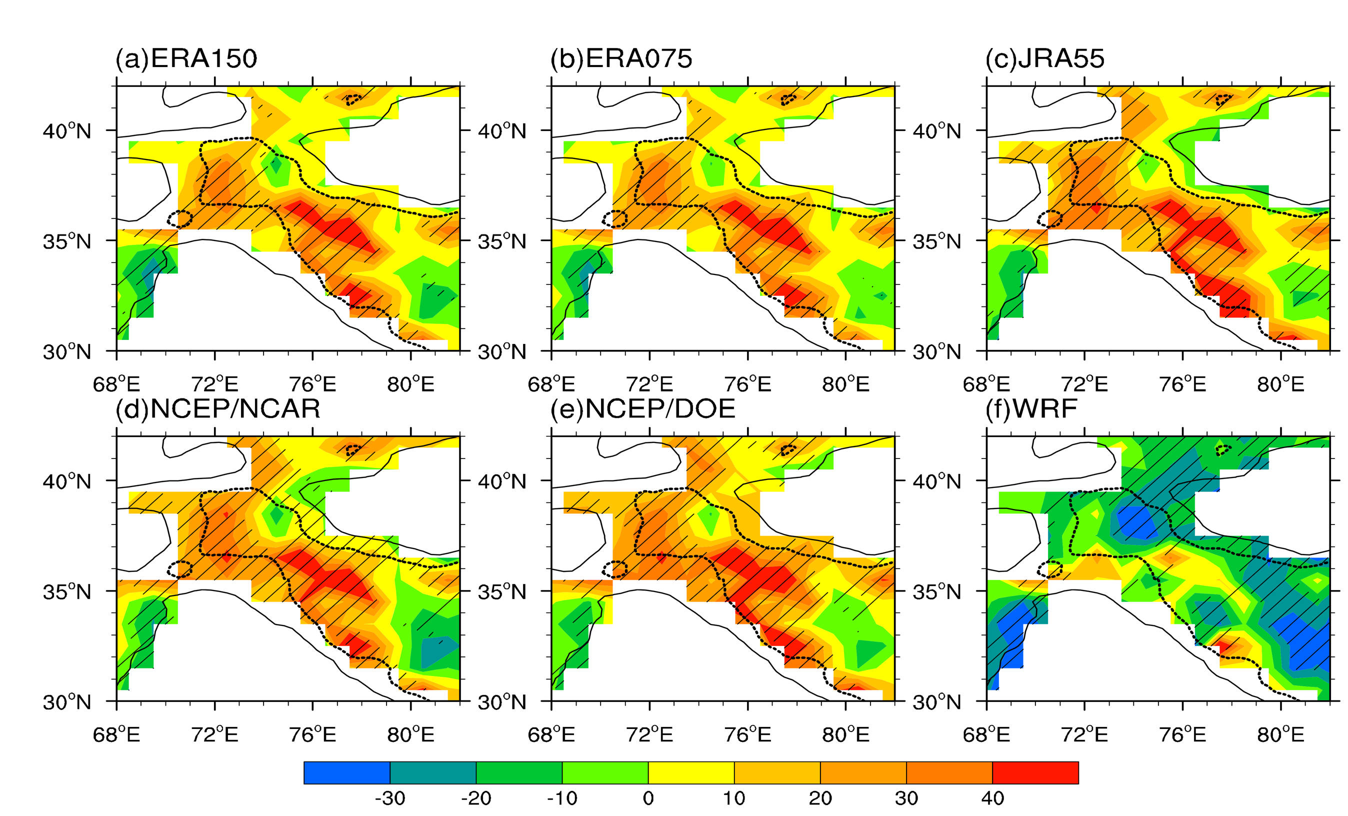

Fig.9 Differences in net longwave radiation (units:Wm^{-2}) between the reanalysis datasets/WRF and the CERES (reanalysis datasets/WRF minus CERES) over the western TP in May from 2011–2016. The hash marked regions denote differences that are significant at the 95% confidence level.

5. Conclusions

- The AHS over the TP is reproduced well by the WRF model in terms of spatial distribution.
- The atmospheric heat sink can be identified over the western TP and the Nyenchen Tanglha Mountains, where the surface height is above 4000 m and the region is covered by thick snow.
- AHS over the western TP is closely connected with snow cover, which could not be found in reanalysis.

Reference: Xiao, Z.X., A.M. Duan, Z.Q. Wang, 2019: Atmospheric heat sinks over the western Tibetan Plateau associated with snow depth in late spring. International Journal of Climatology, 39(13), 5170-5180.