中国气象局地球系统数值预报中心
CMA EARTH SYSTEM MODELING AND PREDICTION CENTRE

Noah-MP development and coupled to CMA global model in China

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1. Noah-MP development

Inclusion of thermal and hydraulic effect of organic soil to reduce the cold bias in winter and warm bias in summer

	λ_s	λ_{sat}	λ_{dry}	c_s	θ_{sat}	k_{sat}	Ψ_{sat}	b
Organic soil	0.25	0.55	0.05	2.5E+6	0.93	2.8E-4	0.0103	2.7
Mineral soil	Geometric mean by quartz	Geometric mean by different component	Computed by dry density	2.0E+6	Prescribed values depending on soil texture			

$$c_p = \theta_{liq} \cdot c_{liq} + (1 - \theta_{sat}) \cdot c_s + (\theta_{sat} - \theta_{tot}) \cdot c_{air} + \theta_{ice} \cdot c_{ice}$$

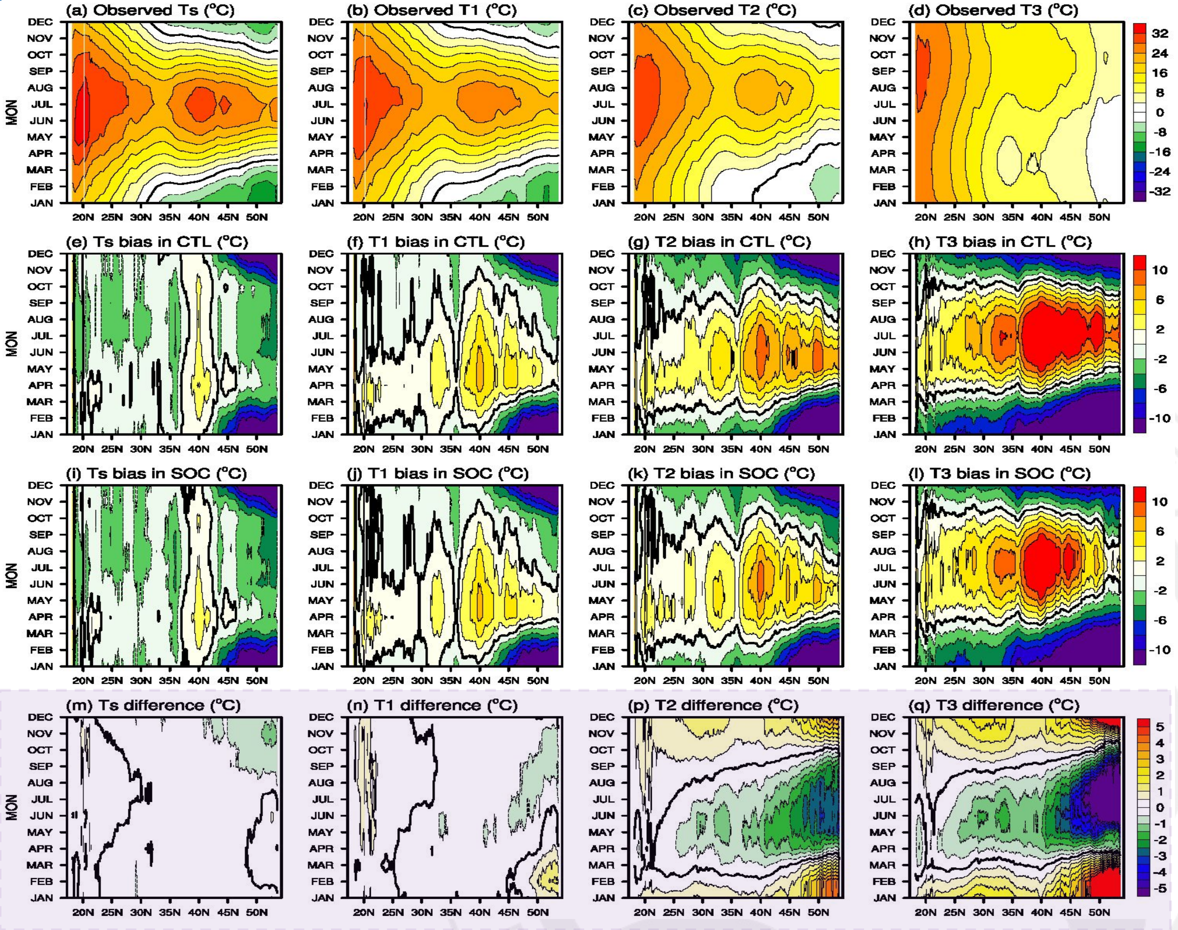
$$\lambda_{sat} = \lambda_s^{1-\theta_{sat}} \cdot \lambda_{ice}^{(1-f_{liq})\theta_{sat}} \cdot \lambda_{liq}^{f_{liq}\theta_{sat}}$$

$$\lambda_{dry} = \frac{0.135\gamma_d + 64.7}{2700 - 0.947\gamma_d}$$

$$p_{soil} = (1 - f_{soc}) \cdot p_{\min} + f_{soc} \cdot p_{soc}$$ arithmetic average

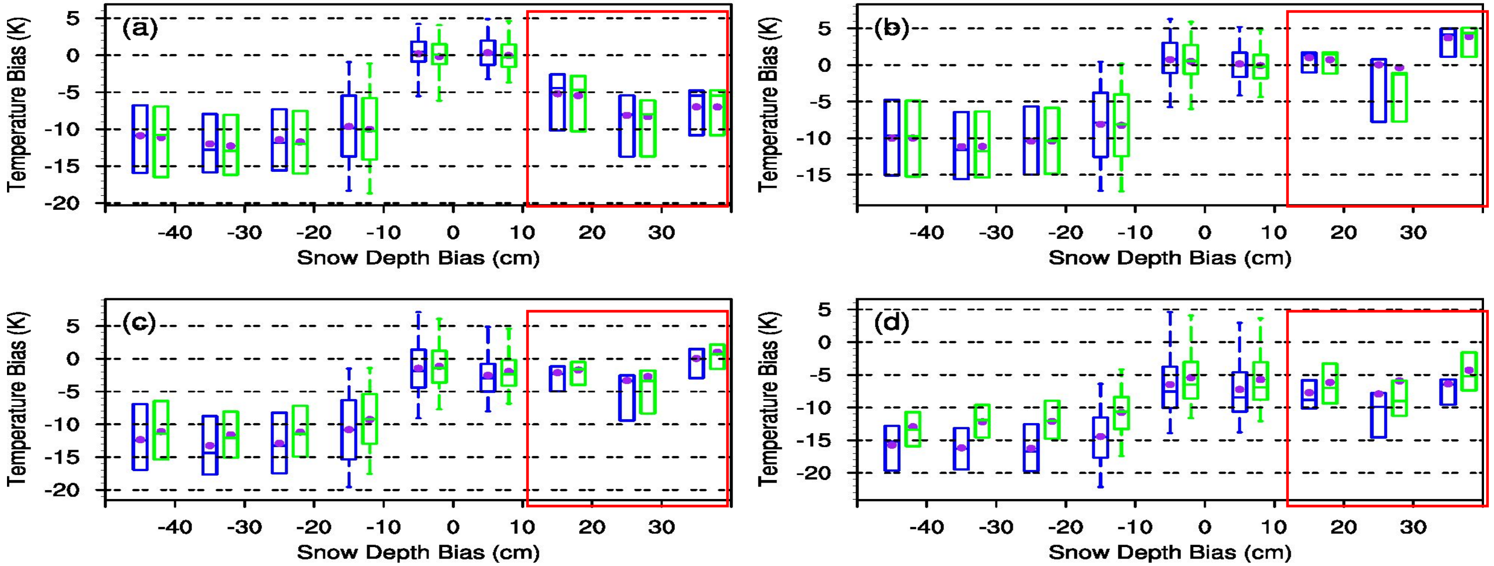
$$p_{soil} = p_{\min}^{1-f_{soc}} \cdot p_{soc}^{f_{soc}}$$ geometric average

(Zhang et al., AR, 2021)



Observations and simulated bias of skin temperature and soil temperature with/without organic soil at different depths

1. Noah-MP development



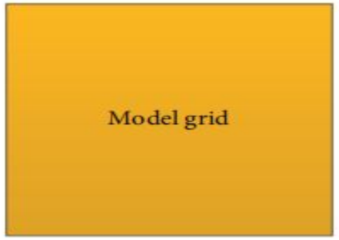
Comparison of monthly mean bias of skin and soil temperature and snow depth bias

	Snow depth (m)	Observation		CTL		SOC	
		Slope	R^2	Slope	R^2	Slope	R^2
T1 vs. T_{air} ($^oC\ ^oC^{-1}$)	<0.045	0.73	0.86	1.05	0.93	1.04	0.94
	[0.045, 0.1)	0.58	0.70	1.02	0.91	1.03	0.92
	[0.1,0.2)	0.41	0.51	0.96	0.82	0.97	0.85
	≥ 0.2	0.30	0.32	0.96	0.71	0.96	0.75
T2 vs. T_{air} ($^oC\ ^oC^{-1}$)	<0.045	0.46	0.43	0.91	0.89	0.83	0.84
	[0.045, 0.1)	0.33	0.32	0.89	0.84	0.81	0.79
	[0.1,0.2)	0.20	0.18	0.82	0.74	0.73	0.70
	≥ 0.2	0.14	0.10	0.82	0.61	0.72	0.59

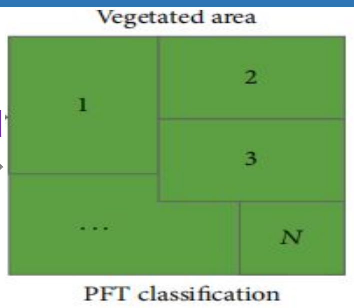
(Zhang et al. 2021, Atmospheric Research)

1. Noah-MP development

Sub-grid effect of land use/land cover to reduce the simulated differences among different horizontal resolutions



Areal fraction of each underlying type in one grid



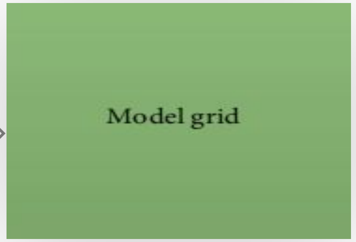
Surface flux and variables computed for type

$$F_i = \frac{\sum_{j=1}^{N} F_{ij} \cdot A_{ij}}{\sum_{j=1}^{N} A_{ij}} \; j$$

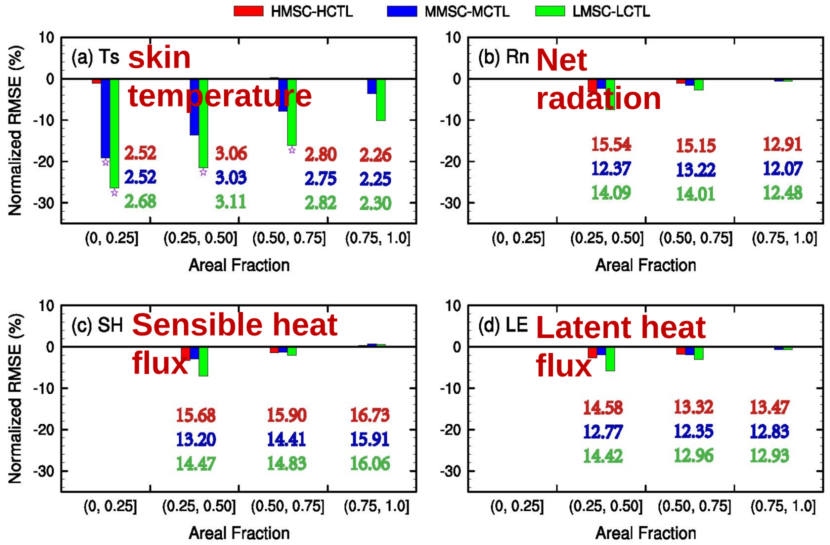
F_i Flux of grid i

F_{ij} Flux of subgrid j

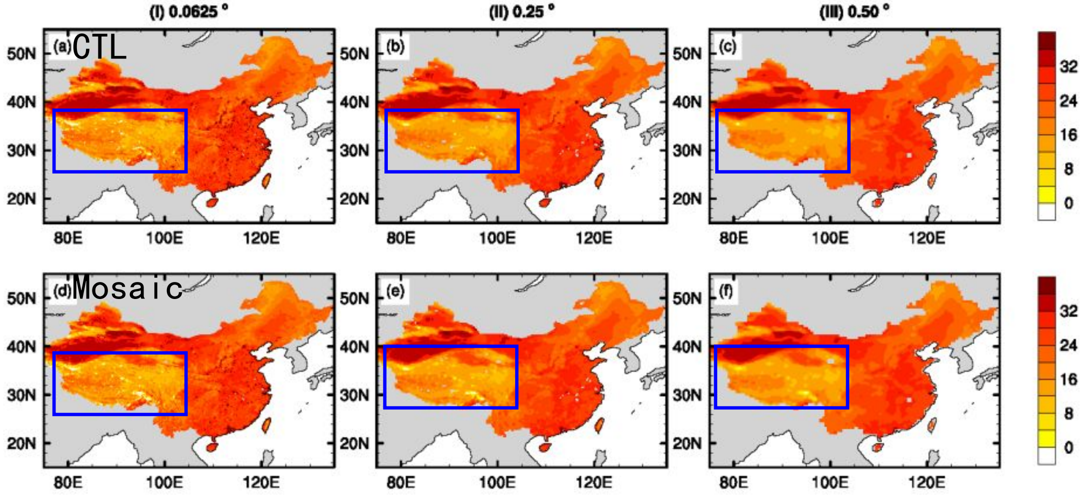
A_{ij} Areal fraction of subgrid j



Weighted average



Red, blue, and green: 0.0625°, 0.25°, and 0.50°horizontal resolution

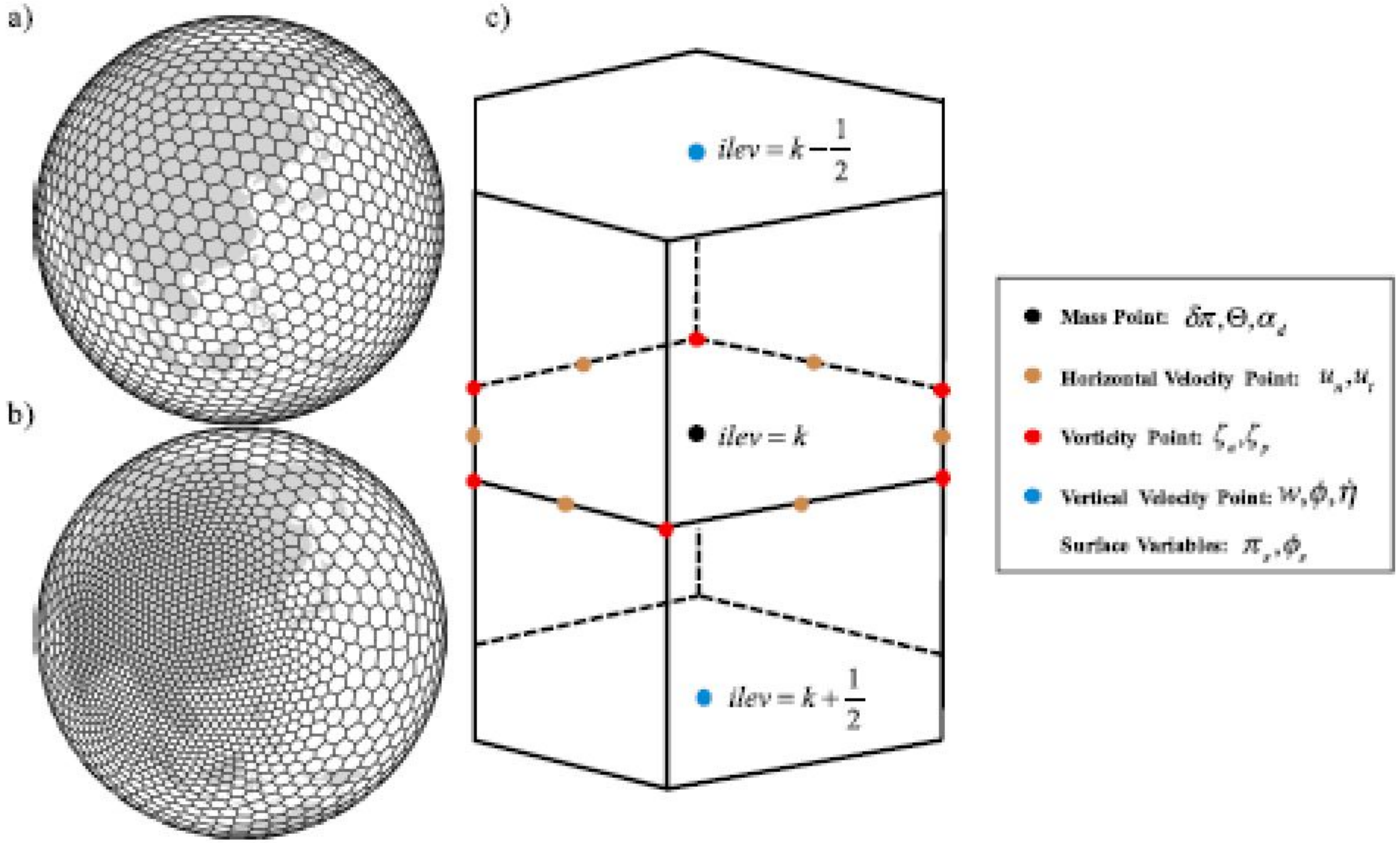


Simulated monthly mean skin temperature in July with/without mosaic

(Zhang et al., JGR, 2021)

2. GRIST/Noah-MP coupling

GRIST(Global-to-Regional Integrated forecast SysTem model



An illustration of the model mesh in (a) quasi-uniform and (b) variable-resolution configurations; (c) the locations of major variables in the 3-D space, k denotes the full level, k±1/2 denotes the face level (from Zhang et al. 2019)

multi-scale; unstructured mesh;

Sigma-mass vertical coordinate allows flexible switching between static and non-static modes;

adopts hexagonal C-grid design scheme based on staggered finite volume method

input and output variables

```fortran
call grist_noahmp_run ( mesh,ncell,istep,nlev,levsoil,                    &  !in
                pstate%u_wind_at_pc_full_level%f(1:nlev,1:ncell) , &      !in
                pstate%v_wind_at_pc_full_level%f(1:nlev,1:ncell) , &  !in
                pstate%temp_at_pc_full_level%f(  1:nlev,1:ncell) , &  !in
                pstate%tracer_mxrt_at_pc_full_level%f(1,1:nlev,1:ncell),&   !in
                pstate%pressure_at_pc_face_level%f (    1:nlevp,1:ncell),&   !in
                pstate%atm_out_fswds_at_pc_surface%f(1:ncell), &  !in ! SWDOWN  [W m-2]
                pstate%atm_out_flwds_at_pc_surface%f(1:ncell), &  !in ! longwave down at surface [W m-2]
                pstate%scalar_prect_surface%f       (1:ncell), &  !in
                !--out later
                pstate%atm_in_lwup_at_pc_surface%f(  1:ncell), & ! out
                pstate%atm_in_shflx_at_pc_surface%f( 1:ncell), & ! out
                pstate%atm_in_qflx_at_pc_surface%f(1,1:ncell), & ! out
                pstate%atm_in_taux_at_pc_surface%f(  1:ncell), & ! out
                pstate%atm_in_tauy_at_pc_surface%f(  1:ncell), &
                pstate%atm_in_asdir_at_pc_surface%f( 1:ncell), &! 0.2-0.7 micro-meter srfc alb: direct rad
                pstate%atm_in_asdif_at_pc_surface%f( 1:ncell), &! 0.2-0.7 micro-meter srfc alb: diffuse rad
                pstate%atm_in_aldir_at_pc_surface%f( 1:ncell), &! 0.7-5.0 micro-meter srfc alb: direct rad
                pstate%atm_in_aldif_at_pc_surface%f( 1:ncell) ) ! 0.7-5.0 micro-meter srfc alb: diffuse rad
```

```fortran
! here give to pstate: out
   lwup    = fire2d
   shflx = hfx
   qflx    = qfx
   taux    = taux2d
   tauy    = taux2d
   albdvis = albd2d(1,:)
   albdnir = albd2d(2,:)
   albivis = albi2d(1,:)
   albinir = albi2d(2,:)
```

```fortran
u(pver,:ncol) = u(pver,:ncol) + tmp1(:ncol)*taux(:ncol)
v(pver,:ncol) = v(pver,:ncol) + tmp1(:ncol)*tauy(:ncol)
```

full level (nlev)

surface

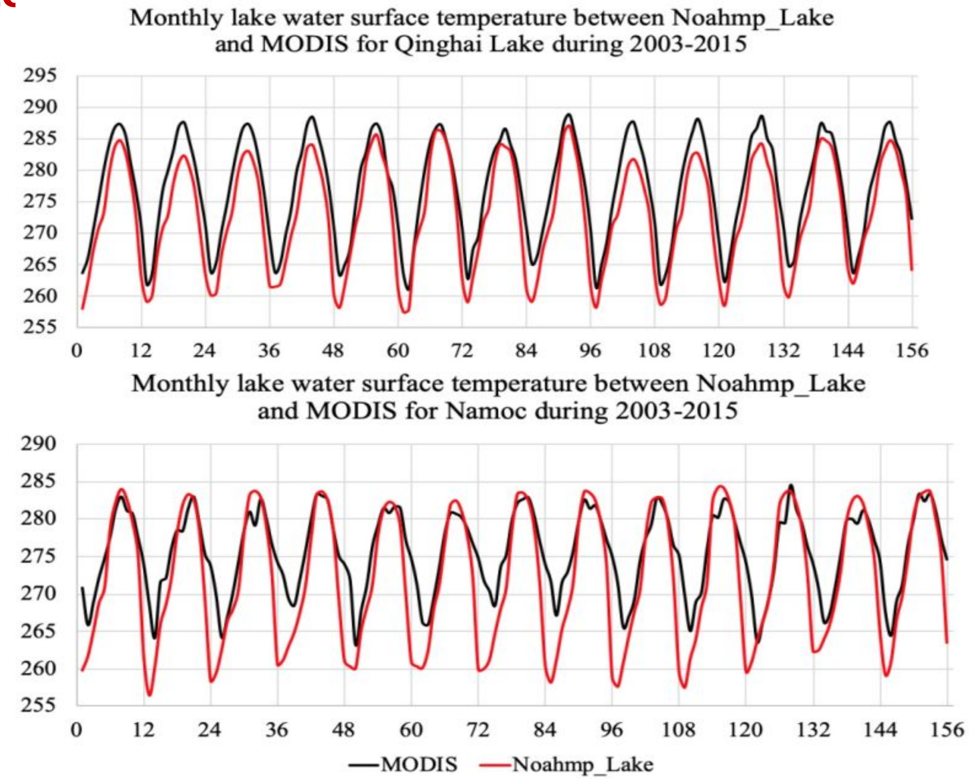
u_wind_at_pc_full_level	wind speed; m/s;
v_wind_at_pc_full_level	
temp_at_pc_full_level	temperature; K;
tracer_mxrt_at_pc_full_level	specific humidity; kg/kg;
pressure_at_pc_face_level	pressure; Pa
atm_out_fswds_at_pc_surface	down shortwave flux at surface;
atm_out_flwds_at_pc_surface	down longwave flux at surface;
scalar_prect_surface	precipitation; m/s;

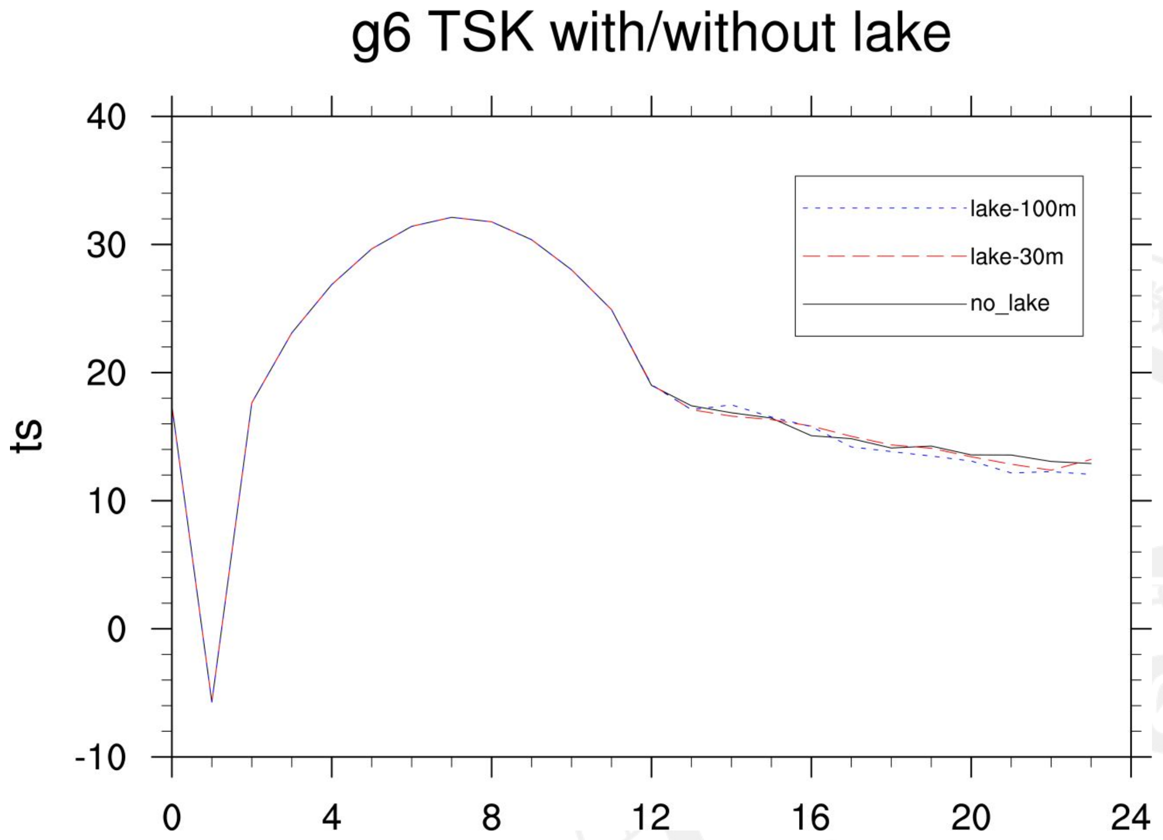
atm_in_lwup_at_pc_surface	upward longwave flux
atm_in_shflx_at_pc_surface	sensible heat flux at the surface; w/m2
atm_in_qflx_at_pc_surface	surface constituent flux; kg/m2/s
atm_in_taux_at_pc_surface	surface momentum flux; N/m2
atm_in_tauy_at_pc_surface	
atm_in_asdir_at_pc_surface, asdif, aldir, aldif	micro-meter surface albedo;

2. GRIST/Noah-MP coupling

Adopt lake model from Weather Research and Forecasting Model into GRIST/Noah-MP

Monthly mean simulated lake surface temperature





3. GRIST/Noah-MP evaluation

Model setup

0.25°x 0.25°horizontal resolution

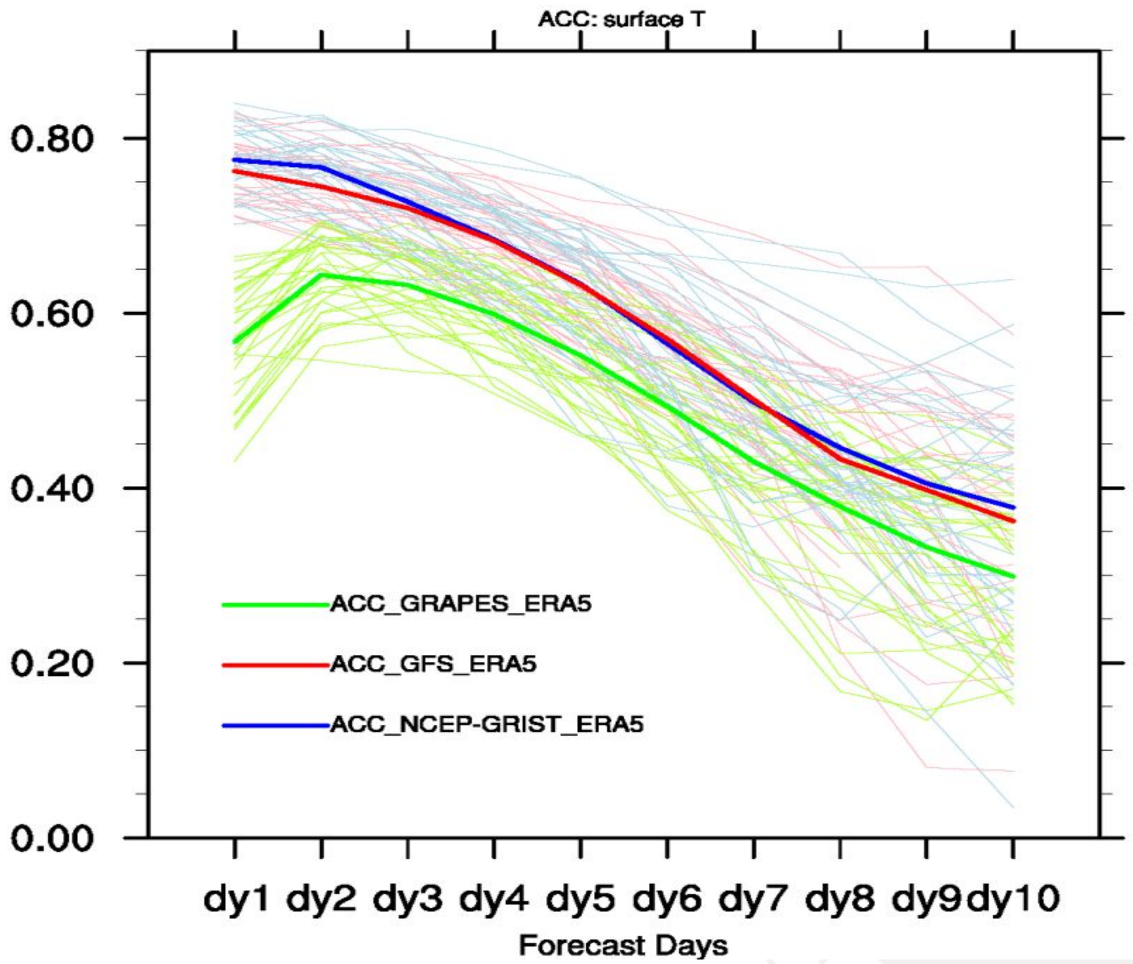
The model starts at UTC 00:00 every day from June 1 to June 30, and each case integrated 10-day continuously. The output is 3-hourly. No data assimilation.

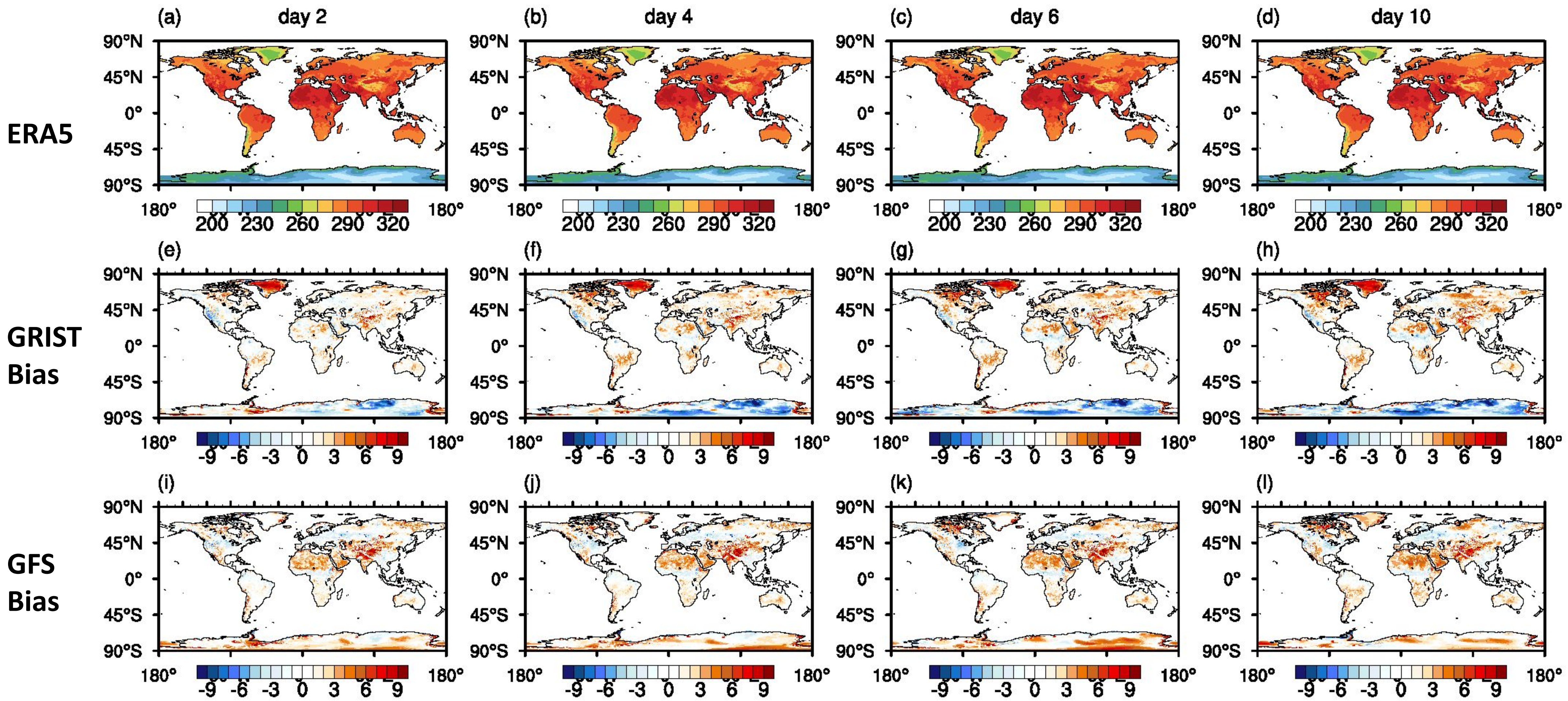
Physical scheme name	option
Dynamic vegetation	4 (table of Leaf Aera Index)
Canopy resistance	1 (The Ball-Berry scheme, Ball et al., 1987)
Soil moisture factor for stomatal resistance	1 (The Noah type, Chen and Dudhia, 2001)
Runoff and groundwater	3 (original surface and subsurface runoff-free drainage)
Surface layer drag coefficien	1 (The Monin-Obukhov scheme, Brutsaert, 1982)
Frozen soil permeability	1 (Hydraulic properties from total soil water and ice, Niu & Yang, 2006)
Supercooled liquid water in frozen soil	1 (General form of the freezing-point depression equation, Niu & Yang, 2006)
Radiation transfer	3 (Canopy gap from vegetation fraction, Niu and Yang, 2004)
Snow surface albedo	2 (Canadian Land Surface Scheme, Verseghy, 1991)
Lower boundary of soil temperature (TBOT)	2 (TBOT read from a file, Chen et al., 1996)
Surface resistance	1 (Sakaguchi and Zeng's scheme, Sakaguchi and Zeng, 2009)
Glacier	1 (Include phase change of ice)

3. GRIST/Noah-MP evaluation

Forecast skill of simulated skin temperature about degree of spatial similarity

The comparison of **Anomaly Correlation Coefficient (ACC)** of skin temperature (Ts) between models (GRIST, GFS, GRAPES) and ERA5 in the forecast days (The thin lines represent the result of each day's forecast, and the thick lines represent the 30-case ensemble mean.)

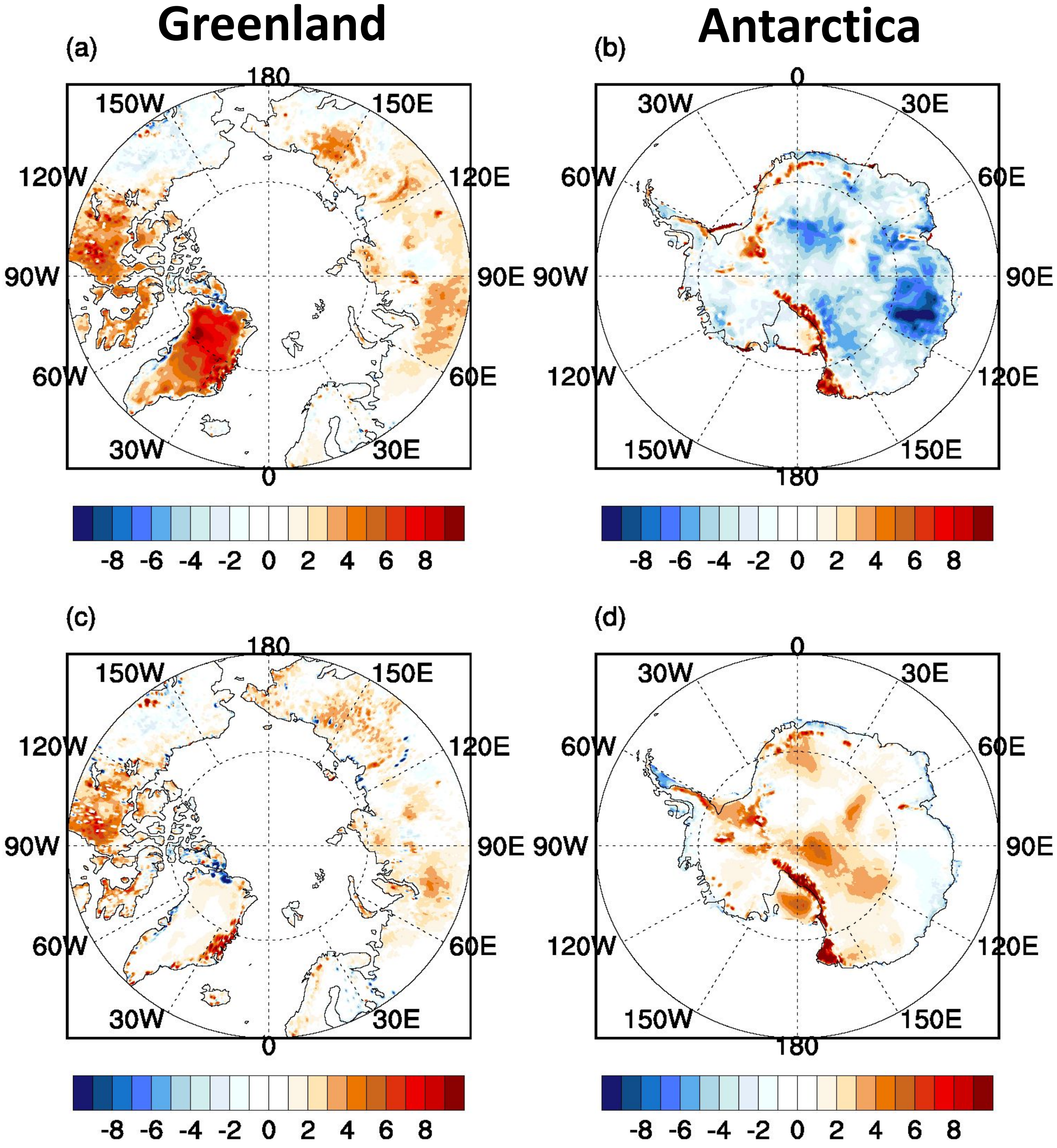




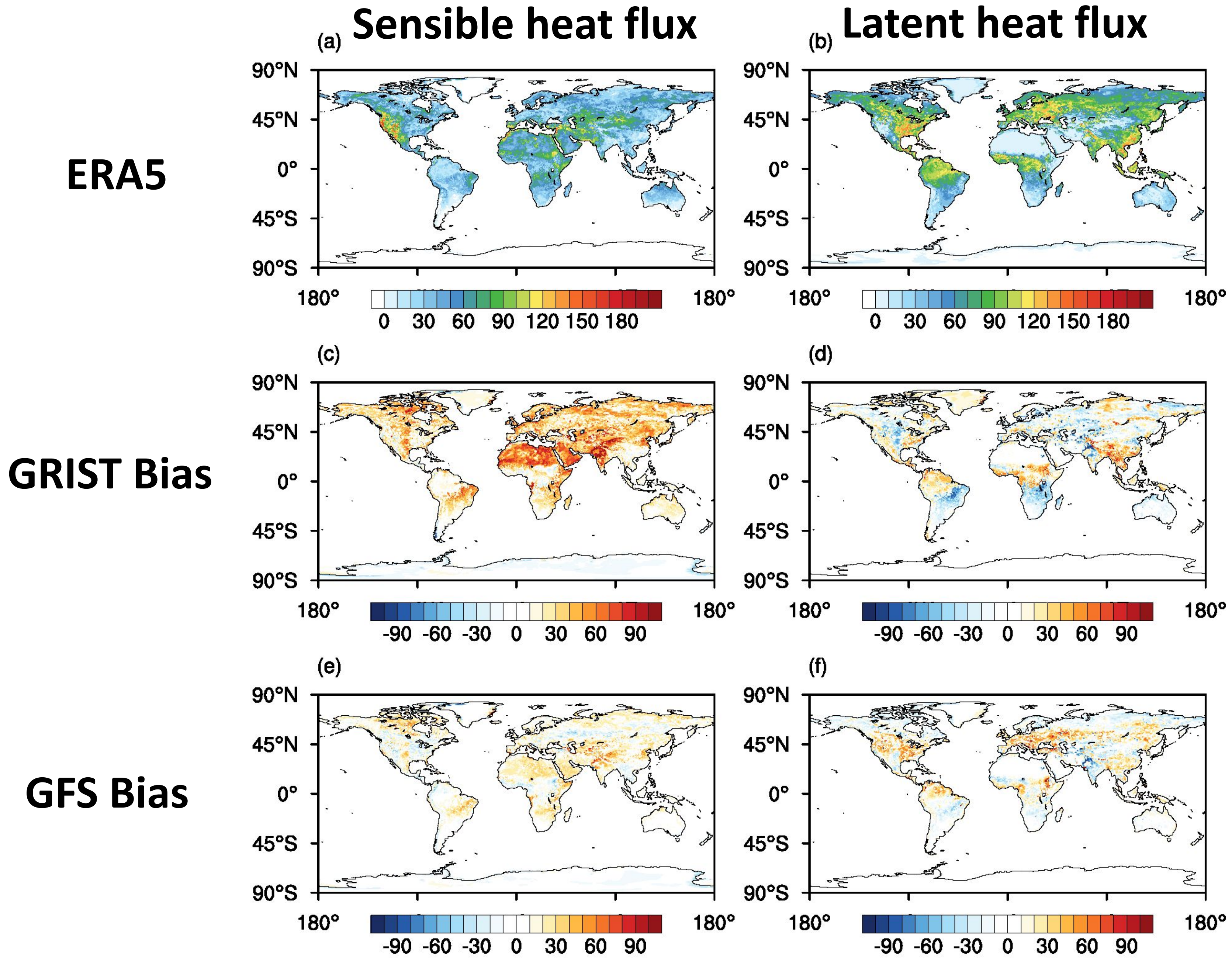
The 30-case ensemble mean Ts (units: K) of ERA5, GRIST bias (GRIST minus ERA5) of Ts and GFS bias (unit: K). Day2: averaged from June 2 to July 1; Day4: averaged from June 4 to July 3; Day6: averaged from June 6 to July 5; Day10: averaged from June 10 to July 9 forecasts.

GRIST Bias

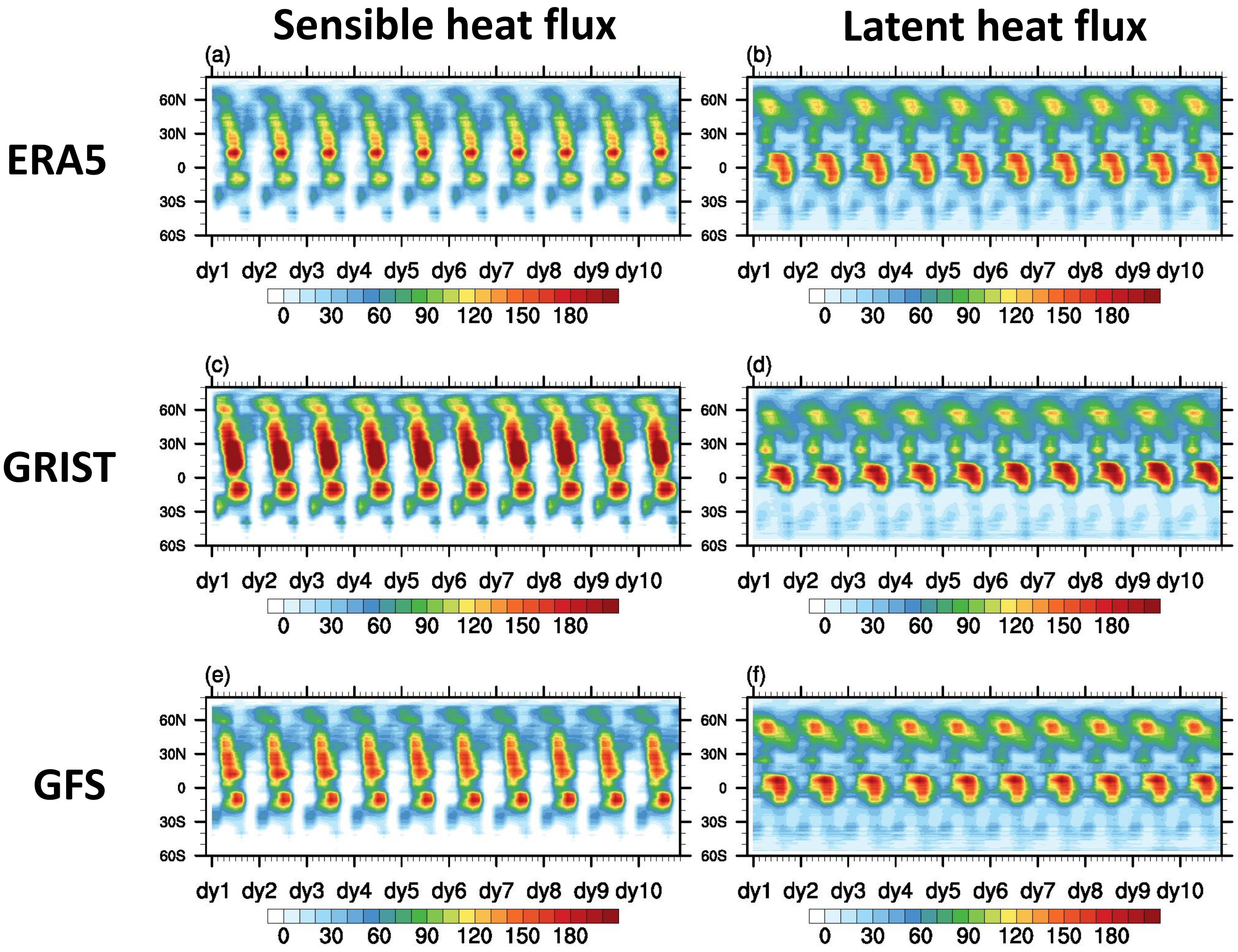
GFS Bias



The 30-case ensemble mean T_s bias (units: K) of GRIST (GRIST minus ERA5) and GFS in polar regions

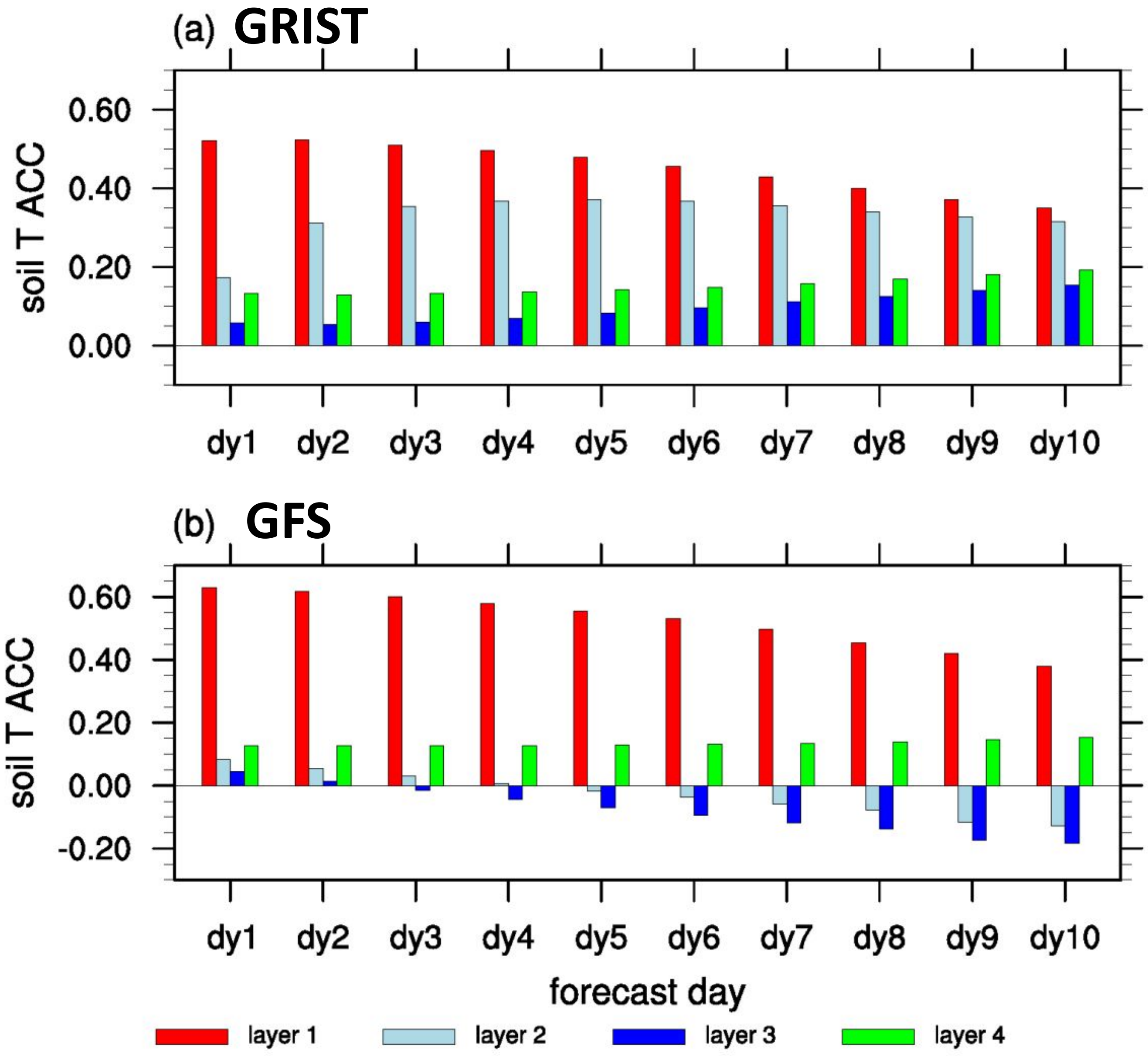


ERA5 30-case ensemble mean of the 10-day averaged surface energy flux (units: W m^{-2}), GRIST bias (GRIST minus ERA5) and GFS bias

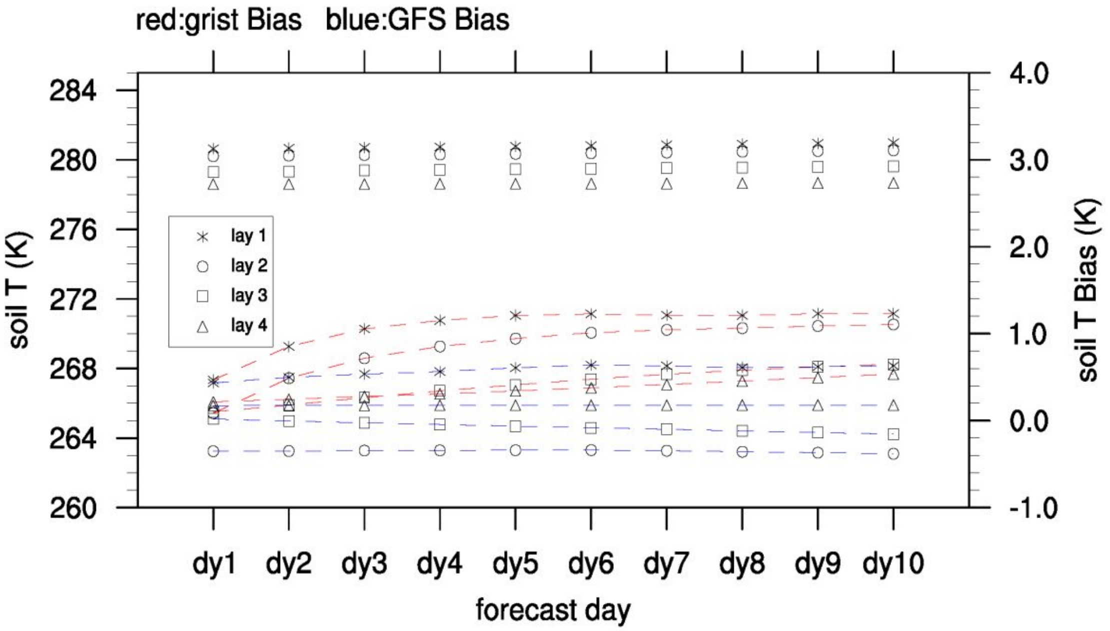


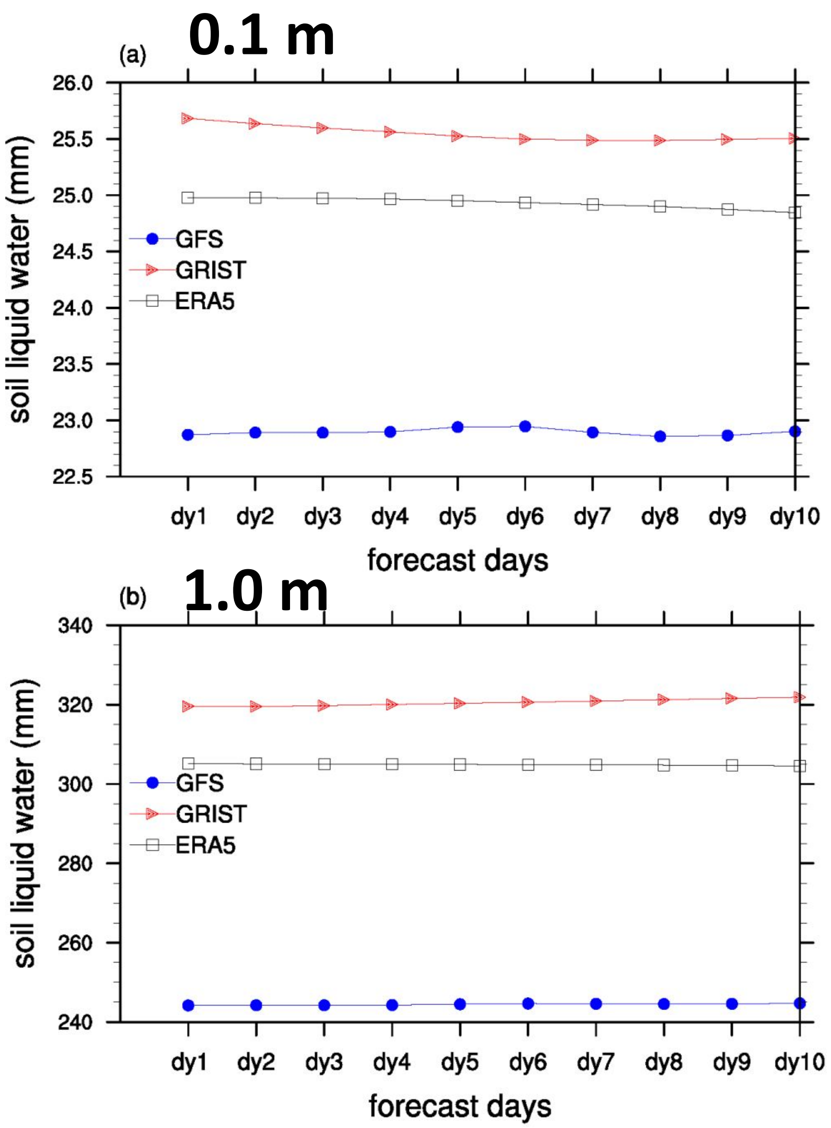
Latitude-time cross section of ensemble mean sensible heat flux and latent heat flux (unit: W m^{-2}).

The histogram of 30-case ensemble mean ACC of the 4 soil layer's temperature (T_{soil})



The time series of the global mean T_{soil} of ERA5 (marks), GRIST bias (red markline, GRIST minus ERA5), and GFS bias (blue markline, GFS minus ERA5) for forecast day.



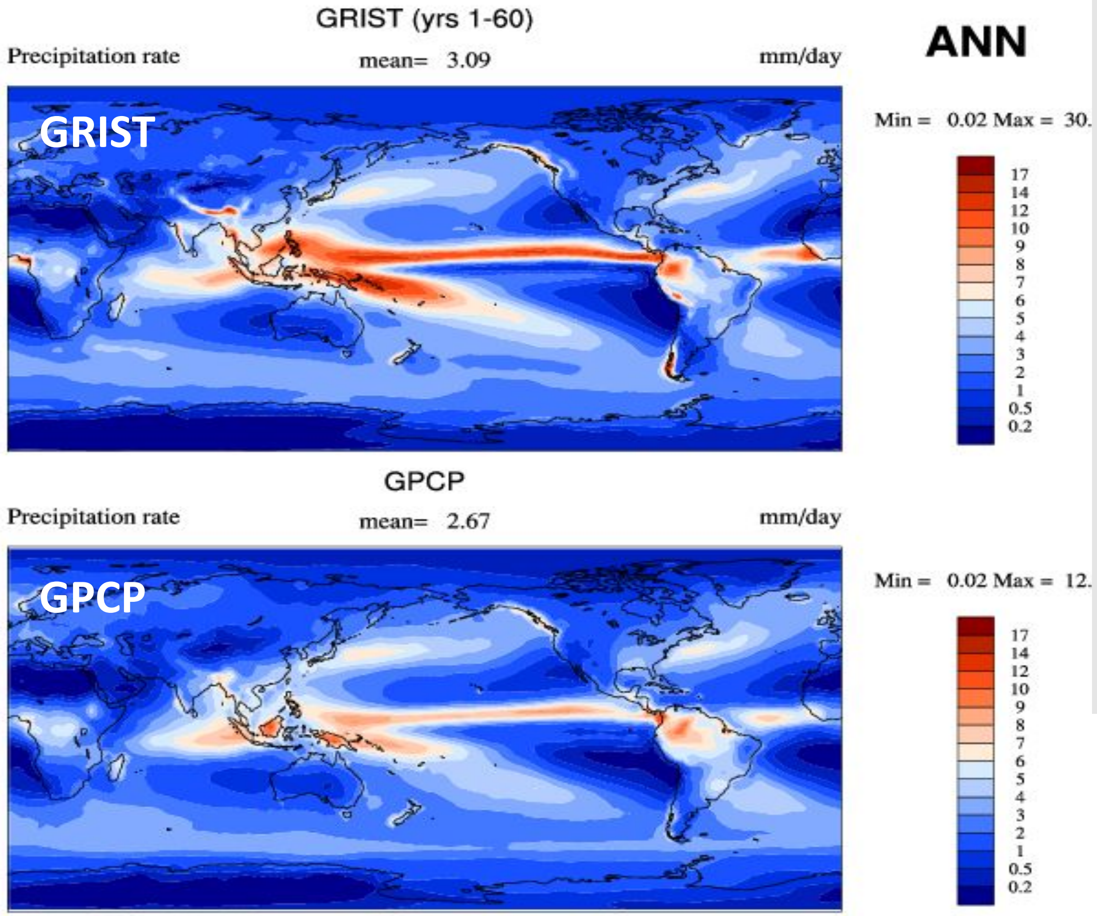


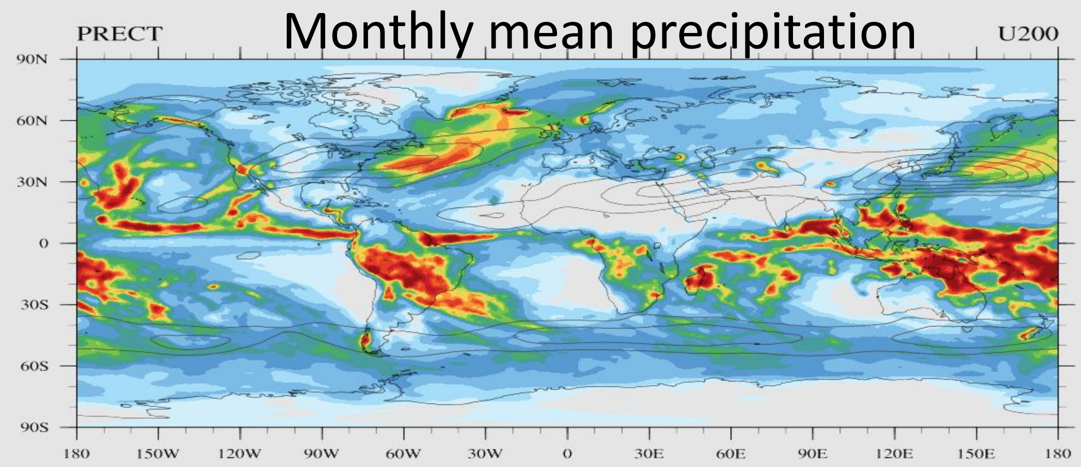
The time series of the global mean of the soil liquid water (unit: mm) of ERA5, GRIST, and GFS for forecast day over two different soil depth

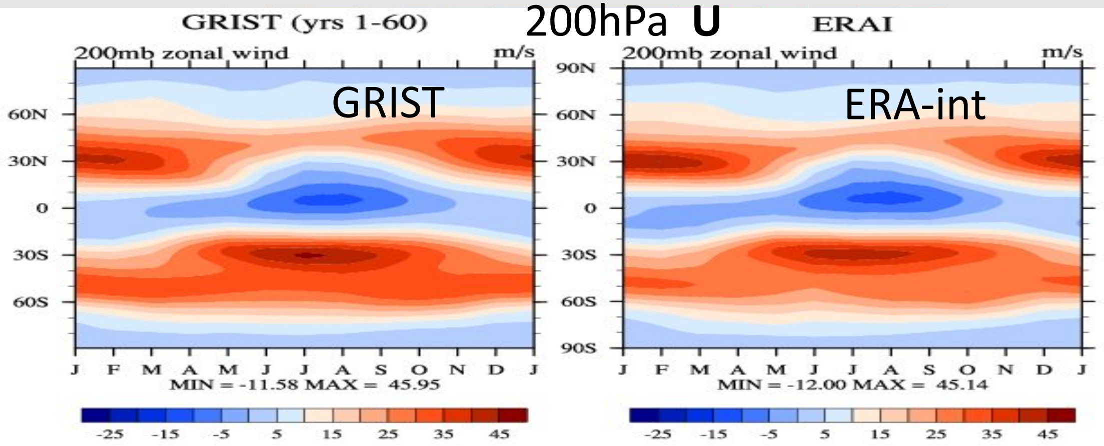
4. GRIST performance

Simulated precipitation of 60 years resolution quasi-uniform mesh

Annual mean precipitation





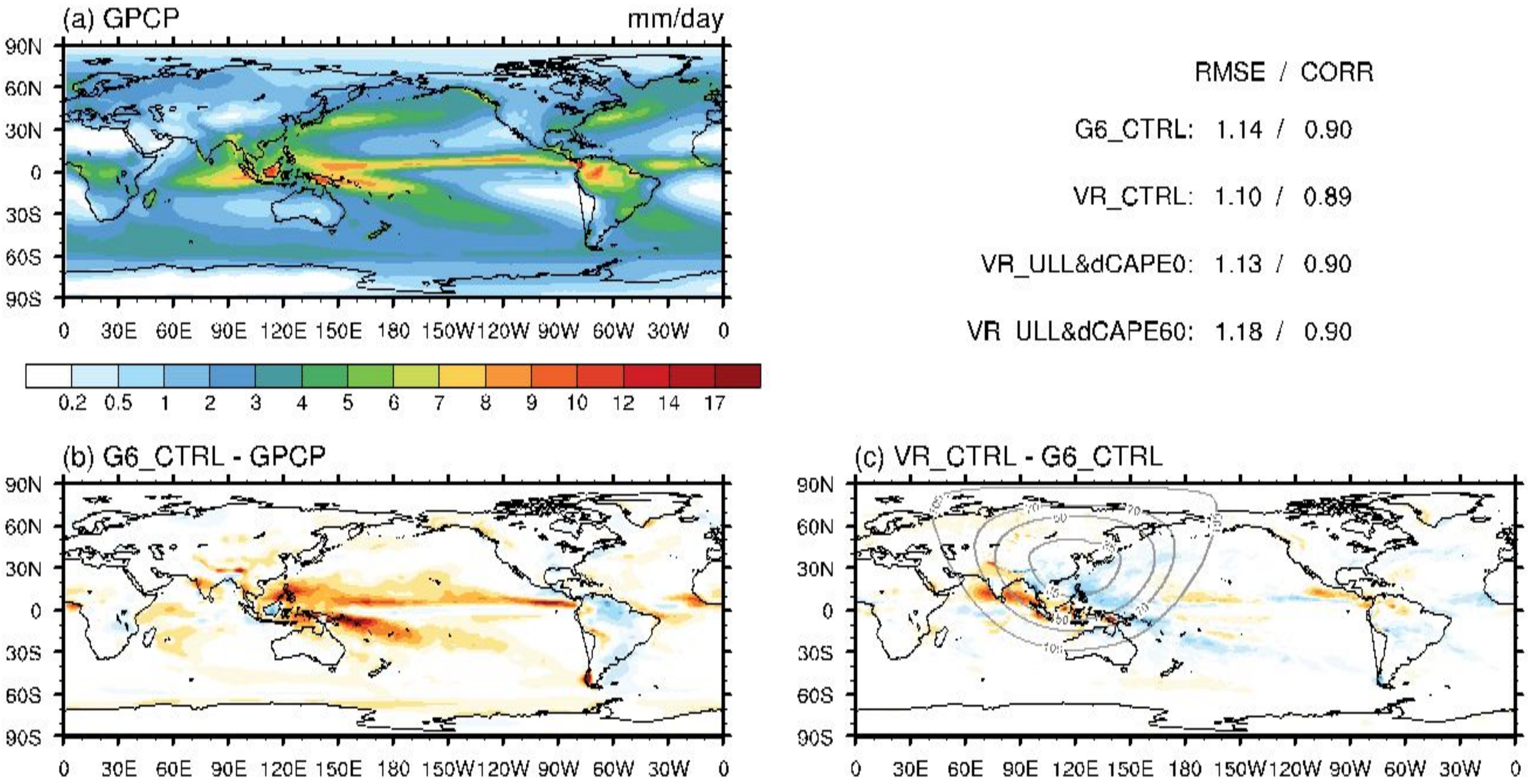


Unstructured mesh global model: long term stable integration

4. GRIST performance

Five years and a half integration of variable resolution model (VR 30—120 km)

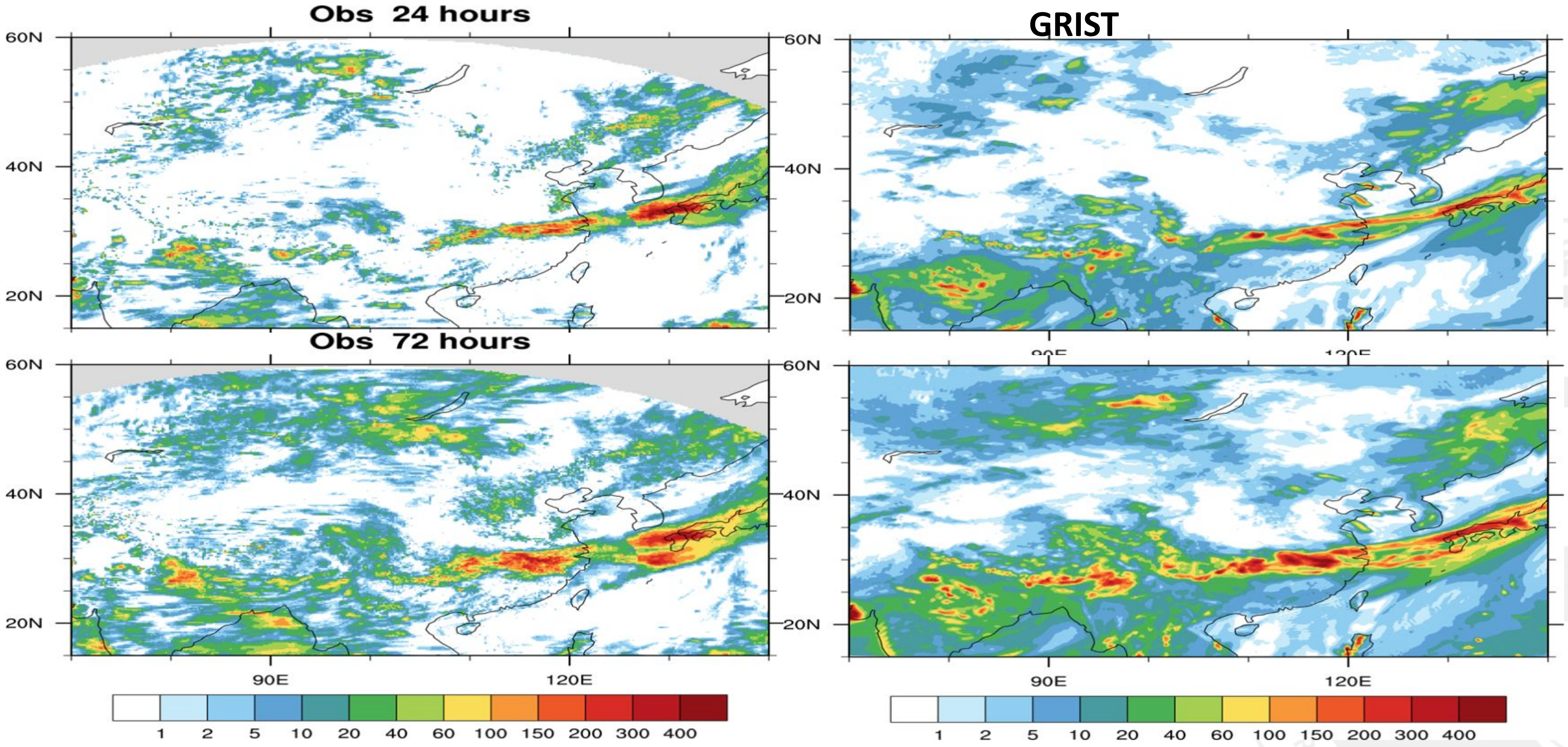
Global precipitation climate is reasonable; improve the precipitation simulations at 120-km resolution



	RMSE / CORR
G6_CTRL:	1.14 / 0.90
VR_CTRL:	1.10 / 0.89
VR_ULL&dCAPE0:	1.13 / 0.90
VR_ULL&dCAPE60:	1.18 / 0.90

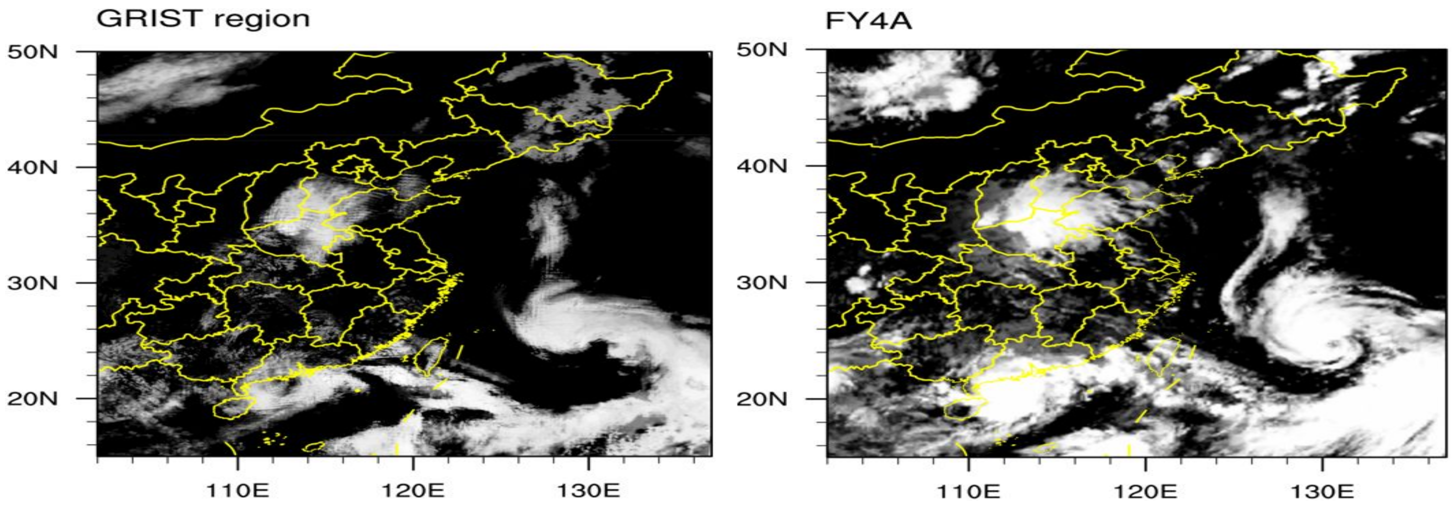
4. GRIST performance

Simulated Jianghuai Meiyu in 2020 of 30-km (g8) resolution quasi-uniform mesh (median-range forecast)



4. GRIST performance

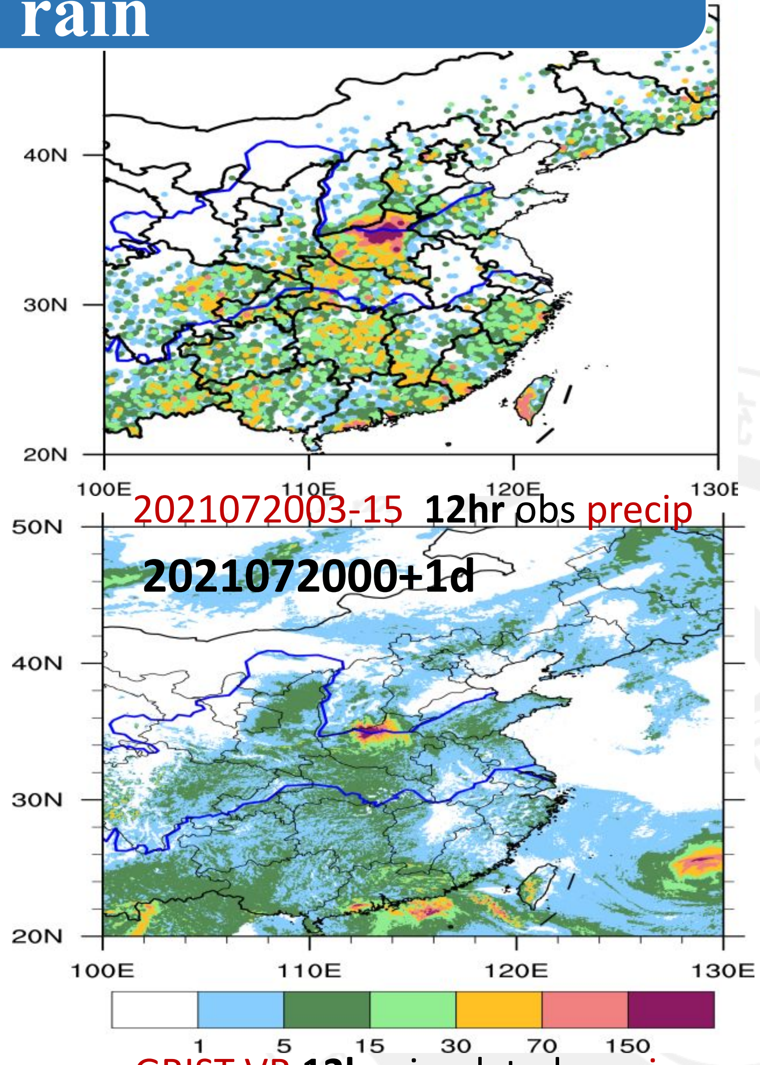
15-day global medium-range forecast of variable resolution model (VR 3—60 km): Zhengzhou torrential rain



2021072003 UTC

GRIST precipitation

FY4A observation



GRIST VR **12hr** simulated precip

Thank you！

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