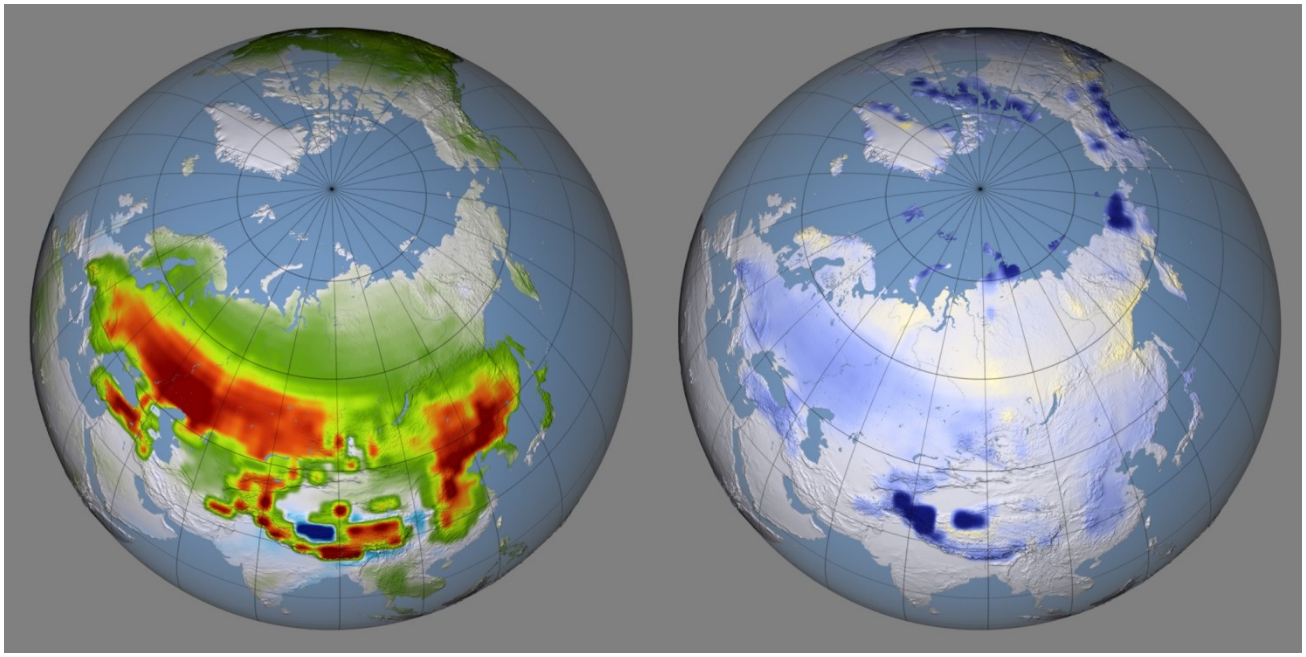
Impacts of snow darkening by absorbing aerosols on Eurasian climate



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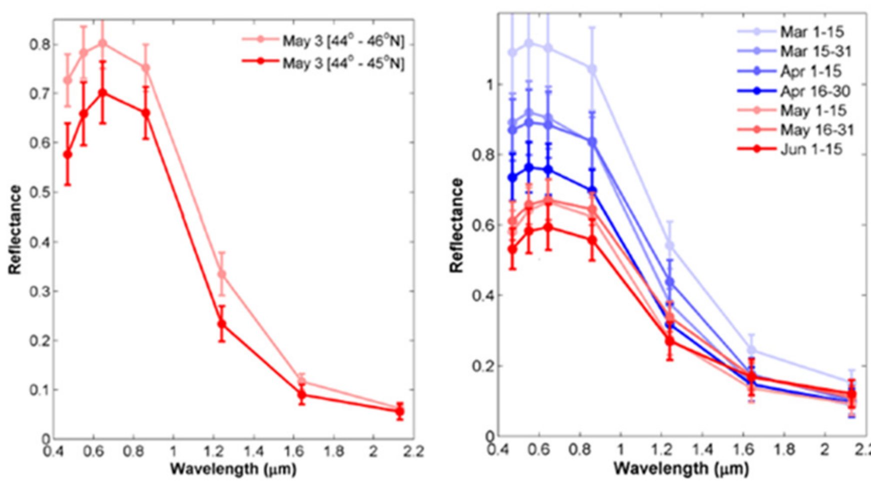
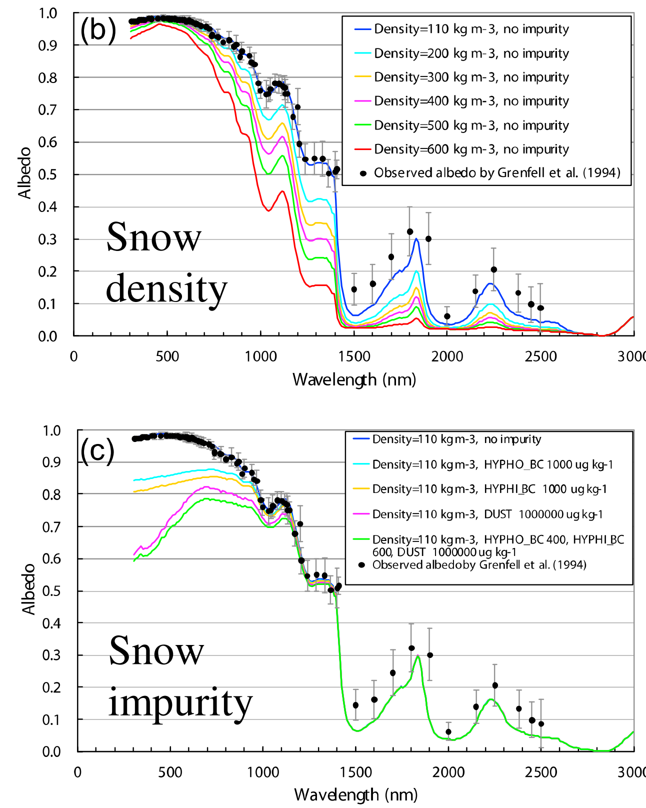
Background:

Snow darkening effect

Deposition of absorbing aerosols on snow surfaces reduces snow-albedo and allows snowpack to absorb more sunlight (Warren and Wiscombe 1980; Hansen and Nazarenko 2004), accelerates snow melting and leads to surface warming in spring (Flanner et al. 2009; Qian et al. 2015).



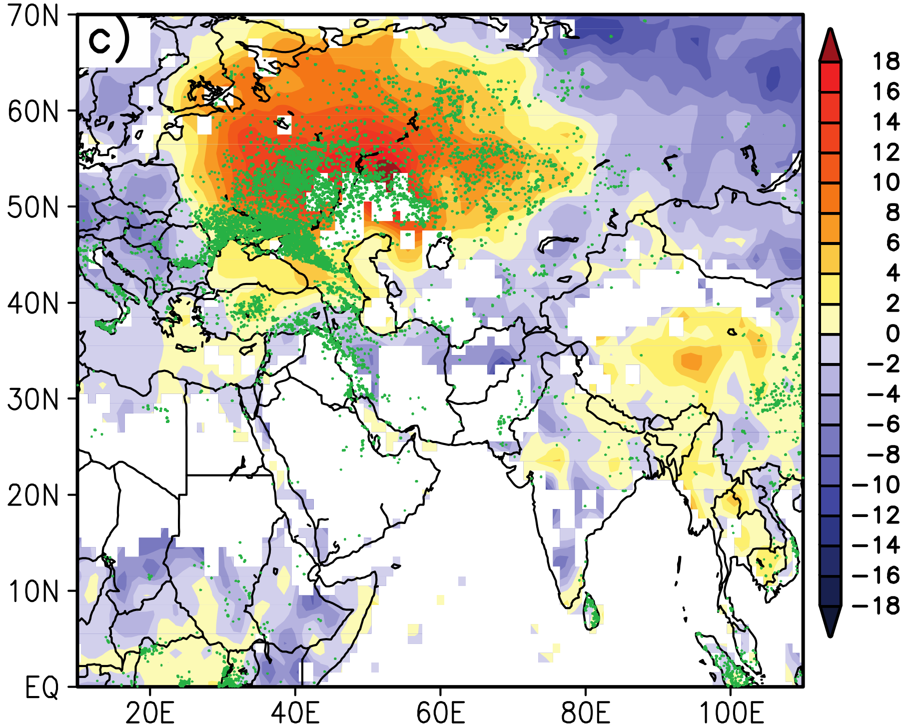
Terra/MODIS image of the dust-laden southern Alps and MODIS spectral surface reflectance. Courtesy of Ritesh Gautum (IIT-Bombay)



Spectral snow albedos changes due to snow density (b) and snow impurity (c) (From Yasunari et al. 2011)

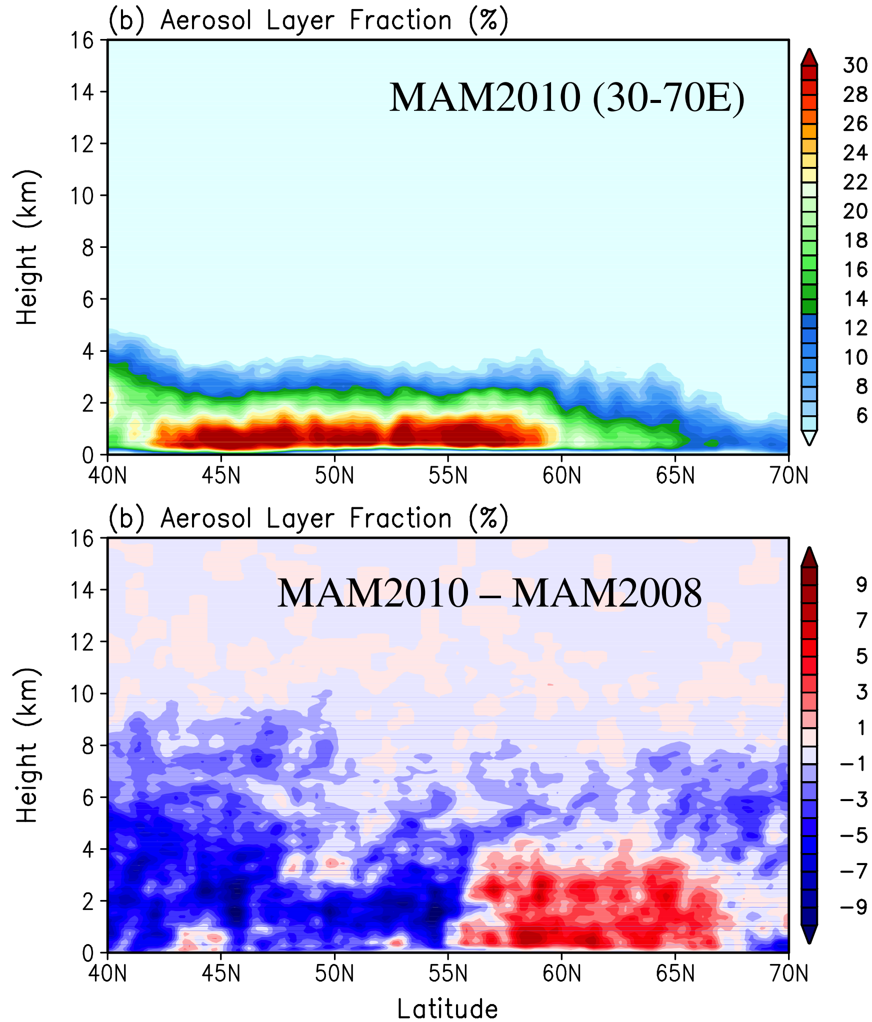
Motivation:

The Russian Heat Waves of 2010



AIRS surface temperature anomaly (shading) and MODIS fire pixel (green dots) for 1 June – 27 August 2010 (From Lau and Kim 2012)

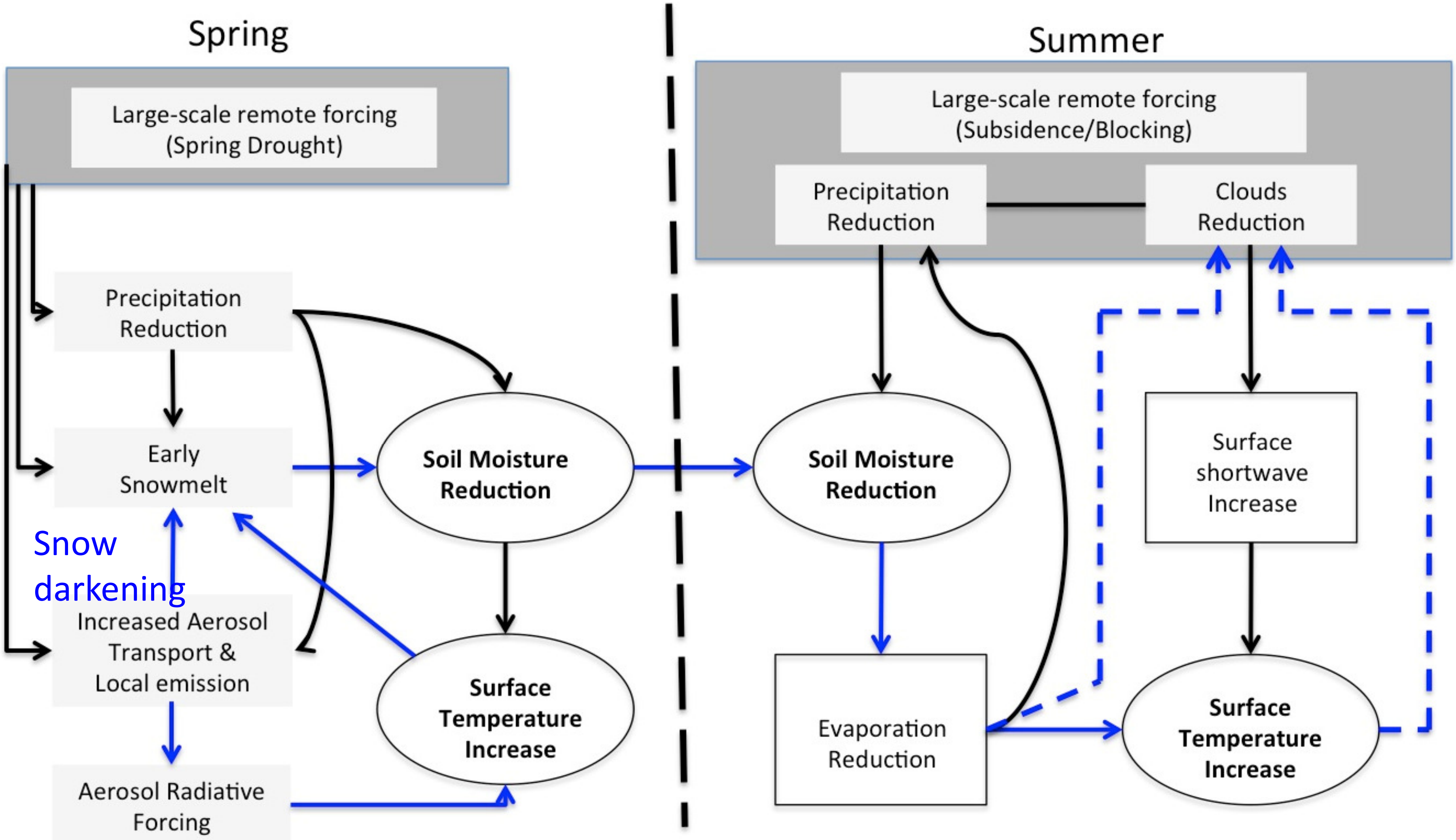
Aerosol layer fraction from CALIPSO



Did spring dryness and associated increase of aerosols provide favorable land surface conditions for the development of a ~~mega~~ heat wave in summer ~~2010~~?

Hypothesis:

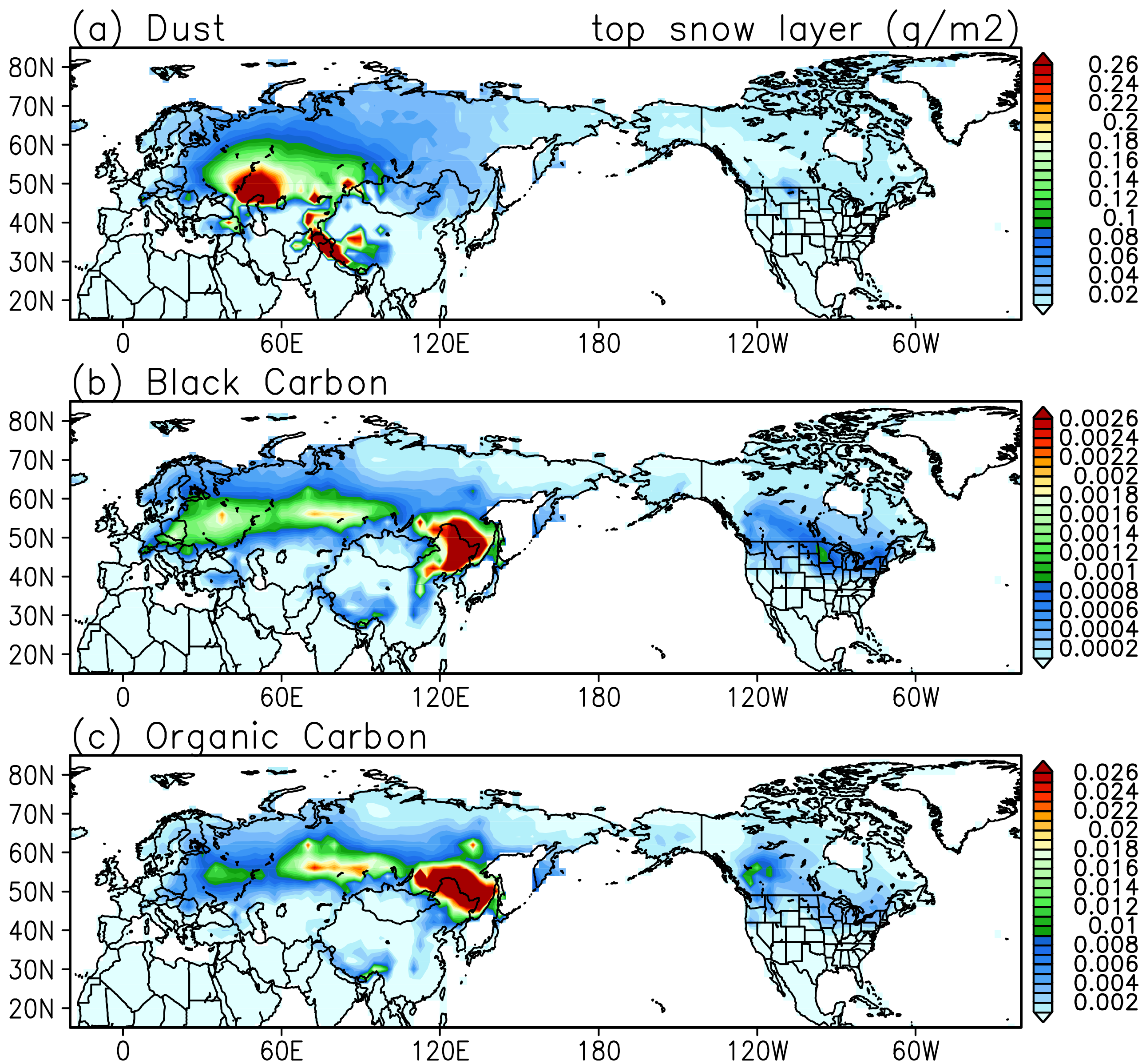
Effect of snow darkening on regional climate



NASA/GEOS-5 GCM Experiments with/without snow darkening effect (SDE)

- Horizontally 2° x2.5° ; vertically 72 layers
- Dust, BC, and OC depositions from GOCART (e.g., Ginoux et al., 2001, *JGR*; Chin et al., 2000, *JGR*, & 2002, *JAS*; Colarco et al., 2010, *JGR*)
- The GOddard SnoW Impurity Module (GOSWIM, Yasunari et al. 2014) is used in the Catchment land surface model (seasonal snowpack only)
- Prescribed observed SST (Reynolds et al., 2002, *J. Clim.*)
- Biofuel and fossil fuel emissions until 2006 based on the emission dataset (A2-MAP-v1; Diehl et al., 2012, *ACPD*; data in 2006 used after 2006). Biomass burning emissions based on the Quick Fire Emission Data set (QFED; Petrenko et al., 2012, *JGR*, and Darmenov and da Silva, *NASA Tech. Rep. Ser. GMDA, in preparation*)
- 10 member, 10-year simulations with and without SDE.

Masses of Dust/BC/OC in the top snow layer (MAM)



Dust

Black Carbon

Organic Carbon

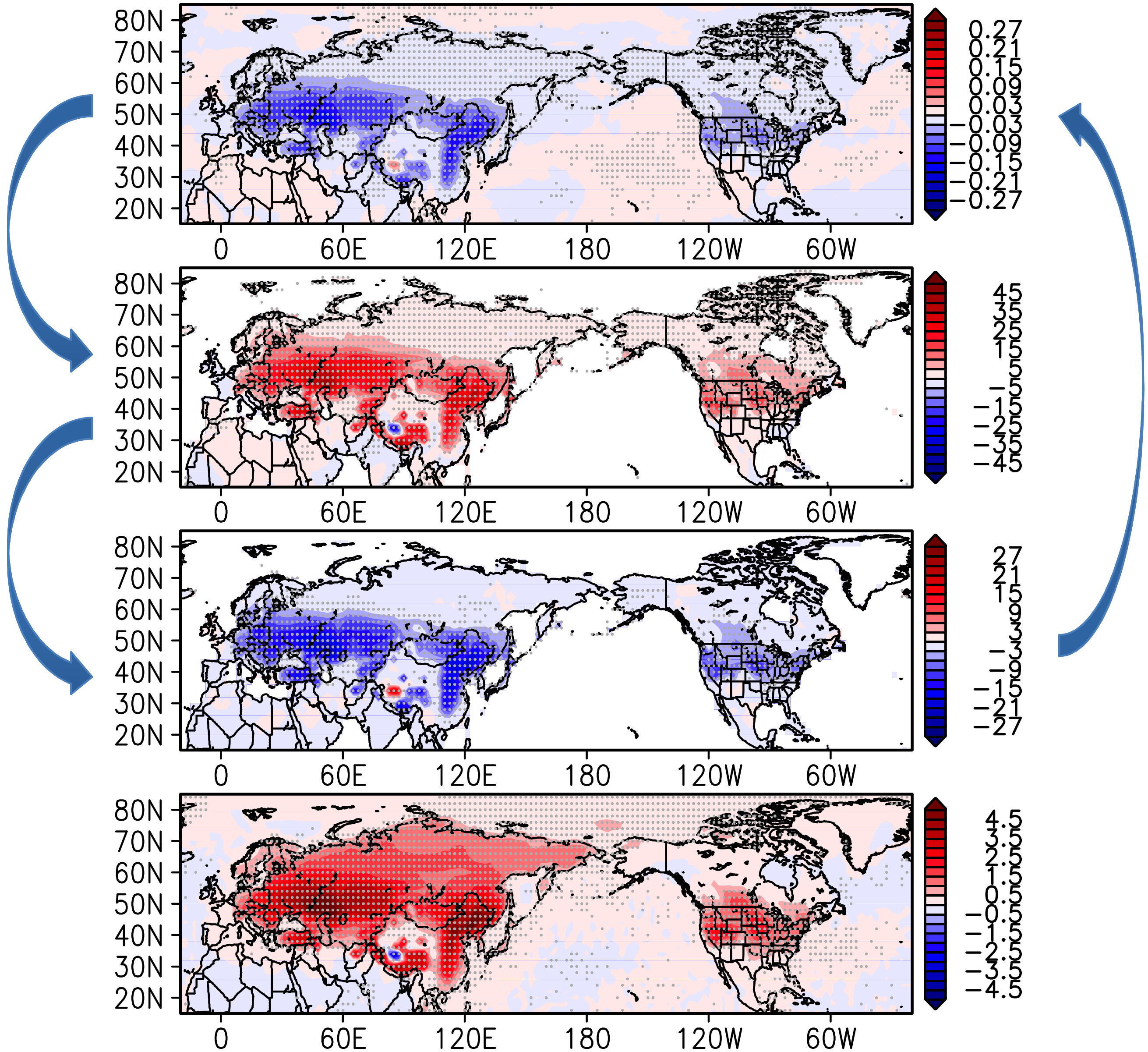
Simulated Snow-Darkening Effect (MAM)

Surface Albedo

Net downward SW flux at SFC (W/m2)

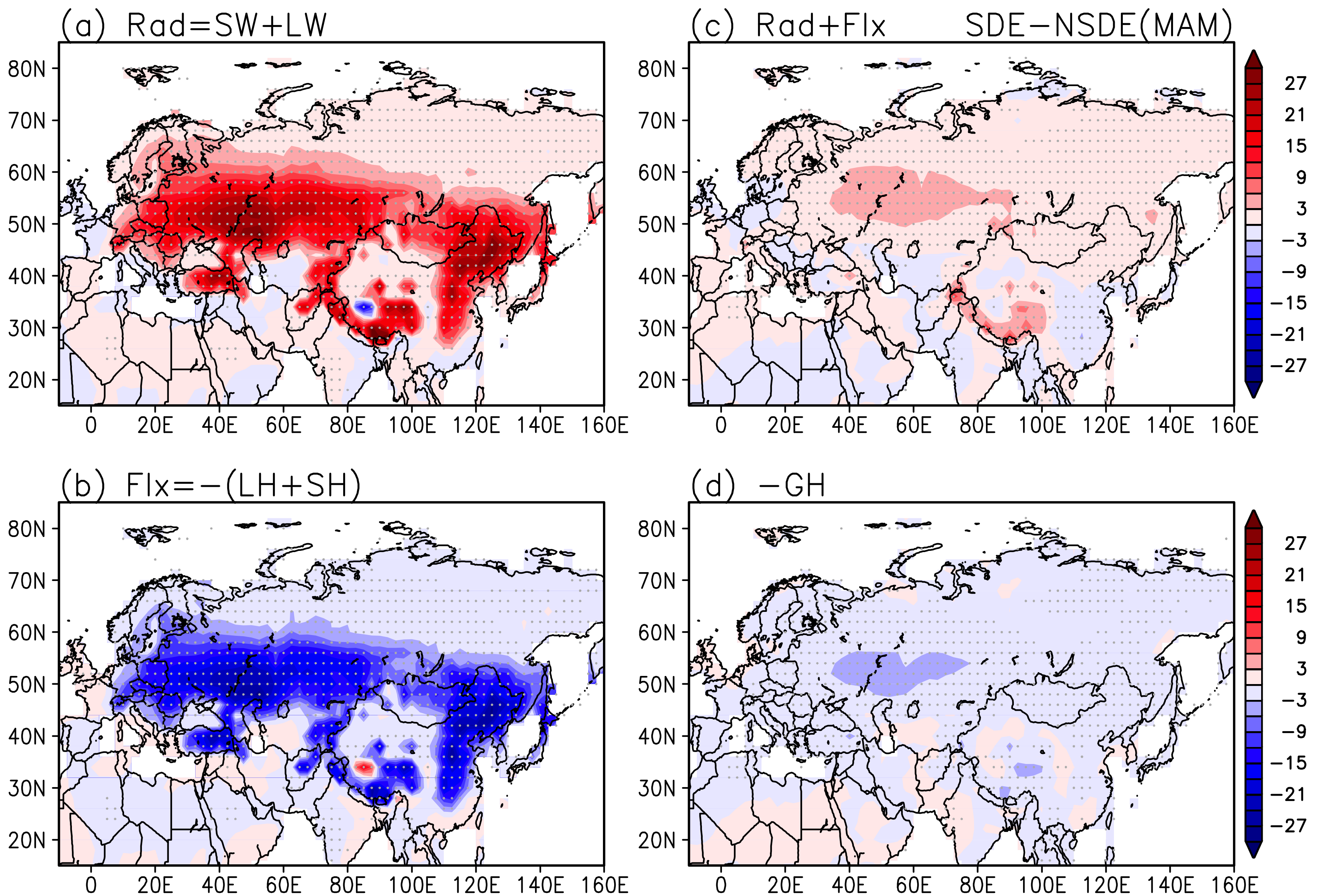
Snow cover (%)

Surface Temperature (K)

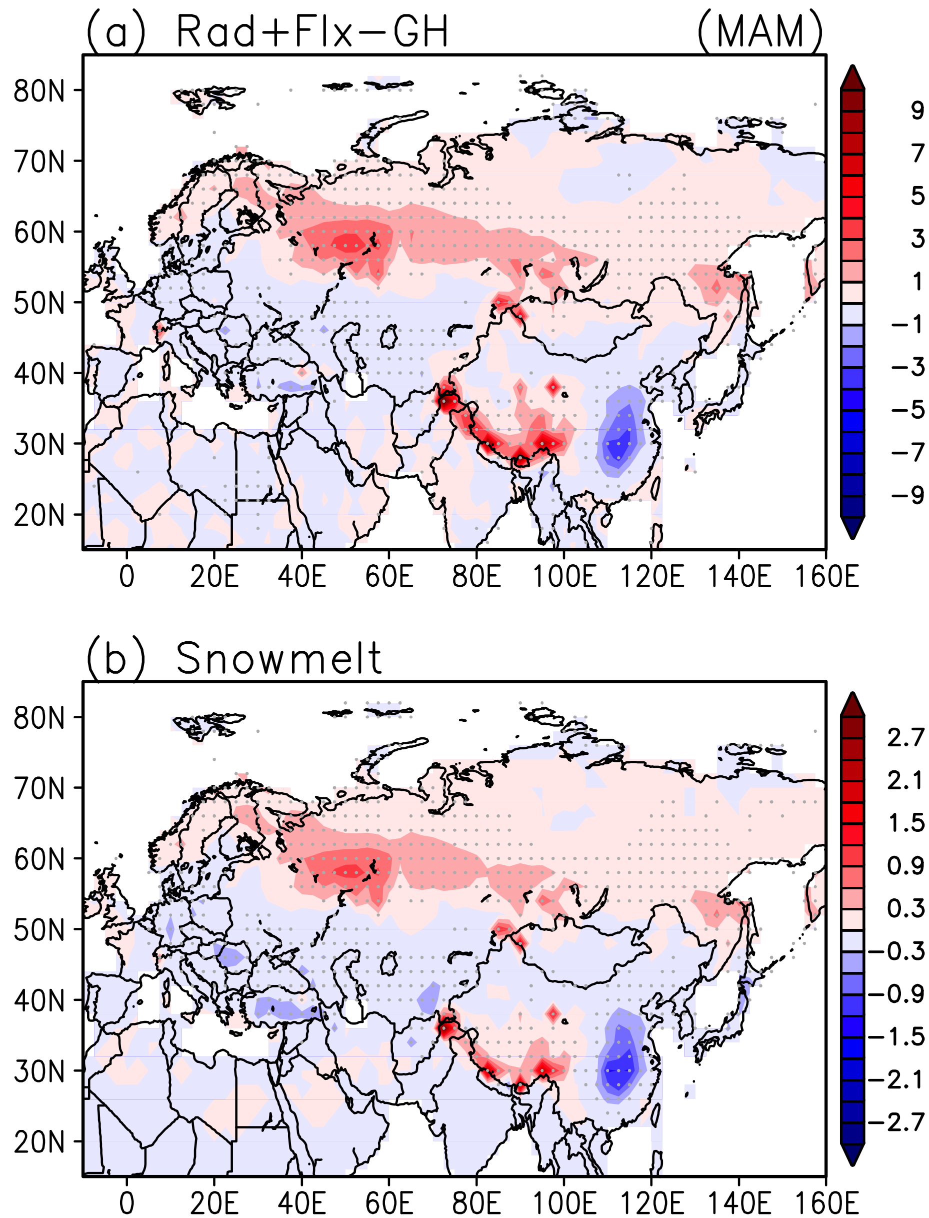


Yasunari et al.(2015) Reproduced.

Surface Energy Budget (MAM)



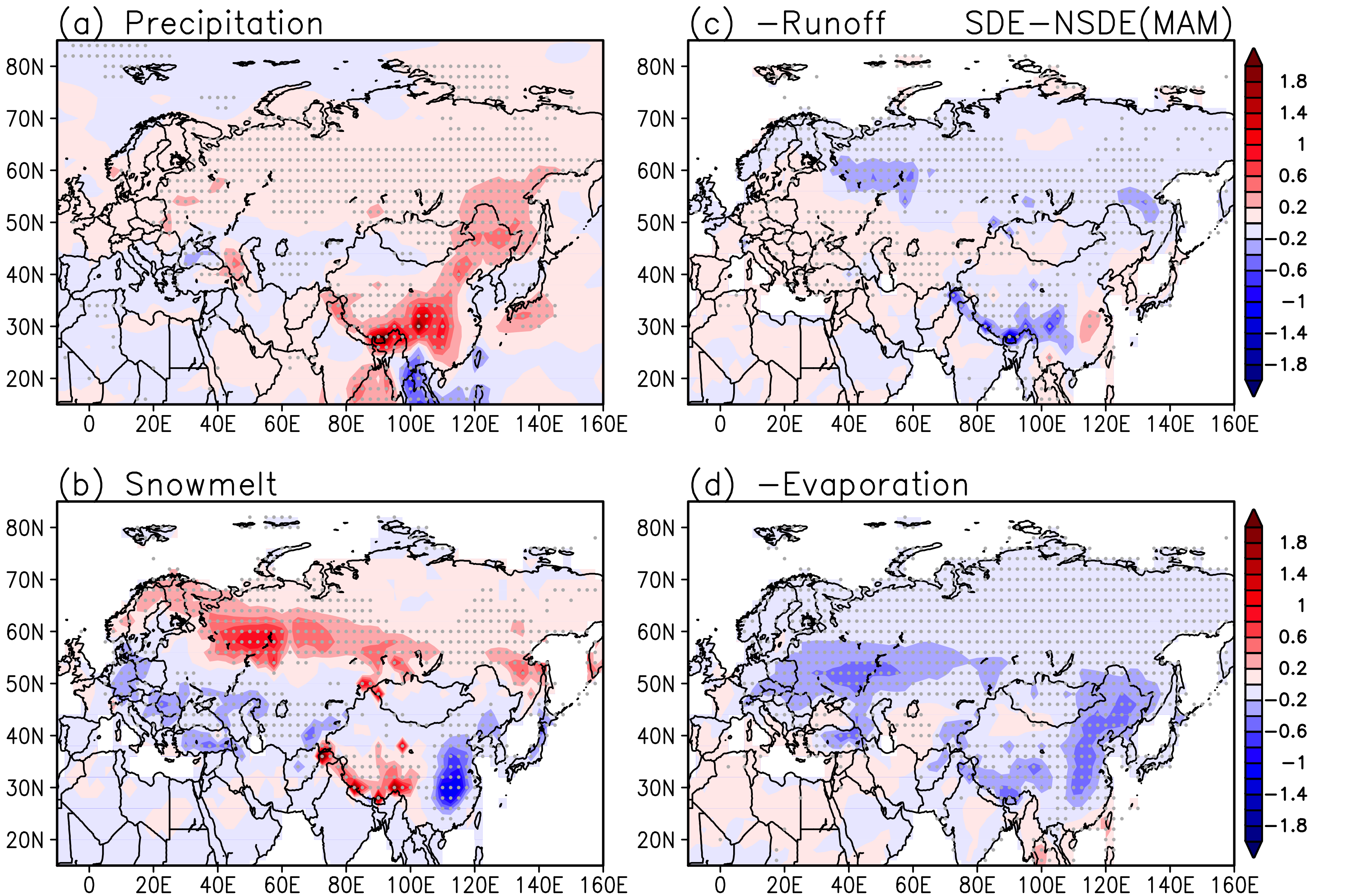
Surface Energy Budget and Snow Melting (MAM)



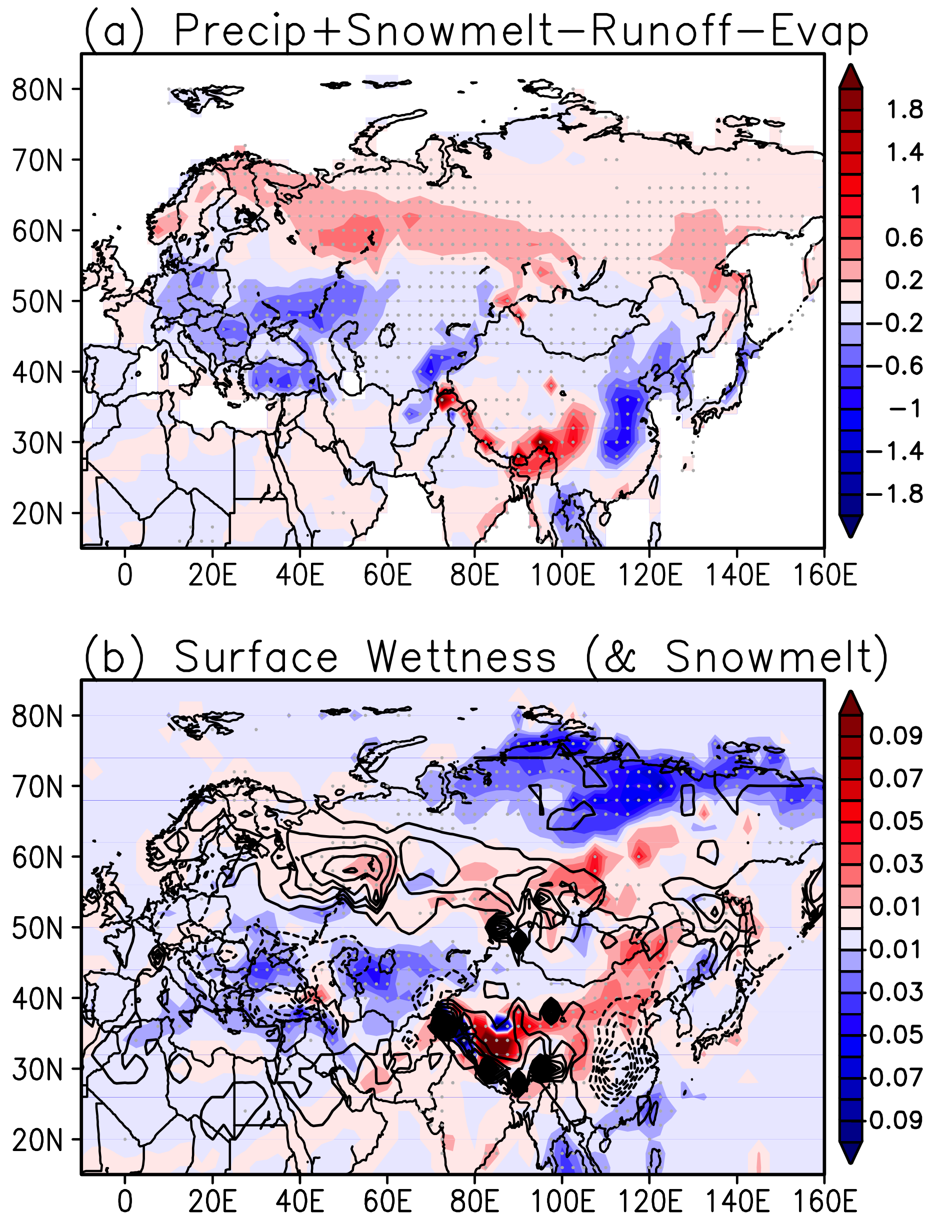
Net energy at surface (W/m2)

Snow melt flux (mm/day)

Surface Water Budget (MAM)



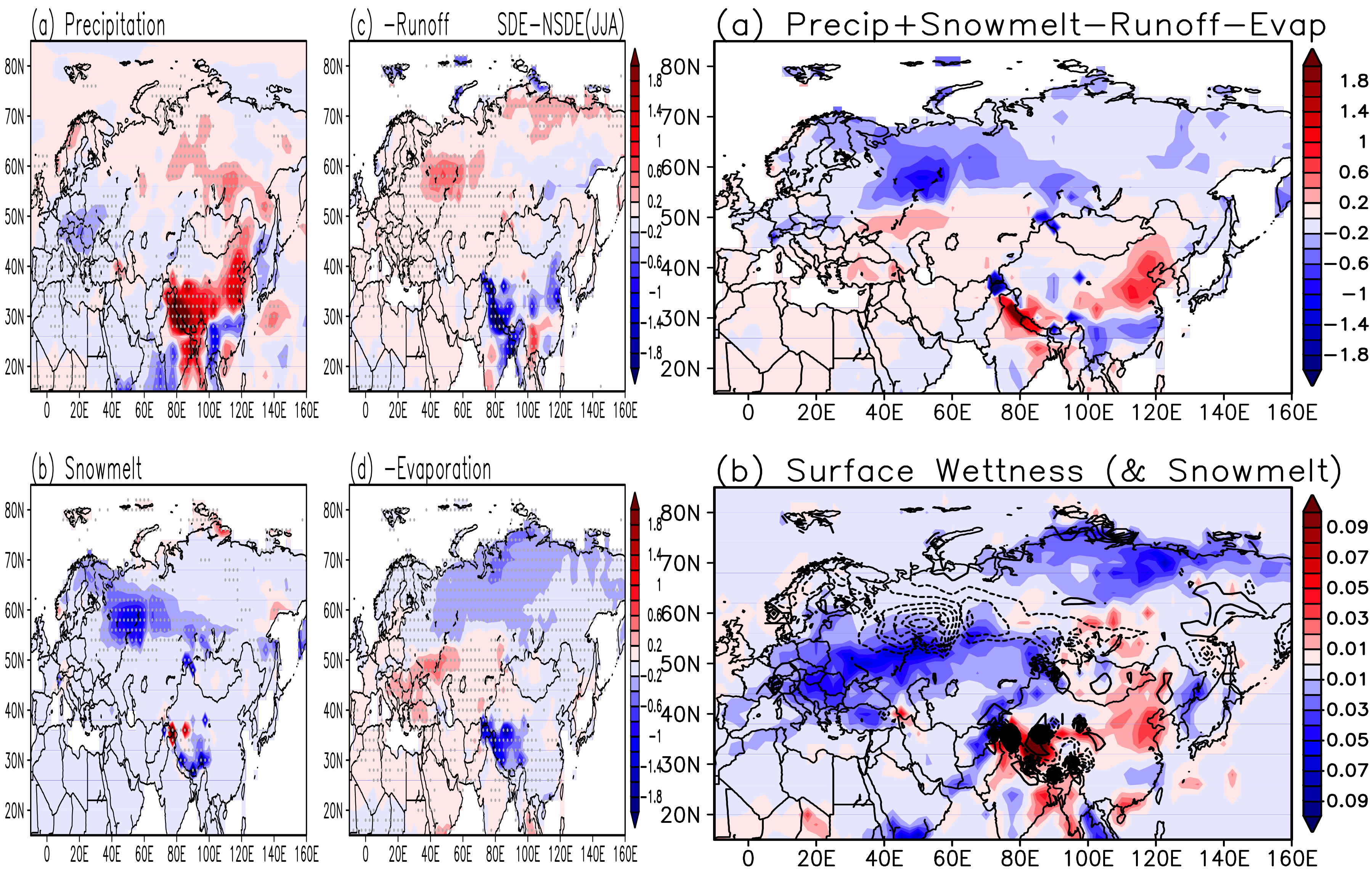
Surface Water Budget and Surface Wetness (MAM)



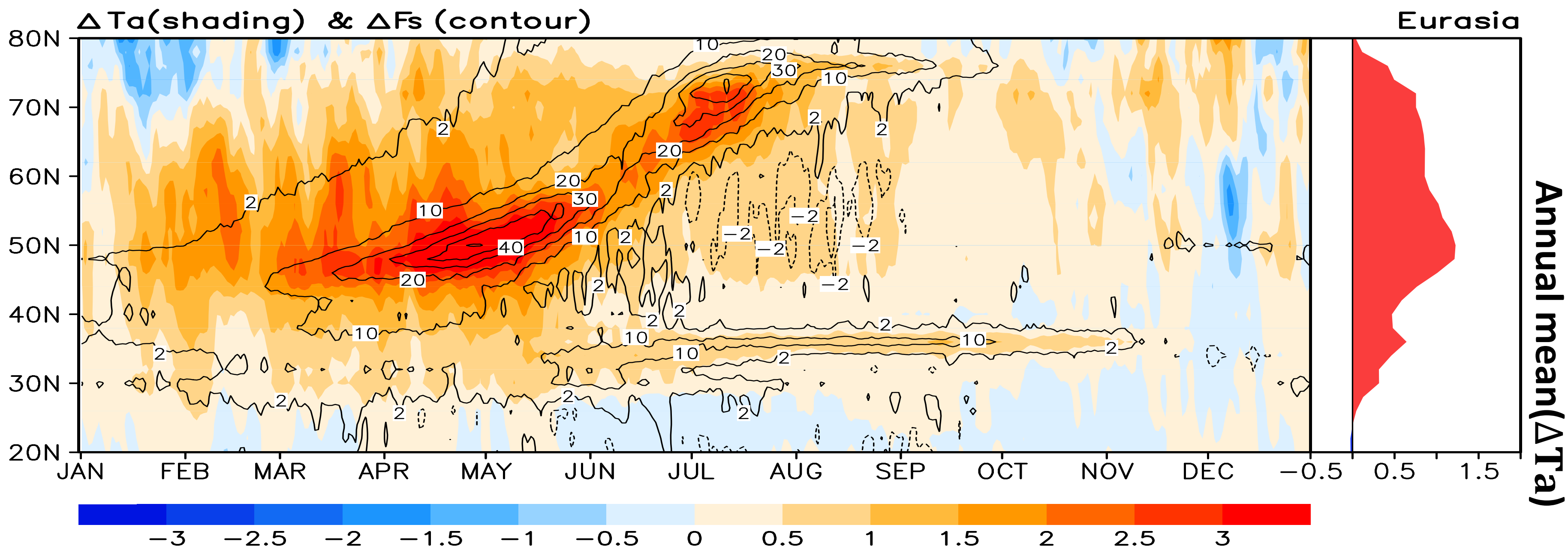
Net water budget at surface (mm/day)

Surface Wetness (shading) & snow melt flux (contour)

Surface Water Budget and Surface Wetness (JJA)



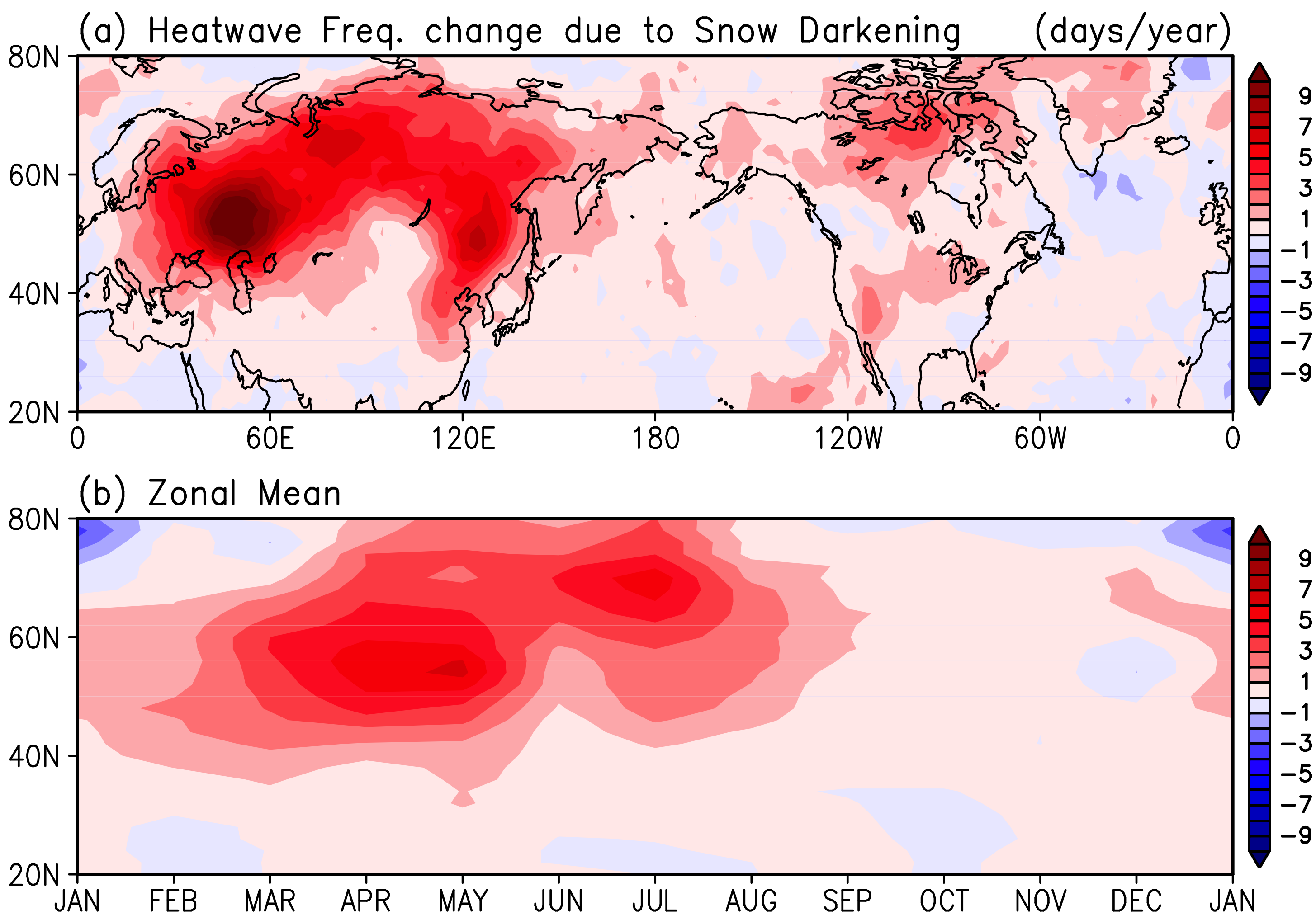
Surface air temperature (shading) & Net SW flux (contour) change due to snow darkening



(℃)

Snow darkening effect on the occurrence of heat waves

Definition of heat waves (Stefanon et al. 2012)



Early snowmelt leads to drier land surface that favors more frequent occurrence of heatwaves.

Summary

Impacts of snow darkening by absorbing aerosols are examined based on two sets of 10 member 10-year simulations of NASA/GEOS-5 model coupled with a snow darkening module, GOddard SnoW Impurity Module (GOSWIM, Yasunari et al. 2014).

Reduced snow albedo increase shortwave downward flux and accelerate snow melting during boreal spring

Early snowmelt leads to drier land surface that favors more frequent occurrence of heat waves.