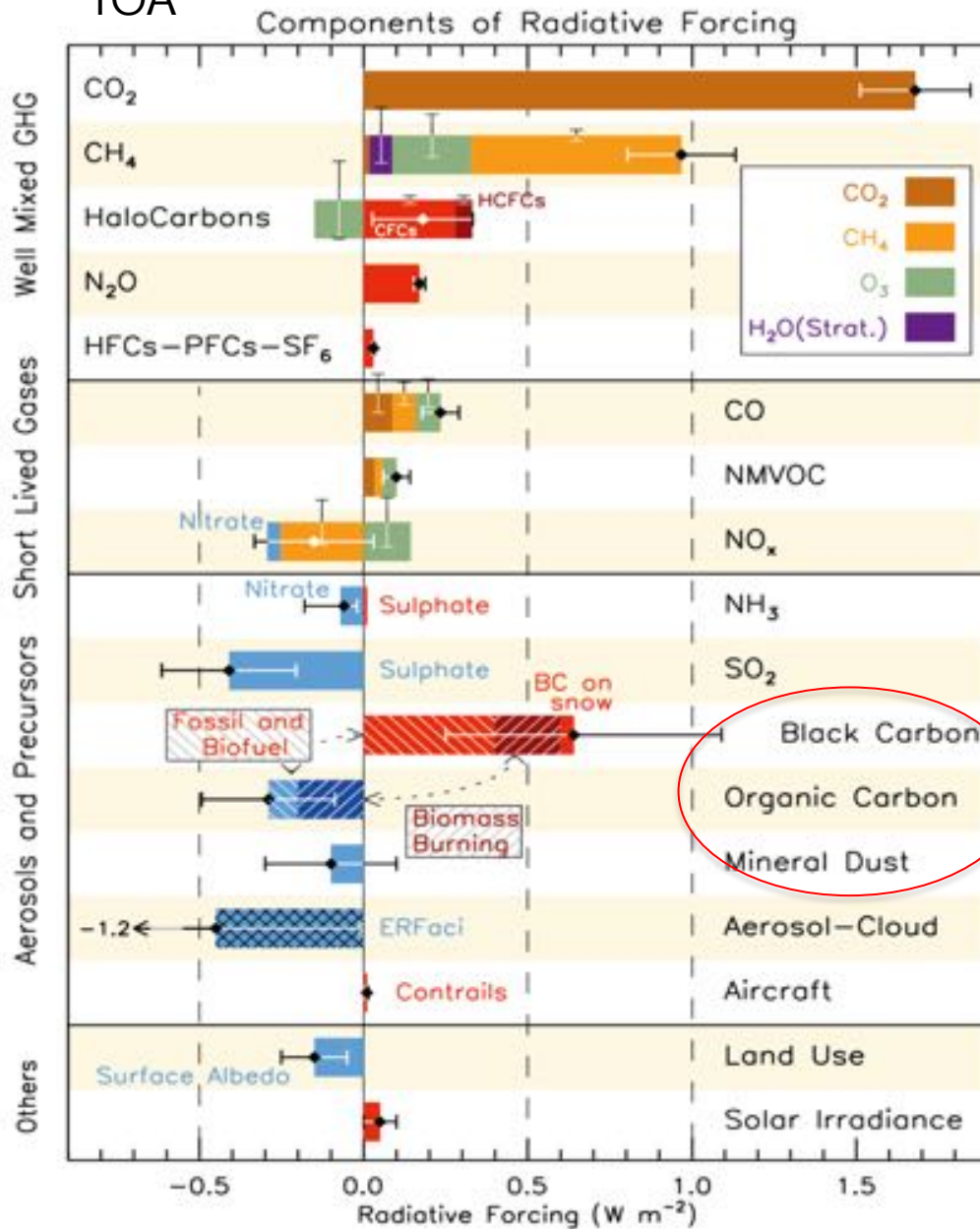


Impacts of aerosol snow-darkening effects on Eurasian hydroclimate and heat waves

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K. M. Kim/GSFC, R. Koster/GSFC,
T. J. Yasunari?Hokkaido U.

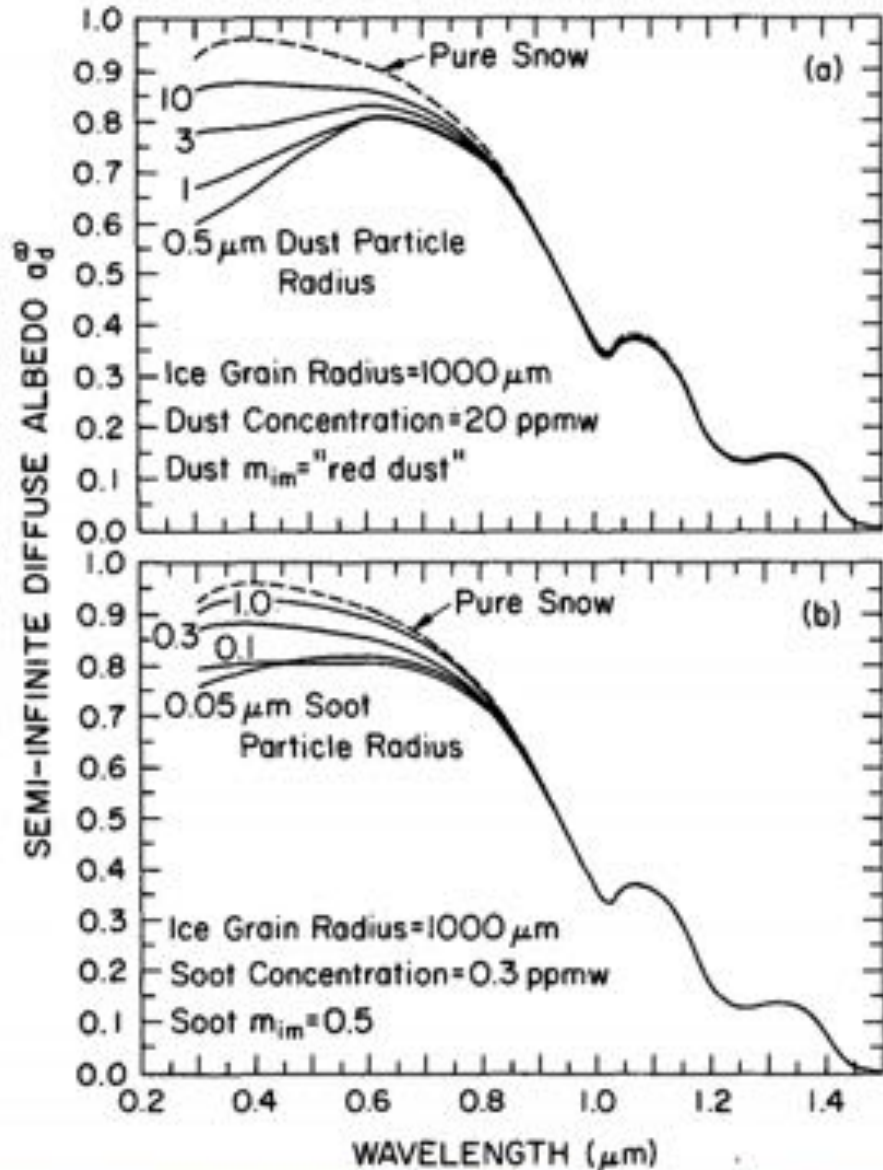
TOA



- Aerosol-Cloud-Climate (ACC) feedback is important for global and regional climate change
- ACC feedback processes involve both anthropogenic and natural aerosols
- Globally, natural aerosols are 6- 10 times more plentiful than anthropogenic aerosols
- Absorbing aerosols (BC, OC and mineral dusts) amplify atmospheric heating
- Snow-darkening by absorbing accelerate snowmelt, amplify global warming by snow-surface albedo feedback

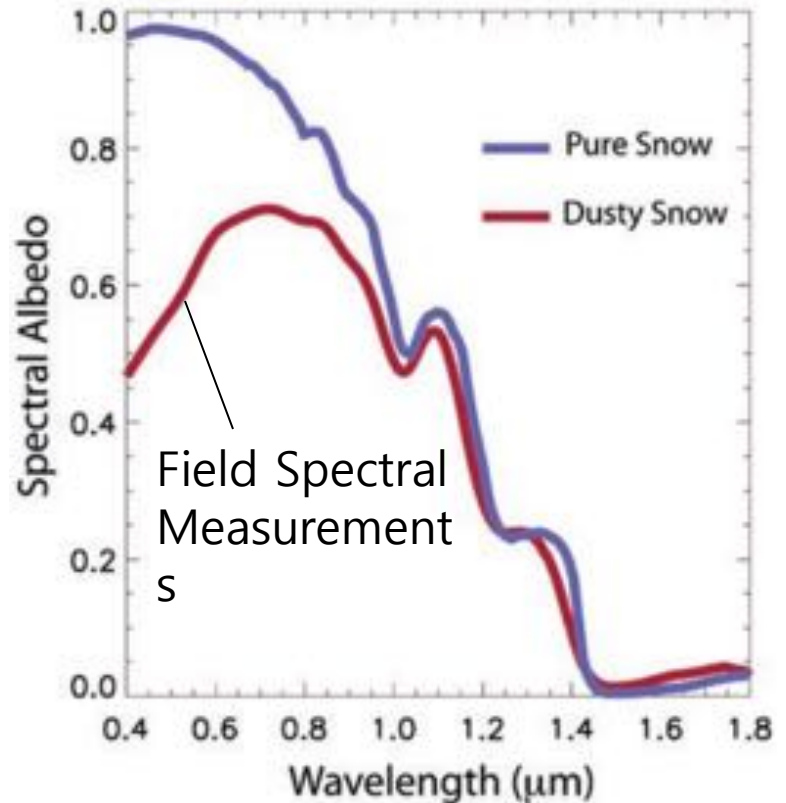
Snow Darkening Effect

Warren and Wiscombe, 1980



Dust and black carbon effectively reduce snow albedo in the visible wavelengths

Painter et al., 2009

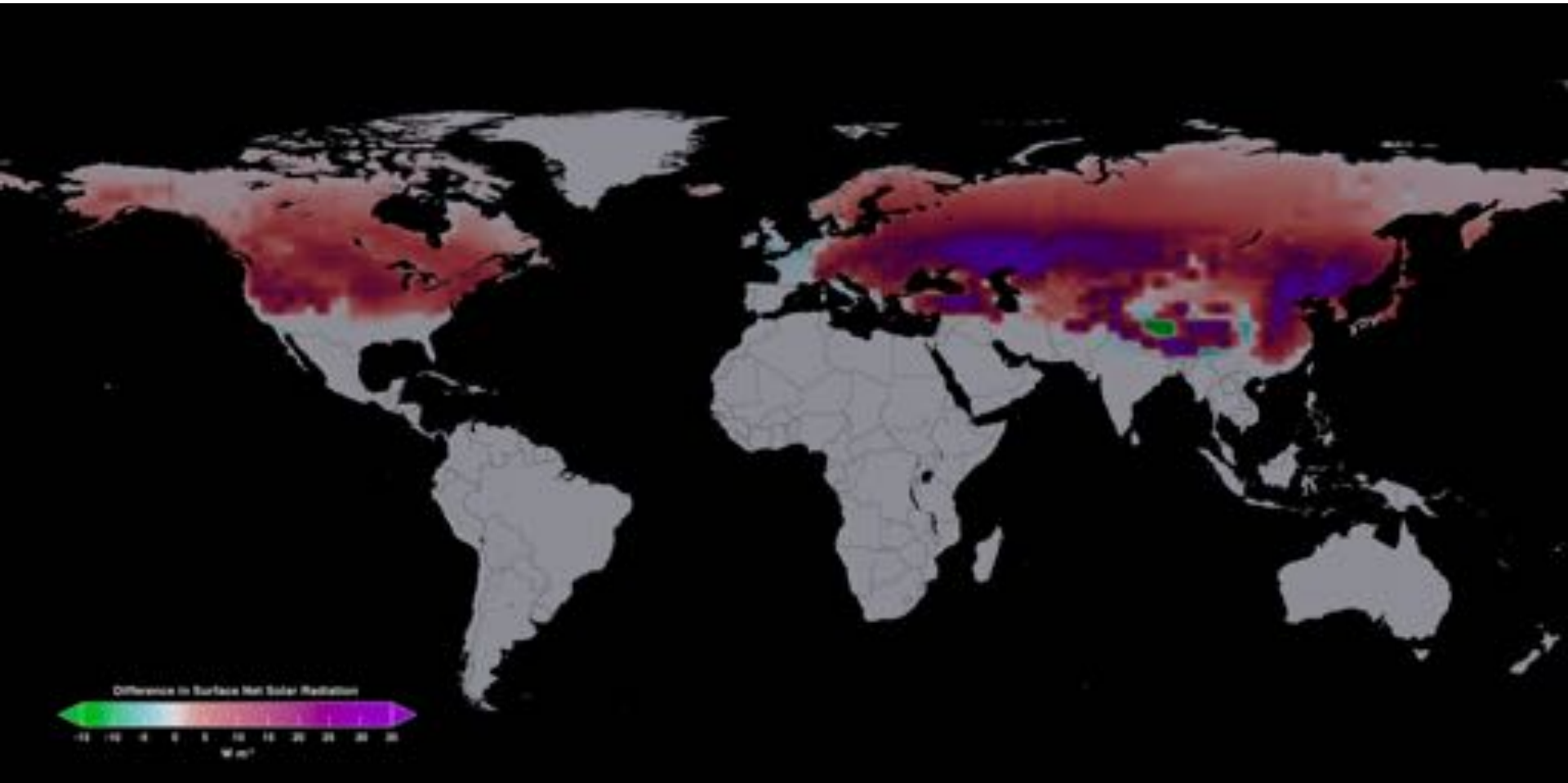


GEOS5 model with a new snow-darkening GOddard SnoW IMpurity (GOSWIM) module

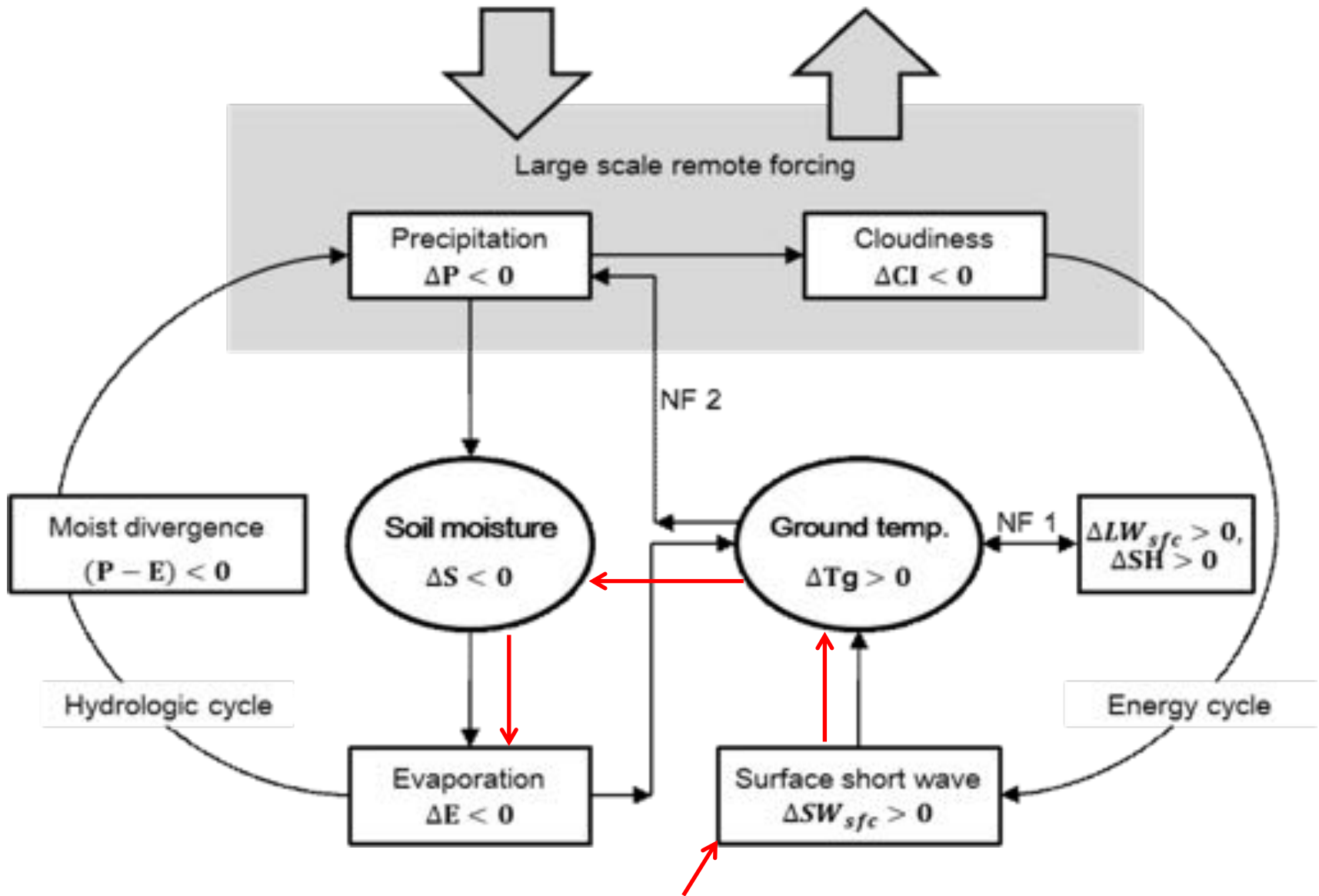
Model	Period	ENS	Experiment	
NASA- GEOS_5	2002.01.01 ~2011.12.31 (10 years)	ENS_MEAN (10 members)	SDE	with snow darkening effect
			NSDE	without snow darkening effect

Snow impurities include dust, BC, and OC (natural + anthropogenic)

Snow-Darkening Effect (SDE): reduced snow albedo by deposition of absorbing aerosols (dust, BC, OC) leads to increased in net surface solar radiation, during the boreal summer melting season (MAM)



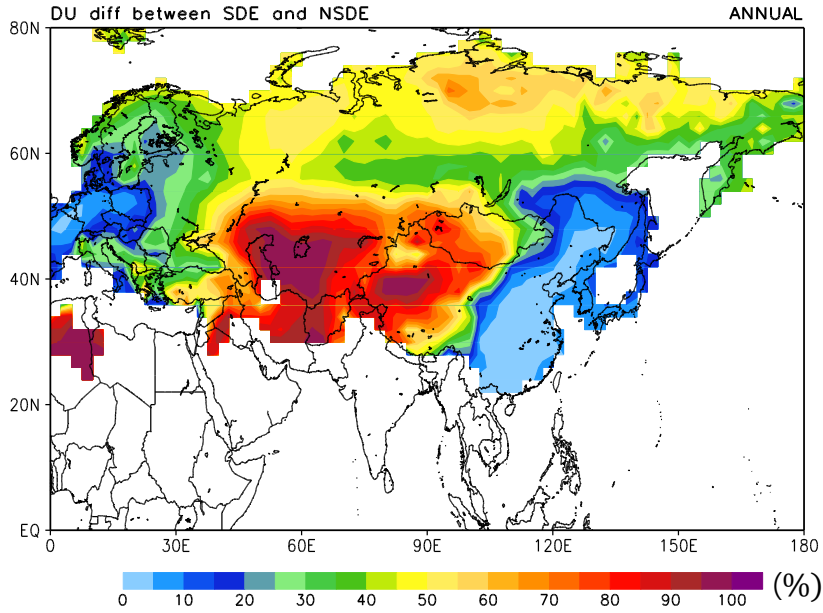
Land-atmosphere coupling



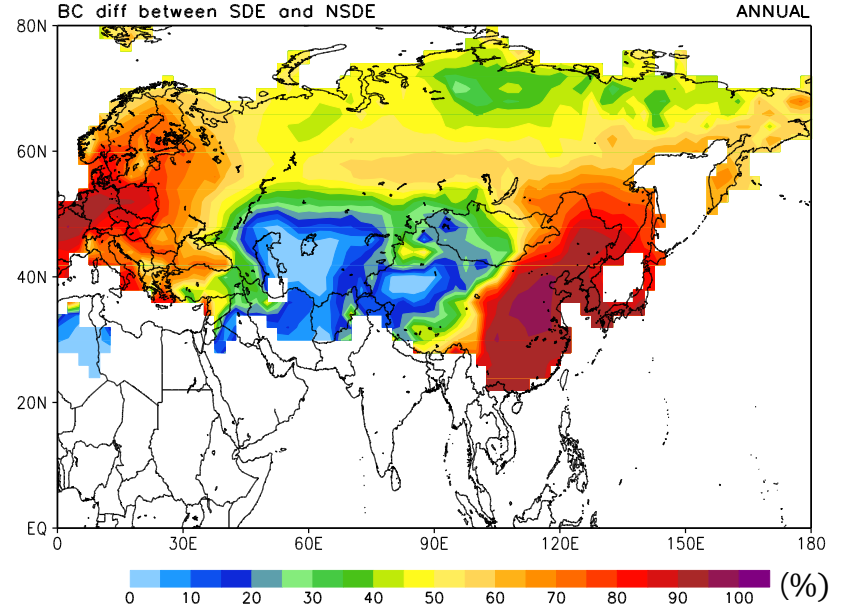
Snow Darkening Effect

Lau and Bua (1998)

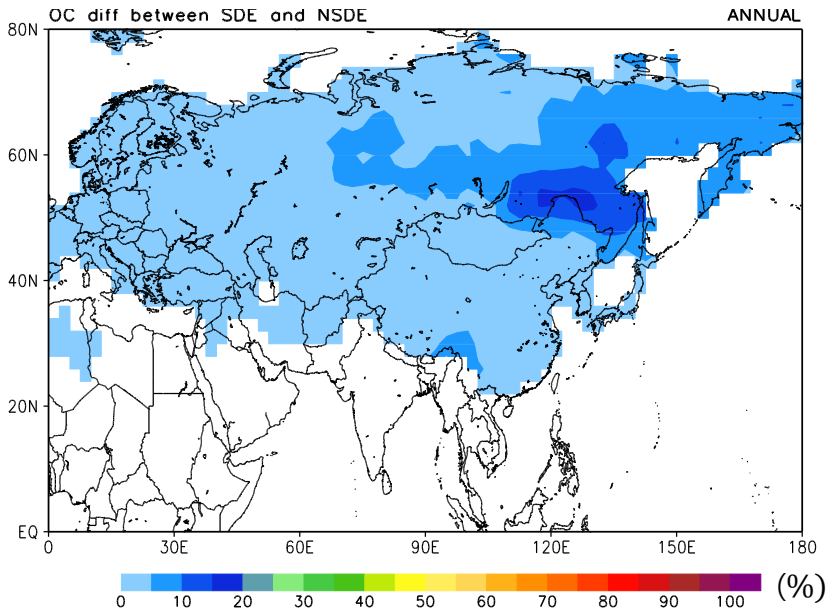
Dust



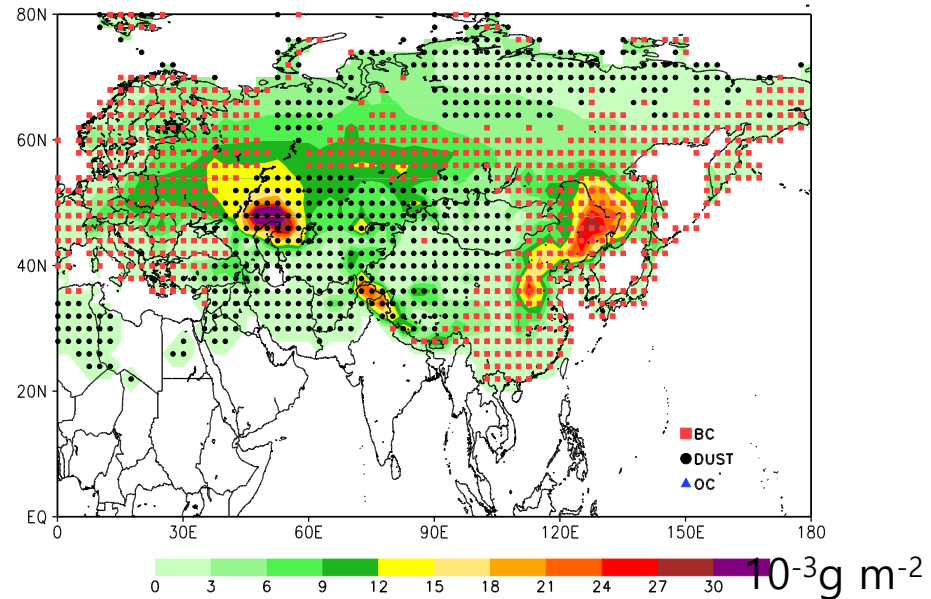
BC



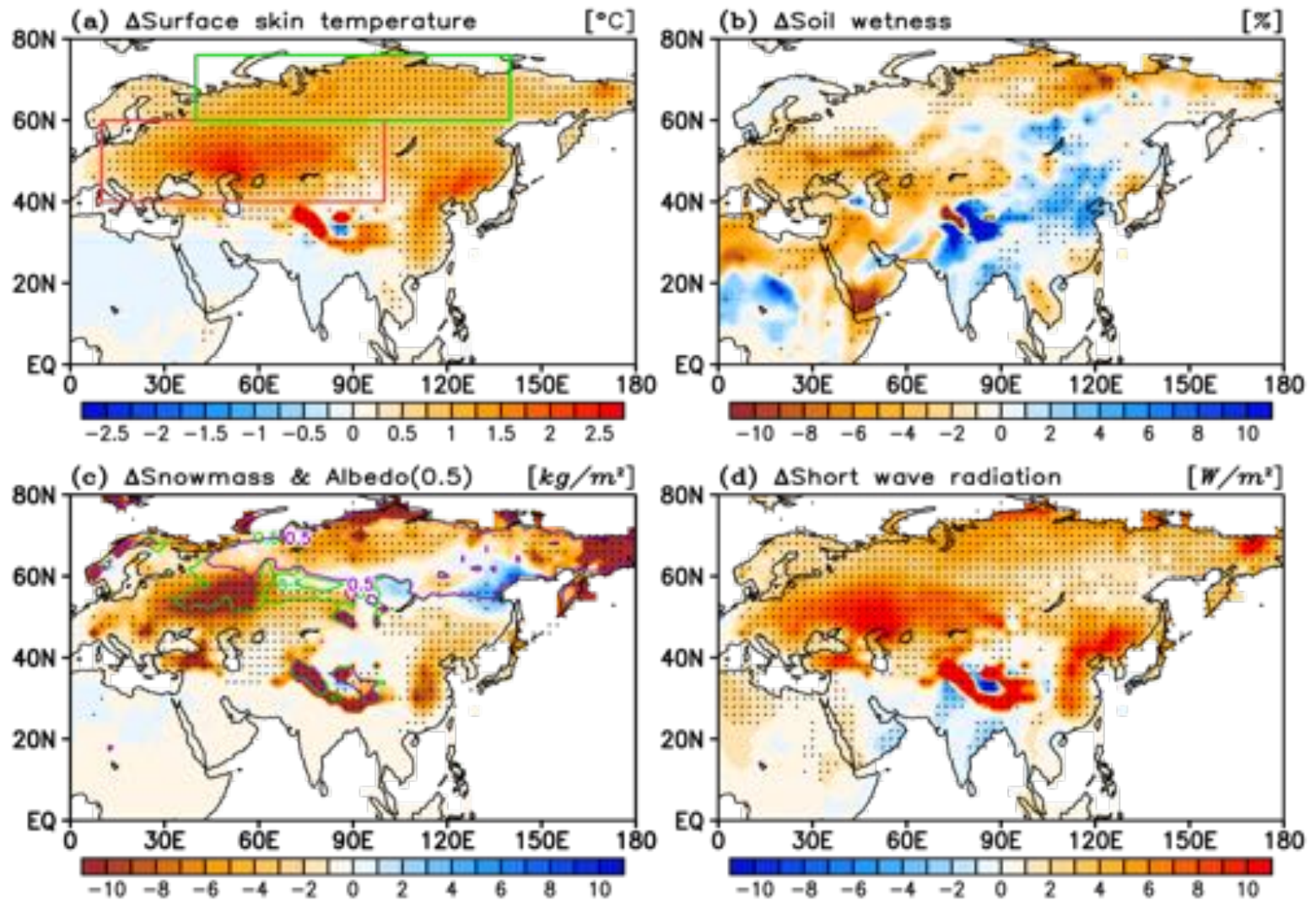
OC



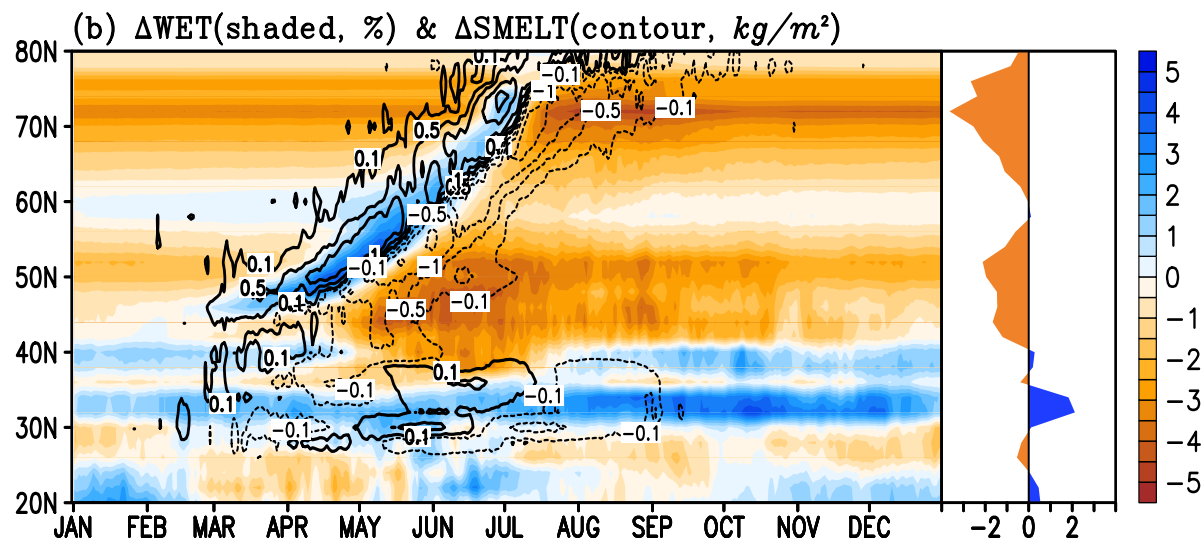
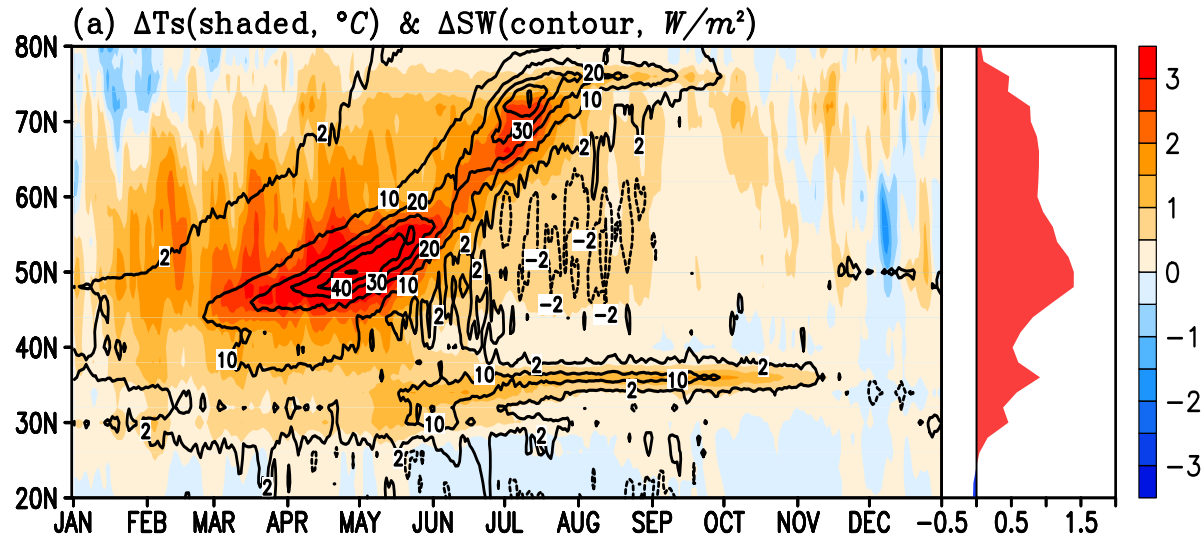
Total snow impurity absorption efficiency



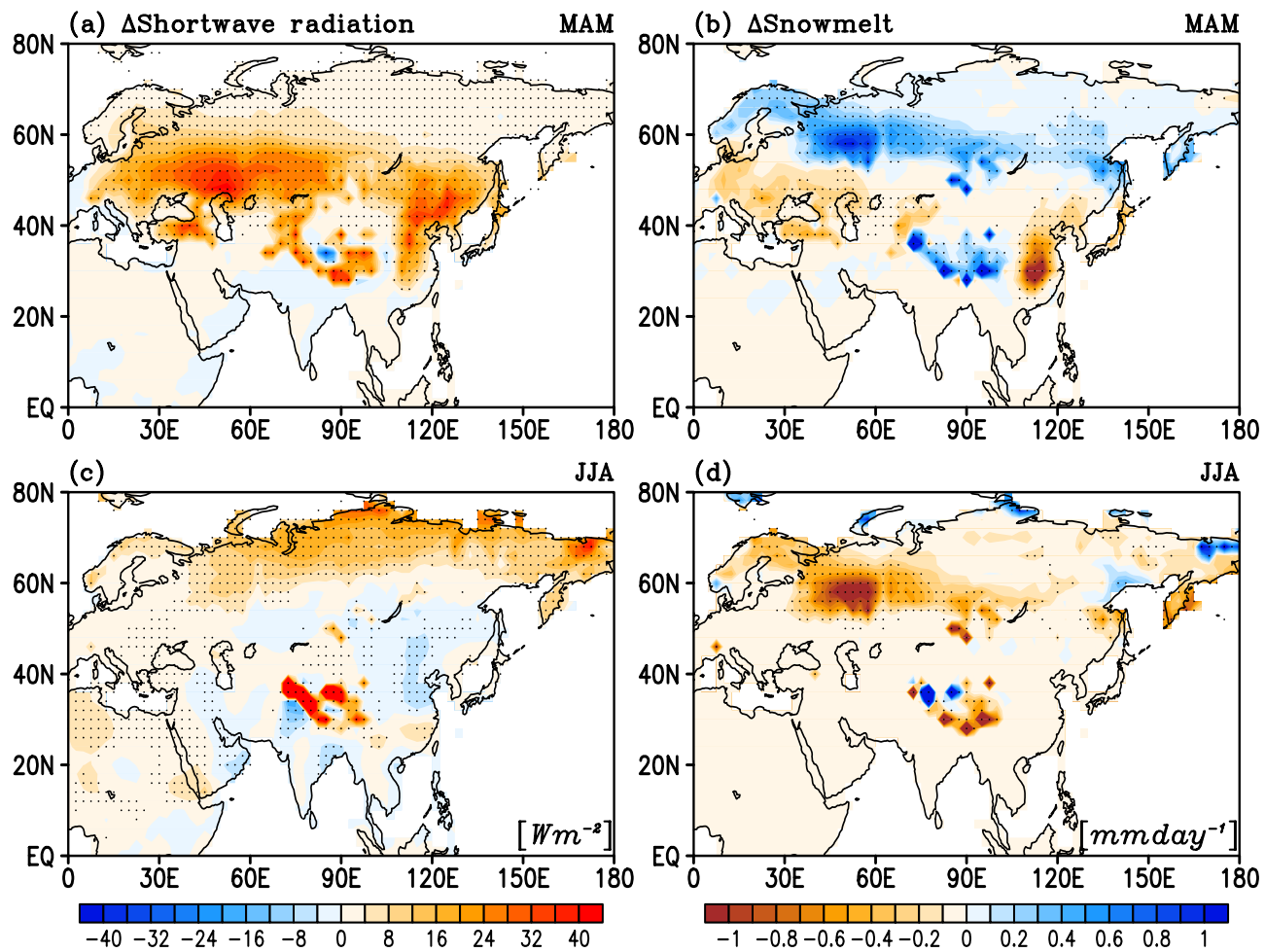
SDE induced annual mean climate change

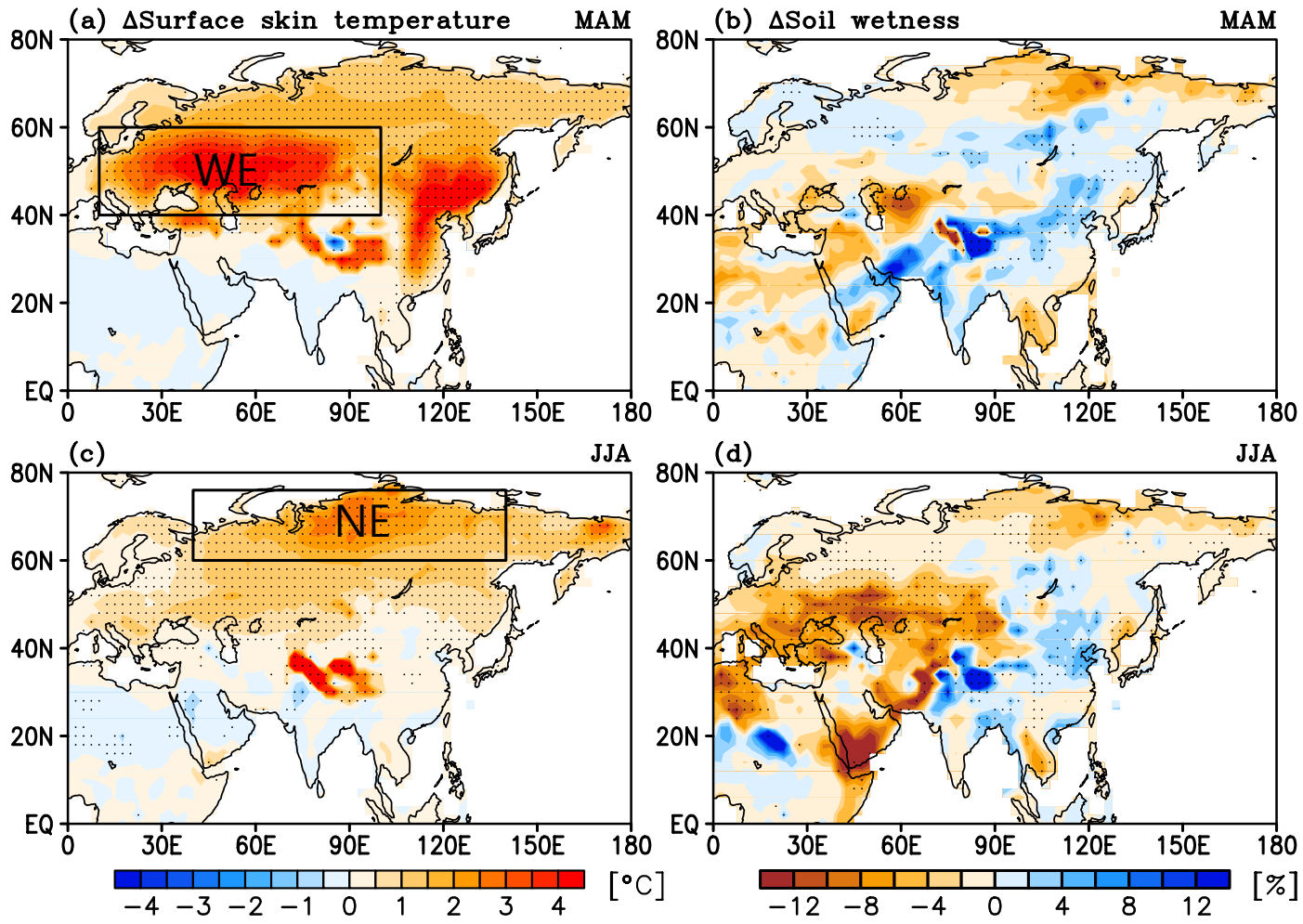


Accelerated snowmelt, warming, soil wetting and drying following the seasonal migration of the snowline over Eurasian land (0-150 E).

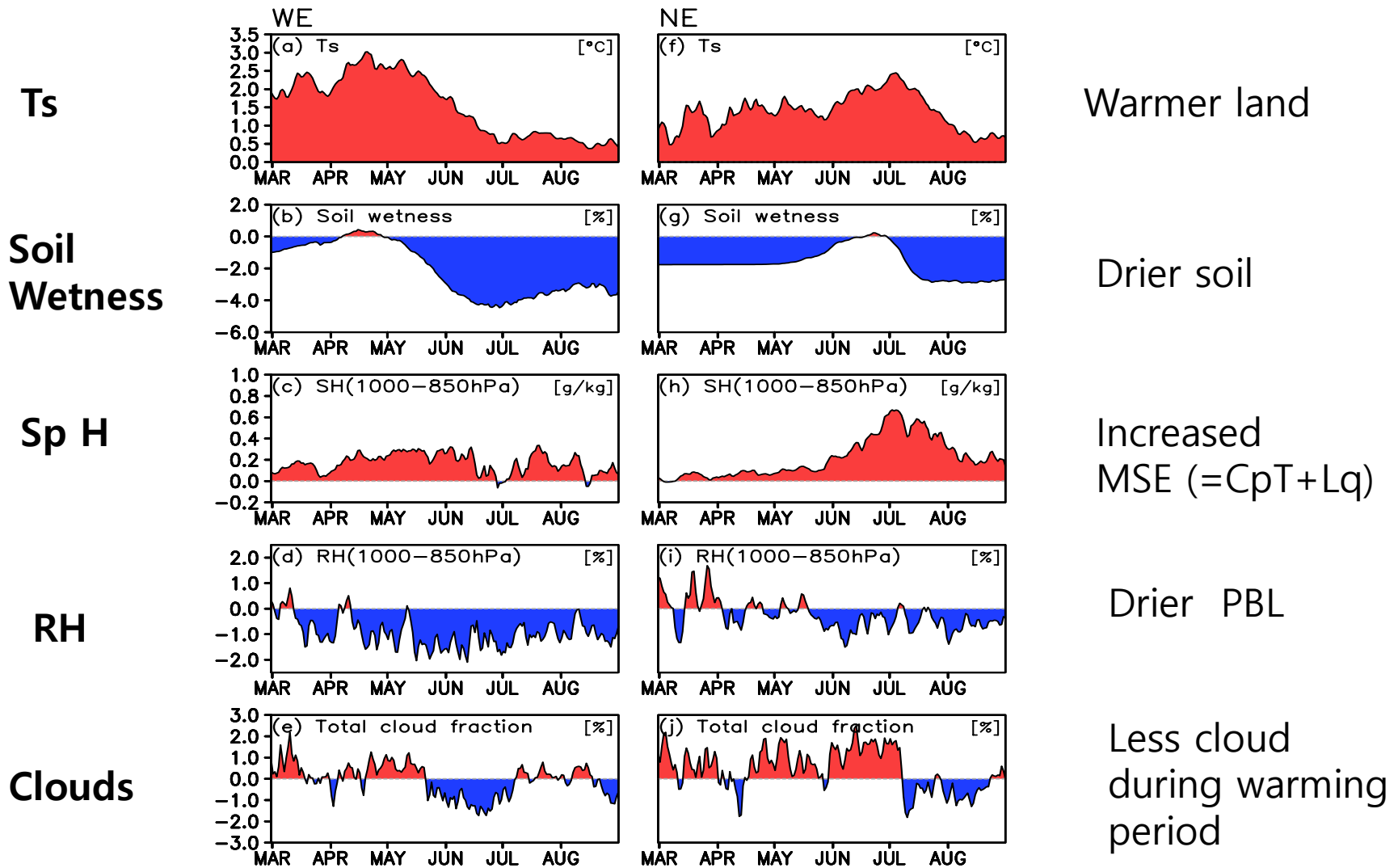


Wet-First
Dry-Later
(WFDL)





SDE induced hydroclimate anomalies



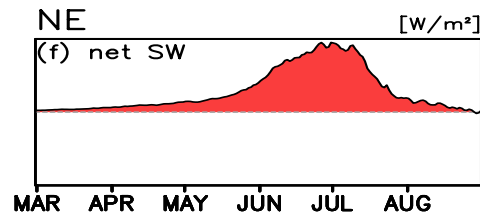
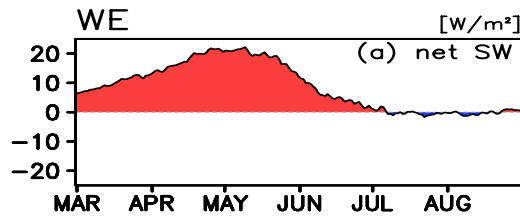
$$\delta RH = \delta q / q_s - \alpha R_h \delta T$$

$$\alpha = L(R_v T^2)^{-1} \sim 6\% K^{-1}$$

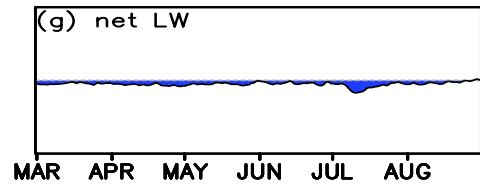
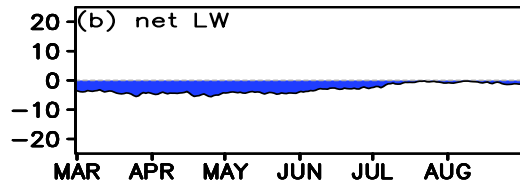
CC relationship,

Land surface energy balance

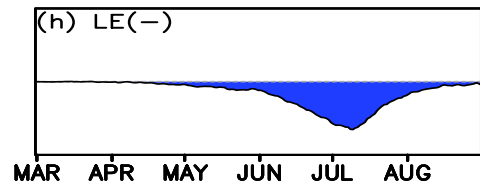
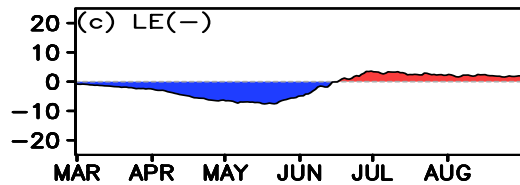
SW



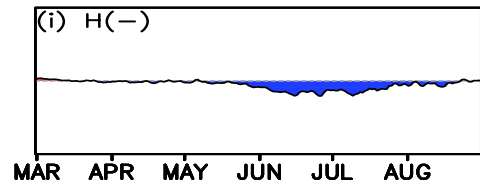
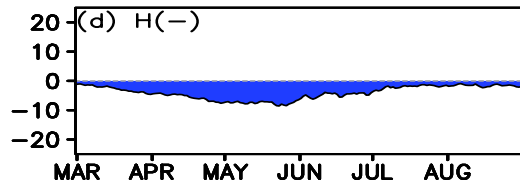
LW



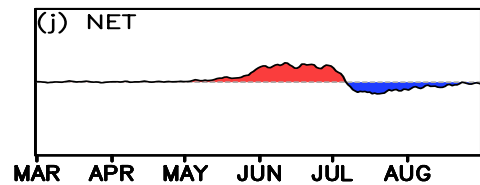
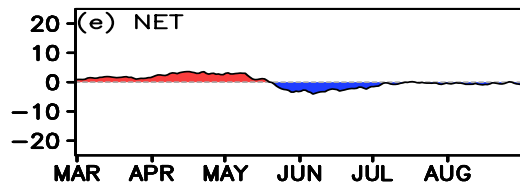
LE



H



Net

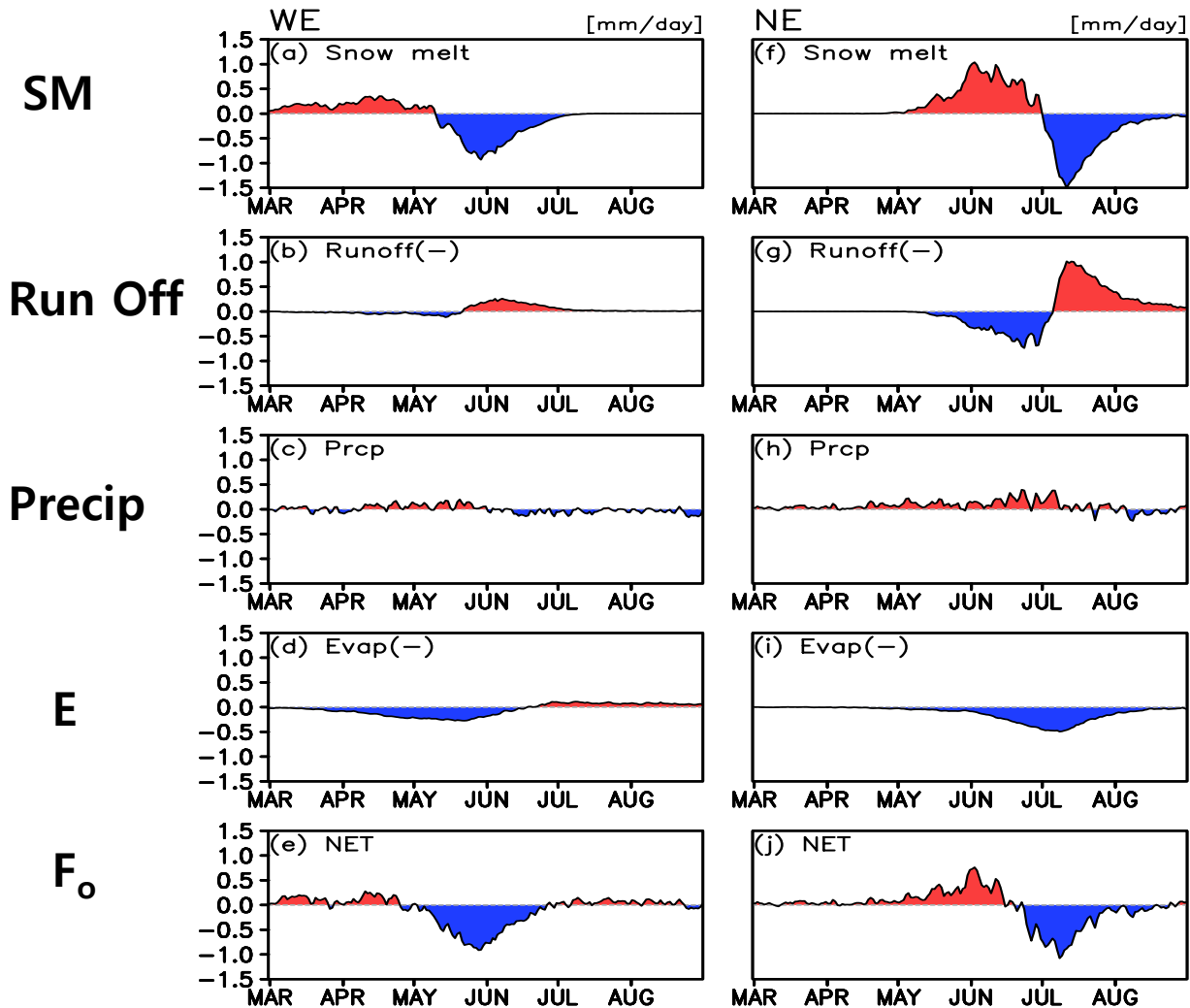


Land gain
Land lost

Land Surface Water Balance:

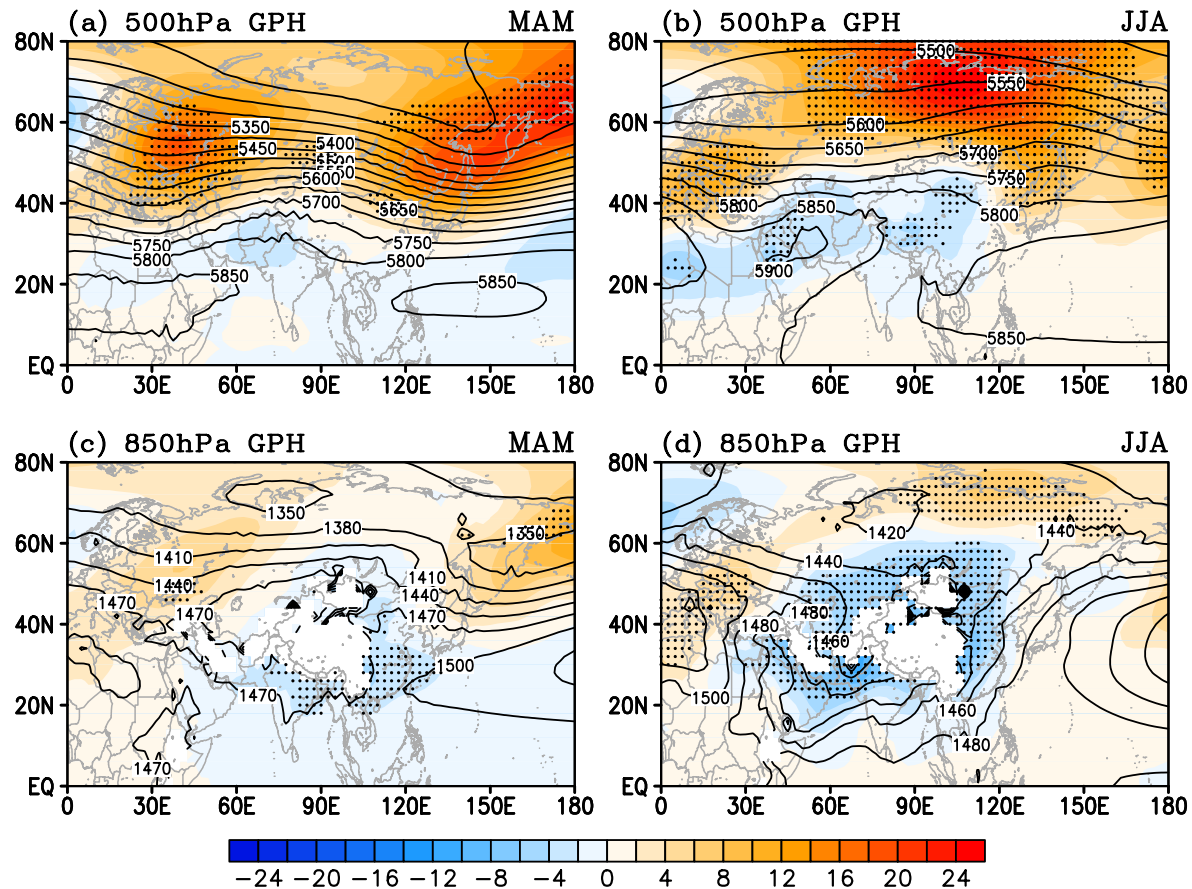
$$dS_w/dt = SM - R + P - E - F_o \approx 0$$

$$F_o = SM - R + P - E$$

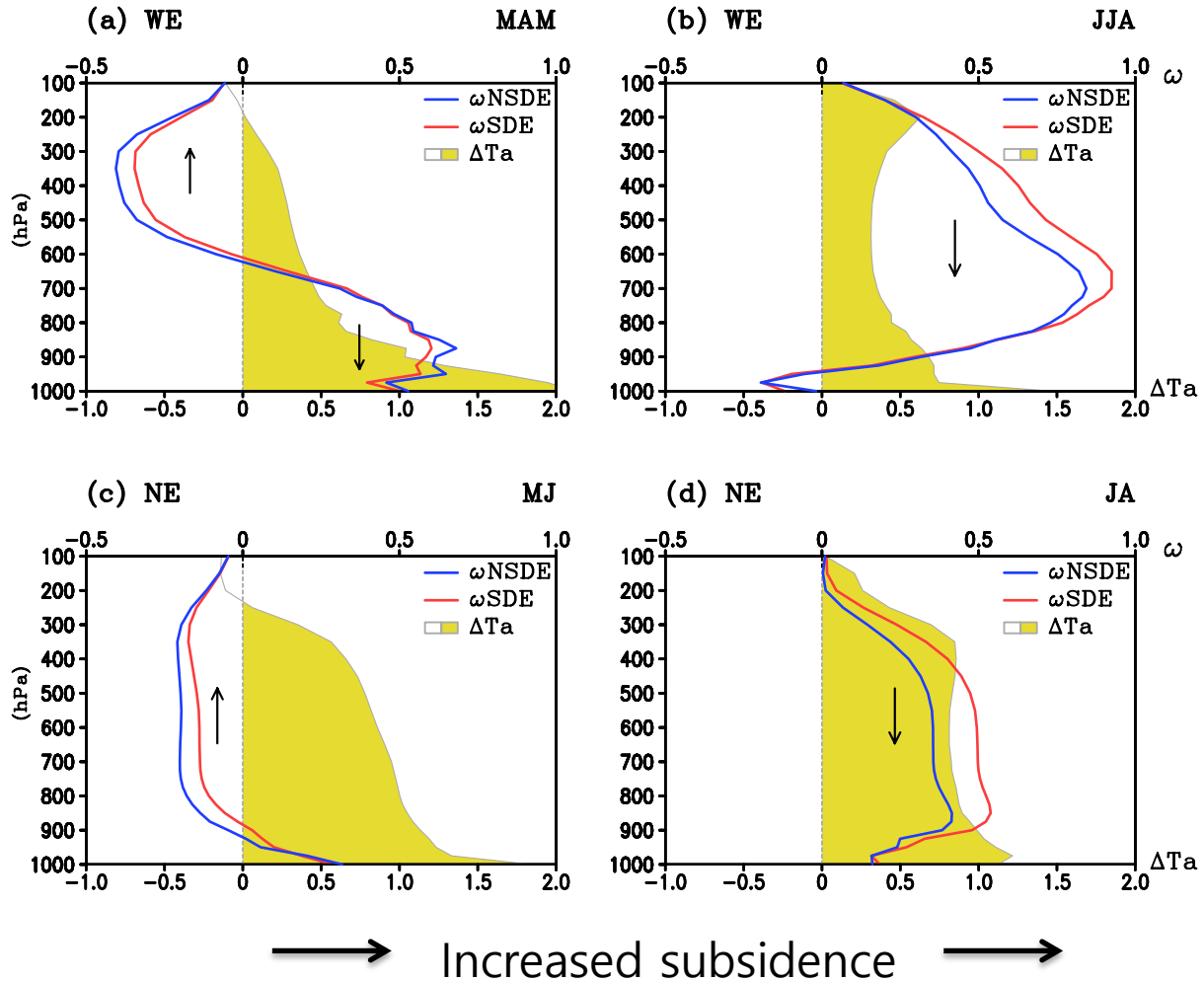


Land Gain
Land Lost

Favorable conditions for heatwaves:
High pressure over WE and NE,

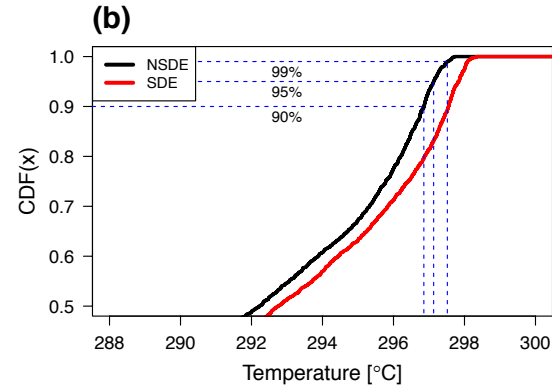
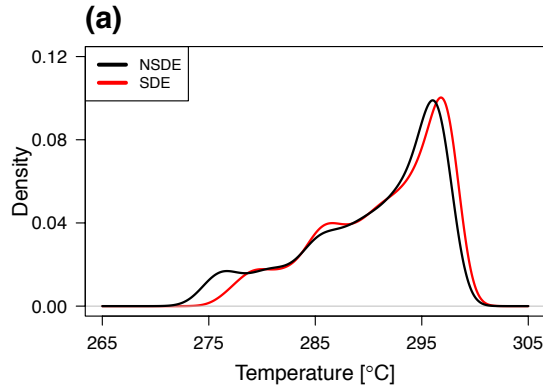


SDE induces warmer surface and troposphere, and stronger subsidence

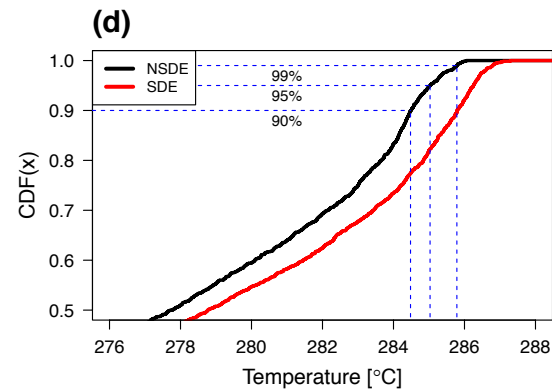
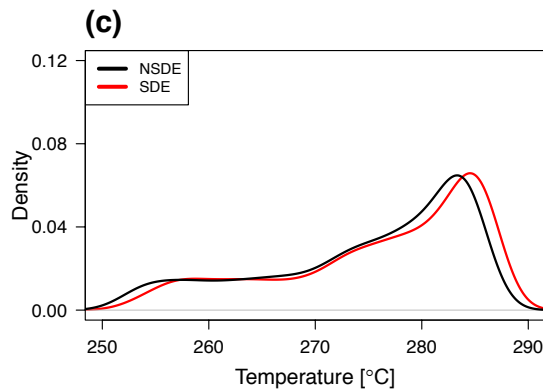


SDE increases frequency of 1% (~10%) extreme heating days (NSDE) by 10 (~20) fold)

WE

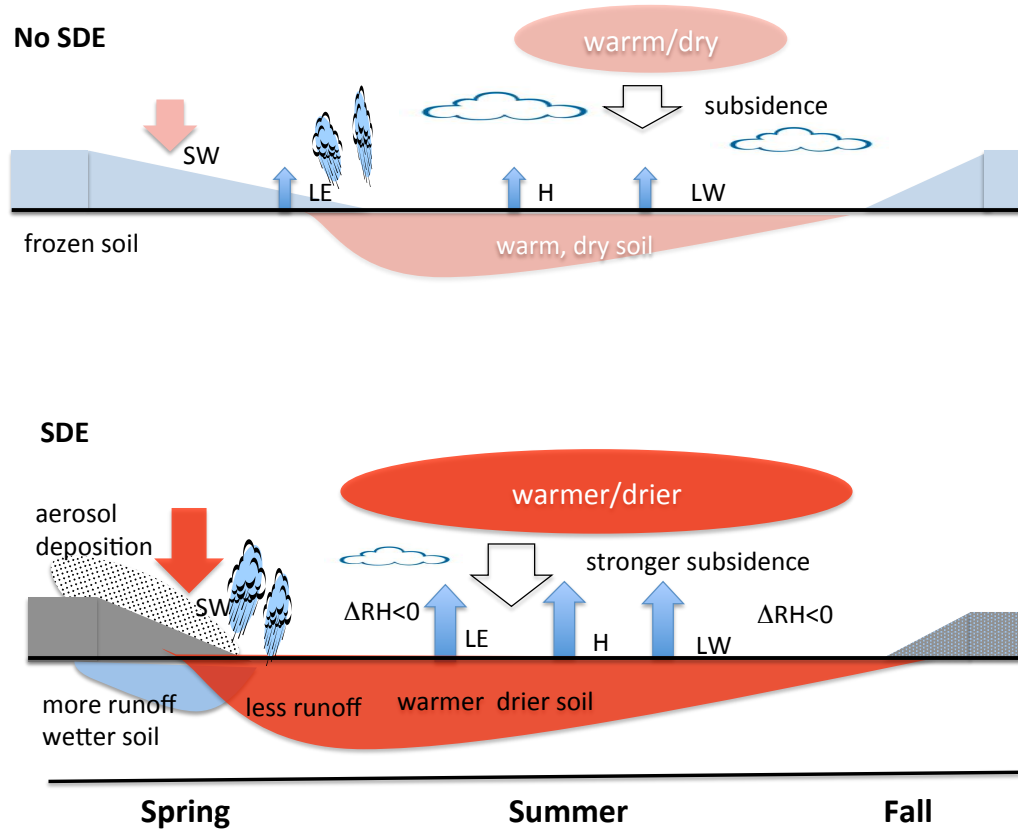


NE



NSDE		10%	5%	1%
SDE	WE	20	17	11
	NE	23	18	10

The Wet-First-Dry-Later (WFDL) hydroclimate feedback induced by snowdarkening effect (SDE)



Continental drying, with increased summertime heat waves over Eurasia (Lau et al., 2018, under revision)
 Enhanced South Asian monsoon, northward migration of East Asian monsoon (ongoing work)
 Impacts on wildfires in subpolar climate, e.g., North America, Siberia and northeastern China (future work)

Conclusions

Aerosol snow-darkening effect leads to:

- **a warmer and drier climate over Eurasia** :an increase in annual mean surface skin temperature of 1-2.5°C, with a substantial reduction (up to 10%) in soil wetness over vast regions of the Europe and increase in Asian summer monsoon
- A continental scale hydroclimate and land-atmosphere WFDL feedback , causing prolonged drying of the land-atmosphere, leading to:
Increased 1% (10%) extreme heating days over western Europe, and northern Eurasia by more than 10 (20) times

Thank you