Pacific Northwest NATIONAL LABORATORY

Uncovering the Interannual Predictability of the 2003 European Summer Heatwave Linked to the Tibetan Plateau

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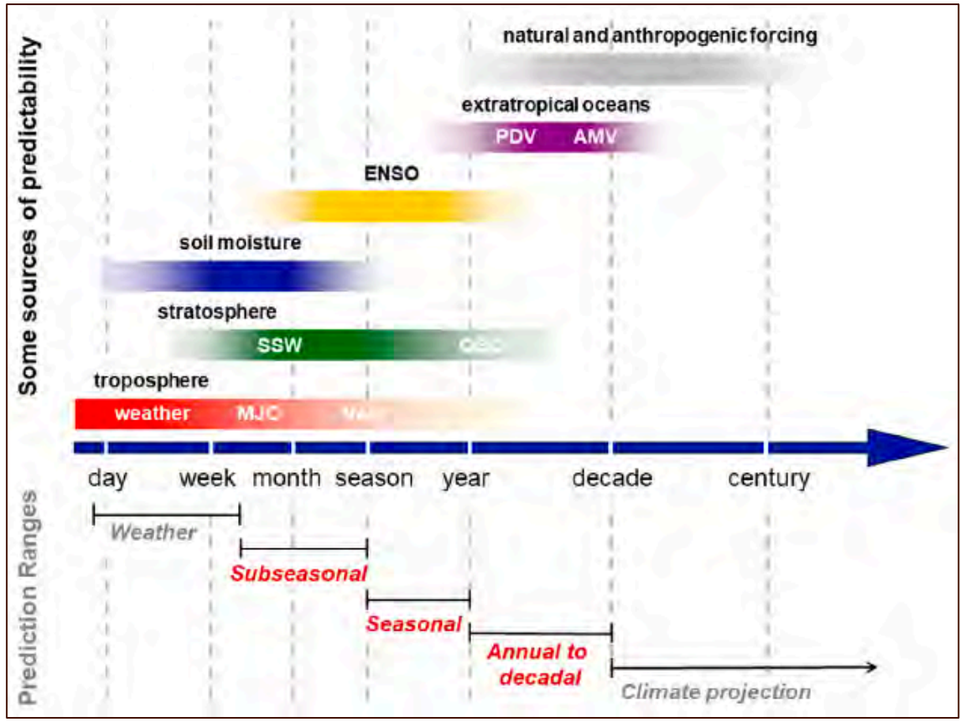
Land as a source of predictability at decadal timescale



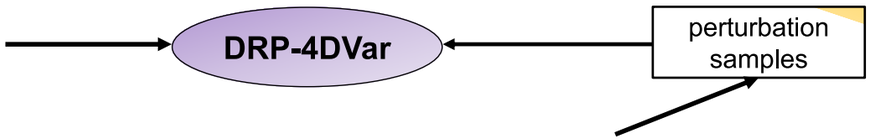
(Merryfield et al. 2020 BAMS)

CMIP6 decadal climate prediction experiments

Project	Model	Initialization			Reference
		Atmosphere	Ocean	Land	
CMIP6	BCC-CSM2-MR	NO	Nudging	NO	Wu et al., 2019
	CanESM5	Nudging	Nudging	NO	Sospedra-Alfonso et al., 2021
	IPSL-CM6A-LR	NO	Nudging	NO	Boucher et al., 2020
	MPI-ESM1.2-HR	ERA40/Interim	ORAS4	NO	Bunzel et al.,2015
	NorCPM1	NO	EnKF	NO	Wang et al., 2017
	MIROC6	JRA55	IAU	NO	Tabete et al., 2012
	CMCC-CM2-SR5	NO	Nudging	NO	Huang et al., 2015
	EC-EARTH3	ERA40/Interim	Nudging	NO	Batte et al., 2015
	NorCPM1	No	EnKF	NO	Bethke et al., 2021

Land as a source of predictability at decadal timescale

A weakly coupled land data assimilation system



observational operator **H**

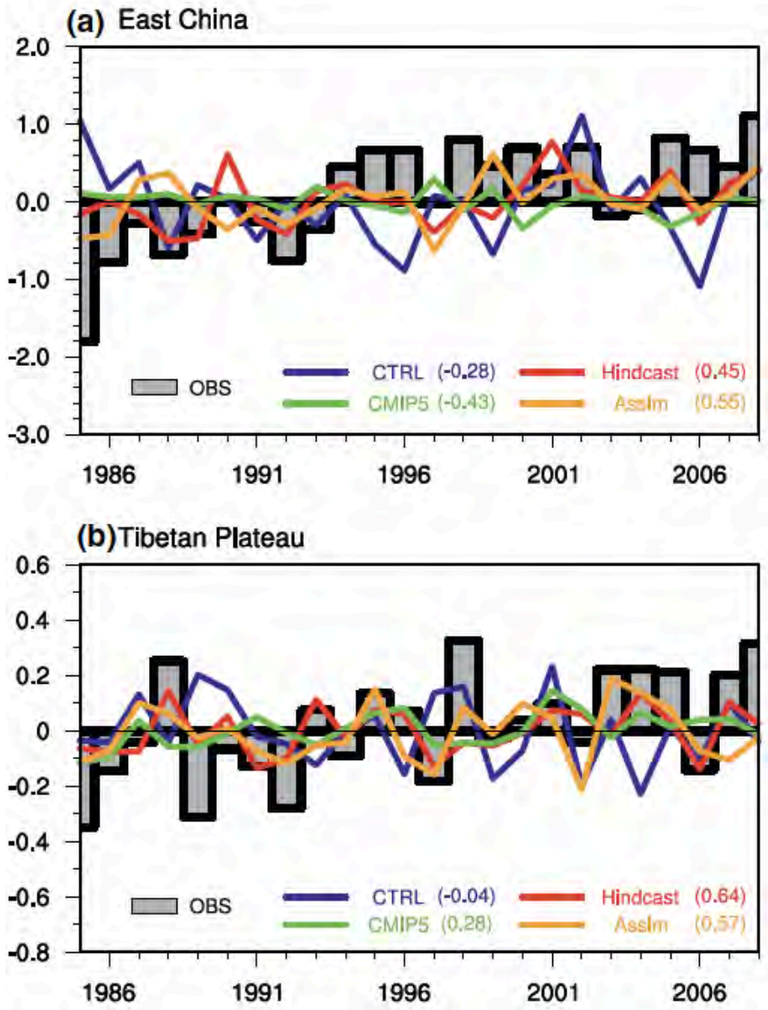
FGOALS

Experiment	Description
CTRL	Free running **fully coupled** simulation
Assim	Assimilate **soil moisture and temperature** into fully coupled climate simulation
Hindcast	Use **initial condition from Assim** to perform hindcast

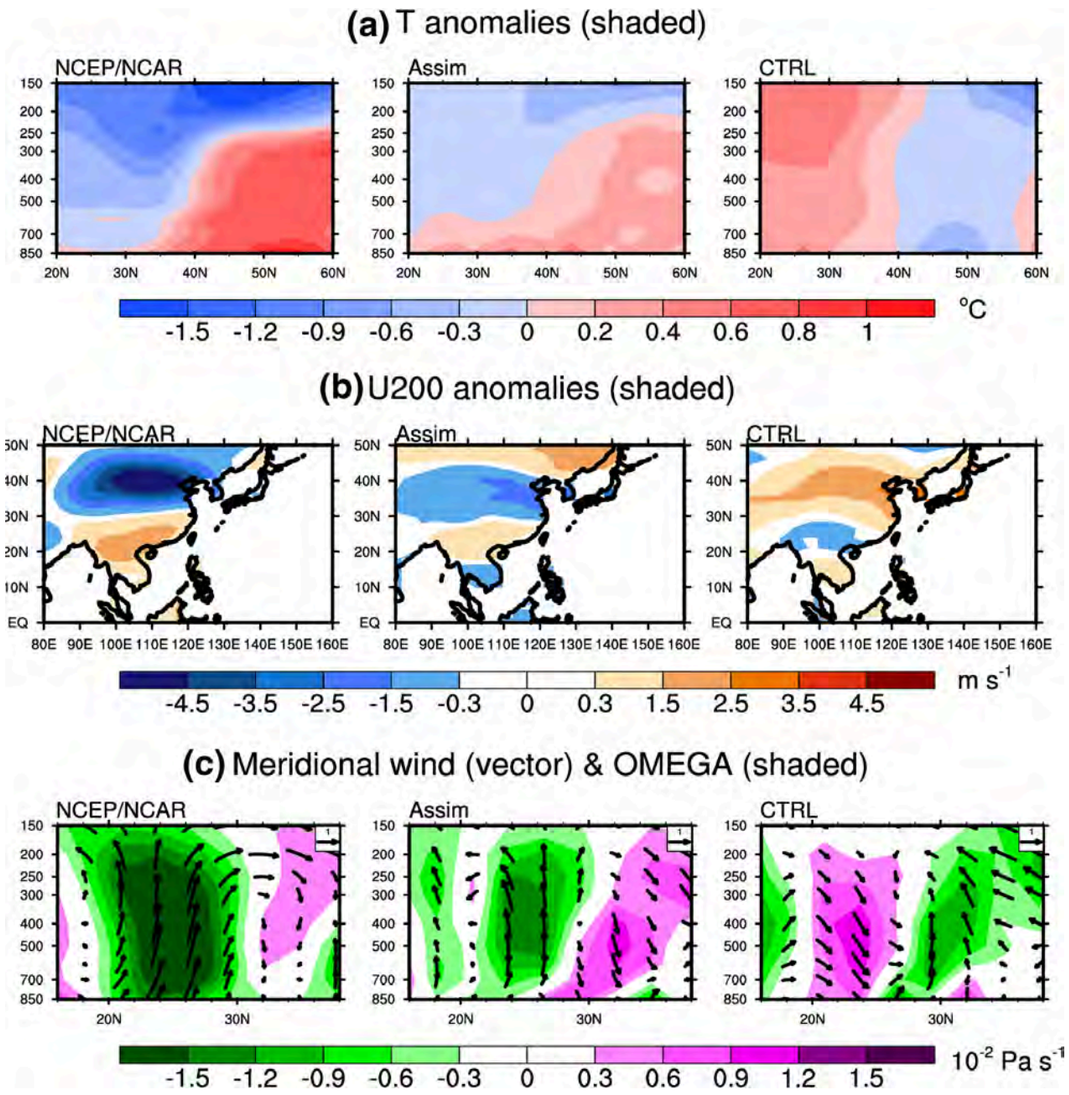
- CTRL and Assim: 36-year long continuous simulations (1980-2015)
- Hindcast: 5-year long simulations consisting of 3-10 ensemble members initialized 5 years apart (1980, 1985, 1990, 1995, 2000, 2005) using restart files from Assim as initial conditions

(Shi et al. 2021 Earth's Future)

Significant interannual-to-decadal hindcast skill with initial conditions from Assim with assimilation of only land states

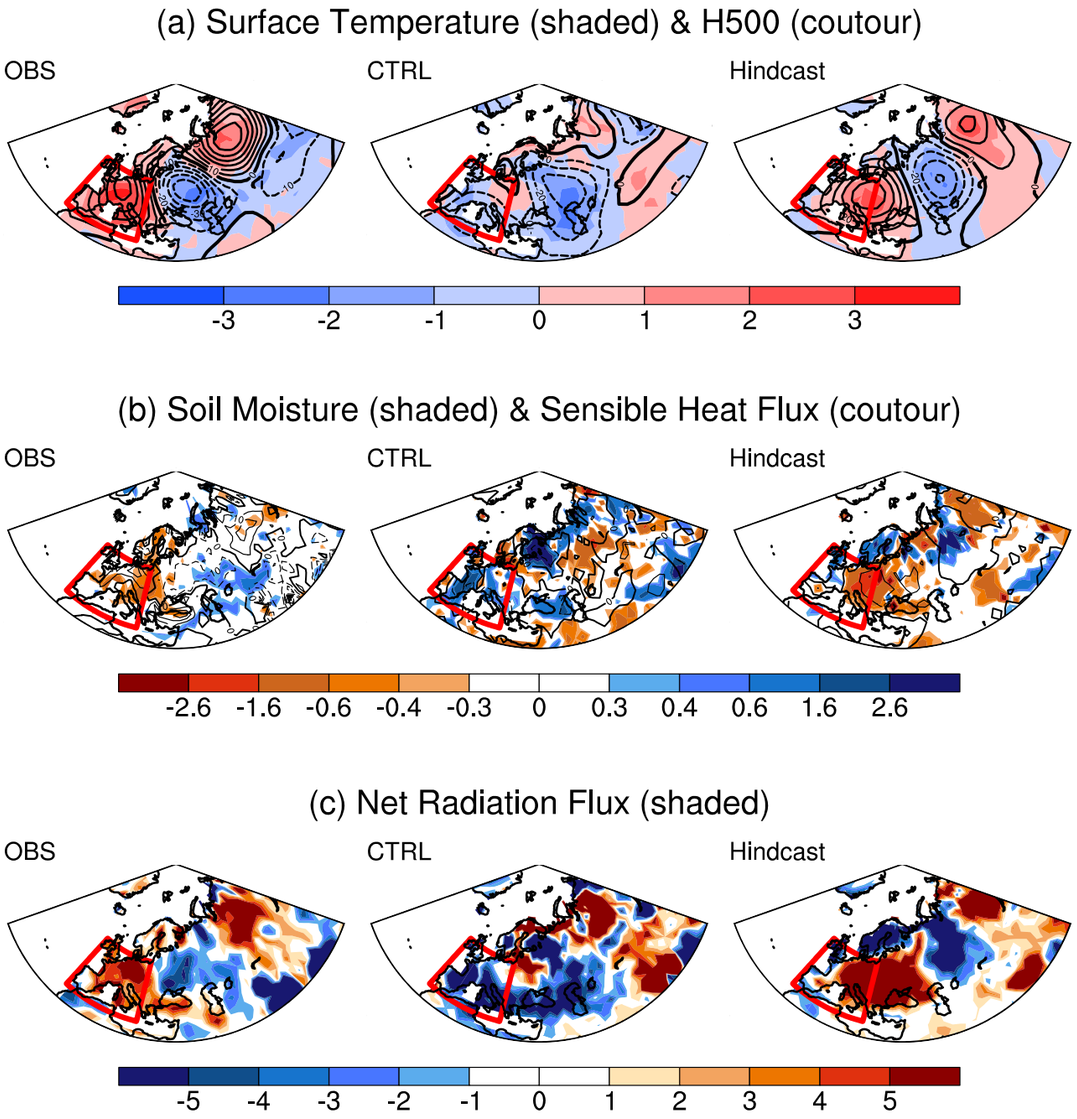


1993–2002 minus 1985–1992



(Shi et al. 2021 Earth's Future)

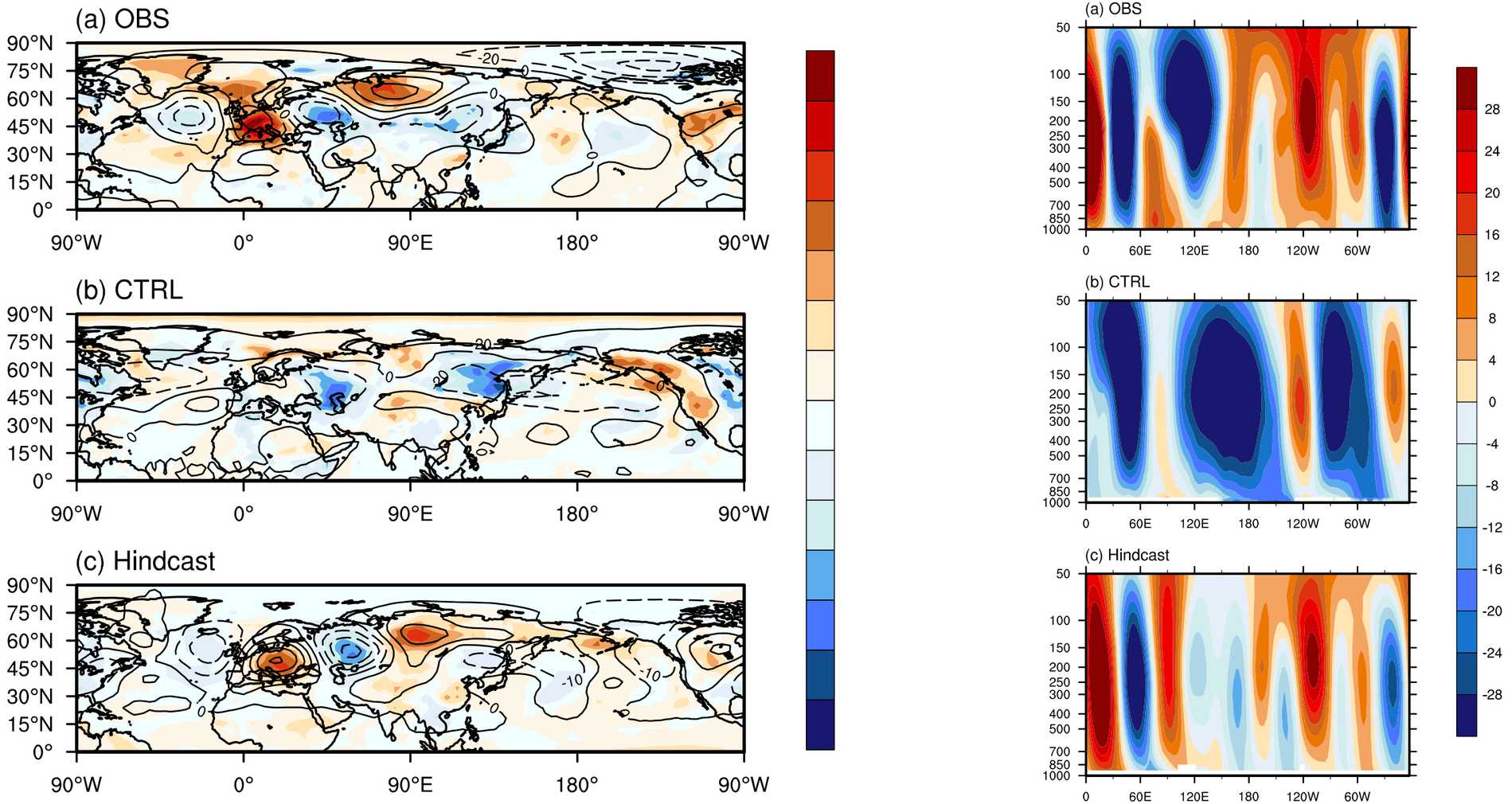
Hindcasts of the 2003 European summer heatwave



- Similar experiments as in Shi et al. (2021), but soil moisture and temperature are only assimilated over the Tibetan Plateau (TP) in Assim
- Hindcast is based on ensemble mean of 10 members initialized between fall 2000 and spring 2001 (2 years in advance of the 2003 European heatwave!)

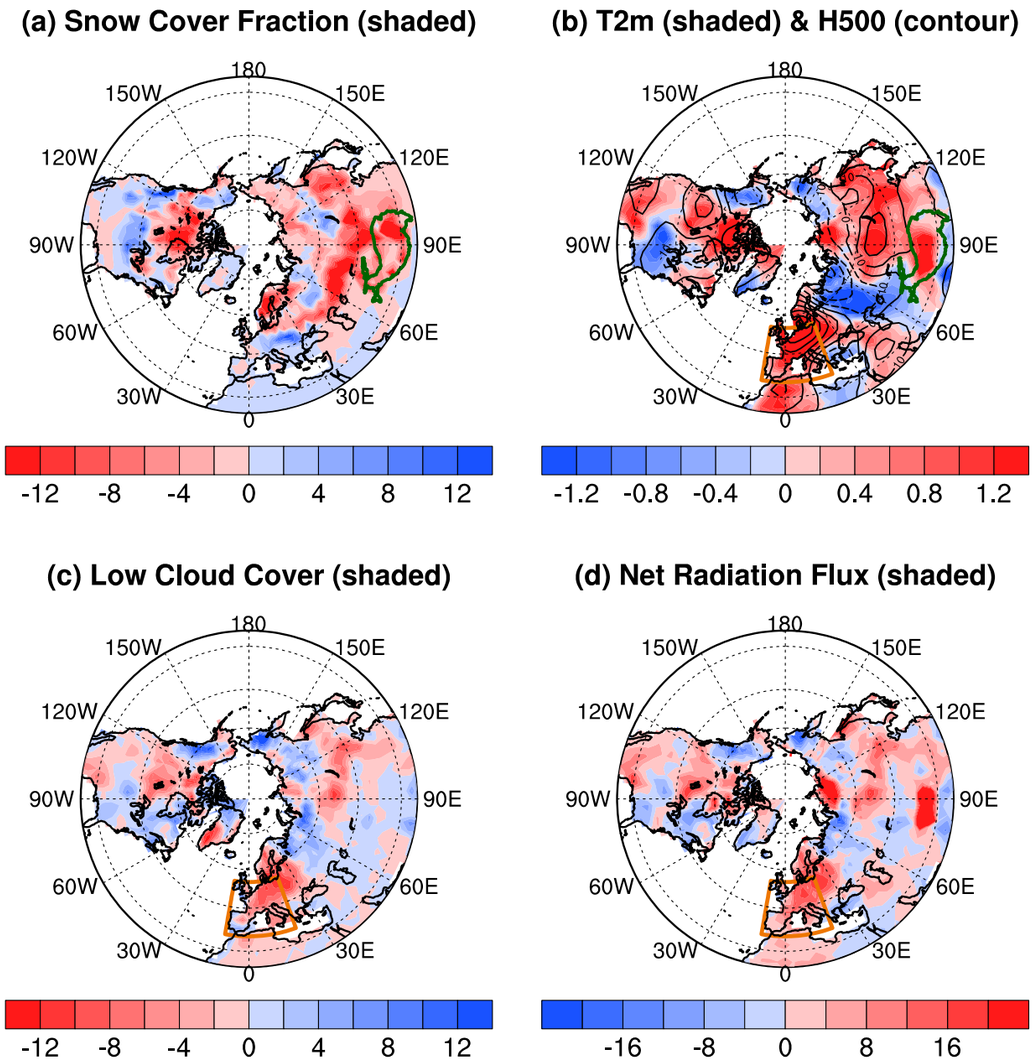
(Shi et al. 2023 in review)

Hindcast reproduces the observed Rossby wave train



(Shi et al. 2023 in review)

Reduced snow cover and warmer temperature over the TP in spring 2003



(Shi et al. 2023 in review)

- Why Hindcast is able to simulate reduced snow cover in spring of 2003 when initialized from Assim in 2001?
- Which components (atmosphere, land, ocean) in the initial conditions from Assim provide the predictability?

Hindcast sensitivity experiments to isolate the sources of predictability

Pattern correlation of surface temperature over Europe in 2003

Experiment	Atmosphere	Land	Ocean	PCC
Hindcast	Assim	Assim	Assim	0.83
SNS1	Assim	CTRL	Assim	-0.33
SNS2	Assim	Assim only over Tibetan Plateau	Assim	0.81
SNS3	CTRL	Assim only over Tibetan Plateau	CTRL	0.53
SNS4	CTRL	Assim only over Tibetan Plateau	Assim	0.65
SNS5	Assim	Assim only over Tibetan Plateau	CTRL	0.50
SNS6	CTRL	CTRL	Assim	-0.42

Impact of both land and ocean

Impact of land

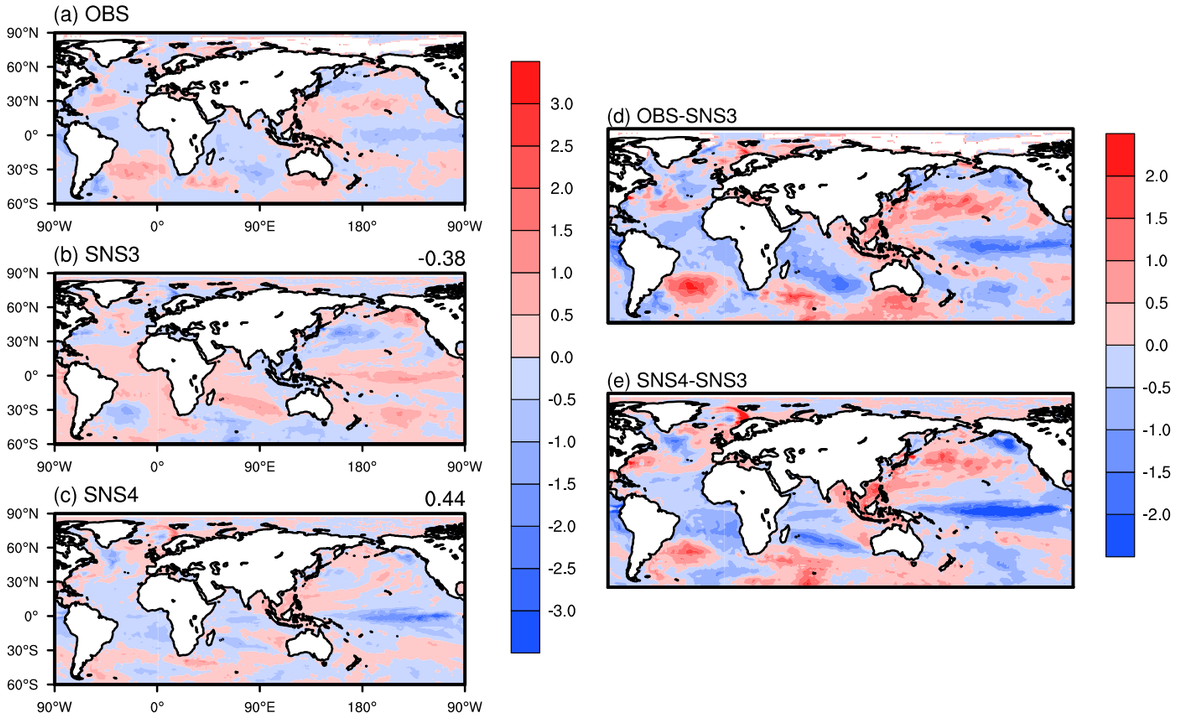
Impact of ocean

(Shi et al. 2023 in review)

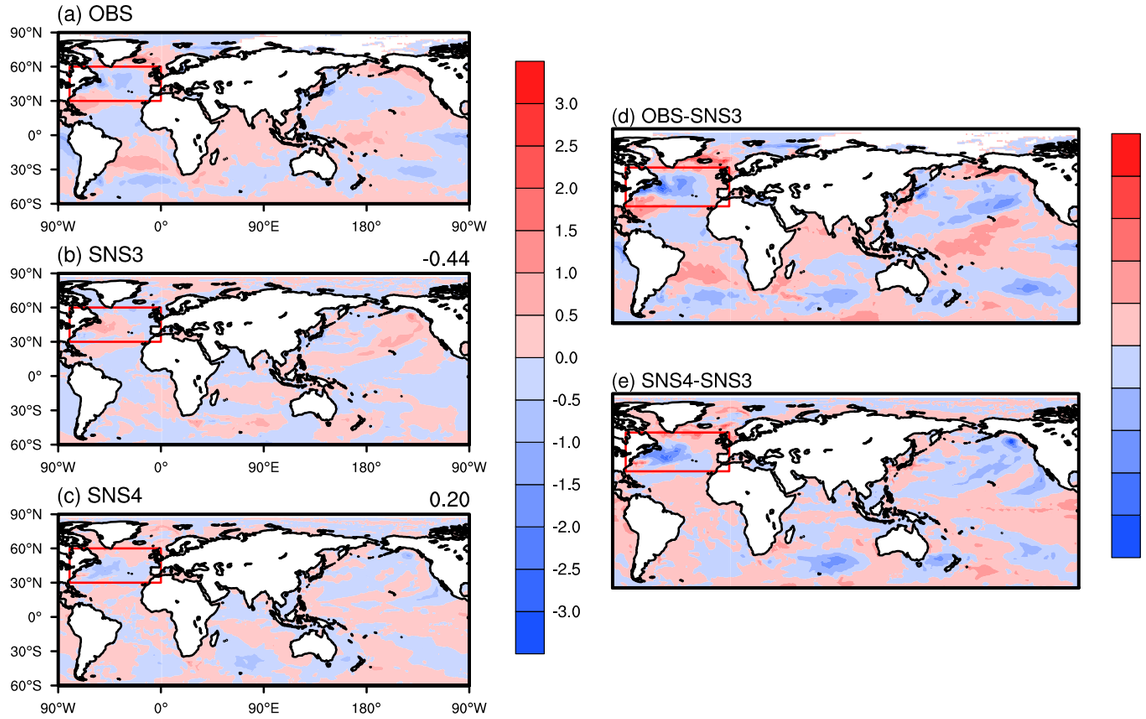
Large differences in the SST initial conditions between SNS3 (from CTRL) and SNS4 (from Assim) in 2001 and persist to 2003

Cooler SST in North Atlantic in January 2003 has been associated with circumglobal teleconnection pattern in summer

SST anomalies in January 2001



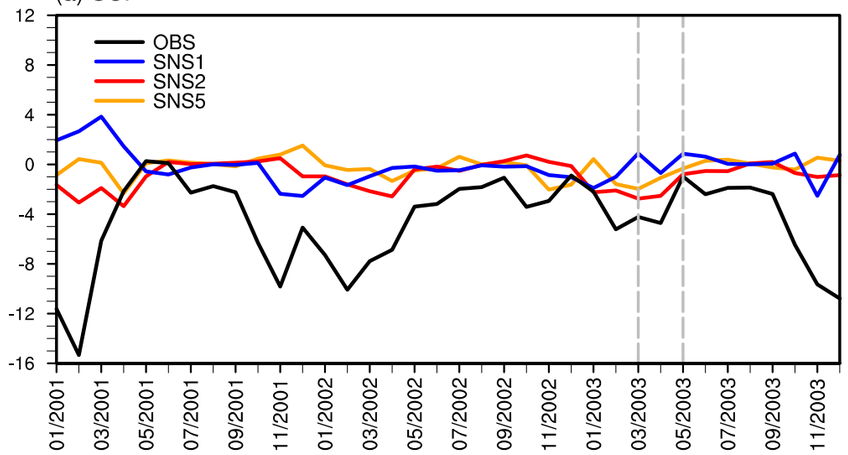
SST anomalies in January 2003



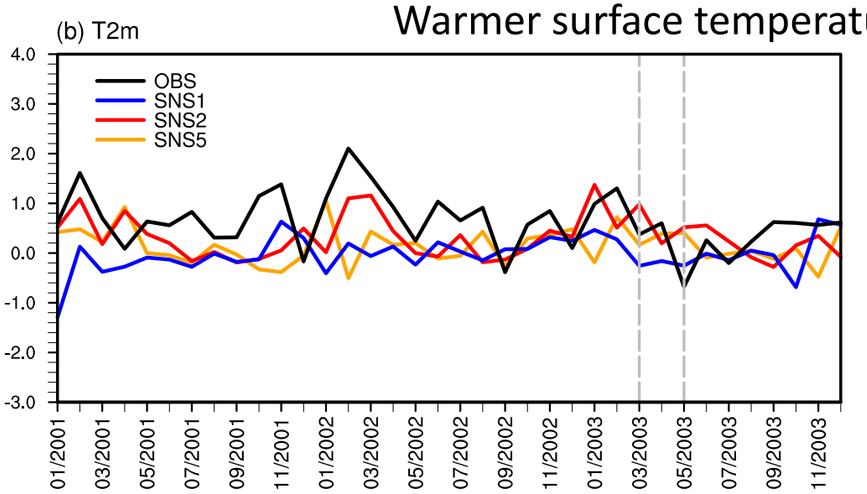
(Shi et al. 2023 in review)

Land surface anomalies better captured in SNS2 and SNS5 with initial land conditions from Assim

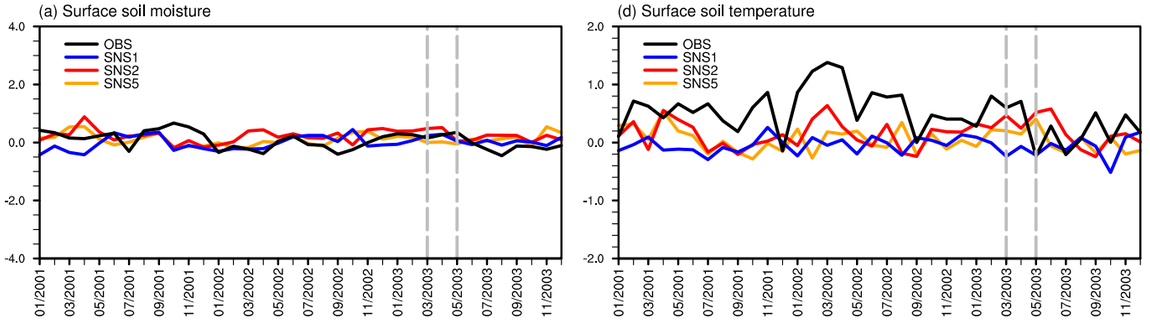
Reduced snow cover

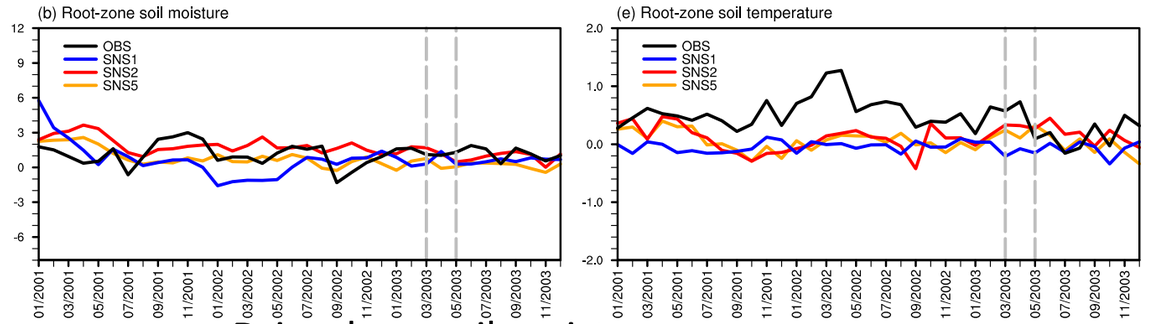


Warmer surface temperature

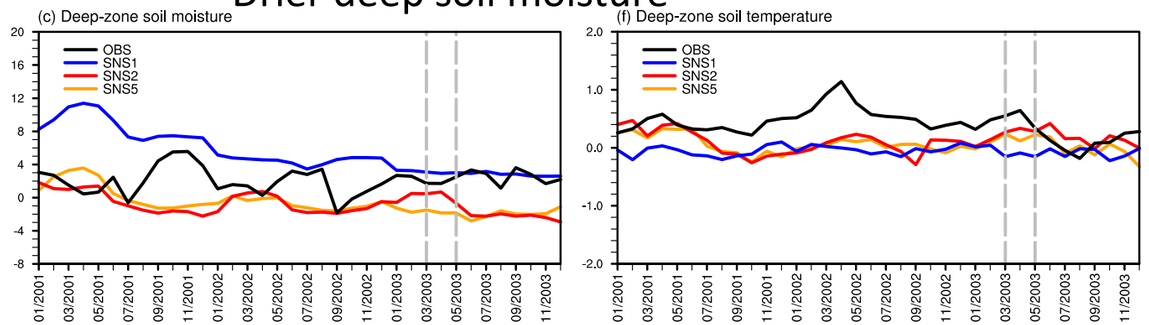


Warmer soil temperature throughout the layers





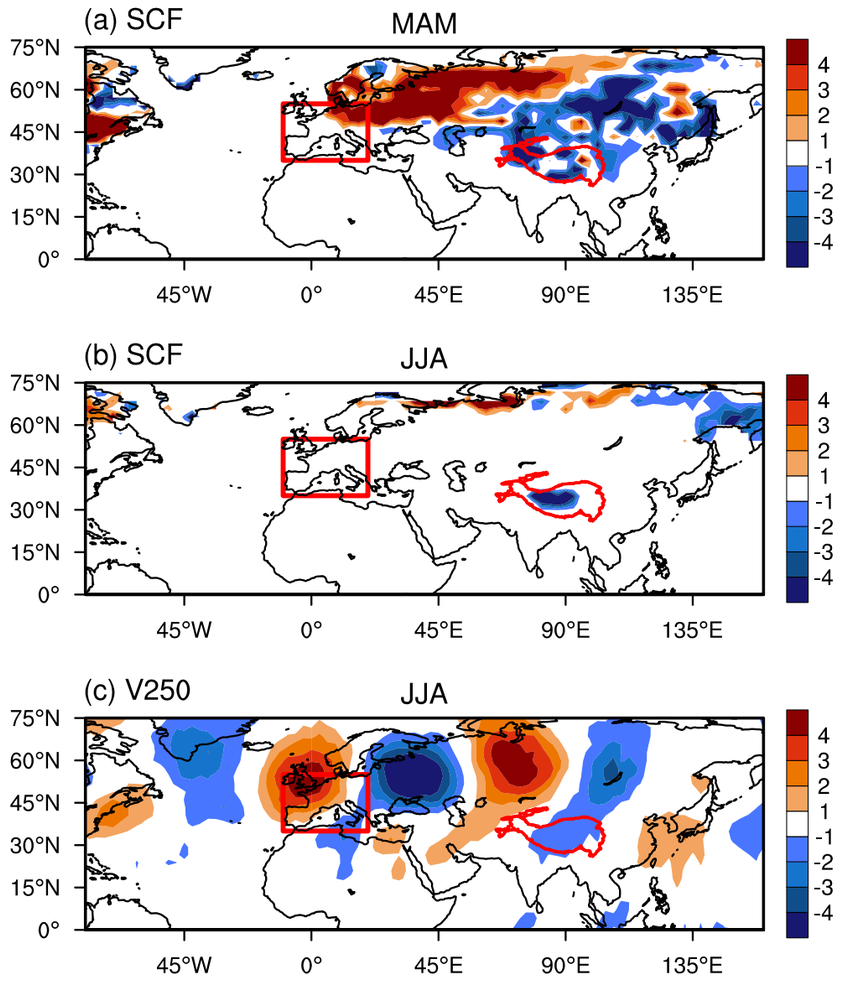
Drier deep soil moisture



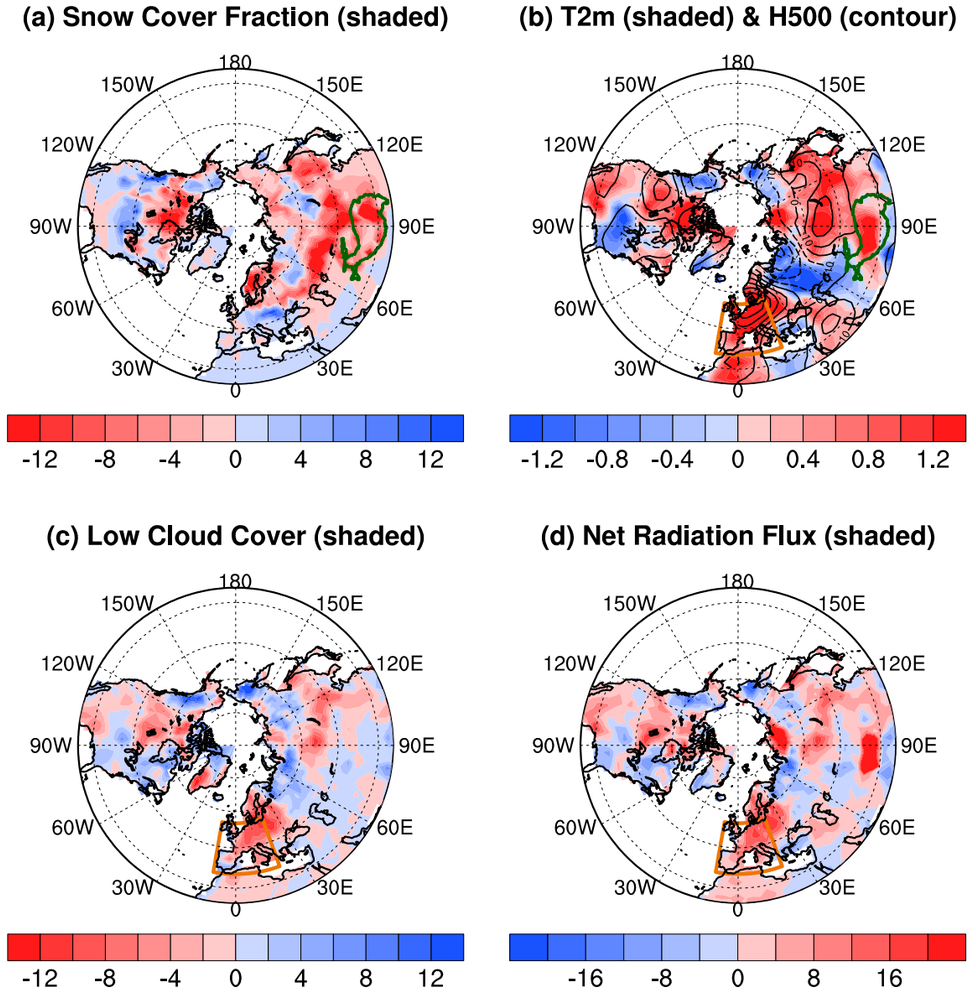
(Shi et al. 2023 in review)

Mechanistic connections

Anomalies in Hindcast in spring and summer of 2003



Difference between SNS1 and SNS2 (impact of land)



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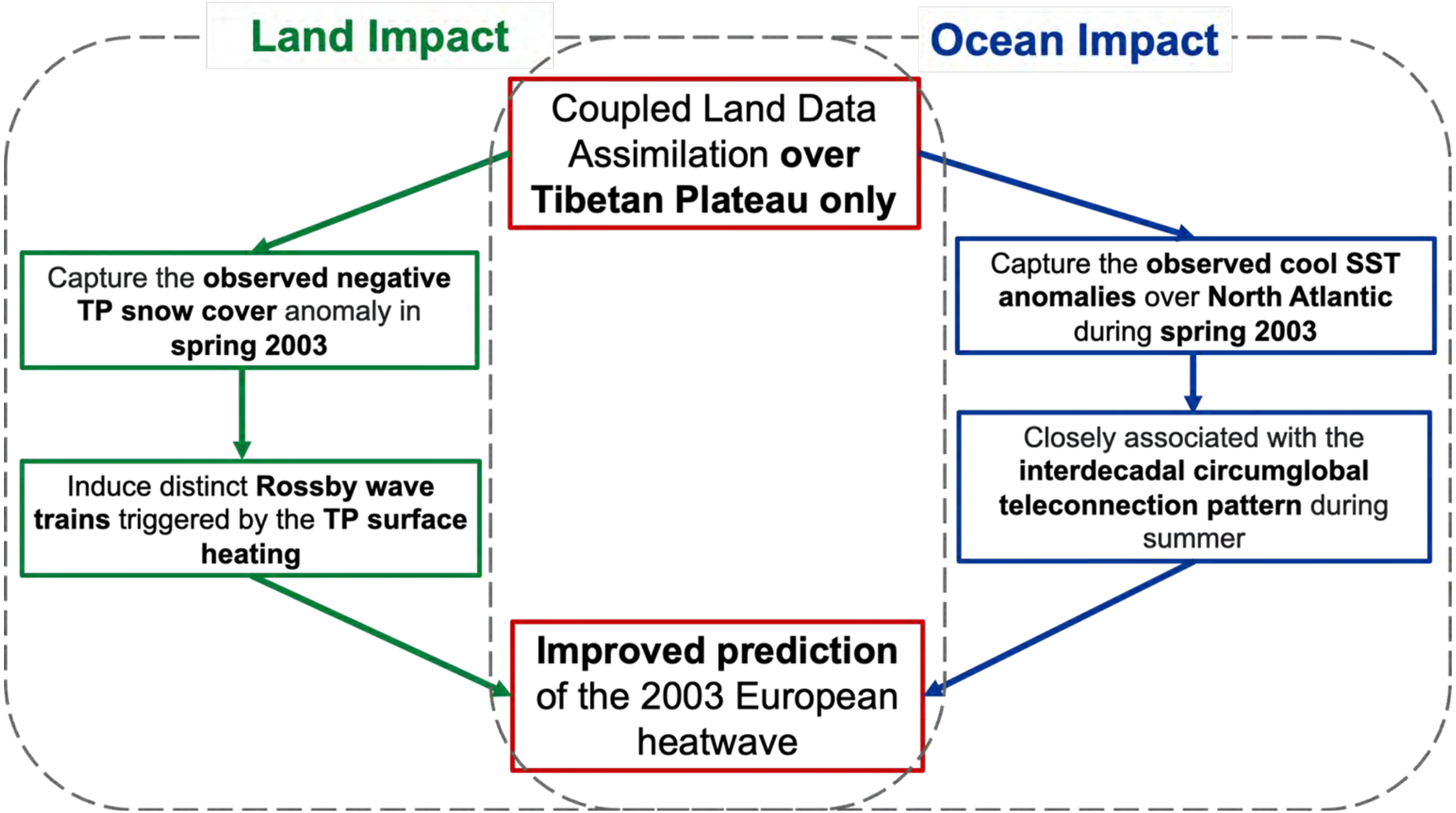
Mechanistic connections



(Shi et al. 2023 in review)

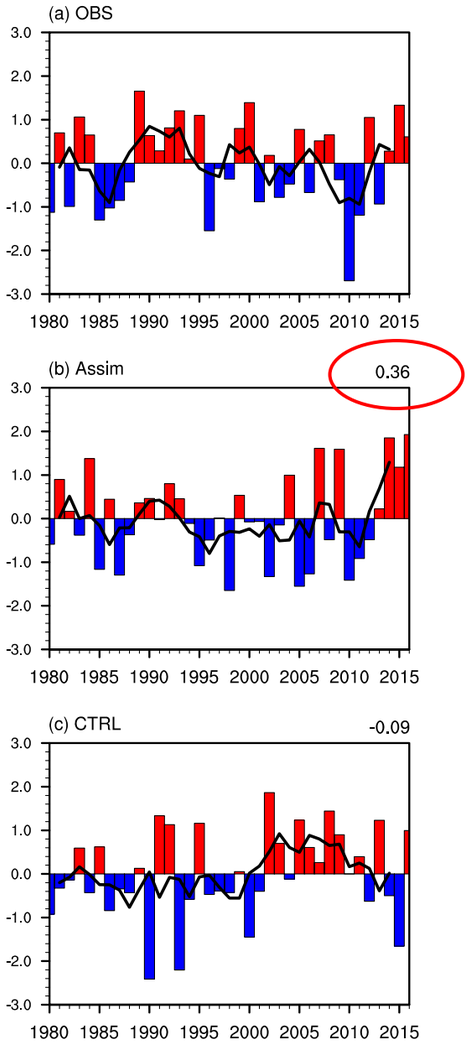
Summary

- Assimilating soil moisture and temperature in a weakly coupled land data assimilation system has important effects on interannual-to-decadal variability
- Hindcast initialized from Assim better captures the decadal variability of the East Asian monsoon circulation and precipitation (Shi et al. 2021 EF)
- Assimilating soil moisture and temperature over the TP alone has important effects on initializing hindcast of the 2003 European summer heatwave
- Hindcast initialized from Assim in 2001 better predicts anomalies of snow cover (low) and surface temperature (warm) over the TP and SST anomalies over the North Atlantic (cool), contributing to predictability of the 2003 European summer heatwave 2 years in advance
- DRP-4DVar has been implemented in E3SM to perform LS4P experiments

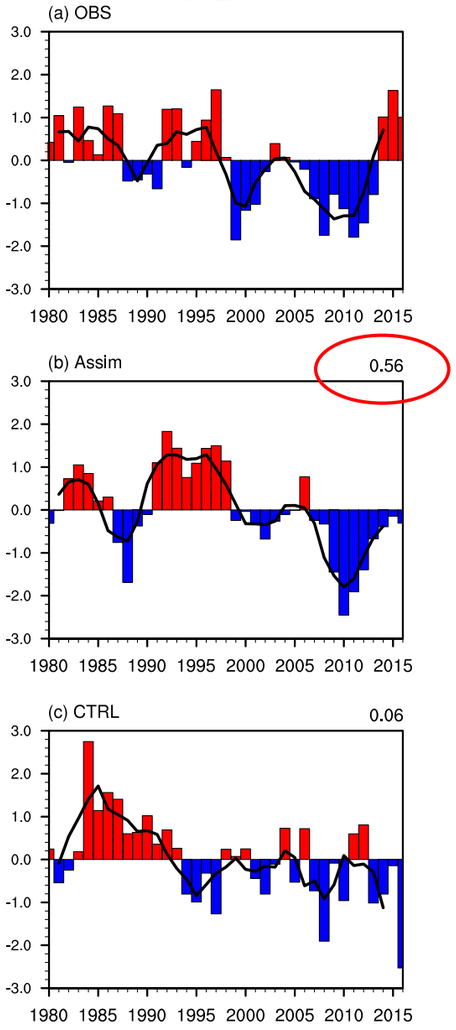
E3SM Assim shows significant skill in capturing the evolution of the decadal modes constrained only by land states

Important two-way connections between land and ocean states

NAO



PDO



AMO