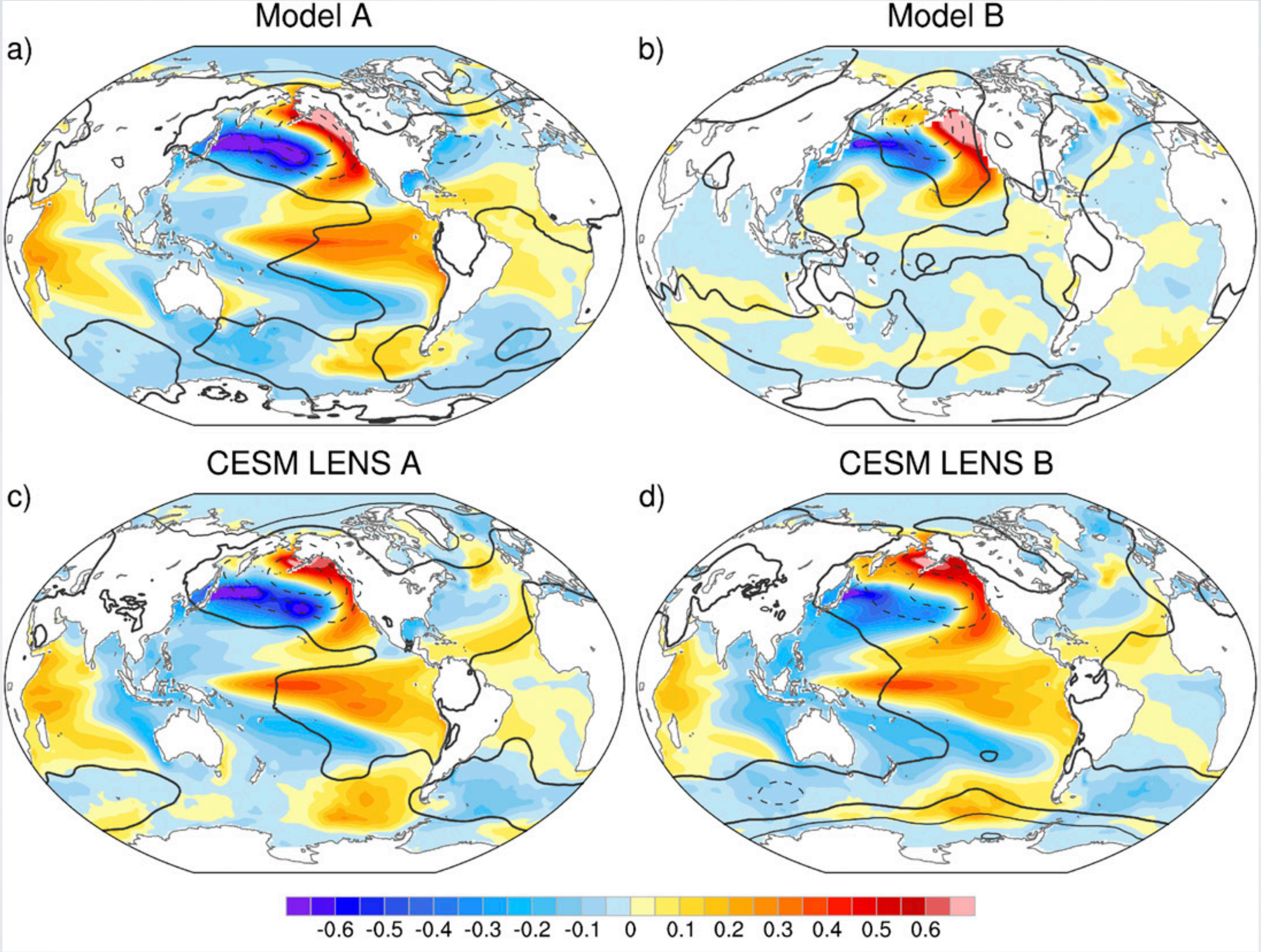
Advancing Teleconnection Simulations

Samantha Stevenson

National Center for Atmospheric Research, University of California at Santa Barbara

Issue: both structural, internal differences matter to teleconnections

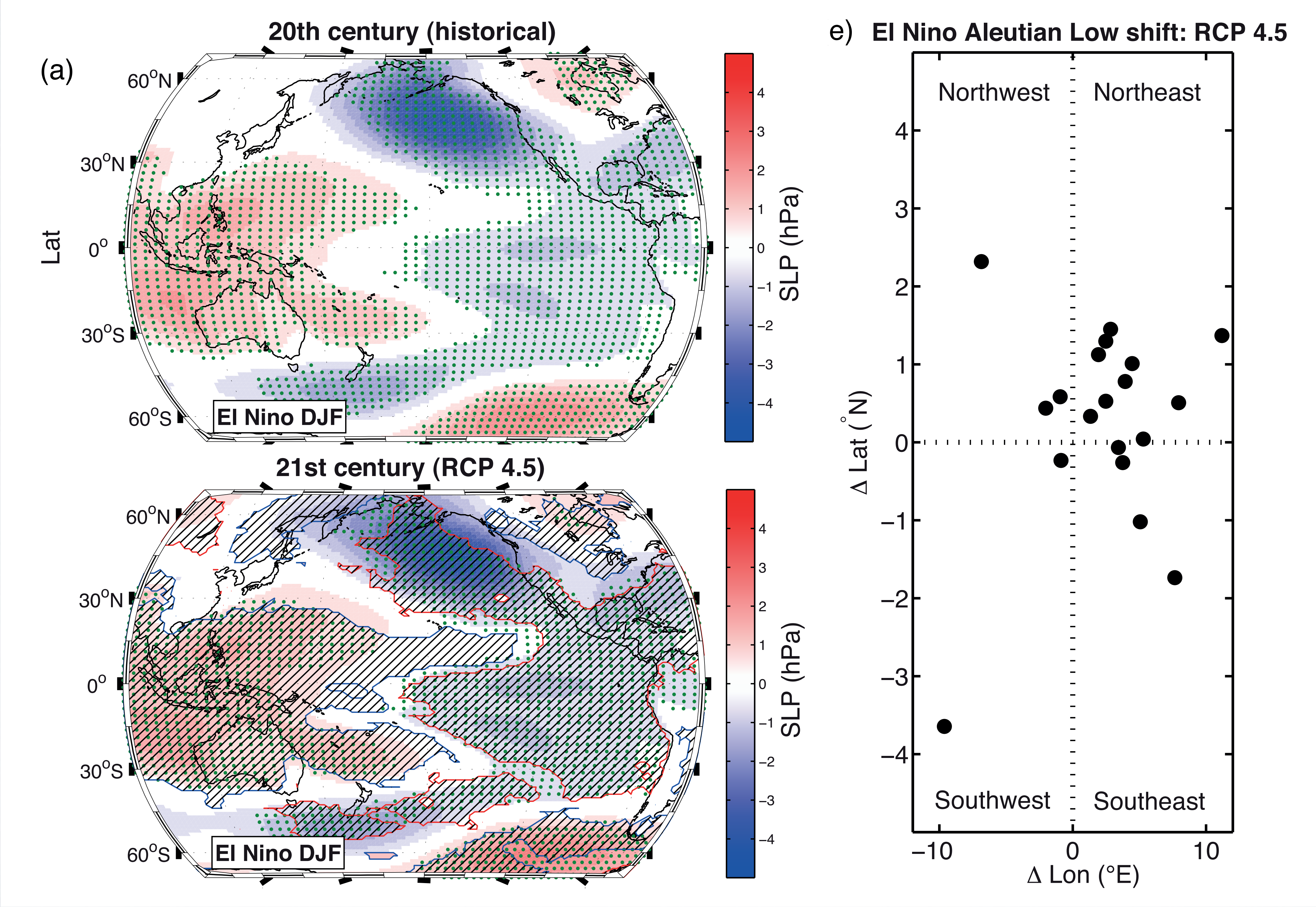
a), b): PDO spatial structure in CMIP5 models closest to, farthest from observations
c), d): Same as a), b) for members of the CESM Large Ensemble



Newman et al. (2016)

CMIP5 projections: shift in location of ENSO teleconnections

SLP composites during DJF of El Nino peak: CMIP5 historical, RCP4.5 projections

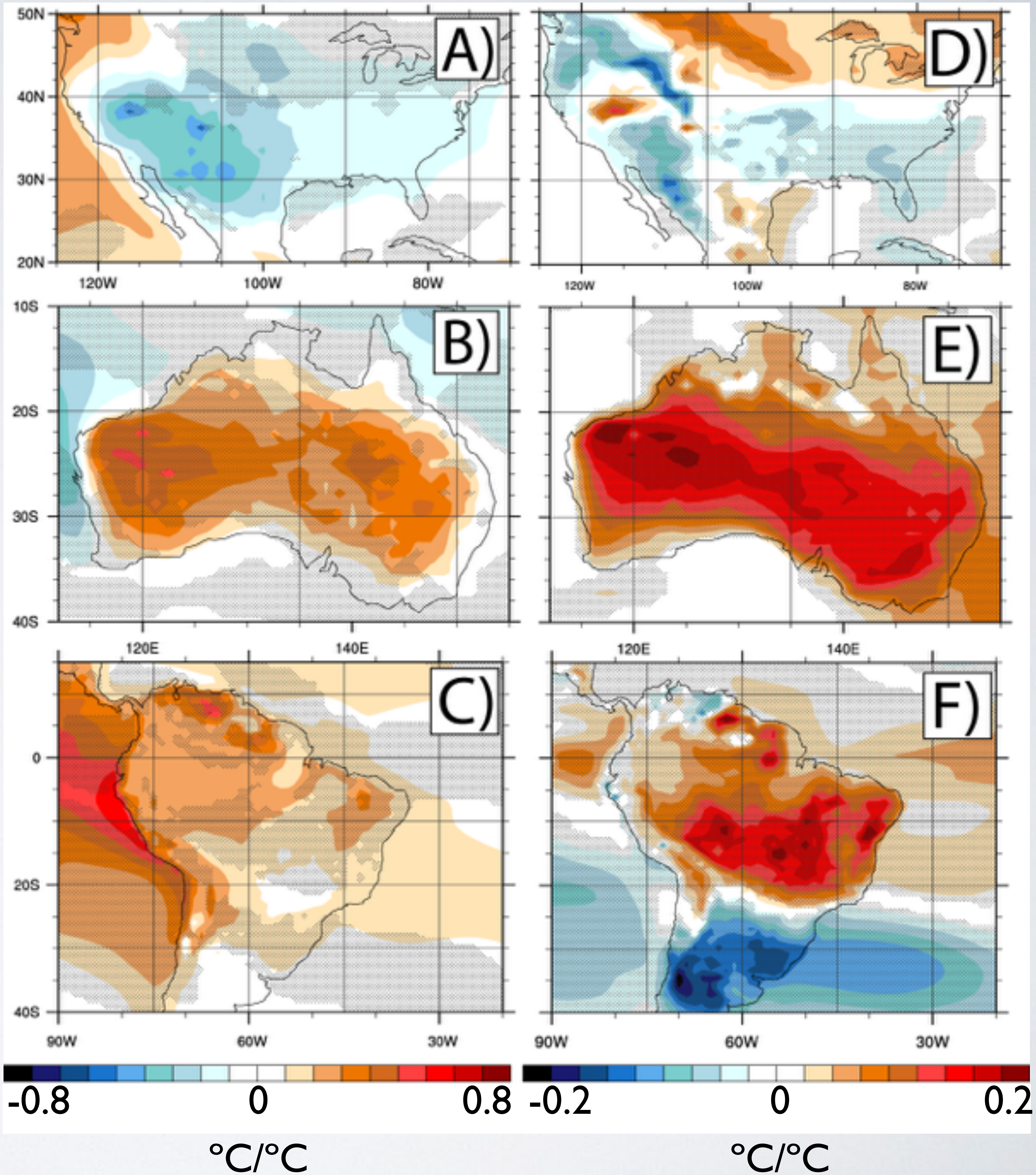


IPCC AR5 WG1

CESM, ESM2M ensembles: ENSO teleconnection intensification

Left: Regression of temperature onto NINO3.4 index in the CESM Large Ensemble (Kay et al. 2015)

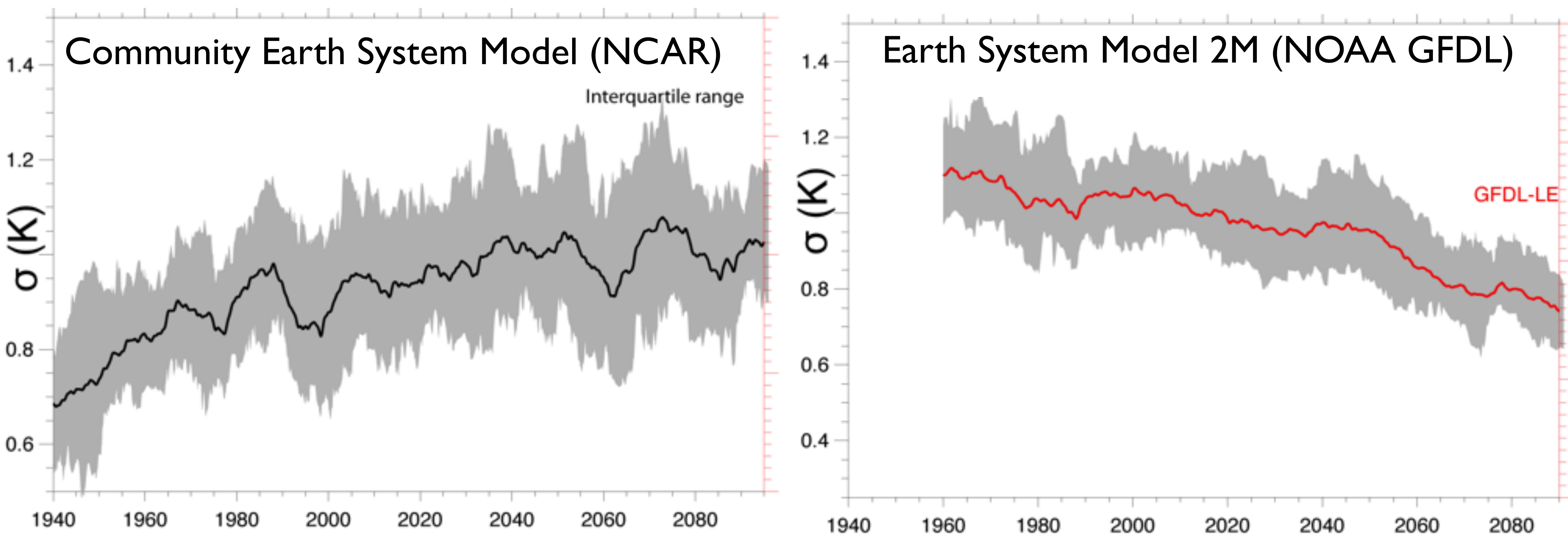
Right: *change* in the regression coefficient between 2040-2100 and 1920-1980



Fasullo, Otto-Bliesner, & Stevenson 2017, Nature Climate Change, in revision

No agreement on future changes in ENSO amplitude

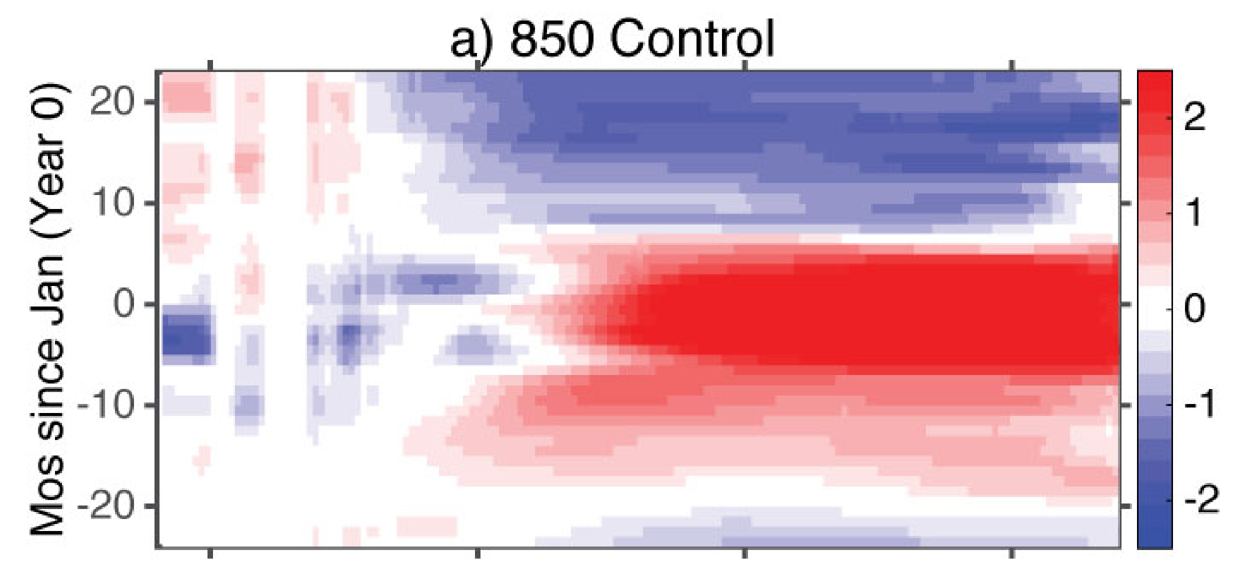
Running 20-year NINO3.4 variance, RCP8.5

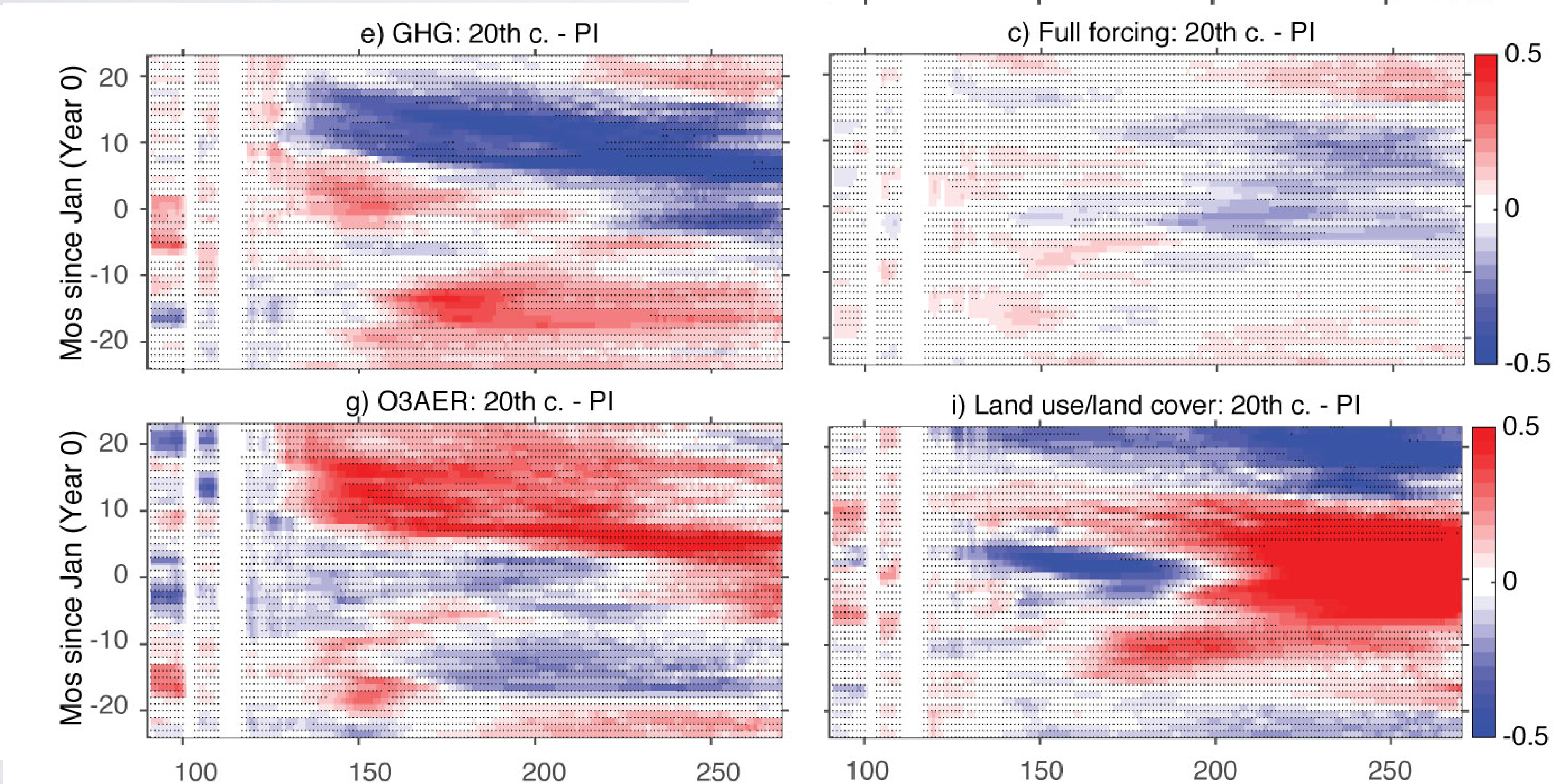


Fasullo, Otto-Bliesner, & Stevenson 2017, Nature Climate Change, in revision

CESM: differential ENSO response to anthropogenic forcings

2S-2N SST vs. lon, time: 0 = January of peak year
PI = 850-1849
20th c. = 1850-2005





Stevenson et al. (2017), Climate Dynamics

What new simulations and observations are needed to improve understanding of teleconnections in climate models?

Simulations planned for CMIP6 (DECK)

Experiment short name	CMIP6 label	Experiment description	Forcing methods	Start year	End year	Minimum no. years per simulation	Major purpose
DECK experiments							
AMIP	*amip*	Observed SSTs and SICs prescribed	All; CO_2 concentration prescribed	1979	2014	36	Evaluation, variability
Pre-industrial control	*piControl* or *esm-piControl*	Coupled atmosphere–ocean pre-industrial control	CO_2 concentration prescribed or calculated	n/a	n/a	500	Evaluation, unforced variability
Abrupt quadrupling of CO_2 concentration	*abrupt-4×CO2*	CO_2 abruptly quadrupled and then held constant	CO_2 concentration prescribed	n/a	n/a	150	Climate sensitivity, feedback, fast responses
$1\,\%\,\mathrm{yr}^{-1}$ CO_2 concentration increase	*1pctCO2*	CO_2 prescribed to increase at $1\,\%\,\mathrm{yr}^{-1}$	CO_2 concentration prescribed	n/a	n/a	150	Climate sensitivity, feedback, idealized benchmark
CMIP6 historical simulation							
Past ~ 1.5 centuries	*historical* or *esm-hist*	Simulation of the recent past	All; CO_2 concentration prescribed or calculated	1850	2014	165	Evaluation

Eyring et al. (2016)

CMIP6: also supports "sub-MIPs" with specific scientific targets

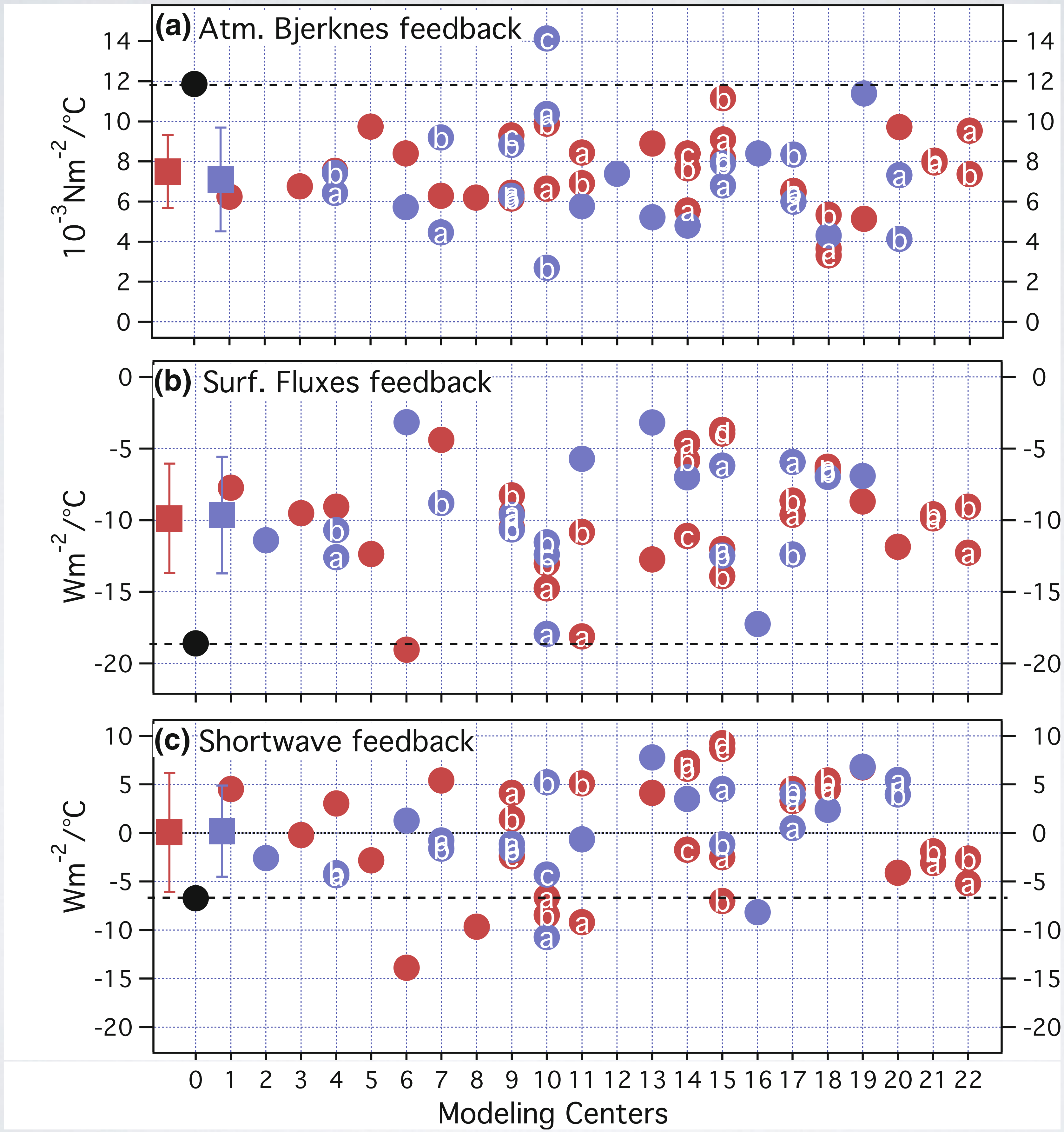
	Questions			Grand science challenges						
	Response to Forcing	Systematic Errors	Variability, Prediction & Projection	Clouds, circulation, sensitivity	Melting ice	Climate extremes	Changes in water availability	Regional sea level change	Biogeochemistry	Near term prediction
AerChemMIP	●		○						●	○
C4MIP	●		○				○		●	
CFMIP	●	○		●			○			
DAMIP	●		○		○	●				
DCPP	○		●				○	○		●
FAFMIP	●	○		○				●		
GeoMIP	○		●	●		○	○			
GMMIP		●	○	●			○			○
HighResMIP	○	●		○			●			
ISMIP6	●		○		●			●		
LS3MIP	○	●			○		●			
LUMIP	●		○				○		●	
OMIP		●	○					○	○	●
PMIP	●	○		●					○	
RFMIP	●		○	●						○
ScenarioMIP	○		●			●	●		○	
VolMIP	●	○		○						○
CORDEX	○		●			●	○			
DynVarMIP	○	●		○						○
SIMIP	○	●			●					
VIACS AB	○		●			●	○	○		

CMIP6: also supports “sub-MIPs” with specific scientific targets

		Questions			Grand science challenges						
		Response to Forcing	Systematic Errors	Variability, Prediction & Projection	Clouds, circulation, sensitivity	Melting ice	Climate extremes	Changes in water availability	Regional sea level change	Biogeochemistry	Near term prediction
Aerosols & Chemistry MIP	AerChemMIP	●		○						●	○
	C4MIP	●		○				○		●	
	CFMIP	●	○		●			○			
	DAMIP	●		○		○	●				
	DCPP	○		●				○	○		●
	FAFMIP	●	○		○				●		
	GeoMIP	○		●	●		○	○			
Global Monsoons MIP	GMMIP		●	○	●			○			○
	HighResMIP	○	●		○			●			
	ISMIP6	●		○		●			●		
Land Surface, Snow and Soil Moisture MIP	LS3MIP	○	●			○		●			
	LUMIP	●		○				○		●	
	OMIP		●	○					○	○	●
	PMIP	●	○		●					○	
Radiative Forcing MIP	RFMIP	●		○	●						○
	ScenarioMIP	○		●			●	●		○	
	VolMIP	●	○		○						○
	CORDEX	○		●			●	○			
Dynamics & Variability MIP	DynVarMIP	○	●		○						○
	SIMIP	○	●			●					
	VIACS AB	○		●			●	○	○		

Uncertainty quantification: process-level insights

Major feedbacks relevant to the ENSO cycle



Bjerknes: sensitivity of SST to wind stress

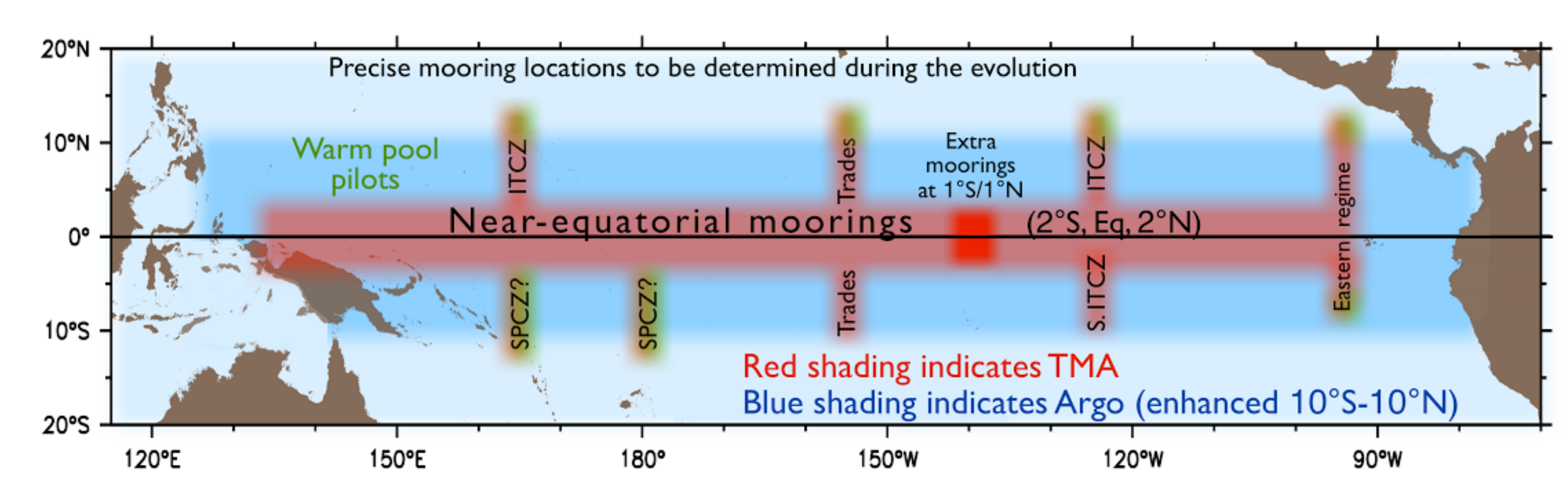
Surf. fluxes: damping of SST by latent heat flux

Shortwave feedback: damping of SST by shortwave fluxes

Bellenger et al. (2014)

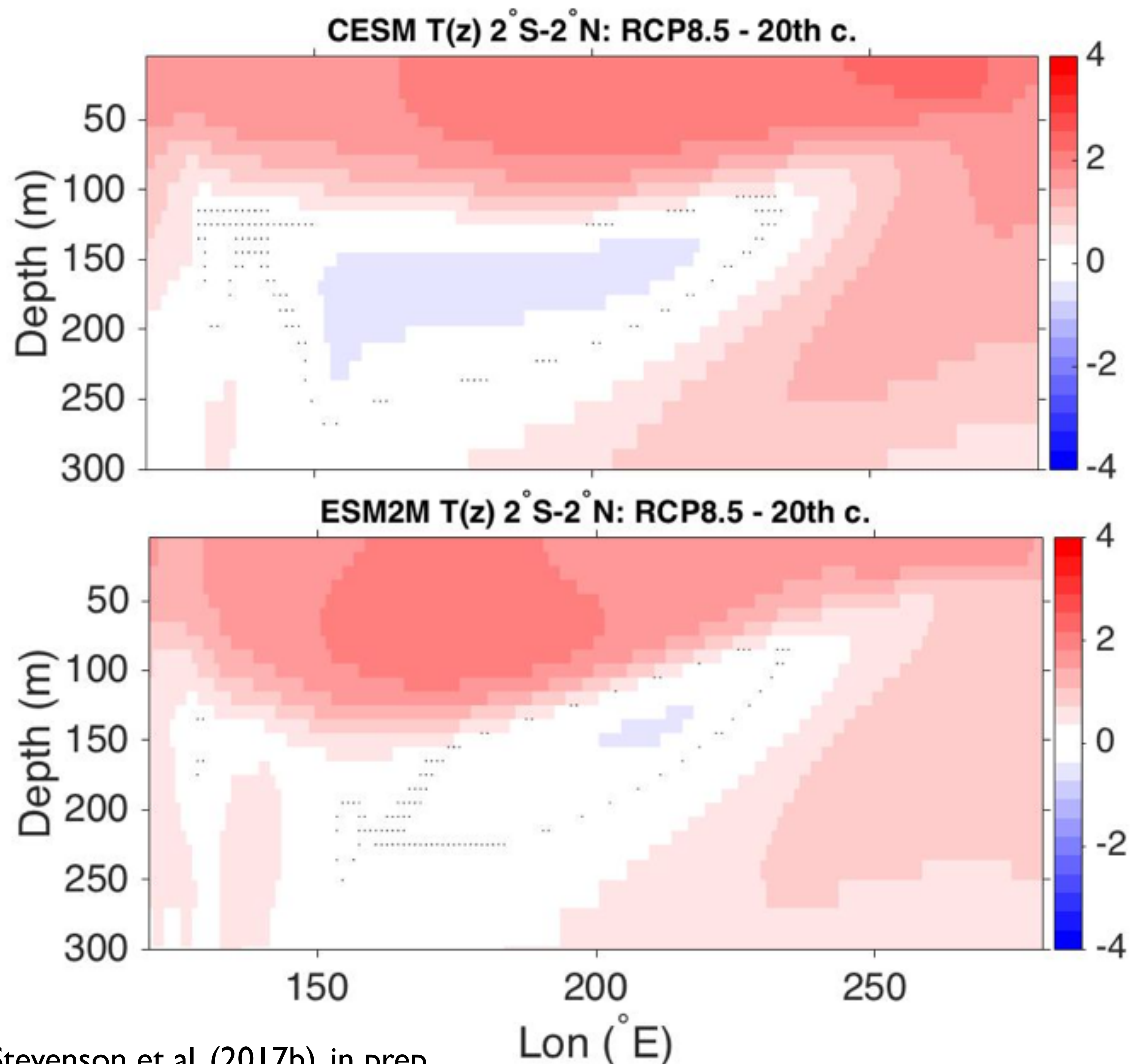
Important observational target: air-sea fluxes

Off-equatorial air/sea fluxes in precursor regions



TPOS2020 First Report

Important observational target: vertical temperature structure



Stevenson et al. (2017b), in prep

CESM: zonal SST gradient weakens, vertical stratification increases

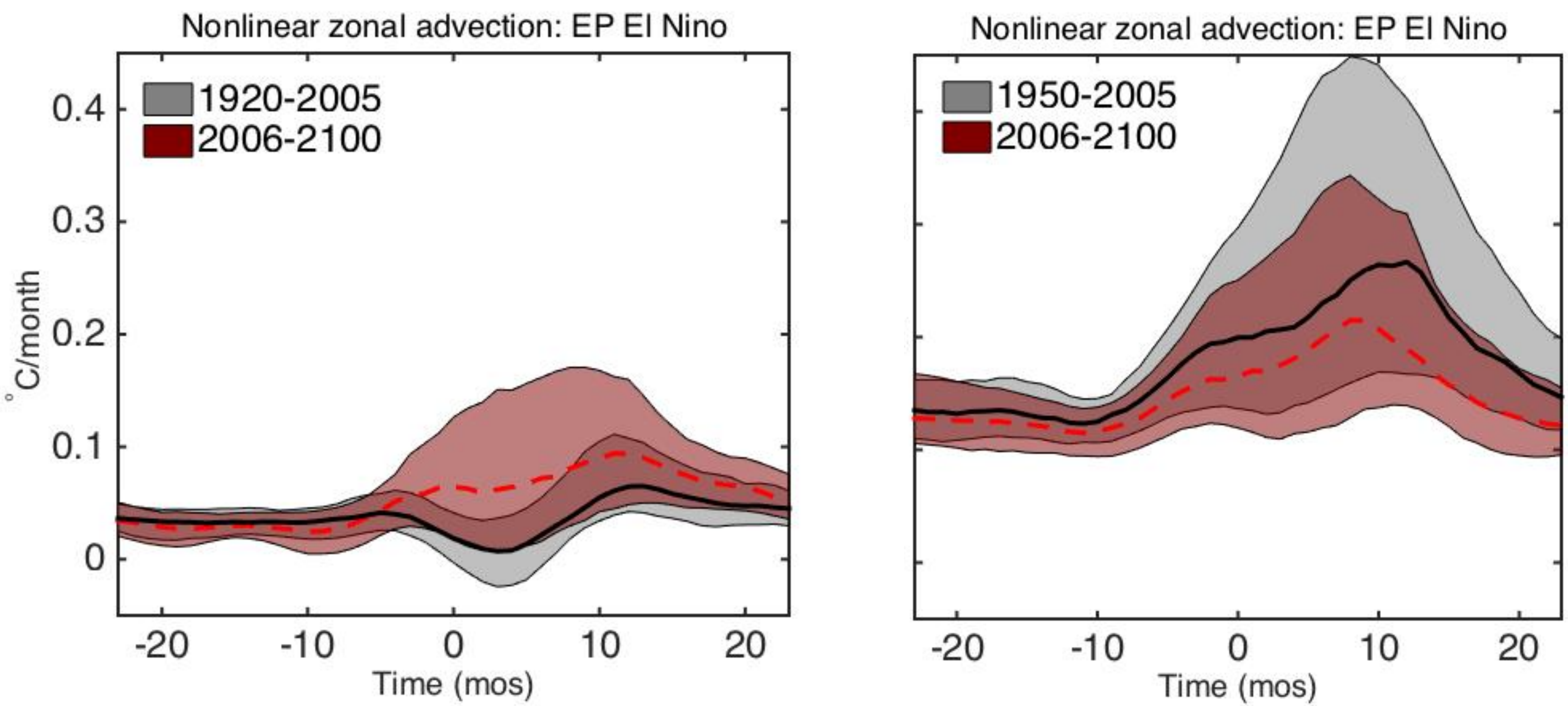
ESM2M: zonal SST gradient strengthens, vertical stratification doesn't increase as much as CESM

Important observational target: mixed-layer eddies

$-u' \cdot \nabla T'$

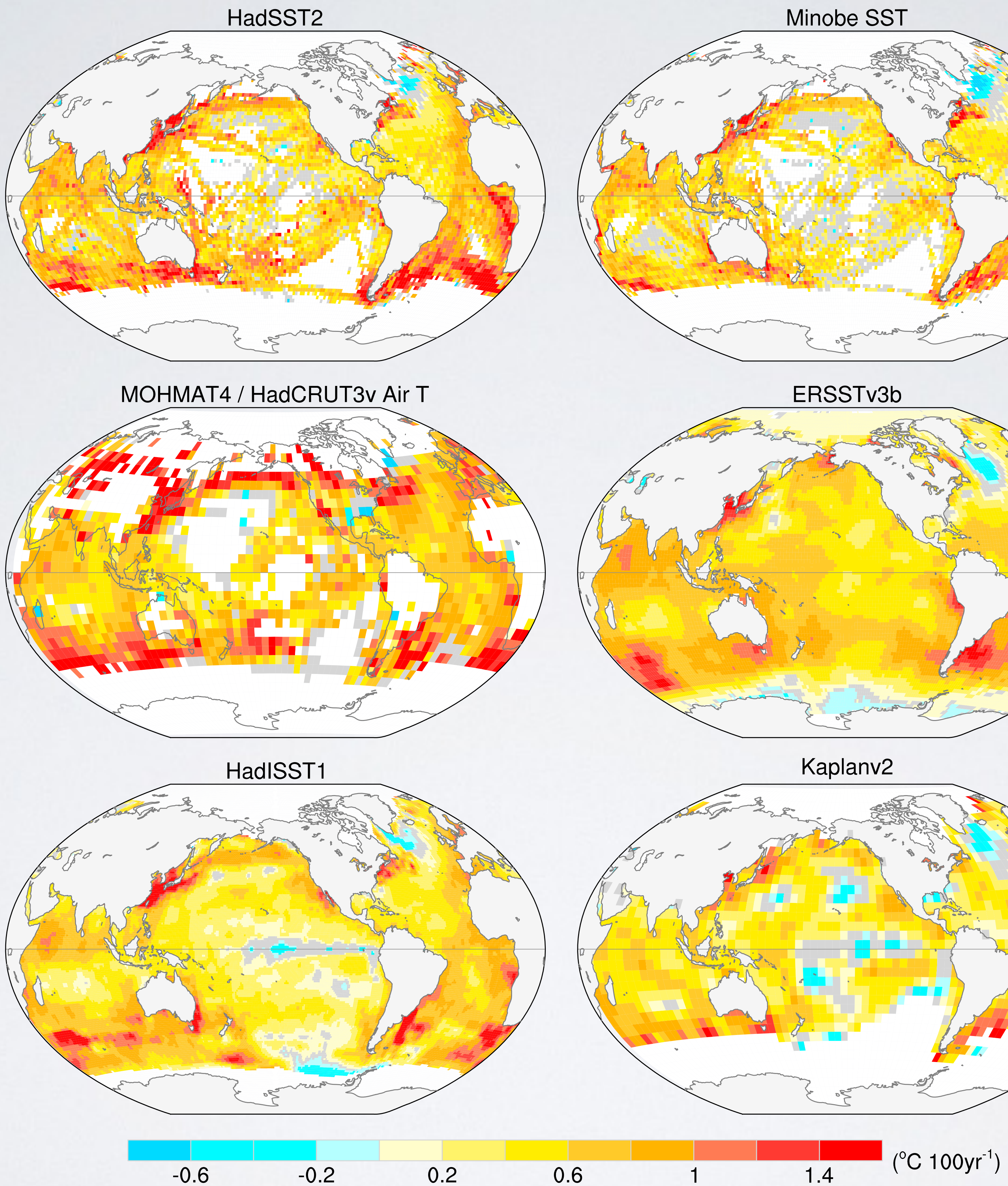
Nonlinear zonal advection: anomalous advection of anomalous gradient
NINO3: Eastern Pacific El Niño

CESM **ESM2M**



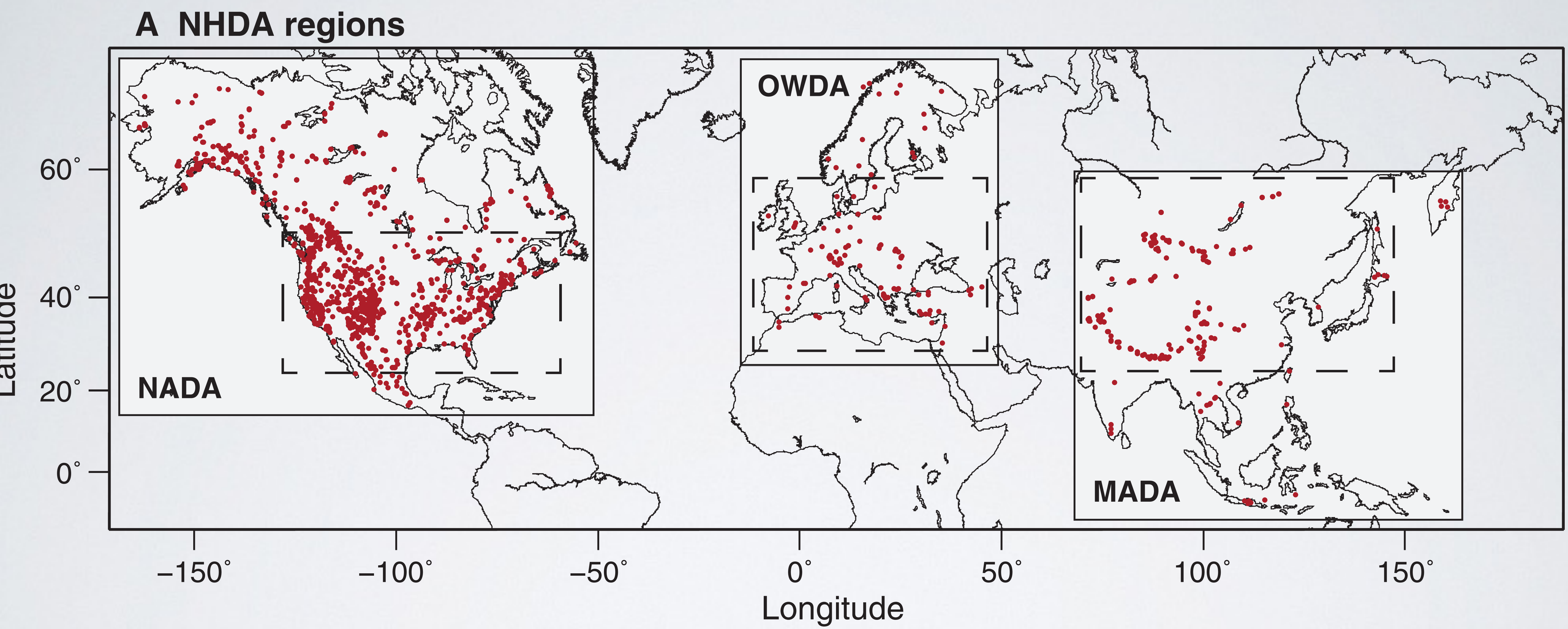
Stevenson et al. (2017b), in prep

Also critical: improving long-term 20th c. estimates



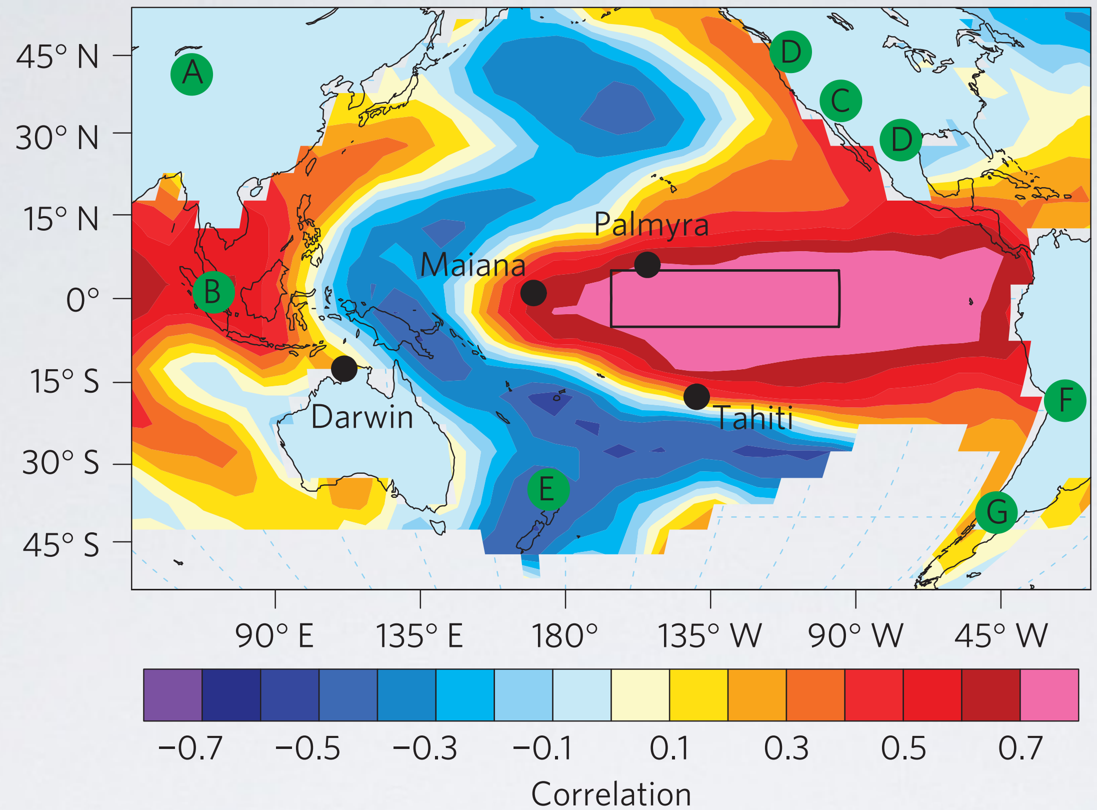
Deser et al. (2010)

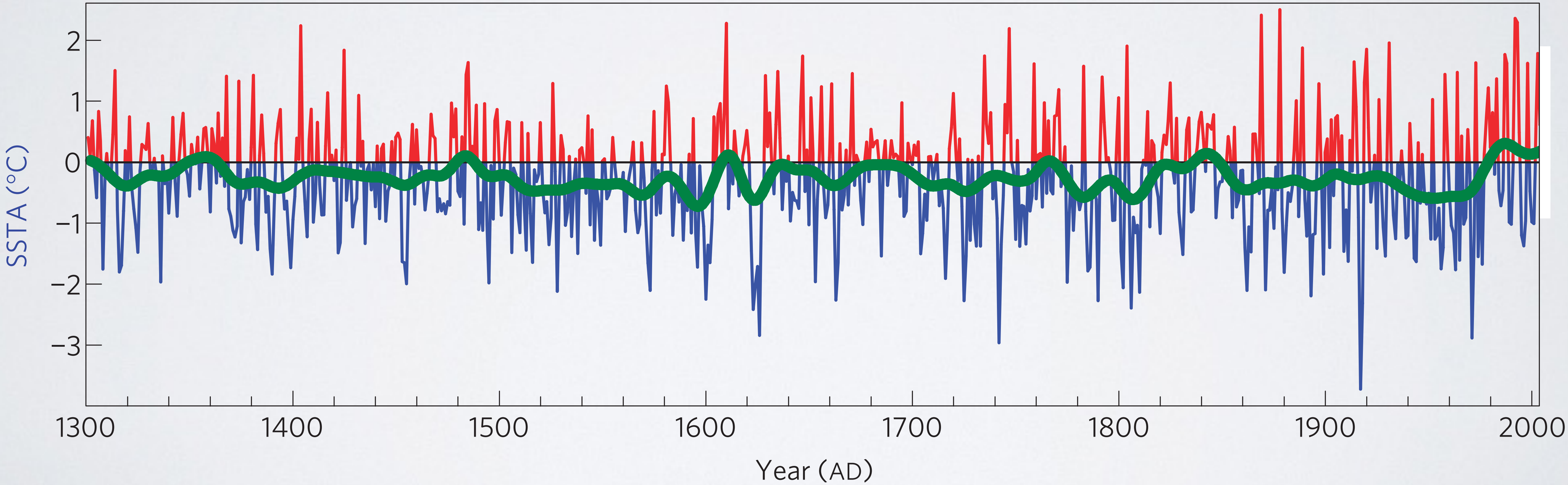
Paleoclimate: key piece of the puzzle



Cook et al. (2015)

Paleoclimate: key piece of the puzzle





Li et al. (2013)

Conclusions

21st c. teleconnected responses governed by changes to modal amplitude, atmospheric responses to SST variability

- Some teleconnection responses are robust across models (El Nino impacts), some may not be
- Anthropogenic forcing is extremely complex, implemented differently across models: e.g. details of land-use changes, aerosol microphysics
- CMIP6-endorsed MIPs may help clarify some issues, as may observational process studies