Patterns of sea-level change in the altimeter record as compared to CMIP6 historical simulations

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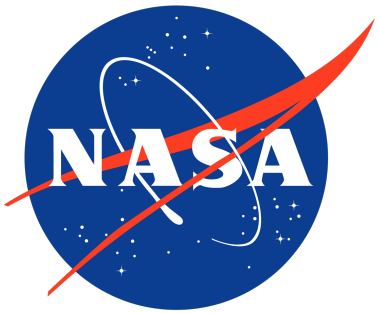
Ocean Surface Topography
Science Team Meeting
November 10, 2023



Jet Propulsion Laboratory

Has the forced pattern of sea level change in the altimeter record has emerged from internal variability?

RESEARCH ARTICLE | EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES |

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John T. Fasullo and R. Steven Nerem Authors Info & Affiliations

Edited by Anny Cazenave, Centre National d'Etudes Spatiales, Toulouse, France, and approved November 5, 2018 (received for review July 31, 2018)

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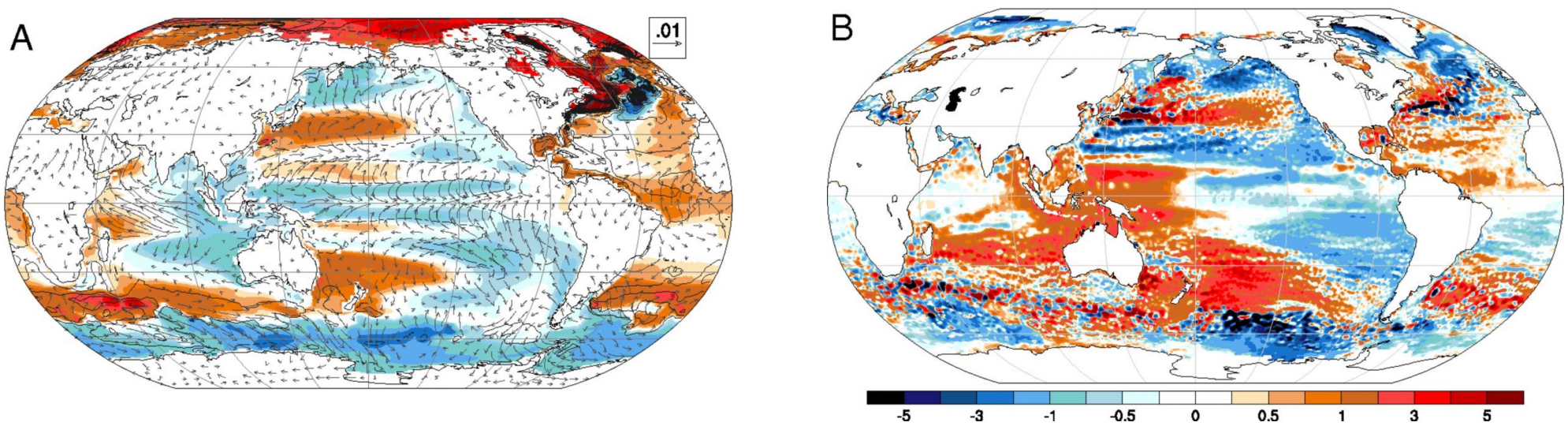

Has the forced pattern of sea level change in the altimeter record has emerged from internal variability?

What do state-of-the-art climate models say?

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Model Name
ACCESS-CM2
ACCESS-ESM1-5
CAMS-CSM1-0
CESM2-FV2
CESM2-WACCM
CESM2-WACCM-FV2
CIESM
CMCC-CM2-HR4
CMCC-CM2-SR5
CMCC-ESM2
CNRM-CM6-1-HR
CanESM5-CanOE
EC-Earth3
EC-Earth3-AerChem
EC-Earth3-CC
EC-Earth3-Veg
EC-Earth3-Veg-LR
FIO-ESM-2-0
GFDL-CM4
HadGEM3-GC31-LL
HadGEM3-GC31-MM
MIROC-ES2L
MPI-ESM-1-2-HAM
MPI-ESM1-2-HR
MPI-ESM1-2-LR
MRI-ESM2-0
NESM3
NorCPM1
NorESM2-LM
SAM0-UNICON
TaiESM1
UKESM1-0-LL
Total: 32

What do state-of-the-art climate models say?

Model Name	# Ens. Members
ACCESS-CM2	3
ACCESS-ESM1-5	19
CAMS-CSM1-0	3
CESM2-FV2	3
CESM2-WACCM	3
CESM2-WACCM-FV2	3
CIESM	3
CMCC-CM2-HR4	1
CMCC-CM2-SR5	1
CMCC-ESM2	1
CNRM-CM6-1-HR	1
CanESM5-CanOE	3
EC-Earth3	22
EC-Earth3-AerChem	2
EC-Earth3-CC	1
EC-Earth3-Veg	6
EC-Earth3-Veg-LR	3
FIO-ESM-2-0	3
GFDL-CM4	1
HadGEM3-GC31-LL	4
HadGEM3-GC31-MM	4
MIROC-ES2L	10
MPI-ESM-1-2-HAM	3
MPI-ESM1-2-HR	10
MPI-ESM1-2-LR	10
MRI-ESM2-0	5
NESM3	5
NorCPM1	13
NorESM2-LM	3
SAM0-UNICON	1
TaiESM1	1
UKESM1-0-LL	17
Total: 32	**Total: 168**

What do state-of-the-art climate models say?

Model Name	# Ens. Members	Preind. Control
ACCESS-CM2	3	500 yrs
ACCESS-ESM1-5	19	900 yrs
CAMS-CSM1-0	3	500 yrs
CESM2-FV2	3	500 yrs
CESM2-WACCM	3	499 yrs
CESM2-WACCM-FV2	3	500 yrs
CIESM	3	500 yrs
CMCC-CM2-HR4	1	
CMCC-CM2-SR5	1	500 yrs
CMCC-ESM2	1	
CNRM-CM6-1-HR	1	300 yrs
CanESM5-CanOE	3	501 yrs
EC-Earth3	22	
EC-Earth3-AerChem	2	
EC-Earth3-CC	1	
EC-Earth3-Veg	6	
EC-Earth3-Veg-LR	3	501 yrs
FIO-ESM-2-0	3	575 yrs
GFDL-CM4	1	500 yrs
HadGEM3-GC31-LL	4	500 yrs
HadGEM3-GC31-MM	4	500 yrs
MIROC-ES2L	10	500 yrs
MPI-ESM-1-2-HAM	3	
MPI-ESM1-2-HR	10	500 yrs
MPI-ESM1-2-LR	10	1000 yrs
MRI-ESM2-0	5	701 yrs
NESM3	5	500 yrs
NorCPM1	13	500 yrs
NorESM2-LM	3	
SAM0-UNICON	1	700 yrs
TaiESM1	1	
UKESM1-0-LL	17	1880 yrs
Total: 32	**Total: 168**	**Tot: 23, Avg: 615 yrs**

What do state-of-the-art climate models say?

Model Name	# Ens. Members	Preind. Control	~Grid Spacing
ACCESS-CM2	3	500 yrs	300 x 360
ACCESS-ESM1-5	19	900 yrs	300 x 360
CAMS-CSM1-0	3	500 yrs	200 x 360
CESM2-FV2	3	500 yrs	384 x 320
CESM2-WACCM	3	499 yrs	384 x 320
CESM2-WACCM-FV2	3	500 yrs	384 x 320
CIESM	3	500 yrs	384 x 320
CMCC-CM2-HR4	1		1051 x 1442
CMCC-CM2-SR5	1	500 yrs	292 x 362
CMCC-ESM2	1		292 x 362
CNRM-CM6-1-HR	1	300 yrs	1050 x 1442
CanESM5-CanOE	3	501 yrs	291 x 360
EC-Earth3	22		292 x 362
EC-Earth3-AerChem	2		292 x 362
EC-Earth3-CC	1		292 x 362
EC-Earth3-Veg	6		292 x 362
EC-Earth3-Veg-LR	3	501 yrs	292 x 362
FIO-ESM-2-0	3	575 yrs	384 x 320
GFDL-CM4	1	500 yrs	1080 x 1440
HadGEM3-GC31-LL	4	500 yrs	330 x 360
HadGEM3-GC31-MM	4	500 yrs	1205 x 1440
MIROC-ES2L	10	500 yrs	256 x 360
MPI-ESM-1-2-HAM	3		220 x 256
MPI-ESM1-2-HR	10	500 yrs	404 x 802
MPI-ESM1-2-LR	10	1000 yrs	220 x 256
MRI-ESM2-0	5	701 yrs	363 x 360
NESM3	5	500 yrs	292 x 362
NorCPM1	13	500 yrs	384 x 320
NorESM2-LM	3		385 x 360
SAM0-UNICON	1	700 yrs	384 x 320
TaiESM1	1		384 x 320
UKESM1-0-LL	17	1880 yrs	330 x 360
Total: 32	**Total: 168**	**Tot: 23, Avg: 615 yrs**	**Average: 416 x 489**

What do state-of-the-art climate models say?

Workflow:

-Regrid to an even 1 by 1 grid

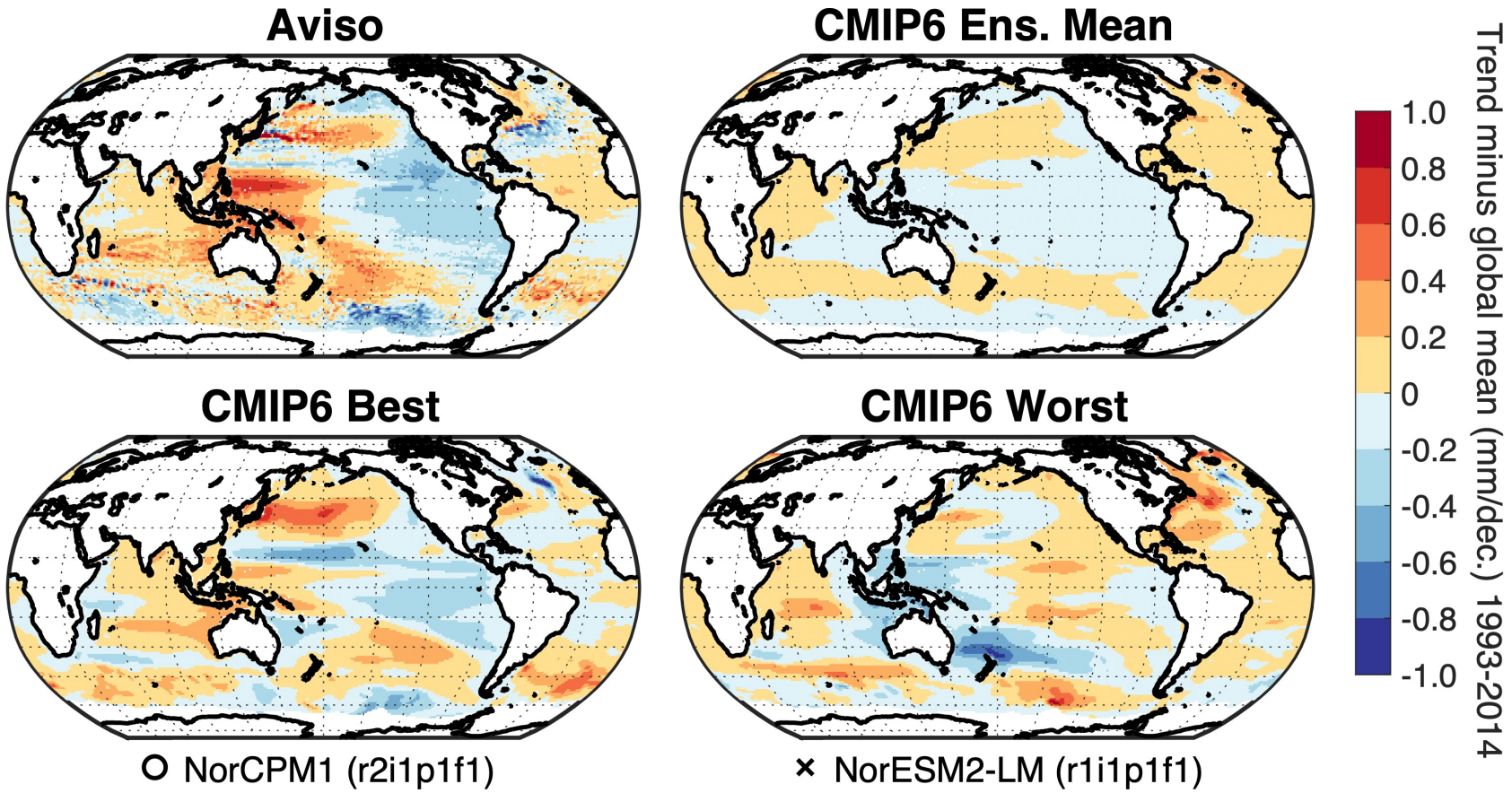
-Take yearly average (as per Fasullo and Nerem)

-Clip to 1993-2014 (overlapping period with altimeter record)

-Calculate linear trend (cm/dec. or m) at each grid point to produce a trend pattern

-Remove global trend (as per Fasullo and Nerem)

What do state-of-the-art climate models say?



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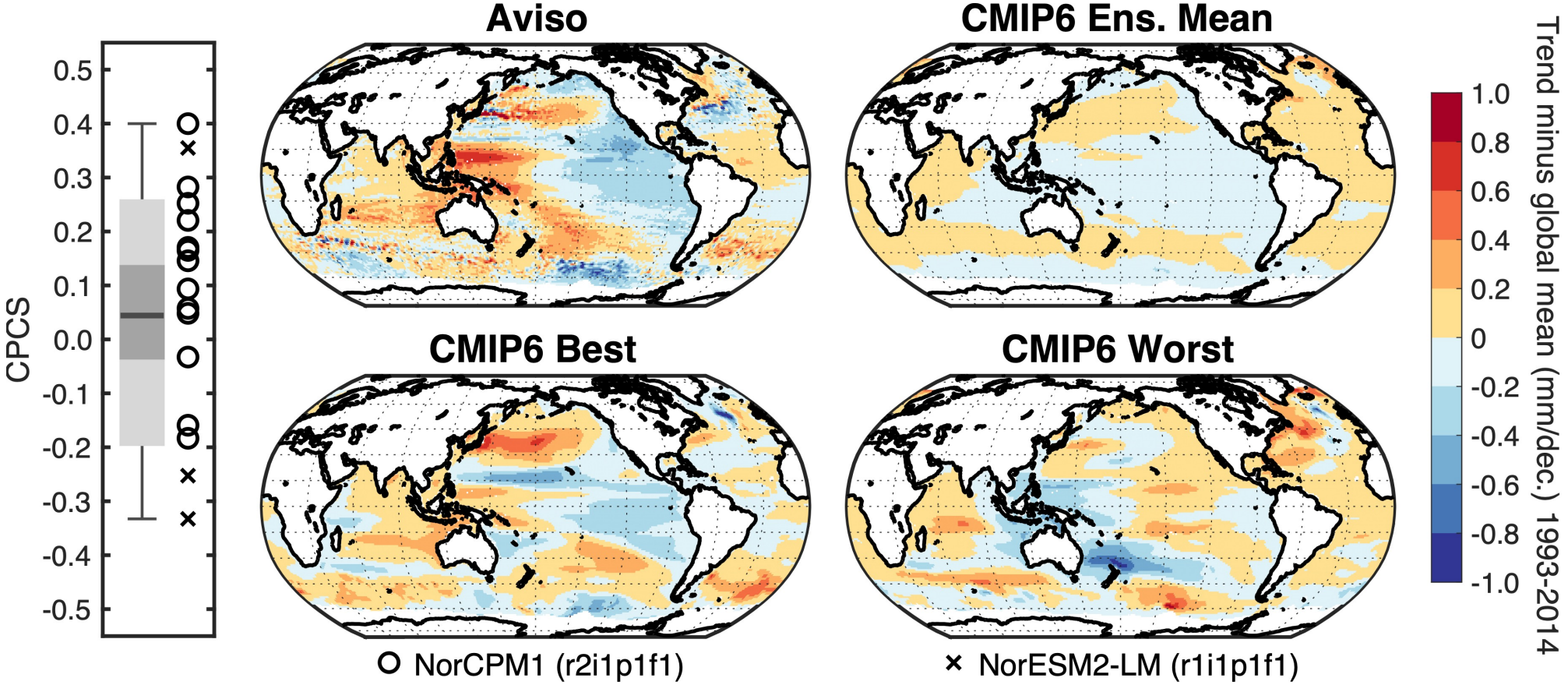

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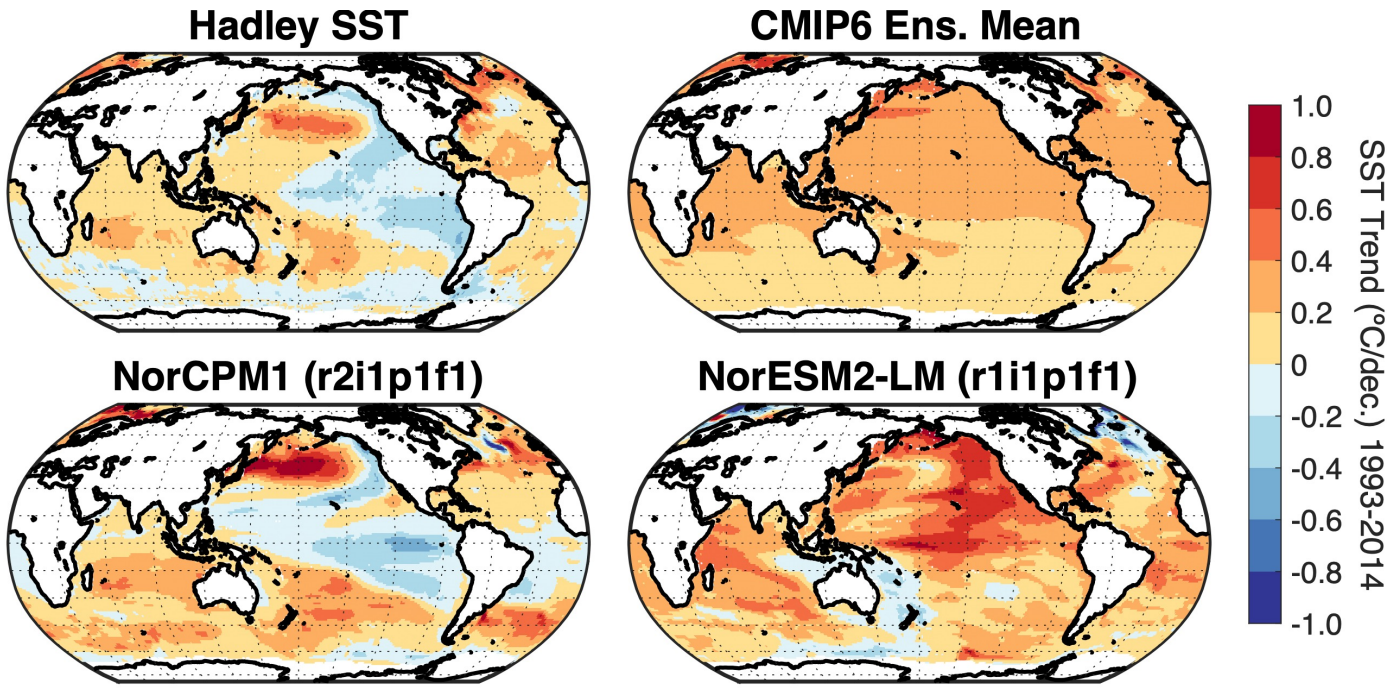

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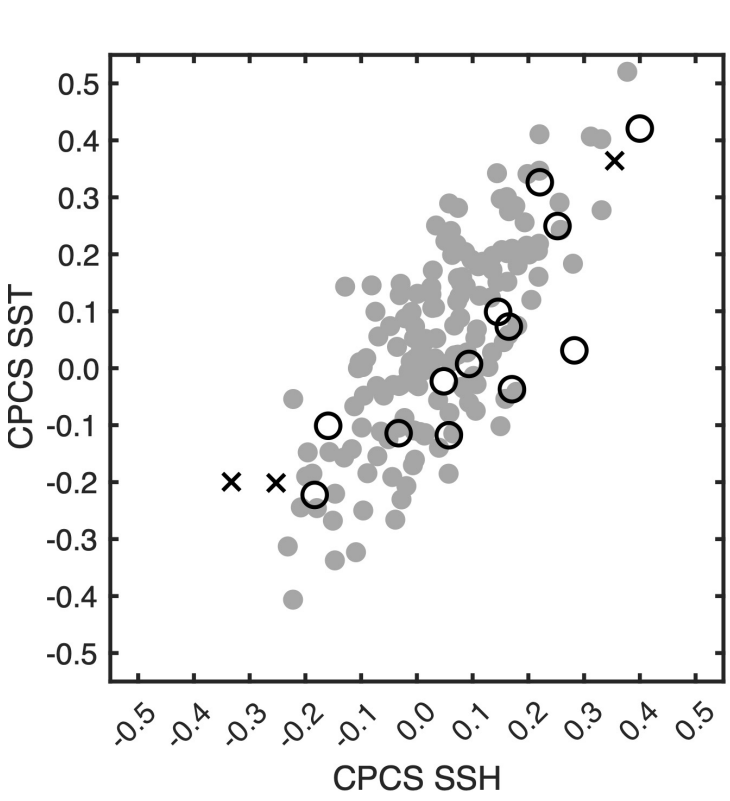

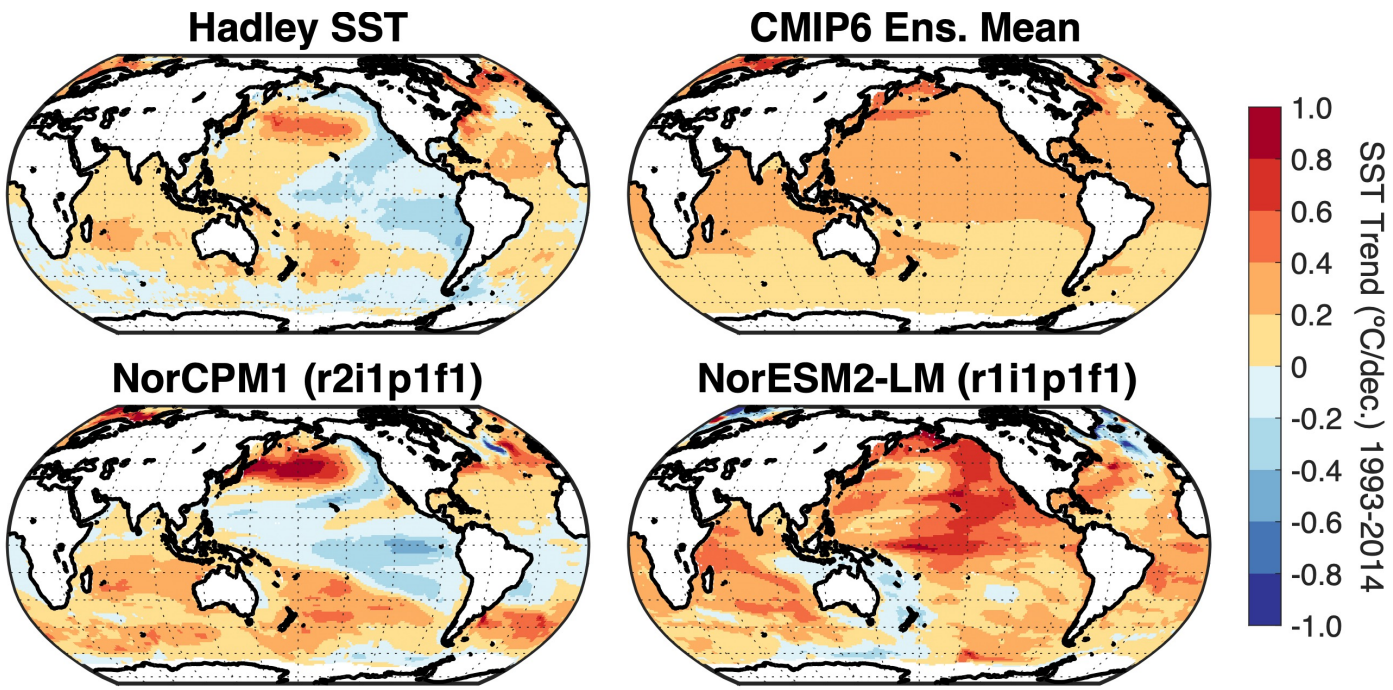

What is driving the inter-simulation spread?

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Workflow:

-Compute trajectory of modes from 1993-2014 (ENSO, AMO, PDO, NAM, SAM, etc.)

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-Compute trajectory of modes from 1993-2014 (ENSO, AMO, PDO, NAM, SAM, etc.)

-Compare to trajectory of modes in simulations to observations using linear correlation

What is driving the inter-simulation spread?

Workflow:

-Compute trajectory of modes from 1993-2014 (ENSO, AMO, PDO, NAM, SAM, etc.)

-Compare to trajectory of modes in simulations to observations using linear correlation

-Can trajectory of modes explain sea level trend spatial patterns?

Stepwise linear regression

Correlation coefficient for modes of variability as independent variables

CPCS values for sea level trend pattern as dependent variable

What is driving the inter-simulation spread?

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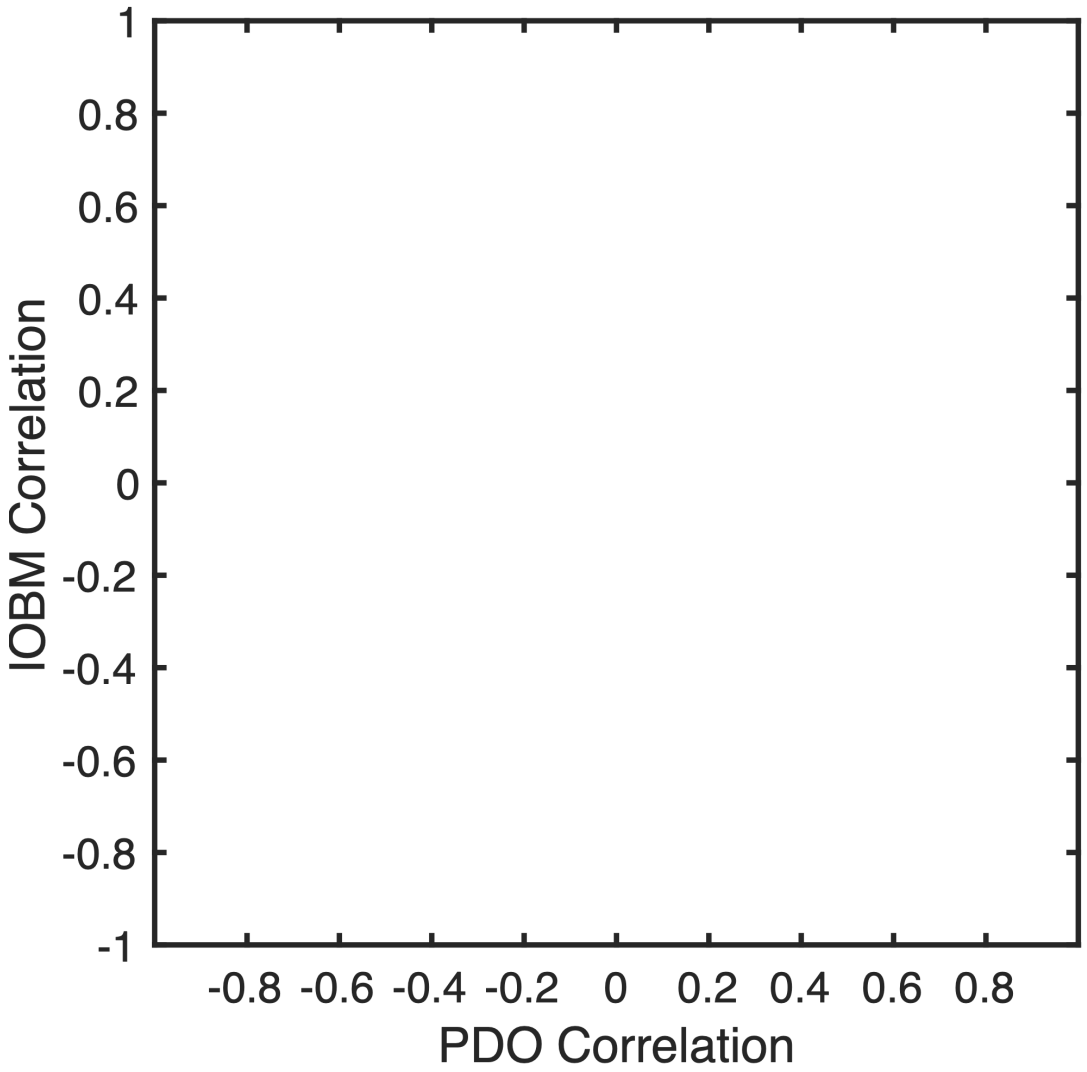

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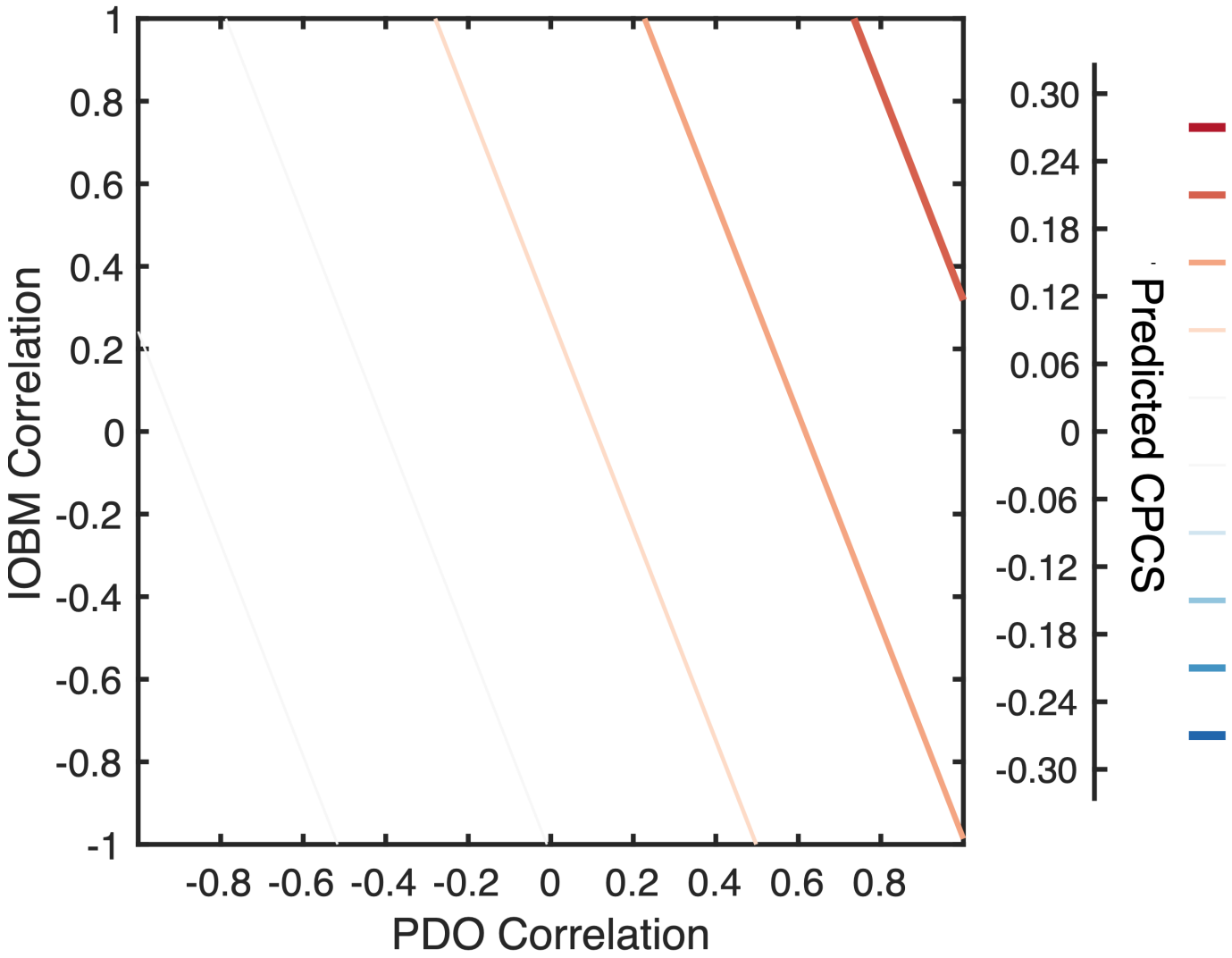

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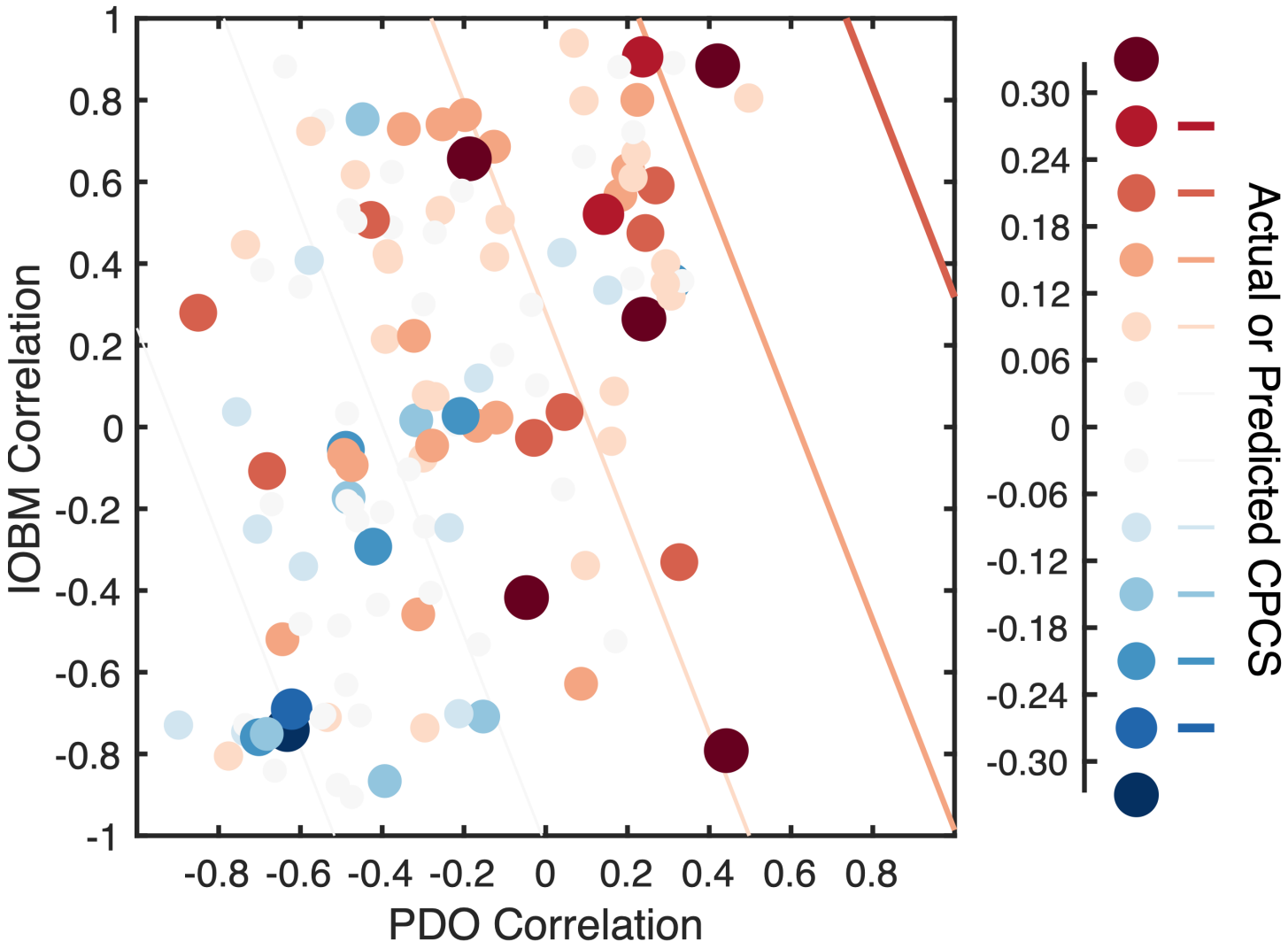


In what regions are sea level trends emerging?

Workflow:

-Regrid to an even 1 by 1 grid

-Take yearly average

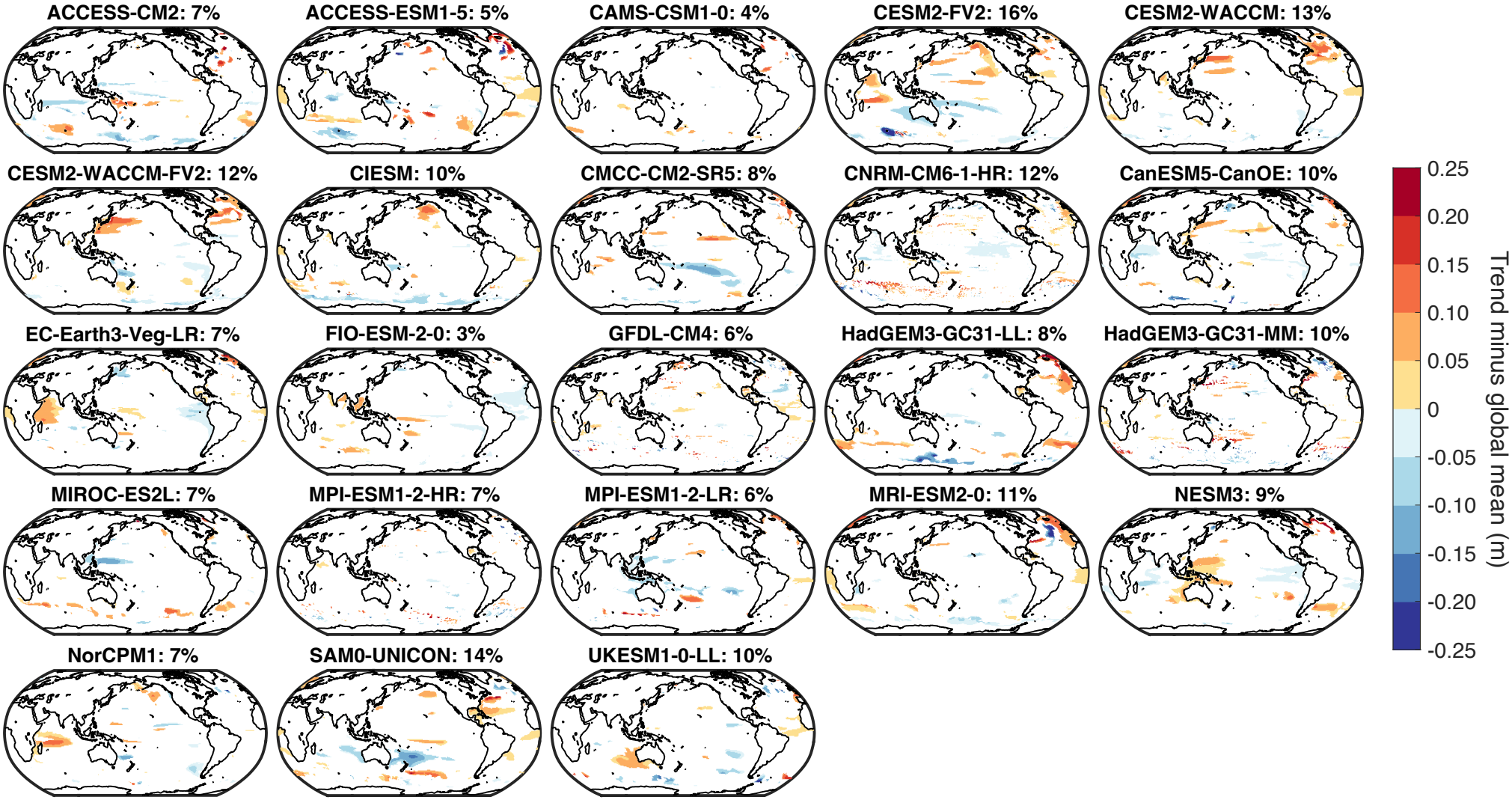
-Clip to 1993-2014 (overlapping period with altimeter record)

-Calculate linear trend (mm/dec. or cm) at each grid point to produce a trend pattern

-Remove global trend (as per Fasullo and Nerem)

-Same workflow above applied to 22 year (length of altimeter record) sliding time periods (slide every ten years) across the preindustrial control simulations

In what regions are sea level trends emerging?



Has the forced pattern of sea level change in the altimeter record has emerged from internal variability?

When will the forced pattern of sea level change emerge from internal variability?