Challenges in Defining the Internal Component of Atlantic Multidecadal Variability in a Changing Climate

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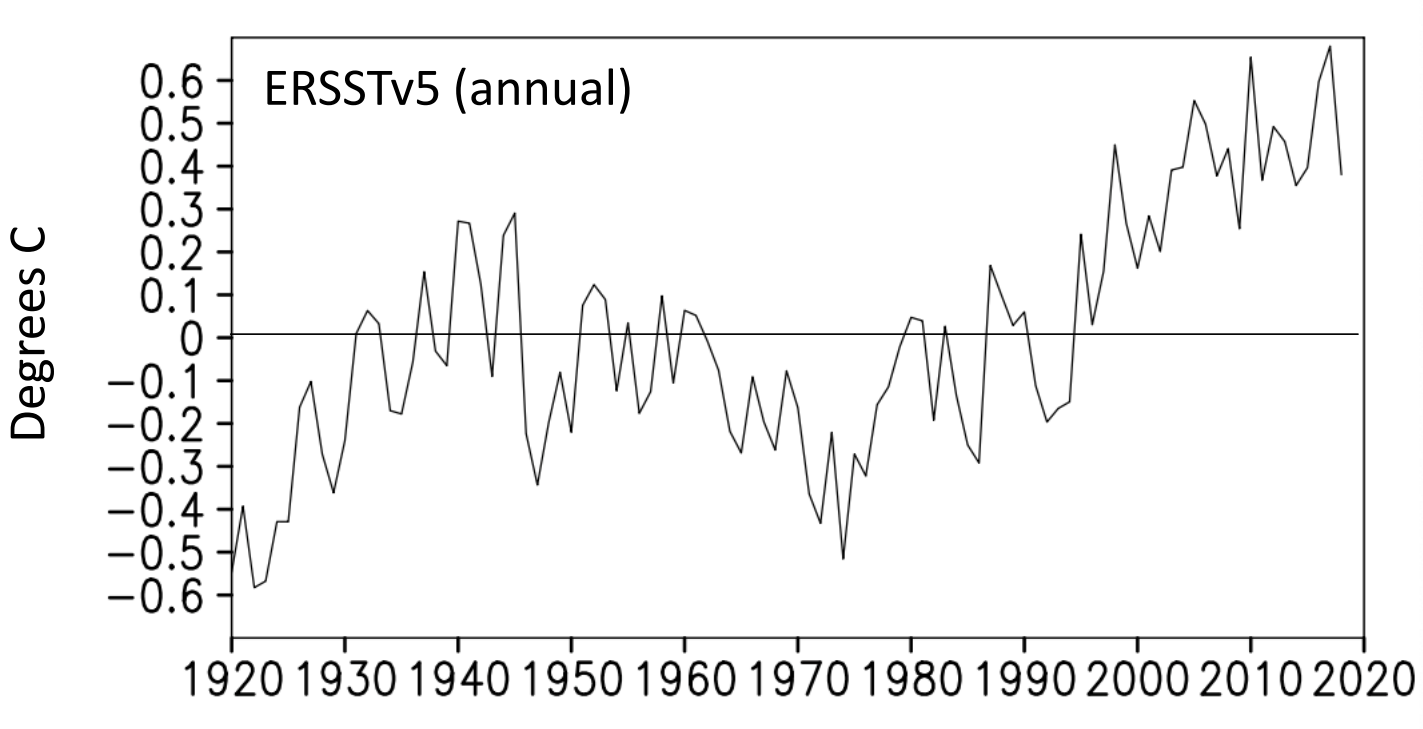
CESM Climate Variability and Change Working Group Meeting
Feb. 17, 2022 (virtual)

Canonical Index of AMV

North Atlantic (0-60N) SSTA(t)

(Enfield et al. 2001)



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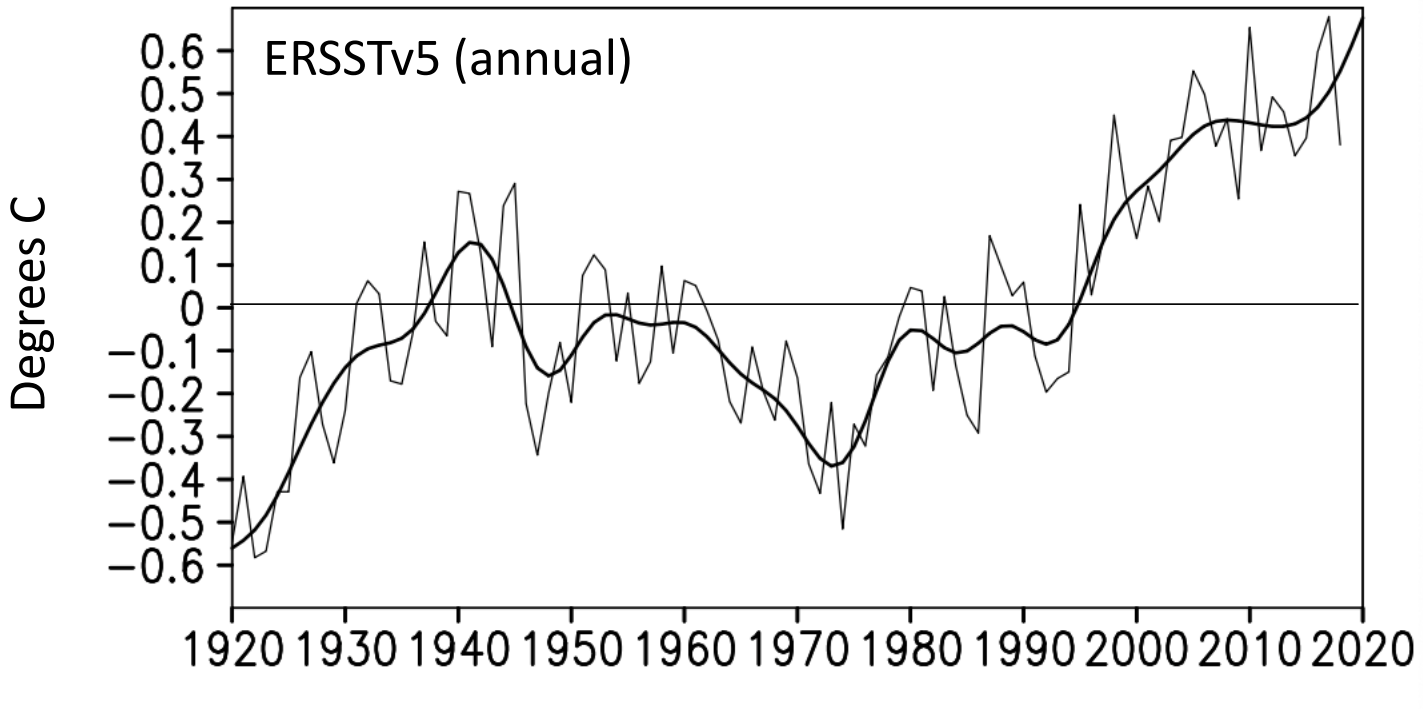

10yr Butterworth Filter

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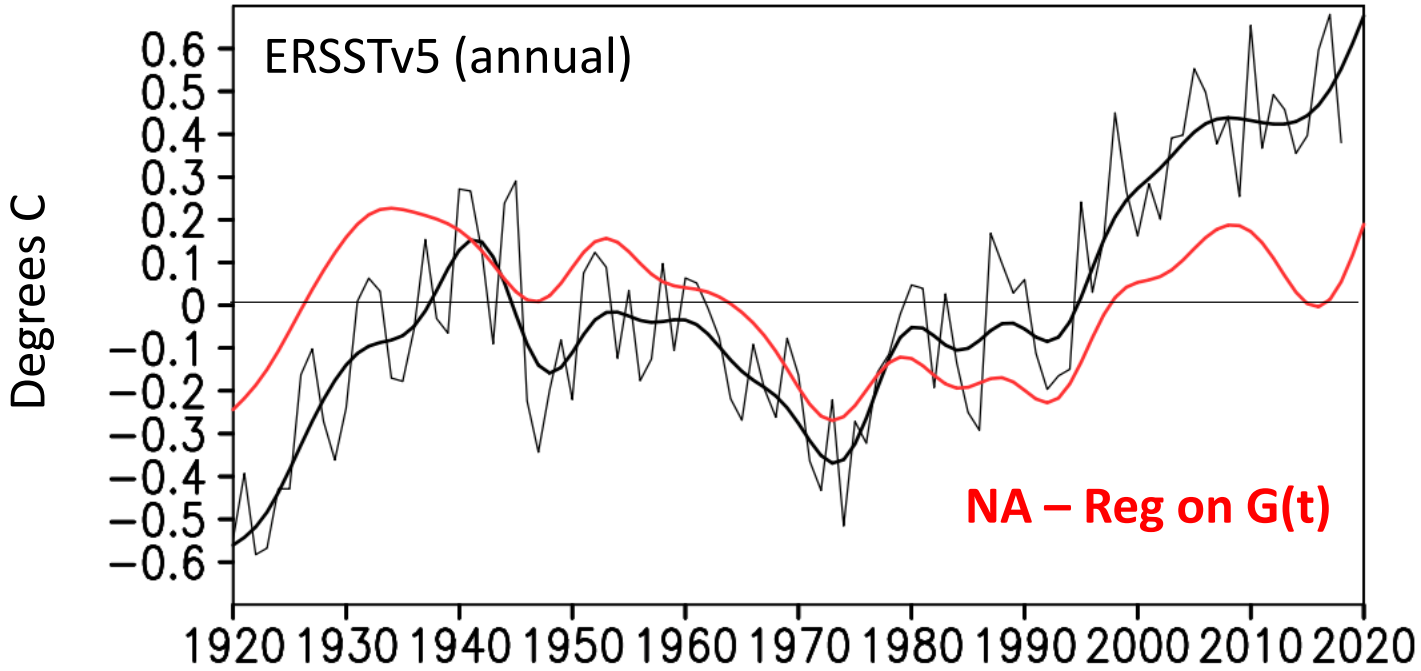

10yr Butterworth Filter

After removing regression on Global Mean SST

(Zhang et al. 2019)

Internal Component

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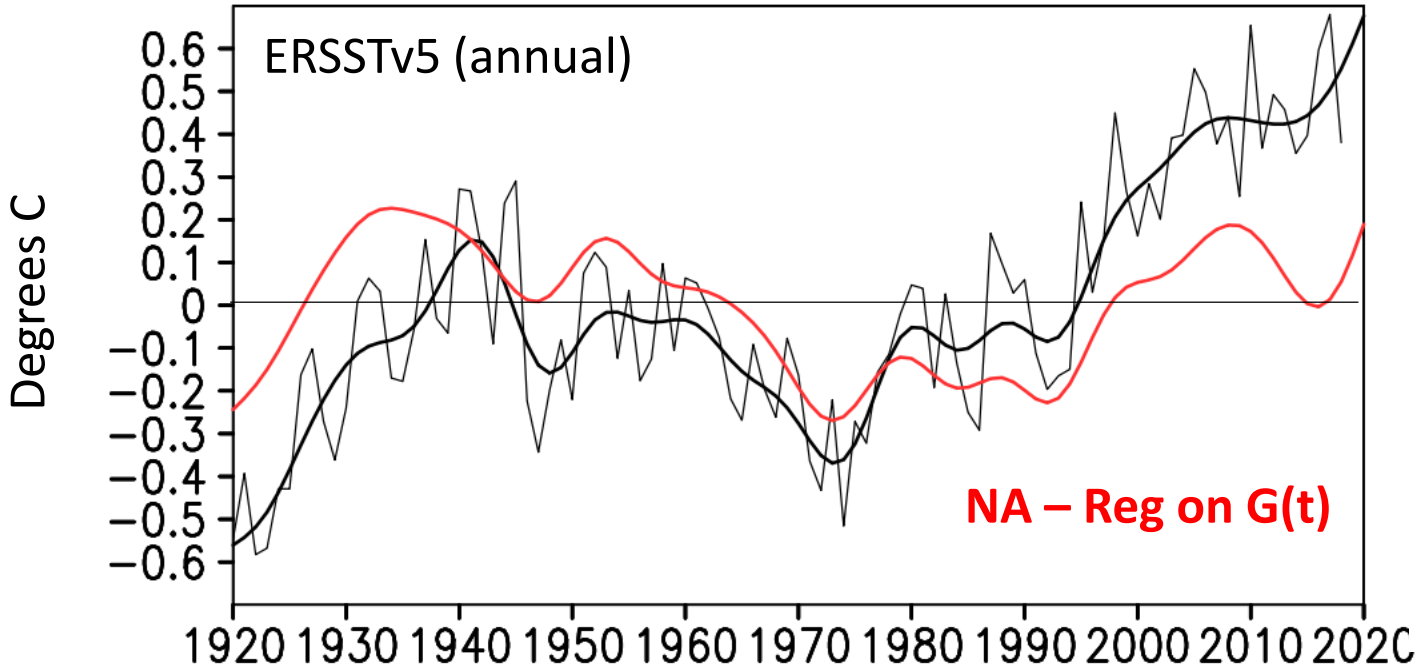

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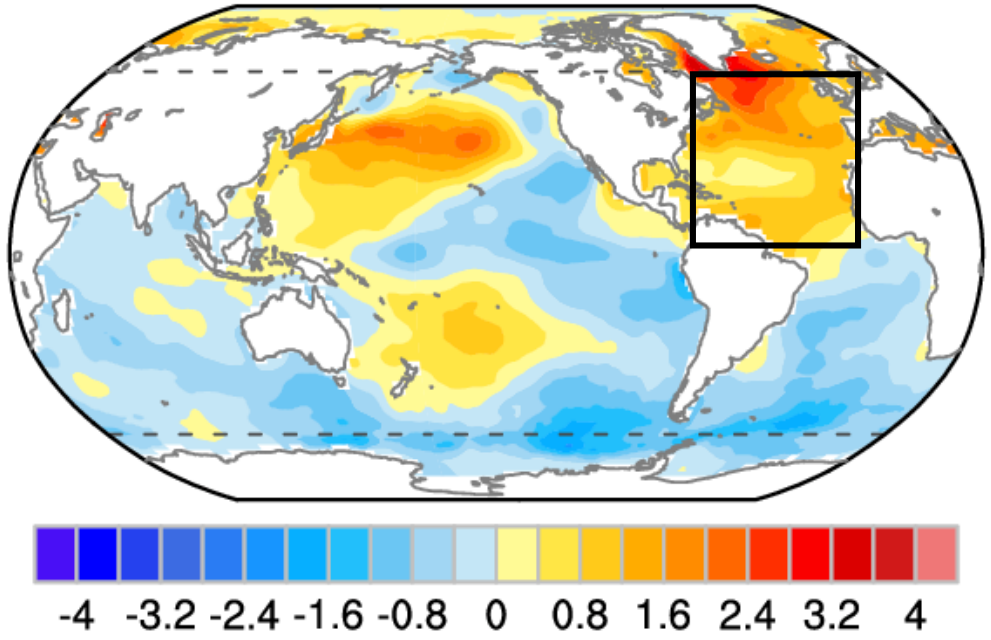
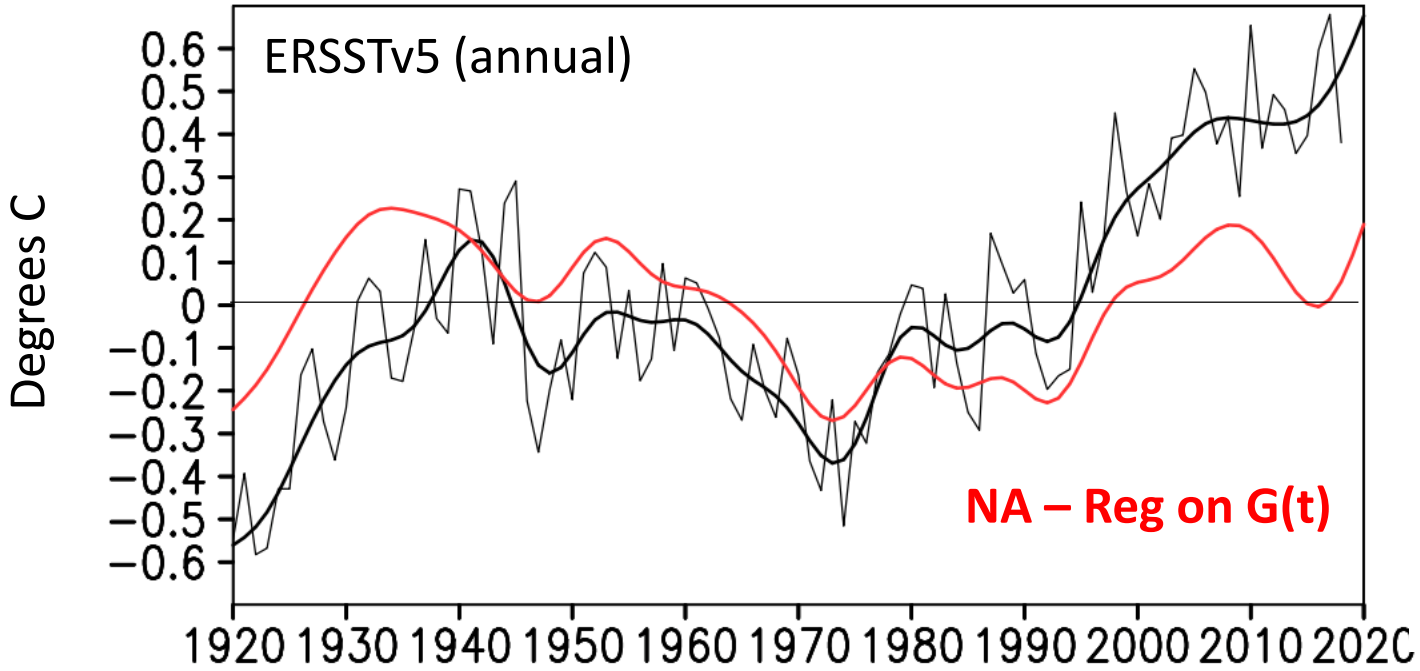


Deser and Phillips (GRL, 2021)

Does this procedure really isolate the internal component of AMV?



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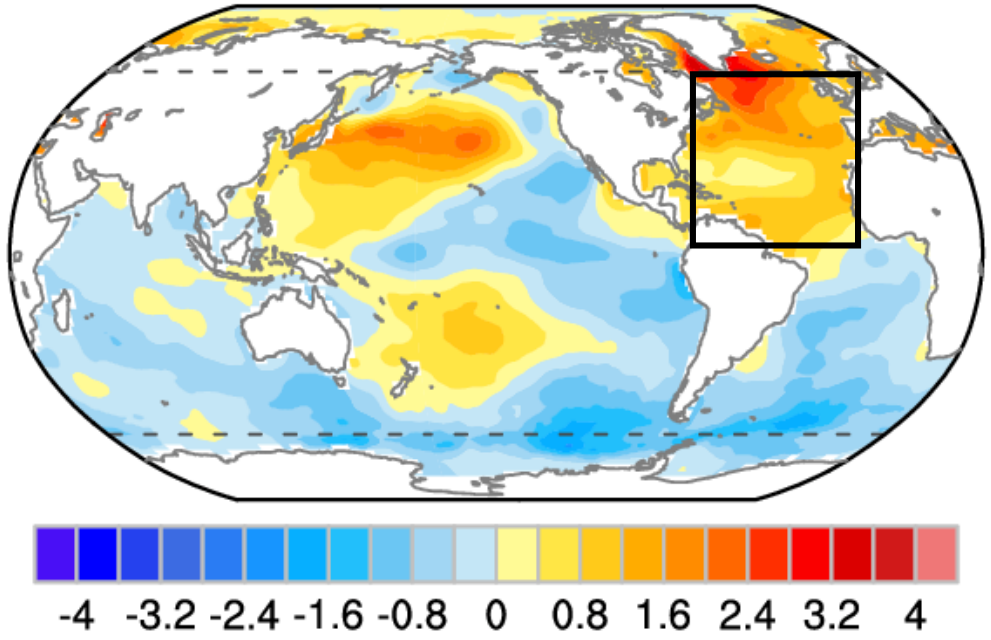

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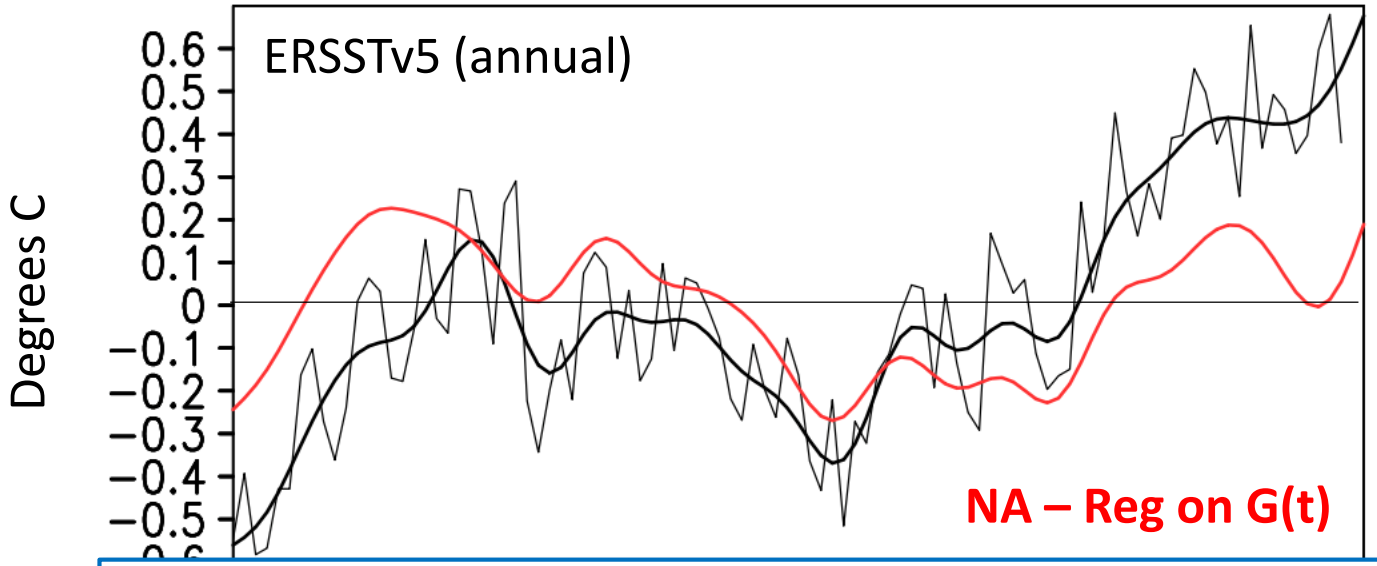
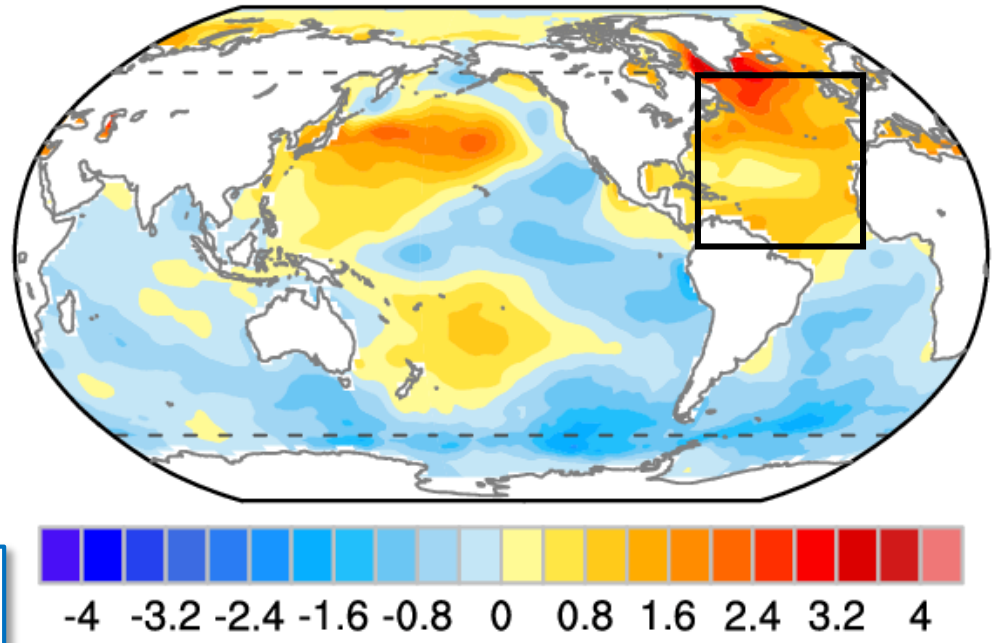


Test with model Large Ensembles, where the true internal variability can be well estimated.

After removing regression on Global Mean SST

Internal Component



Deser and Phillips (GRL, 2021)

Roadmap

Aim is to isolate the internal component of AMV.

Step 1) Use the Residual Method to isolate internal variability (iSSTA).
Step 2) Compute AMV index and associated spatial pattern from iSSTA.
Step 3) Test method accuracy using model Large Ensembles where the true internal variability is known *a priori*.

Roadmap

Aim is to isolate the internal component of AMV.

Step 1) Use the Residual Method to isolate internal variability (iSSTA).

Residual Method

iSSTA(x,y,t) = SSTA(x,y,t) – [Reg of SST(x,y,t) on G(t)]

Global mean SSTA

Estimated forced component

Roadmap

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Note that G(t) contains both forced and internal components

G(t) = fG(t) + iG(t)

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CSIRO (30)
CESM1 (40)
CanESM2 (50)
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7 Model Large Ensembles (430 Members Total)

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Procedure for each model

1a) **True** Internal Variability

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e = ensemble member

EM = ensemble mean

1b) **Estimated** Internal Variability

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2) Regress iSSTA(x,y,t,e) onto iAMV_index(t,e).

3) Average the regression maps across all members.

4) Average the 7 models' average regression maps.

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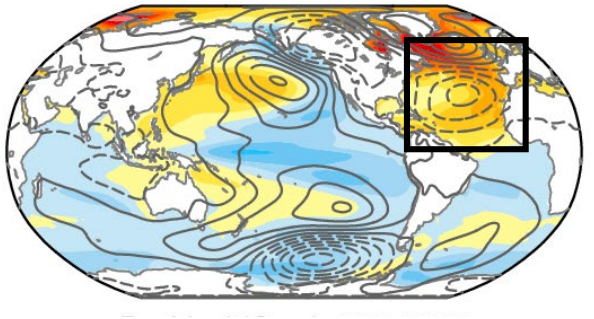
1950-2020 **Estimated**

SST & SLP

iNA (-iG)



-4 -3.2 -2.4 -1.6 -0.8 0 0.8 1.6 2.4 3.2 4

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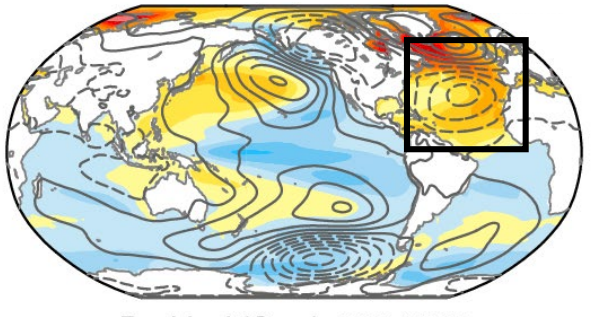

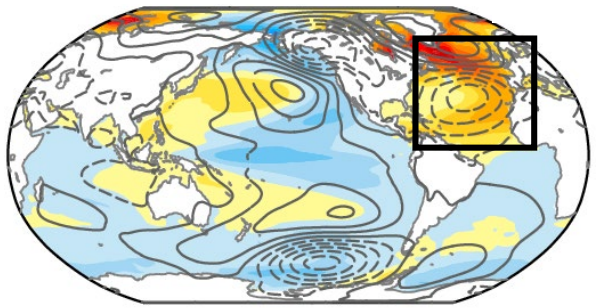

iNA-iG

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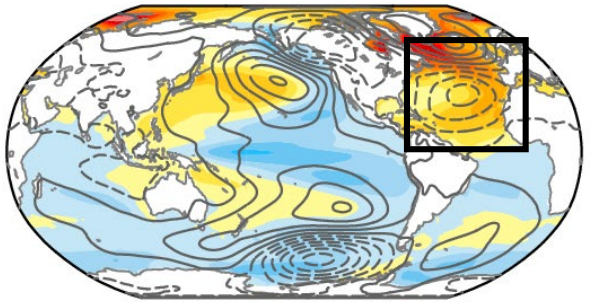

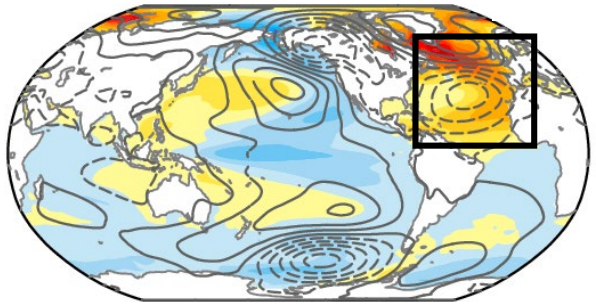

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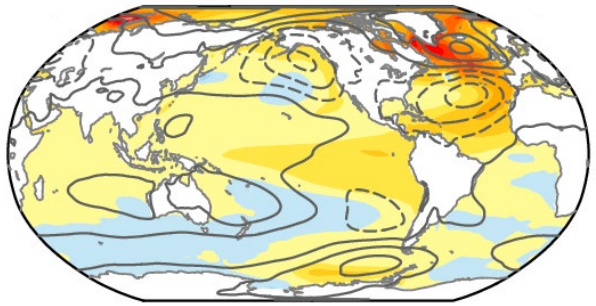

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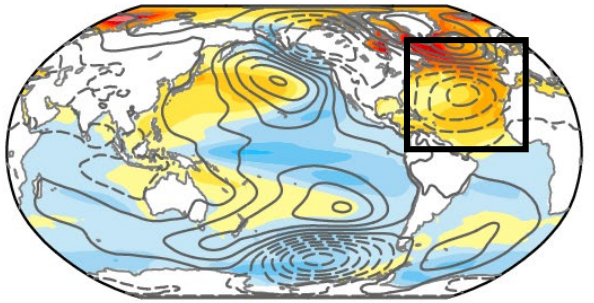

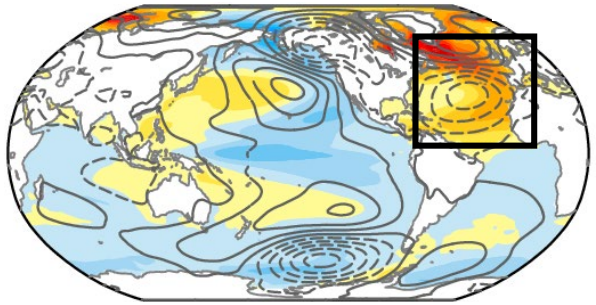

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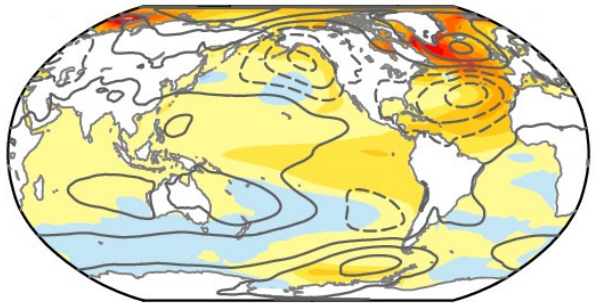

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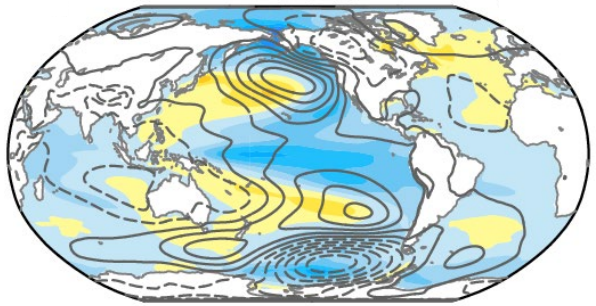
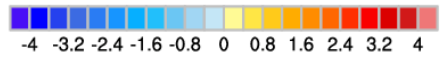


Diff



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SST & SLP

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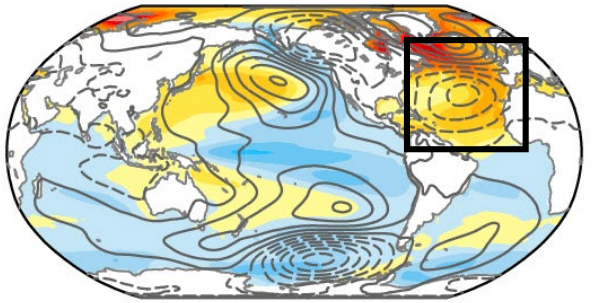

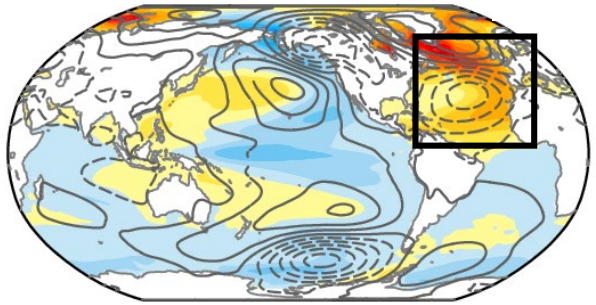

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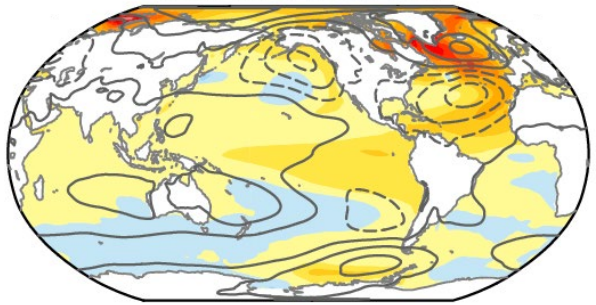

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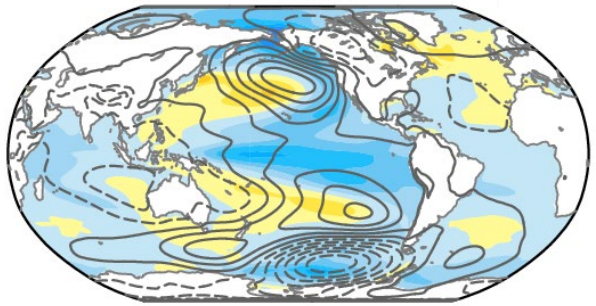

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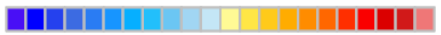

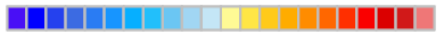

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True
SST & SLP

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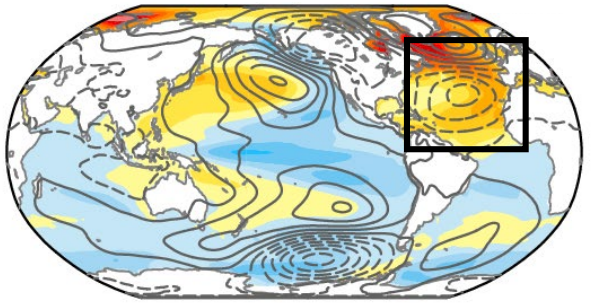

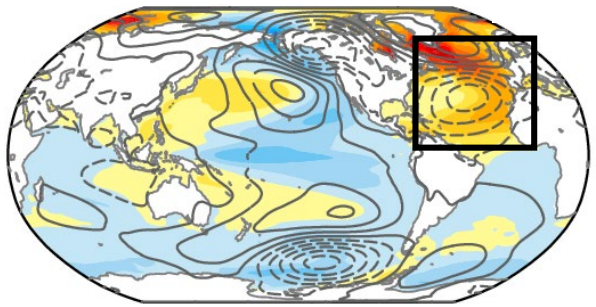

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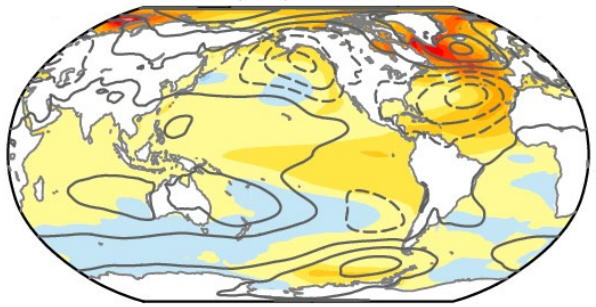

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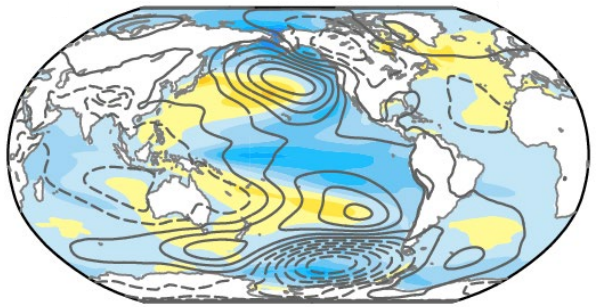

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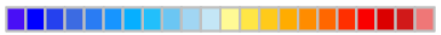

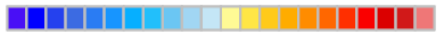

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EM = ense

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Modified Residual method using EM_G(t) (which makes it like iNA)

1950-2020

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SST & SLP

True
SST & SLP

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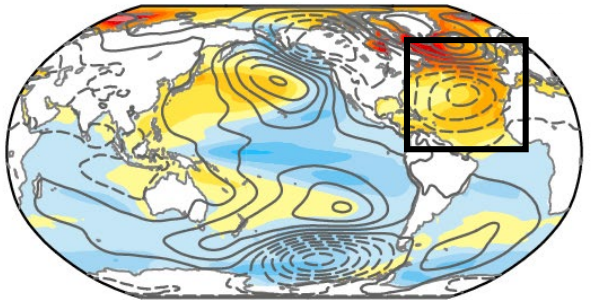
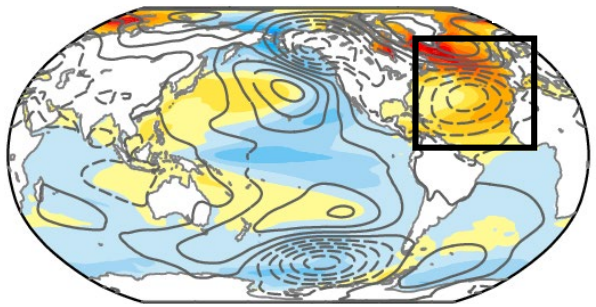
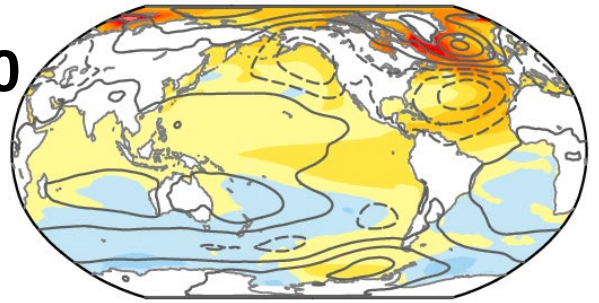


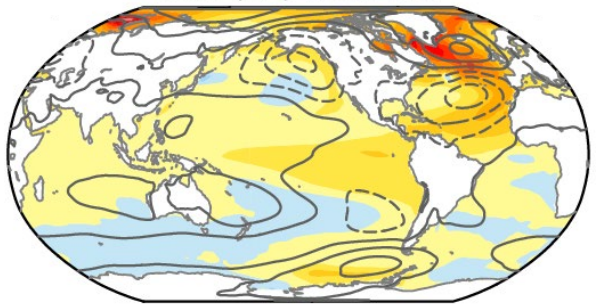


iNA-iG

0

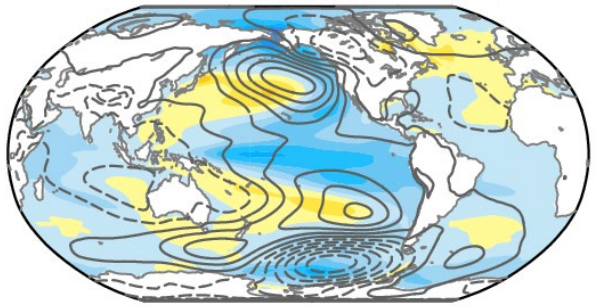
iNA-iG



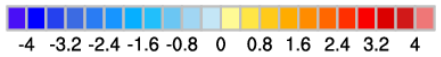


iNA

$[iNA(t) - iG_{NA}(t)] - iG^*(t)$



Diff



7 Model Large Ensembles (430 Members Total)

MPI (100)	MIROC6 (50)
GFDL-ESM2M (30)	CanESM5 (50)
CSIRO (30)	GFDL-SPEAR_MED (30)
CESM1 (40)	CESM2 (50)
CanESM2 (50)	

Procedure for each model

1a) **True** Internal Variability

iSSTA(x,y,t,e) = SSTA(x,y,t,e) – EM_SSTA(x,y,t)

e = ensemble member

EM = ense

1b) **Estimated** In

iSSTA(x,y,t,e) =

[Reg SST(x,y,

2) Regress iSST

iAMV_index(t,e).

3) Average the regression maps across all members.

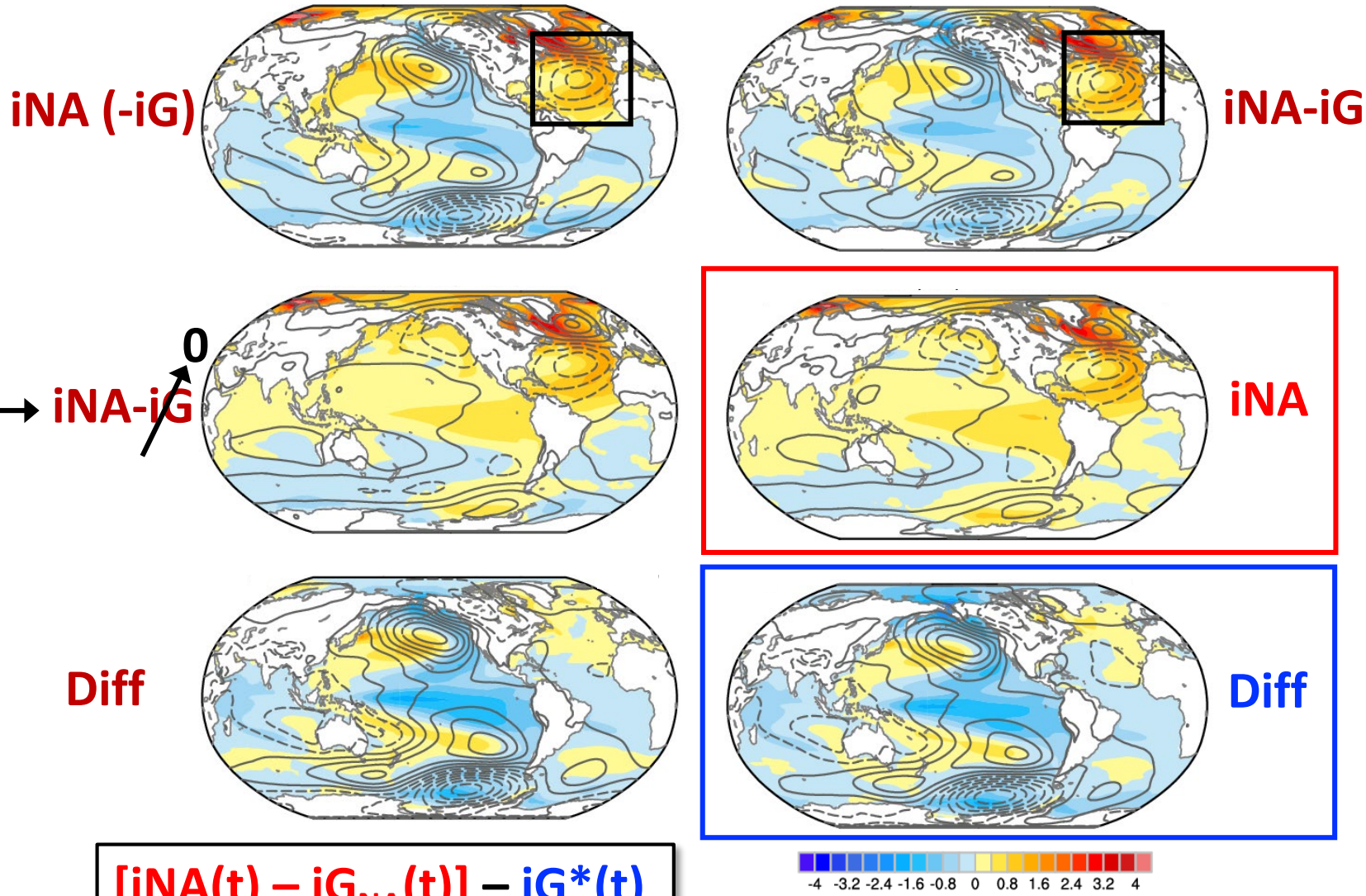
4) Average the 7 models' average regression maps.

Modified Residual method using EM_G(t) (which makes it like iNA)

1950-2020

Estimated
SST & SLP

True
SST & SLP



$[iNA(t) - iG_{NA}(t)] - iG^*(t)$

CONCLUSIONS

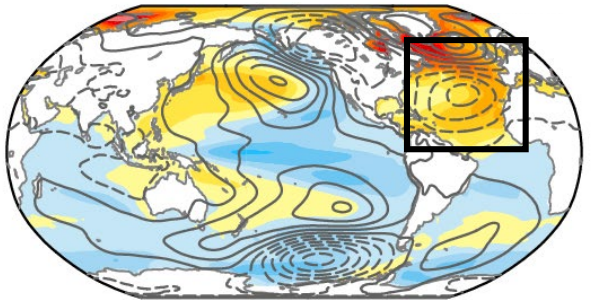
7 Model Large Ensembles (430 Members Total)

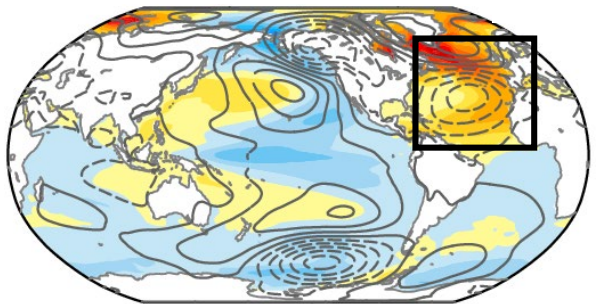
1950-2020

Estimated
SST & SLP

True
SST & SLP

iNA (-iG)

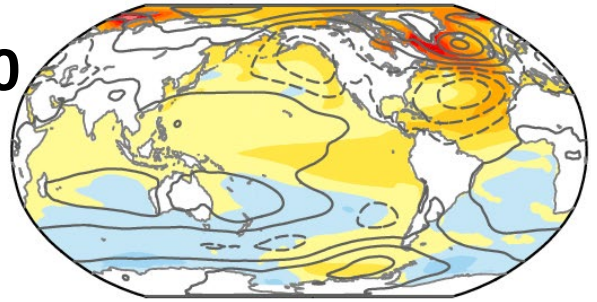


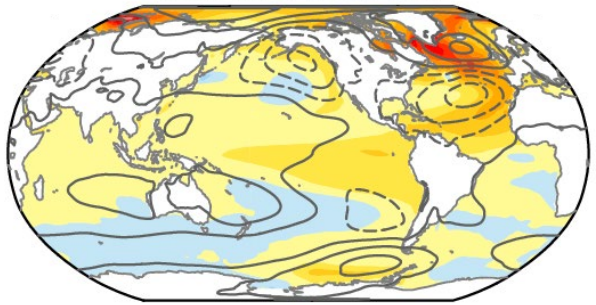


iNA-iG

0

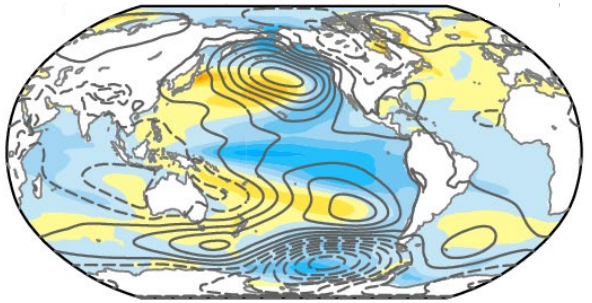
iNA-iG

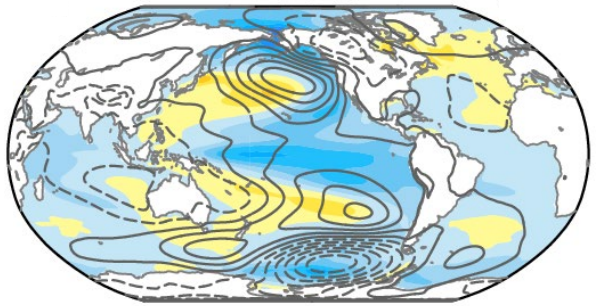




iNA

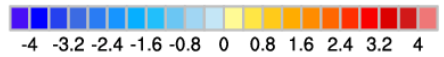
Diff





Diff

$[iNA(t) - iG_{NA}(t)] - iG^*(t)$



CONCLUSIONS

1) **Estimating the forced component with the global-mean T regression method introduces a spurious connection between the Atlantic and Pacific in the definition of internal AMV in models.**

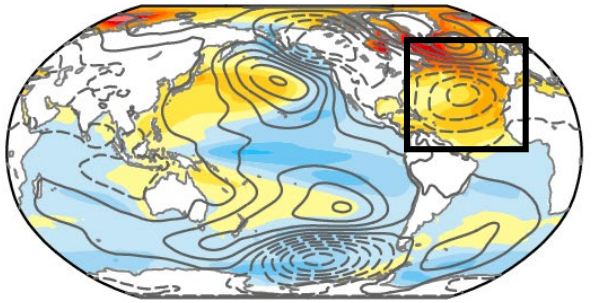
7 Model Large Ensembles (430 Members Total)

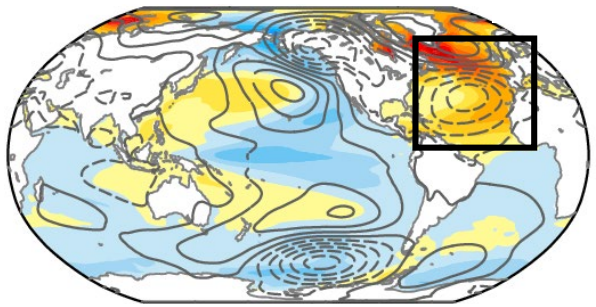
1950-2020

Estimated
SST & SLP

True
SST & SLP

iNA (-iG)

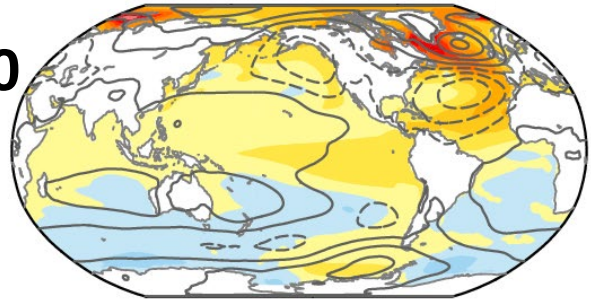


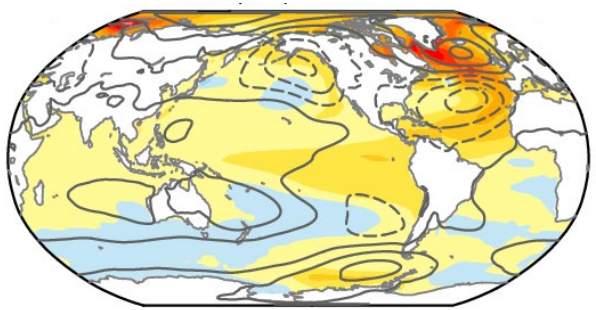


iNA-iG

0

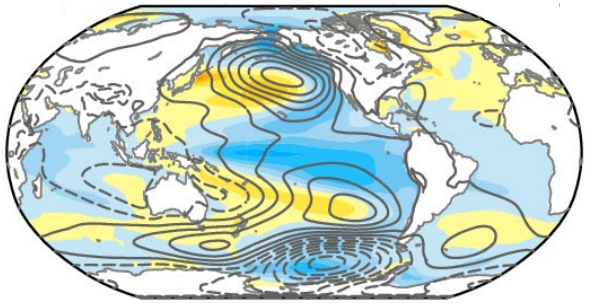
iNA-iG

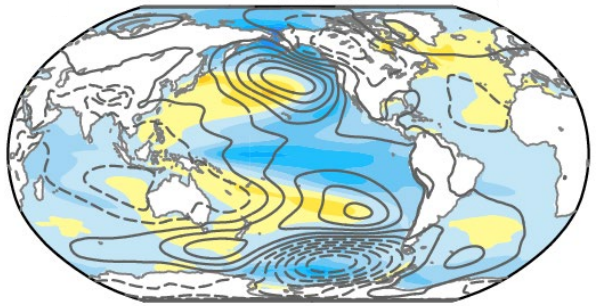




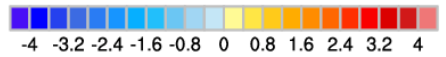
iNA

Diff





Diff



$[iNA(t) - iG_{NA}(t)] - iG^*(t)$

CONCLUSIONS

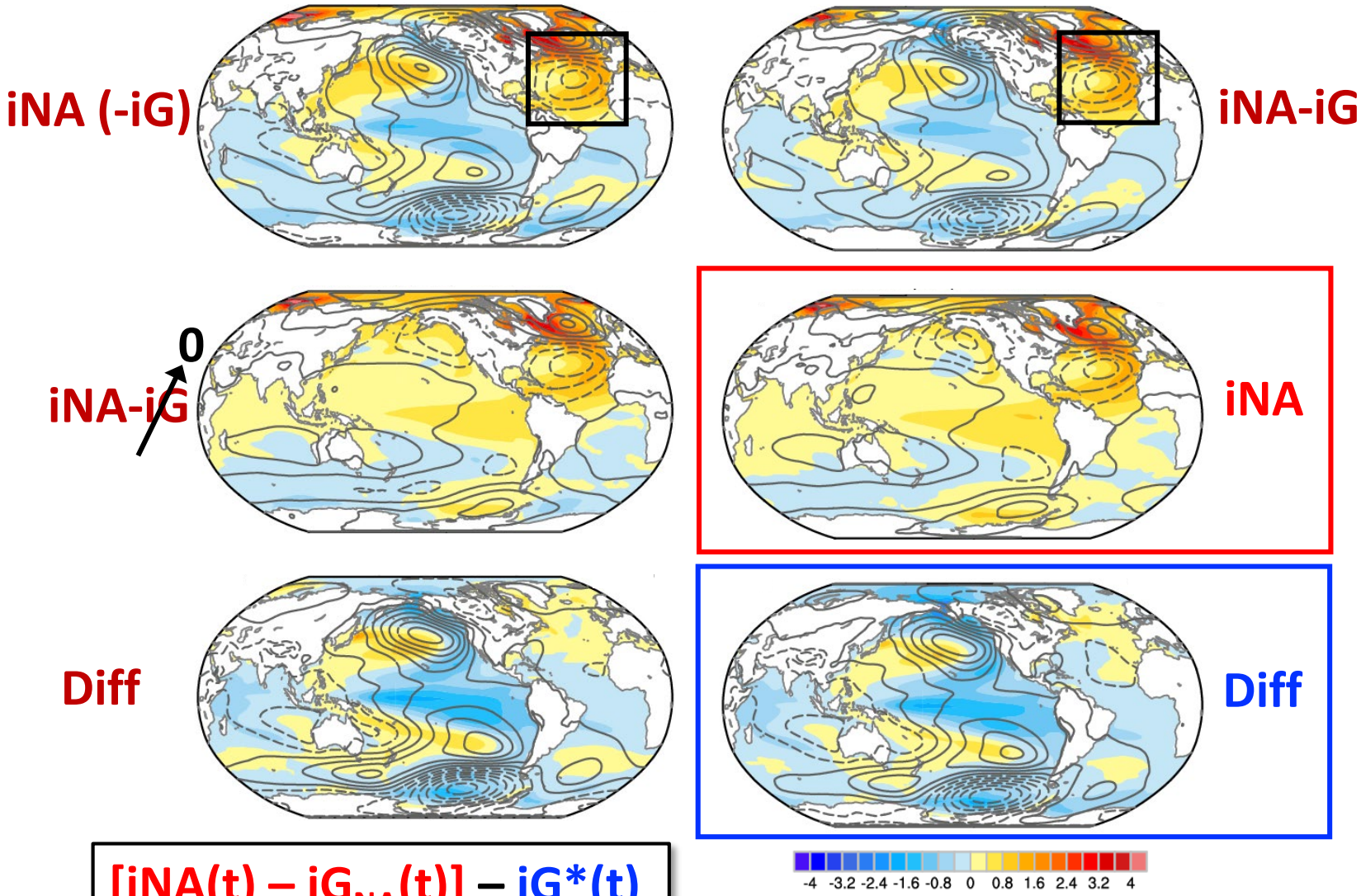
1) **Estimating the forced component with the global-mean T regression method introduces a spurious connection between the Atlantic and Pacific in the definition of internal AMV in models.**
2) **Redefining the method to use the ensemble-mean global-mean T alleviates the problem.**

7 Model Large Ensembles (430 Members Total)

1950-2020

Estimated
SST & SLP

True
SST & SLP



$[iNA(t) - iG_{NA}(t)] - iG^*(t)$

CONCLUSIONS

1) **Estimating the forced component with the global-mean T regression method introduces a spurious connection between the Atlantic and Pacific in the definition of internal AMV in models.**
2) **Redefining the method to use the ensemble-mean global-mean T alleviates the problem.**
3) **Results are robust across models and time periods (not shown).**

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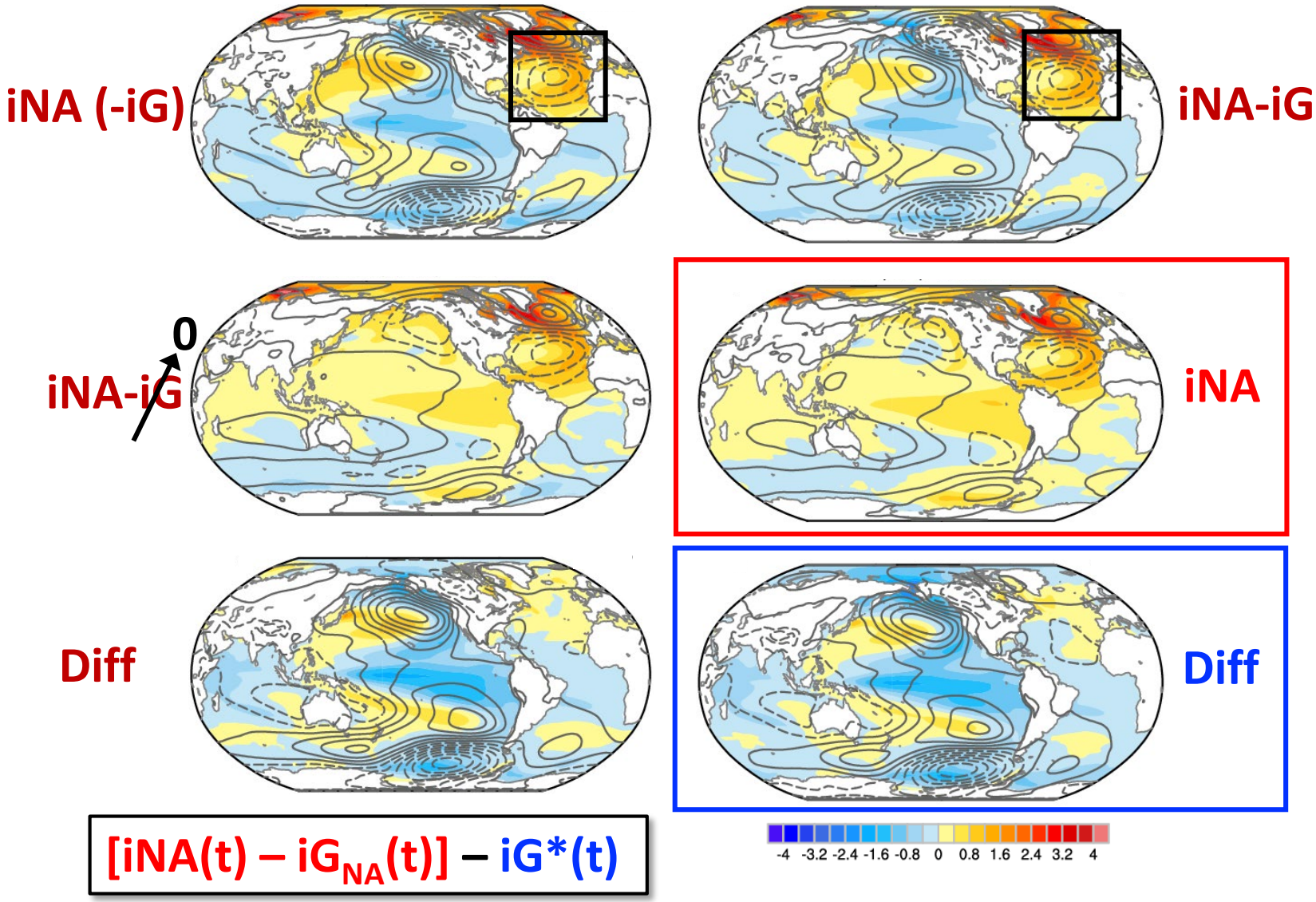
1950-2020

Estimated
SST & SLP

True
SST & SLP



$[iNA(t) - iG_{NA}(t)] - iG^*(t)$

CONCLUSIONS

1) **Estimating the forced component with the global-mean T regression method introduces a spurious connection between the Atlantic and Pacific in the definition of internal AMV in models.**
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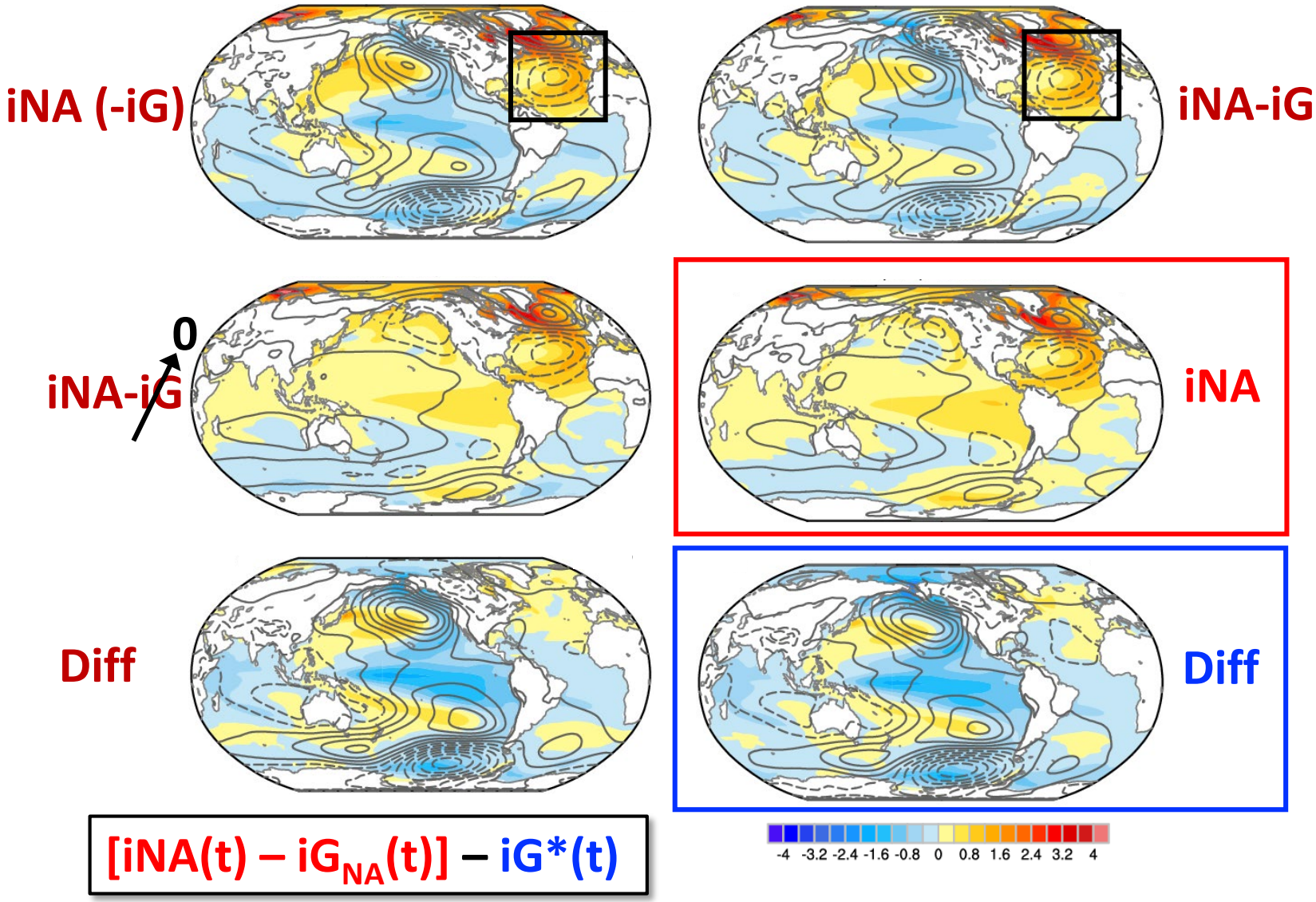
4) **iG* related to IPV/PDV**

7 Model Large Ensembles (430 Members Total)

1950-2020

Estimated
SST & SLP

True
SST & SLP



$[iNA(t) - iG_{NA}(t)] - iG^*(t)$

7 Model Large Ensembles (430 Members Total)

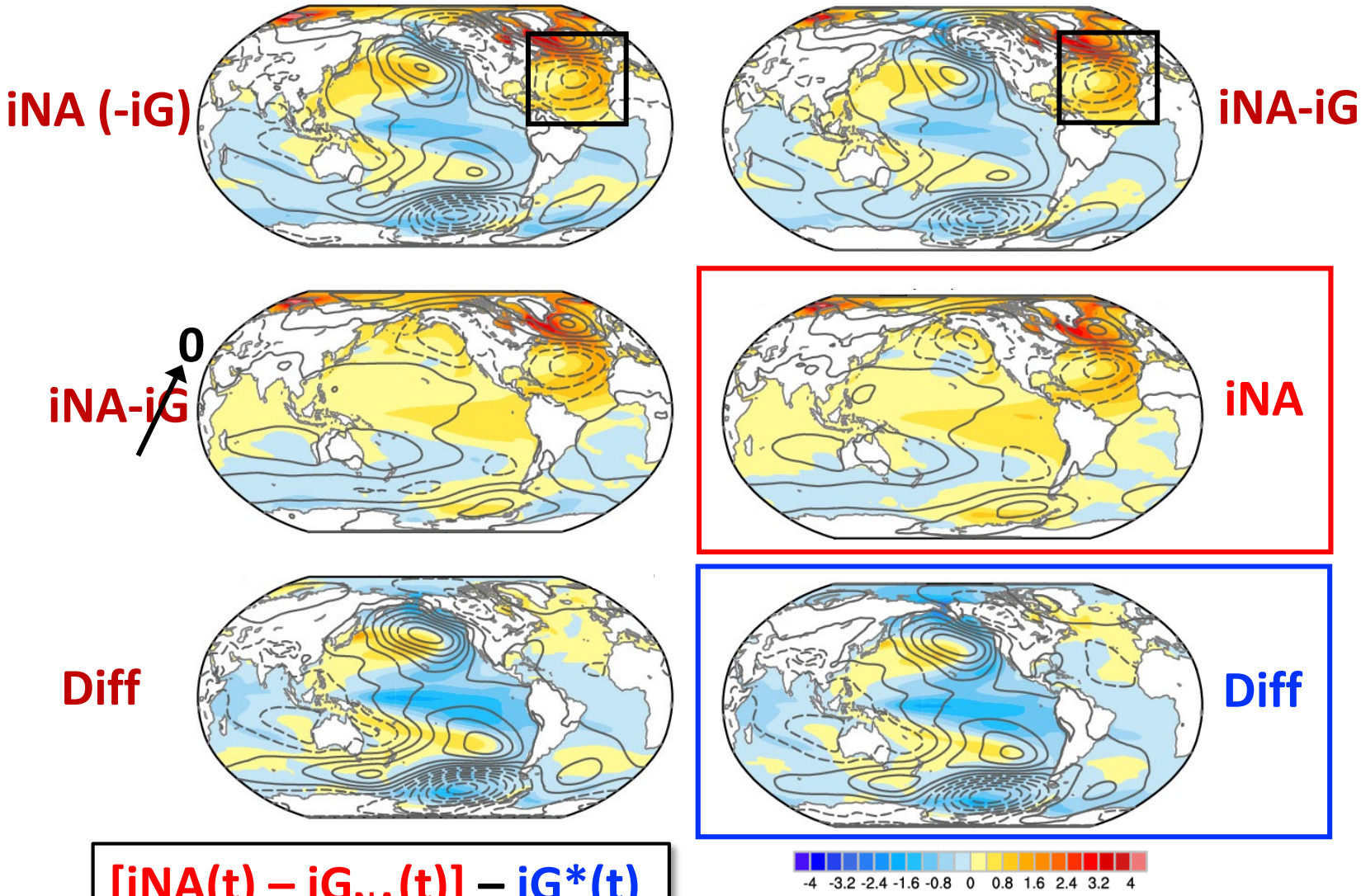
CONCLUSIONS

1) **Estimating the forced component with the global-mean T regression method introduces a spurious connection between the Atlantic and Pacific in the definition of internal AMV in models.**
2) **Redefining the method to use the ensemble-mean global-mean T alleviates the problem.**
3) **Results are robust across models and time periods (not shown).**
4) **iG* related to IPV/PDV**
5) **iNA related to AMOC?**

1950-2020

Estimated
SST & SLP

True
SST & SLP

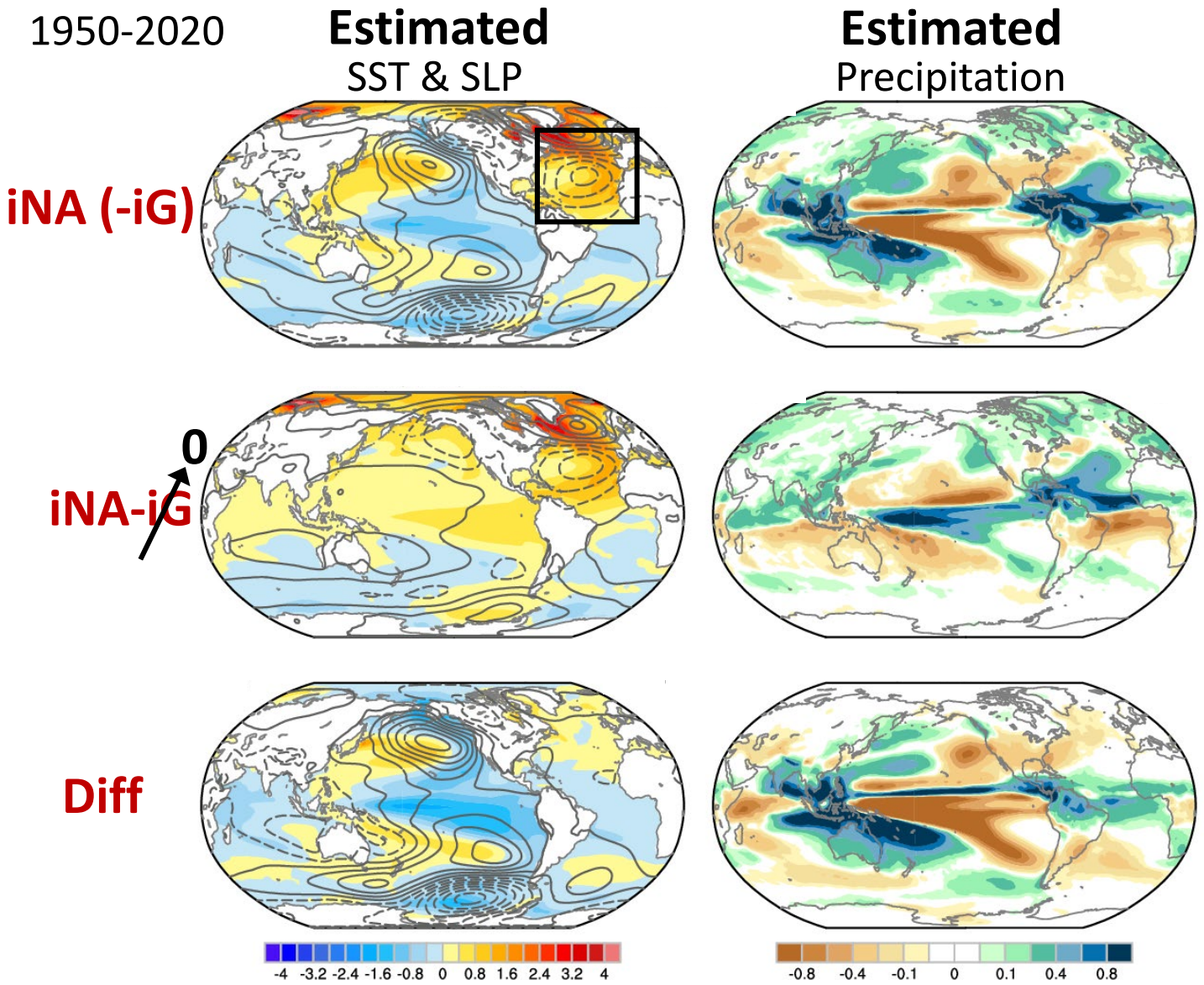


$[iNA(t) - iG_{NA}(t)] - iG^*(t)$

7 Model Large Ensembles (430 Members Total)

CONCLUSIONS

1) **Estimating the forced component with the global-mean T regression method introduces a spurious connection between the Atlantic and Pacific in the definition of internal AMV in models.**
2) **Redefining the method to use the ensemble-mean global-mean T alleviates the problem.**
3) **Results are robust across models and time periods (not shown).**
4) **iG* related to IPV/PDV**
5) **iNA related to AMOC?**



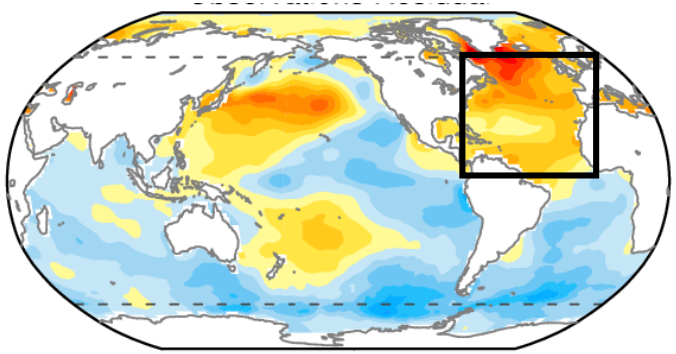
EXTRA SLIDES

Observations

(ERSSTv5, 1950-2020, 10yrLP)

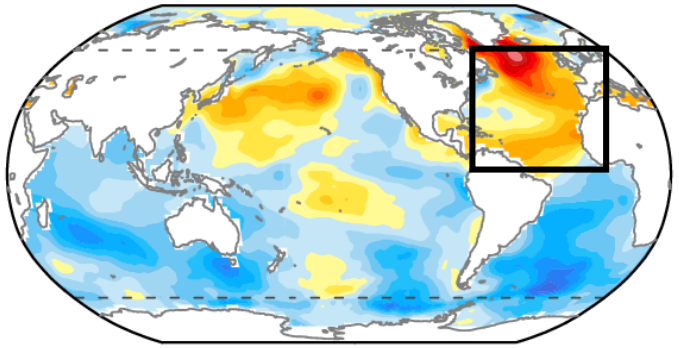
Residual Method using Obs G(t)

iNA (-iG)

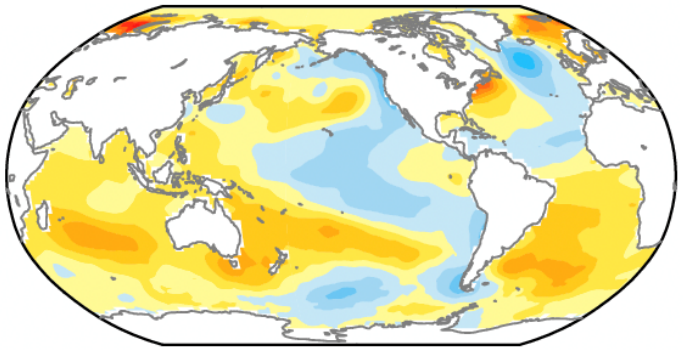


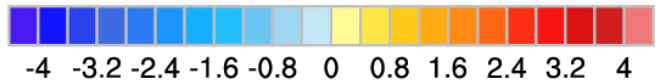
Residual Method using ensemble-mean G(t) averaged across the 7 model LEs

iNA-iG



Diff



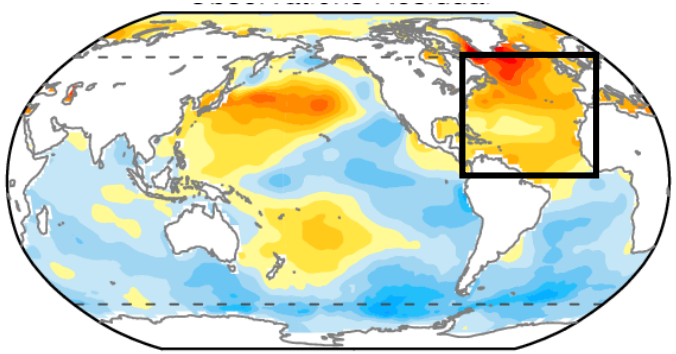


Observations

(ERSSTv5, 1950-2020, 10yrLP)

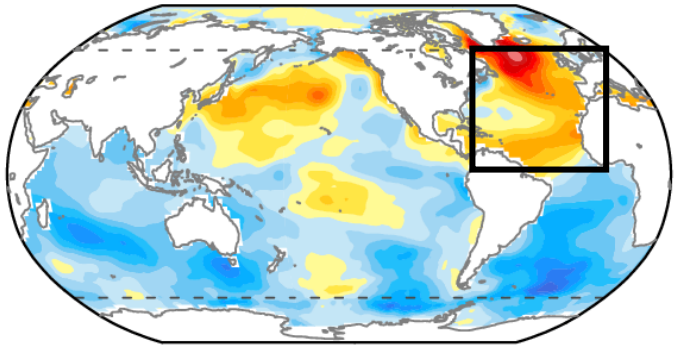
Residual Method using Obs G(t)

iNA (-iG)

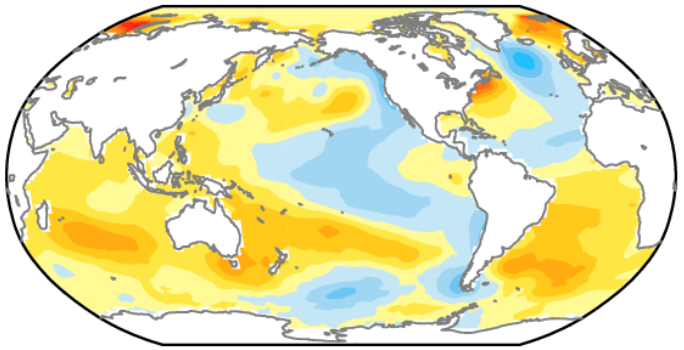


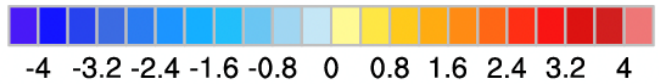
Residual Method using ensemble-mean G(t) averaged across the 7 model LEs

iNA-iG

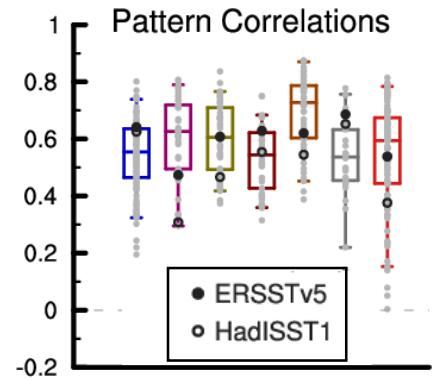


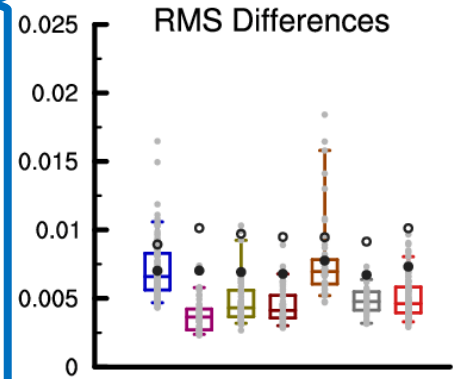
Diff





Sampling variability of AMV pattern

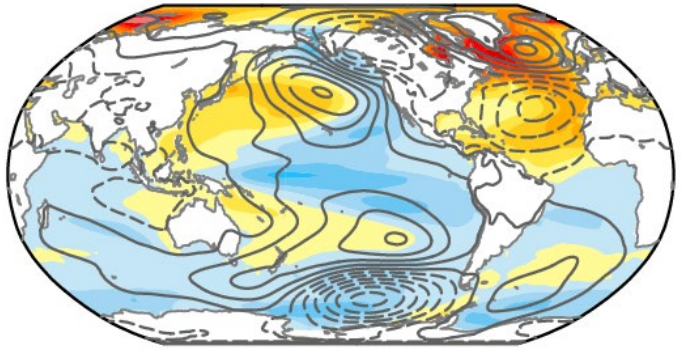




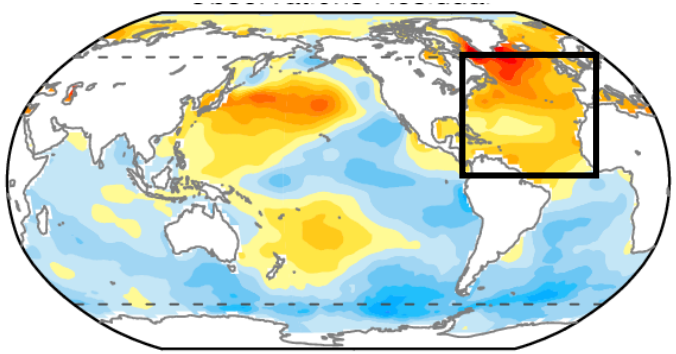
MPI (100)
CESM1 (40)
CanESM2 (50)
MIROC6 (50)
CanESM5 (50)
GFDL-SPEAR_MED (30)
CESM2 (100)

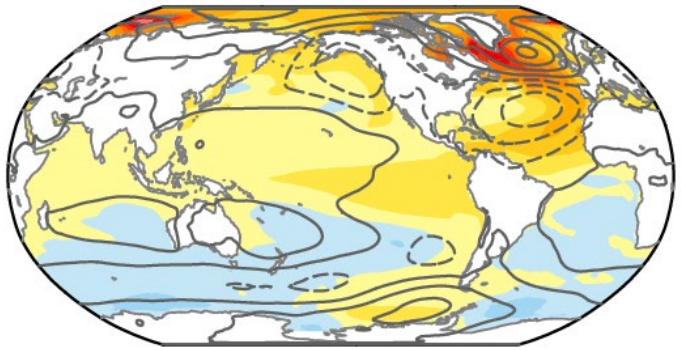
Model Avg

Observations
(ERSSTv5, 1950-2020, 10yrLP)

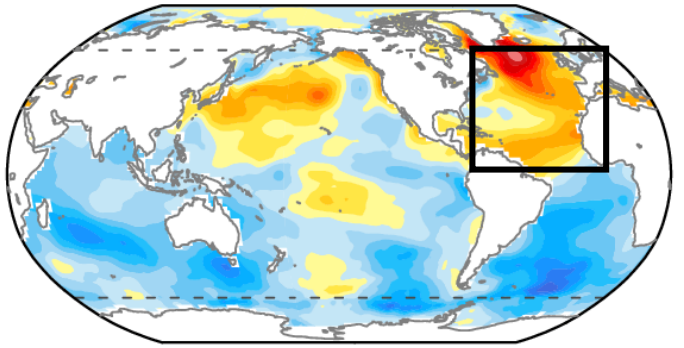


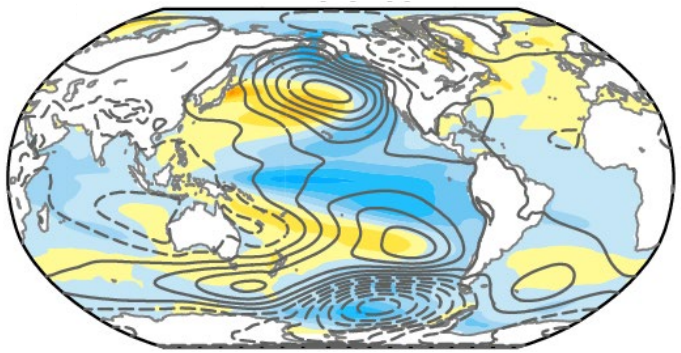
iNA (-iG)



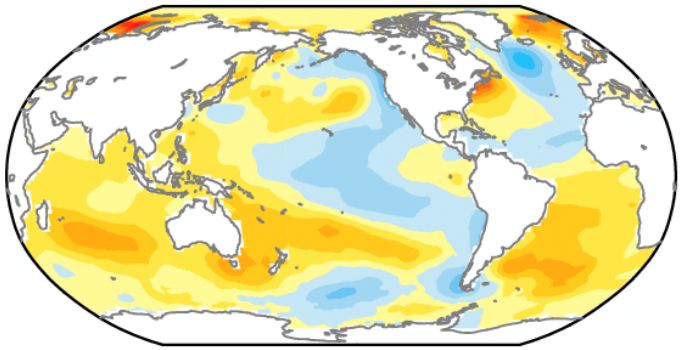


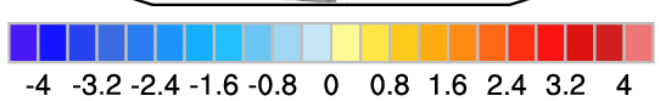
iNA-iG = 0



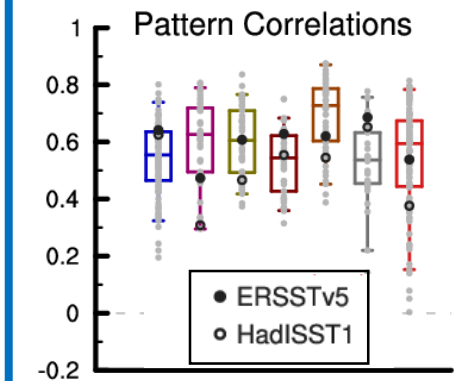


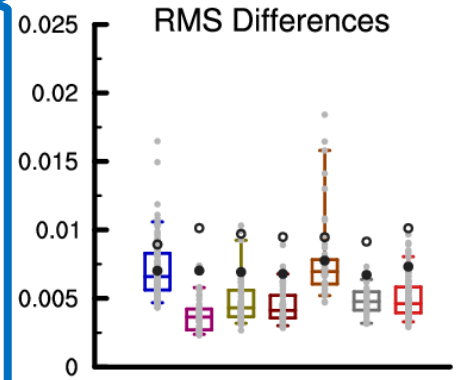
Diff





Sampling variability of AMV pattern





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CESM2 (100)