NCAR
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US AMOC Science Team
Task Team 3 Webinar Series
March 23, 2017

AMOC-related climate prediction using CESM

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AMOC-related climate prediction using CESM

I. CESM Decadal Prediction Experiments
II. Understanding Subpolar North Atlantic (SPNA) mechanisms: how important is AMOC for predictions?
III. Remote impacts associated with SPNA SST

IPCC 5th Assessment Report

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Near-term Climate Change: Projections and Predictability

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Lead Authors:
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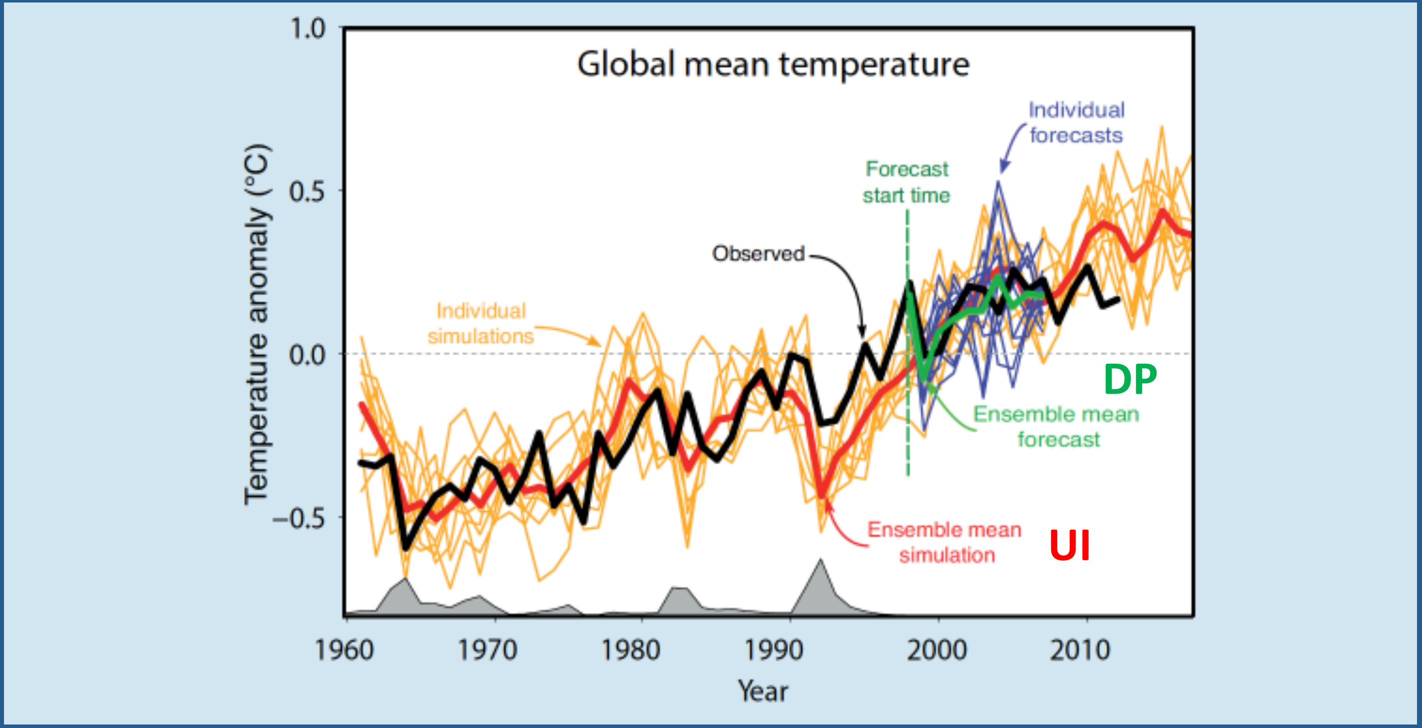


DP: initialized decadal prediction simulations
UI: ”uninitialized” 20th century simulations

CESM Decadal Prediction (DP) Simulations

	OLD (completed early 2011)	NEW (completed late 2015)
Coupled Model -atm -ocn -ice -lnd	CCSM4 1º CAM4 (FV, 26 lvl) 1º POP2 (60 lvl) CICE4 CLM4	CESM1.1 (LENS tag) 1º CAM5 (FV, 30 lvl) ★ 1º POP2 (60 lvl) w/ BGC ★ CICE4 CLM4
Start Dates	Jan. 1, 1955-2014 (N=60)	Nov. 1, 1954-2015 ★ (N=62)
Ensemble Size (per start date)	10	10
Sim. Length (per ensemble mem)	120 months	122 months
Ensemble Generation	variable Jan. start days + Round-off perturbation of atm ic	Round-off perturbation of atm ic
Initial Conditions	ocn/ice: CORE-forced POP-CICE atm/lnd: CESM1 20C ensemble	ocn/ice: CORE*-forced POP-CICE ★ atm/lnd: CESM1 Large Ensemble
Initialization Procedure	Full field	Full field
External Forcings	Full CMIP5 20C + RCP4.5	Full CMIP5 20C + RCP8.5
Uninitialized Complement	6-member CCSM4 20C/RCP4.5	40+-member CESM1-LE 20C/RCP8.5
Total # simulation-years	6,000	6,300

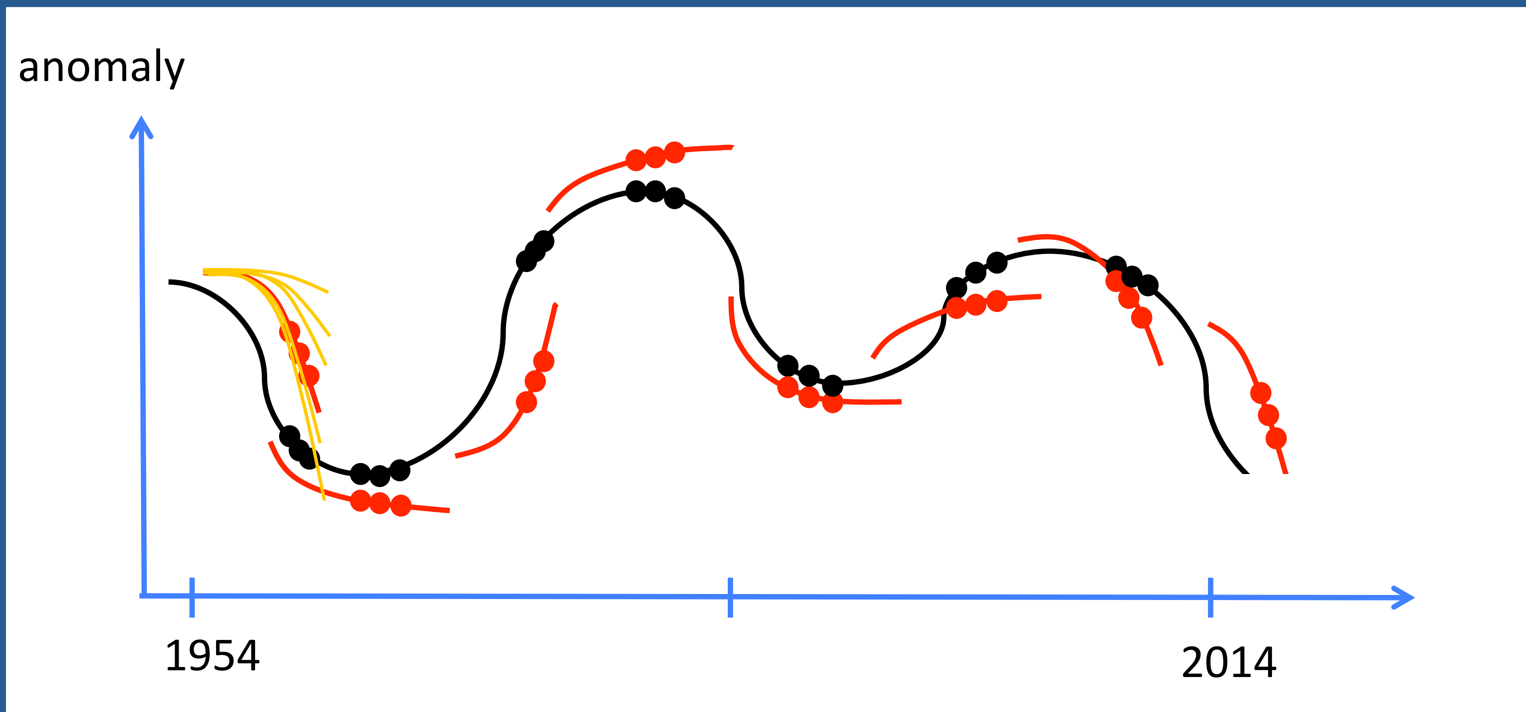
CESM Decadal Prediction (DP) Simulations

	OLD (completed early 2011)	NEW (completed last week)
Coupled Model -atm -ocn -ice -lnd	CCSM4 1º CAM4 (FV, 26 lvl) 1º POP2 (60 lvl) CICE4 CLM4	CESM1.1 (LENS tag) 1º CAM5 (FV, 30 lvl) ★ 1º POP2 (60 lvl) w/ BGC ★ CICE4 CLM4
Start Dates	Jan. 1, 1955-2014 (N=60)	Nov. 1, 1954-2015 ★ (N=62)
Ensemble Size (per start date)	10	40
Sim. Length (per ensemble mem)	120 months	122 months
Ensemble Generation	variable Jan. start days + Round-off perturbation of atm ic	Round-off perturbation of atm ic
Initial Conditions	ocn/ice: CORE-forced POP-CICE atm/lnd: CESM1 20C ensemble	ocn/ice: CORE*-forced POP-CICE ★ atm/lnd: CESM1 Large Ensemble
Initialization Procedure	Full field	Full field
External Forcings	Full CMIP5 20C + RCP4.5	Full CMIP5 20C + RCP8.5
Uninitialized Complement	6-member CCSM4 20C/RCP4.5	40+-member CESM1-LE 20C/RCP8.5
Total # simulation-years	6,000	25,213

Skill Assessment

DP hindcast ensemble mean (H)
"observations" (O)

drift-adjusted predicted anomalies (LY 5-7)
corresponding O anomalies



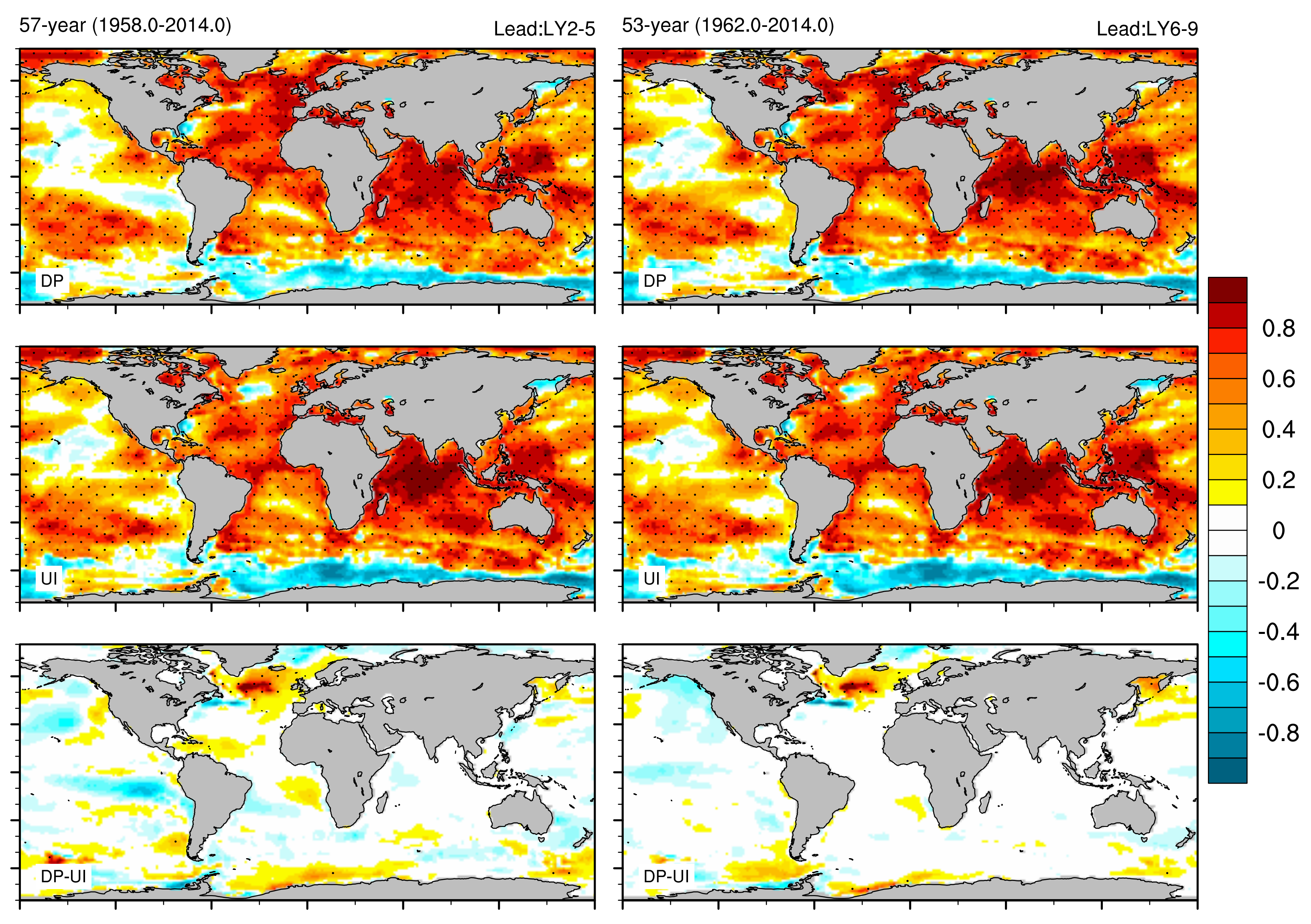
$$ACC = \frac{Cov(OH)}{\sqrt{Var(O)Var(H)}}$$

$$MSSS = 1 - \frac{MSE}{MSE_{ref}}$$

$$MSE = \frac{1}{n}\sum_{j=1}^{n}(H_j - O_j)^2$$

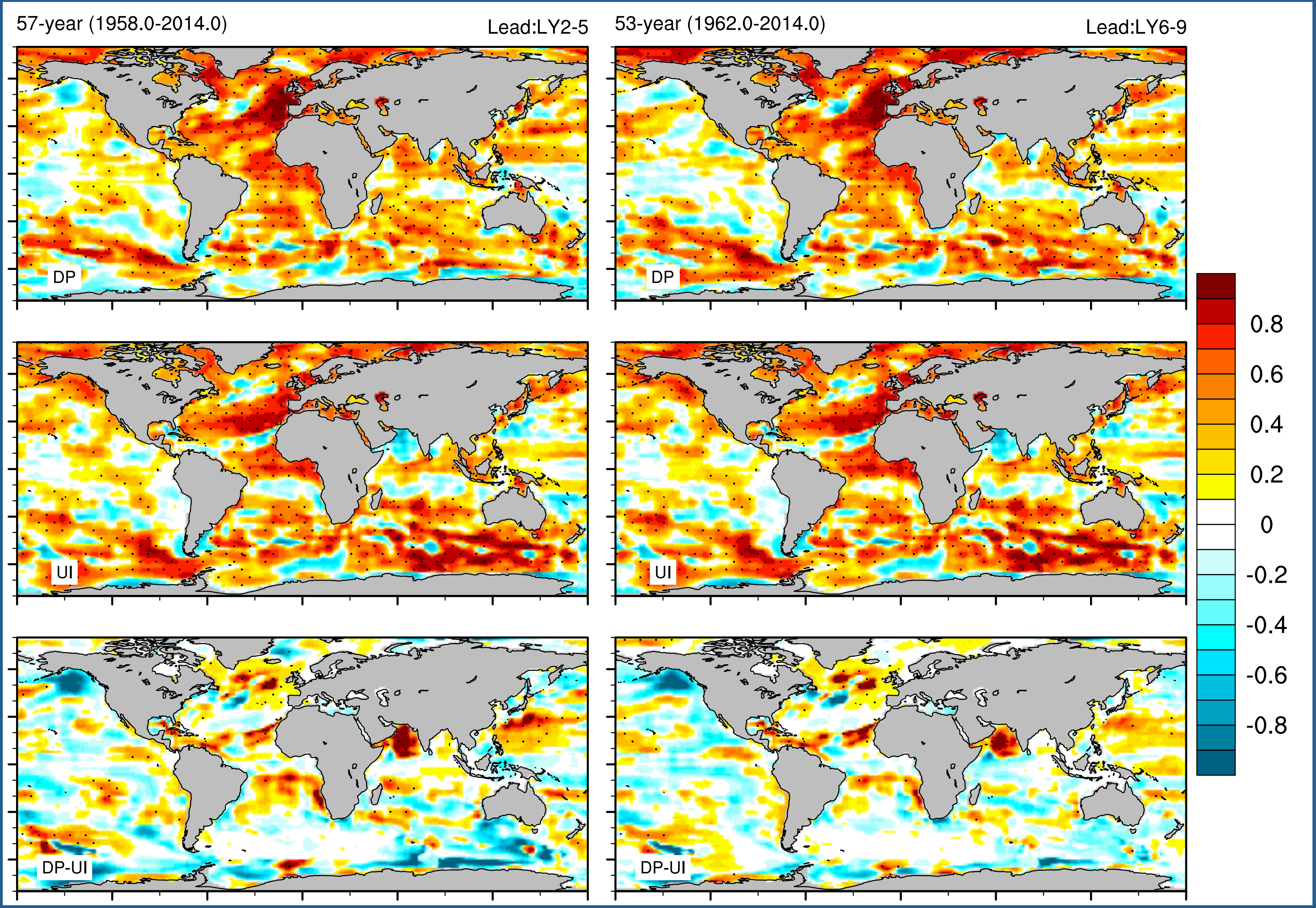
Goddard et al., 2013, *Clim Dyn*, doi: 10.1007/s00382-012-1481-2
Boer et al., 2013, *Clim Dyn*, doi: 10.1007/s00382-013-1705-0

Annual SST

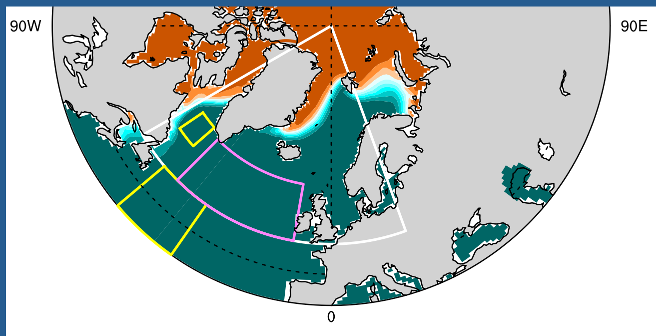


Similar result as seen in CCSM4 DP: Karspeck et al., 2014, *Clim Dyn*, doi: 10.1007/s00382-014-2212-7

Annual T700


57-year (1958.0-2014.0)
Lead:LY2-5
53-year (1962.0-2014.0)
Lead:LY6-9
DP
DP
UI
UI
DP-UI
DP-UI
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8

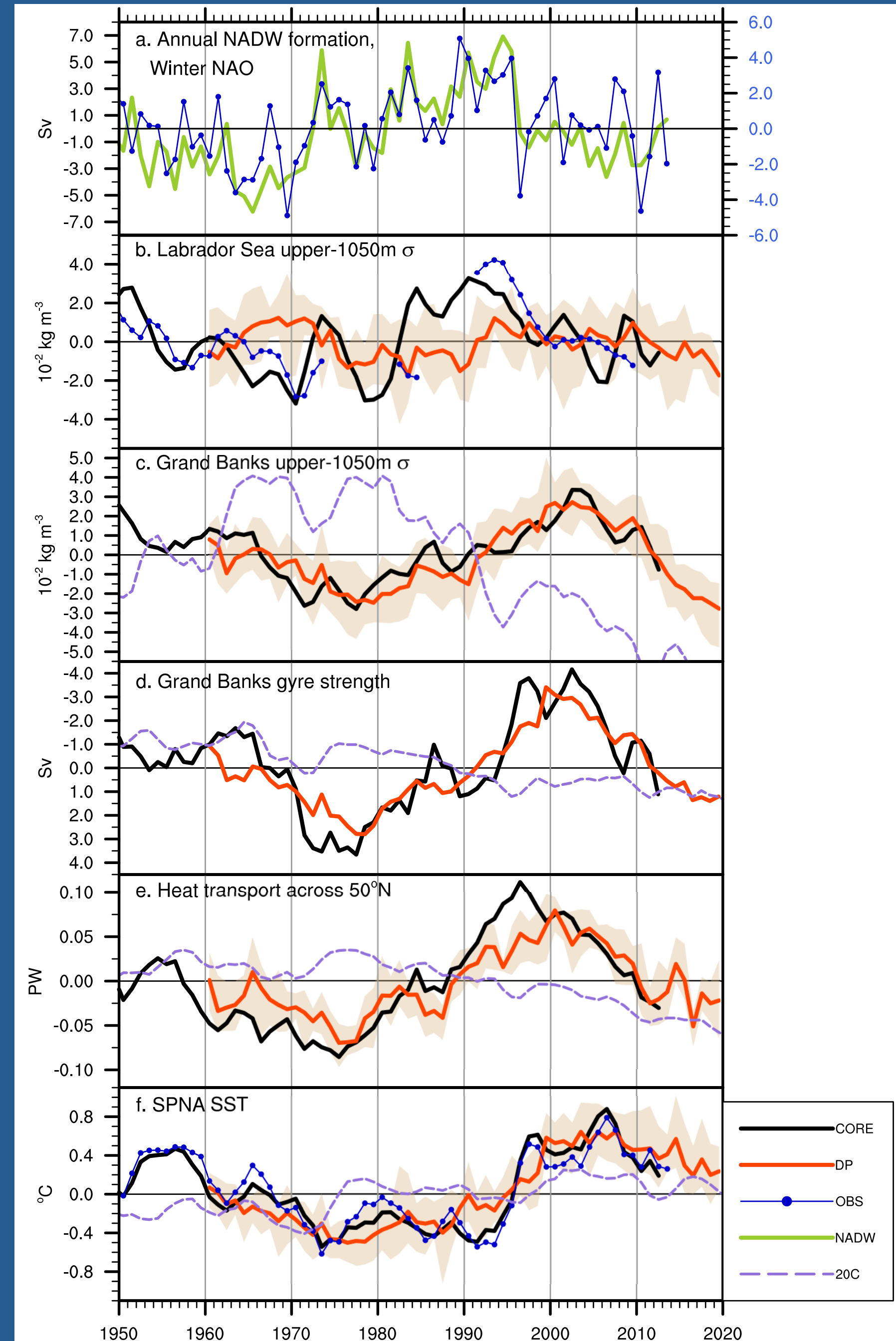
Subpolar N Atlantic



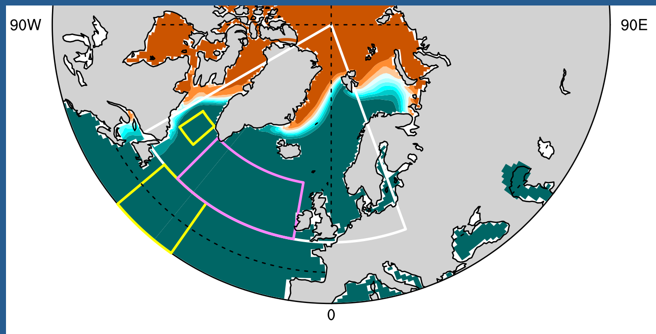
- Predictable propagation of pre-formed (i.e., initialized) NADW anomalies gives some <u>THC</u> skill at long lead times. This contributes to skillful prediction of ocean heat transport, upper ocean heat content, SST, & winter sea ice extent in SPNA.

- Yeager, Karspeck, & Danabasoglu, 2015: Predicted slowdown in the rate of Atlantic sea ice loss, *Geophys Res Lett*, doi: 10.1002/2015GL065364.

- Yeager & Robson, 2017: Recent Progress in Understanding and Predicting Atlantic Decadal Climate Variability, *Curr Clim Change Rep*, in press, doi: 10.1007/s40641-017-0064-z.

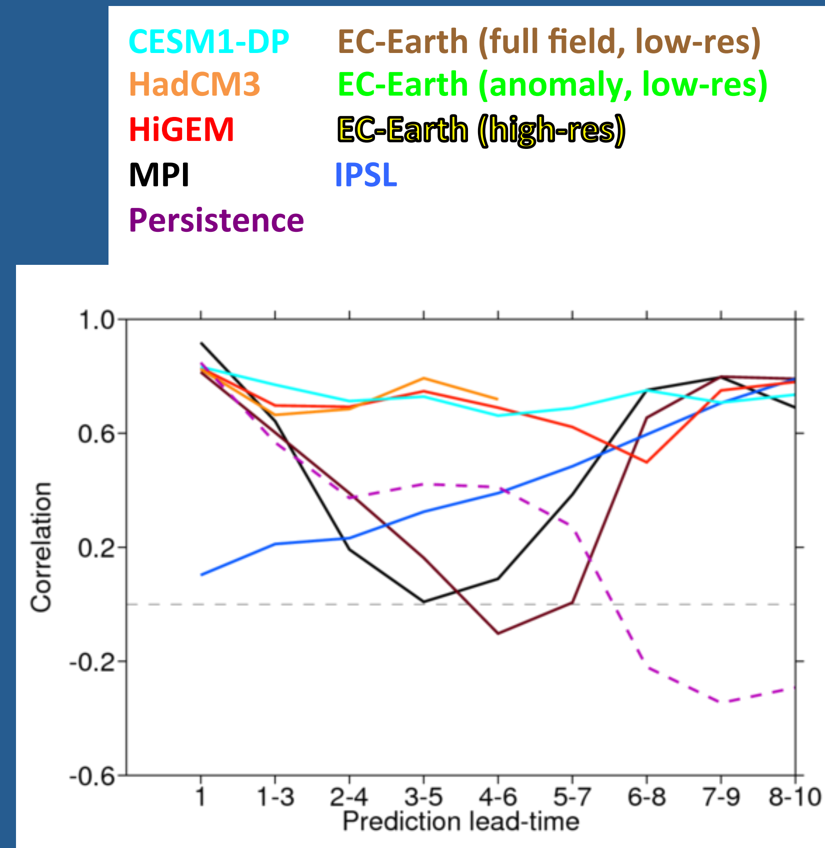


Subpolar N Atlantic



- Upper 500m heat content in the SPNA (50°-65°N, 60°W-10°W)

• CESM1-DP skill compares well with other decadal prediction systems. Significant skill improvement over persistence and uninitialized.

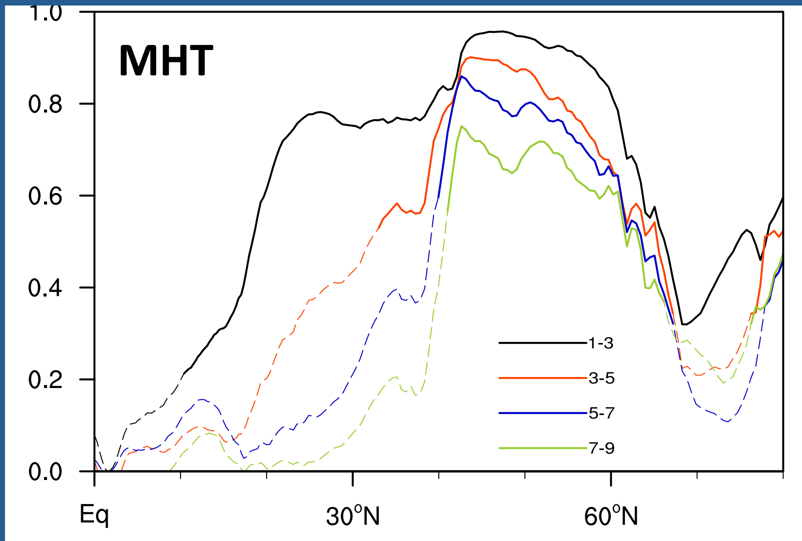


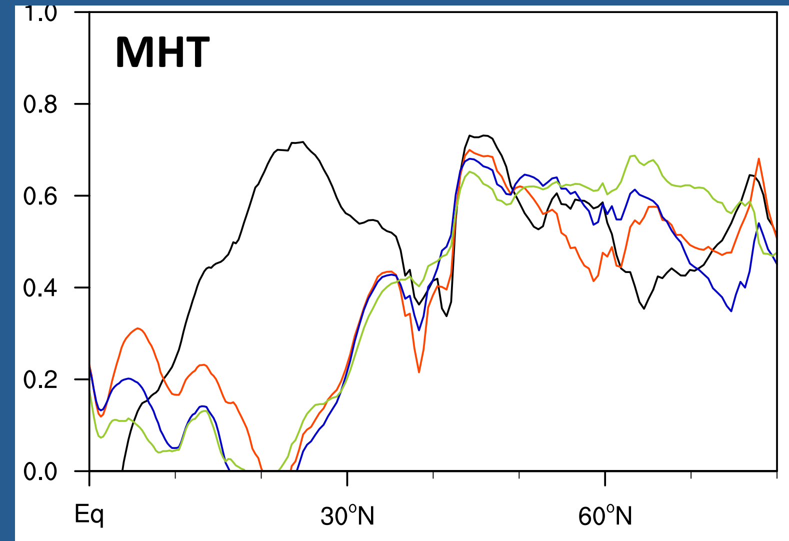
(Figure courtesy Jon Robson)

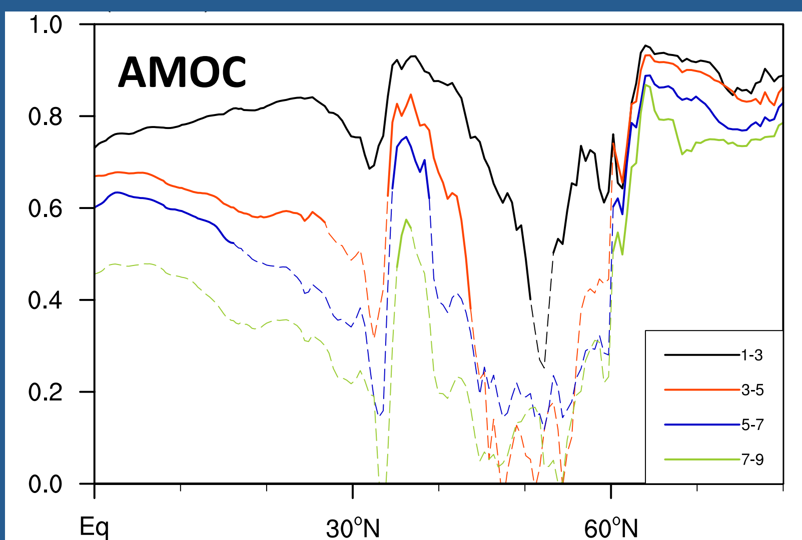
Meridional Heat Transport & AMOC (at 1000m)

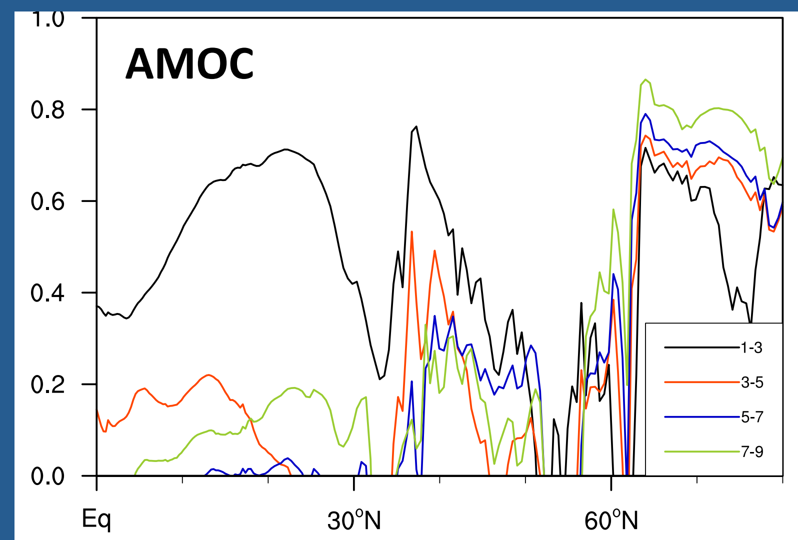
r(DP,CORE)

MSSS(DP,CORE) relative to persistence





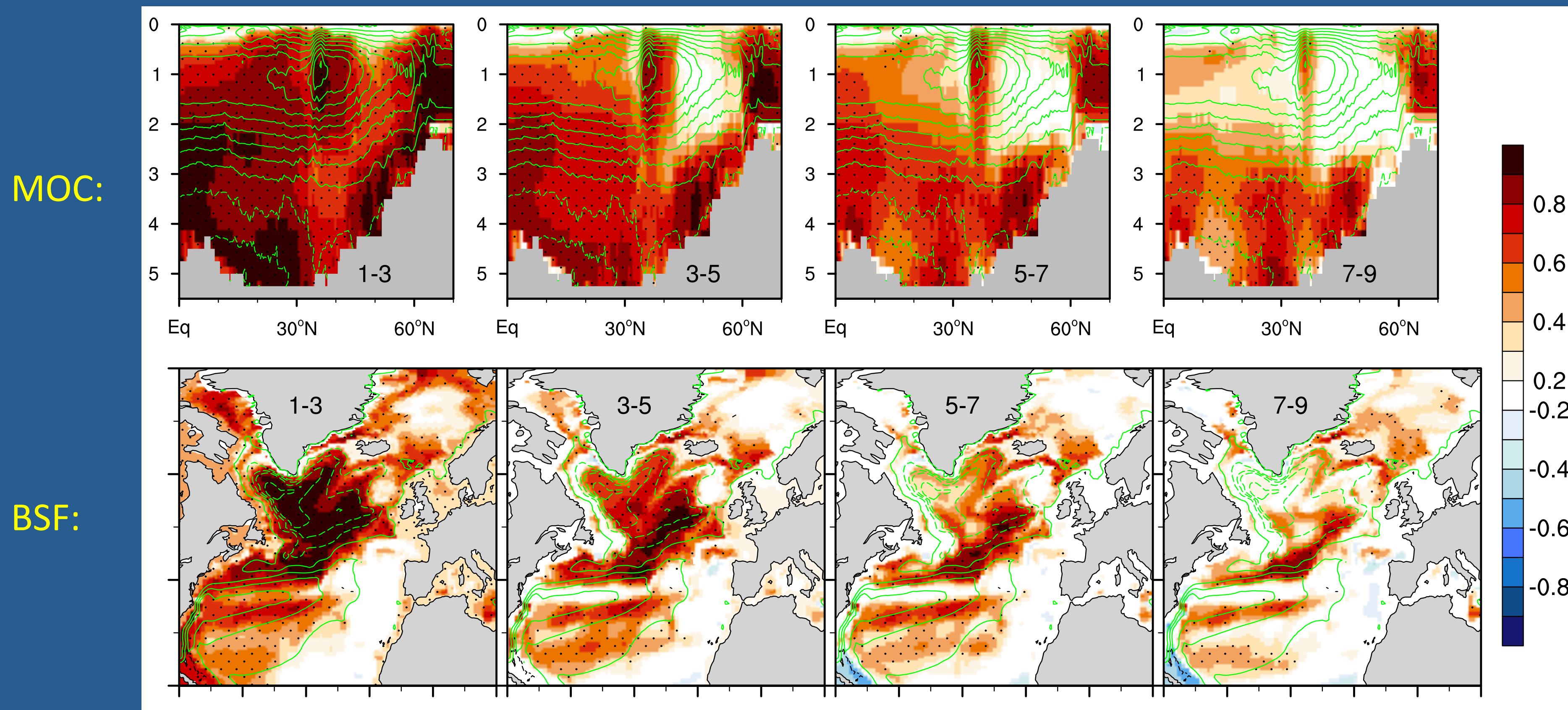




(detrended 3-year means)

Large-scale Circulation

r(DP,CORE)

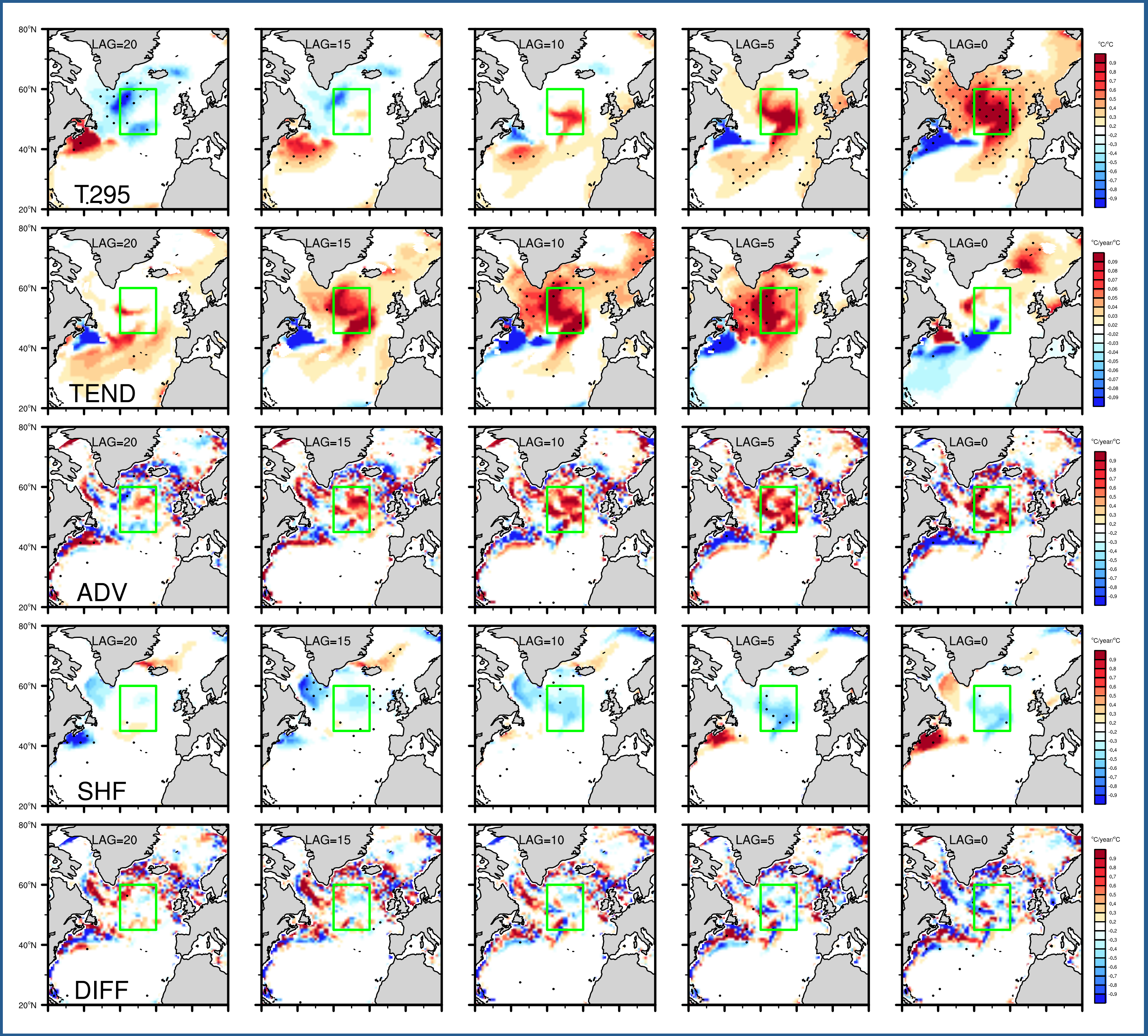


(detrended 3-year means)

- Rapid loss of $AMOC_{max}$ skill
- Good skill at predicting deep AMOC
- Good skill at predicting gyre variations on the western flank of the MAR, where buoyancy forcing dominates in this model (Yeager, 2015, *JPO*, doi: 10.1175/JPO-D-14-0100.1)

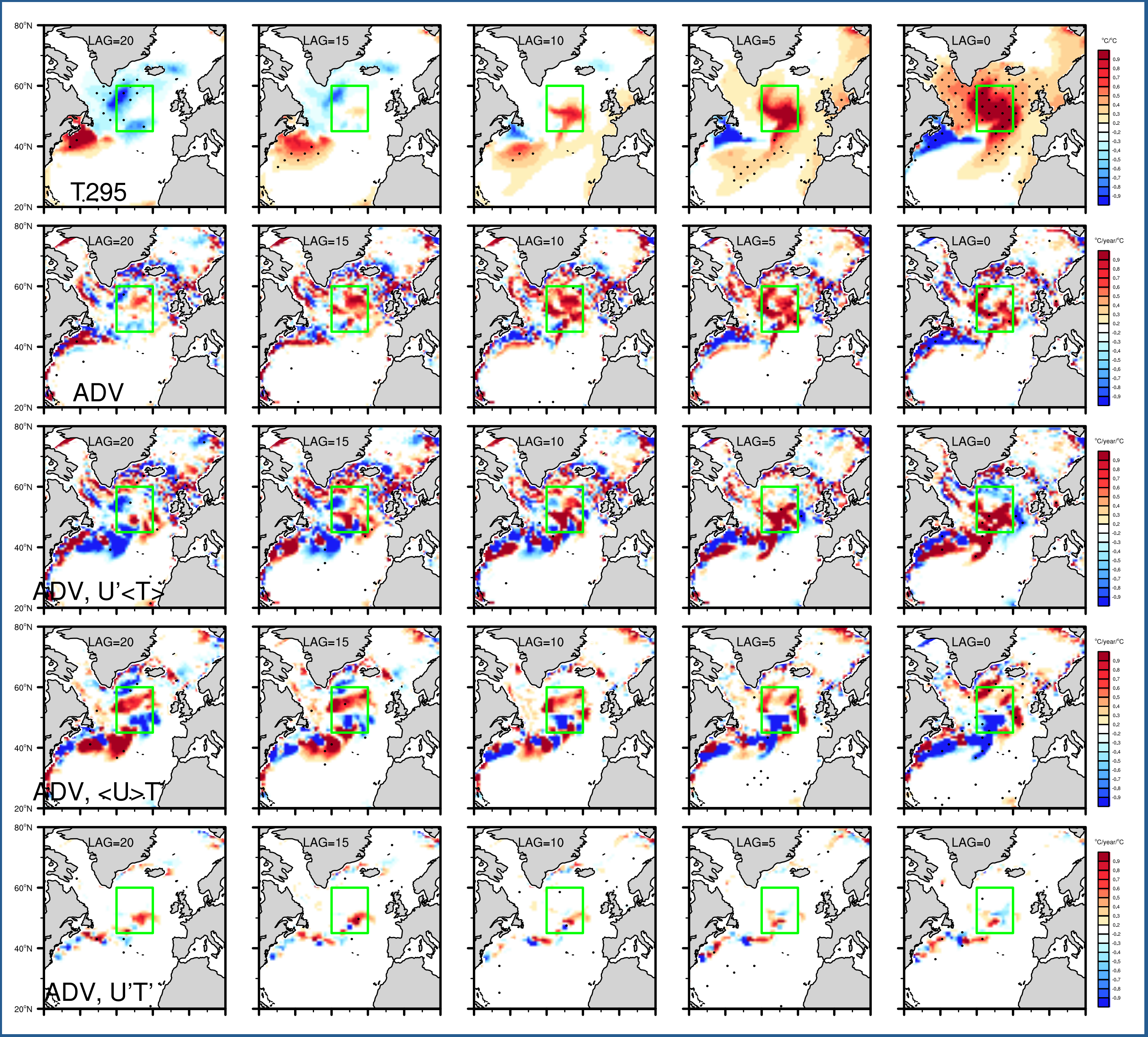
Regressions on SPG T295: CORE-forced ocean-ice (HD)

SPG T295 lags

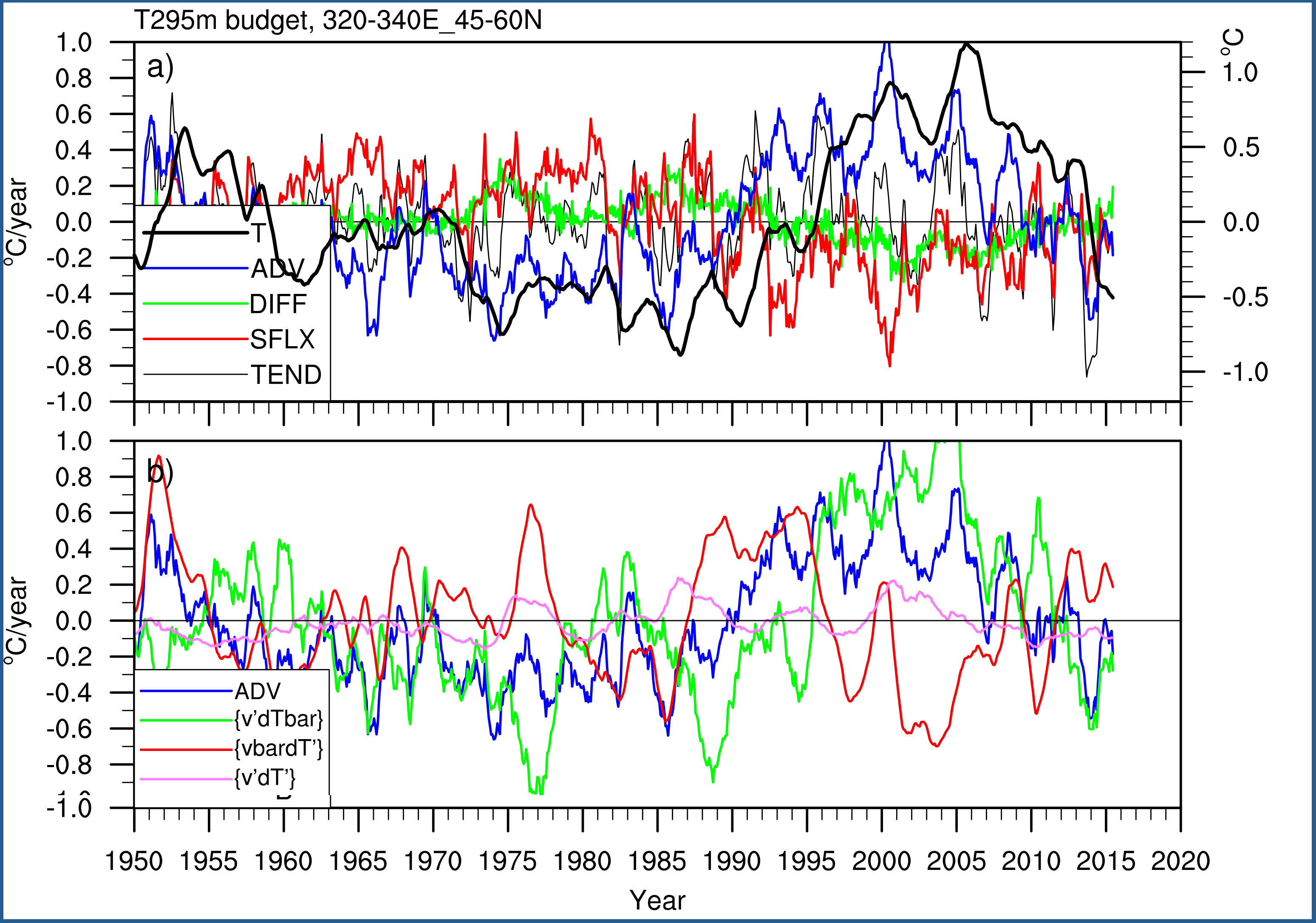


Regressions on SPG T295: CORE-forced ocean-ice (HD)

SPG T295 lags

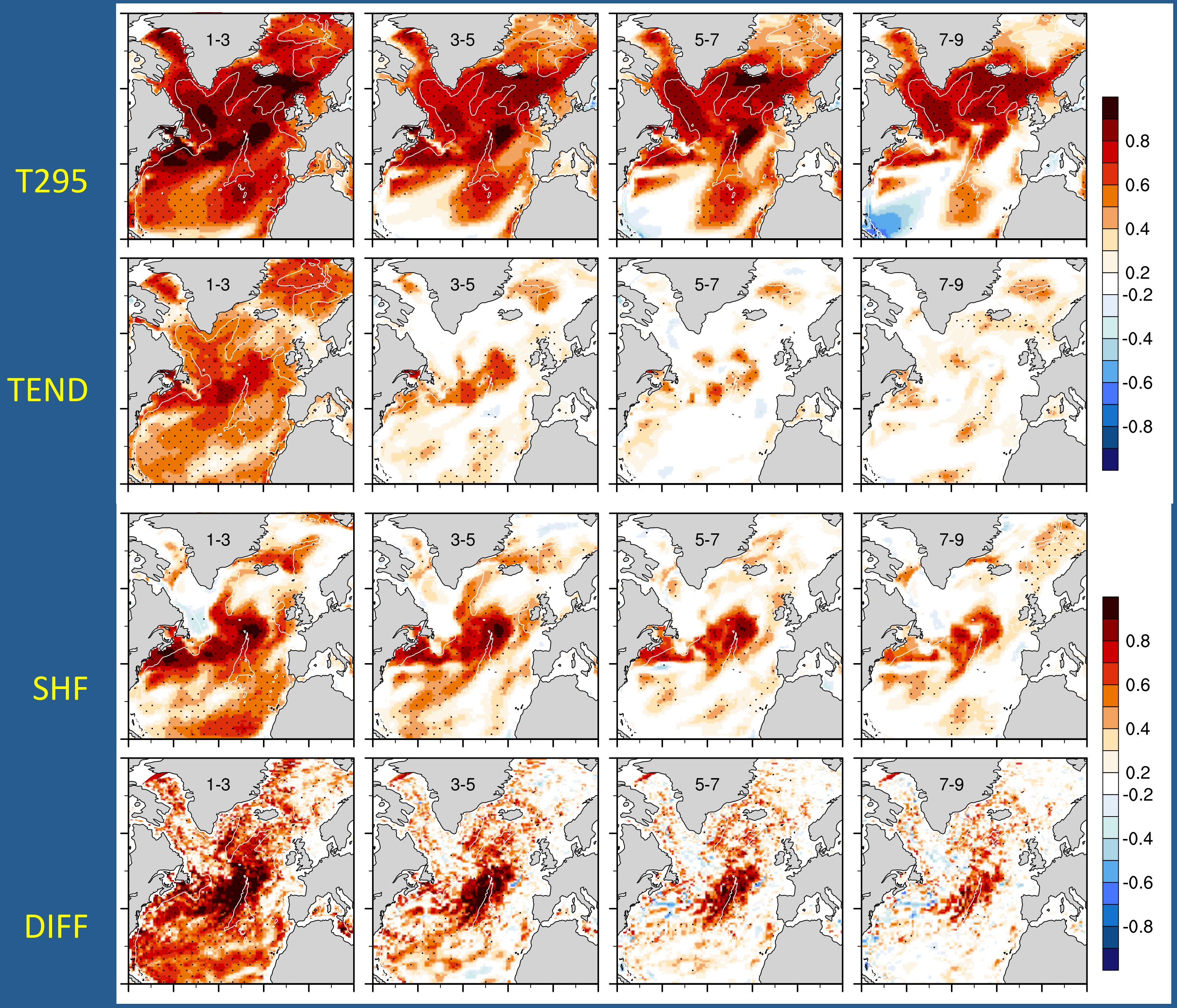


SPG T295 Heat Budget: CORE-forced ocean-ice (HD)

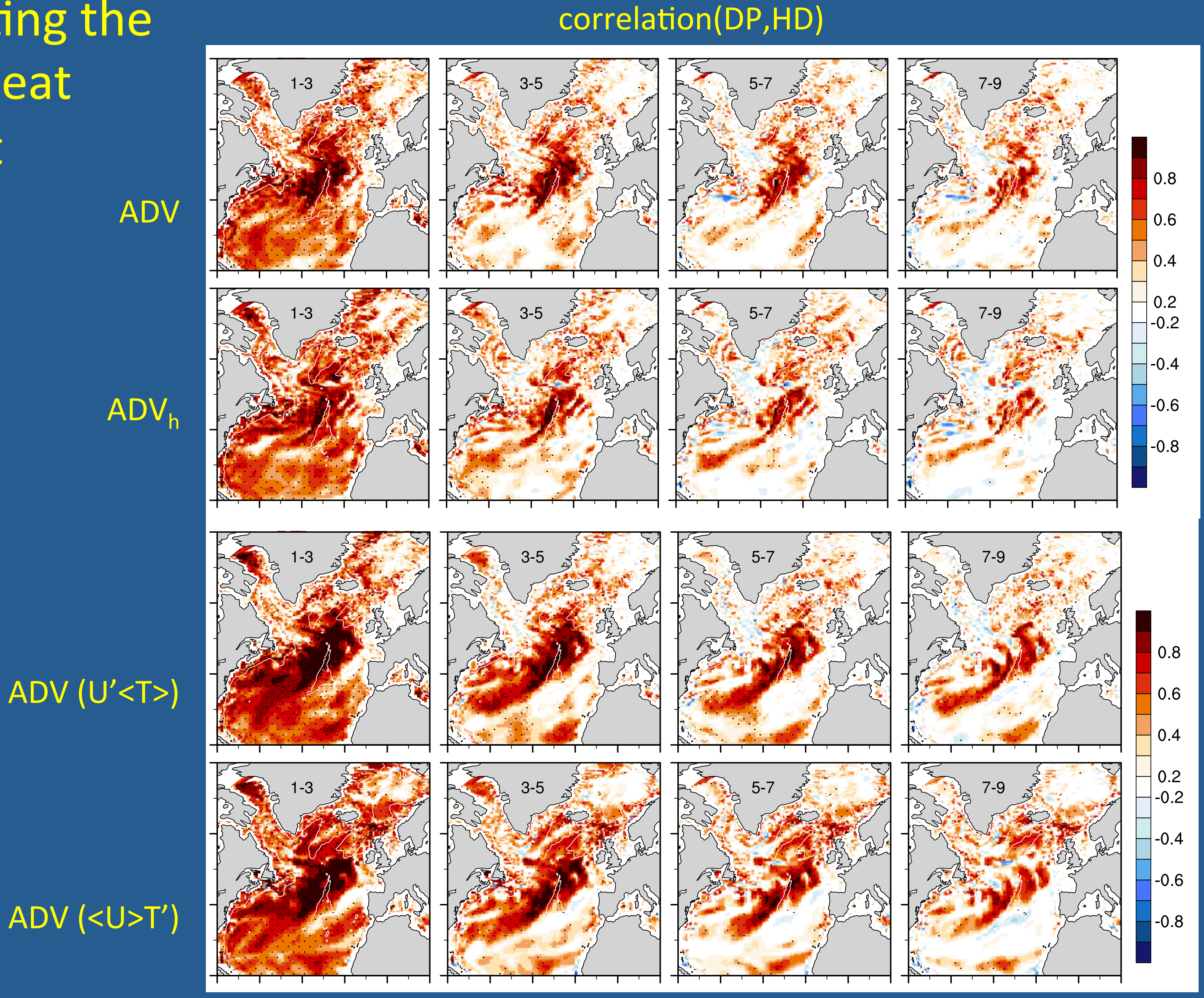


Predicting the T295 Heat Budget

correlation(DP,HD)



Predicting the T295 Heat Budget



- Initialization yields greatly enhanced skill at predicting SPNA heat content & SST at long lead times (above and beyond that due to persistence and/or knowledge of external forcing)
- Southward propagation of NADW anomalies through interior pathways appears to be an important mechanism for SPNA decadal prediction of:
    - THC (V')
    - Heat transport at subpolar latitudes

HOWEVER:

- THC skill is highest and most long-lasting for barotropic gyre flow, not AMOC
- Advective heat convergence is important and skillfully predicted, but VbarT' may be as important for prediction as V'Tbar.
- Role of AMOC is dubious in current CESM-DP → room for improvement?

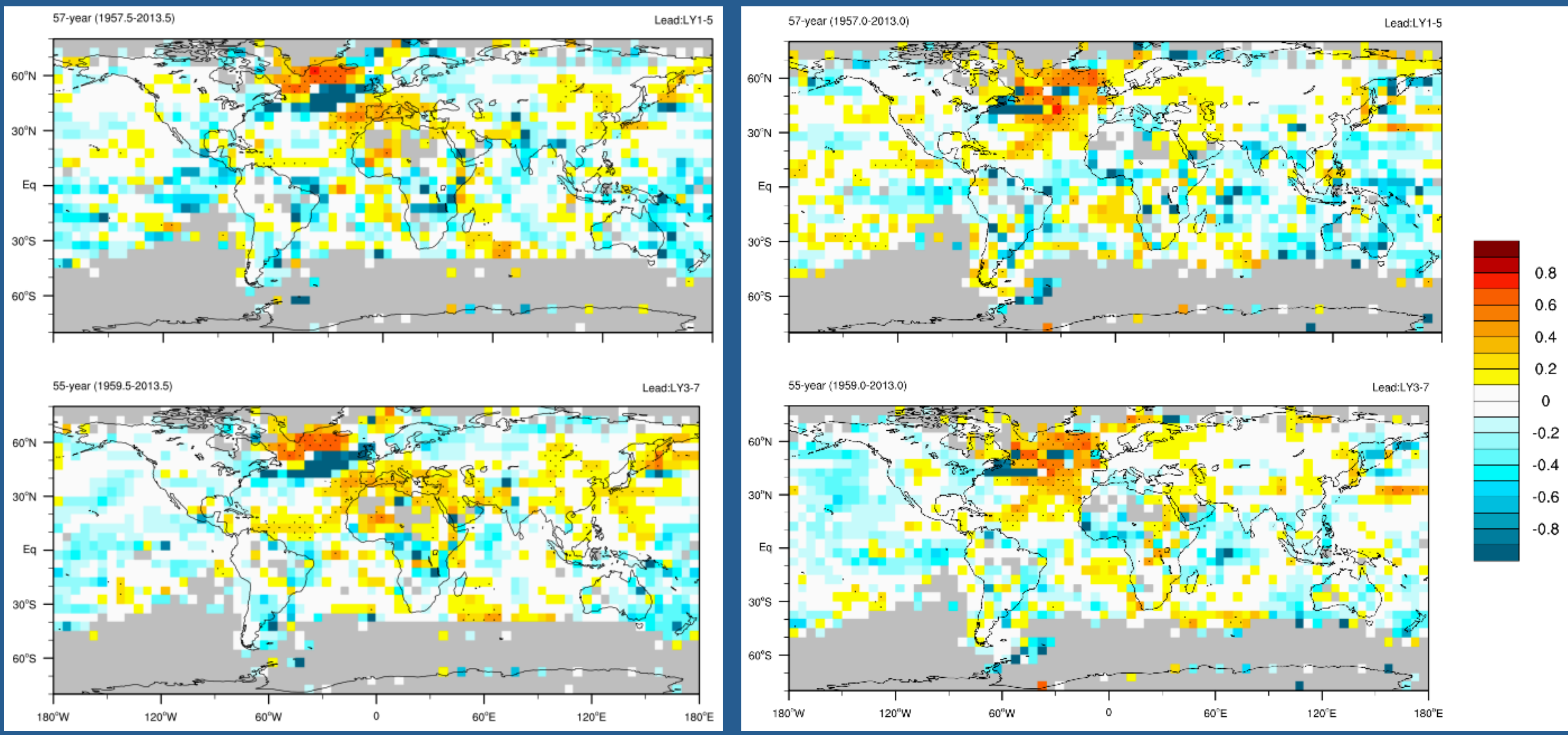
CESM1-DP : Seasonal SAT, MSSS (ref=UI), obs=HadCRUT4

(40-member)

JJA DJF

LY1-5

LY3-7



- SPNA-related skill improvement in summer SAT over tropical Atlantic, Africa, and Mediterranean?
- SPNA-related skill improvement in winter SAT over Eurasia, western US?

CESM1-DP vs. CCSM4-DP: Annual Surface Air Temperature (obs=HadCRUT4)

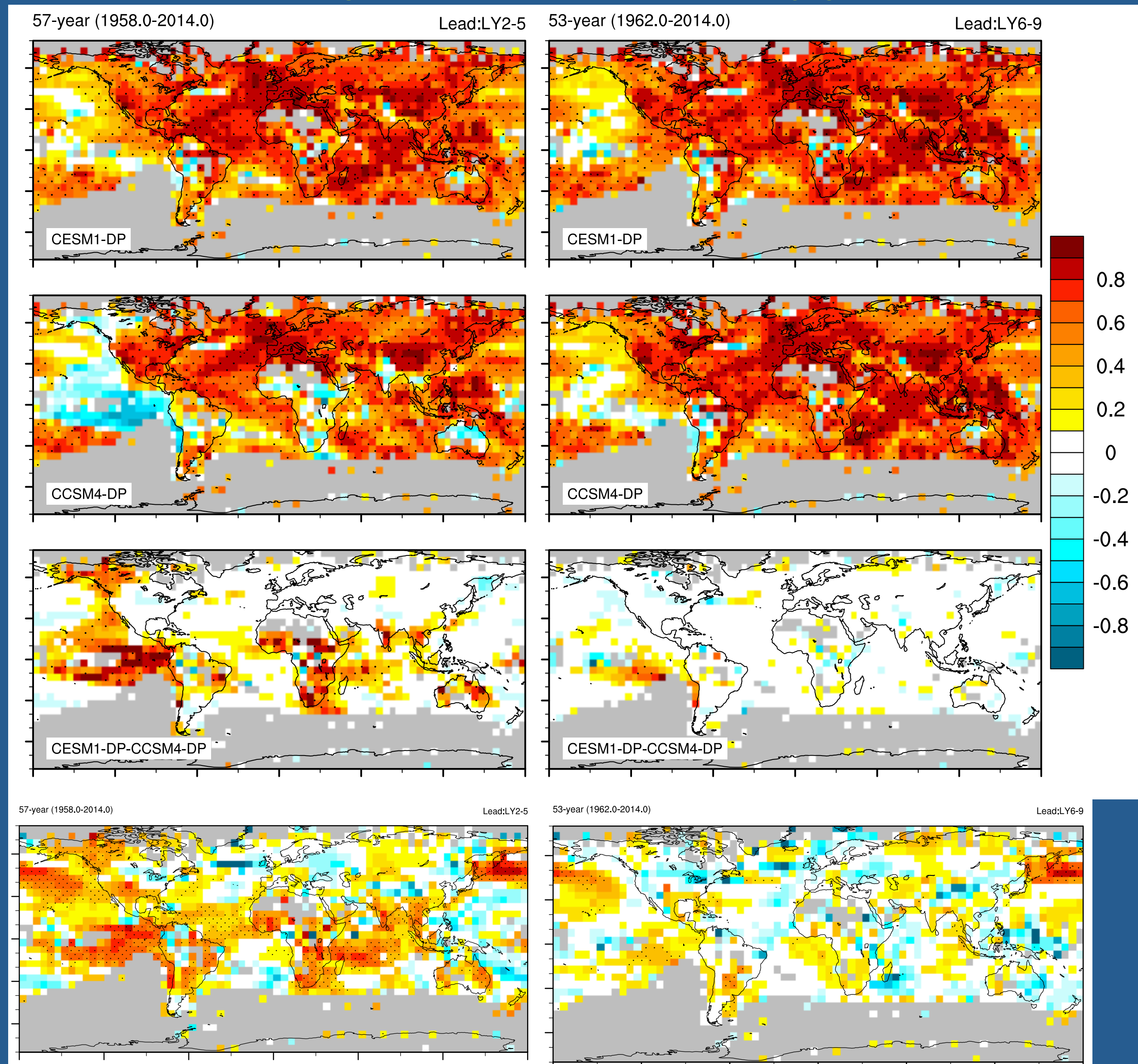
LY2-5 LY6-9

$ACC_{CESM1\text{-}DP}$

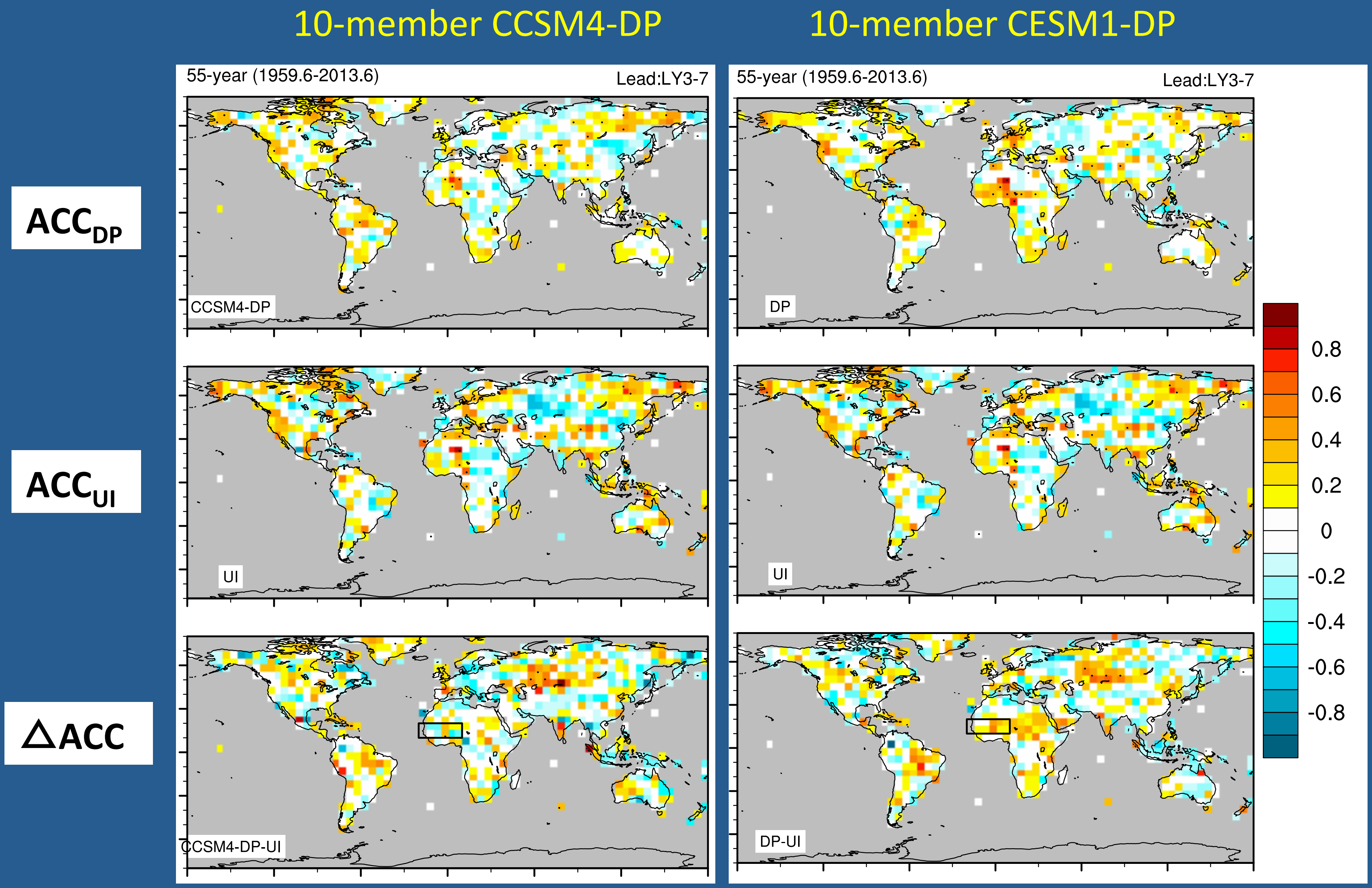
$ACC_{CCSM4\text{-}DP}$

$\triangle$ACC

MSSS
(CESM1 relative to CCSM4)



CESM1-DP vs. CCSM4-DP: JAS Precipitation (obs=CRU), LY3-7



(UI = 30-member CESM1-LE)

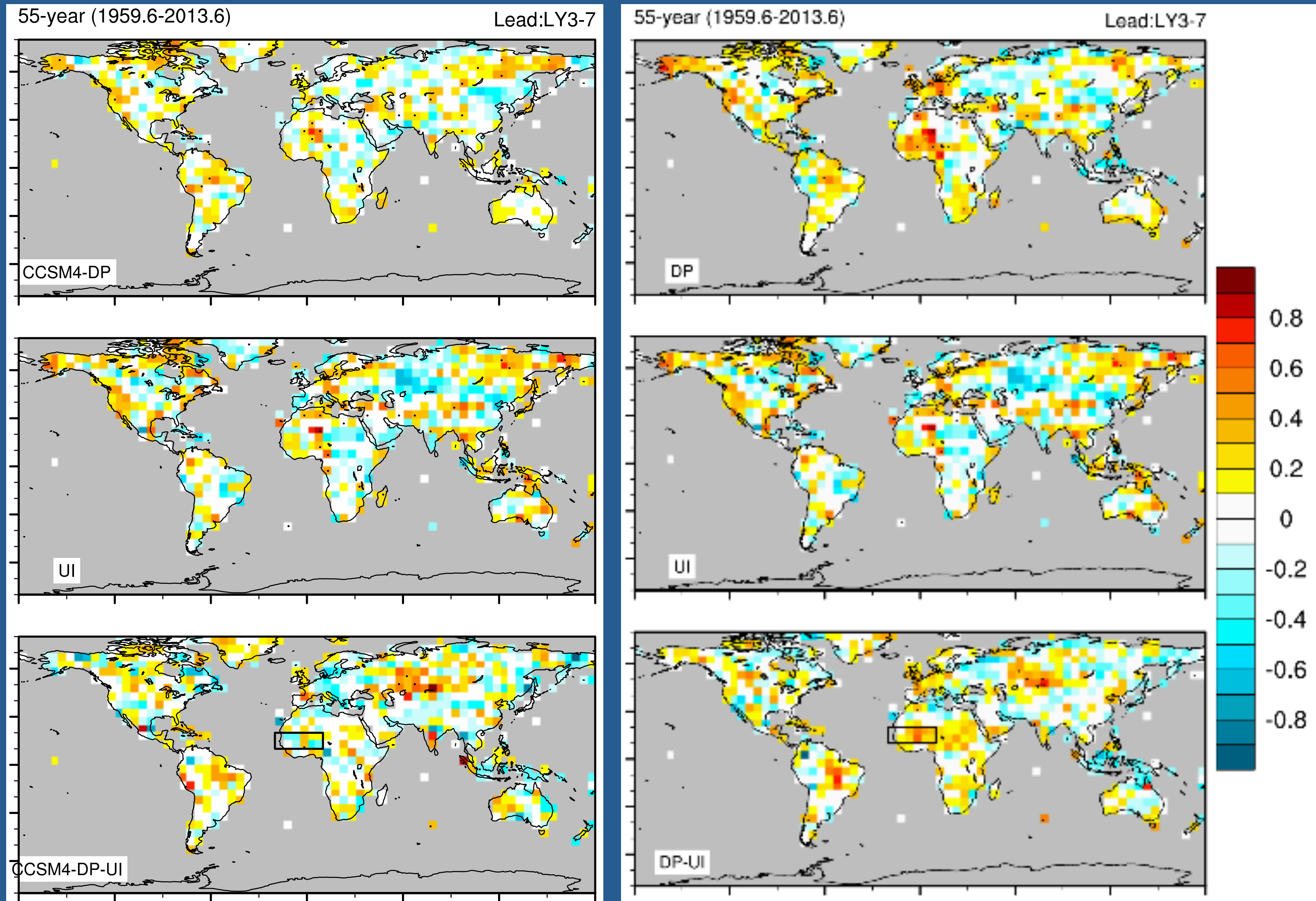
CESM1-DP vs. CCSM4-DP: JAS Precipitation (obs=CRU), LY3-7

10-member CCSM4-DP | 40-member CESM1-DP

ACC_{DP}

ACC_{UI}

$\triangle ACC$

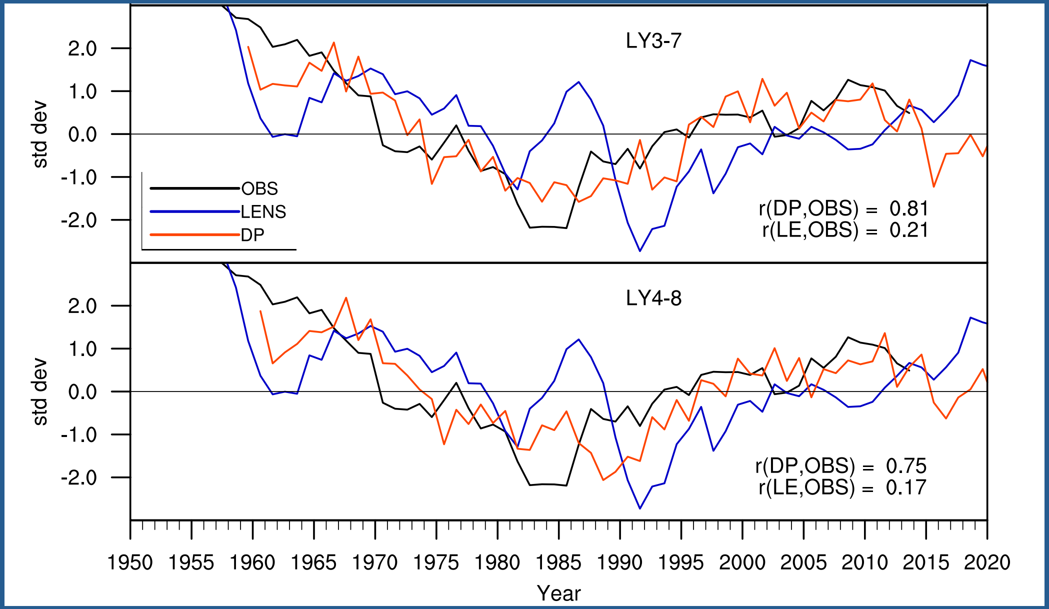


(UI = 30-member CESM1-LE)

See: Eade et al., 2014, GRL, doi: 10.1002/2014GL061146

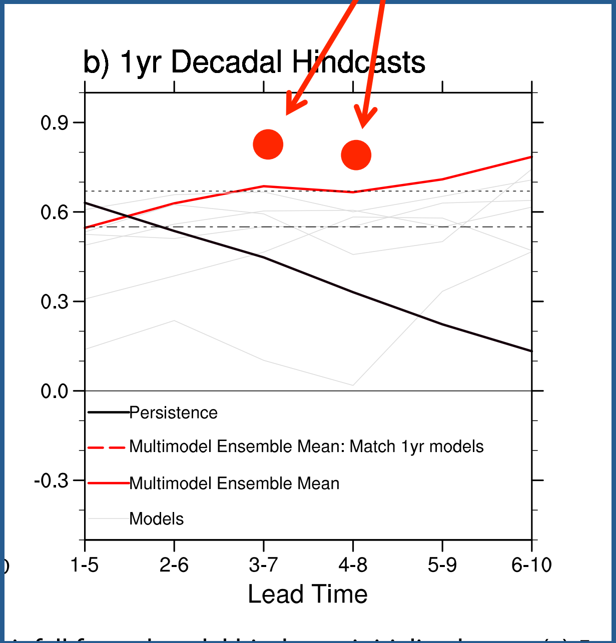
CESM1-DP: JAS Precipitation (obs=CRU), LY3-7

JAS Precipitation, SAHEL



(“LE” = “LENS” = 30-member average of CESM1 Large Ensemble)

40-member CESM1-DP



Martin & Thorncroft, 2014: Sahel rainfall in multimodel CMIP5 decadal hindcasts, *Geophys. Res. Lett.*, doi: 10.1002/2014GL059338.

- **Good skill at predicting Sahel precipitation at decadal lead times**

Summary

- Initialization yields greatly enhanced skill at predicting SPNA heat content & SST at long lead times (above and beyond that due to persistence and/or knowledge of external forcing)
- Southward propagation of NADW anomalies through interior pathways appears to be an important mechanism for SPNA decadal prediction of:
  - THC (V')
  - Heat transport at subpolar latitudes

HOWEVER:

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- Advective heat convergence is important and skillfully predicted, but VbarT' may be as important for prediction as V'Tbar.
- Role of AMOC is dubious in current CESM-DP → room for improvement?

- THC-related SPNA SST skill would appear to reverberate as improved seasonal SAT over land, and…
- Improved summer precipitation over Brazil & Sahel (given a decent tropical Pacific)