NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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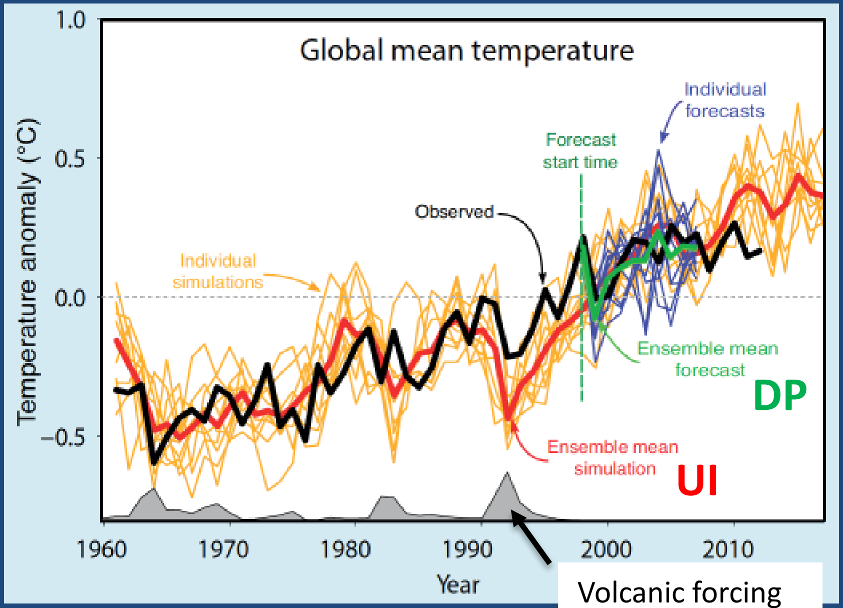
Decadal Climate Prediction in the Large Ensemble Limit

Steve Yeager

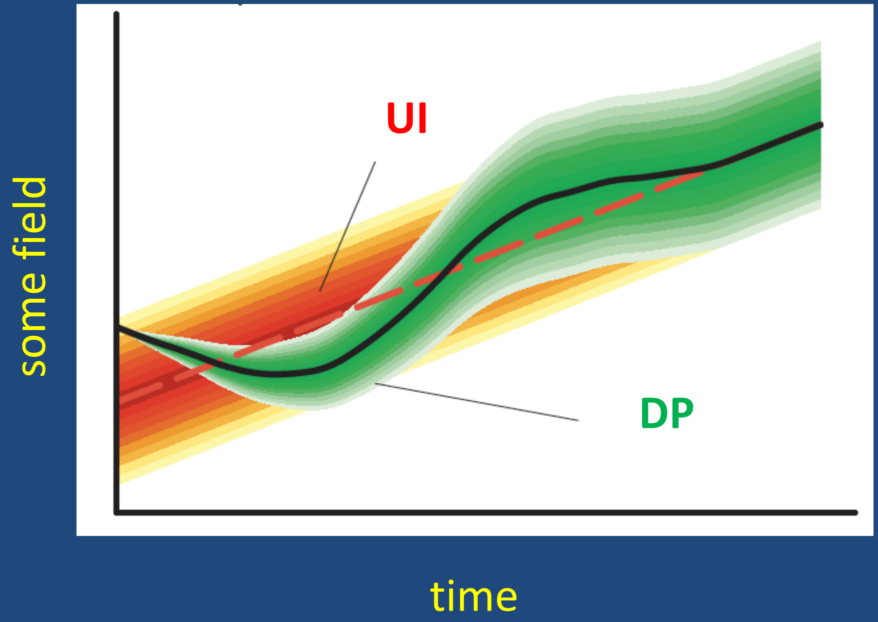
with the NCAR Decadal Prediction Group
(Nan Rosenbloom, Gary Strand, Gokhan Danabasoglu, Alicia Karspeck, Keith Lindsay, Matt Long, Susan Bates, Jerry Meehl, Haiyan Teng)

Climate Projections vs. Climate Predictions



DP: initialized decadal prediction ensemble
UI: "uninitialized" 20th century ensemble

Kirtman & Power (2013)

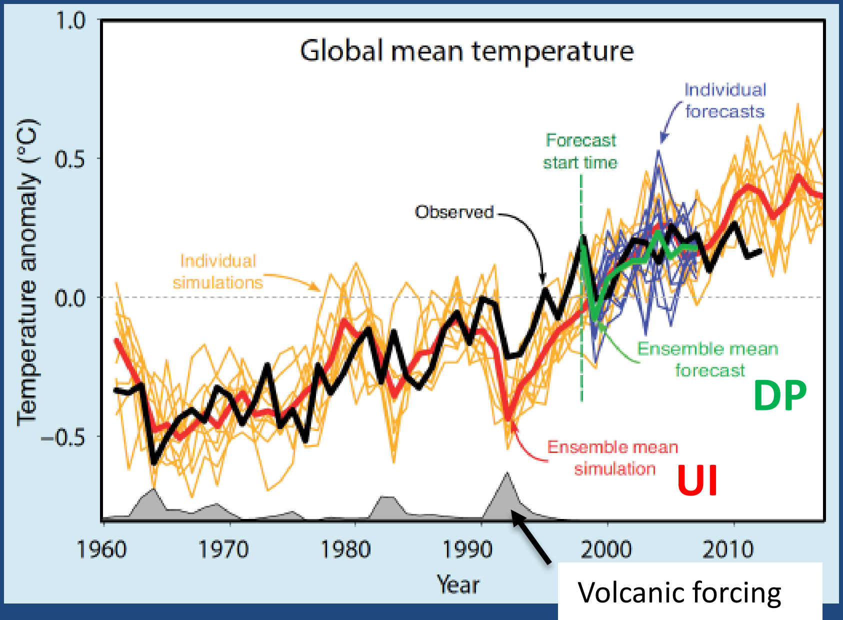


Branstator & Teng (2010)

UI → Earth system response to **external** forcing (greenhouse gases, volcanic & anthropogenic aerosols, solar variations). "historical/projection simulations"

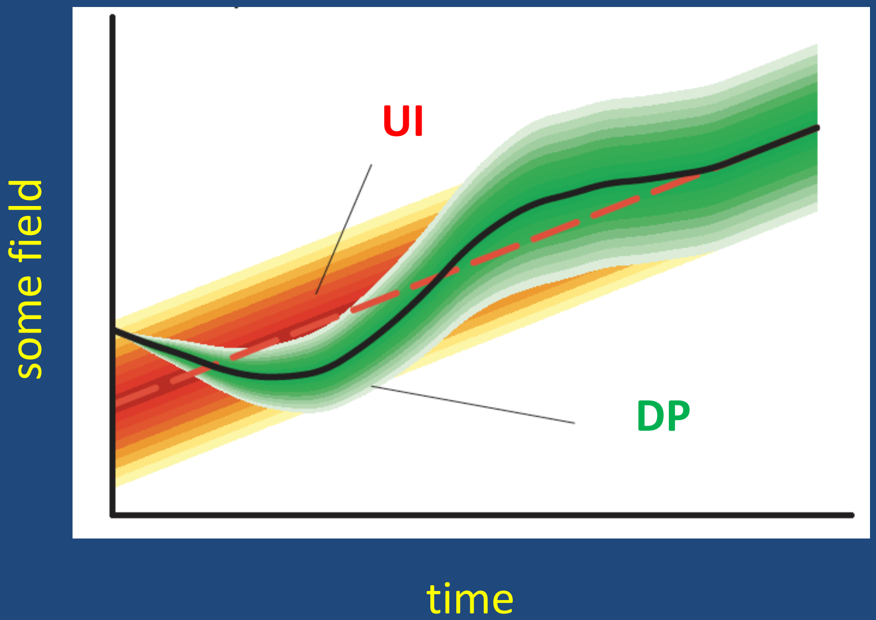
DP → Earth system response to external forcing and **internal** property redistributions (of heat, etc.) related to historical initialization. "hindcasts/forecasts"

Climate Projections vs. Climate Predictions



DP: initialized decadal prediction ensemble
UI: "uninitialized" 20th century ensemble

Kirtman & Power (2013)



Branstator & Teng (2010)

➔ Both ensembles (UI and DP) are needed to fully understand the mechanisms underpinning Earth system prediction. To what extent does initialization improve near-term regional climate outlooks?

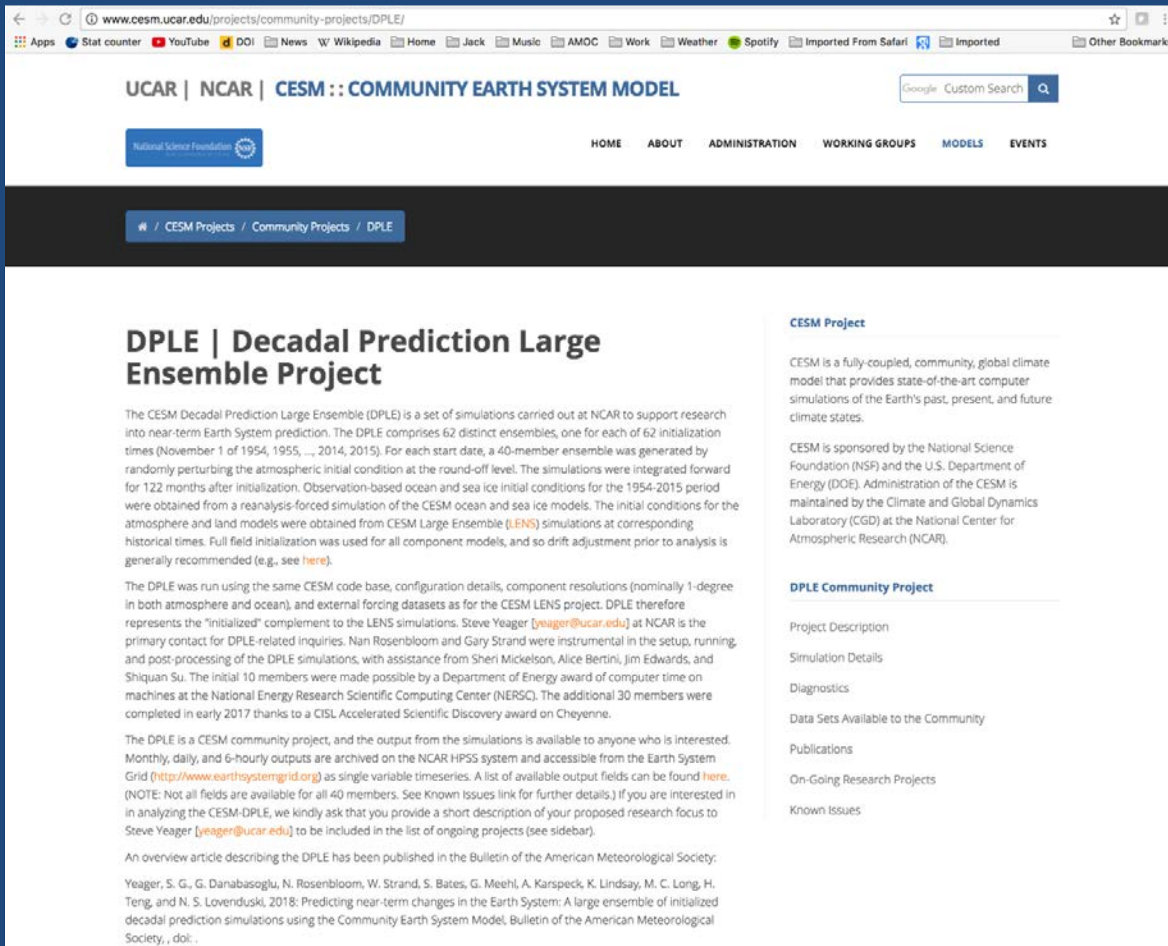
The CESM Decadal Prediction Large Ensemble

Experiment Name	CCSM4-DP	CESM-DP-LE
<u>Model</u> -atm -ocn -ice -lnd	CCSM4 CAM4 (FV 1°, 26lvl) POP2 (1°, 60lvl) CICE4 (1°) CLM4	**CESM1.1** **CAM5** (FV 1°, **30lvl**) POP2 (1°, 60lvl) **w/ BGC** CICE4 (1°) CLM4
UI Ensemble	6-member CCSM4 20th century ensemble (Meehl et al., 2012)	**40-member CESM 20th century Large Ensemble** (Kay et al., 2015)
Forcing	-2005: CMIP5 historical 2006-: CMIP5 RCP 4.5	-2005: CMIP5 historical 2006-: CMIP5 **RCP 8.5**
<u>Initialization</u> -method -atm -ocn -ice -lnd	 full field UI CORE-forced FOSI CORE-forced FOSI UI	 full field UI **CORE*-forced FOSI** **CORE*-forced FOSI** UI
<u>DP Ensembles</u> -ensemble size -start dates -ensemble generation -simulation length	 10 annual; Jan. 1st 1955-2014 (N=60) Variable January start days + round-off perturbation of atm initial conditions 120 months	 **40** annual; **Nov. 1st 1954-2015** (**N=62**) round-off perturbation of atm initial conditions 122 months

CMIP5-era (2011) CMIP6-era (2017)

The CESM Decadal Prediction Large Ensemble

http://www.cesm.ucar.edu/projects/community-projects/DPLE/



www.cesm.ucar.edu/projects/community-projects/DPLE/

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UCAR | NCAR | CESM : : COMMUNITY EARTH SYSTEM MODEL

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/ CESM Projects / Community Projects / DPLE

DPLE | Decadal Prediction Large Ensemble Project

The CESM Decadal Prediction Large Ensemble (DPLE) is a set of simulations carried out at NCAR to support research into near-term Earth System prediction. The DPLE comprises 62 distinct ensembles, one for each of 62 initialization times (November 1 of 1954, 1955, ..., 2014, 2015). For each start date, a 40-member ensemble was generated by randomly perturbing the atmospheric initial condition at the round-off level. The simulations were integrated forward for 122 months after initialization. Observation-based ocean and sea ice initial conditions for the 1954-2015 period were obtained from a reanalysis-forced simulation of the CESM ocean and sea ice models. The initial conditions for the atmosphere and land models were obtained from CESM Large Ensemble (LENS) simulations at corresponding historical times. Full field initialization was used for all component models, and so drift adjustment prior to analysis is generally recommended (e.g., see here).

The DPLE was run using the same CESM code base, configuration details, component resolutions (nominally 1-degree in both atmosphere and ocean), and external forcing datasets as for the CESM LENS project. DPLE therefore represents the "initialized" complement to the LENS simulations. Steve Yeager (yeager@ucar.edu) at NCAR is the primary contact for DPLE-related inquiries. Nan Rosenbloom and Gary Strand were instrumental in the setup, running, and post-processing of the DPLE simulations, with assistance from Sheri Mickelson, Alice Bertini, Jim Edwards, and Shiquan Su. The initial 10 members were made possible by a Department of Energy award of computer time on machines at the National Energy Research Scientific Computing Center (NERSC). The additional 30 members were completed in early 2017 thanks to a CISL Accelerated Scientific Discovery award on Cheyenne.

The DPLE is a CESM community project, and the output from the simulations is available to anyone who is interested. Monthly, daily, and 6-hourly outputs are archived on the NCAR HPSS system and accessible from the Earth System Grid (http://www.earthsystemgrid.org) as single variable timeseries. A list of available output fields can be found here. (NOTE: Not all fields are available for all 40 members. See Known Issues link for further details.) If you are interested in in analyzing the CESM-DPLE, we kindly ask that you provide a short description of your proposed research focus to Steve Yeager (yeager@ucar.edu) to be included in the list of ongoing projects (see sidebar).

An overview article describing the DPLE has been published in the Bulletin of the American Meteorological Society:

Yeager, S. G., G. Danabasoglu, N. Rosenbloom, W. Strand, S. Bates, G. Meehl, A. Karspeck, K. Lindsay, M. C. Long, H. Teng, and N. S. Lovenduski, 2018: Predicting near-term changes in the Earth System: A large ensemble of initialized decadal prediction simulations using the Community Earth System Model. Bulletin of the American Meteorological Society, , doi: .

CESM Project

CESM is a fully-coupled, community, global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states.

CESM is sponsored by the National Science Foundation (NSF) and the U.S. Department of Energy (DOE). Administration of the CESM is maintained by the Climate and Global Dynamics Laboratory (CGD) at the National Center for Atmospheric Research (NCAR).

DPLE Community Project

- Project Description
- Simulation Details
- Diagnostics
- Data Sets Available to the Community
- Publications
- On-Going Research Projects
- Known Issues

Want to analyze CESM-DP-LE? Send me a short description of your research topic.

Yeager et al., 2018: Predicting near-term changes in the Earth System: A large ensemble of initialized decadal prediction simulations using the Community Earth System Mode, *Bull Amer Meteor Soc,* in revision.

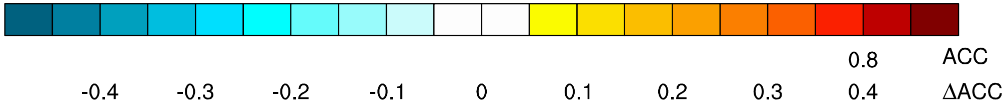
Annual Ocean Heat Content (295m)

(OBS = EN4)

→ Anomaly correlation coefficient (ACC)

→ Skill improvement over persistence

→ Skill improvement over UI



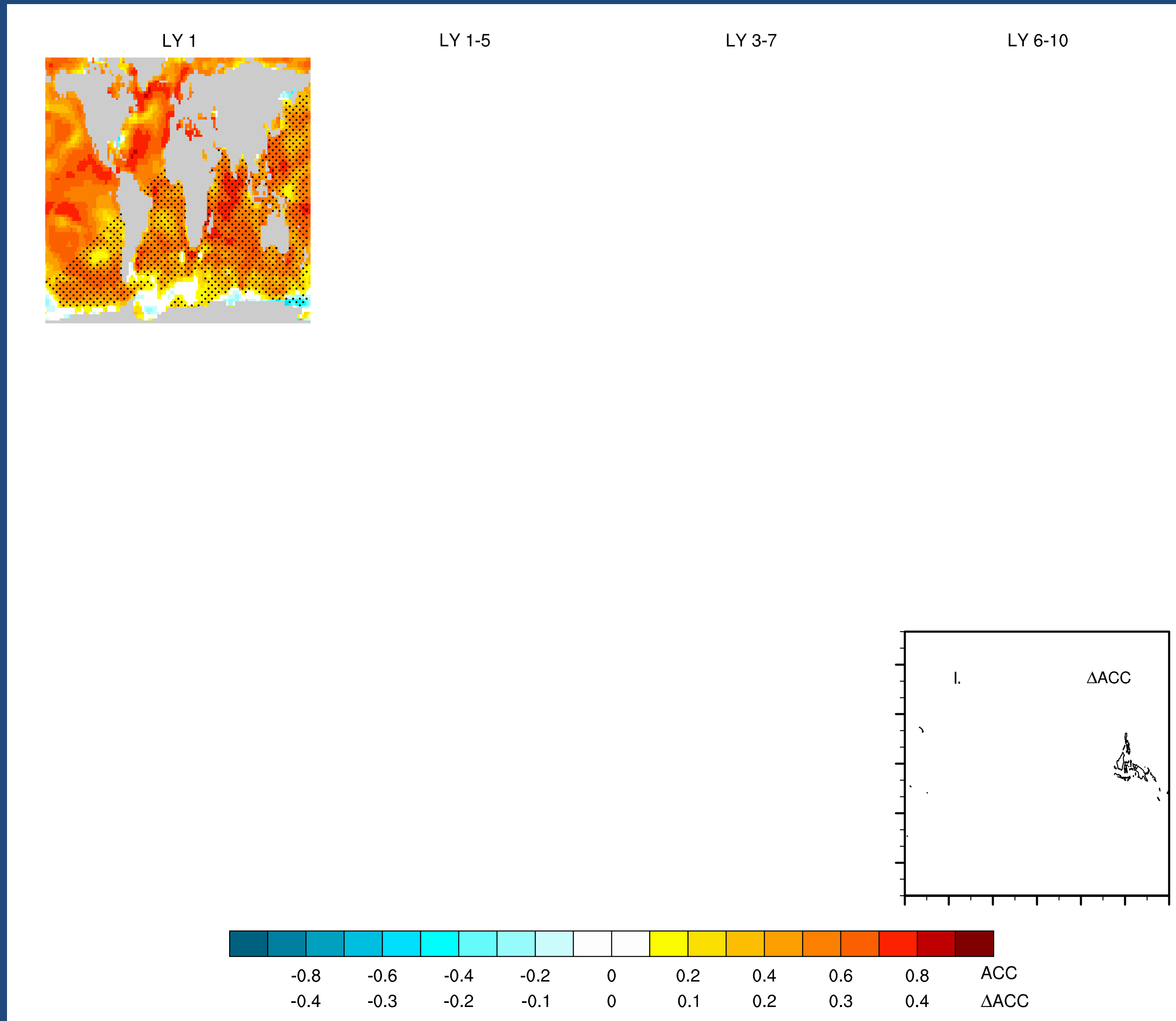
Annual Sea Surface Temperature

(OBS = Hurrell)

→ Anomaly correlation coefficient (ACC)

→ Skill improvement over persistence

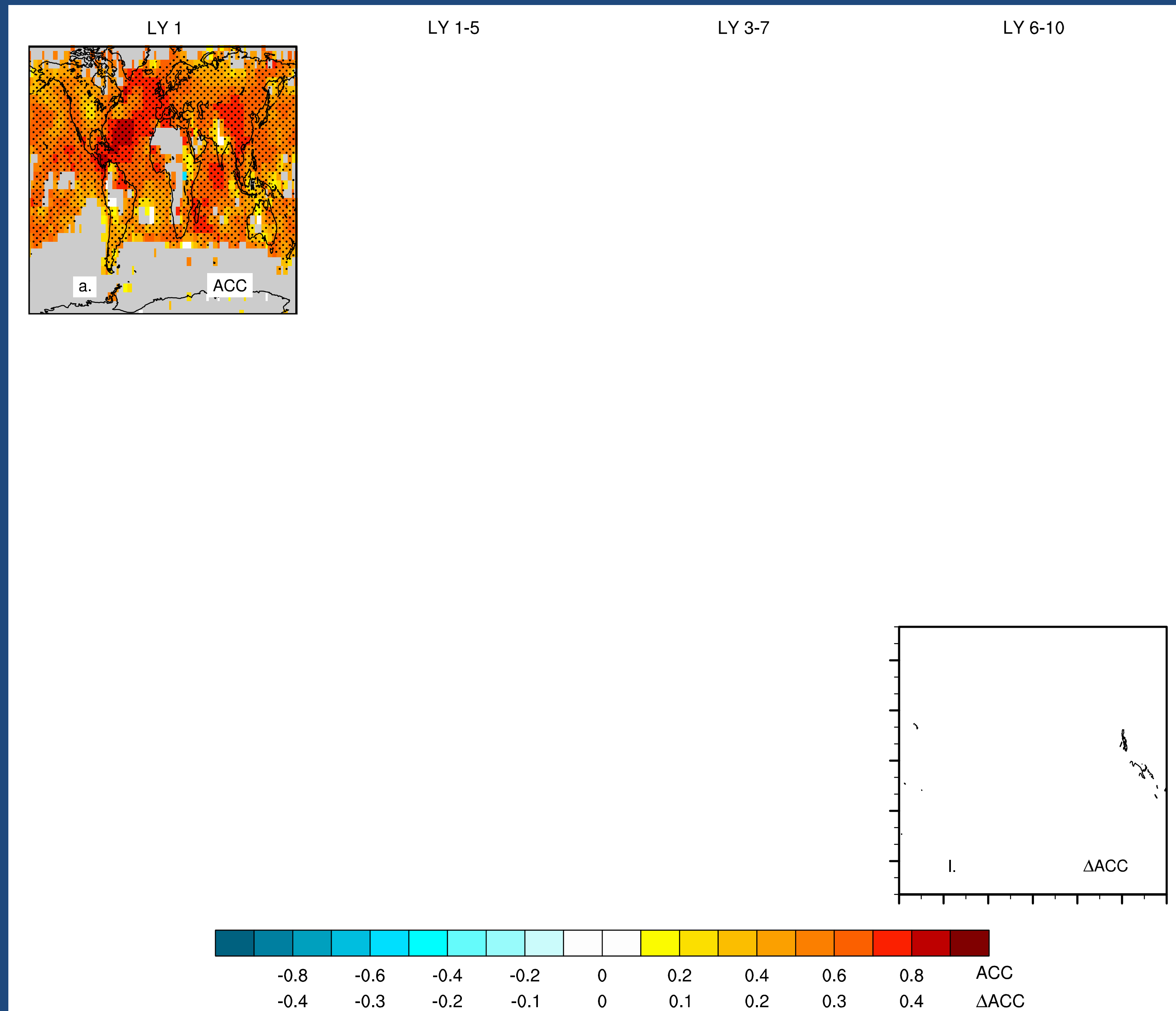
→ Skill improvement over UI



Annual Surface Air Temperature

(OBS = HadCRUT4)

- ➔ Anomaly correlation coefficient (ACC)
- ➔ Skill improvement over persistence
- ➔ Skill improvement over UI



Annual O2 on σ_0=26.5 kg/m^3

(OBS = FOSI)

→ Anomaly correlation coefficient (ACC)

→ Skill improvement over persistence

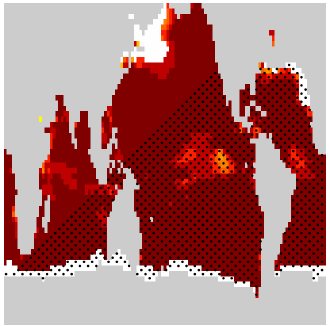
→ Skill improvement over UI

LY 1

LY 1-5

LY 3-7

LY 6-10



ACC

ΔACC

0 0.1 0.2 0.3 0.4

Surface Air Temperature

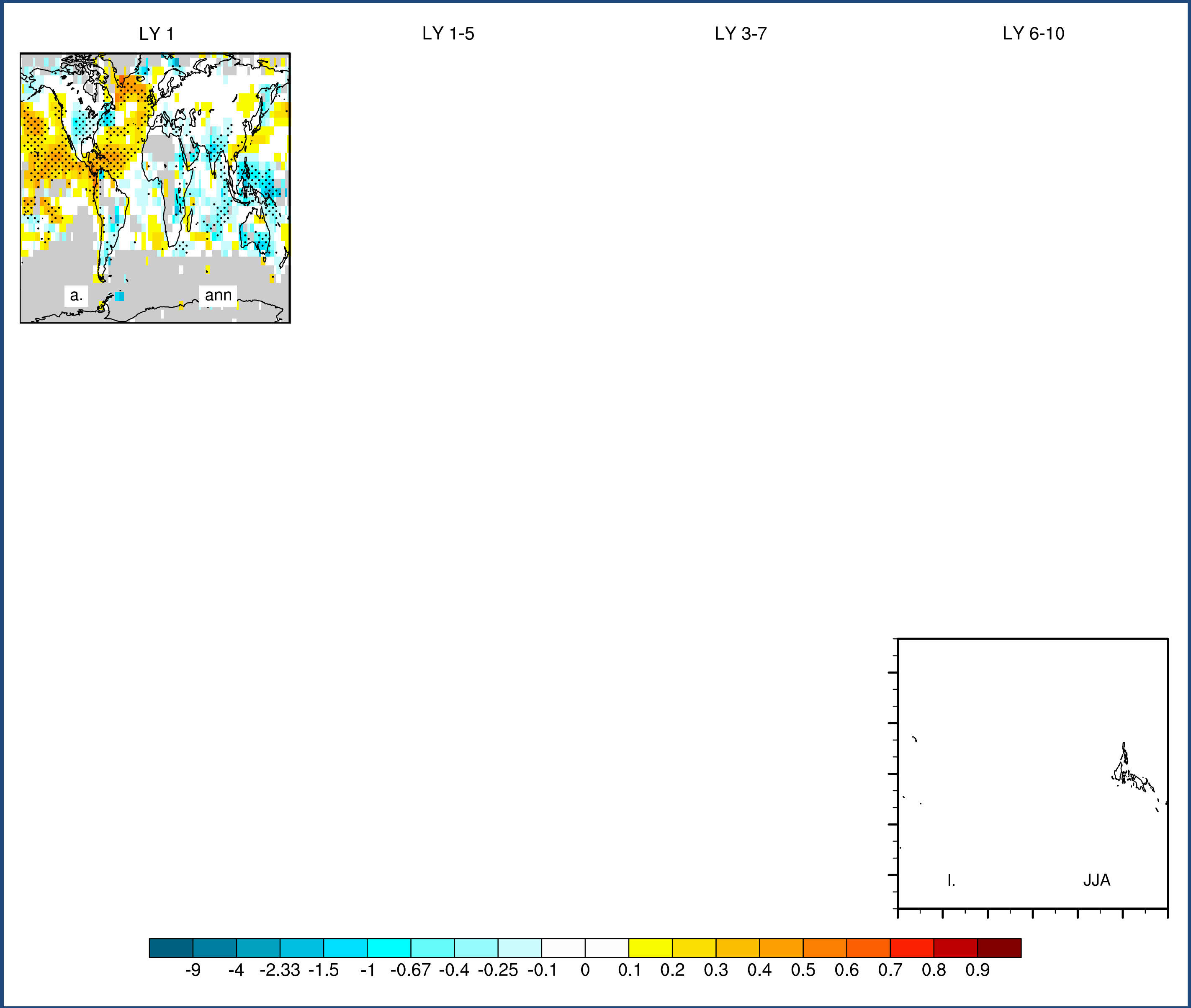
(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=40, N_UI=40)

→ Annual

→ DJF

→ JJA



$$1 - \frac{MSE_{DP}}{MSE_{ref}}$$

Surface Air Temperature

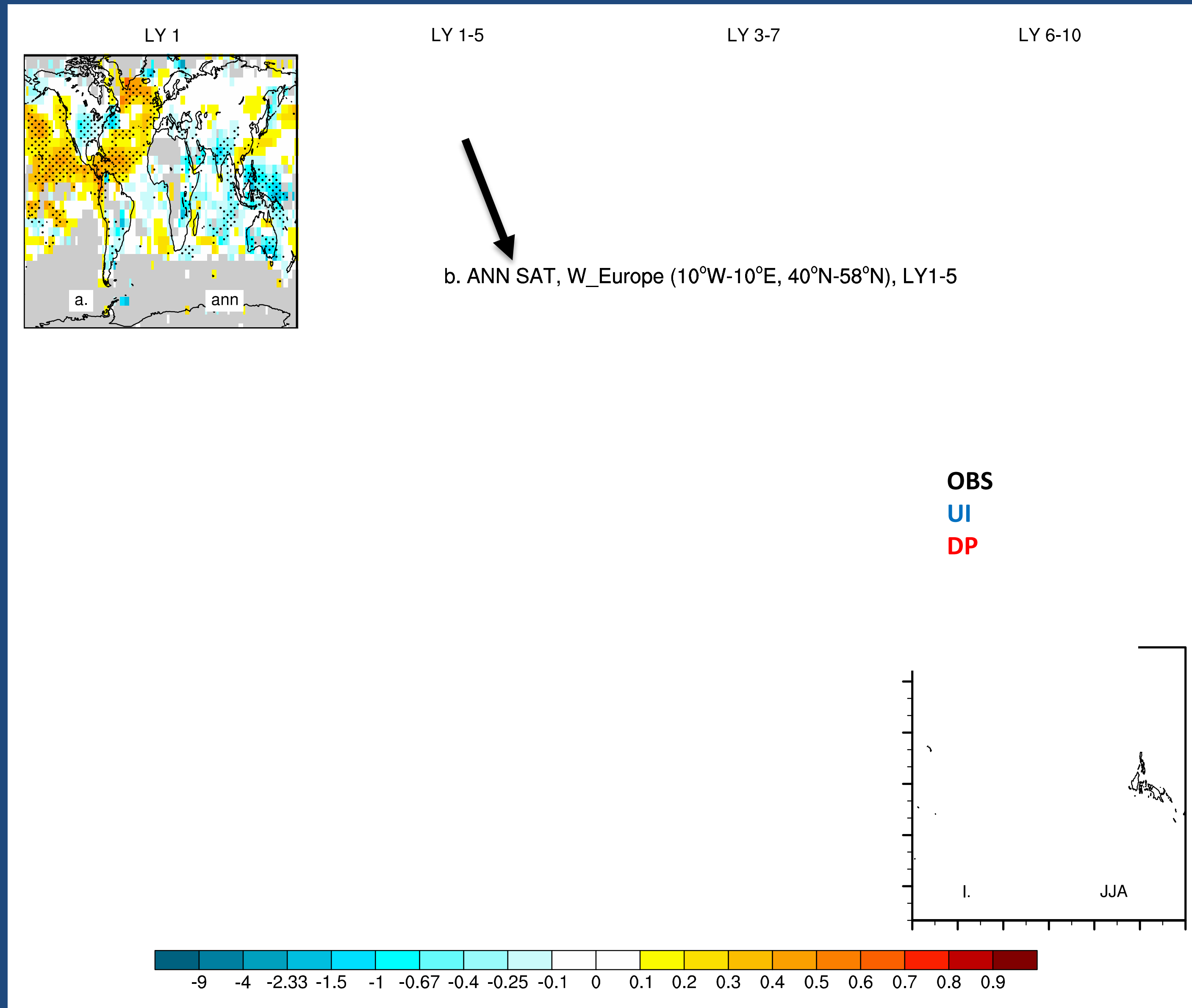
(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=40, N_UI=40)

➔ Annual

➔ DJF

➔ JJA



Surface Air Temperature

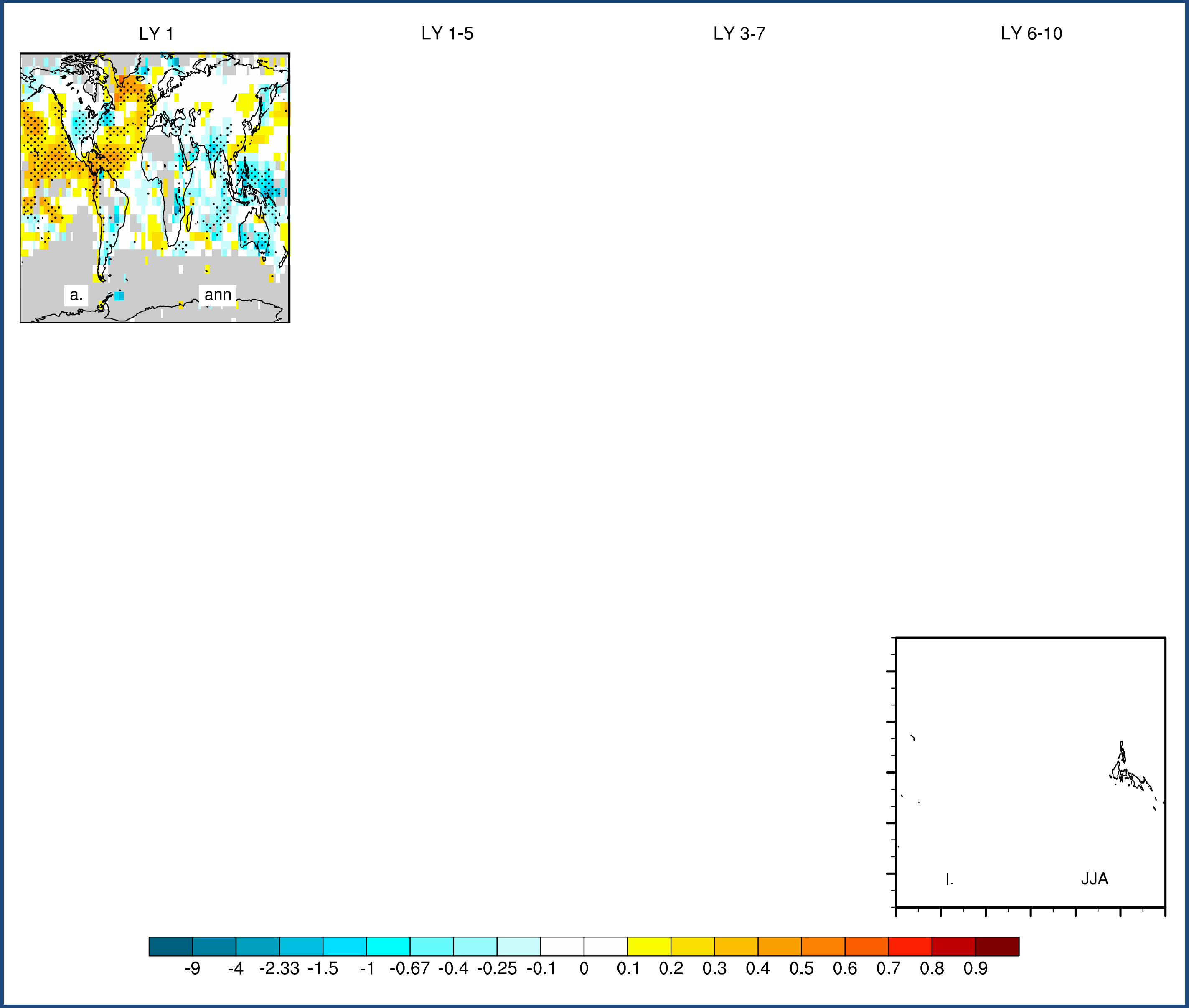
(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=40, N_UI=40)

➔ Annual

➔ DJF

➔ JJA



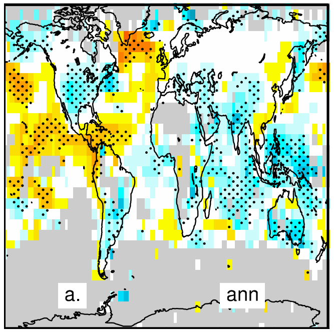
Surface Air Temperature

(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=10, N_UI=40)

LY 1 | LY 1-5 | LY 3-7 | LY 6-10

→ Annual



→ DJF

→ JJA

5 -1 -0.67 -0.4 -0.25 -0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

Surface Air Temperature

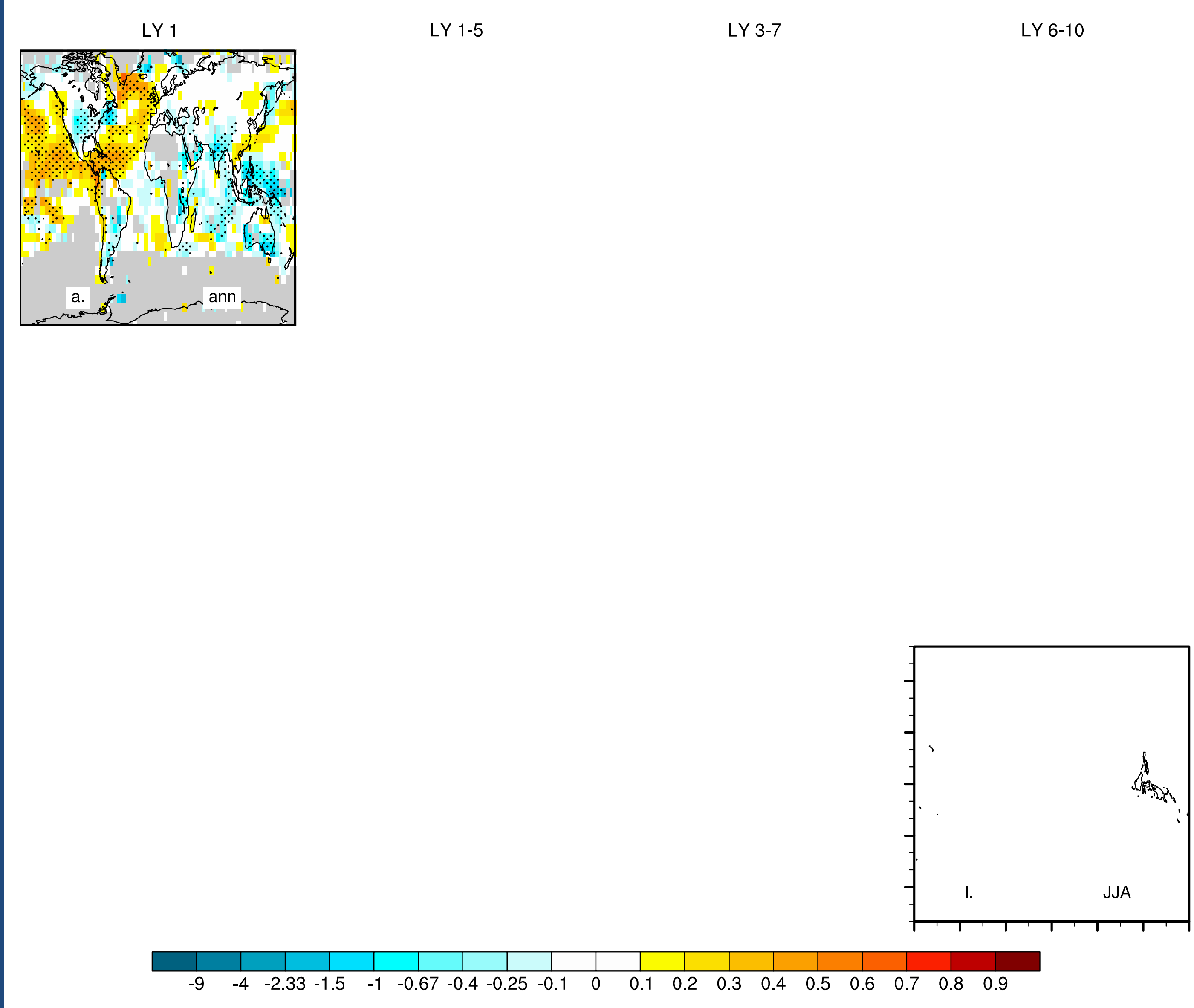
(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=40, N_UI=40)

→ Annual

→ DJF

→ JJA



Surface Air Temperature

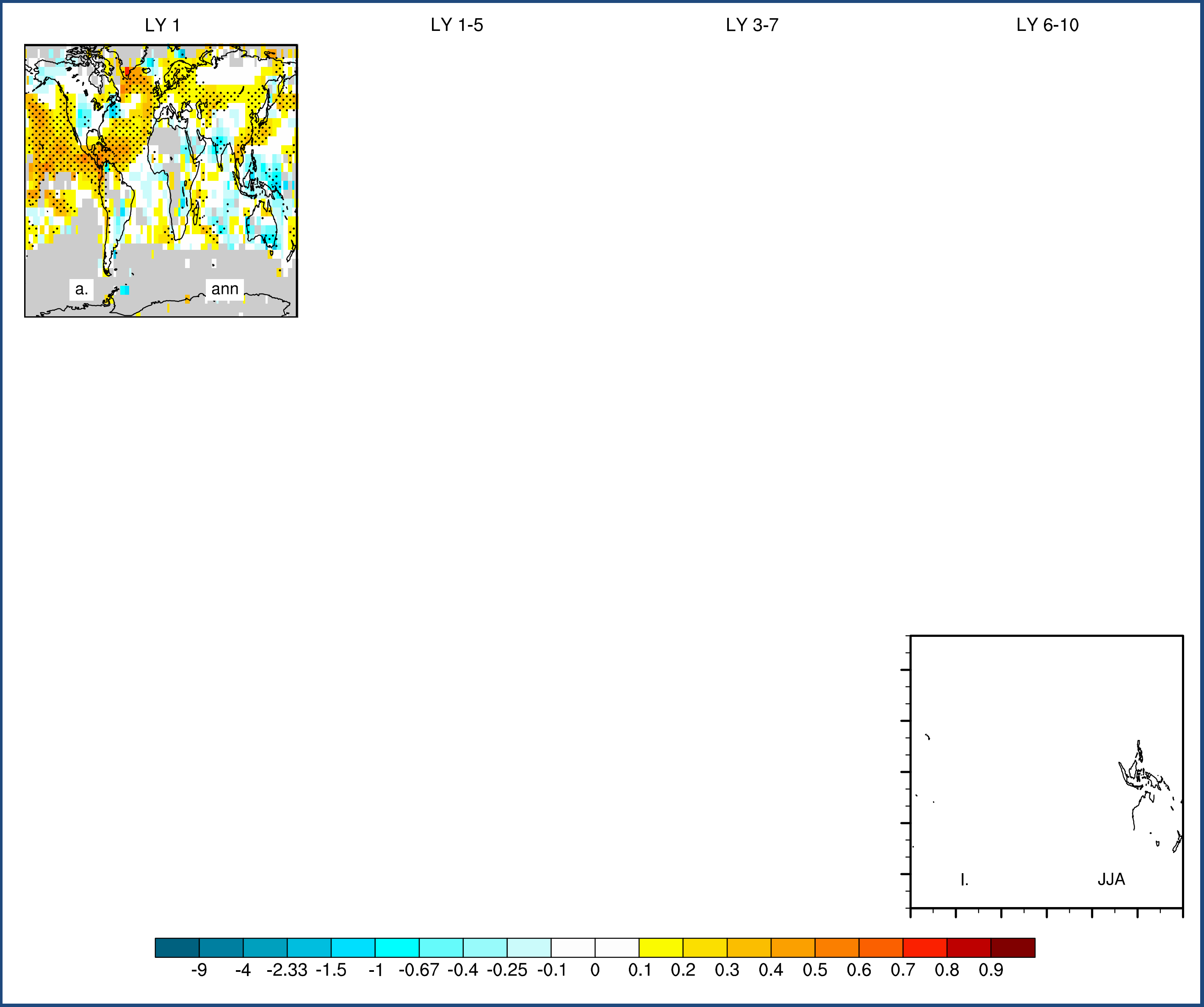
(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=40, N_UI=10)

→ Annual

→ DJF

→ JJA



Surface Air Temperature

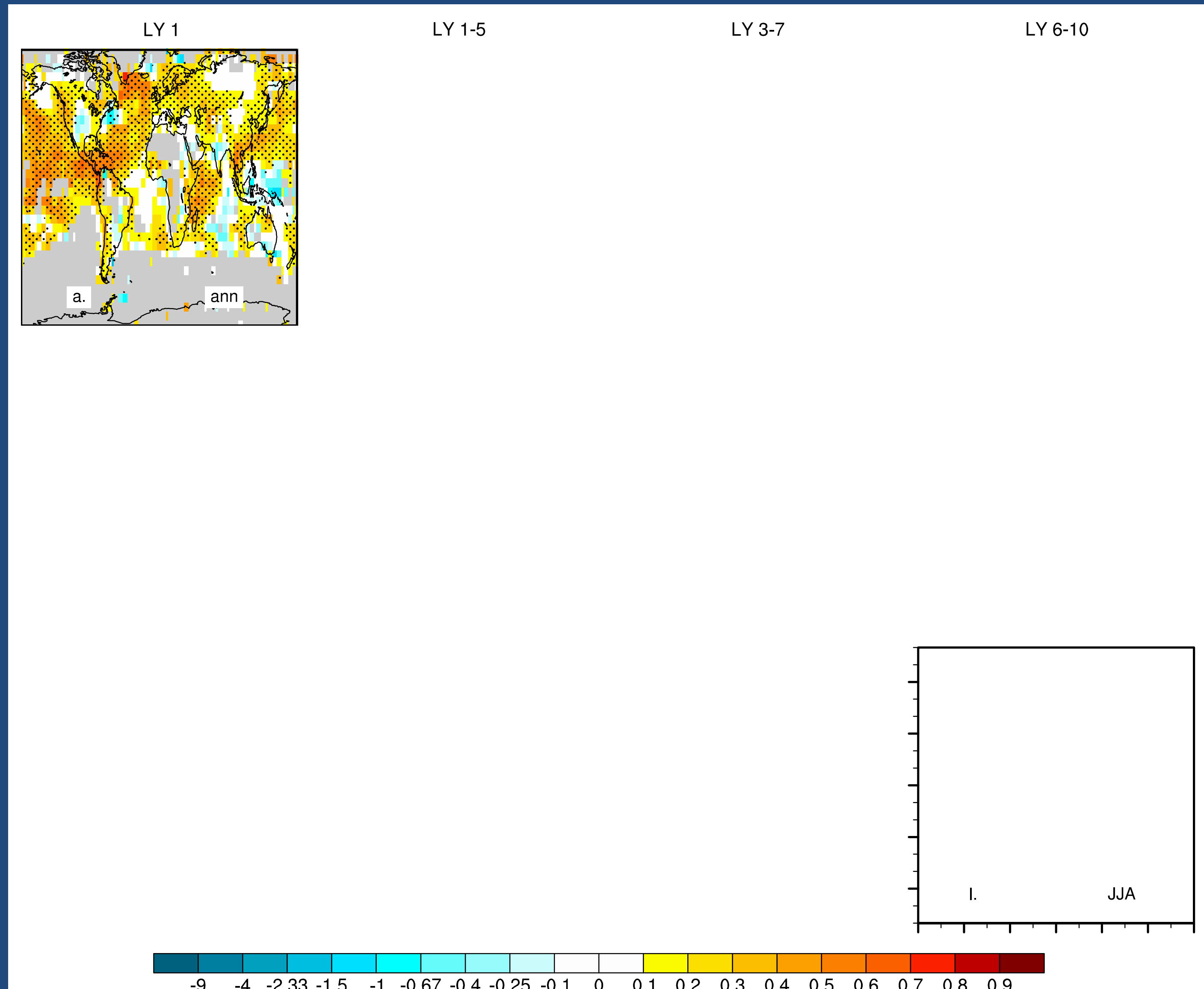
(OBS = HadCRUT4)

MSSS using UI as reference forecast (N_DP=40, N_UI=5)

→ Annual

→ DJF

→ JJA



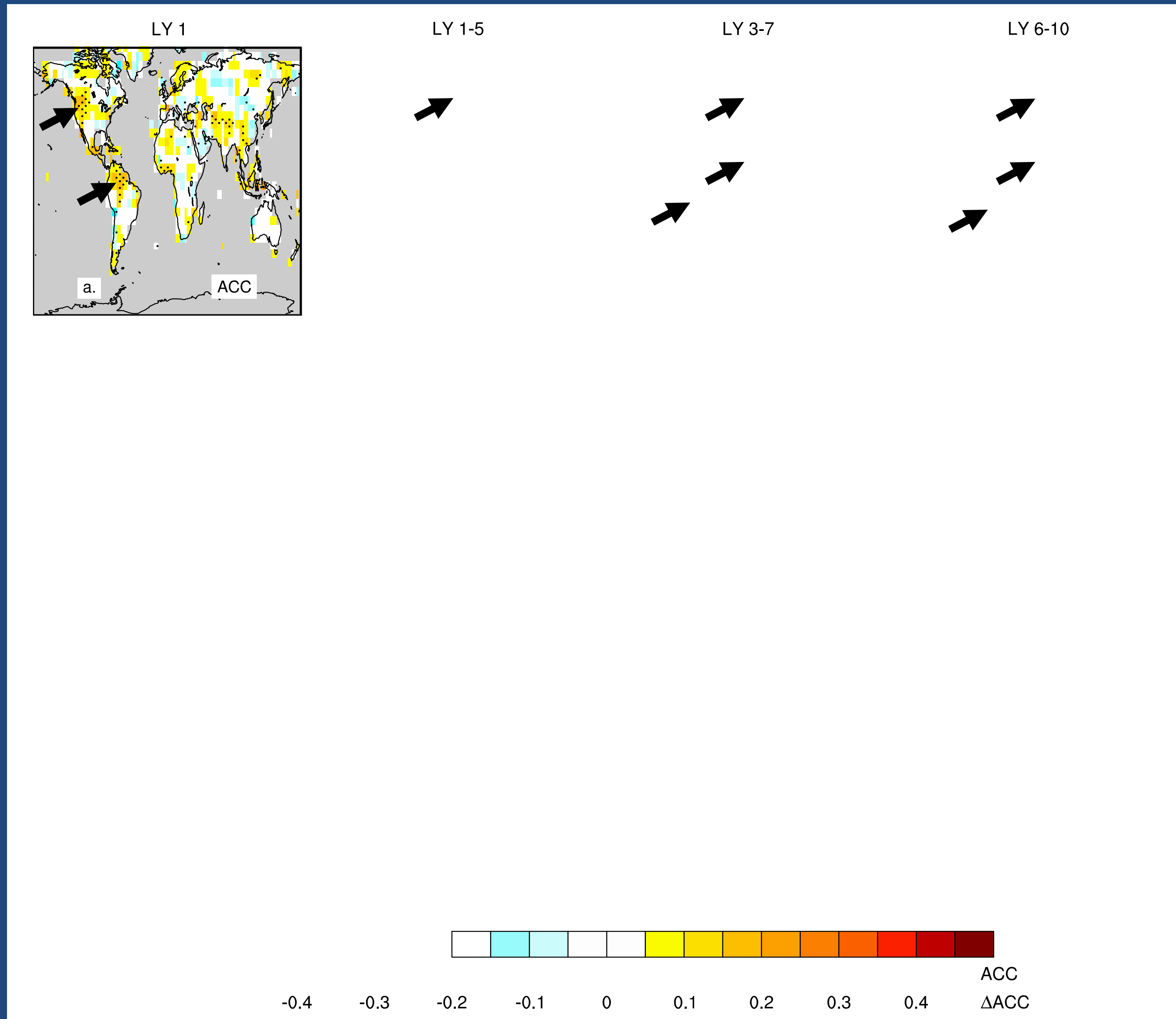
Seasonal Precipitation (JAS)

(verified against CRU-TS 3.24)

ACC

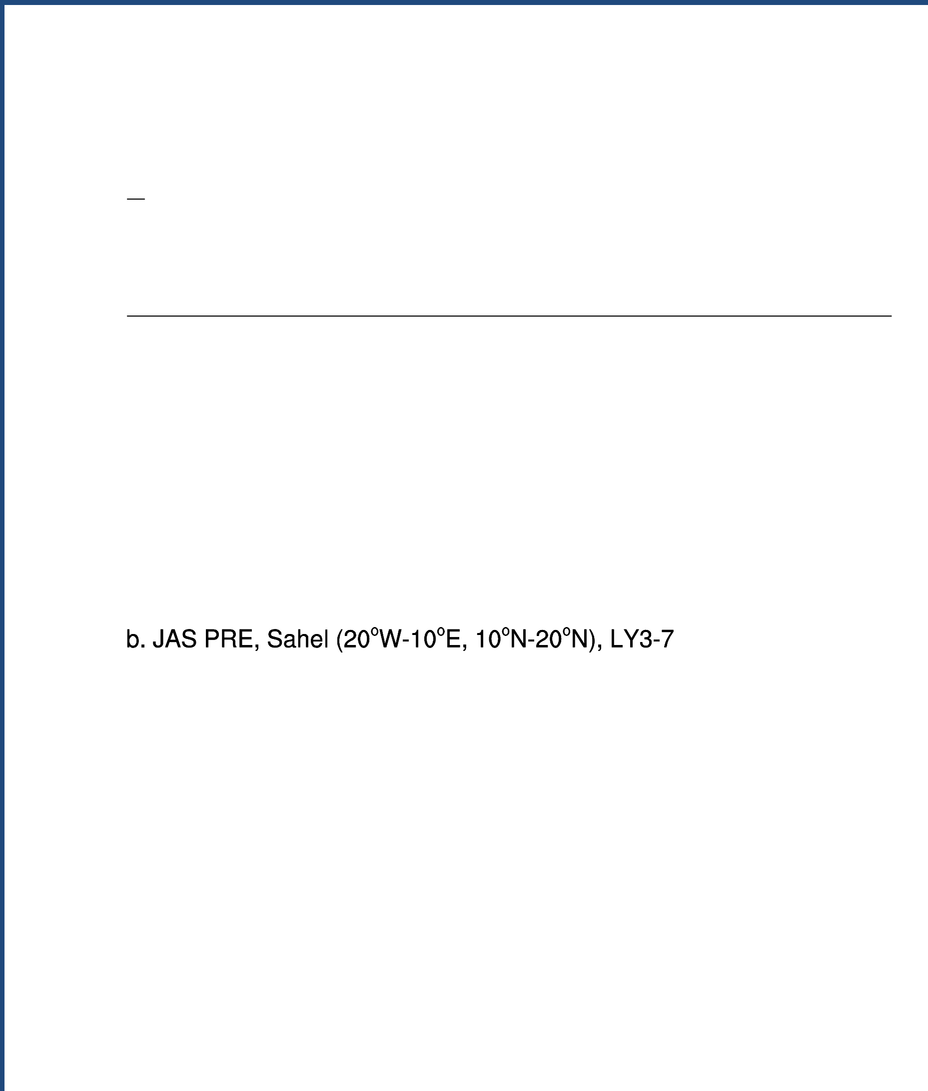
ΔACC (relative to persistence)

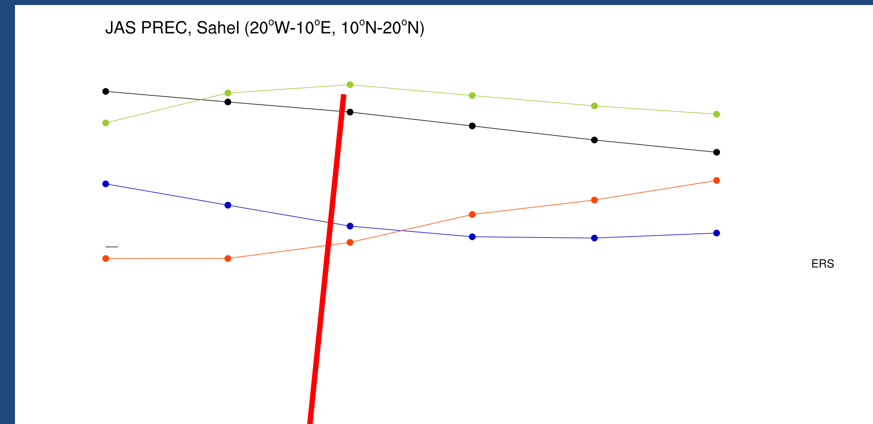
ΔACC (relative to uninitialized)



Sahel Precipitation (JAS)

(verified against CRU-TS 3.24)





LY 3-7

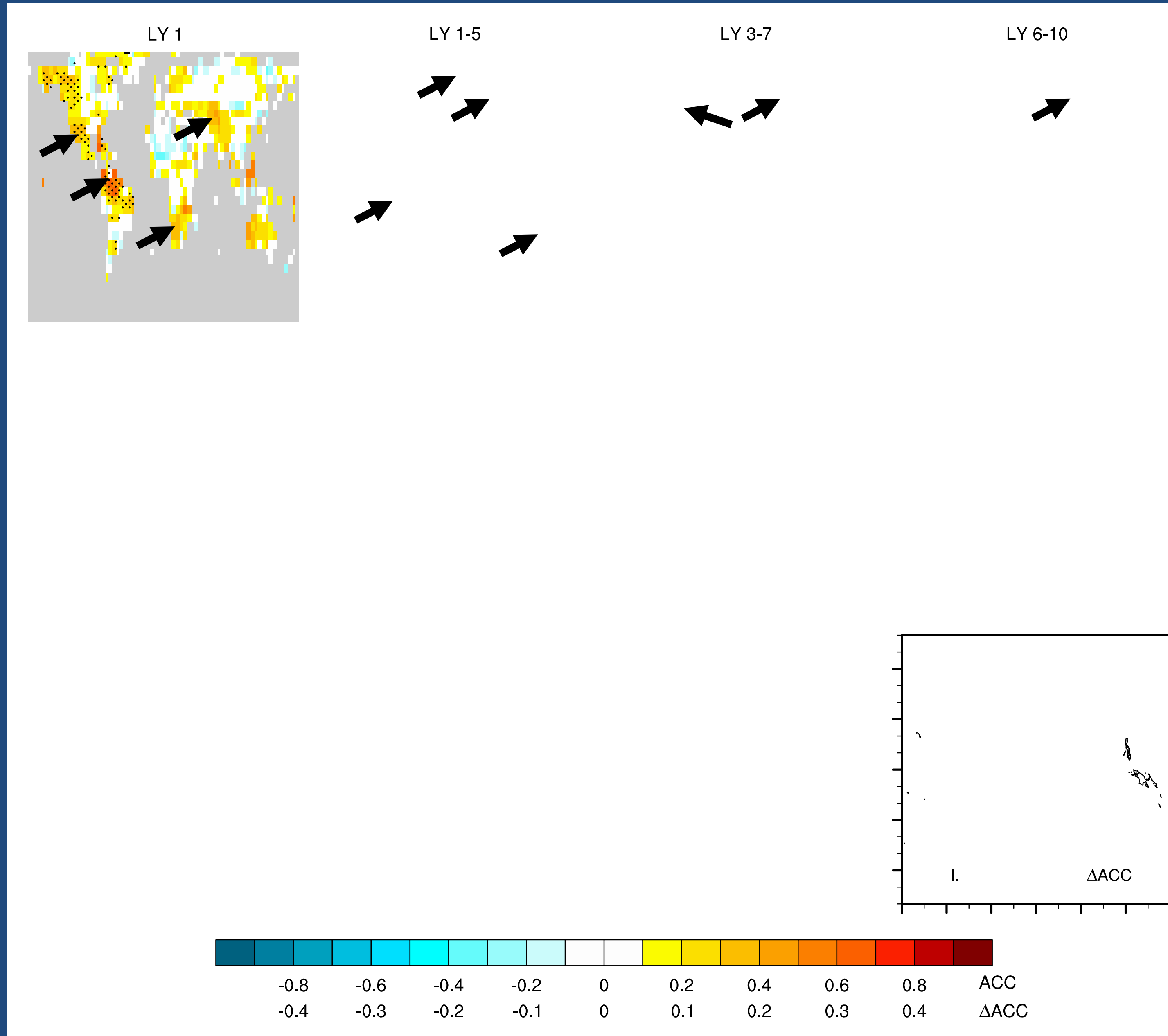
Seasonal Precipitation (JFM)

(verified against CRU-TS 3.24)

ACC

ΔACC (relative to persistence)

ΔACC (relative to uninitialized)



JFM Precipitation

(OBS = CRU-TS3.24)

(N_DP=40, N_UI=**40**)

LY 1 LY 1-5 LY 3-7 LY 6-10

Scandinavia

Scandinavia

55°N-70°N), LY1-5

0°N), LY1-5

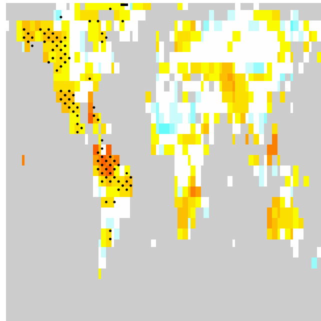
JFM Precipitation

(OBS = CRU-TS3.24)

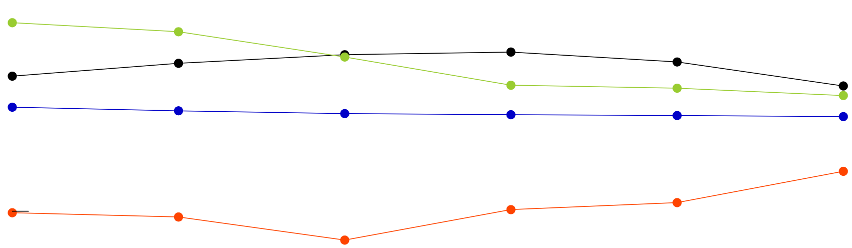
(N_DP=40, N_UI=**40**)

→ Anomaly correlation coefficient (ACC)

LY 1	LY 1-5	LY 3-7	LY 6-10

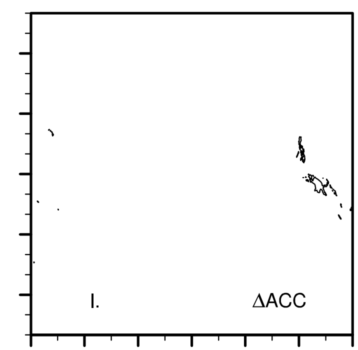


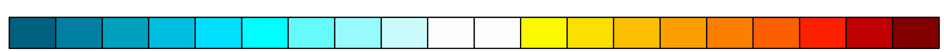
JFM PREC, Scandinavia (0°W-30°E, 55°N-70°N)



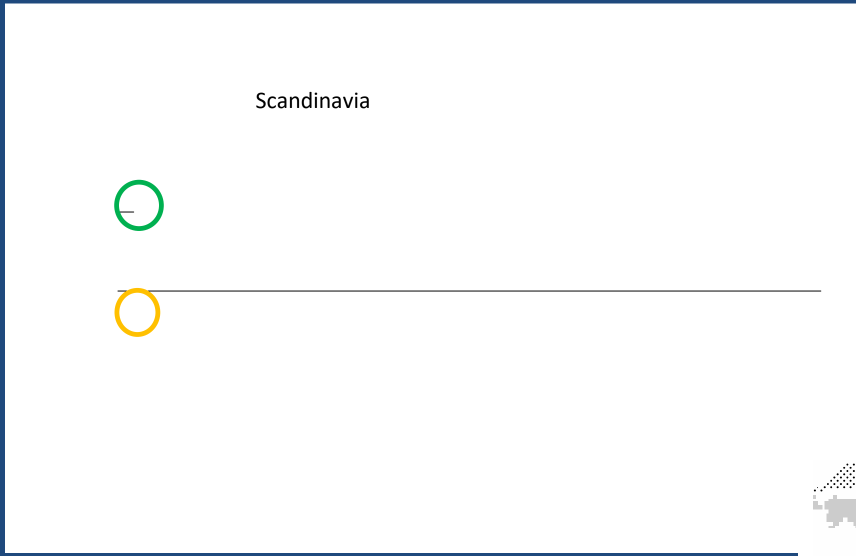
ERS

over UI

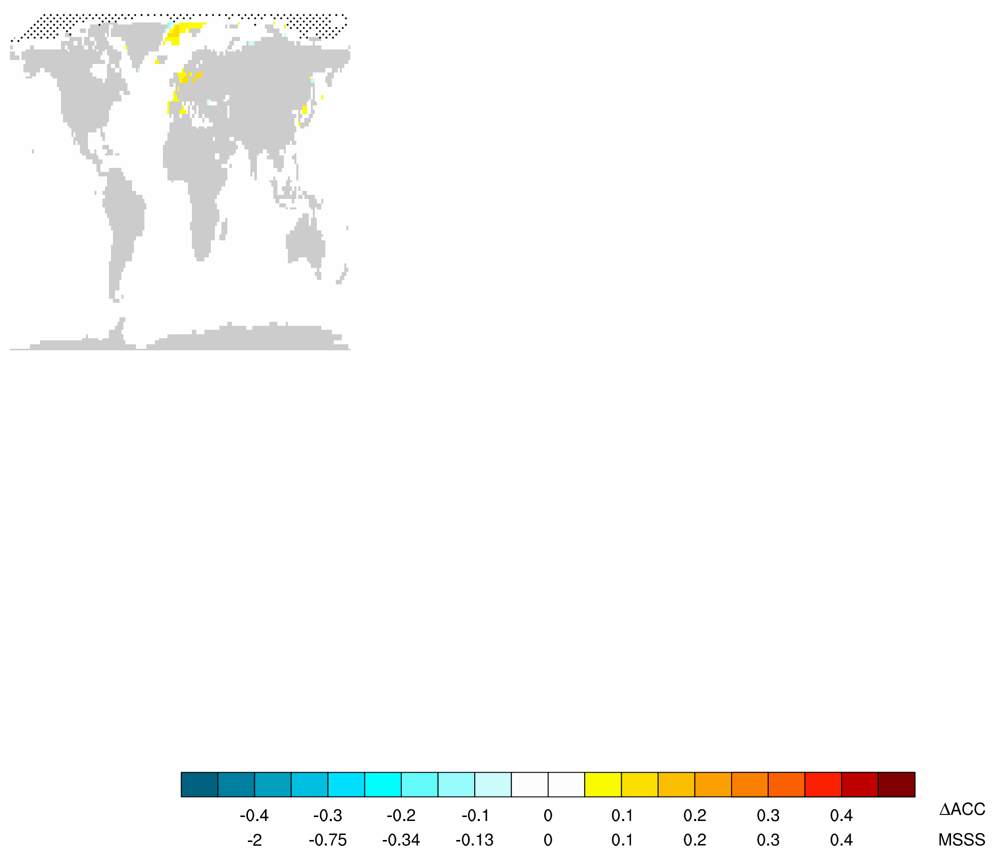




What influences JFM PRECIP skill over Scandinavia?



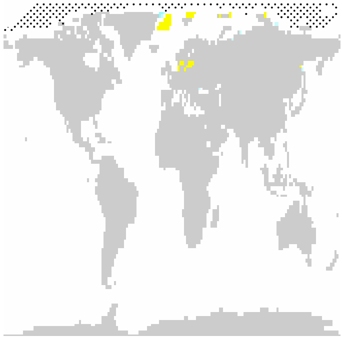
LY1-5 skill conditioned on JFM Scandinavia PRECIP (ensemble size = 1) : GREEN - ORANGE



Hindcasts skillful at JFM PRECIP over Scandinavia tend to show improved NAO-like winter SLP, but no clear improvement in SST skill.

What influences JFM PRECIP skill over Scandinavia?

LY1-5 skill conditioned on JFM Scandinavia PRECIP (ensemble size = 10) : GREEN - ORANGE



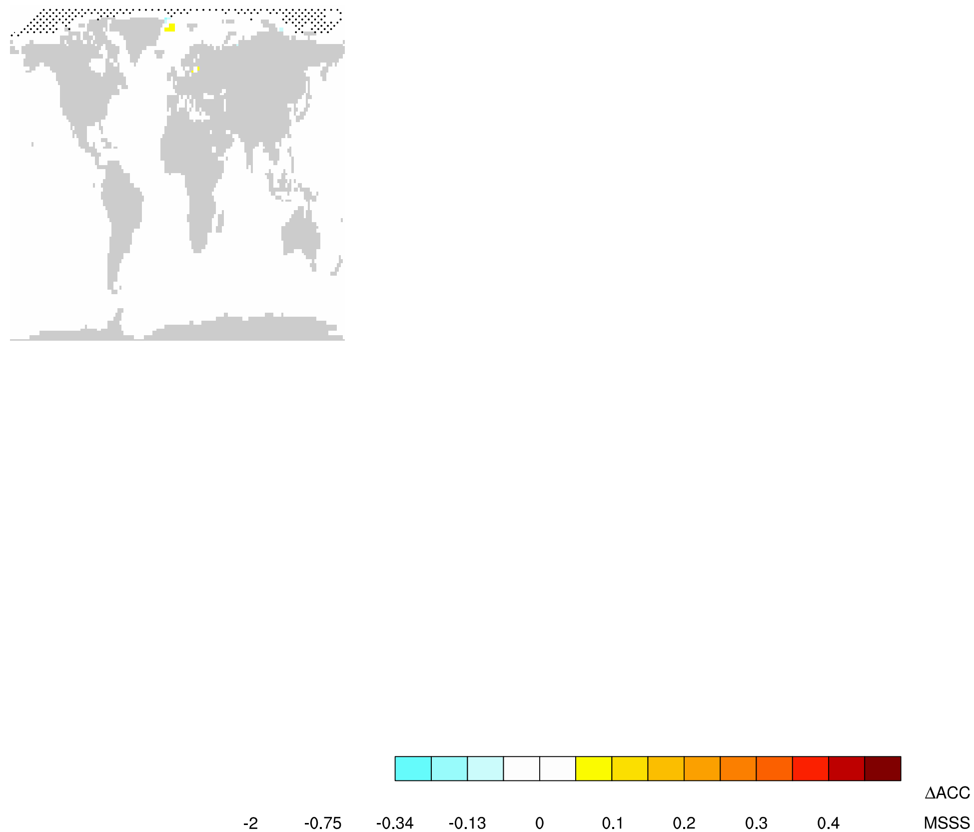
Hindcasts skillful at JFM PRECIP over Scandinavia tend to show improved NAO-like winter SLP, but no clear improvement in SST skill.

CC

MSSS

What influences JFM PRECIP skill over Scandinavia?

LY1-5 skill conditioned on JFM Scandinavia PRECIP (ensemble size = 30) : GREEN - ORANGE

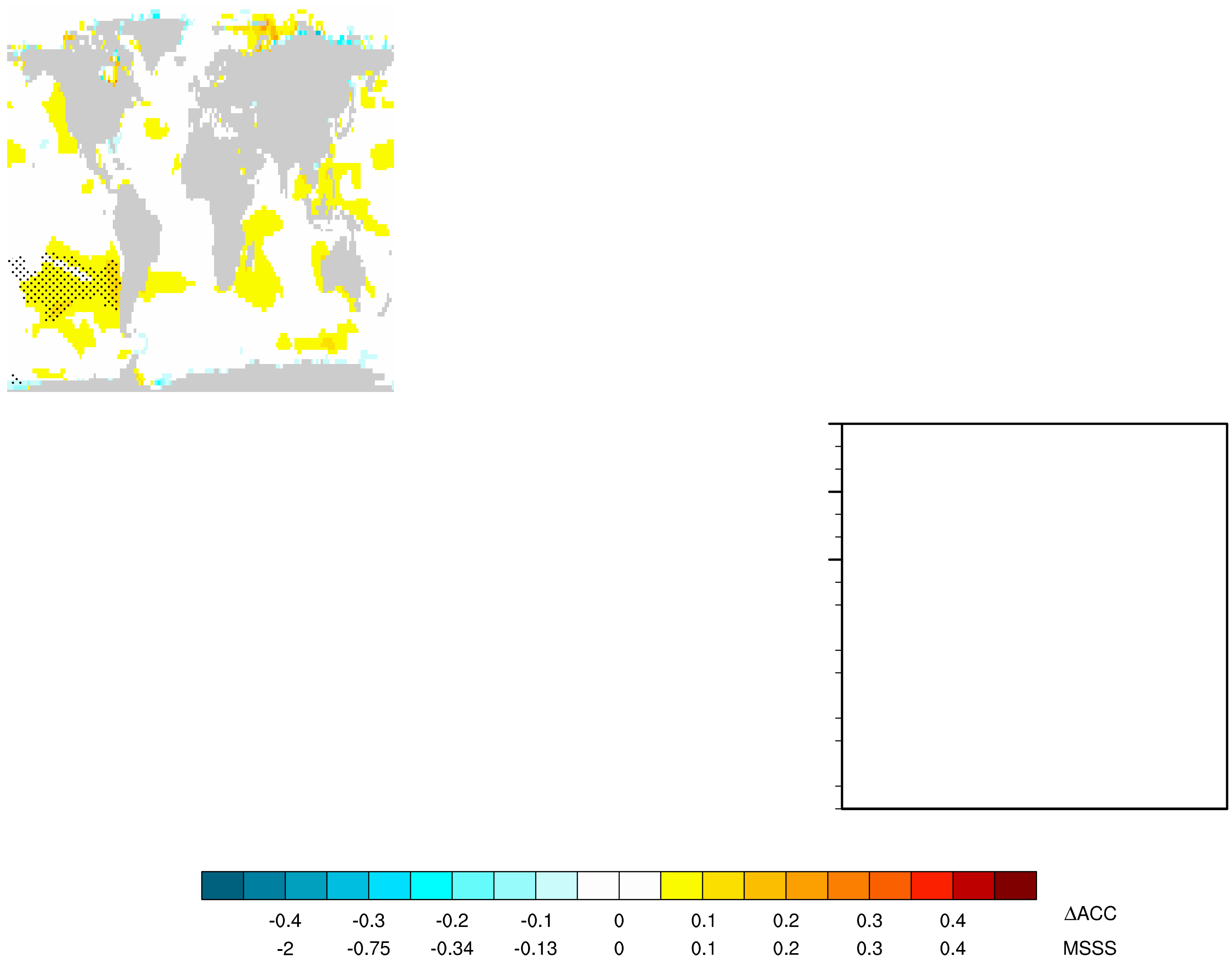


Hindcasts skillful at JFM PRECIP over Scandinavia tend to show improved NAO-like winter SLP, but no clear improvement in SST skill.

How does JFM skill change with ensemble size?

Winter SLP over Nordic Seas appears particularly amenable to improvement through increased ensemble size.

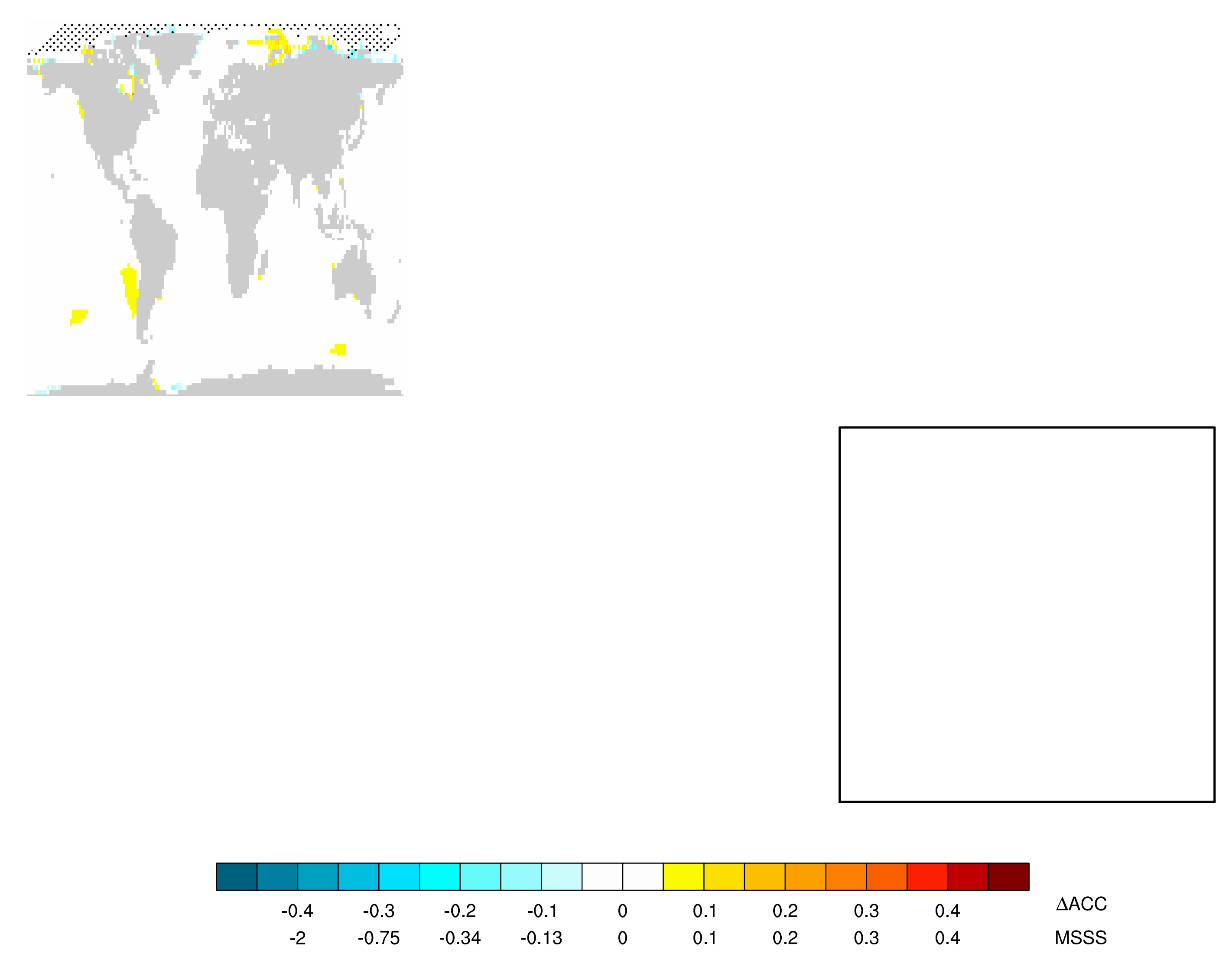
JFM LY1-5 skill difference for different DP ensemble sizes: (N=40) - (N=5)



How does JFM skill change with ensemble size?

JFM LY1-5 skill difference for different DP ensemble sizes: (N=40) - (N=10)

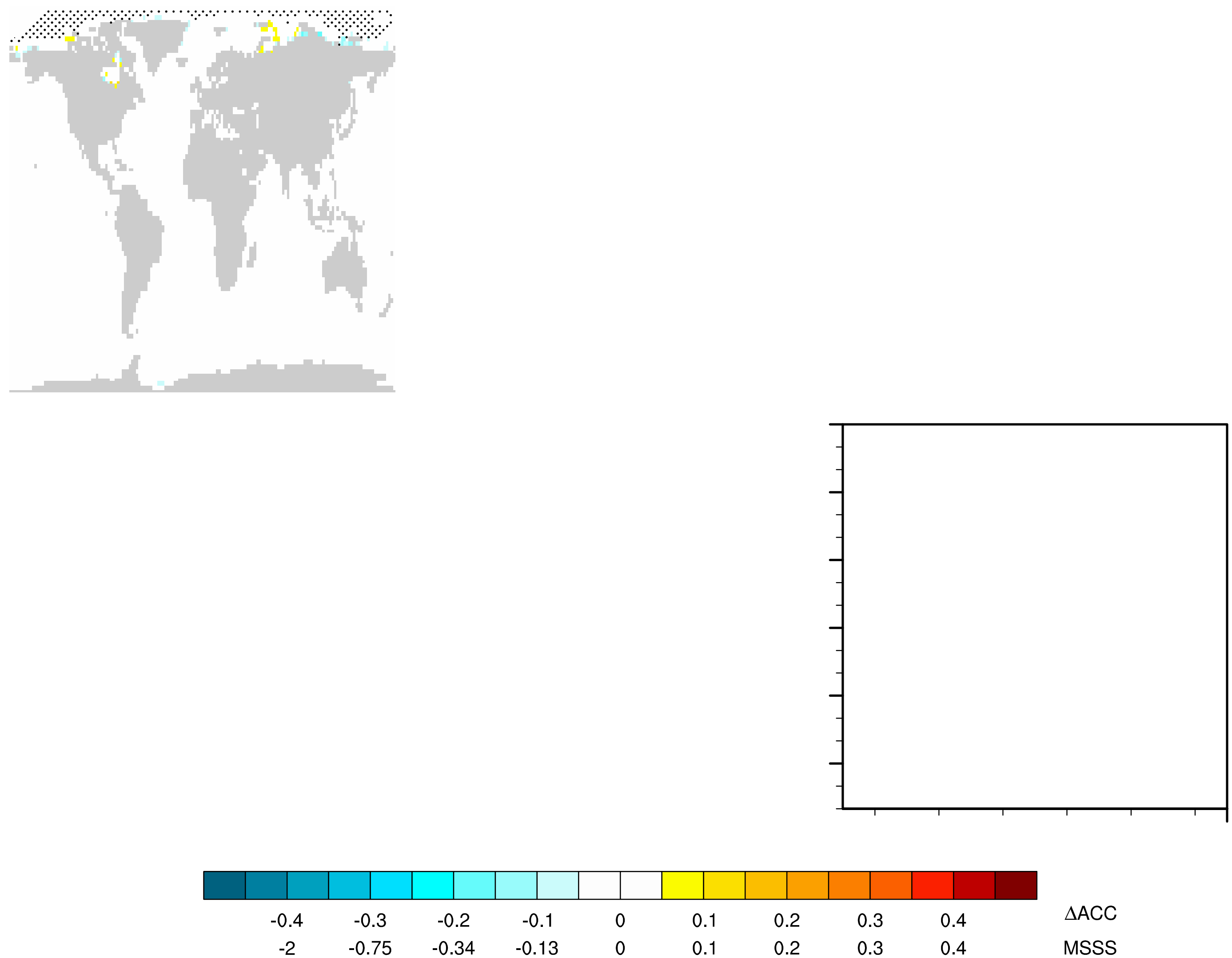
Winter SLP over Nordic Seas appears particularly amenable to improvement through increased ensemble size.



How does JFM skill change with ensemble size?

JFM LY1-5 skill difference for different DP ensemble sizes: (N=40) - (N=15)

Winter SLP over Nordic Seas appears particularly amenable to improvement through increased ensemble size.



Summary

- CESM-DP-LE is a rich community data resource in support of near-term Earth System prediction research. Public release with web/journal[1] documentation coming soon (Check http://www.cesm.ucar.edu/projects/community-projects/).

- Significant skill improvements over NCAR's previous (CMIP5-era) decadal prediction system, particularly over land.

- Ocean biogeochemistry fields permit exploration of new frontiers in DP science.

- Complementary large ensembles for both initialized and uninitialized[2] sets offer unprecedented statistical power for disentangling the relative roles of external forcing & internal dynamics in recent climate variability & predictability.

[1]Yeager et al., 2018: Predicting near-term changes in the Earth System: A large ensemble of initialized decadal prediction simulations using the Community Earth System Mode, *BAMS,* in revision.

[2]Kay et al., 2015: The Community Earth System Model (CESM) Large Ensemble Project: A Community Resource for Studying Climate Change in the Presence of Internal Climate Variability, *BAMS*, doi:10.1175/BAMS-D-13-00255.1.

Winter NAO

Is skill for winter precip over Scandanavia related to prediction of low-frequency winter NAO?

b. DJF NAO (station-based), LY2-6