Earth System Prediction Working Group, Winter Meeting
February 22, 2023

Is ENSO Predictability Limited by the Atlantic?

Preliminary Results from CLIVAR TBI Atlantic Hindcast Pacemaker Experiments using CESM2

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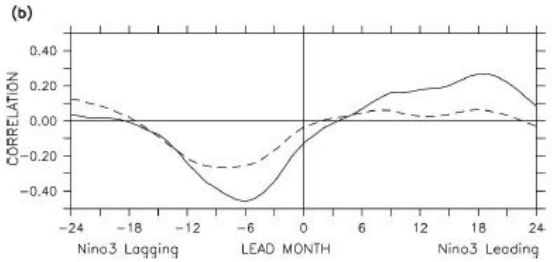
Background

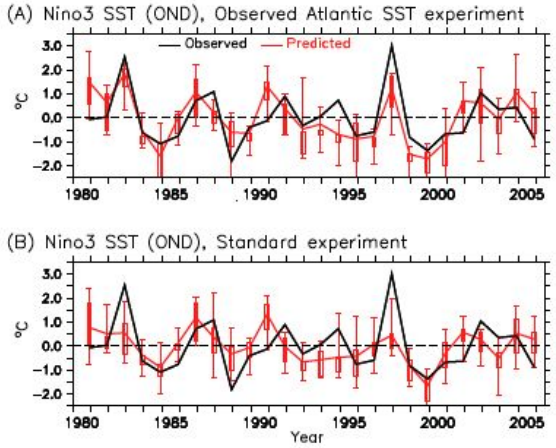
- Keenlyside & Latif, 2007: Understanding Equatorial Atlantic Interannual Variability, *J Climate*

  - observational analysis



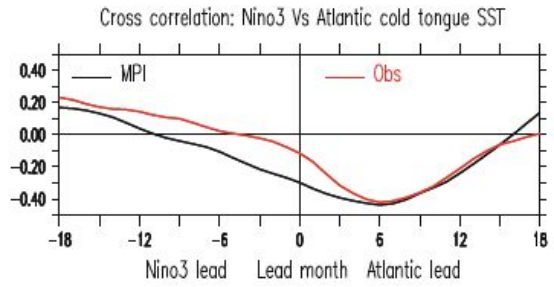
- Keenlyside, Ding, & Latif, 2013: Potential of equatorial Atlantic variability to enhance El Niño prediction, *GRL*

  - seasonal predictions with/without full SST restoring in Atlantic



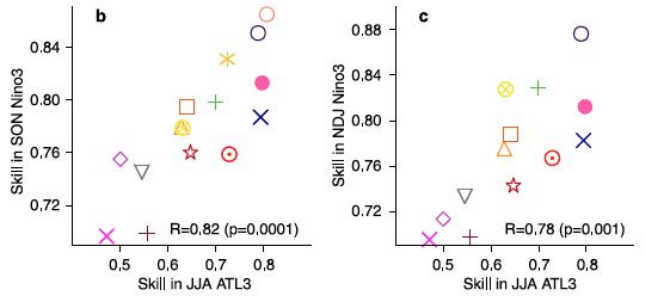
- Ding, Keenlyside, & Latif, 2012: Impact of the Equatorial Atlantic on the El Nino Oscillation, *Clim Dyn*

  - fully coupled Atlantic pacemaker ensemble (full SST restoring)



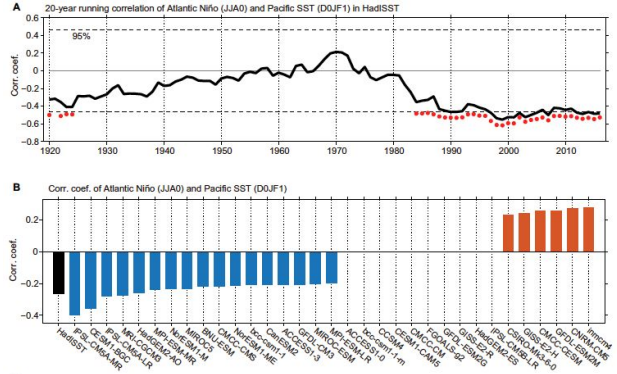
- Exarchou et al., 2021: Impact of equatorial Atlantic variability on ENSO predictive skill, *Nat Comm*

  - analysis of seasonal predictions, including ATL-nudged predictions



- Jia et al., 2019: Weakening Atlantic Niño-Pacific connection under greenhouse warming, *Sci Adv*

  - analysis of observations & CMIP5 historical/projection runs



- Richter et al., 2022: The tropical Atlantic as a negative feedback on ENSO, *Clim Dyn*

  - perfect model predictability with/without tropical Atlantic variability

> "the results indicate that, in this particular GCM, the tropical Atlantic mostly acts as a negative feedback to ENSO by accelerating the decay of events. It has little impact on the development of ENSO events."

Background

- Coordinated Pacemaker experiments organized by CLIVAR Tropical Basin Interaction Research Focus (TBI CoEx). [Co-chairs: Richter & Okumura]

- Uninitialized (Standard) & Initialized (Hindcast) pacemaker simulations with SST restoring in each of: tropical Atlantic, Pacific, Indian

- Common protocol:
  - -Time period: 1982-2021
  - -SST restoring target: CMIP6 AMIP SST
  - -SST restoring region: 10°S-10°N, with linear tapering to ±30°
  - -10-member ensembles
  - -CMIP6 forcing
  - -FEB 1st initialization for Hindcasts (+ MAY, AUG, NOV if possible)

- Flexible/Undecided:
  - -Method for generating Hindcast control
  - -full-field vs. anomaly restoring
  - -restoring strength

CESM2 SMYLE

Geosci. Model Dev., 15, 6451–6493, 2022
https://doi.org/10.5194/gmd-15-6451-2022

Geoscientific Model Development
Open Access
EGU

2022

The Seasonal-to-Multiyear Large Ensemble (SMYLE) prediction system using the Community Earth System Model version 2

Stephen G. Yeager[1], Nan Rosenbloom[1], Anne A. Glanville[1], Xian Wu[1], Isla Simpson[1], Hui Li[1], Maria J. Molina[1], Kristen Krumhardt[1], Samuel Mogen[2], Keith Lindsay[1], Danica Lombardozzi[1], Will Wieder[1], Who M. Kim[1], Jadwiga H. Richter[1], Matthew Long[1], Gokhan Danabasoglu[1], David Bailey[1], Marika Holland[1], Nicole Lovenduski[2], Warren G. Strand[1], and Teagan King[1]

Overview:

- ~1° CESM2 (CAM6-32L, POP2-60L, CICE5, CLM5)
- Prognostic ocean BGC (using MARBL)
- Quarterly initializations (1st of Nov/Feb/May/Aug 1958-2020)
- 24-month simulations
- 20-member ensembles
- ~10,000 sim-year experiment

Initialization:

- Ocean/Ice/BGC:
  -OMIP2* **F**orced **O**cean/**S**ea-**I**ce (FOSI) run
  -JRA55-do forcing (Tsujino et al. 2018)
- Atmosphere :
  - JRA55 Reanalysis
- Land:
  - Forced land-only run
  - CRU-JRAv2 forcing (TRENDY S3 protocol; Friedlingstein et al. 2020)

SMYLE Skill: Niño-3.4 SST

- CESM2-SMYLE has quite good (competitive) ENSO prediction skill

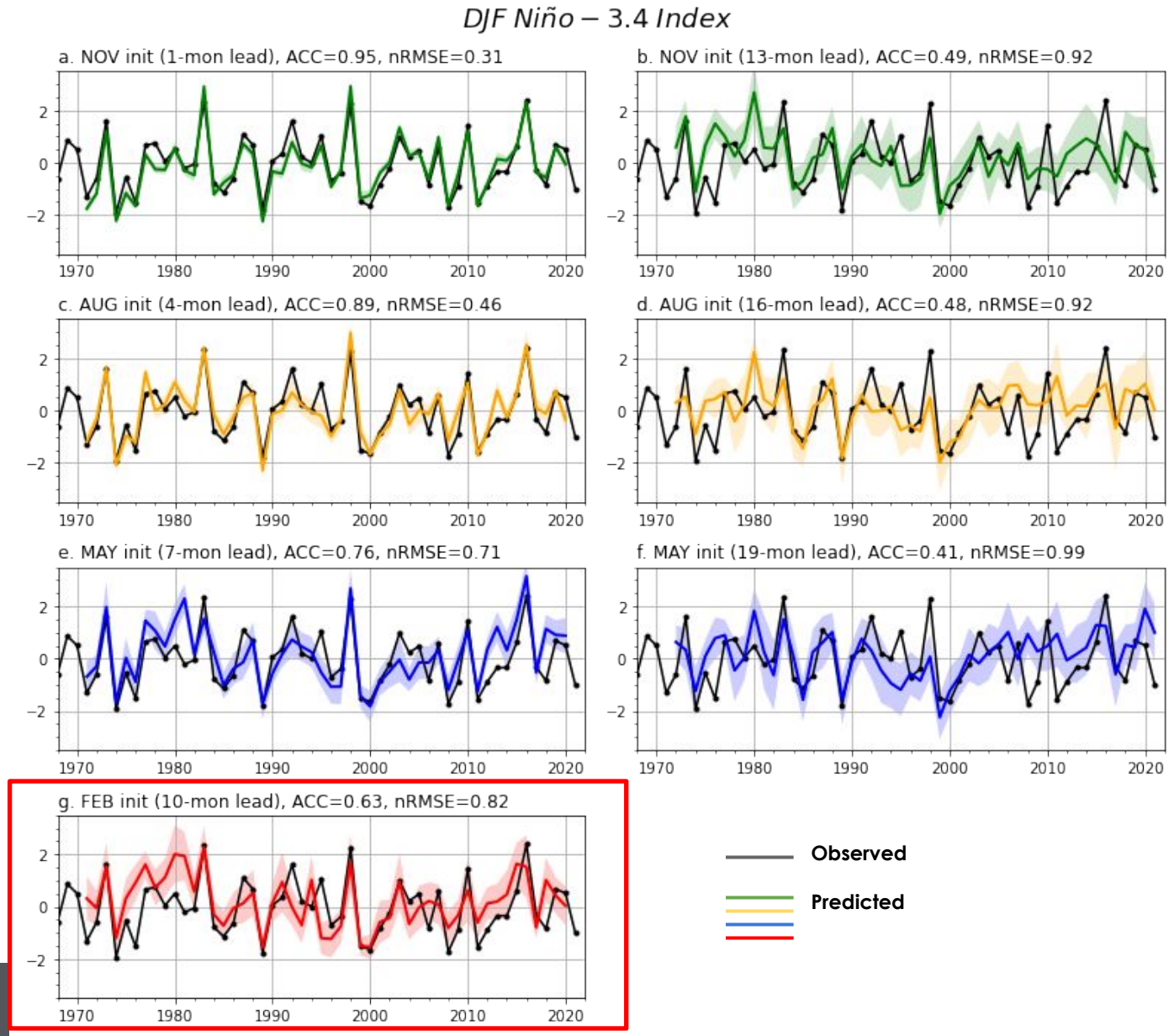


Figure credit: Xian Wu

SMYLE Skill: Niño-3.4 SST

- SMYLE skill for **1982-2016** is higher than for **1970-2019**
- **SMYLE** skill compares well with 8-model **NMME** skill (significantly better for FEB-init)
- **SMYLE** skill for monthly Niño-3.4 only slightly lower than ECMWF **SEAS5** at 12-month lead

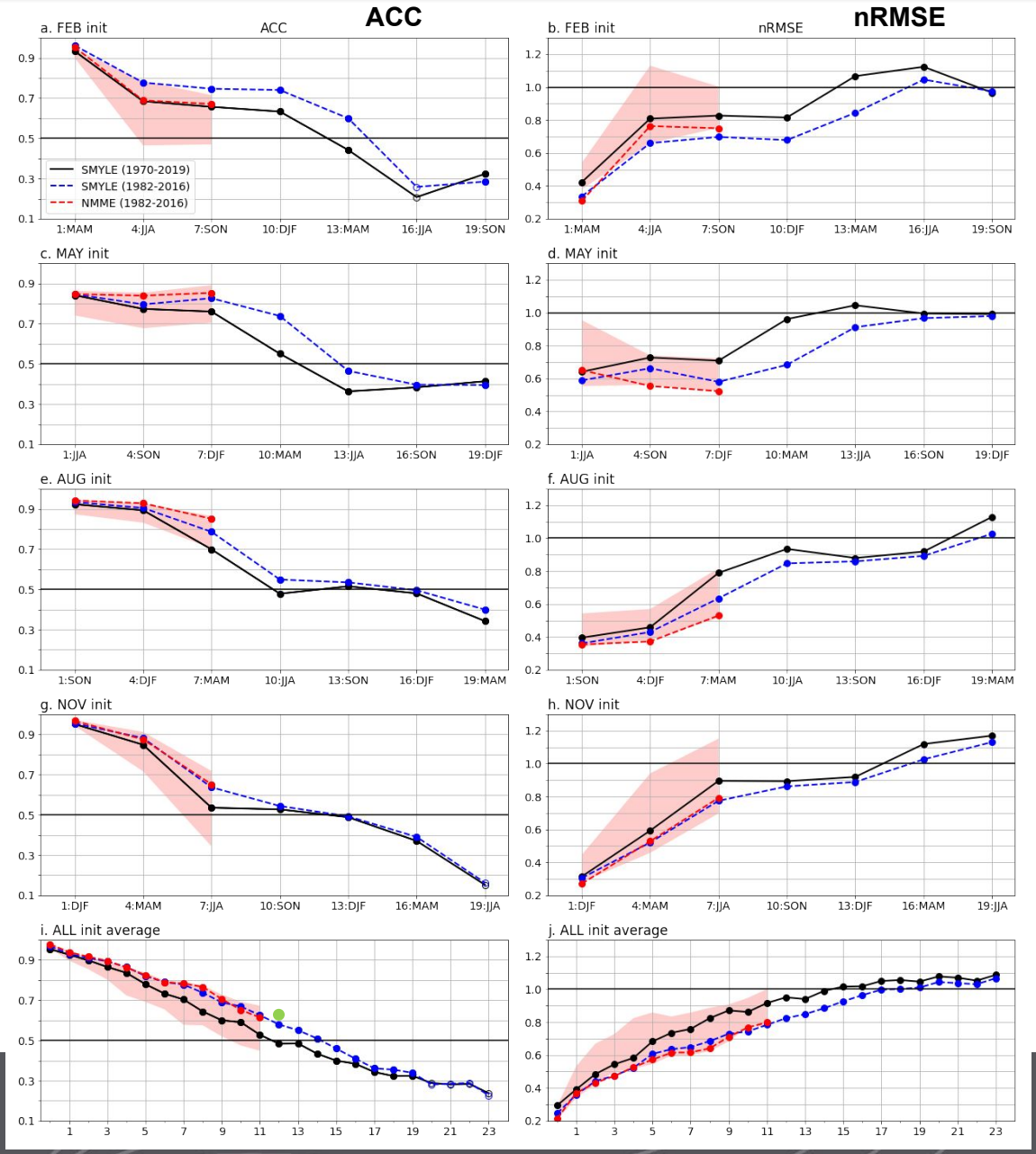


Figure credit: Xian Wu

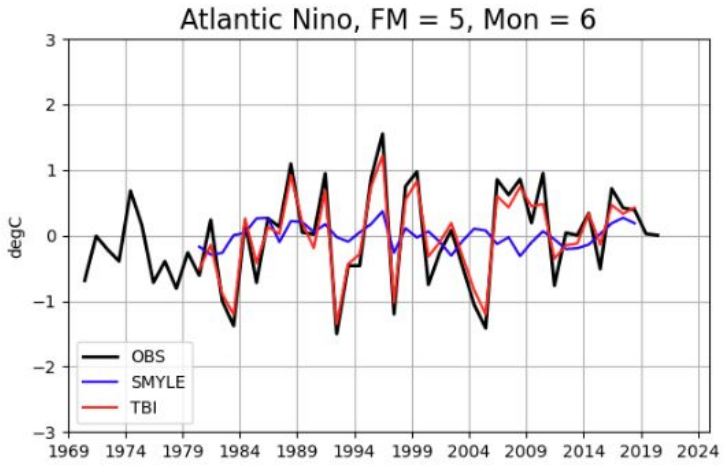
SMYLE TBI-ATL Hindcast Pacemaker Experiment

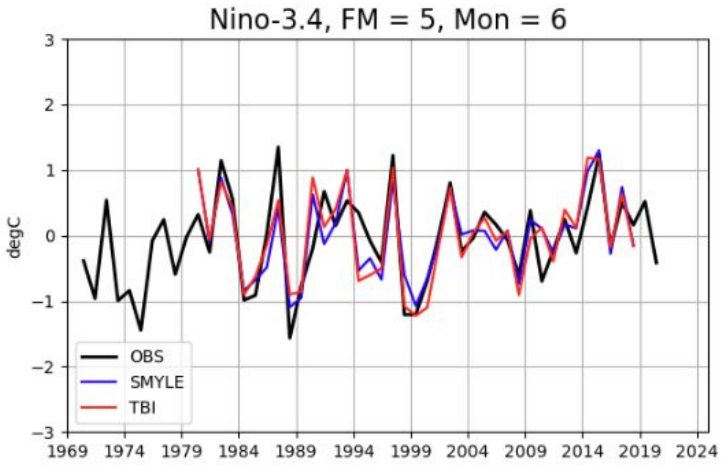
- Equivalent set-up to CESM2-SMYLE except:
  - SST anomalies restored to monthly SST observations in tropical Atlantic

- SST anomaly restoring:
  - target: CMIP6 AMIP SST (OISST+HadISST)
  - restoring: SMYLE lead-dependent 1970-2019 climatology +
    observed monthly SST anomalies from 1970-2019 climatology
  - domain: tropical Atlantic 10°S-10°N with linear ramp-down to 30°S/30°N
  - strength: 2day/10m == 10day/50m

→ TBI-ATL has same (lead-dependent) climatology as SMYLE

- 5-member ensembles initialized each February 1st 1980-2018, integrated 23 months

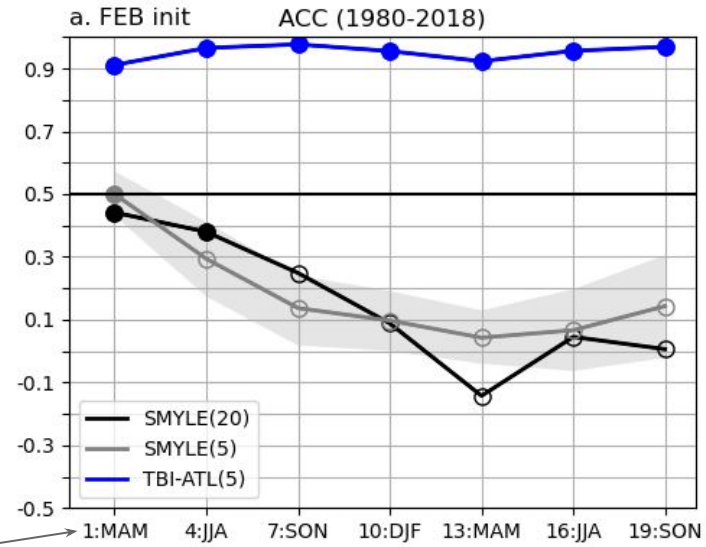


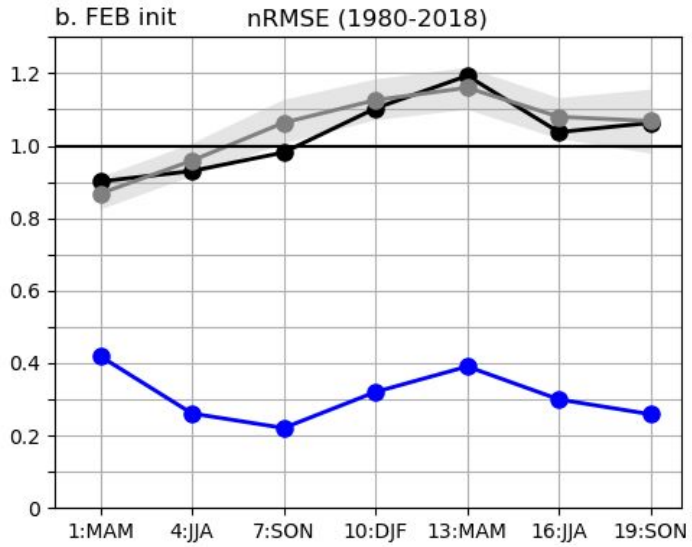


Skill Comparison: Regional SST

- ACC & nRMSE for seasonal SST
- Verification data (1980-2018):
  - HadISST

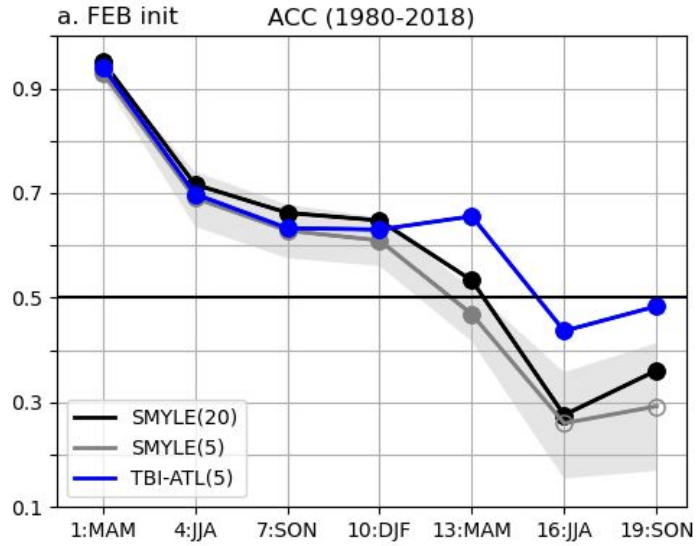
Atlantic Niño (ATL3)

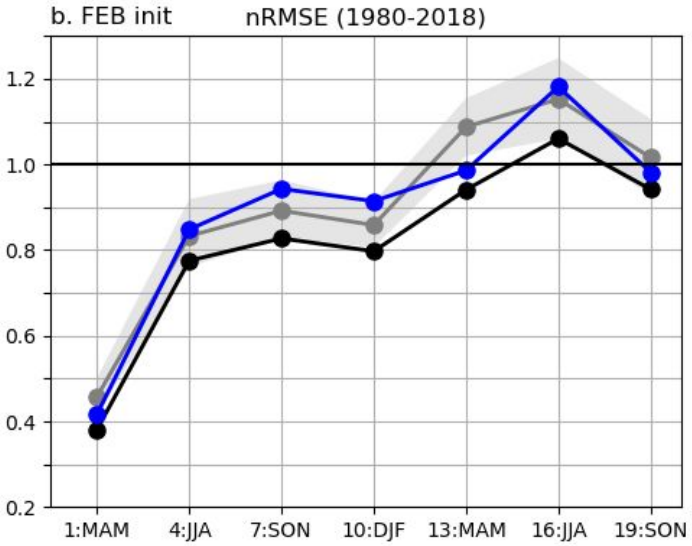




Lead month: Target season

Niño-3.4





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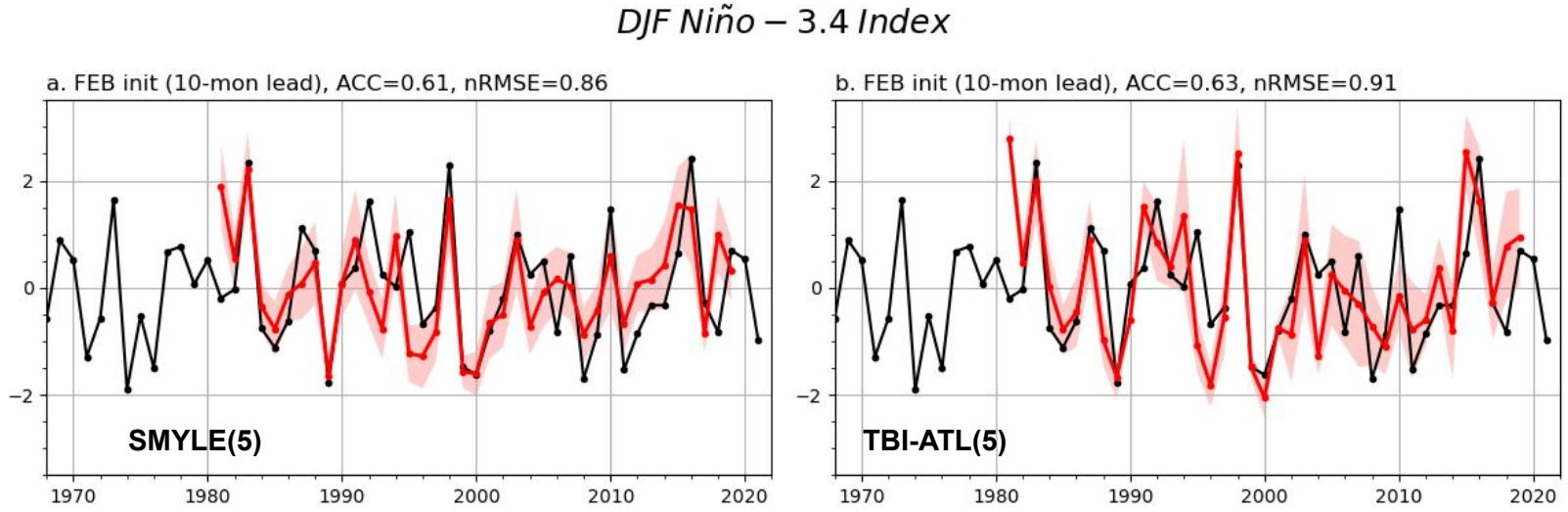
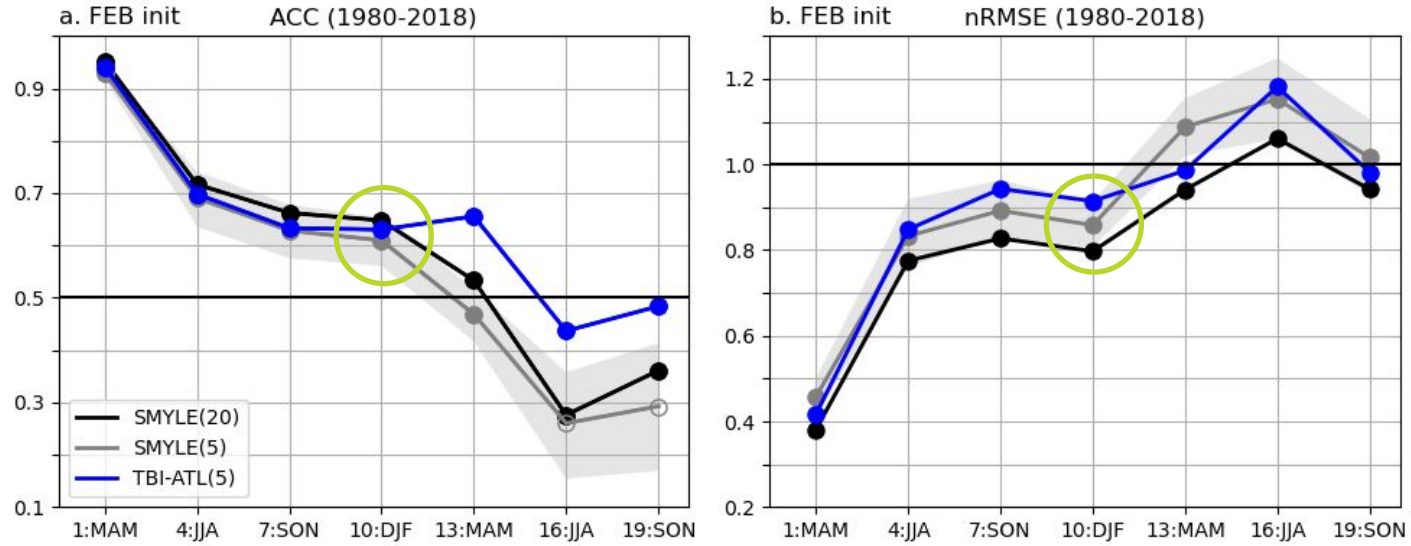


No obvious improvement for major El Niño/La Niña events in DJF[1]

Niño-3.4



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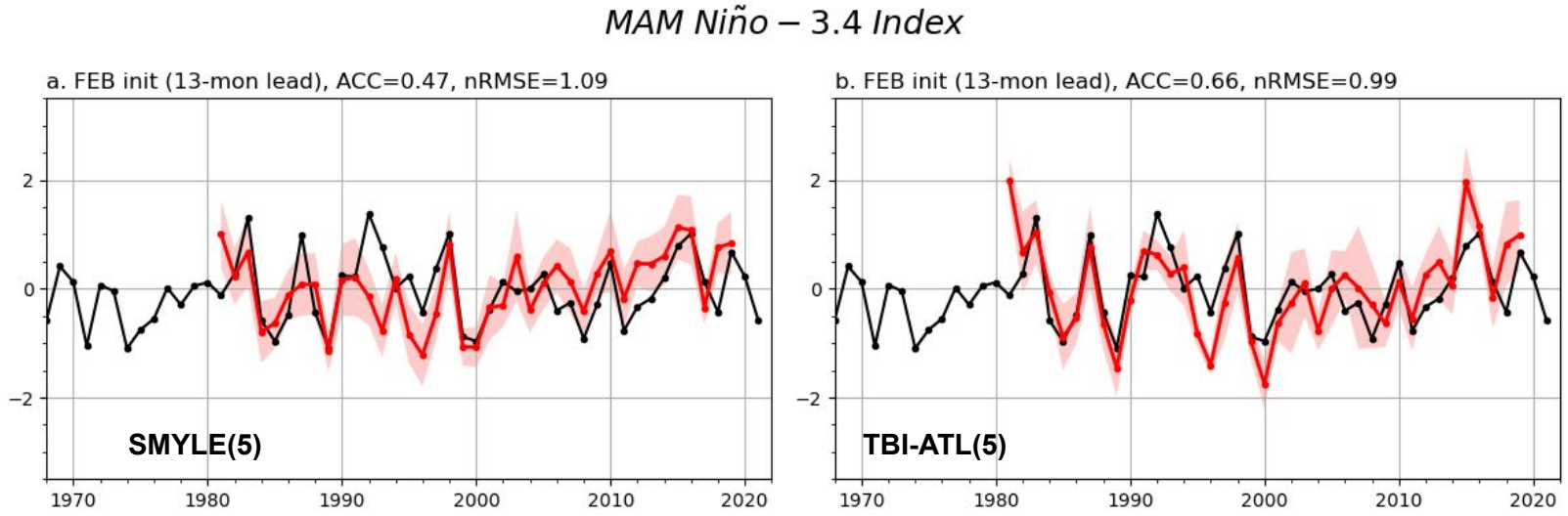
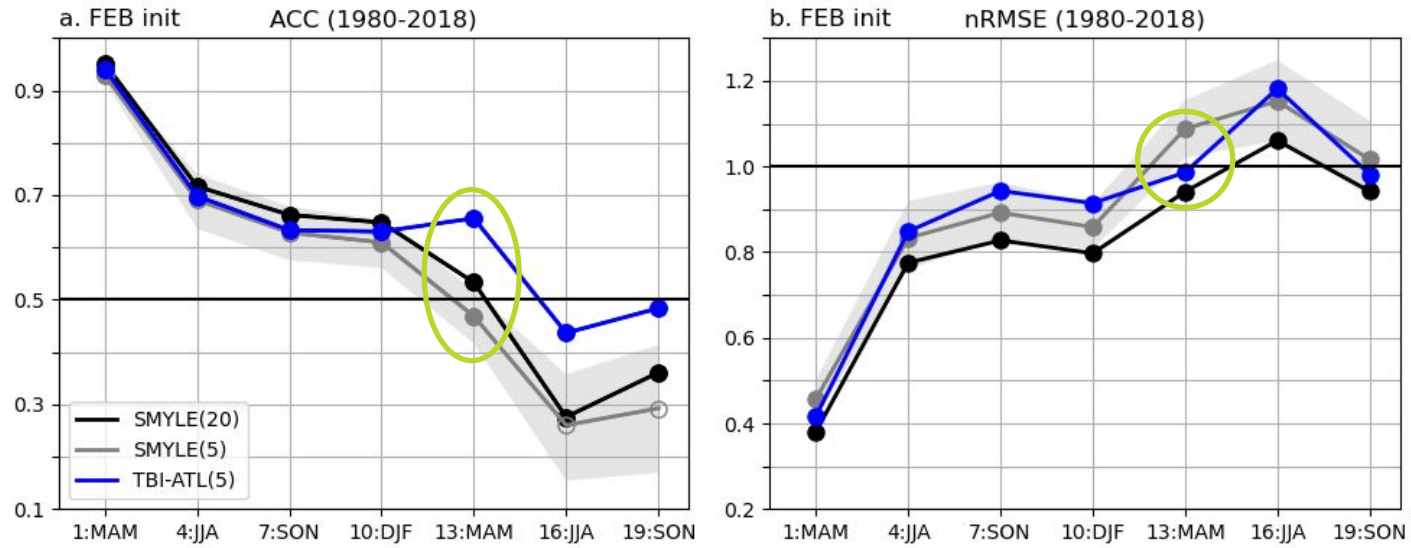


Better prediction of MAM[1] conditions in 1980s, 1990s

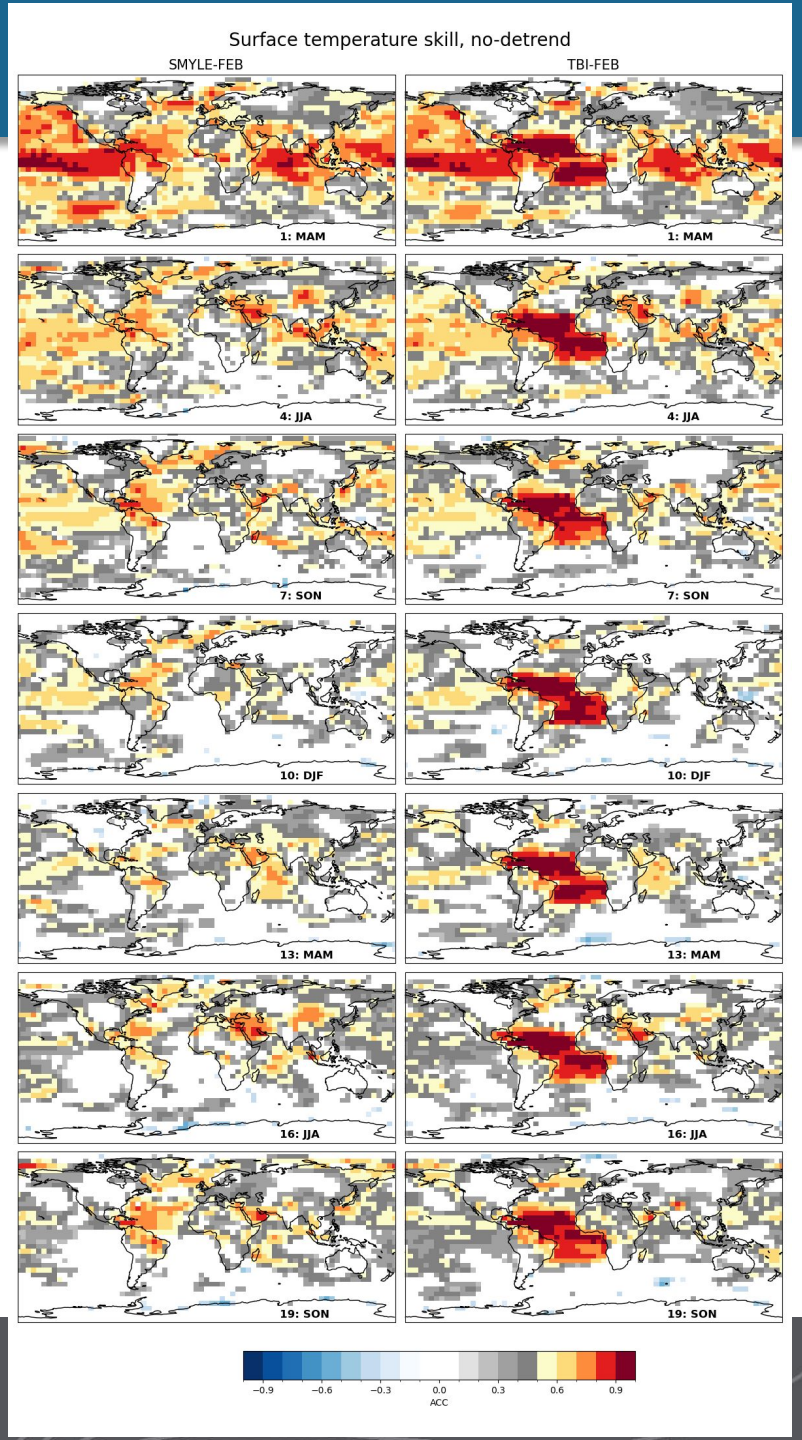
Niño-3.4



Skill Comparison: SAT

- Anomaly Correlation Coefficient (ACC) for seasonal surface temperature
- Verification data (1980-2018):
  - CRU-TS4.05 (land)
  - HadISST (ocean)
- Compare SMYLE(20) to TBI(5)

Lead Month:
Target Season



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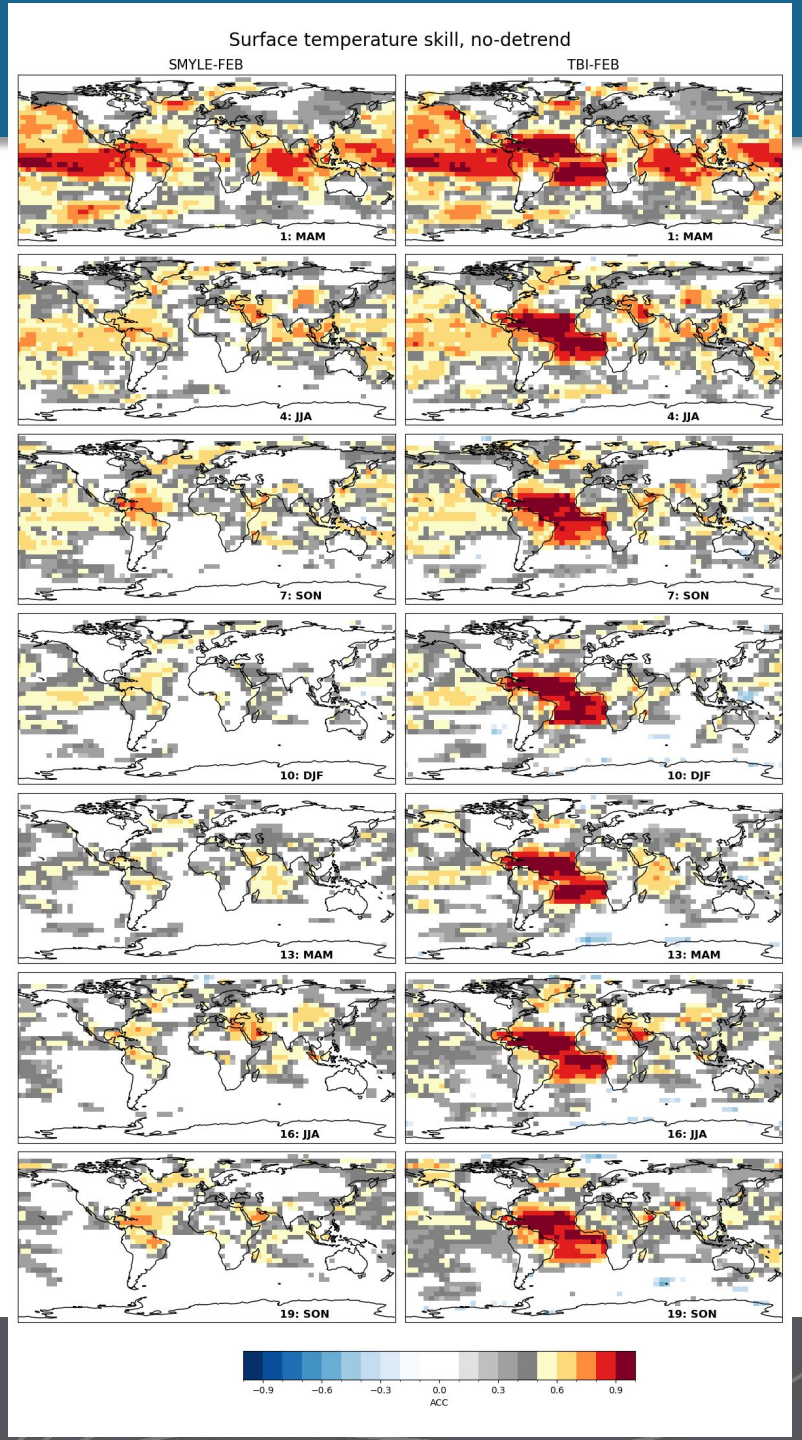
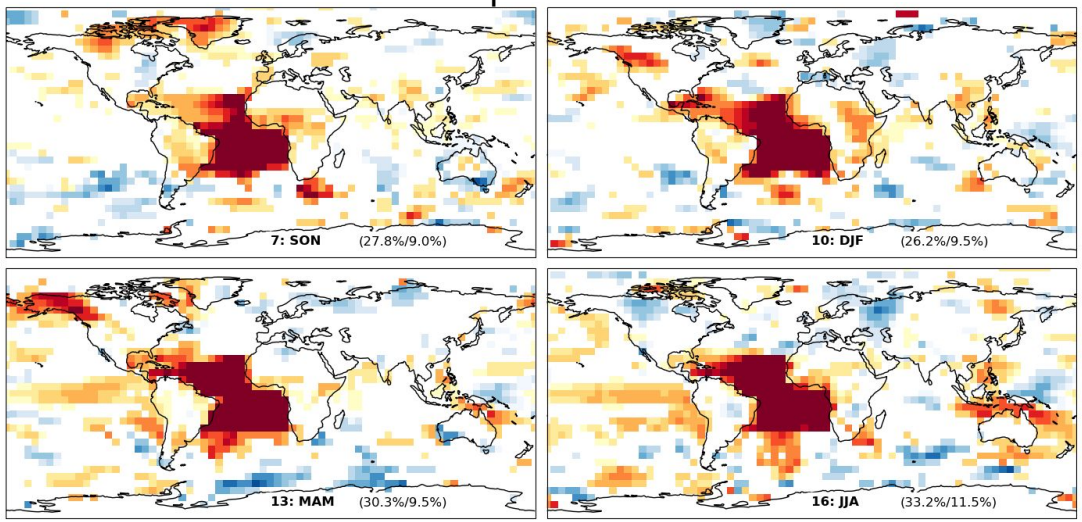
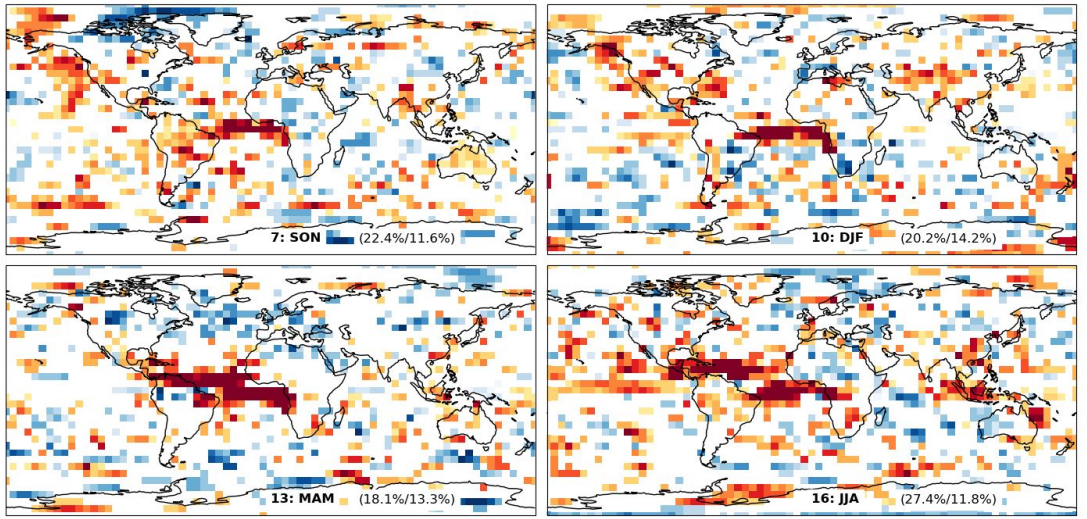


ACC Skill Difference: TBI-ATL(5) – SMYLE(5)

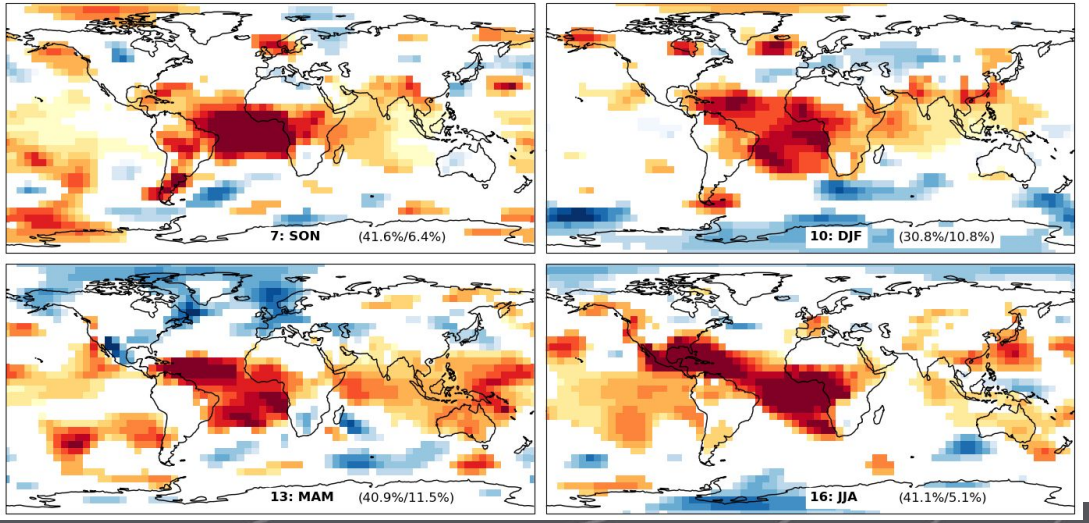
Surface Temperature

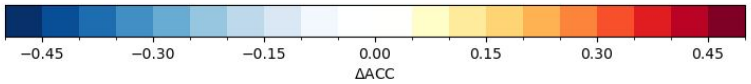


Precipitation



Sea Level Pressure

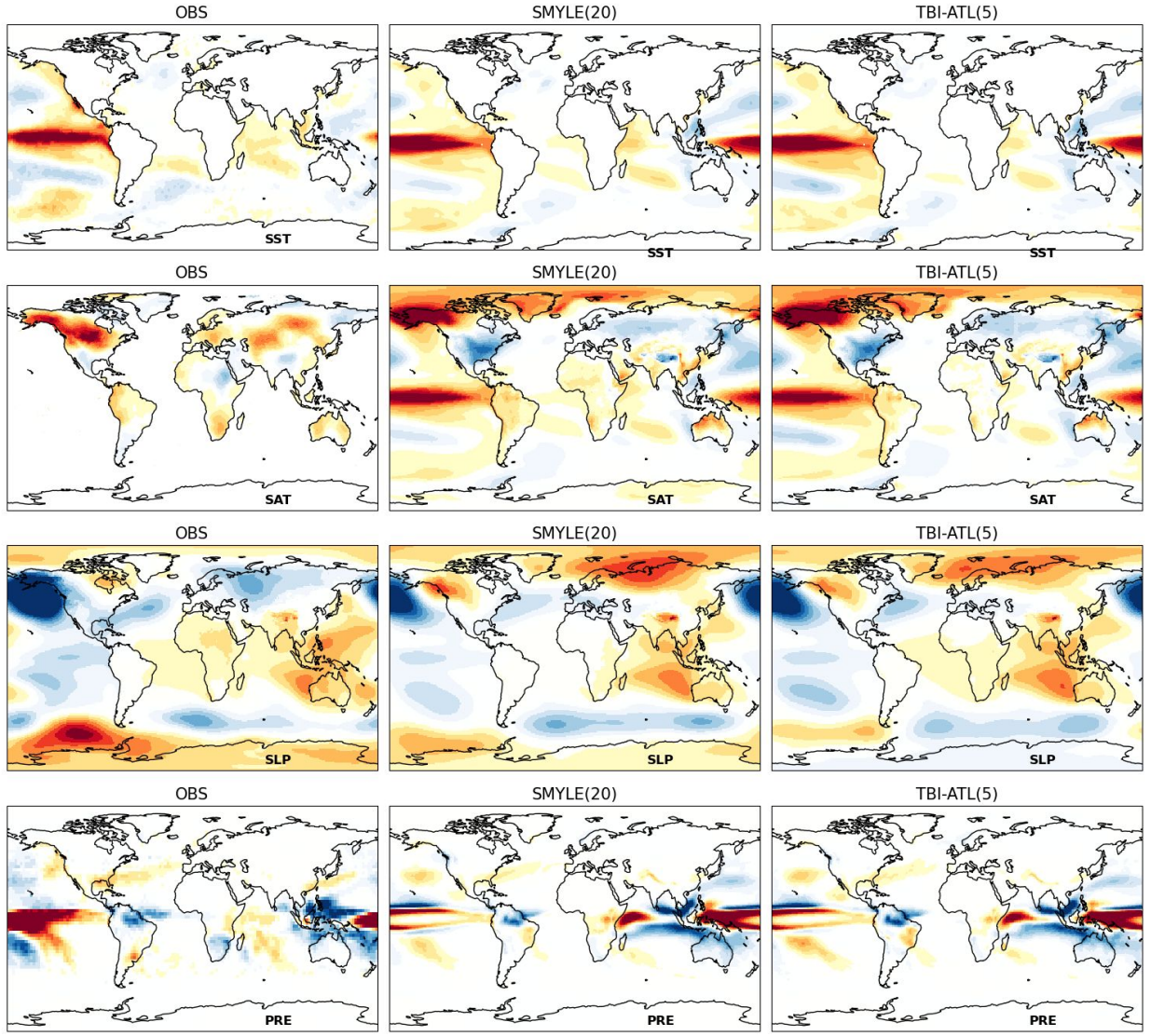




Improved ENSO Teleconnections?

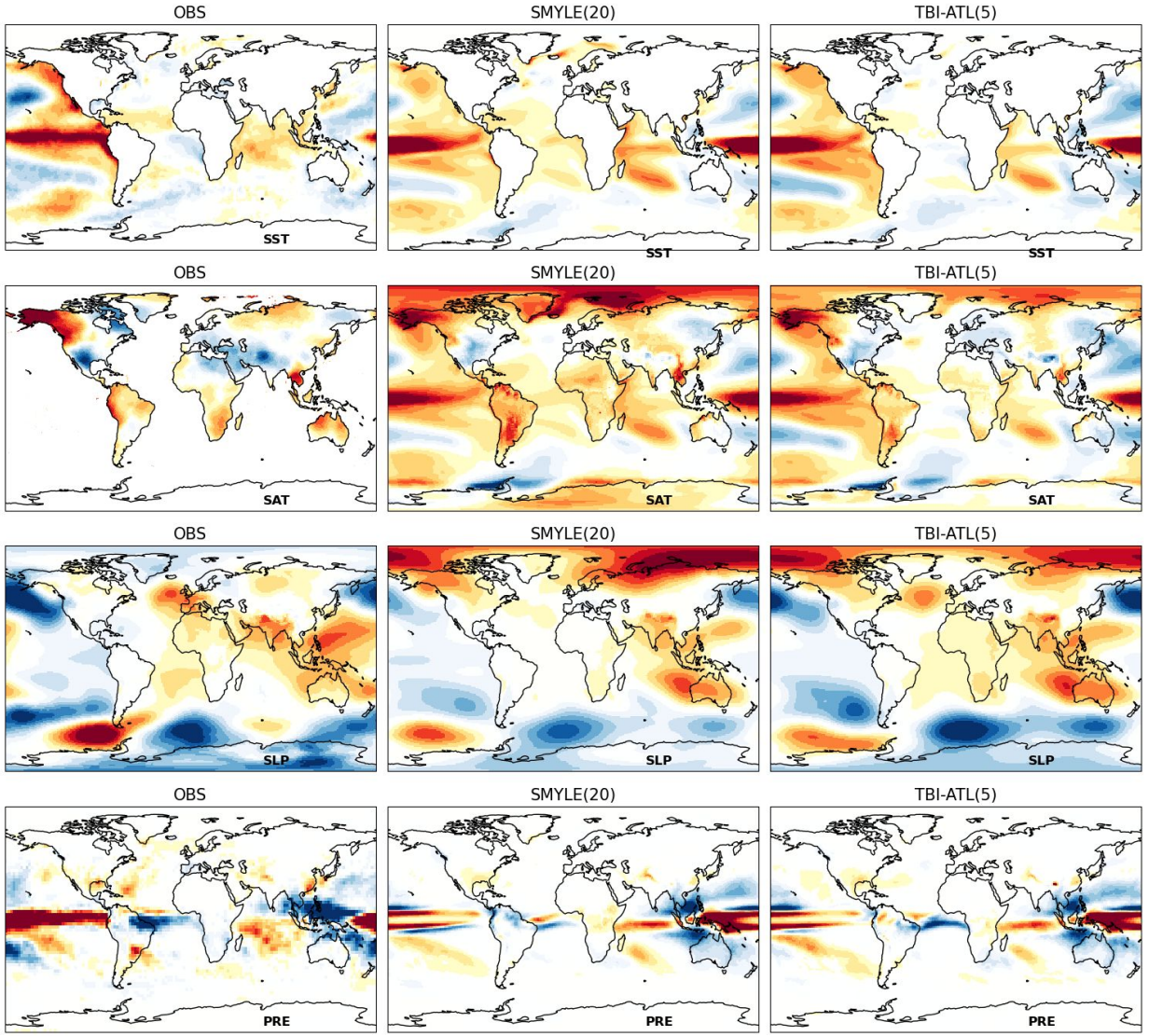
- Regressions of DJF fields on DJF Nino3.4 SST (1981-2019)
- Lead month 10

No obvious improvement in ENSO teleconnections in DJF[1]



Improved ENSO Teleconnections?

- Regressions of MAM fields on MAM Nino3.4 SST (1981-2019)
- Lead month 13



Slight improvement in ENSO teleconnections in MAM[1] ?

Summary

- Successful test of TBI-ATL hindcast pacemaker experiments with CESM2 (FEB init)

- Evidence for improved ENSO skill appears to be weak in this system
  - less skill reduction in spring of FY2 (consistent with Richter et al. 2022)
  - minor improvements in ENSO teleconnections in FY2
  - strong Atlantic influence on DJF[1] may be limited to specific events
    - need for case study focus w/ larger ensemble
  - high skill in SMYLE control might explain discrepancy with earlier studies

- Questionable whether FY2 improvements are realizable (beyond tropical Atlantic predictability limit?)

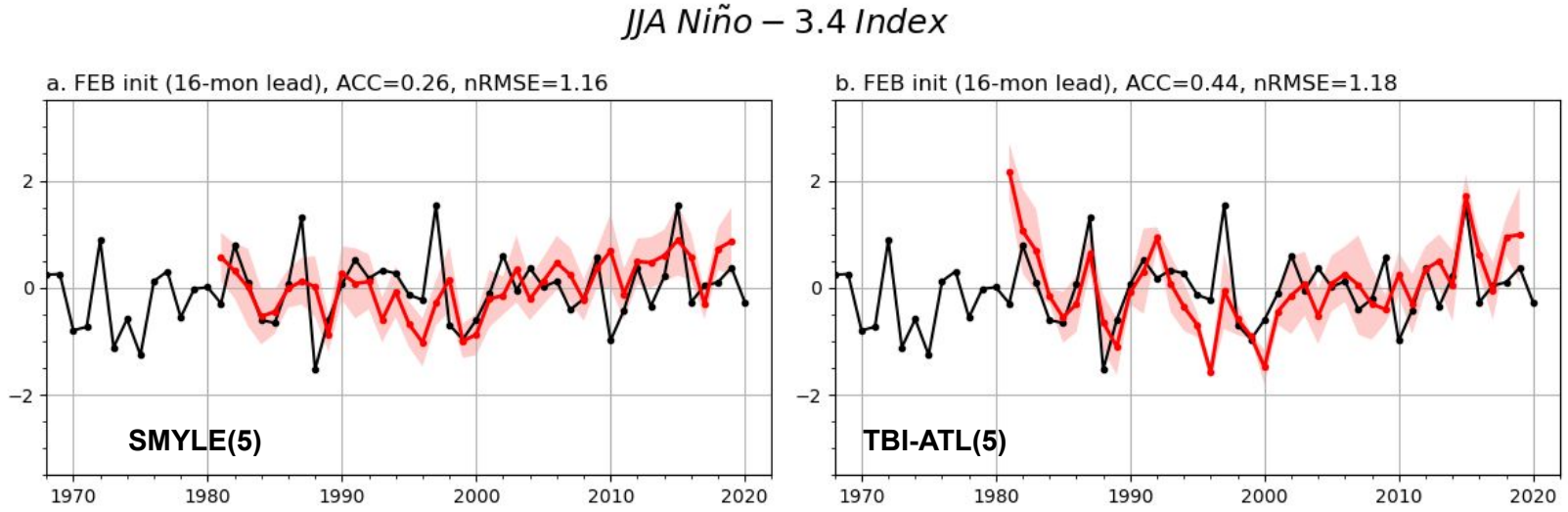
- Difficult to disentangle regional skill enhancements in surface climate
  - direct result of imposed Atlantic SST?
  - Atlantic modulation of ENSO and/or ENSO teleconnections?

- Preliminary analysis suggests TBI CoEx experimental design is sound and multi-model application could be useful

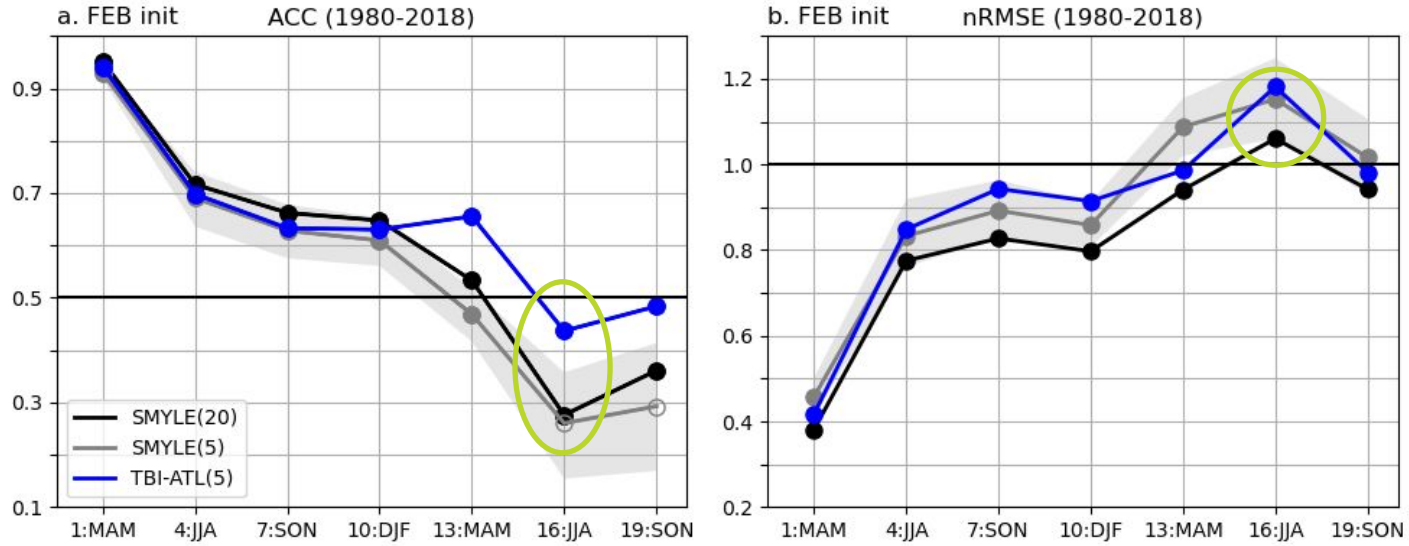
Extra Slides

Skill Comparison: Regional SST

- ACC & nRMSE for seasonal SST
- Verification data (1980-2018):
  - HadISST



Niño-3.4



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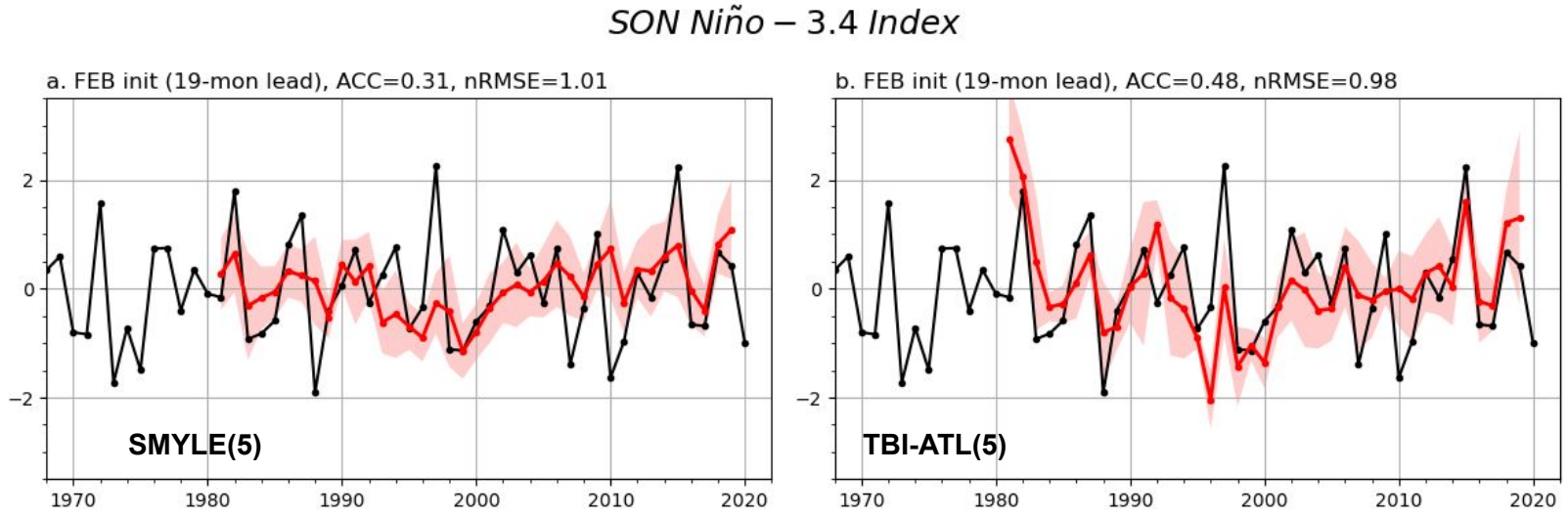

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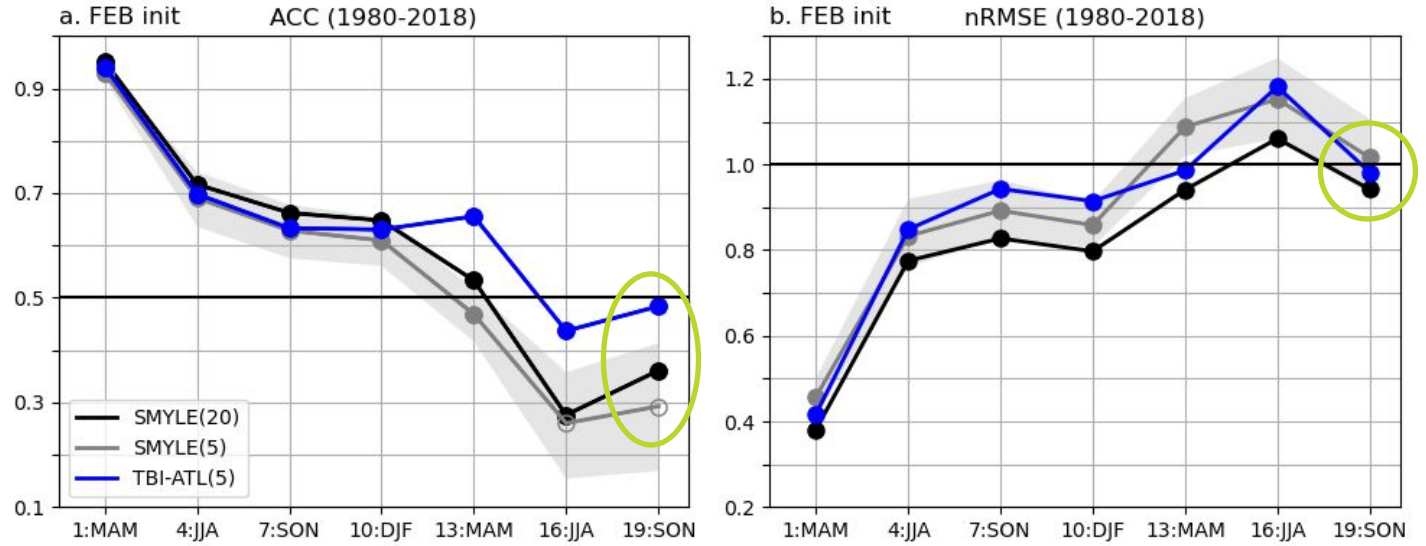
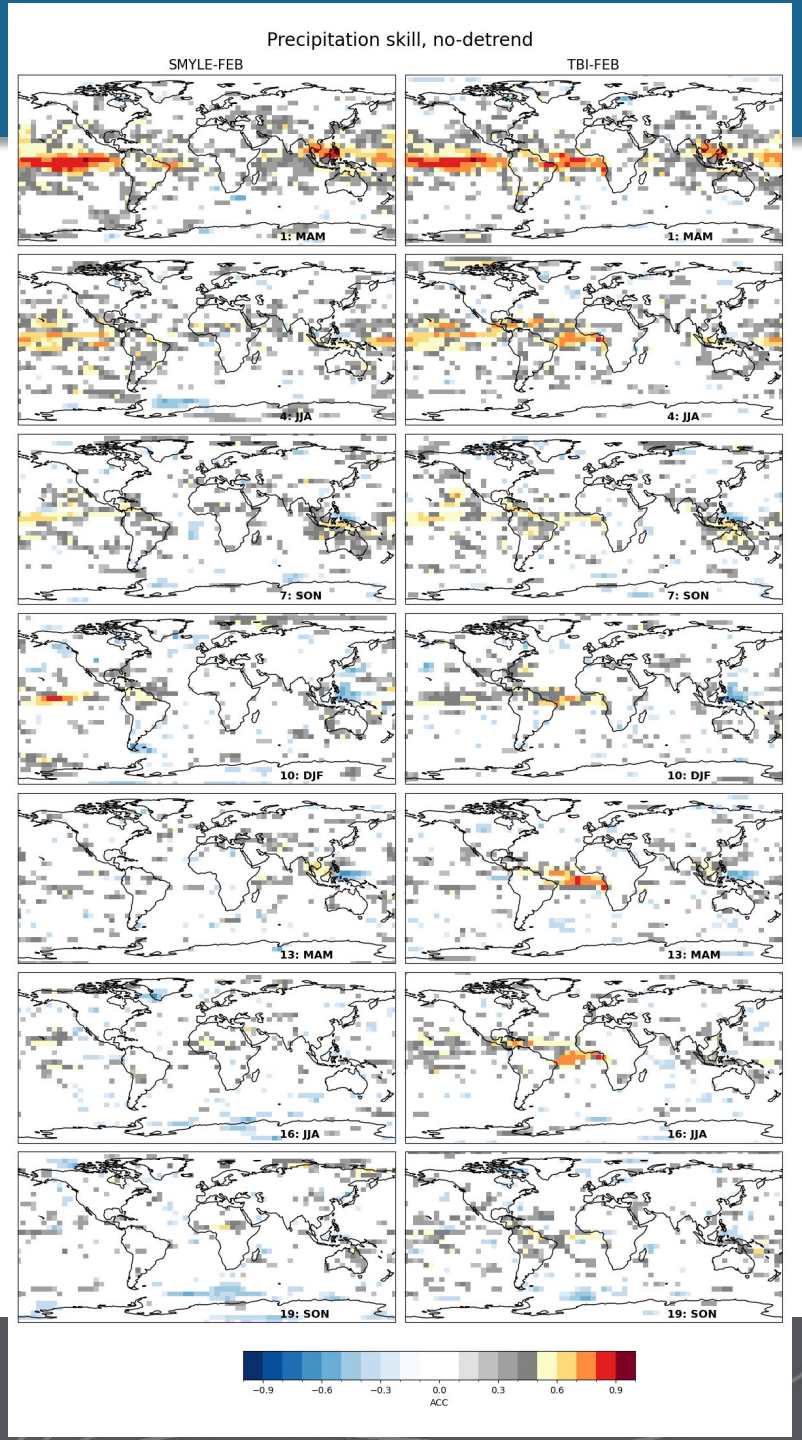


Skill Comparison: PRE

- Anomaly Correlation Coefficient (ACC) for seasonal surface temperature
- Verification data (1980-2018):
  - GPCPv2.3
- Compare SMYLE(20) to TBI(5)

Lead Month:
Target Season



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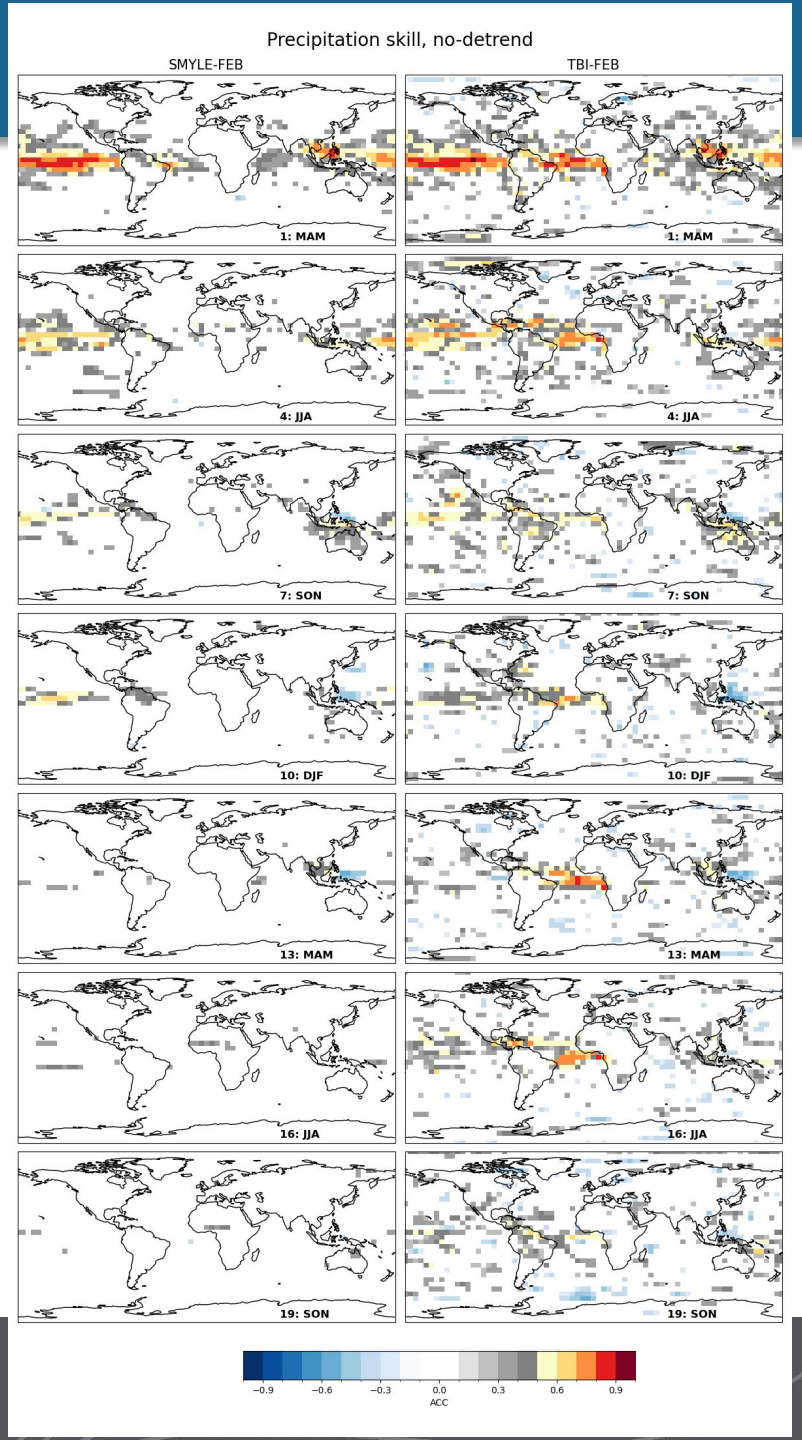

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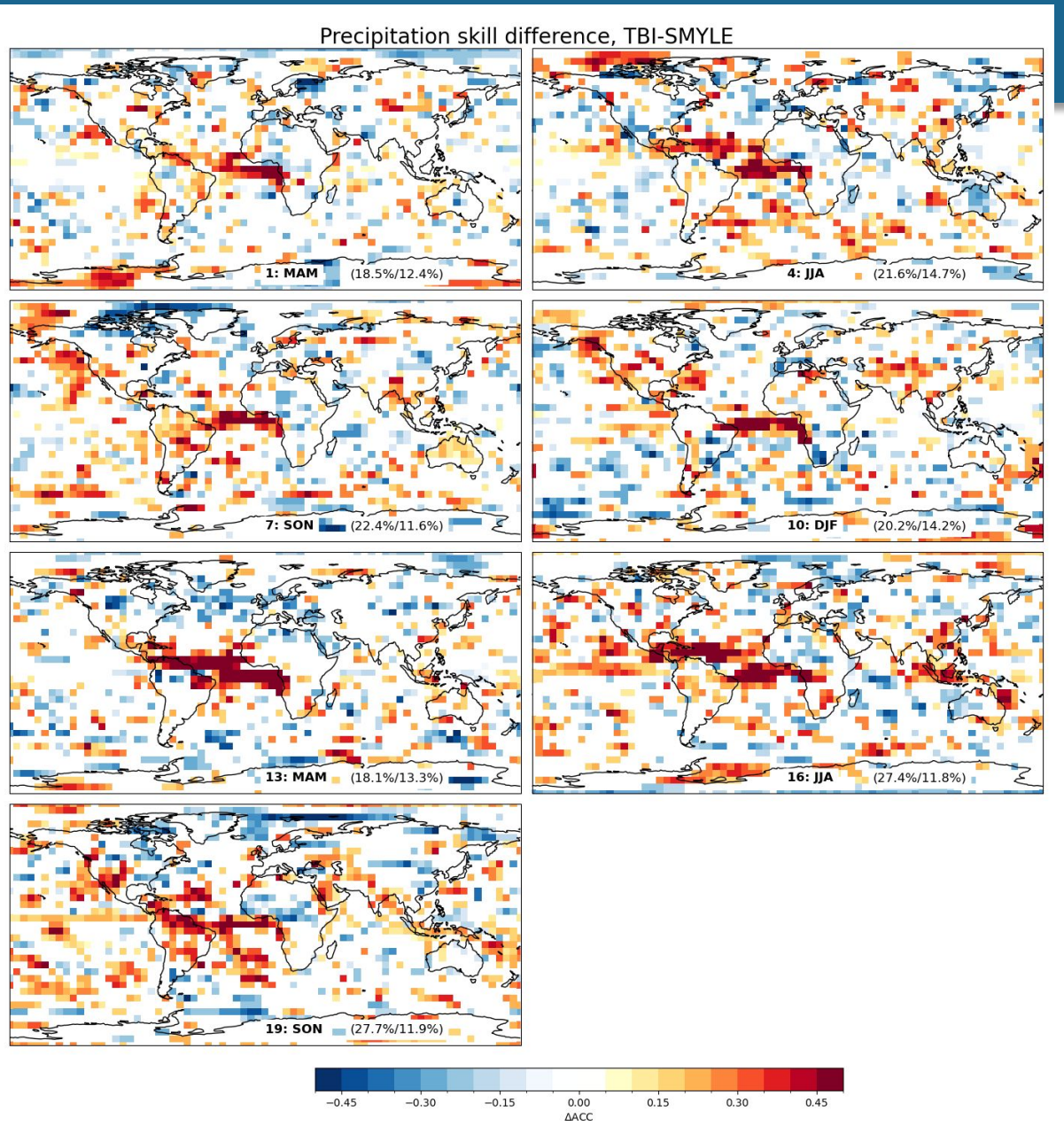
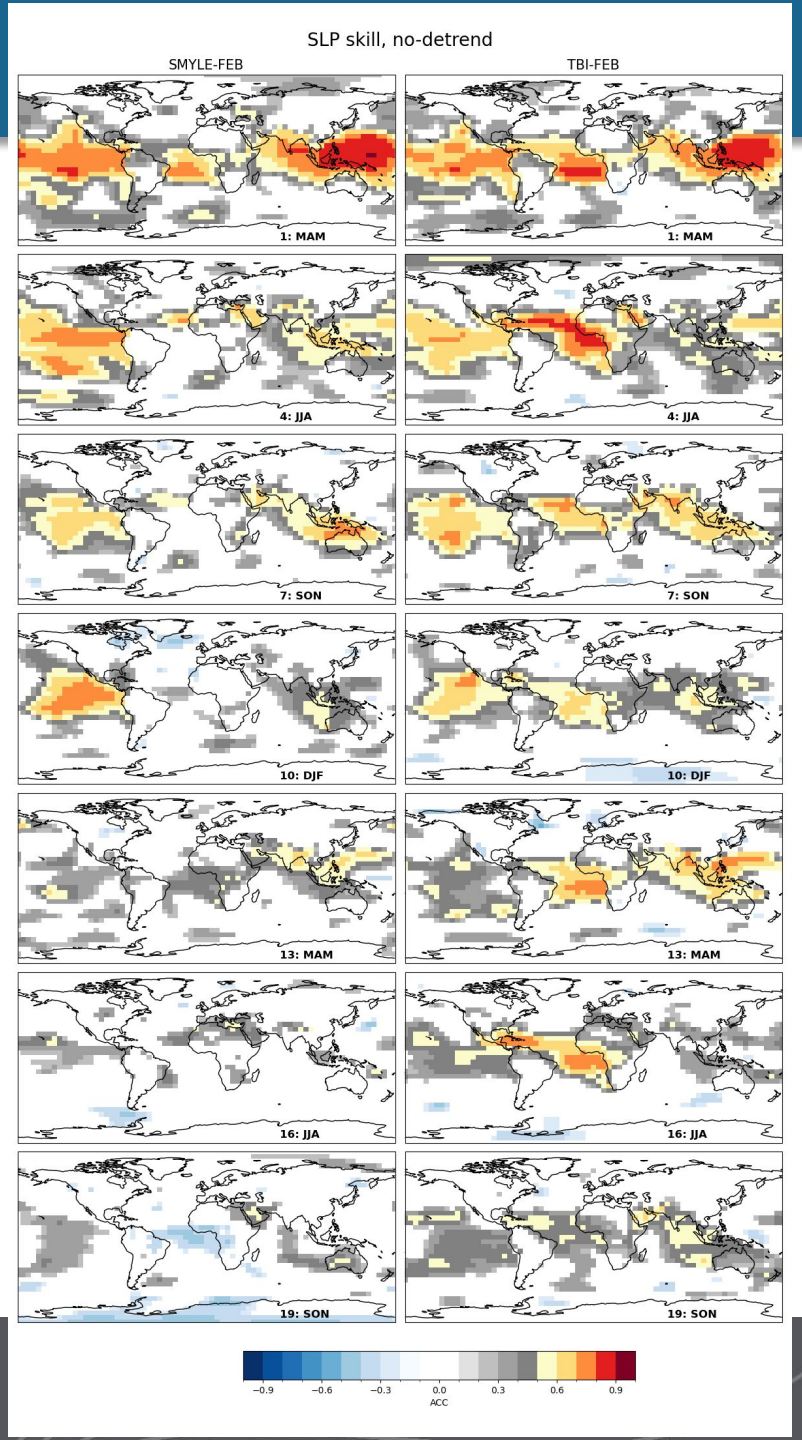


Skill Comparison: SLP

- Anomaly Correlation Coefficient (ACC) for seasonal surface temperature
- Verification data (1980-2018):
  - ERA5
- Compare SMYLE(20) to TBI(5)

Lead Month: Target Season



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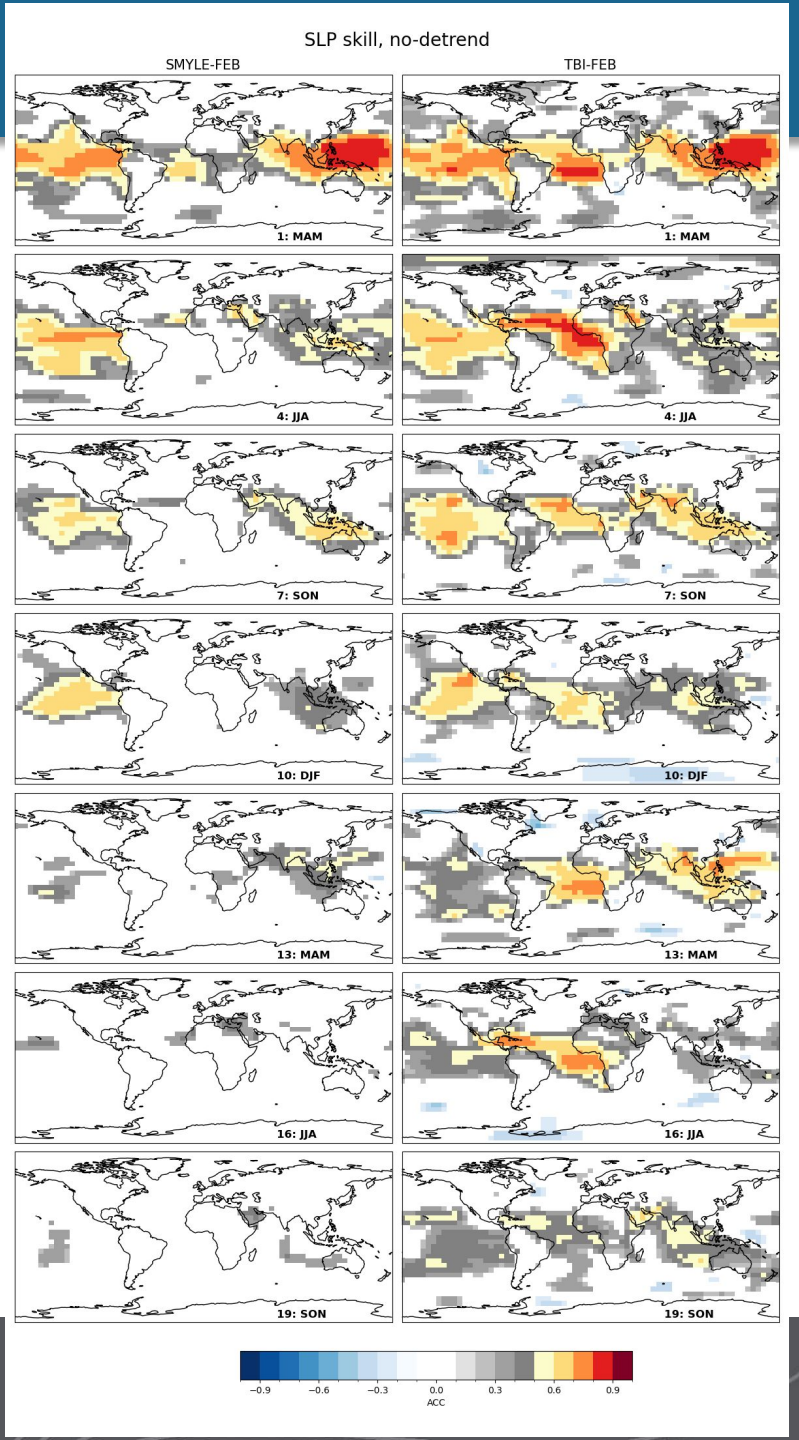

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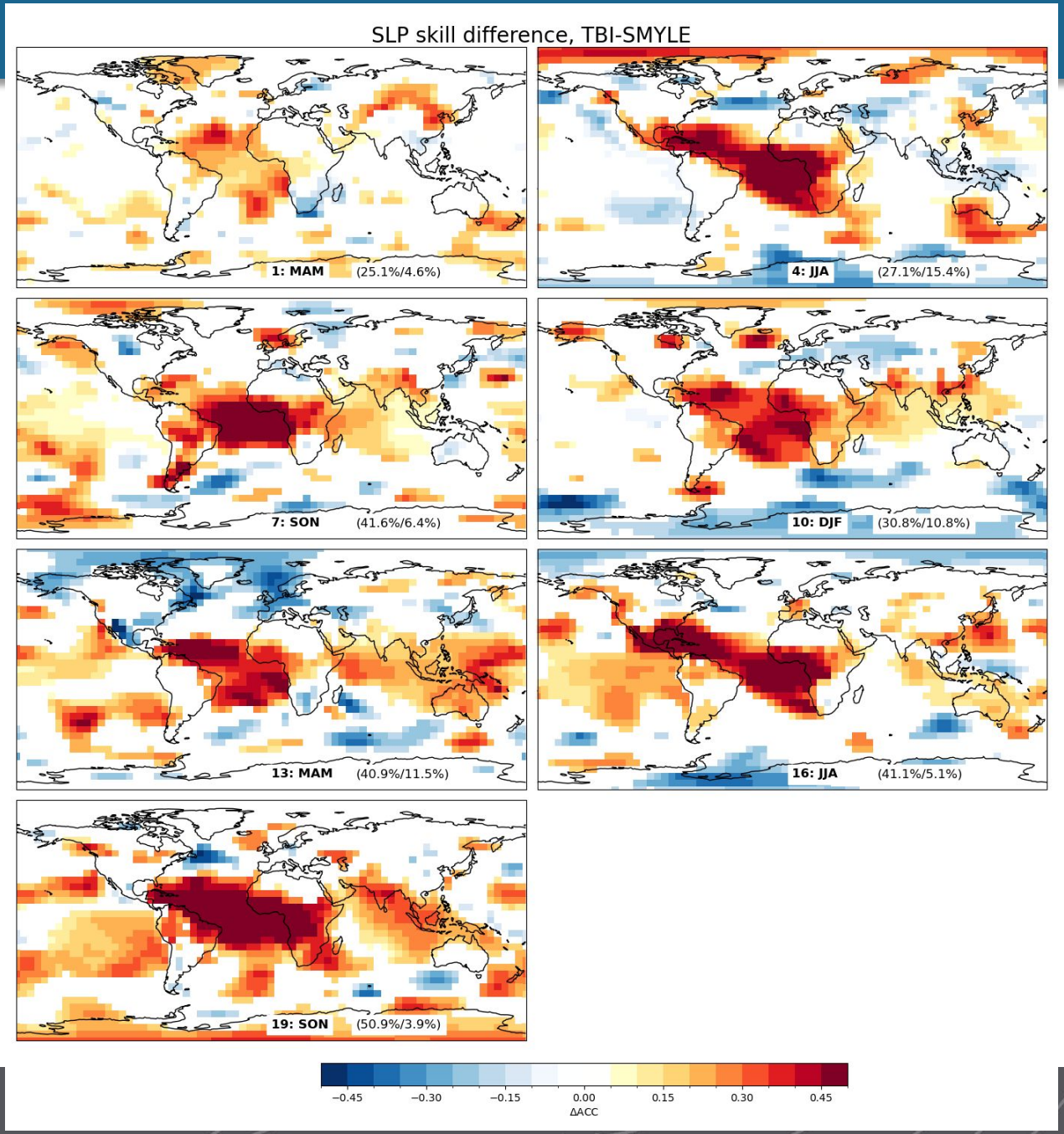
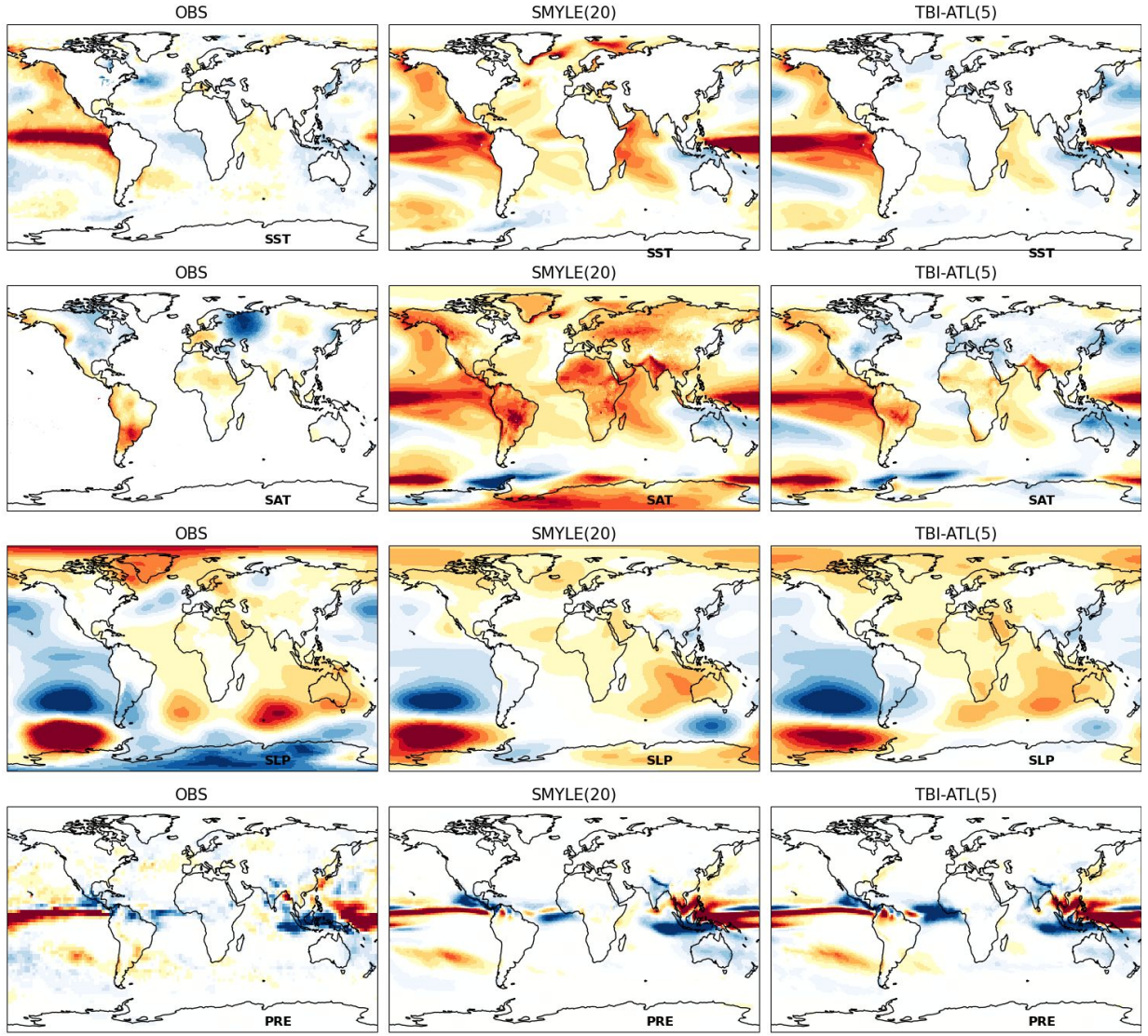


Improved ENSO Teleconnections?

- Regressions of JJA fields on JJA Nino3.4 SST (1981-2019)
- Lead month 16



SST normalized RMSE