Impacts of Bias Correction in GFDL SPEAR Seasonal Predictions

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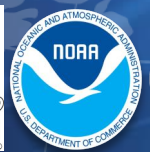
Collaborators:
GFDL/SD-Division
GFDL/Ocean & Cryosphere-Division
Princeton University/CIMES
M2LInES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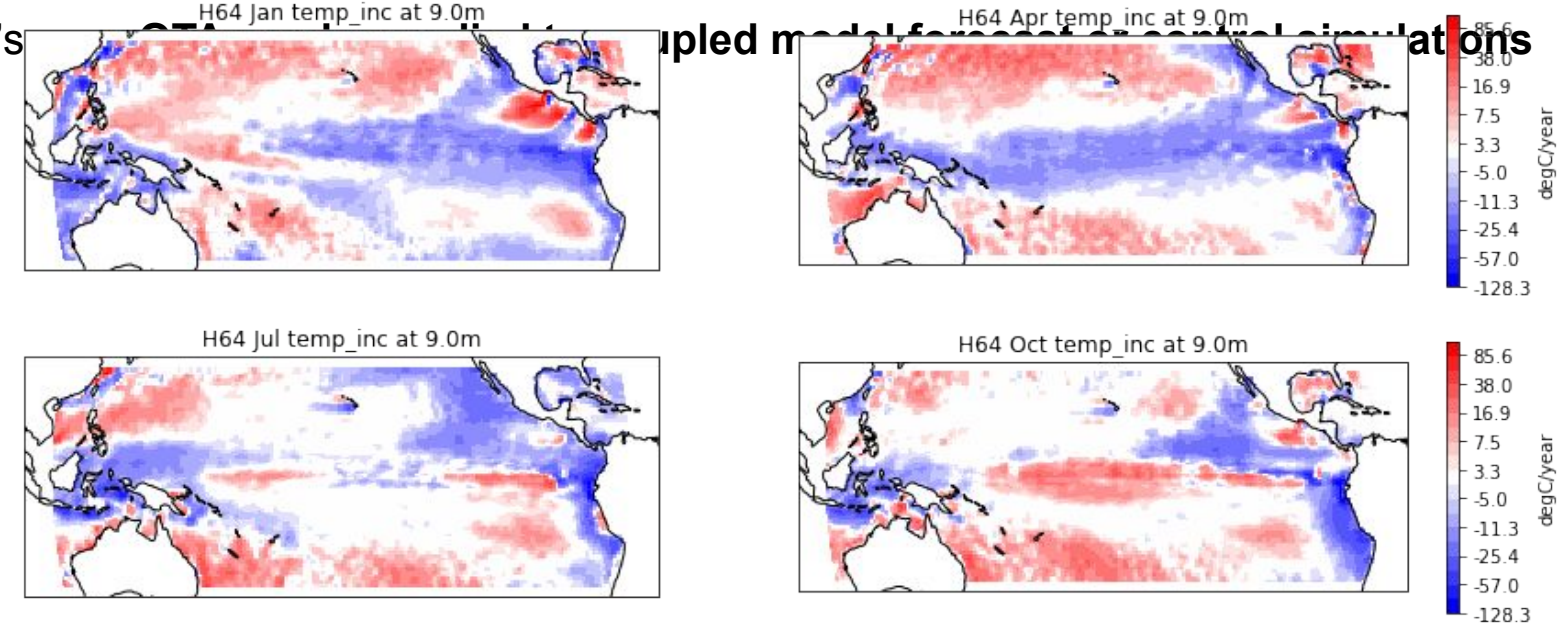
S2S Community Workshop, June 2024

(Seamless) SPEAR

- SPEAR **large ensemble** simulations
  - 30-member ensembles over the period 1921-2100 (Historical + SSP585)
  - https://www.gfdl.noaa.gov/spear_large_ensembles/
- Real-time **seasonal** prediction (GFDL SD Division)
- **Subseasonal** prediction (Baoqiang Xiang – GFDL W Division)
- **Decadal** predictions (Xiaosong Yang – GFDL SD Division)
- **Sea ice** assimilation and ML (Mitch Bushuk, Yongfei Zhang, Will Gregory – GFDL Ocean & Cryosphere Division, Princeton, M2LInES)
- **Ocean BGC** simulation and assimilation (Xiao Liu – GFDL B Division)

OTA (Ocean Tendency Adjustment)

- Idea: use DA increments for bias correction
- How: apply climatological (annual-cycle) temperature and salinity increments from 2007-2018 based on ARGO and SST to forecast model
- What's **OTA ... upled model forecast or control simulations**



Model SST Prediction Drift

January initialized SST prediction bias

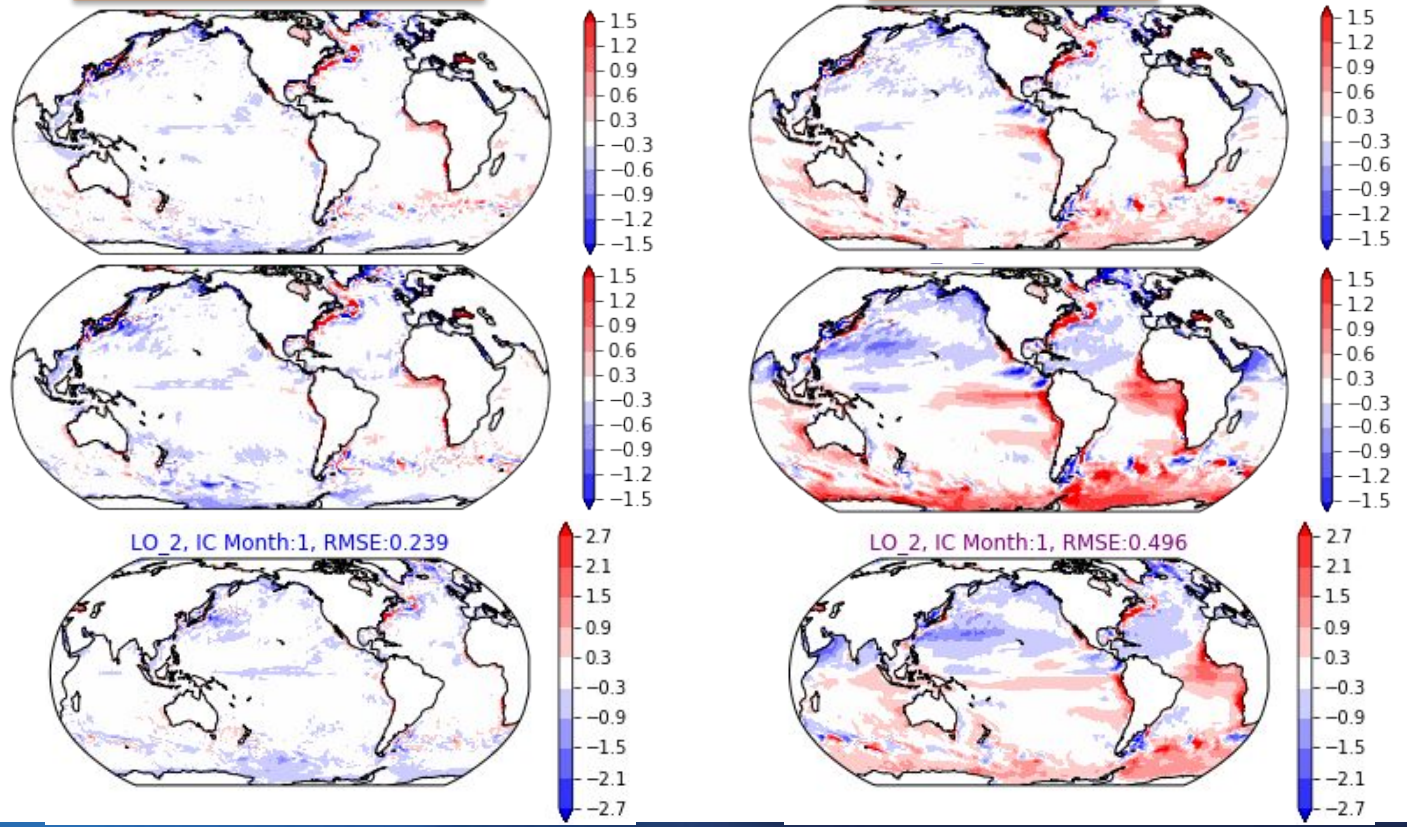
SPEAR_LO & OTA

SPEAR_LO

Lead Month 0

Lead Month 1

Lead Month 2



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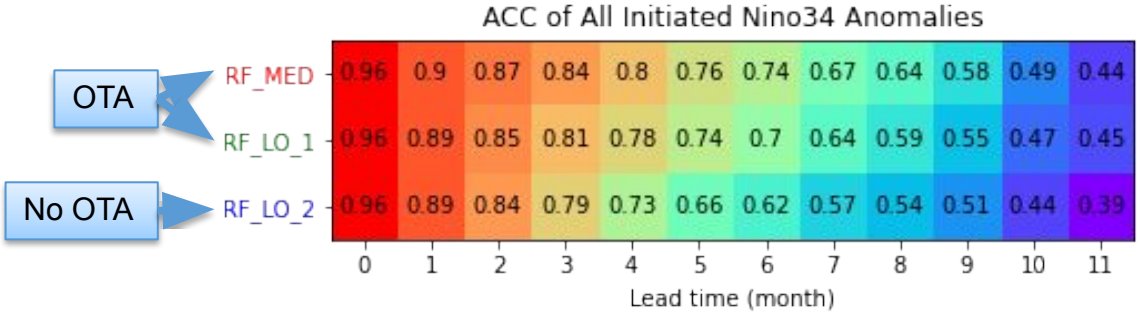
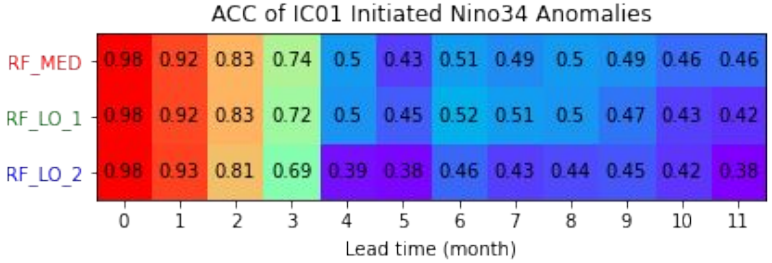
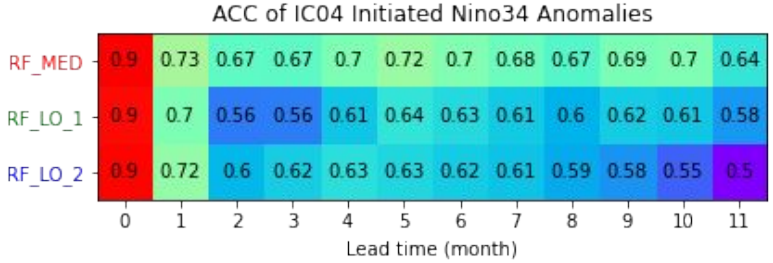
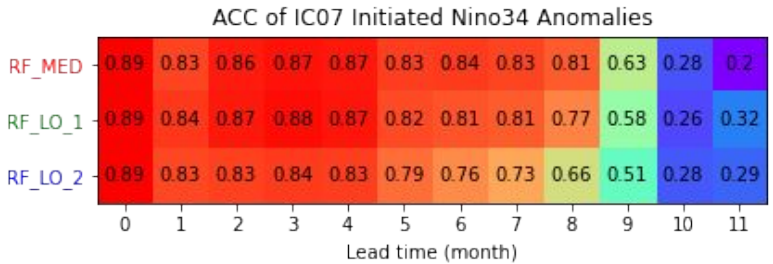
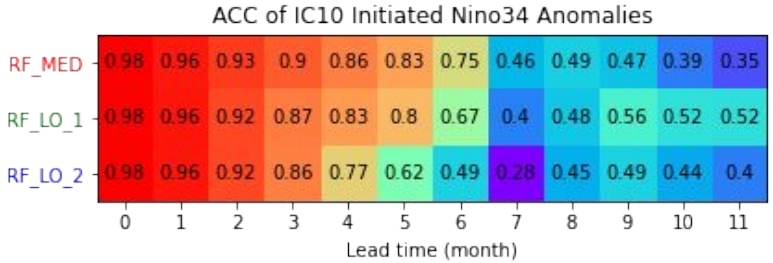
Ensemble-mean Nino3.4 Skills (30yr hindcast)









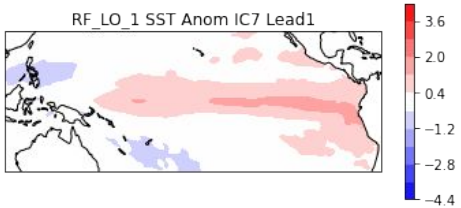
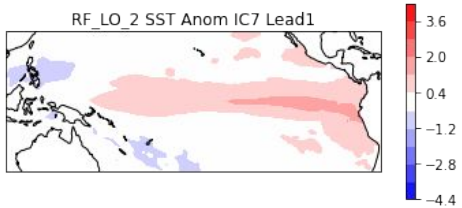
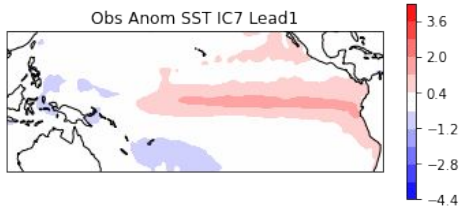
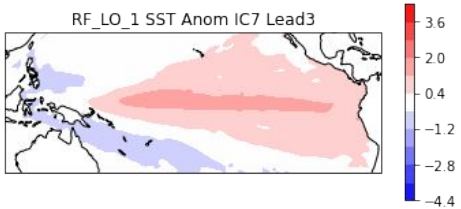
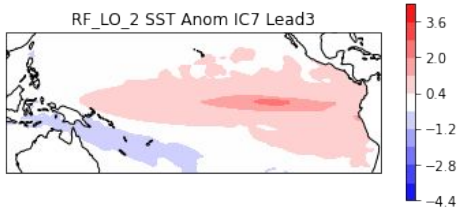
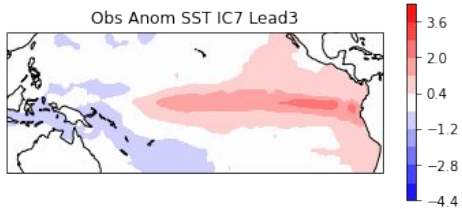
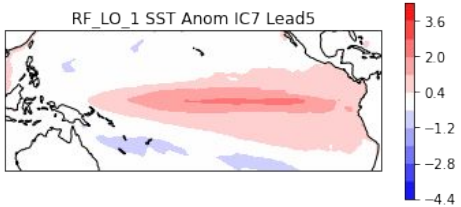
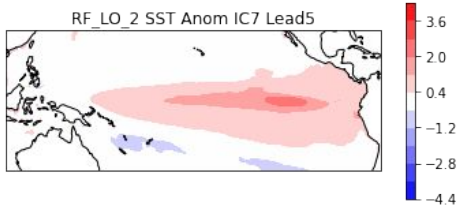
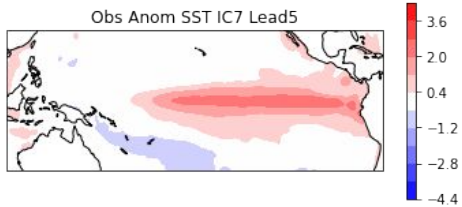


Similar results have been shown in several similar studies, where empirical bias correction significantly reduces model bias/drift but has limited impact on prediction skills.

What does bias correction give us then?

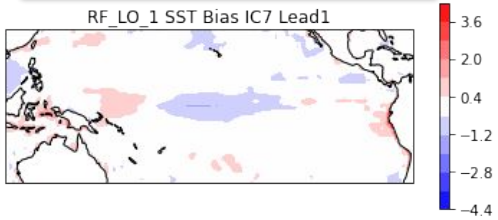
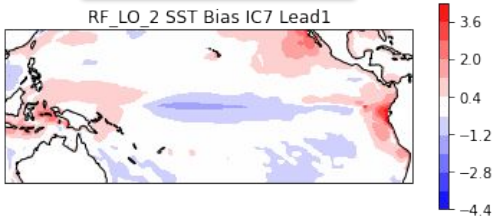
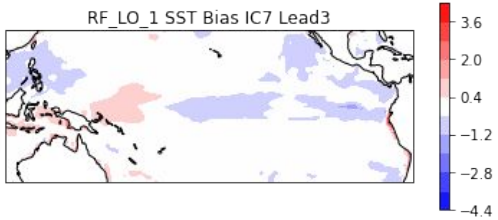
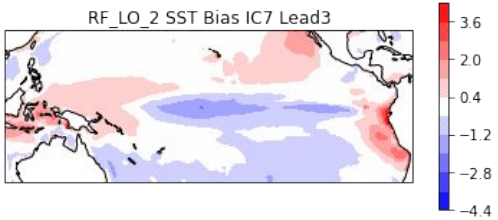
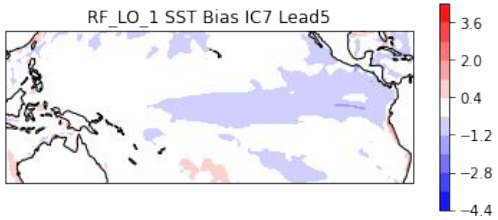
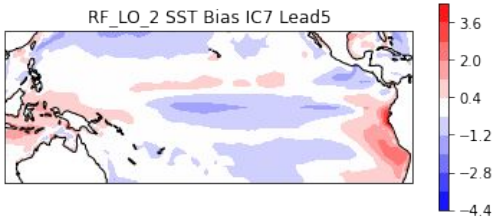
El Niño Composite SST Anomalies

July-initiated forecasts **SST anomalies** for El Niño years (1994, 1997, 2002, 2006, 2009, 2015)

	SPEAR_LO & OTA	SPEAR_LO	OI SST
August			
October			
December			

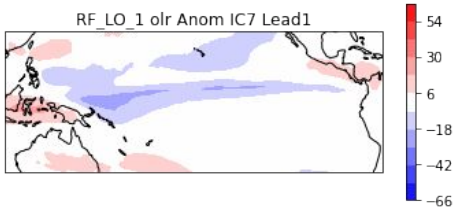
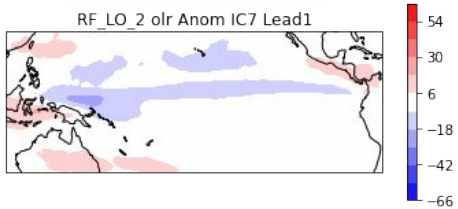
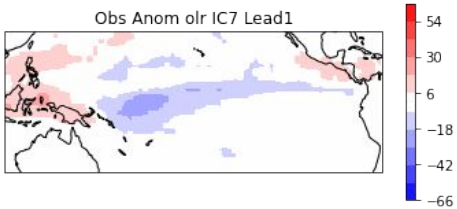
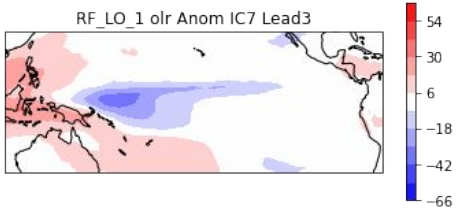
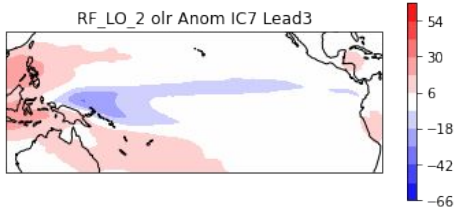
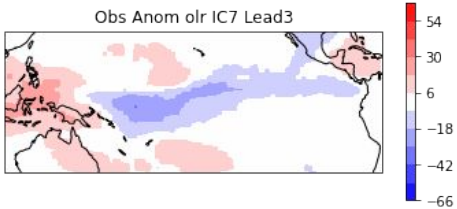
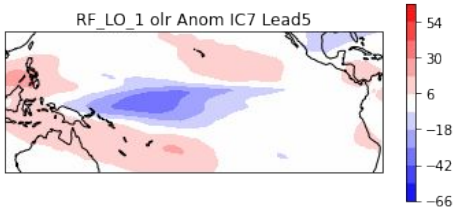
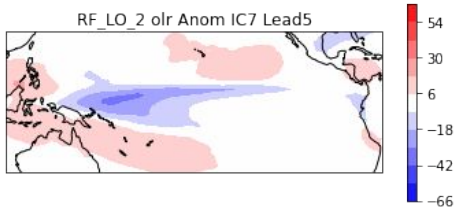
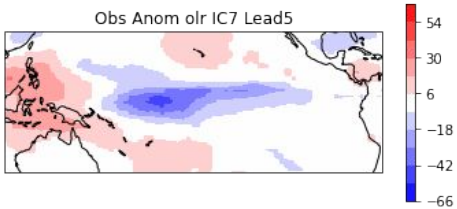
El Niño Composite SST Bias

July-initiated forecasts **SST biases** for El Niño years (1994, 1997, 2002, 2006, 2009, 2015)

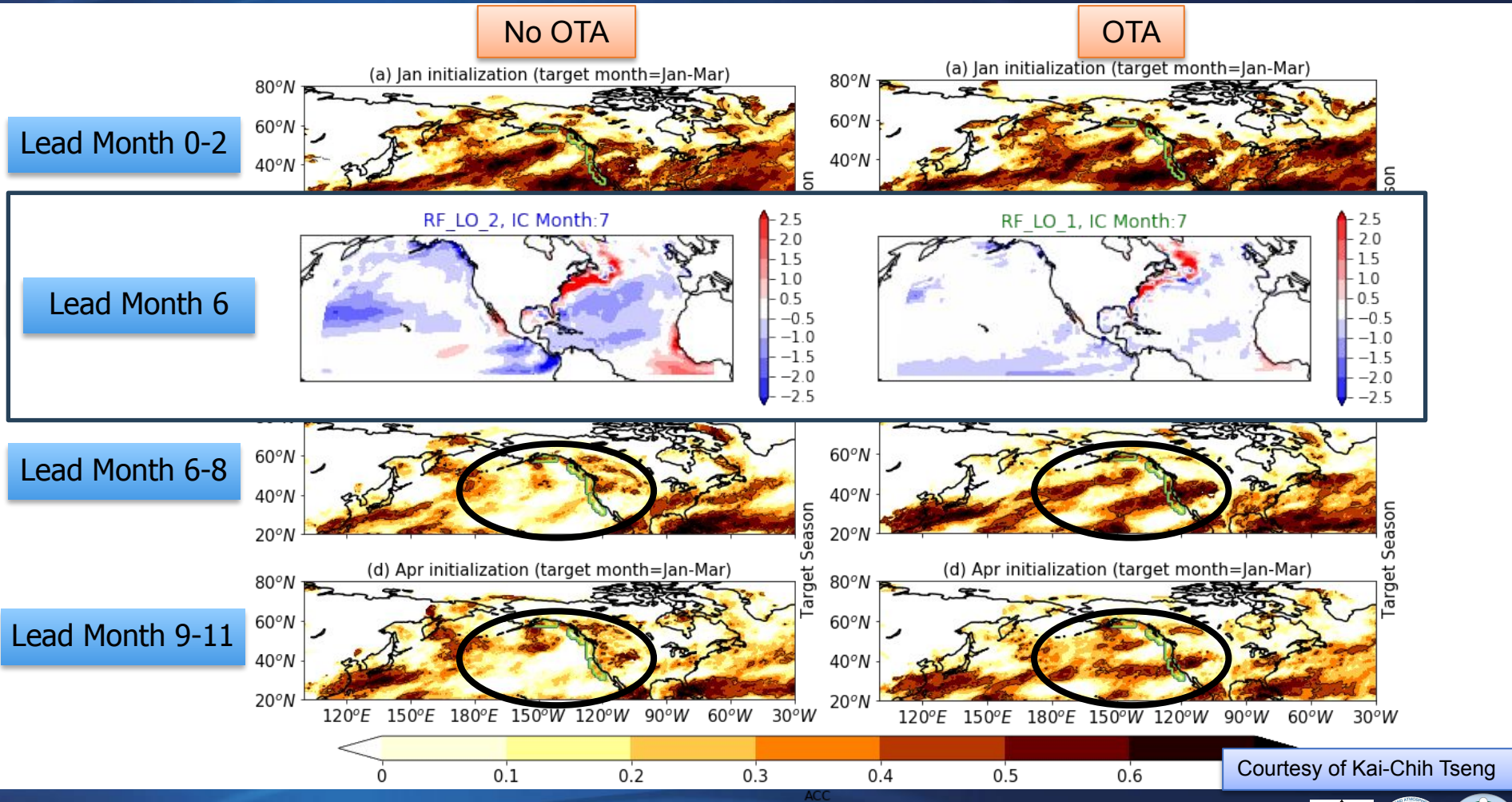
	SPEAR_LO & OTA	SPEAR_LO
July		
September		
November		

El Niño Composite OLR Anomalies

July-initiated forecasts **OLR anomalies** for El Niño years (1994, 1997, 2002, 2006, 2009, 2015)

	SPEAR_LO & OTA	SPEAR_LO	OI SST
August			
October			
December			

Seasonal Prediction of Atmospheric River



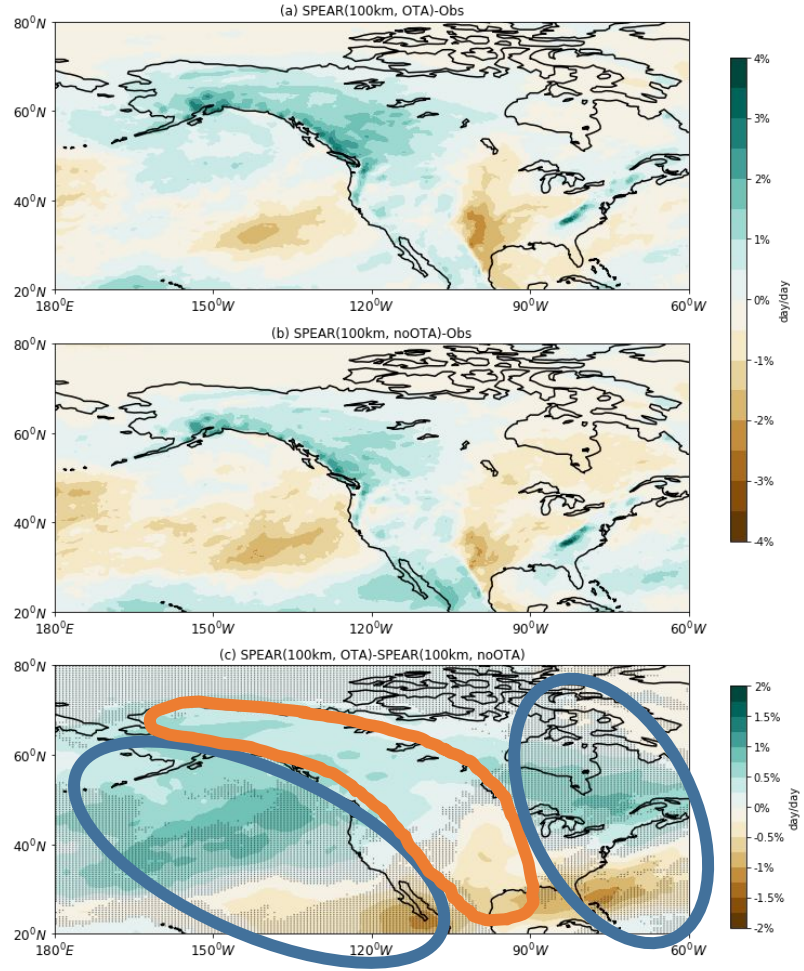
AR Climatology & OTA

The bias in AR frequency averaged over all forecast lead times

OTA

No OTA

OTA – No OTA

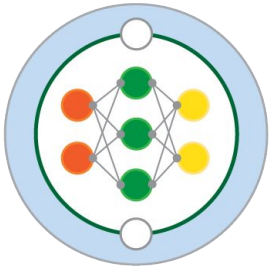


OTA reduces AR forecast bias over the oceans and eastern Canada

OTA increases AR forecast bias over Alaska, western Canada and US by revealing **compensating biases** between

- **Low AR frequency from Pacific**
- **Easier AR penetration inland due to coarse-resolution topography**

OTA and Machine Learning (M2LInES)



- Issues about current OTA implementation
  - Insufficient Argo coverage spatially/temporally
  - Stationary increments
  - Mixture of all bias sources
- Enhance OTA with machine learning
  - OTA increments **f(lat, lon, time)** -> **f(local state variables, surface fluxes)**
- Goals of ML-OTA
  - Improve coupled model prediction and projection
  - Connect with ML efforts that learn from high-res simulations

Summary

- Prognostic bias correction based on data assimilation increments is applied to SPEAR coupled seasonal prediction system.
- Model drift in the ocean is significantly reduced, but the improvement in the top-line ENSO prediction skills is moderate.
- Reduced model drift via bias correction should bring additional benefits and uncover model deficiencies.