Summer Large-Scale Surface Air Temperature Bias Pattern over the CONUS in UFS Prototype 8
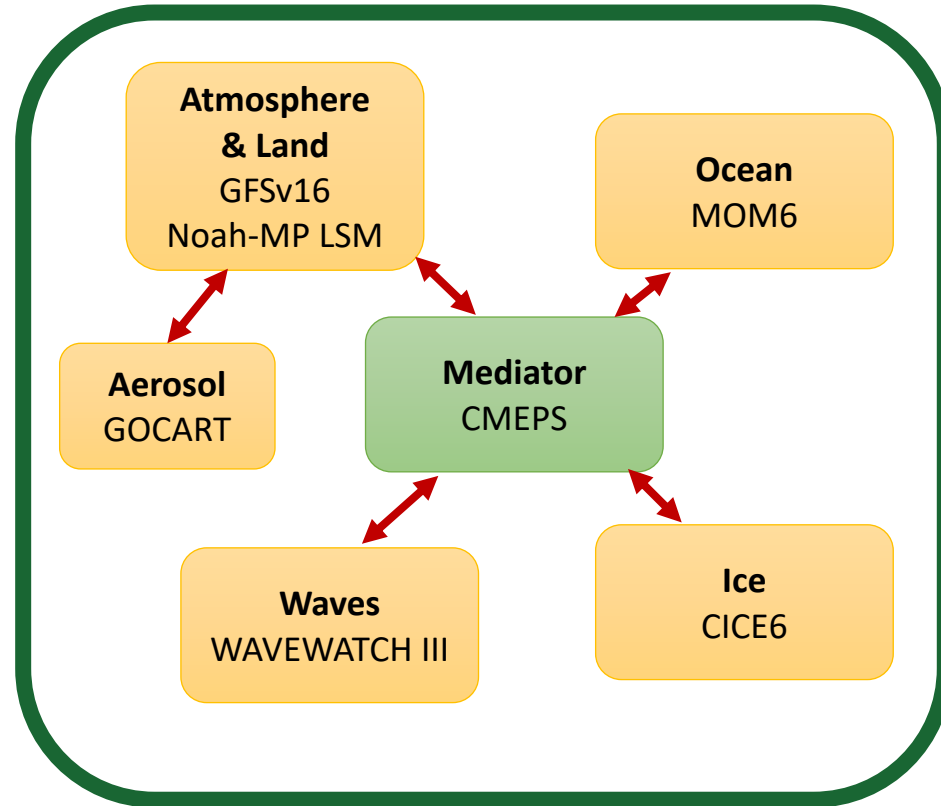
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6/7/2024

S2S Community Workshop

Boulder, CO

Unified Forecasting System (UFS) Prototype 8, NOAA

Prototype 8

Atmosphere and Land
 - FV3 C384 (~ ¼ degree)
 - 127 vertical layers with 80 km top
 - GEFSv12 reanalysis for Atmos. Init.
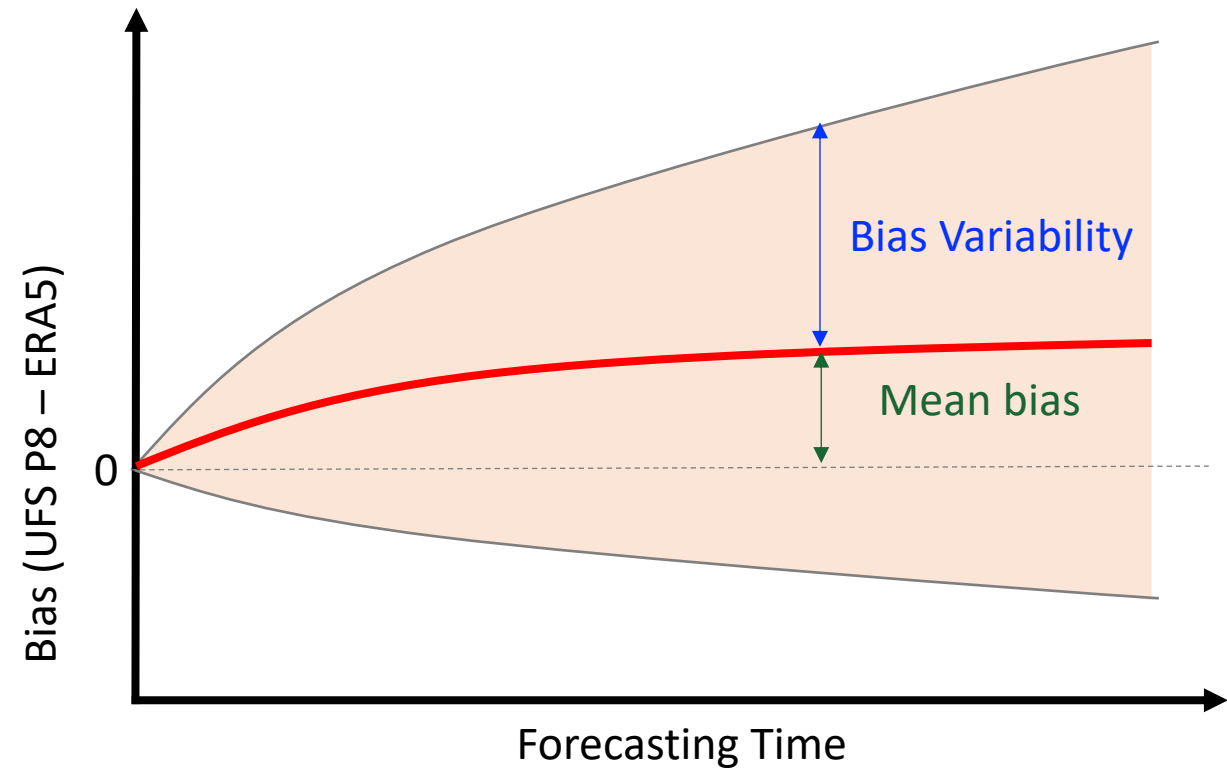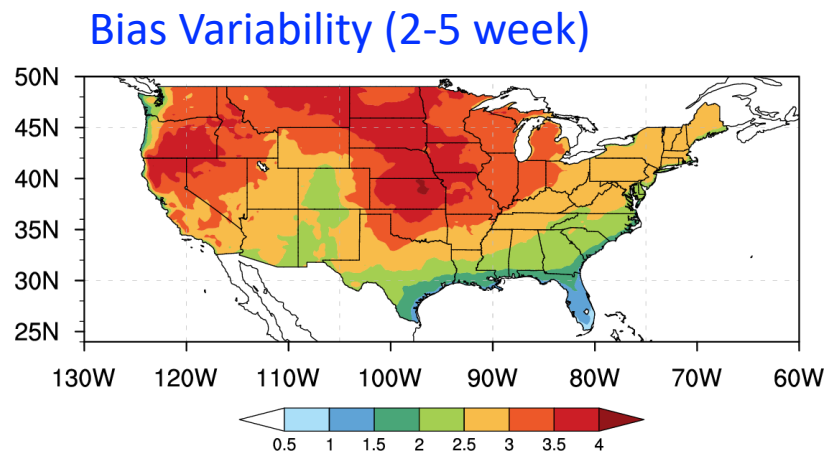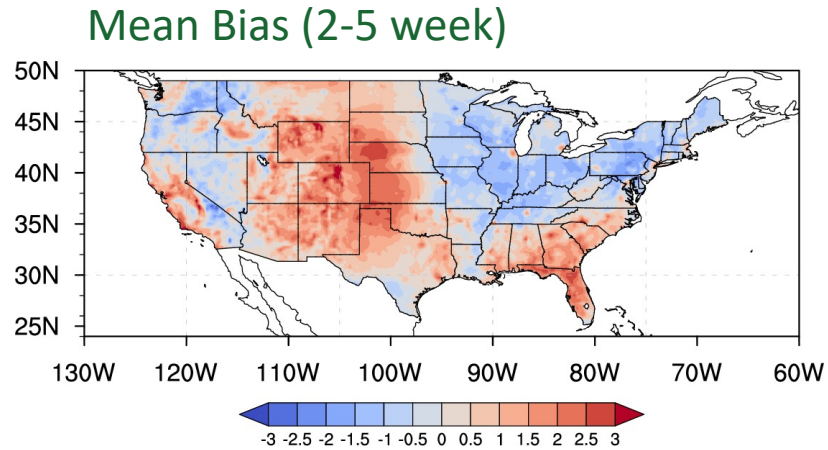 - Spin up Noah-MP with NASA GLDAS forcing for Land Init.

Ocean and Sea Ice
 - Tripolar ¼ degree
 - 75 hybrid vertical levels
 - CPC 3DVAR Analysis for Ocean Init.
 - CPC-CSIS Analysis for CICE Init.

UFS Prototype 8 has integrated 35 days hindcast during 2011 Apr – 2018 Mar, initialized at every 1st and 15th

Reference Data

- ECMWF **ERA5 Reanalysis** is used for Atmospheric Variables (Surface Air Temperature, Wind, Geopotential height)

- NOAA **OISSTv2** is used for SST and **AVHRR** satellite-based dataset is used for the Outgoing Longwave Radiation (OLR), respectively

- This study is focused on the warm season (JJAS)

Importance of Bias Variability

Mean Bias (2-5 week)

Bias Variability (2-5 week)

Bias Variability

Mean bias

Bias (UFS P8 − ERA5)

0

Forecasting Time

- Actual forecast can contain a larger bias than the mean bias
- Mean bias is much easier to be handled (e.g., bias correction)

# Surface Air Temperature (T2m) Bias Pattern (JJAS)
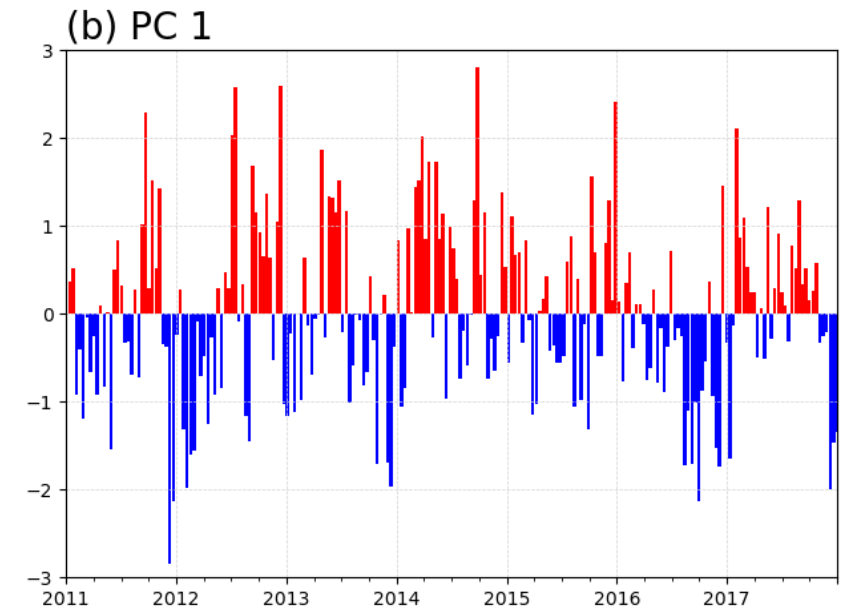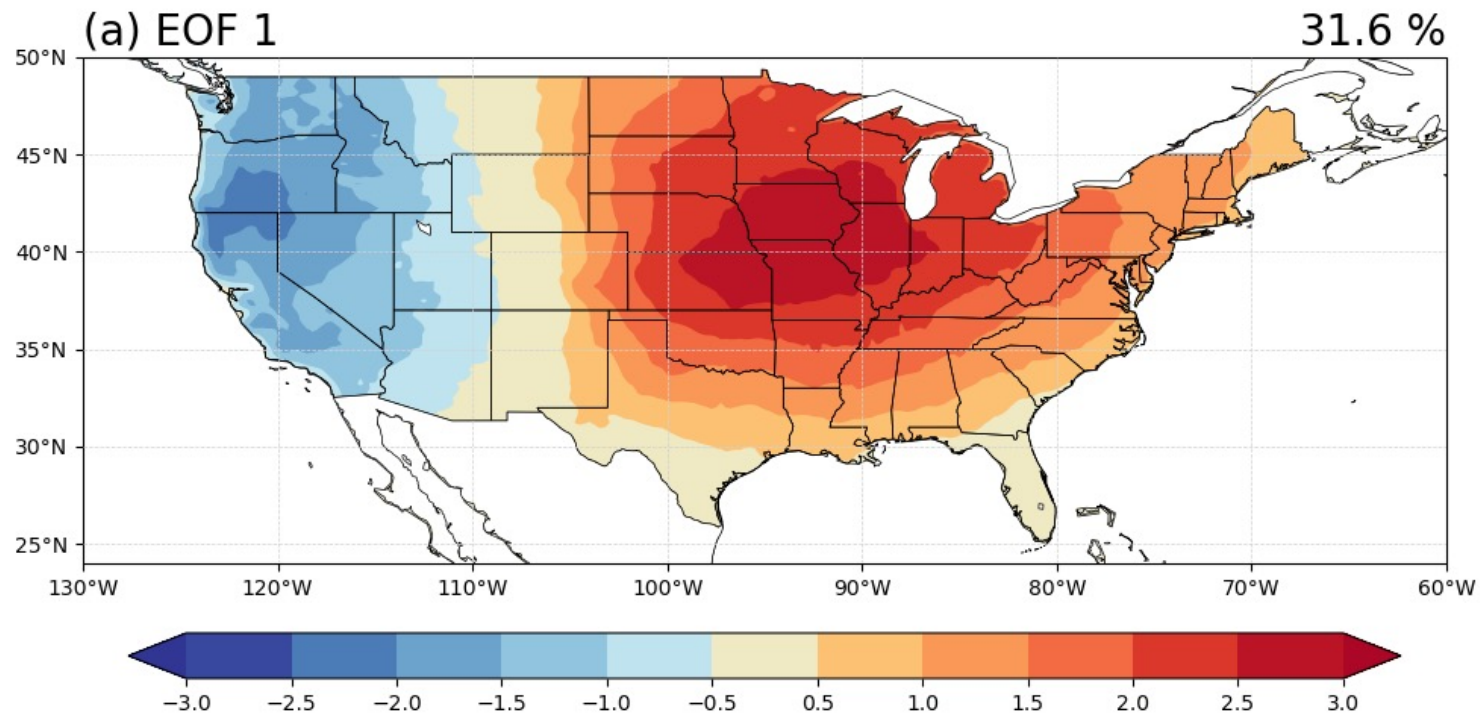
- Combine weeks 2-5 (total 224 samples: 7 years x 4 months x 2 initial dates x 4 weeks)
- The purpose of this study is to understand the source of error related to T2m bias over CONUS

Large-Scale Atmospheric Circulations

(a) Regressed Z500

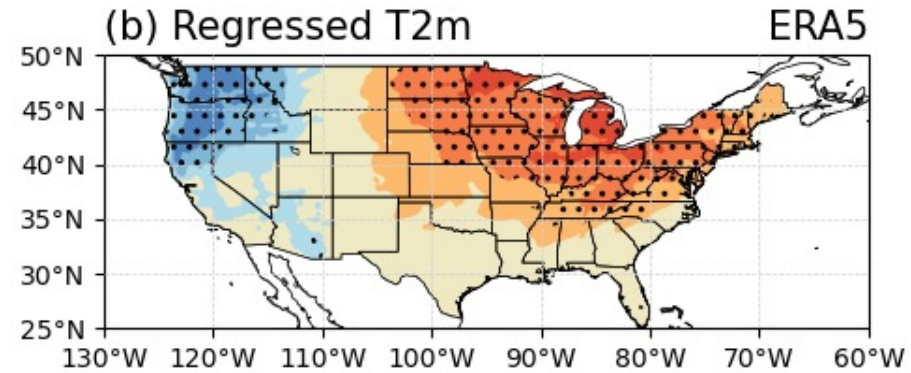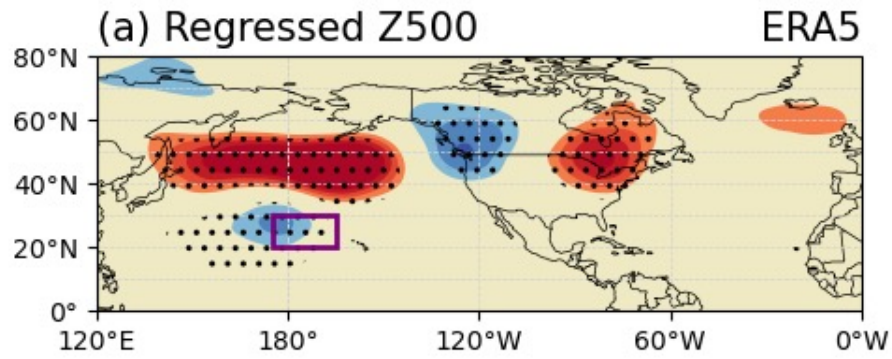(b) Regressed SST

(c) Regressed OLR
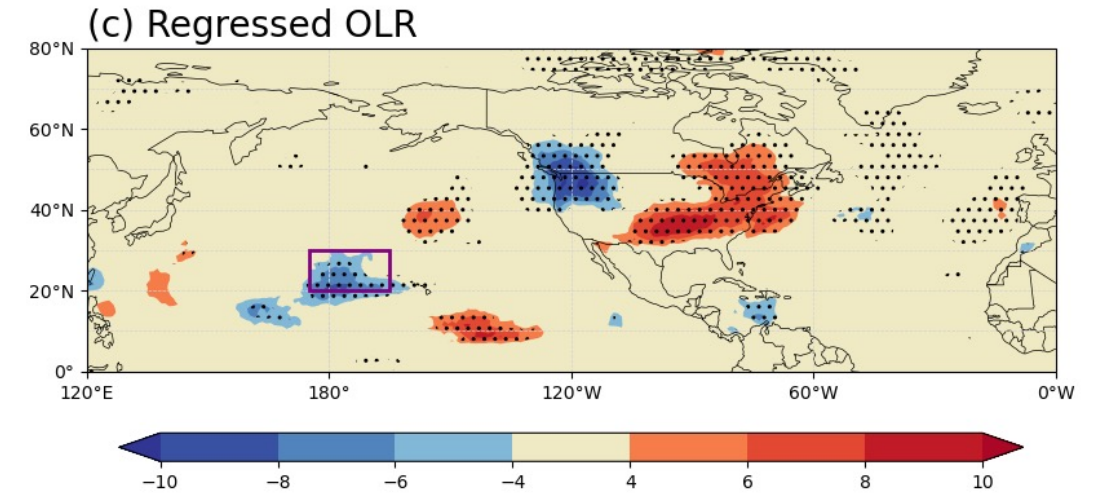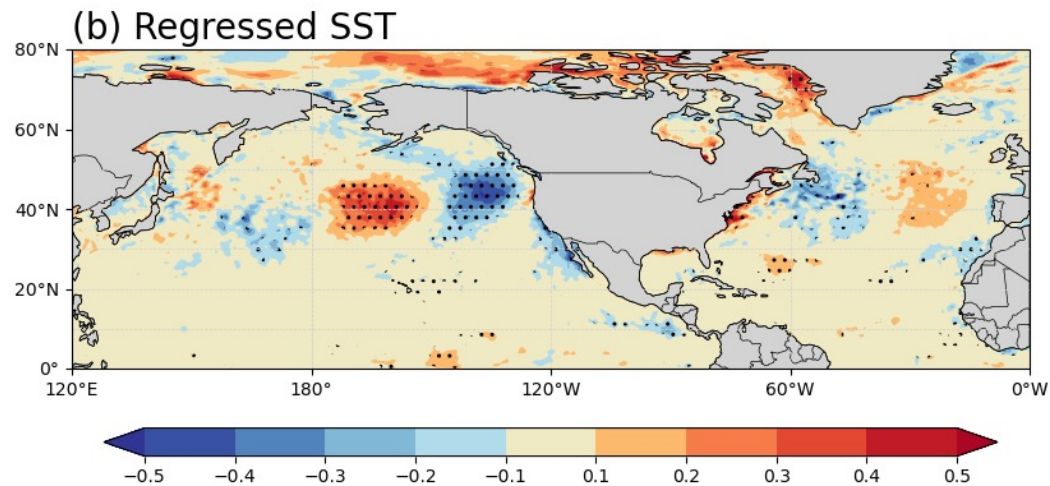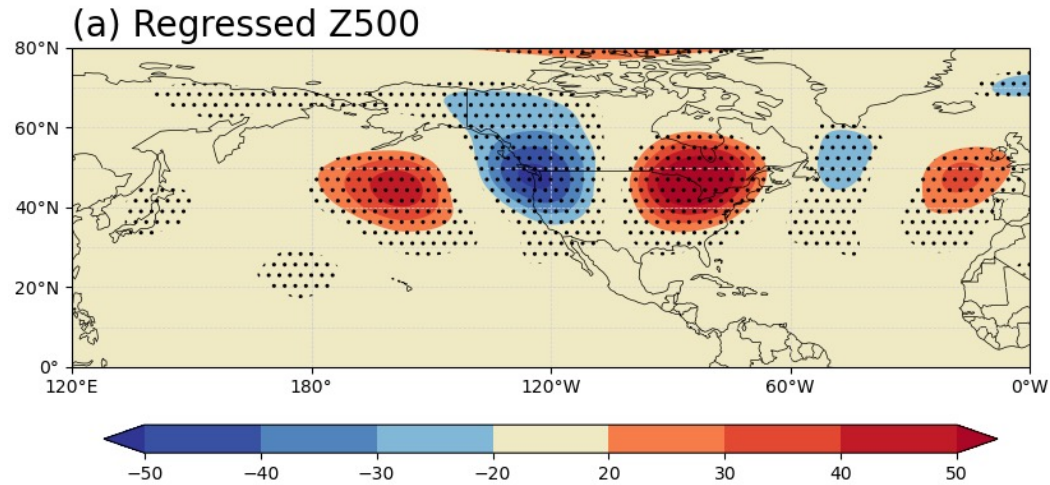
- Temperature Bias Pattern is strongly related to upper-level atmospheric circulations
- Relationship to SST seems to be the response, not the source
- Convection (negative OLR anomaly) appears as a source of erroneous upper-level circulations

1) Impact of Tropical OLR Bias

(a) Regressed Z500

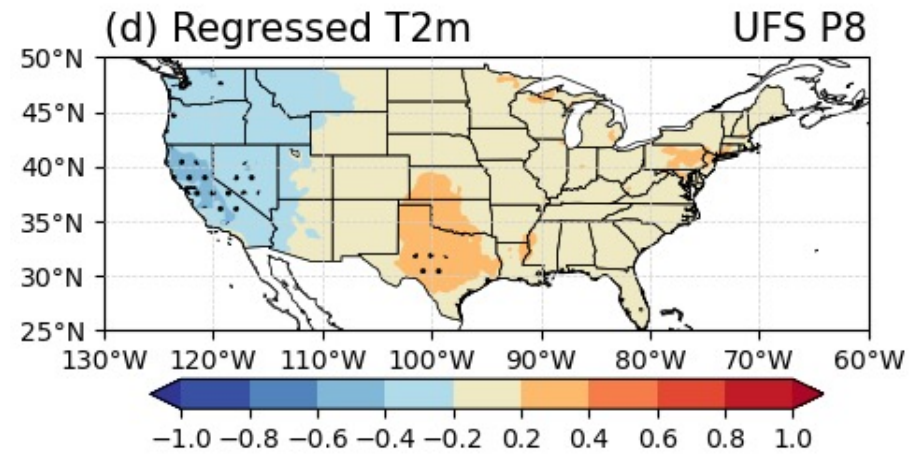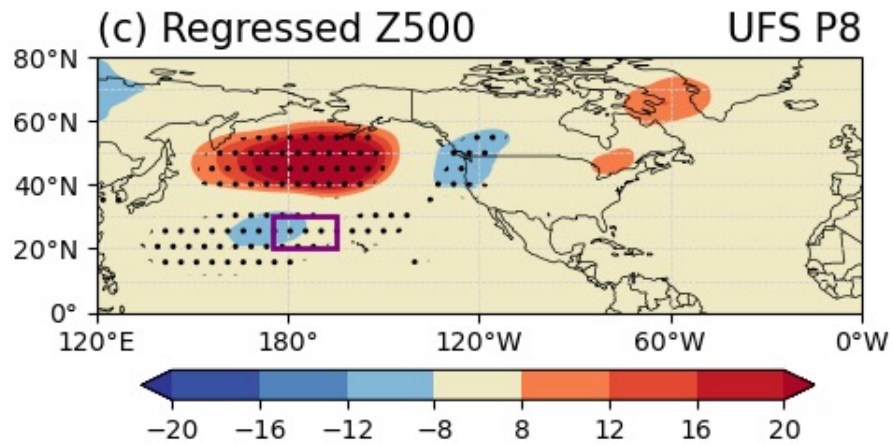(b) OLR Forecasting Skill

(b) Regressed T2m
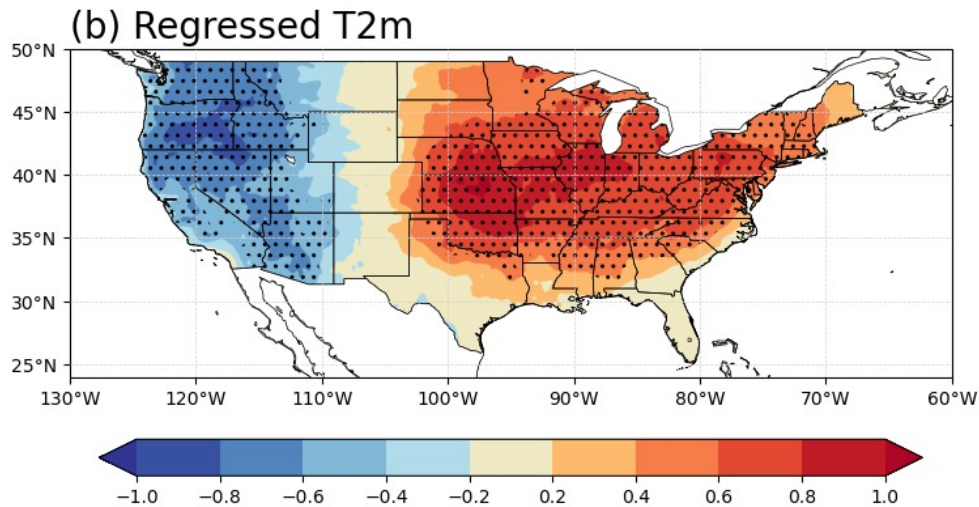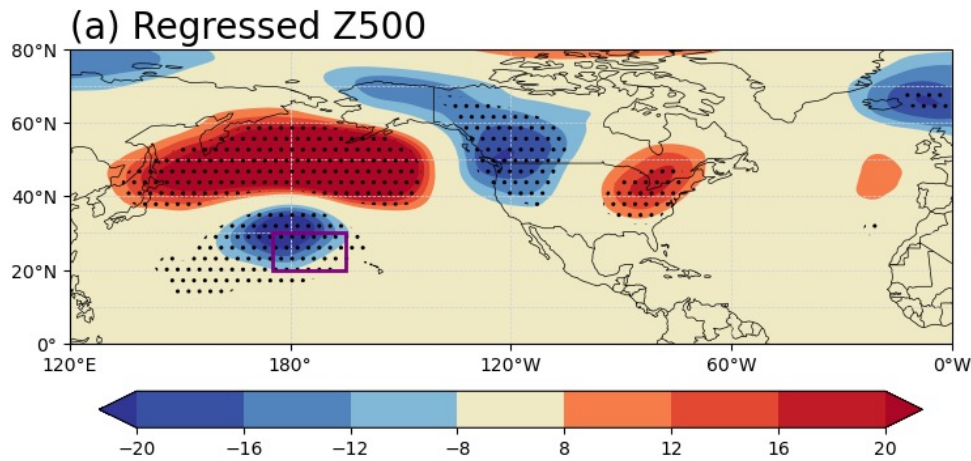
- Regression is onto the OLR bias in the Central Tropical Pacific
- Forecasting skill of OLR in this region is rapidly decreasing after 2 week
  → OLR bias is one of the reasons for SAT bias over CONUS!

Representation of Large-Scale Circulation

(a) Regressed Z500 — ERA5

(b) Regressed T2m — ERA5

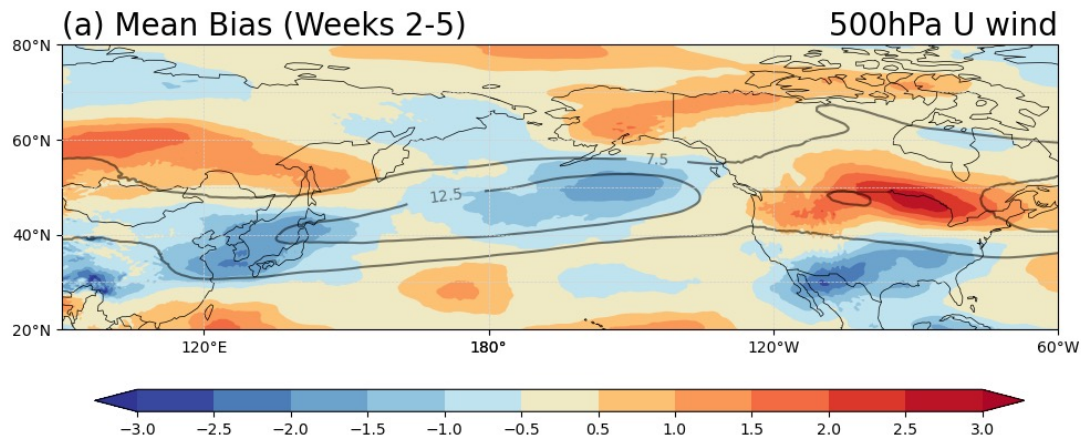(c) Regressed Z500 — UFS P8

(d) Regressed T2m — UFS P8

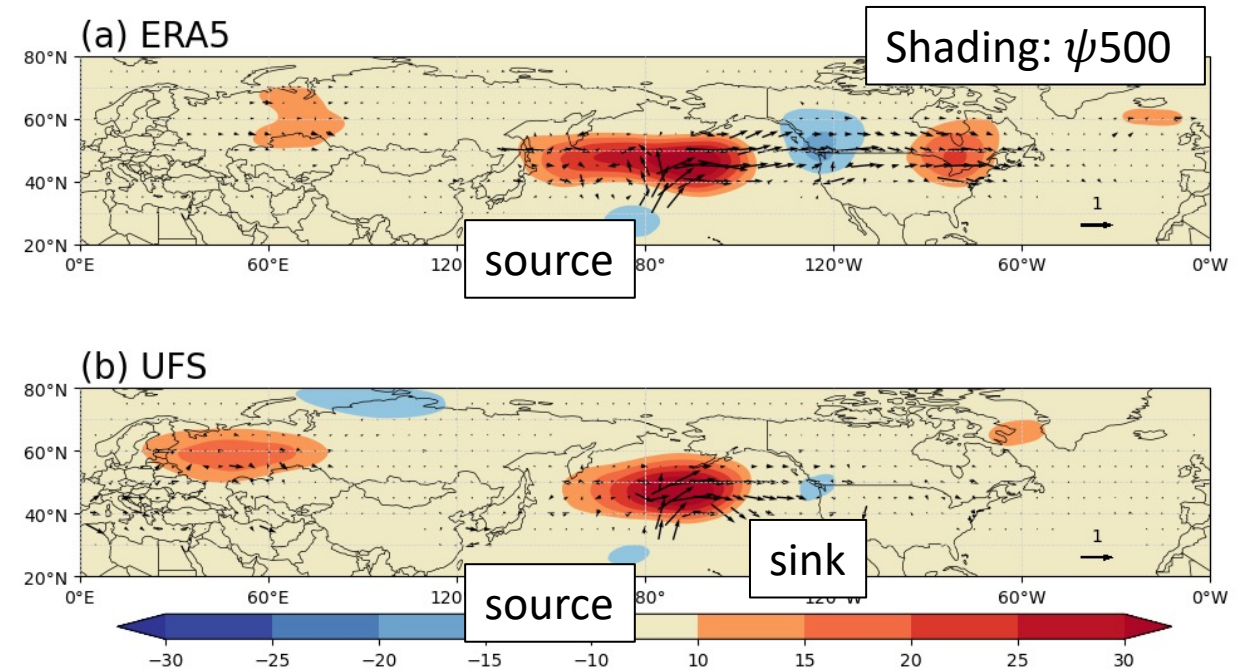500hPa GPH and T2m anomalies are regressed on OLR anomalies in each ERA5 and UFS

- ERA5 shows a Rossby wave train to CONUS
- This wave is not well reproduced in UFS P8

2) Zonal Wind in UFS P8

(a) Mean Bias (Weeks 2-5)   500hPa U wind

Shaded: U500 diff (UFS P8 – ERA5)
Contour: Climatology of ERA5

UFS P8 has a weak subtropical Jet in the Pacific
→ Weaker waveguide

(a) ERA5   Shading: $\psi 500$

source

(b) UFS

sink

source

Vector : Wave Activity Flux (Nakamura and Takaya, 2001)

3) Vertical Wind Shear in UFS P8

Vertical Wind Shear (U200 - U850) UFS P8 - ERA5

Contours: GPH UFS P8 ERA5
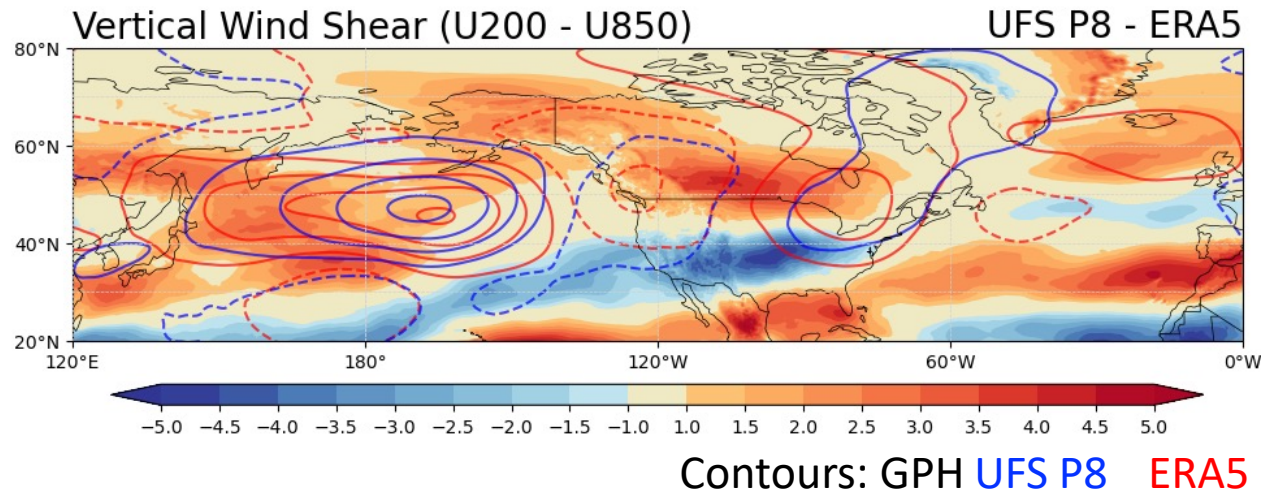
UFS P8 has stronger vertical shear
According to Fandry and Leslie (1984):
Strong vertical shear → weak amplitude & long wavelength

Using Yang and Hoskins (1996) Ray Tracing methods,
Each wave Source is located on
"170° - 185°E, 20° - 35°N, 5° spacing" and dt = 6 hour
Wave paths are averaged when waves propagate over 200°E

(a) ERA5 wave ray

(b) UFS wave ray
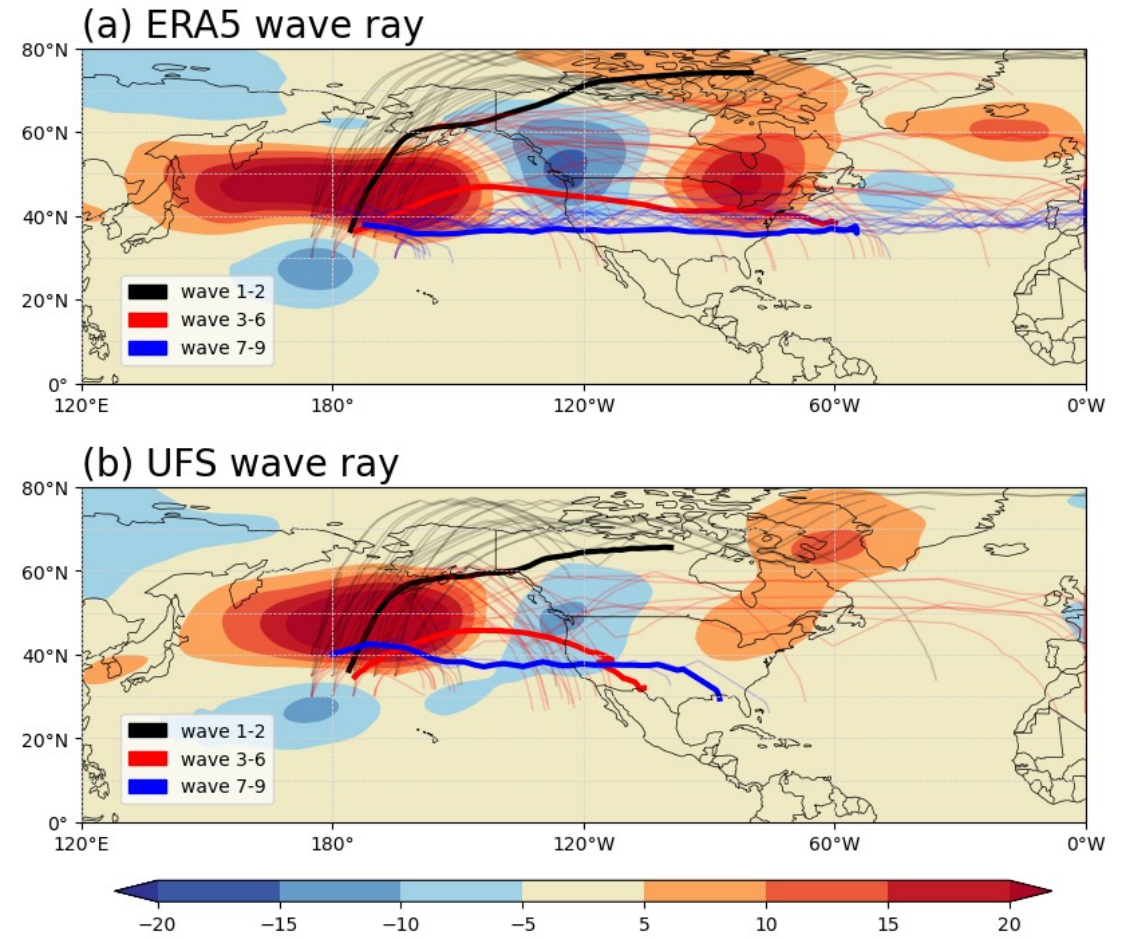
Idealized Model Experiment

Stationary Wave Model (Ting and Yu, 1998)

Rhomboidal wavenumber-30 truncation with 14 sigma level
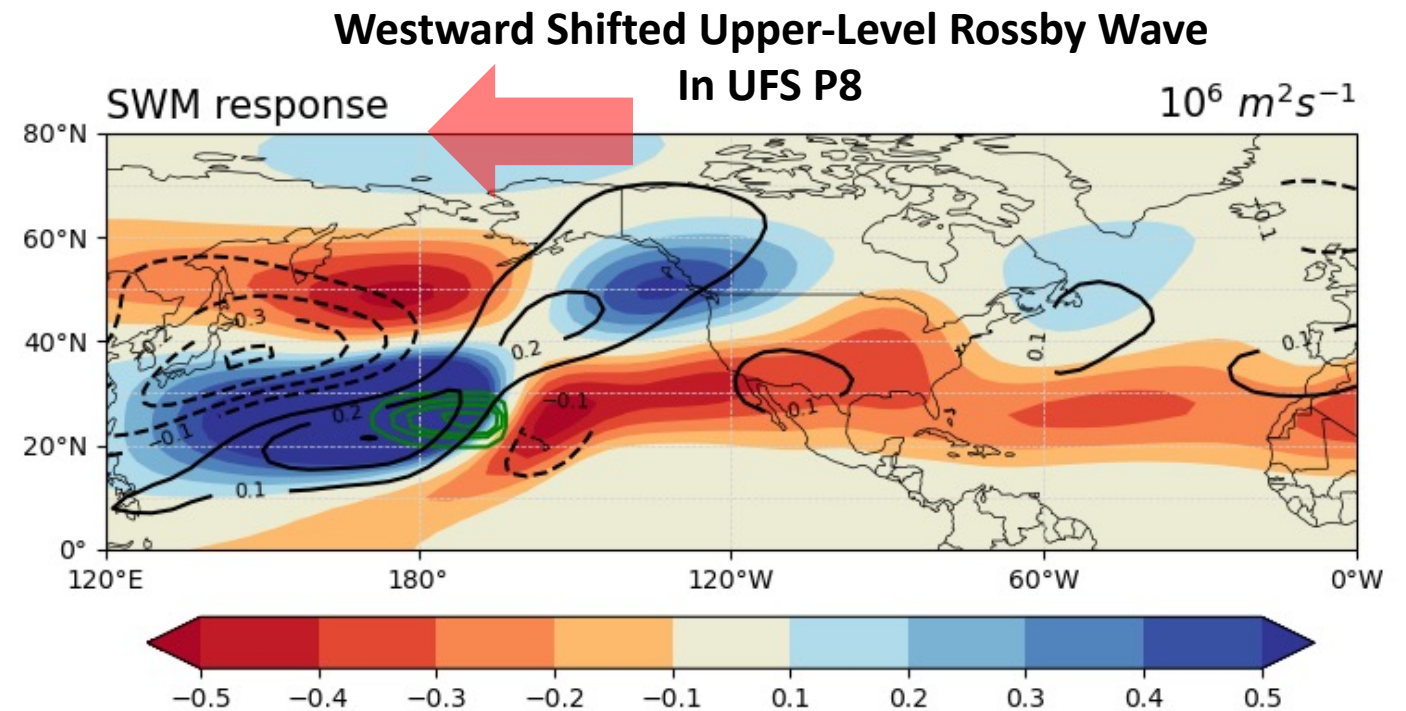(R30L14, 2.25° lat x 3.75° lon)
Diabatic Heating maximum at 0.9353 sigma level
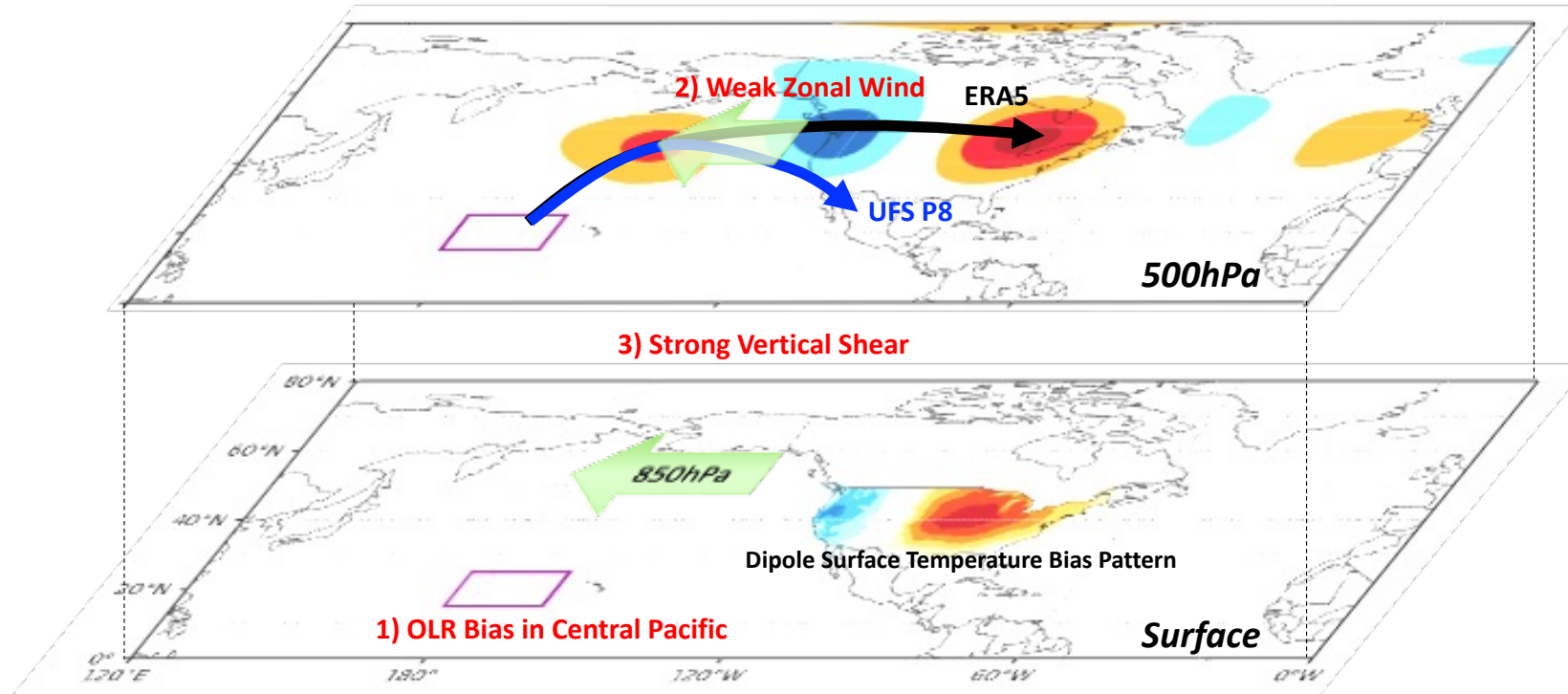
Background filed: (2011-2017 JJAS)
 EXP1) ERA5 Wind/Temp.
 EXP2) UFS P8 Wind/Temp.

Streamfunction Anomaly
Shaded : ERA5 (Exp1)
Contour: Diff (Exp2 – Exp1)

Westward Shifted Upper-Level Rossby Wave In UFS P8

Sources of Summer Surface Air Temperature Bias in UFS P8

The surface air temperature bias pattern seems to come from:
1) **The bias of OLR** over the Central Tropical Pacific
2) Poor representation of upper-level Rossby wave in UFS P8 due to **biases in the background flows** such as **mid-latitude zonal wind** and **vertical wind shear**

Thanks for your Attention!

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