

Extended-Range Prediction of Clouds in Coupled Global Ensembles

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DoD Cloud Post-Processing and Verification Workshop




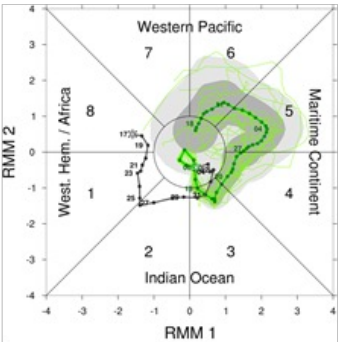
September 13th, 2023

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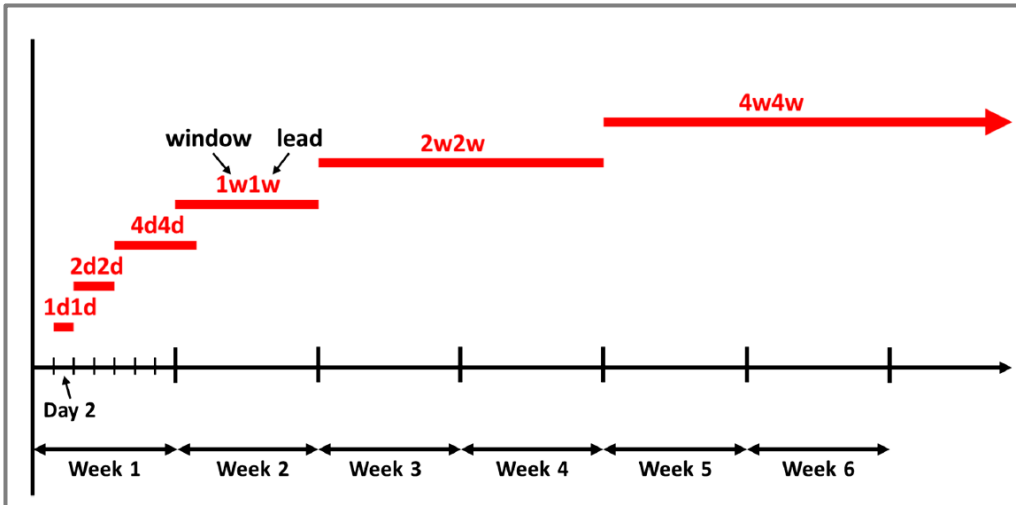
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Navy Applications of Subseasonal to Seasonal Prediction

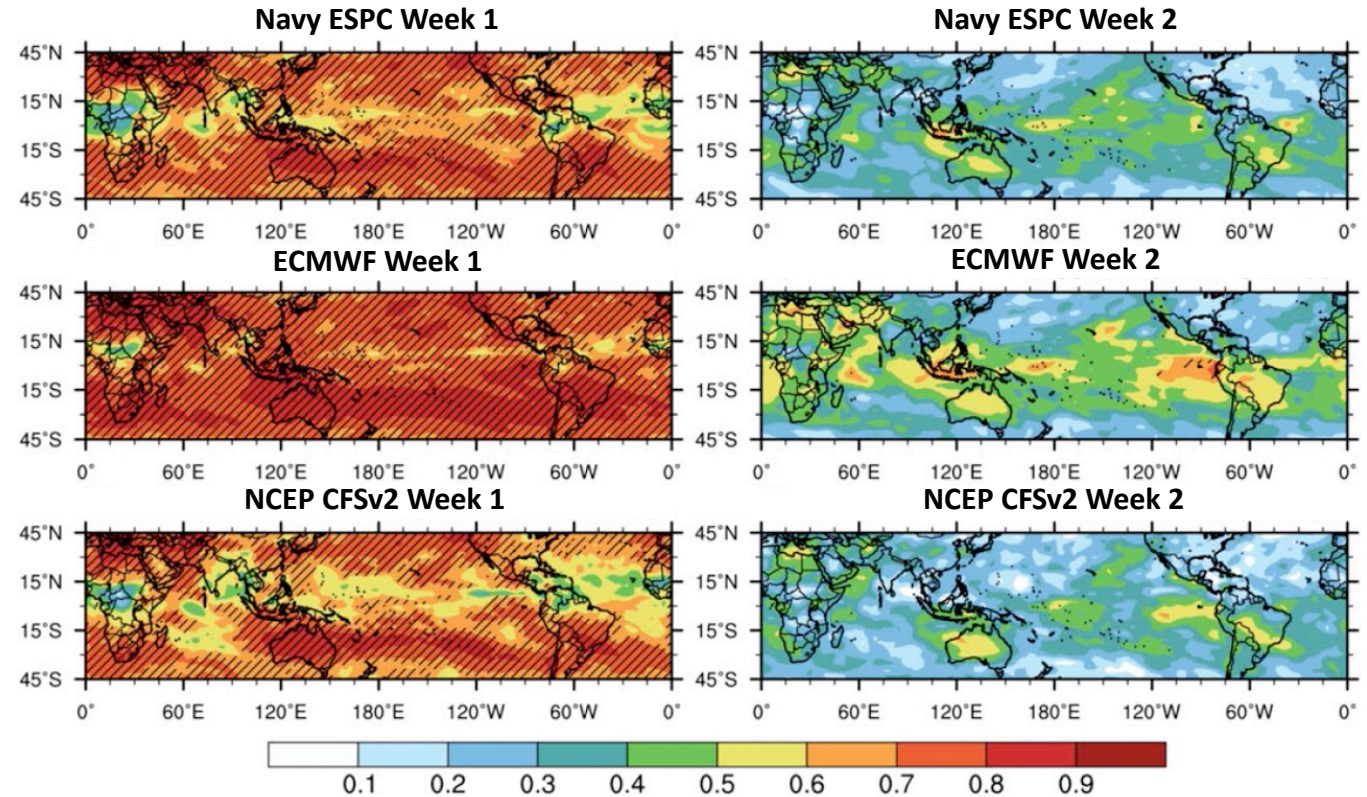
		Prediction Time-Scale	
		Hours to Days	Weeks to Months
Need	 <p>Tactics, Fleet Safety, and Operational Readiness</p>	<p>Force Positioning, Preparedness, Situational Awareness</p> 	
	Capability	<p>Limited-Area and Global Atmospheric Models Provide Information About Individual Weather Events</p>  <p>Forecast of Irene (2011) Radar Reflectivity</p>	<p>Earth System Models Provide Information About Slowly Varying Modes (e.g. MJO, ENSO) that Influence Weather and the Ocean</p> 

Current State of Extended-Range Cloud Prediction Knowledge

Wheeler et al. (2016) explored the concept of “seamless verification” where window length increases with lead time.



Janiga et al. (2018) compared the ability of different coupled global models to predict outgoing longwave radiation (OLR) and zonal winds.



Anomaly correlation (CORa) of week 1 and 2 OLR forecasts from Navy ESPC, ECMWF, and NCEP CFSv2 control member during JJA 1999-2015. **(Janiga et al. 2018)**

Current State of Extended-Range Cloud Prediction Knowledge

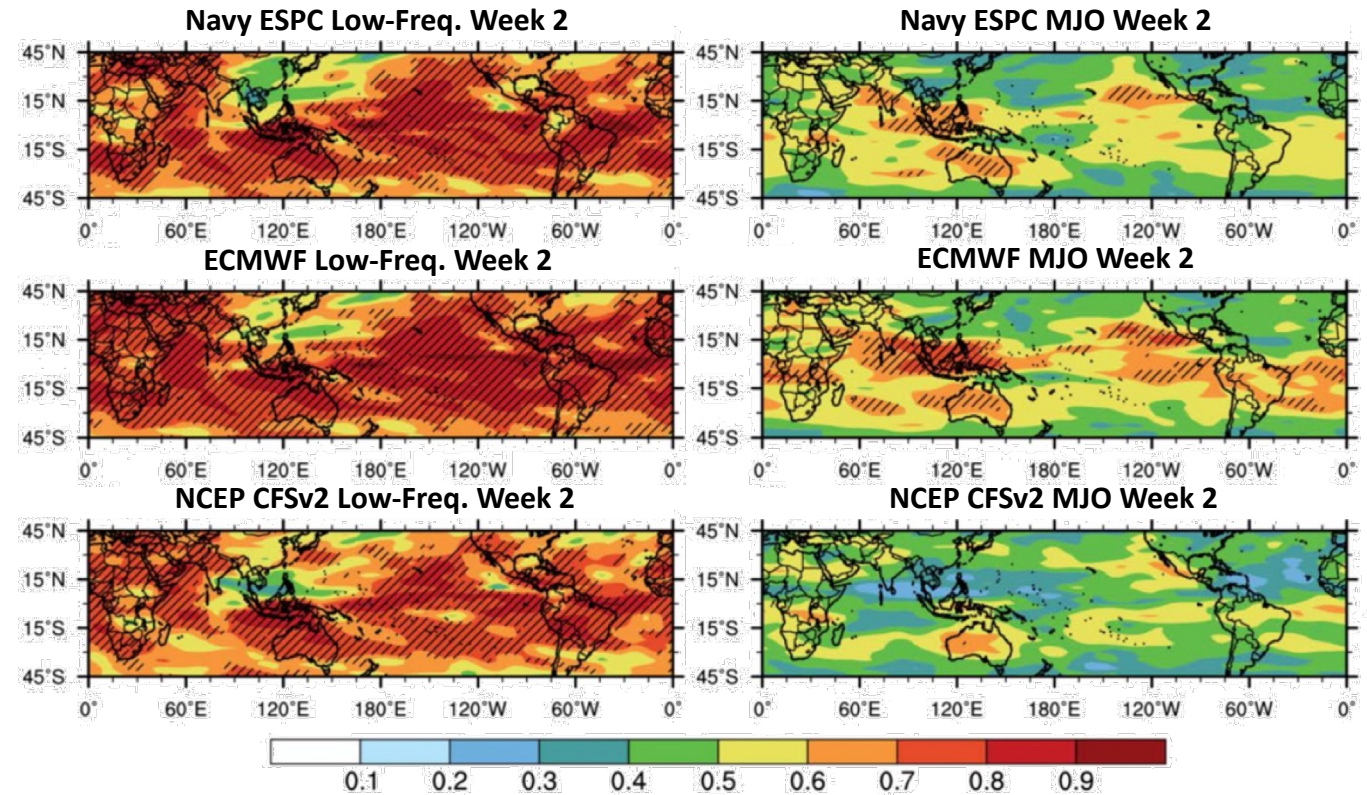
[Janiga et al. \(2018\)](#) also showed that much of the skill we see at week 2 comes from low-frequency (> 100 day) signals which they attributed to SST anomalies.

The Madden Julian Oscillation (MJO) does provide skill at week 2 on top of the low-frequency signals but this is small in most regions outside of the tropical Indo-Pacific.

However, this study only used control member forecasts.

Open Questions:

- **Benefit of ensembles?**
- **Potential predictability?**
- **Impact of spatial averaging?**



CORa of low-frequency (> 100 d) and MJO week 2 forecasts from Navy ESPC, ECMWF, and NCEP CFSv2 control member during JJA 1999-2015. ([Janiga et al. 2018](#))

Data and Methodology

Model Total Cloud Cover:

- ECMWF CY47R3 11-mem reforecasts (2002-2021) and 2021 and 2022 operational 51-mem ensemble
- UKMO 2021 and 2022 4-mem operational ensemble
- NCEP CFSv2 2021 and 2022 16-mem operational ensemble
- Navy ESPC 2021 and 2022 16-mem operational ensemble

ERA5 Reanalysis Total Cloud Cover:

- Used for verification with 1991-2020 annual cycle used to calculate anomalies

Method:

- Anomaly correlation applied to ensemble mean
- Potential correlation calculated by comparing members to ensemble means excluding that member (**Buizza 1997**)
- Both temporal and spatial radial averaging applied

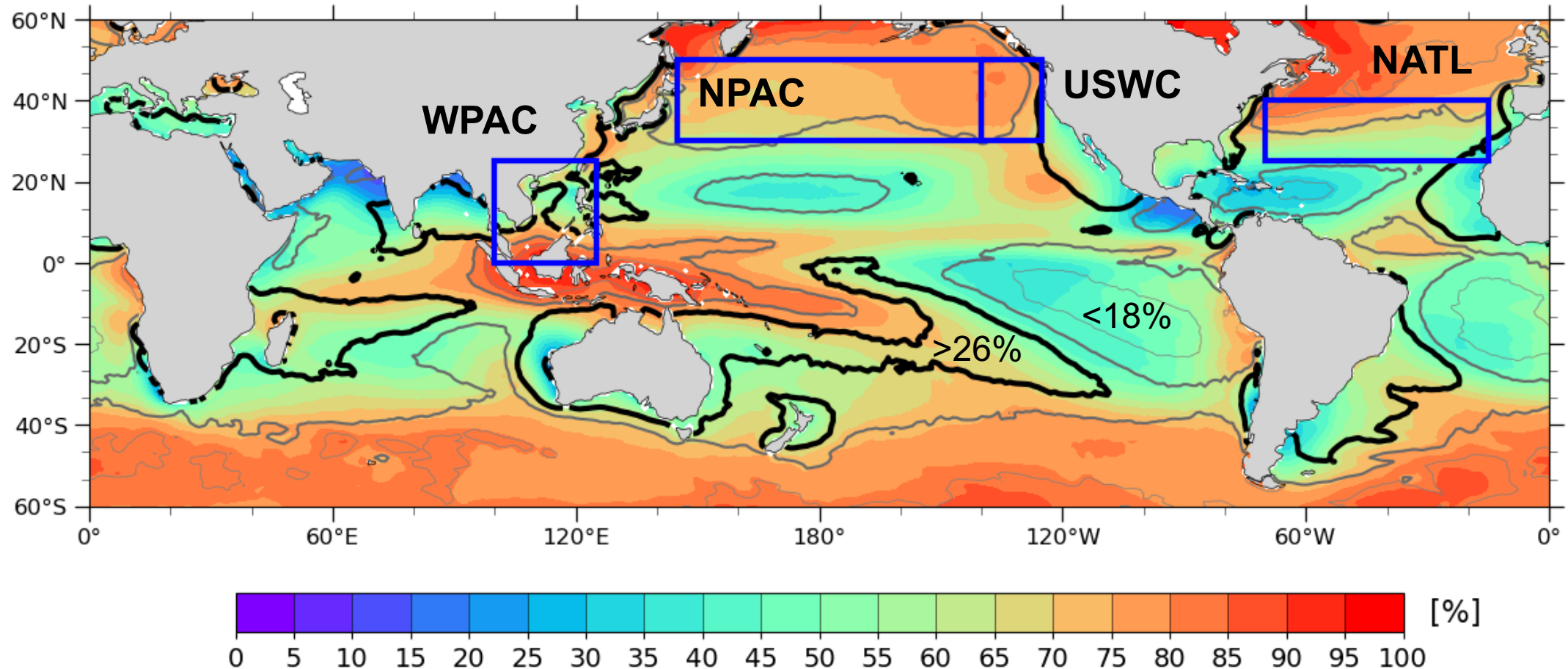
Domains:

- 100-125°E, 0-25°N – West Pacific
- 145-220°E, 30-50°N – North Pacific
- 220-235°E, 30-50°N – US West Coast
- 290-345°E, 25-40°N – North Atlantic

- 1. Potential and Actual Prediction Skill of Cloud Cover in the ECMWF Reforecasts**
- 2. Multi-Model Comparison of Cloud Cover Prediction Skill During 2021 and 2022**
- 3. Current and Potential Navy ESPC Products Related to Cloud Cover**

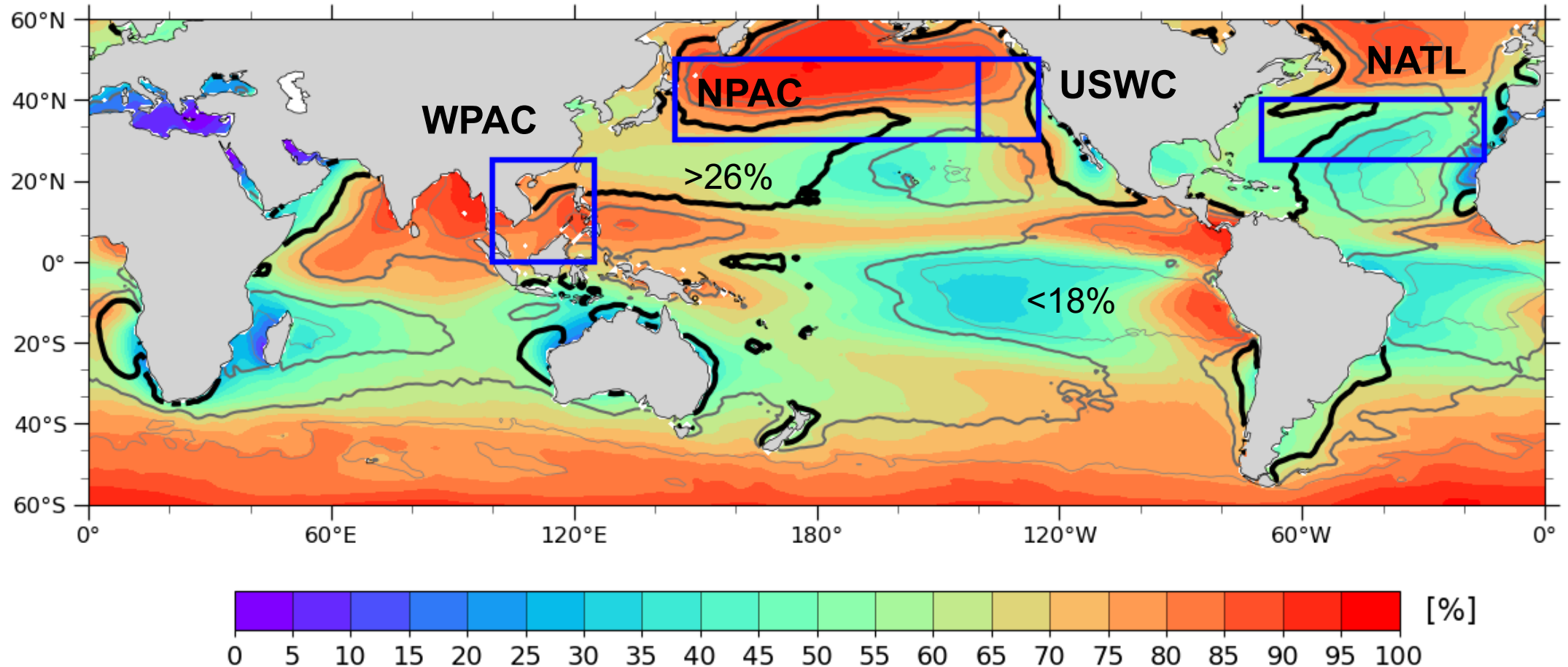
DJF Climatological Cloud Cover

DJF 1991-2020 Cloud Cover (shaded, %) and Standard Deviation (contours)



JJA Climatological Cloud Cover

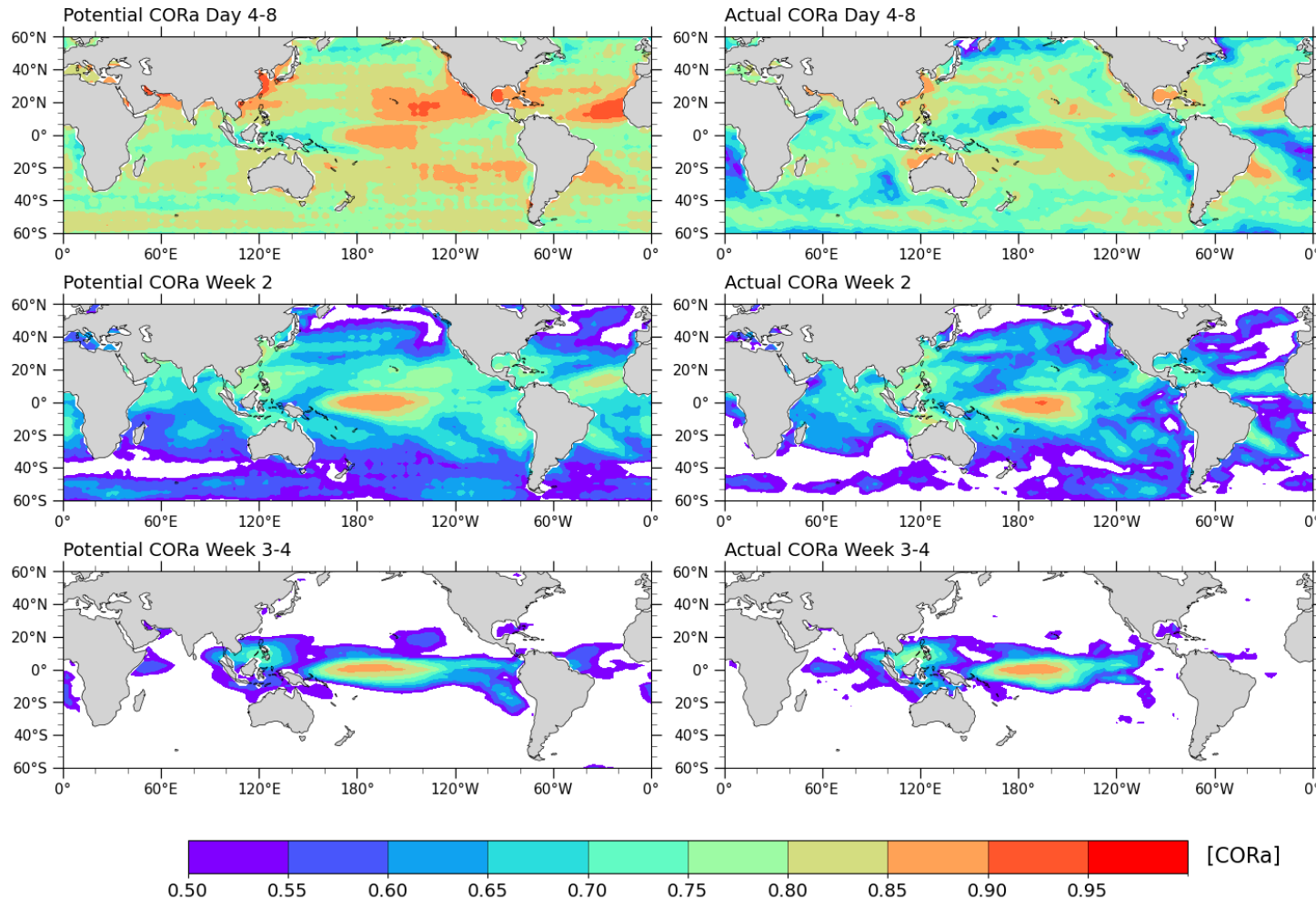
JJA 1991-2020 Cloud Cover (shaded, %) and Standard Deviation (contours)



Potential and Actual Prediction Skill of Cloud Cover in the ECMWF Reforecasts

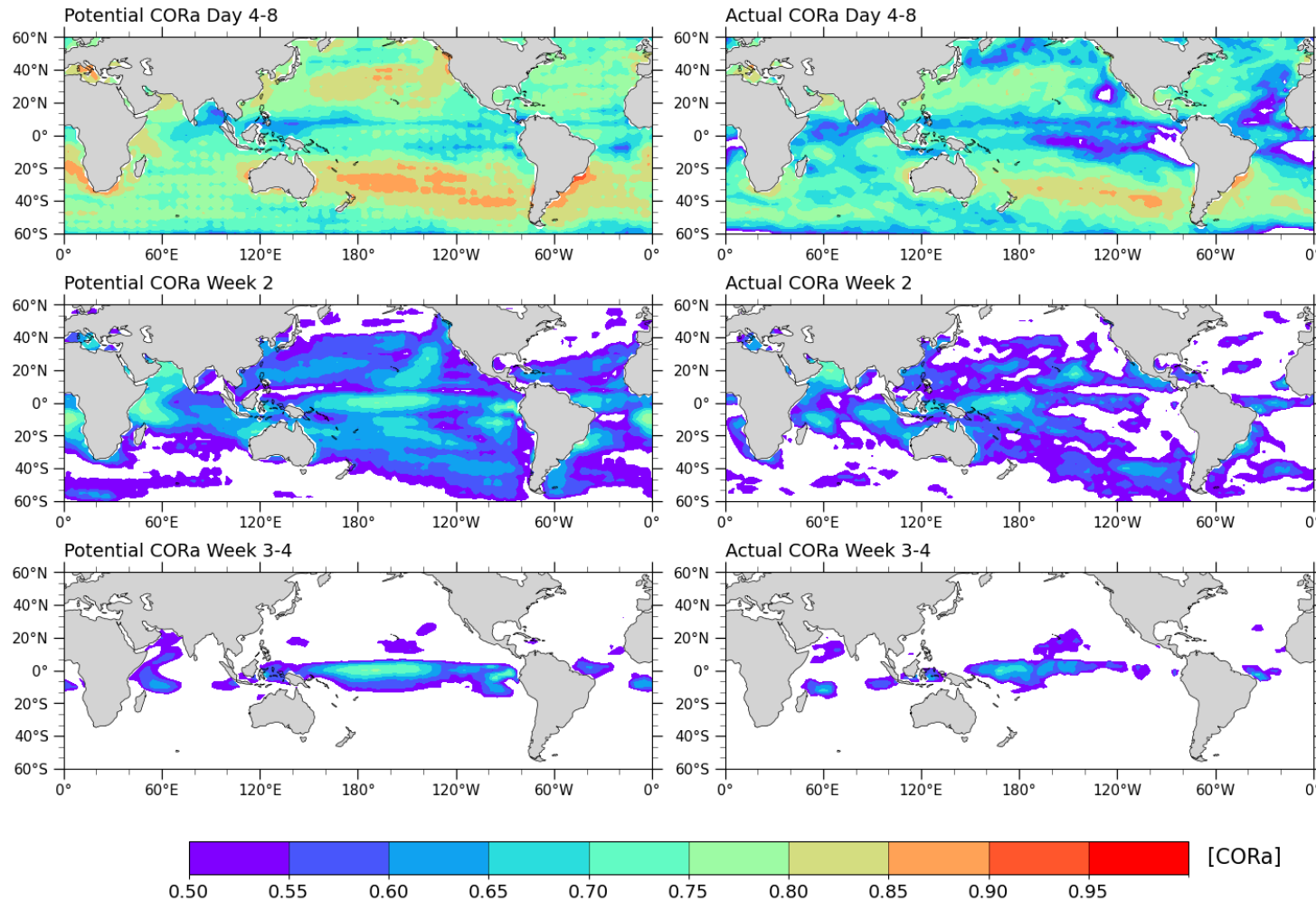
ECMWF Reforecasts DJF 2002-2021 Potential and Actual Skill

ECMWF DJF 2002-2021 Potential and Actual CORa



ECMWF Reforecasts JJA 2002-2021 Potential and Actual Skill

ECMWF JJA 2002-2021 Potential and Actual CORa

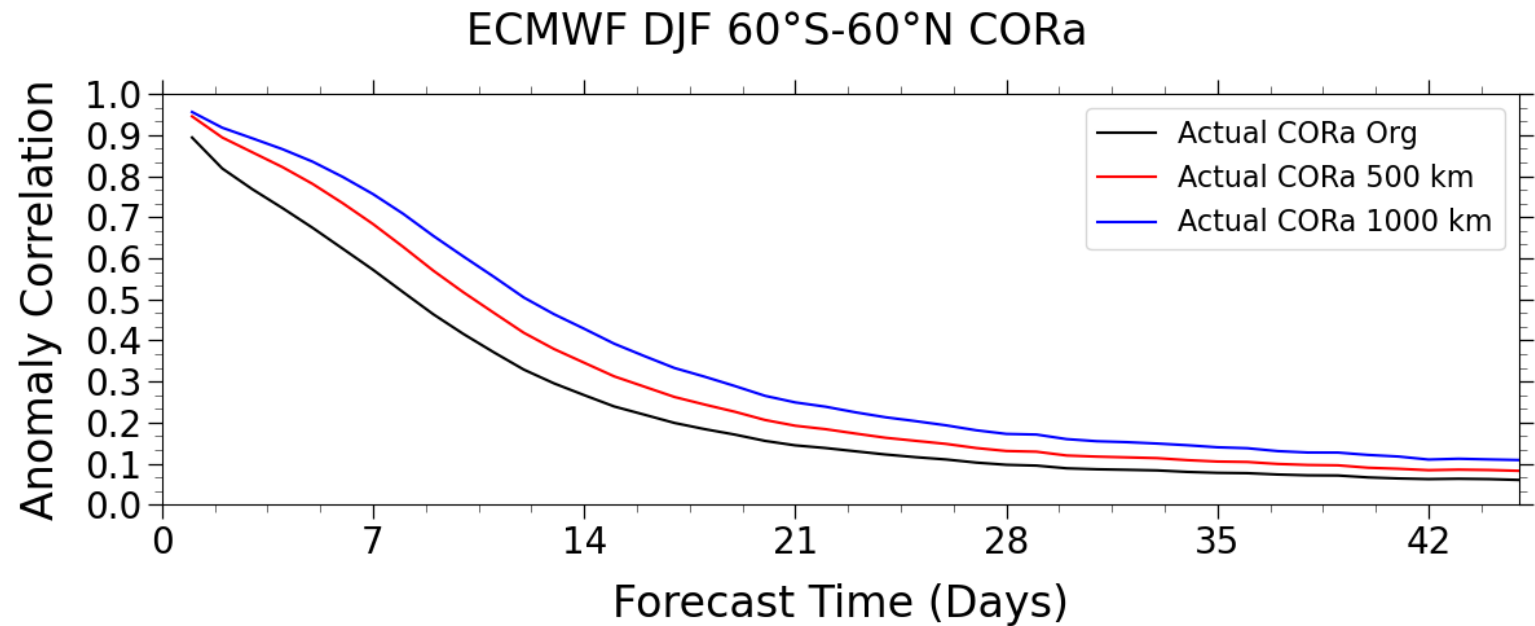


Impact of Radial Averaging

In addition to temporal window averaging, spatial averaging of the forecasts and observations also increases prediction skill.

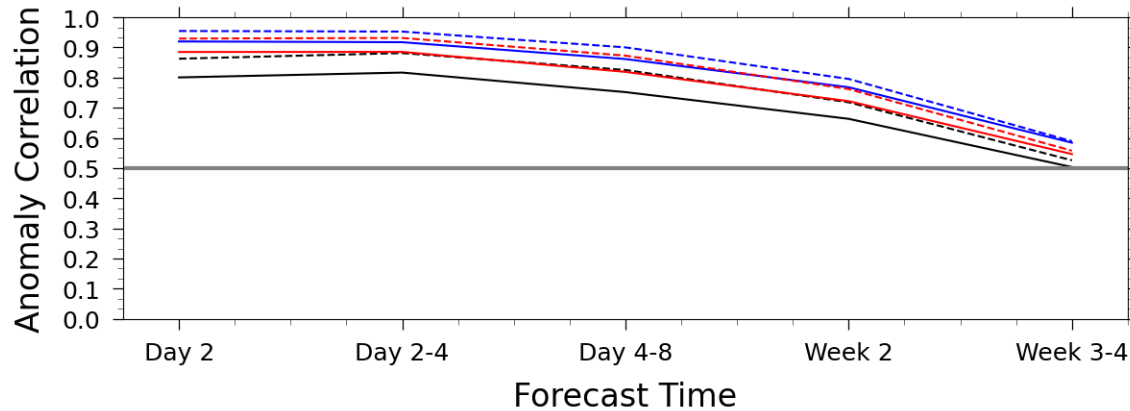
Approximately several days of skill are added when 500 and 1000 km radial averages are applied to daily-averaged forecast data.

Radial averaging also addresses the problem of higher latitude $2.5^\circ \times 2.5^\circ$ grid points having smaller footprints which lowers skill.

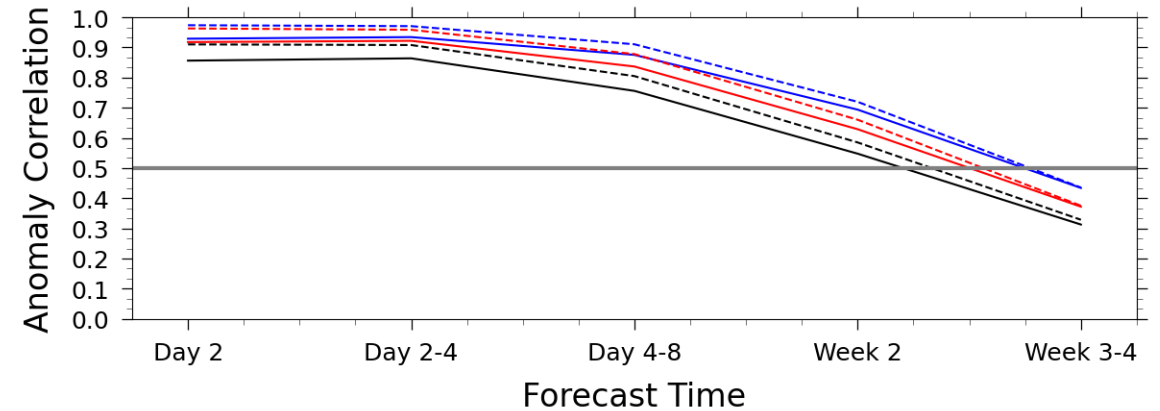


ECMWF Reforecasts DJF 2002-2021 Seamless Skill by Region

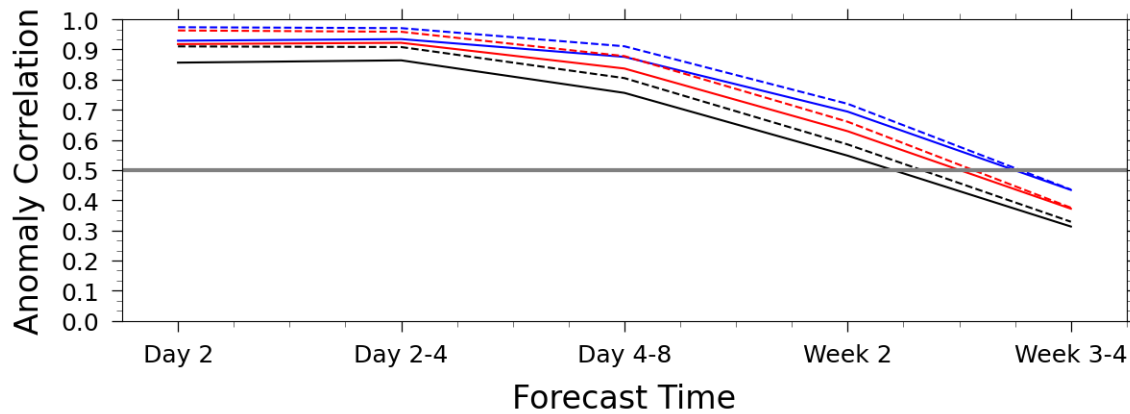
ECMWF DJF WPAC CORa



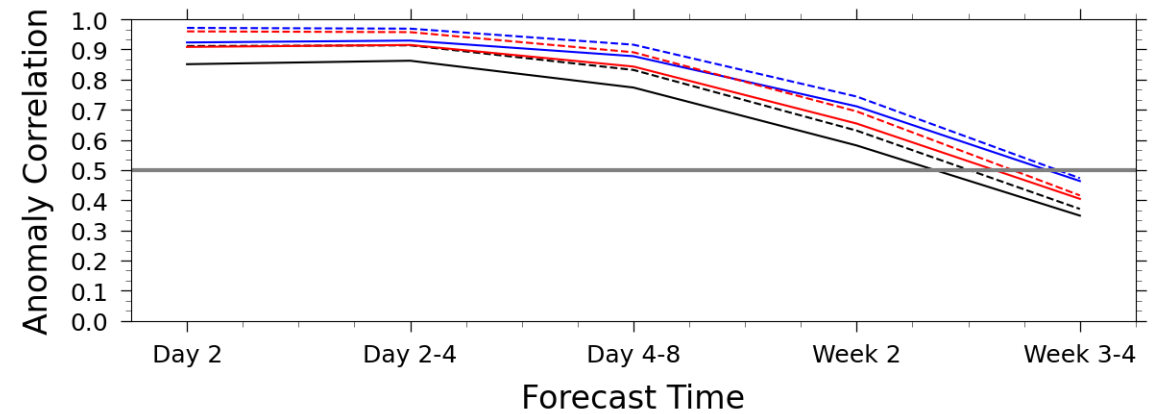
ECMWF DJF NPAC CORa



ECMWF DJF USWC CORa



ECMWF DJF NATL CORa

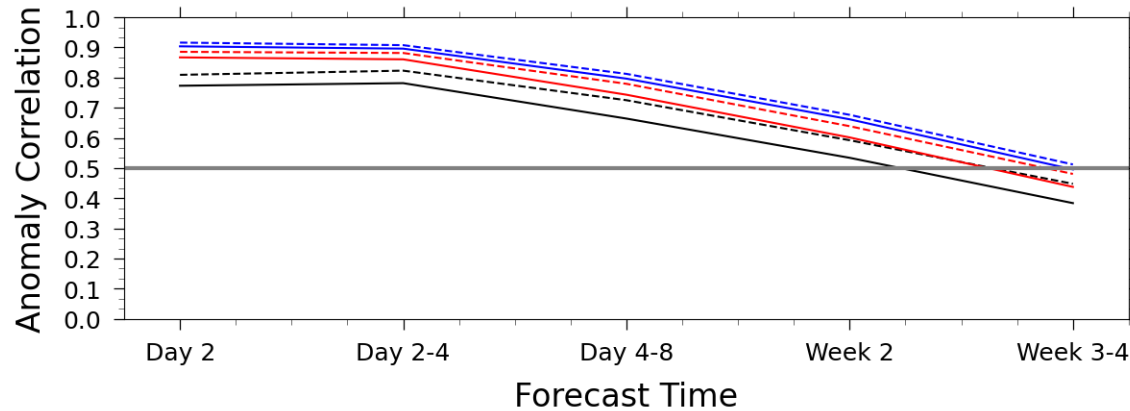


——— Org
 ——— 500 km
 ——— 1000 km
 Solid = Actual / Dashed = Potential

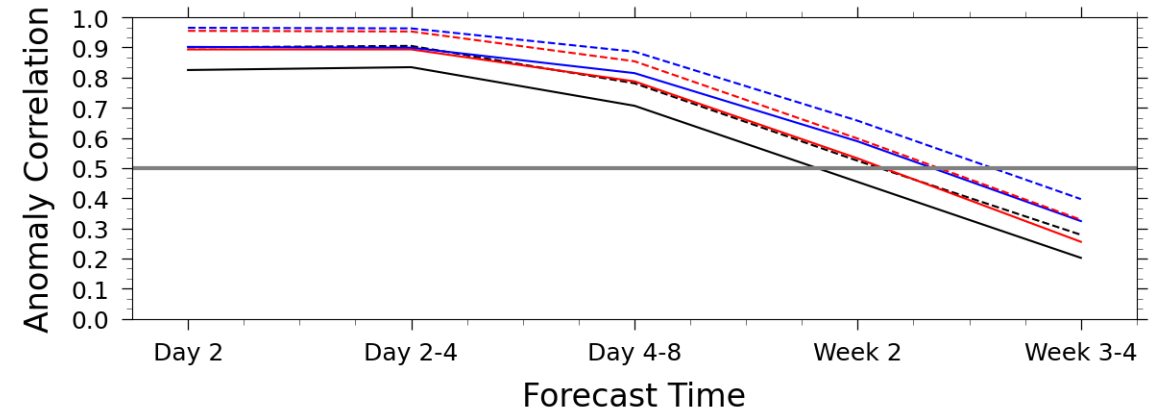
ECMWF Reforecasts

JJA 2002-2021 Seamless Skill by Region

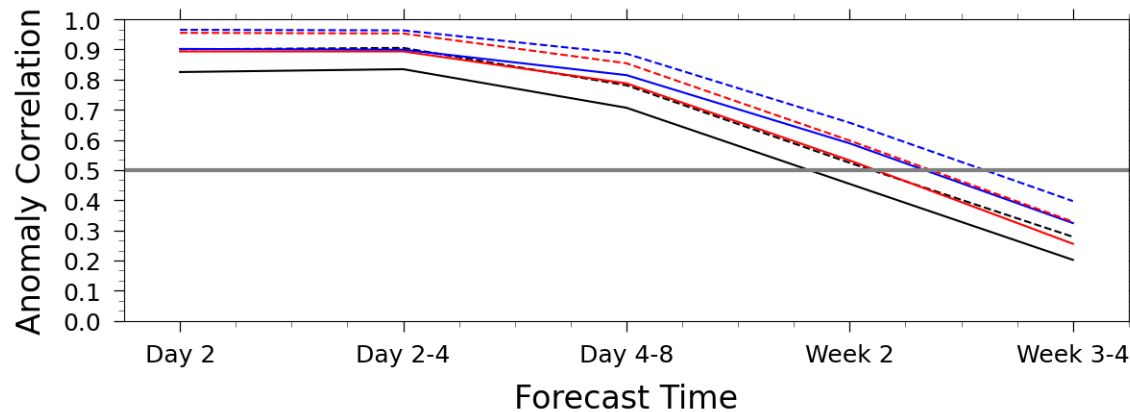
ECMWF JJA WPAC CORa



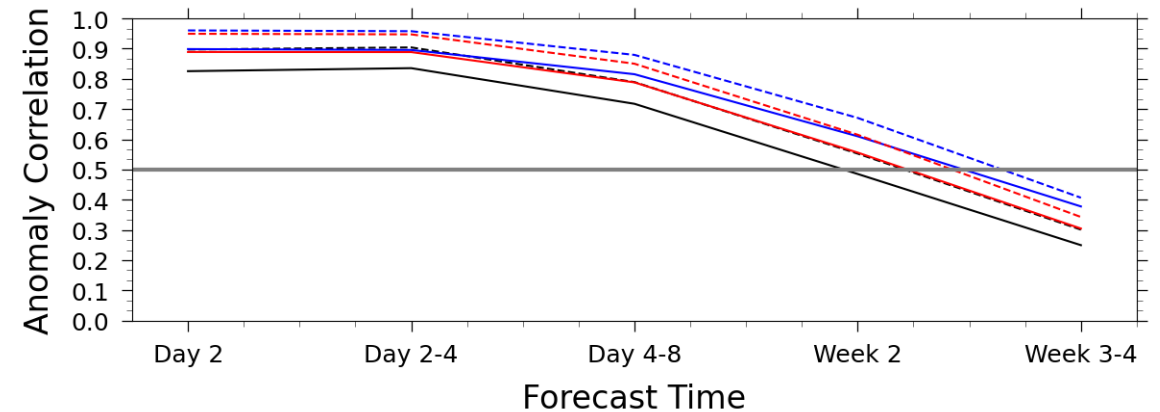
ECMWF JJA NPAC CORa



ECMWF JJA USWC CORa



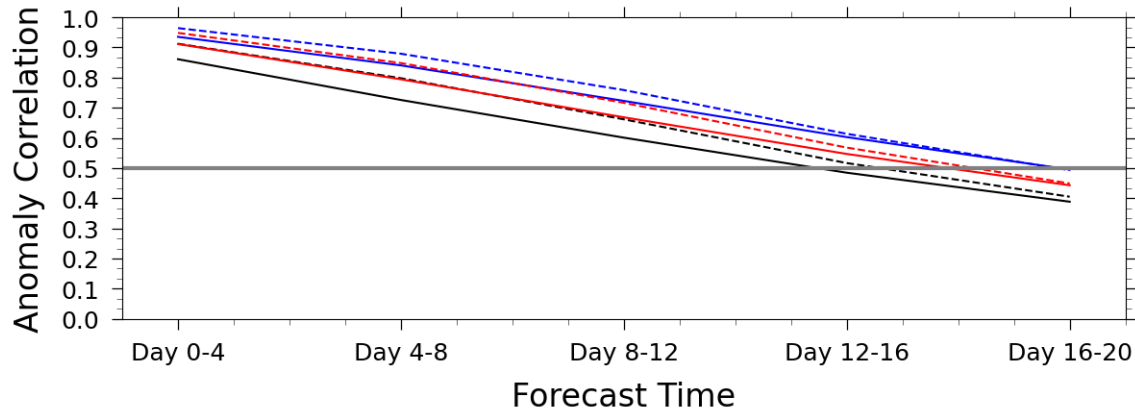
ECMWF JJA NATL CORa



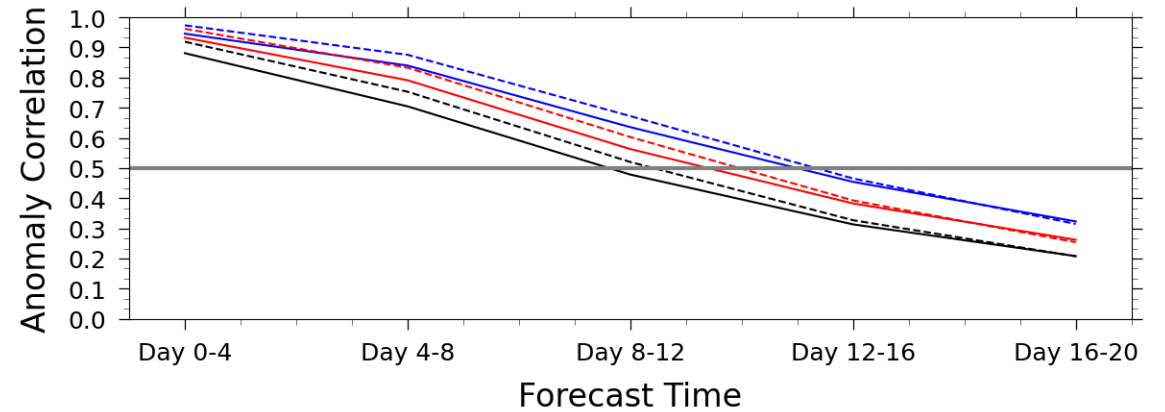
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ECMWF Reforecasts DJF 2002-2021 4-Day Window Skill by Region

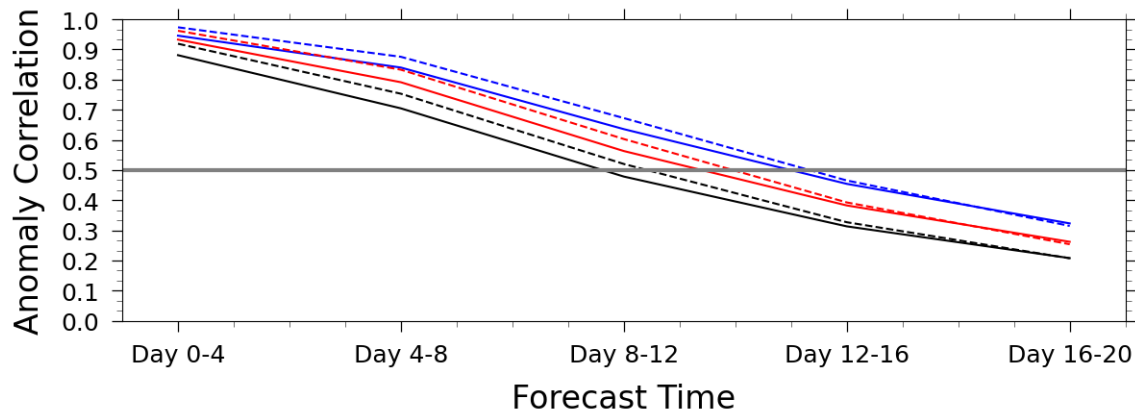
ECMWF DJF WPAC CORa



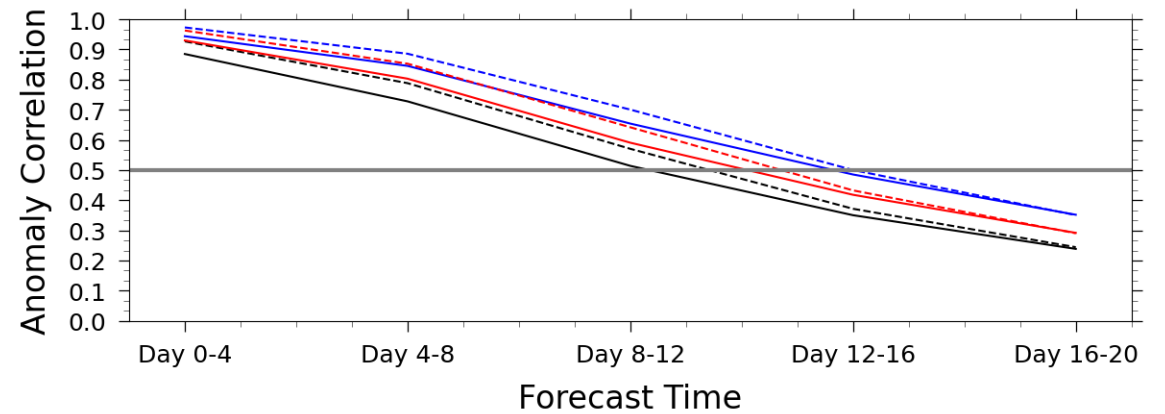
ECMWF DJF NPAC CORa



ECMWF DJF USWC CORa



ECMWF DJF NATL CORa

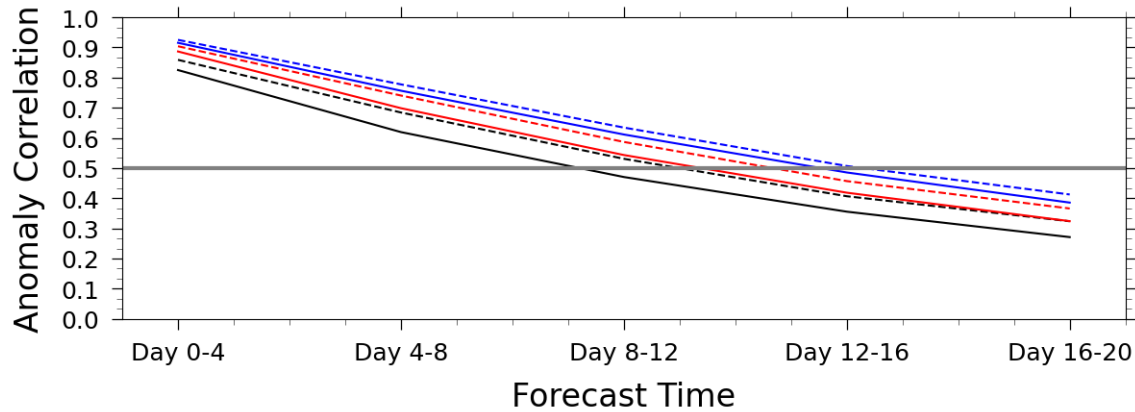


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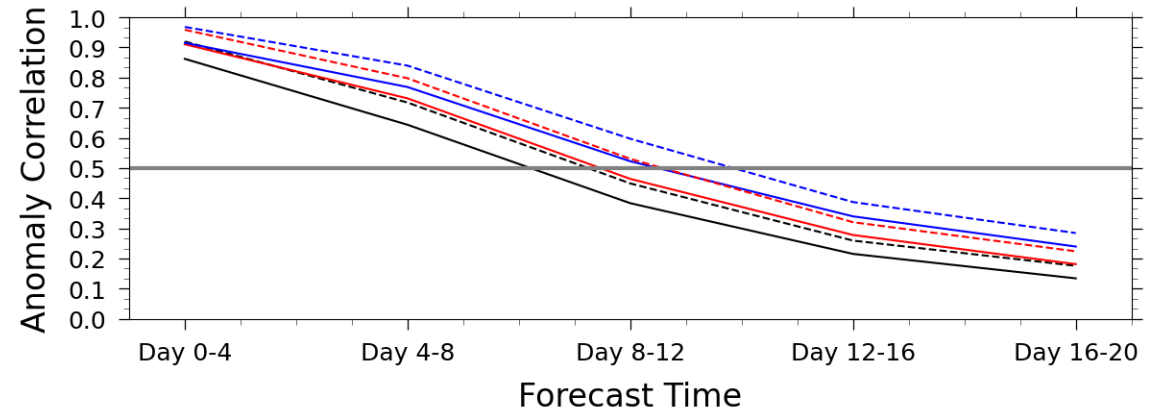
ECMWF Reforecasts

JJA 2002-2021 4-Day Window Skill by Region

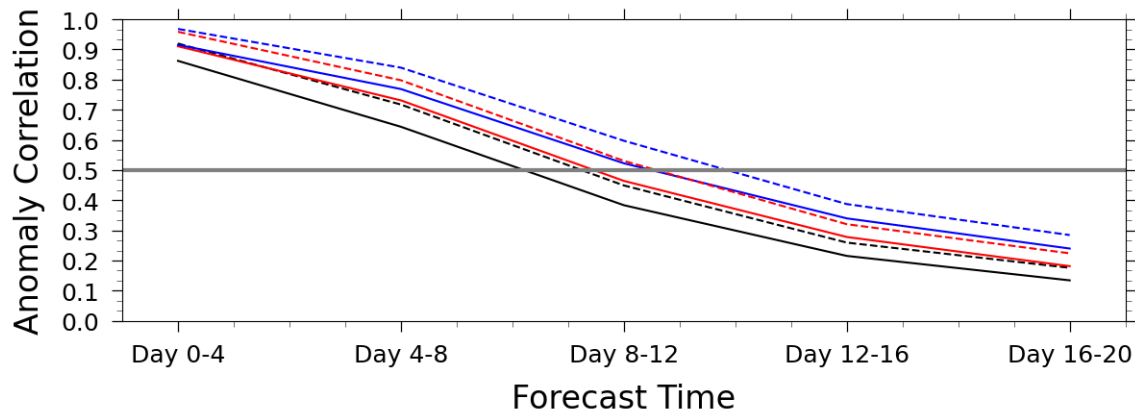
ECMWF JJA WPAC CORa



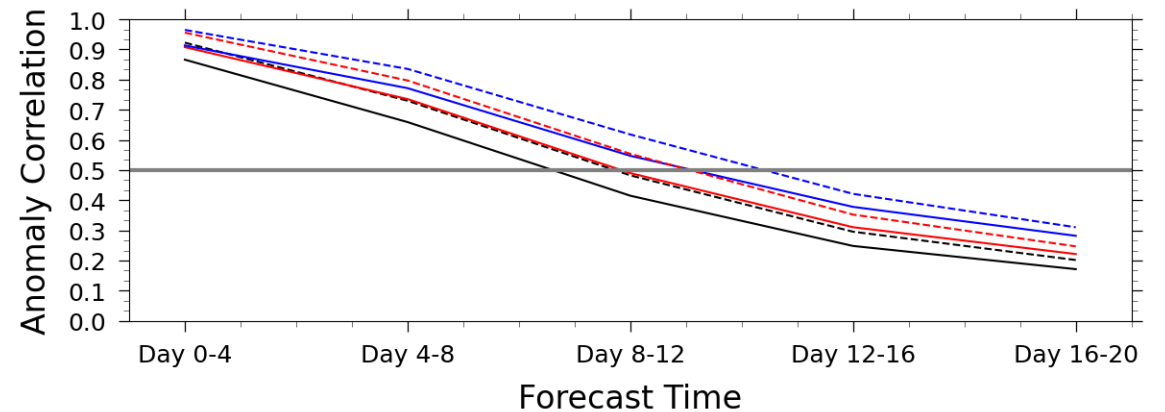
ECMWF JJA NPAC CORa



ECMWF JJA USWC CORa



ECMWF JJA NATL CORa

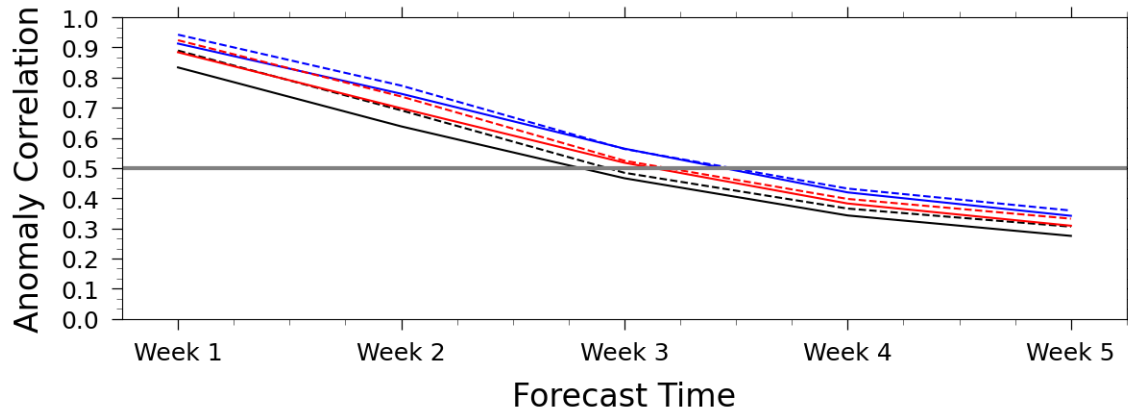


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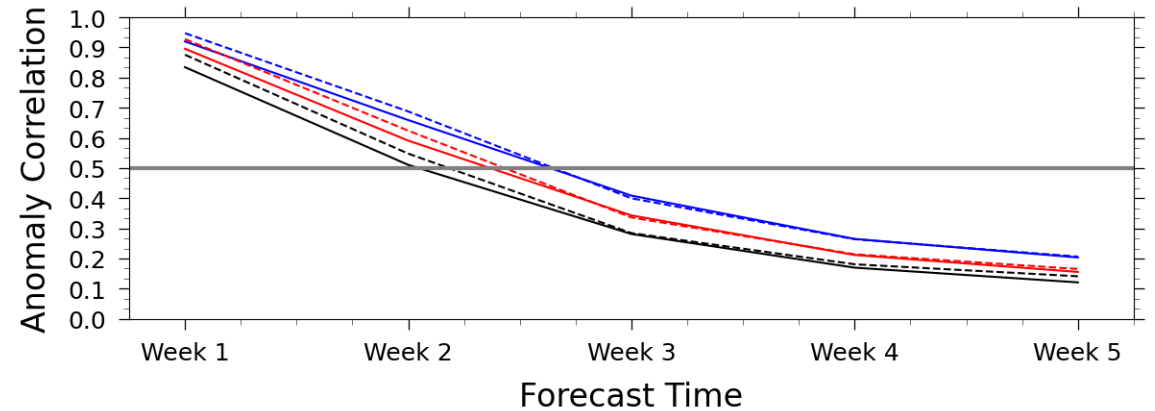
ECMWF Reforecasts

DJF 2002-2021 7-Day Window Skill by Region

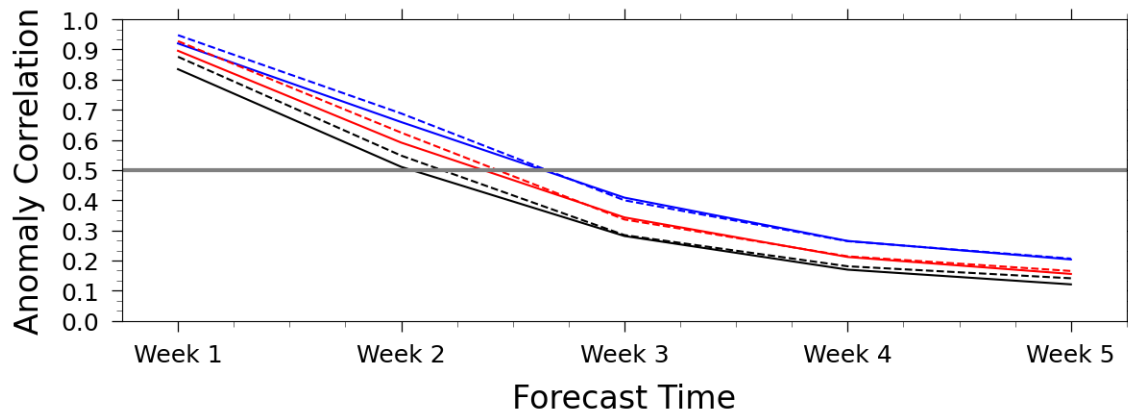
ECMWF DJF WPAC CORa



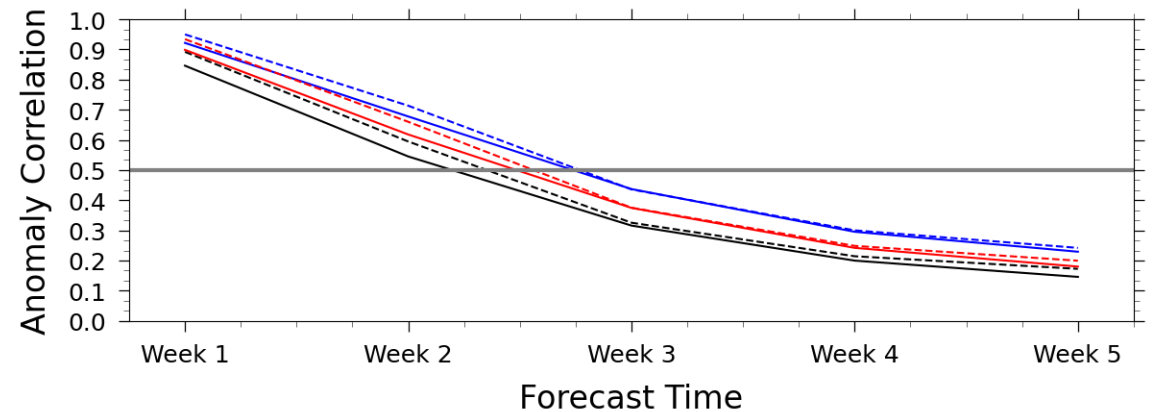
ECMWF DJF NPAC CORa



ECMWF DJF USWC CORa



ECMWF DJF NATL CORa

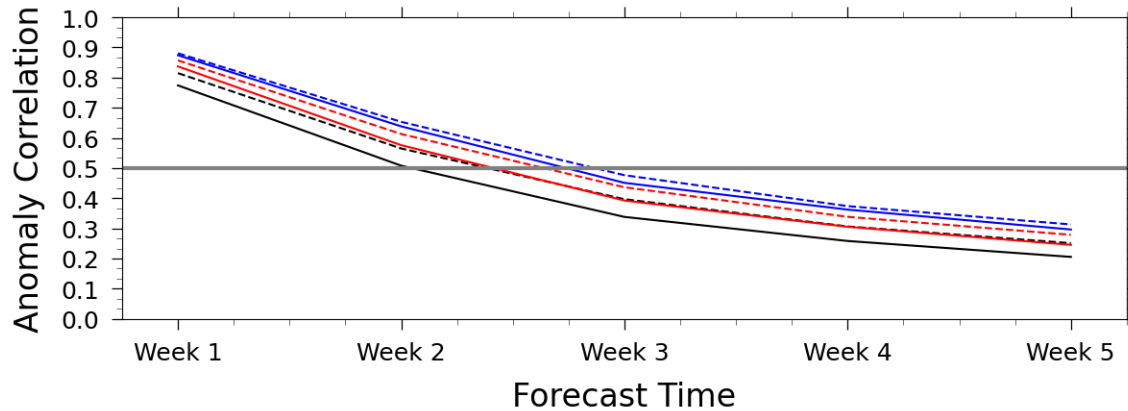


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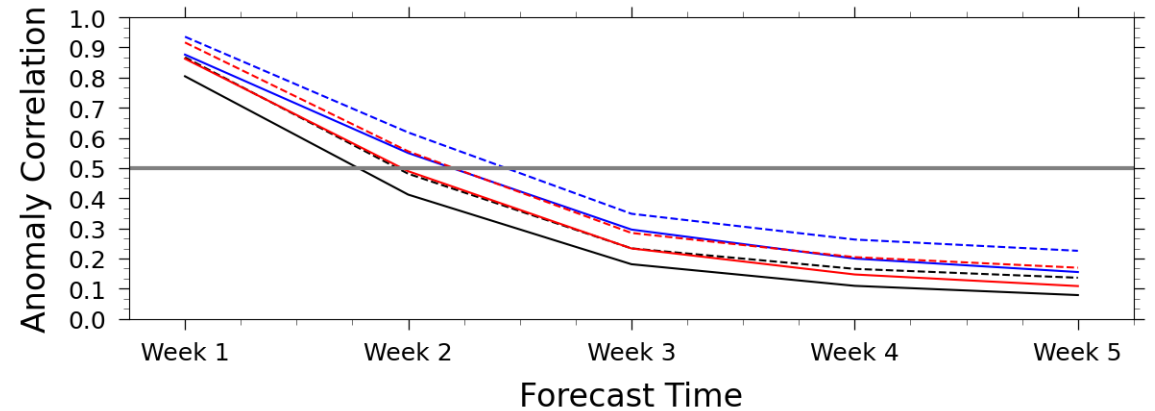
ECMWF Reforecasts

JJA 2002-2021 7-Day Window Skill by Region

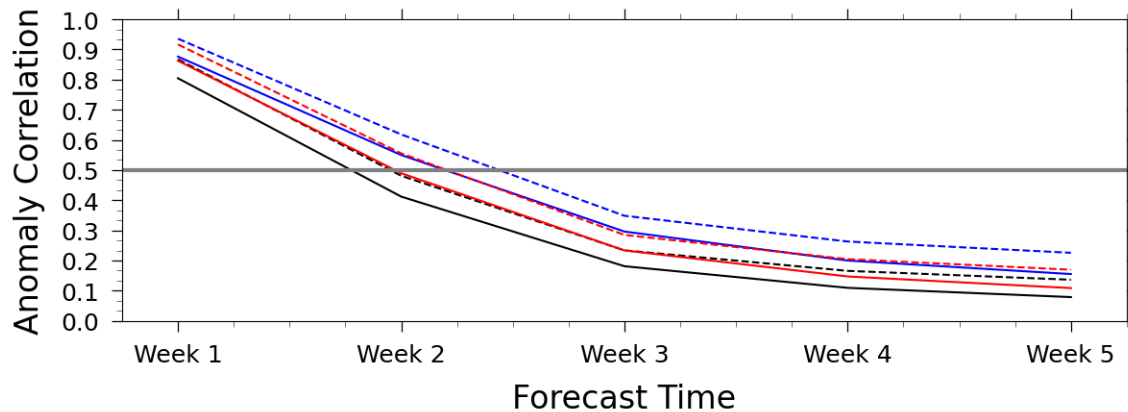
ECMWF JJA WPAC CORa



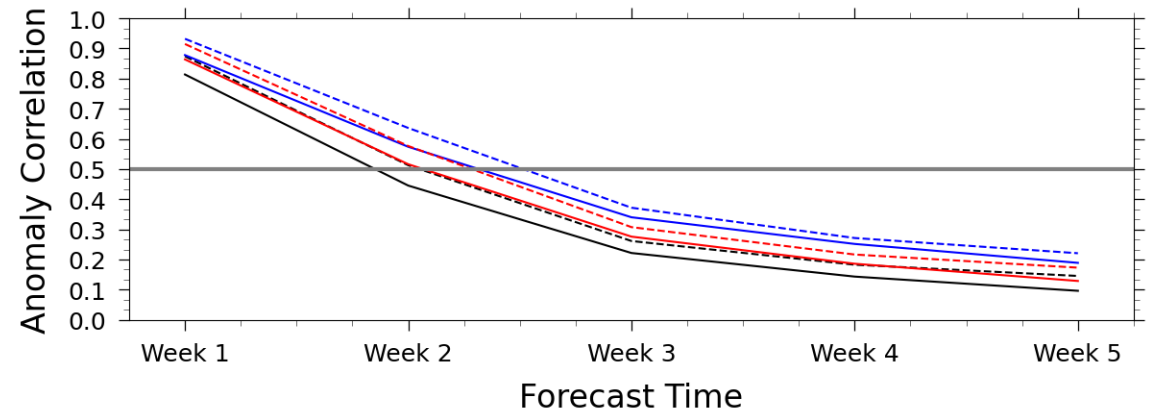
ECMWF JJA NPAC CORa



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— Org

— 500 km

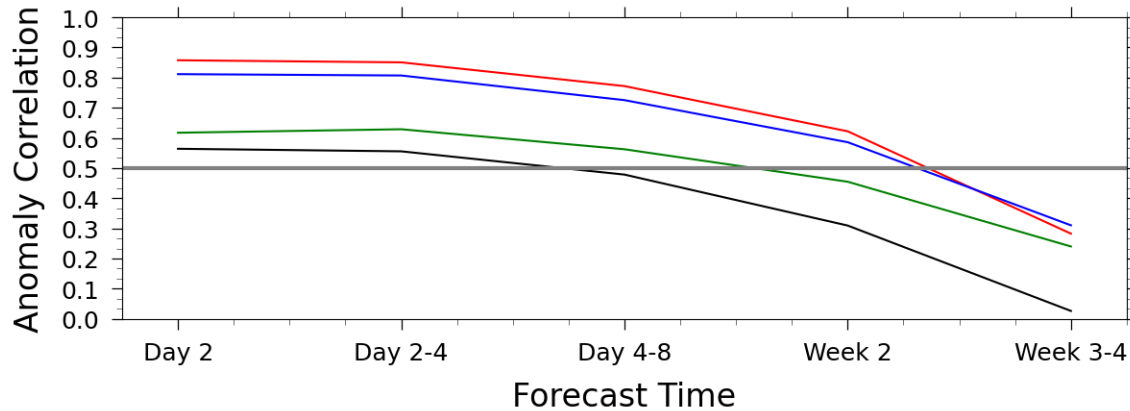
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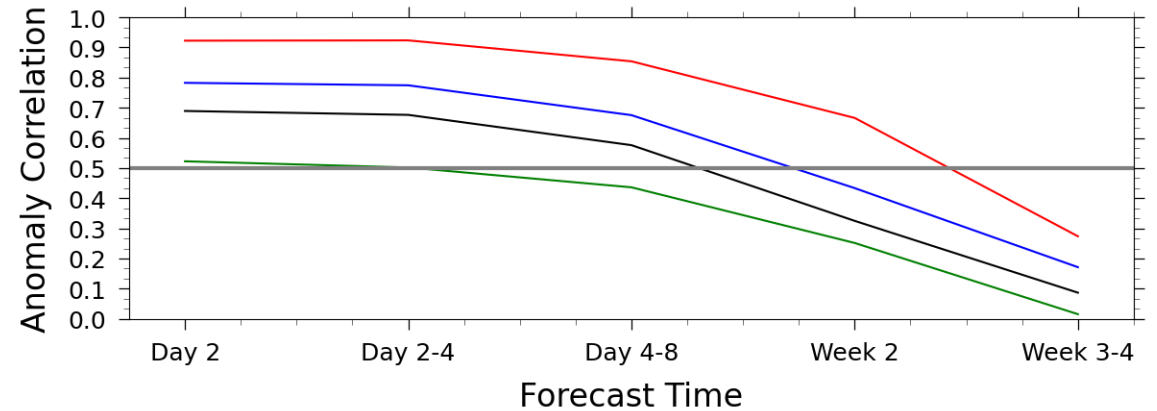
Multi-Model Comparison of Cloud Cover Prediction Skill During 2021 and 2022

Multi-Model 1000 km Radius Real-Time Forecasts DJF 2021-2022 Seamless Window Skill by Region

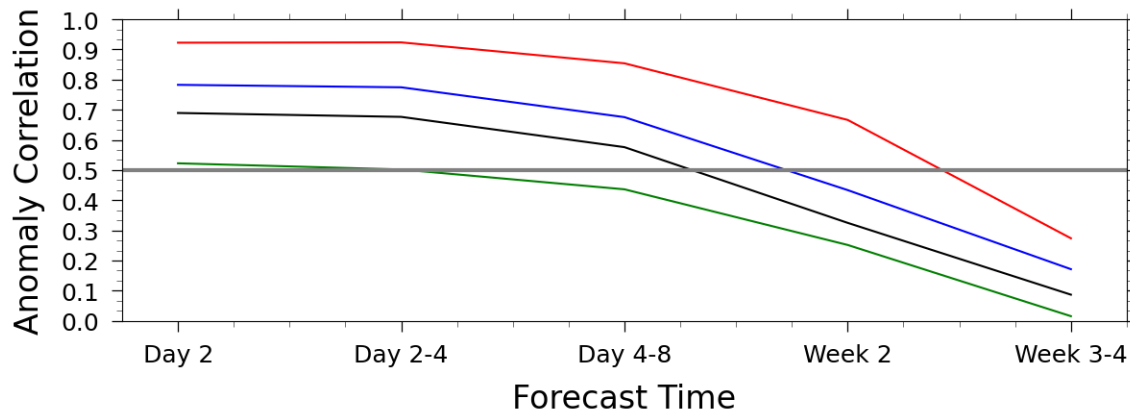
DJF 2021-2022 WPAC CORa



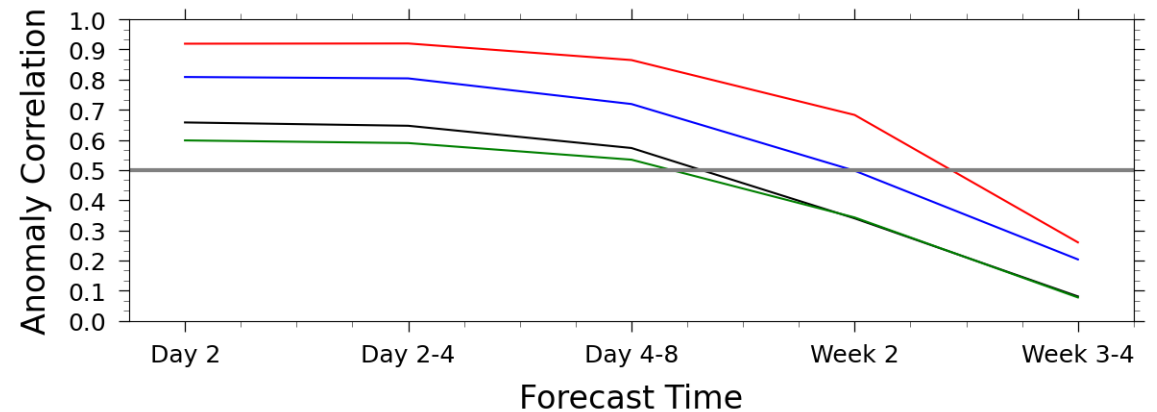
DJF 2021-2022 NPAC CORa



DJF 2021-2022 USWC CORa



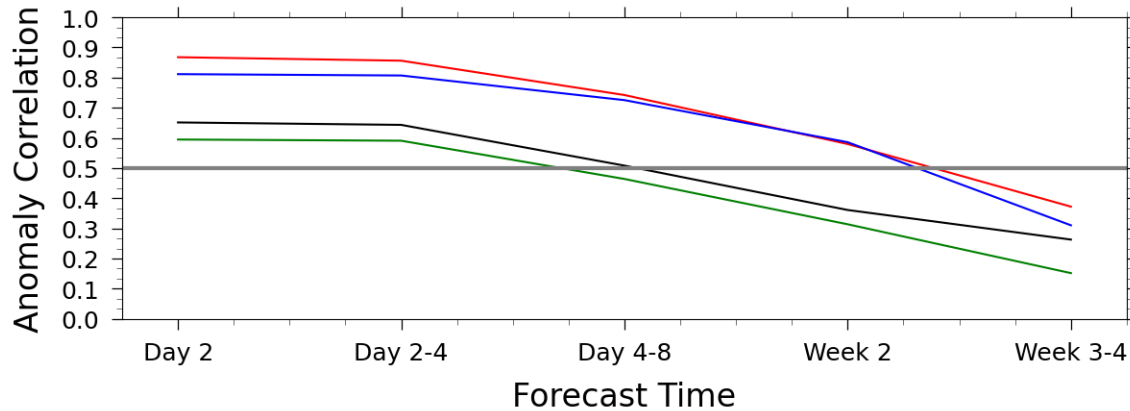
DJF 2021-2022 NATL CORa



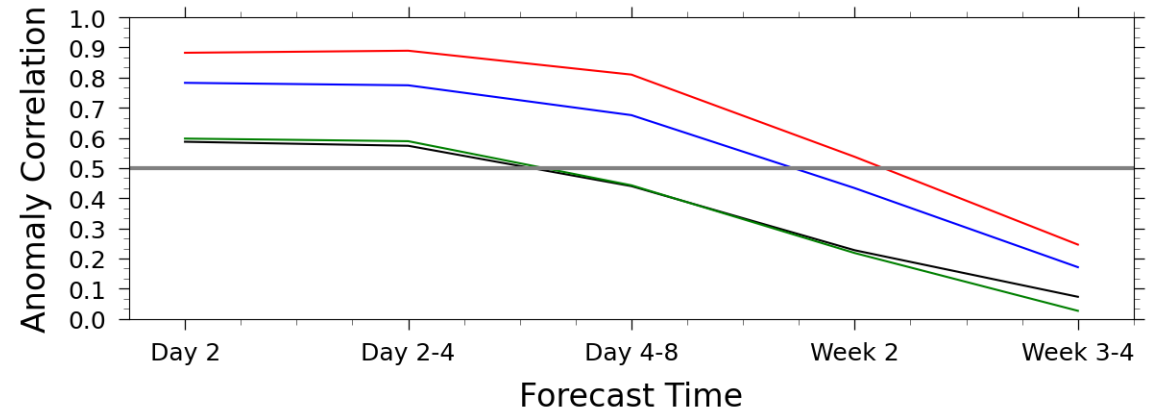
Navy ESPC
 ECMWF
 UKMO
 NCEP

Multi-Model 1000 km Radius Real-Time Forecasts JJA 2021-2022 Seamless Window Skill by Region

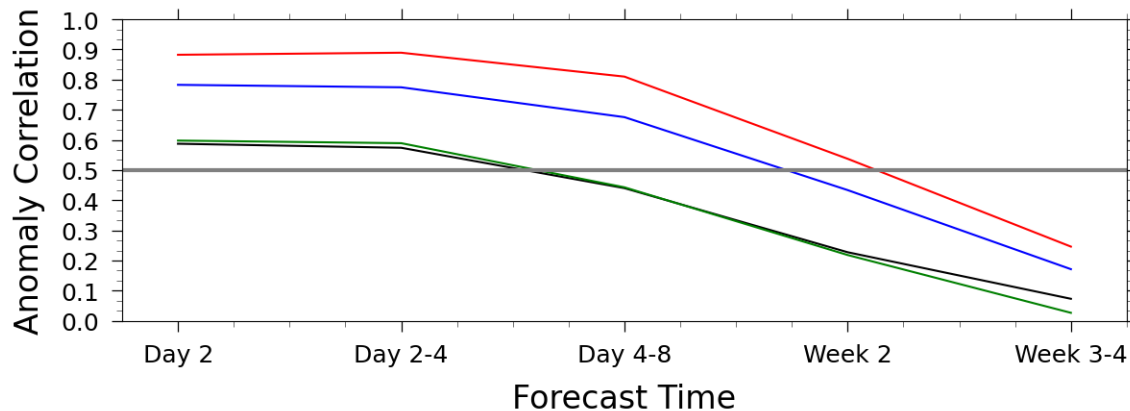
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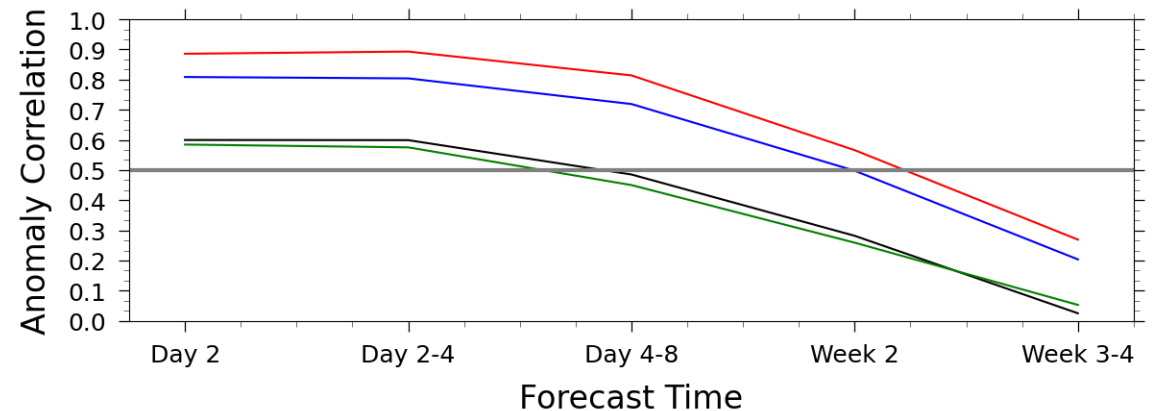
JJA 2021-2022 NPAC CORa



JJA 2021-2022 USWC CORa



JJA 2021-2022 NATL CORa



— Navy ESPC
 — ECMWF
 — UKMO
 — NCEP

Current and Potential Navy ESPC Products Related to Cloud Cover

Navy ESPC v1 and v2 Ensemble

Navy ESPC v1 and v2 Ensemble:

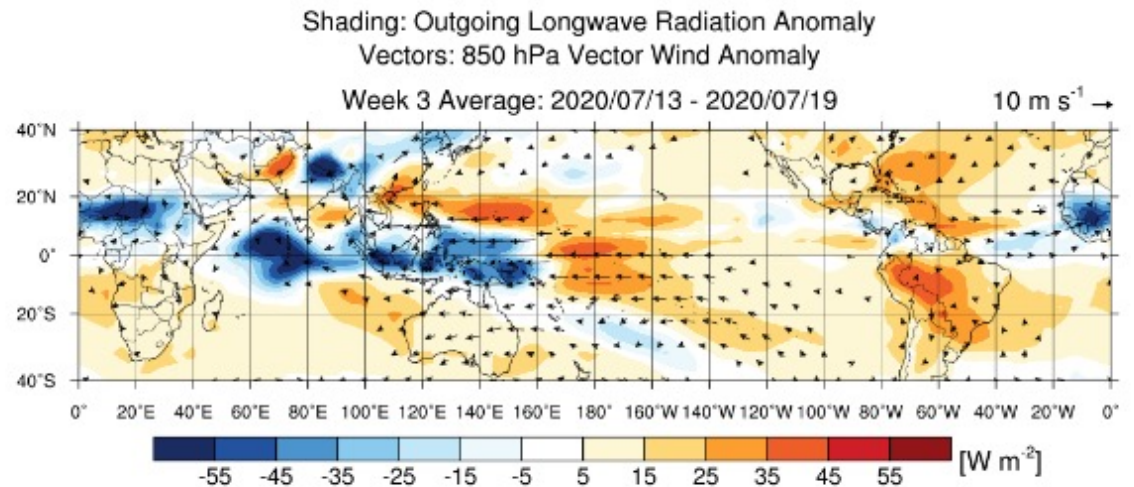
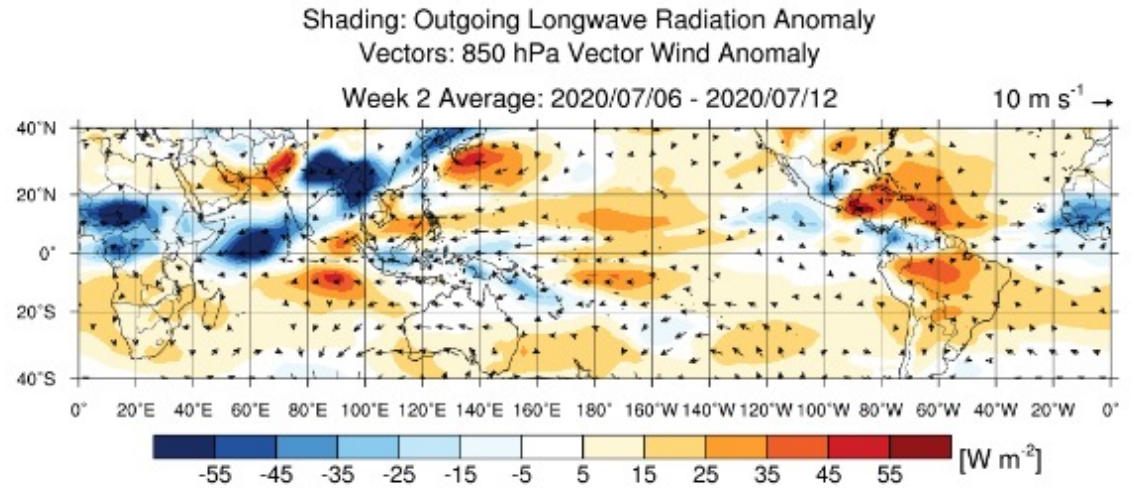
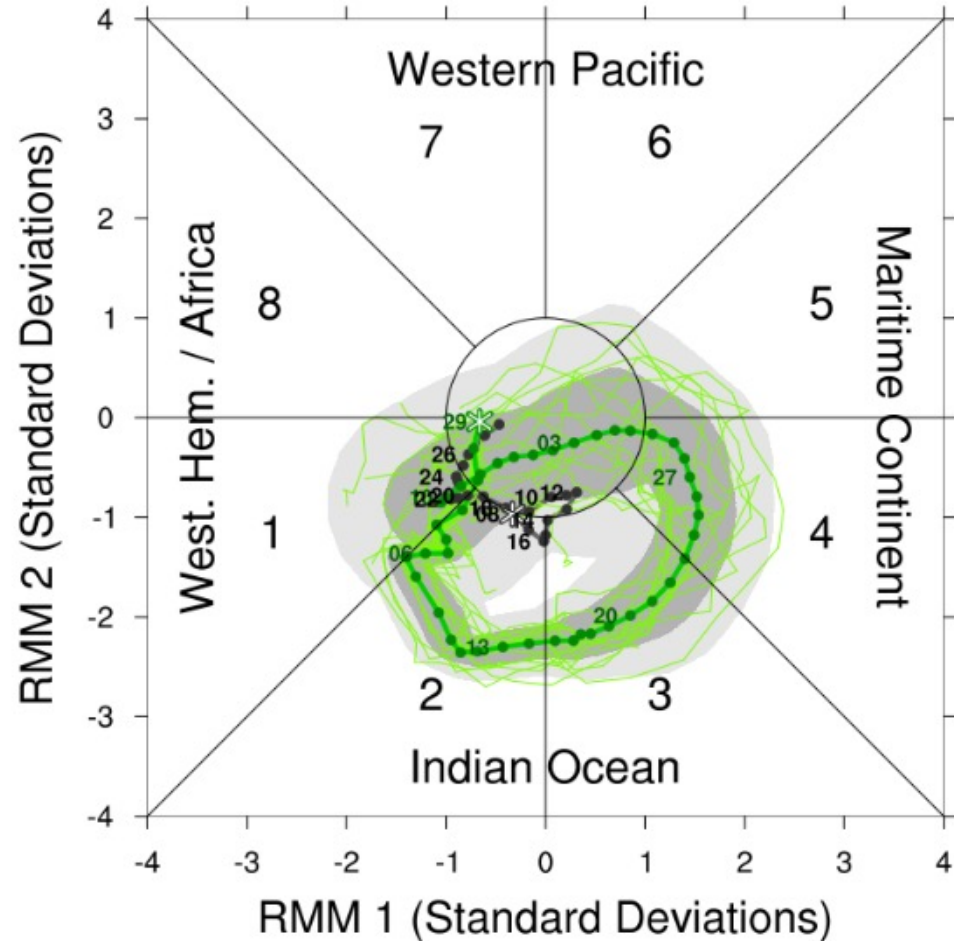
Version	Time Range, Frequency	Atmosphere (NAVGEM)	Ocean (HYCOM)	Ice (CICE)	Waves (WW3)
V1 Aug. 2020 - Present	0-45 days 16 Members each Sunday	T359 (37 km) 60 Levels	1/12° (9 km) 41 Layers	1/12° (3.5 km)	None
V2 FY24	0-45 days 16 Members 2x Weekly	T681 (19 km) L143 - Middle Atmosphere	1/12° (9 km) 41 Layers	1/12° (3.5 km)	1/4° (24 km)

Operational Navy ESPC Products:

<https://portal.fnmoc.navy.mil/espcwx/>

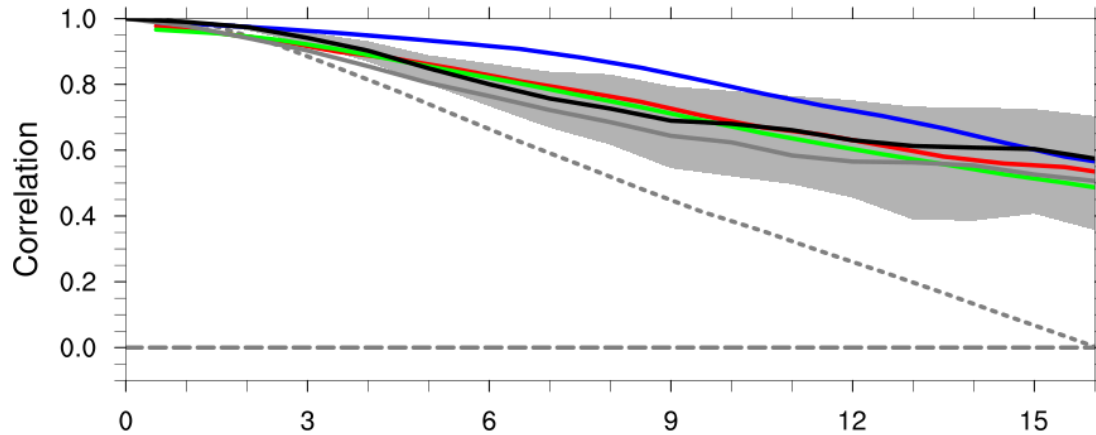
Navy ESPC Real-Time MJO and Weekly-Averaged OLR Forecasts

Initialized June 28th 2020 at 12Z

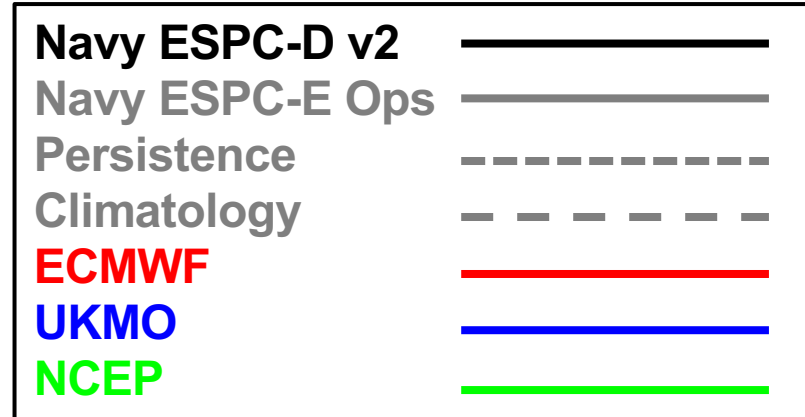
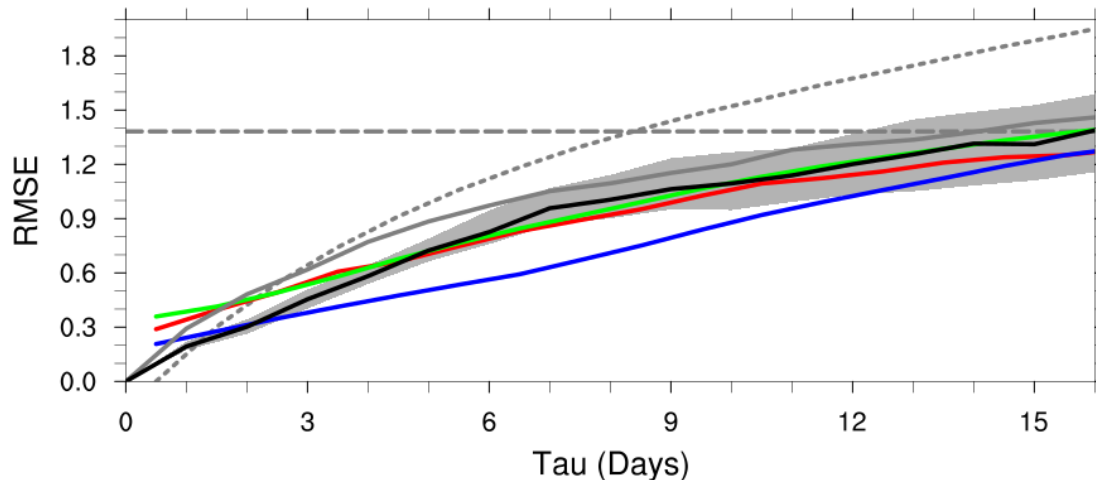


Navy ESPC v2 Deterministic Performance

RMM Deterministic Bivar. Anom. Cor.



RMM Deterministic Bivar. RMSE



Statistics are calculated using forecasts initialized between 2020/09/13 – 2021/07/18 with the high resolution single member version of Navy ESPC.

Potential for Extended-Range Cloud Cover Prediction:

- Cloud cover can be skillfully predicted over large areas of the tropics extending into the mid-latitudes at days 8-12 and week 2. There may be skill beyond this in certain situations (e.g. strong MJO events).
- Temporal and spatial averaging have large impacts on skill.
- There is substantial variability in skill between seasons and operational ensembles from different centers.

Updates to Navy ESPC in v2:

- Increased resolution and new components (waves, upper atmosphere) in Navy ESPC v2 (FY2024).
- VTR tests show that Navy ESPC Deterministic v2 has slightly improved MJO performance.

Current/Future Products:

- Are weekly-averaged anomalies of the ensemble mean the best way to convey cloud cover predictions? More investigation into probabilistic products and their skill is needed.
- There are large variations in skill over time, how reliable is the ensemble distribution?

Updates to Navy ESPC beyond v2:

- Exploration of the physical causes of cloud cover biases in Navy ESPC.
- ACAI adds several days of MJO skill. Working to incorporate into Navy ESPC v2.1 (FY2025). How does ACAI impact cloud cover?
- Exploration of post-processing methods for bias correction and ensemble calibration of Navy ESPC forecasts through ESPC WU9 is ongoing.