

Extended-Range Prediction of Oceanic Surface Windspeed and Waves in the Navy Earth System Prediction Capability

Matthew A. Janiga¹, Erick Rogers², Colin Snyder³, Kurt Hansen⁴, Jon Christophersen¹, William Crawford¹

Naval Research Laboratory Marine Meteorology Division¹, Naval Research Laboratory Oceanography Division²,
Mississippi State University³, National Research Council⁴

Email: matthew.janiga@nrlmry.navy.mil

Introduction / Data and Methodology

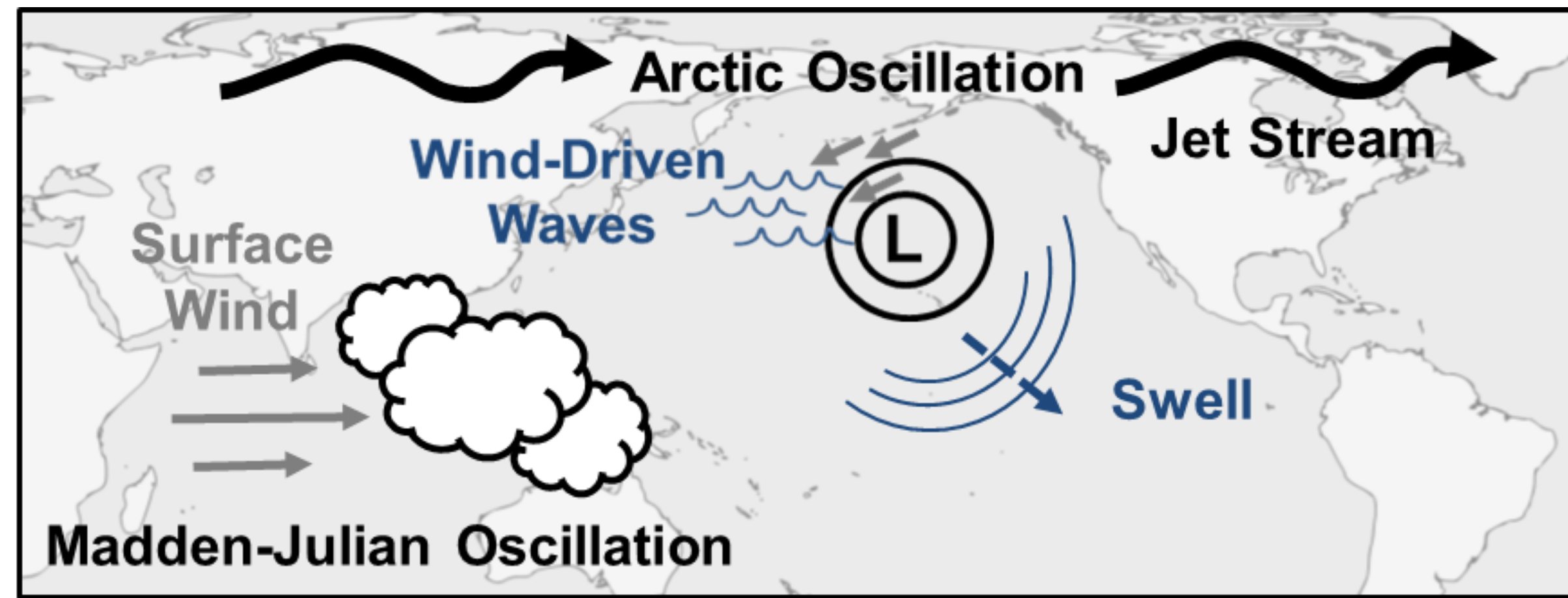
Introduction:

Hazardous oceanic surface winds and waves impact both civilian and defense maritime trafficability. However, oceanic surface wind and wave prediction on extended-range time scales remains poorly understood. This is in part due to the complex multi-scale interactions between intraseasonal modes of variability such as the Madden-Julian Oscillation (MJO) and Arctic Oscillation (AO) and synoptic-scale tropical and extratropical cyclones. In this study we examine the prediction skill of oceanic surface windspeed and significant wave height at extended-range time scales in the ECMWF and Navy Earth System Prediction Capability (ESPC) coupled global models. We also examine a case study of an extreme event which impacted Kwajalein Atoll in Jan. 2024 representing the types of events which may be predictable at extended-range time scales.

Data and Methodology:

We examine the surface windspeed prediction skill of the 20-year ECMWF reforecasts run during 2022 and Navy Earth System Prediction Capability (ESPC) v2 run during the winter of 2020-2021, which includes a one-way forced WAVEWATCH III model. Forecasts are verified against ECMWF ERA5 reanalyses for the 10 m windspeed and significant wave height. Following Wheeler et al. (2016), we explore the sensitivity of the prediction skill to verification windows that expand at later forecast leads. In addition, we examine the impact of both radial averaging and wavenumber-frequency filtering on the prediction skill of the surface windspeed.

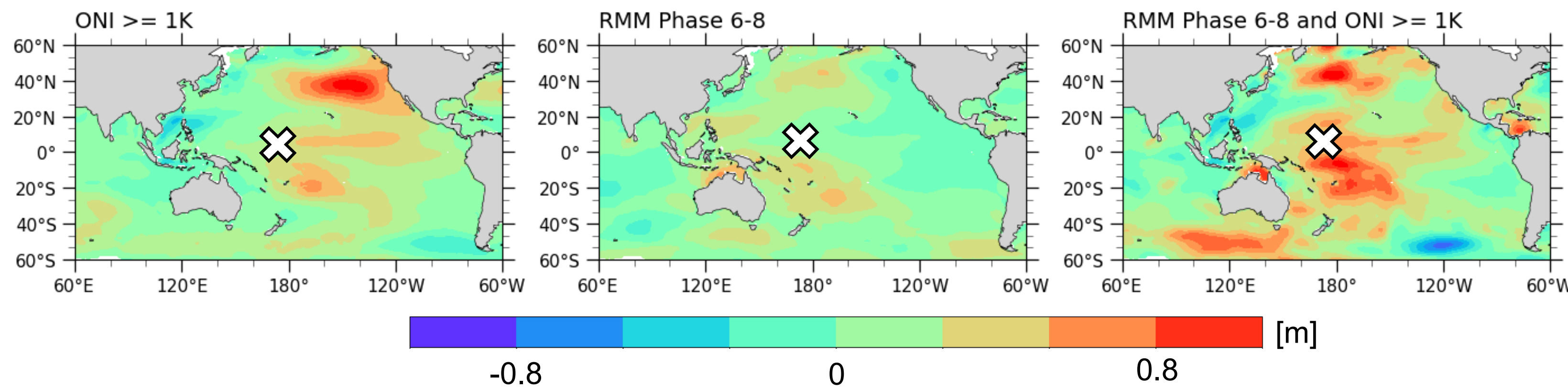
Key Processes and Modes of Variability



Large-scale modes of extratropical variability (e.g., AO), extratropical cyclones, and MJO westerly wind bursts generate surface ocean waves which mature into swell. In addition, large-scale modes of variability can interact (e.g., El Niño events enhance MJO activity in the Western and Eastern Pacific)

Case Study

Separate and Combined Impact of ENSO and the MJO on Wave Height

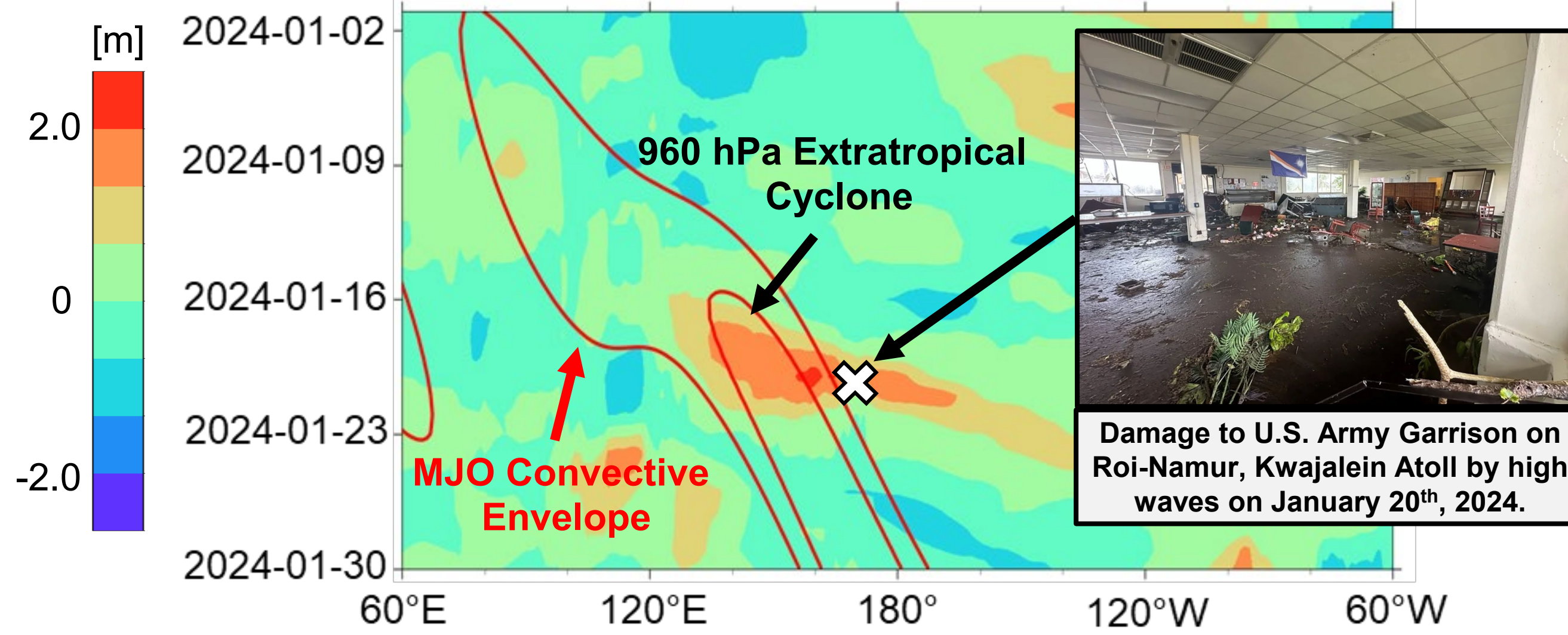


Composite of ERA5 significant wave height anomalies (m) during DJF 1991-2020 with (a) Oceanic Nino Index (ONI) > 1°K, (b) Real-Time Multivariate MJO (RMM) Phase 6-8 / amplitude > 1.5, and (c) ONI > 1°K and RMM MJO Phase 6-8 / amplitude > 1.5. Kwajalein noted with X.

Key Takeaways:

Large-scale wind and wave events occur at the intersection of high amplitude intraseasonal-to-interannual large-scale conditions such as the El Niño Southern Oscillation and Madden-Julian Oscillation.

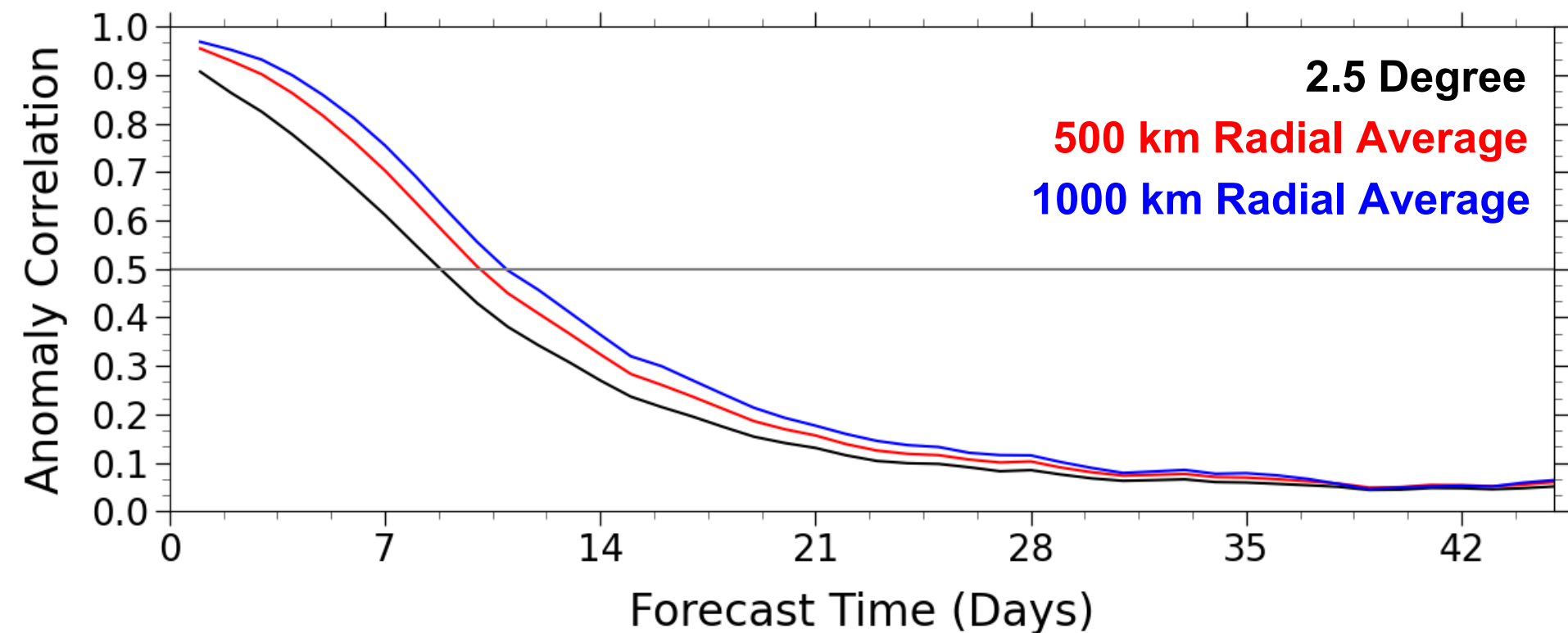
Jan. 2024 Kwajalein Atoll Wave Event and the MJO



Time-longitude diagram of MJO-filtered NOAA satellite outgoing longwave radiation (OLR) (contoured in red at -10, -20, and -30 W m⁻²) averaged over 5-15°S and ERA5 significant wave height anomalies (m, shaded) averaged over 0-15°N. Key features are annotated.

Extended-Range Windspeed Prediction

ECMWF Daily Surface Windspeed is Skillful to ~10 Days

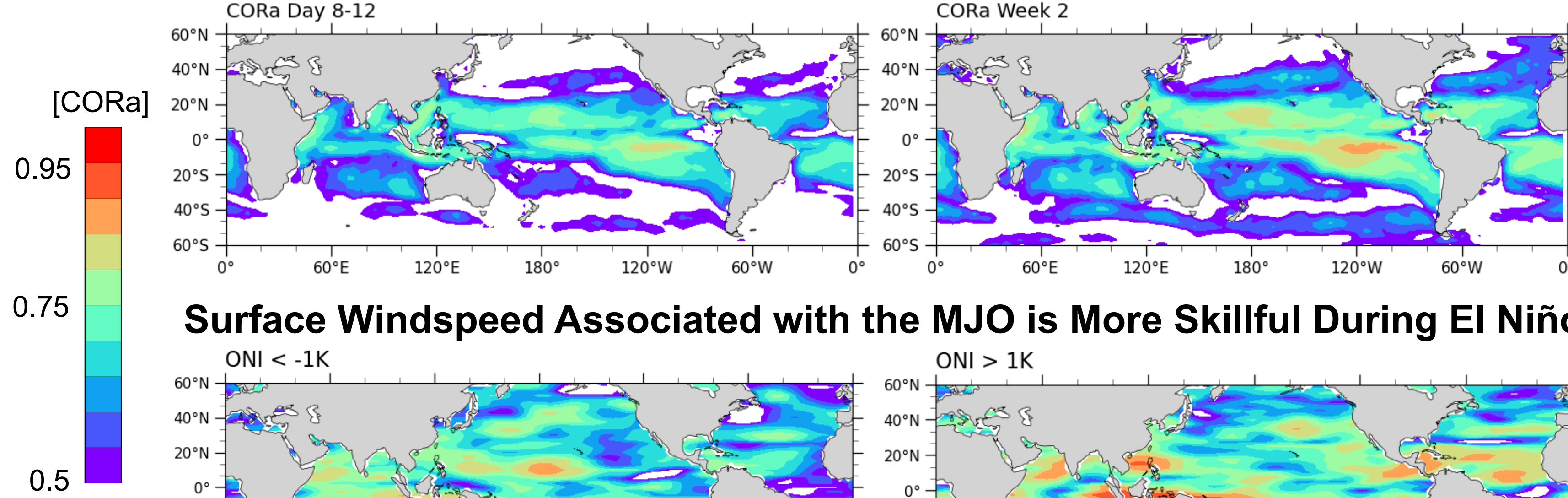


Impact of radial averaging on daily 10 m windspeed anomaly correlation averaged globally over the ocean for DJF 2002-2021 ECMWF reforecasts.

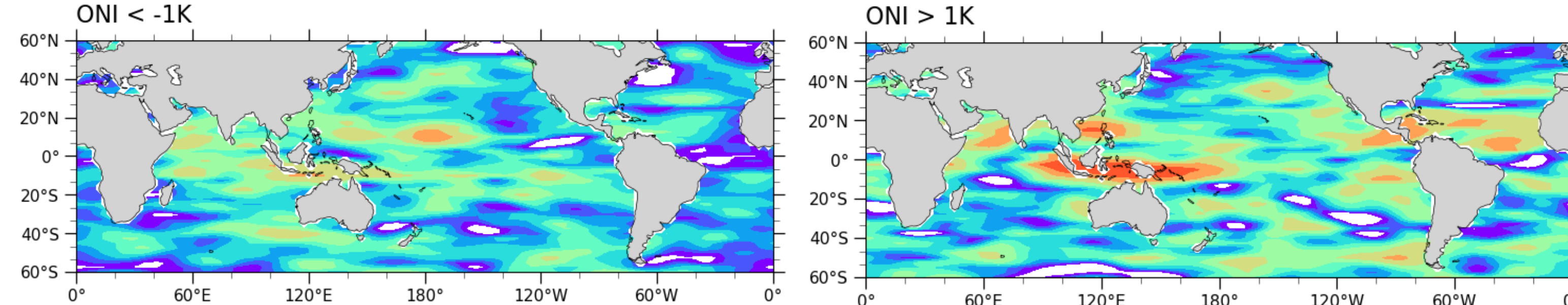
Key Takeaways:

Coupled models are capable of skillful oceanic surface windspeed forecasts in the 8-12 day and week 2 windows. Regional differences in MJO-filtered surface windspeed skill occur due to the influence of ENSO on MJO activity.

Surface Windspeed is Skillful for the 8-12 Day and Week 2 Windows



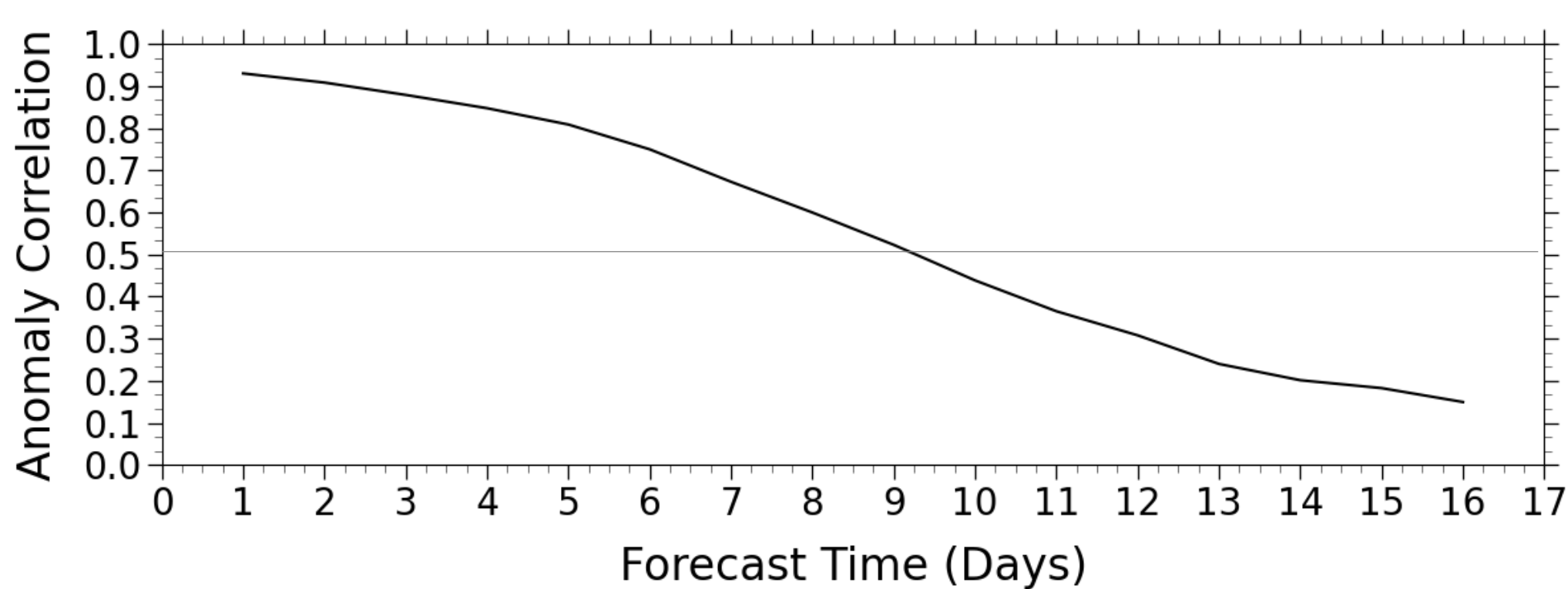
Surface Windspeed Associated with the MJO is More Skillful During El Niño



Anomaly correlation of DJF 2002-2021 ECMWF surface windspeed (top) at day 8-12 and week 2 and (bottom) for MJO-filtered forecasts and observations following Janiga et al. (2018) during La Niña and El Niño at week 2.

Extended-Range Ocean Wave Prediction

Navy ESPC Daily Wave Height is Skillful to ~9 Days



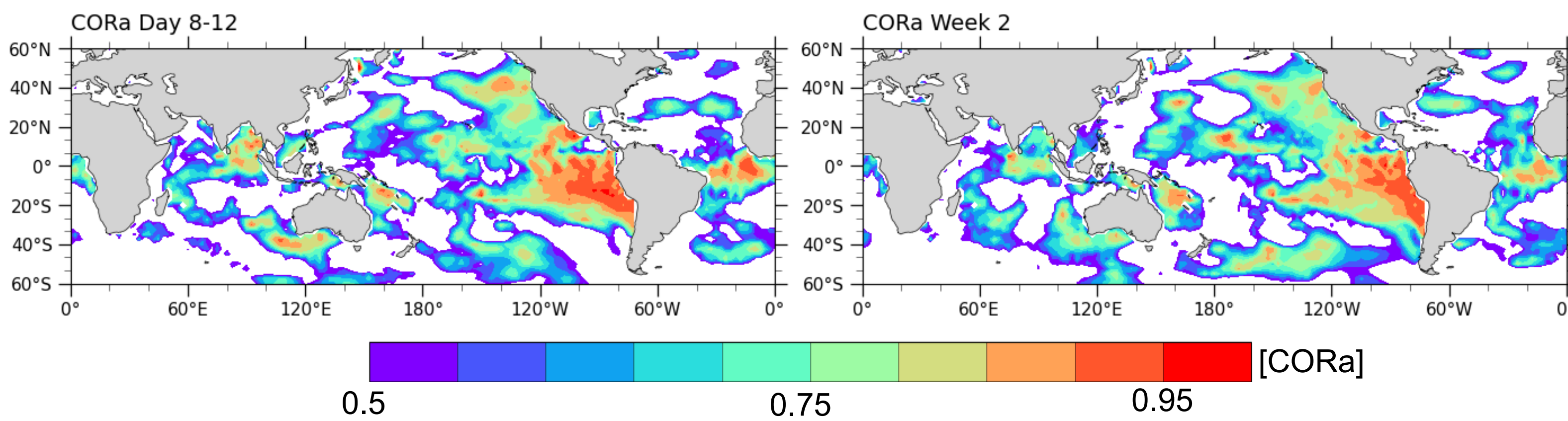
Anomaly correlation of daily significant wave height from DJF 2020-2021 Navy ESPC v2 reforecasts.

Key Takeaways:

Coupled models are capable of skillful wave height forecasts in the 8-12 day and week 2 windows despite daily forecasts only being skillful out to day 9.

Because of the limited reforecast period, these results should be viewed with caution as there could be substantial interannual variability in the prediction skill.

Wave Height is Skillful for the 8-12 Day and Week 2 Windows



Significant wave height anomaly correlation from DJF 2020-2021 Navy ESPC v2 reforecasts for (left) day 8-12 and (right) week 2.

Summary and Future Work

Summary:

- Large-scale high impact boreal winter wind and wave events in the North Pacific, such as the one which impacted Kwajalein in January 2024, seem to be most common during El Niño events and favorable phases of high amplitude MJO events.
- Daily surface windspeed CORa drops below 0.5 around day 10. However, surface windspeed exhibits useful skill in the ECMWF reforecasts in the 8-12 day and week 2 windows over large areas of the ocean with the highest skill in the tropics. Extended-range prediction skill of the MJO and associated surface windspeed is enhanced during El Niño events. This appears to be associated with the greater strength and eastward propagation of MJO events during these years.
- Significant wave height prediction skill in the Navy ESPC v2 reforecasts show potential for extended-range prediction but more work is required to place the skill within the context of interannual variability.

Future Work:

- More detailed study of how extreme wind and wave events are modulated by ENSO, the MJO, and extratropical large-scale patterns
- More detailed examination of the Navy ESPC v2 ensemble forecasts, including case studies, and additional wave properties

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