Multi-month forecasts of marine heatwaves and ocean acidification extremes

Samuel Mogen

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What are we trying to forecast?

(1) marine heatwaves (90th percentile)

(2/3) two types of ocean acidification extremes

$[H^+]$ > 90th percentile

Ω_{arag} < 10th percentile

} **Both** important for organisms

[H+]

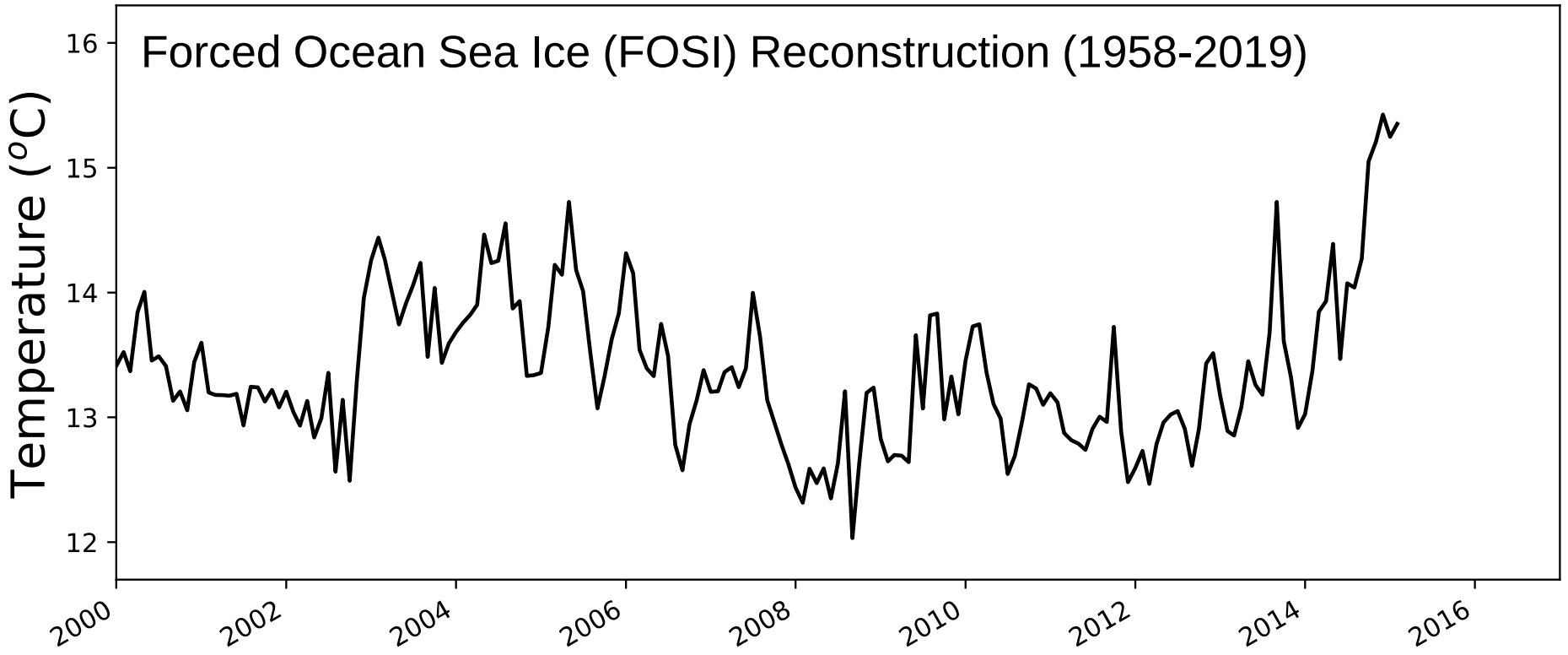
temperature sensitive

Ω_{arag}

(aragonite saturation state)

not temperature sensitive

CESM Seasonal to Multiyear Large Ensemble (SMYLE)



Yeager et al. 2022

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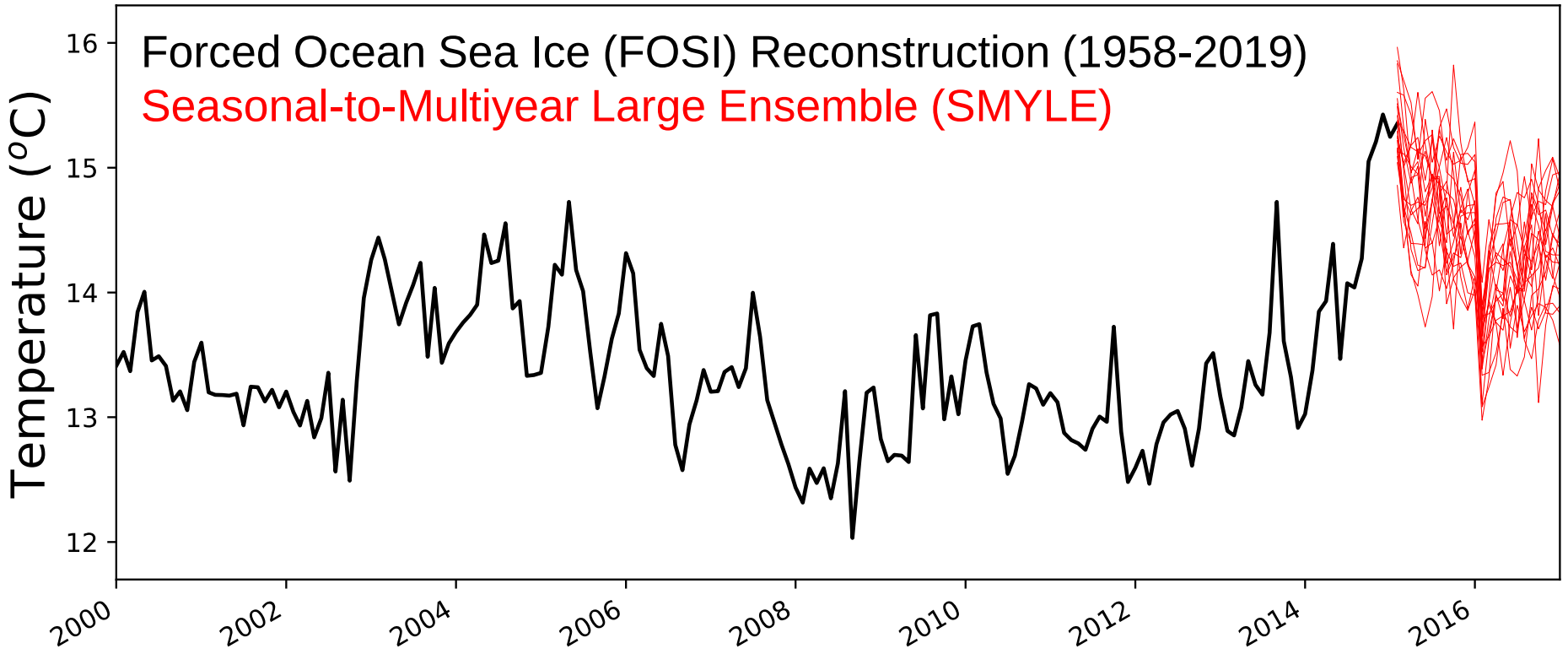

- Initialized 4 times / year (Feb. 1, May 1, Aug. 1, Nov. 1) from 1970-2019
- Each forecast integrated for 2 years

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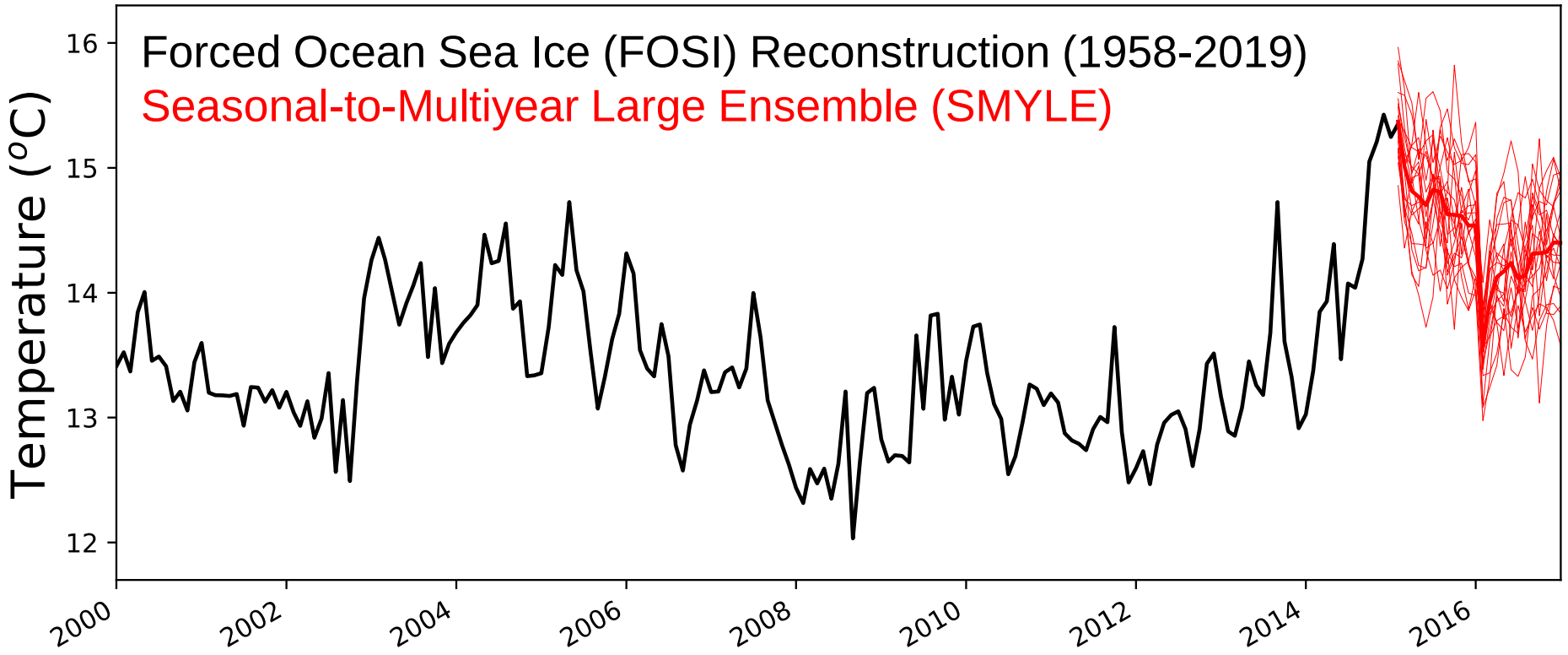

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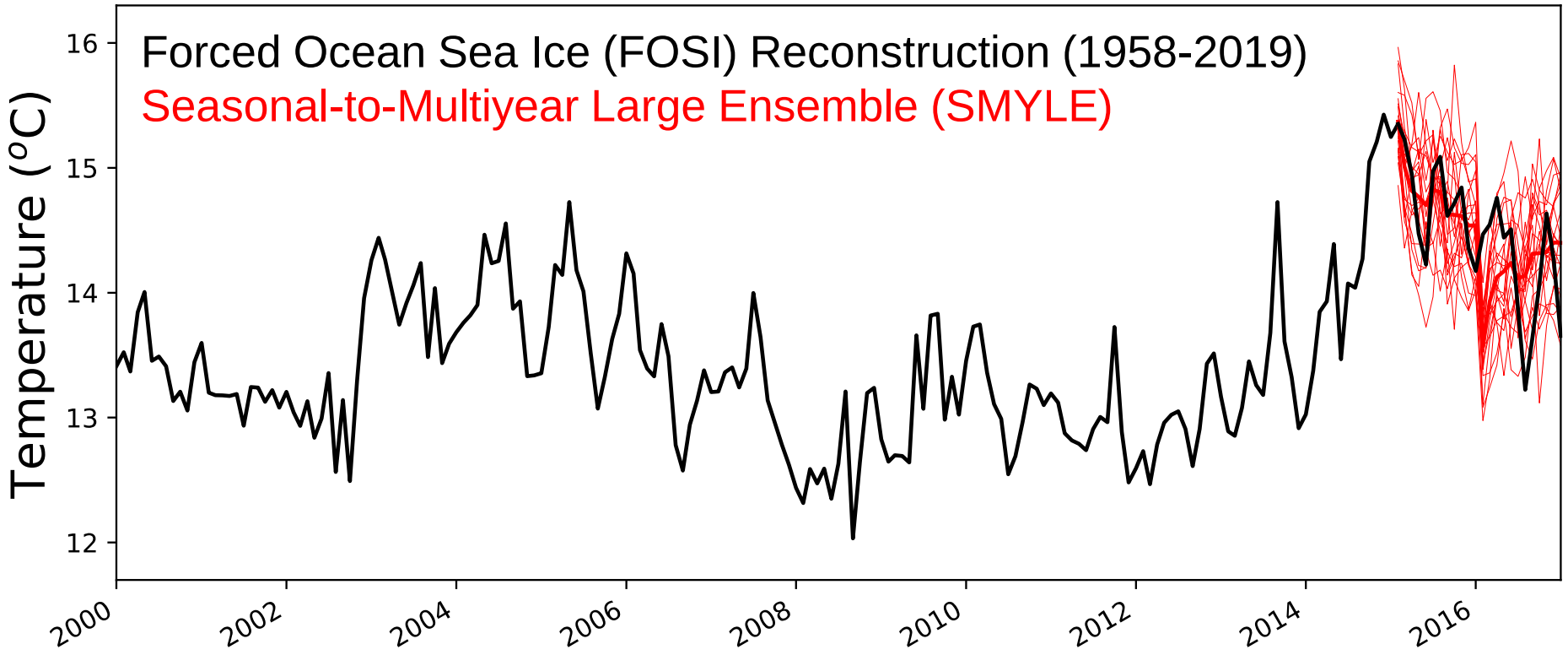

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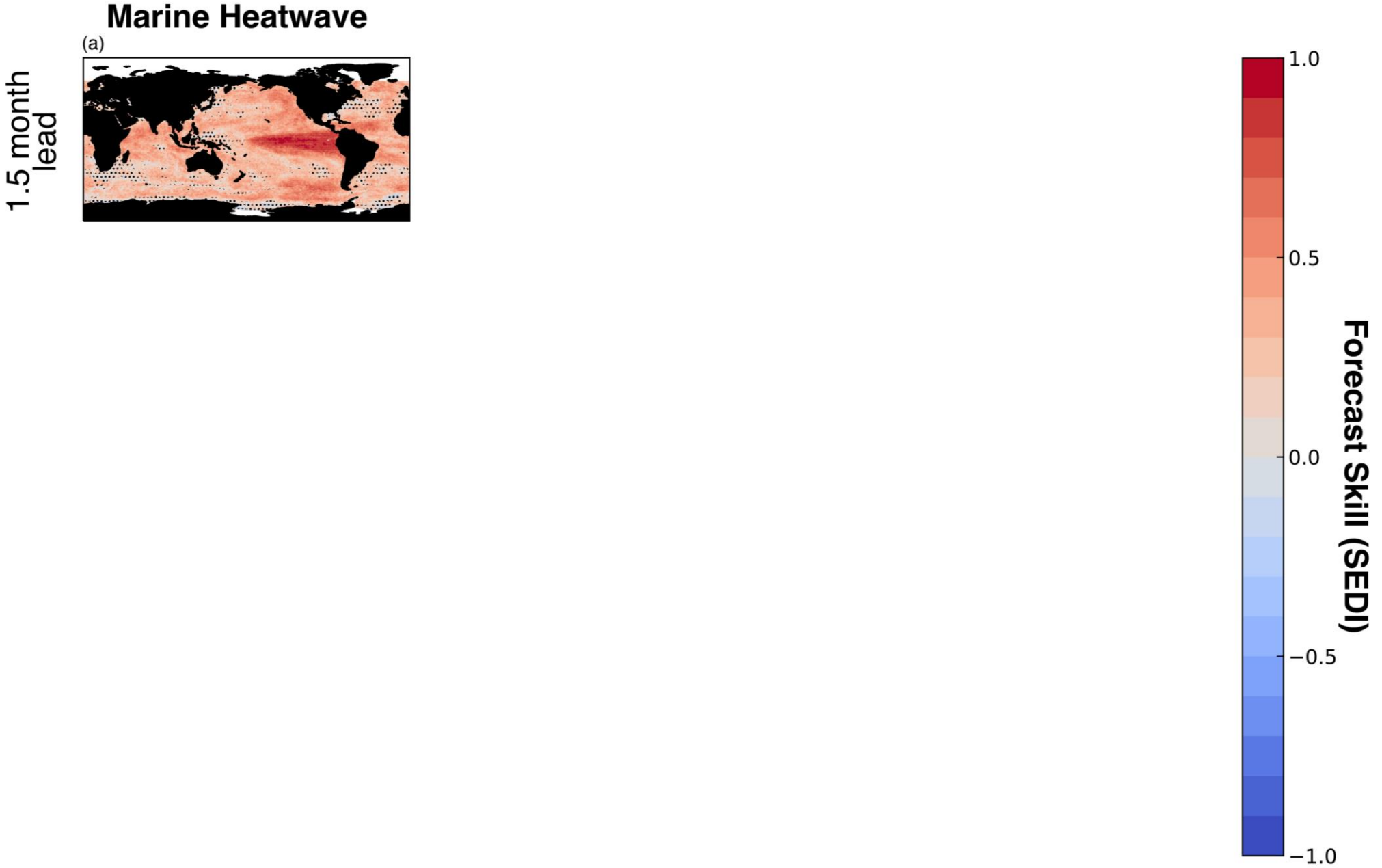
Compare to observation-based product (OceanSODA-ETHZ)

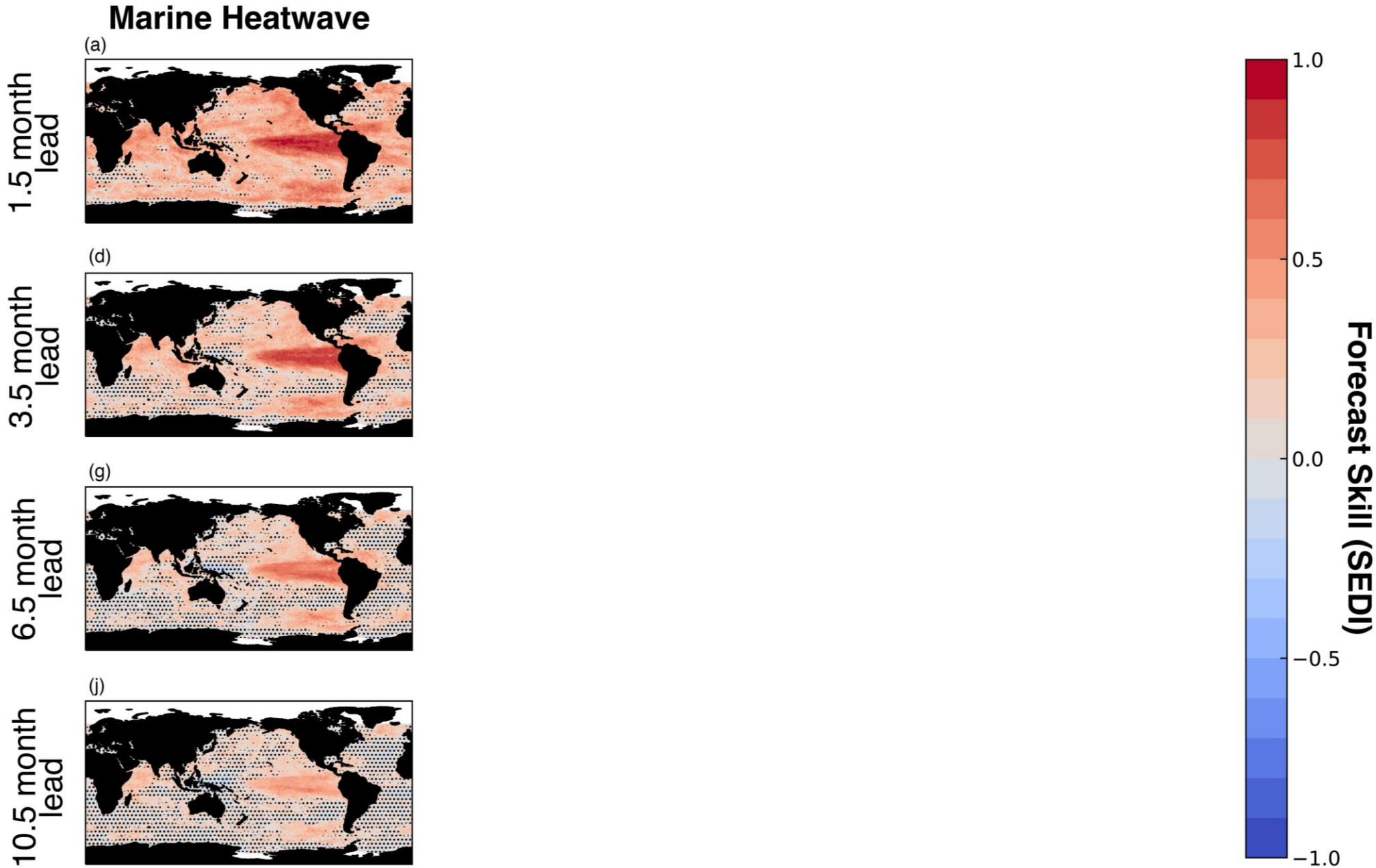
Yeager et al. 2022



SEDI = Symmetric Extremal Dependence Index

Stippling indicates insignificant skill

Mogen et al., in press; NGS



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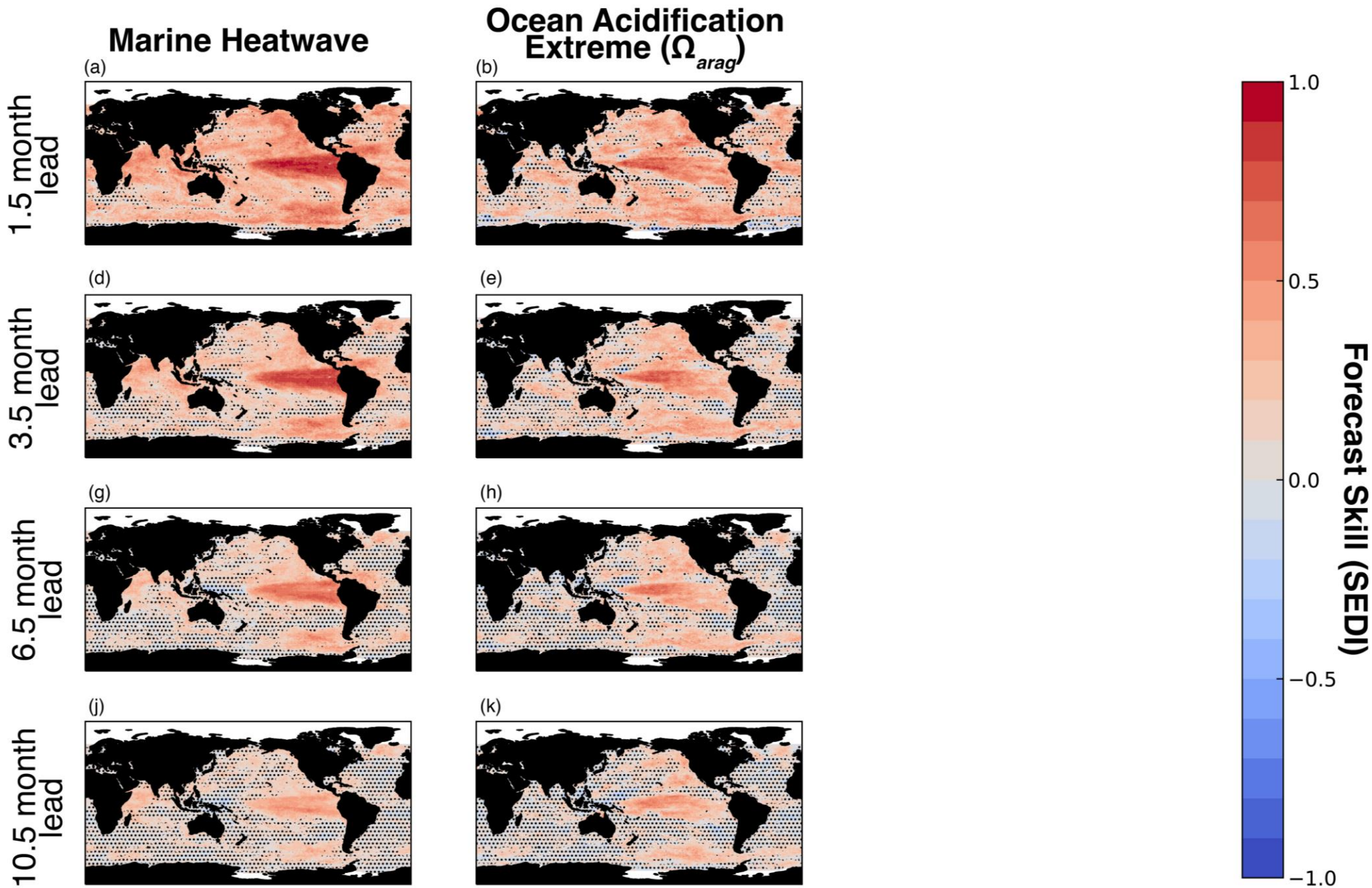

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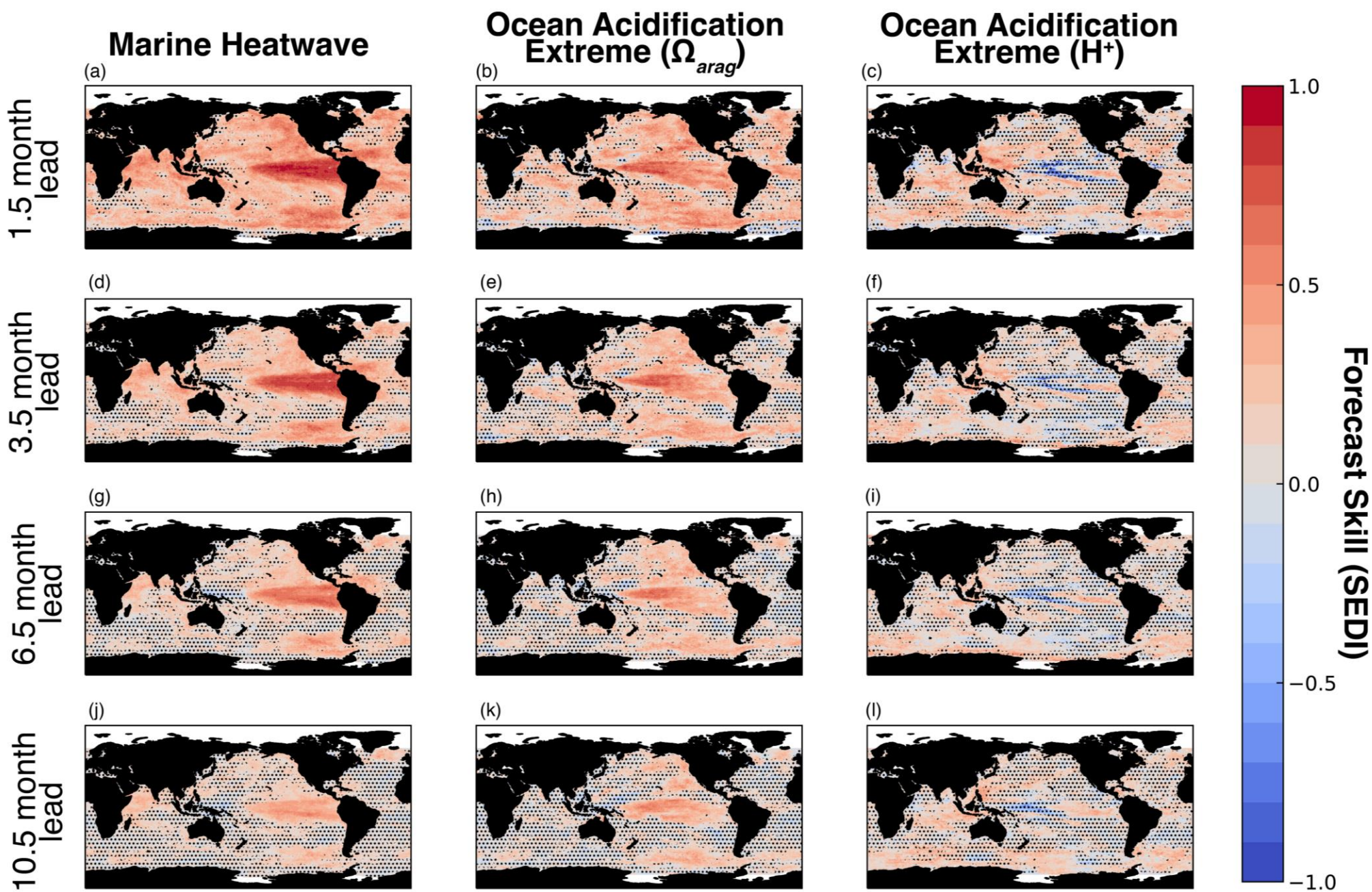

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We find high skill for MHW and OAX (Ω_{arag})

Skill is highest in the eastern Pacific

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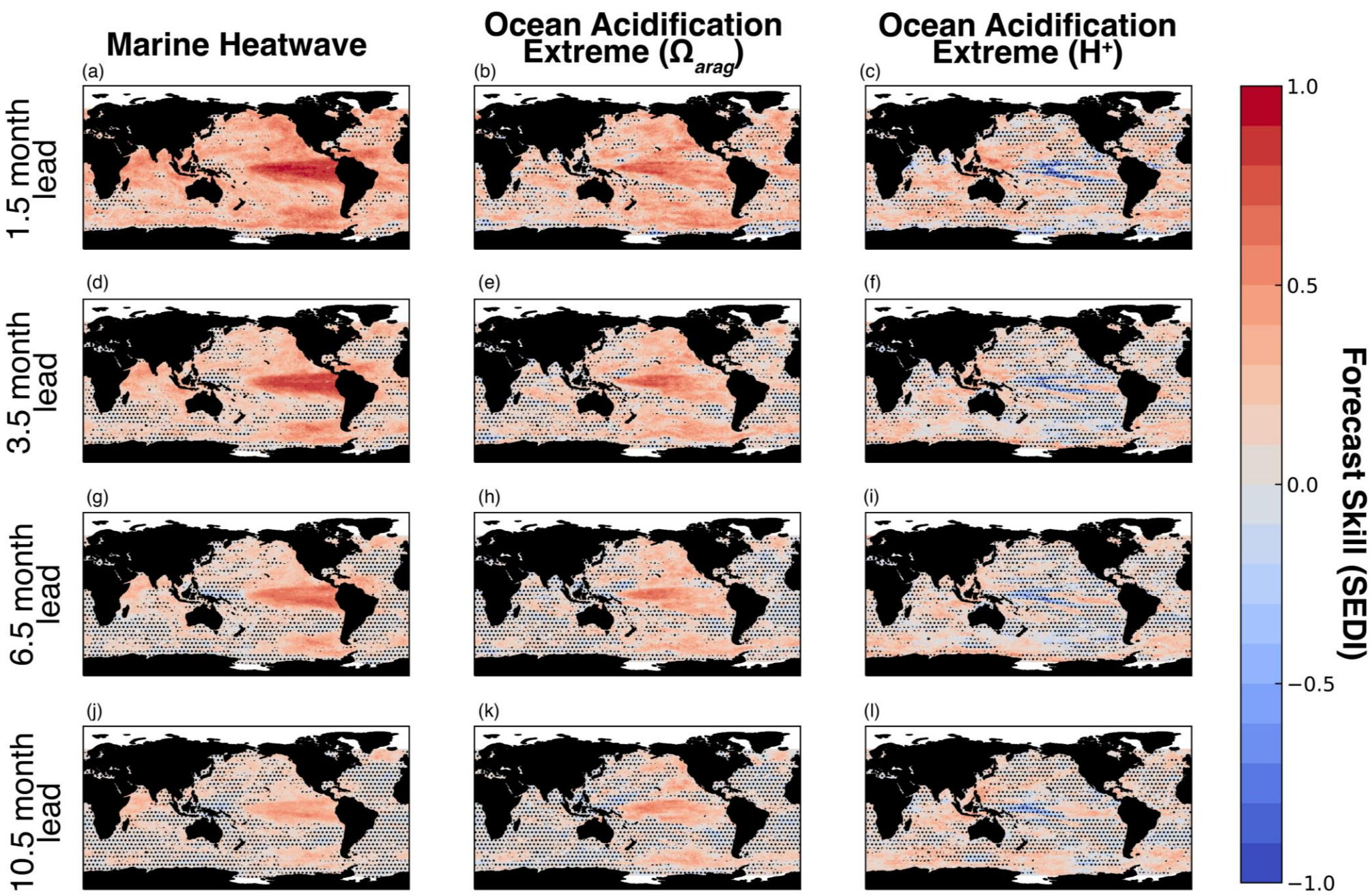

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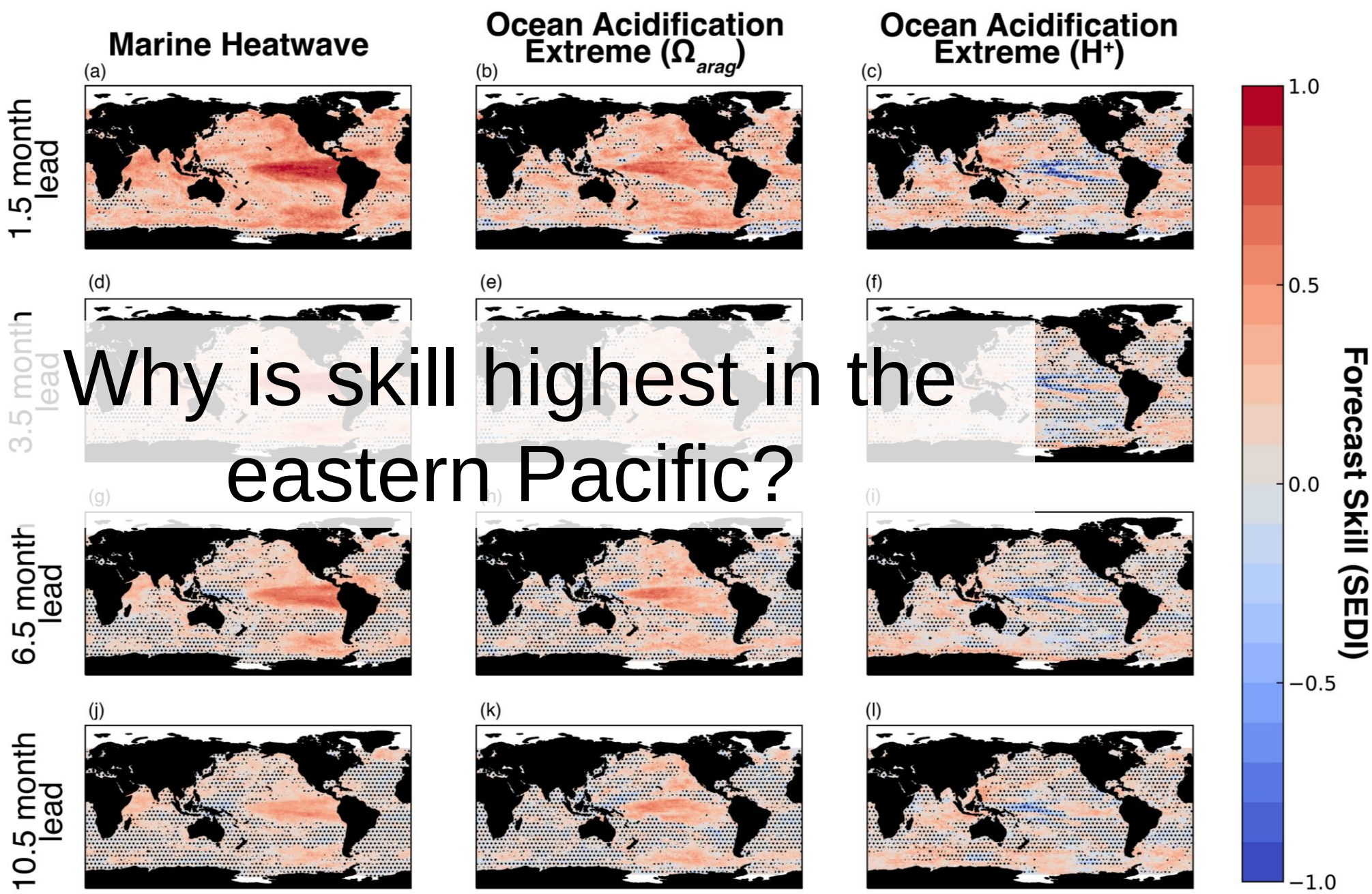
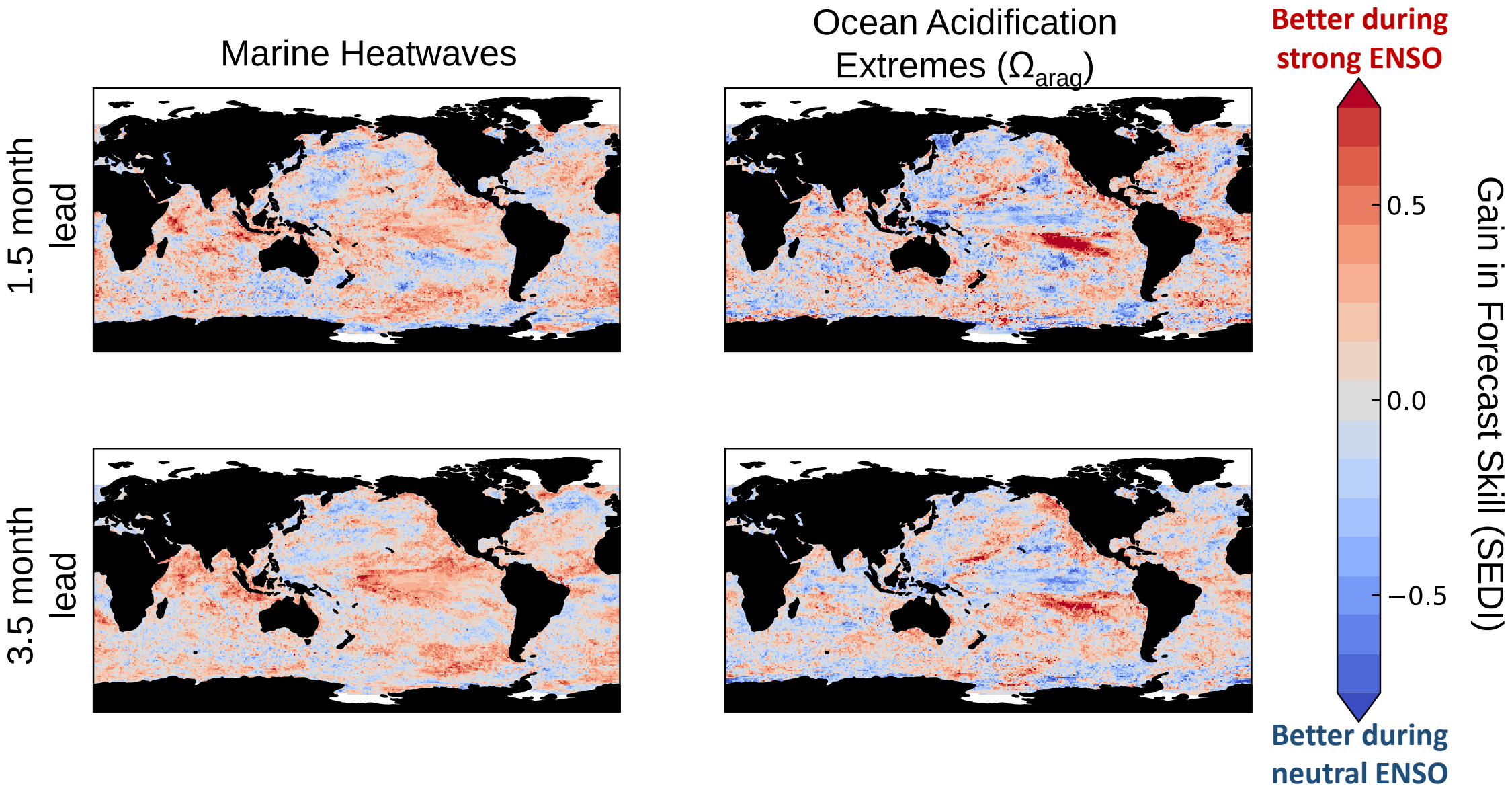


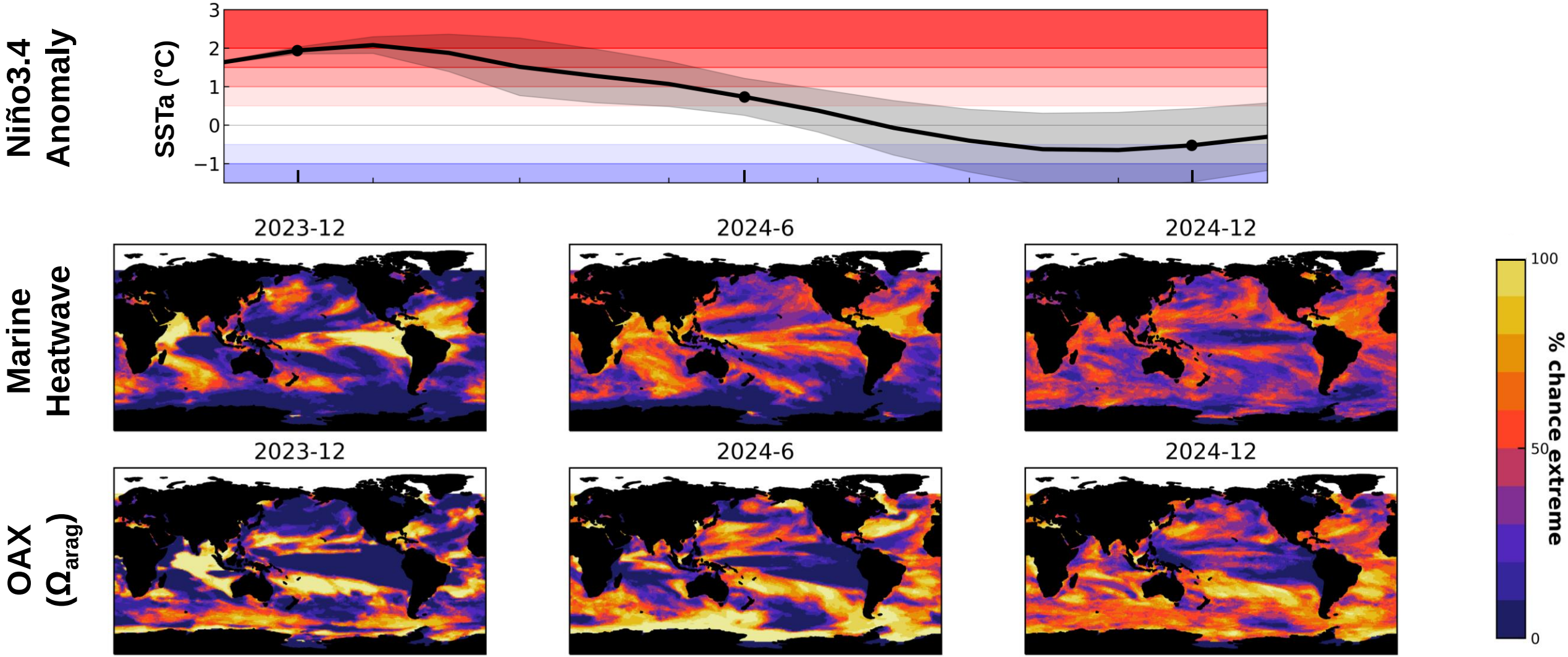
Why is skill highest in the eastern Pacific?

Forecasts initialized during strong ENSO events* demonstrate higher skill



Mogen et al., in press; NGS

* Combined Niño and Niña

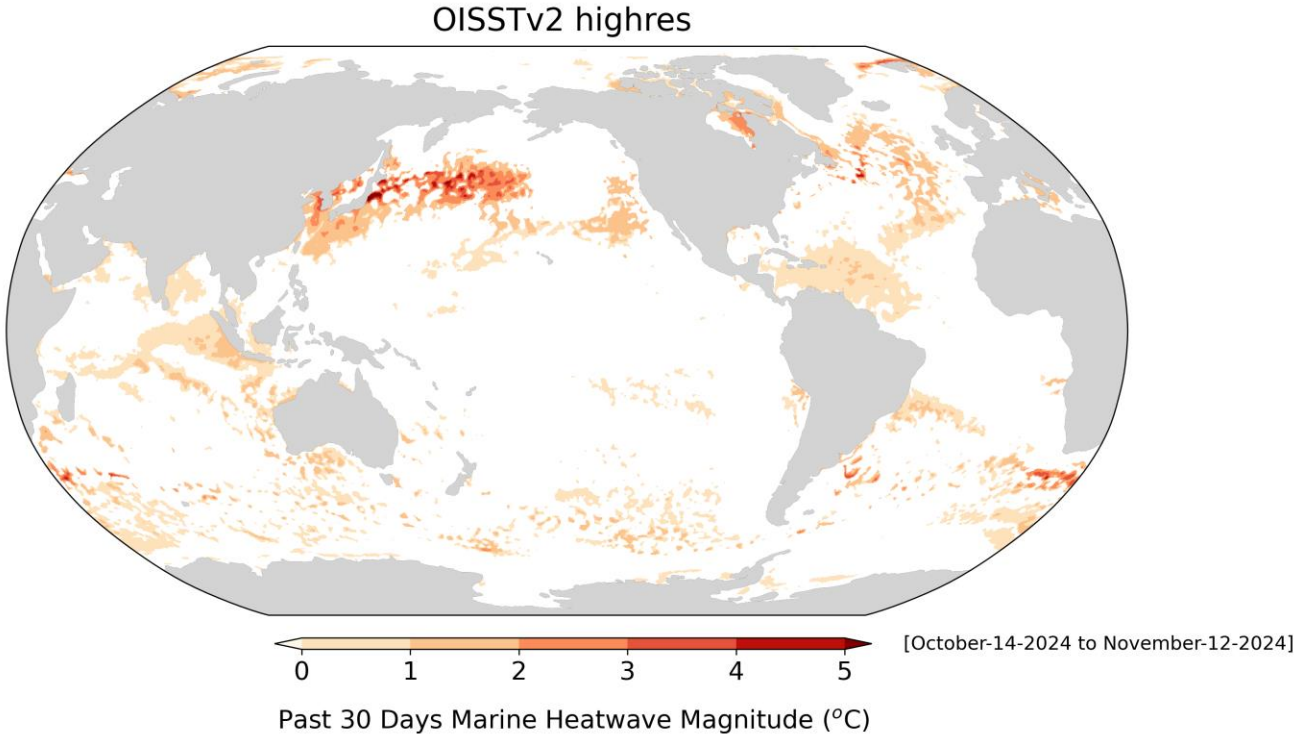


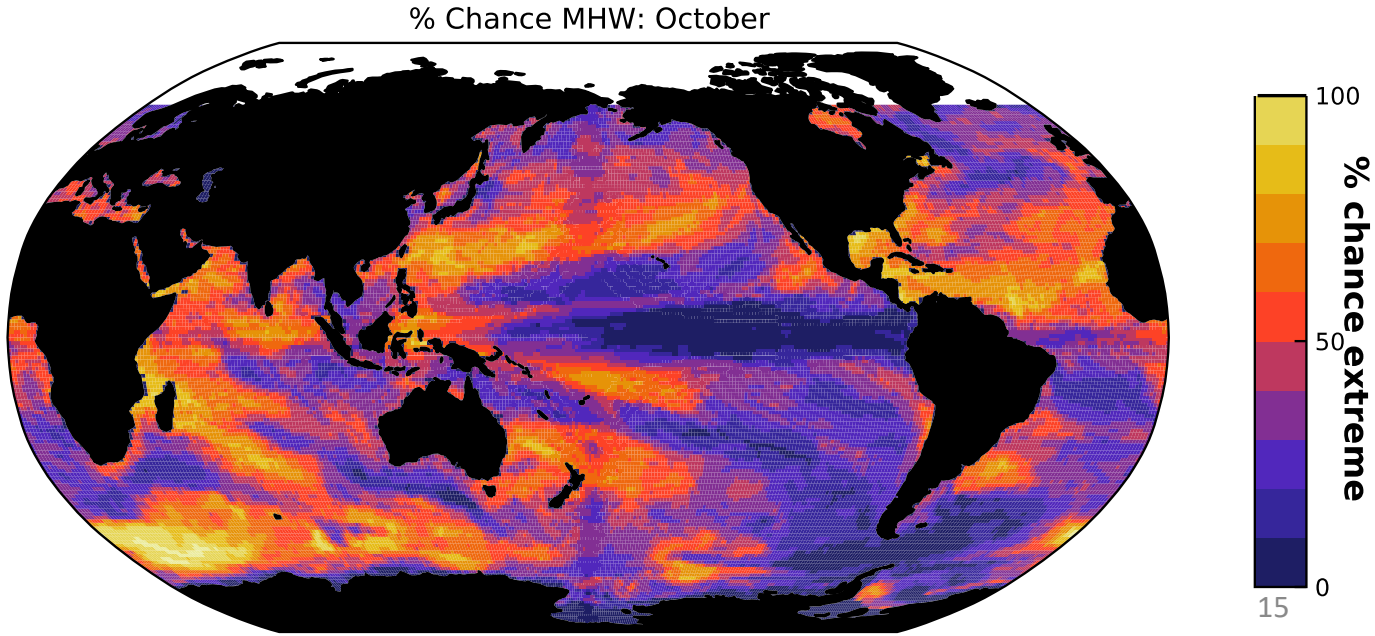
Near real-time forecast initialized in November 2023

We forecast widespread MHW and OAX through 2024

Mogen et al., in press; NGS

Observed vs. Forecast MHW occurrence





Mogen et al., in press; NGS

We can skillfully forecast MHW and OAX (Ω_{arag}) up to a year in advance

OAX (Ω_{arag}) are **more predictable** than OAX ($[H^+]$)

Forecasts enhanced when initialized during ENSO events

We forecast widespread MHW and OAX in 2024

(preprint)

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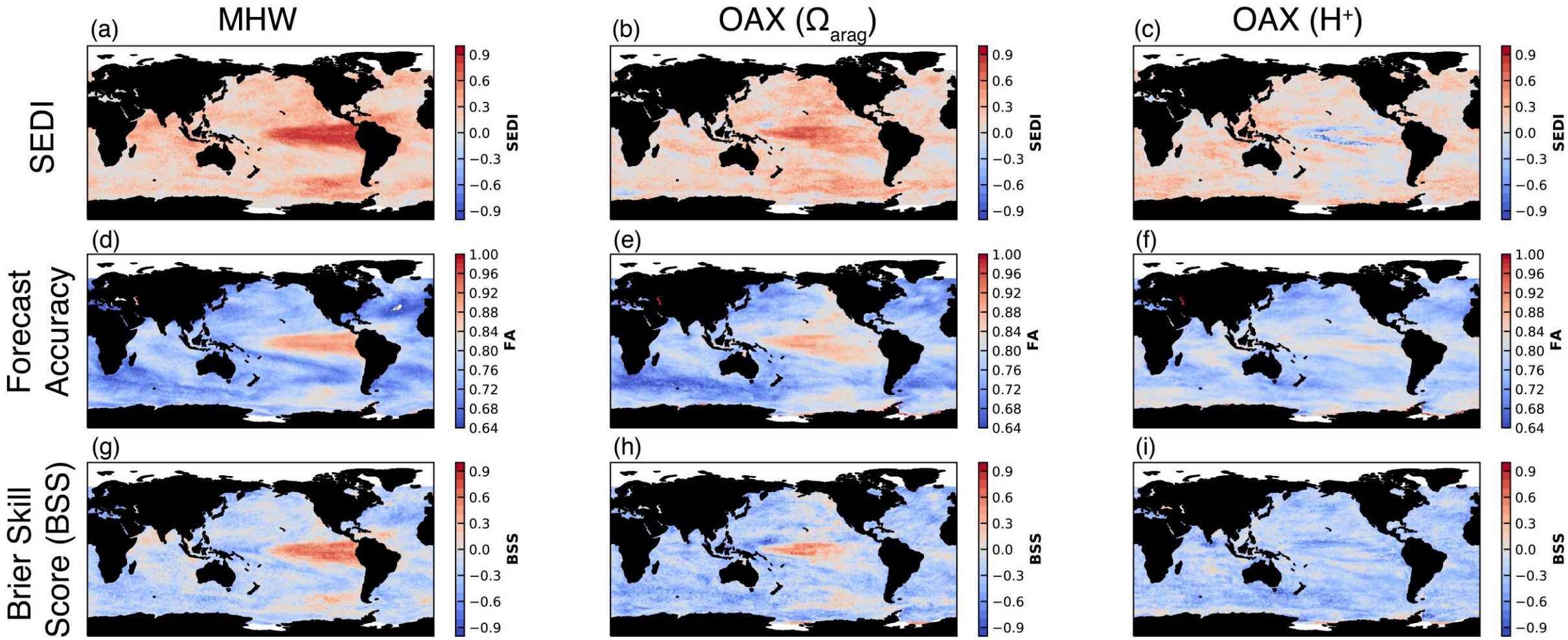
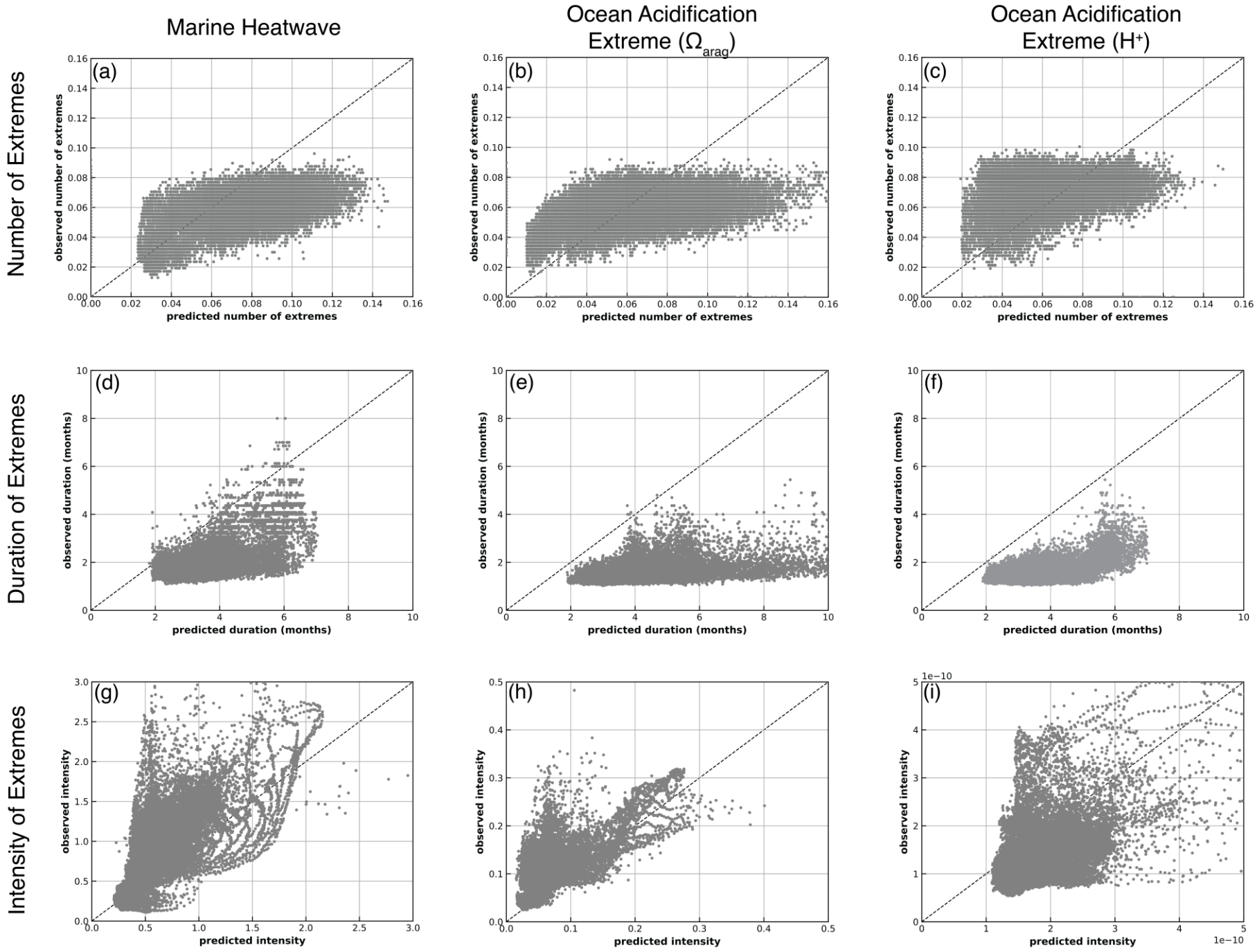
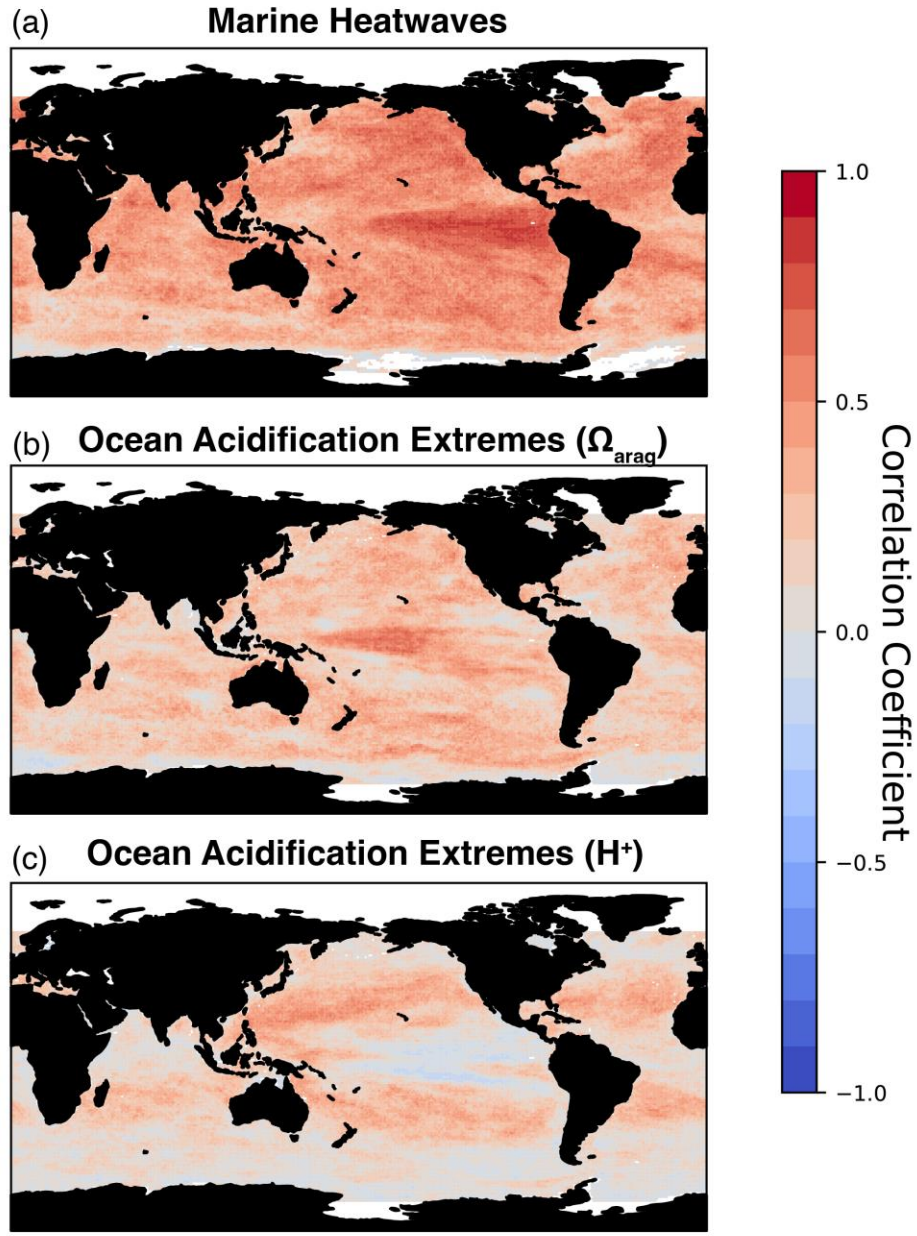
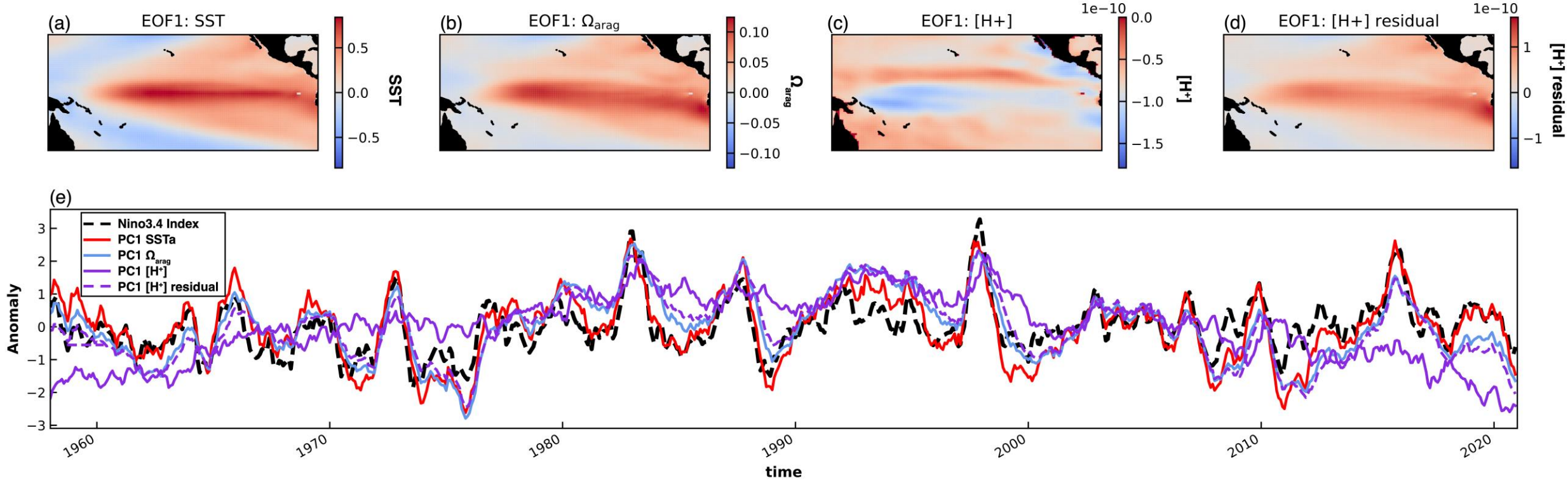
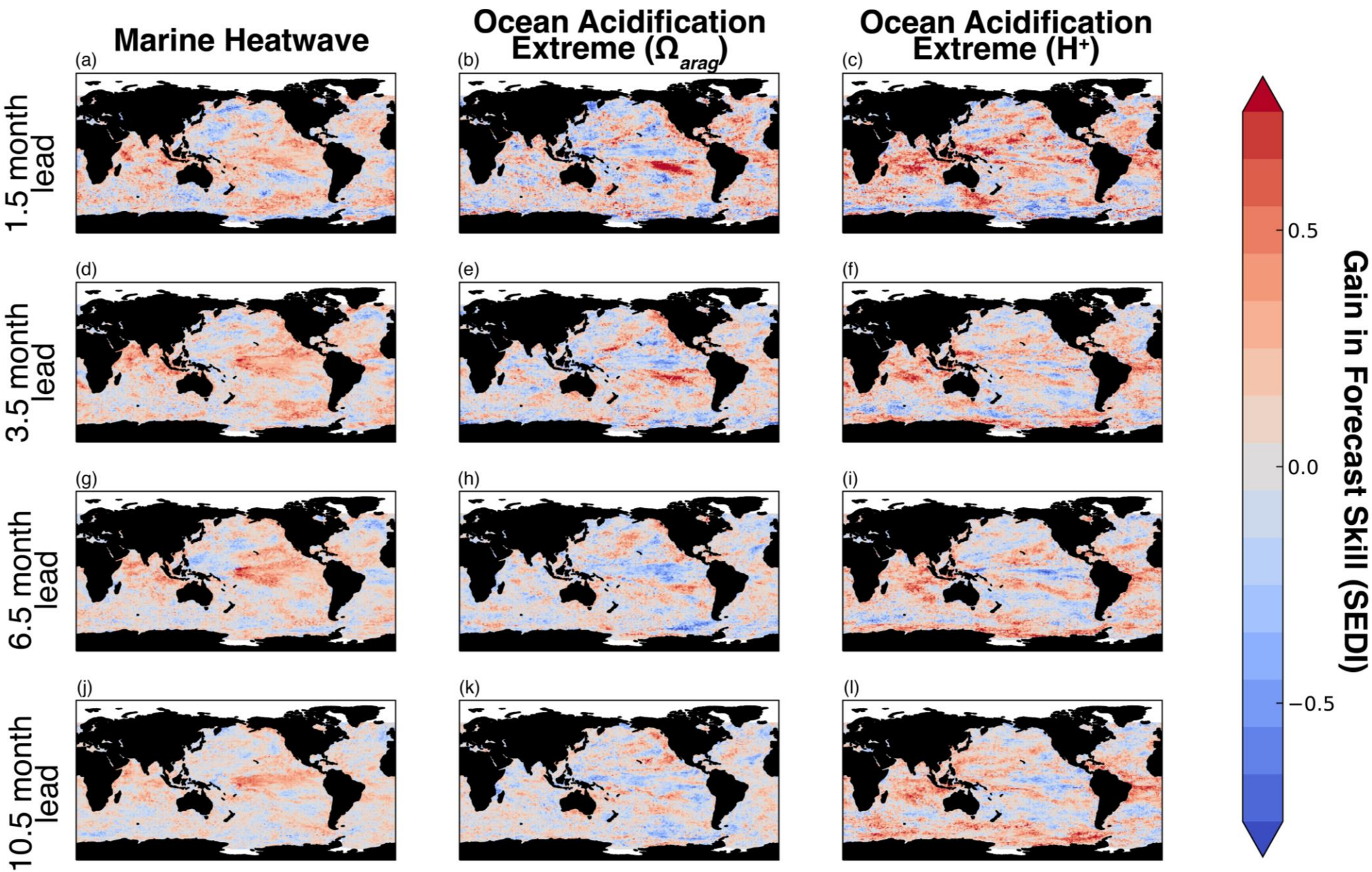
supplemental


MHW
OAX (Ω_{arag})
OAX (H^+)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
SEDI
Forecast Accuracy
Brier Skill Score (BSS)
SEDI
0.9
0.6
0.3
0.0
−0.3
−0.6
−0.9
FA
1.00
0.96
0.92
0.88
0.84
0.80
0.76
0.72
0.68
0.64
BSS


Marine Heatwave
Ocean Acidification Extreme (Ω_{arag})
Ocean Acidification Extreme (H^+)
Number of Extremes
Duration of Extremes
Intensity of Extremes
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
observed number of extremes
predicted number of extremes
observed duration (months)
predicted duration (months)
observed intensity
predicted intensity
1e−10


(a) Marine Heatwaves
(b) Ocean Acidification Extremes (Ω_{arag})
(c) Ocean Acidification Extremes (H^+)
1.0
0.5
0.0
−0.5
−1.0
Correlation Coefficient


(a)
EOF1: SST
0.5
0.0
−0.5
SST
(b)
EOF1: Ωarag
0.10
0.05
0.00
−0.05
−0.10
Ωarag
(c)
EOF1: [H+]
1e−10
0.0
−0.5
−1.0
−1.5
[H+]
(d)
EOF1: [H+] residual
1e−10
1
0
−1
[H+] residual
(e)
Nino3.4 Index
PC1 SSTa
PC1 Ωarag
PC1 [H+]
PC1 [H+] residual
Anomaly
3
2
1
0
−1
−2
−3
1960
1970
1980
1990
2000
2010
2020
time



Forecasts initialized during strong ENSO events* demonstrate higher skill

* Combined Niño and Niña

Better during strong ENSO

Better during neutral ENSO

Mogen et al., in review