Learning from a failed prediction: Why prediction systems struggle with the 2015 cold blob

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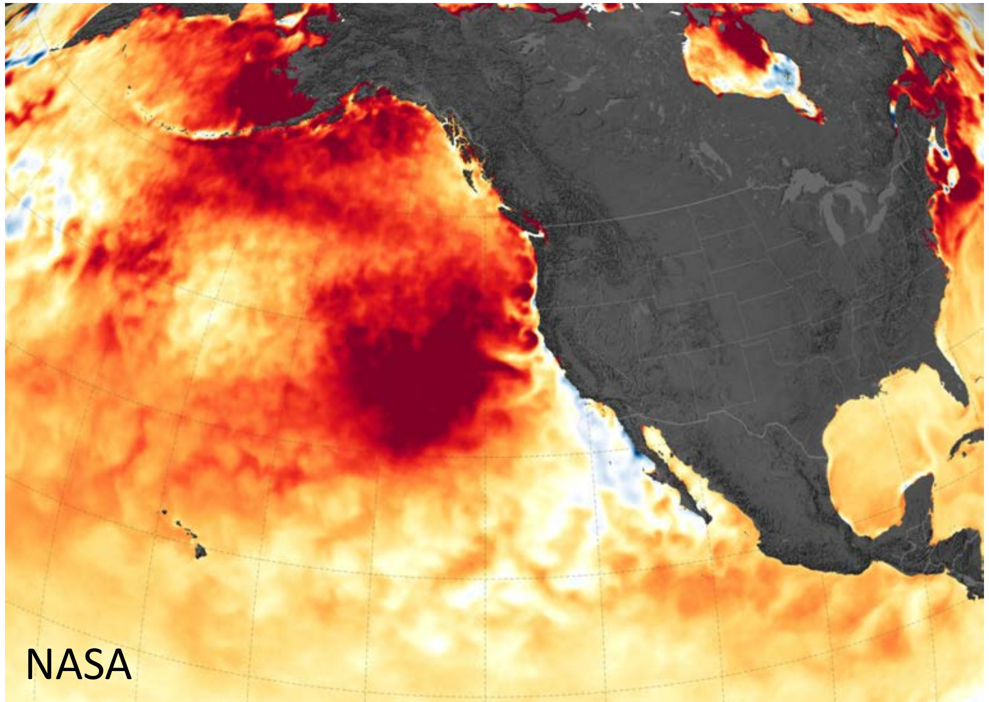
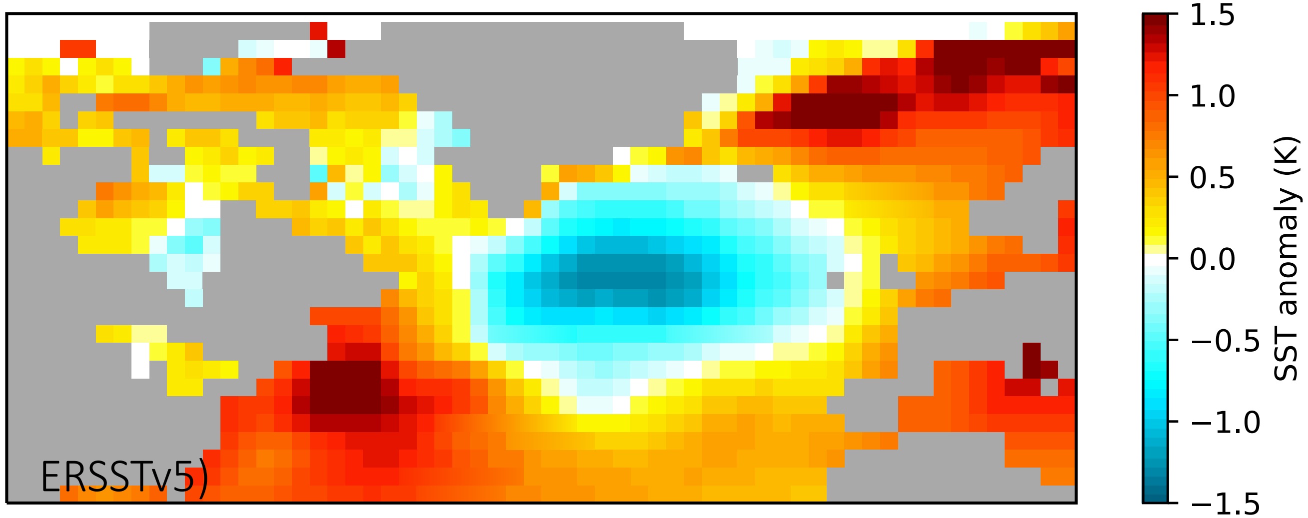
The ability to predict extreme oceanic events with monthly to annual lead time would be valuable.

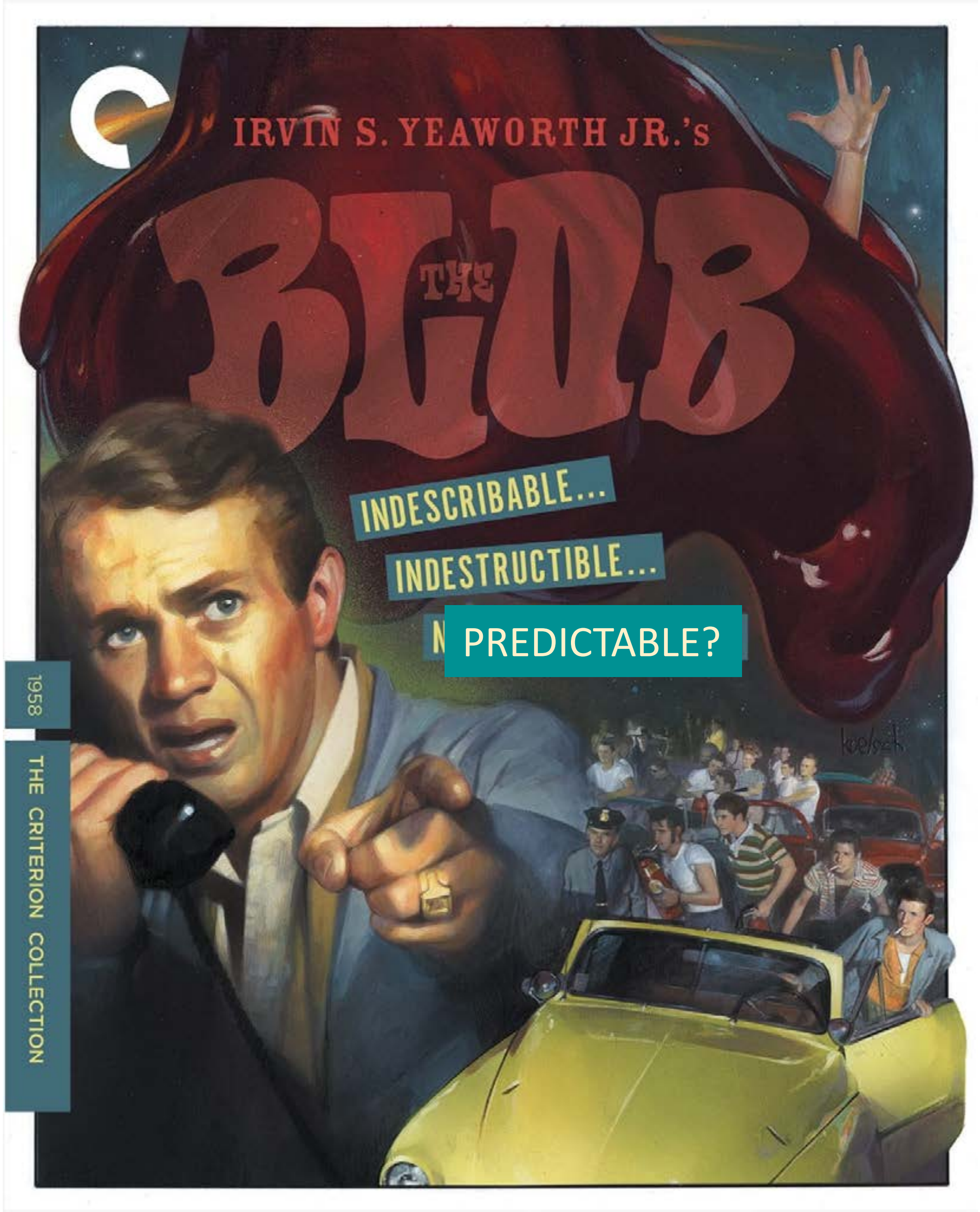


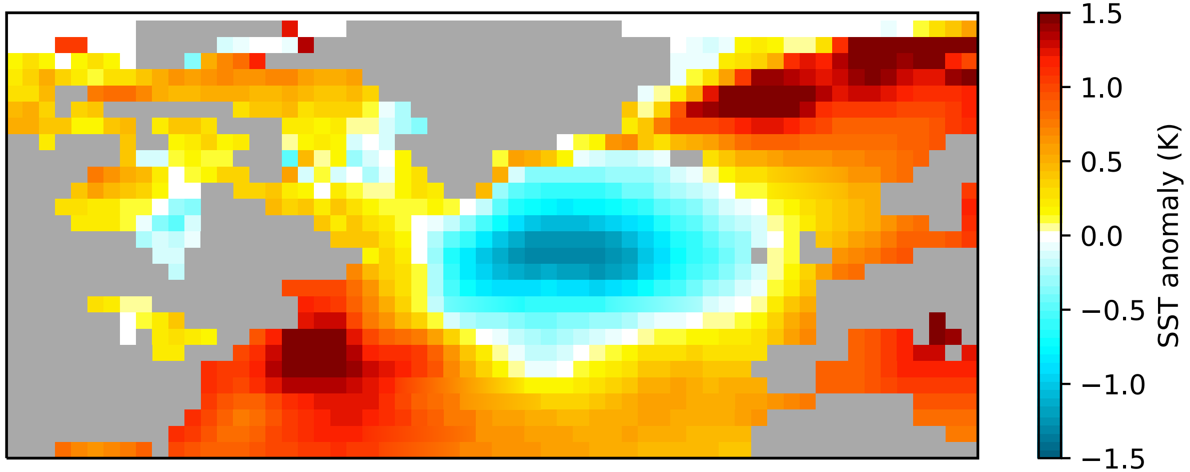
Marine heat waves



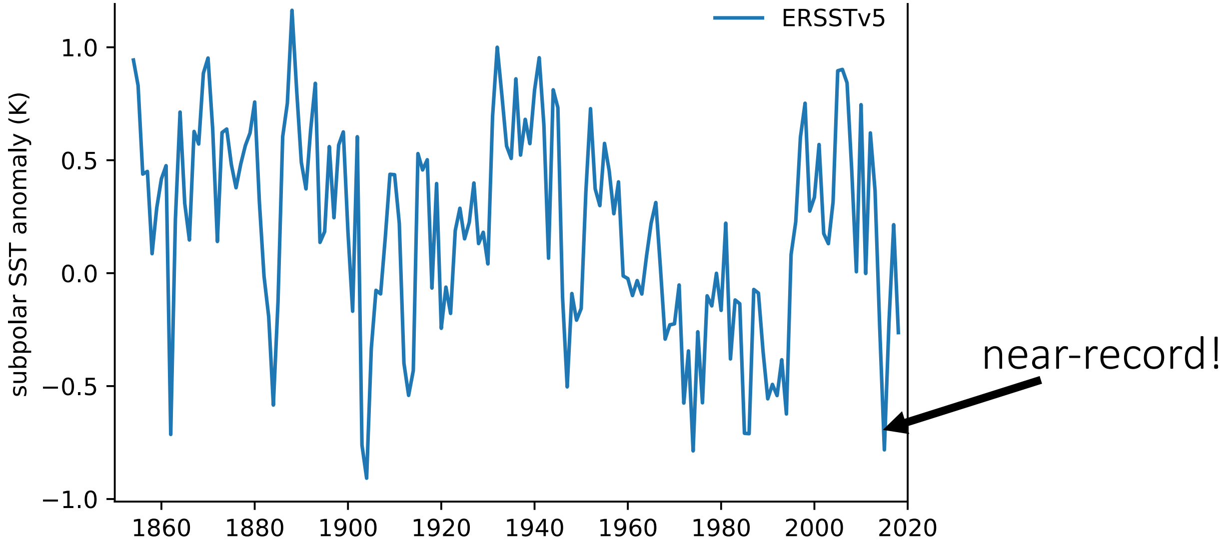
Marine cold spells and cold blobs

The 2015 Subpolar North Atlantic (SPNA) Cold Blob

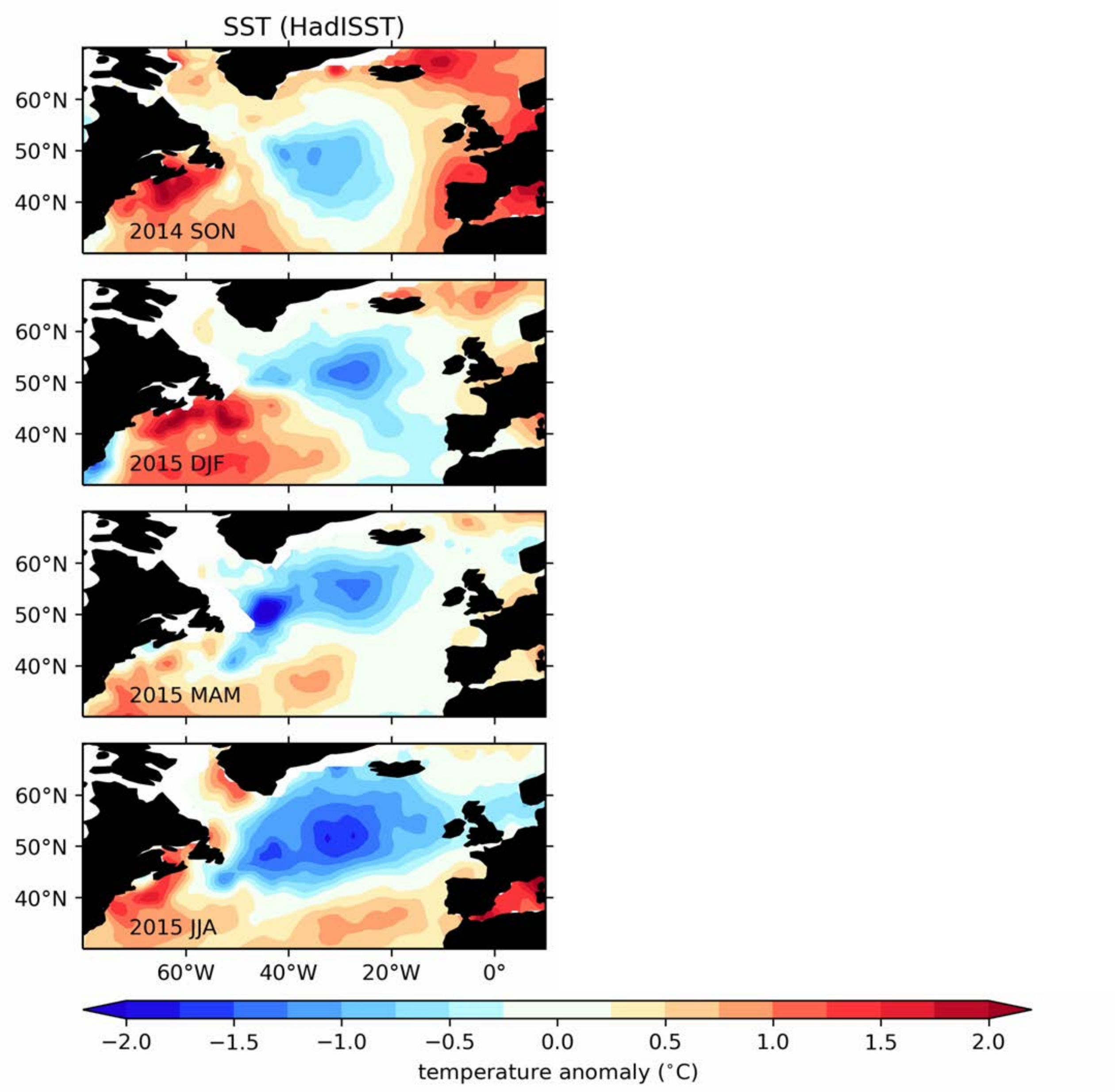




JJA 2015 (ERSSTv5; Huang et al., 2017)



Characteristics of the event from late 2014 into 2015



At surface, the event amplified in both intensity and extent from late 2014 until its peak in 2015.

Maroon et al. (in prep)

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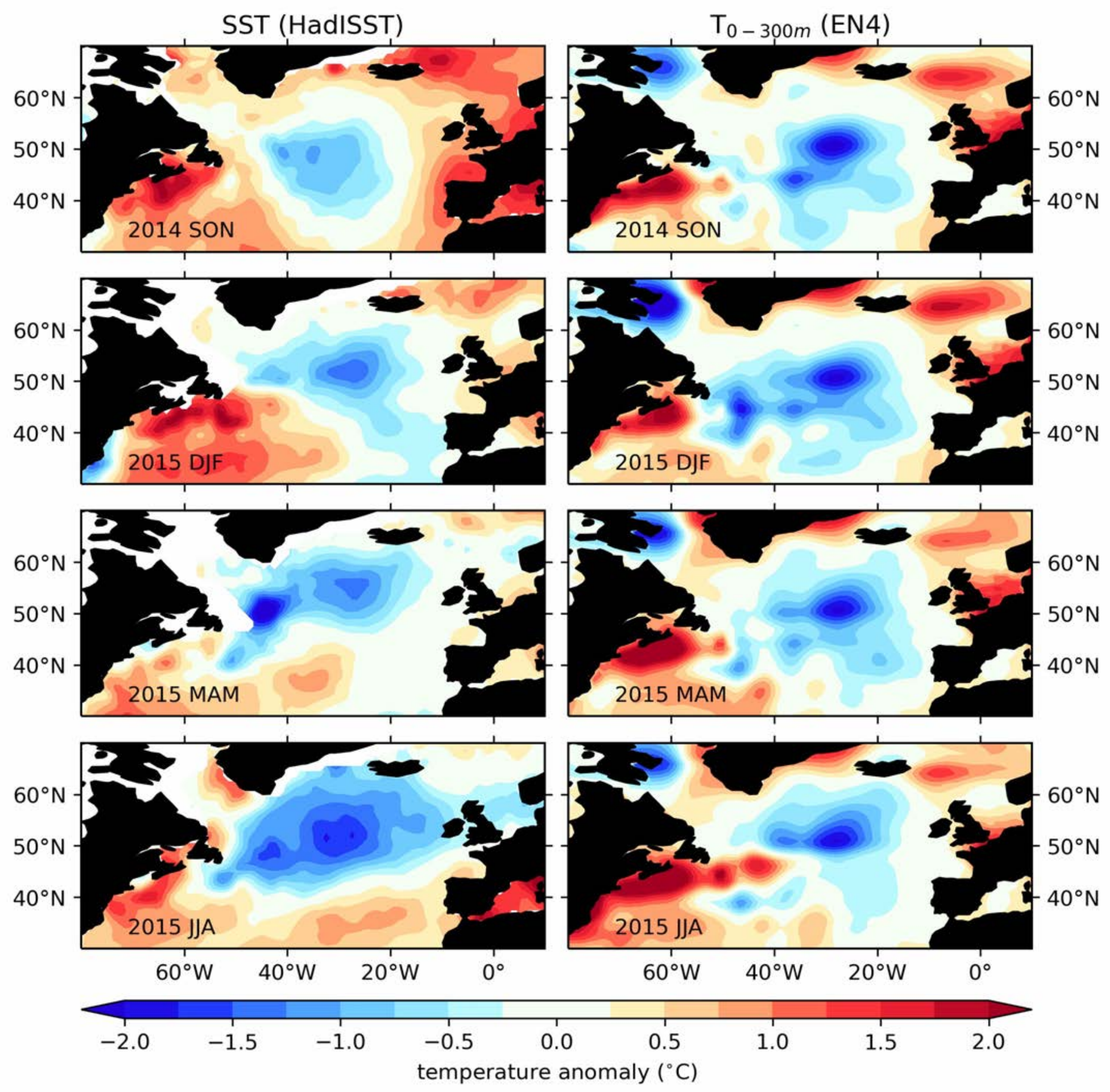

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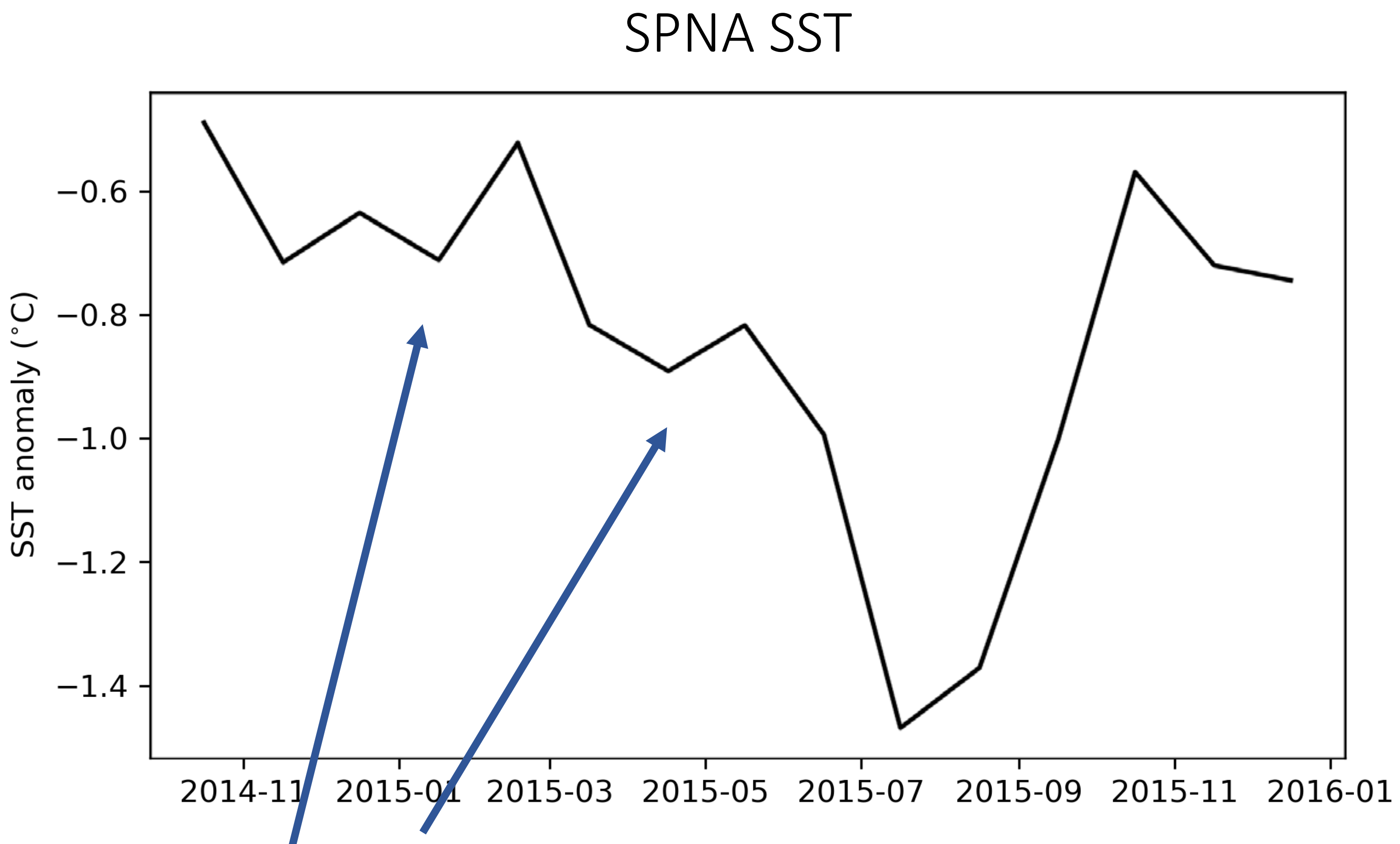
The pattern of the upper 300m average temperature, however, was stable over the same time period.

Maroon et al. (in prep)

Two periods of cooling after November 2014



January – April: -0.2 degrees Celsius
Positive winter+spring NAO
→ strong surface cooling + winter mixed layer
→ sustained and slightly intensified the cold anomaly

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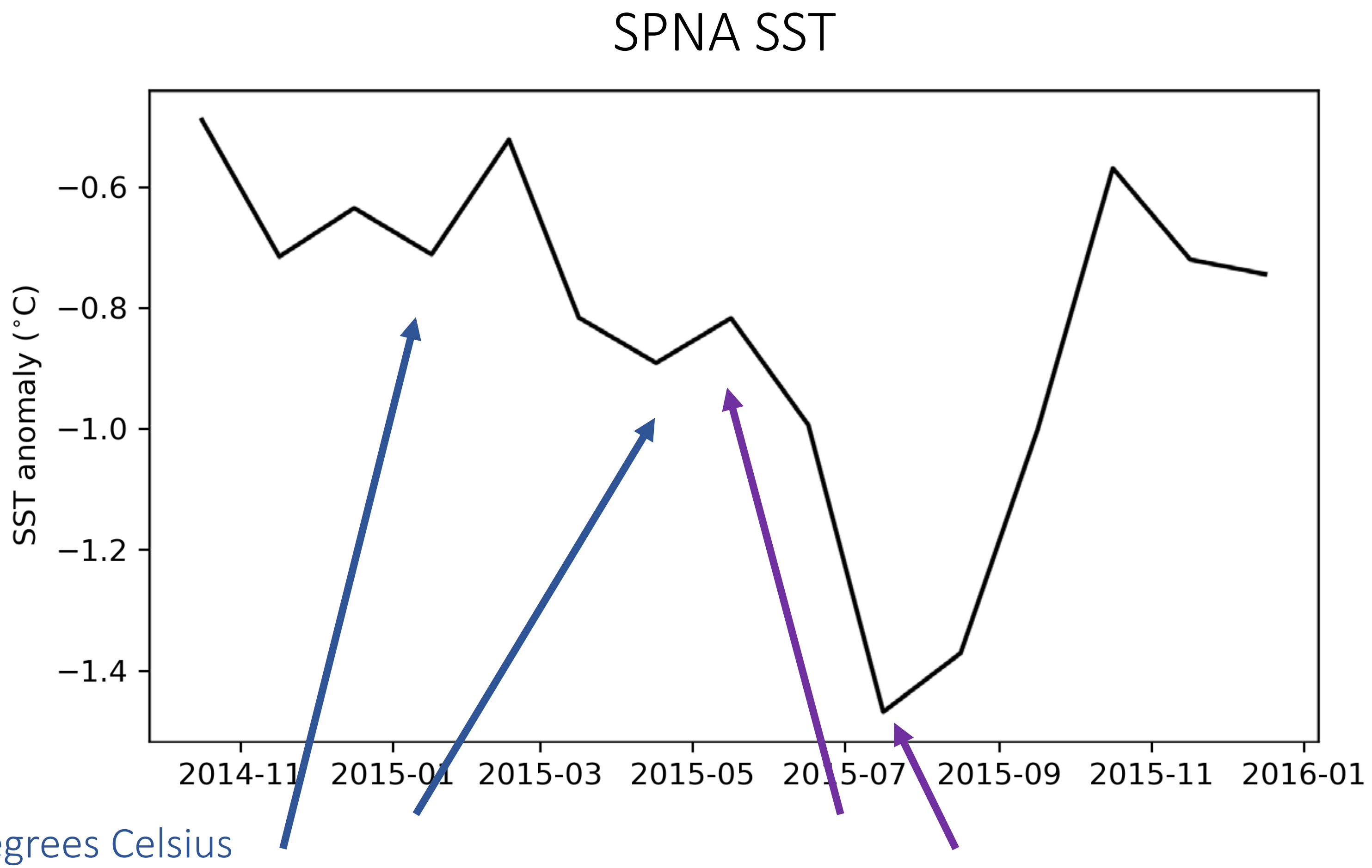

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May – July: -0.6 degrees Celsius
Modest cooling (~10 W/m^2) + shallow summer mixed layer
→ strong surface cooling

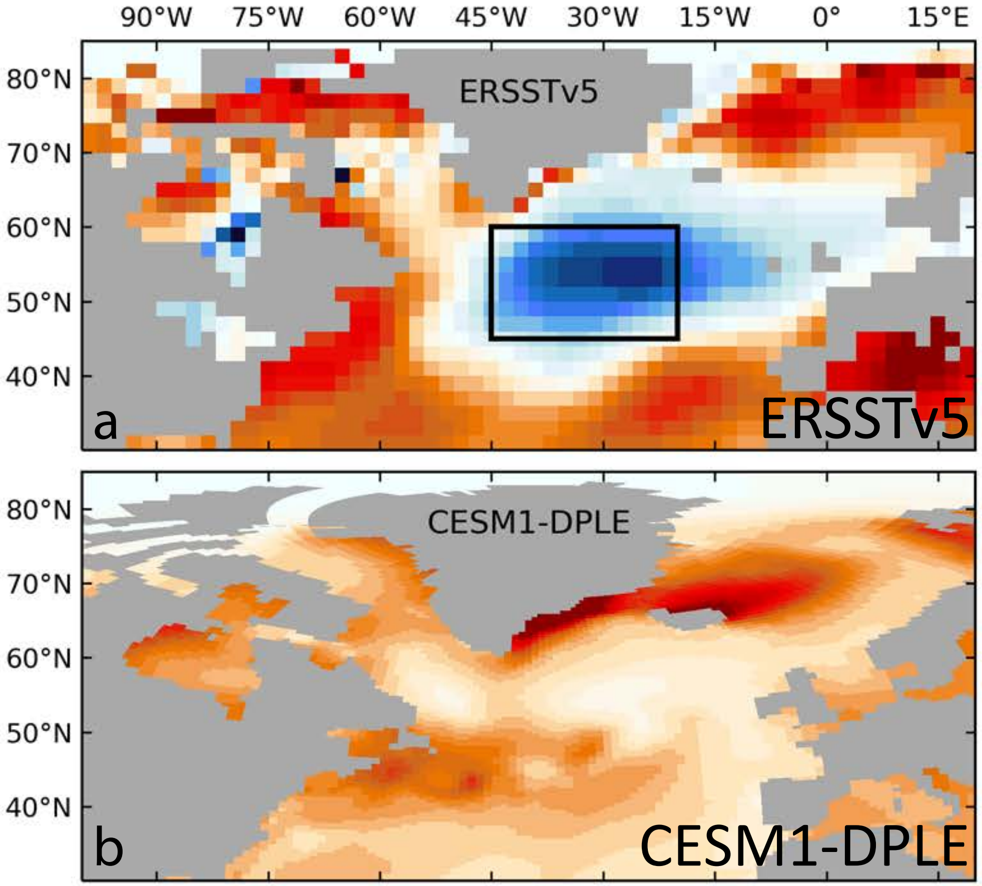
Three features needed for a skillful cold blob 2015 prediction:

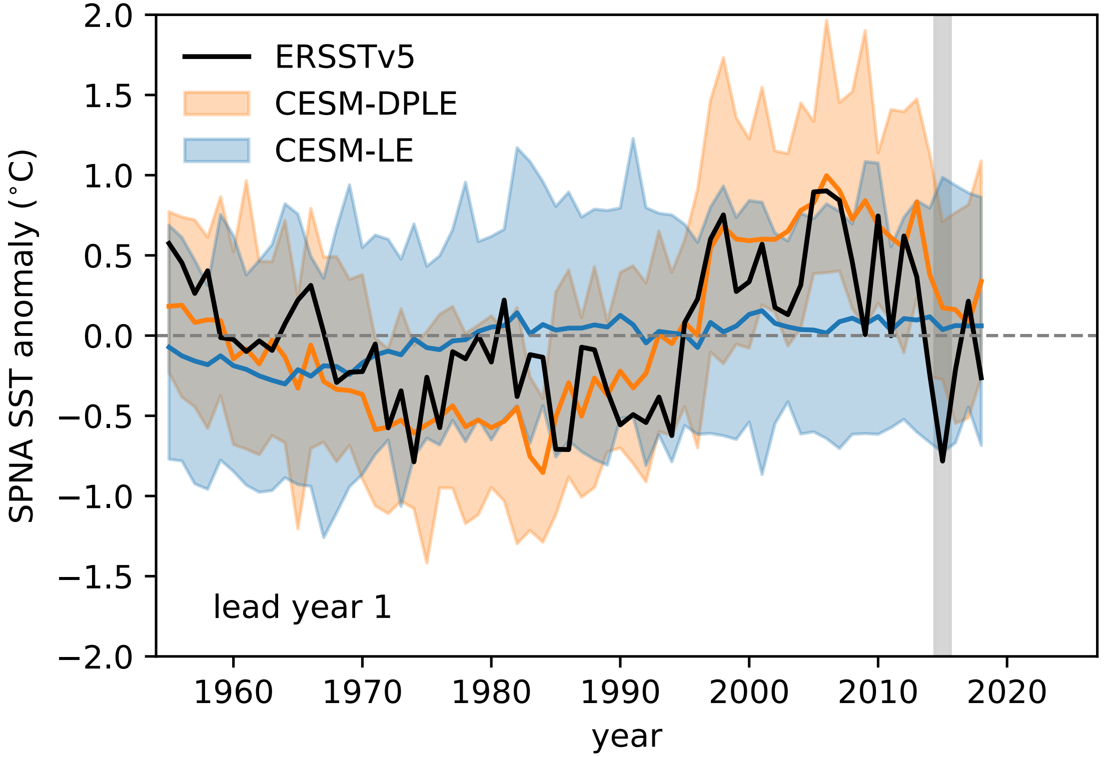
1. A reasonable initialization at both the surface and in the upper ocean
2. Positive JFM NAO prediction
3. Sufficient spread in summertime surface heat fluxes for surface amplified cooling from May through July

(4. A model that represents North Atlantic climate processes well enough)

The Community Earth System Model Decadal Prediction Large Ensemble (CESM1-DPLE), struggled with this cold event, despite otherwise high SPNA SST skill and cold SPNA initial conditions.

9-month lead time prediction for JJA 2015





Maroon et al. (2021)

Why did CESM1-DPLE struggle with this event?

Many possibilities:

- CESM cannot produce these kinds of events

Maroon et al. (2021)

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Three initial condition related deficiencies identified and tested:

- ~~Too much Barents-Kara sea ice degrades NAO evolution?~~
- DPLE SPNA upper ocean too warm and too fresh: Possibly an issue
- DPLE atmospheric ICs not based on observations: ERA-I based IC degraded hindcast further

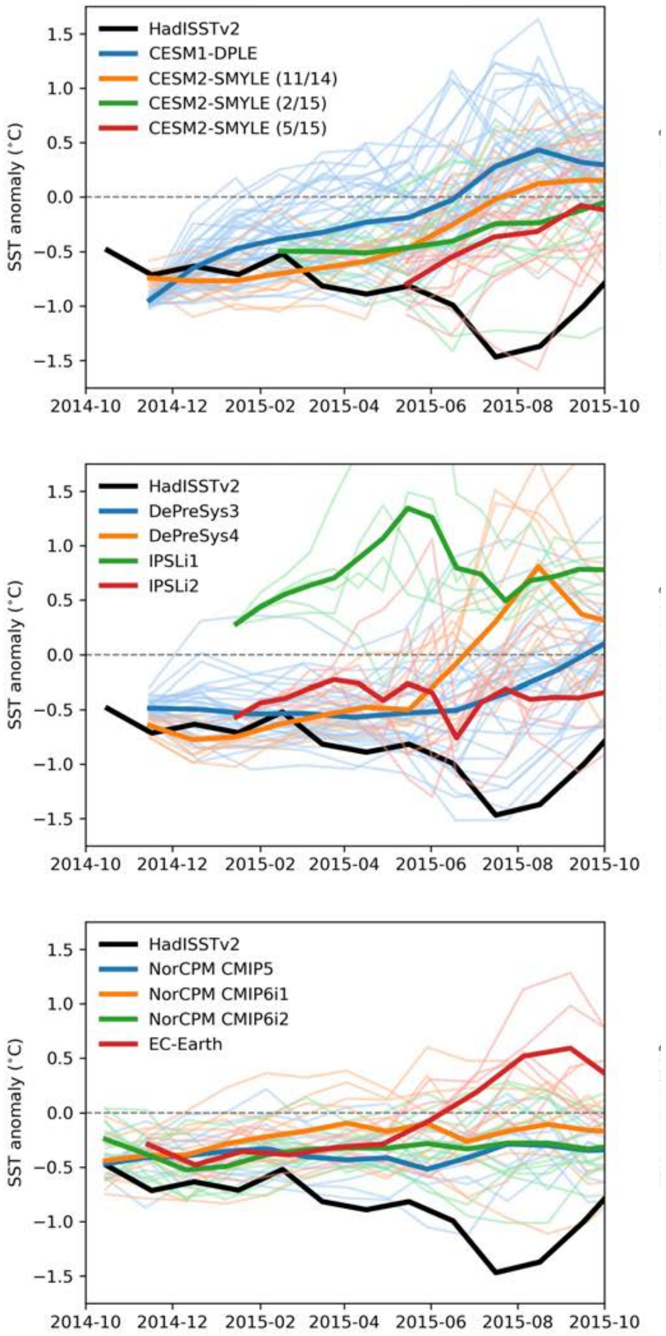
Maroon et al. (2021)

Maybe it's just the CESM1-DPLE. What about other systems?

Prediction System	Resolution	Start Date	Initialization technique	Ensemble size	Years used	Reference
CESM1-DPLE	Atm: 1°, 30 levels Ocn: 1°,60 levels	Nov 1	Full field initialization from CESM1-FOSI	40 members	1954-2017	Yeager et al. (2018)
CESM2-SMYLE	Atm: 1°, 30 levels Ocn: 1°,60 levels	Nov 1, Feb 1, May 1	Full field initialization from CESM2-FOSI	10 members	1983-2017	In progress
DePreSys3	Atm: 0.83°x 0.55°, 85 levels Ocn: 0.25°, 75 levels	Nov 1	Full field data assimilation	40 members	1981-2017	Dunstone et al. (2016) Dunstone et al. (2018)
DePreSys4	Atm: N316, 85 levels Ocn: ~0.25 deg	Nov 1	Full field data assimilation	10 members	1982-2017	In progress
EC-Earth3	Atm: 80km, 91 levels Ocn: 1°, 75 levels	Nov 1	Anomaly initialization with ORAS5/ERA-I	5 members	1979-2017	In progress
IPSL-CM5A-LR	Atm: 96x96, 39 levels Ocn: 182x149, 31 levels	Jan 1	Anomaly initialization from nudged hindcast	5 members x 2 hindcasts in initialized in 2015	1969-2014	Swingedouw et al. (2013), Mignot et al. (2016)
NorCPM1 (CMIP5)	Atm: 1.9°x2.5°, 26 levels Ocn: 1°, 53 levels	Oct 15	Anomaly initialization from multivariate/flow-dependent DA hindcast	10 members	1983-2017	Counillon et al. (2016) Wang et al. (2017)
NorCPM1 V1C (CMIP6)	Atm: 1.9°x2.5°, 26 levels Ocn: 1°, 53 levels	Oct 15	Anomaly initialization from multivariate/flow-dependent DA hindcast	10 members x 2 hindcasts initialized in 2014	1960-2017	Counillon et al. (2016) Wang et al. (2017)

Anomalies calculated with drift correction using a 1983-2014 climatology. Analyzing anomalies from hindcasts initialized in late 2014/early 2015

Intensity

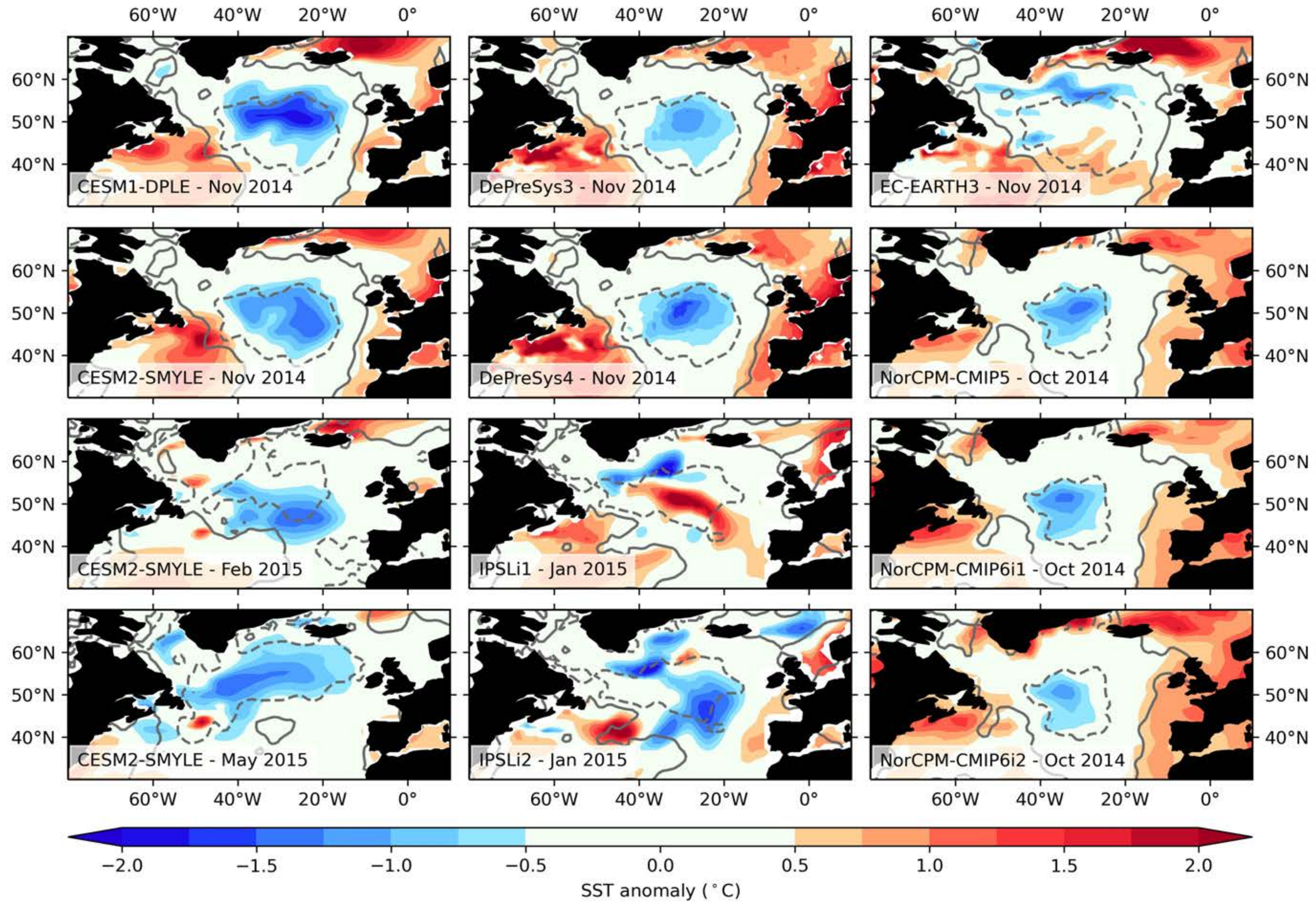


No hindcast mean captured the intensity of the summer cold anomaly, though a few ensemble members did.

Intensity: Area-averaged SST from (45-60N, 45-20W)

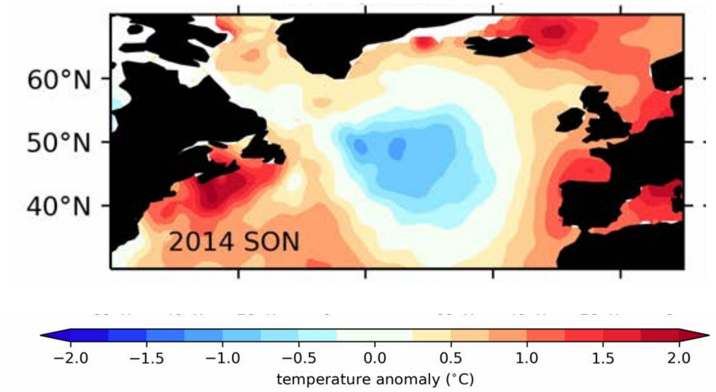
Maroon et al. (in prep)

Month 1 SST hindcast predictions



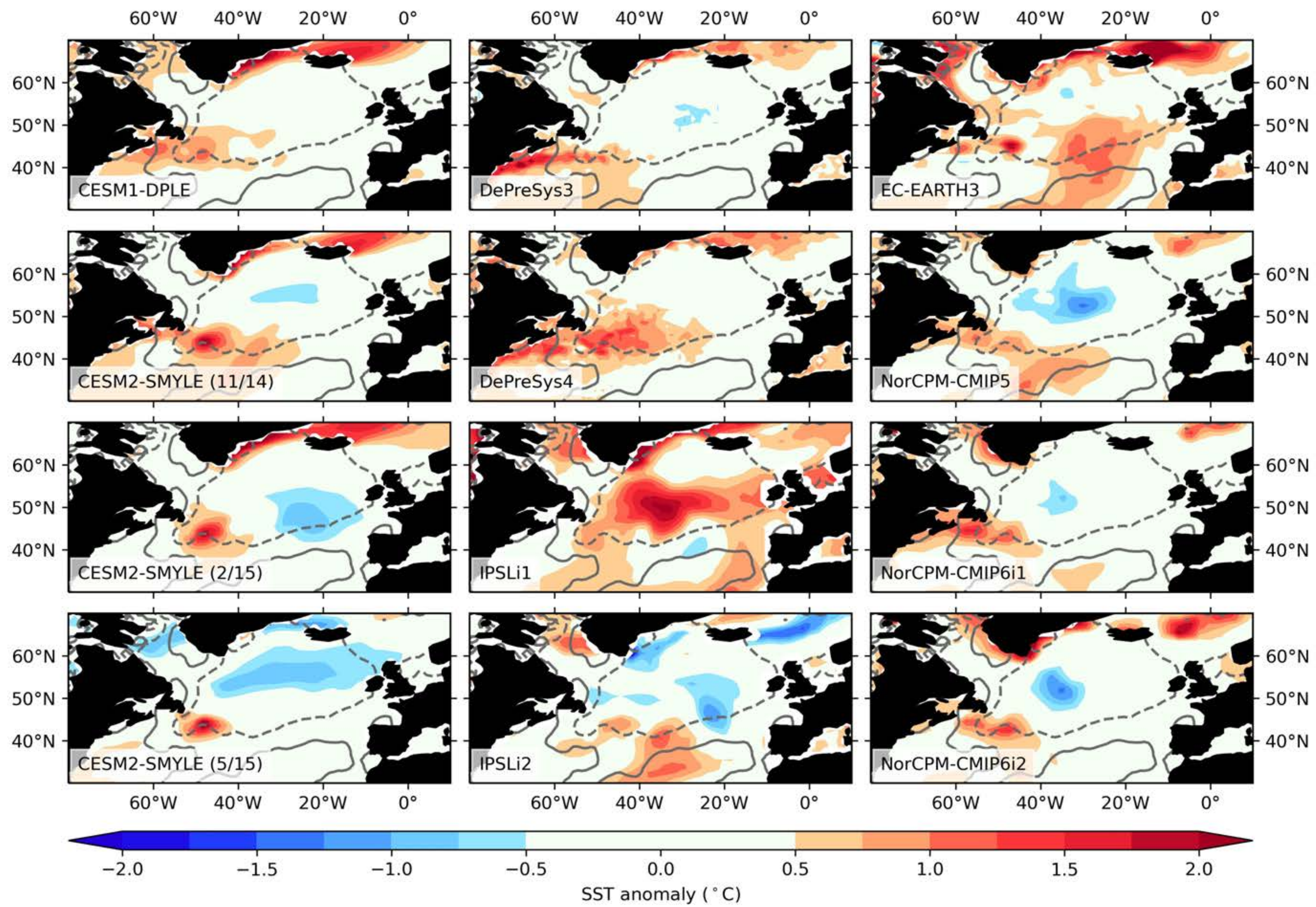
Most hindcasts show SST placement that approximates observations during the first month.

HadISST



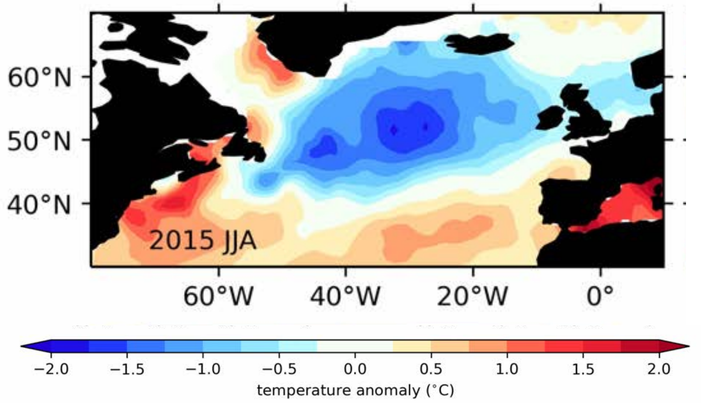
Gray lines = +/- 0.5°C anomaly from HadISST
First shaded colors = +/- 0.5°C from hindcasts

JJA SST hindcast predictions



The predicted blobs largely fade by summer 2015.

HadISST



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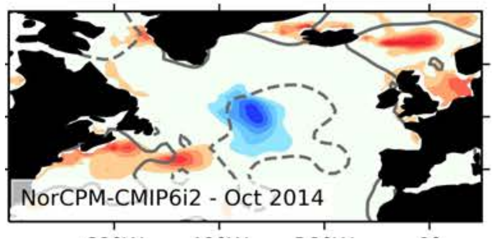
Summary of Multimodel Comparison



Upper ocean temperature was often initialized with a smaller spatial cold anomaly extent than observed.

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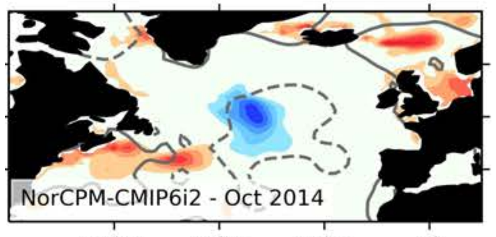
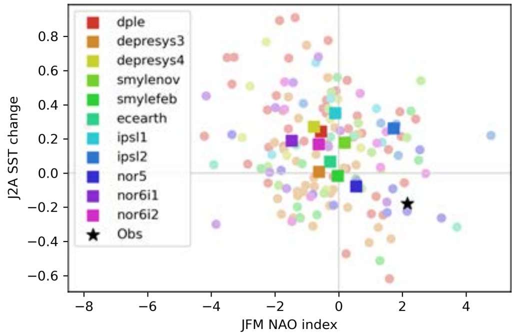


Upper ocean temperature was often initialized with a smaller spatial cold anomaly extent than observed.

The strong positive 2015 JFM NAO was not predicted by any hindcast ensemble mean, though by a few ensemble members



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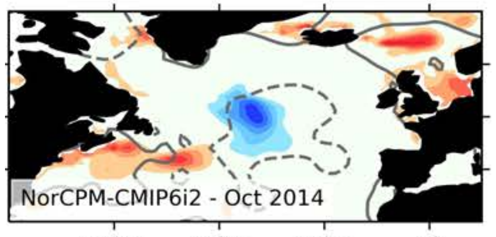

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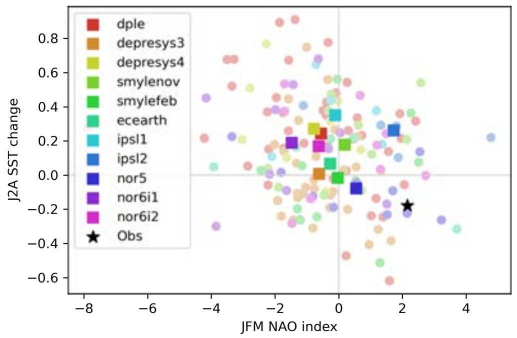

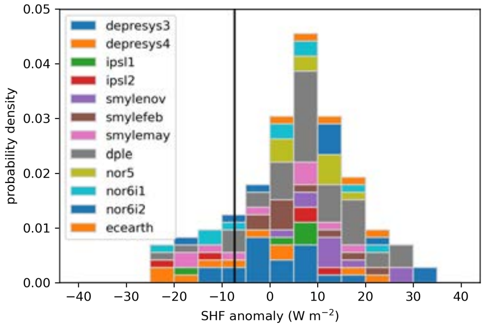

Spread in SHF across all hindcasts encompassed observed modest summer cooling.

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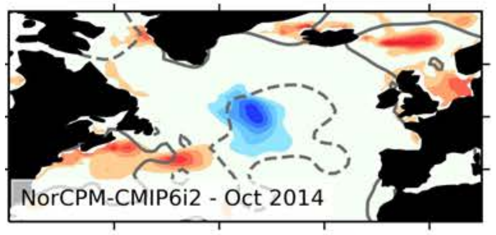

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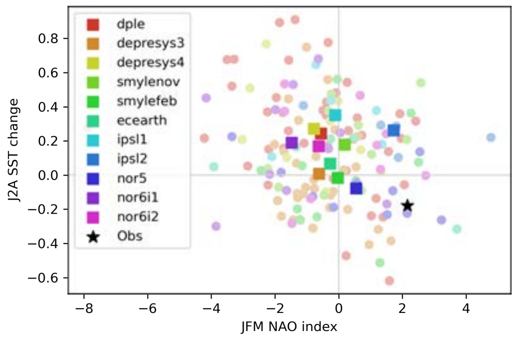
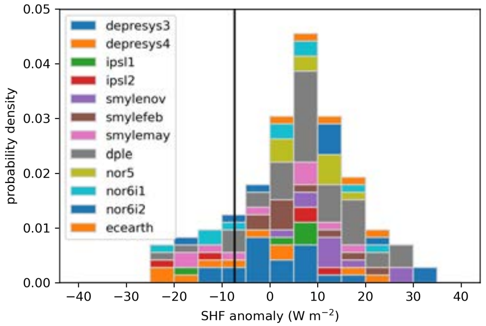
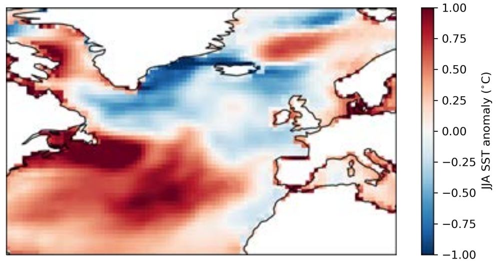




Spread in SHF across all hindcasts encompassed observed modest summer cooling.

The four ensemble members that have positive JFM NAO and modest summer cooling by chance also have cold blob.



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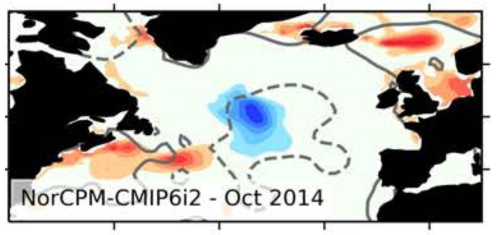

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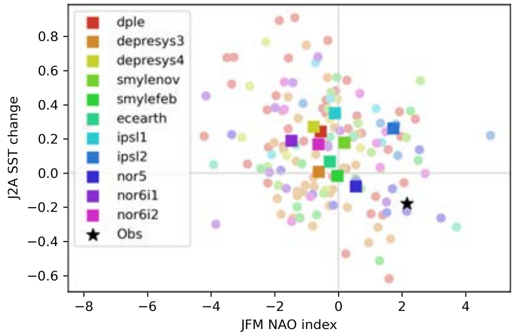

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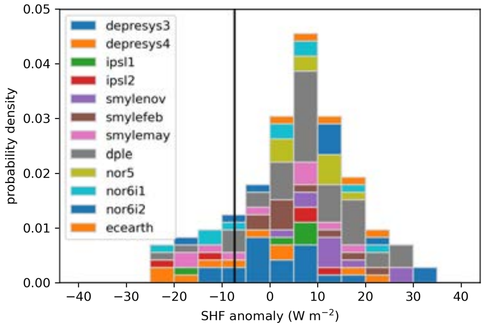

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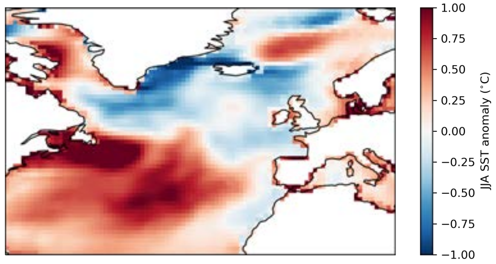

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