

A Teleconnection Reanalysis and Forecast Monitoring Tool for GMAO Model Products

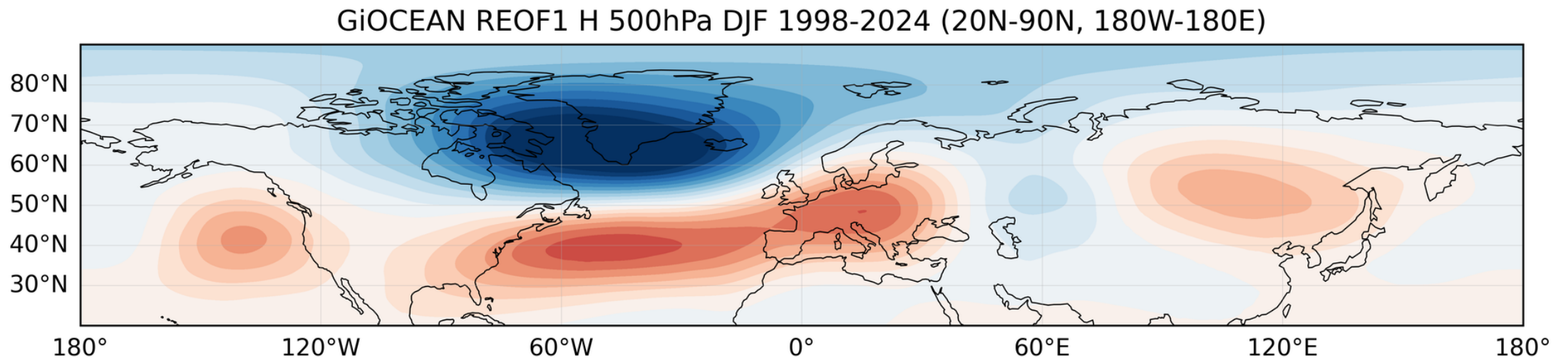
Vir S Gandhi

Mentors: Priyanka Yadav · Michael Bosilovich

Global Modeling and Assimilation Office · Summer Internship · July 30, 2026

Why teleconnections?

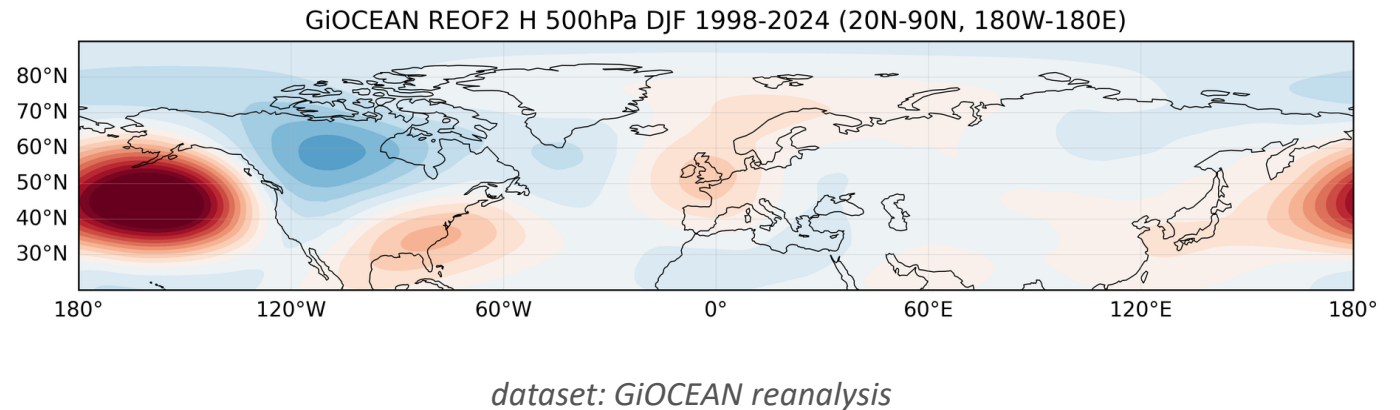
- They drive regional weather: the NAO steers Atlantic storm tracks and European winters; the PNA shapes North American temperature and rainfall.
- Computing them consistently - across datasets, levels and seasons - is computationally heavy.
- **This summer: a tool that computes teleconnection indices for the GMAO datasets.**



The winter AO (Arctic Oscillation) pattern in the GiOCEAN dataset - the first of ten modes the tool tracks.

GMAO forecasts ENSO. What about the extratropics?

- I developed a tool that produces teleconnection indices for GEOS-S2S.
- GMAO publishes forecast plumes for Nino 3.4; this extends that product family to the AO and PNA, which carry most of the NH seasonal predictability.
- Observed patterns from the reanalysis; forecast indices from GEOS-S2S-3.



Right: REOF2, the Pacific North American pattern - the second of the ten winter modes; the AO on the previous slide is the first.

One tool - every choice is one line

```
# ===== settings =====
# the initialization month to process (all start dates inside it)
INIT_YEAR   = 2026
INIT_MONTH  = 7

VARIABLE    = "H"                # field to analyze
LEVELS      = [500, 250]         # hPa
DOMAIN      = "20N_90N"

# how each index is computed: "projection" (each map onto one standardized
# observed pattern at a time) or "least_squares" (all patterns at once)
METHOD      = "projection"

SEASON_OF   = {12: "DJF", 1: "DJF", 2: "DJF",
               3: "MAM", 4: "MAM", 5: "MAM",
               6: "JJA", 7: "JJA", 8: "JJA",
               9: "SON", 10: "SON", 11: "SON"}

N_PLOT      = 10                 # modes to draw a plume for
# =====
```

- Initialization month: any month with forecasts in the archive.
- Variable and pressure level: H at 500 or 250 hPa - or any field in the collection.
- Domain and season: the pattern set follows the verifying month automatically.
- Index convention: projection or least squares.

The settings block of the forecast script: rerunning for a new case is an edit to one line.

hPa: hectopascal (pressure) | DJF, MAM, JJA, SON: three-month seasons by month initials

Documented and versioned on GitHub

The screenshot displays the GitHub interface for the repository `virsgandhi20 / GEOS-S2S-3`. The left sidebar shows the file tree with the `docs` directory expanded, highlighting `methodology.md`. The main content area shows the file path `GEOS-S2S-3 / docs / methodology.md` and a commit message by `virgandhi2`. Below the commit information, tabs for `Preview`, `Code`, and `Blame` are visible. The `Preview` tab is active, showing the content of `methodology.md`. The document is titled **Methodology** and includes sections for **Overview** and **The dataset and its consequences for the code**. The **Overview** section describes the GIOCEAN analysis and the forecast height map. The **The dataset and its consequences for the code** section describes the GEOS-S2S-3 near-real-time archive (PFE) and its initialization and forecast processing.

Methodology

This document describes how the GEOS-S2S-3 forecast teleconnection indices and the plume figures are computed, with the reasoning behind each step. Each section names the function that implements it, so the document can be read alongside the code. The settings that control a run are at the top of each script.

Overview

The GIOCEAN analysis identifies the recurring patterns of Northern Hemisphere height variability (the North Atlantic Oscillation, the Pacific/North American pattern, and so on) and saves them as data (`patterns.nc`). This repository does not derive any new patterns. Each forecast height map is measured against the saved patterns, giving one teleconnection index per pattern per forecast, on the same scale as the historical record. A complicated forecast map is thereby reduced to a short set of interpretable quantities, such as a positive NAO phase and a negative PNA phase.

The method was developed and verified on the GEOS-S2S-2 hindcast archive (the GEOS-S2S-2 repository), where the indices could be checked against the observed record; the leading winter modes verify at about 0.6 correlation at one month lead. The identical chain runs here on the GEOS-S2S-3 near-real-time forecasts.

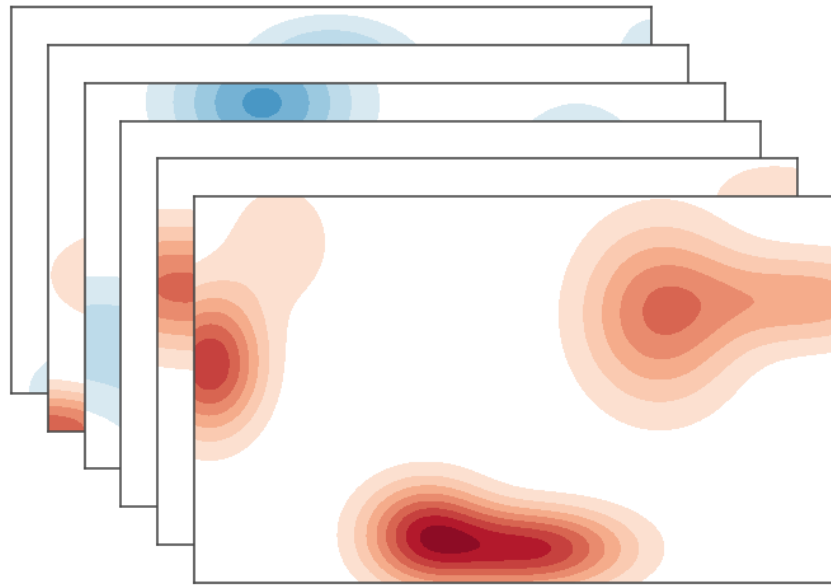
The dataset and its consequences for the code

The GEOS-S2S-3 near-real-time archive (PFE) holds an initialization every five days, each carrying five ensemble members; a subset of members, including several on the month's final start date (which carries fifteen), extends to nine lead months while the rest stop at three. Every run includes the partial initialization month itself, and all available forecast months are processed. The height field `H` sits on pressure levels, on the same half-degree grid as GIOCEAN, so no regridding is needed (`read_field` falls back to interpolation should a dataset differ).

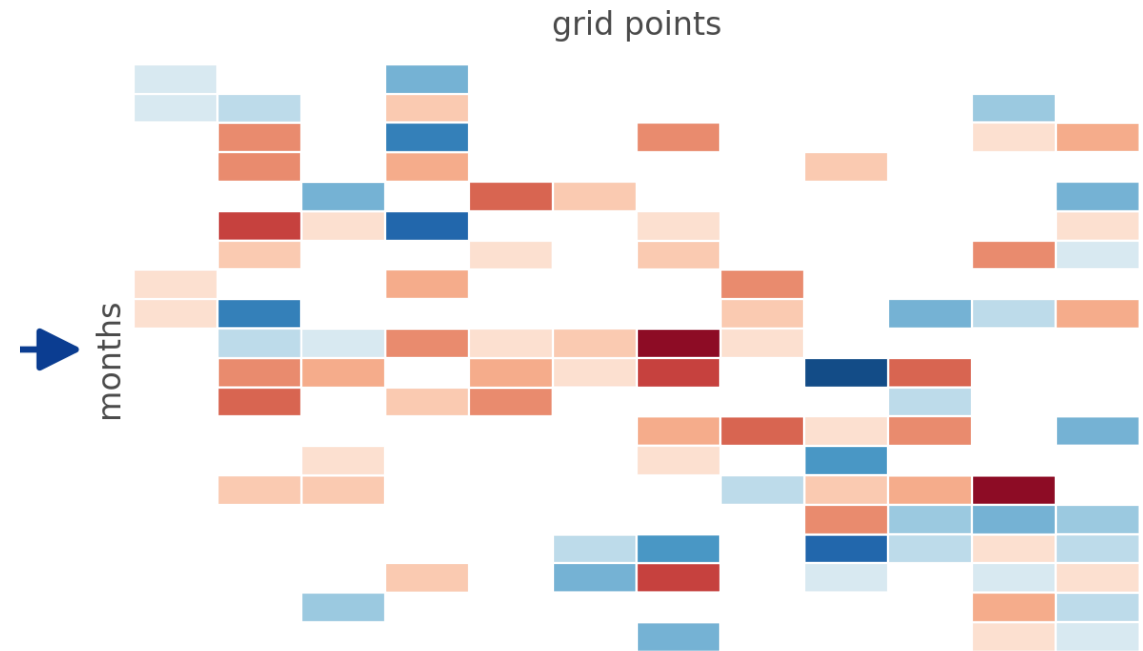
The methodology document in the GEOS-S2S-3 repository: every step written down, every script and output under version control - and a README with instructions for anyone who wants to replicate it.

GEOS-S2S-3: Goddard Earth Observing System Subseasonal-to-Seasonal, version 3

Every month is a mix of a few basic patterns



... x 81 winter months

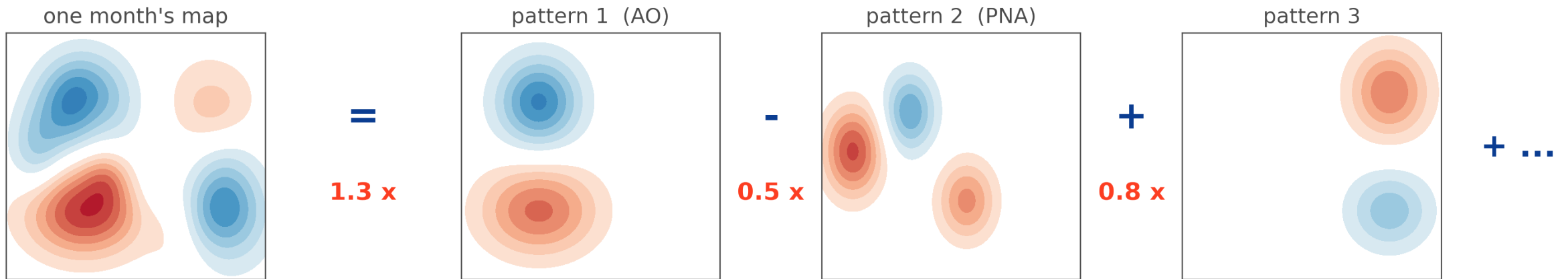


one table: 81 months x ~100,000 grid points

27 years of monthly height maps, repeated for every season - each map becomes one row of the table. (Schematic: synthetic fields, for illustration.)

height map: the geopotential height field (H), the altitude of a pressure surface

Every month is a mix of a few basic patterns



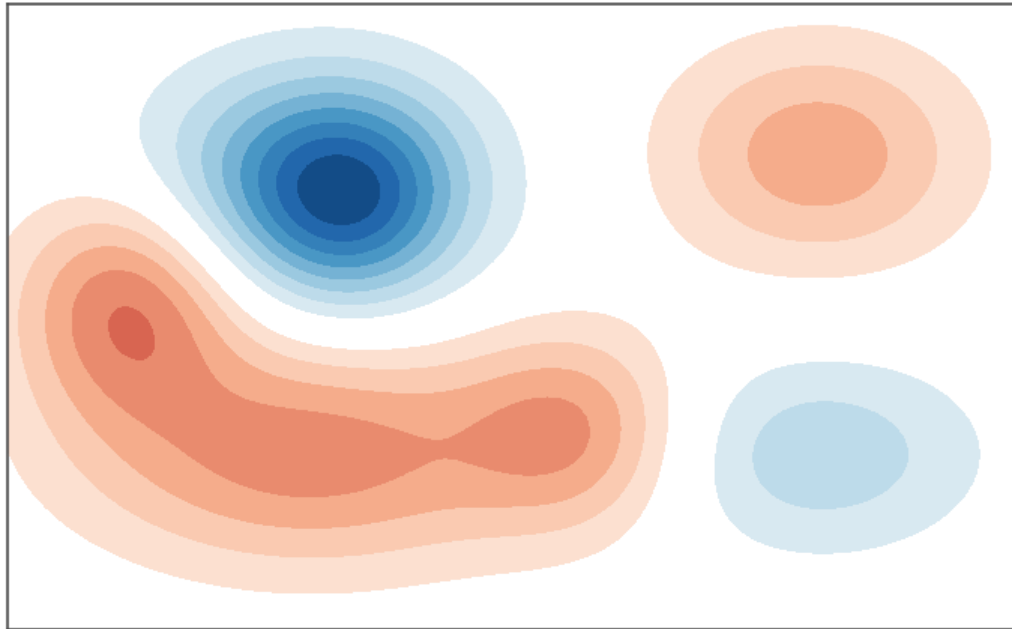
the amounts change every month - the patterns never do (synthetic fields, for illustration)

EOF analysis discovers the ingredient list: fixed patterns, monthly amounts. (Schematic: synthetic fields, for illustration.)

EOF: empirical orthogonal function

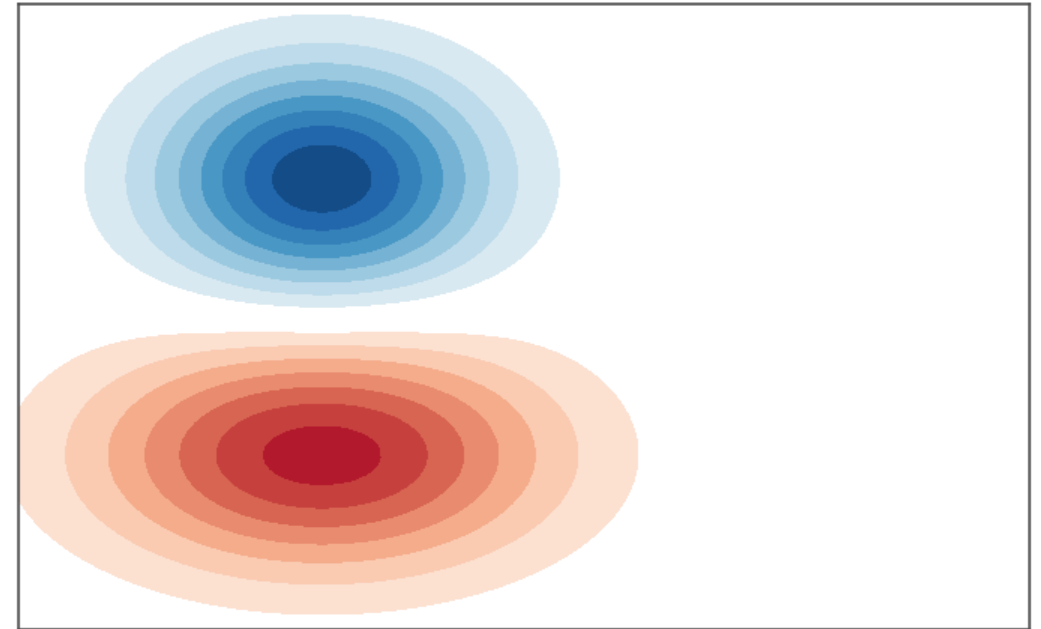
Why the patterns are rotated

raw EOF: mathematically optimal,
spread across the hemisphere



after rotation: one region,
one nameable pattern

rotate

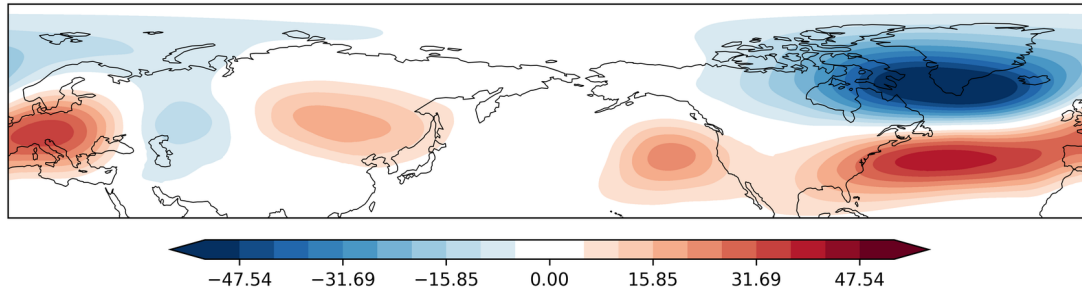


Rotation refocuses each pattern on one region - same information, but now each mode has a name: AO, PNA, ... (Schematic, for illustration.)

Two independent reanalyses, the same indices

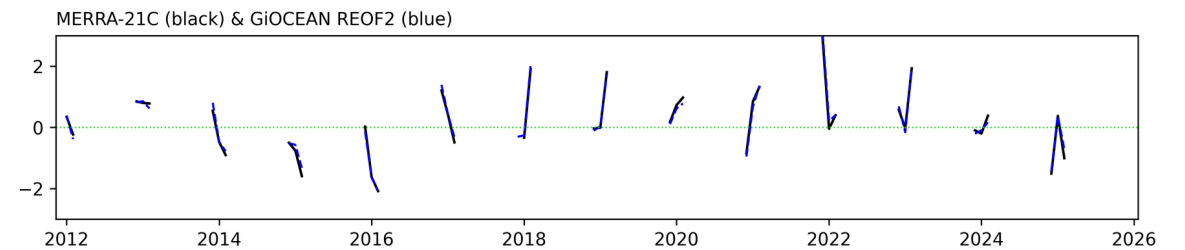
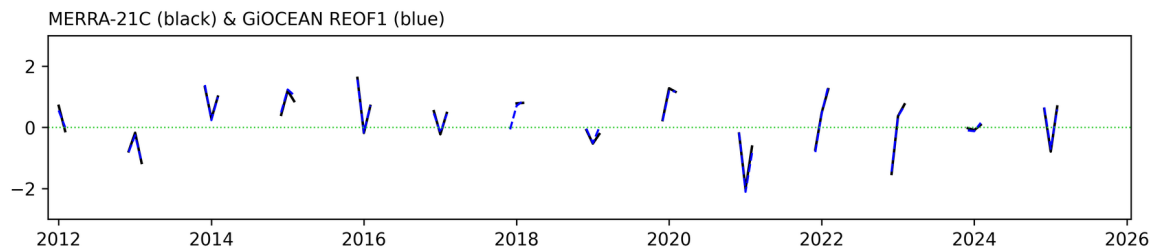
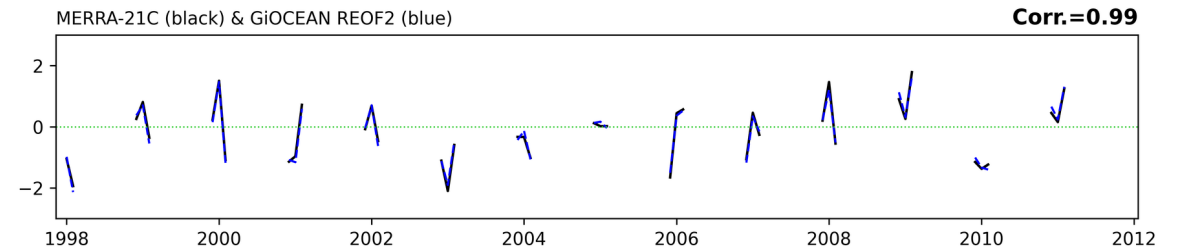
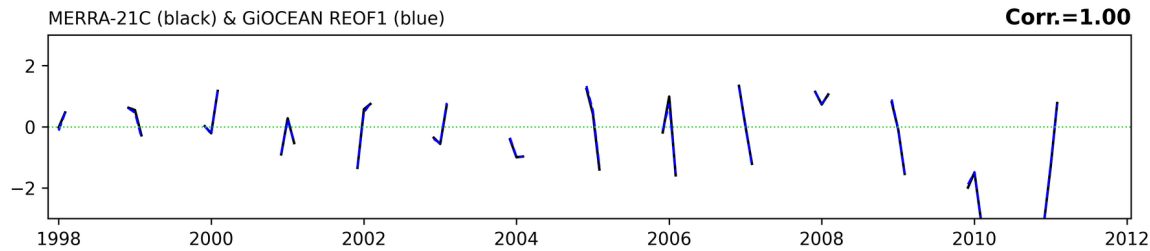
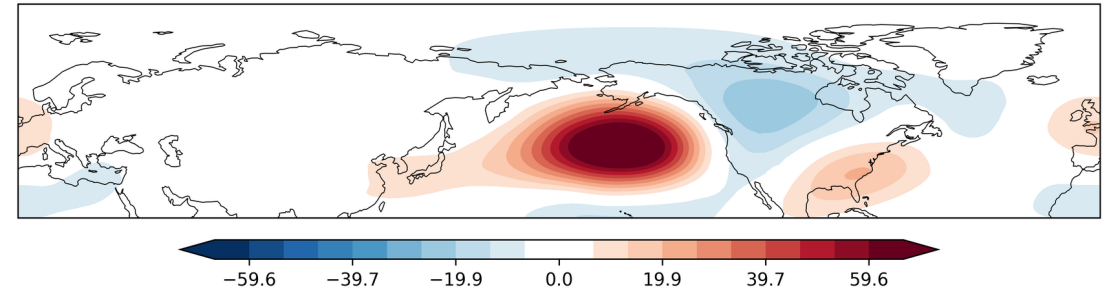
REOF1: the Arctic Oscillation (AO)

MERRA-21C REOF1 H 500hPa DJF 1998-2024 (20N-90N)



REOF2: the Pacific North American pattern (PNA)

MERRA-21C REOF2 H 500hPa DJF 1998-2024 (20N-90N)



MERRA-21C and GIoCEAN analyzed independently: REOF1 (the AO) correlates at 1.00, REOF2 (the PNA) at 0.99 - black and blue curves sit on top of each other.

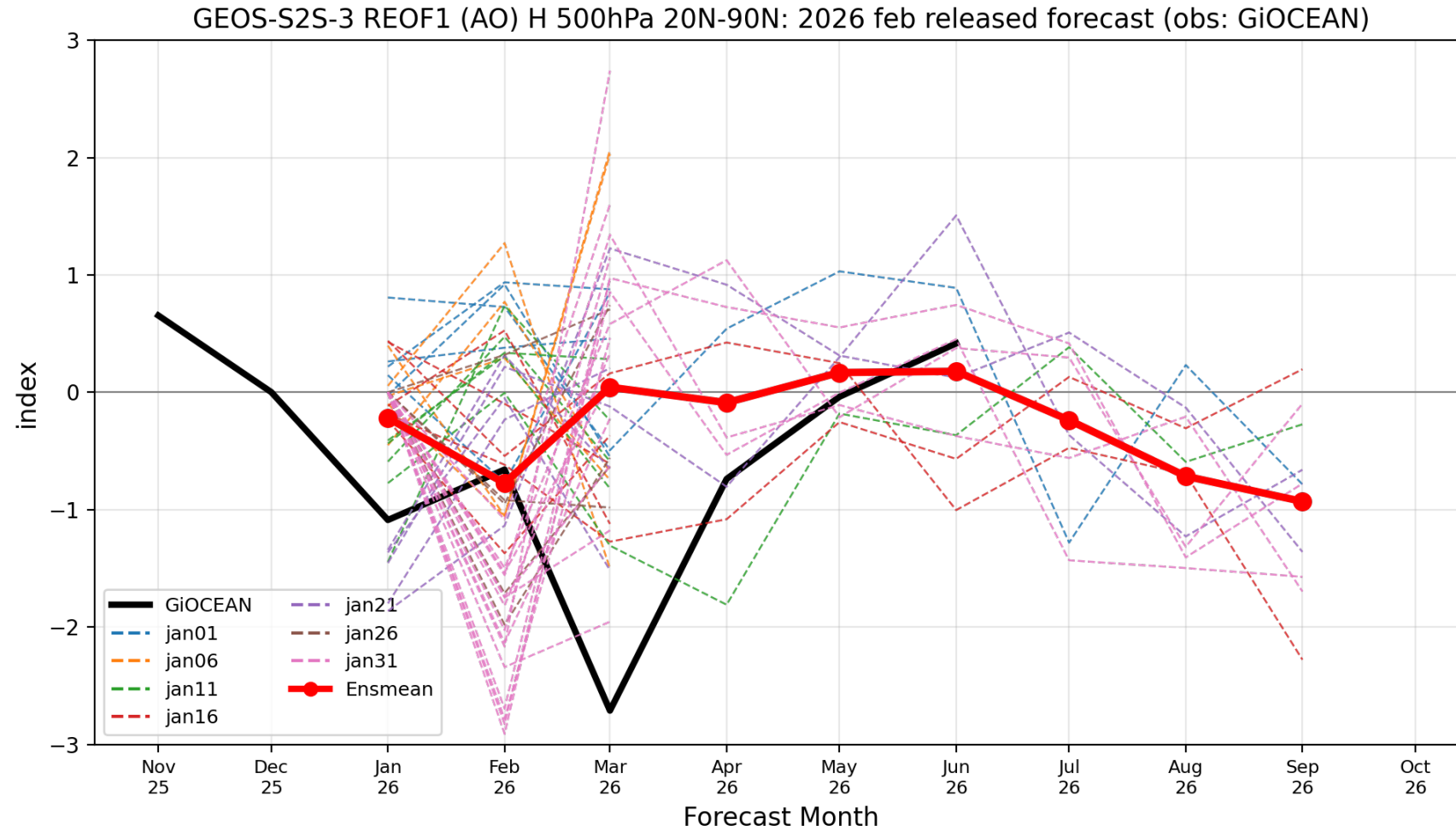
REOF: rotated empirical orthogonal function | NAO: North Atlantic Oscillation | AO: Arctic Oscillation | PNA: Pacific North American pattern

From reanalysis to forecast



Drift correction: forecasts are compared with the model's own typical state for that start month and lead - what remains is the actual prediction.

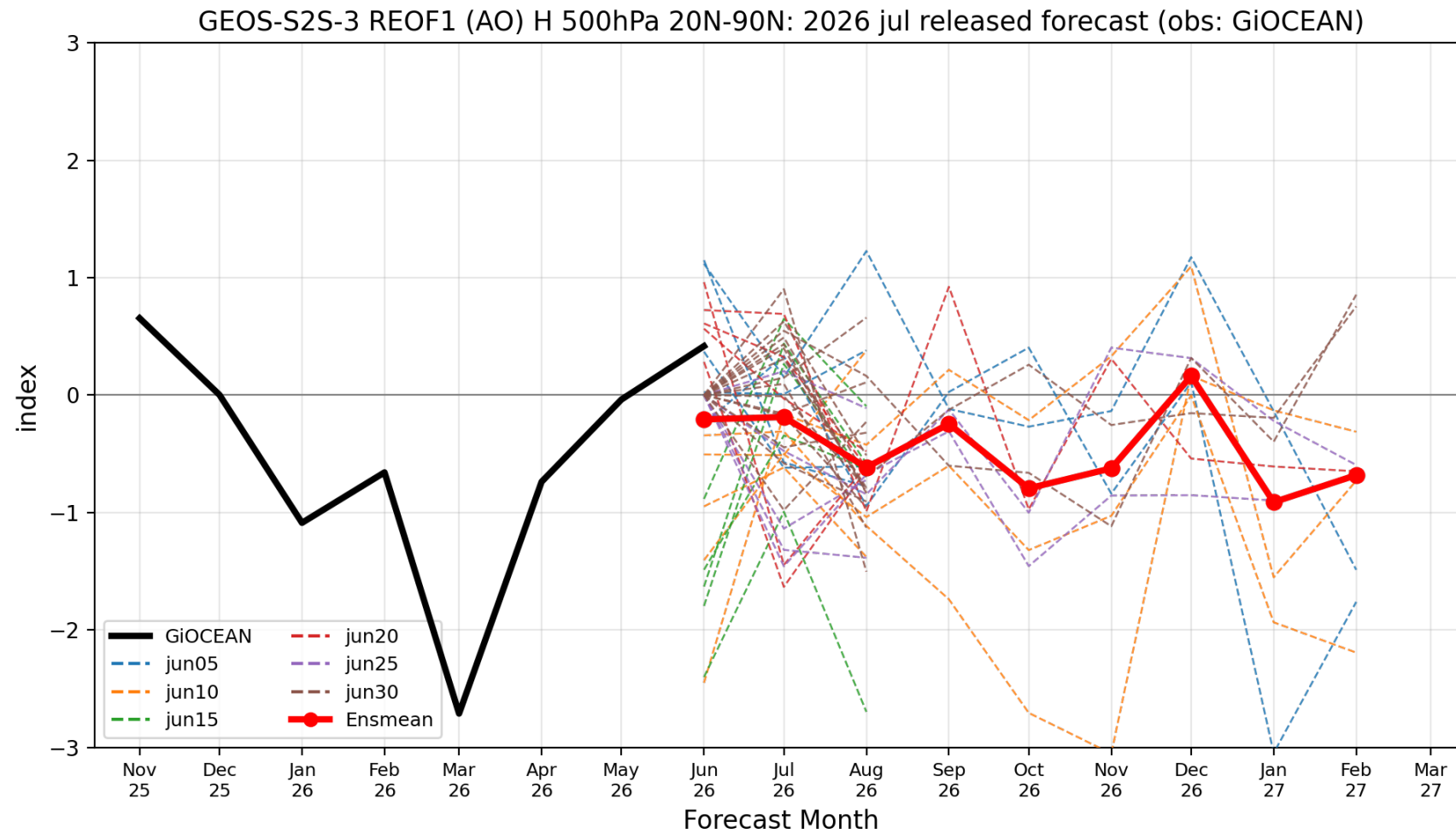
The product: a teleconnection forecast plume



REOF1, the AO. Black: observed (GiOCEAN, through June). Dashed: 45 ensemble members by start date. Red: the ensemble mean. Where black overlaps the plume, the forecast can be judged against what happened.

REOF: rotated empirical orthogonal function | NAO: North Atlantic Oscillation | AO: Arctic Oscillation | H: geopotential height | hPa: hectopascal (pressure)

And this is what it says right now: the July release



The current release: 40 members from the June 2026 starts; a subset of extended members runs nine months, into the 2026-27 winter.

REOF: rotated empirical orthogonal function | NAO: North Atlantic Oscillation | AO: Arctic Oscillation | H: geopotential height | hPa: hectopascal (pressure)



GMAO

Thank you



github.com/virsgandhi20/GEOS-S2S-3

Vir S Gandhi · Mentors: Priyanka Yadav · Michael Bosilovich