NOAA / SCOUT COUPLED REANALYSIS · OBSERVING-SYSTEM EXPERIMENTS

An Evaluation of the impact of ocean observations on a weakly coupled data assimilative Earth System Model

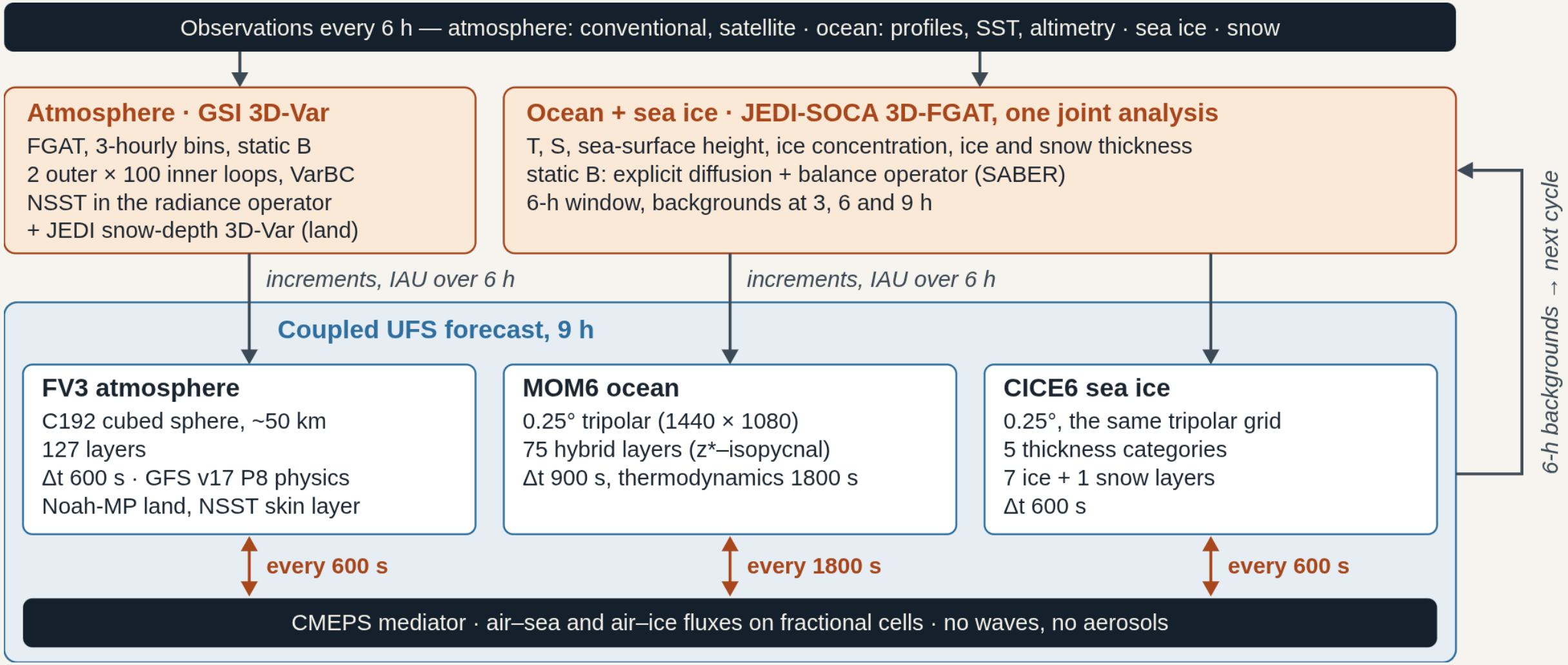
Developing NOAA's next reanalysis

Joao Marcos A. C. Souza - Joao.Souza@colorado.edu / Joao.Souza@noaa.gov

Sergey Frolov, Jeffrey Whitaker, Adam Schneider, Jack Woollen, Gilbert Compo, Phillip Pegion, Jessica Knezha, Sherrie Fredrick.

Jan 1 – Dec 6, 2023 · 340 days · 1 360 six-hourly cycles

Model: weakly coupled UFS cycling, identical in all four runs



Four experiments, three fishing-vessel networks

Experiment	Tropical moorings	Fishing vessels	Other in-situ ocean (WOD)
FULL_INPUT	✓	✓	✓
NO_MOORINGS	—	✓	✓
NO_FVON	—	—	✓
NO_INSITU	—	—	—

FVON · US northeast shelf

eMOLT and CFRF vessels; loggers on trawls and lobster traps

Accuracy: ±0.1 °C (Lowell)

Latency: cell upload on haul-back, hours to days

Here: all year; 1 382 sites, 94 215 obs, O−B 0.8 °C

fvon.org · erddap.fvon.org

FishSOOP · Australia (IMOS)

Moana sensors on the gear of 30+ vessels in 2023

Accuracy: ±0.05 °C, depth ±0.5%

Latency: deck unit on haul-back; near real time, GTS

Here: from 14 Apr; 21 103 sites, 861 317 obs, O−B 0.7 °C

imos.org.au · AODN portal

Moana · New Zealand

Mangōpare (Moana TD) sensors on 250+ vessels

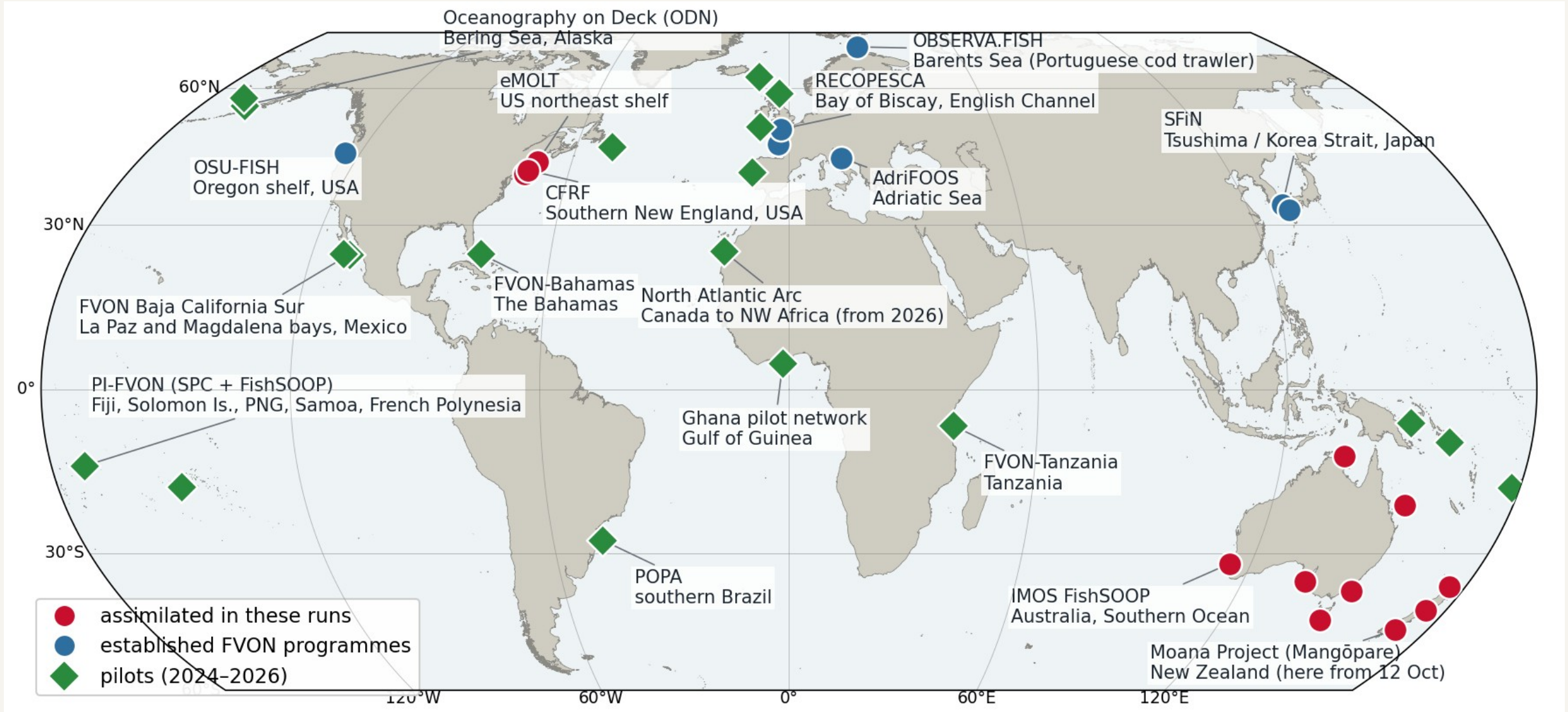
Accuracy: ±0.05 °C

Latency: automatic deck unit, near real time, GTS

Here: from 12 Oct; 12 022 sites, 407 785 obs, O−B 0.6 °C

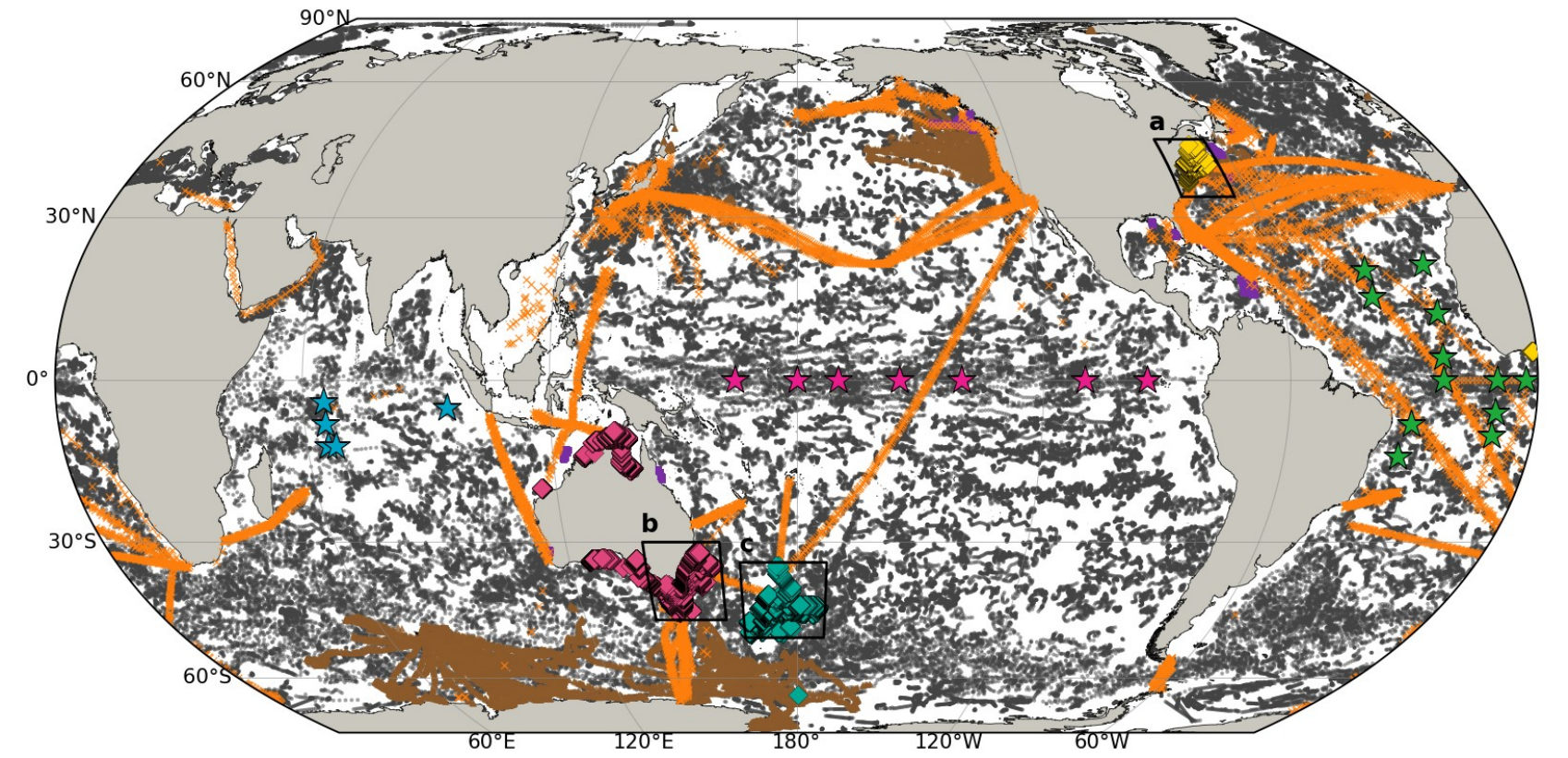
moanaproject.org

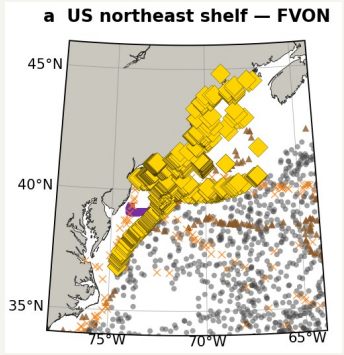
Fishing-vessel observing programmes worldwide



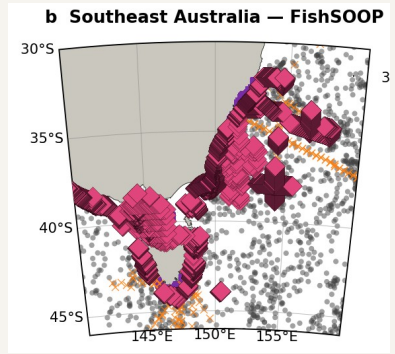
There is movement towards organized EU and US FVON networks (contact me if interested!)

Two denial pairs; fishing vessels sample the shelves

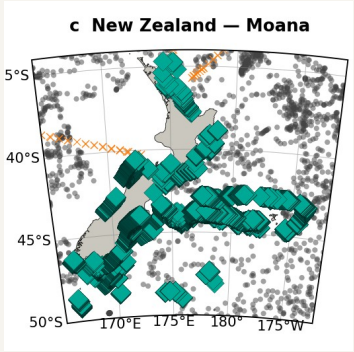




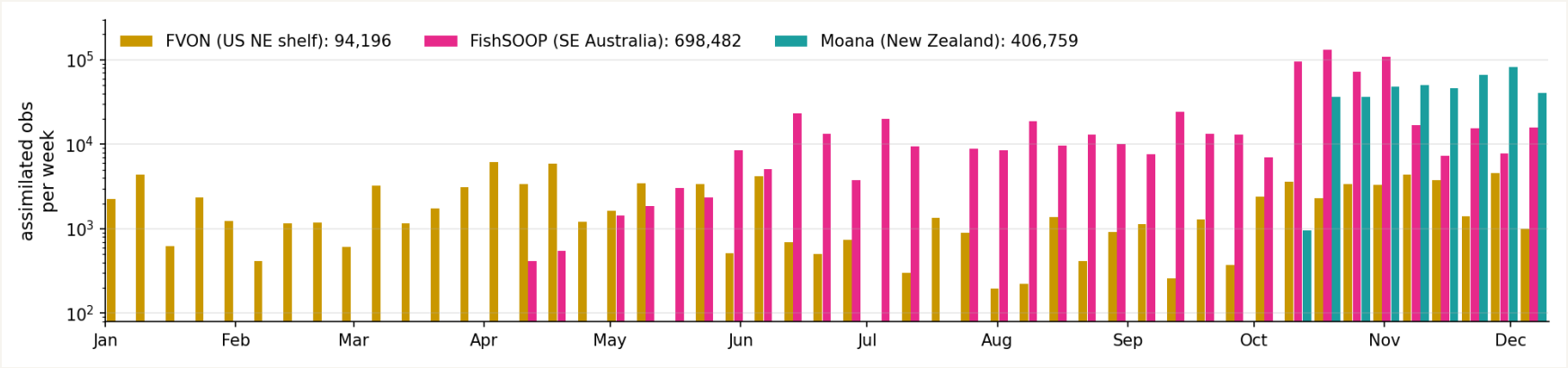
a · FVON · 1 382 sites



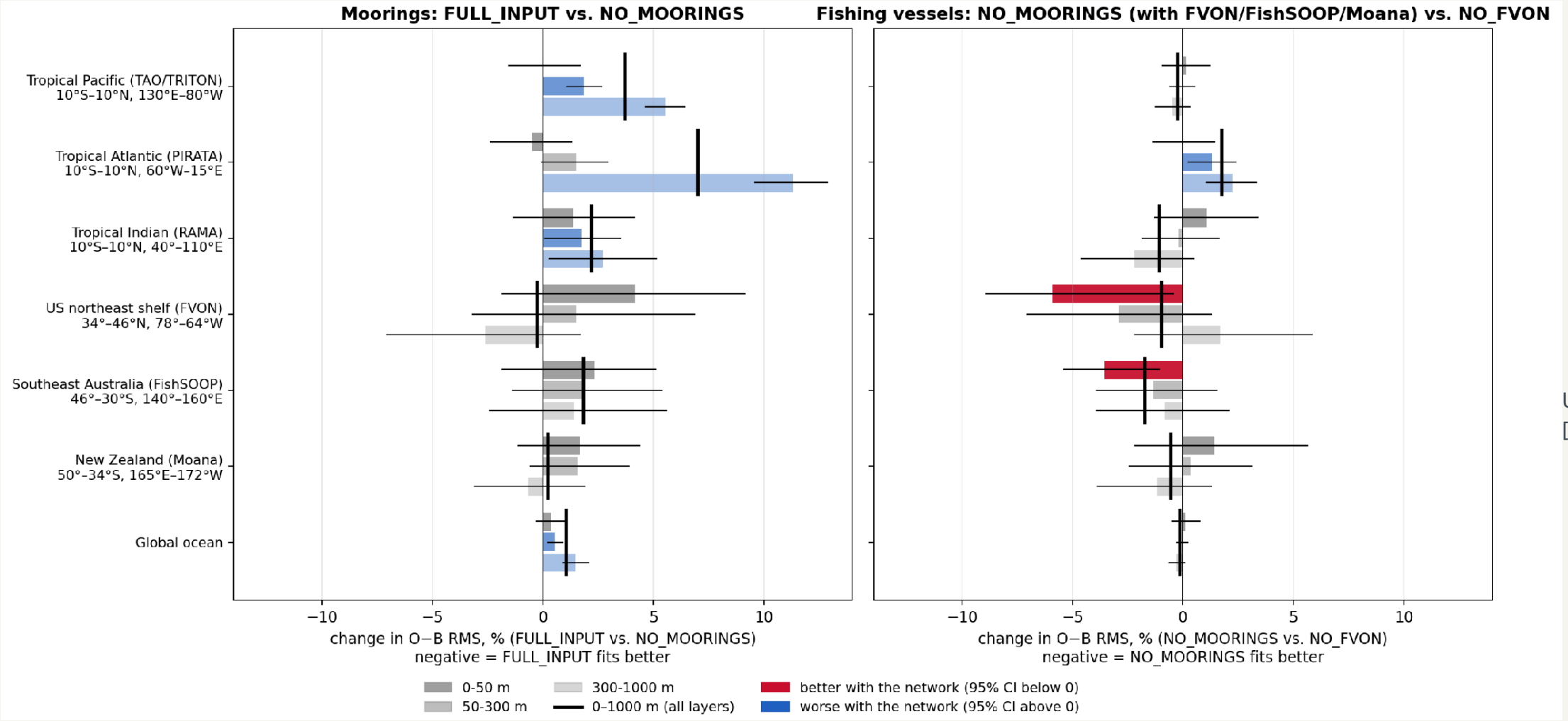
b · FishSOOP · 21 103, from 14 Apr



c · Moana · 12 022, from 12 Oct



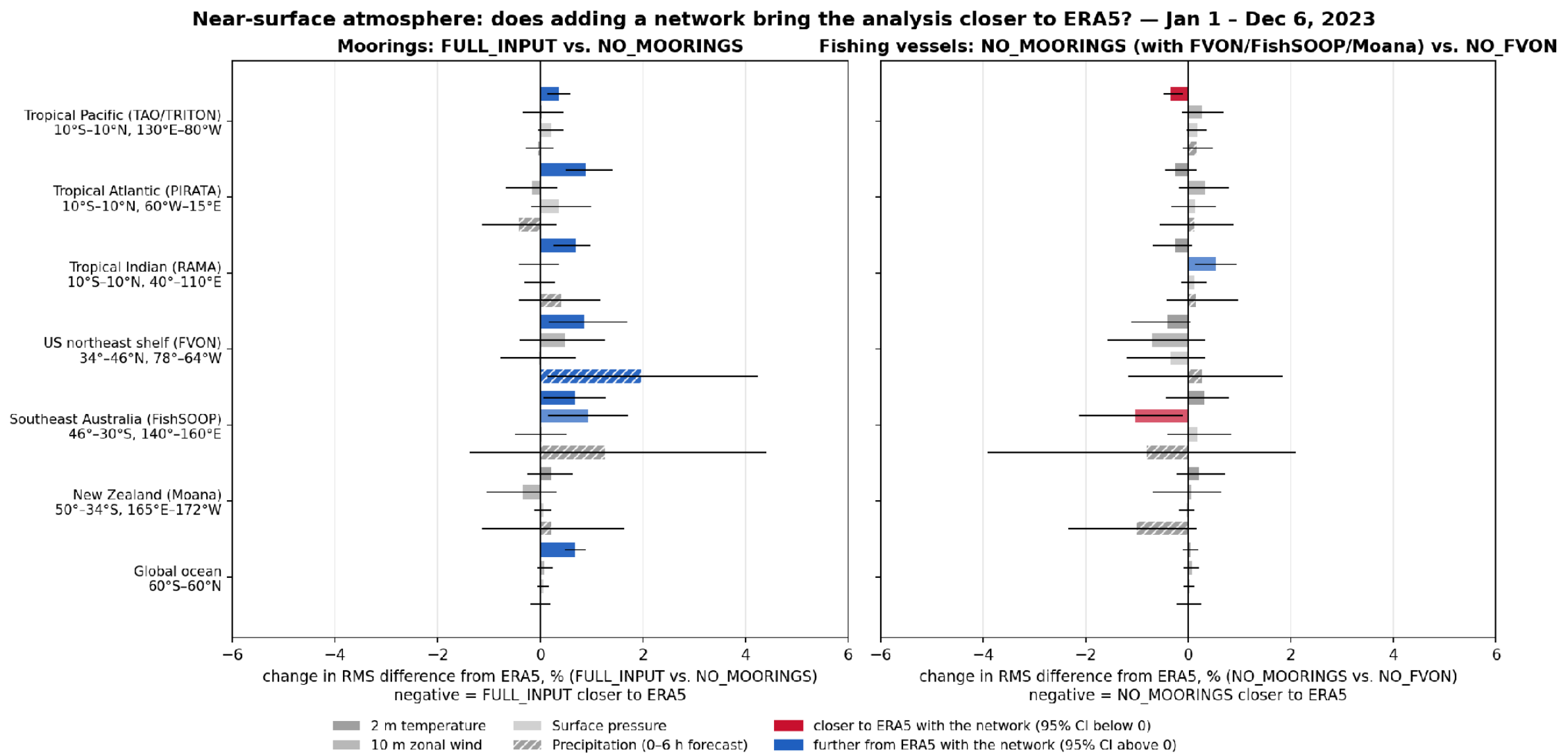
O−B change by region and layer



−5.9%

US shelf, top 50 m
[−9.0, −0.4]

Near-surface atmosphere vs. ERA5, all regions

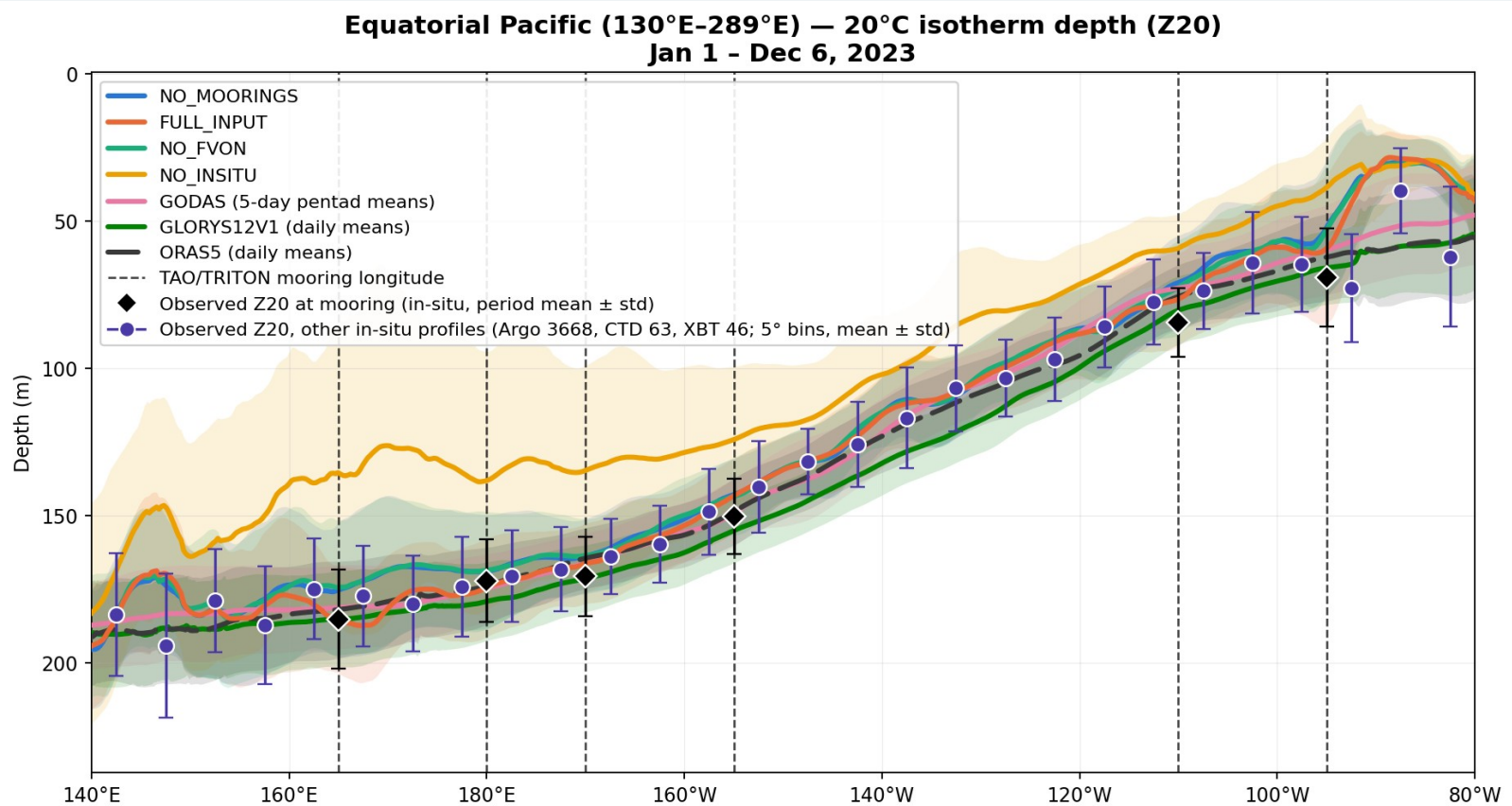


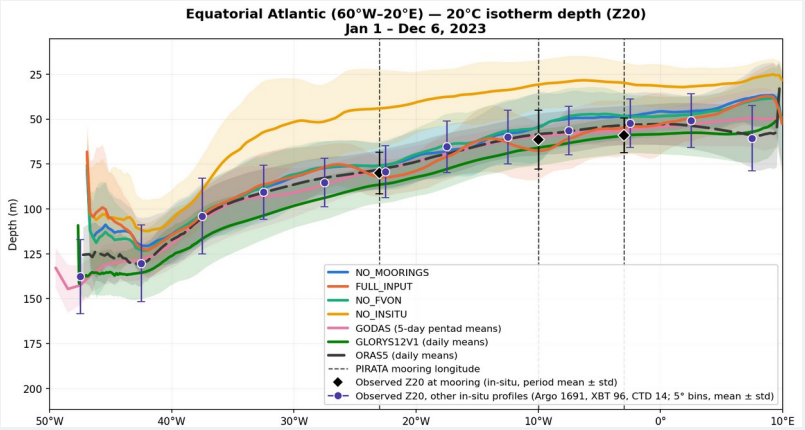
Each experiment's analysis-time (0-hour) 2 m temperature, 10 m zonal wind and surface pressure at every 6-hourly cycle, minus ERA5 at the same hour (hourly 0.25° analyses from the NSF NCAR ERA5 archive, regridded onto the model's grid). RMS of that difference over the ocean points of each region (cos-latitude weighted), run with the network relative to the run without it; whiskers: 95% interval from resampling whole 5-day blocks of cycles. Precipitation (hatched): each run's 0–6 h forecast accumulation (the analyses do not contain it) against ERA5's over the same 6 hours (large-scale + convective). Red = the run with the network is closer to ERA5 and the interval excludes zero, blue = further, grey = not distinguishable from zero. The global box stops at 60° latitude. ERA5 is itself an analysis, so closer to ERA5 means agreeing better with an independent estimate, not necessarily being more correct. Placebo: in the FishSOOP box the FVON pair's 2 m temperature change is -0.2% before FishSOOP was assimilated (14 Apr 18Z) and +0.5% after it; in the New Zealand box +0.2% before Moana (12 Oct) and +0.6% after it.

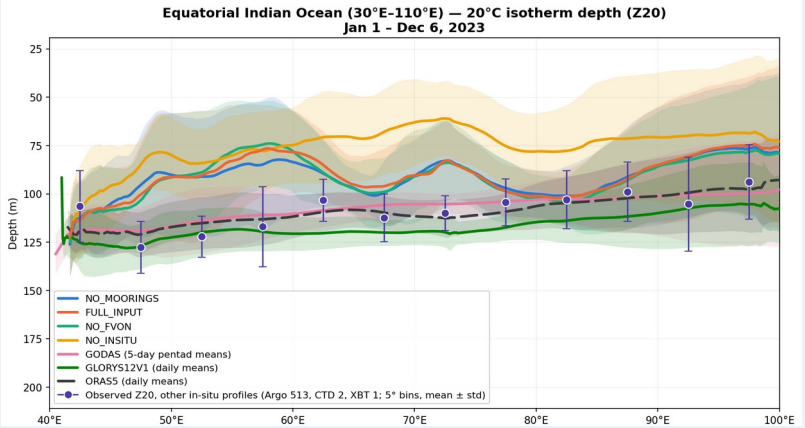
Tropical Moorings

Effects in the equatorial region and El Nino representation?

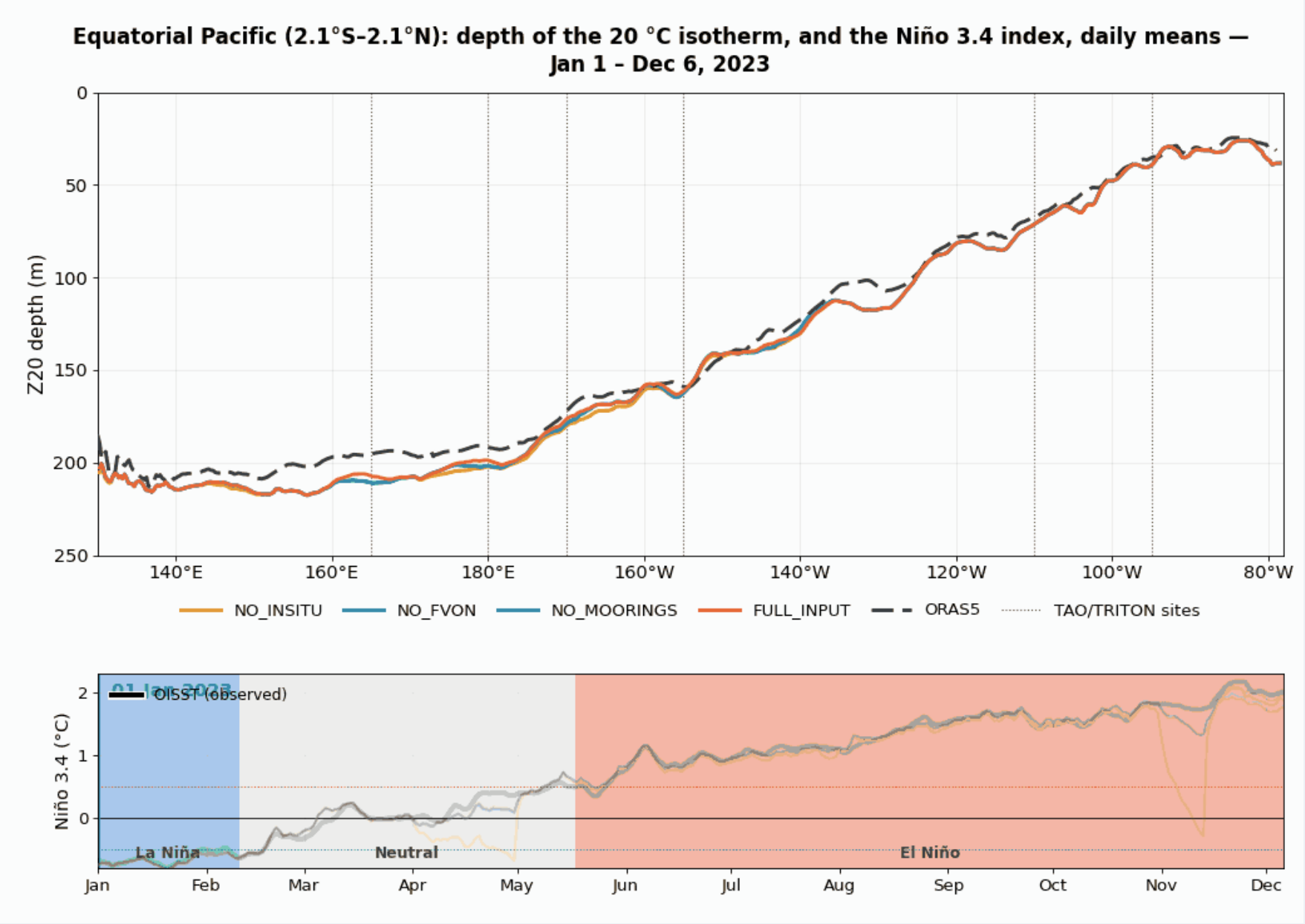
Equatorial Z20: four runs vs. references







Equatorial Pacific Z20 and Niño 3.4, daily



Mean |Z20 error| at the moorings (lower = better)

TAO · Oct 1 – Dec 6

5.7 m FULL_INPUT

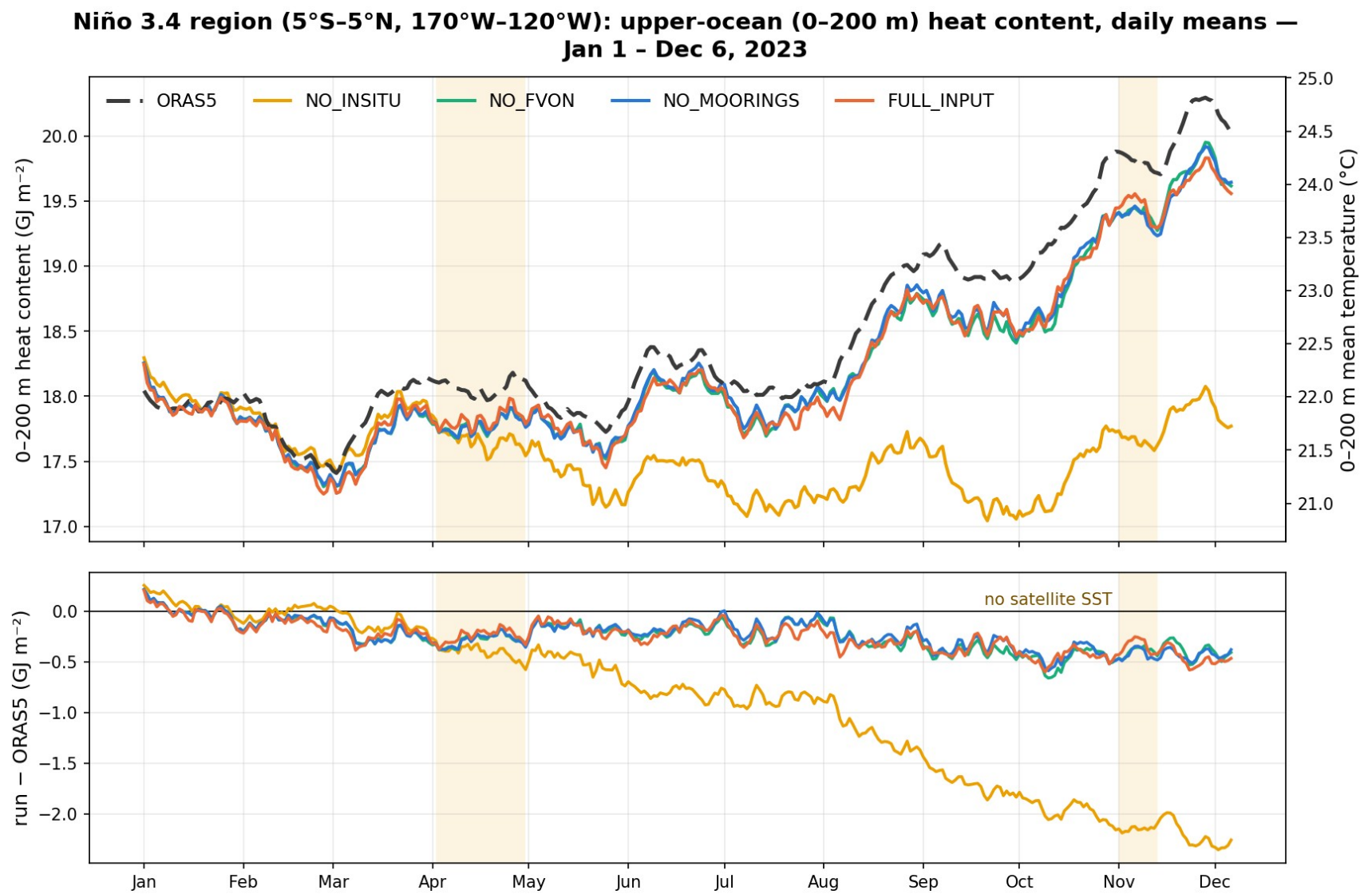
10.8 m NO_MOORINGS

PIRATA · whole period

4.2 m FULL_INPUT

7.3 m NO_MOORINGS

Niño 3.4 heat content (0–200 m) vs. ORAS5



Heat content = ρ₀·c_p·∫T dz over 0–200 m (ρ₀ = 1025 kg m⁻³, c_p = 3990 J kg⁻¹ K⁻¹, T in °C), area-weighted over the box's ocean cells; right axis: the same as the 0–200 m mean temperature (1 °C = 0.82 GJ m⁻²). Runs: MOM6 temperature of every 6-hourly analysis cycle (f000), averaged to daily means; ORAS5 daily means (Copernicus Marine). Bottom: each run minus ORAS5 (RMS difference over the period: NO_INSITU 1.19, NO_FVON 0.29, NO_MOORINGS 0.28, FULL_INPUT 0.29). Shaded: 2–30 Apr and 1–13 Nov, when no satellite SST reached any run.

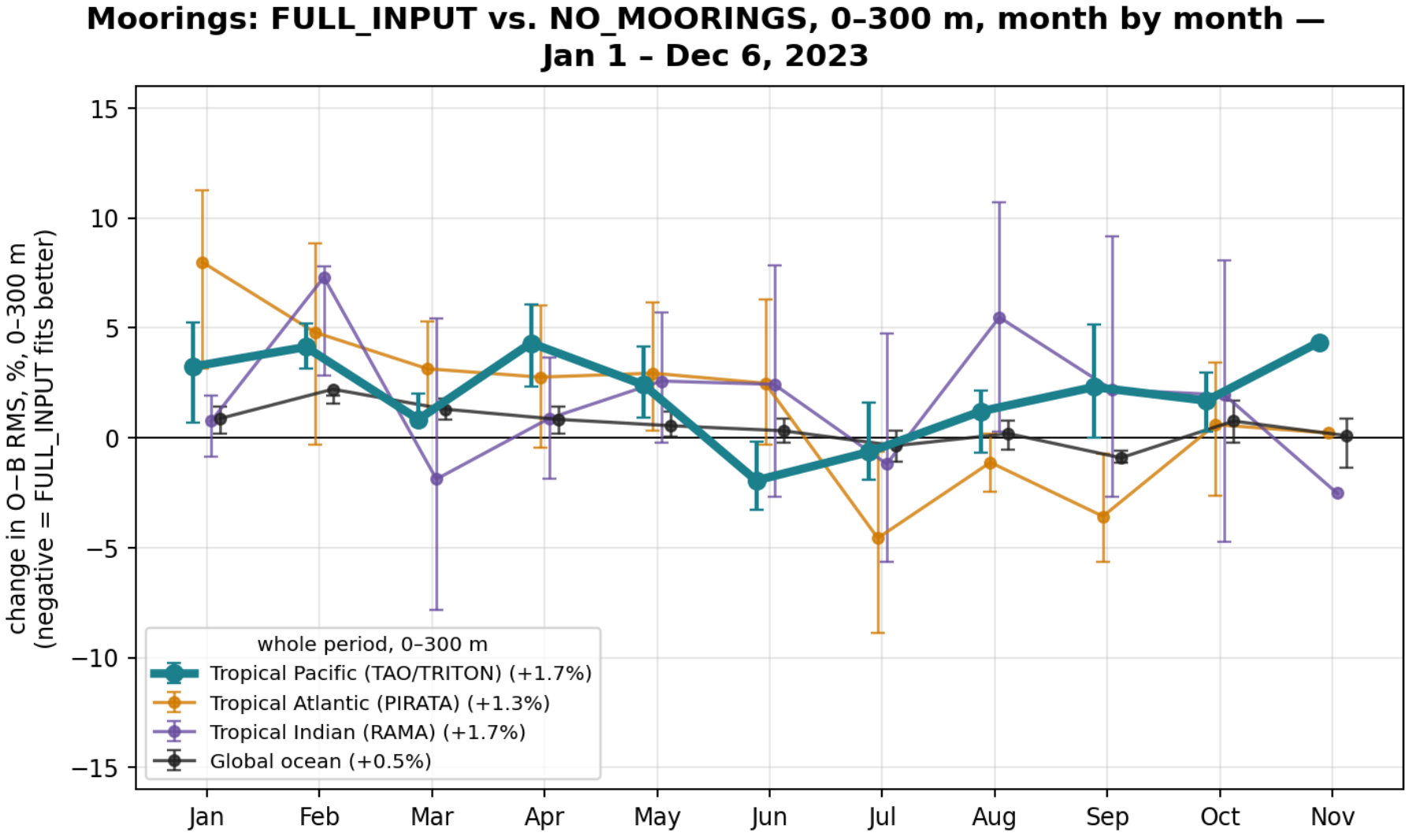
−2.3

GJ m⁻² NO_INSITU − ORAS5 by Dec (≈ −2.8 °C)

0.28–0.29

GJ m⁻² RMS, runs with in-situ data

Moorings pair: O−B (0–300 m) at the other profiles, by month



Monthly change in RMS(O−B) over 0–300 m of FULL_INPUT (with the tropical moorings) relative to NO_MOORINGS, at every in-situ temperature report both runs assimilate (the moorings themselves excluded), paired report by report; tropical boxes 10°S–10°N. Whiskers: 95% intervals from resampling 5-day blocks within the month; months with at least 15 days only (no interval where fewer than five blocks have data, e.g. November in the tropical boxes). Positive = worse with the moorings. Same y-axis as the 0–1000 m version.

+1.7 / +1.3%

Pacific / Atlantic, 0–300 m

Atlantic within chance

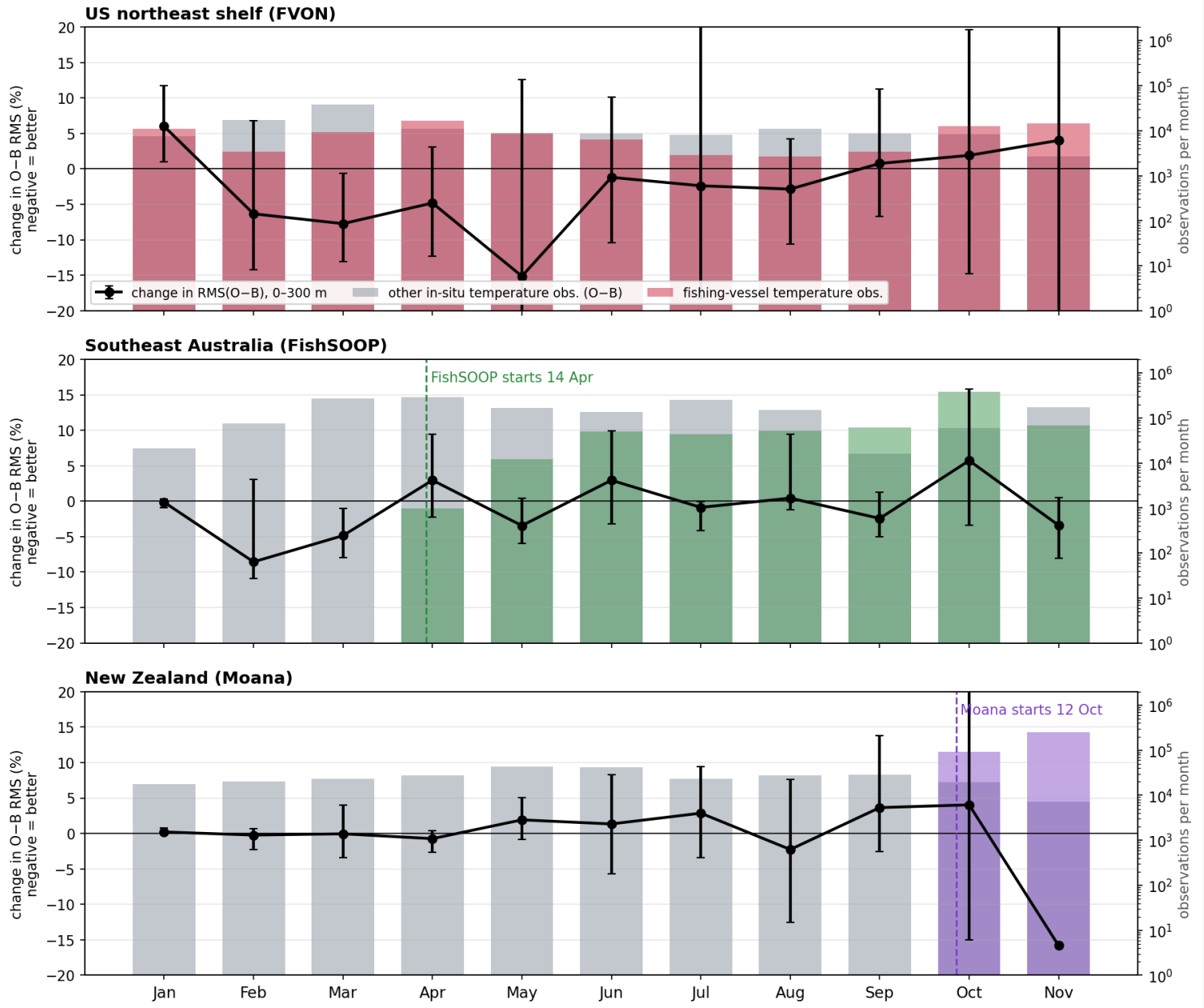
+3.7 / +7.0%

0–1000 m

Fishing vessel observations

Regional impacts ina global model?

Temperature O−B (0–300 m), month by month



−3.9%

US shelf · FVON
[−6.7, 0.0], all year

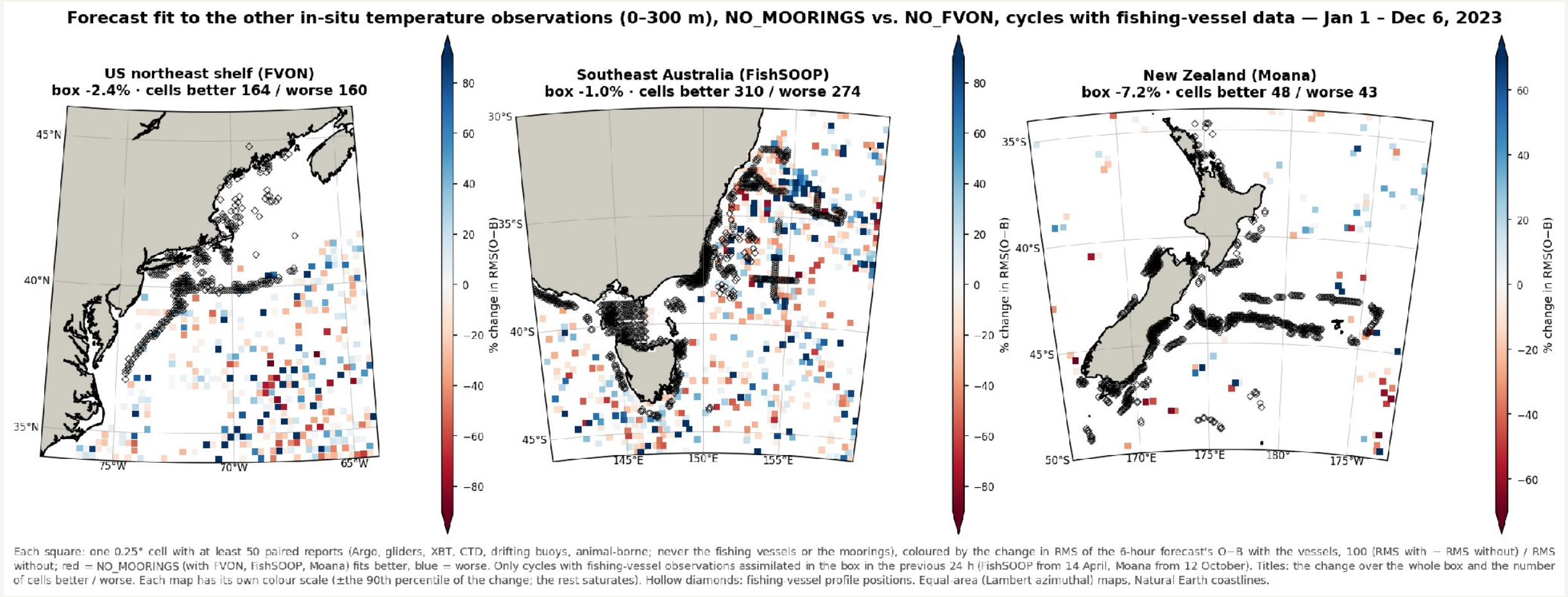
+0.3%

SE Australia · FishSOOP
after 14 Apr; −5.0% before

−7.9%

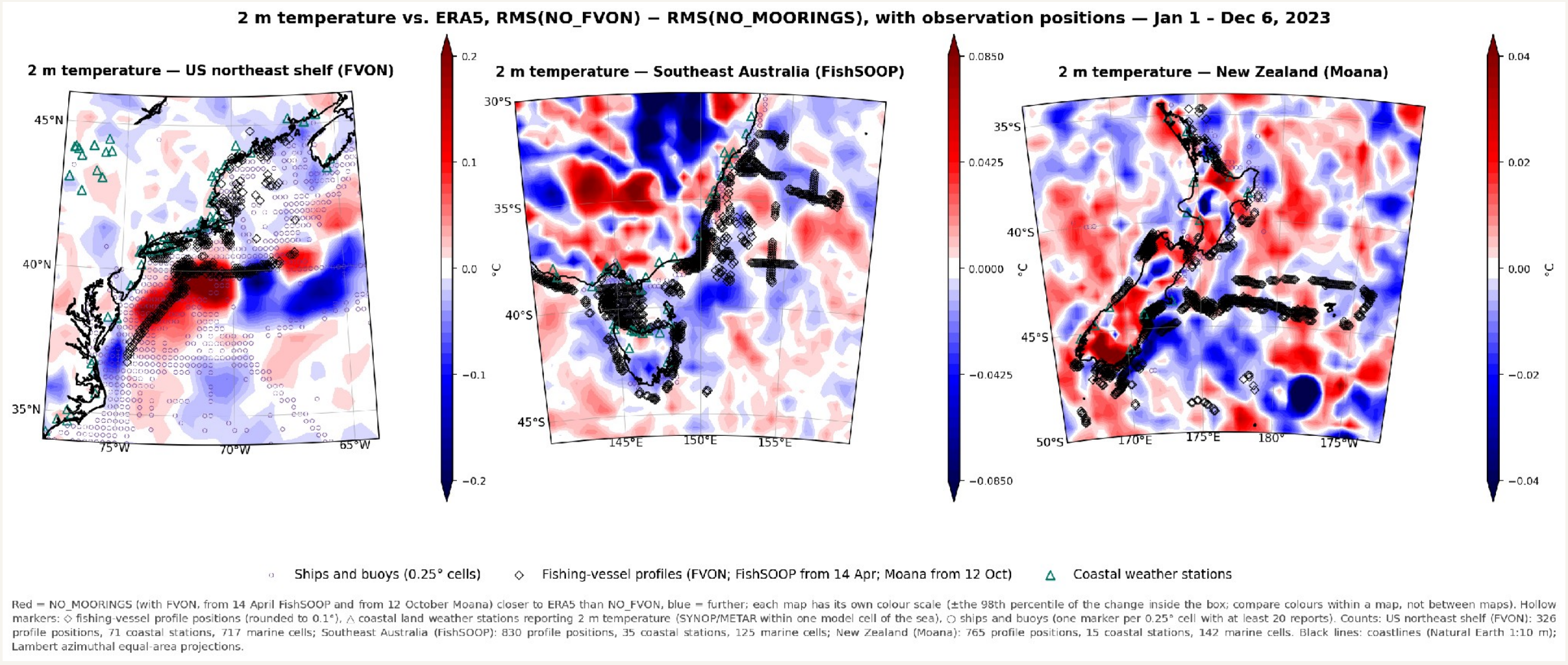
New Zealand · Moana
[−19, +5], 8 weeks; +1.2% before

Temperature O−B (0–300 m) at the other in-situ observations



Each square: one 0.25° cell with at least 50 paired reports (Argo, gliders, XBT, CTD, drifting buoys, animal-borne; never the fishing vessels or the moorings), coloured by the change in RMS of the 6-hour forecast's O−B with the vessels, 100 (RMS with − RMS without) / RMS without; red = NO_MOORINGS (with FVON, FishSOOP, Moana) fits better, blue = worse. Only cycles with fishing-vessel observations assimilated in the box in the previous 24 h (FishSOOP from 14 April, Moana from 12 October). Titles: the change over the whole box and the number of cells better / worse. Each map has its own colour scale (±the 90th percentile of the change; the rest saturates). Hollow diamonds: fishing-vessel profile positions. Equal area (Lambert azimuthal) maps, Natural Earth coastlines.

2 m air temperature vs. ERA5



Red = NO_MOORINGS (with FVON, from 14 April FishSOOP and from 12 October Moana) closer to ERA5 than NO_FVON, blue = further; each map has its own colour scale (±the 98th percentile of the change inside the box; compare colours within a map, not between maps). Hollow markers: ◇ fishing-vessel profile positions (rounded to 0.1°), △ coastal land weather stations reporting 2 m temperature (SYNOP/METAR within one model cell of the sea), ○ ships and buoys (one marker per 0.25° cell with at least 20 reports). Counts: US northeast shelf (FVON): 326 profile positions, 71 coastal stations, 717 marine cells; Southeast Australia (FishSOOP): 830 profile positions, 35 coastal stations, 125 marine cells; New Zealand (Moana): 765 profile positions, 15 coastal stations, 142 marine cells. Black lines: coastlines (Natural Earth 1:10 m); Lambert azimuthal equal-area projections.

US shelf · all year

ocean −0.4% [−1.1, +0.1]

coast +0.2% [+0.0, +0.4]

SE Australia · from 14 Apr

ocean +0.5% [−0.3, +1.1]

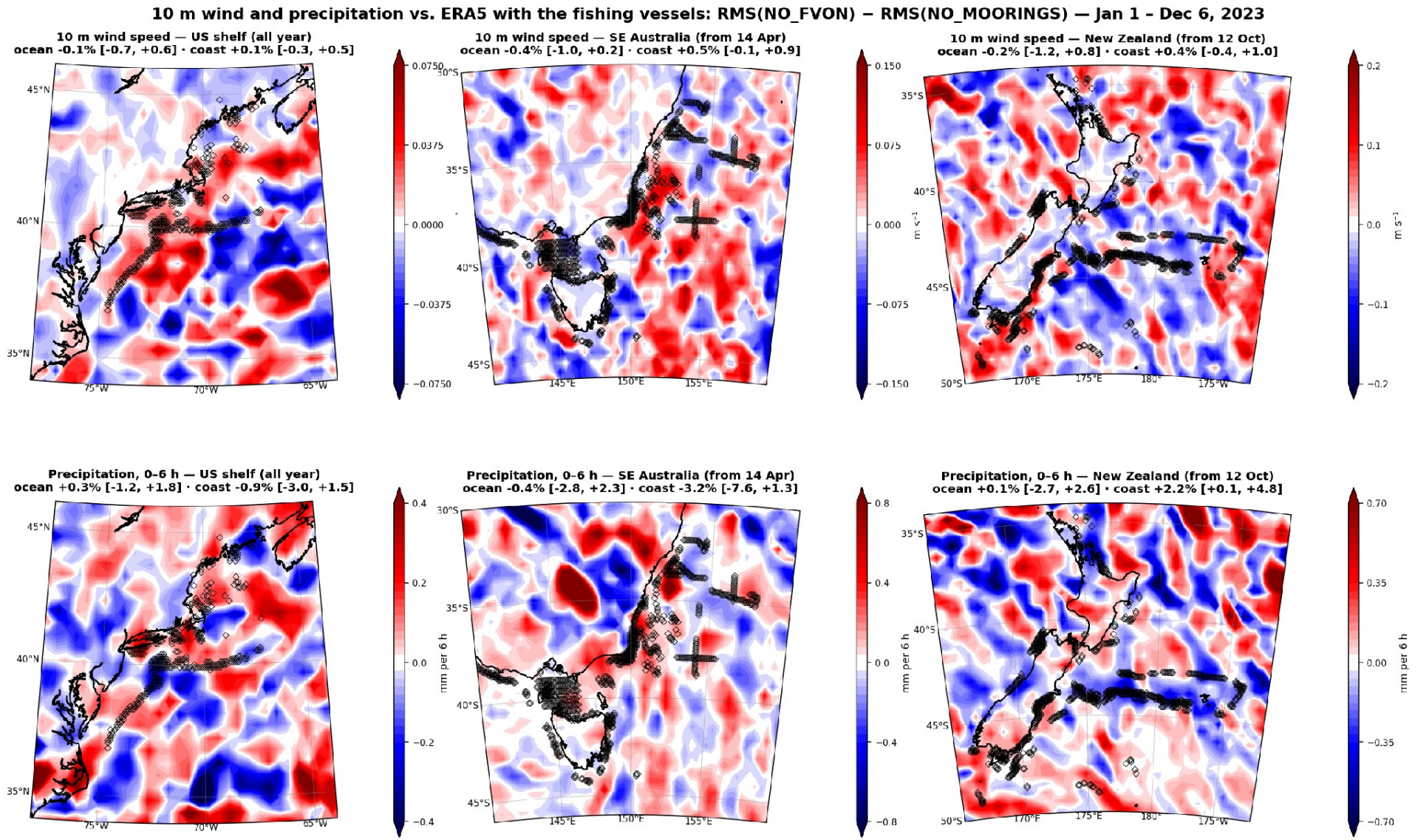
coast +0.1% [−0.4, +0.7]

New Zealand · from 12 Oct

ocean +0.6% [−1.5, +2.6]

coast −0.2% [−1.3, +0.8]

10 m wind speed and precipitation vs. ERA5



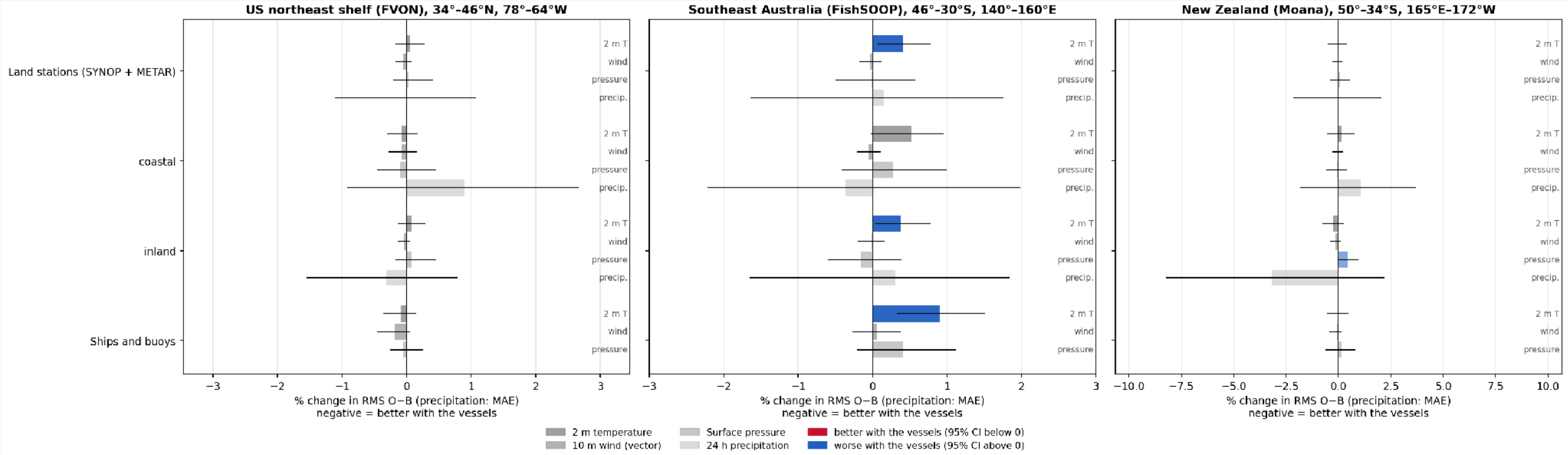
US shelf
Wind: ocean **−0.1%** · coast **+0.1%**
Precip.: ocean **+0.3%** · coast **−0.9%**

SE Australia
Wind: ocean **−0.4%** · coast **+0.5%**
Precip.: ocean **−0.4%** · coast **−3.2%**

New Zealand
Wind: ocean **−0.2%** · coast **+0.4%**
Precip.: ocean **+0.1%** · coast **+2.2%**

Only NZ coast precip. clear of zero [+0.1, +4.8]

Weather-station O−B change by region



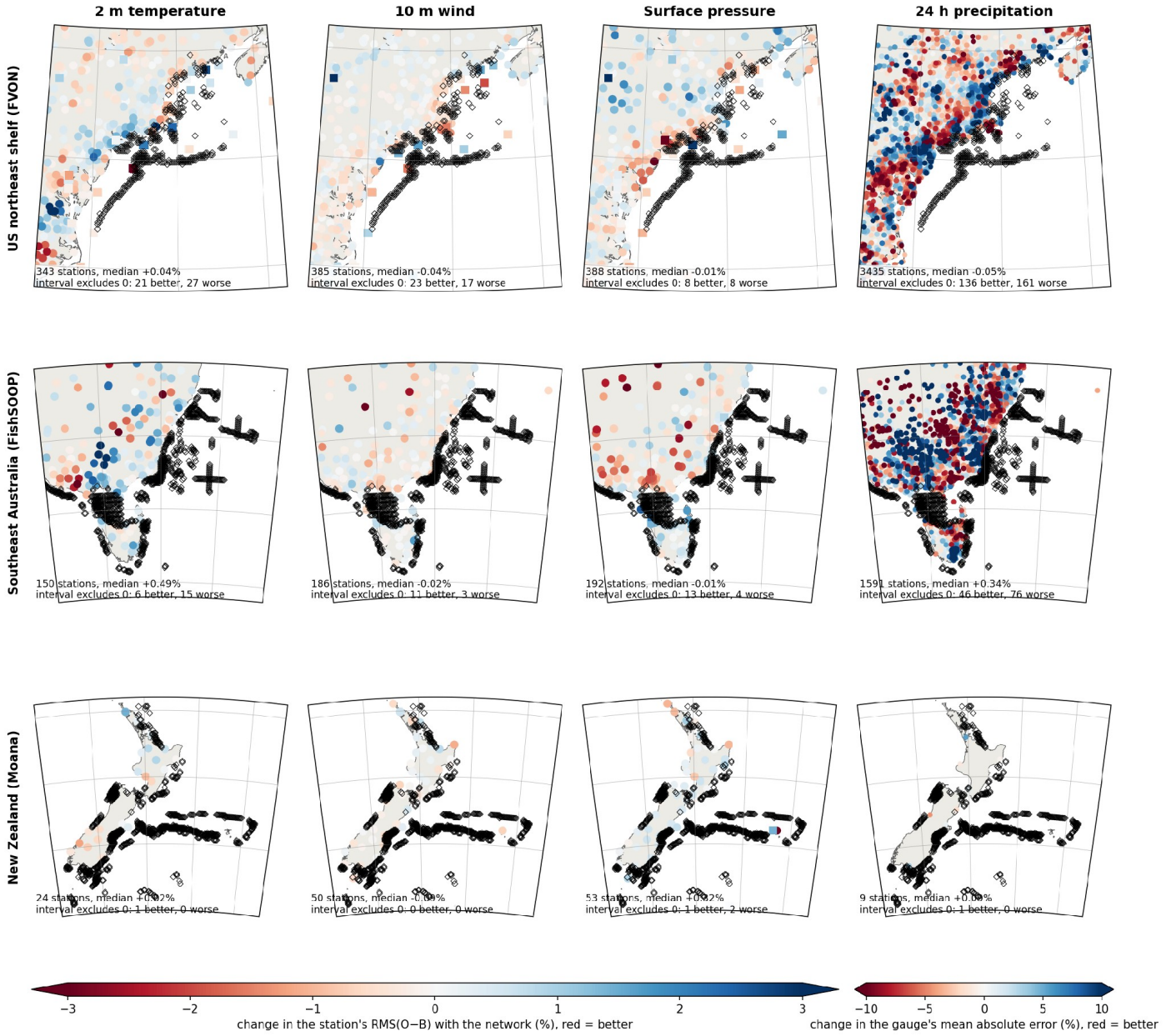
±0.1%

US-shelf land stations:
2 m T, wind, pressure

0.0%

precipitation, ±1%

Weather stations, one by one



Take-away

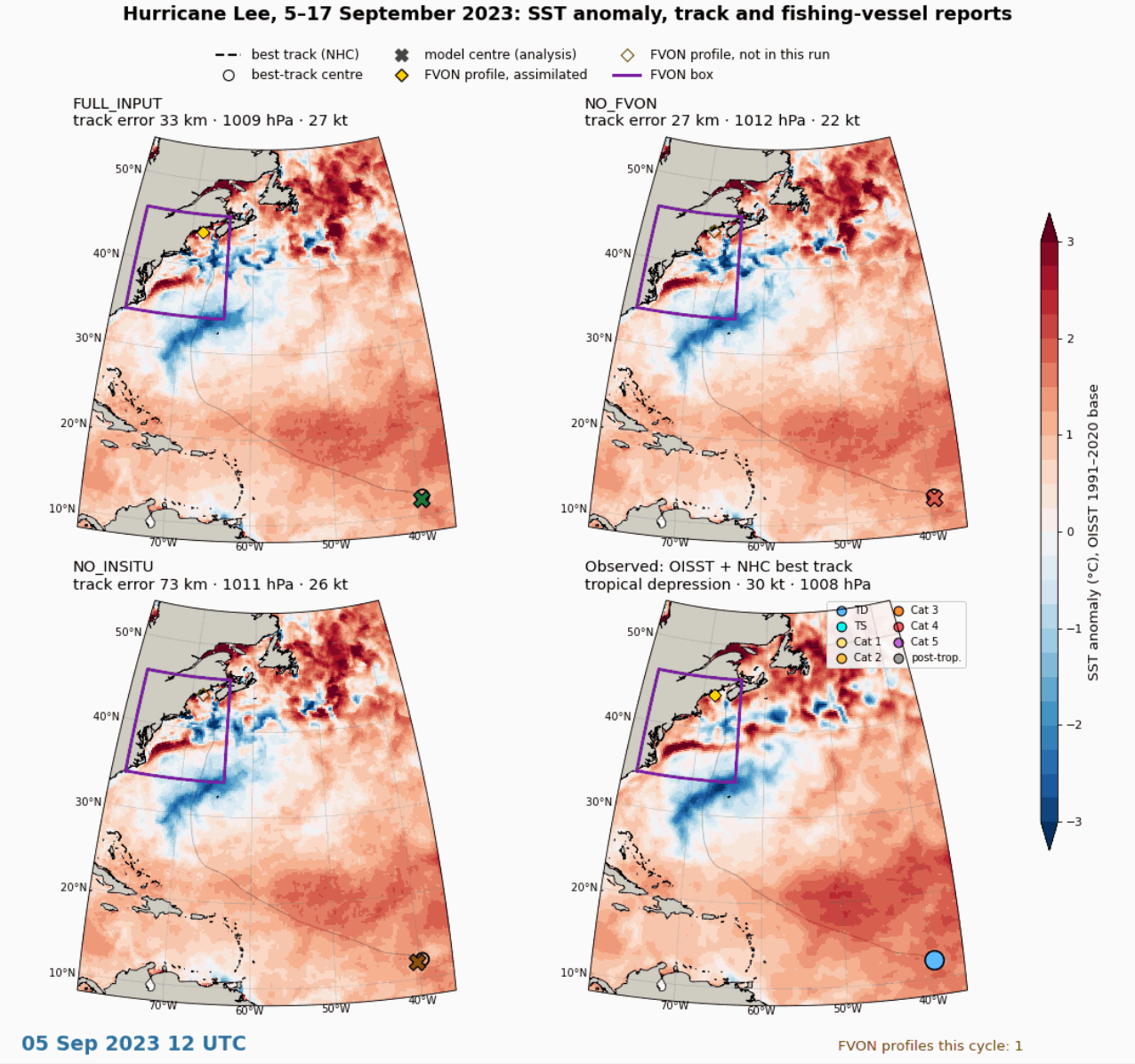
1. **Fishing vessels:** the US-shelf forecast is 4–6% better near the surface, and FVON also improves shelf salinity (−2.6%); FishSOOP and Moana show a small effect. Missing physical processes?

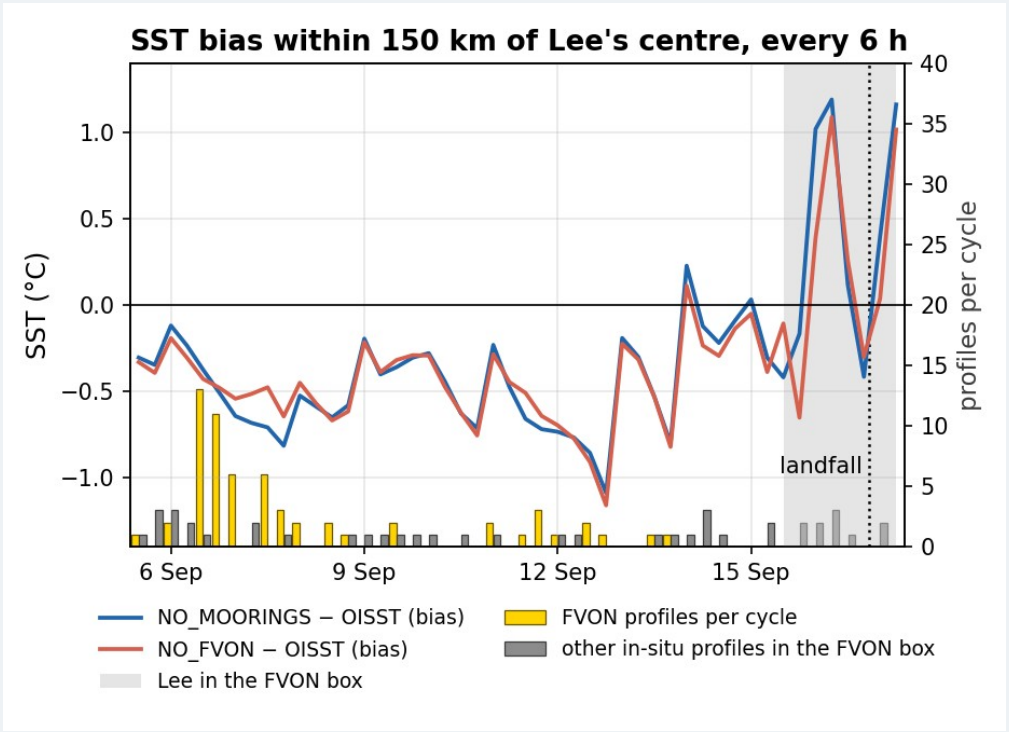
2. **Atmosphere:** fishing-vessel signal at weather stations or against ERA5 are inconclusive; small Australian changes predate FishSOOP.

3. **Moorings:** the analysis follows the moored thermocline (TAO error 5.7 vs 10.8 m), but fits other profiles slightly worse over 0–300 m (+1.7% Pacific); Does not translate into better UOHC or Nino SST anomaly extent.

4. **Coupling:** the atmosphere feels ocean updates only through SST, on a ~50 km grid, and its own 6-hourly analysis resets it; this likely damps any ocean signal (not tested)

Hurricane Lee, 5–17 September 2023: track, SST and FVON





	FULL_INPUT	NO_FVON	NO_INSITU	observed
track error, all	28 km	**27 km**	29 km	—
track error, FVON box	**37 km**	39 km	40 km	—
landfall offset	15 km	**14 km**	**14 km**	16 Sep 20Z
lowest pressure	**964 hPa**	**964 hPa**	965 hPa	926 hPa
cold wake	**−2.21 °C**	−2.15 °C	−1.85 °C	−2.32 °C

No FVON profiles 13 Sep 18Z – 17 Sep 12Z · mean |SST bias| under Lee in the box:
NO_MOORINGS **0.61**, NO_FVON **0.48 °C** (0.47 / 0.46 south of it)