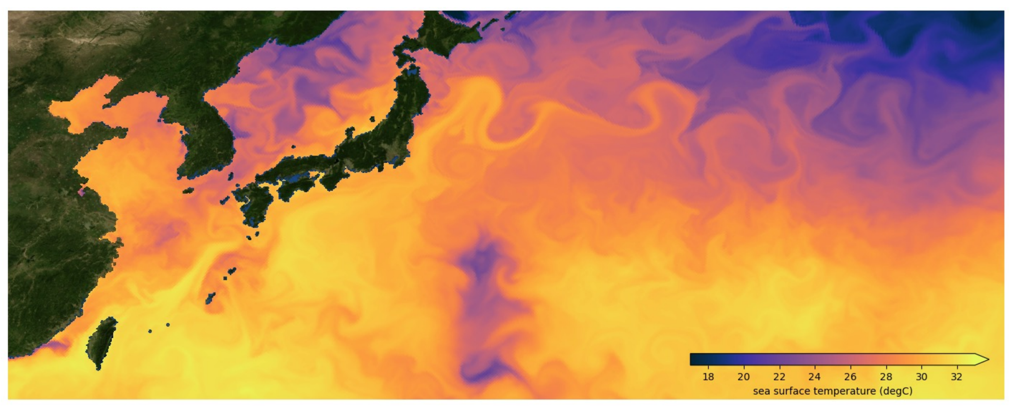
ENSO teleconnections in eddy-rich climate models: Insights from the EERIE project

Bianca Mezzina[1] (bianca.mezzina@ecmwf.int), Christopher Roberts[1], Matthias Aengenheyster[1] & colleagues from EERIE | [1]ECMWF

1. What is EERIE?

EERIE (European Eddy-Rich Earth-System Models) is a Horizon Europe project aiming to transform climate modeling by **explicitly resolving ocean eddies**—small-scale currents that play a crucial role in heat, carbon, and freshwater transport. Unlike conventional climate models that approximate these features, EERIE uses **high-resolution simulations** (~10 km) in both the ocean and the atmosphere that enable **more realistic processes and interactions**.



Courtesy of M. Aengenheyster

2. ENSO teleconnections

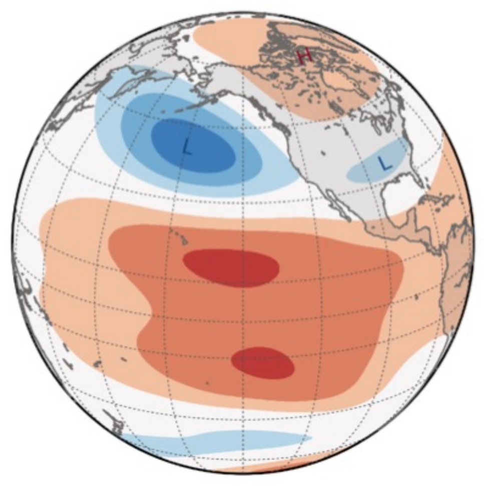
El Niño-Southern Oscillation (ENSO) is a prominent mode of climate variability that can impact remote regions through **atmospheric teleconnections**. The main mechanism for these teleconnections entails a large-scale Rossby Wave train triggered by upper-level divergence anomalies in the tropical Pacific, which then propagates towards the mid and high latitudes.

Our key questions:

How are ENSO teleconnections **represented** in the eddy-rich EERIE models?

Is there an **improvement** compared to existing state-of-the-art models?

... And **how** to assess this?



From B. Mezzina's PhD Thesis

3. Data & Methods

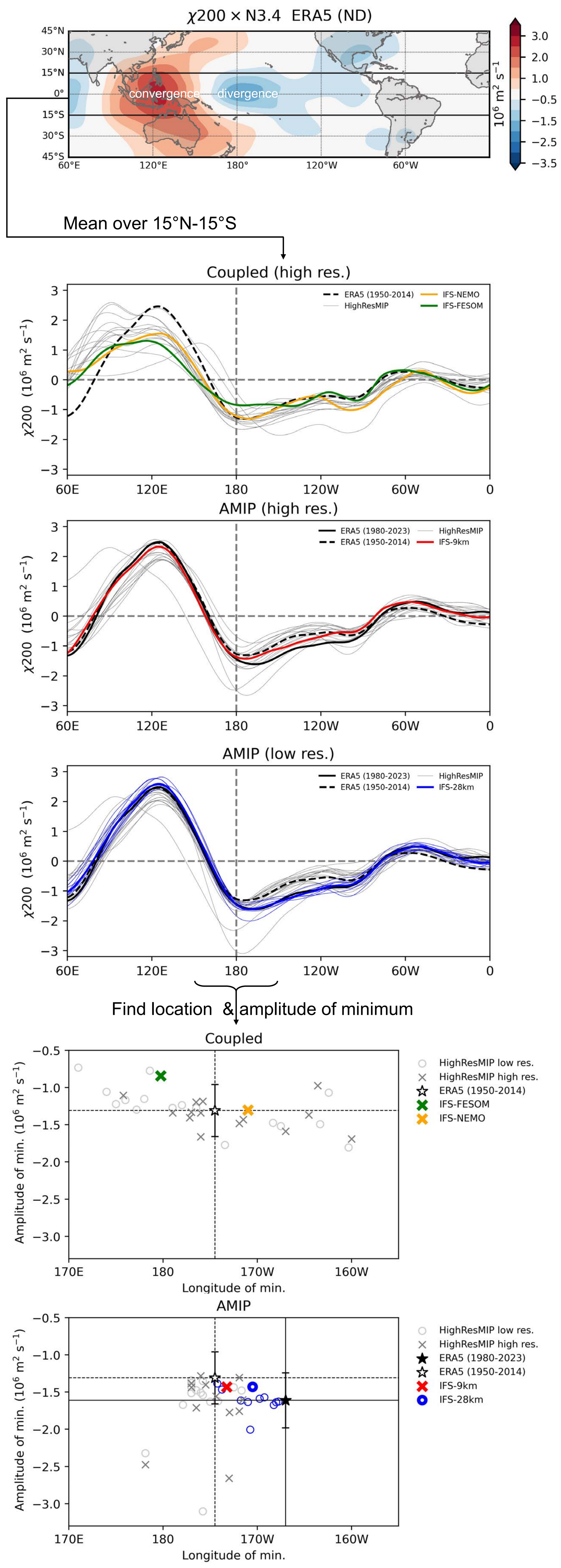
Simulations performed within EERIE:

Type	Institution	Model	Resolution (atm.,ocean)	Members	Period
Coupled	AWI	IFS-FESOM	Tco1279 (~9 km), 4.5-13 km	1	1950-2014
	BSC	IFS-NEMO	Tco1279 (~9 km), eORCA12 (~8 km)	1	1950-1996
AMIP	ECMWF	IFS	Tco1279 (~9 km)	1	1980-2023
	ECMWF	IFS	Tco399 (~28 km)	10	1980-2023

- *Comparison with HighResMIP*: simulations from 6 models, each with a "low resolution" (50-250 km) and "high resolution" (25-100 km) version, over 1950-2014
- *Comparison with reanalysis*: ERA5 (1980-2023 for the EERIE-AMIP runs, 1950-2014 for the rest)
- **Linear regressions** on DJF Niño3.4-index

4. Tropical Response

We can use the 200-hPa velocity potential to diagnose the upper-tropospheric flow anomalies related to ENSO:

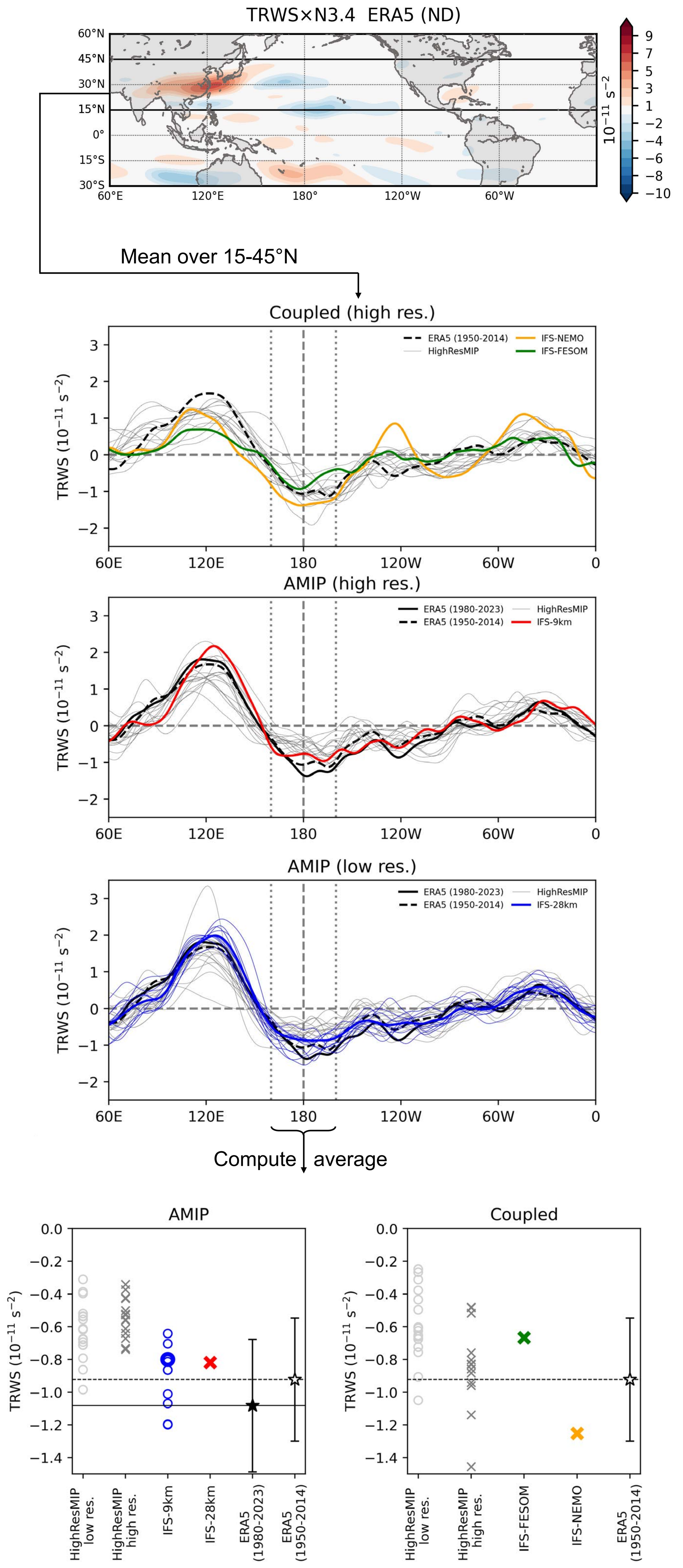


- IFS-NEMO accurately captures the minimum; IFS-FESOM underestimates the amplitude & is more shifted.
- Minor differences between IFS-9km and the ensemble mean from IFS-28km. Some IFS-28km members closer to ERA5.

5. Rossby Wave Source (RWS)

We consider the tropical component of the RWS at 200hPa:

$$TRWS = -\mathbf{V}'_\chi \cdot \nabla(\bar{\zeta} + f)$$



- The RWS in the central tropical Pacific is underestimated in IFS-FESOM ⟶ consistent with velocity potential.
- It is overestimated in IFS-NEMO ⟶ role of mean flow $\bar{\zeta}$?
- Still minor differences between IFS-9km and the ensemble mean from IFS-28km.

Grant Agreement #101081383

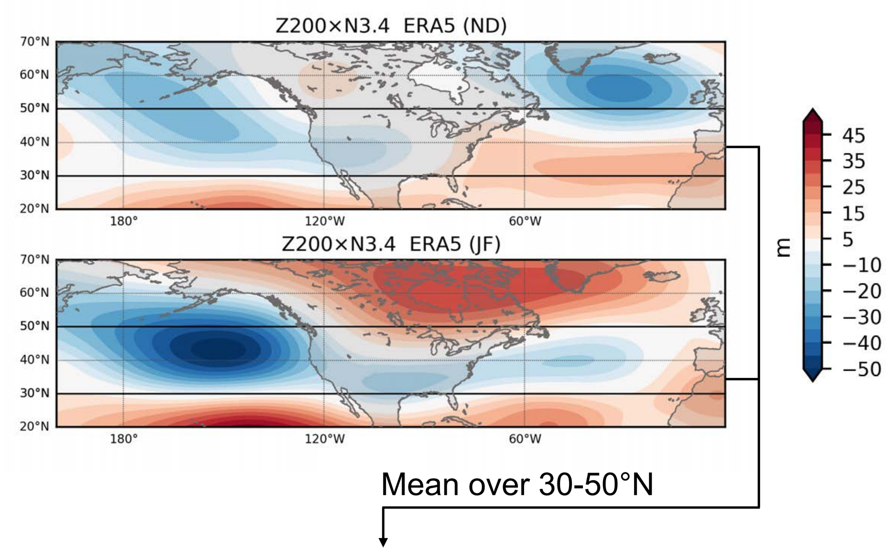
Funded by the European Union

UK Research and Innovation

Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

6. Rossby Wave Train (mid latitudes)

We can detect the wave train using the 200-hPa geopotential height, in early and late winter:

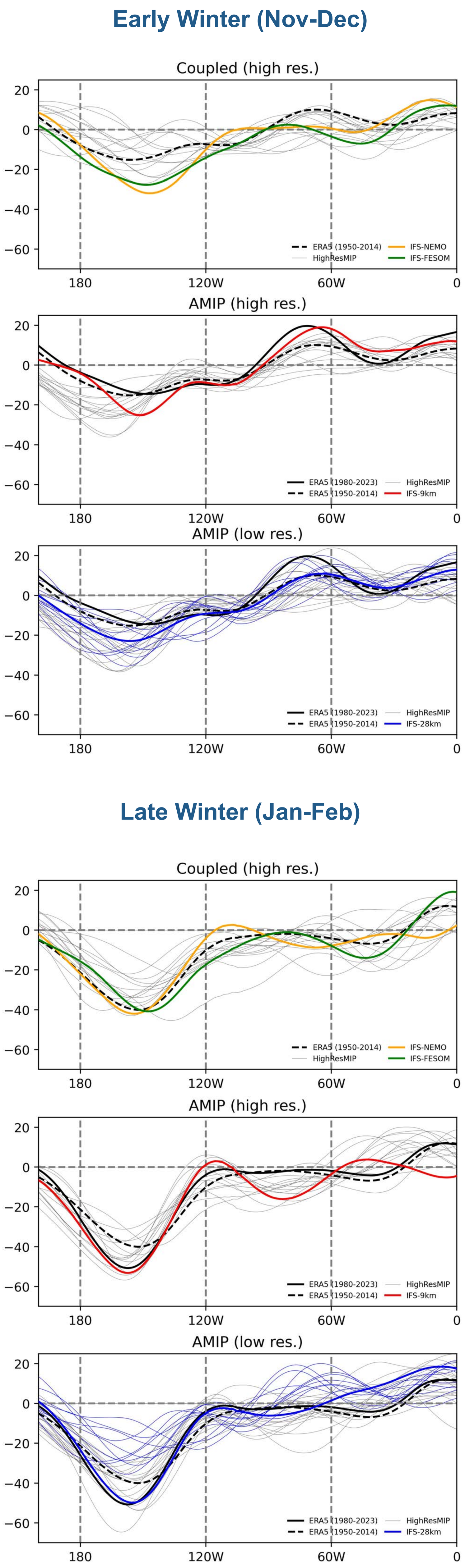


Early Winter (Nov-Dec)

IFS-NEMO and IFS-FESOM struggle in both the North Pacific and western North Atlantic ⟶ JF-like response ☹

Some differences between IFS-9km and the ensemble mean of IFS-28km.

Late Winter (Jan-Feb)



Despite some differences in the tropical response and RWS, **all models** capture properly the extra-tropical late-winter signal in the **North Pacific**.

The **North Atlantic** remains a challenge, and no model is a clear winner…