

Exceptional Heat and Basin-Scale Connections in the Kuroshio-Oyashio Region in the Early 2020s

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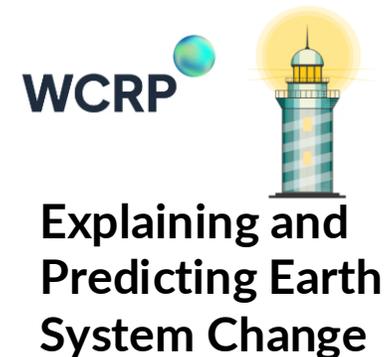
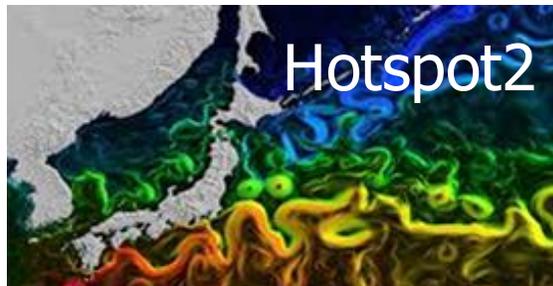
A WG49 member as a **liaison** of WCRP Light House Activity,
Explaining and Predicting Earth System Change.

Outline

- Introduction of heat studies in climate science
- North Pacific Heat/Temperature
- North Pacific Circulation and Wind Forcings
- Discussions & Conclusions

For a better communication between
PICeS and WCRP

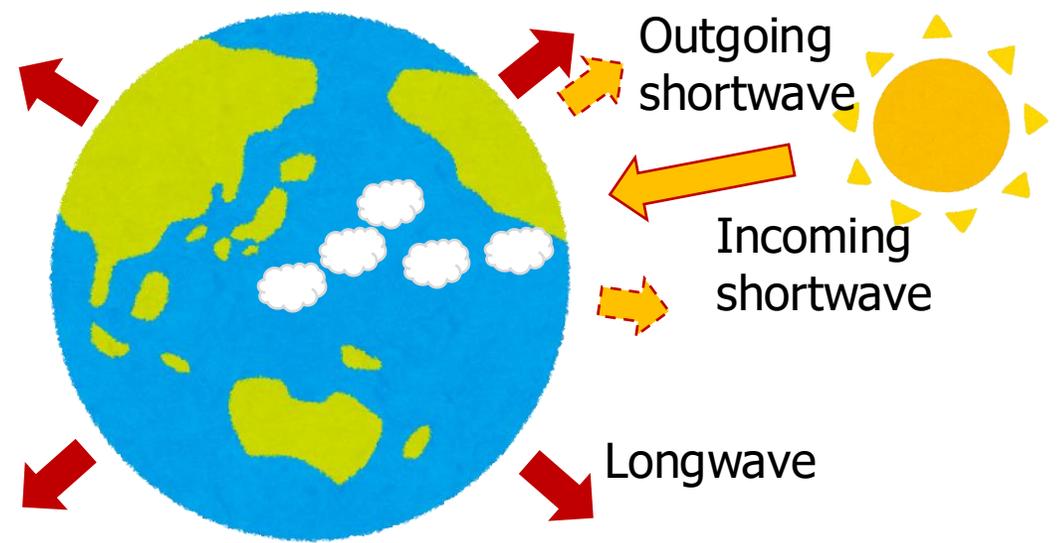
This study has been published in Journal of Oceanography June 2025. Anybody can read through the share link <https://rdcu.be/etVPC> or the QR code.



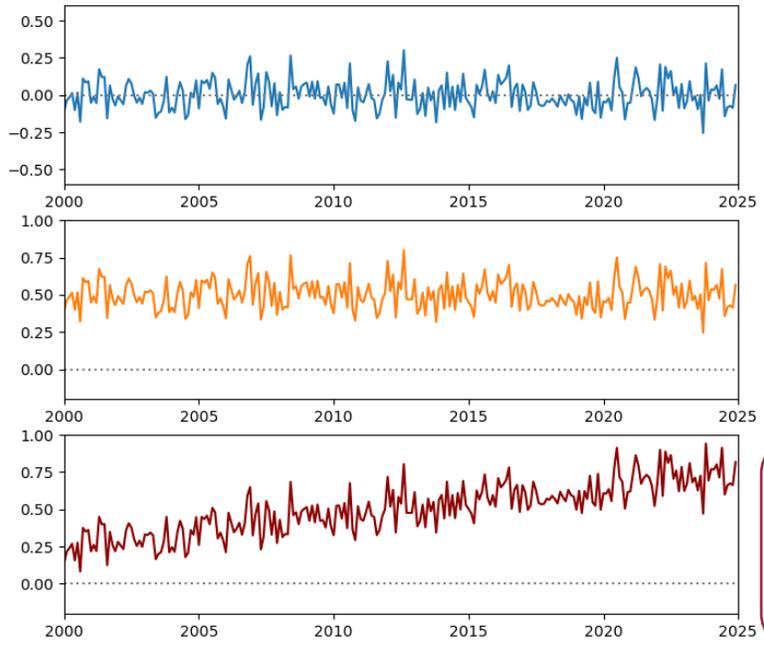
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1. Introduction & Data

EI indicates accelerating global warming



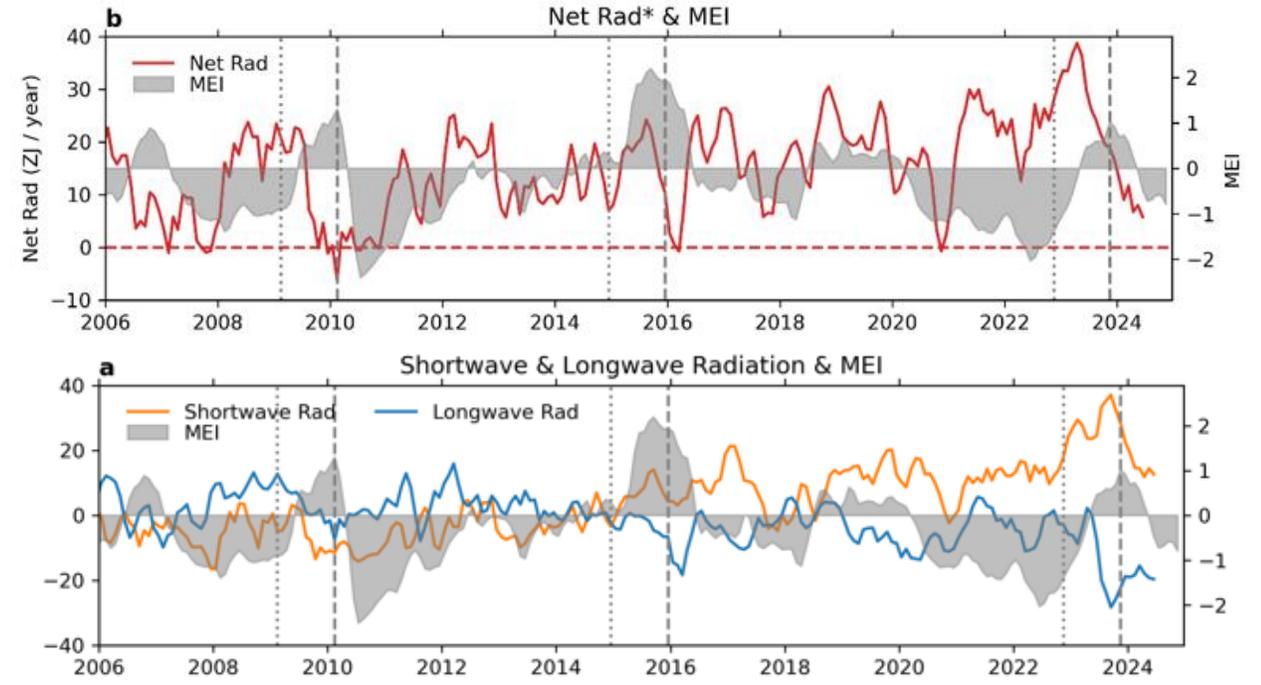
Earth's Energy Imbalance (EEI)
 = Incoming Shortwave Radiation
 - Outgoing Shortwave Radiation
 - Outgoing Longwave Radiation



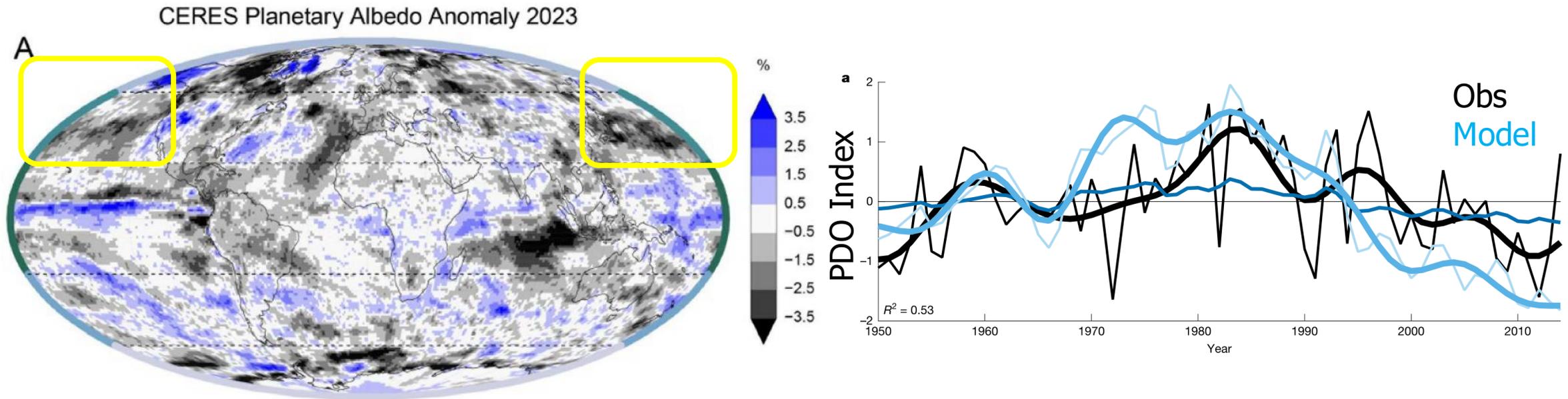
Zero EEI ⇒
 No Global Warming (GW)

Positive & constant EEI ⇒
 Constant GW

Positive & increasing EEI ⇒
Accelerating GW



EEI increase is due to **net-downward shortwave increase**,
 Indicating that **shortwave reflection decreases**.



Goessling et al. (2025 Science) suggested that the decrease of Albedo and increase of solar radiation (albedo reduction) due to decrease of low-cloud cover was prominent over the North Pacific.

Klavans et al. (Nature 2025 July) suggested that multidecadal variability of PDO is caused by external forcings (GHG, aerosols, ...).

So, there are large interests in the North Pacific in climate science community.

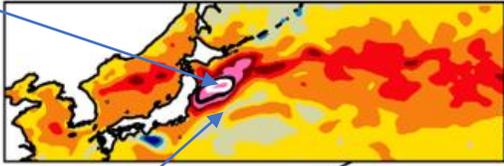
However, most of these studies treat only SST do not go to subsurface.

Since 89% of EEI goes to the ocean (von Shuckmann et al. 2023 ESSD), it is important to monitor, understand, and predict ocean heat.

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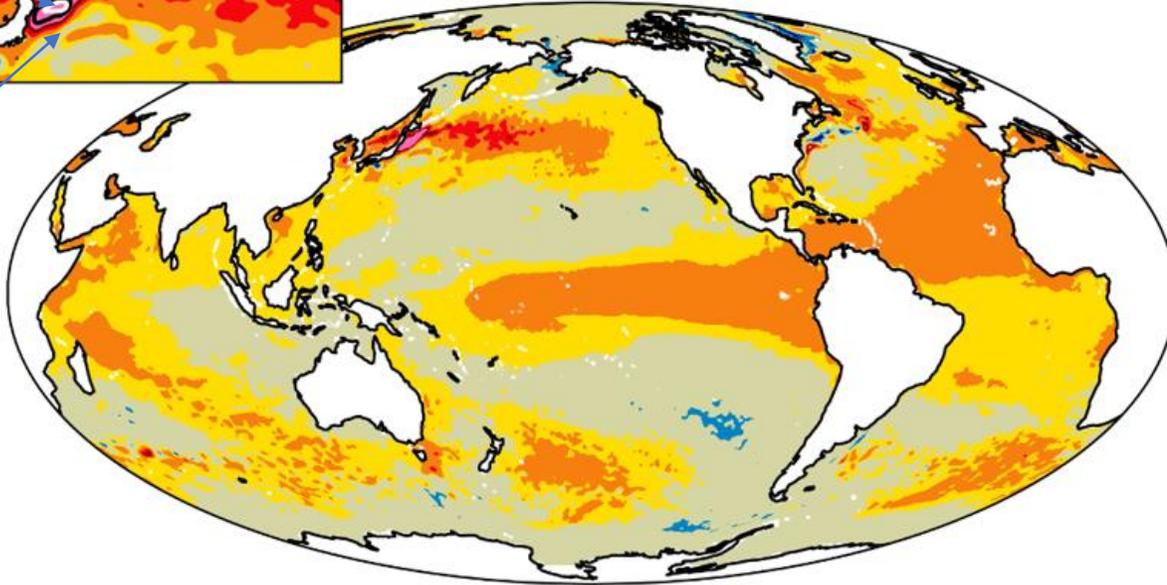
SST Anomalies, 2023 Jul - 2024 Jun

+6C



Black:

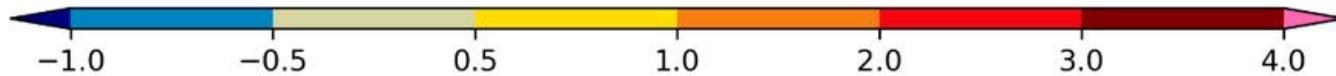
+5C



Hiroaki also showed similar figure in the opening plenary talk.

In this study, I aim to document major features of the 2020s anomalous heat in the North Pacific and its relationship to ocean circulations and wind forcings changes.

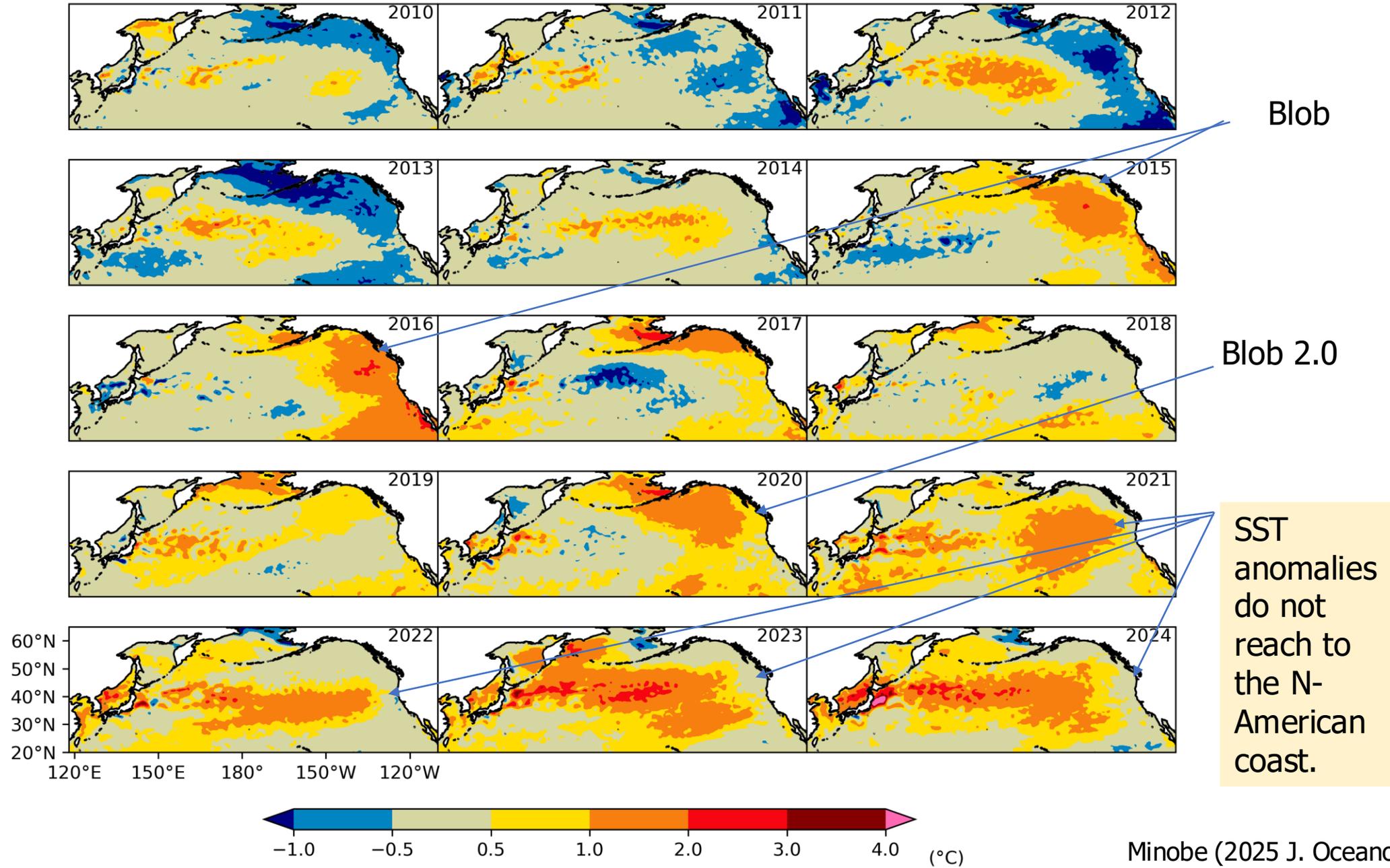
This is my first step to relate anomalous North Pacific heat to the mainstream of climate science, i.e., global heat movements.



Minobe (2025 J. Oceanogr)

2. Heat/Temperature Change

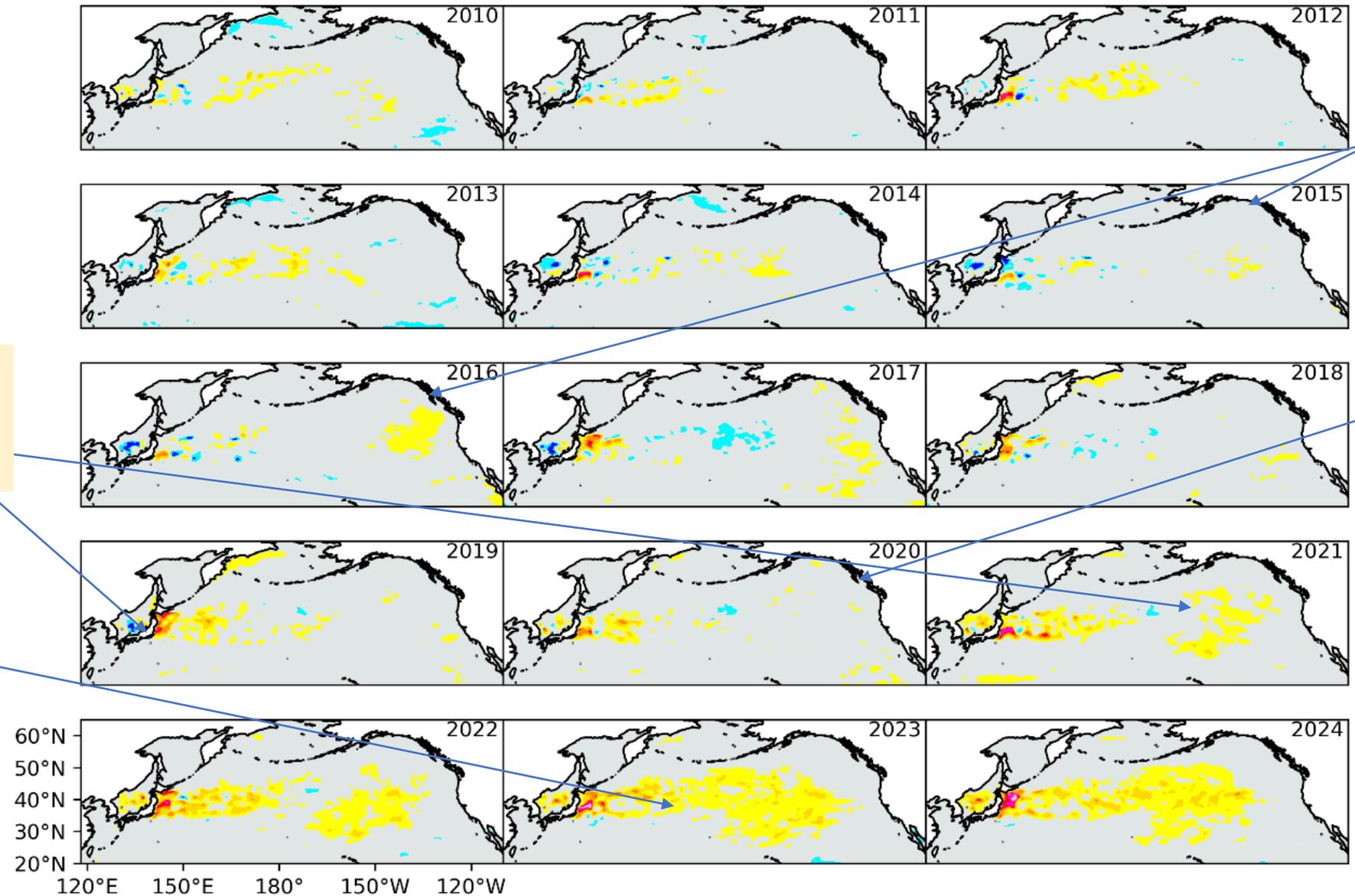
SST anomalies in NP developed east and west separately in 2020s



Separate start
in western and
eastern NP



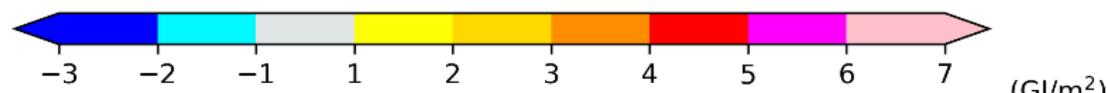
merged or
overlapped in
2023



Blob

Blob 2.0

2021-24
anomalies are
stronger than
the Blob and
the Blob 2.0



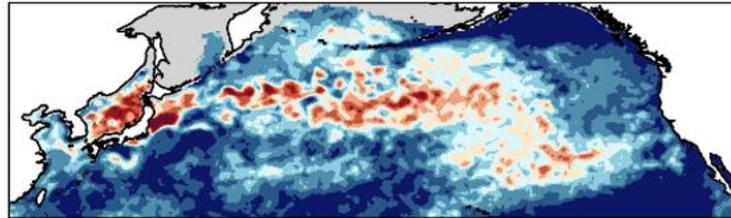
0-300 m OHC change 2020-2024 minus 2010-2019

Area name	Area share (%)	OHC change (ZJ)	OHC change share (%)	OHC change/area (MJ/m ²)
Global	100.0	49.5 (2.5)	100.0 (0.0)	127 (18)
NH mid-high lats (20-90N)	26.7	24.1 (1.4)	48.7 (1.1)	240 (59)
Western NP (20-65N, 110E-175W)	5.8	7.8 (0.6)	15.8 (0.5)	346 (56)
Eastern NP (20-65N, 175W-100W)	5.7	5.8 (0.4)	11.8 (0.9)	265 (47)
North Atlantic (20-65N, 100W-30E)	8.4	8.9 (0.9)	18.0 (1.4)	271 (50)
Tropics (20S-20N)	36.3	12.9 (1.2)	26.1 (1.3)	91 (9)
SH mid-high lats (90S-20S)	37.1	12.5 (0.6)	25.2 (1.5)	86 (8)

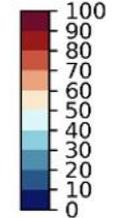
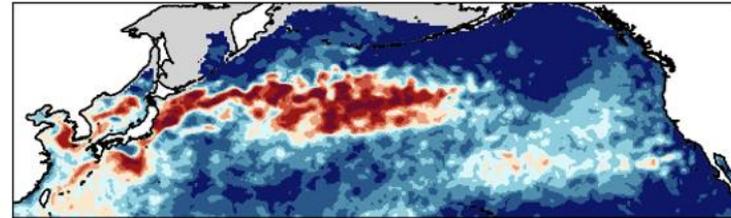
OHC increase per unit area in the western NP is about 3-times larger than the global average and has global share of 15.8% (about 1/6)! This share has a substantial meaning.

North Pacific contributed more than 1/4 th.

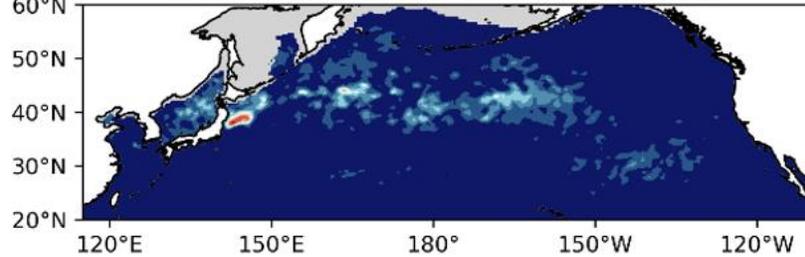
a) 2023, Moderate or Higher (1 < Intensity)



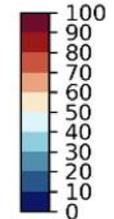
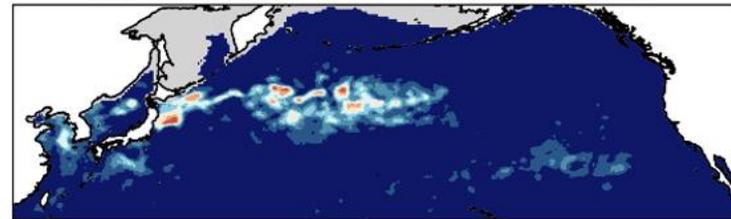
b) 2024, Moderate or Higher (1 < Intensity)



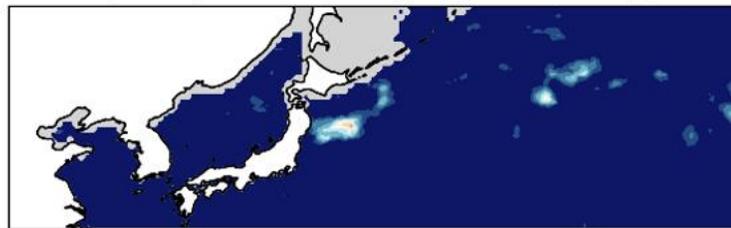
c) 2023, Strong or Higher (2 < Intensity)



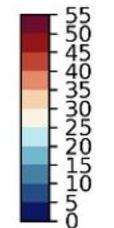
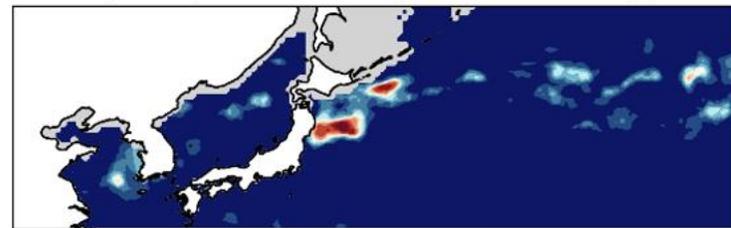
d) 2024, Strong or Higher (2 < Intensity)



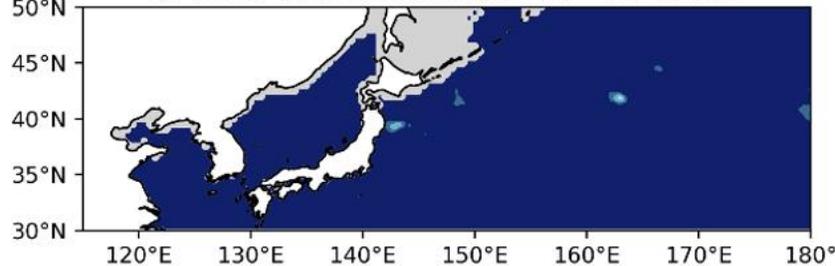
e) 2023, Severe or Higher (3 < Intensity)



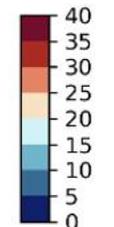
f) 2024, Severe or Higher (3 < Intensity)



g) 2023, Extreme or Higher (4 < Intensity)



h) 2024, Extreme or Higher (4 < Intensity)



Severe, extreme, and ultra MHWs occurred in coastal waters near Japan.

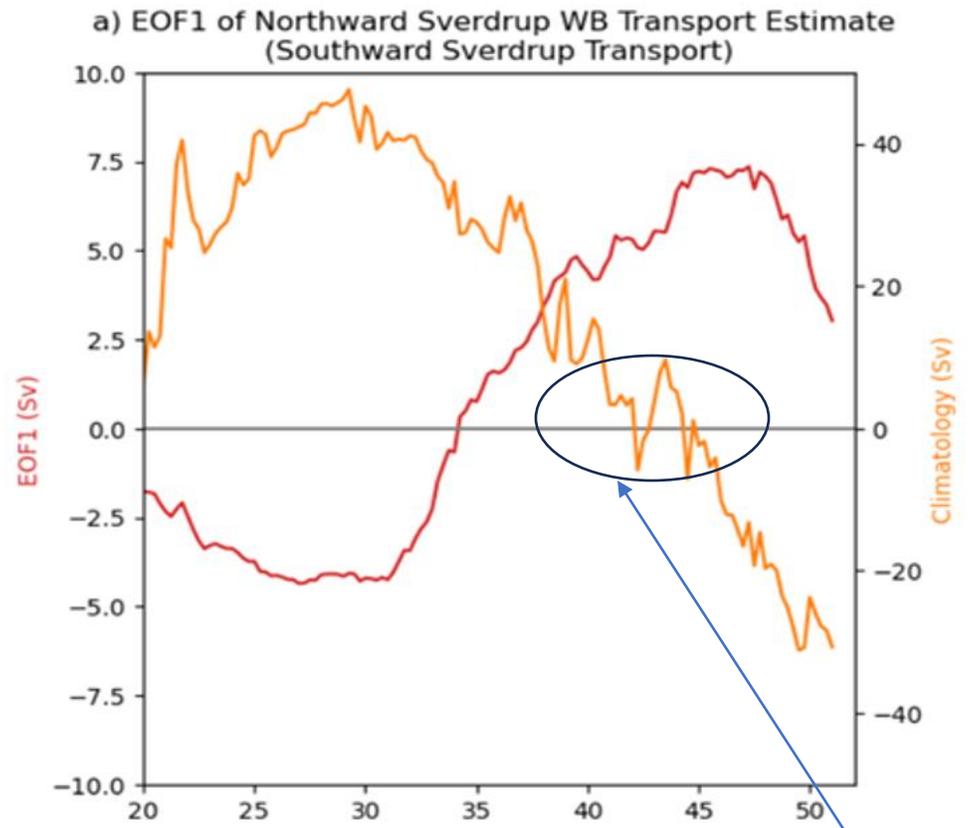
There are lots of influence on marine ecosystems, including marked reduction of salmon catch in northern Japan.

3. Ocean Circulation & Wind Forcing Change

In order to understand overall spatio-temporal development of Sverdrup transport, I use EOF analysis for Sverdrup Transport as follows.

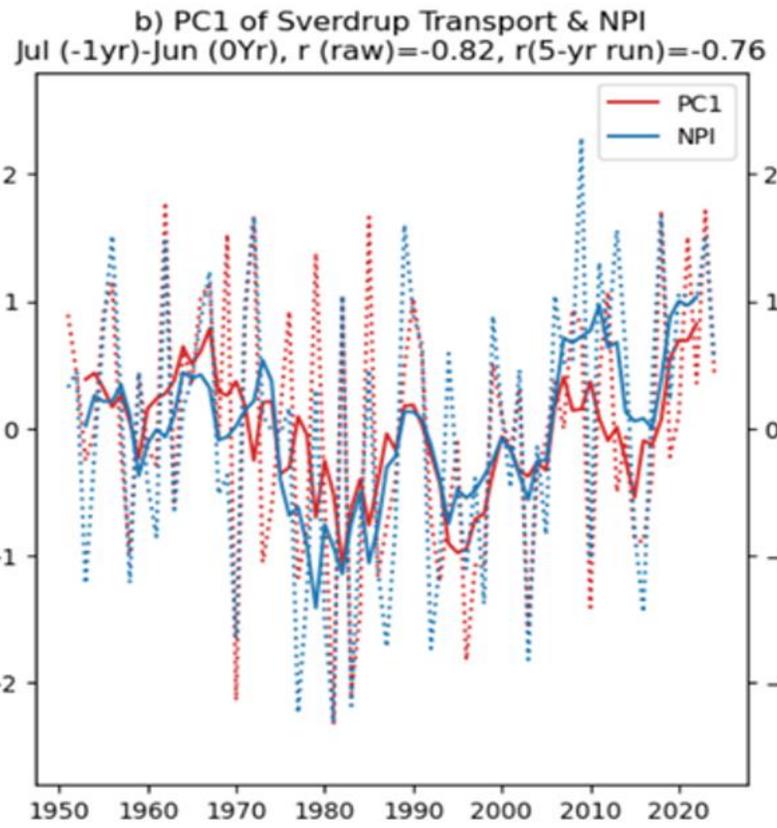
1. Sverdrup meridional interior transport, V_i , is calculate at each grid point.
2. V_i is integrated over the basin zonally.
3. Integration of V_i with sign-reverse is treated as the estimated western boundary current transport, V_b , as a function of latitude and time.
4. Conduct EOF analysis of V_b to get EOF1 pattern and time function.

Sverdrup transport is an approximation and has potential problems especially in the subarctic basin. If you are interested in detailed discussion about this, please read my paper.



EOF1, with opposing polarities to climatology, tends to weaken the subtropical and subpolar gyres.

EOF1, positive around climatological zero latitude, tends to push the gyre boundary to the North.



North Pacific Index (Aleutian Low Strength) highly correlated to Sverdrup PC1

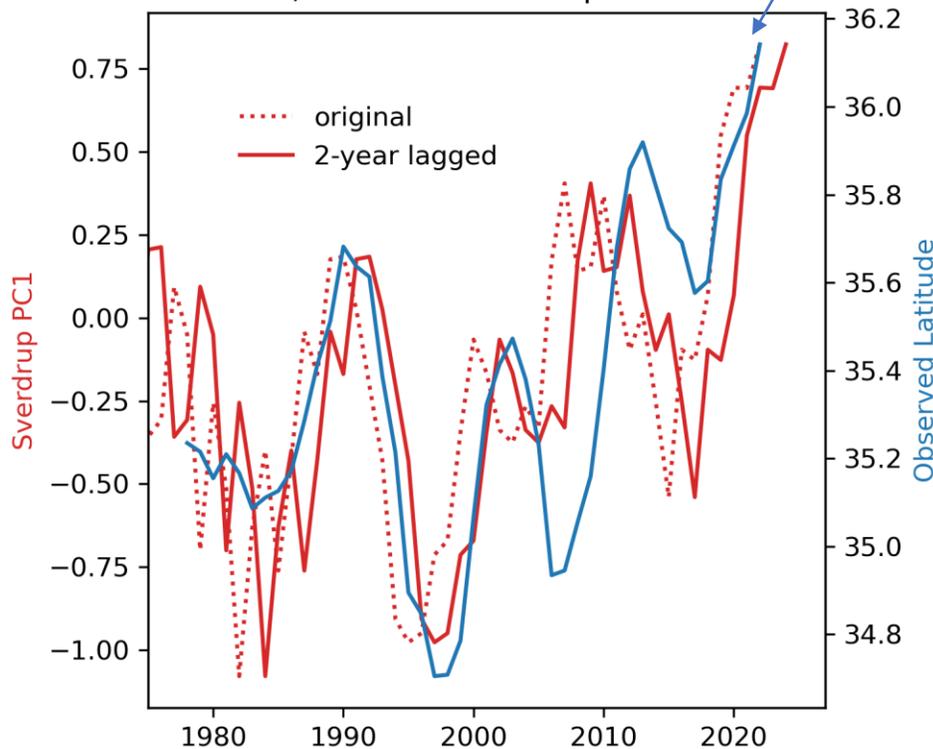
1960s (before the 1970s regime shift) was also anomalous similar to the present.

Aleutian Low Strength largely controls the basin-scale Sverdrup transport, whose EOF1 is anomalously positive in the 2020s.

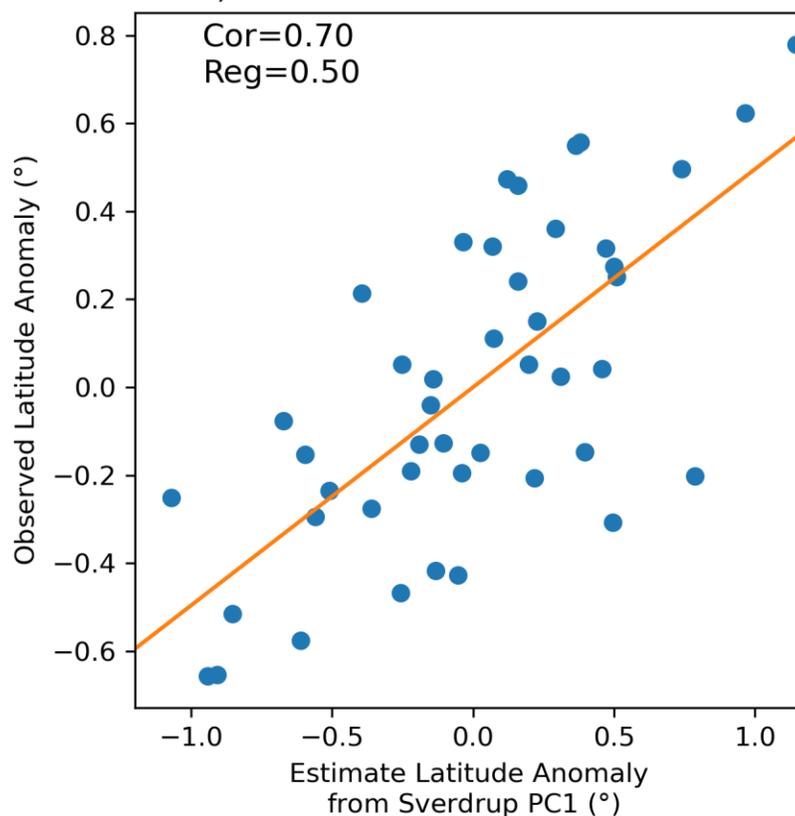
Mean latitude of eastward transport between between 30° and 40°N.

Mean Latitude of 0-300 m U averaged over 155-165°E between 30-40°N

a) Time Series Comparison



b) Estimated vs Observed Latitude

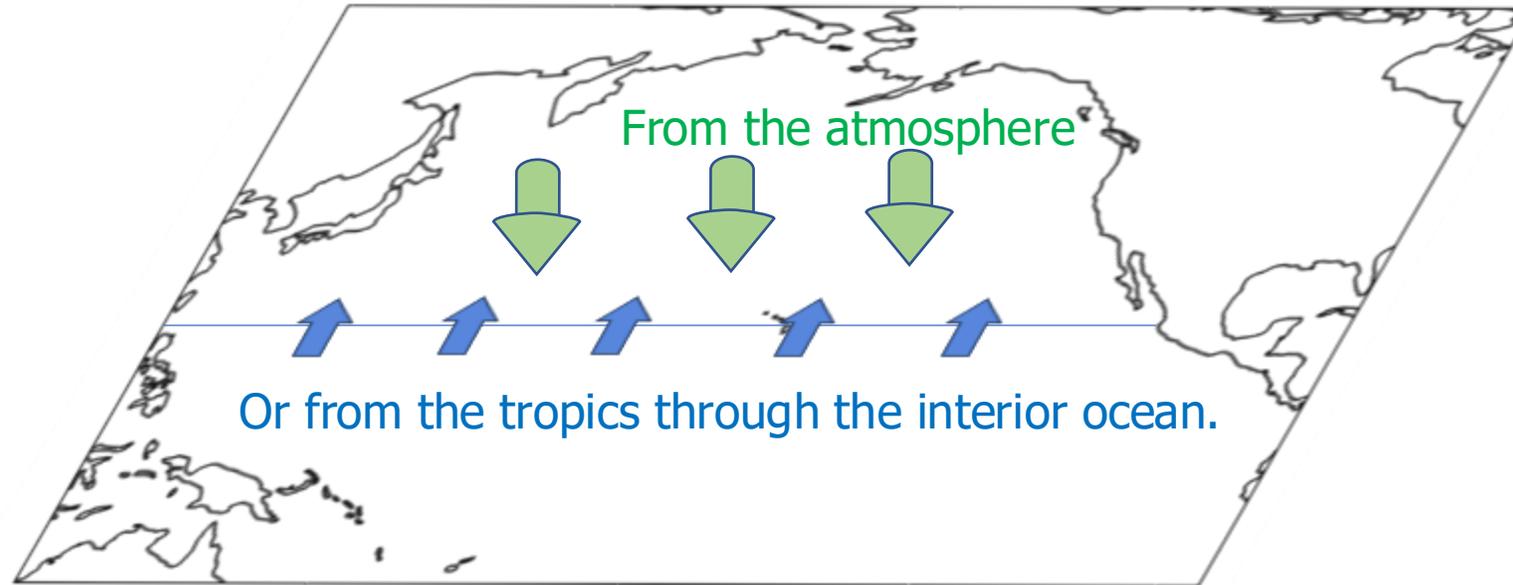


Wind-stress is important.

However, only by winds we cannot explain unprecedented Kuroshio-Oyashio conditions.

Further questions & conclusions

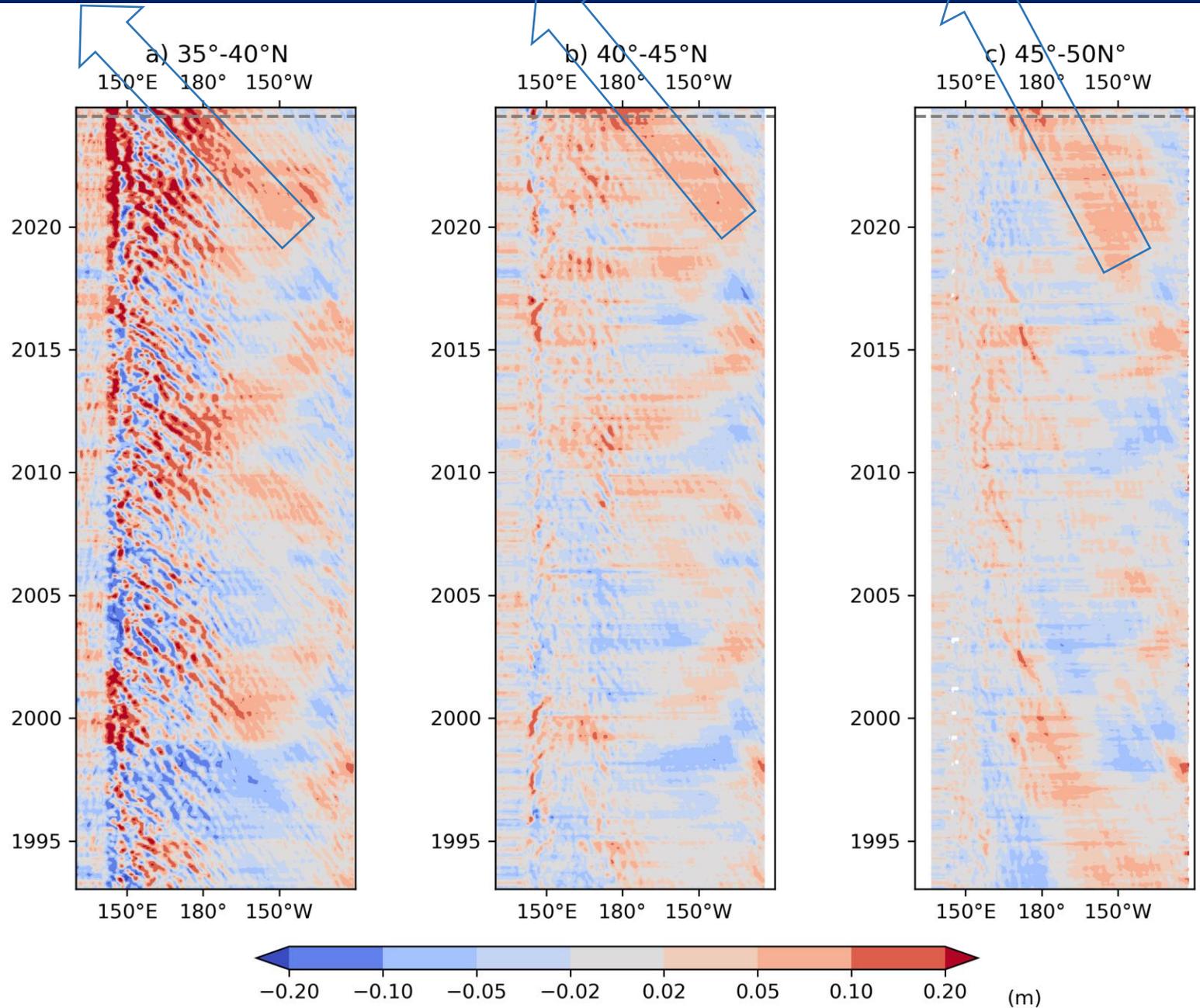
Kuroshio transport has been weakened.



I am trying to distinguish these two possibilities.

Since heat flux and heat transport data are not very reliable, and thus we need to carefully compare different datasets.

SSH anomalies with global mean removed



More SSH > 0 anomalies can come to the western NP in 5-10 years.

We need to keep watching!

- The North Pacific has **heated up in the 2020s**, with abnormal conditions of the Kuroshio and Oyashio.
- The 0-300 m western NP OHC increase in the western NP explains **15.8%**.
- **Extreme Marine Heatwaves** occurred around Japan in 2023 and 2024.
- **Winds** act to weaken the subtropical and subpolar gyres, and move the gyre boundary northward, consistent with observed (in ORAS5) features.
- It is unclear whether **weakened Aleutian low** is due to **global warming**.
- **More SSH>0 anomalies appear to come**. We need to watch!

The Kuroshio-Oyashio is the hottest spot in the global-boiling in the 20

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<https://rdcu.be/etVPC>

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