



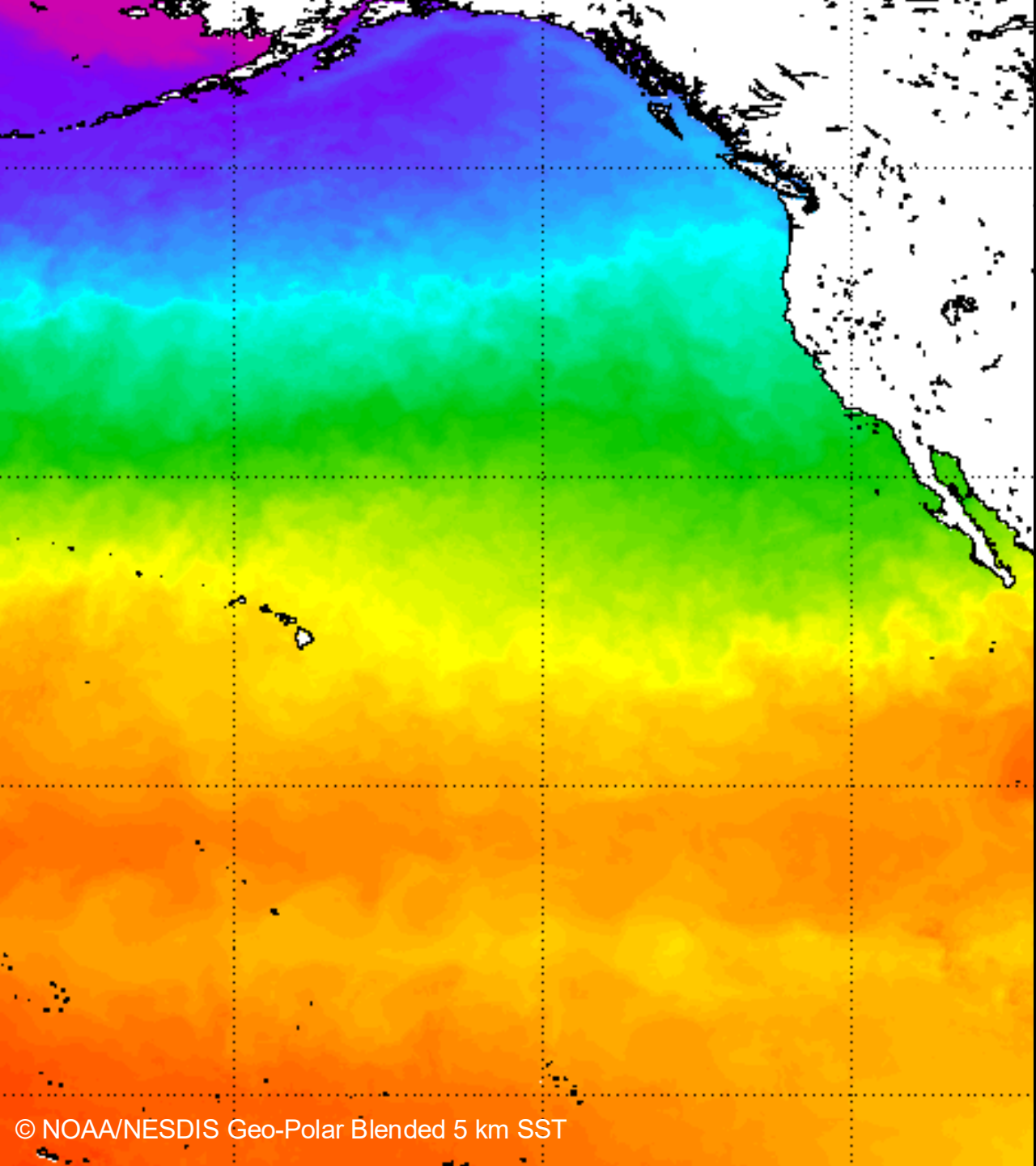
esa

Do latitudinal variations in the transfer efficiency of the BCP exist?

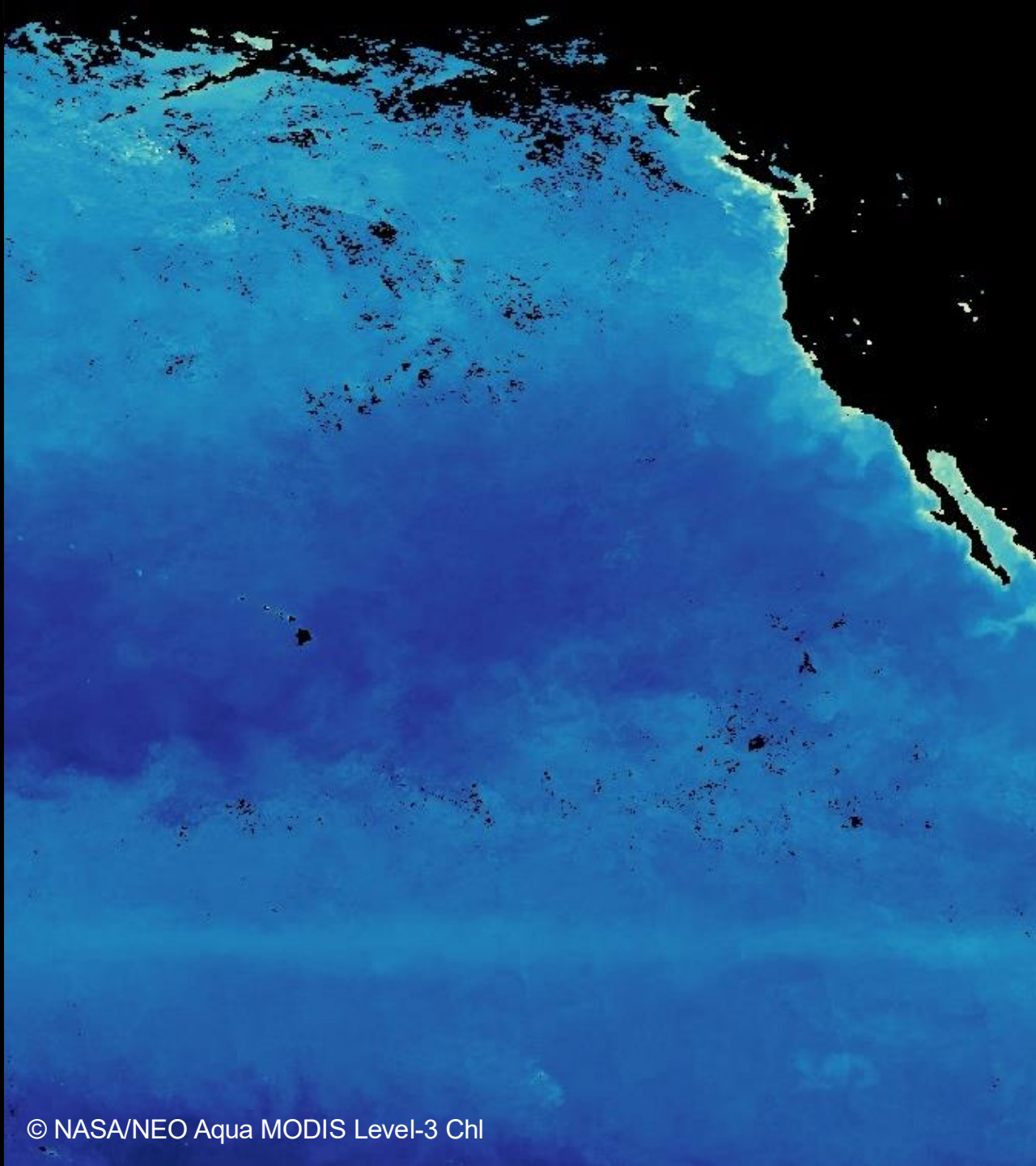
Anna Rufas

Department of Earth Sciences, University of Oxford

With contributions from: S. Khatiwala (Waseda), H.A. Bouman (Oxford), K.M. Bisson (NASA) & A.P. Martin (NOCS)



© NOAA/NESDIS Geo-Polar Blended 5 km SST



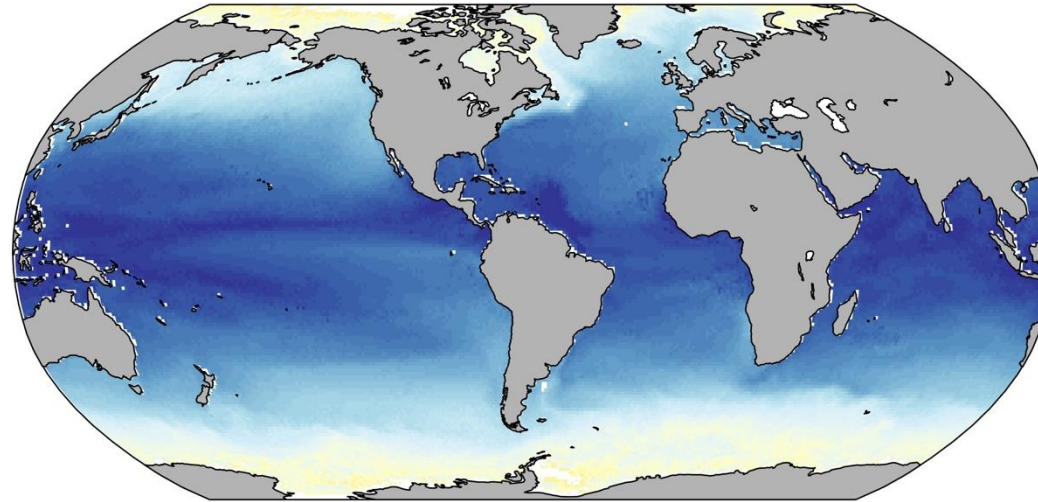
© NASA/NEO Aqua MODIS Level-3 Chl

Opposing latitudinal gradients

Henson et al. (2012)

high lat: $\downarrow T_{\text{eff}}$

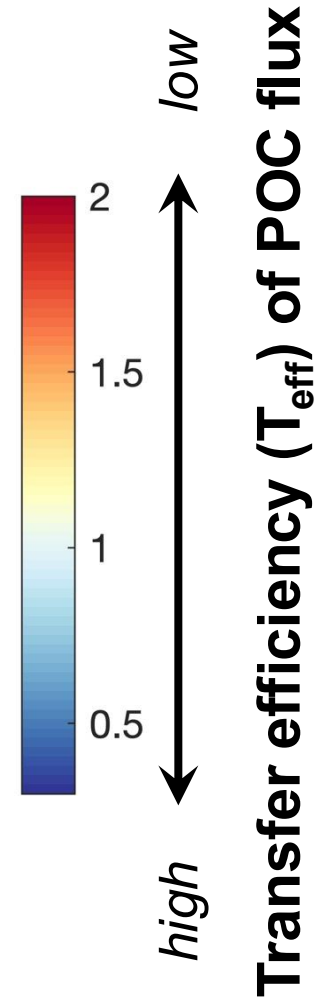
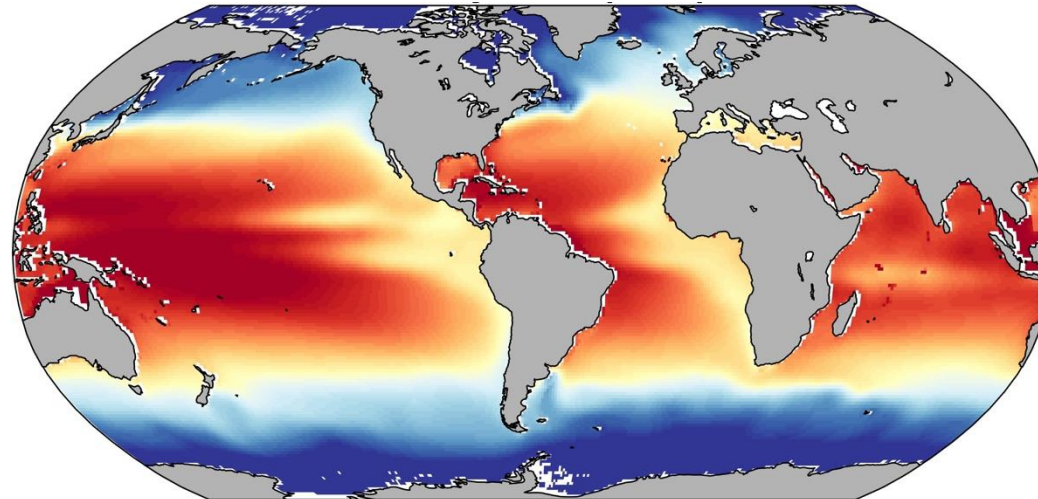
low lat: $\uparrow T_{\text{eff}}$



Marsay et al. (2015)

high lat: $\uparrow T_{\text{eff}}$

low lat: $\downarrow T_{\text{eff}}$



Causes for the disagreement

The disagreement might not be ecological –but methodological:

The disagreement might not be ecological –but methodological:

Geophysical Research Letters®






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK



Causes for the disagreement

The disagreement might not be ecological –but methodological:

Geophysical Research Letters®






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK

- Sparse spatial coverage

Causes for the disagreement

The disagreement might not be ecological –but methodological:

Geophysical Research Letters[®]






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK

- Sparse spatial coverage
- Different seasonal windows

Causes for the disagreement

The disagreement might not be ecological –but methodological:

Geophysical Research Letters[®]






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK

- Sparse spatial coverage
- Different seasonal windows
- Different depth horizons

Causes for the disagreement

The disagreement might not be ecological –but methodological:

Geophysical Research Letters[®]






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK



- Sparse spatial coverage
- Different seasonal windows
- Different depth horizons
- Different metric definitions

Causes for the disagreement

The disagreement might not be ecological –but methodological:

Geophysical Research Letters[®]






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK



- Sparse spatial coverage
- Different seasonal windows
- Different depth horizons
- Different metric definitions
- Inconsistent uncertainty treatment

Causes for the disagreement

The disagreement might not be ecological –but methodological:

Geophysical Research Letters[®]






RESEARCH LETTER

10.1029/2024GL111203

Received 16 JUL 2024

Accepted 9 DEC 2024

Can We Constrain Geographical Variability in the Biological Carbon Pump's Transfer Efficiency From Observations?

A. Rufas¹ , S. Khatiwala² , K. M. Bisson^{3,4} , A. P. Martin⁵ , and H. A. Bouman¹ 

¹Department of Earth Sciences, University of Oxford, Oxford, UK, ²School of International Liberal Studies, Waseda University, Tokyo, Japan, ³Earth Science Division, Ocean Biology and Biogeochemistry Program, NASA Headquarters, Washington, DC, USA, ⁴Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR, USA, ⁵National Oceanography Centre, Southampton, UK

- Sparse spatial coverage
- Different seasonal windows
- Different depth horizons
- Different metric definitions
- Inconsistent uncertainty treatment

Before attributing structure to ecology,
we must rule out structure introduced by
methodology.

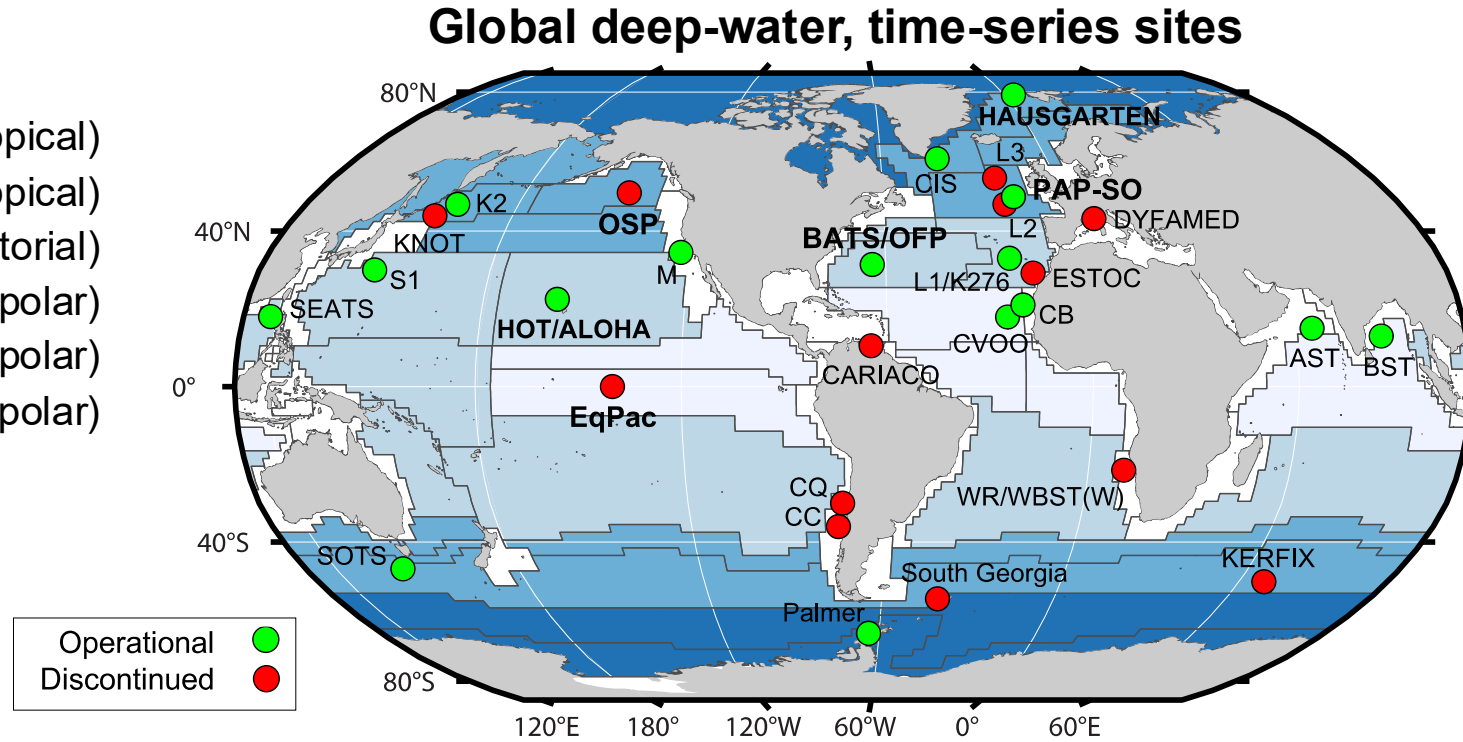
Our approach: harmonised methods and uncertainty

To test this properly:

Our approach: harmonised methods and uncertainty

To test this properly:

- HOT/ALOHA** (subtropical)
- BATS/OFP** (subtropical)
- EqPac** (equatorial)
- PAP-SO** (subpolar)
- OSP** (subpolar)
- HAUSGARTEN** (polar)



Rufas et al. (2025)

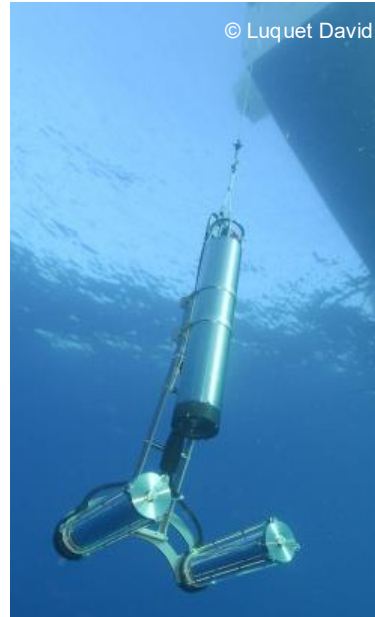
- **6 data-rich time-series sites** across biomes

Our approach: harmonised methods and uncertainty

To test this properly:



+ radionuclide disequilibria +



+

Francois et al. (2022)
Buesseler & Boyd (2009)
Lam et al. (2011)
Guidi et al. (2015)
Mouw et al. (2016)
Henson et al. (2012)
Marsay et al. (2015)
Weber et al. (2016)
SLAMS-2.0 (Rufas et al., *submitted*)

- **6 data-rich time-series sites** across biomes
- **Multiple methods integrated**

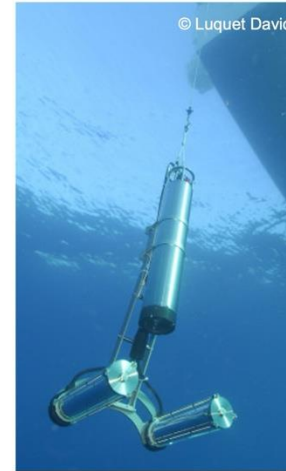
Our approach: harmonised methods and uncertainty

To test this properly:

HOT/ALOHA (subtropical)
BATS/OFP (subtropical)
EqPac (equatorial)
PAP-SO (subpolar)
OSP (subpolar)
HAUSGARTEN (polar)



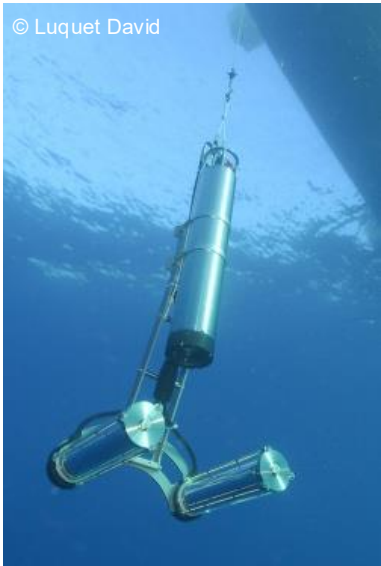
+ radionuclide disequilibria +



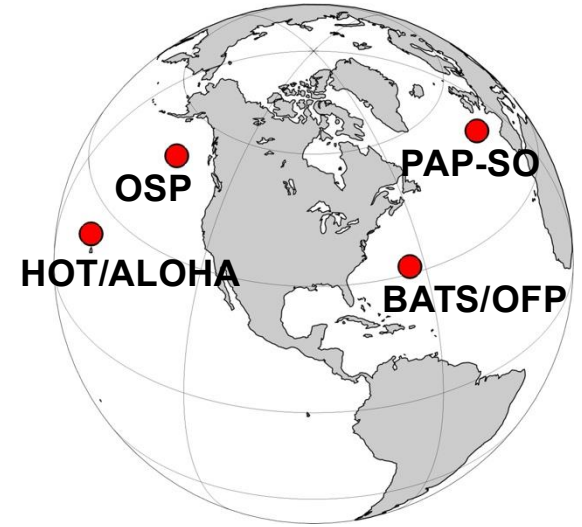
+ Francois et al. (2022)
Buesseler & Boyd (2009)
Lam et al. (2011)
Guidi et al. (2015)
Mouw et al. (2016)
Henson et al. (2012)
Marsay et al. (2015)
Weber et al. (2016)
SLAMS-2.0 (Rufas et al., *submitted*)

- **6 data-rich time-series sites** across biomes
- **Multiple methods integrated**
- **Harmonised data treatment:**
 - Consistent depth definitions ($z_{eu} \rightarrow z_{meso}$)
 - Monte Carlo uncertainty propagation

Do methods agree locally?

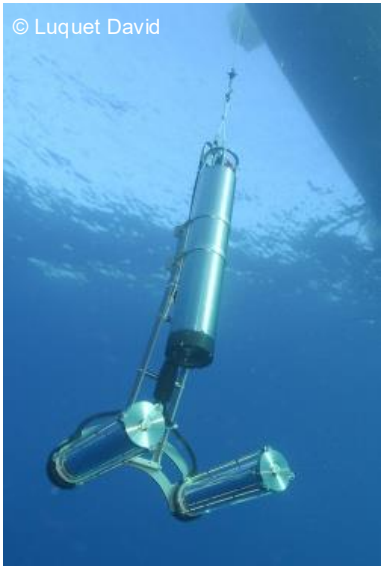


© Luquet David
UVP5 POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)

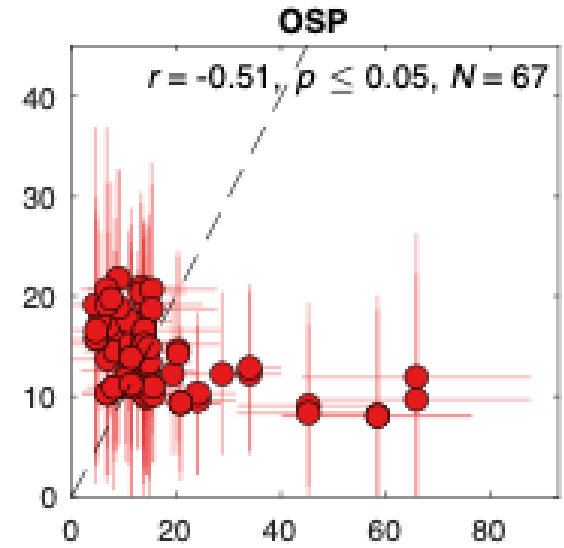
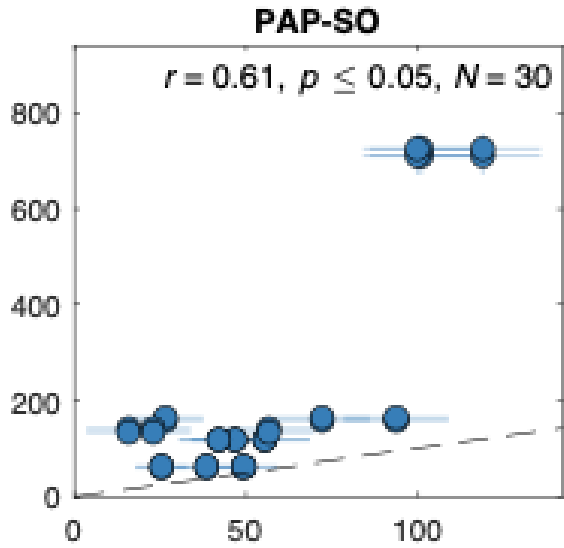
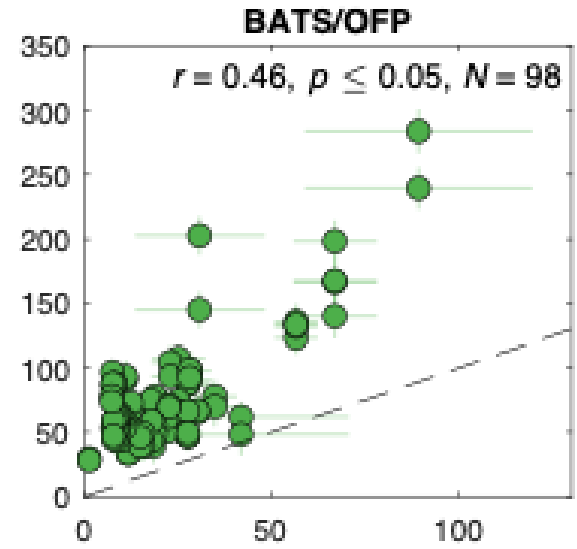
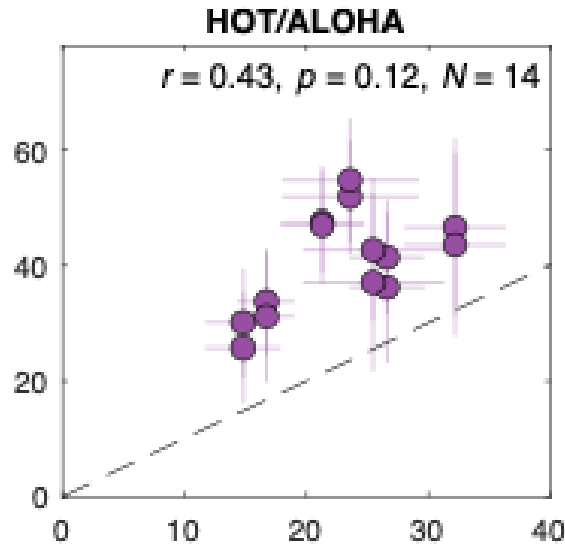


© MBARI
Sediment trap & radionuclide POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)

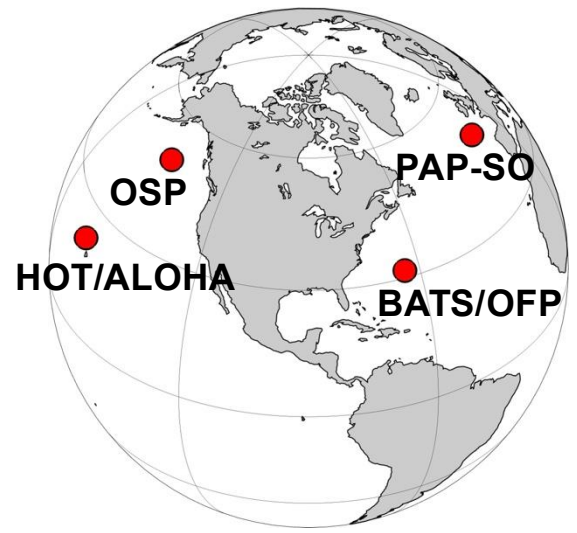
Do methods agree locally?



UVP5 POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)



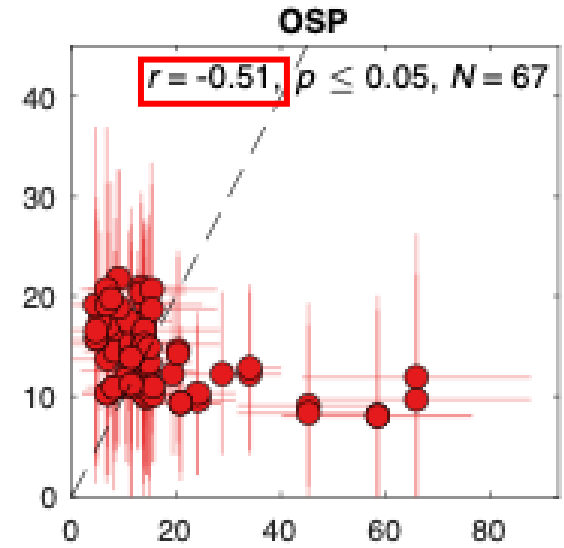
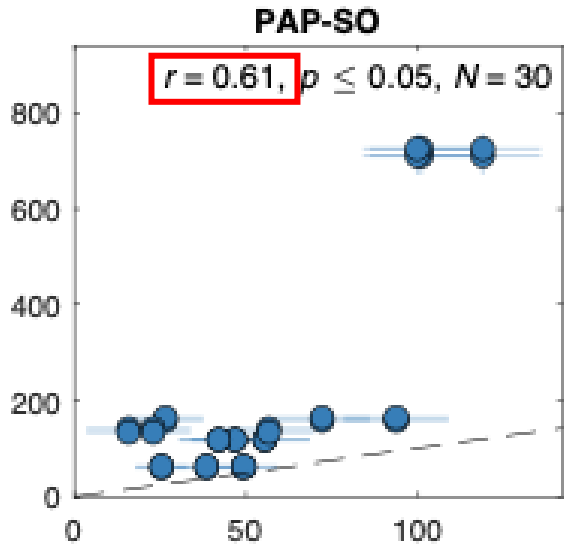
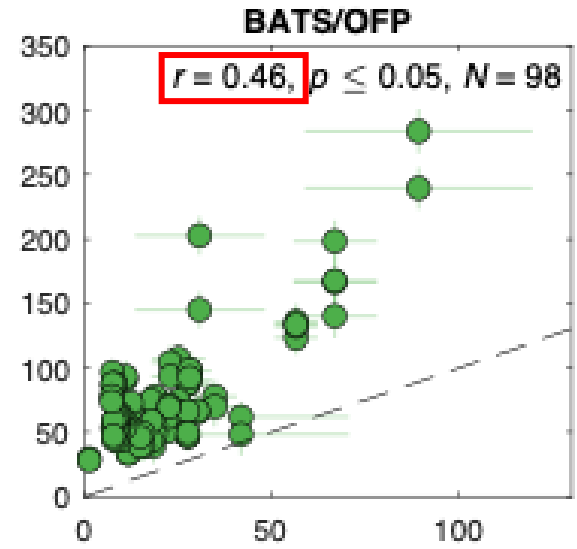
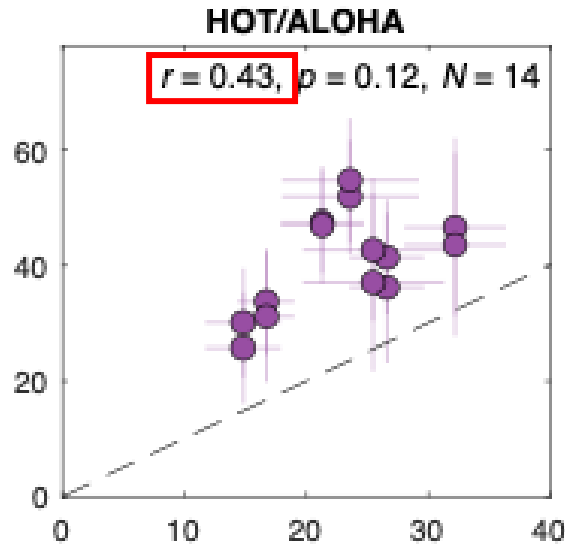
Sediment trap & radionuclide POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)



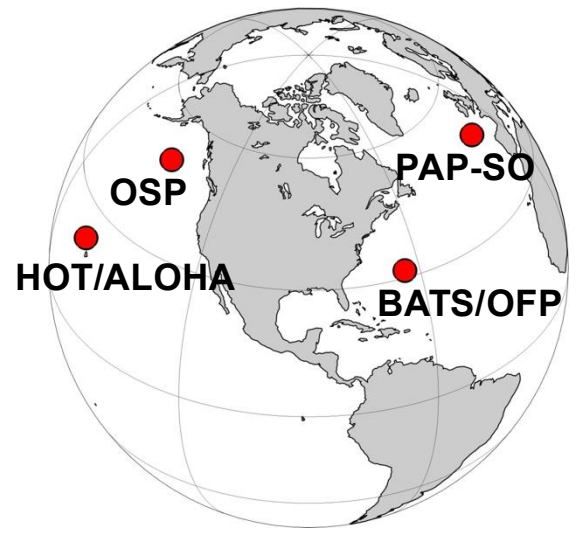
Do methods agree locally?



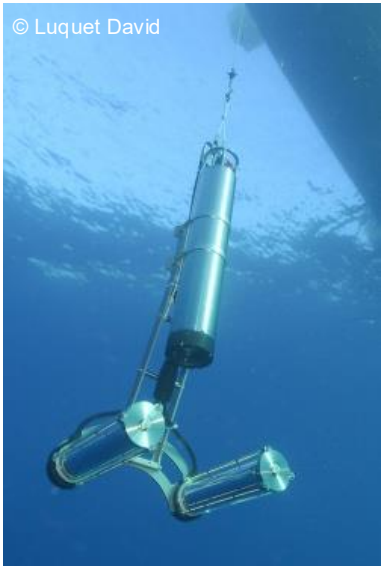
UVP5 POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)



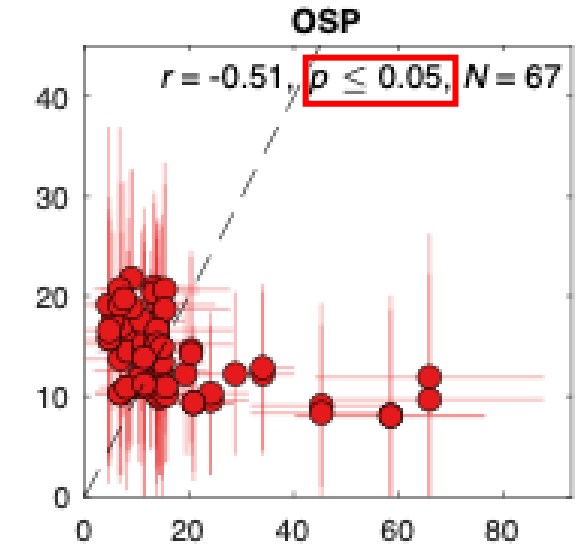
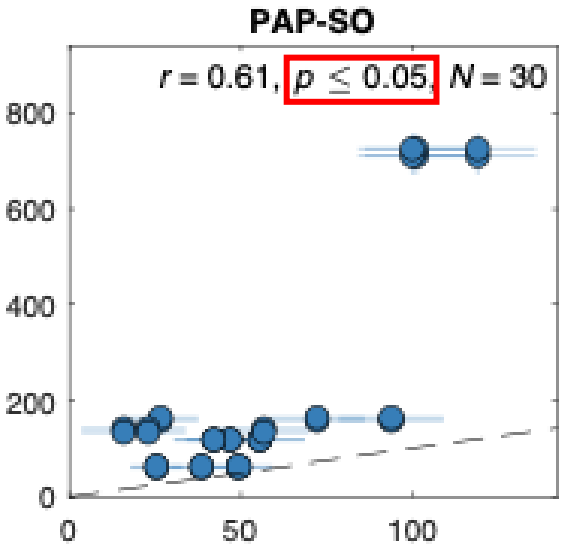
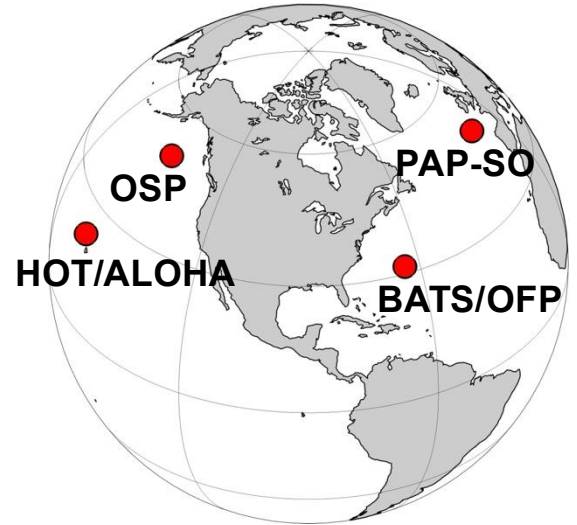
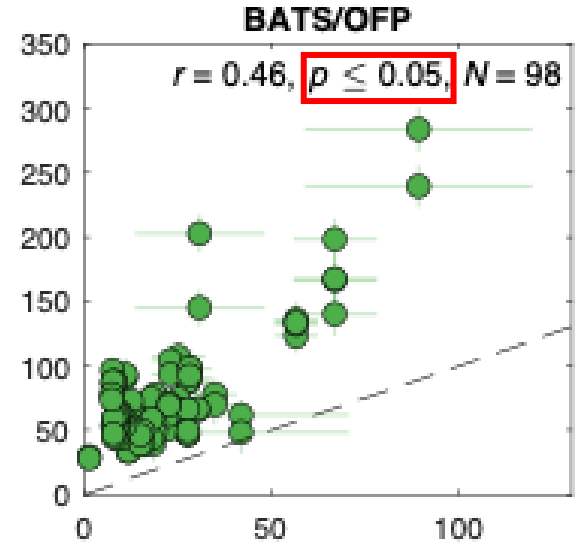
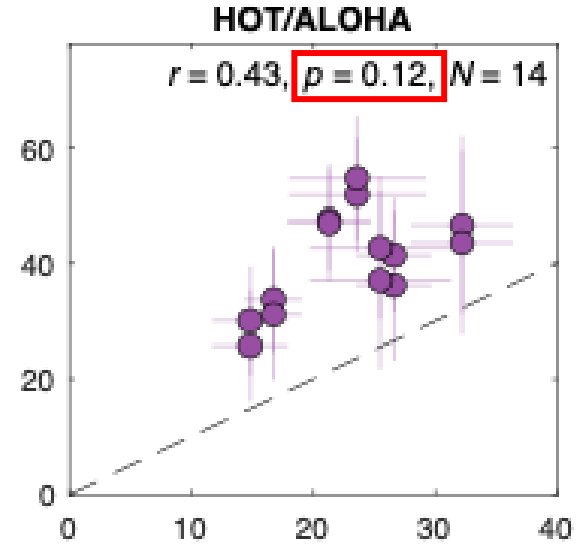
Sediment trap & radionuclide POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)



Do methods agree locally?



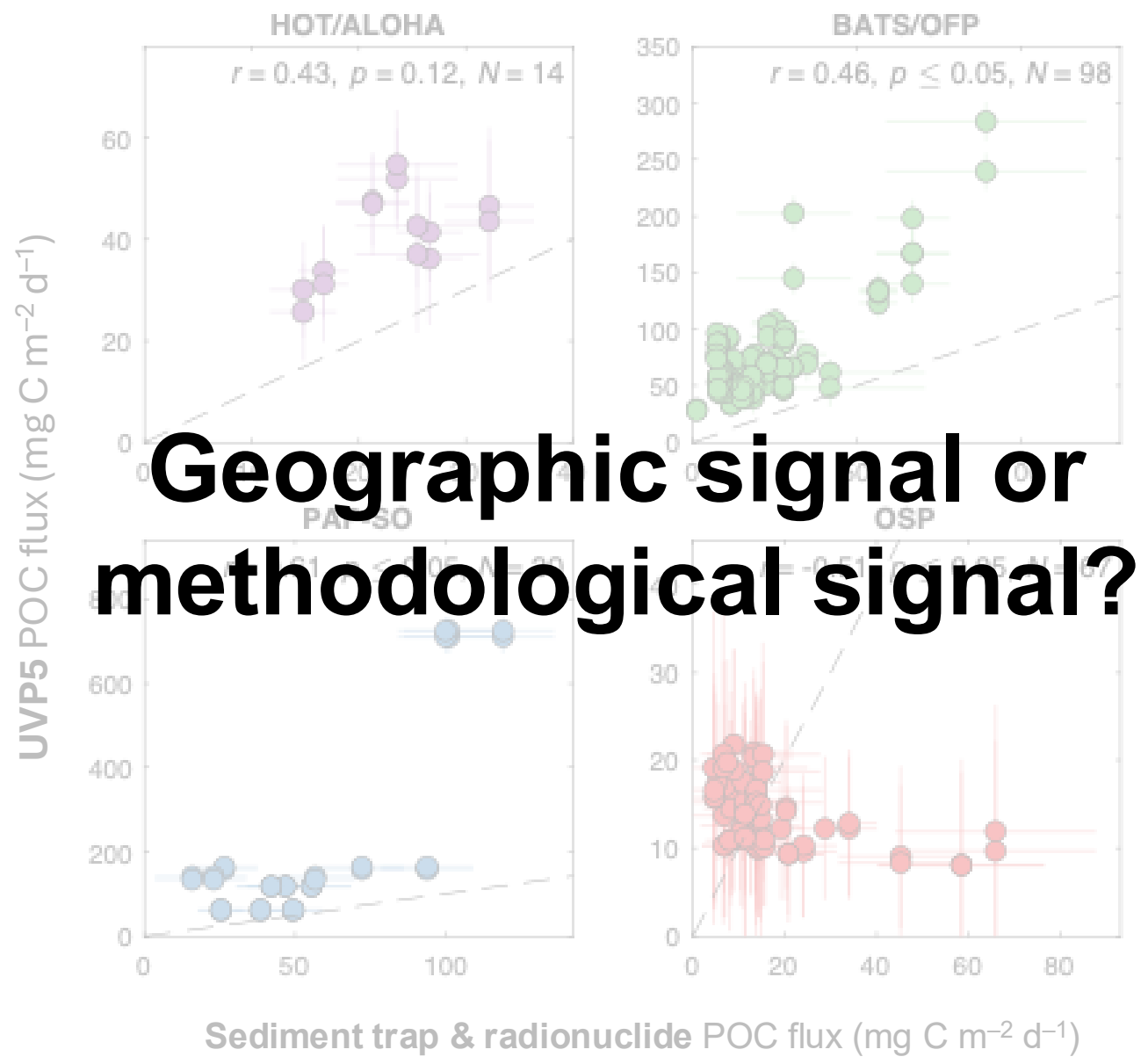
UVP5 POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)



Sediment trap & radionuclide POC flux ($\text{mg C m}^{-2} \text{d}^{-1}$)



Do methods agree locally?



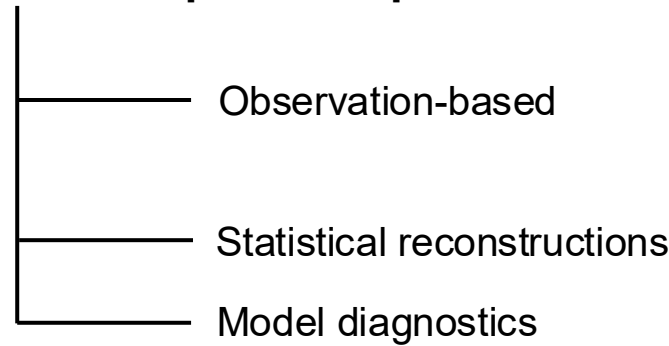
Geographic signal or methodological signal?

No detectable latitudinal gradient

- Francois et al. (2022)
- Buesseler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)

No detectable latitudinal gradient

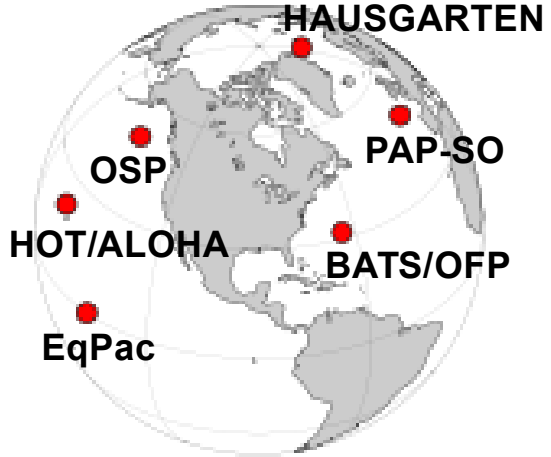
Metrics as reported in prior studies



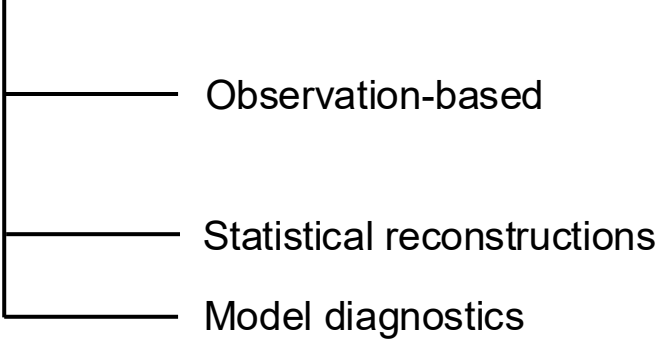
Metrics recomputed from raw flux

- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)

No detectable latitudinal gradient

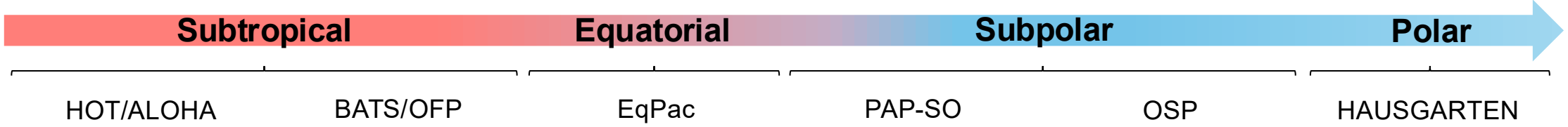


Metrics as reported in prior studies

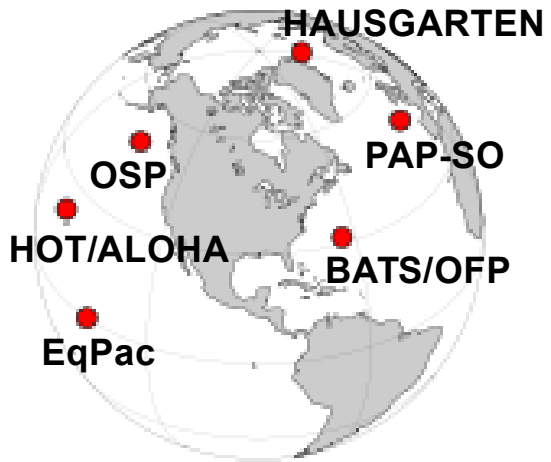


- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)

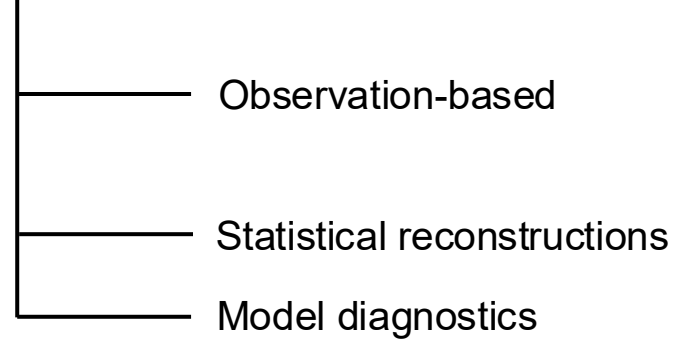
Metrics recomputed from raw flux



No detectable latitudinal gradient

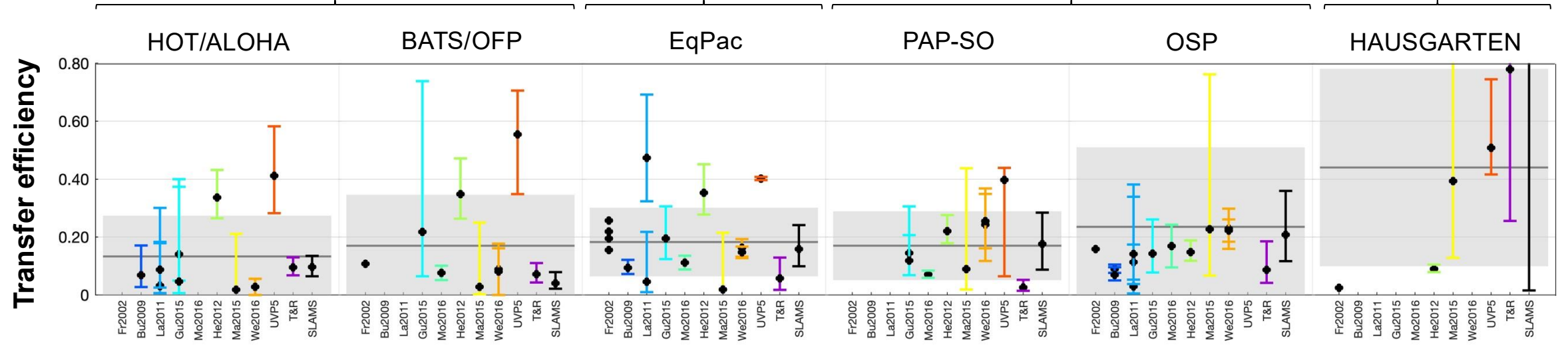


Metrics as reported in prior studies



- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)

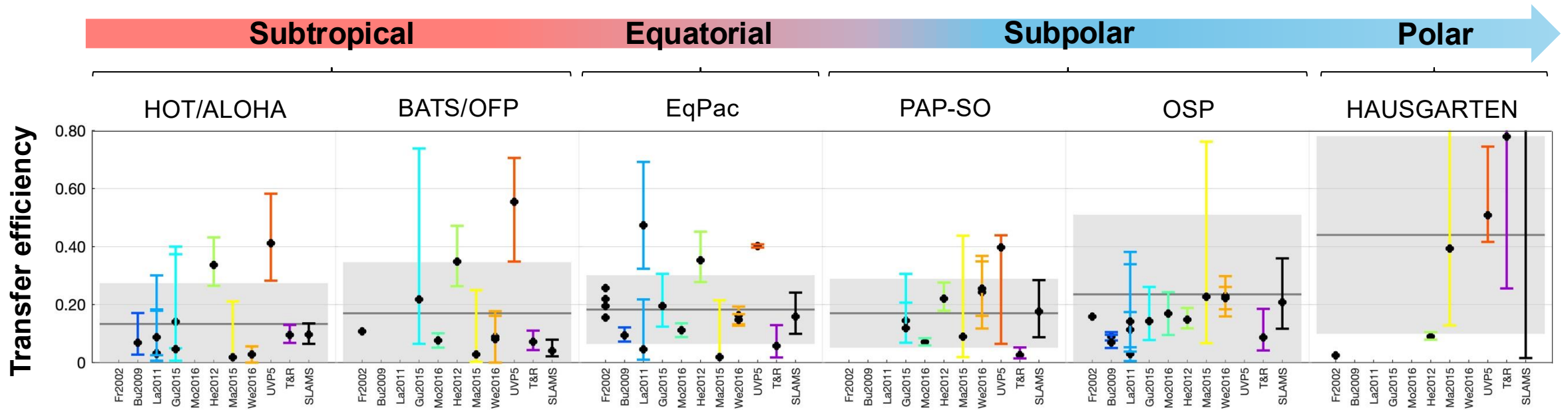
Metrics recomputed from raw flux



No detectable latitudinal gradient

- Noisy observational-based data

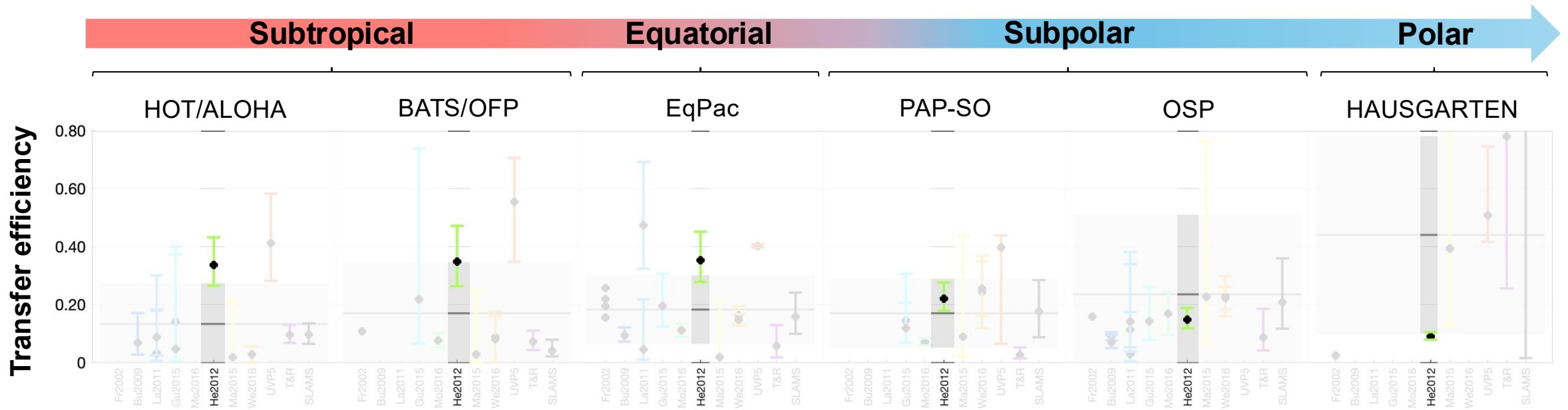
- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)



No detectable latitudinal gradient

- Noisy observational-based data
- Trends within individual studies

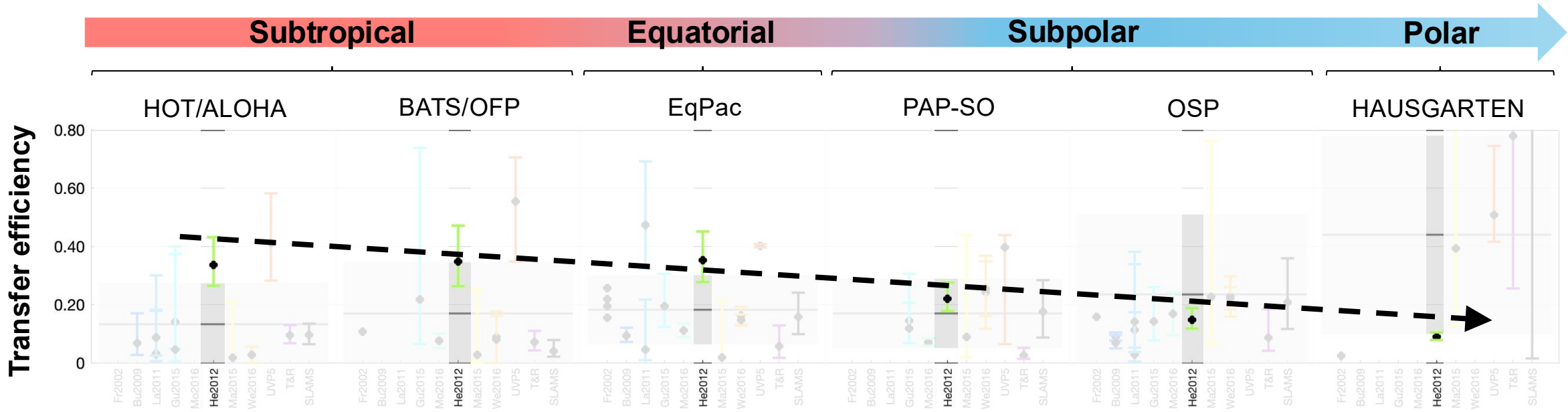
- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)



No detectable latitudinal gradient

- Noisy observational-based data
- Trends within individual studies

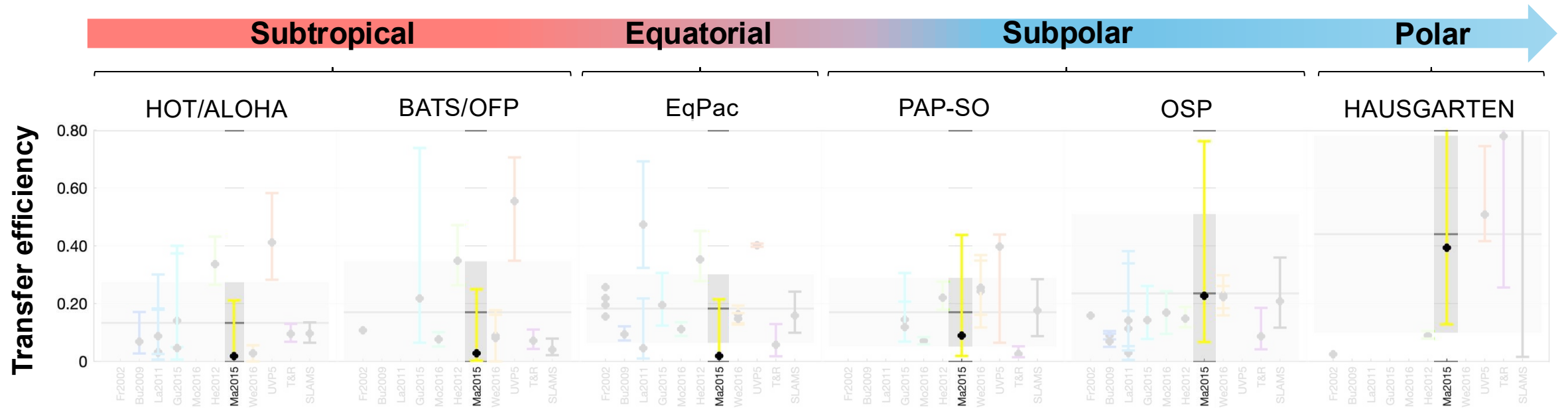
- Francois et al. (2022)
- Buesseler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)



No detectable latitudinal gradient

- Noisy observational-based data
- Trends within individual studies

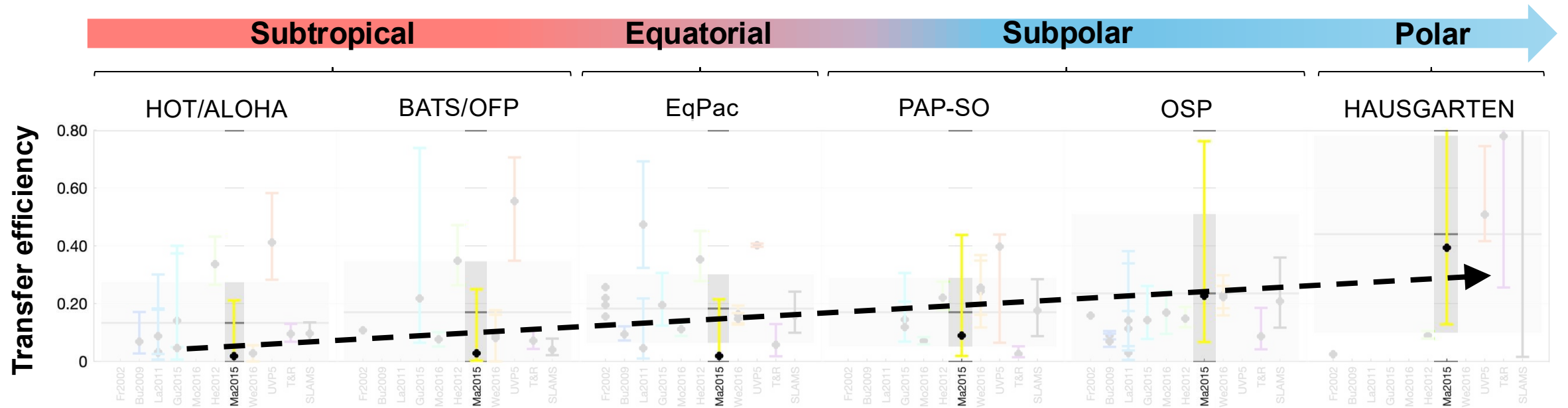
- Francois et al. (2022)
- Buesseler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)



No detectable latitudinal gradient

- Noisy observational-based data
- Trends within individual studies

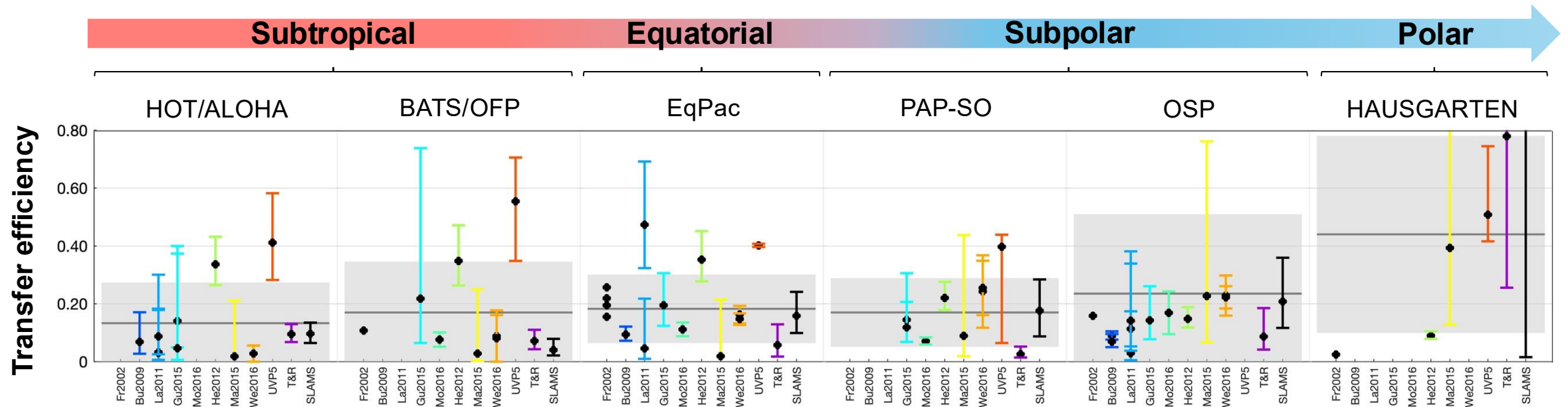
- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)



No detectable latitudinal gradient

- Noisy observational-based data
- Trends within individual studies
- No clear latitudinal gradient when combined

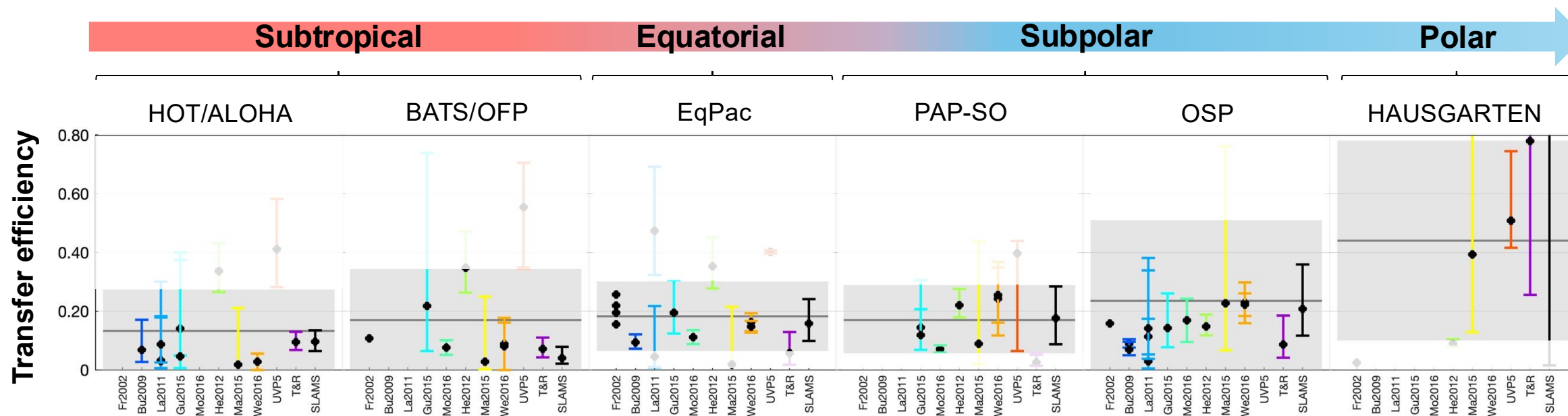
- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)



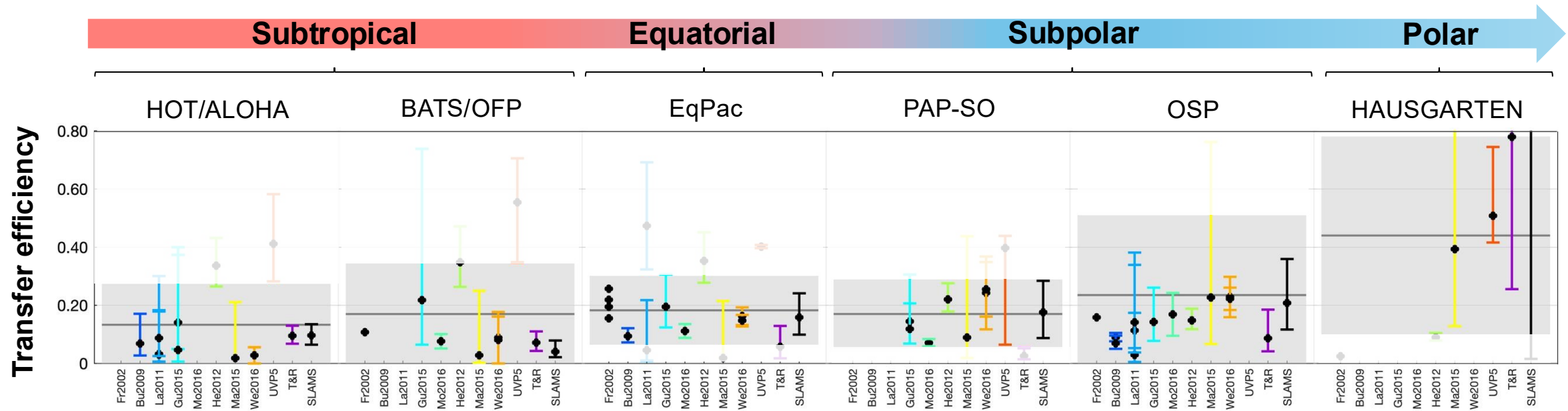
No detectable latitudinal gradient

- Noisy observational-based data
- Trends within individual studies
- No clear latitudinal gradient when combined
- No significant biome separation (Kruskal-Wallis $p > 0.05$)

- Francois et al. (2022)
- Buessler & Boyd (2009)
- Lam et al. (2011)
- Guidi et al. (2015)
- Mouw et al. (2016)
- Henson et al. (2012)
- Marsay et al. (2015)
- Weber et al. (2016)
- SLAMS-2.0 (Rufas et al., *submitted*)
- UVP5 compilation (Kiko et al., 2022)
- Trap & radionuclide compilation (Rufas et al., 2025)

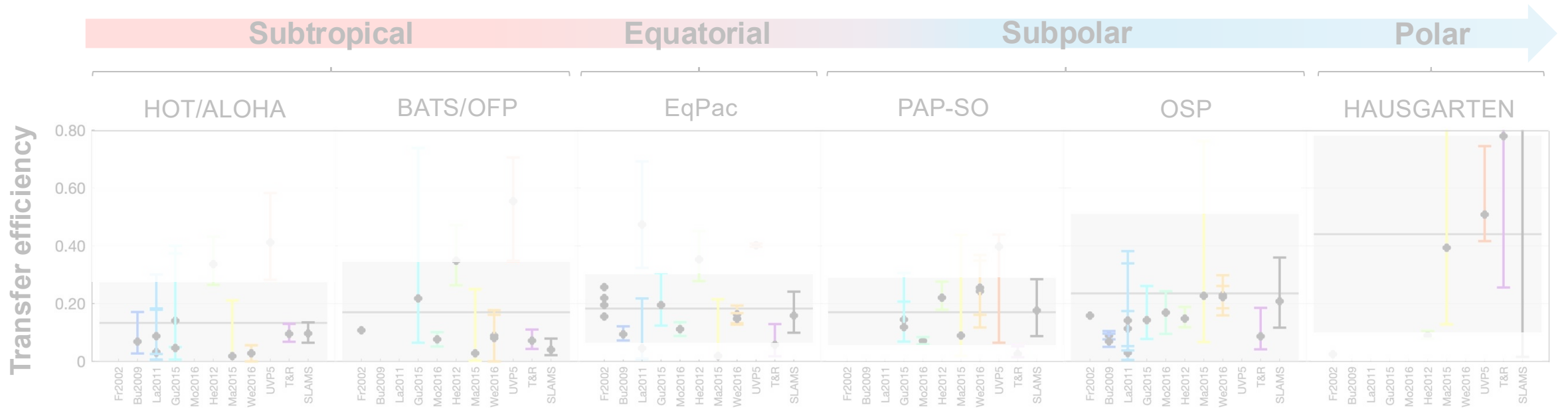


Why is the gradient hard to detect?



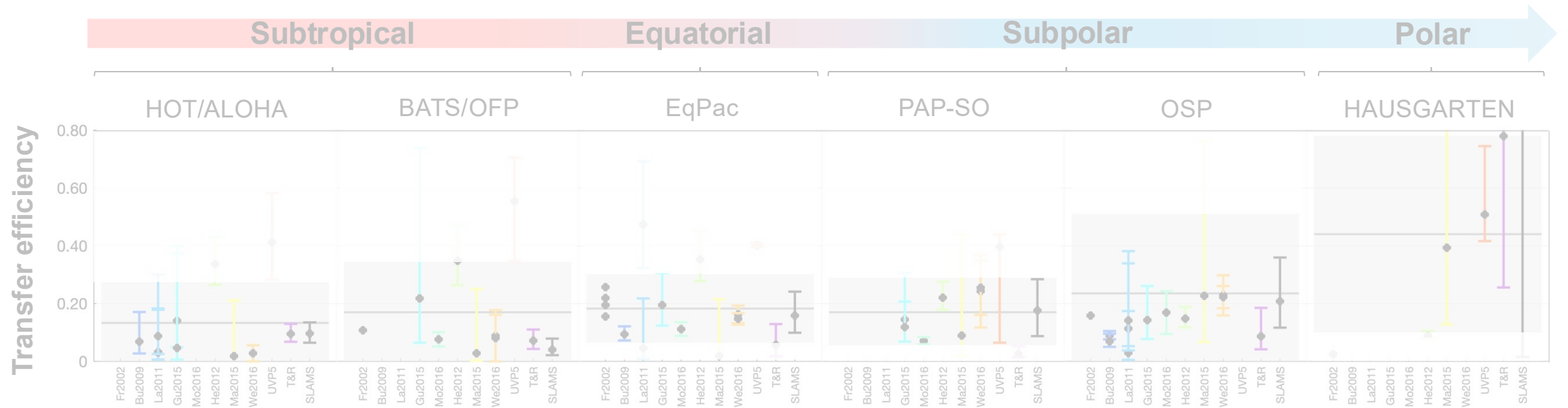
Why is the gradient hard to detect?

- Gradient may exist –but be weak



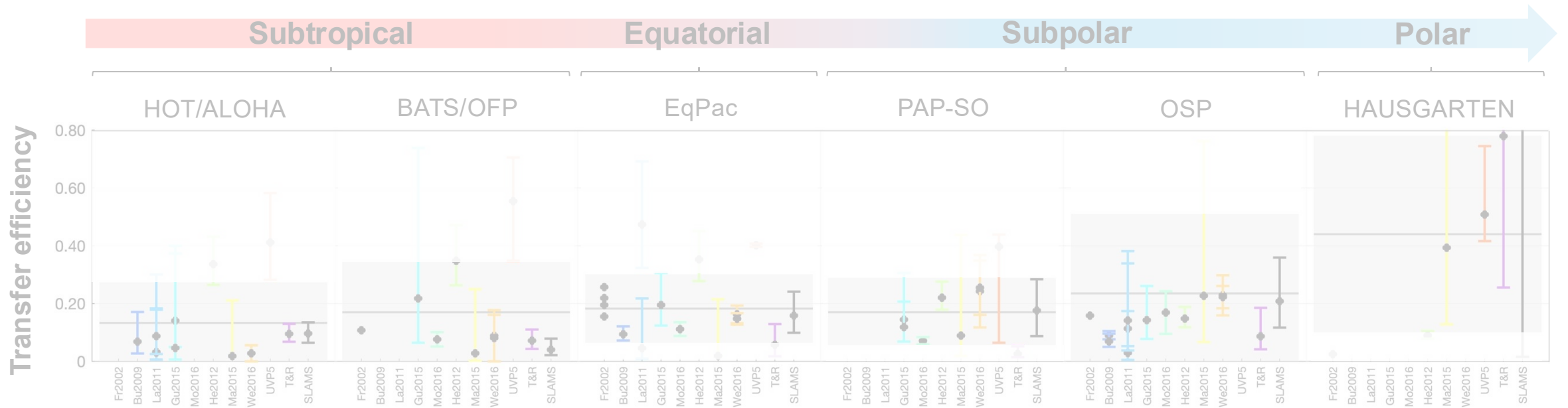
Why is the gradient hard to detect?

- Gradient may exist –but be weak
- Seasonal variability may dominate



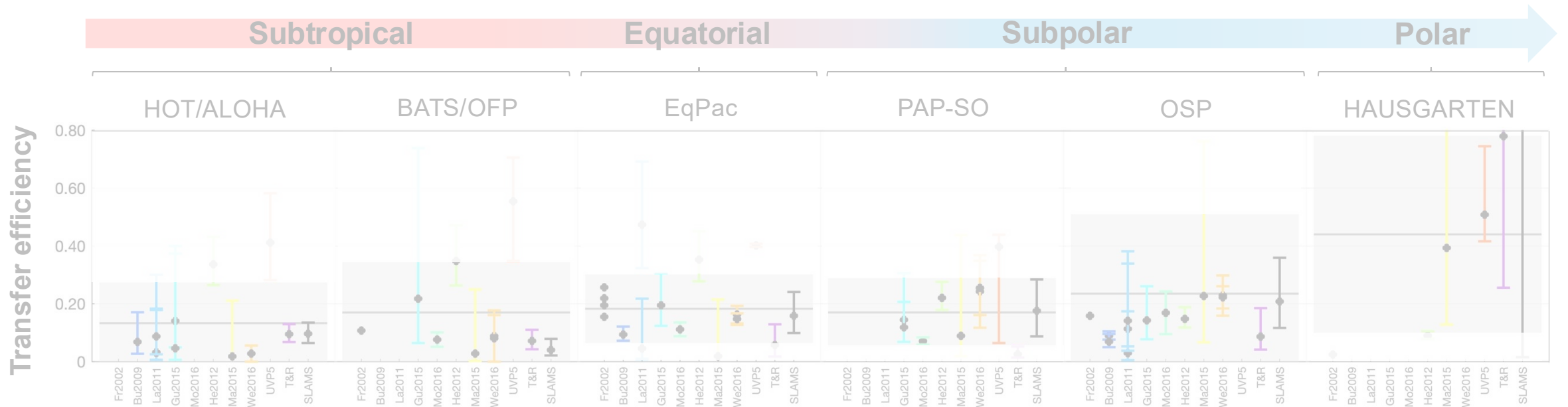
Why is the gradient hard to detect?

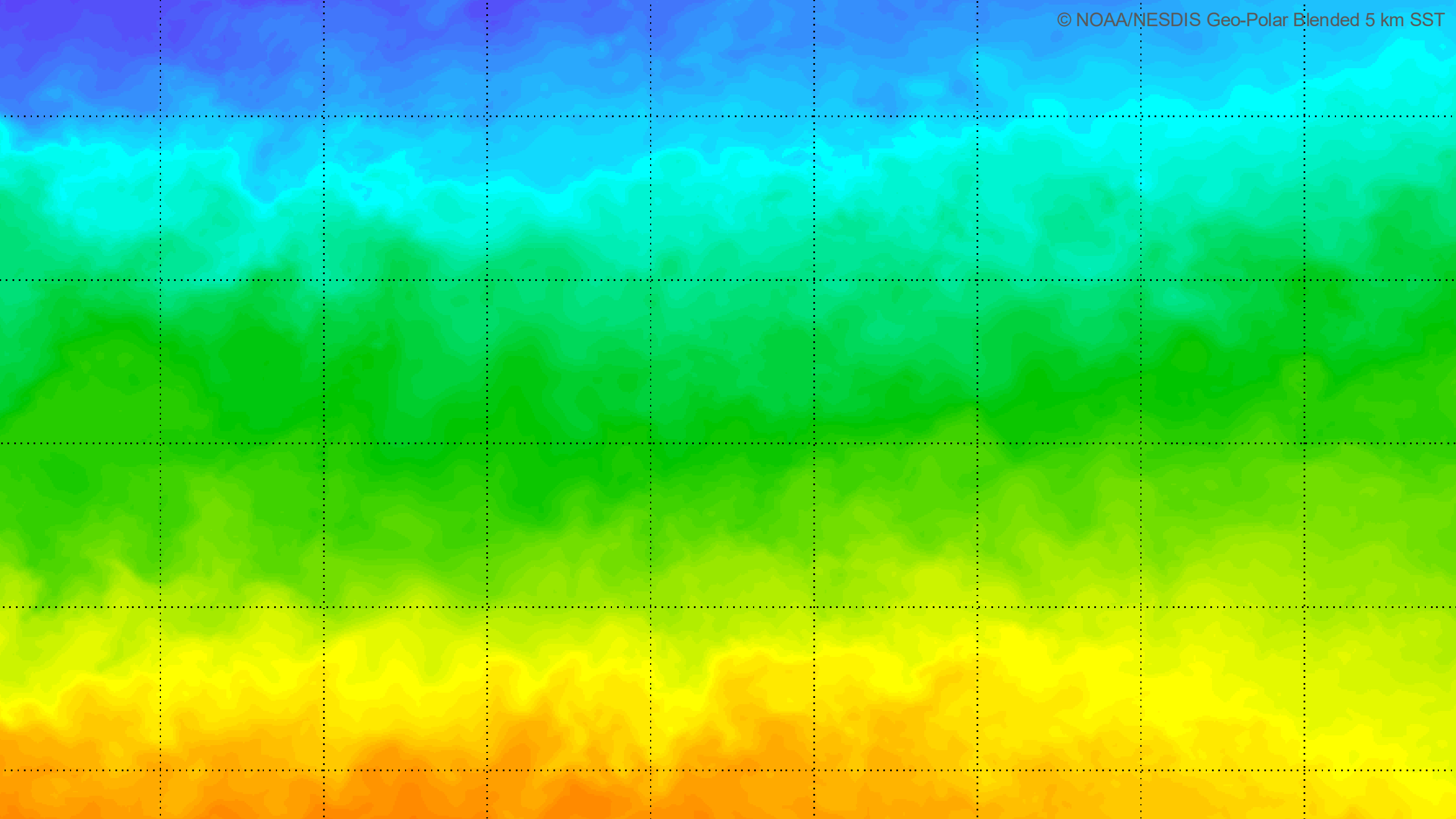
- Gradient may exist –but be weak
- Seasonal variability may dominate
- Observational uncertainty masks structure



Why is the gradient hard to detect?

- Gradient may exist –but be weak
- Seasonal variability may dominate
- Observational uncertainty masks structure
- Temperature may not be the dominant control





**Do latitudinal variations in
the transfer efficiency of the BCP
exist?**

Do latitudinal variations in the transfer efficiency of the BCP exist?

- The ocean has strong temperature gradients

Do latitudinal variations in the transfer efficiency of the BCP exist?

- The ocean has strong temperature gradients
- If temperature drives transfer efficiency, we would see structure

Do latitudinal variations in the transfer efficiency of the BCP exist?

- The ocean has strong temperature gradients
- If temperature drives transfer efficiency, we would see structure
- We flip the question: is the signal-to-noise ratio high enough?

Do latitudinal variations in the transfer efficiency of the BCP exist?

- The ocean has strong temperature gradients
- If temperature drives transfer efficiency, we would see structure
- We flip the question: is the signal-to-noise ratio high enough?
- Observational heterogeneity might be the bottleneck

Do latitudinal variations in the transfer efficiency of the BCP exist?

- The ocean has strong temperature gradients
- If temperature drives transfer efficiency, we would see structure
- We flip the question: is the signal-to-noise ratio high enough?
- Observational heterogeneity might be the bottleneck
- **Intercalibrate. Standardise. Sustain**

Do latitudinal variations in the transfer efficiency of the BCP exist?

With thanks to

Samar Khatiwala
Heather A. Bouman
Kelsey M. Bisson
Adrian P. Martin
B.B. Cael



Questions?

Anna.RufasBlanco@earth.ox.ac.uk

Open to postdoctoral and research opportunities
(Summer 2026)

Marine aggregates | Particle dynamics | BCP modelling
SLAMS-2.0 model (submitted to *JAMES*)

Read the paper

