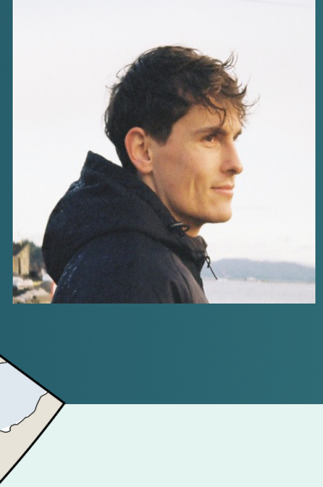
Variability in the Subpolar Gyre circulation and throughput towards the Nordic Seas

Johannes Unegg[1,2]
Helene Asbjørnsen[1,2], Lea Svendsen[1,2]
[1] Geophysical Institute, University of Bergen
[2] Bjerknes Centre for Climate Research

✉ johannes.unegg@uib.no

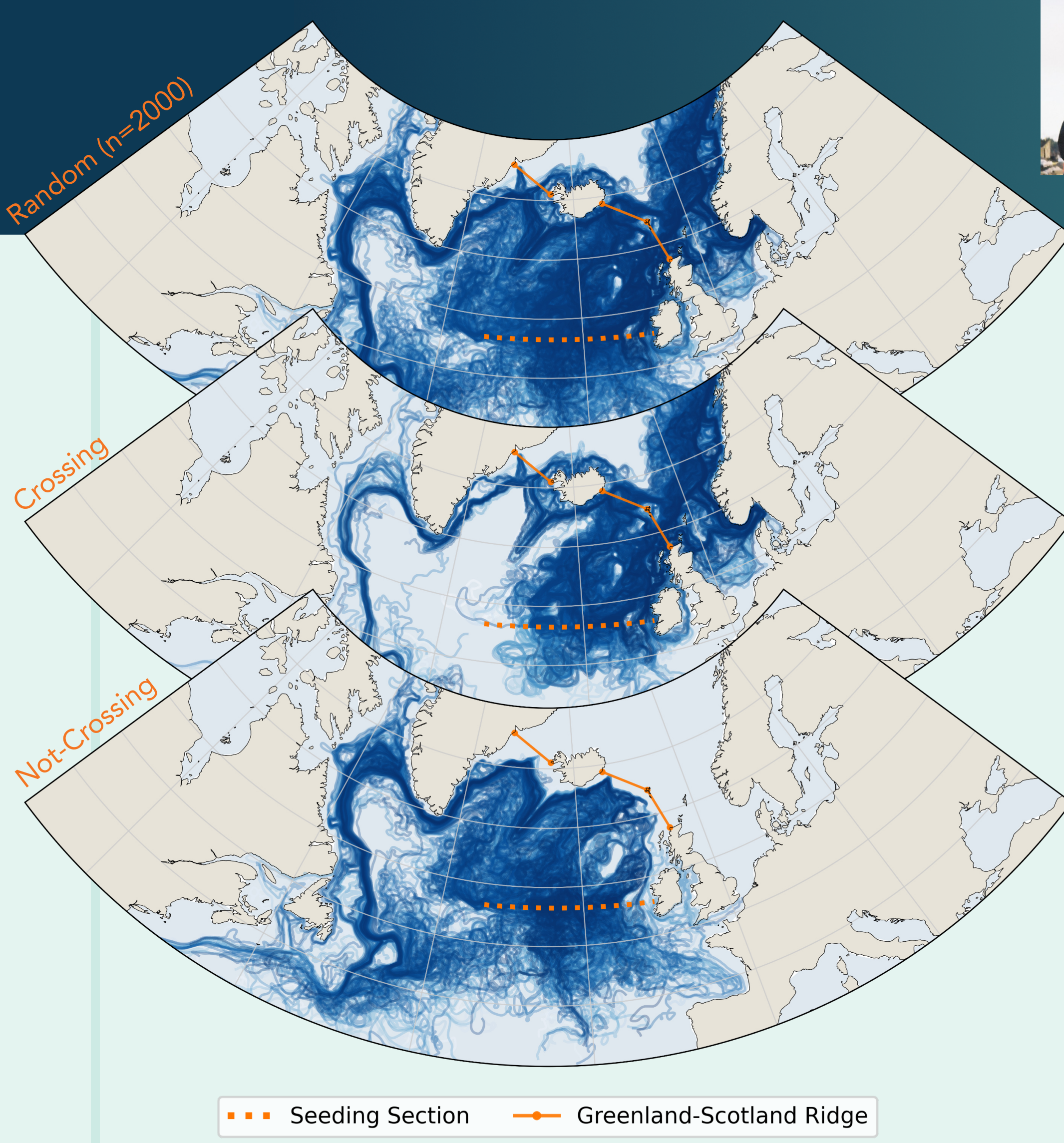


1. Context and Motivation

Although the Atlantic Meridional Overturning Circulation (AMOC) is often described as a conveyor belt, implying a coherent and closed system, evidence increasingly suggests a more intricate and dynamically variable structure. A lack of interannual to decadal coherence in the Atlantic basin leaves critical gaps in our ability to detect and attribute changes in the overturning circulation. Understanding how regional processes, such as gyre dynamics and wind forcing, obscure **basin-wide coherence** remains a key challenge.

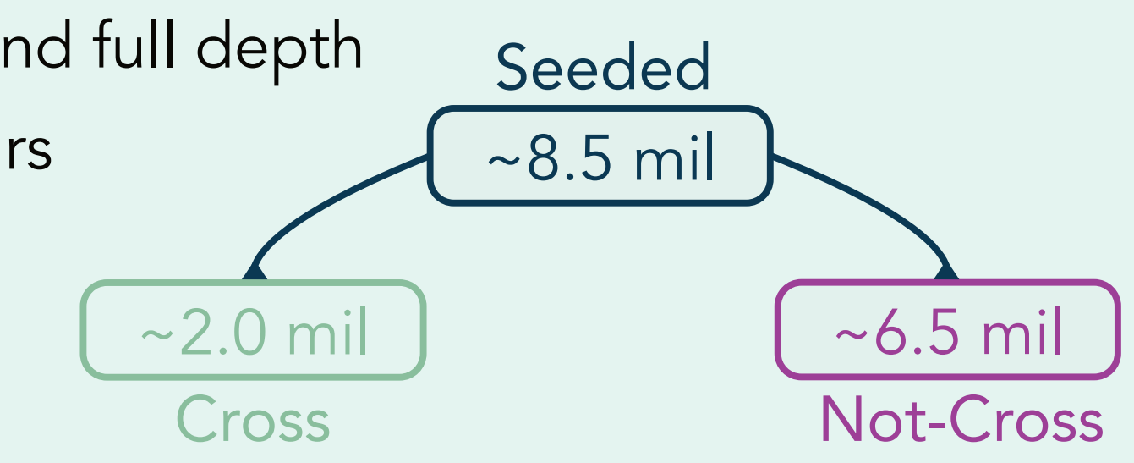
2. Objectives

- Quantify **mechanisms** driving variability in the **Nordic Seas inflow** across the Greenland-Scotland Ridge (GSR) versus Subpolar Gyre (SPG) **recirculation**
- Assess how these **processes modulate northward transport** of warm, saline **Atlantic waters** and associated heat flux across the GSR



3.1 Lagrangian Seeding

- seeding in North Atlantic Current (NAC) at ~53°N
- monthly seeding 1979–2017
- positive v-cells and full depth
- tracking of 4 years



3. Data and Methods

We use **Eulerian** and **Lagrangian** techniques to determine the **Nordic Seas inflow variability** from 1979 to 2017.

NEMO GOv8.7 JRA55 eORCA12:	TRACMASS:
• ocean hindcast	• Lagrangian tracking tool
• forced with JRA55	• analytical trajectory solution
• 1/12° horizontal grid; 75 levels	• mass/volume conserving
• monthly resolution; 1979–2021	• Eulerian velocity input fields

We employ **multivariate linear regression** with **physically motivated indices** to reconstruct and quantify variability in the Nordic Seas inflow.

$$I(t) = \beta_0 + \sum_{j=0}^{P} \sum_{l \in L_j} \beta_{j,l} X_j(t-l) + \epsilon(t)$$

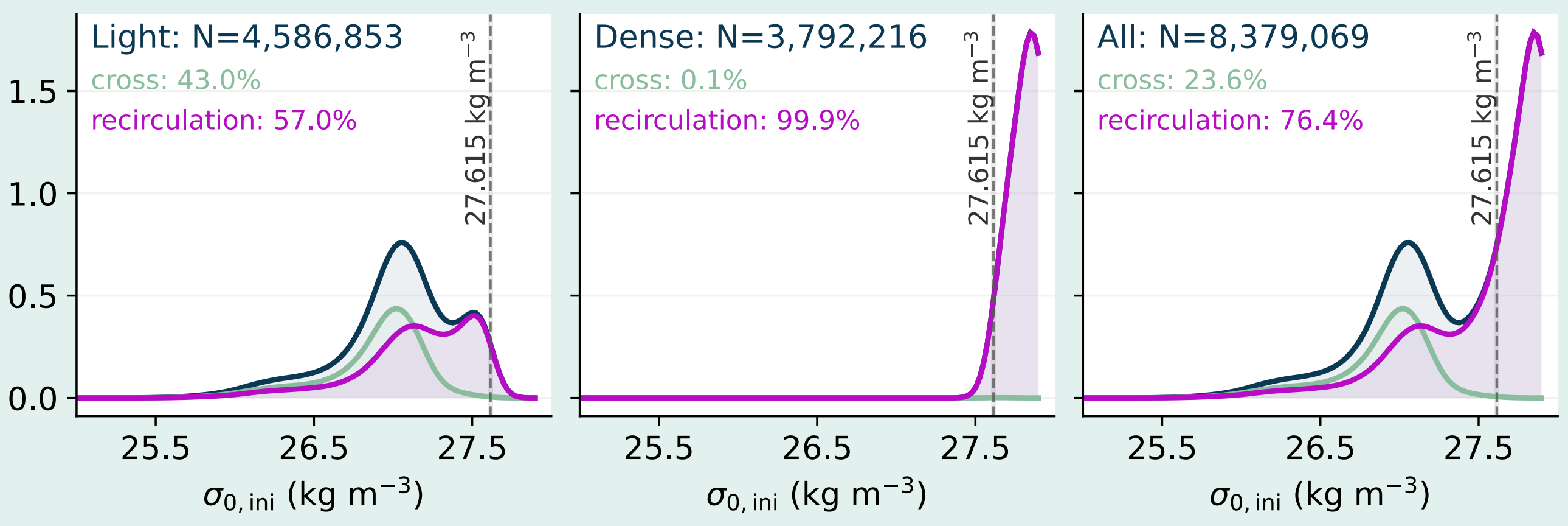
- $I(t)$ … GSR inflow index
- β_0 … intercept
- $\beta_{j,l}$ … regression coefficient j at lag l
- P … number of predictors
- L_j … set of lags considered for predictor j
- $X_j(t-l)$ … predictor j at lag l
- $\varepsilon(t)$ … residual

4. Results

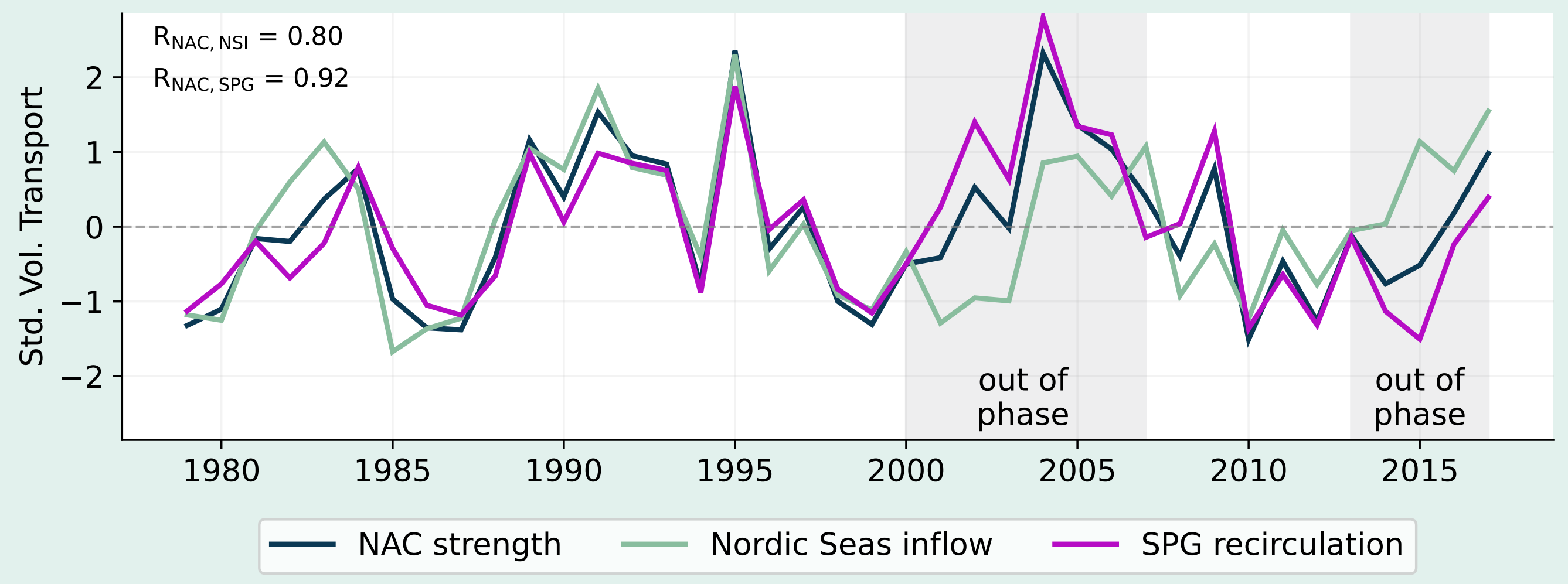
4.1 North Atlantic Current

Question: Is NAC strength determining Nordic Seas Inflow?

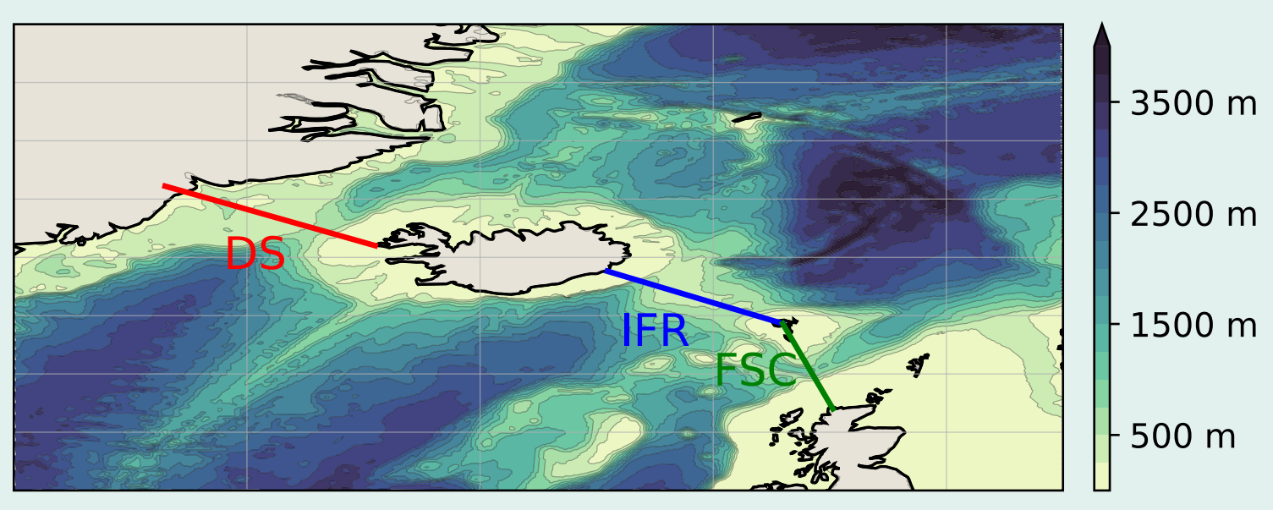
We define the NAC as the transport of all water masses lighter than $\sigma_{0,NAC}$ **= 27.615 kg m⁻³** (maximum Eulerian overturning isopycnal) at the seeding section. This enables a clear separation between light and dense waters.



The probability density distribution of particle density at seeding time t_0 shows that virtually **no particles denser** than $\sigma_{0,NAC}$ will **cross** the **GSR**. This indicates that **density** at the **seeding section** is a **prerequisite** for crossing the GSR and contributing to Nordic Seas inflow. Therefore, only particles **lighter** than $\sigma_{0,NAC}$ (i.e. NAC particles) are considered in the following analysis.



The NAC appears to drive both Nordic Seas inflow and SPG recirculation. However, periods of **out-of-phase variability** between NAC transport and Nordic Seas inflow suggest the presence of **additional mechanisms** controlling the **inflow** at the **GSR**.

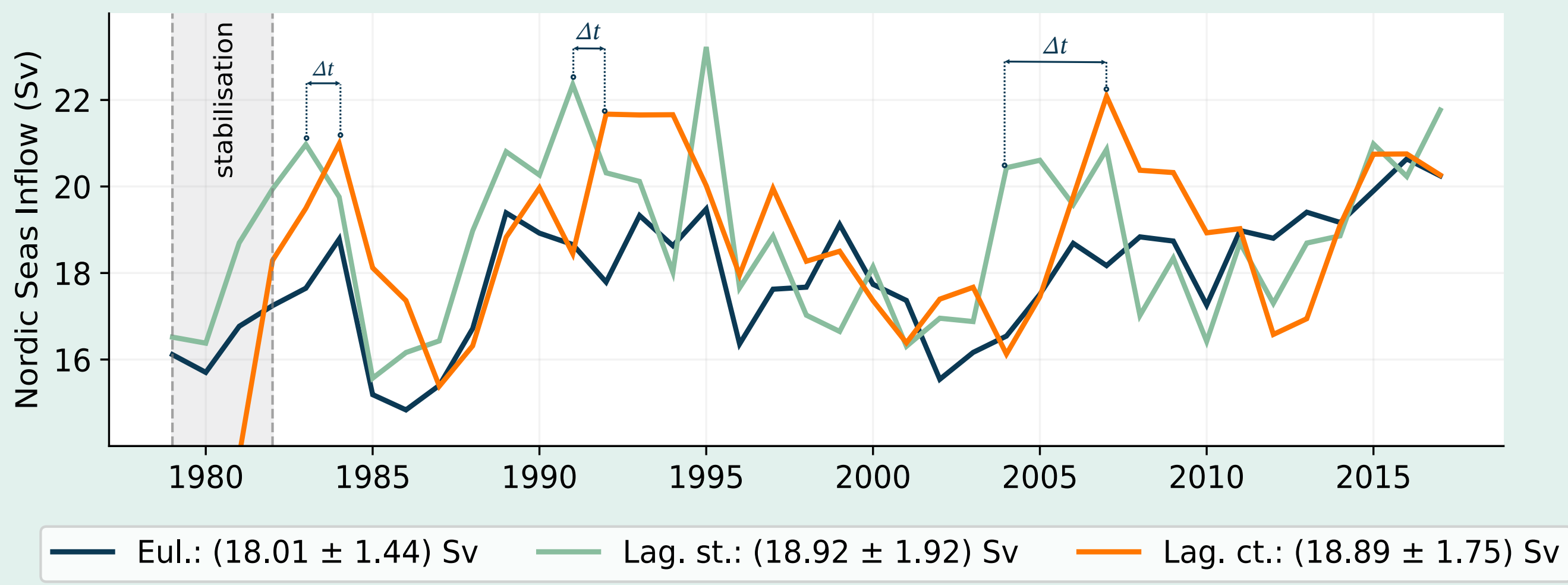


Greenland-Scotland Ridge

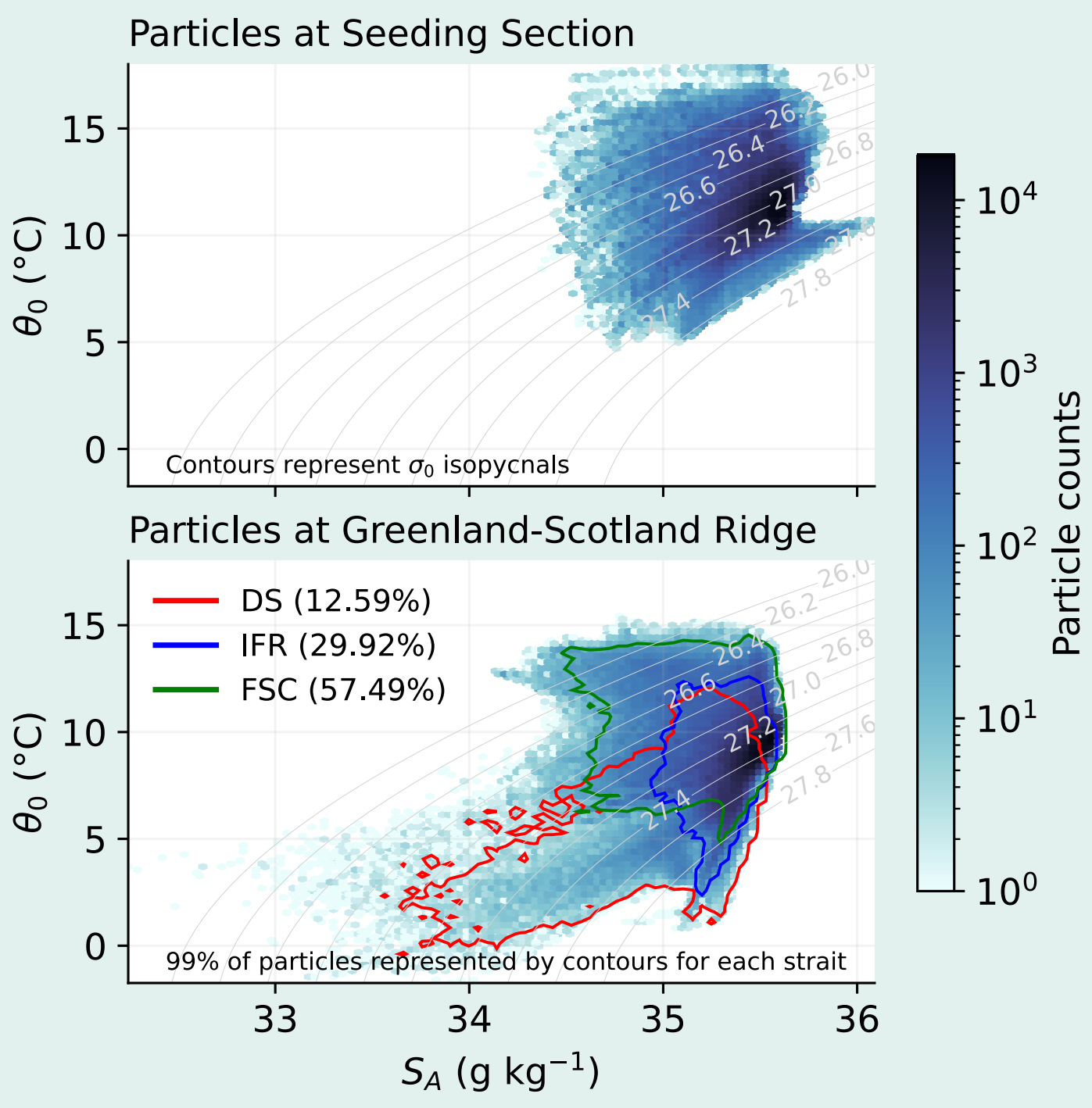
1. Denmark Strait (DS)
2. Iceland-Faroe Ridge (IFR)
3. Faroe-Shetland Channel (FSC)

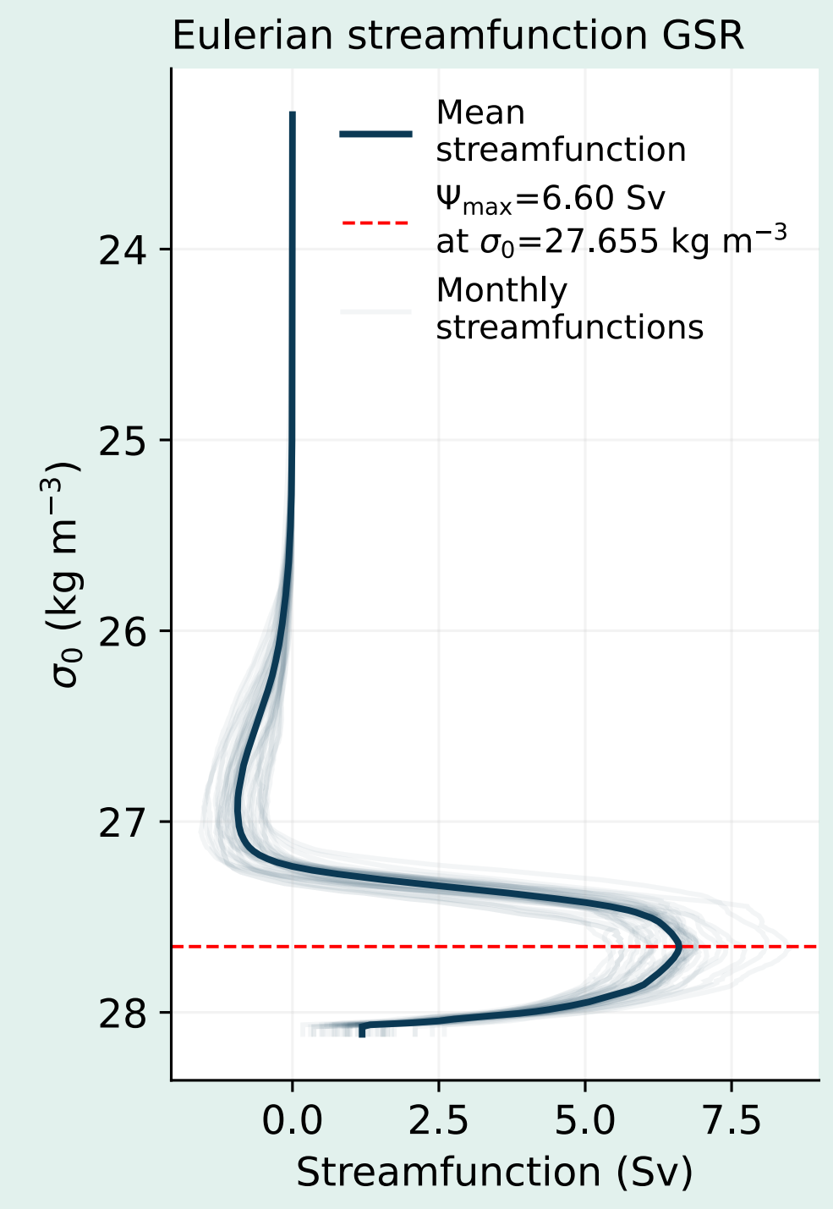
4.2 At the Greenland-Scotland Ridge

The GSR is the **principal gateway** from the Atlantic to the Arctic via the Nordic Seas, comprising three main passages (DS, IFR, and FSC). To validate the Lagrangian transport estimates, we compute the **Eulerian inflow** using **normal vector projection** across the defined GSR.



During their trajectory, particles undergo **water mass transformation**. This is reflected in a shift towards higher densities between the seeding section and the GSR, with most **particles densifying** and **preferentially** reaching the ridge via the **FSC.**





4.3 Mechanisms Nordic Seas Inflow

Question: Which mechanisms reconstruct inflow?

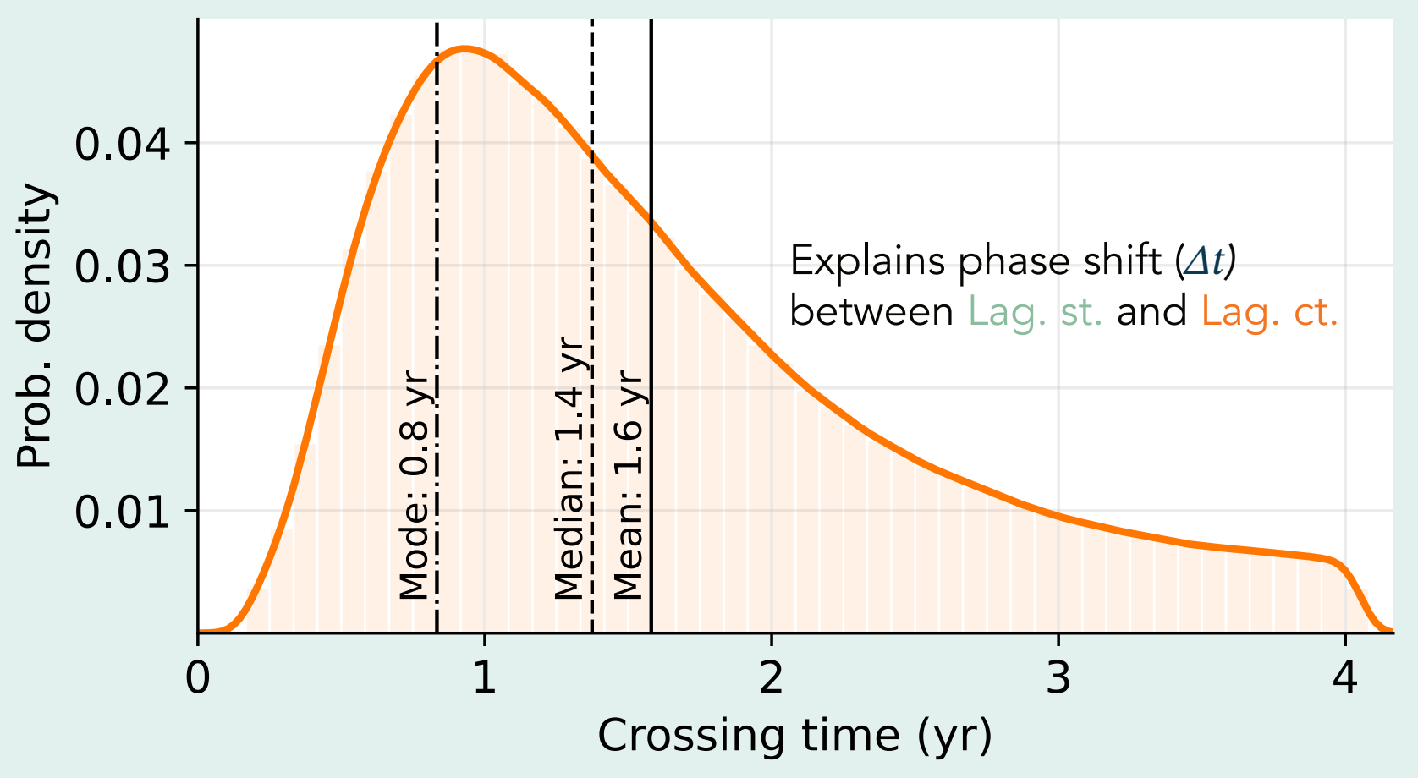
To address this, we use a Multivariate Linear Regression Model (MVLR) that estimates **Nordic Seas Inflow** as a **function** of multiple physically motivated **predictors** (large and small scale).

Spatial Scale	Predictor	L_j	ΔR_j^2
Large-Scale	North Atlantic Oscillation	0–12	62%
	Scandinavian Pattern	0–12	27%
	Scandinavian Blocking	0–12	18%
	East Atlantic Pattern	0–12	3%
Small-Scale (at GSR)	Vertical Ekman Velocity	0–12	90%
	Cross-Ridge Dynamic SSH	0–12	20%

L_j … set of lags ΔR_j^2 … unique explained variance

Crossing Time

Particles crossing the GSR follow different pathways and do **not share a unique transit time**. Instead, their travel times are described by a **probability distribution** called Transit Time Distribution (TTD).



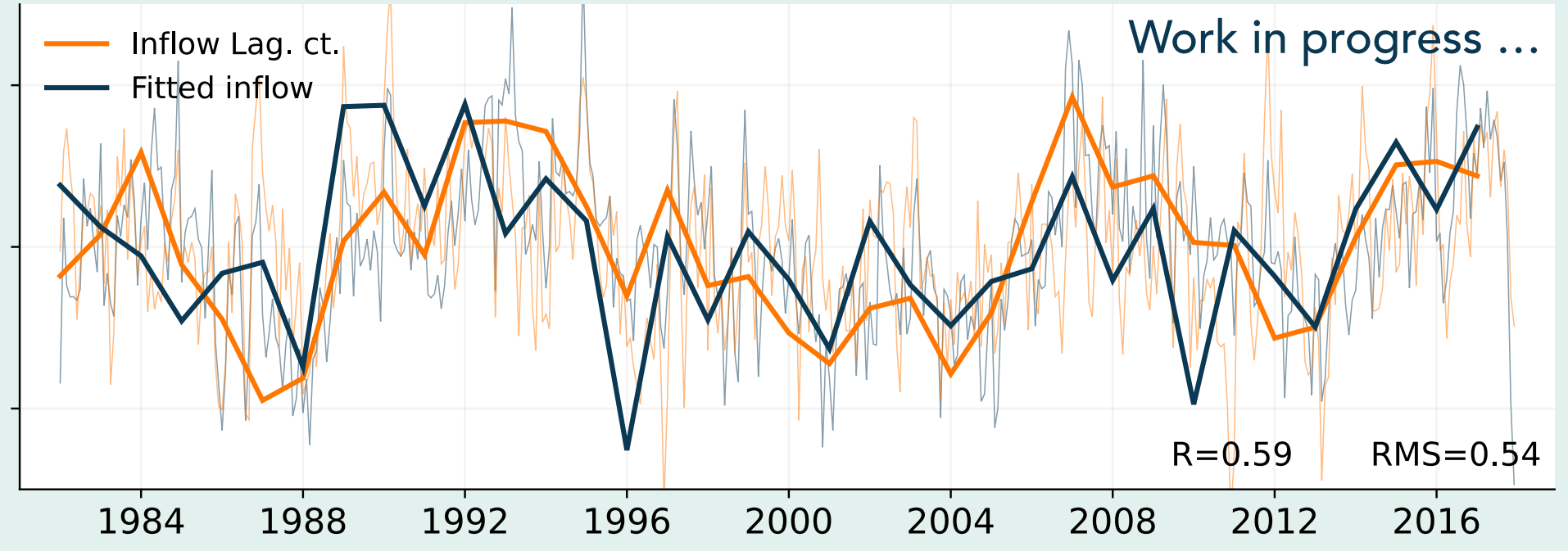
Two **Lagrangian** approaches to estimate Nordic Seas inflow:

- Seeding time (st): group crossing particles by release period
- Crossing time (ct): group crossing particles by actual crossing time

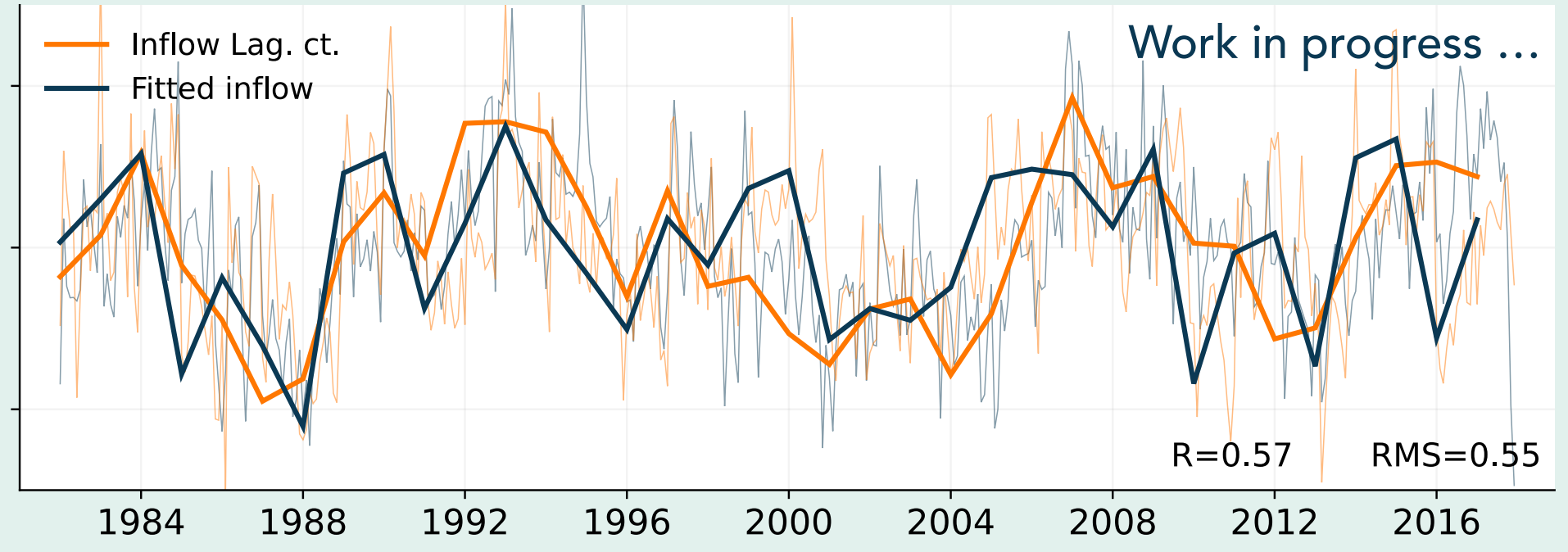
5. Future Work

- **Additional** inflow **mechanisms**
- **Unique** vs. **shared variance** of predictors?
- **Information transfer** between predictors
- **Passage transports** and **heat fluxes**

Large-scale predictors



Small-scale predictors



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