

Variations in barotropic inflow characteristics and their relation to Baltic Sea salinity variability

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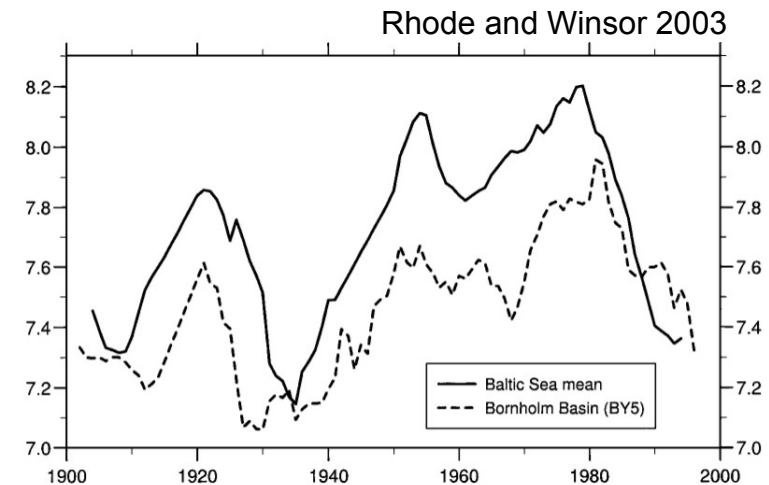
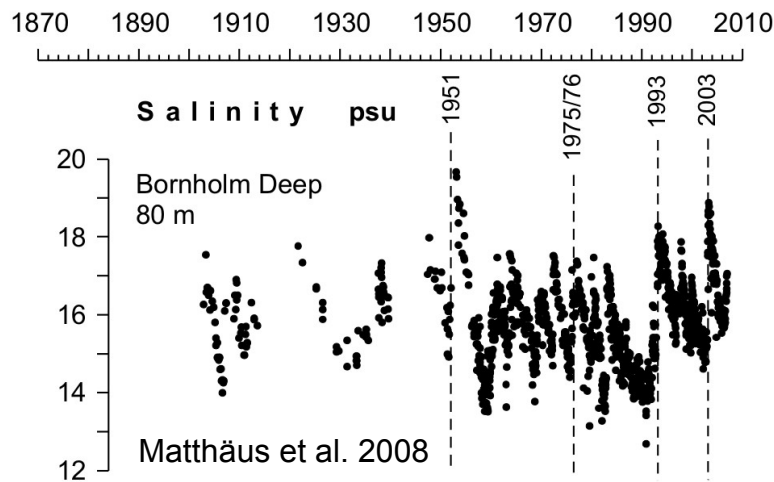
Monday, June 11th, 2018



Introduction

Observed Baltic Sea salinity variations

- important for physics AND biogeochemistry / ecosystem dynamics
- **external drivers are saltwater inflows and net freshwater supply!** internal ones are dynamics at air-sea interface and non-linear mixing processes, ...
- scales of variation are “event-based” (saltwater inflow occurrence) and “integral” as combined effect including changes in total freshwater supply?

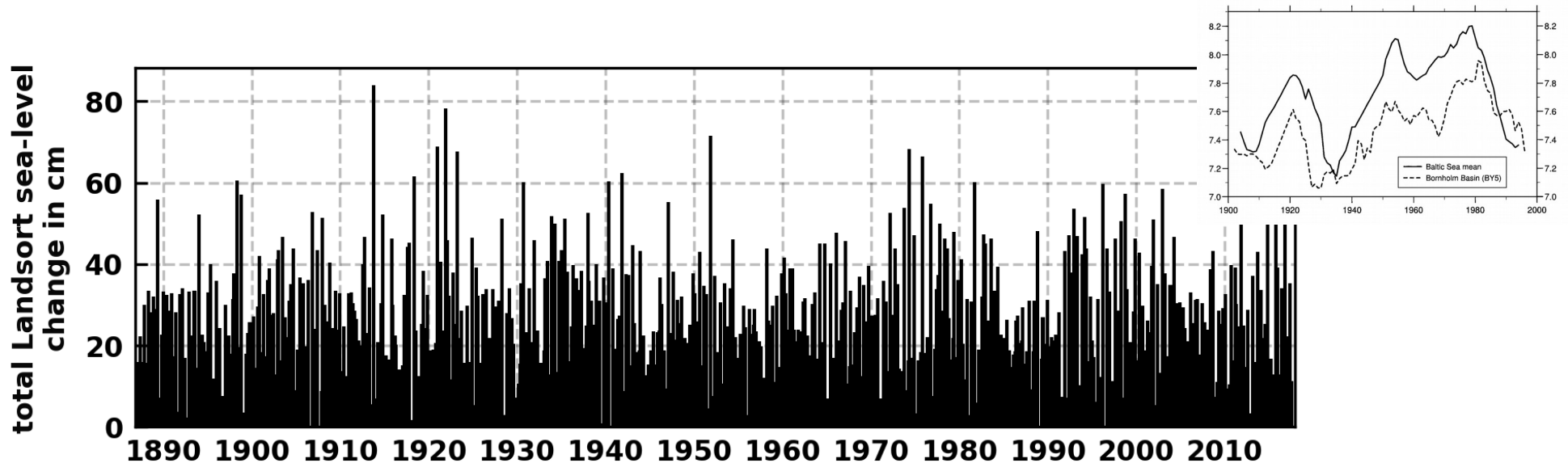


Understanding **future changes to Baltic Sea salinity/hydrography** and hence the physics and biogeochemistry of the system requires **correct attribution of past salinity variations** and **process-based understanding of related phenomena!**

Introduction

Barotropic water exchange

- deducible from Landsort sea-level variations (especially at scales of $t > 10$ days)
- exchange driven by succession of synoptic-scale atmospheric circulation patterns
- **major Baltic inflows are subset to numerous barotropic inflows**

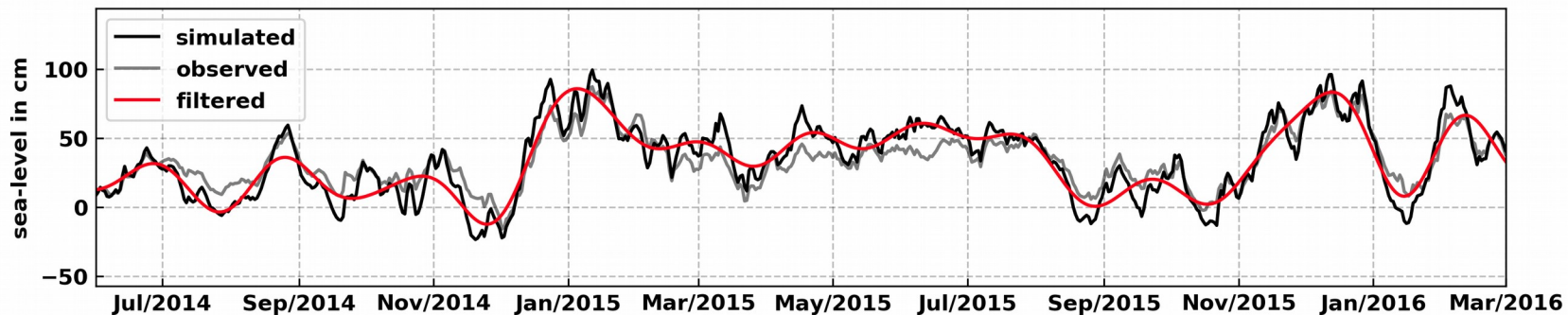


Hypothesis: Variability in Baltic Sea salinity can be explained by variations in barotropic inflow activity / characteristics of barotropic water exchange with North Sea!

Methods

Overview

- identification of barotropic inflows based on low-pass filtered sea-level variations at Landsort (non-periodic “energy” peaks at scales associated with saltwater inflows)



- understand salinity fluxes associated with barotropic inflows based on analysing hydrography, sea-levels and currents in “realistic” 38-year long Baltic Sea OGCM setup (Lehmann et al. 2014) currently forced by ERA-Interim reanalysis data
- apply knowledge to observed Landsort sea-level variations over 131-year period since Nov/1886 estimated from Landsort, Landsort Norra and Stockholm tide-gauges

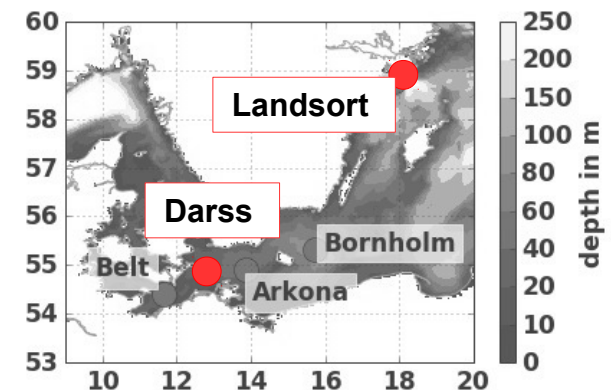
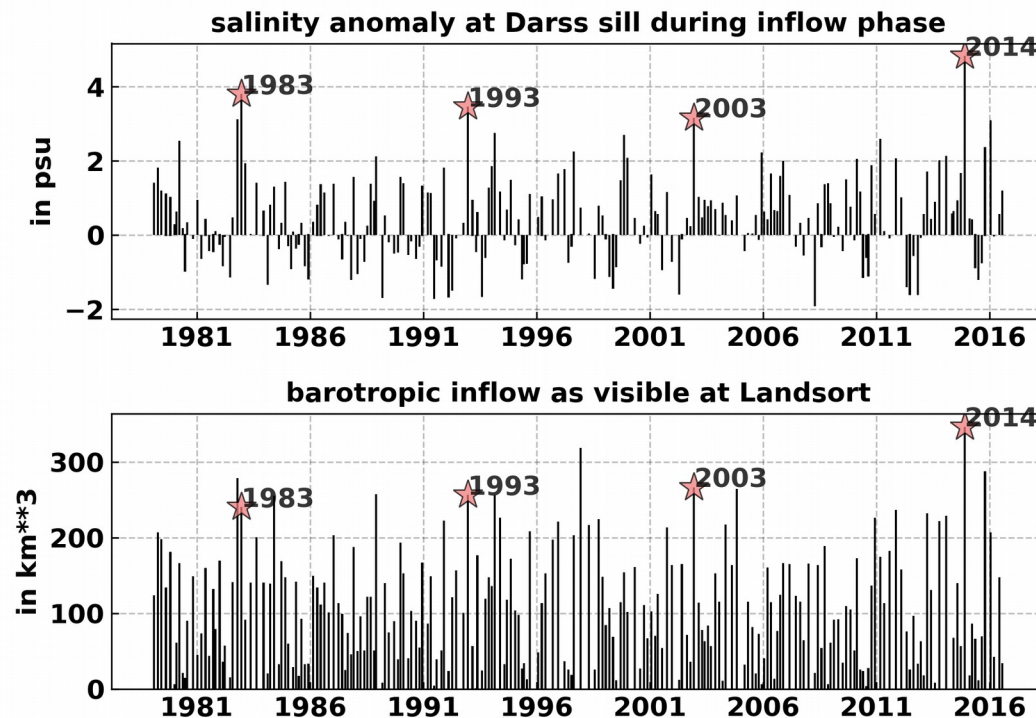
Question:

- Which circumstances determine the salinity of barotropic inflows and especially the occurrence of major Baltic inflows?

Results

Barotropic inflow salinity

- barotropic inflows identified from local extrema of low-pass filtered Landsort sea-level and salinity is taken as vertical and temporal inflow period average at Darss sill

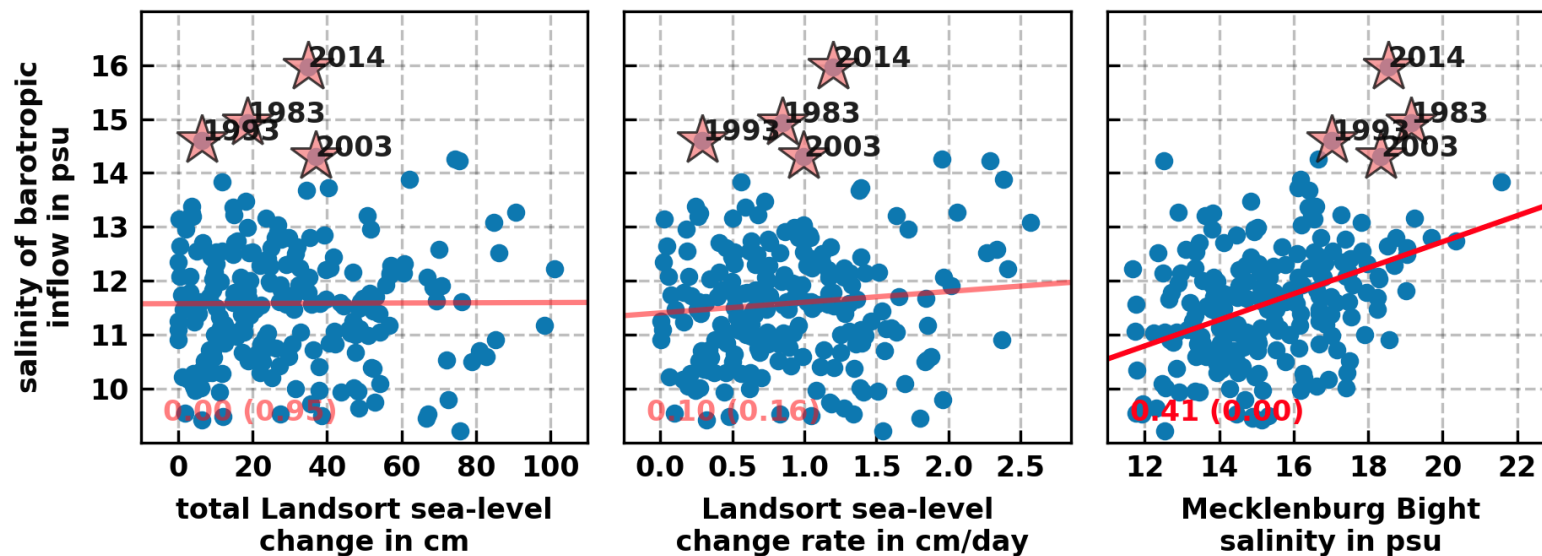


Result: barotropic inflows are useful framework to understand major Baltic inflows which are most saline inflows in the spectrum at $T_c = 44.1$ days

Results

Explaining salinity

- determine importance of previous outflow period characteristics, Danish straits hydrography, atmospheric forcing characteristics and freshwater supply

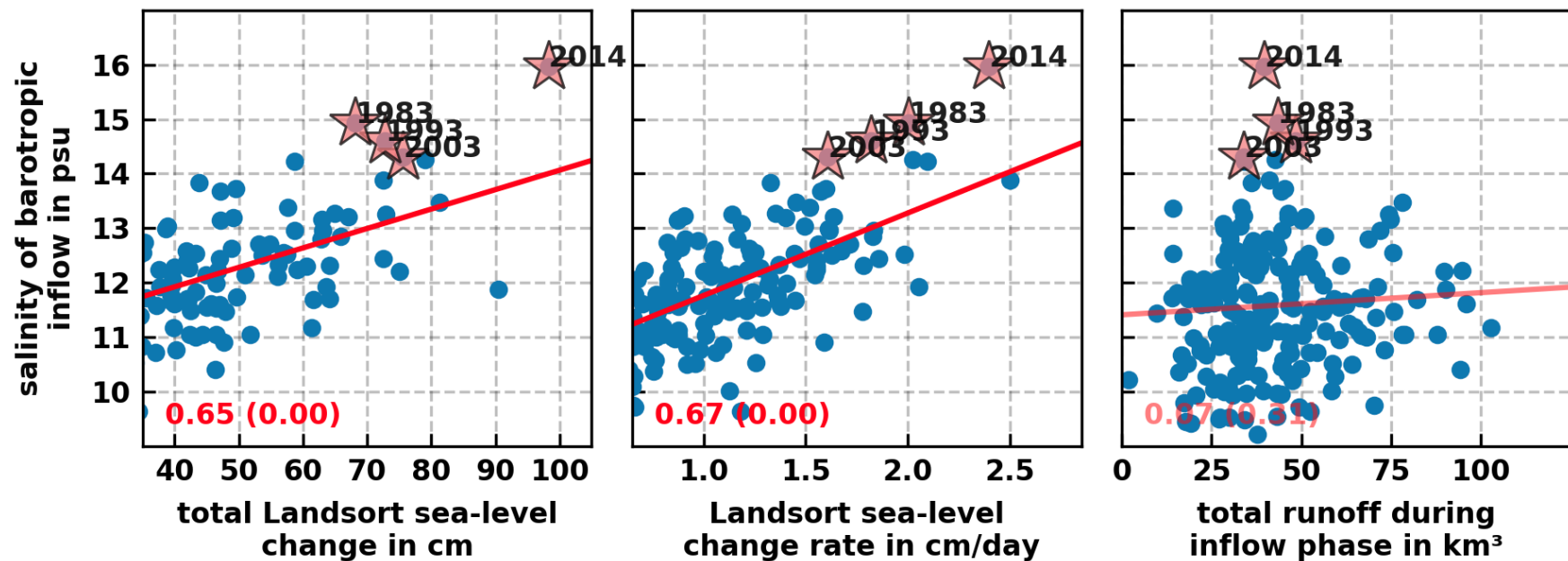


Result: magnitude and rapidness of the previous outflow period are not important for salinity of the inflowing water mass, but hydrography/salinity is!

Results

Explaining salinity

- determine **importance** of previous outflow period characteristics, Danish straits hydrography, **atmospheric forcing characteristics and freshwater supply**



Result: magnitude and rapidness of the inflow period are important for salinity of the inflowing water mass, total runoff and precipitation (not shown) are not

Results

Total freshwater supply

- made responsible for stagnation periods and non-occurrence of saltwater inflows
- sensitivity with freshwater supply increase by +18% (runoff) and +35% (precipitation)

Hypothesis: freshwater supply has impact upon occurrence of saltwater inflows by altering the salinity in the Danish straits (which has shown to be important)



Results: impact on Mecklenburg Bight salinity at order of 7-9‰ in comparison to atmospheric-driven range of variations (± 4.9 psu)

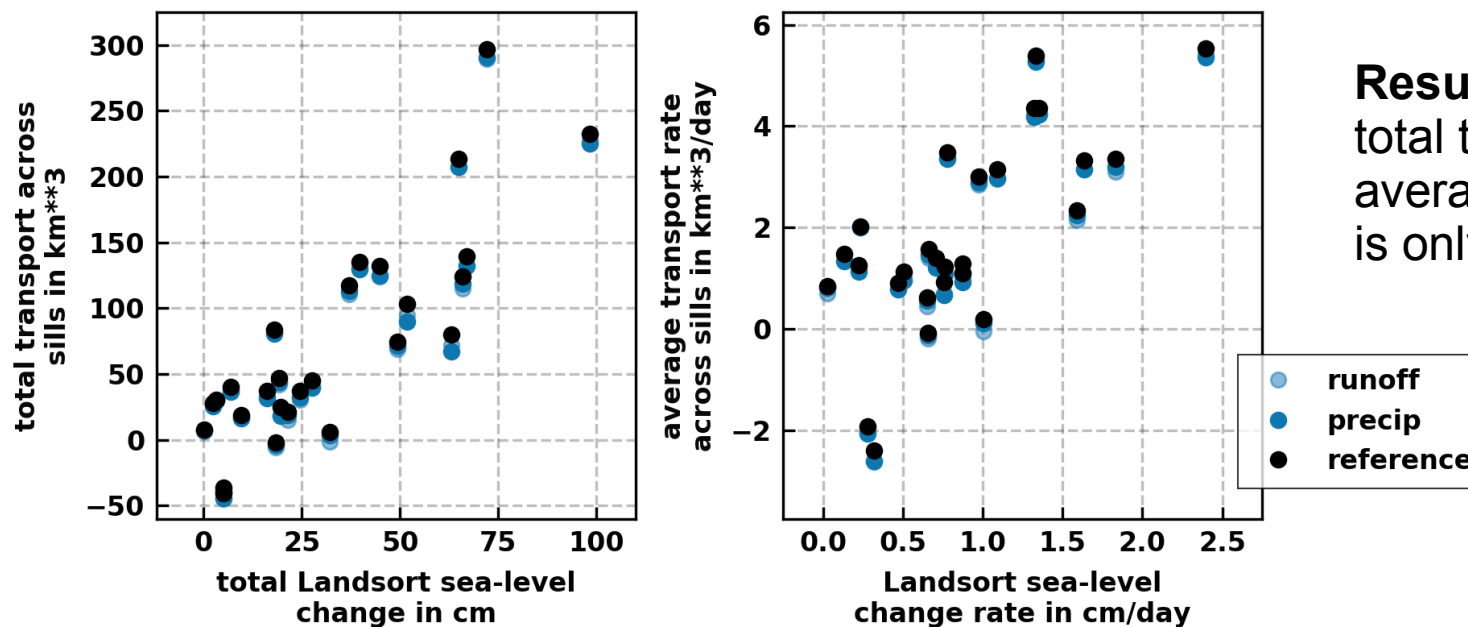
atmospheric variations are more important for salinity than variations in freshwater supply!

Interlude

Barotropic inflow characteristics

- **atmospheric forcing during inflow phase determines** transports across the sills and magnitude and rapidness of barotropic inflows as deduced at Landsort
- sensitivity with freshwater supply increase by +18% (runoff) and +35% (precipitation)

Hypothesis: freshwater supply has impact upon occurrence of saltwater inflows by altering the total transport into the Baltic Sea across the Darss and Drogden sills

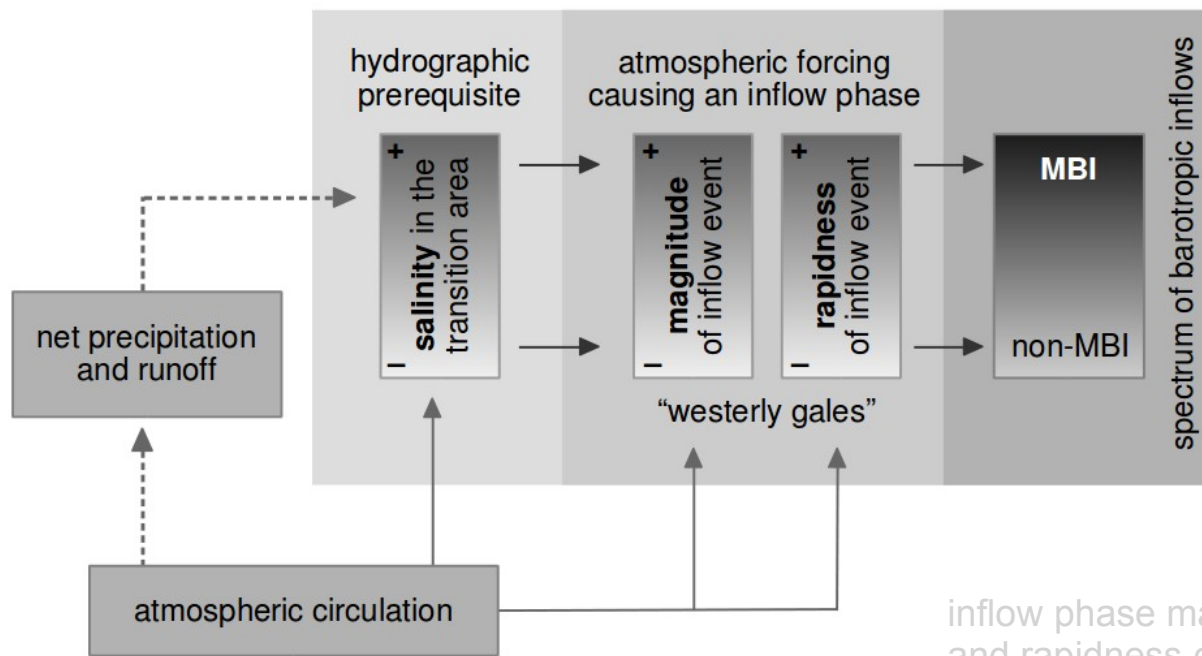


Results: impact upon total transports and average transport rates is only on order of 5%

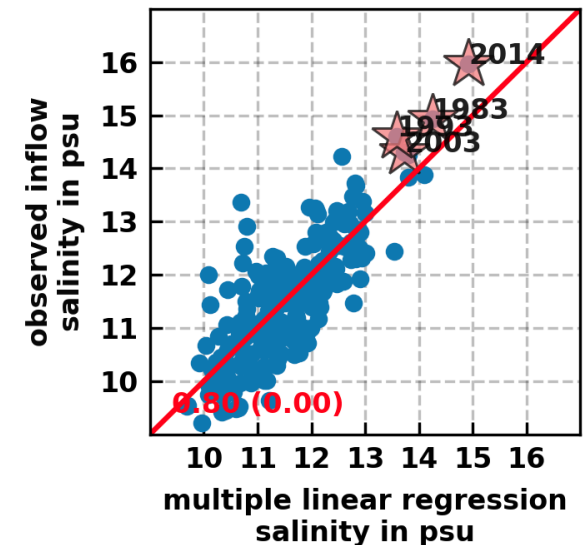
Interlude

Mechanistic understanding of major saltwater inflows

- salinity in Danish straits and evolution of atmospheric forcing during inflow phase are the most important factors in determining the salinity of inflowing water masses



inflow phase magnitude and rapidness correlations are +0.65 and +0.67

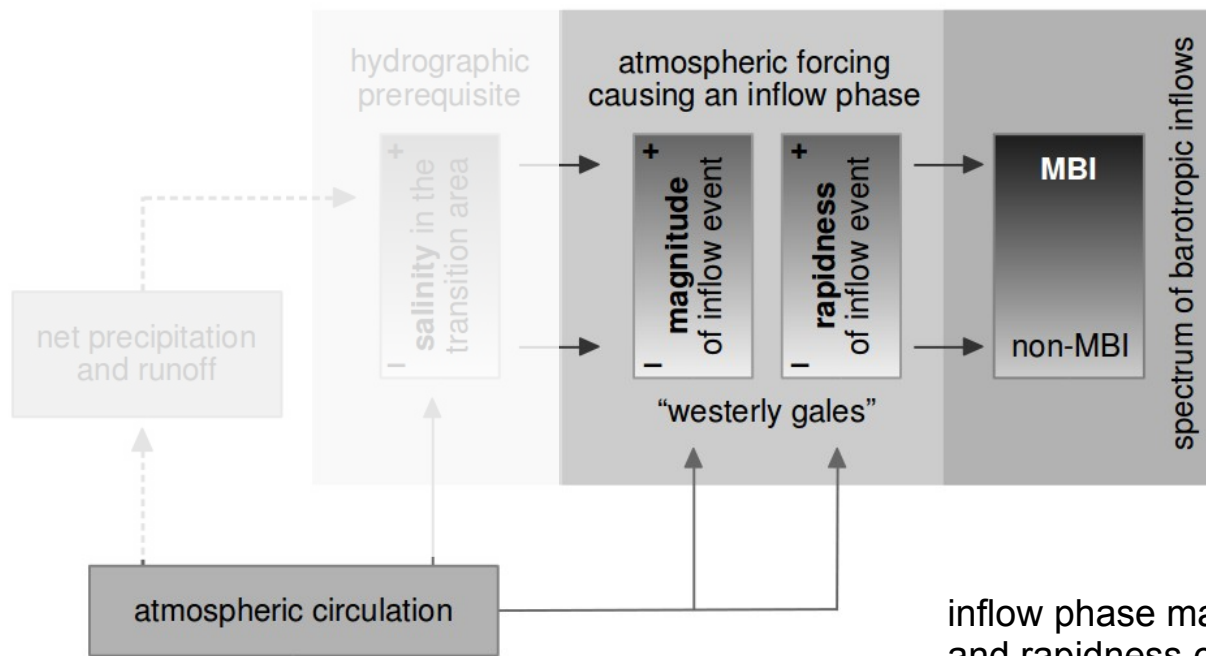


Hypothesis: longer-term Baltic Sea salinity variability can be understood from variations in these barotropic inflow characteristics!

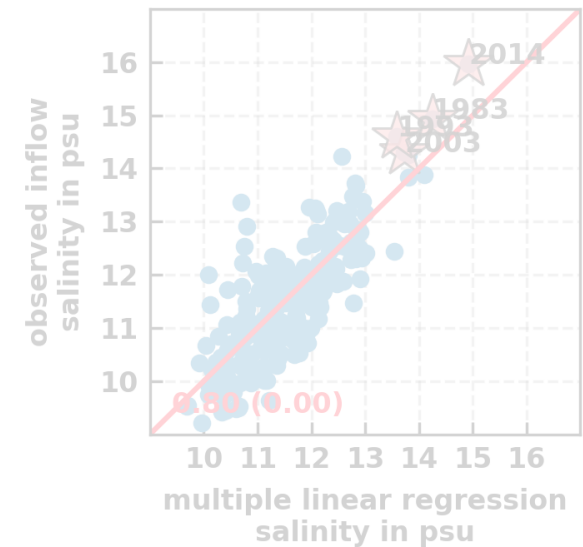
Interlude

Mechanistic understanding of major saltwater inflows

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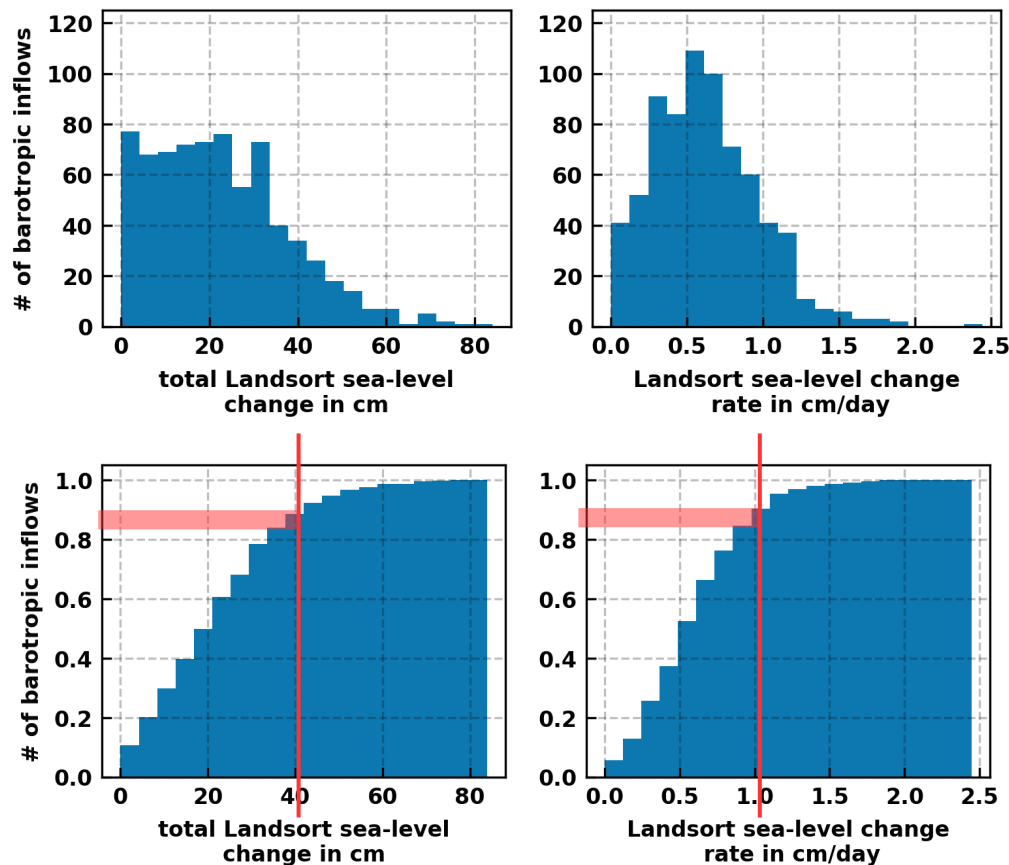


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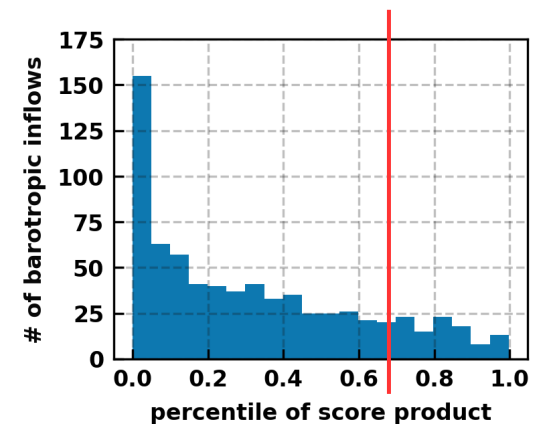
Methods

Barotropic inflow characteristics through the last century

define **index** that summarizes characteristics of barotropic inflows in terms of **magnitude and rapidness** of inflow process as observed at Landsort



percentile of score product

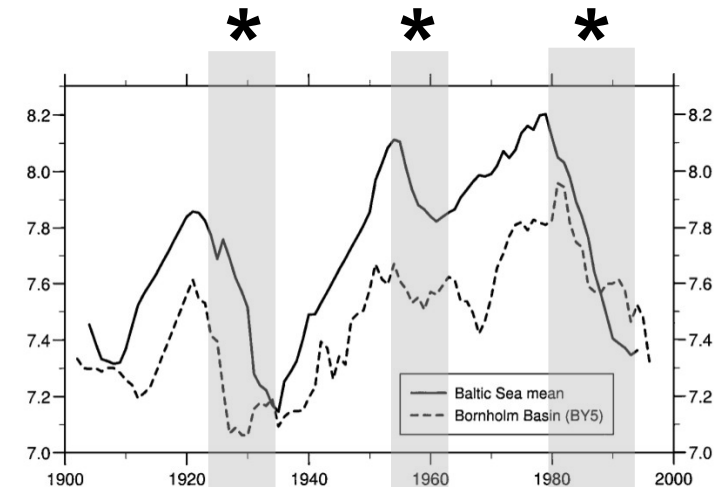
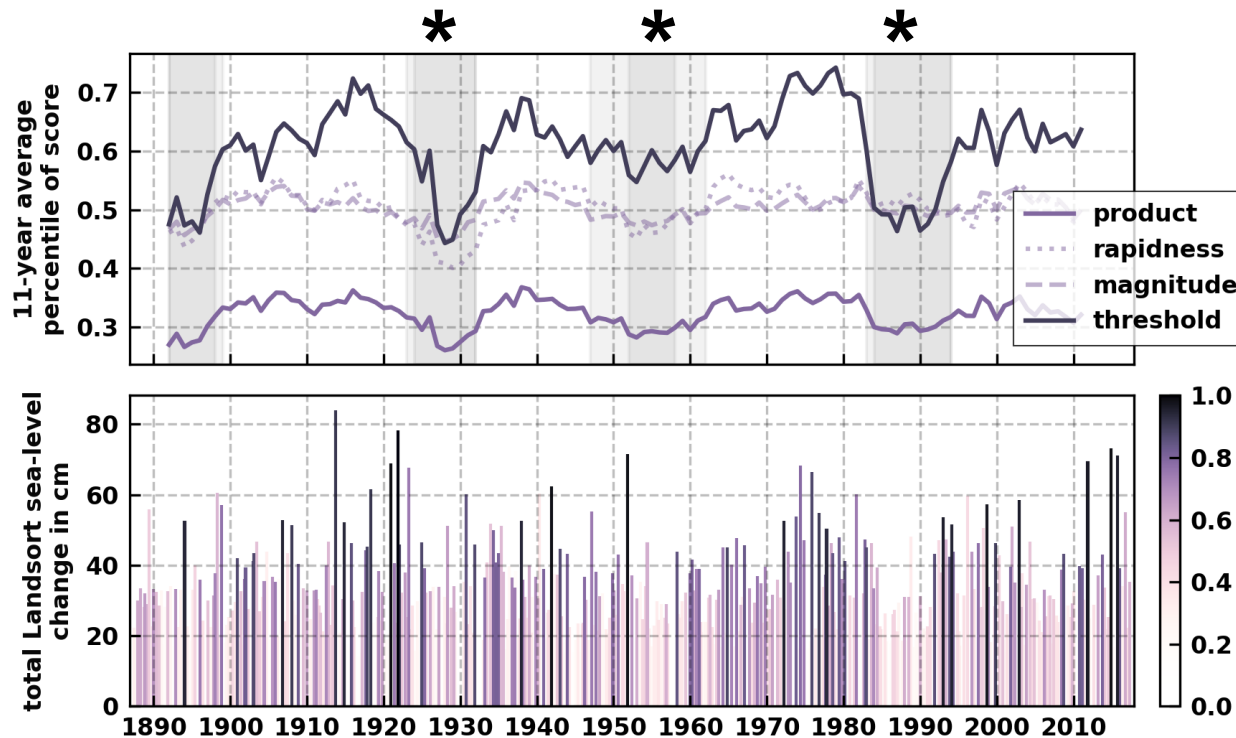


Result: many small/slow inflows
not much large/rapid ones

Results

Barotropic inflow characteristics through the last century

Hypothesis: longer-term Baltic Sea salinity variability can be understood from variations in barotropic inflow characteristics



stagnation periods during the 1920/30s, 1950/60s and 1980/90s

Results: decadal variations in barotropic inflow characteristics indeed coincide with observed Baltic Sea salinity decreases / periods of stagnation



Summary and Remarks

Understanding **future changes to Baltic Sea salinity/hydrography** and hence the physics of the whole system requires **correct attribution of past salinity variations** and **process-based understanding of the related phenomena!**

- Danish Straits salinity and magnitude and rapidness of inflow process determine the salinity of barotropic inflows across the Darss sill both are mainly driven by variability in synoptic-scale atmospheric circulation patterns
- freshwater supply has neglectable impact upon salinity in Danish Straits, actual and total transport rates making its significance in causing Baltic Sea salinity variability (at least from a saltwater inflow perspective) questionable
- variability in Baltic Sea salinity (both in an event-based and long-term manner) is caused by variations in barotropic inflow characteristics and corresponding local barotropic overflow dynamics at the Darss sill
(barotropic inflows are a useful generic framework to understand the occurrence of major Baltic inflows and low-frequent salinity variations of the Baltic Sea)
- in order to better assess future changes to Baltic Sea salinity variability especially natural scales in atmospheric circulation and drivers behind synoptic-scale weather patterns need to be well predicted and understood