Analysis of Spatial Patterns of Currents in the Gulf of Finland using the Okubo–Weiss parameter

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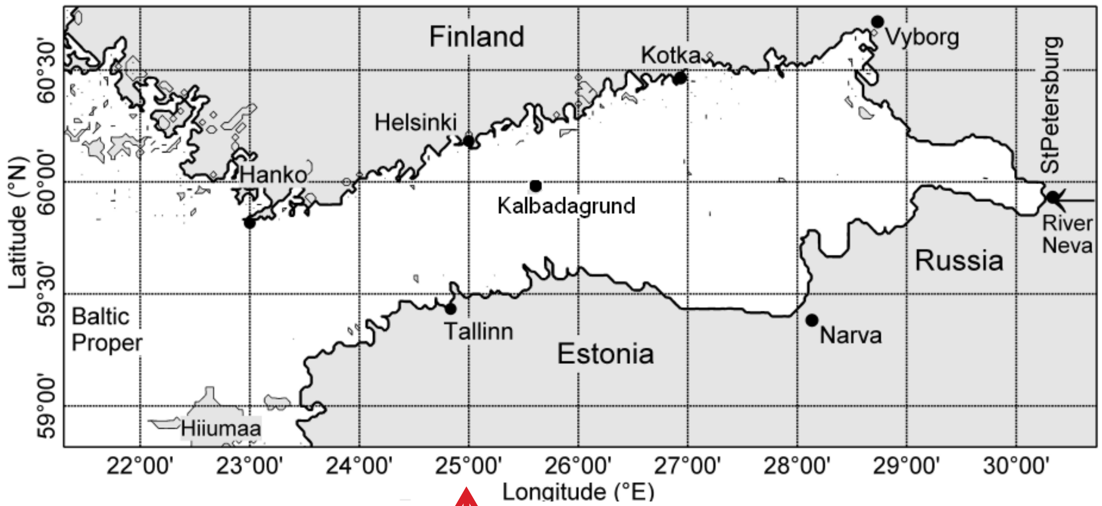
Introduction

Gulf of Finland:
- Length ~400 km
- Max width ~125 km
- Mean depth 37 m

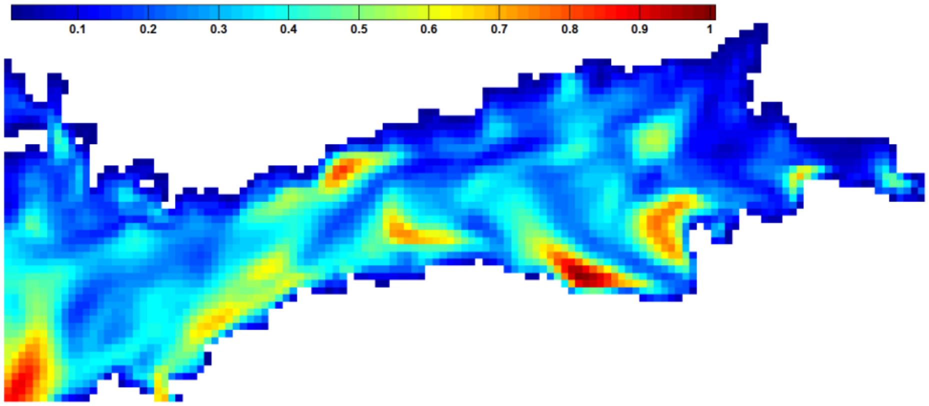


Increased risk of potential release of adverse impacts (oil, chemical pollution, lost containers) or natural hazards to environment or other vessels

Exceptionally high traffic, major fairway from St Petersburg to Baltic Proper crosses with very intense fast ferry traffic from Tallinn to Helsinki

A challenge

- Transport by wind and waves known, current transport less known
- Surface currents highly variable both seasonally and annually
- Semi-persistent patterns of currents
- **Strong meridional transport**
- Patterns with a lifetime of a few weeks can enhance the current-driven transport
- **Use marine dynamics to reduce the risk of coastal pollution – a new technology**
- Minimize probability, maximize time



Average meridional transport, “windy-to-calm” season (March–April) 1987, Soomere, Delpeche, Viikmäe, Quak, Meier, Döös 2011, *Boreal Env Res*

Circulation model

• OAAS model, (O. Andrejev and A. Sokolov 1989)

• Horizontal resolution 1nm, vertical resolution 1m

• Forced with the meteorological data from a regionalization of the ERA-40 re-analysis with a horizontal resolution of 25 km

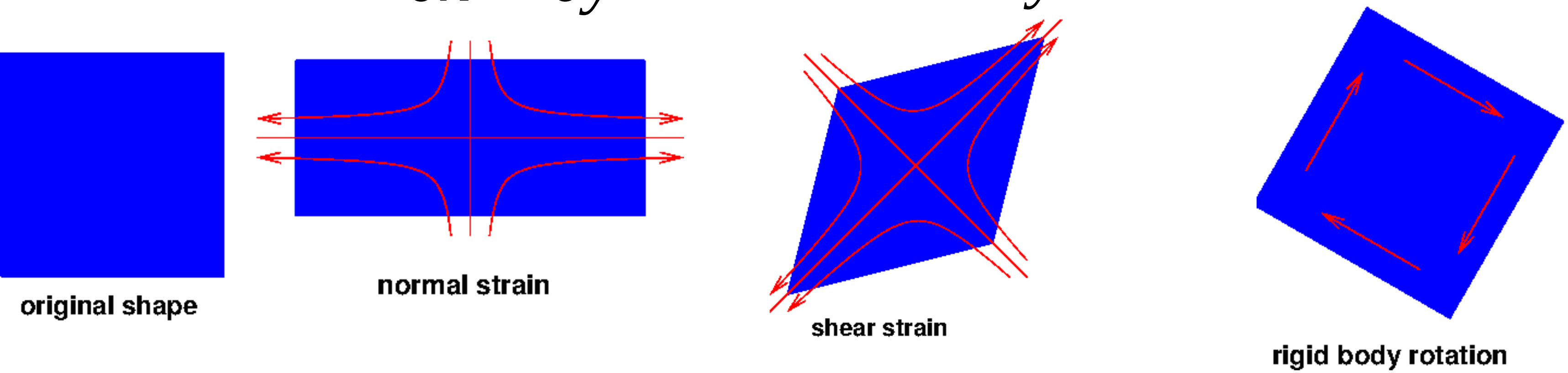
• Model specifically designed for the use in basins with complicated bathymetry and hydrography

• Timestep of saved velocity data 3h

Method

- Okubo-Weiss parameter : $$W = s_n^2 + s_s^2 - \omega^2$$

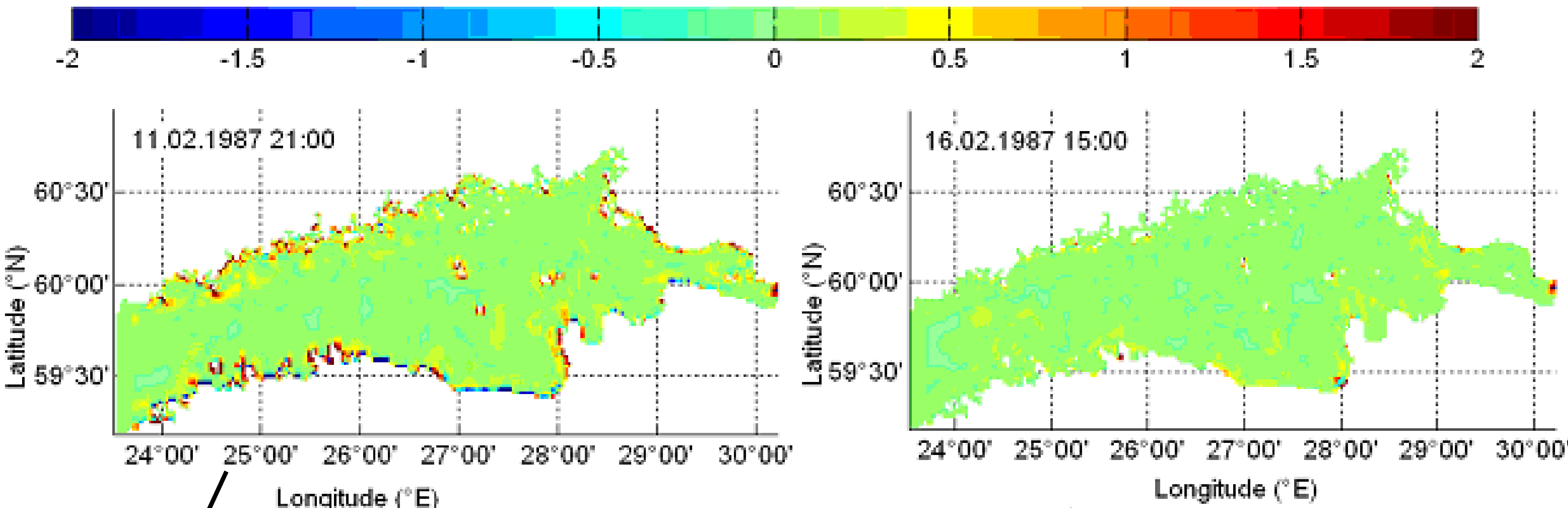
$$s_n = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} \qquad s_s = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \qquad \omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

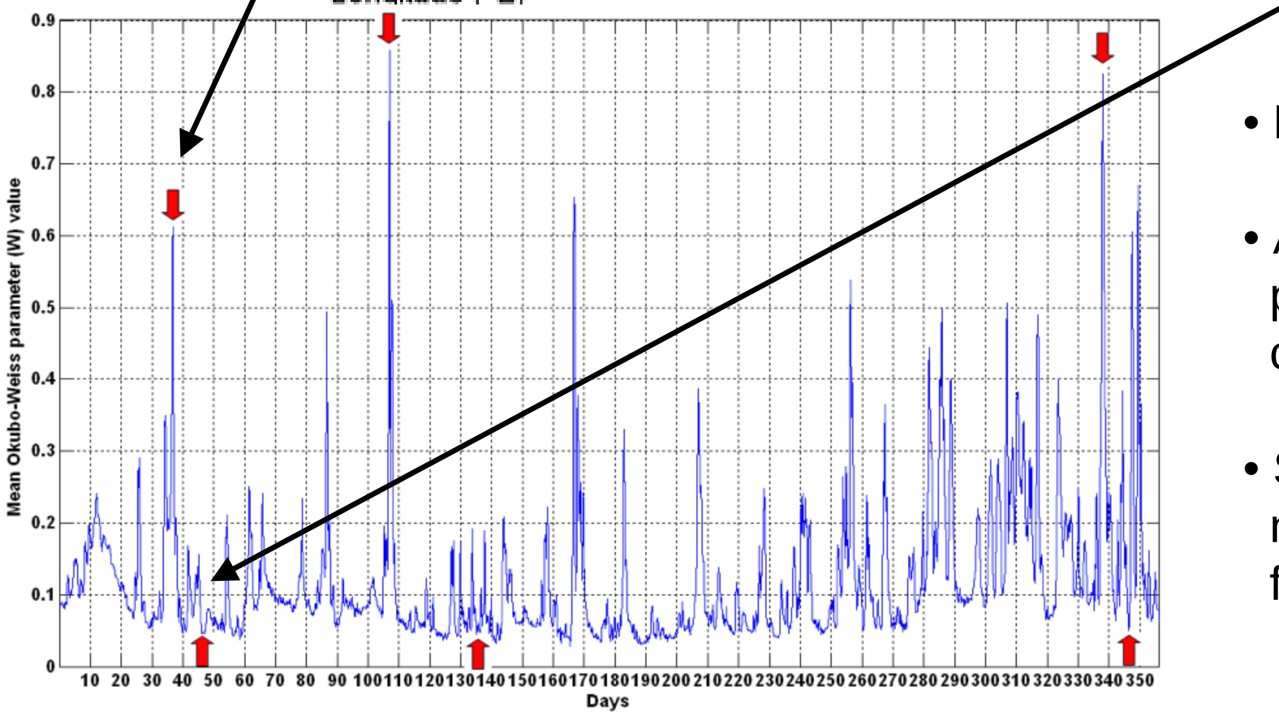


- A flow region is **strain-dominated** (**W > 0**) or **vorticity-dominated** (**W < 0**)
- Horizontal components of flow velocities (u, v) (calculated from the OAAS model)

- In the sense of pollution transport the Okubo-Weiss parameter reveals whether fast net transport can occur in some narrow sea area
- Bigger W values do not guarantee fast net transport, but smaller values indicate its absence

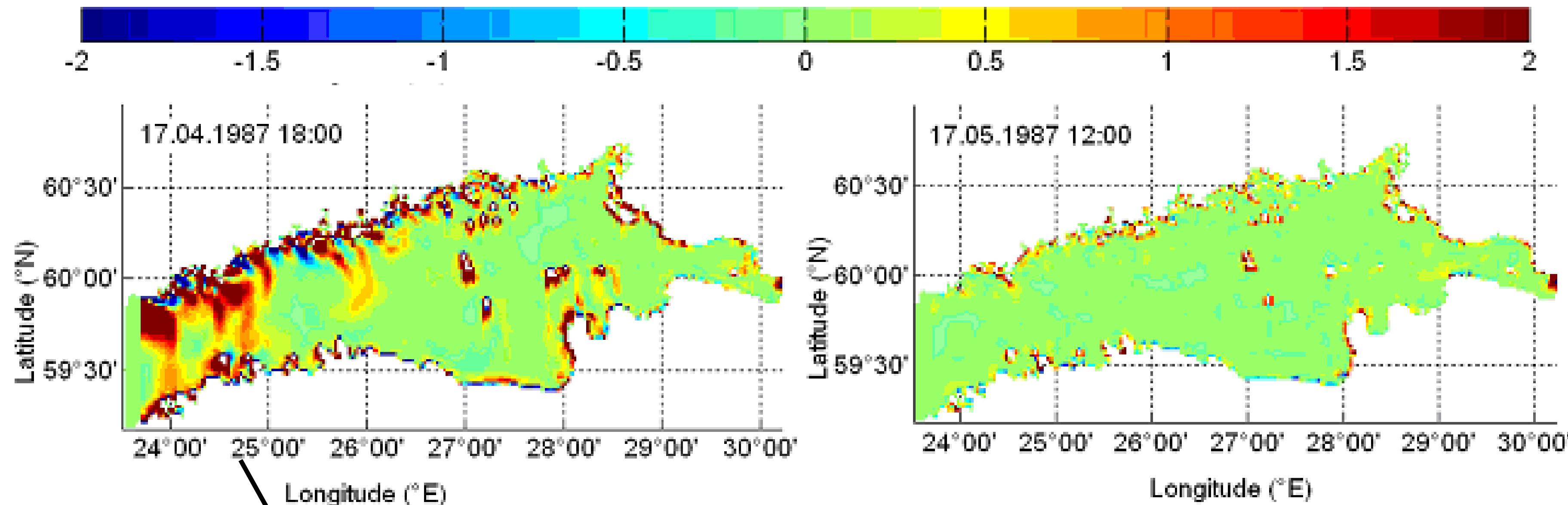
Results

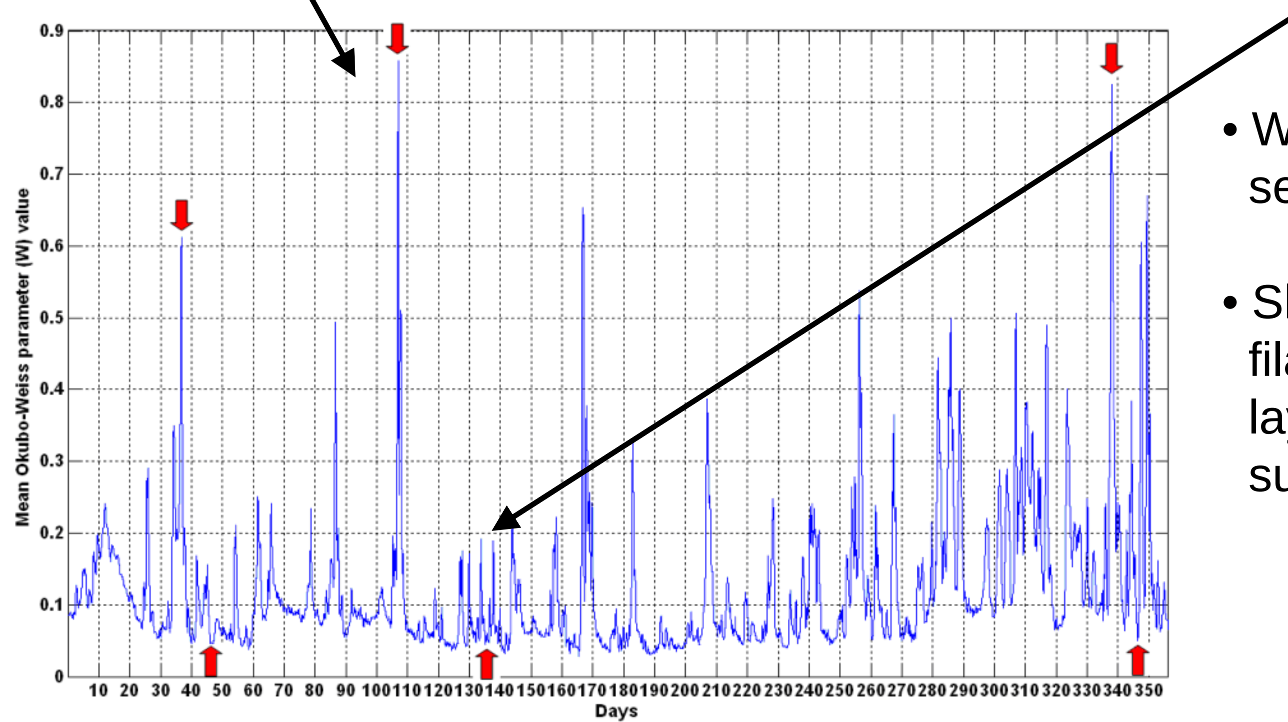




- End of windy season (Feb)
- Absolute values of OW parameter higher near the coast and in vicinity of islands
- Shear flow in the nearshore (offshore currents faster)

Results

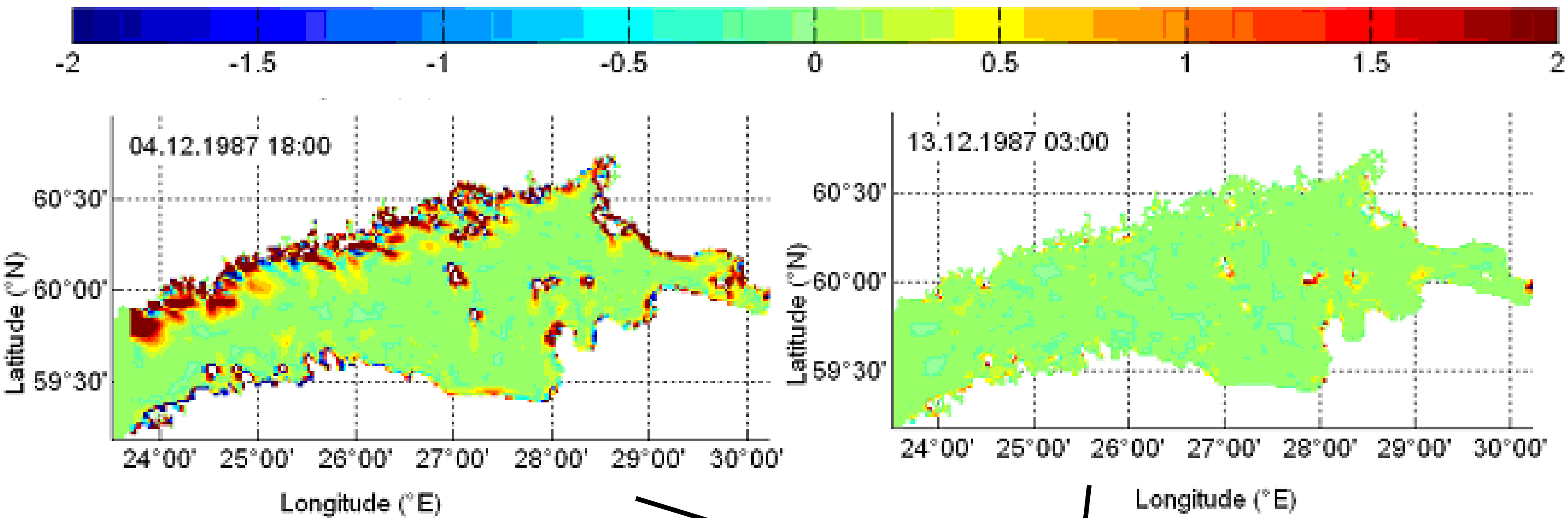


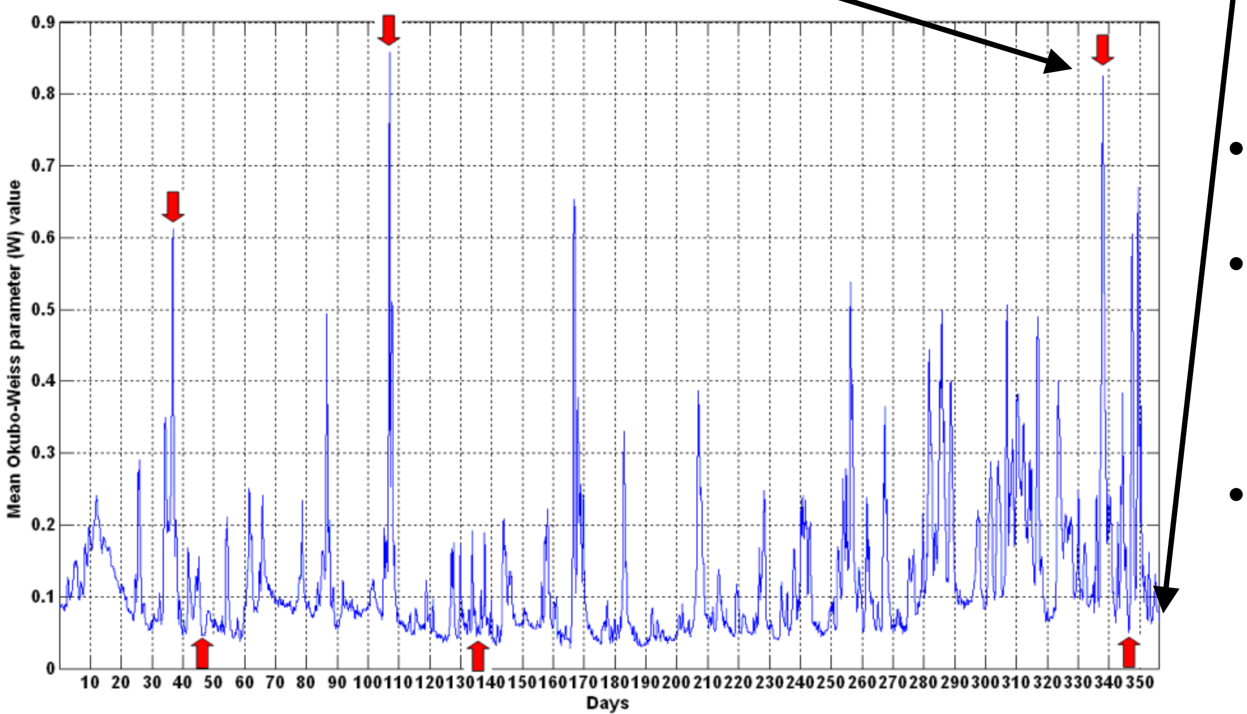


- Windy to calm transitional season (Apr-May)

- Shear flow in upwelling filaments (water in the surface layer moves faster than in subsurface)

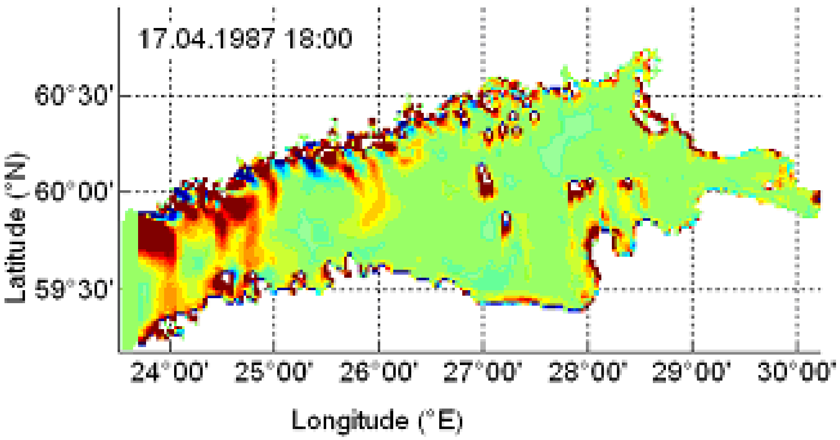
Results

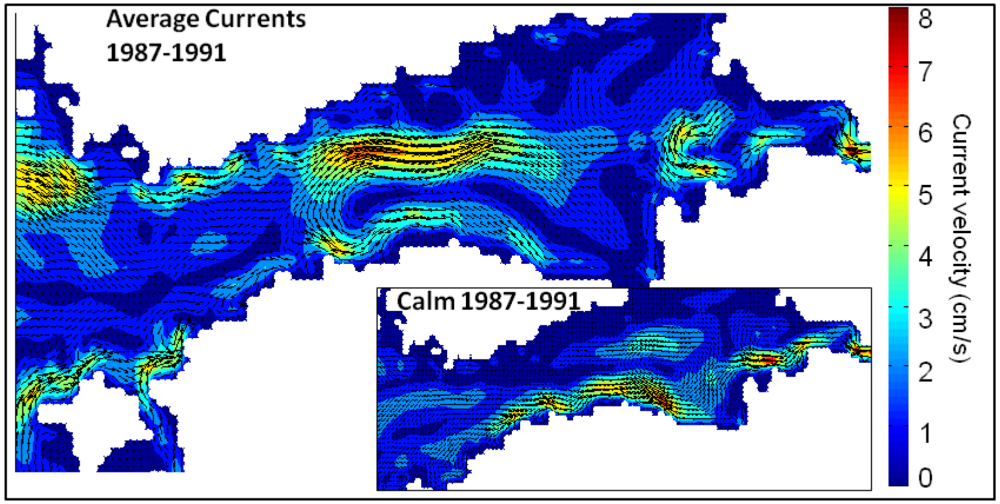




- Windy season (Dec)
- Absolute value of OW parameter higher near the coast and in vicinity of islands
- Also to some extent reaches to the offshore areas

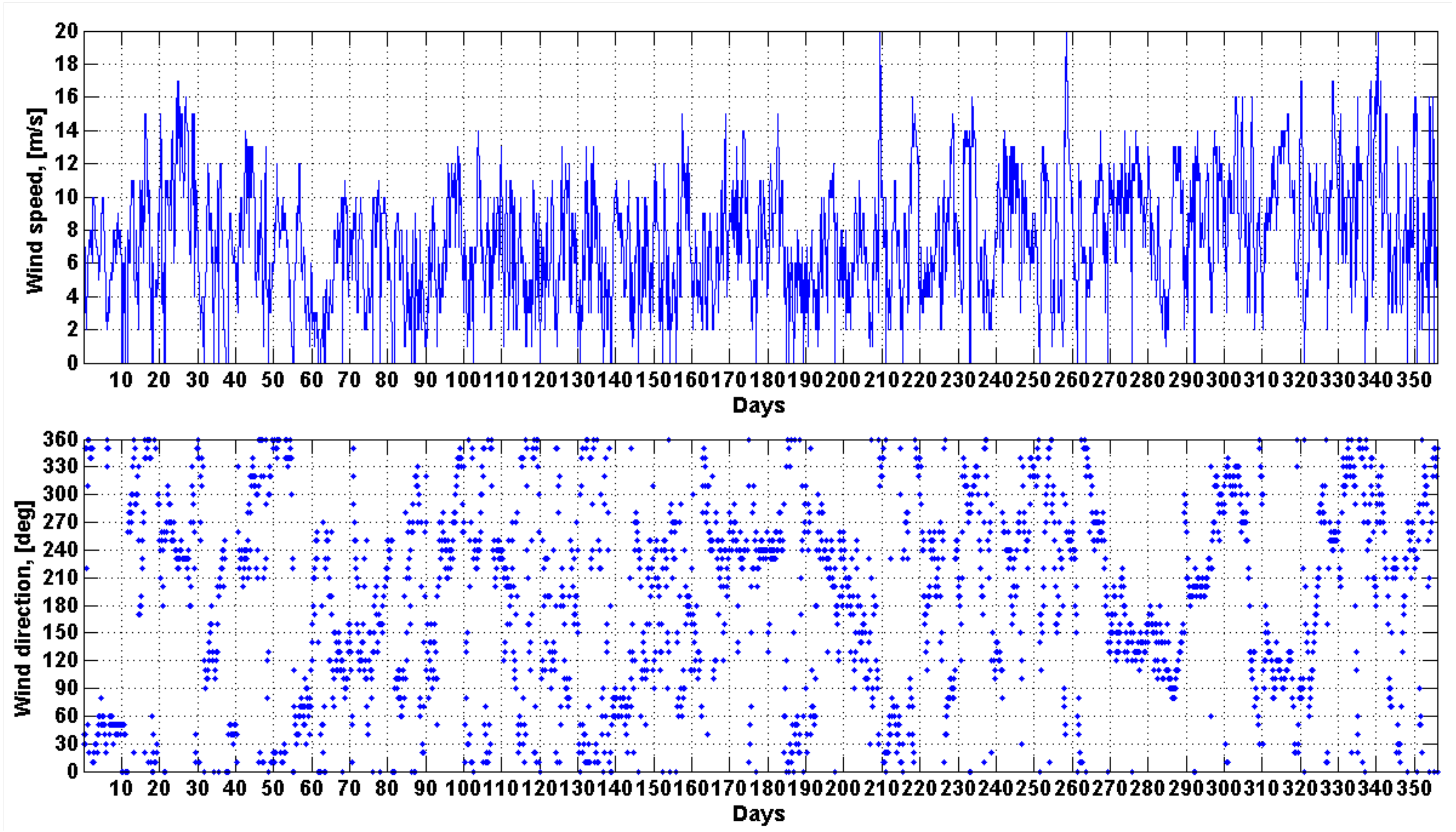
Revealing a hidden gyre?





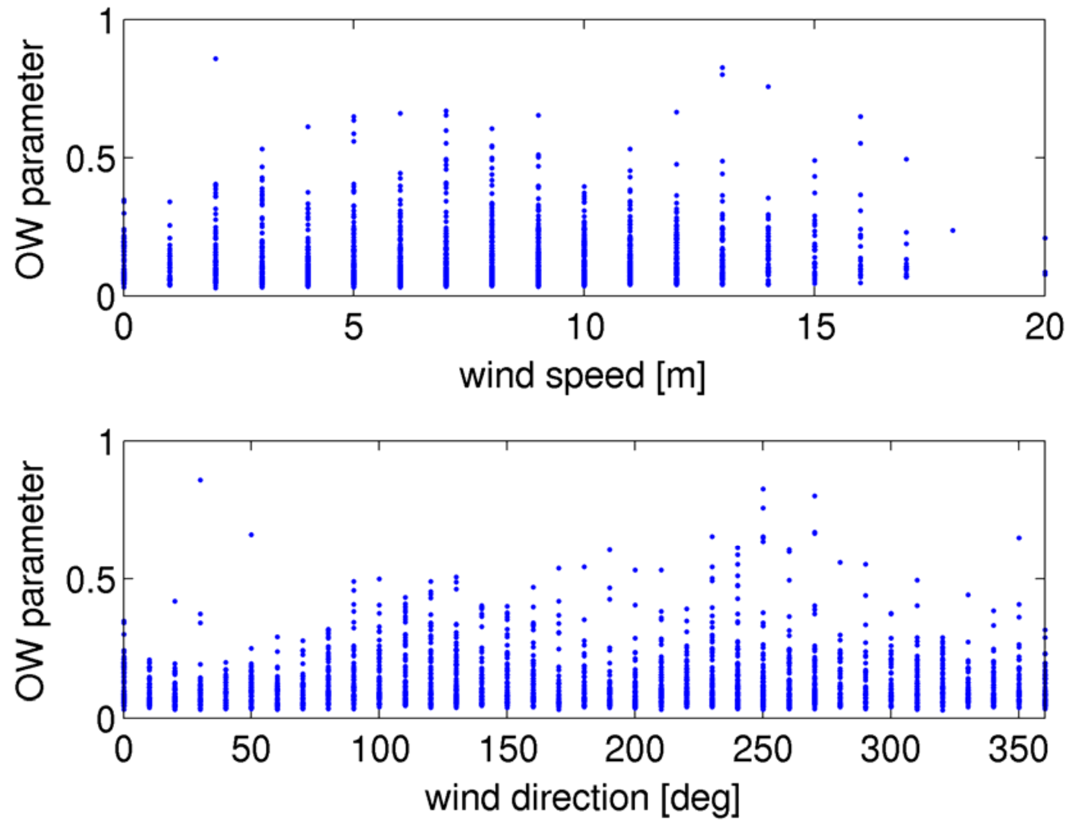
Soomere, Delpeche, Viikmäe, Quak, Meier, Döös 2011, *Boreal Env Res*)

Results



- Extreme values of the OW parameter do not correspond to extreme wind speed
- No correlation between the OW parameter and wind speed or direction

Results



- Pearson correlation coefficient for the OW parameter and wind speed is *r* = 0.1108

- Dynamics of the Gulf of Finland wind dominated ?

- Extreme values in the current field may lag behind the peak wind speed values in time or correspond to specific events driven by rapidly moving wind patterns

- Maxima and minima related to topography

- Large values near the coast – retardation of coastal current

Conclusions

- Okubo-Weiss parameter may reveal certain otherwise hidden features of the motion of water masses

- Patches of strong strain and relative vorticity regularly occur :
  (i) along the coast, due to topographic effects and coastal current fluctuations
  (ii) at specific offshore areas
    - in the eastern part near the mouth of the Neva river and
    - in the north-western part of the basin where the Gulf of Finland narrows between the cities of Tallinn, Helsinki and Hanko.

- May be due to
    - a strong upwelling or
    - the presence of different gyres in the eastern and western part of the Gulf of Finland

- Results are to a large extent consistent with the outcome of earlier studies performed using Lagrangian trajectories