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Circulation patterns in the Gulf of Finland

BOOS Workshop on Coastal Operational Oceanography

Brussels, 2018-05-22

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Marine Research

Aim: model Gulf of Finland mean circulation

- Useful for estimating transport, distribution and residence times of substances
  - E.g. nutrients, oil spills, chemicals from accidents
- Need for numerical models to accurately represent circulation
  - E.g. decision support systems for environmental protection measures
- Reference: Westerlund A., Tuomi L., Alenius P., Myrberg K., Miettunen E., Vankevich R. E., Hordoir R.. Tellus, 2018. (revised)

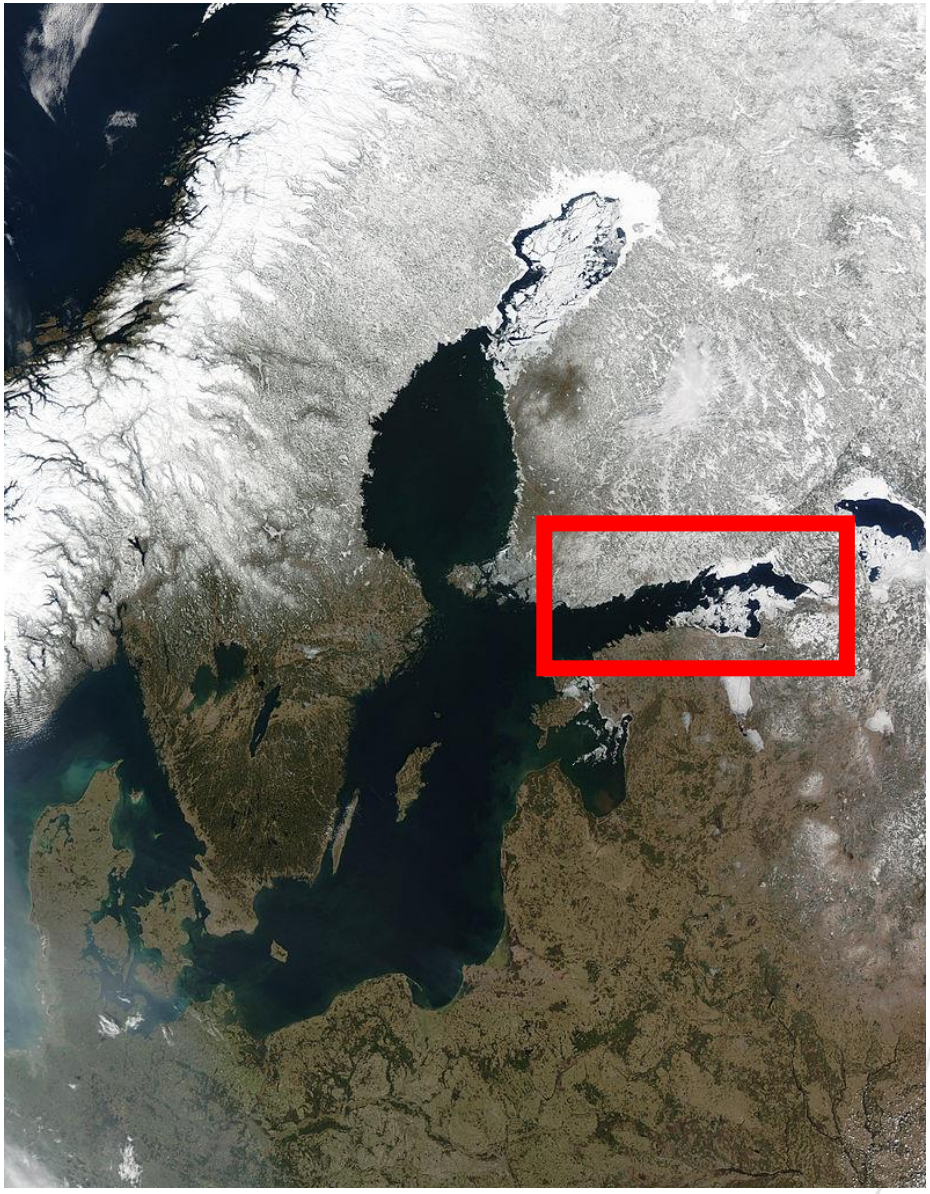
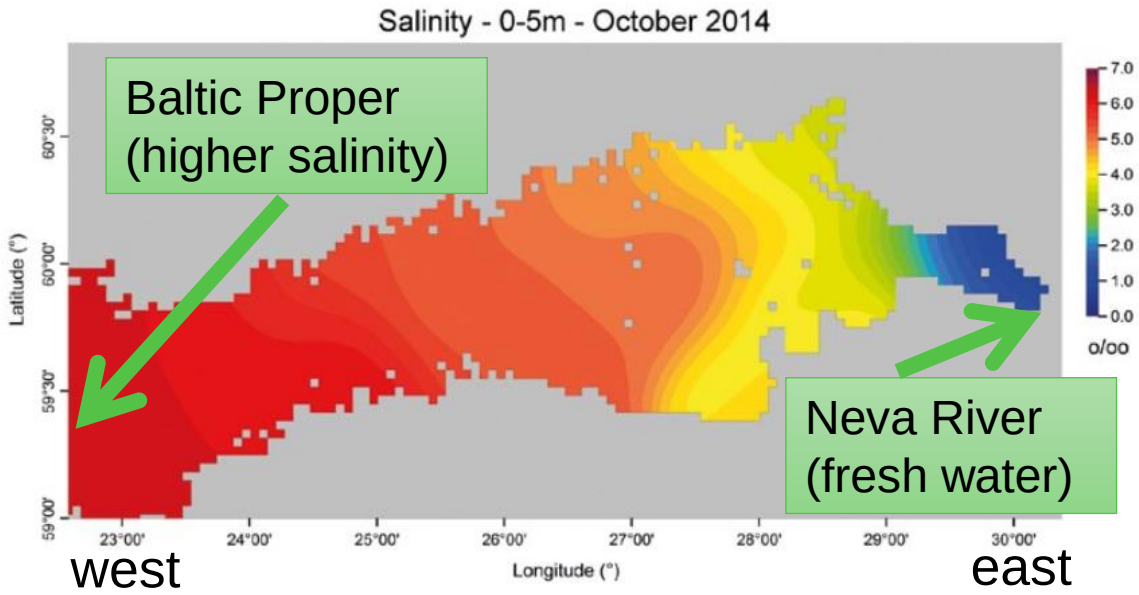
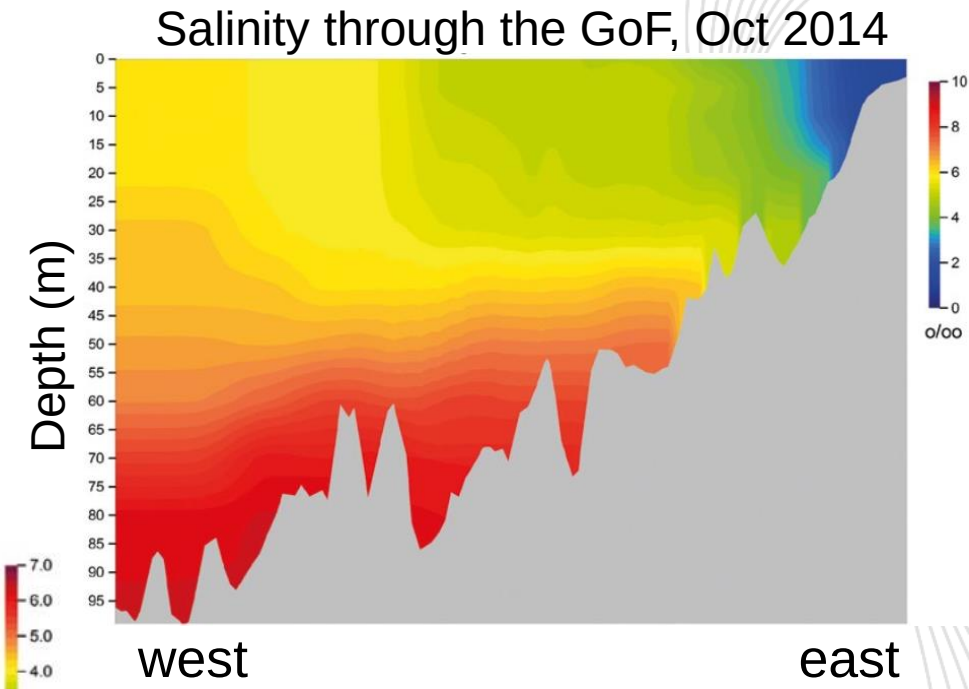


Figure: https://www.visibleearth.nasa.gov/view.php?id=70636 (NASA, PD)

Background: Gulf of Finland is like a big estuary

- Transition zone
  - Fresh water from the east
  - More saline water from the west





”*Salt wedge estuary*”

Figure source: Alenius et al., Gulf of Finland Physics, 2016 http://hdl.handle.net/10138/166296

Background: GoF mean circulation

- Long-term mean surface currents
- Witting's *Atlas of Finland*, 1910
- Based on light ship observations
- Persistency of currents low

- Cyclonic circulation pattern

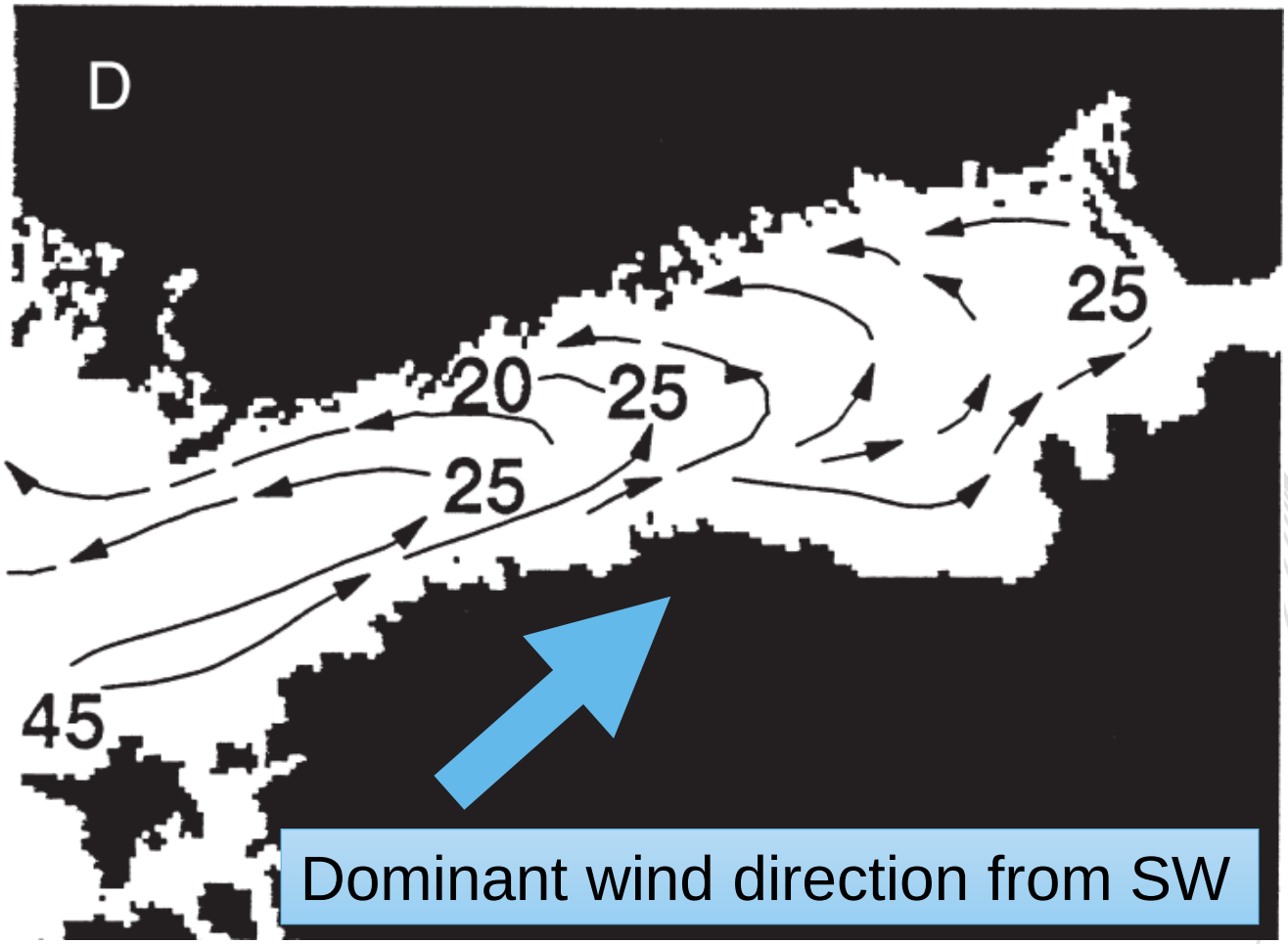
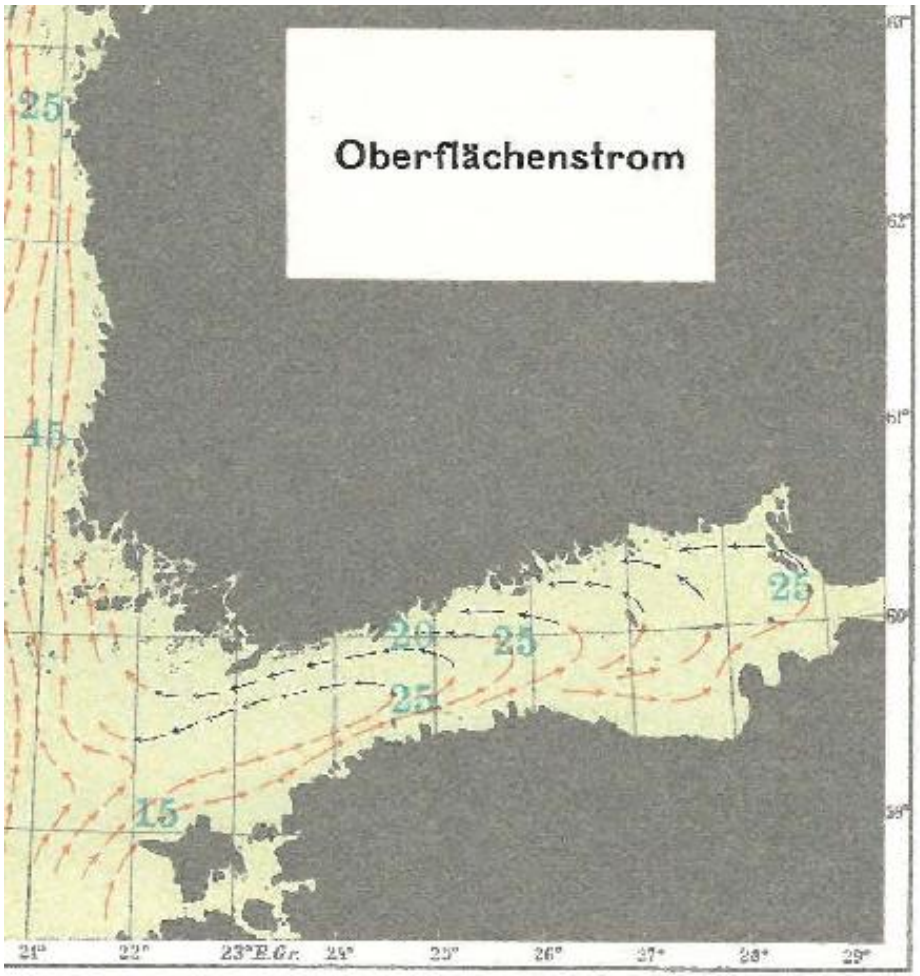
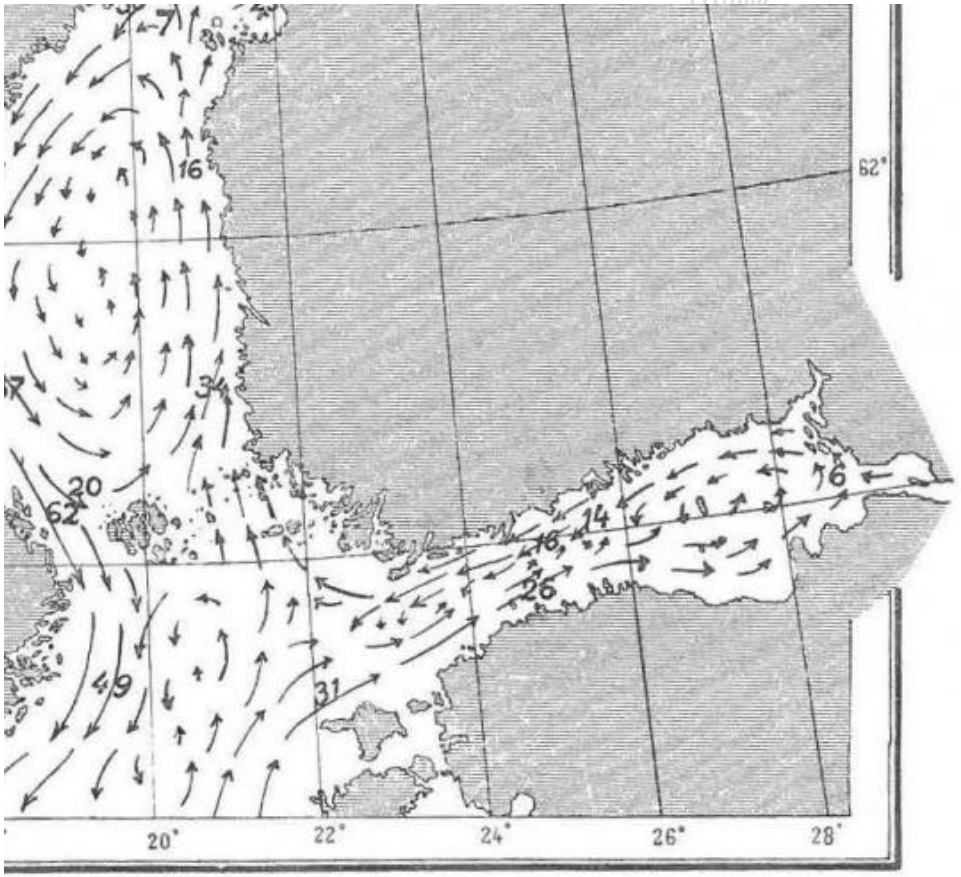


Figure: Alenius et al. The physical oceanography of the Gulf of Finland: a review. *BER* 3 (2), 97–125, 1998.

History: ancient studies show a cyclonic pattern



Witting, 1912



Durchschnittliche Strömung im nördlichen Baltischen Meere.

Palmén, 1930

Witting, R. (1912). Soc. Scient. Fenn., Finländische Hydr.-Biol. Untersuchungen, (7)

Palmén, E. (1930). Soc. Scient. Fenn., Comm. Phys.-Math., V(12).

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Background: older studies mostly show cyclonic pattern

- Mostly cyclonic loops and eddies
- Cyclonic circulation pattern

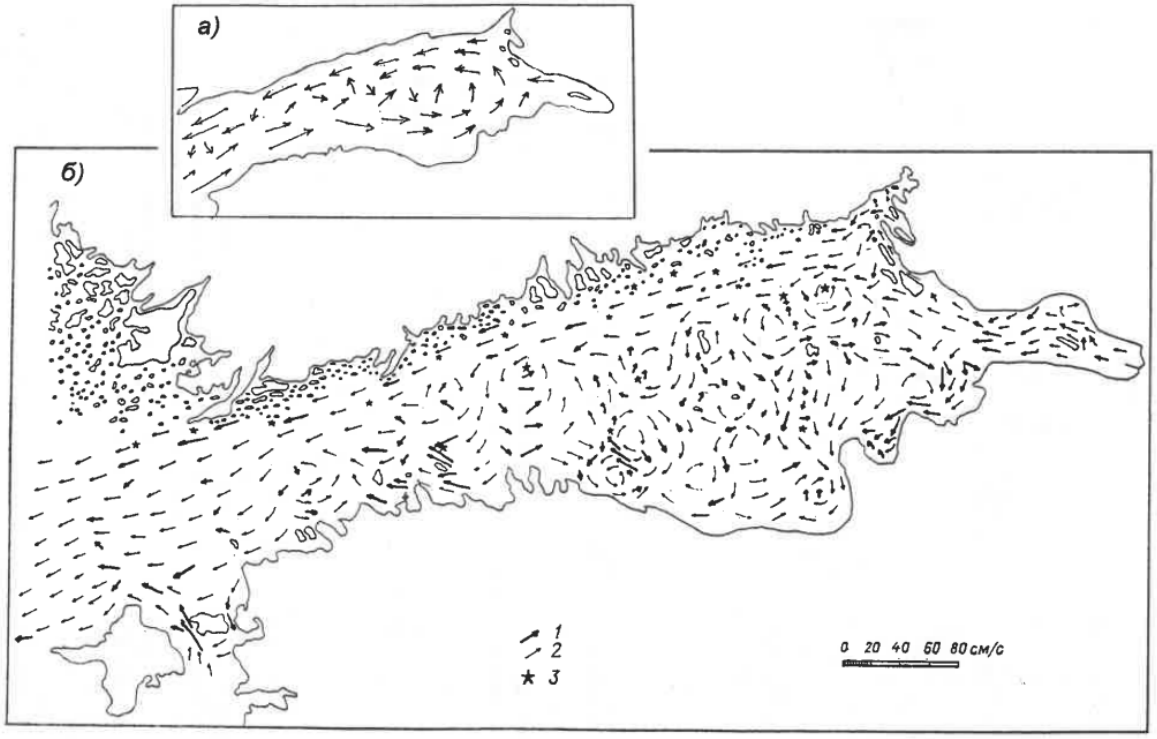
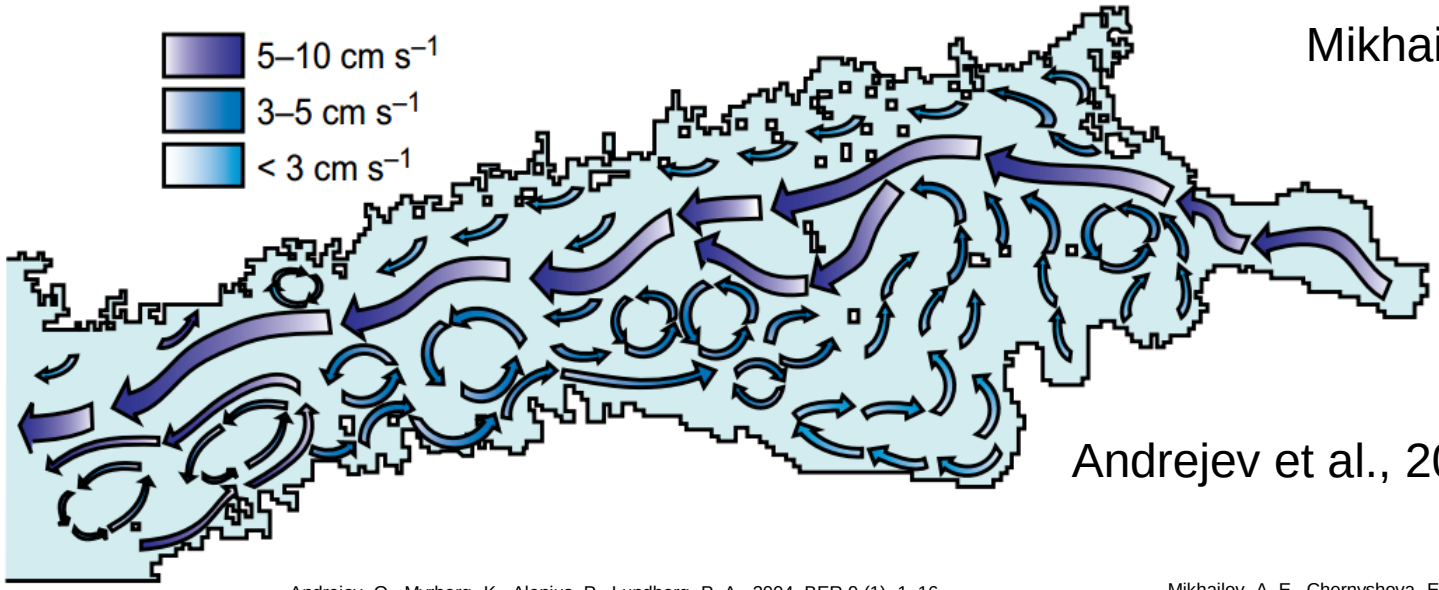


Рис. 7.25. Схема постоянных течений.
а – средняя годовая циркуляция [221]; *б* – по данным аэрофотосъемки [23, 24]:
1 и *2* – соответственно измеренные и предполагаемые течения; *3* – плавмаяки.



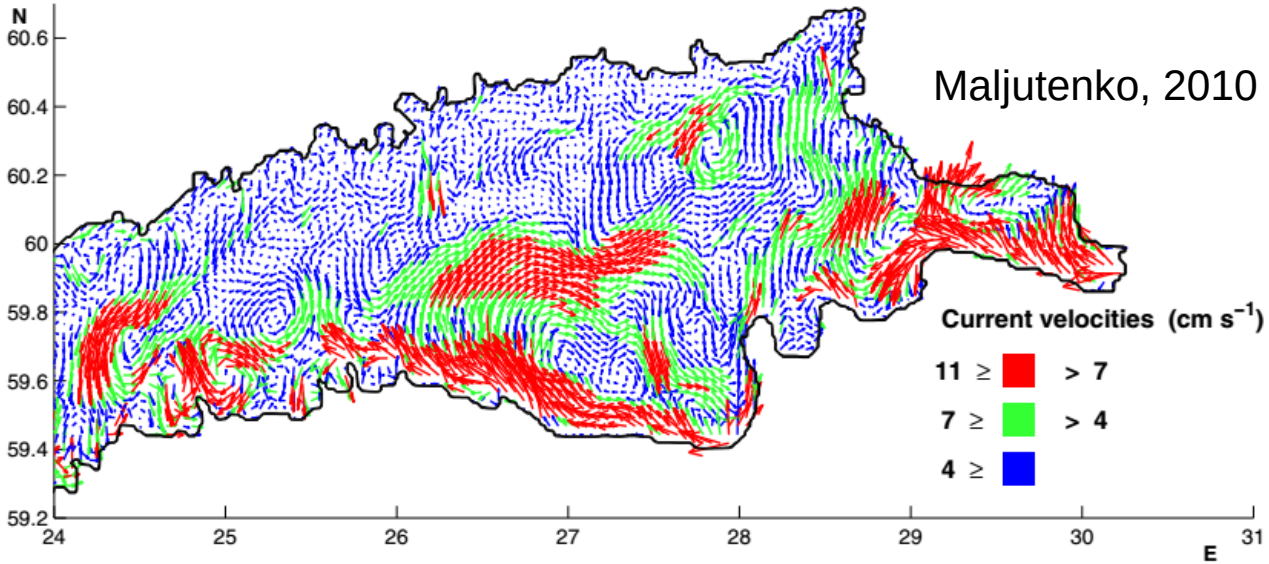
Mikhailov and Chernyshova, 1997

Andrejev et al., 2004

Andrejev, O., Myrberg, K., Alenius, P., Lundberg, P. A., 2004. BER 9 (1), 1–16.

Mikhailov, A. E., Chernyshova, E., 1997. General water circulation. In: "Baltica" Project, 5: 2. 245–260

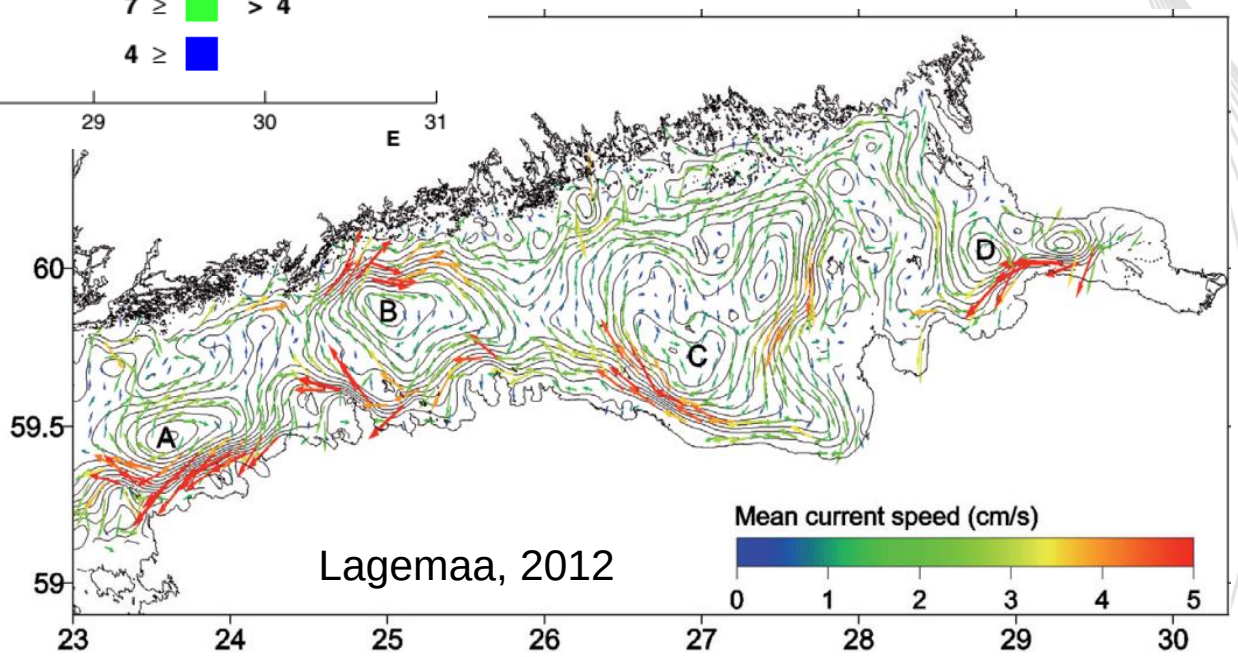
Background: newer modelling shows differences



Maljutenko, 2010

- Also anticyclonic loops, eddies in the averages
- No clear cyclonic pattern

- **Why?**
  - **Different years and forcings** – but that is not the full story
  - Let's see what we get with our model



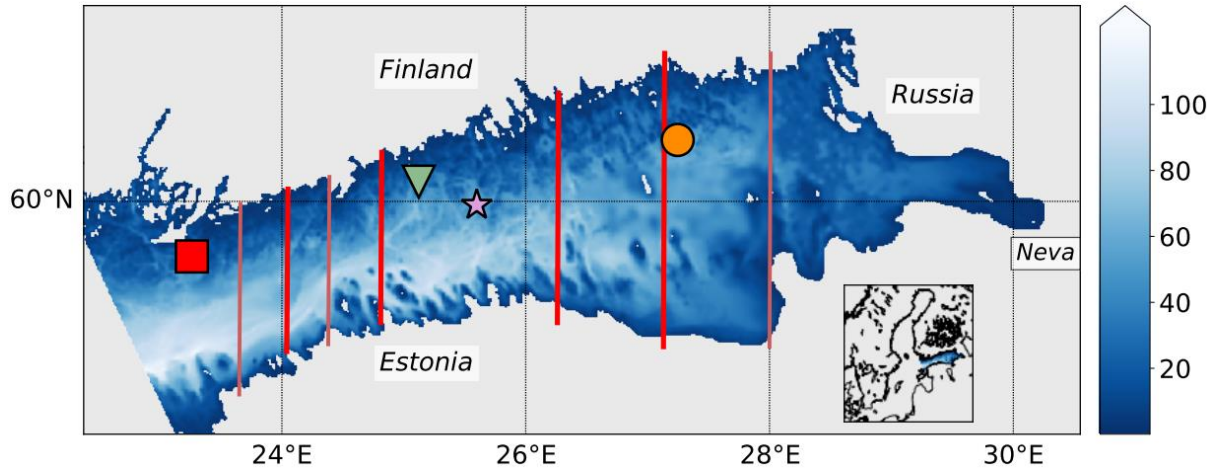
Lagemaa, 2012

Maljutenko, I., Laanemets, J., Raudsepp, U., 2010. In: BALTIC, IEEE/OES US/EU. 1–7.

Lagemaa, P., 2012. TUT Press, MSI, Tallinn University of Technology, Tallinn.

Methods: GoF with the NEMO model

- NEMO (Nucleus for European Modelling of the Ocean)
  - Community 3D ocean model
  - From global to local
  - From climate to operational



- High-resolution GoF configuration
  - Based on the cfg by Vankevich et al. (2016)

- 0.25 NM resolution, 94 lvls
- Forcing EURO4M atmospheric reanalysis
- 2007-2013 run

www.nemo-ocean.eu

Vankevich R. E., et al. *Ocean Sci.* 12 (4):987-1001, (2016).

Baltic Sea
NEMO at FMI

- For a number of years, FMI has been engaged in the NEMO Nordic co-operation (North Sea - Baltic Sea)
  - **co-operation with SMHI**
  - Westerlund, Tuomi. *J. Mar. Syst.*, 158: 34-44, 2016.
- FMI is applying NEMO to high resolution modelling in the Gulf of Finland (GoF)
  - **co-operation with IORAS, SYKE**
  - Westerlund, Tuomi, Alenius, Miettunen, Vankevich. *Oceanologia* , 60(1):16-31, 2018.

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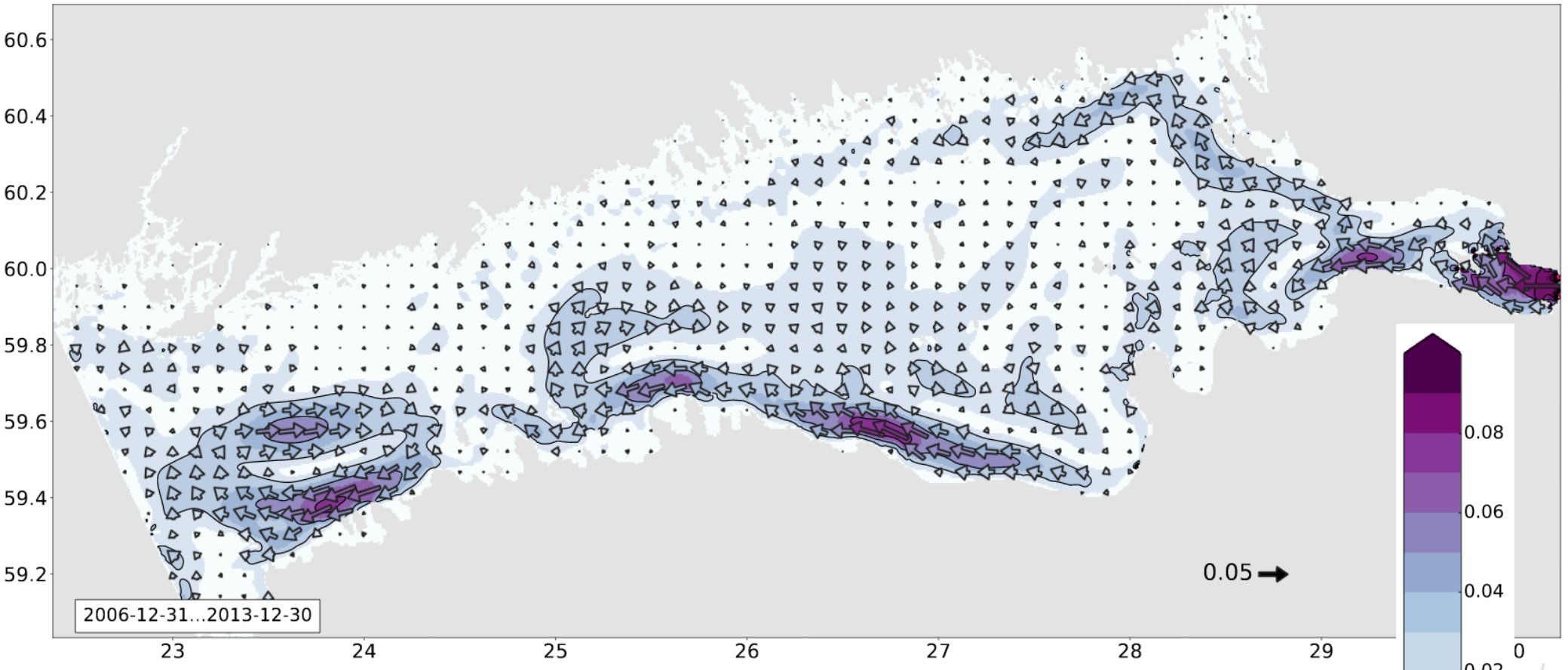
Results: NEMO GoF mean currents, 500 m configuration, 2007-2013

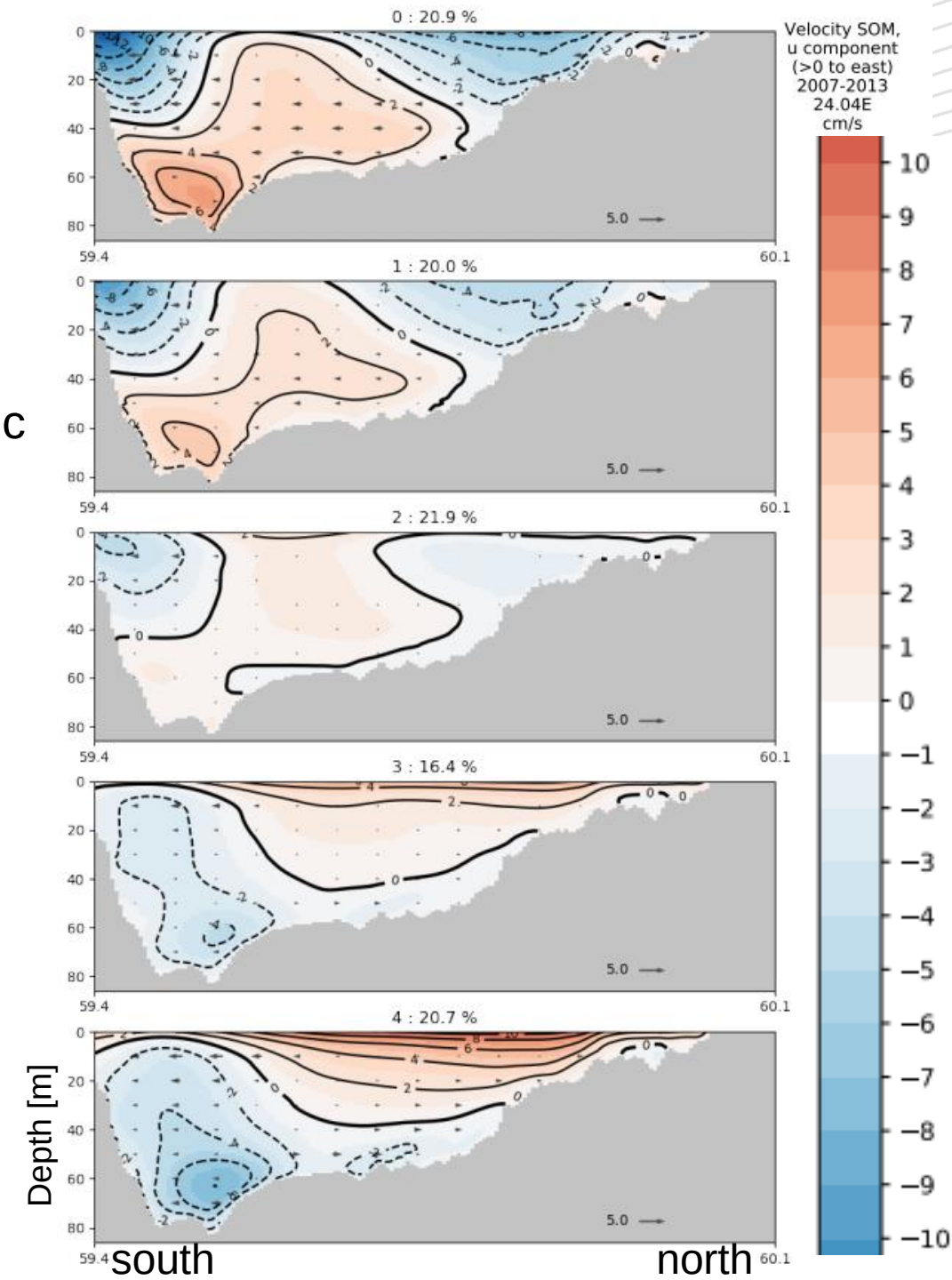


No clear cyclonic pattern…

Mean circulation from 0 to 7.5 m

How does this mean circulation field emerge?

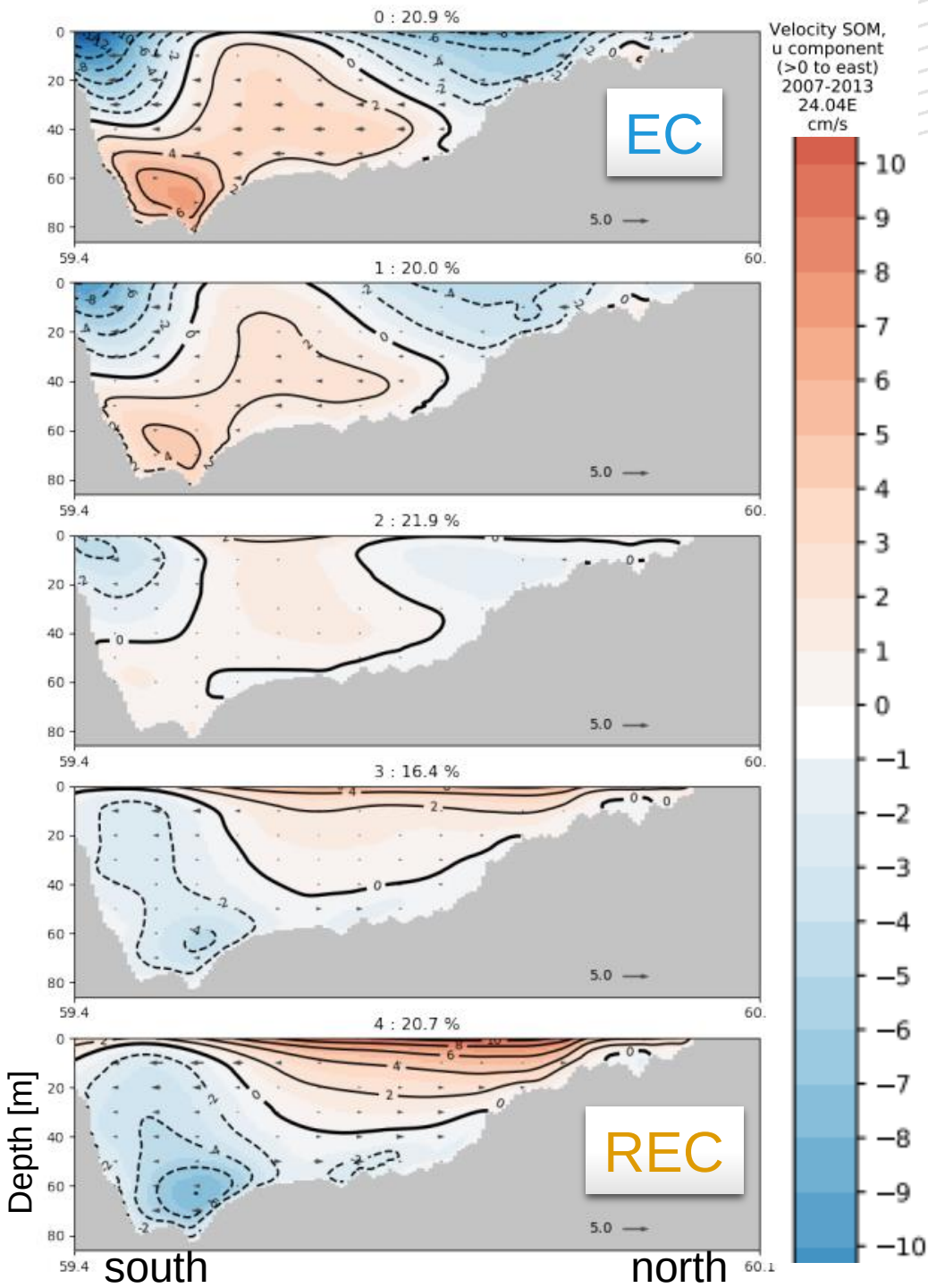
- Analyse by extracting characteristic patterns
- 7-year model run
  - Daily circulation fields
  - Cluster into 5 *nodes* or *archetypes* (1D)
- SOM analysis (Self-organising map, Kohonen map)
  - Unsupervised machine learning algorithm
  - Used for feature extraction from a large data set
- North-south section at 24°E
- Blue: current towards west
- Red: current towards east



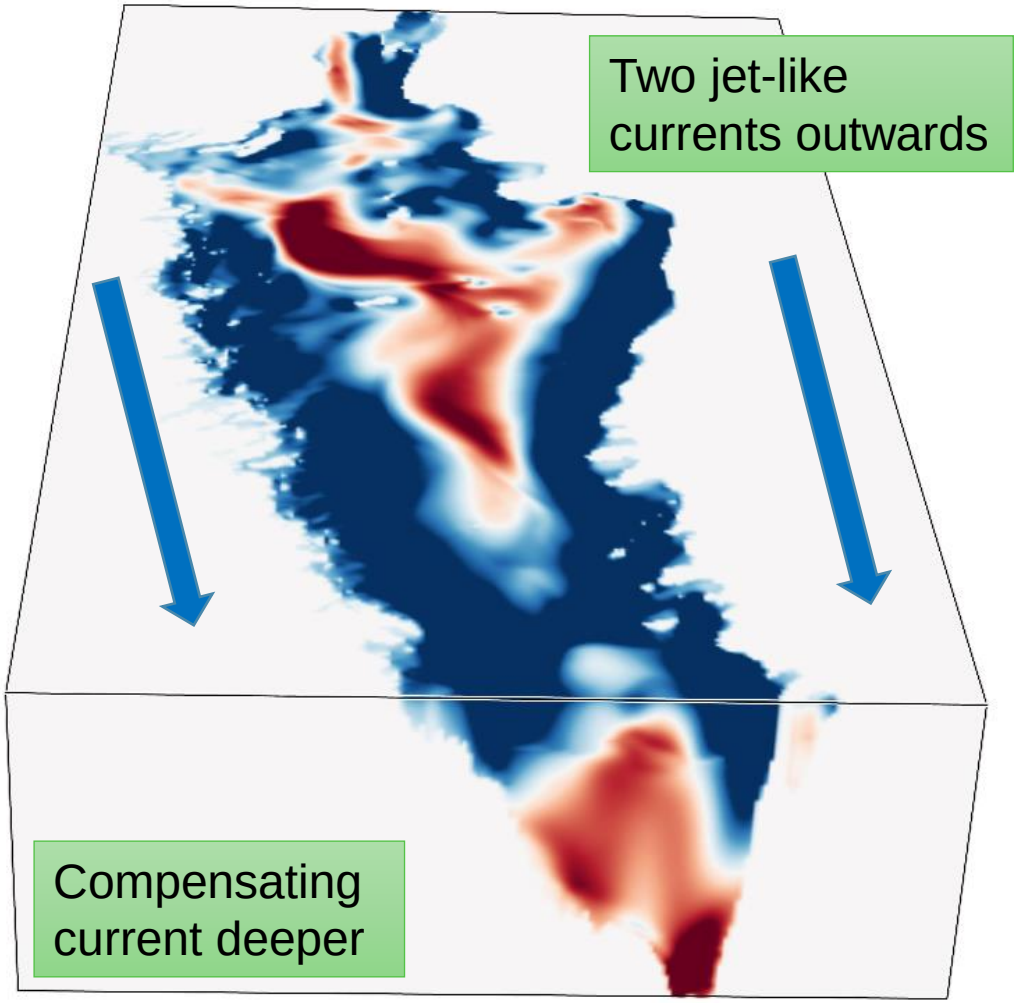
Characteristic circulation fields

- **From the analysis we can identify**
  - Normal estuarine circulation (EC)
  - 3 transitional nodes
  - Reversed estuarine circulation (REC)

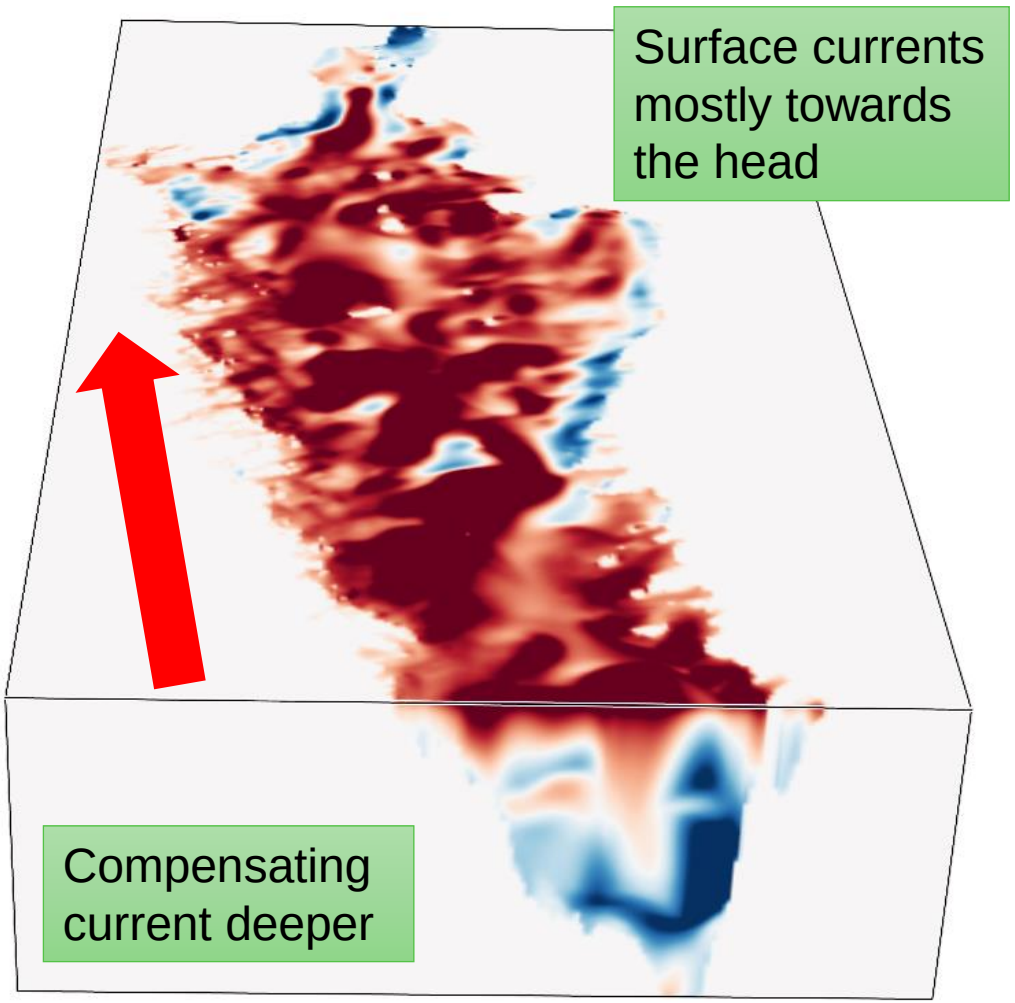
- EC and REC roughly as common
- EC more heterogeneous in the surface



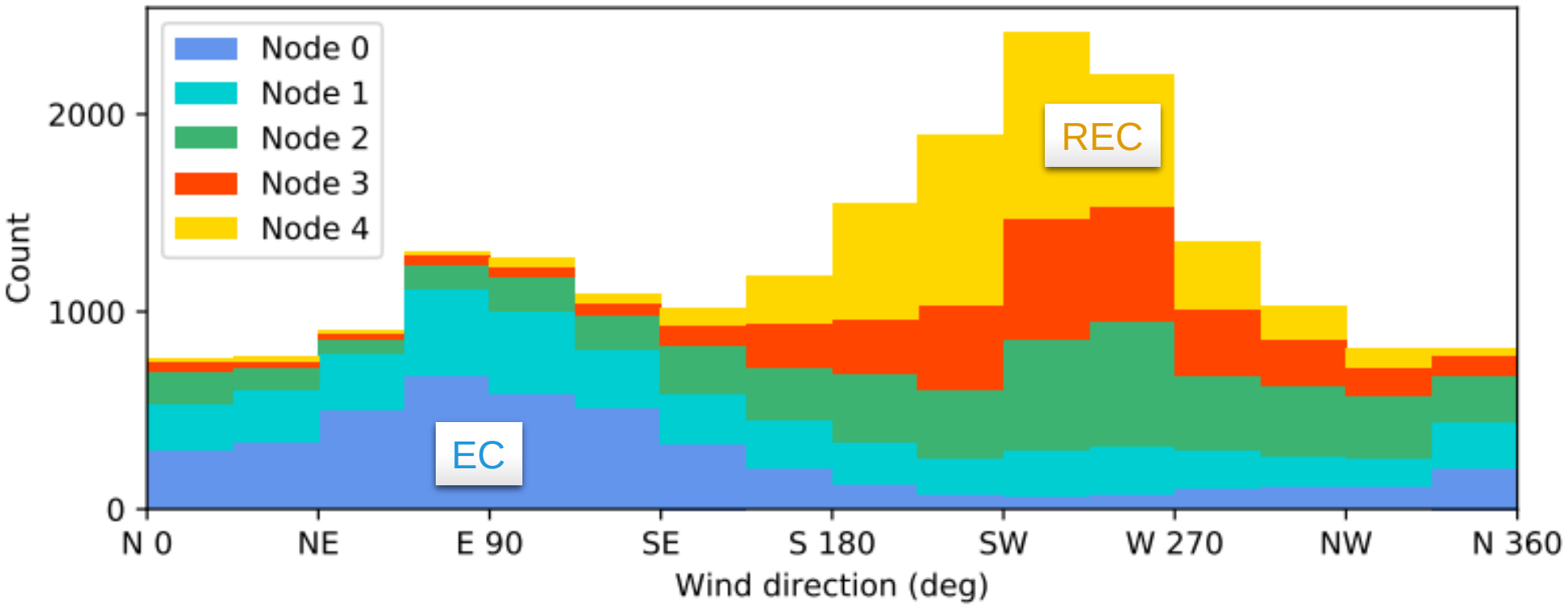
Example of estuarine circulation (EC)



Example of reversed estuarine circulation (REC)

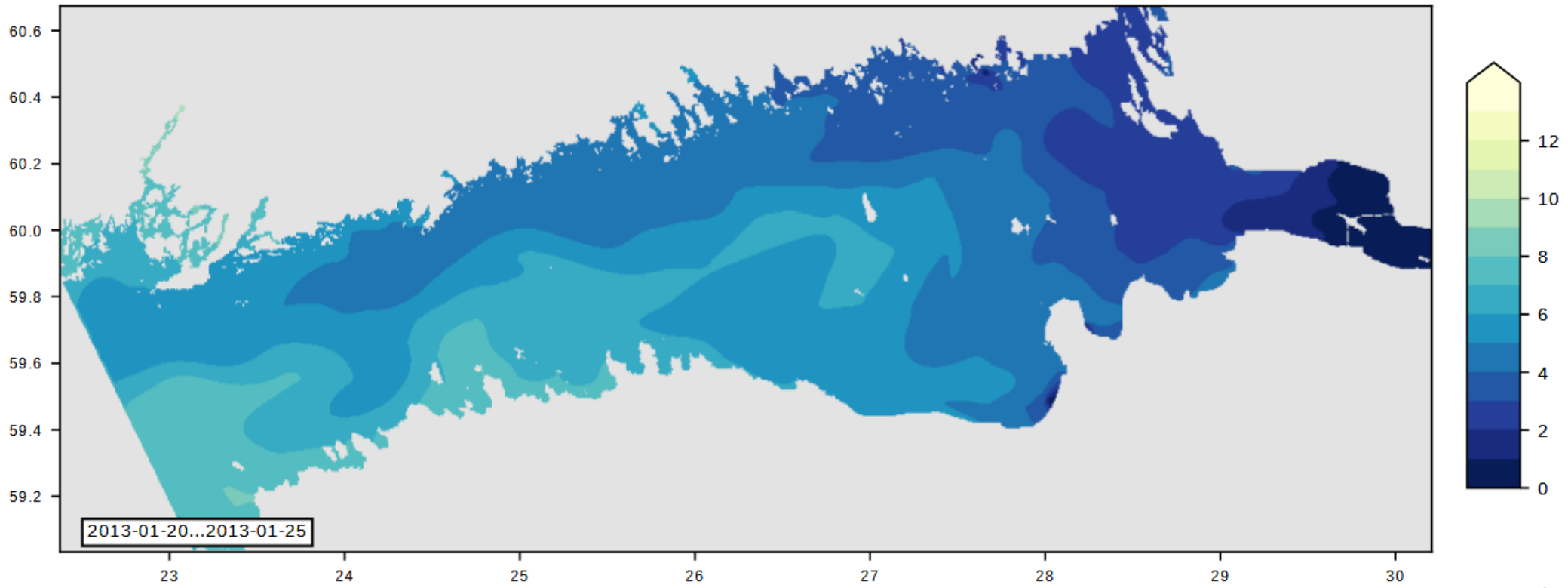


Wind direction is related to the circulation pattern



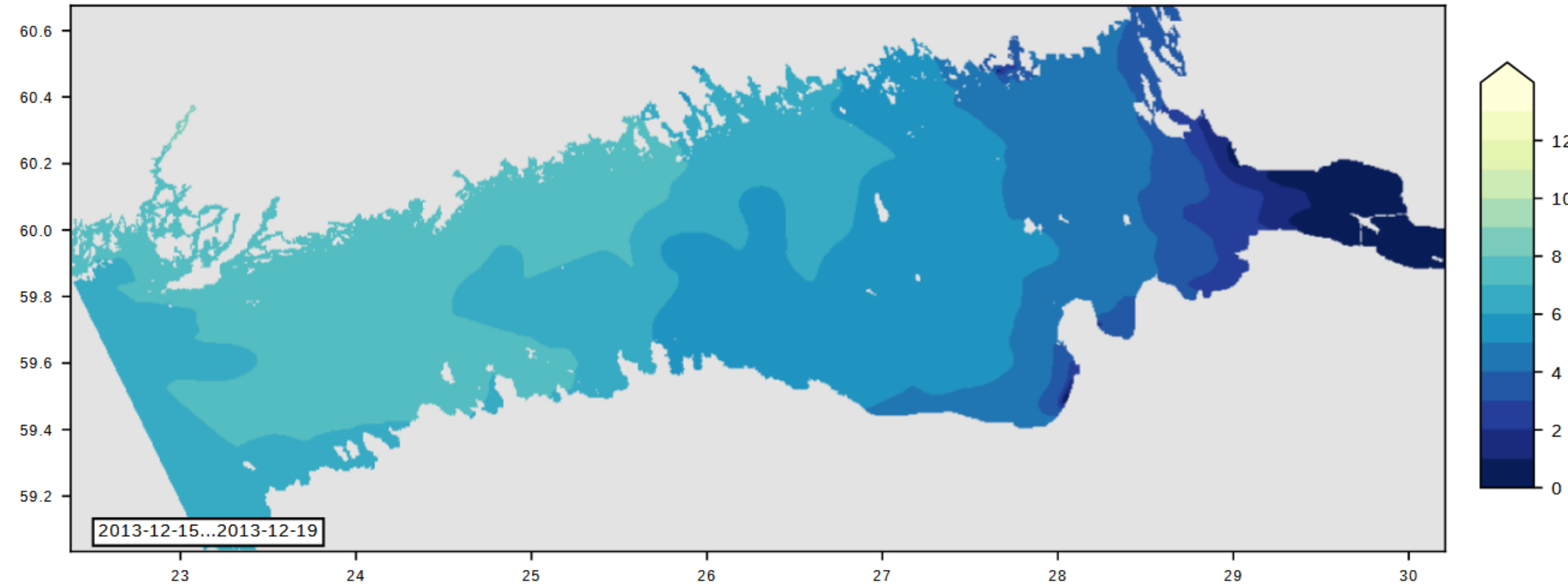
SW winds reverse the circulation in the GoF

Salinity gradients after longer period of estuarine circulation...



Slanted salinity gradients, lower salinities on northern coast

...look different from gradients after reversed estuarine circulation



Lower salinities on southern coast

Conclusions

- Analysis emphasized that the GoF is like a big estuary
- We did not get the traditional cyclonic overall mean circulation pattern

- Circulation in the GoF changes rapidly between
  - normal estuarine circulation (EC) and
  - reversed estuarine circulation (REC)

- Dominant winds (SW) in the GoF support REC

- Cyclonic mean circulation pattern seems to need enough EC
  - Any changes to wind direction distribution affect mean circulation patterns and salinity in the GoF

Figure: http://digi.narc.fi/digi/view.ka?kuid=24767256 (Kansallisarkisto/Luotsi- ja majakkalaitoksen arkisto, Uaab:139)

Going forward

Observations: model vs. reality?

Forcing biases: wind and runoffs?

Climate change: will wind direction distribution change?

More information:

Westerlund, Tuomi, Alenius, Myrberg, Miettunen, Vankevich, Hordoir. *Tellus*, 2018. (revised)

Westerlund, Tuomi, Alenius, Miettunen, Vankevich. *Oceanologia*, 60(1):16-31, 2018. doi.org/10.1016/j.oceano.2017.05.003

Acknowledgements

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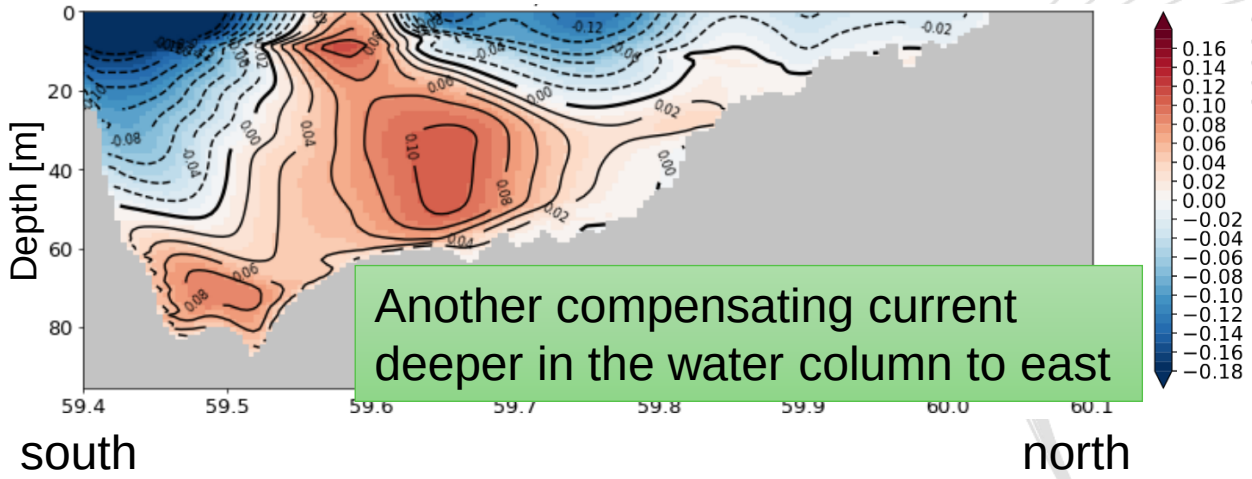
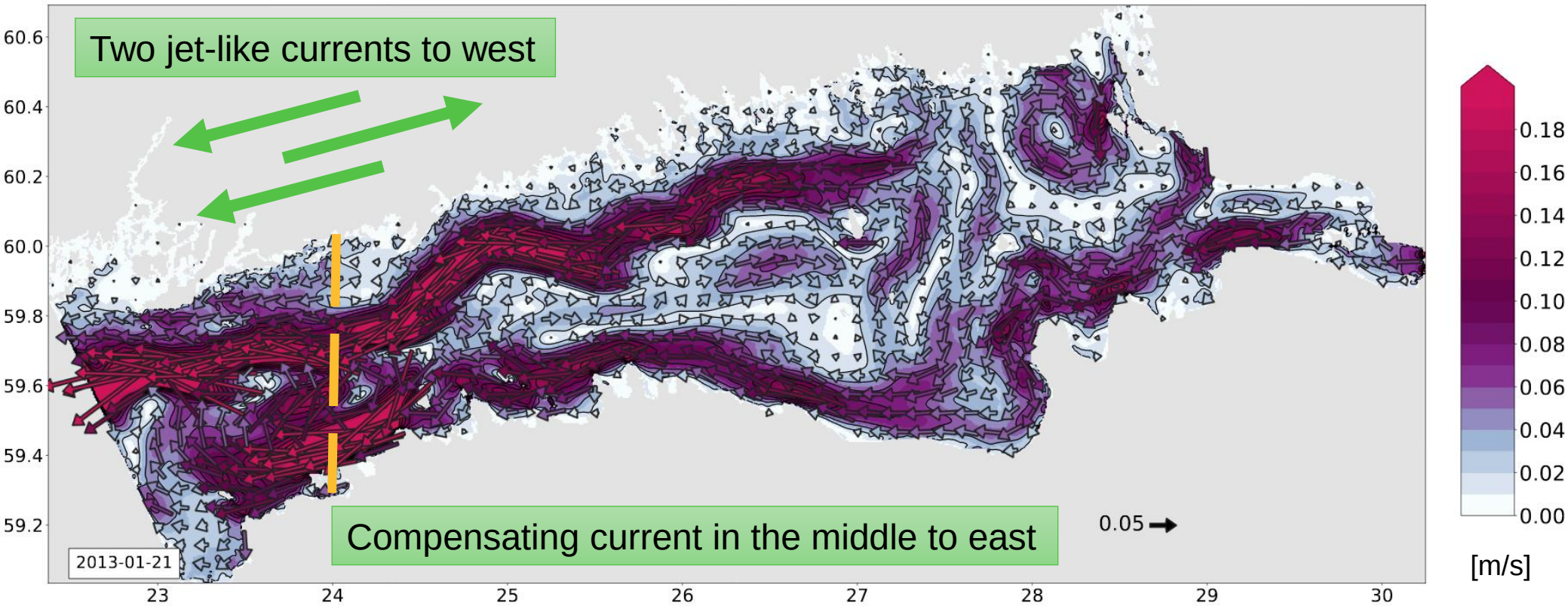
Example of estuarine circulation (EC), Jan 2013





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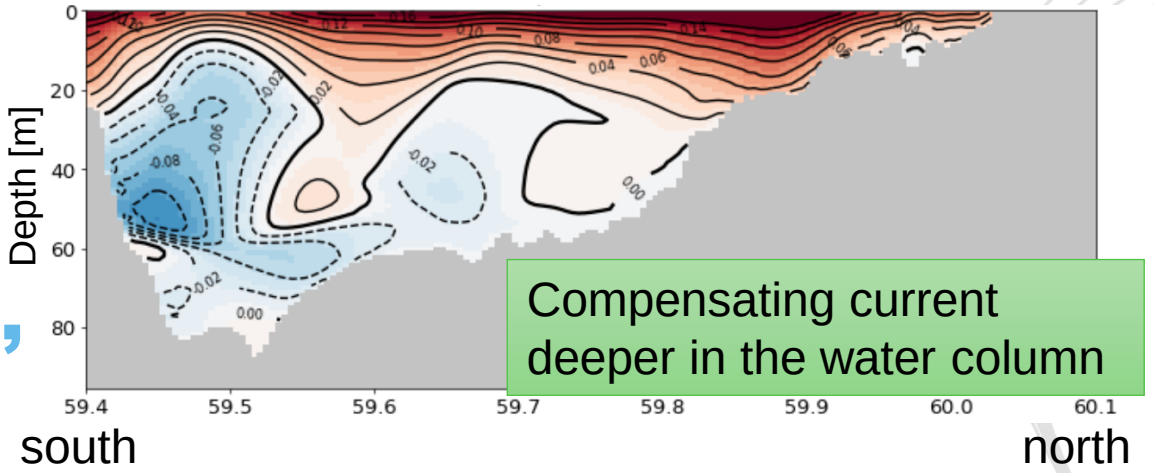
Example of reversed estuarine circulation (REC), Dec 2013



Compensating current deeper in the water column