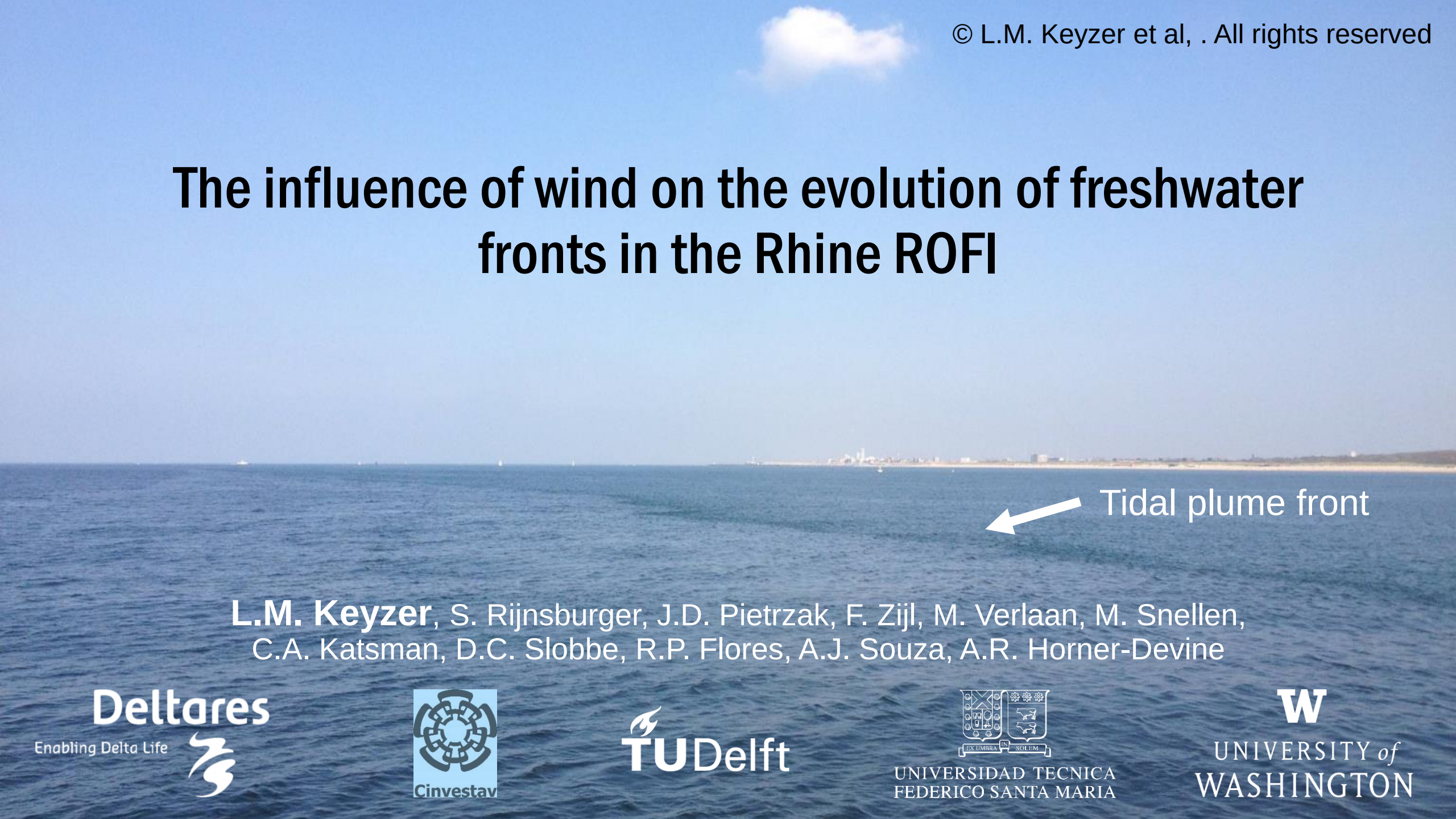
The influence of wind on the evolution of freshwater fronts in the Rhine ROFI



L.M. Keyzer, S. Rijnsburger, J.D. Pietrzak, F. Zijl, M. Verlaan, M. Snellen, C.A. Katsman, D.C. Slobbe, R.P. Flores, A.J. Souza, A.R. Horner-Devine

Deltares
Enabling Delta Life

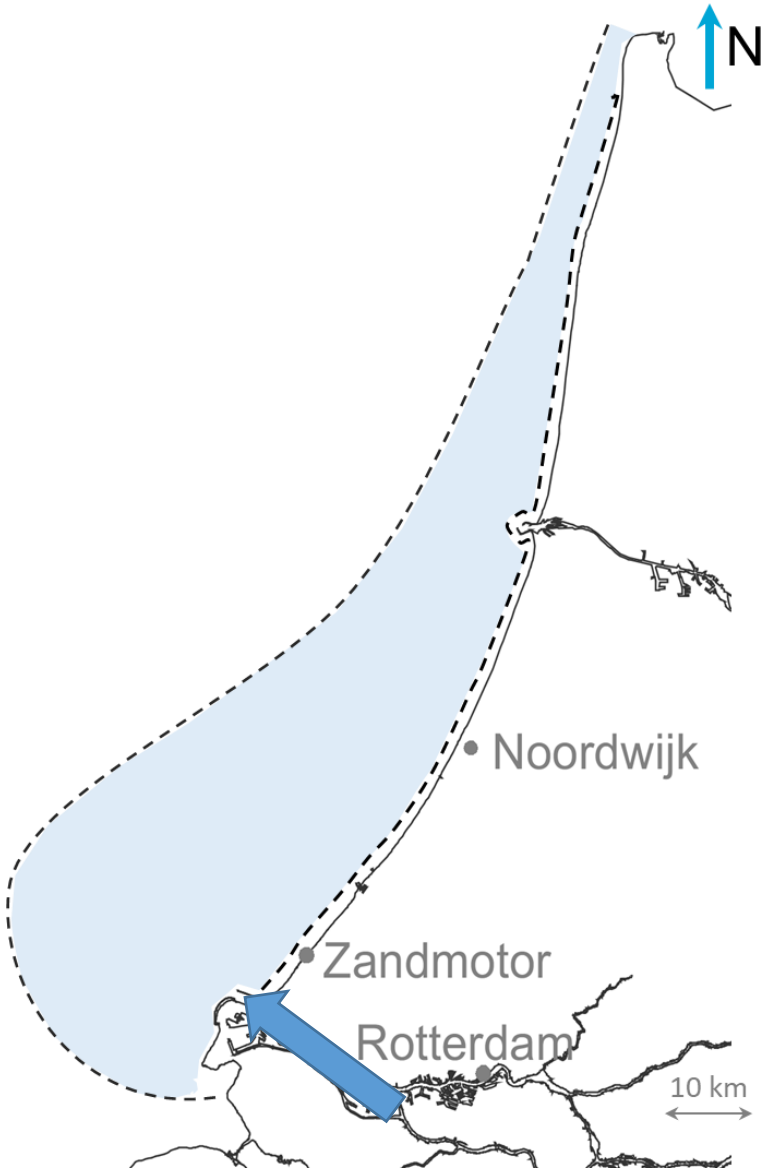
Cinvestav

TU Delft

UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

UNIVERSITY of WASHINGTON

The Rhine ROFI: a tidal river plume along the Dutch coast

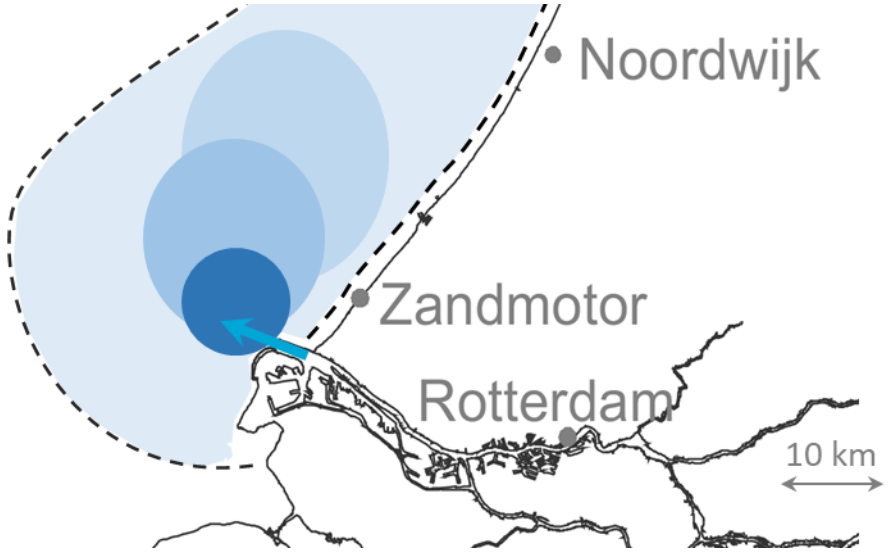


The Rhine ROFI: the near-field region

In the near-field region, the dynamics are dominated by tidal plume fronts.

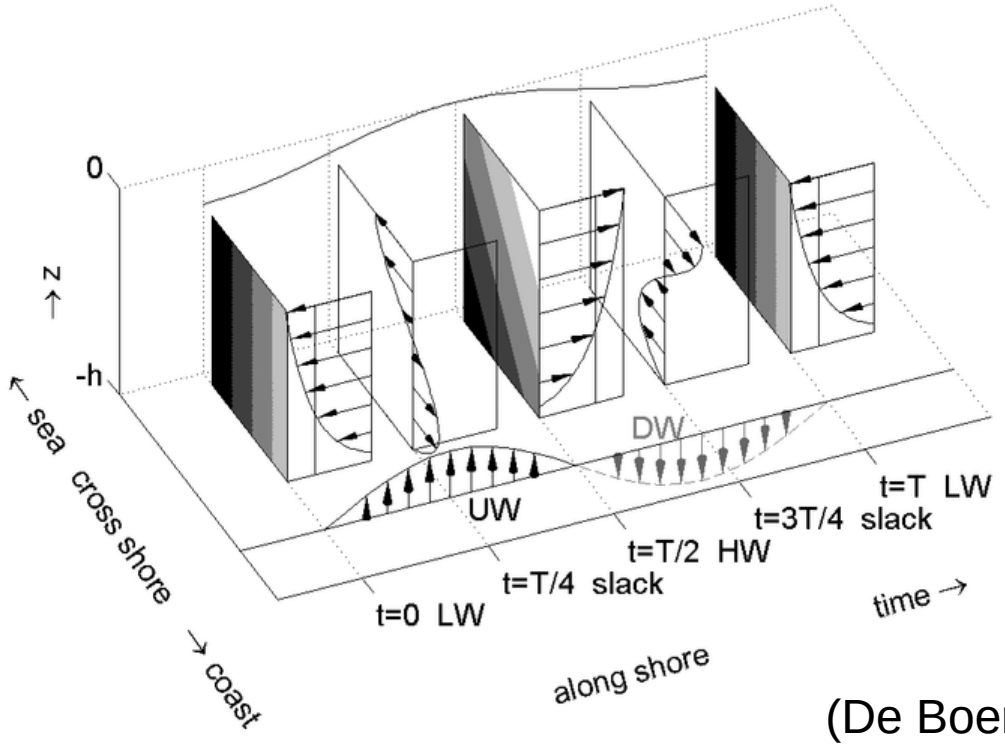
Every tidal cycle, a new tidal plume front is formed.

The tidal plume fronts from previous tidal cyles can still be present while a new one is formed.

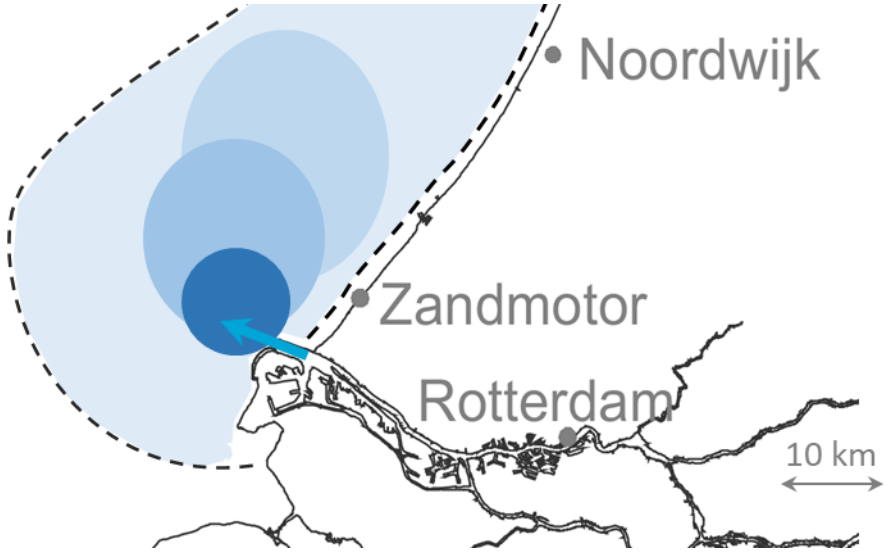


The Rhine ROFI: the near-field region

Tidal plume fronts are advected by tidal straining

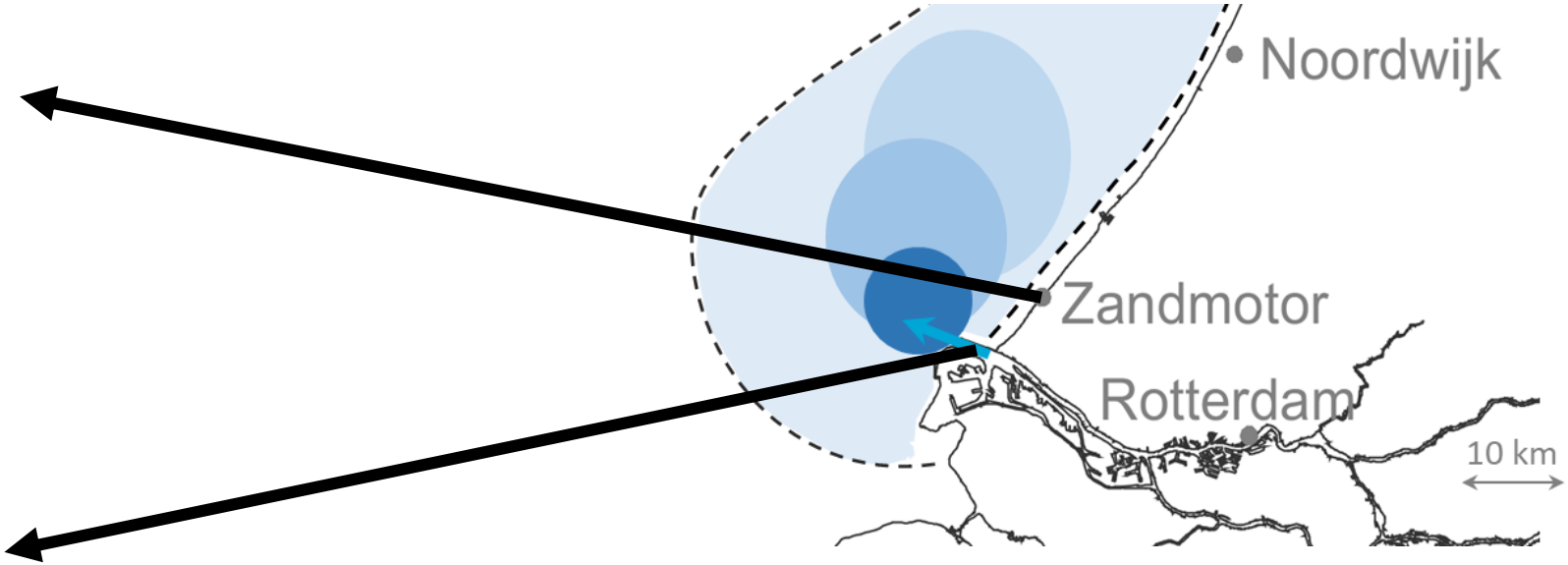


(De Boer, 2006)



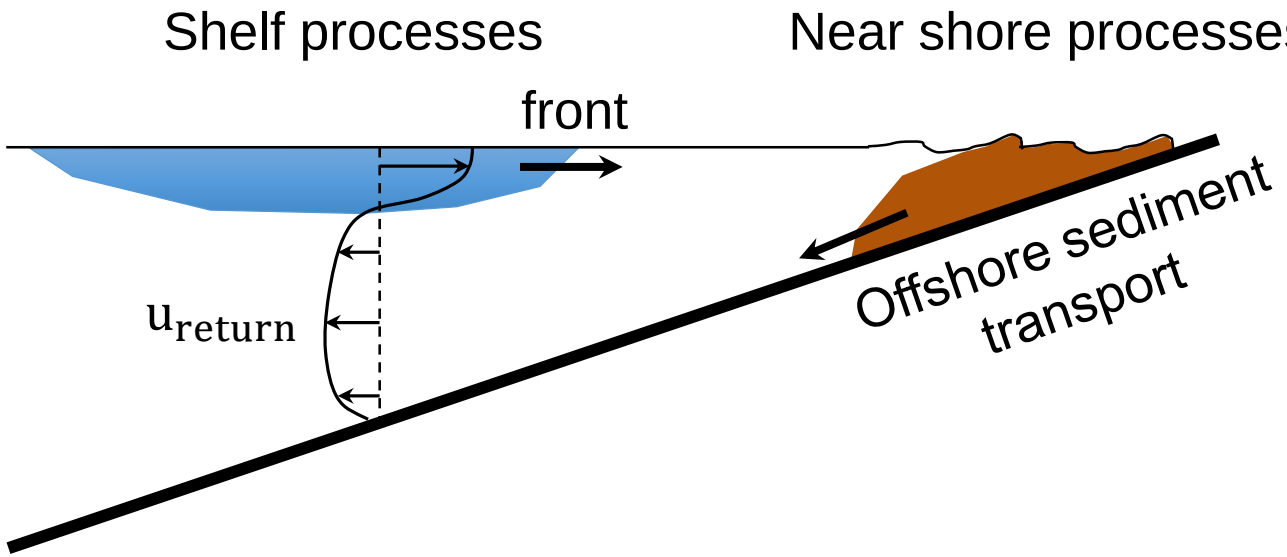
Why we need to understand impact of fronts

Zandmotor
(a mega nourisment)



Port of Rotterdam

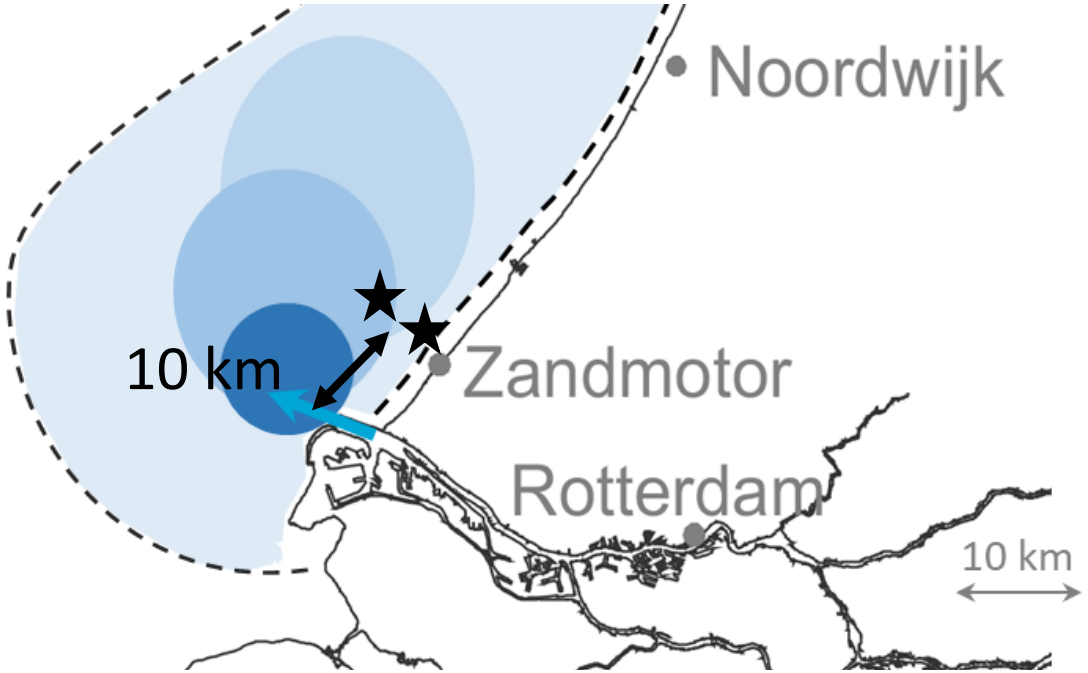
Fronts can impact sediment transport



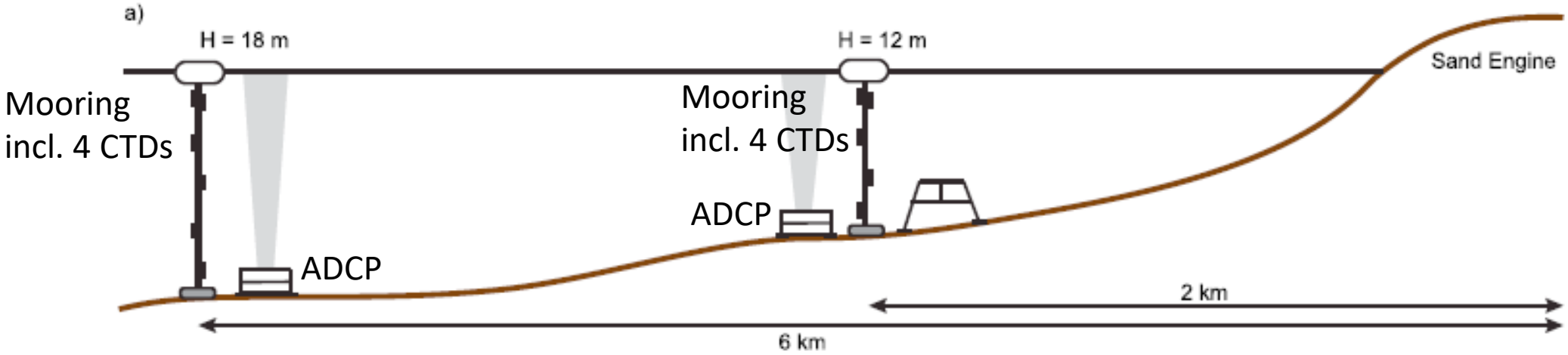
(Horner-Devine et al., 2017)

1. Front propagates onshore
2. Return flow moves suspended sediment offshore

STRAINS measurement campaigns

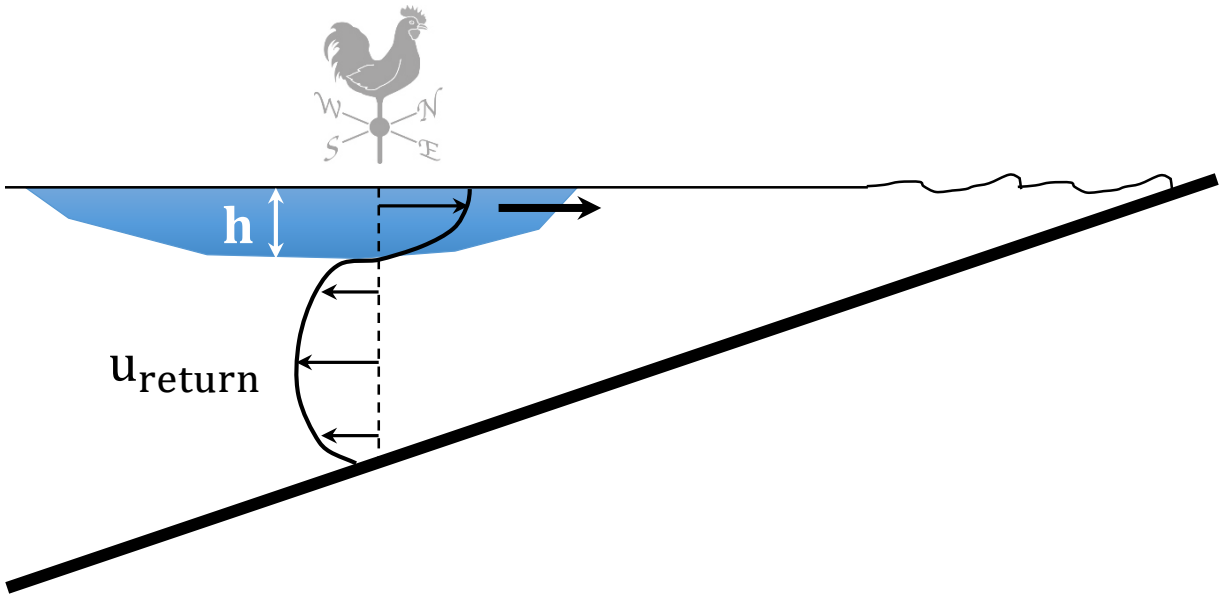


PI's:
J.D. Pietrzak,
A.R. Horner-Devine,
A.J. Souza



Role of the wind

STRAINS campaign: strongest fronts are found under downwelling winds (Rijnsburger, 2018)



How does the **wind direction** affect:

- Location of the river plume?
- Cross-shore velocities?
- Tidal plume fronts?

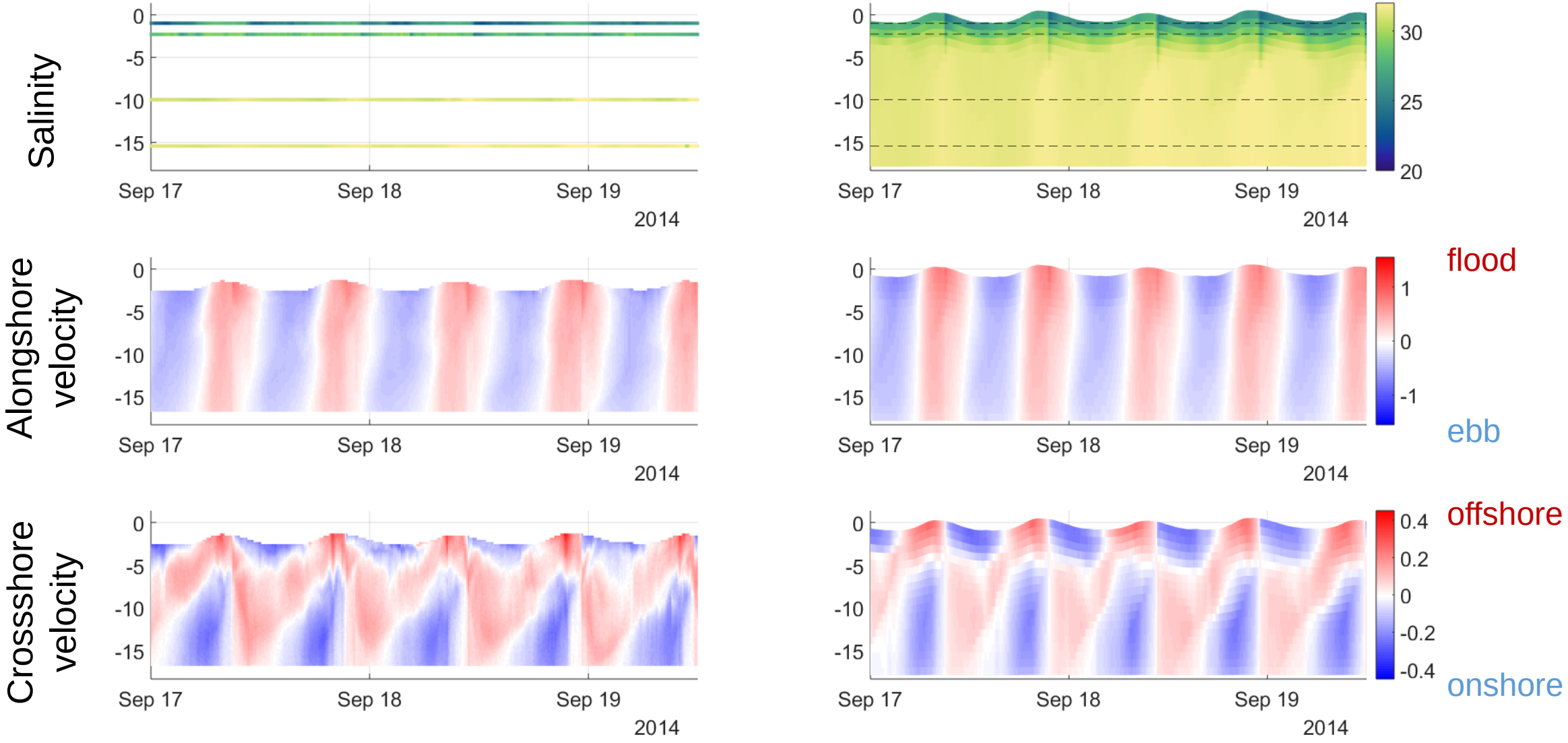
Dutch Continental Shelf Model

- 3D: 20 sigma layers
- Open boundary conditions
  - Tide
  - Temperature and salinity (WOA2013)
  - Steric height correction
- Forcing:
  - Wind and atmospheric pressure (ERA5)
  - Heat-flux model
  - River discharges
- Unstructured grid

Model validation

Measurements (CTD and ADCP)

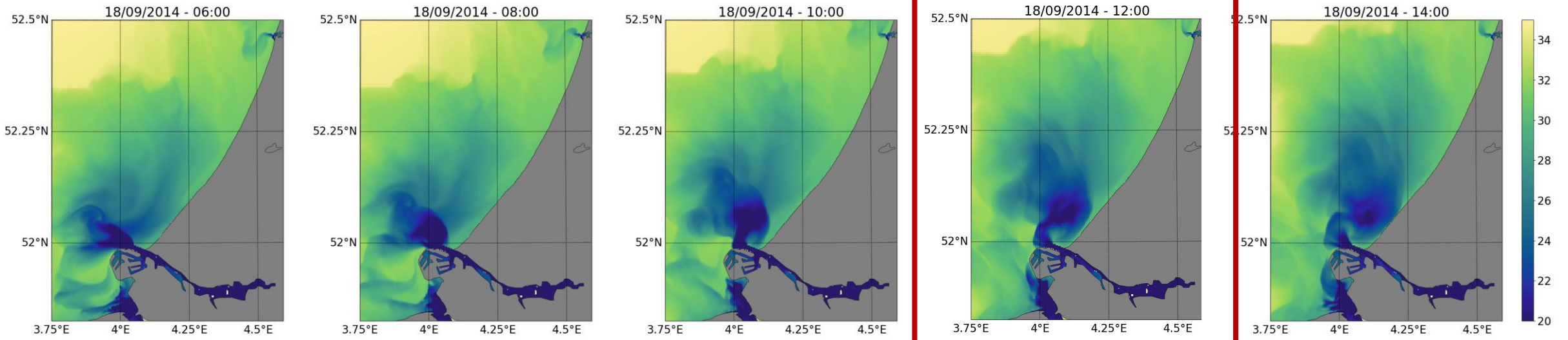
Model output



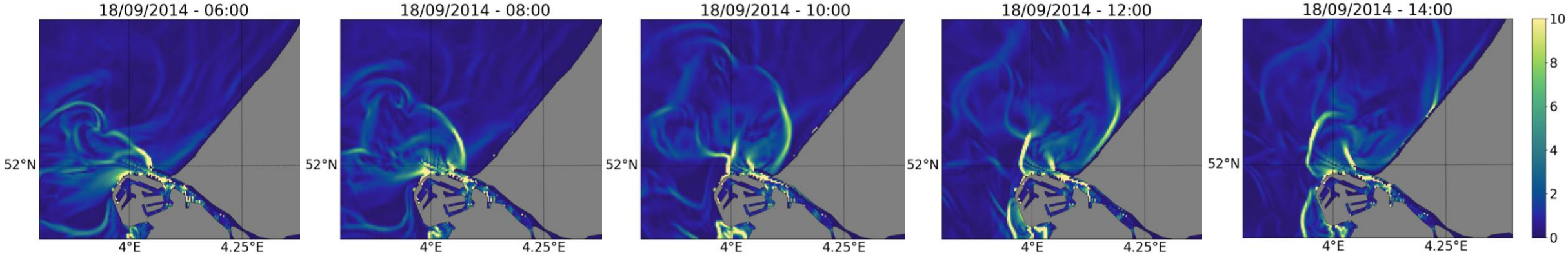
Tidal cycle

HW -4hrs | HW -2 hrs | HW | HW +2 hrs | HW +4 hrs

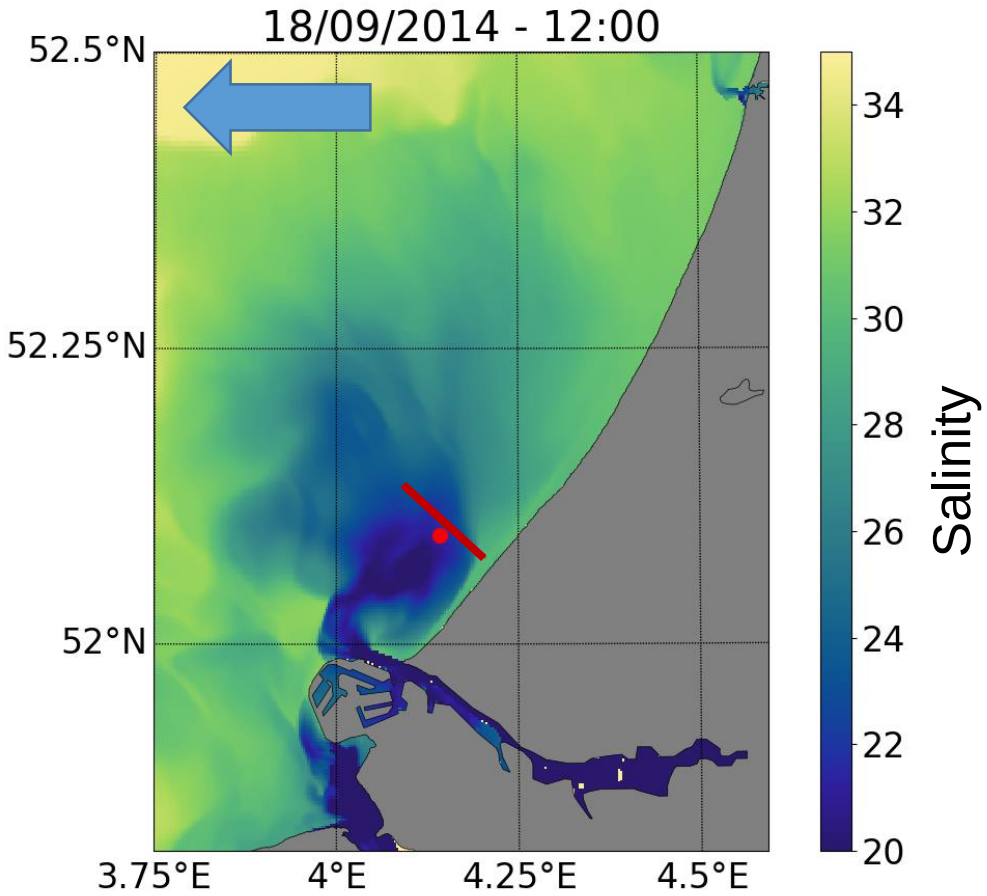
Salinity (surface)

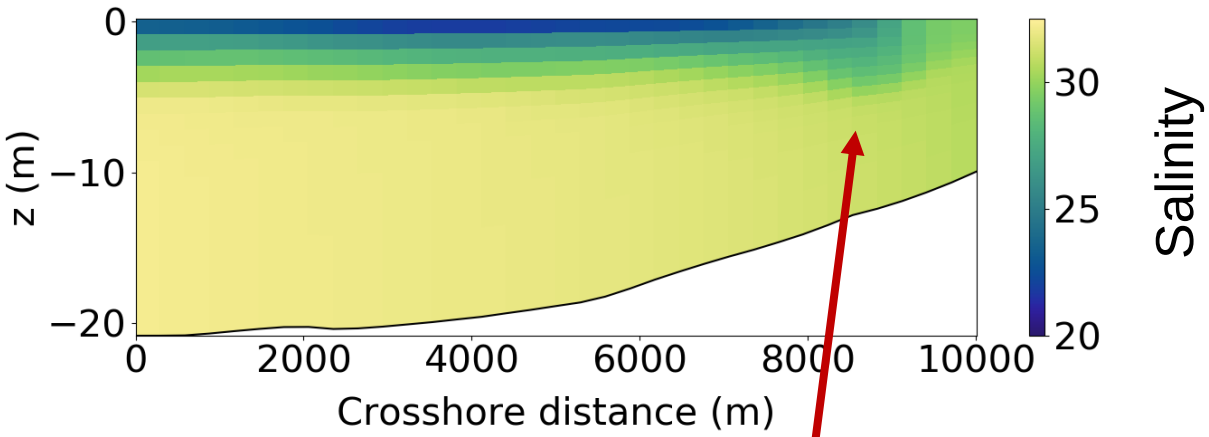


Salinity gradient [ppt/km]



HW +2hrs

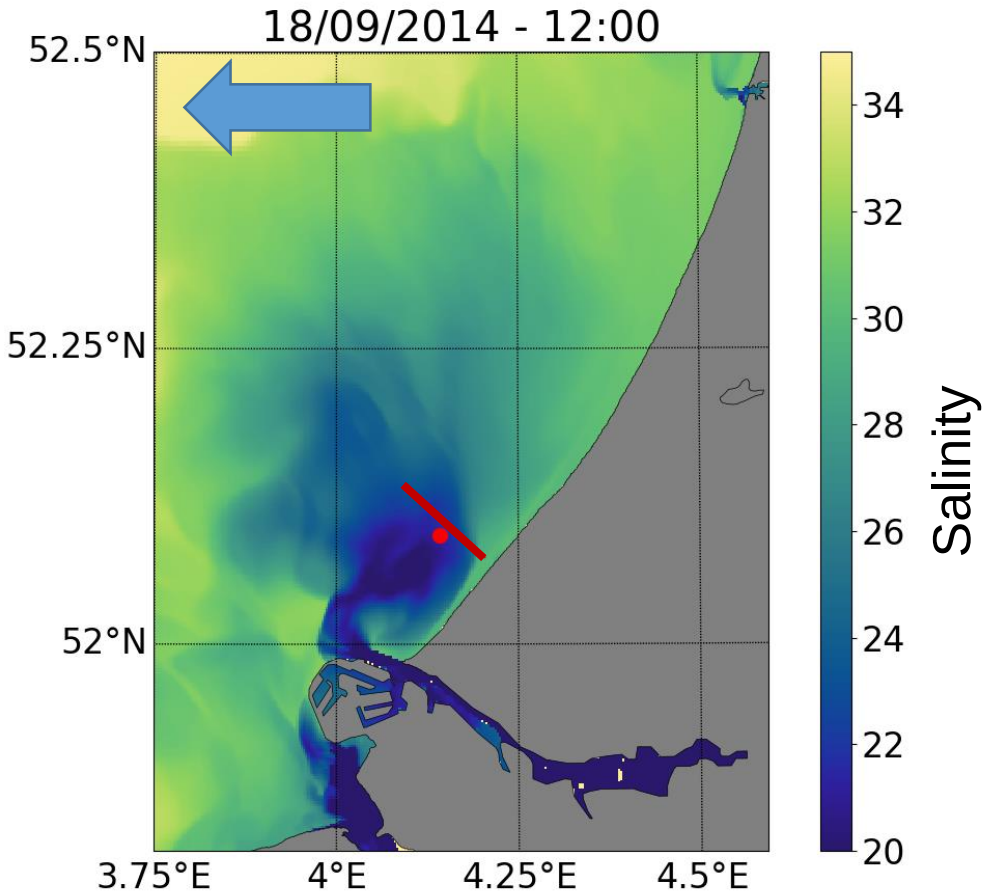


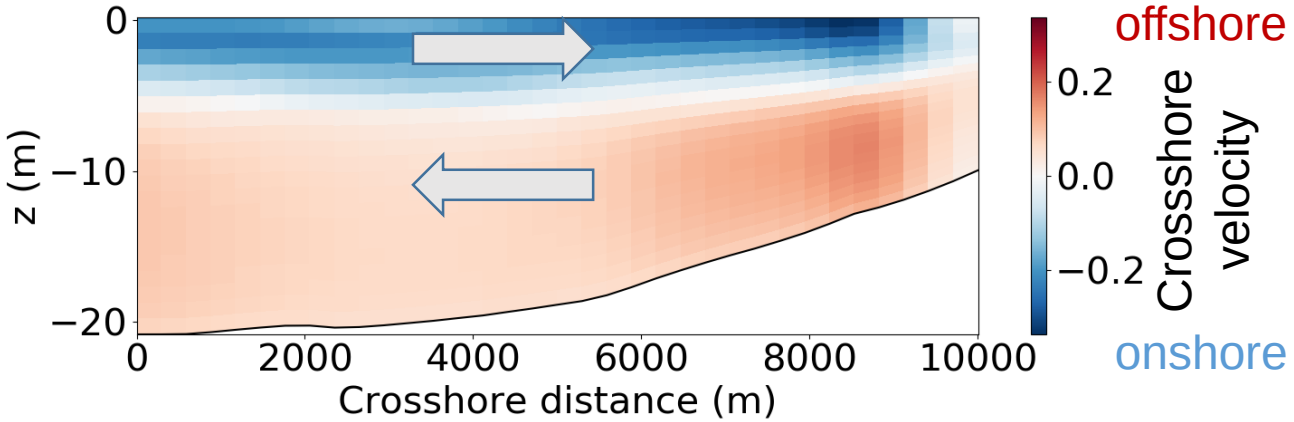


- Stratified
- ‘Plunging head’ indicates front
- Front almost reached shore

Wind direction STRAINS 18m site

HW +2hrs

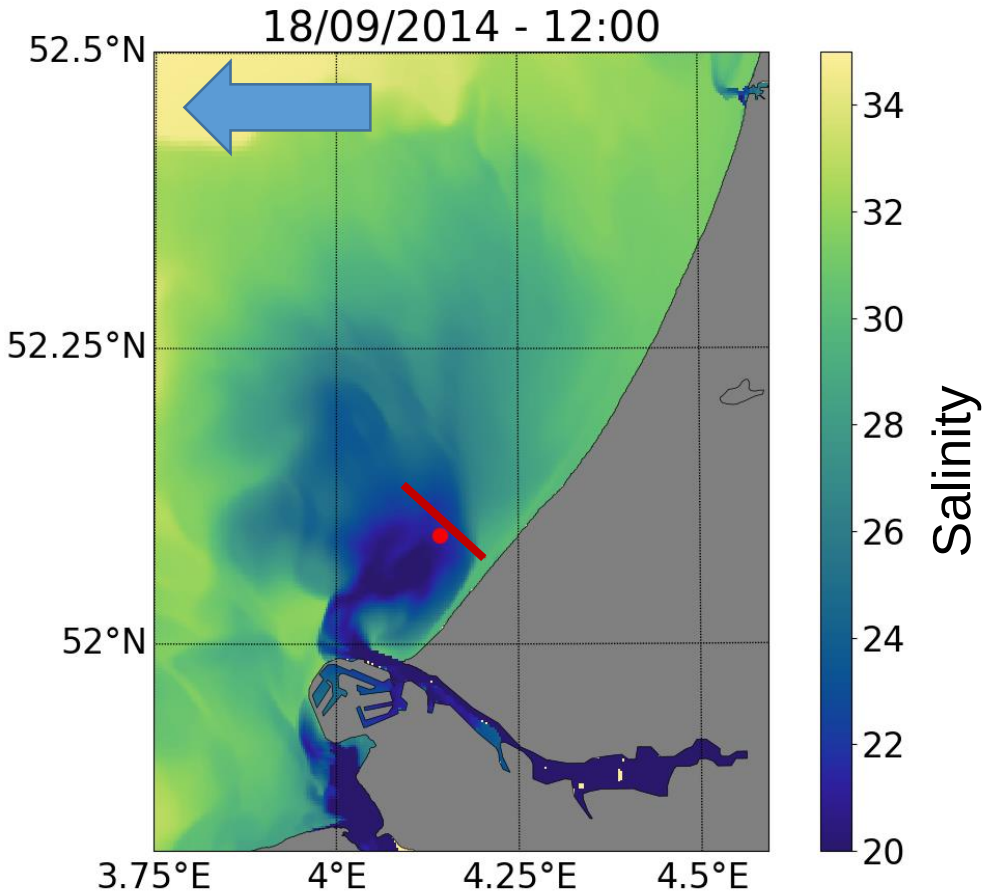


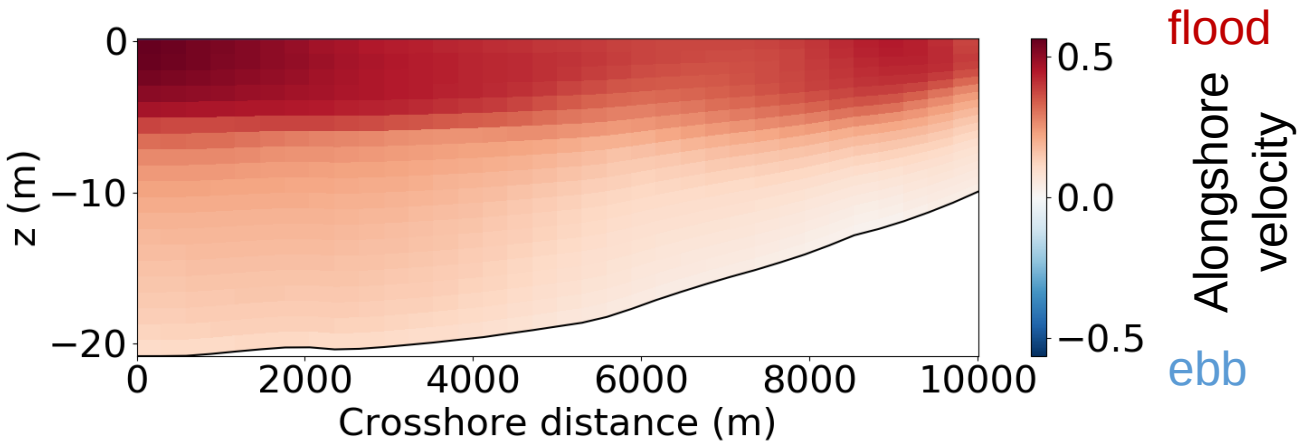


- Strong onshore velocities in upper layer
- Offshore directed return flow in bottom layer

Wind direction STRAINS 18m site

HW +2hrs

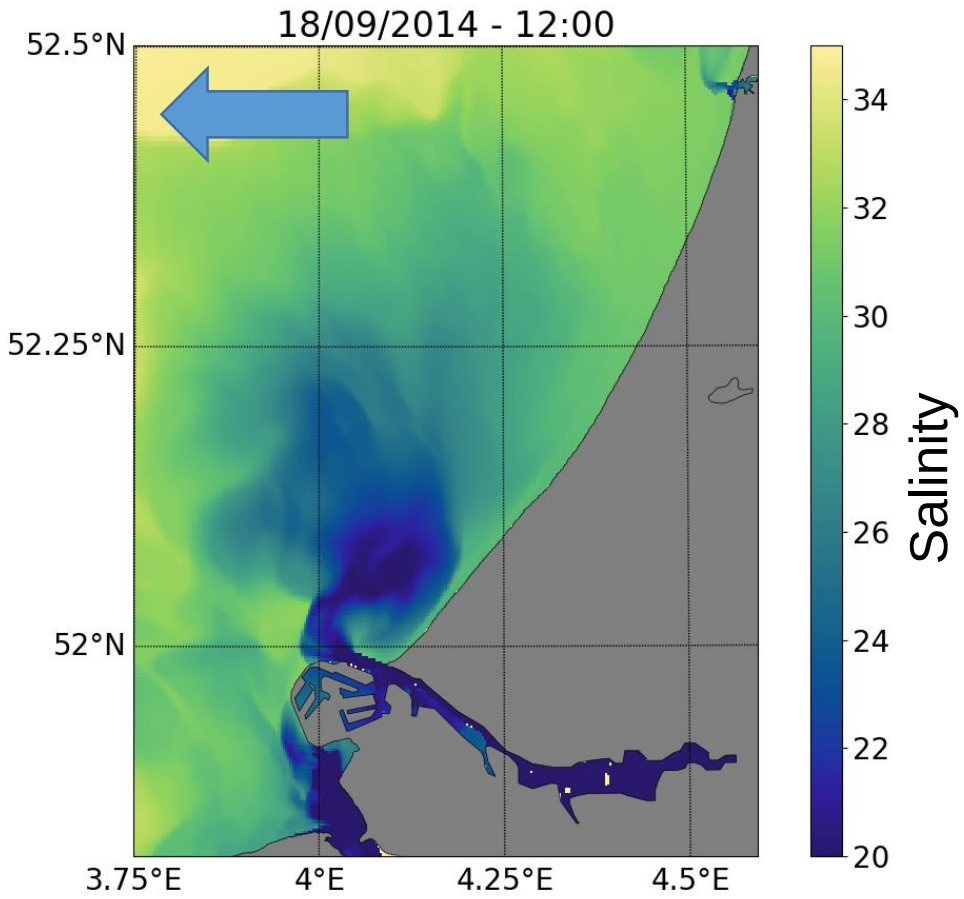




- Also vertical structure in alongshore velocities, although uniformly directed
- Important for differential advection of tidal plume fronts

Wind direction STRAINS 18m site

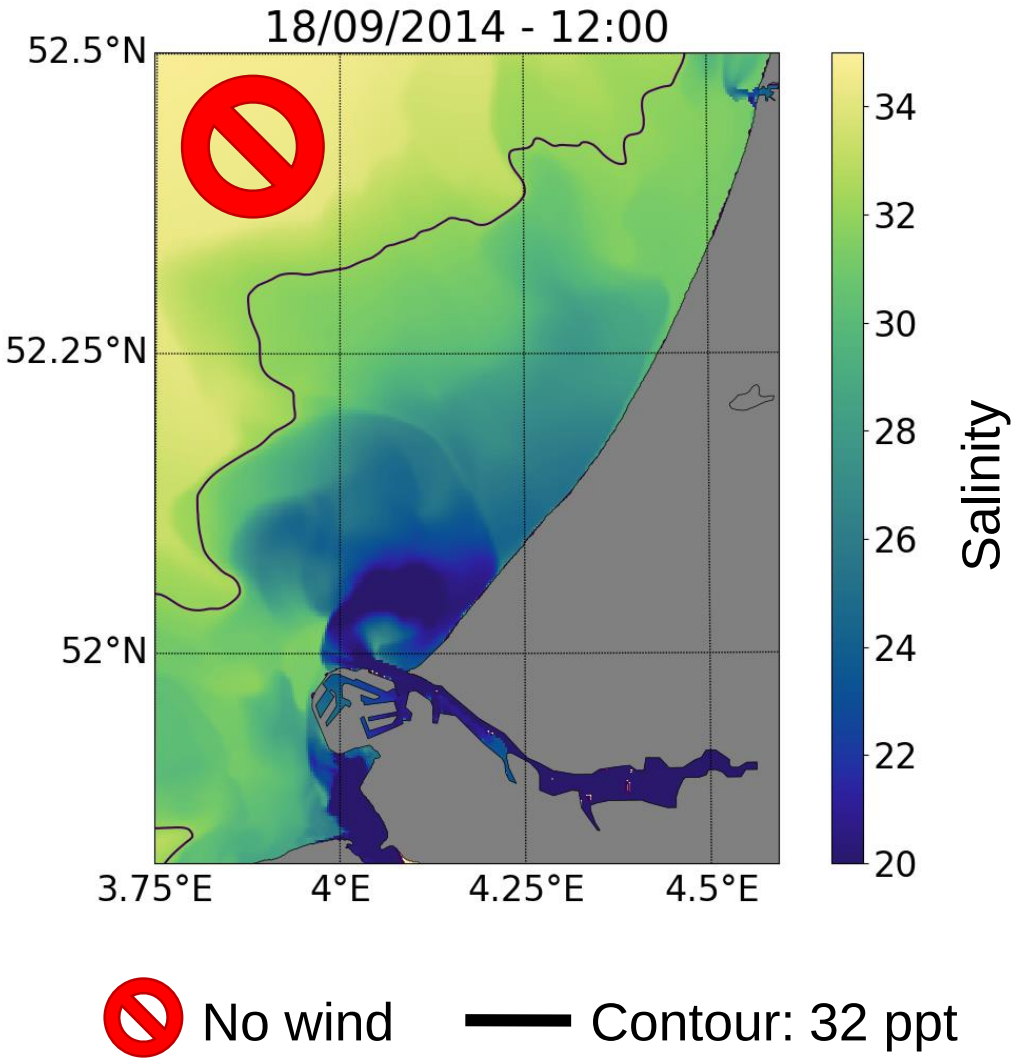
What is the role of the wind?



- Neap tide, eastern wind (5 m/s)
- What is the role of the wind?
  → Modify wind direction

Wind direction

What is the role of the wind?

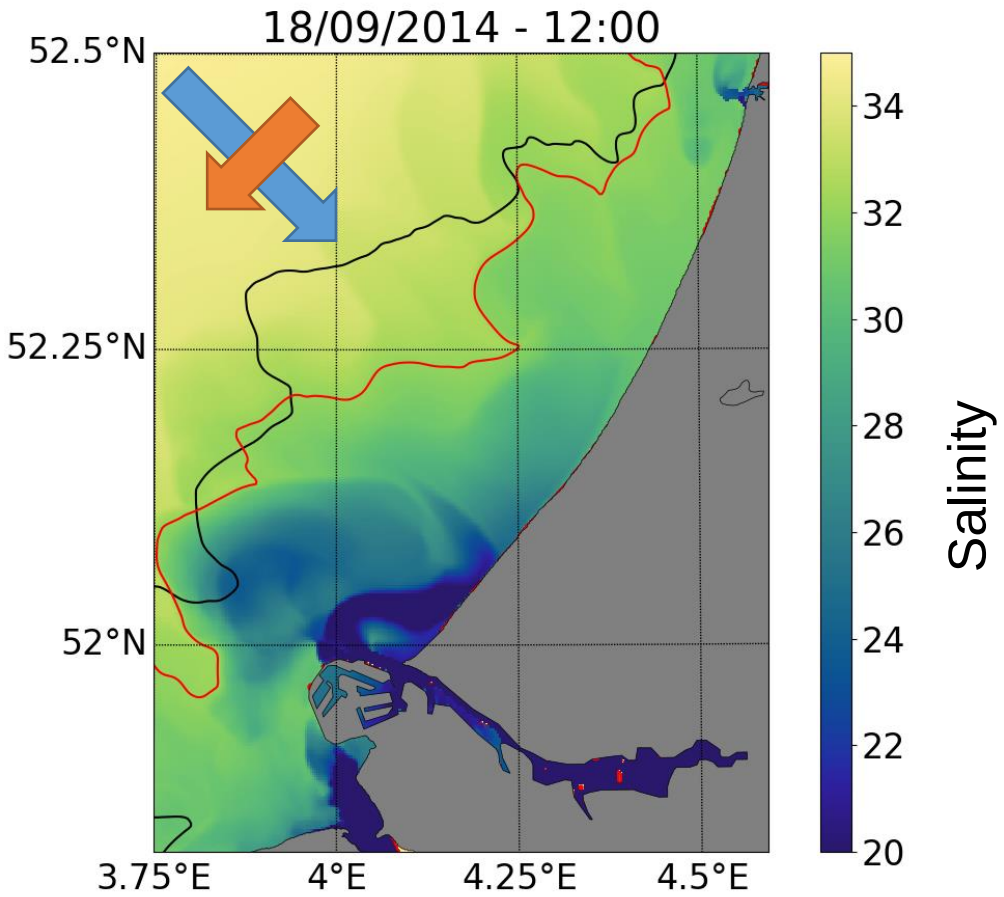


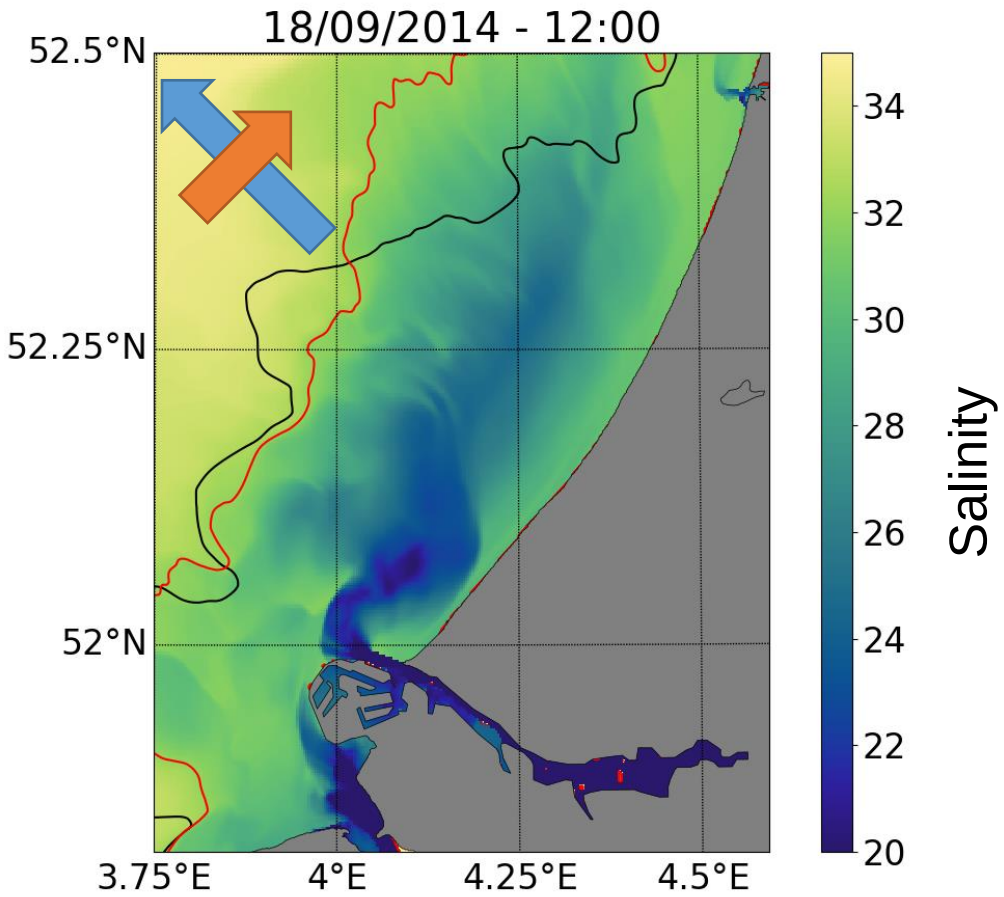
Reference case: no wind

Compare 4 different wind directions

- Onshore (NW)
- Offshore (SE)
- Upwelling (NE)
- Downwelling (SW)

Onshore vs offshore





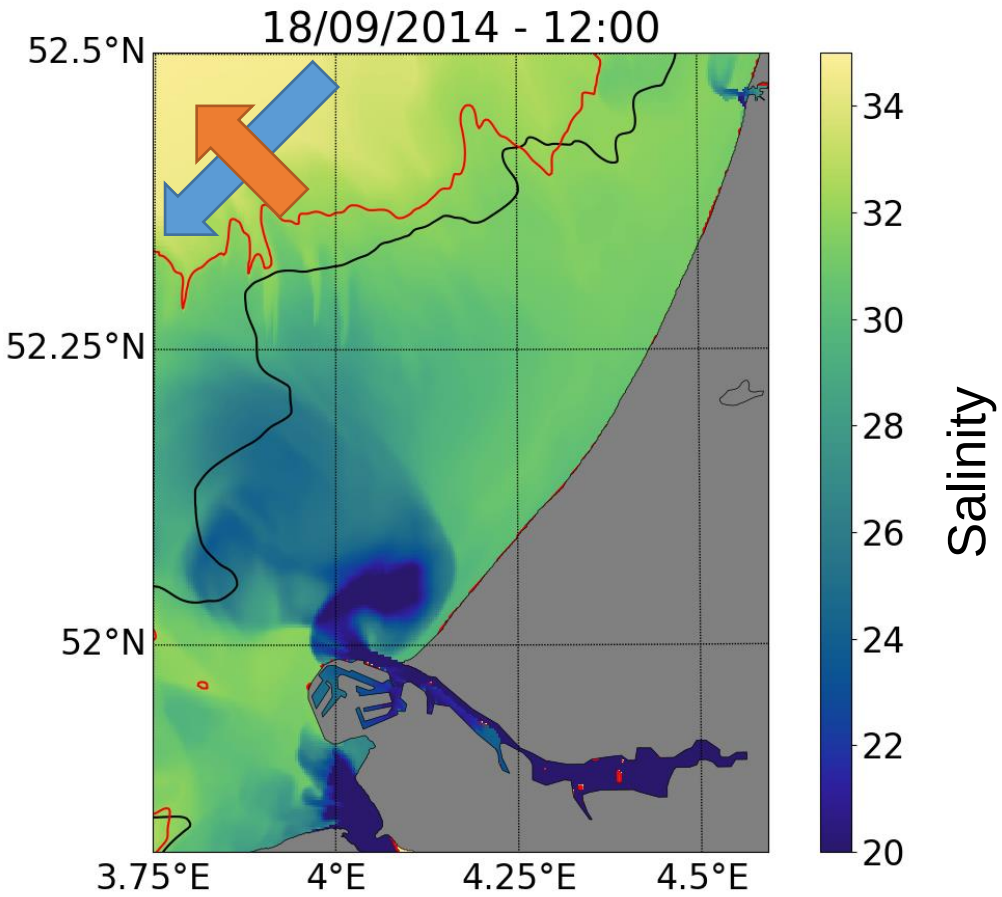
Wind direction

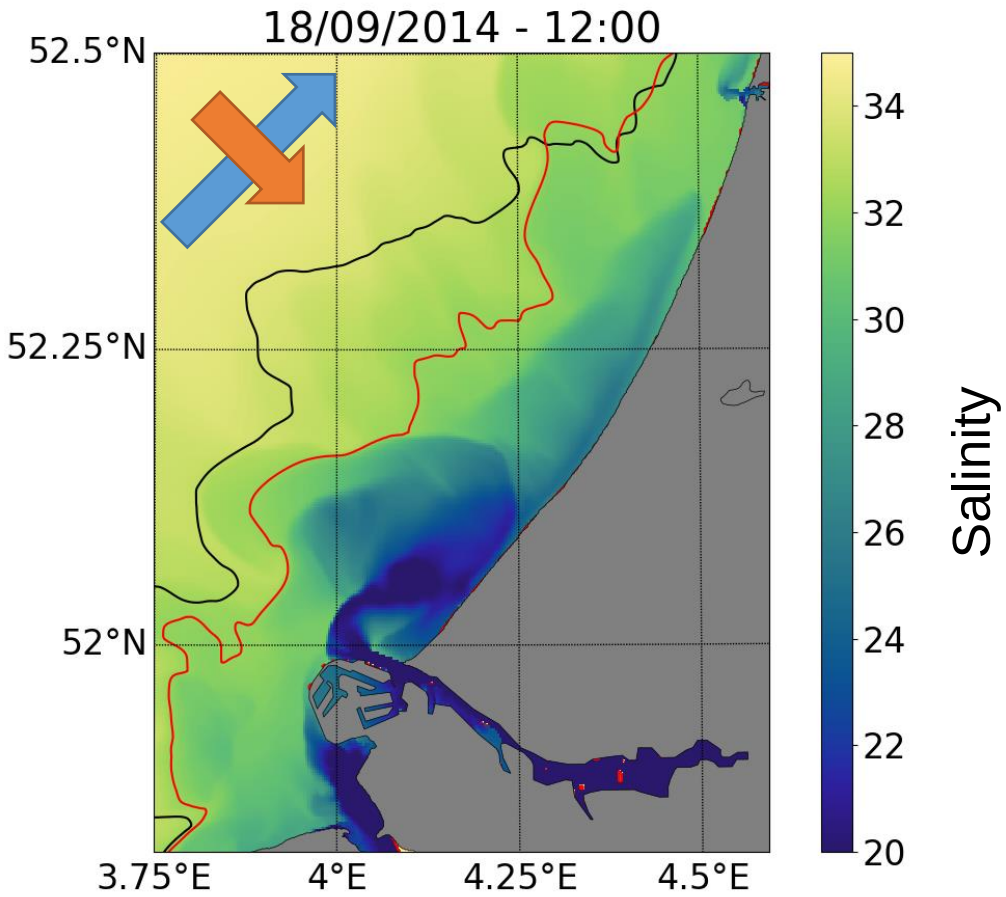
Ekman transport

Contour: 32 ppt

'No wind' plume

Upwelling vs downwelling





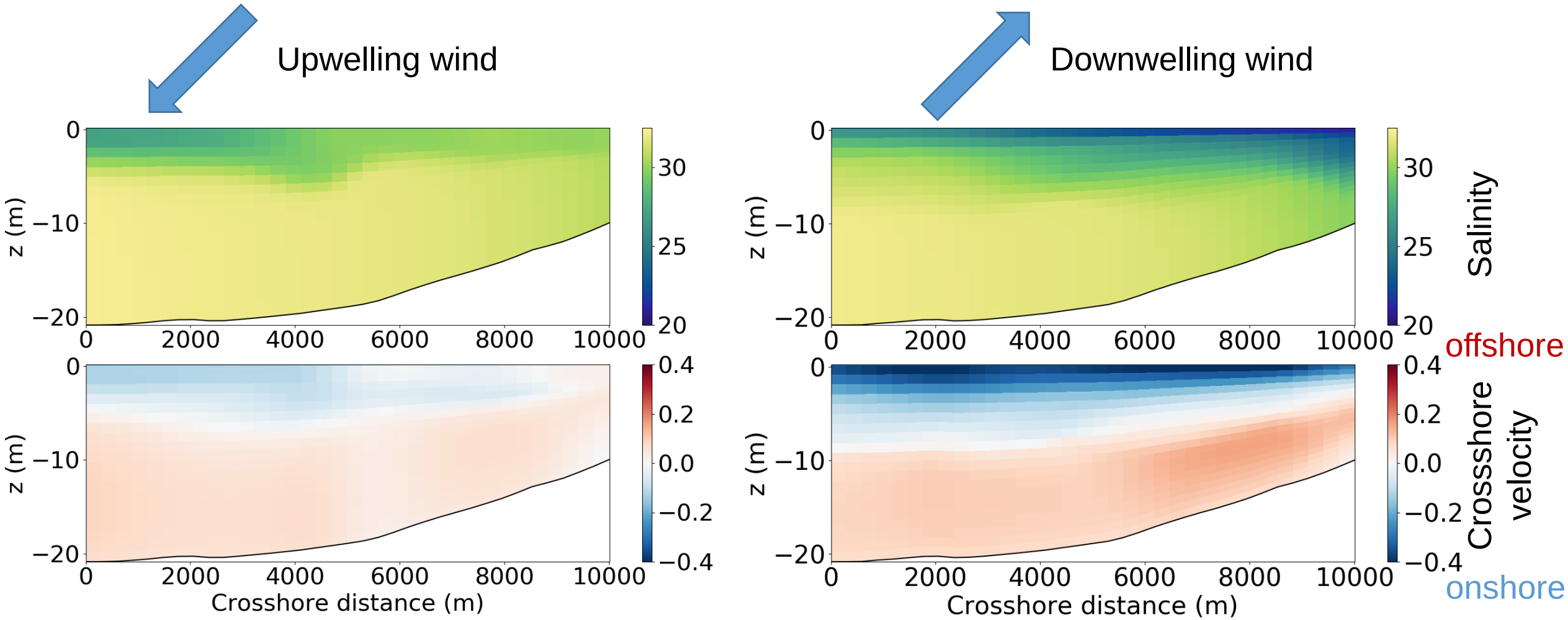
Wind direction

Ekman transport

Contour: 32 ppt

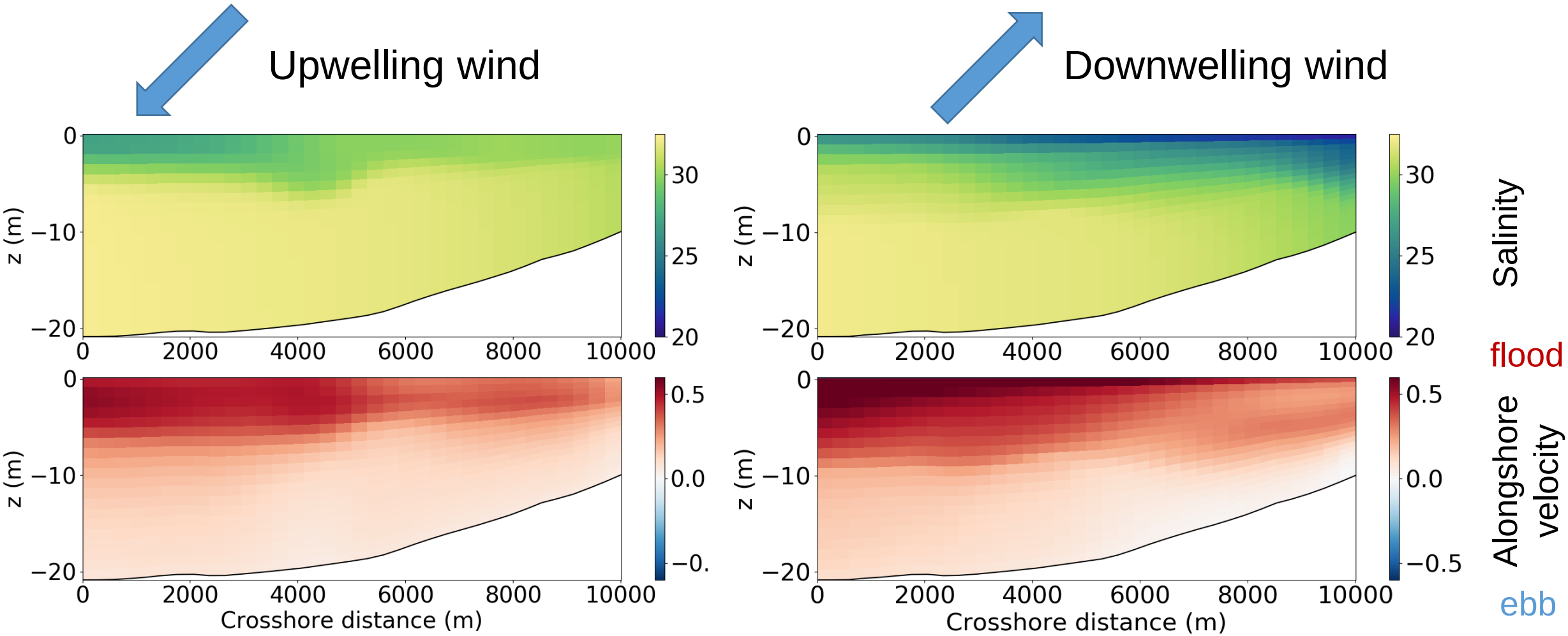
'No wind' plume

Upwelling vs downwelling: crossshore velocity



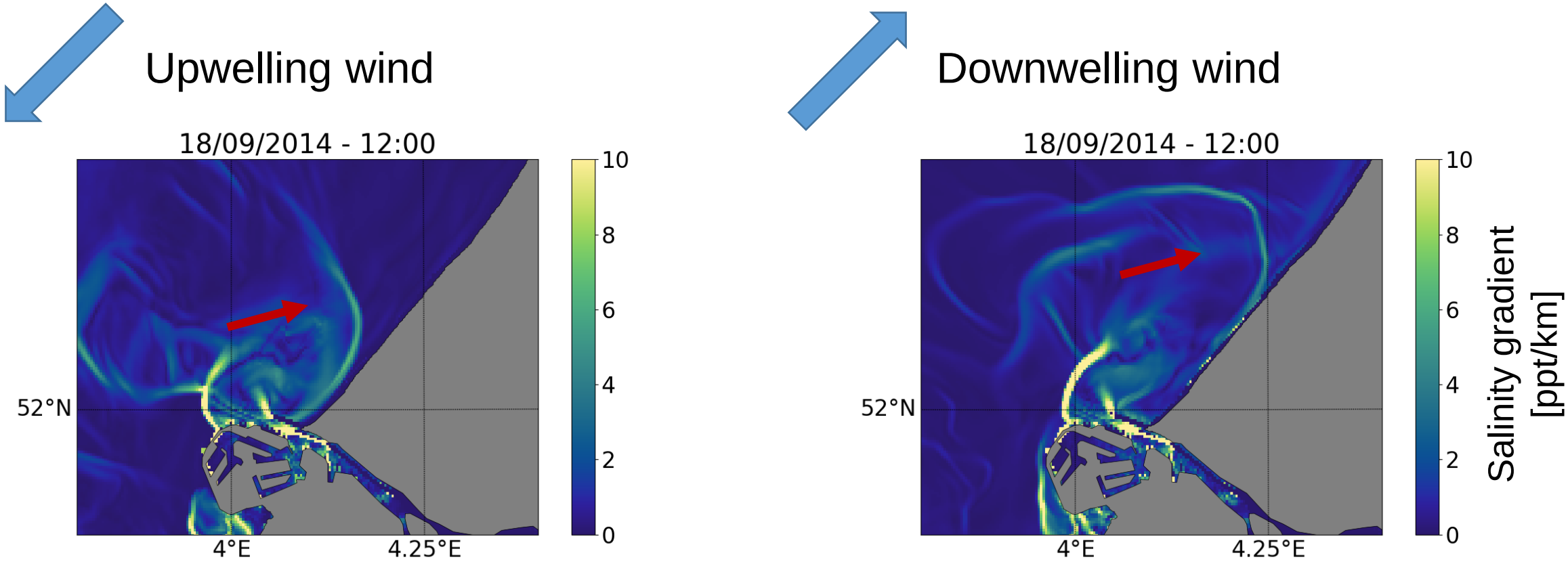
Stronger stratification and larger crossshore velocities found under downwelling winds

Upwelling vs downwelling: alongshore velocity



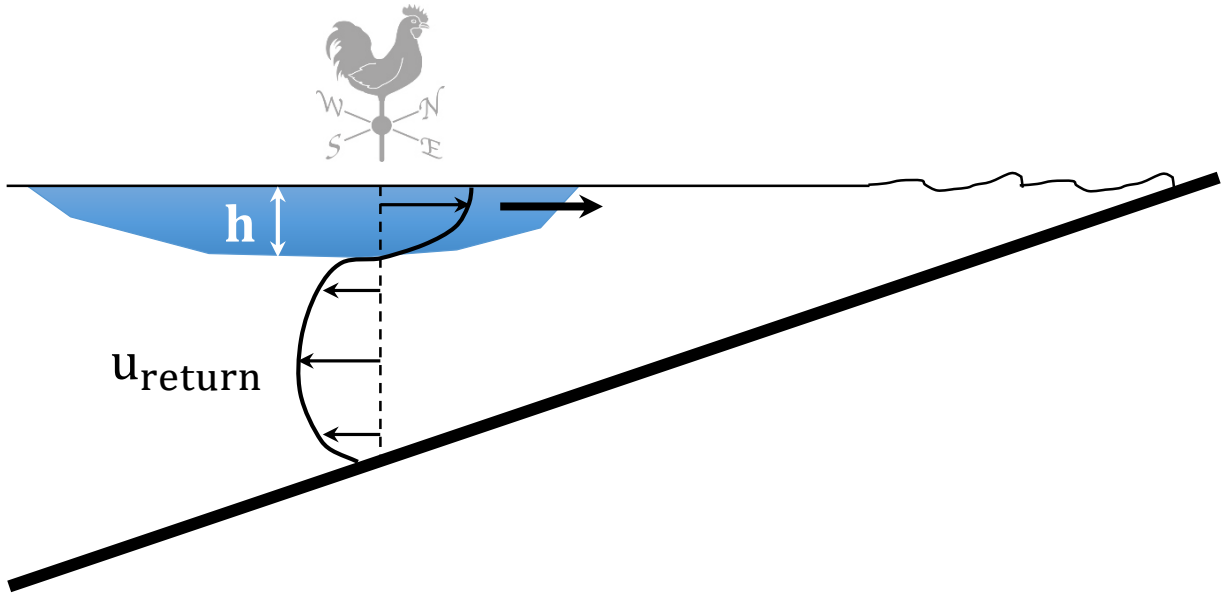
Differential advection is stronger under downwelling winds

Upwelling vs downwelling: fronts



Tidal plume front propagated/advected faster under downwelling winds

Conclusions



- Location of the tidal river plume is strongly influenced by wind direction
- Under downwelling winds we find
  - Thicker stratification
  - Larger crossshore velocities
  - Faster propagating tidal plume fronts

References

de Boer, G. J., Pietrzak, J. D., & Winterwerp, J. C. (2009). SST observations of upwelling induced by tidal straining in the Rhine ROFI. Continental Shelf Research, 29(1), 263-277.

Horner-Devine, A. R., Pietrzak, J. D., Souza, A. J., McKeon, M. A., Meirelles, S., Henriquez, M., ... & Rijnsburger, S. (2017). Cross-shore transport of nearshore sediment by river plume frontal pumping. *Geophysical Research Letters*, *44*(12), 6343-6351.

Rijnsburger, S., Flores, R. P., Pietrzak, J. D., Horner-Devine, A. R., & Souza, A. J. (2018). The influence of tide and wind on the propagation of fronts in a shallow river plume. Journal of Geophysical Research: Oceans, 123(8), 5426-5442.