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Semidiurnal currents in the Arctic Ocean's eastern Eurasian Basin

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- **Current** dynamics are **increasing** in the eastern Arctic
- **Tides** in the region are highly **variable** and much more **energetic** than expected
- Together with vigorous **wind-driven inertial currents**, **tides** may contribute to **enhanced mixing** in a changing Arctic

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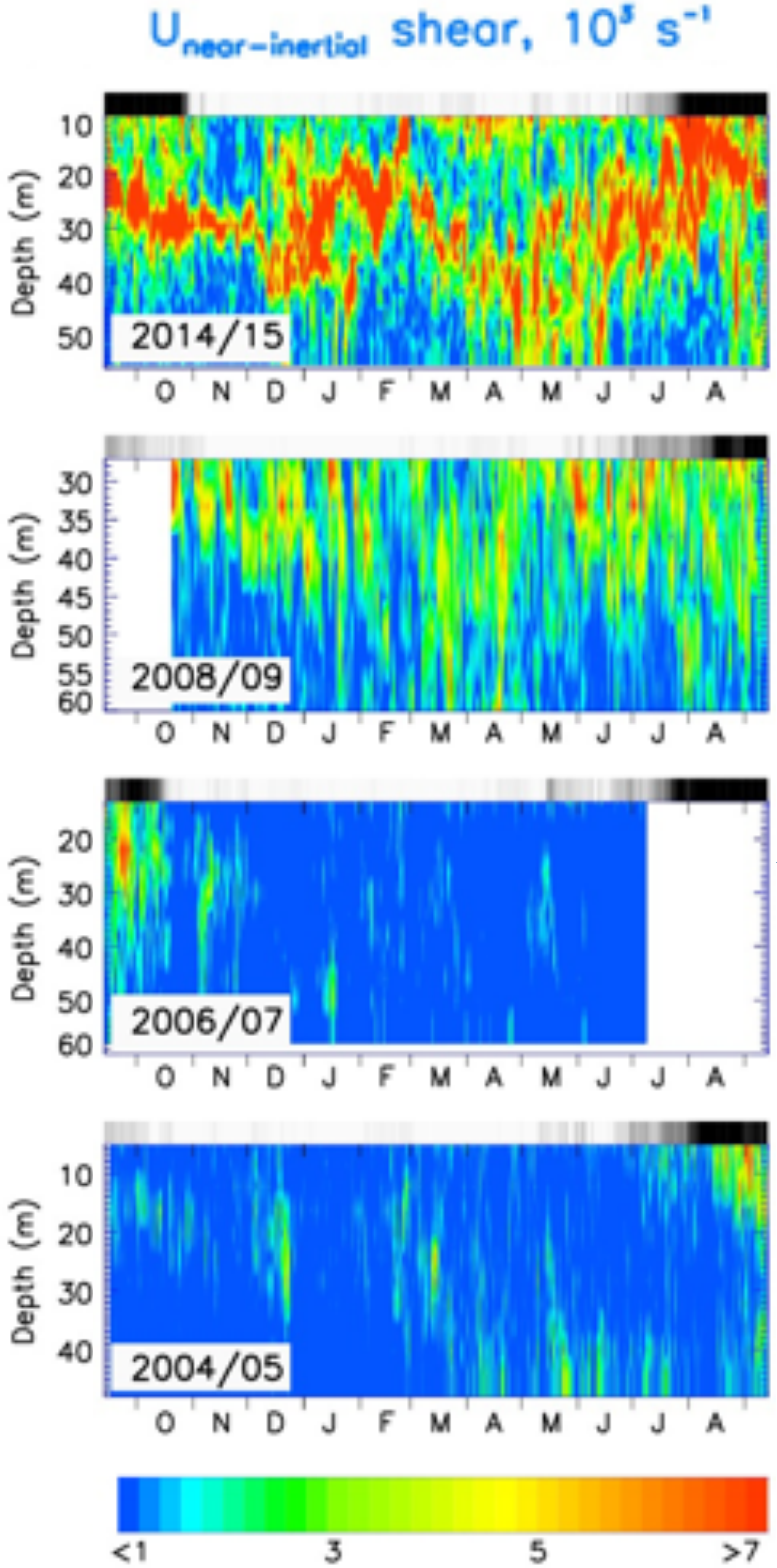
Motivation

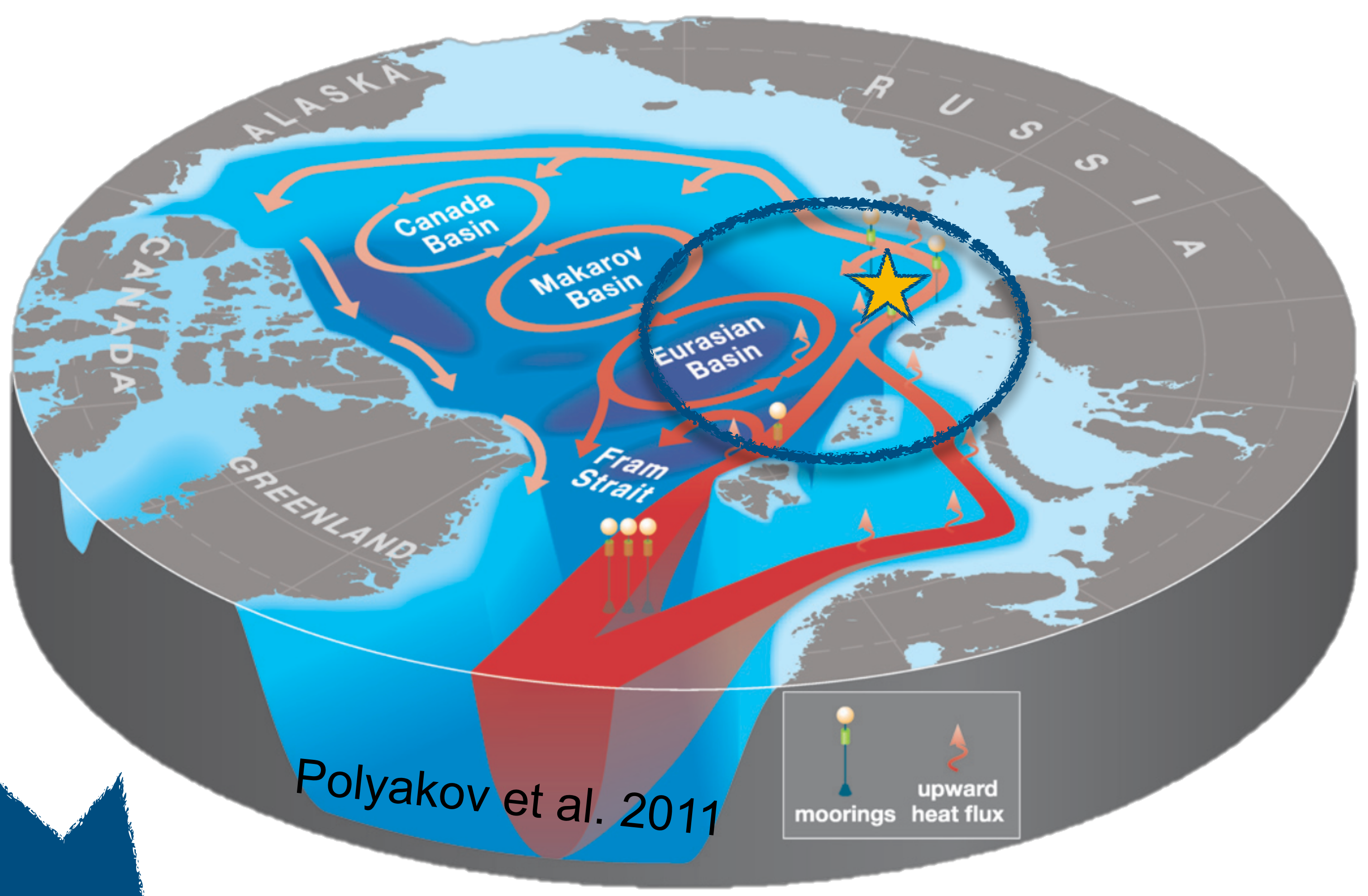


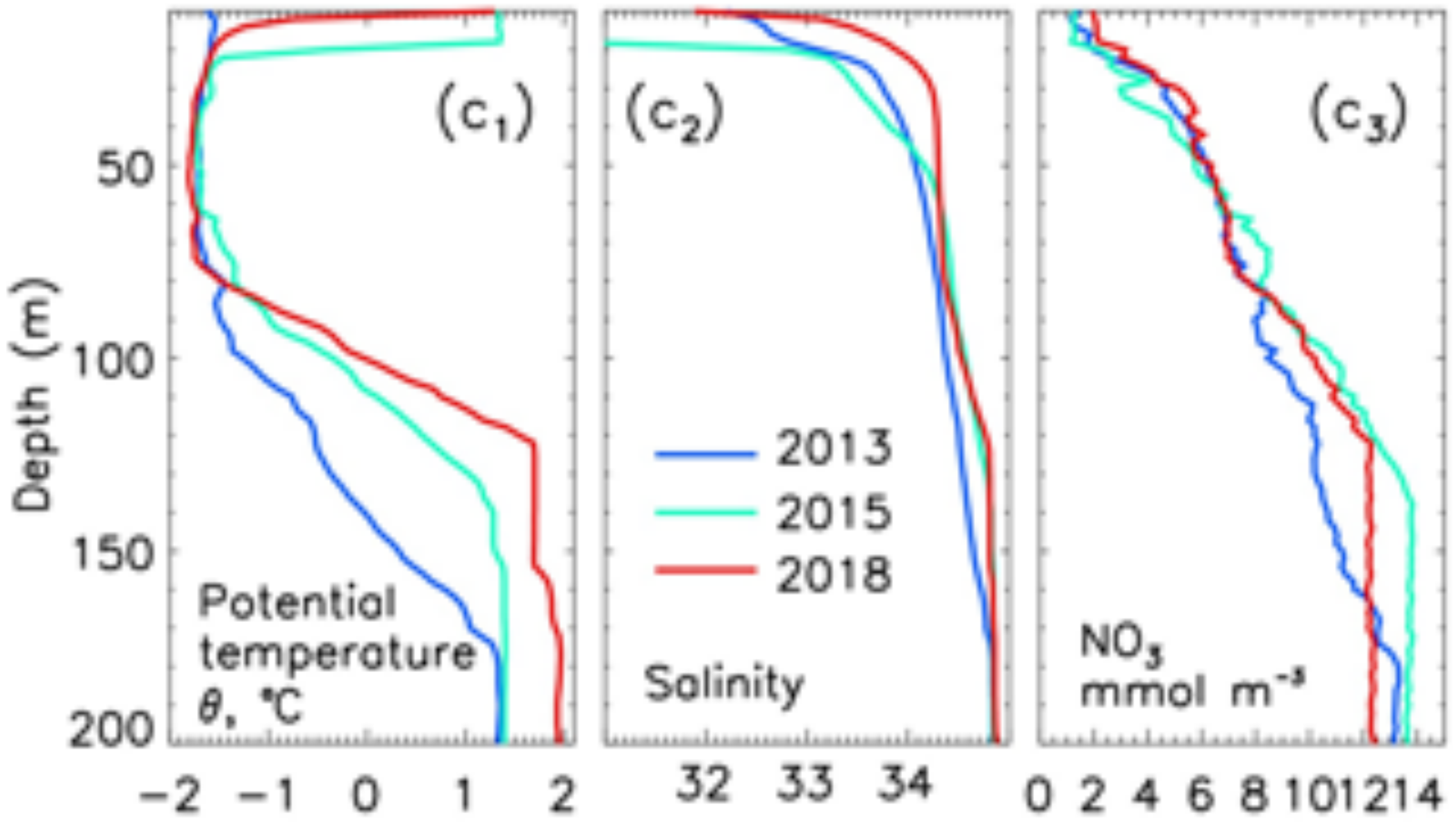
Atlantification of the eastern Arctic Ocean leads to shoaling of warm Atlantic Water (c1), reduced stratification (c2) and a shoaling of the nutricline (c3), effectively bringing nutrients closer to the surface

Long term observations show increased dynamics in the region in recent years that may indicate increased mixing and thus reshape the Arctic Ocean ecosystem

Where is this dynamic coming from?

Annual records of magnitude of the near-inertial current $|U_{near\text{-}inertial}|$ shear in the upper ocean layer at the ★-location as a function of time and depth (adapted from Polyakov et al. submitted).





Vertical profiles of θ, S, and nutrients at ★ made on August 27, 2013, September 20, 2015, and September 2, 2018 (adapted from Polyakov et al. submitted).

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Background

Two drivers of semidiurnal currents in the Arctic:

Tides

- Often the dominant source of **current variability** in the Arctic
- Tidal signals are the sum of various tidal constituents

  e.g : M_2 = Lunar semi-diurnal (12.42h)

  S_2 = Solar semi-diurnal (12h)

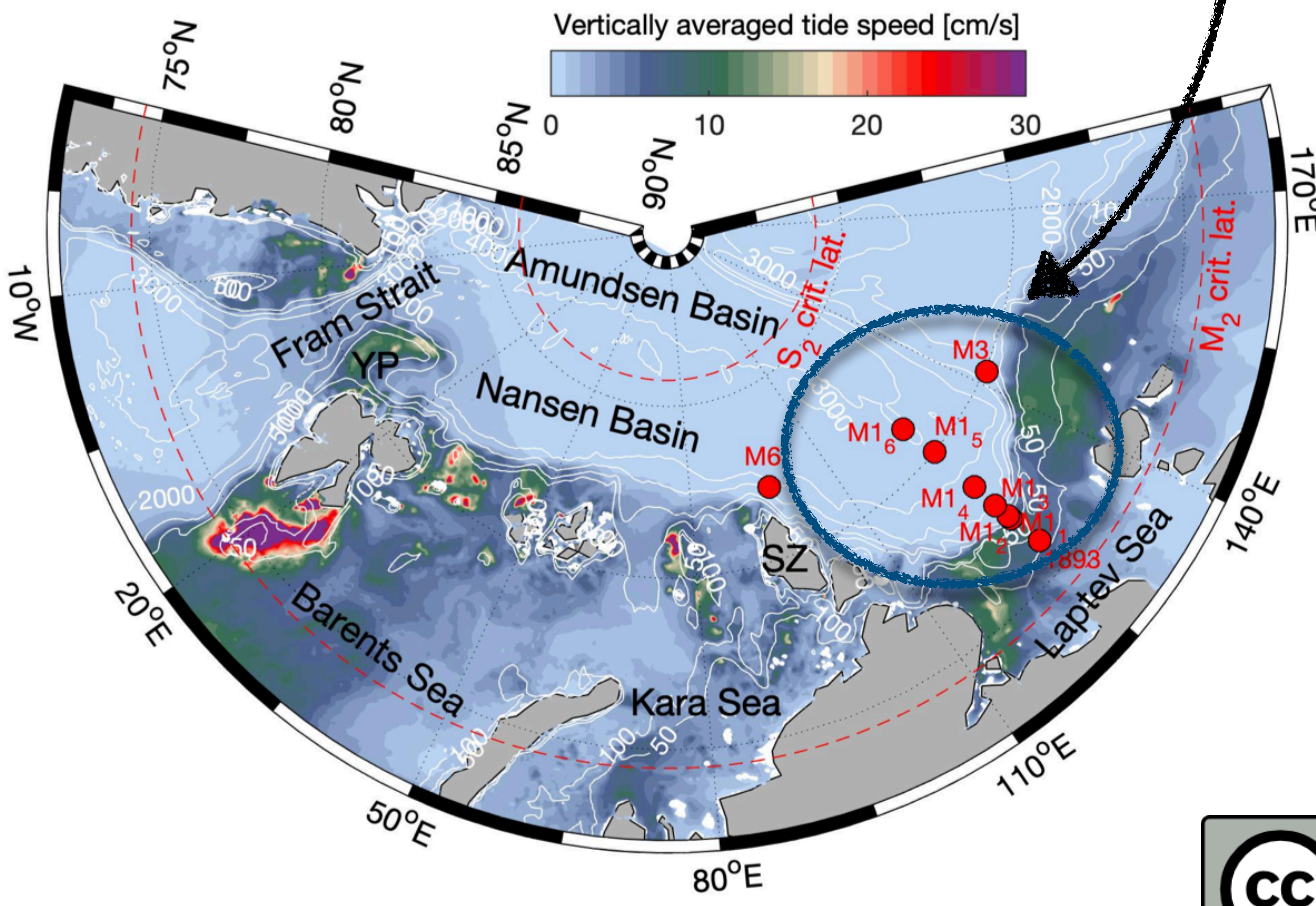
- “Mean-state” aptly simulated by *barotropic* models

  -> Very small (~0.5 cm/s) tidal currents throughout Arctic Basin

- Is that the whole story?

Inertial currents

- Inertial currents are (mostly) **wind driven**
- They oscillate at inertial periods (the natural period for oscillations on Earth, depending on latitude and Earth’s rotation)
- In the Arctic, inertial periods lay (mostly) between S_2 and M_2 periods
- ***Difficult or impossible to separate from tides***



Map showing vertically averaged barotropic tidal current speed from the inverse barotropic tidal model of Padman and Erofeeva (2004)

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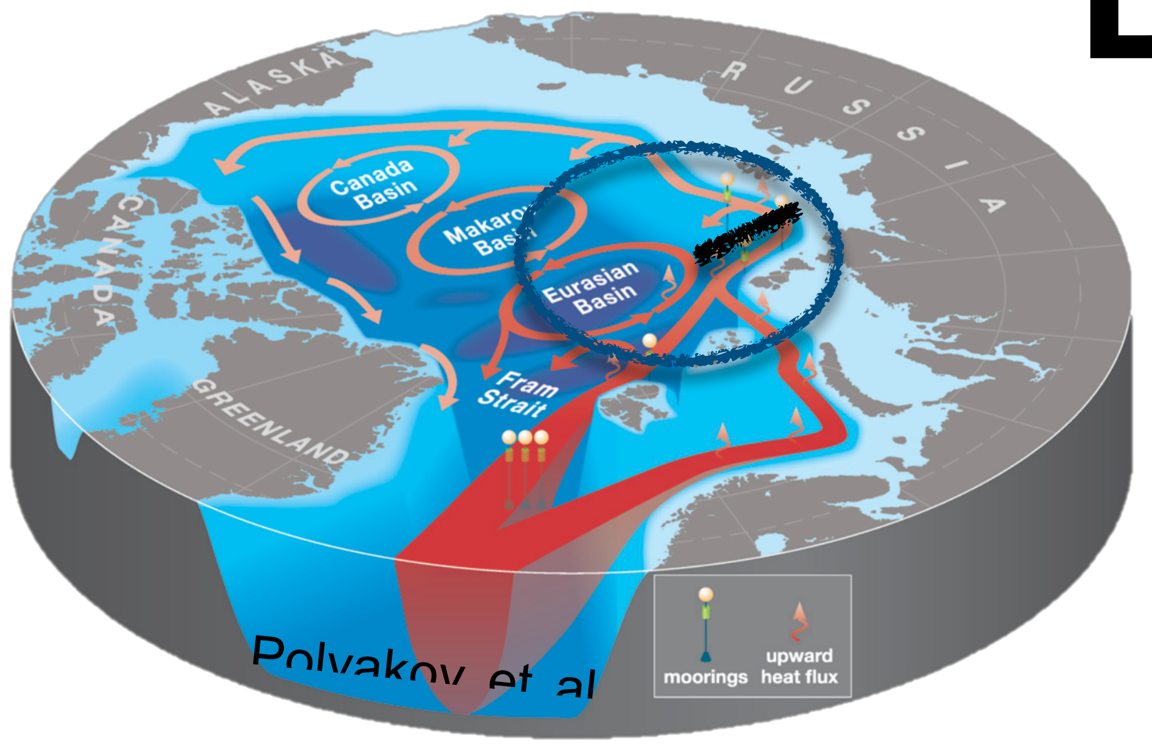
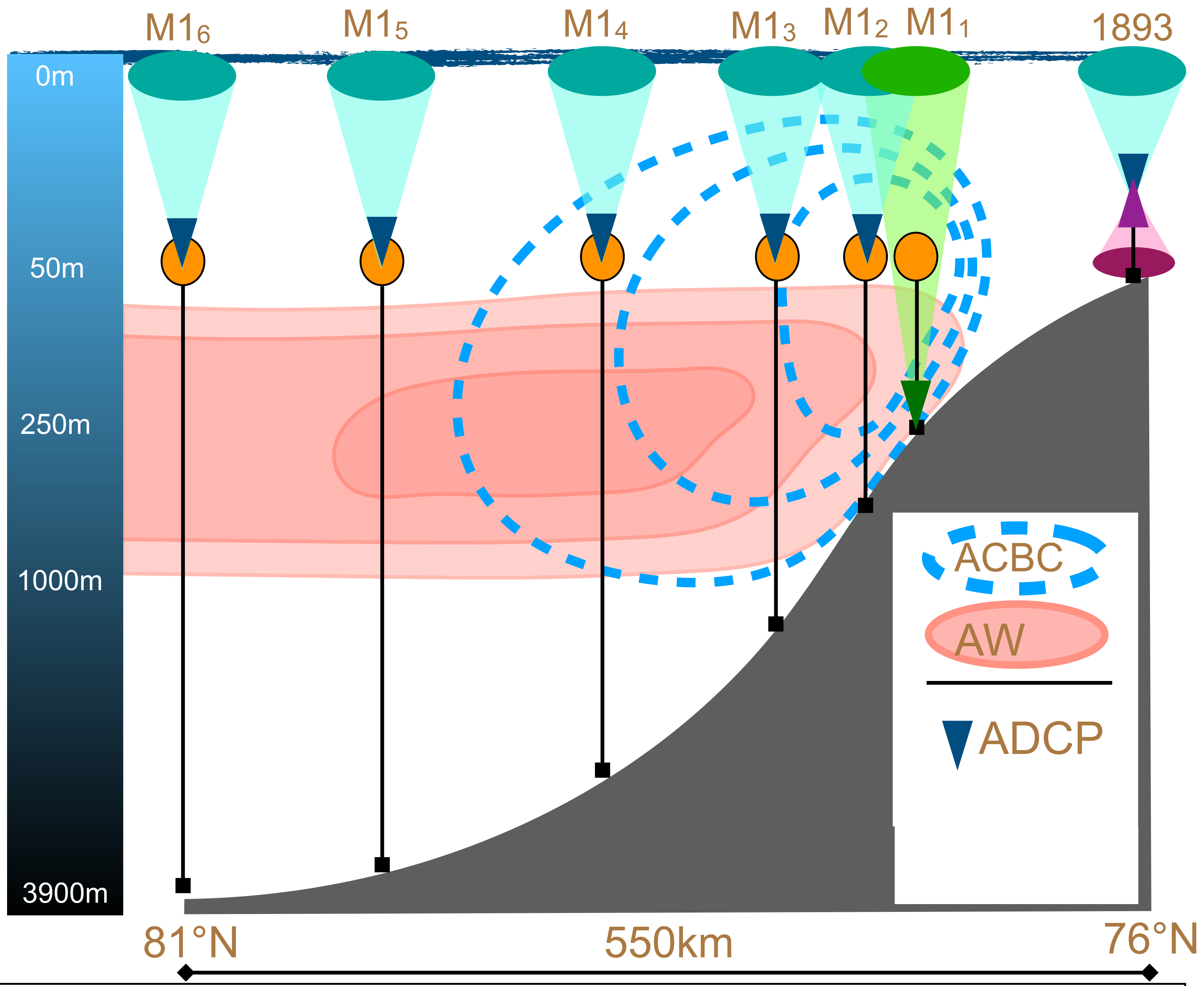
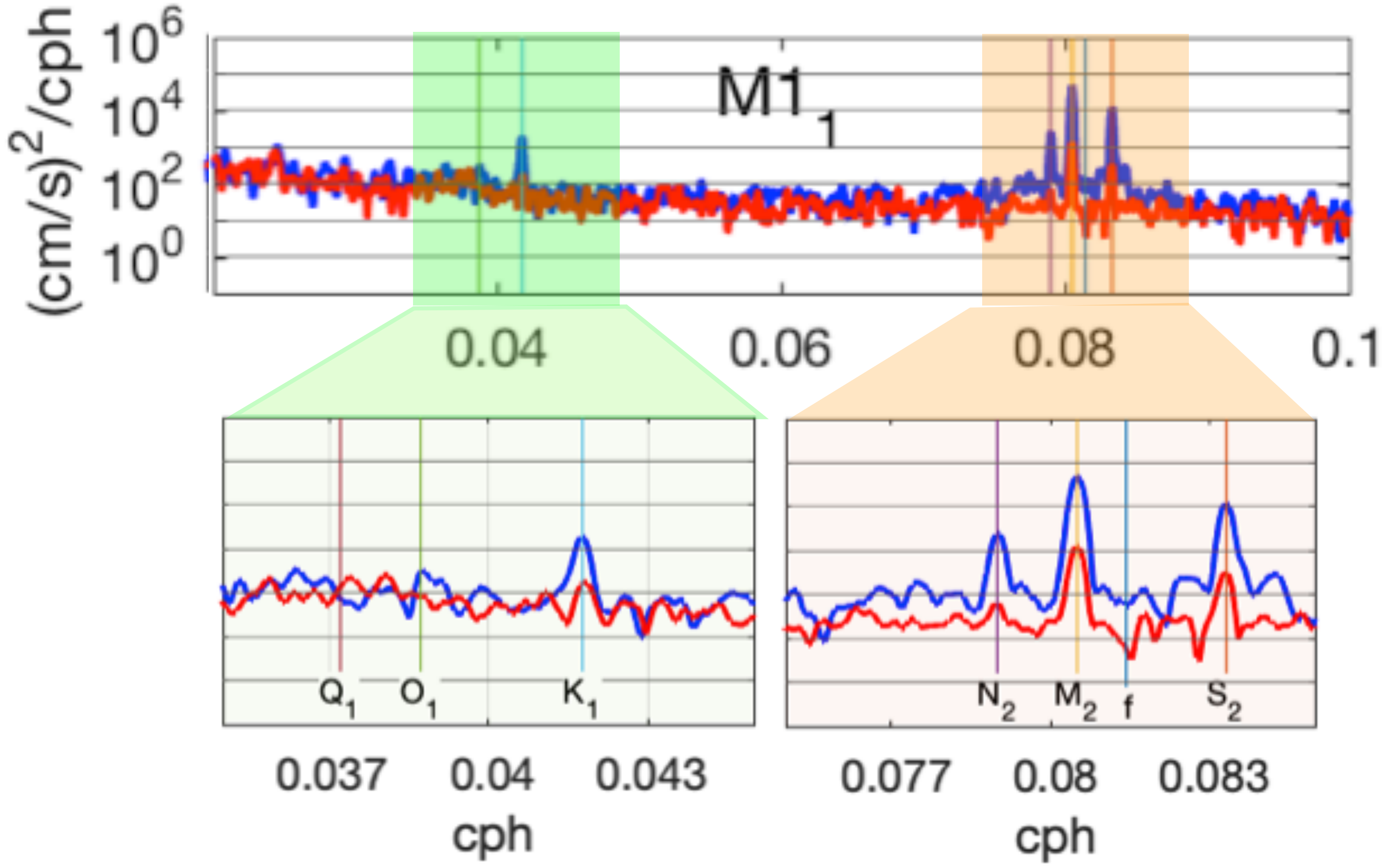
Data





Sketch (not to scale) of the moorings comprised in the section along 126°E and their approximate location relative to the Atlantic Water (AW) layer and the Arctic Circumpolar Boundary Current (ACBC). ADCP = Acoustic Current Doppler Profiler.

Methods



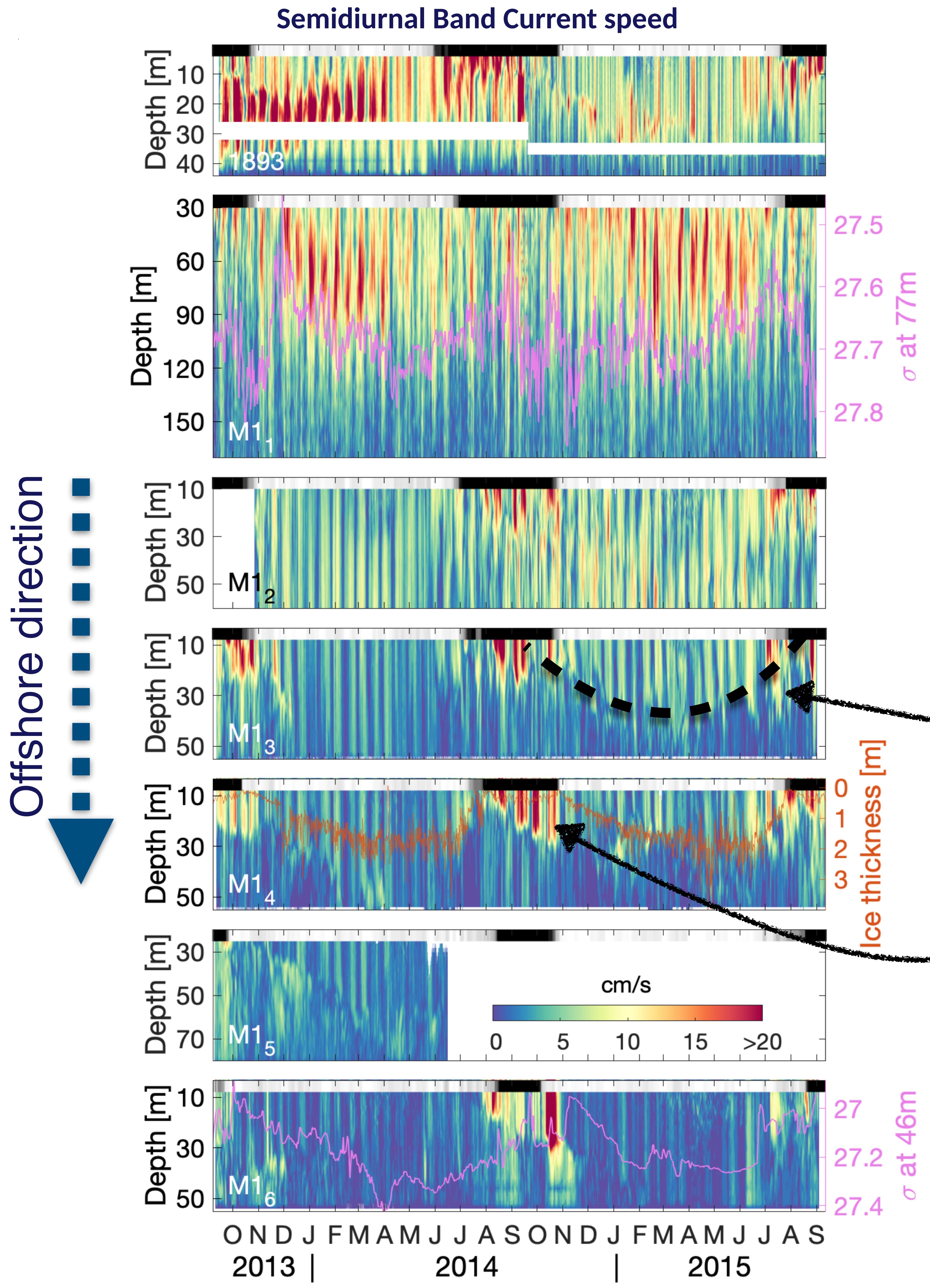
Example rotary-spectra of currents at mooring $M1_1$ (red: CCW, blue CW): Most energy is confined in the semidiurnal band around tidal frequencies.

Tidal analysis

- Harmonic tidal analysis provides tidal ellipse parameters in 30-day sliding windows to resolve M_2 and S_2
- Effectively **30-day smoothed**
- ***Caveat****: Wind-driven inertial currents can lead to* ***spurious tidal signals***

Band-pass filtering

Currents are band-pass filtered over the semidiurnal domain (10-14h); this **includes** semidiurnal **tides** as well as wind-driven **inertial currents**



Results

At first glance:

- Highly **energetic** (> 20 cm/s) and highly **variable**
- Fortnightly stripes indicate **tides** (as opposed to inertial currents)

To be discussed in more detail: Seasonal variability

1. ***Wintertime deepening***
   -> Visible almost at everywhere; where does it come from?
2. ***Summertime amplification***
   -> Currents > 30 cm/s in ice-free summers
   -> Signature of **wind-driven inertial currents**
   -> What role do tides play in this?

10-14 h band pass filtered raw speed, representing near-inertial currents.Gray shading at the top of the plots indicates sea-ice concentration (white=100% , black=0%).

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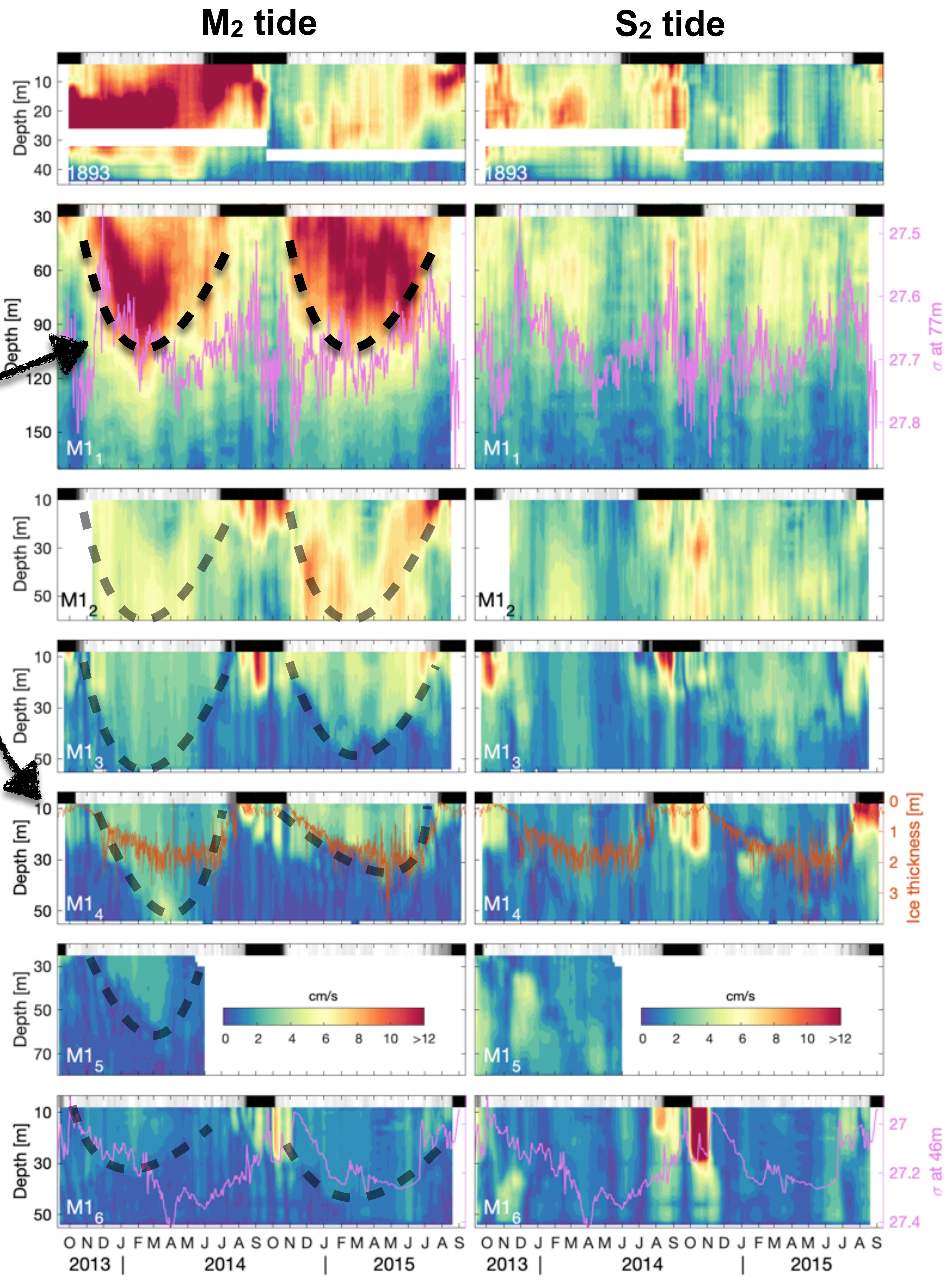
Results

1. Wintertime deepening

- Mostly due to **baroclinic M_2 tide**
- Deepening **follows pycnocline** and is **correlated with sea ice** cycle
- Decreases in offshore direction (due to critical latitude effect)
- Tides are **much stronger** than expected (and predicted by barotropic model)



As on previous slide, but now showing time-depth plots of major axis amplitudes of the M_2 (left) and S_2 (right) constituents at the moorings across the continental slope. Pink lines show detrended potential density (σ) at the shallowest available level (for moorings at which this level is above the deepest ADCP observations) and the red line in the $M1_4$ panel shows sea-ice thickness from upward looking sonar observations (one-day low-pass filtered).

2. Summertime amplification

- Most likely **wind-driven** (surface intensified and during ice-free season)
- **S_2 signal** probably mostly **spurious**!
- Is there any tidal contribution?

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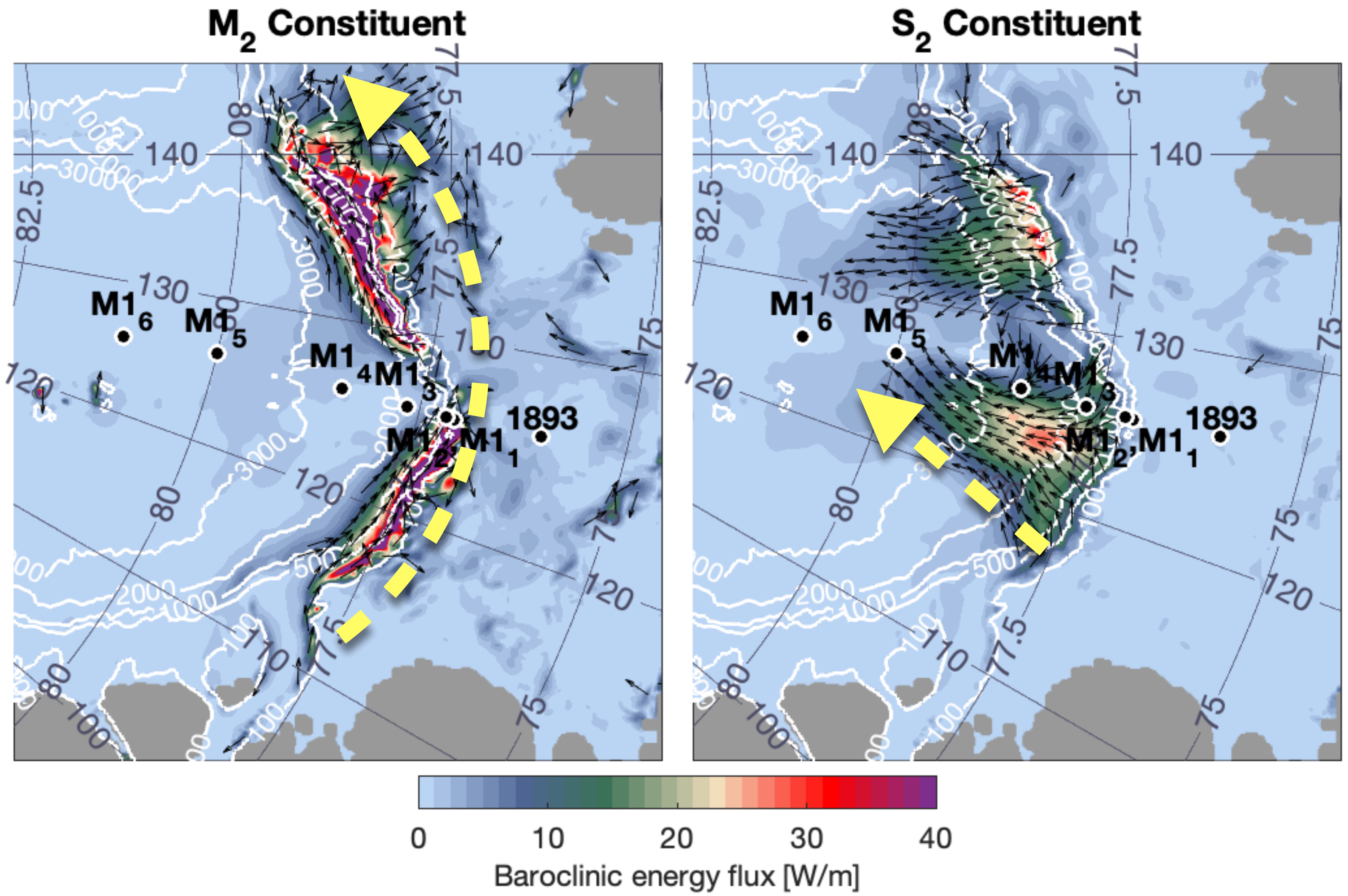
Results

Regional ocean model set-up with realistic hydrography and forced by 3D tides



Regional maps of the eastern EB showing vertically integrated horizontal baroclinic energy flux for simulated tidal currents of M_2 (left) and S_2 (right) constituents for summer stratification without sea ice. Colors indicate the amplitude, arrows show the direction of flux higher than 10 W/m. Dots indicate the locations of the moorings across the continental slope.

- **Baroclinic** (internal) **tidal waves** are generated at the continental slope
- Baroclinic tides are strongest in summer (not shown)
- **M_2** energy flux **along the slope**, due to critical latitude effects
- **S_2** energy flux propagates **into the deep basin**
  -> Qualitative pathway for S_2 energy to reach far offshore and **contribute to amplification**

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Conclusion

Summary

- Semidiurnal currents in the eastern EB are **vigorous and highly baroclinic**
- **Tides** dominate **during winters** and undergo vertical seasonal cycle correlated with sea ice
- **Wind-driven inertial currents** dominate during **ice-free summers**

Concluding remarks

- **Current** dynamics in the eastern Arctic have been **increasing** in recent years
- Inertial currents and tides directly **interact with changing sea ice cover**
- **Models** need to adequately **resolve baroclinic tides** in order to capture this dynamic
- There is potential for **ecosystem changes** in the central basin through enhanced wind-driven and tidal mixing