Arctic tides: Role in the coupled ocean/sea-ice system

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Earth & Space Research

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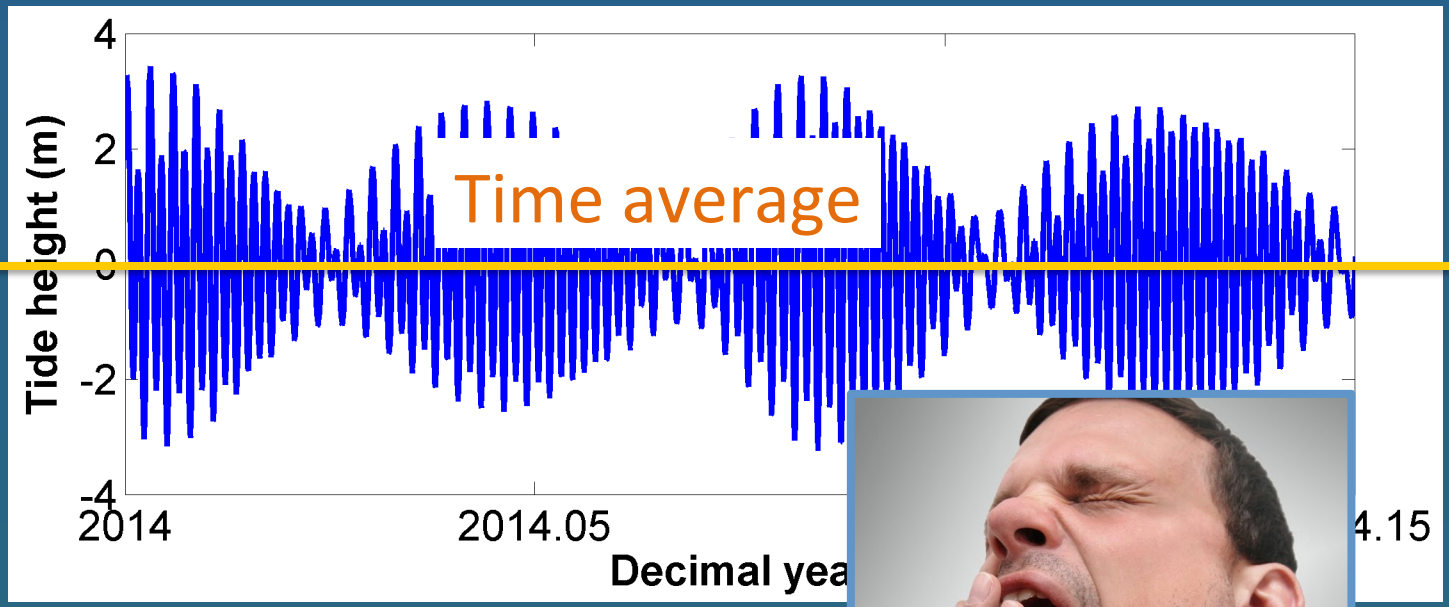
Sponsored by NSF & NASA

Goal of talk

Tides go up and down, back and forth, …



Mean is zero. So … ?

Nonlinear and irreversible processes rectify tides

Sea ice

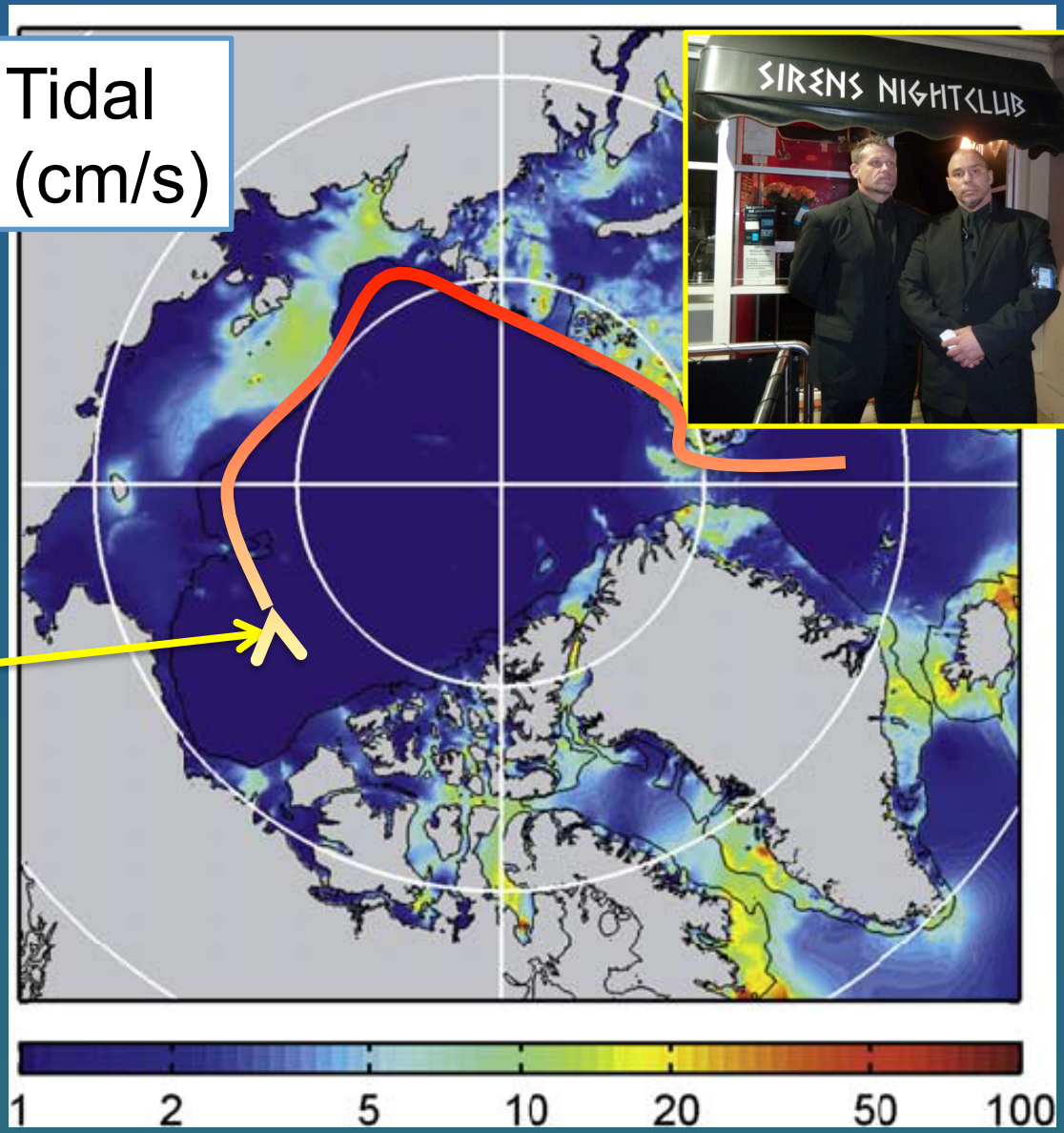
- Change ocean/atmosphere thermodynamics
- Shear and strain (roughness)
- Flexure and stresses on land-fast ice

Ocean mixing

- Friction at seabed and sea-ice base
- Turbulence in pycnocline from internal tides and HF waves

Arctic tides: background

Mean Tidal Current (cm/s)



Do tides matter here?

Padman & Erofeeva [2004]

Sea ice

"It is evident that the (ice) pressure stands in connection with … the tidal wave. The pressure has happened in the morning ... and afternoon, and in between we have always lain part of the time in open water."

(10/13/1893; Northern Laptev Sea)

[Nansen, "*Farthest North*", 1898]

Tidal divergence

Sea ice moves with ocean tidal currents (“free drift”) unless ice concentration is too high.

Spatial gradients of tidal currents cause periodic divergence of sea ice (the “ice accordion” that Nansen saw).

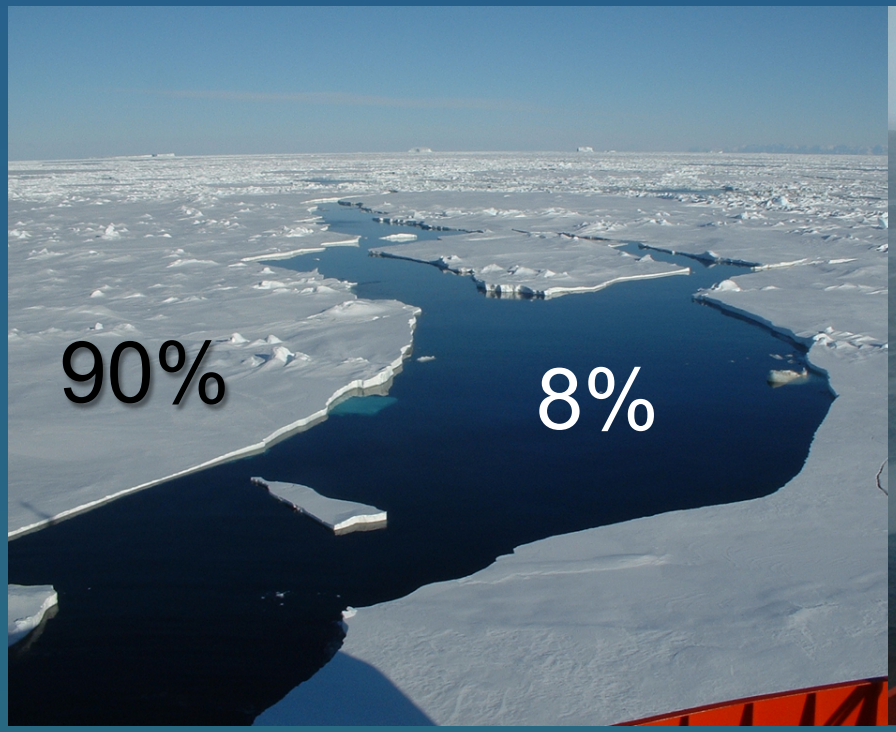
Inc fraction causes higher
oce ge.

In v and more salt added to
oce

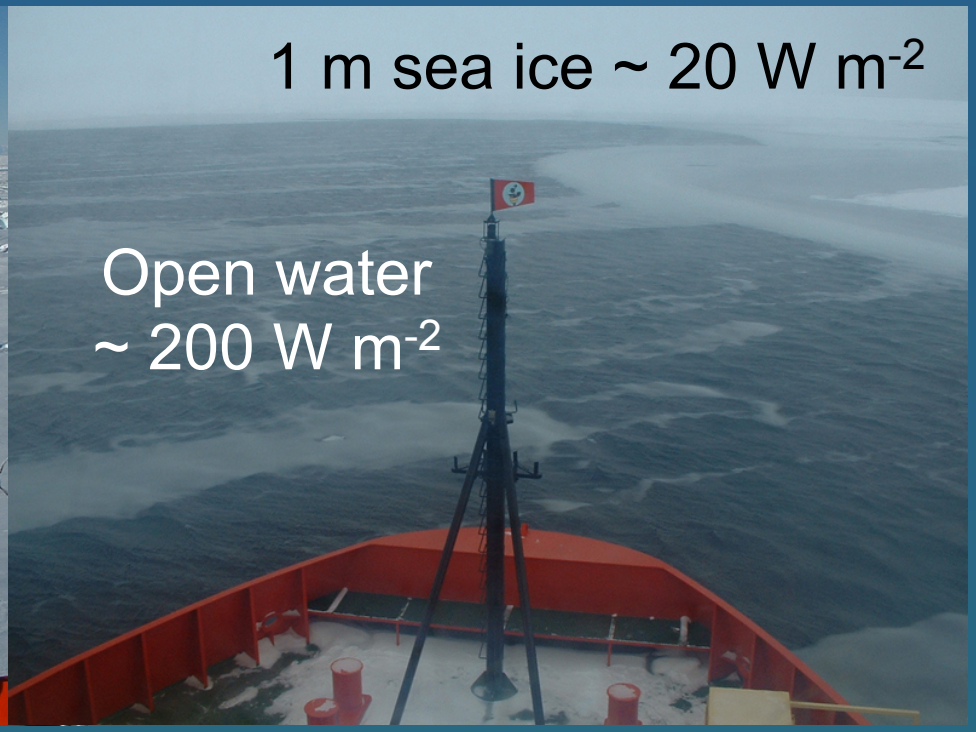
In s heating and more rapid
sea

Tidal impact on sea ice (*mean lead fraction*): Depends on season

Difference in albedo

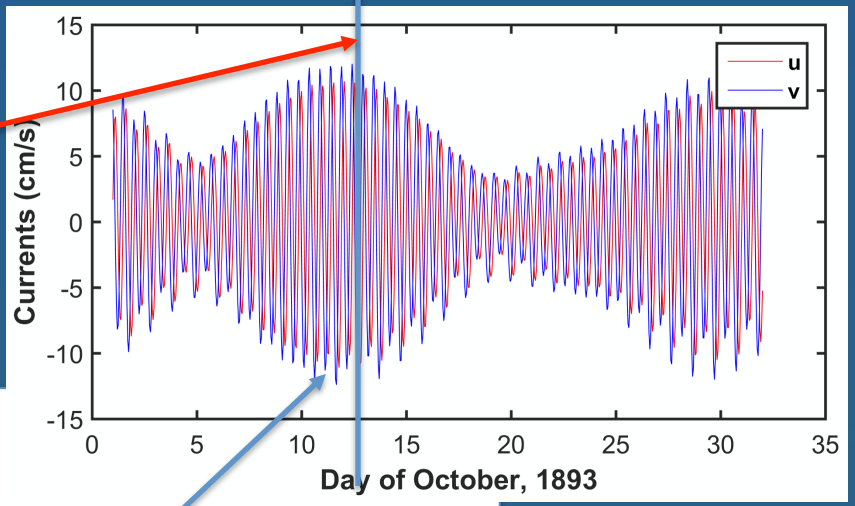


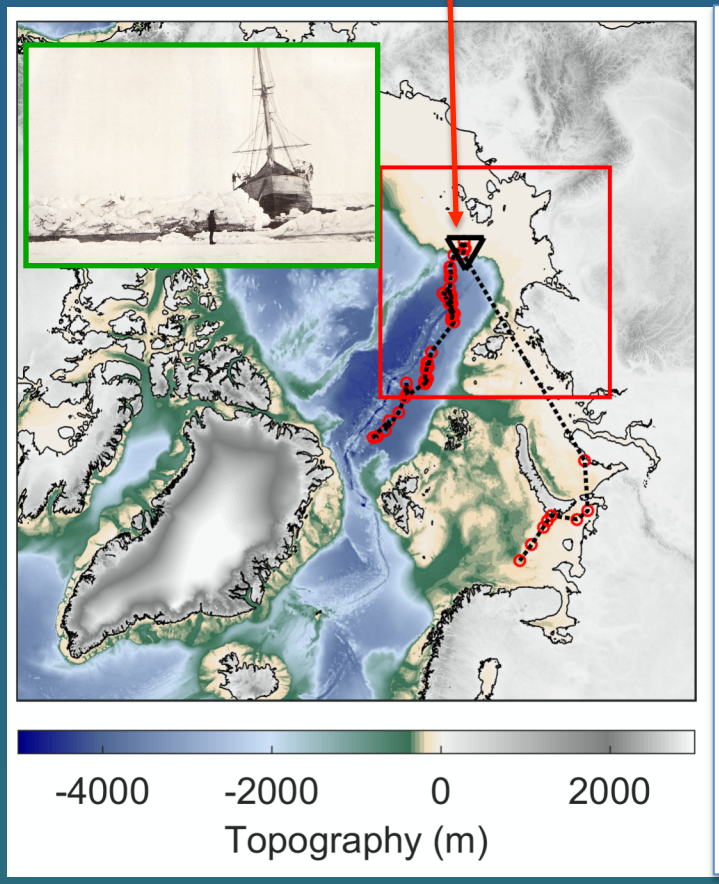
Winter ocean heat loss



Drift of Nansen's *Fram*

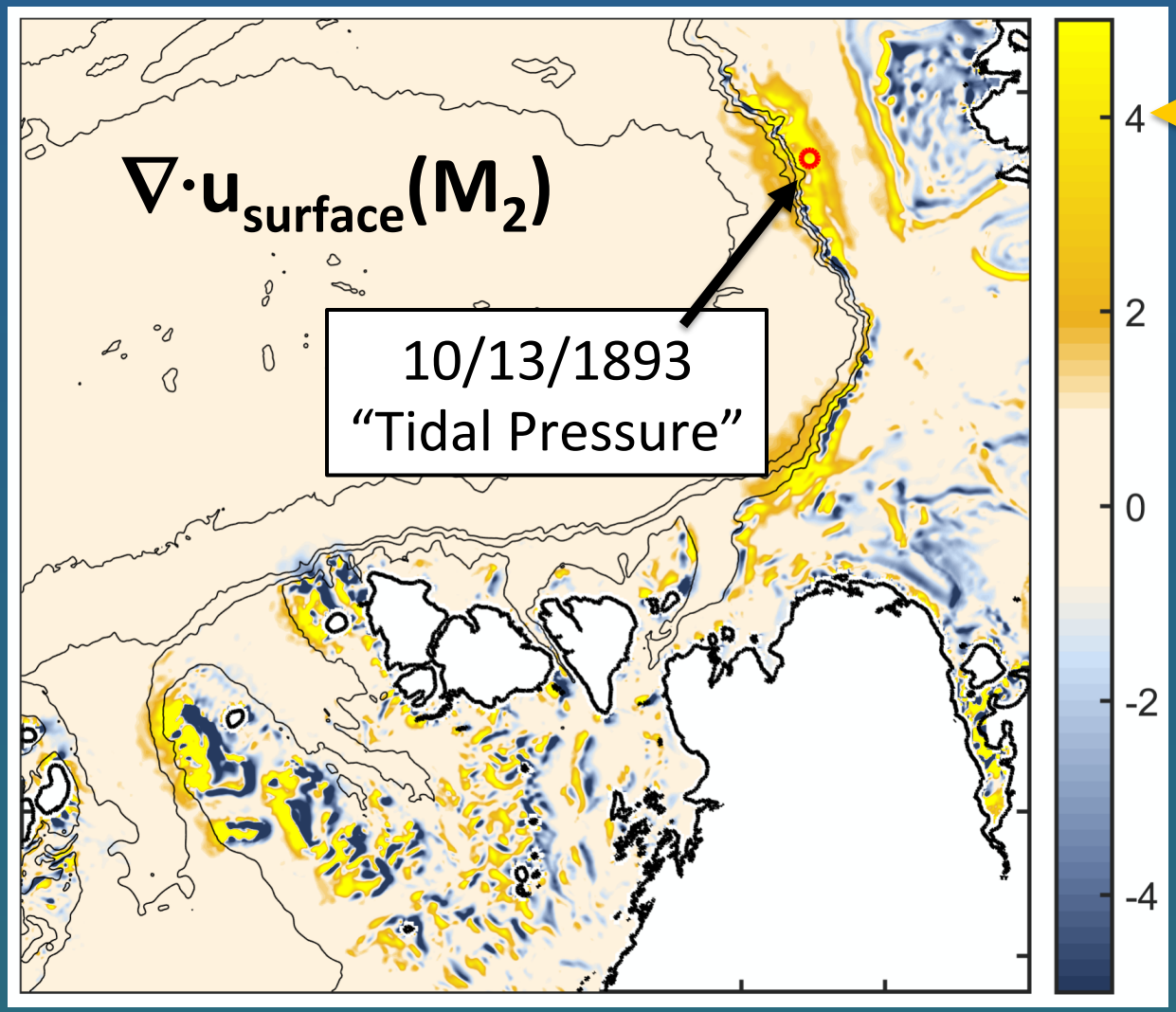
10/13/1893
"Tidal Pressure"





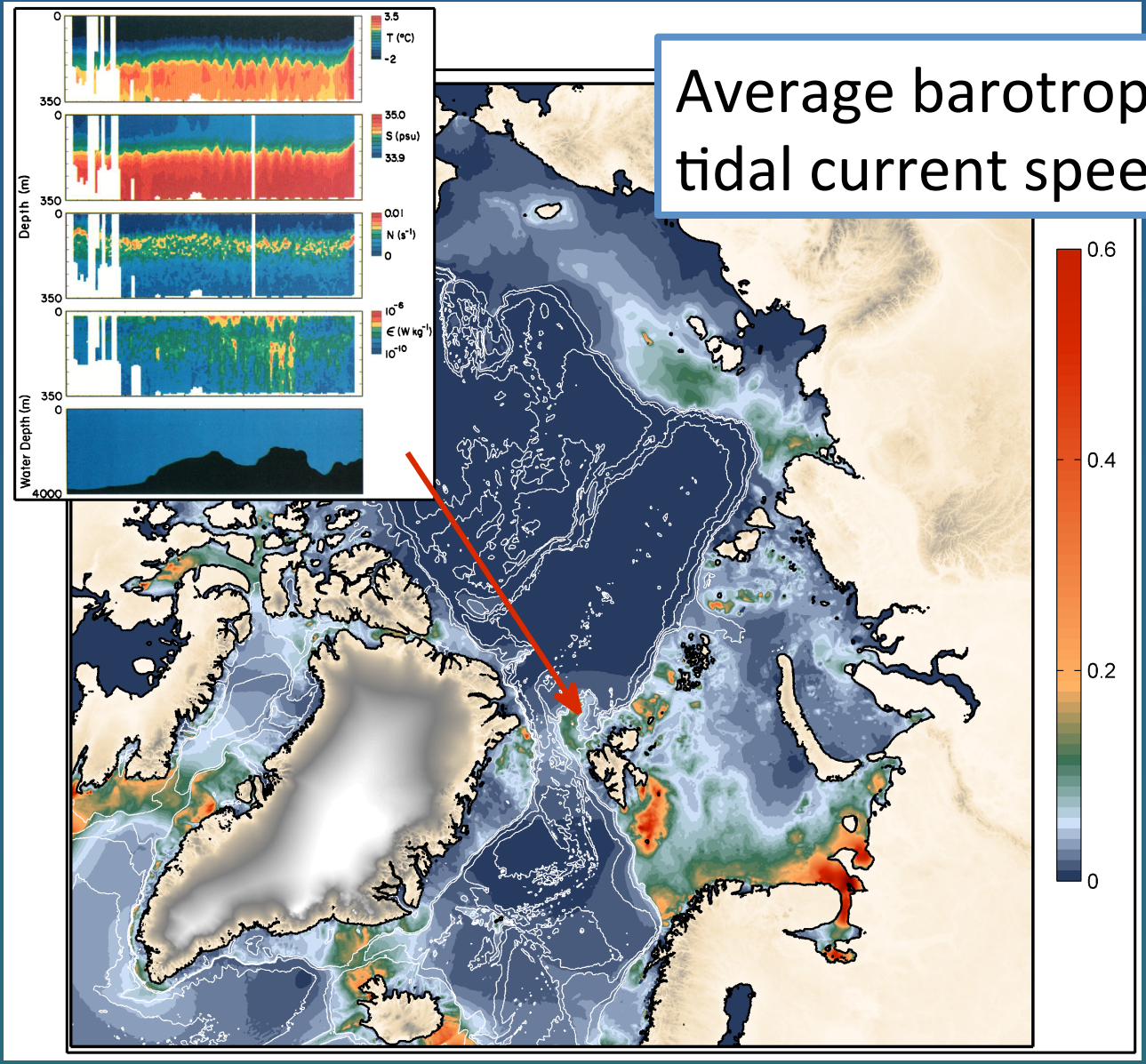
Tidal pressure comes from $\nabla \cdot \mathbf{u}$, not $|\mathbf{u}|$

Surface tidal divergence: snapshot



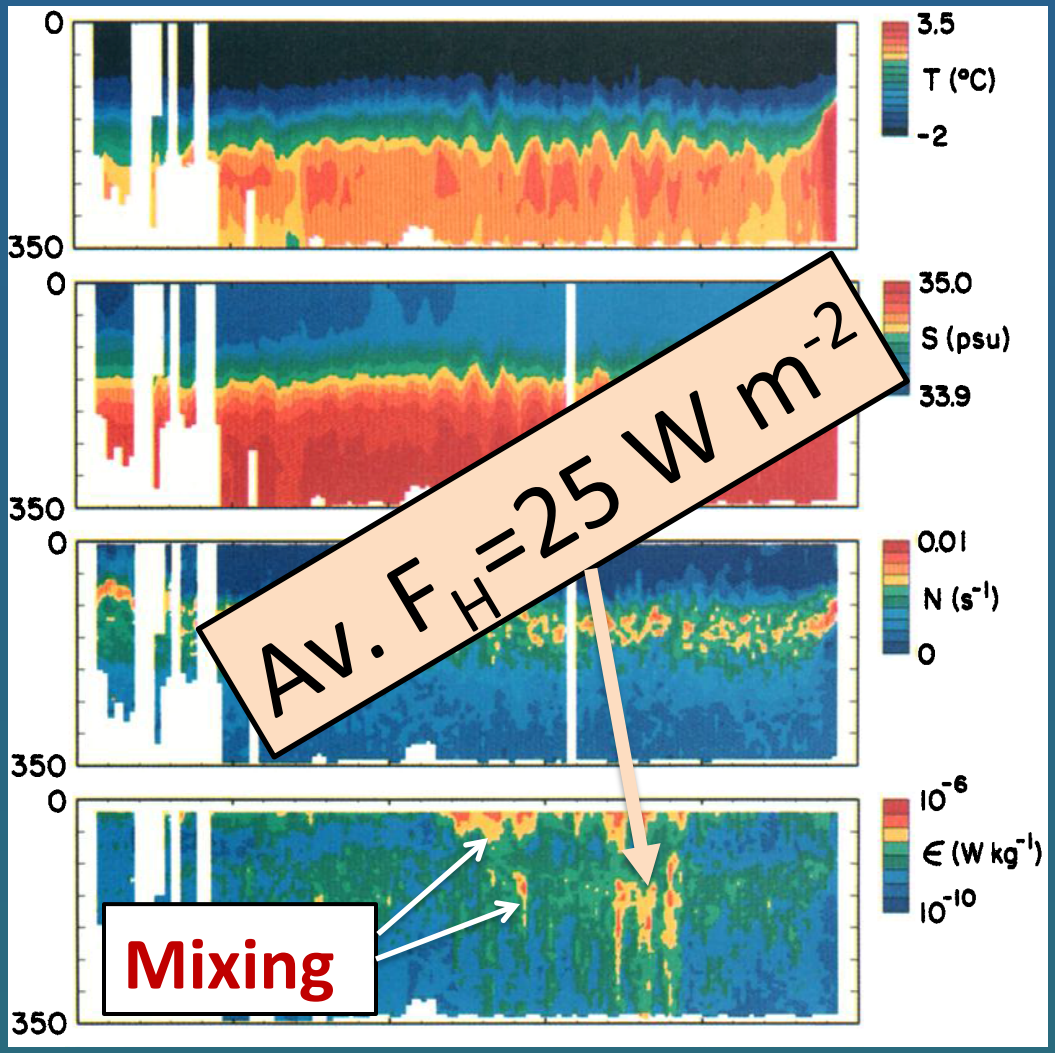
~5% mean lead fraction (M_2 only)

Ocean mixing: Yermak Plateau, CEAREX 1989



Ocean mixing

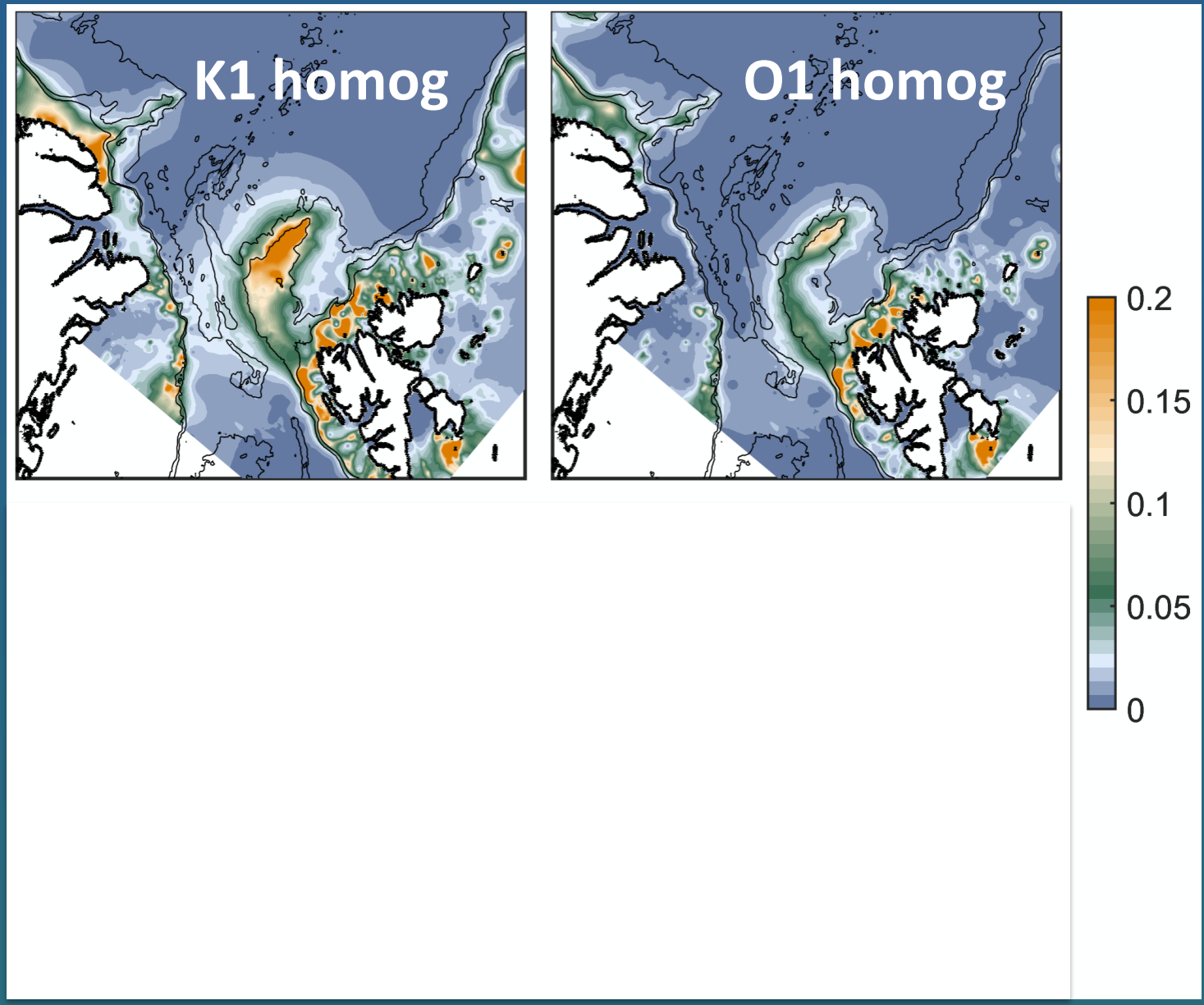
CEAREX: Drifting ice camp, Yermak Plateau 1989



Burst of mixing on ~1-day (and ~6-h) cycles: SML & pycnocline

Padman & Dillon [1991]

Yermak Plateau: Diurnal tides (U_{maj})



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, C04S06, doi:10.1029/2006JC003643, 2007

Click Here for Full Article

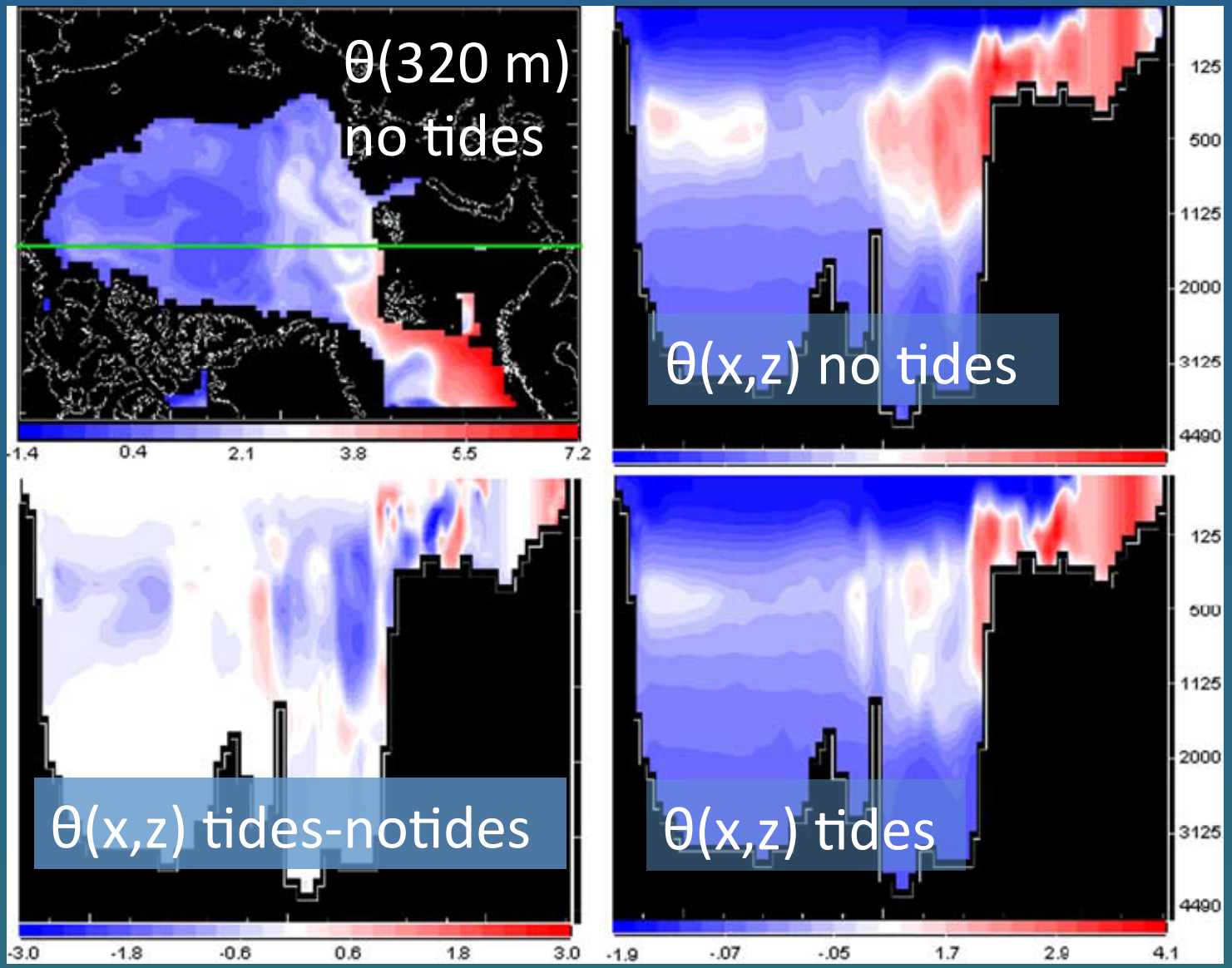
Role of tides in Arctic ocean/ice climate

Greg Holloway[1] and Andrey Proshutinsky[2]

Received 13 April 2006; revised 7 November 2006; accepted 14 December 2006; published 28 March 2007.

Parameterized bottom friction from tides changes Arctic hydrography and circulation

Holloway & Proshutinsky [2007; JGR-Oceans]



nature geoscience

LETTERS

PUBLISHED ONLINE: 16 FEBRUARY 2015 | DOI: 10.1038/NGEO2350

Tide-mediated warming of Arctic halocline by Atlantic heat fluxes over rough topography

Tom P. Rippeth[1]*, Ben J. Lincoln[1], Yueng-Djern Lenn[1], J. A. Mattias Green[1], Arild Sundfjord[2] and Sheldon Bacon[3]

"… pan-Arctic microstructure measurements … identify tides as the main energy source that supports enhanced dissipation, which generates vertical heat fluxes of more than 50 W m^{-2}."

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
10.1002/2014JC010310

Special Section:
Forum for Arctic Modeling and Observing Synthesis (FAMOS): Results and Synthesis of Coordinated Experiments

The effects of tides on the water mass mixing and sea ice in the Arctic Ocean

Maria V. Luneva[1], Yevgeny Aksenov[2], James D. Harle[1], and Jason T. Holt[1]

[1]National Oceanography Centre, Joseph Proudman Building, Liverpool, UK, [2]National Oceanography Centre, European Way, Southampton, UK

3-D model with barotropic and baroclinic tides (dx=15 km): substantial effects on

- Arctic hydrography and circulation
- Sea-ice loss rate
- Freshwater flux pathways from rivers

BAMS: 2015: In Press

ARTICLES

TOWARD QUANTIFYING THE INCREASING ROLE OF OCEANIC HEAT IN SEA ICE LOSS IN THE NEW ARCTIC

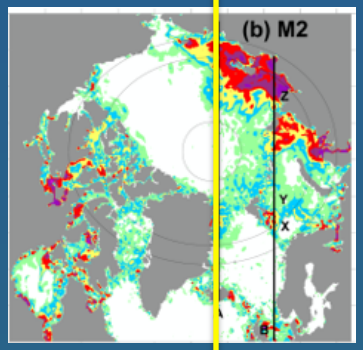
BY E. CARMACK, I. POLYAKOV, L. PADMAN, I. FER, E. HUNKE, J. HUTCHINGS, J. JACKSON, D. KELLEY, R. KWOK, C. LAYTON, H. MELLING, D. PEROVICH, O. PERSSON, B. RUDDICK, M.-L. TIMMERMANS, J. TOOLE, T. ROSS, S. VAVRUS, AND P. WINSOR

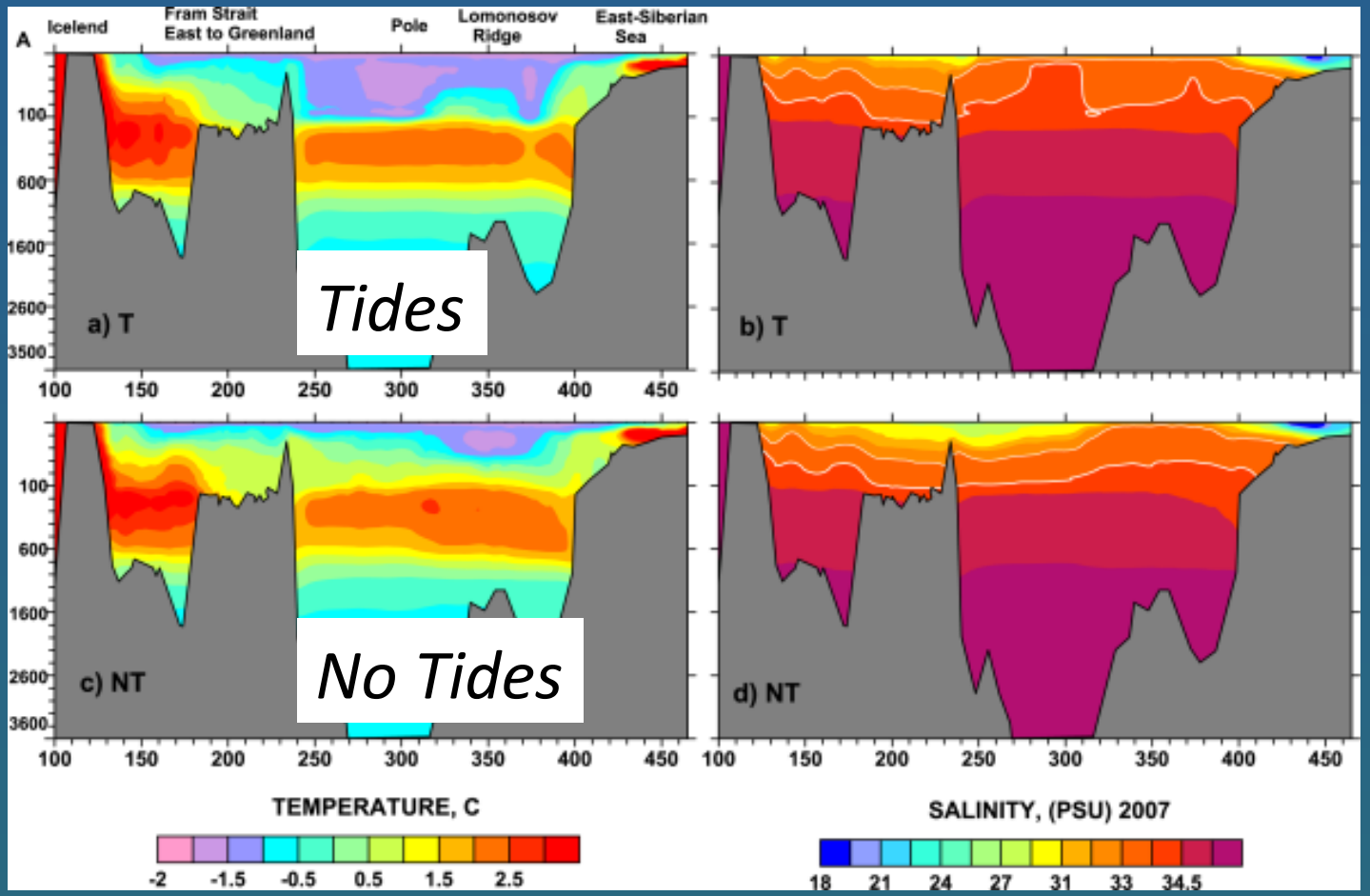
Small changes in the ways that the ocean transports heat to the overlying ice cover could have a substantial effect on future changes in Arctic ice cover.


Thank you

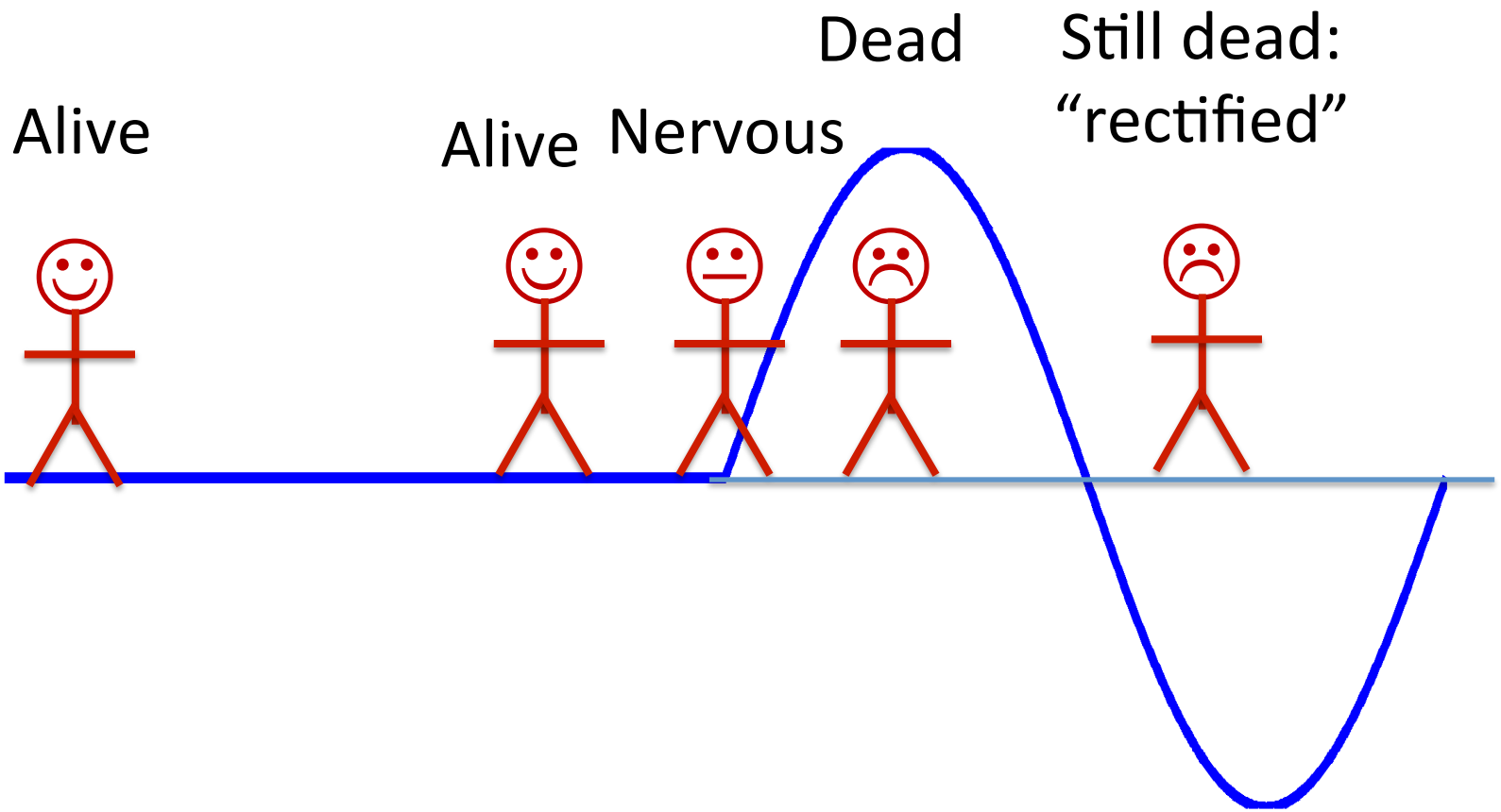
End formal talk

Luneva et al. [2015; JGR-Oceans]

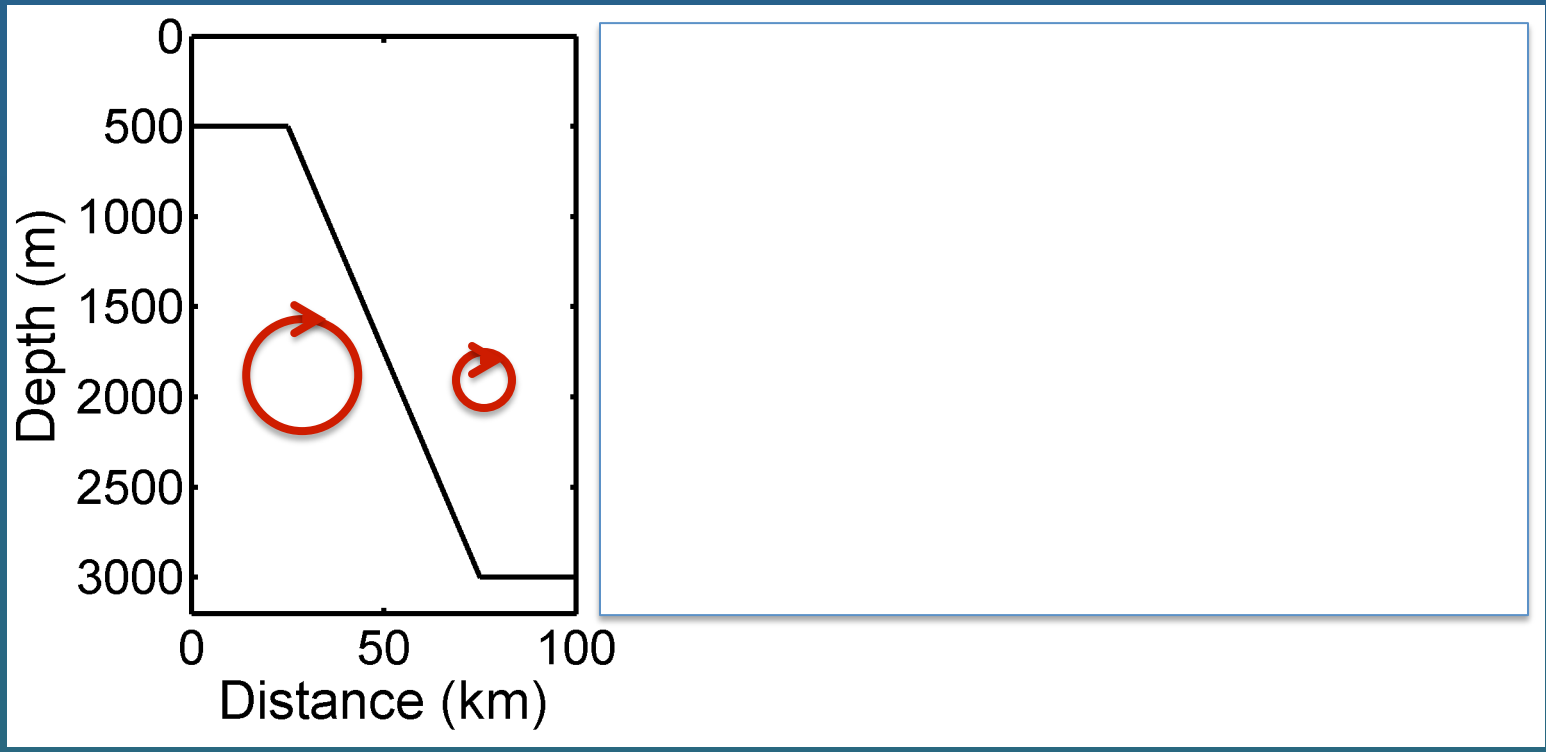




Rectification



Rectified tidal currents



Tidal currents larger in shallow water

Uncertain ocean mixing: Arctic model sensitivity

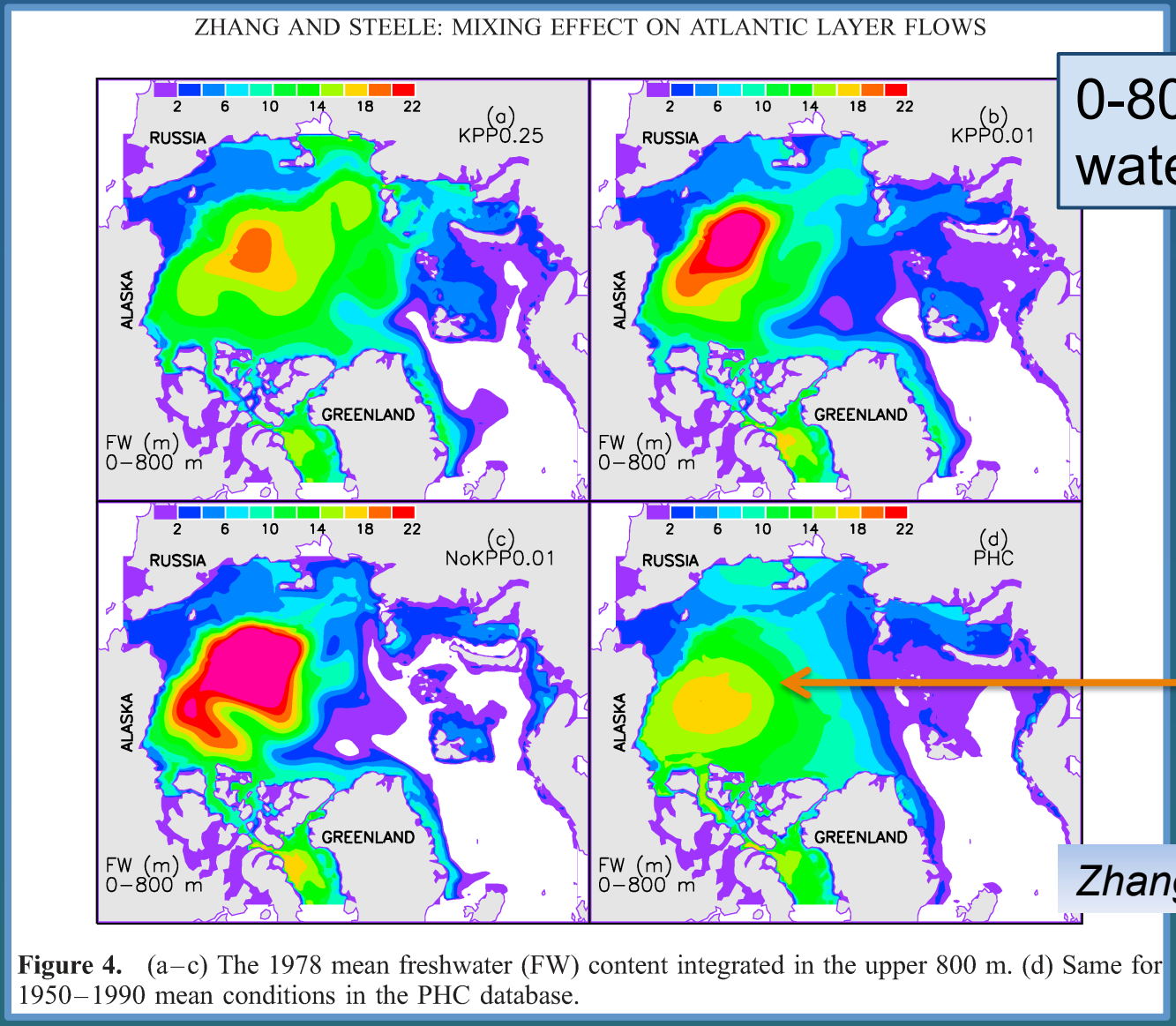


Figure 4. (a–c) The 1978 mean freshwater (FW) content integrated in the upper 800 m. (d) Same for 1950–1990 mean conditions in the PHC database.

0-800 m fresh-water content

Data (PHC)

Zhang & Steele [2007]

Ice is complex, but at least we can see it: What about the ocean?

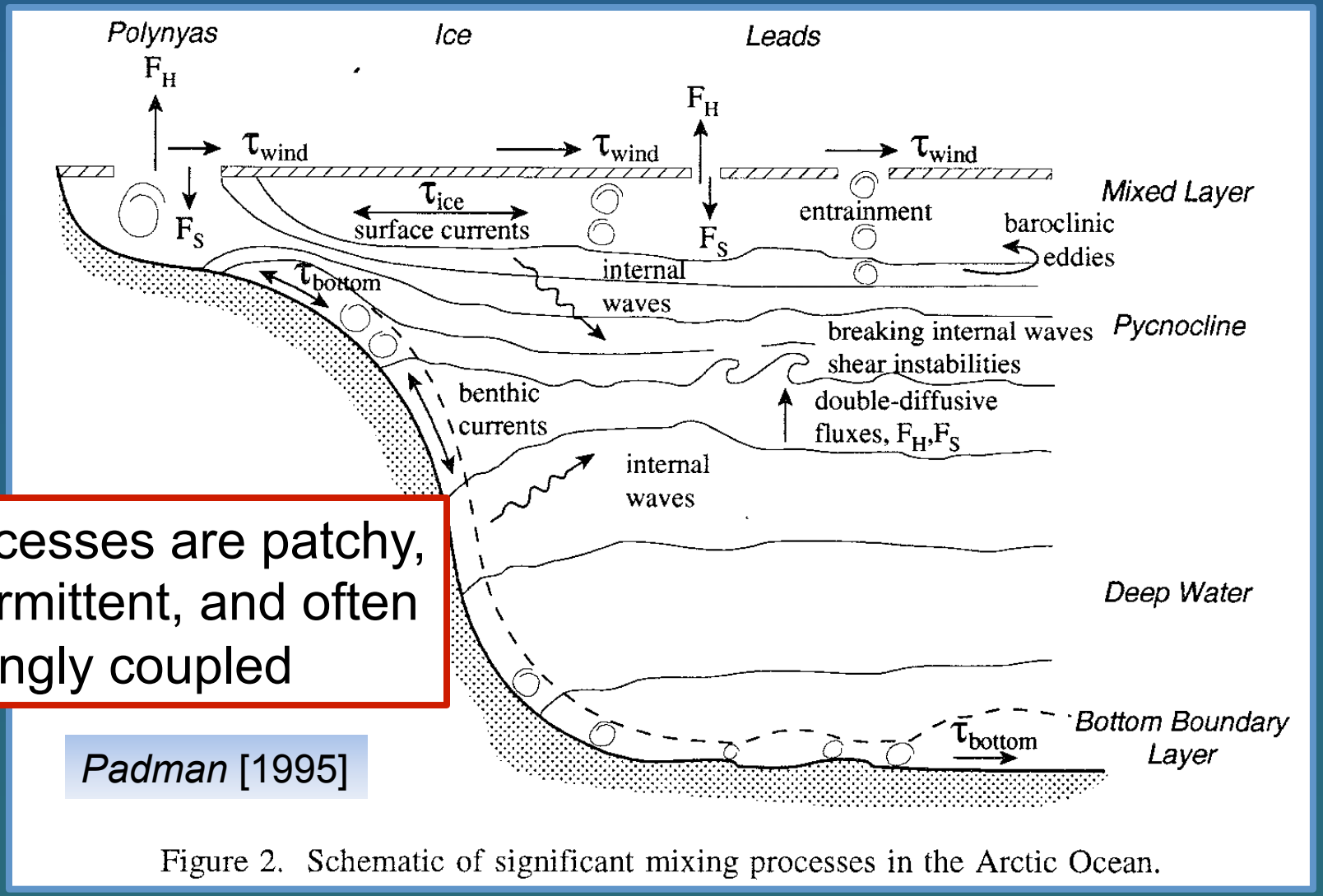
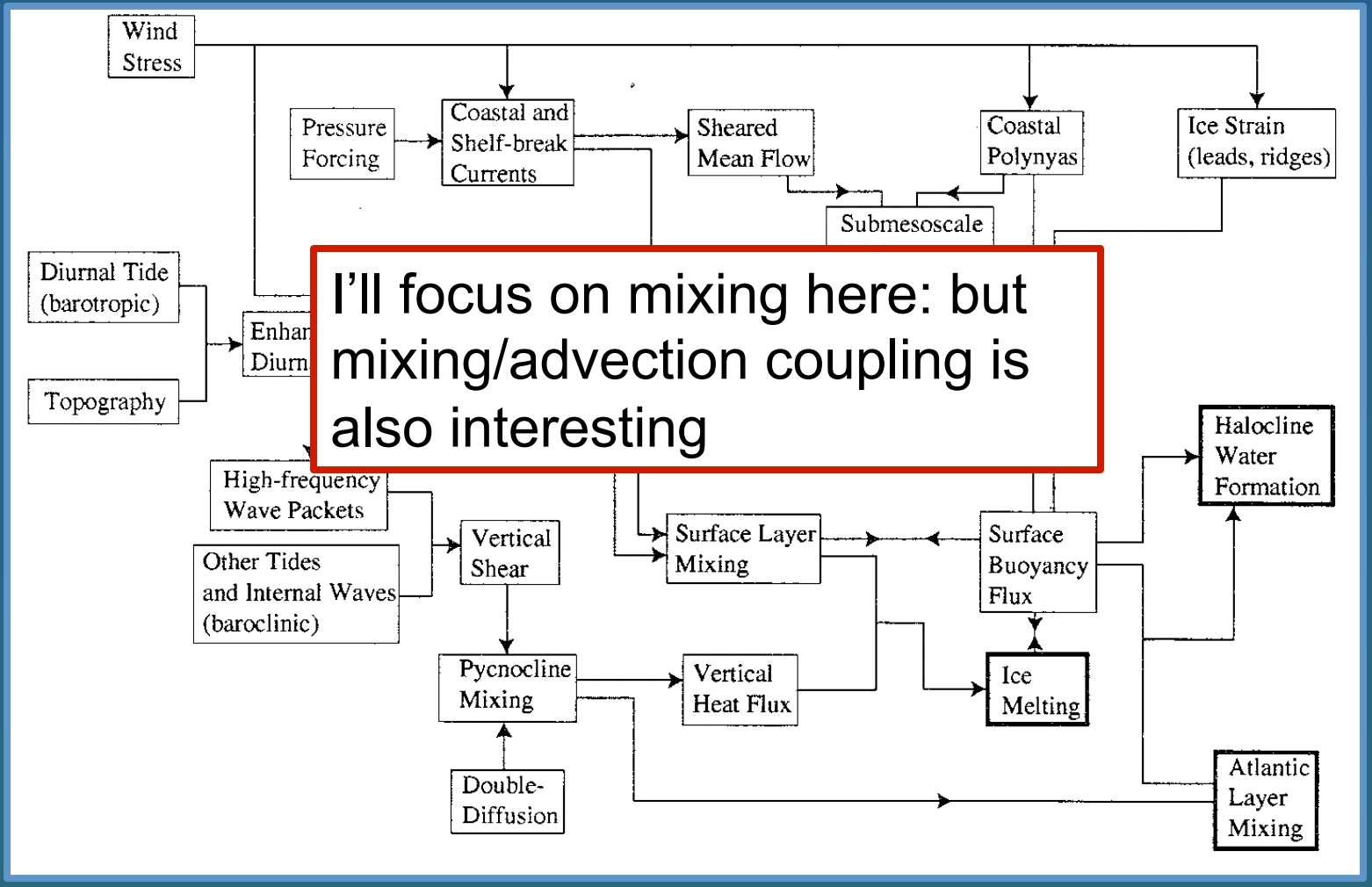


Figure 2. Schematic of significant mixing processes in the Arctic Ocean.

Processes are patchy, intermittent, and often strongly coupled

Padman [1995]

Lots of processes and interactions



Padman [1995]