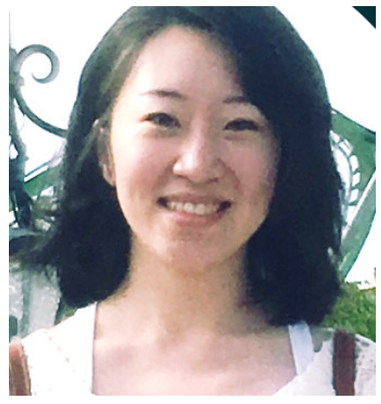
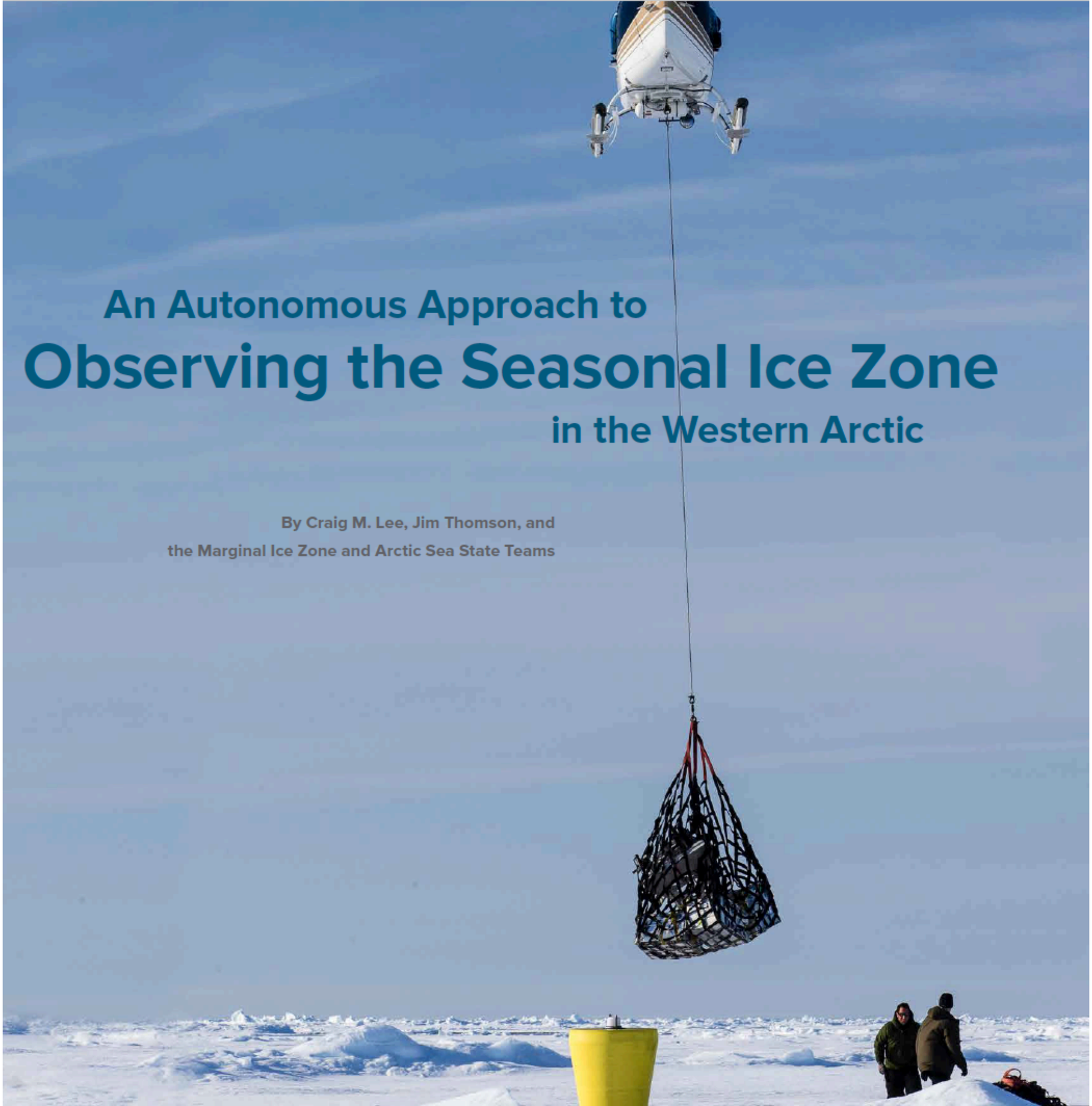
Autonomous Observations in the Arctic

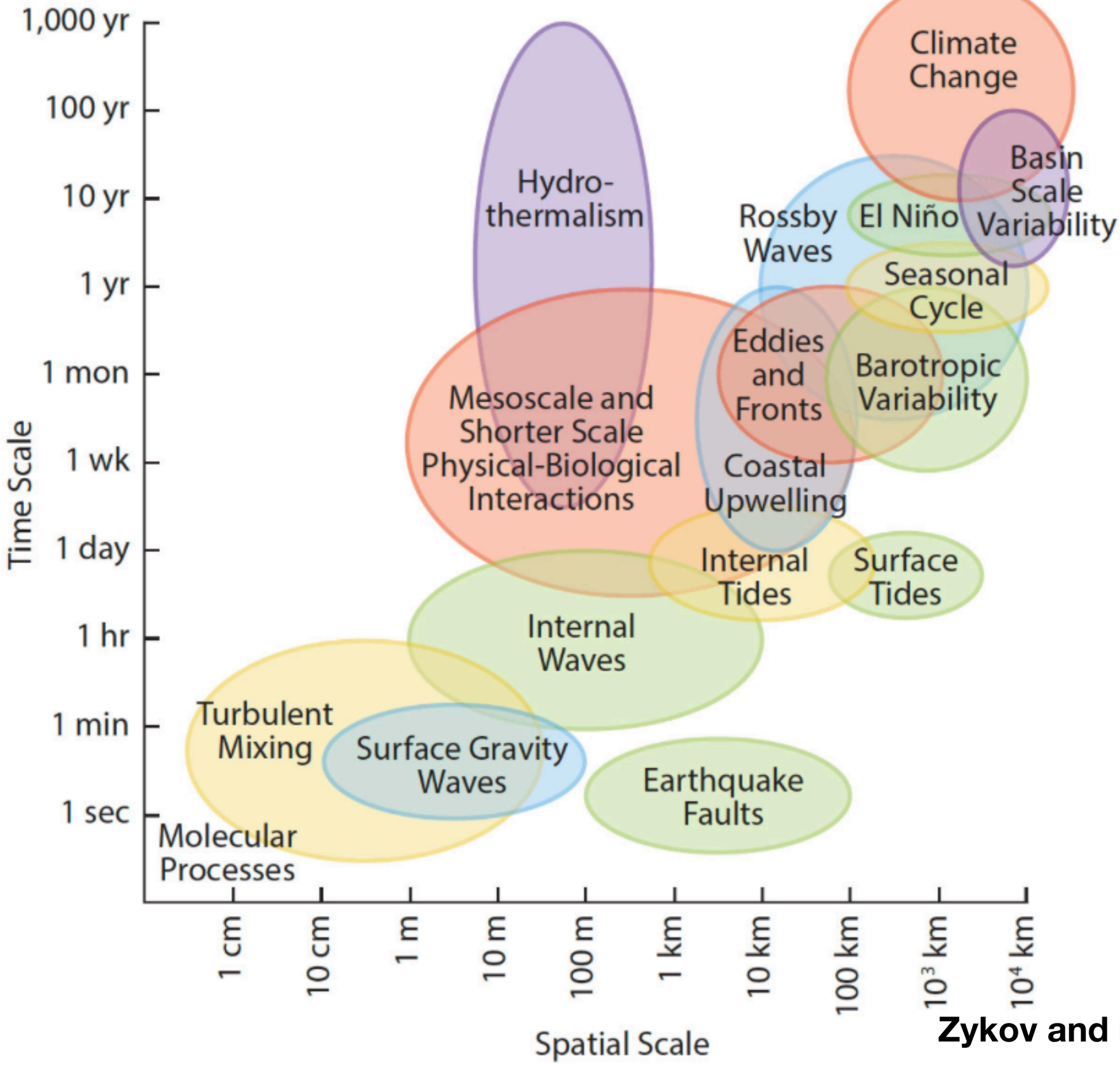
Lee and Thompson 2017
Zhao et al. 2016





An Autonomous Approach to Observing the Seasonal Ice Zone in the Western Arctic

By Craig M. Lee, Jim Thomson, and
the Marginal Ice Zone and Arctic Sea State Teams



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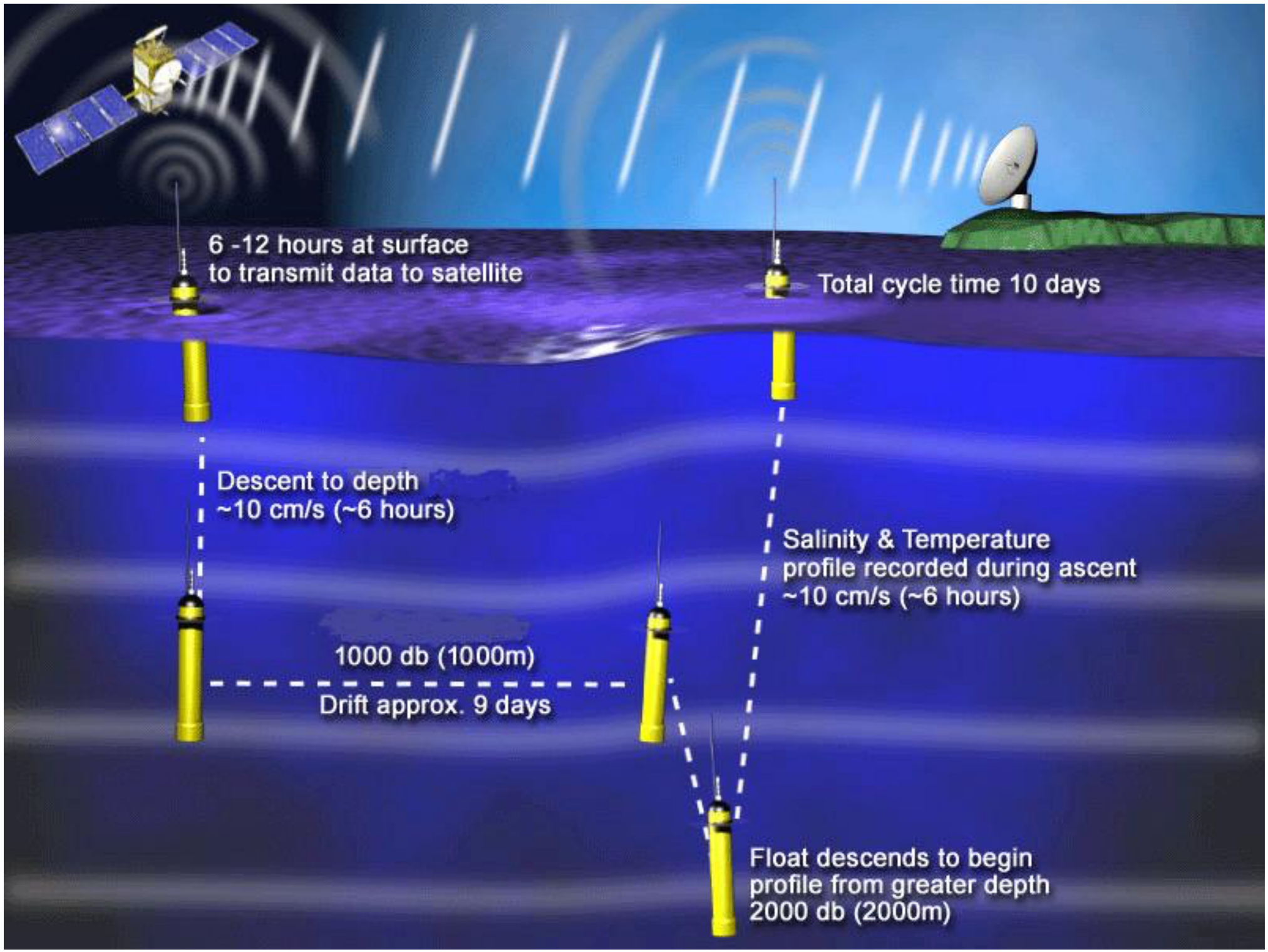
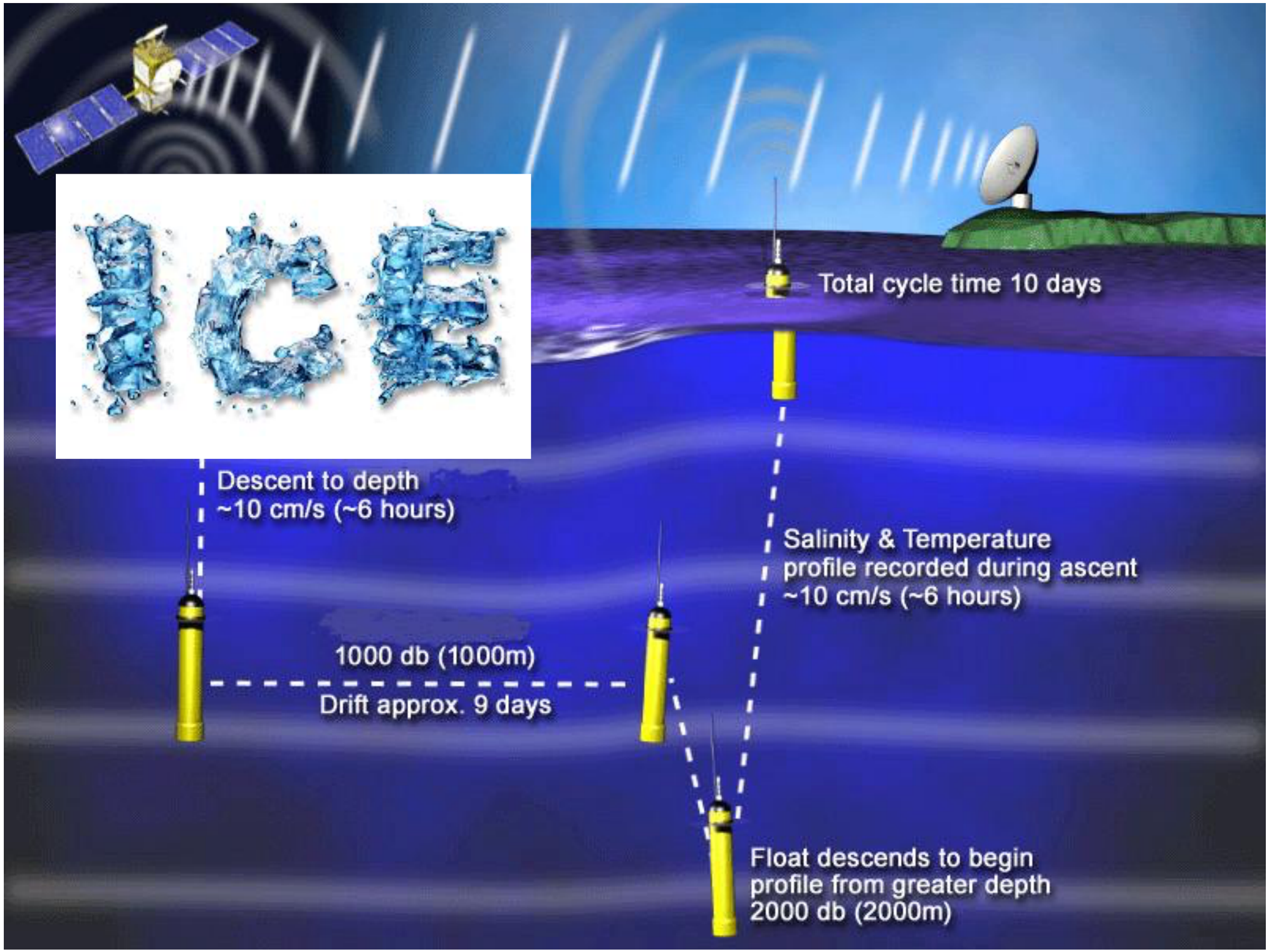
Motivation Video

Argo Under Ice…



credit: http://www.argo.ucsd.edu/

Argo Under Ice…



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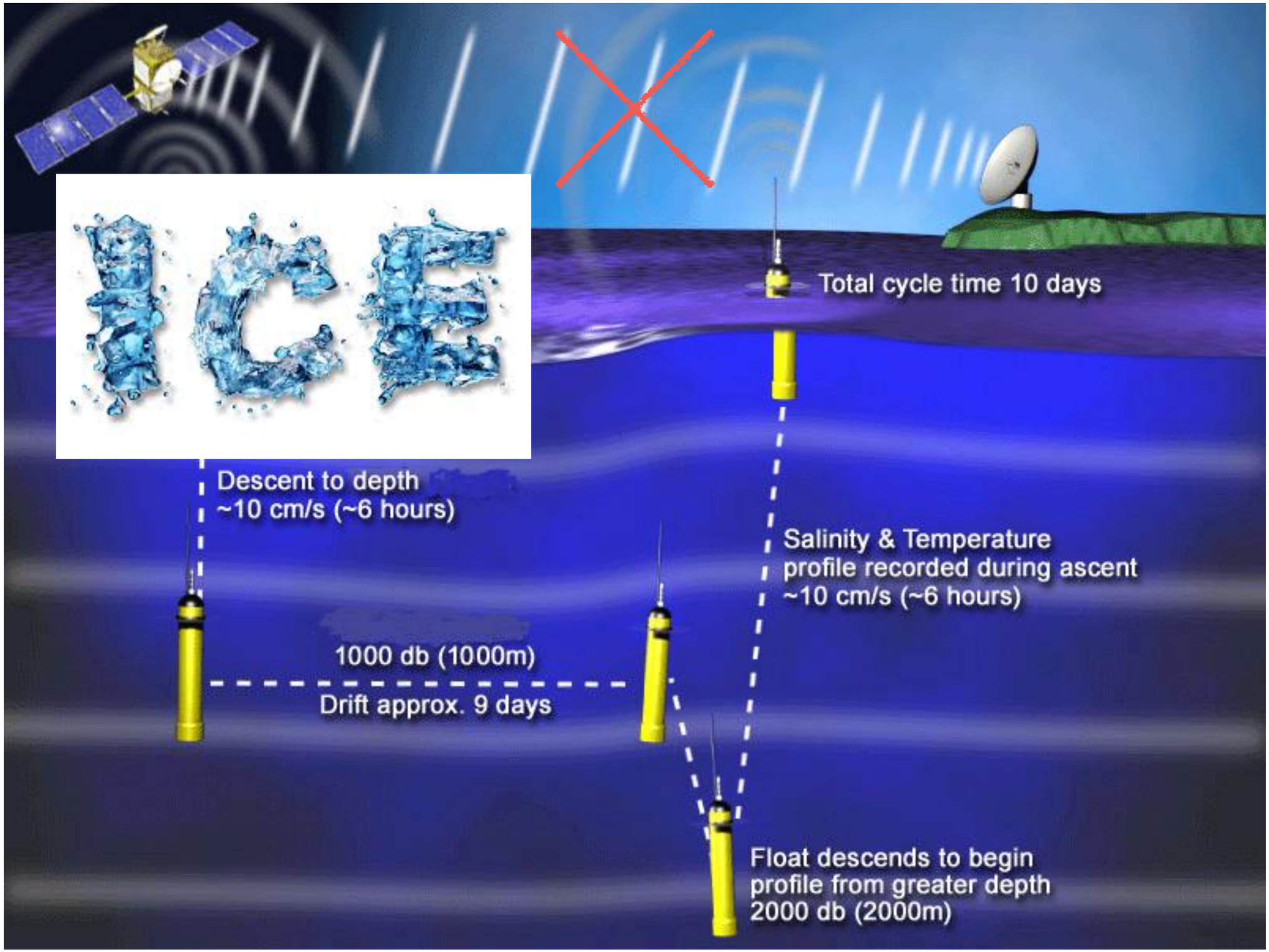
Argo Under Ice…



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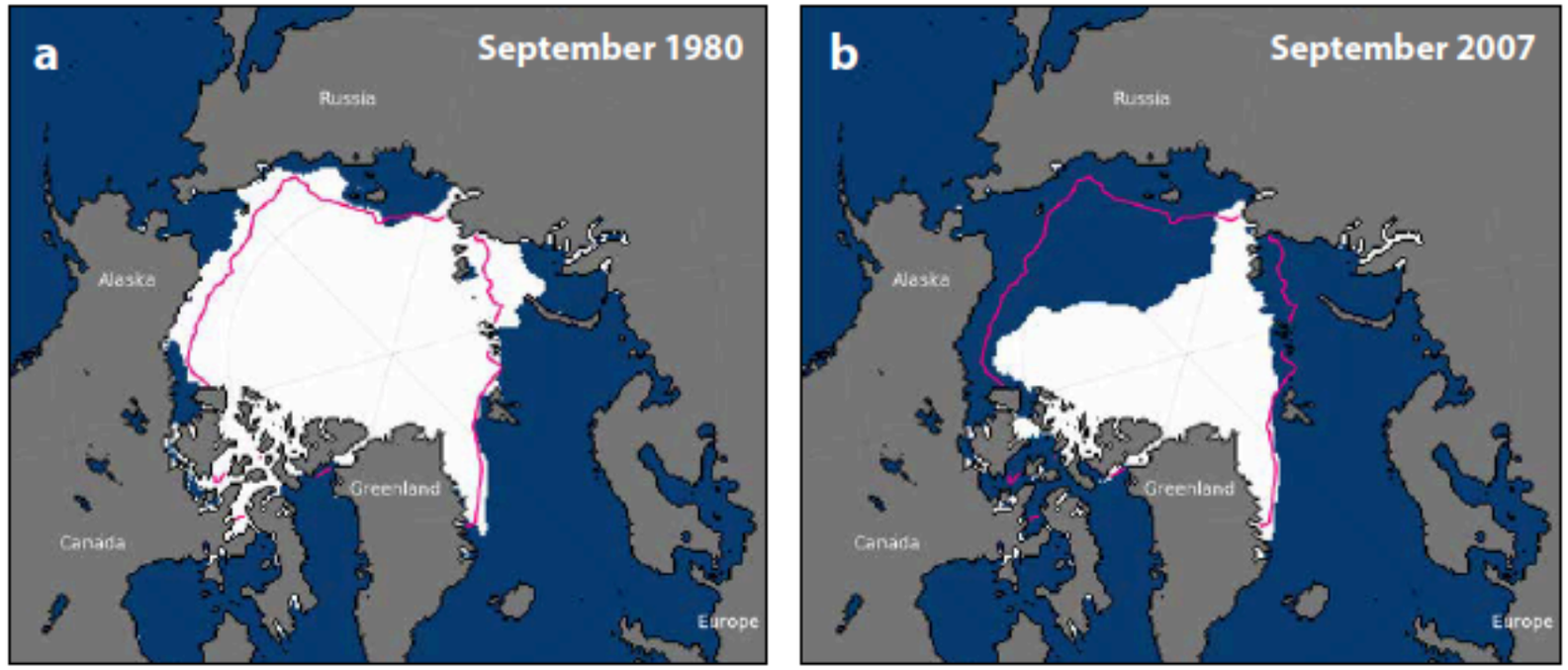

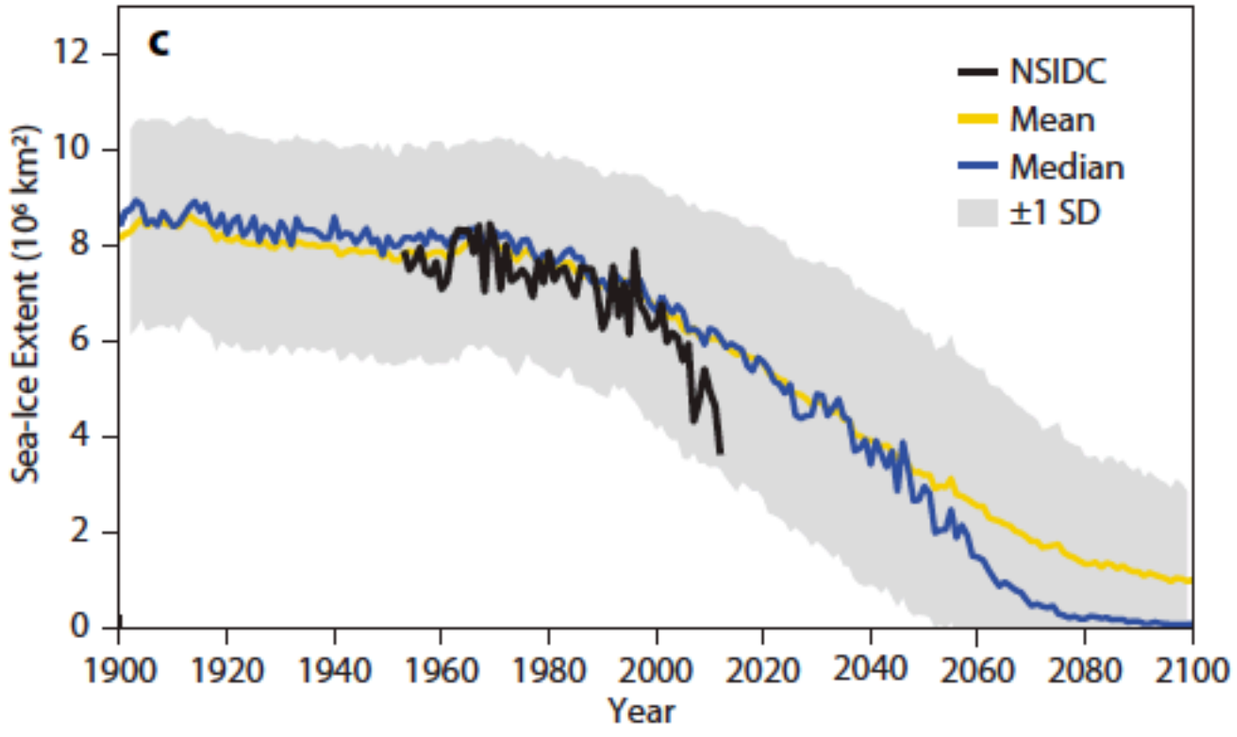

FIGURE 1. September sea ice cover in 1980 (a) and in 2007 (b). The red outline shows the difference in ice coverage, which is most notable in the western Arctic. *Credit: NSIDC* (c) Time series of the sea ice area at the September minimum each year. The black line is a satellite data product from the US National Snow and Ice Data Center. The yellow and blue lines mark the mean and median of September sea ice minimum predictions from an ensemble of climate models, with gray shading marking the one standard deviation bounds. *From Jeffries et al. (2013)*

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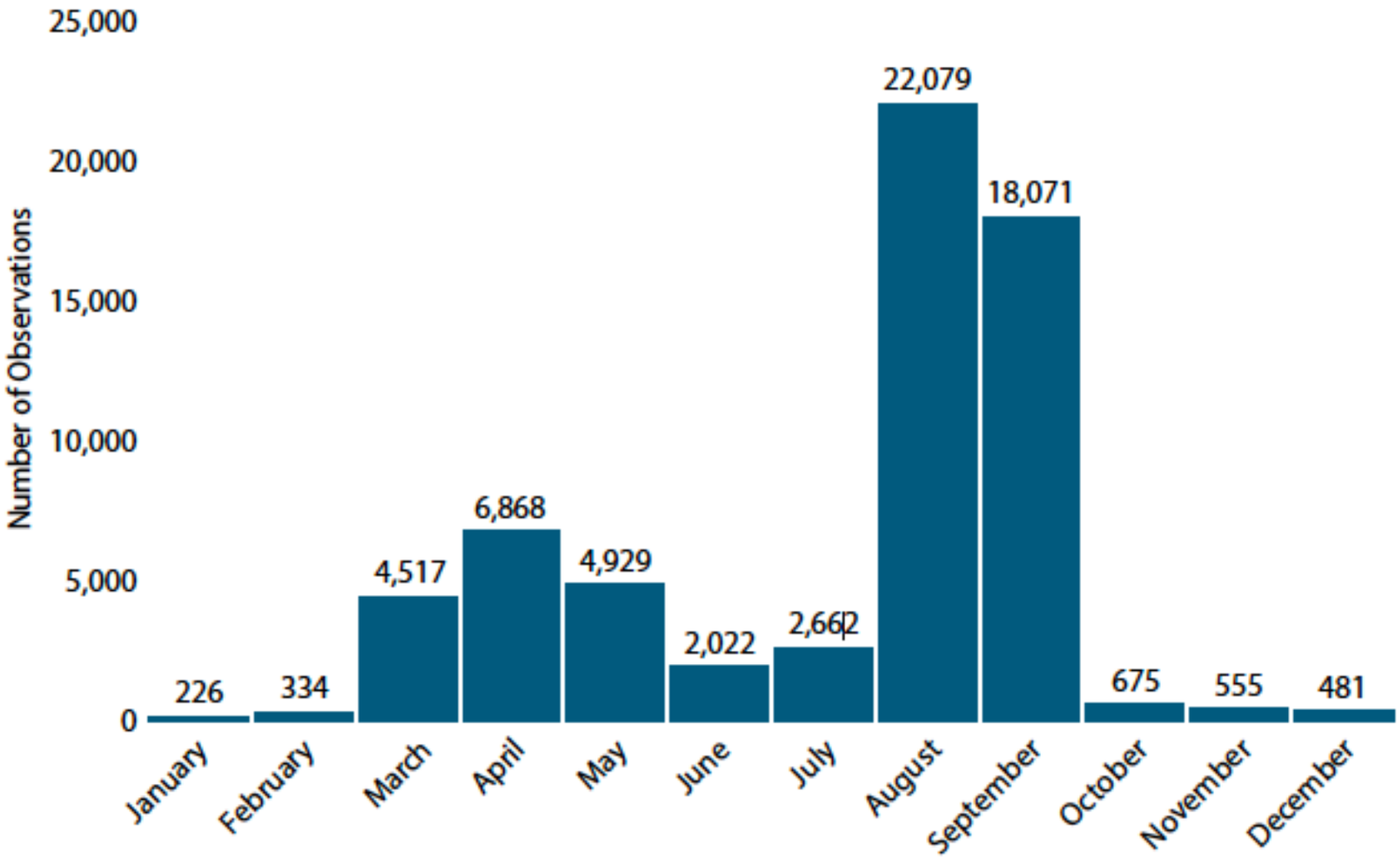

FIGURE 3. Number of sea ice thickness measurements, by month, in the western Arctic. These include on-ice (~in situ) sea ice thickness measurements taken by augers, cores, and surface electromagnetic radiation compiled from field experiments conducted from the 1890s (*Fram*) through 2011. *Source: Benjamin Holt, NASA/JPLCaltech*

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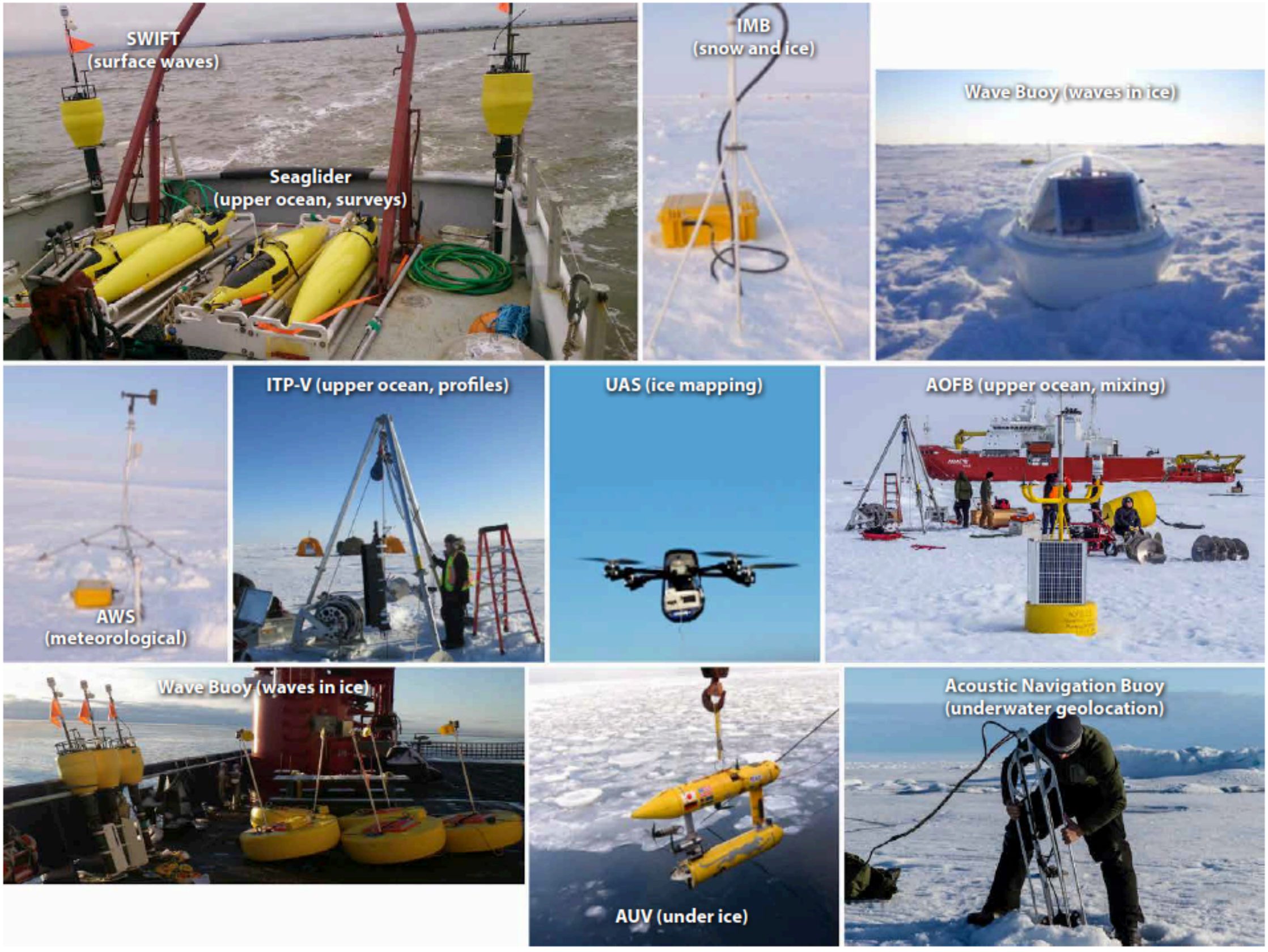

FIGURE 4. Autonomous platforms used in the field programs. SWIFT = Surface Wave Instrument Float with Tracking drifter. IMB = Ice Mass Balance Buoy. AWS = Autonomous Weather Station. ITP-V = Ice-Tethered Profiler with Velocity. UAS = Unmanned Aerial System. AOFB = Autonomous Ocean Flux Buoy. AUV = Autonomous Underwater Vehicle.

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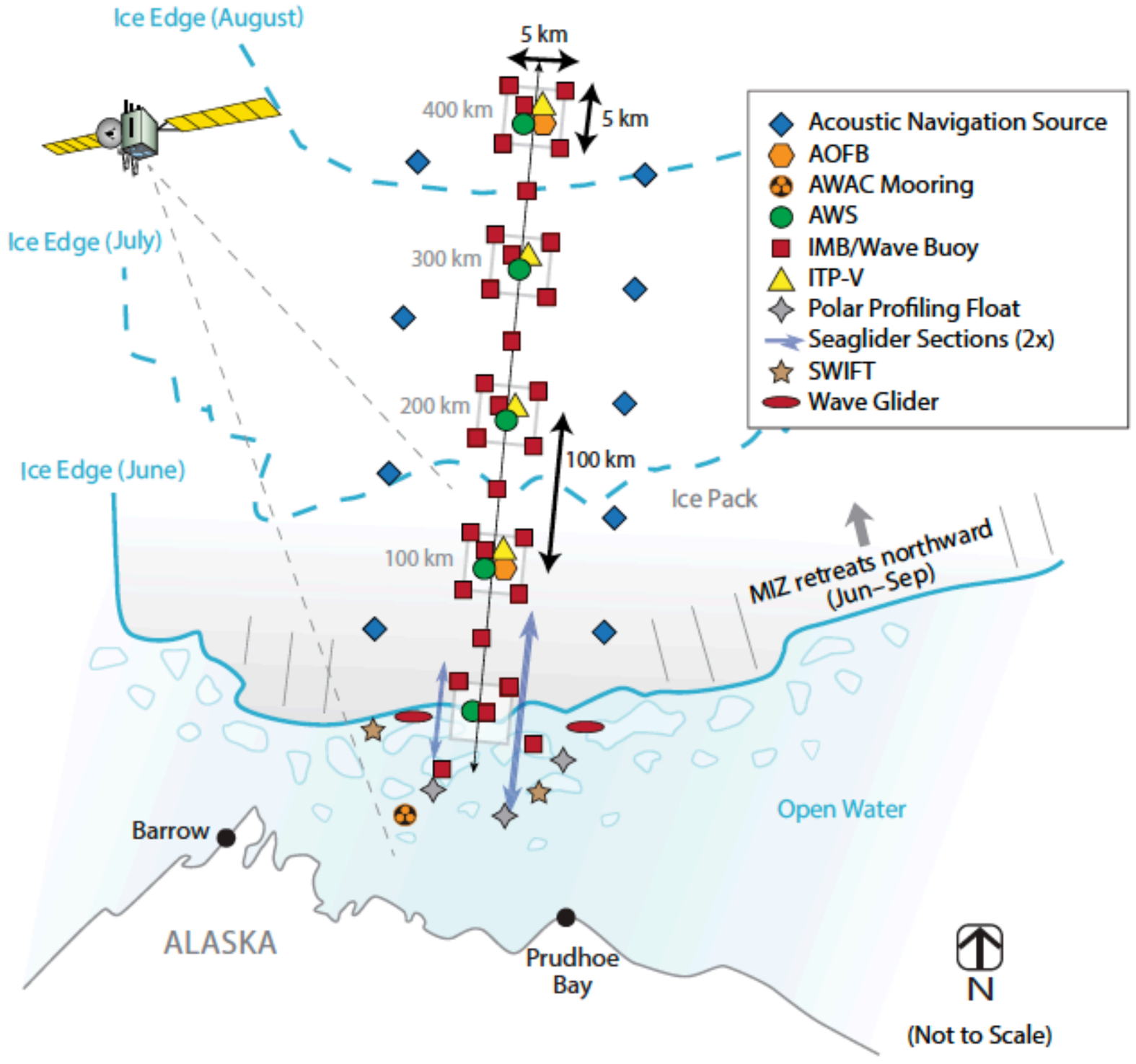

FIGURE 5. Idealized Marginal Ice Zone (MIZ) program observing array configuration. Note the markers indicating various instrument separations (drawing is not to scale). The northernmost cluster (400 km) was deployed by IBRV *Araon*. All other ice-based instruments were deployed using aircraft. Ice-based instruments melt out from the south as the MIZ retreats northward. Blue, double-ended arrows mark glider sections that follow the northward retreat of the sea ice to remain centered on the MIZ. Solid (dashed) light blue lines mark notional positions of the ice edge in June (July and August) relative to the observing array. *From Lee et al. (2012)*

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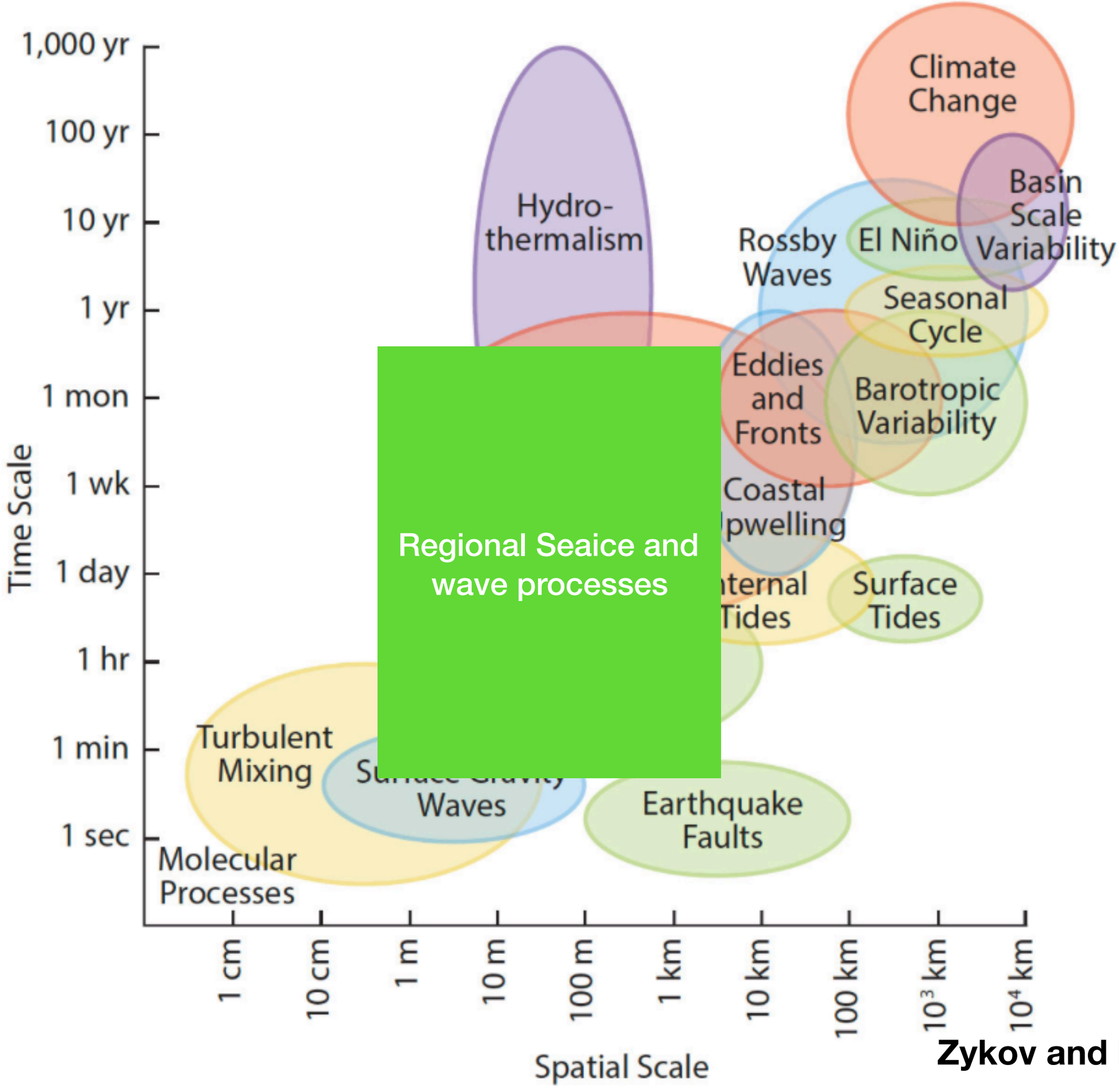

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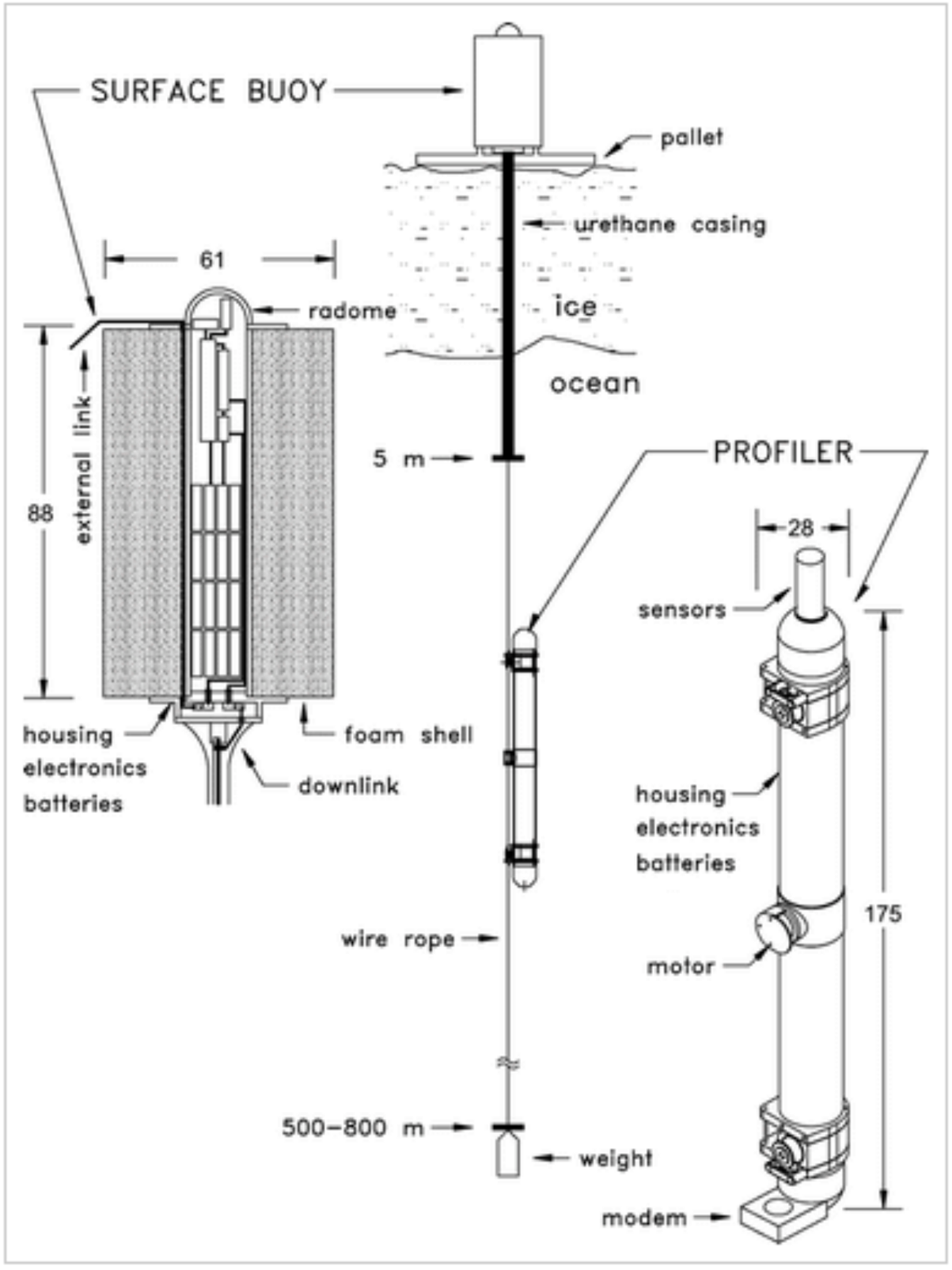


Krishfield et al. 2007

MIZ

Beaufort Gyre Exploration Project

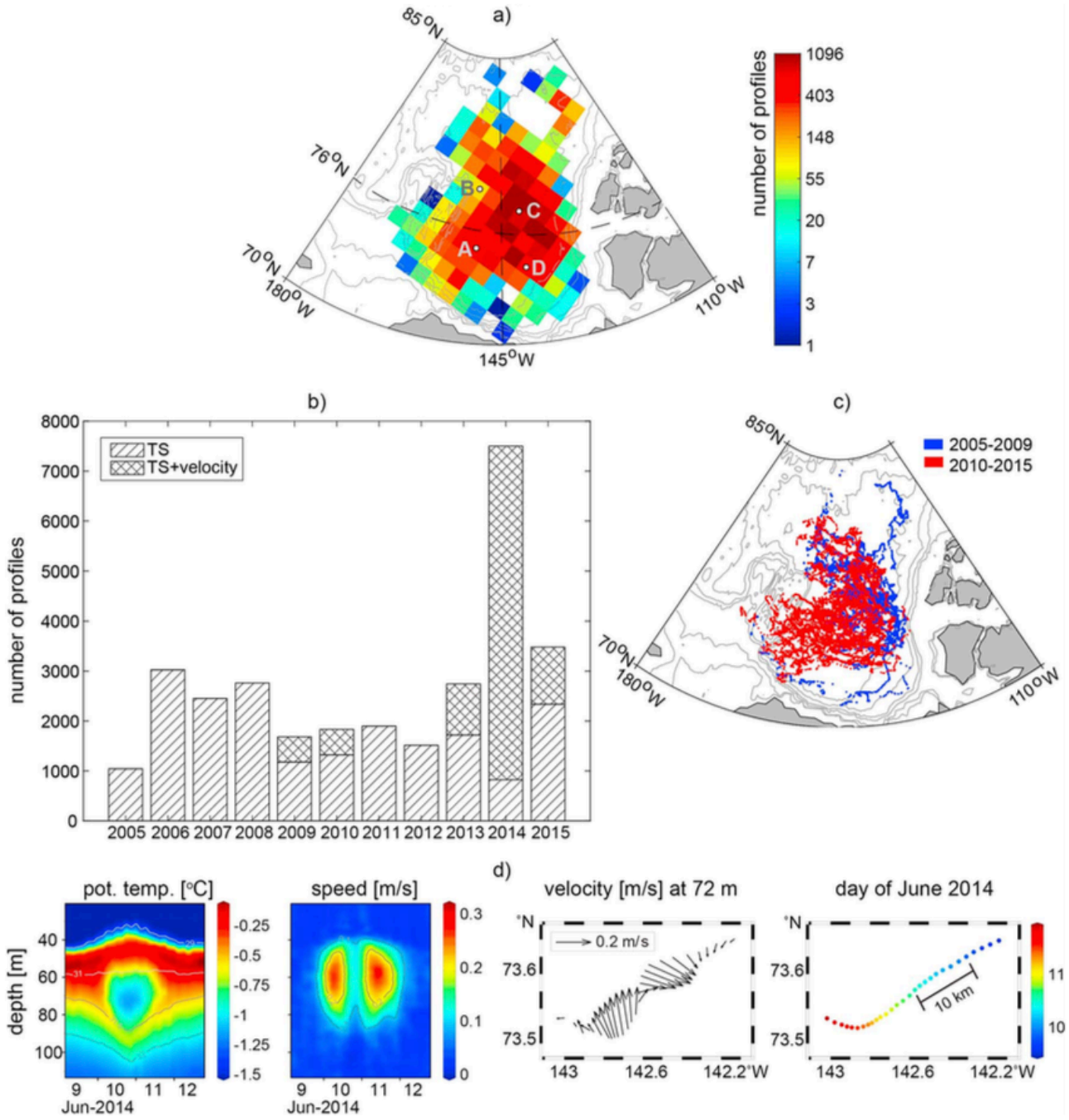
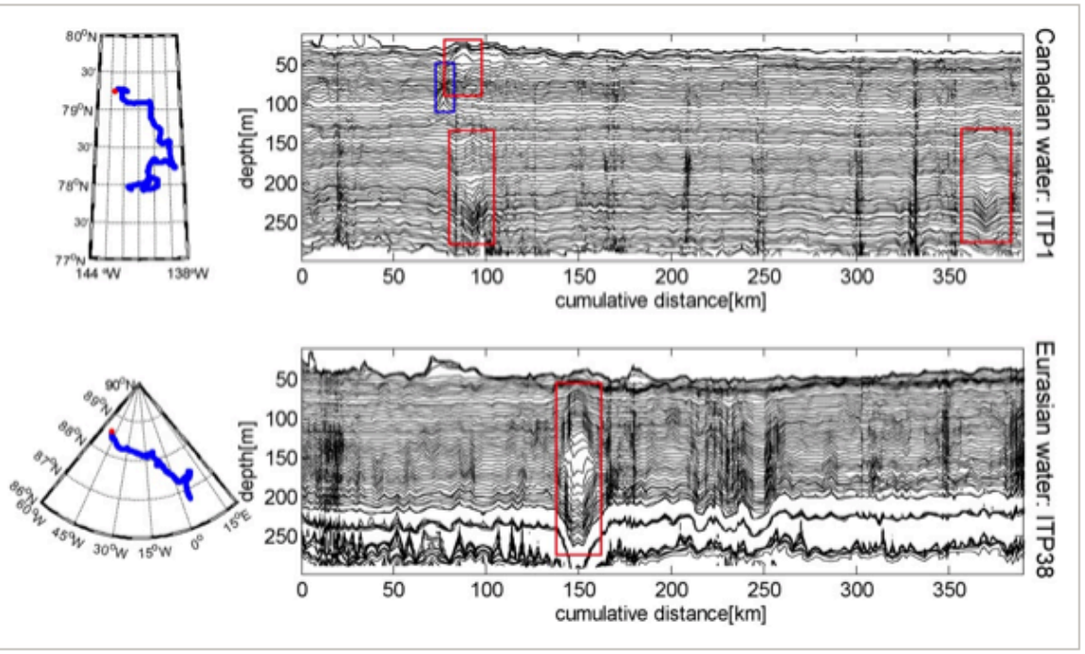


Figure 1. (a) Number of profiles used in this analysis per 100 km × 100 km cell in the Canada Basin between 2005 and 2015 from all ITPs. The locations of the four BGEP moorings (A, B, C, and D) are also indicated. Dashed lines divide the basin into four sectors corresponding to each of the four moorings. (b) Number of profiles with measurements from ITP-Vs (including horizontal velocity in addition to temperature and salinity) and ITPs (only temperature and salinity) in each year. (c) The locations of all ITP measurements from 2005 to 2009 (blue) and 2010 to 2015 (red). (d) A typical upper halocline eddy (core salinity <32, sampled by ITP 77 in 2014 in the southern portion of the basin). First panel: potential temperature (°C)-depth (m) section overlaid with salinity contours; second and third panels: velocity magnitude (m/s)-depth (m) section and the velocity field at the eddy core depth; fourth panel: ITP drift track through the eddy showing dates and horizontal scale.

Zhao et al 2016



igure 5

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xample cumulative distance-density section from ITPs that drifted in Canadian Water (ITP 1) and Eurasian Water (ITP 38) in October to December 2005 and June o August 2010, respectively, along the tracks shown in the left panels (red dots mark the beginning of the drift and blue dots mark positions of subsequent rofiles). Both ITPs returned four profiles per day with intervals of 6 h between rofiles. Mean drift speeds were estimated to be about 7 km/d for ITP 1 and 8 m/d for ITP 38. Isopycnal values are chosen to be densities separated in depth y 4 m at the start profiles of the sections shown. Red boxes indicate anticyclonic ddies and the blue box shows a rare cyclonic eddy. The two shallower eddies ighlighted in the top panel may be an example of dipole pair.

Zhao et al 2014

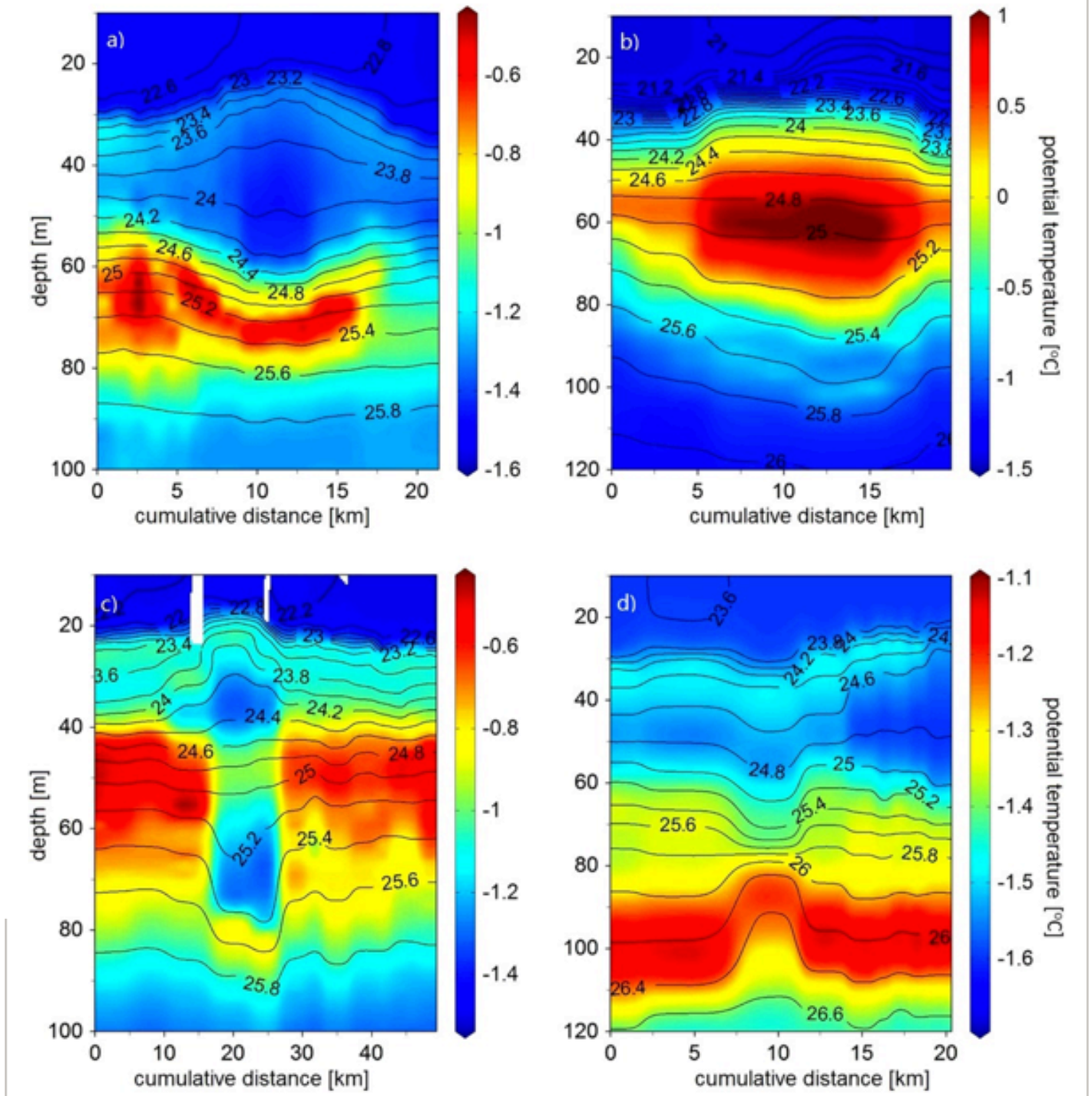

Figure 6

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Representative potential temperature (color) and potential density (referenced to the surface) [kg/m^3, contours] of all eddy types. (a) A cold-core eddy (ITP 3, 76.1°N, 136.0°W, December 2005); (b) a warm-core eddy (ITP 5, 76.1°N, 144.9°W, February 2007); (c) a combination-temperature-core eddy (ITP 64, 78.8°N, 141.0°W, October 2012); (d) a cyclonic eddy (ITP 1, 79.1°N, 140.6°W, November 2005).

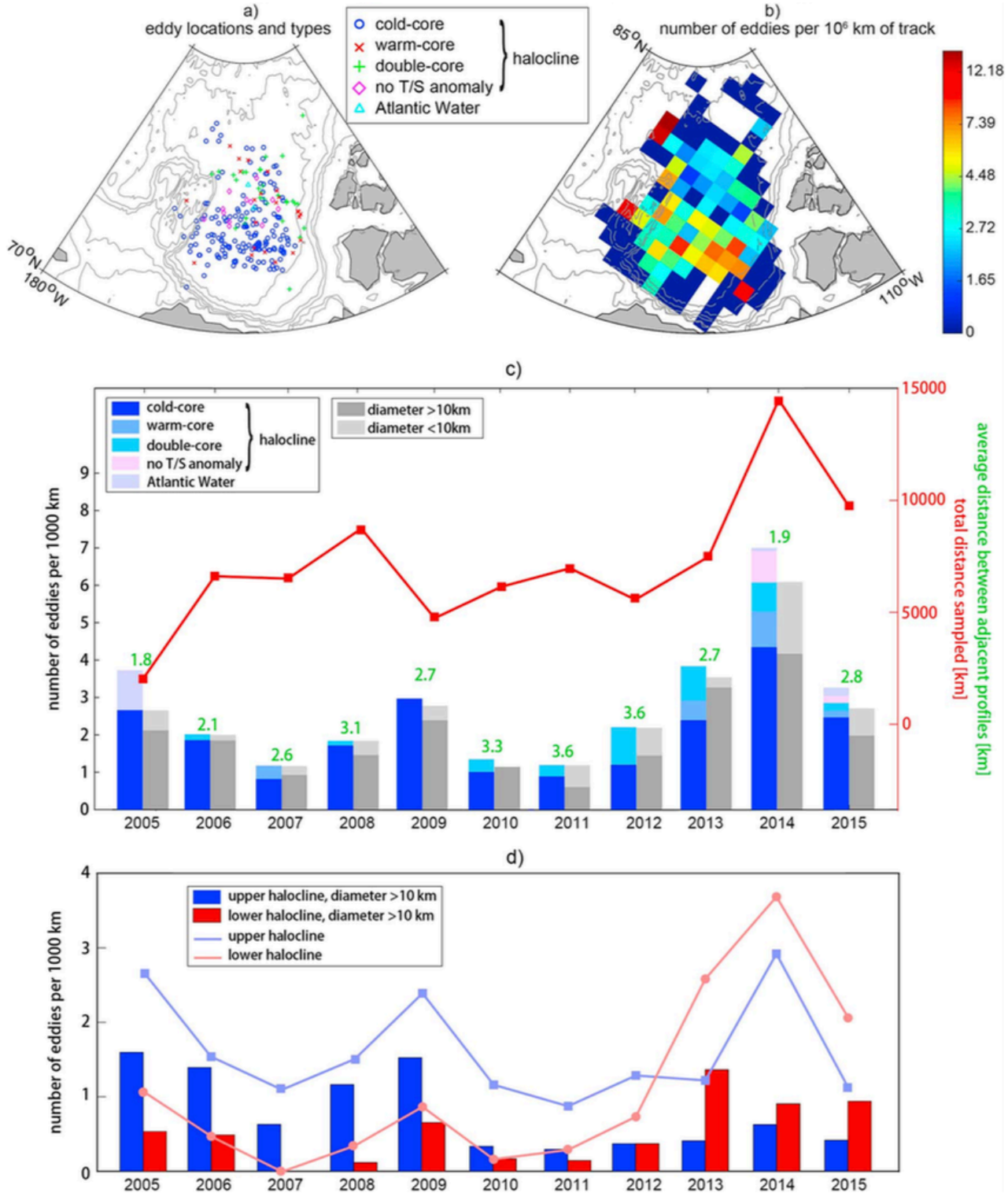

Figure 2. (a) Eddy locations and types sampled between 2005 and 2015 from all ITPs. (b) Number of eddies per 10^6 km of ITP drift track in each 100 km×100 km cell. (c) Time series of the number of anticyclonic eddies per 1000 km (bars) and total cumulative (along track) distance (red line) sampled from 2005 to 2015. Green numbers indicate the average distance (km) between adjacent ITP profiles (i.e., average horizontal resolution). Colored bars include all types of anticyclonic eddies. Grey bars include only halocline anticyclonic eddies detected based on temperature and salinity fields and not velocity. (d) Time series of the number of upper halocline eddies (blue, core salinity <32) and the number of lower halocline eddies (red, core salinity >32) per 1000 km. The lines include all halocline anticyclonic eddies identified only from temperature and salinity measurements, and the bars include only eddies larger than 10 km in diameter.

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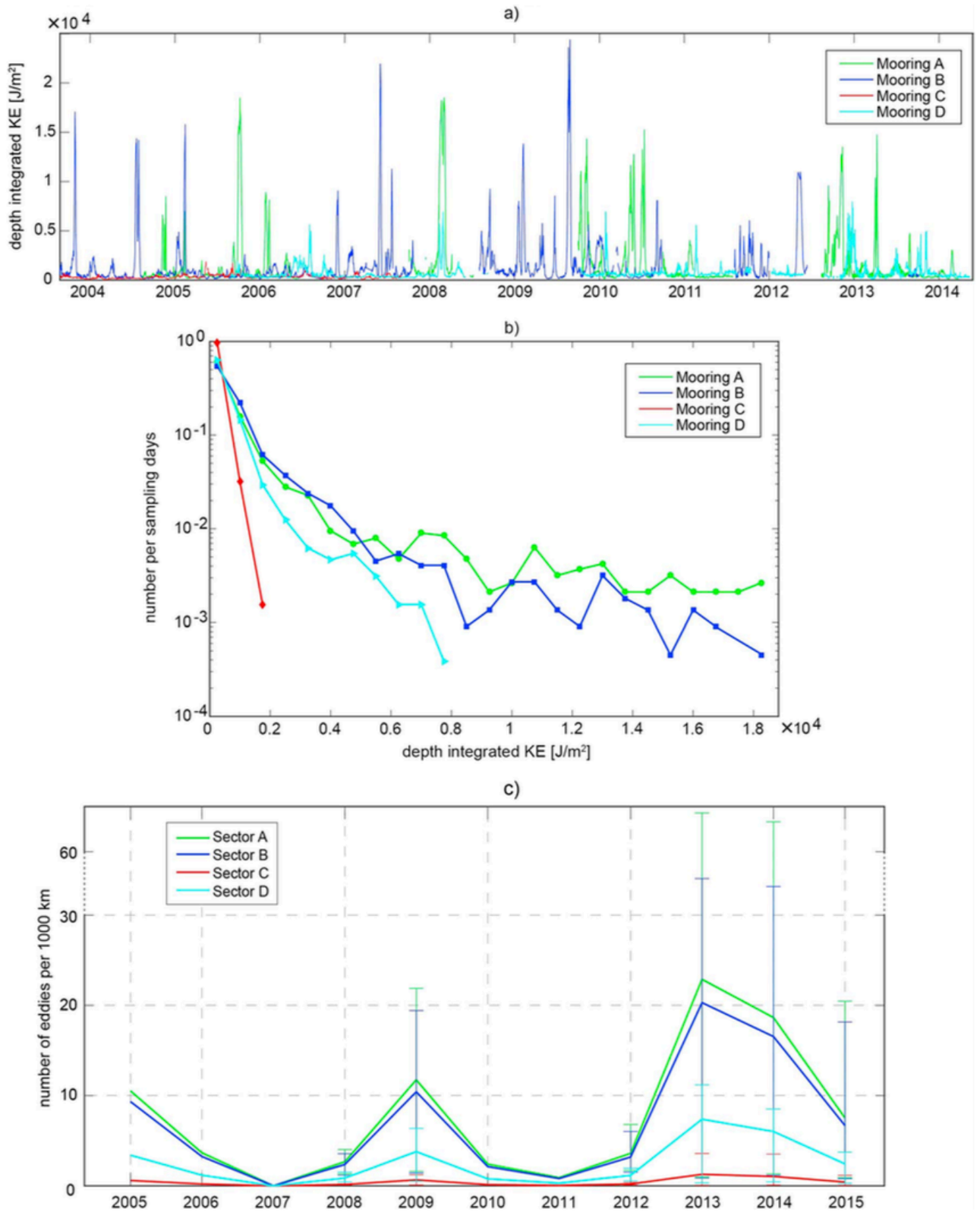

Figure 3. (a) Depth-integrated kinetic energy (KE) from 90 m to 750 m (see text) from all mooring measurements between 2003 and 2013. The absence of measurements indicates gaps in the mooring records. (b) A histogram of depth-integrated KE (J/m^2) between 90 m and 750 m for a bin size of 750 J/m^2 normalized by the total number of sampling days. (c) The number of lower halocline eddies per 1000 km estimated from ITP data in each of the four sectors accounting for the spatial variability indicated by the moorings (see text). Vertical bars indicate the minimum and maximum estimates when ITP measurements in 1 year cover more than one of the four sectors.

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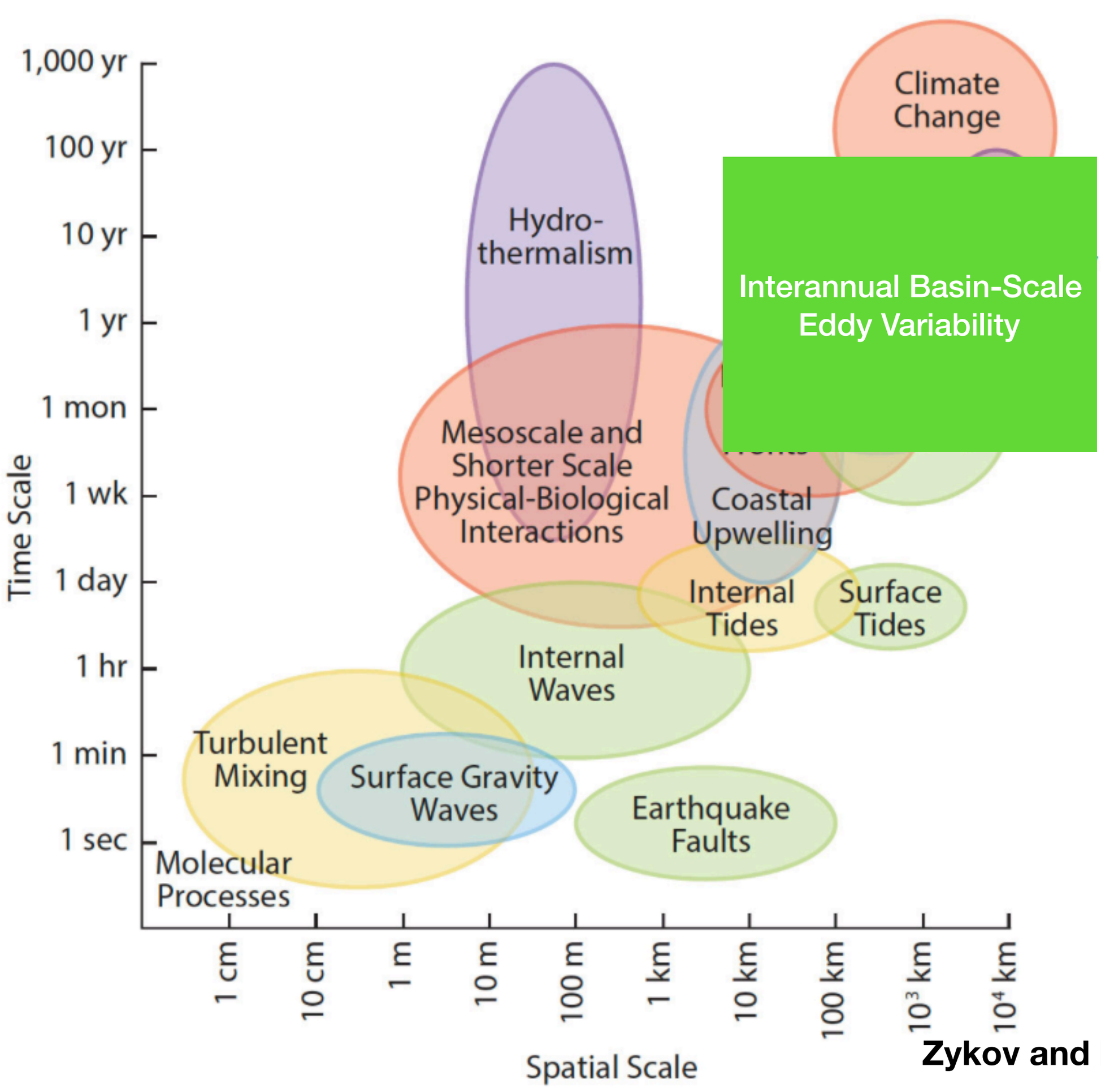

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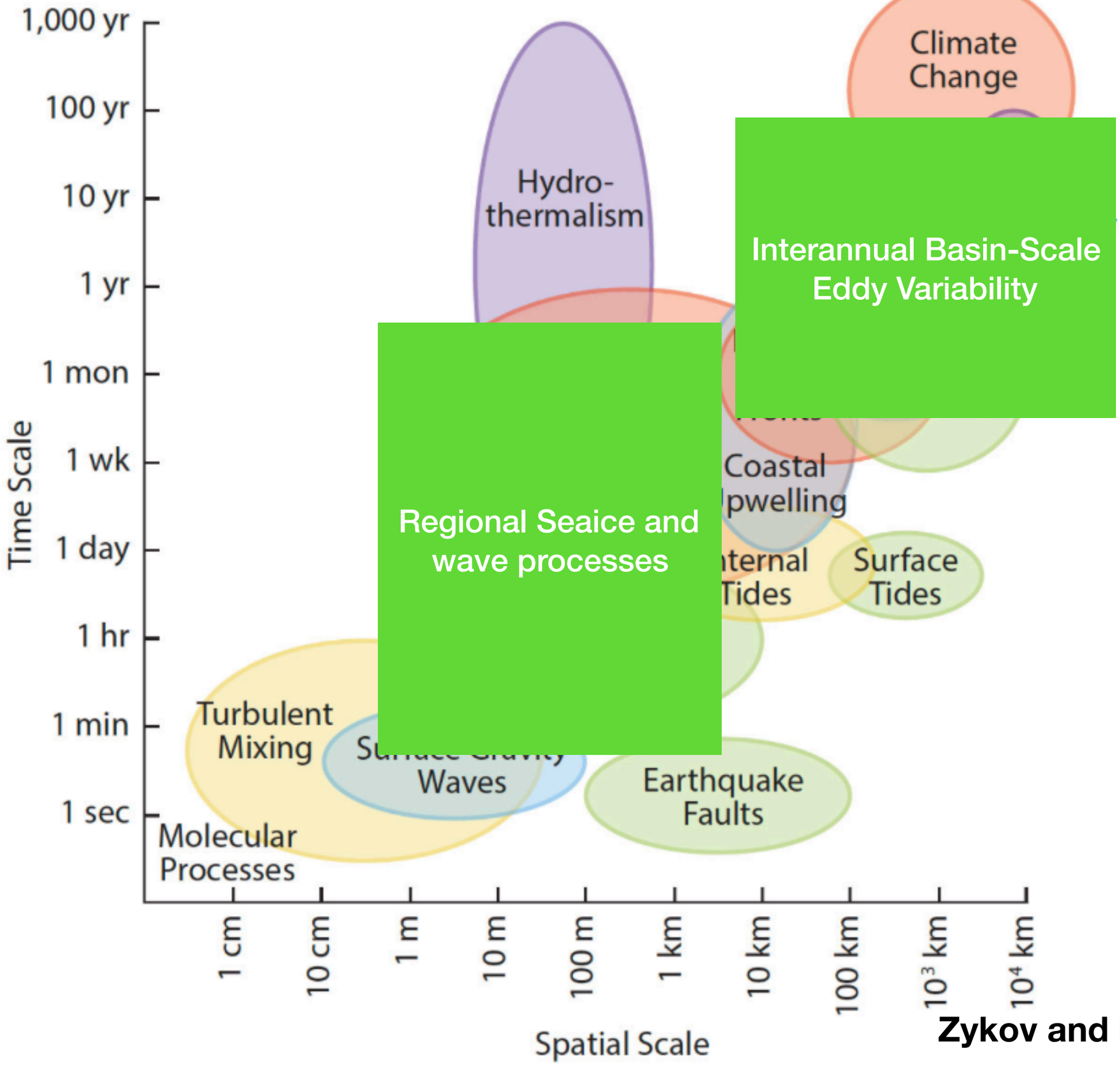

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Questions

- Is increased wind stress in the Beaufort increasing transport, or is energy cascading to the eddy field?

- If the increased fresh water and eddy fields are to be a sustained signal, what are the longer term consequences and feedbacks?

- How can oceanographers best leverage increased arctic seasonal ice area to practice the craft?