Water mass properties derived from satellite observations in the Barents Sea

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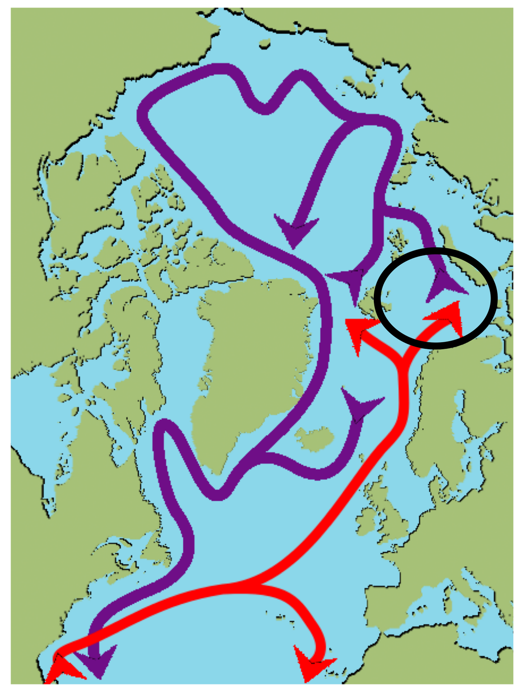
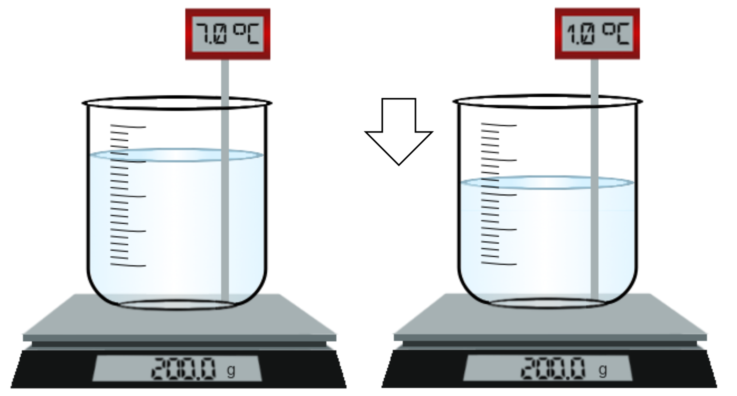
1. Motivation:

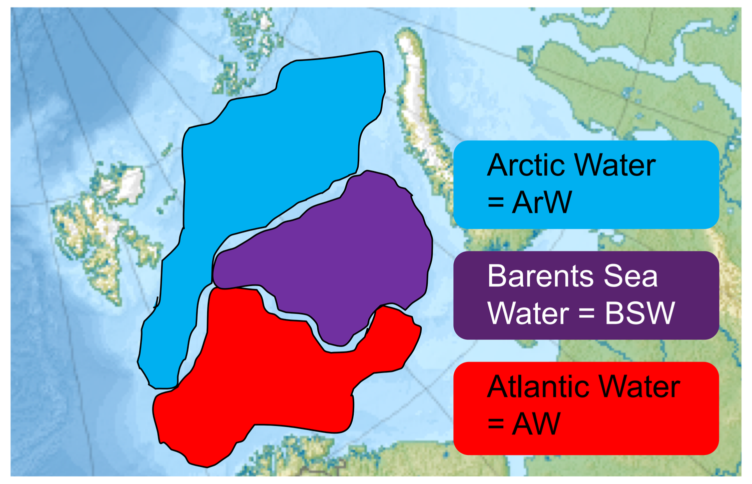
- The Barents Sea is an Arctic region that has shown a strong decline in winter sea ice extent since 1979[1], caused by warming AW[2].
- The heat loss from the ocean in the Barents Sea is known to affect weather patterns in Europe[3].
- The water mass formed during heat loss (Barents Sea Water) makes up 50 to 80 % of Arctic Intermediate Water, a contributor to the deep Atlantic meridional overturning circulation (AMOC)[4].



2. Background:

- If we know the mass and volume of a body of water we can calculate the steric height i.e. integrated inverse density.
- If we observe a change in steric height and we know the temperature change we should be able to calculate any salinity change.
- BSW is formed seasonally, through heat loss and freshwater input.
- Following an increase in AW temperature and salinity, since the mid-2000s BSW has become warmer and saltier[5] suggesting a need to monitor it before it is exported to Arctic Intermediate Water.



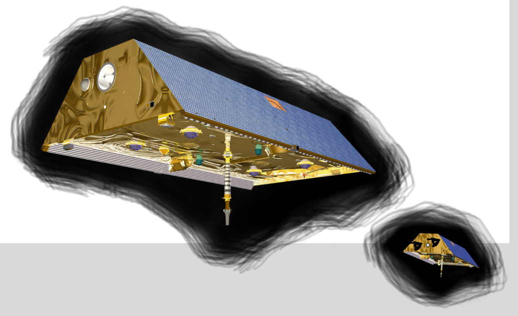


Questions:

- **Can we use satellite sea surface height (SSH), ocean bottom pressure (OBP) and sea surface temperature (SST) to estimate steric height, heat content and freshwater content in the Barents Sea?**
- **What causes variability in BSW properties?**

3. Datasets:

- Under-sea-ice SSH from CPOM (available 2003 to 2013).
- OBP from the Gravity Recovery and Climate Experiment (GRACE).
- Satellite Sea Surface Temperature and Sea Ice Analysis (OSTIA).
- Subsurface ocean profiles and objective analyses (EN4).
- Global atmospheric reanalysis (ECMWF ERA-Interim).



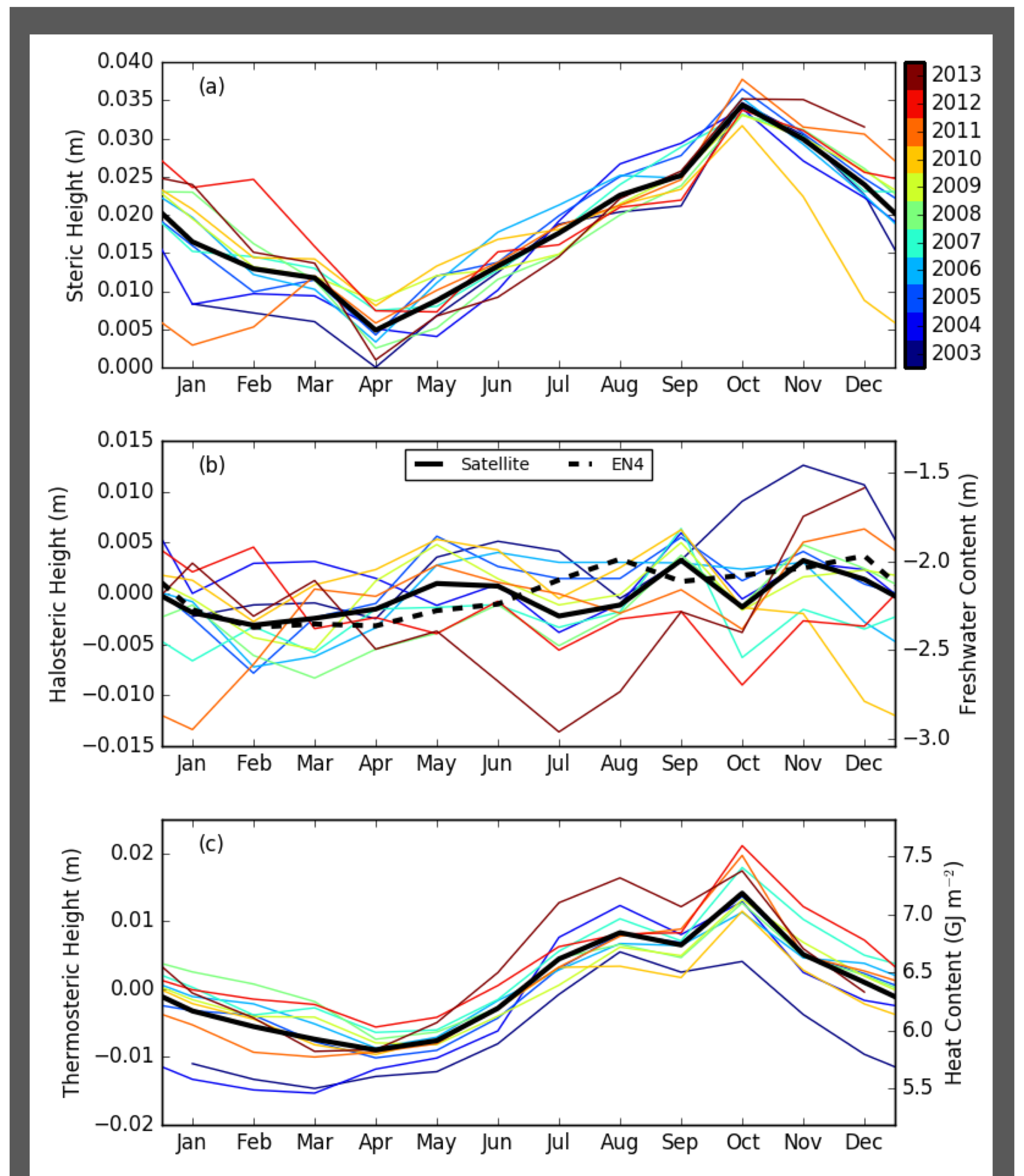


Figure 4: (a) Mean seasonal cycle and interannual variability in an area averaged box in Central Basin (35° E to 47° E and 71° N to 76° N, purple box on Figure 3). The thick line shows mean seasonal cycle and coloured lines show individual years for; (a) satellite steric height, (b) satellite halosteric height and (c) satellite thermosteric height.

4. Water properties from satellite data:

- SST is converted to heat content using a bi-modal statistical model to account for the change in mixed layer depth between summer (AMJJAS) and winter (ONDJFM) (Figure 1).
- Satellite SSS observations do not overlap with the other datasets so Figure 2 shows what could be possible using EN4 data.
- Satellite steric height is calculated from SSH and OPB and has regression values with *in situ* EN4 data around 0.8 in the southern Barents Sea (Figure 2).
- Satellite heat content is converted to thermosteric height and subtracted from satellite steric height to estimate halosteric height i.e. freshwater content (Figure 3).

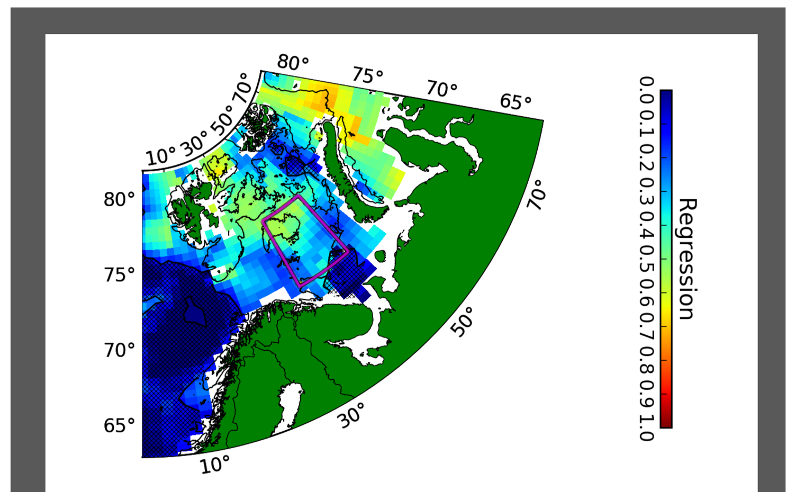


Figure 3: Regression of satellite freshwater content with EN4 freshwater content. Hatching shows areas with significance < 95 %. White, coastal areas show where data is not available. The purple box shows the Central Basin.

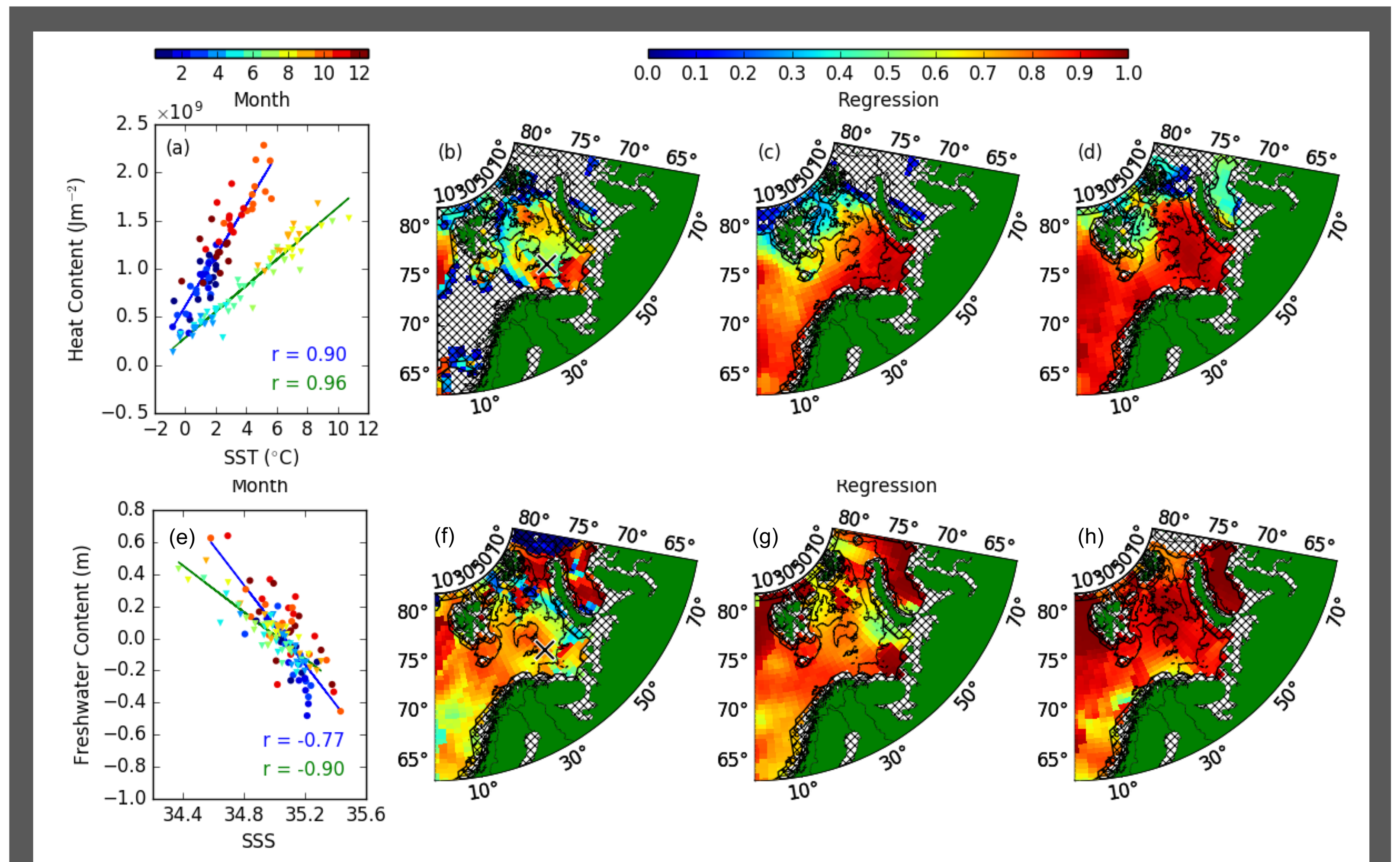


Figure 1: (a) Regression of satellite SST with EN4 heat content at single point in the Barents Sea, marked by "X" in (b). SST is regressed against heat content calculated to the optimum integration depths. Blue line and circles show winter season, green line and triangles show summer season. Regression of SST with heat content using (b) a one model system, (c) winter model and (d) summer model. Hatching on maps shows areas with significance < 95 %. (e,f,g,h) are the same as (a,b,c,d) but for EN4 SSS and EN4 freshwater content.

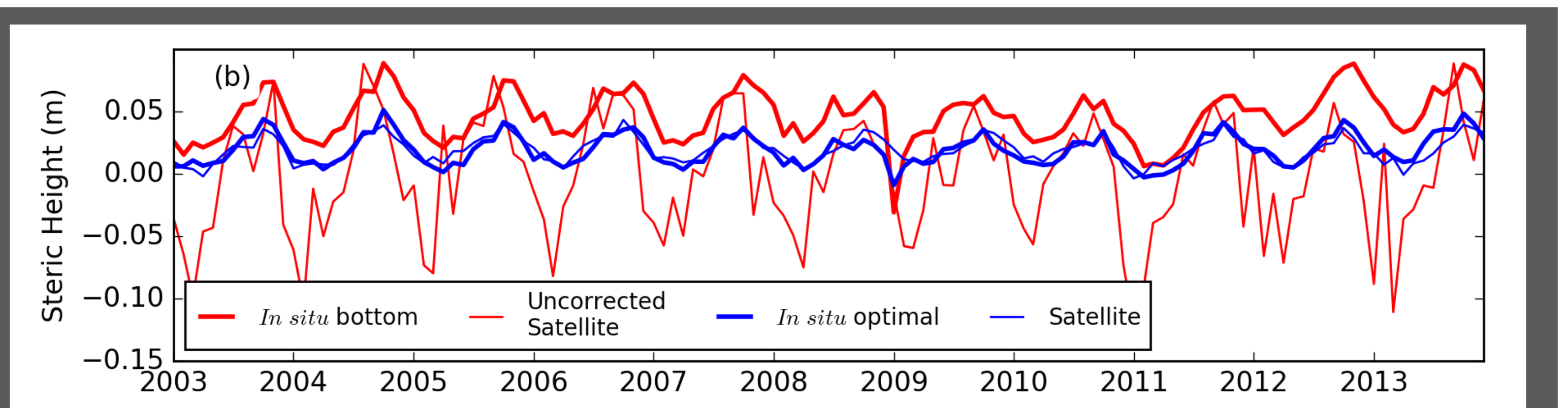


Figure 2: Satellite steric height plotted along side *in situ* EN4 steric height at the location marked "X" in Figure 1. The uncorrected satellite over-estimates *insitu* data (red) but is correlated with variability in the upper ocean (blue).

5. Variability in BSW properties:

- The strong seasonal cycle in steric height is caused by the seasonal cycle in heat content (Figure 4). A balance between the heat transport and atmospheric heat flux (Figure 5a).
- Interannually there is a shift in the steric height seasonal cycle towards increased winter steric height and decreased summer steric height (Figure 4). The shift results from a combination of interannual variability in heat and freshwater content.
- Interannual variability in freshwater content comes from a shifting seasonal cycle in sea ice extent towards earlier summer melt and later autumn freeze (Figure 5).
- Atmospheric freshwater fluxes also shift towards to increased winter evaporation and precipitation (Figure 5).

6. Conclusions:

- Using satellite observations alone we can estimate steric height, heat and freshwater content in the Barents Sea.
- The Barents Sea Water properties can be measured by satellites in the Central Basin, enabling monitoring of this key component of AMOC.
- Over 2003 to 2013, a delay in the seasonal cycle of steric height is a result of changes in sea ice melt-freeze and the hydrological cycle.

References:

1. Parkinson, C. and Cavalieri, D. 2008. Arctic sea ice variability and trends, 1979-2006. JGR: Oceans.
2. Årthun, M. et al. 2012. Quantifying the influence of atlantic heat on barents sea ice variability and retreat. Journal of Climate.
3. Hoshi, K. et al. 2019. Weak Stratospheric Polar Vortex Events Modulated by the Arctic Sea-Ice Loss. JGR Atmospheres.
4. Maslowski W. et al. 2004. On climatological mass, heat, and salt transports through the Barents Sea and Fram Strait from a pan-Arctic coupled ice-ocean model simulation. JGR.
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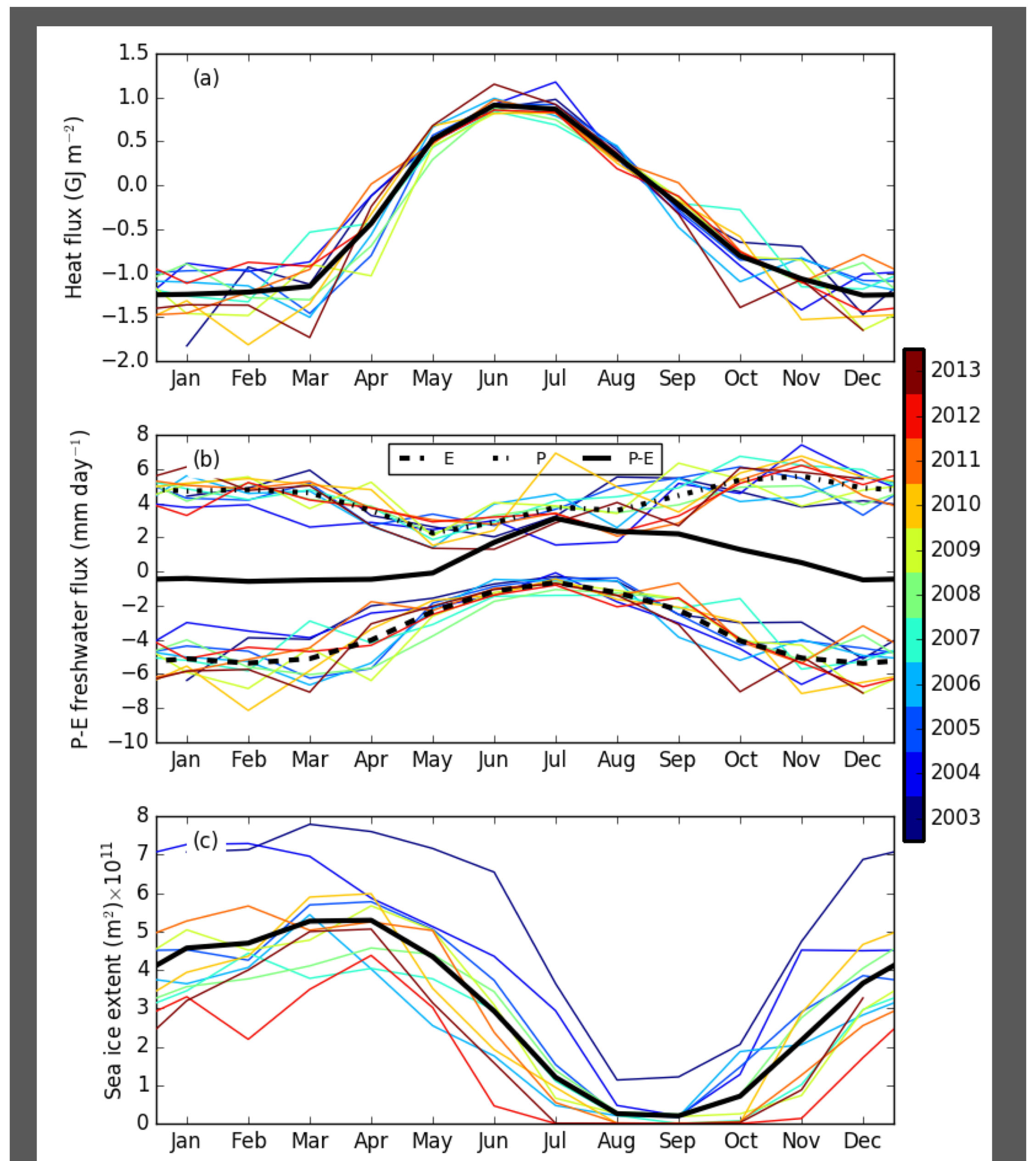

Figure 5: As Figure 5 but for (a) heat flux, (b) net atmospheric freshwater flux into ocean P-E with precipitation (P) and evaporation (E), (c) sea ice extent in the whole Barents Sea, a box defined by 10° E – 65° E and 68° N – 80° N.