2003-2016 freshwater changes in the Beaufort Gyre

Summary: The 2003-2016 hydrographic data collected from research cruises, moorings, Ice-Tethered buoy observations and satellite altimetry for the Beaufort Gyre region of the Arctic Ocean document an increase of over 6,500km³ of liquid freshwater content (a 40% growth) relative to climatology of the 1970s. This freshwater accumulation was a result of persistent anticyclonic atmospheric forcing (1997-2016) accompanied by ice melt, an anomalous wind-forced redirection of Makenzie River discharge from predominantly eastward to westward flow supplying the Beaufort Gyre region with its fresh water, and fresh water supply coming with waters of Pacific Ocean origin via Bering Strait. The fresh water contribution to the Beaufort Gyre freshwater reservoir from Siberian rivers in 2003-2011 was negligible but the presence of these waters in the region detected by geochemical analysis can be explained by suggesting that there are remnants of these waters penetrated into the region in 1989-1996 during cyclonic circulation regimes. A slight decrease of freshwater content in the region between 2010 and 2013 was associated with some relaxation of anticyclonic winds; however, in 2015 and 2016, the magnitude of freshwater was greater than ever measured previously due to combination of intensification of anticyclonic winds and fresh water supply from both ice melt and river discharge. In general, numerical models reproduce tendency of freshwater accumulation in the Beaufort Gyre region very well but underestimate freshwater content changes due to unavailing numerical mixing.

Above: Beaufort Gyre Region FWC (thousands km³) from different observations and wind stress curl (x1.E4, gcm⁻²s⁻¹). Dark blue narrow bars depict FWC from 2003-2016 August-October (depending on year) hydrographic surveys. Wide light blue bars show annual FWC inferred from 2003-2014 satellite altimetry. Blue solid line is monthly FWC from satellite altimetry data. Solid red and dashed black lines show monthly liquid FWC from TTPs and moorings, respectively. Solid blue line depicts changes in FWCI (in sea ice). Light blue solid line shows monthly and wide red bars show annual wind-stress curl over the region. Dotted lines are trends in FWC from hydrography (0.44x1.E3±0.08x1.E3 km³a⁻¹), moorings (0.45x1.E3±0.05x1.E3 km³a⁻¹), ITP data (0.55x1.E3±0.06x1.E3 km³a⁻¹) and altimetry (0.47x1.E3±0.05x1.E3 km³a⁻¹). Blue dotted line depicts -0.05x1.E3±0.06x1.E3 km³a⁻¹ trend in sea ice FWC. Wind stress curl has negative trend of -0.09 x1.E4± 0.01x1.E4 (gcm⁻²s⁻¹) indicating increase of Ekman pumping and tendency to potential freshwater accumulation in the region.

Right: Trajectories of floats released from Bering Strait in 2000 by the end of 2003, 2007, 2010 and 2013 based on results of ICMCG model. Colored bars show percentage of floats released 1 (0-1), 2 (1-2), 3 (2-3), 4 (3-4) and more than 5 years (>5) after release in 2003. Information at top right corner shows number of floats crossed Western, Northern, Eastern and Southern boundaries in the shown years. "Income" indicates number of floats accumulated in the region, while "Total" indicates number of floats remaining in the region since 2000. "Alive" show the total number of floats in the domain.

Above: Observed and simulated FWC anomalies (black solid and dashed, respectively). Solid blue: FWC from ice melt. Mackenzie River, Bering Strait and Siberian rivers contributions are: solid red, dashed red, and solid green lines. Dotted blue – FWC from boundaries.

Below: FWC (m, colors) climatology. Solid black line indicates climatology of Arctic freshwater content. Blue bars show observed and simulated freshwater content (blue bars) and CCRs (red bars) with a period of 10-14 years while during the last 17 years a strong ACCR has dominated over the Arctic Ocean. Vertical colored lines show beginning of GSAs of the 1970s, 1980s, and 1990s from Belkin et al. [1998].