The State of the Arctic

Martin Jeffries, PhD
Office of Naval Research
Arctic & Global Prediction Program

Naval Academy Science & Engineering Conference • 9 November, 2015 • Annapolis, MD
Sea Ice

**Maximum ice extent** in 2015 occurred on 25 February, 15 days earlier than average, and was the lowest in the satellite record.

**Minimum ice extent** in September 2015 was the 4\(^{th}\) lowest in the satellite record.

**Maximum ice extent** is declining at a rate of -2.6% per decade relative to the 1981-2010 average.

**Minimum ice extent** is declining at a rate of -13.4% per decade relative to the 1981-2010 average.

The age of sea ice, a proxy for thickness, is decreasing.
Age of Sea Ice: A Movie

Age of the Ice
September 2015

Source: NSIDC
Outline

1. The U.S. Navy & The Arctic
2. Look Beyond the Sea Ice
The U.S. Navy & The Arctic: 1

Source: Perovich et al., 2014

Ice Extent, March
Ice Extent, September

Source: Jeffries et al., 2013

USS Alexandria (SSN 757), ICEX-07
Photograph: U.S. Navy
Navy’s Strategic Objectives for the Arctic Region

- Ensure U.S. Arctic sovereignty and provide homeland defense
- Prepare naval forces to respond to potential crises and contingencies to maintain security and stability in the Arctic
- Preserve freedom of the seas
- Promote partnerships within the U.S. Government and with international friends and allies
ONR Arctic and Global Prediction Program

Program Motivation
The changing Arctic marine environment, particularly the rapid decline in summer ice extent, has implications for future safe and effective US Navy operations.

Program Goal
Improve Navy understanding of, and capability to predict, the Arctic operational environment: Sea Ice, Winds, Waves, Sea Spray, Icing, Fog .........

Program Thrusts
1. Fully-coupled ocean-wave-ice-atmosphere system **modelling** with sufficient resolution to represent key processes, and assimilation of *in situ* and remotely-sensed observations.
2. Improve **understanding** of the Arctic environment and processes to enable more accurate representation in models, leading to improved prediction.
3. Develop **observing** technology for sustained measurements that can provide long-term monitoring, further scientific understanding and constrain the models.
..... and you see change occurring throughout the Arctic environmental system.

- Change is occurring on land, in the atmosphere and in the ocean.
- The changes are physical and biological.
- Arctic environmental change affects people and has global consequences.
In 2014, the mean annual surface air temperature anomaly for Arctic lands was +1.1°C (relative to the 1981-2010 mean).

The rate of warming in the Arctic is >2x the rate of the rest of the World.

In early 2014, Arctic and mid-latitude weather patterns were strongly connected: *The Polar Vortex!!!!!*

Autumn air temperature anomaly: early 21st Century vs. late 20th Century.

Alaska: +10°C January temperature anomaly.

Atlanta, GA: -14°C on 7 January.

Record rainfall and flooding in southern England.

NOAA PMEL
Spring Snow Cover Extent is declining in Eurasia & North America

- Record low snow cover extent in April 2014 in Eurasia.
- Below average snow cover extent in May 2014 in Eurasia and North America for the 9th time in the last 10 years.
- Below average snow cover extent in 2014 in Eurasia and North America for the 10th consecutive June.
Snow Cover & Sea Ice

Emerging evidence that Arctic warming is driving synchronous pan-Arctic responses in the terrestrial and marine cryosphere.

Per decade decline, 1979-2014
- May snow cover extent: -7.3%.
- June snow cover extent: -19.8%.
- September sea ice extent: -13.4%.

The rates of decline in terrestrial snow cover extent in May and June bracket the rate of decline in September sea ice extent.

Albedo

Snow: 0.9
Bare Ice: 0.6
Ocean: 0.06

Albedo: 1
Albedo: 0

Why loss of snow and ice matters.

Don Perovich, CRREL
Greenland Ice Sheet

No. of days with melting in June (L) and July (R) 2014. Anomaly relative to 1981-2010 average.

Summer 2014 albedo anomaly (relative to 2000-2011).

In 2014, a record low albedo for August.

GRACE satellite measurements show that the total mass balance ($\Delta M$, in gigatonnes) of the ice sheet has been declining since observations began in 2002.
(a) SST is increasing, with the most significant trend occurring in the Chukchi Sea (+0.5°C per decade during 1982-2010. (b) In 2014, SST was highest in the Chukchi and Barents seas, reflecting the timing and rate of ice retreat.
Primary production: The conversion, primarily by photosynthesis, of atmospheric or aqueous CO₂ to organic matter. In the ocean, almost all photosynthesis is by algae, and in the Arctic it is dependent on ice retreat, light and nutrients. Arctic Ocean primary production is increasing.

Data source: Petrenko et al., 2013

The timing of primary production is changing, with a shift to secondary blooms in the autumn. Reason: extended open water season, autumn storms, upper ocean mixing and increased nutrient availability.
Arctic-wide, Maximum (Max)-NDVI, which is strongly correlated with above-ground biomass, increased ~20% between 1982 and 2013, equivalent to a biomass increase from ~357 g m$^{-2}$ to 430 g m$^{-2}$.

NDVI integrated over the entire growing season (TI-NDVI) increased (greening) until ~2000, then began to decline (browning). Reasons: decrease in growing season length due to permafrost degradation and hydrological change; declining summer air temperature in Eurasia.
Summary

Change is occurring throughout the Arctic environmental system. It’s not all about sea ice.

- Change is occurring on land, in the atmosphere and in the ocean.
- The changes are physical and biological.
- Arctic environmental change has global consequences.
- The “State of the Arctic” is reported annually in the Arctic Report Card (December) and in the State of the Climate report (July/August).

- **Arctic Report Card**: [http://www.arctic.noaa.gov/reportcard](http://www.arctic.noaa.gov/reportcard)

**Acknowledgement**: My co-editors Jackie Richter-Menge (U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory) and Jim Overland (National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory).
Thank You.

Are there any Questions?

Shameless Promotion: Arctic Report Card 2015 will be released on Tuesday, 15 December at the American Geophysical Union Fall Meeting in San Francisco, CA