Trends in Arctic Sea Ice Characteristics, 1982-2004

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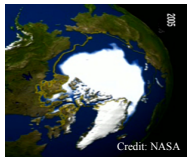
Introduction

Sea ice is a very important indicator and an effective modulator of regional and global climate change. Changes in sea ice will significantly affect the complex exchanges of momentum, heat, and mass between the sea and the atmosphere, and will have profound socio-economic influences due to its role in transportation, fisheries, hunting, polar animal habitat. Over the last two decades of the 20th century, the Arctic underwent significant changes in sea ice. More accurate, consistent, and detailed ice thickness, extent, age, and volume data are critical for a wide range of applications including climate change detection, climate modeling, and operational applications such as shipping and hazard mitigation.

Satellite data provide an unprecedented opportunity to estimate and monitor Arctic sea ice routinely with relatively high spatial and temporal resolutions.

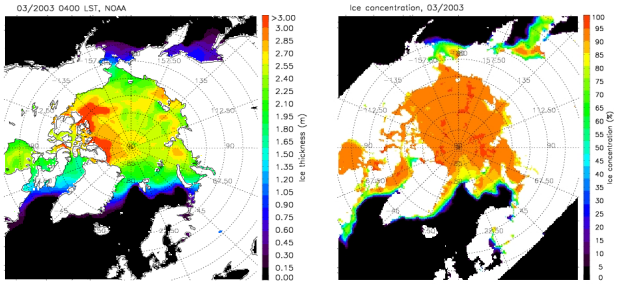


Data and Methods

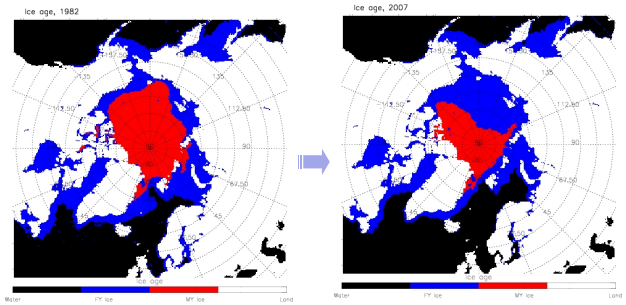
In this study, a **One-dimensional Thermodynamic Ice Model (OTIM)** has been developed to estimate sea ice thickness based on the surface energy balance at thermo-equilibrium state. It has been extensively validated against submarine Upward-Looking Sonar (ULS) measurements, meteorological station measurements, and numerical model simulations. Overall, OTIM-estimated sea ice thickness is accurate to within about 20% when compared to submarine ULS ice thickness measurements and Canadian meteorological station measurements for ice not greater than 3 m.

The OTIM has been used with satellite data from the extended Advanced Very High Resolution Radiometer (**AVHRR**) Polar Pathfinder (**APP-x**) products to derive Arctic sea ice thickness for the period 1984~2004. Ice volume is estimated using thickness derived by OTIM with AVHRR data, and ice concentration and extent derived by the NASA Team Algorithm with Nimbus-7 SMMR and DMSP SSM/I passive microwave Data. A statistical analysis of spatial and temporal distributions and trends in sea ice concentration, extent, thickness, age, and volume over the satellite period has been performed. The preliminary results show clear evidence that the Arctic sea ice has been experiencing significant changes over the past two decades of the 20th century. It has been shrinking at an unexpected rate since 1997; the decline being particularly apparent in the autumn.

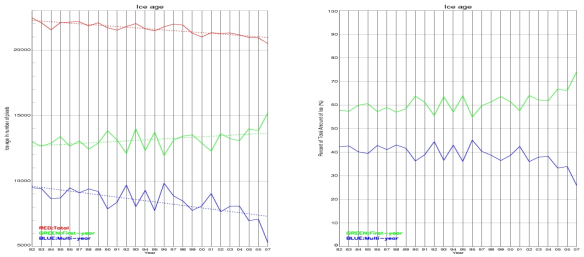
Arctic Sea Ice Spatial and Temporal Characteristics



OTIM retrieved Arctic sea ice thickness distribution in March, 2003 from AVHRR data (left) and the corresponding ice concentration at the same time from Nimbus-7 SMMR and DMSP SSM/I passive microwave data (right).



Ice age change from 1982 (left) to 2007 (right). FY=first-year ice; MY=multi-year ice.

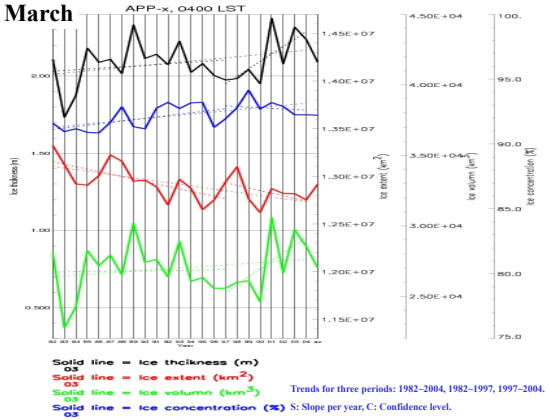


Times series of total ice extent (red), first-year (FY) ice extent (green), and multi-year (MY) ice extent (blue), and the ratios of FY and MY ice extent to the total ice extent. Pixel size is 625 km^2. Over 1982~2007, the total ice extent declined at the rate of ~32.6x10^3 km^2/yr, MY ice extent declined at the rate of ~ 57.3x10^3 km^2/yr, while FY ice extent increased at the rate of ~ 24.7x10^3 km^2/yr. All three trends are statistically significant at the significant level greater than 95%.

Arctic Sea Ice Changes over 1982~2004

Trends in Arctic sea ice extent, thickness, volume, and concentration (1982-2004 from extended AVHRR Polar Pathfinder (APP-x) dataset, 04:00)

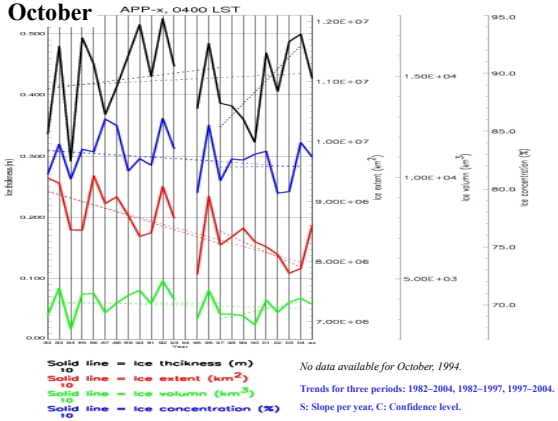
• Ice extent (km^2), thickness (m), volume (km^3), and concentration (%) - March



Ice thickness: *S=0.007, C=0.87; S=0.005, C=0.47; S=0.048, C=0.96.* **Ice extent**: *S=-17030, C=0.99; S=-25760, C=0.99; S=-27550, C=0.77.* **Ice volume**: *S=56.16, C=0.64; S=10.19, C=0.08; S=560.2, C=0.92.* **Ice concentration**: *S=0.08, C=0.99; S=0.11, C=0.98; S=-0.05, C=0.31.*

Trends in Arctic sea ice extent, thickness, volume, and concentration (1982-2004 from extended AVHRR Polar Pathfinder (APP-x) dataset, 04:00)

• Ice extent (km^2), thickness (m), volume (km^3), and concentration (%) - October



Ice thickness: *S=0.0009, C=0.33; S=0.0023, C=0.46; S=0.0190, C=0.96.* **Ice extent**: *S=-53200, C=0.99; S=-58870, C=0.97; S=-85480, C=0.99.* **Ice volume**: *S=-14.27, C=0.51; S=-0.12, C=0.00; S=120.8, C=0.93.* **Ice concentration**: *S=-0.065, C=0.68; S=-0.060, C=0.37; S=0.010, C=0.02.*