Use of observational data sets: Arctic and Antarctic sea ice

- **Current**
  - Sampling, continuity, and calibration

- **Future**
  - CMIP6 model evaluation/assessment
  - Development? Processes?
Regional trends in ice coverage and mean ice motion (33-year)

Arctic

- Siberia: +7.3%
- Alaska: -2.2%
- Barents Sea: -2.5%
- Greenland: -9.3%

5 km per day

Antarctic

- Antarctic Peninsula: +3.2%
- Weddell Sea: +1.3%
- Ross Sea: +4.3%

10 km per day

Extent anomalies (10⁶ km²)
- Arctic: -3.8% per decade
- Antarctic: +1.5% per decade

obs4mips-2014

IPCC WG1-Ch 4 FAQ 2 Kwok
Summary of Arctic sea ice changes in AR5-WG1 Chapter 4: Cryosphere

5 Key Indicators

- **Extent**: Ice extent anomaly (10^6 km²)
  - 1980-2010: -3.9±0.2%/decade

- **Thickness**: Ice thickness (m)
  - Winter: -0.62 m/decade

- **Multiyear ice**: Multiyear ice coverage (Jan-1)
  - 1980-2010: -0.80±0.2 x 10^6 km²/decade

- **Length of melt season**: Length of melt season (days/decade)
  - 1980-2010: 6.0±1.0 days/decade

- **Drift speed/Circulation**: Drift speed (km/day/decade)
  - 1980-2010: 0.55±0.04 km/day/decade
Arctic summer ice extent: Comparison with models

Stroeve and Barrett, 2012

RCP4.5 = CMIP5
SRESA1B = CMIP3

September Ice Extent

10^6 km^2

1953-2011
- Observed = -9.0 + 0.60%/dec
- RCP4.5 = -4.6 + 0.30%/dec
- SRESA1B = -4.2 + 0.25%/dec

1979-2011
- Observed = -13.0 + 1.49%/dec
- RCP4.5 = -8.2 + 0.37%/dec
- SRESA1B = -6.6 + 0.42%/dec

Stroeve and Barrett, 2012
Decline in sea ice thickness from submarine and ICESat records: 1978 - 2009

Note: Submarine estimates based on regression of available ice draft from US Navy submarines

(Kwok and Rothrock, 2009)
ICESat/CryoSat-2
Arctic basin ice volume

- Intersatellite bias: ~700 km³
- Yearly decrease: -406 km³/yr in Feb-Mar, -1042 km³/yr in Oct-Nov
- Total decrease: 4000 km³

Data from ICESat and CryoSat-2.
Sea ice thickness/volume
Ice thickness – spatial distribution
Comparisons with models

observed

Ice Thickness

meters

0  2.5  5
Thickness distribution (CCSM4 vs ICESat)

Jahn et al., 2012
Ice thickness distribution

Sample thickness distribution: ~100 km transect

Extremes are Associated with Dynamics

New Ice in fractures
Limit of Seasonal Growth
Thick multiyear ice and Ridges

Thick multiyear ice and Ridges

Thickness distribution: Variability due to Thermodynamics and Dynamics
Ice Drift:
Large Scale
The average winter sea ice thickness within the Arctic Basin decreased between 1980 and 2008 (high confidence). The average decrease was likely between 1.3 and 2.3 m. High confidence in this assessment is based on observations from multiple sources: submarine, electro-magnetic (EM) probes, and satellite altimetry, and is consistent with the decline in multi-year and perennial ice extent. Satellite measurements made in the period 2010-2012 show a decrease in sea ice volume compared to those made over the period 2003-2008 (medium confidence). There is high confidence that in the Arctic, where the sea ice thickness has decreased, the sea ice drift speed has increased.
Ice thickness – spatial distribution
Comparisons with models

observed
Ice Thickness

meters
0  2.5  5

obs4mips-2014  13  Kwok
Large scale circulation/export
Model geostrophic winds

- Center of High
- Model center

5 m/s Geostrophic Wind

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Ice Area/Volume Export – variability
(mass/area balance)
Satellite Ice Drift and MY ice coverage
1992-2010

MY ice coverage trend

-0.80 \times 10^6 \text{km}^2/\text{decade}

Trend in drift speed

Kwok et al., 2013
Some of the wind-driven trends reported were noted in AR-5 1992-2010

Holland and Kwok, 2013
Summary (1)

- Modelers are actively using the available products for model evaluation
  - Available gridded data sets
  - Variables examined:
    - Coverage, age, thickness, volume, melt season, motion

- Limitations
  - Still limited to ~30 years of data
Summary (2)

Observational data sets - Current
• (Arctic)
  • Ice Thickness/Volume
  • Mix of satellite, submarine, in-situ obs
  • Coarse Ice Drift (32 years)
  • Length of melt season (Onset to freeze-up) (32 years)
  • Ice Age (multiyear, seasonal ice)

• (Antarctic)
  • Ice Drift (32 years)
  • Length of melt season (32 years)
Summary (3)

Future

- (Arctic)
  - Ice Thickness/Volume (monthly)
  - Better satellite obs (CryoSat-2, ICESat-2)
  - Coarse Ice Drift (continuing time series)
  - Fine scale ice drift (ice deformation)
  - Length of melt season (continuing)
  - Melt pond coverage

- (Antarctic)
  - Coarse Ice Drift (continuing)
  - Length of melt season (continuing)
  - Ice thickness (???)
Summary (4)

CMIP6 sampling (Arctic/Antarctic) needs

- Ice Thickness/Volume (monthly)
- Coarse Ice Drift (monthly – daily?)
- Length of melt from ice/snow surface temperatures (surface daily)
- Multiyear ice coverage (that's more difficult)