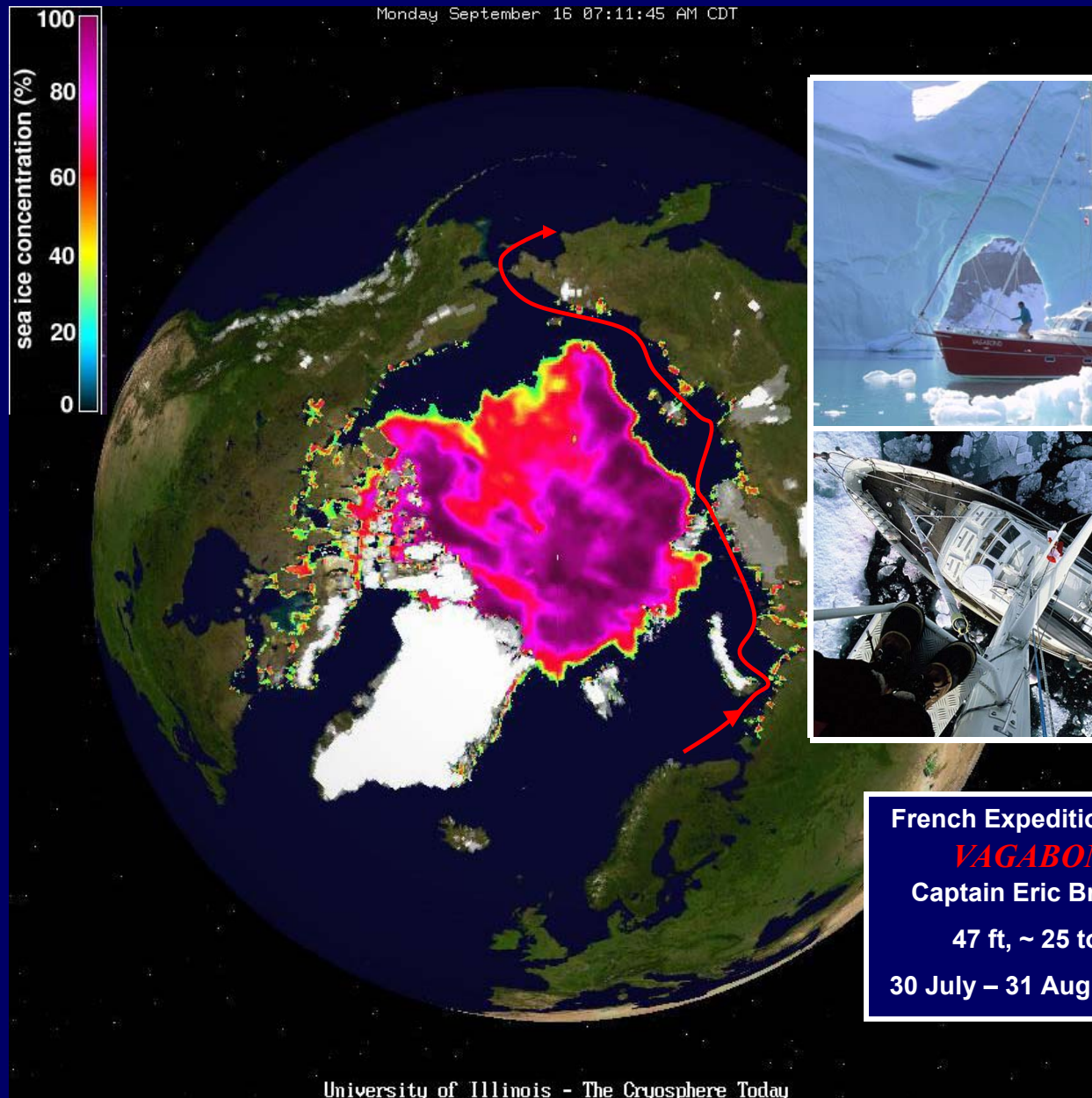
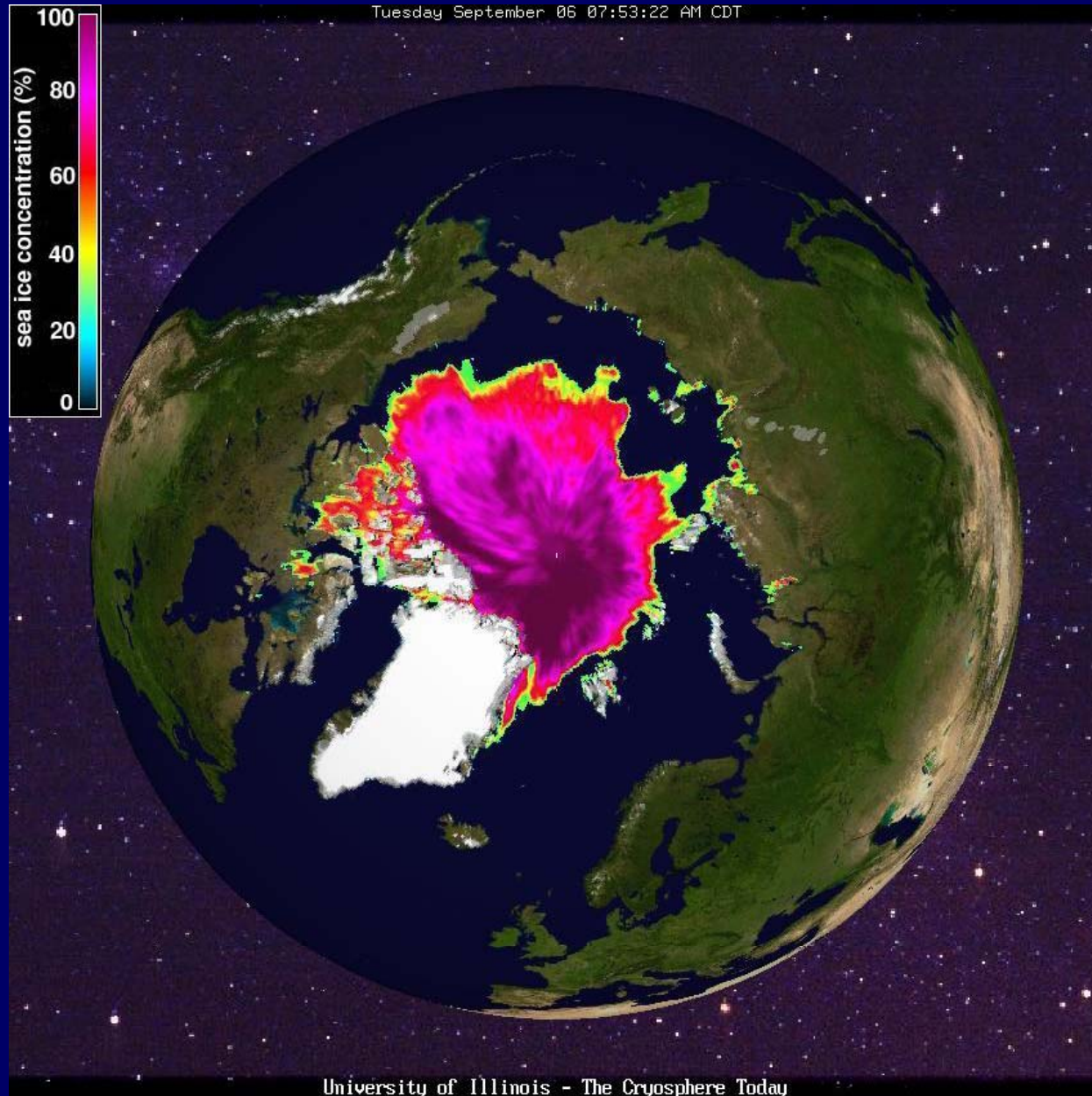


16 September 2002

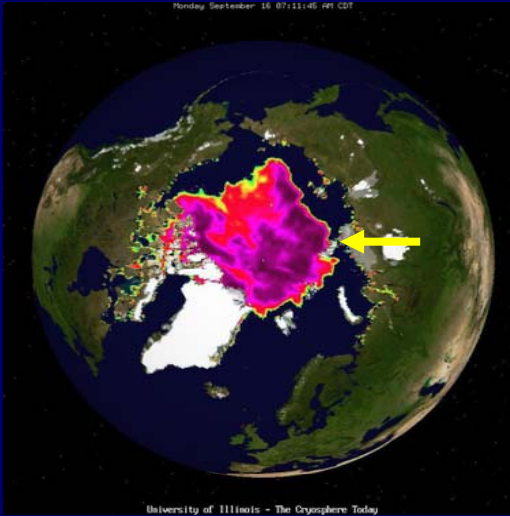


6 September 2005

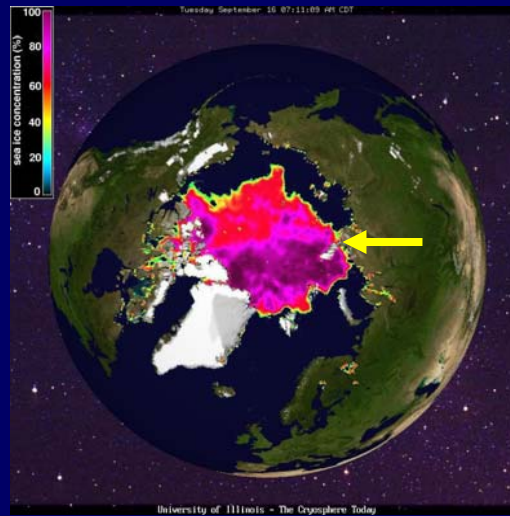
Historic Minimum Arctic Sea Ice Extent



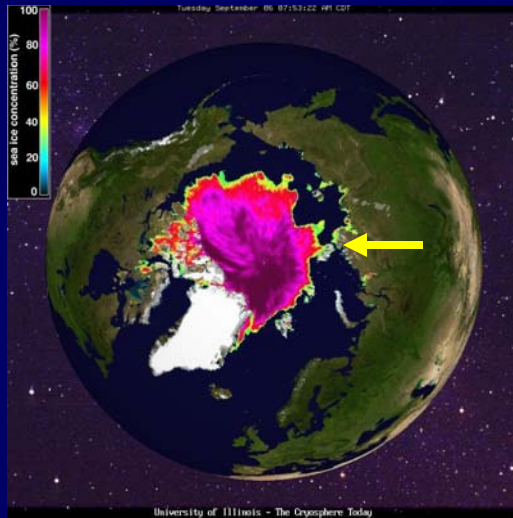
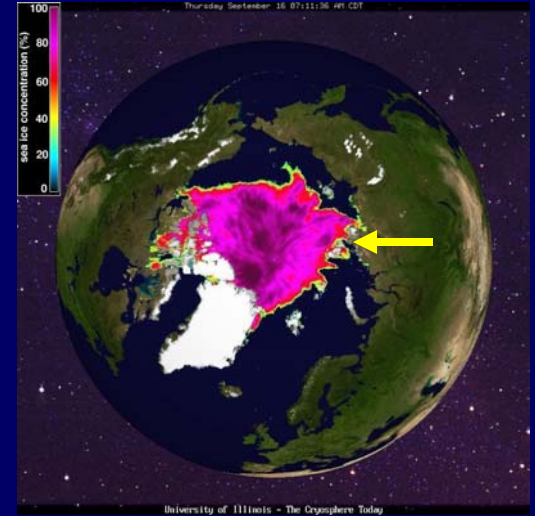
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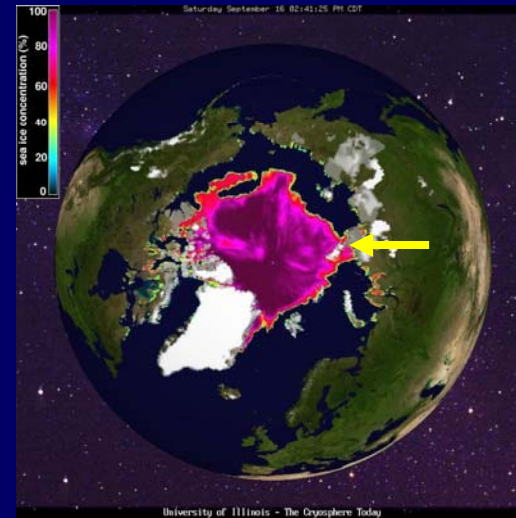
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16 September 2004



6 September 2005

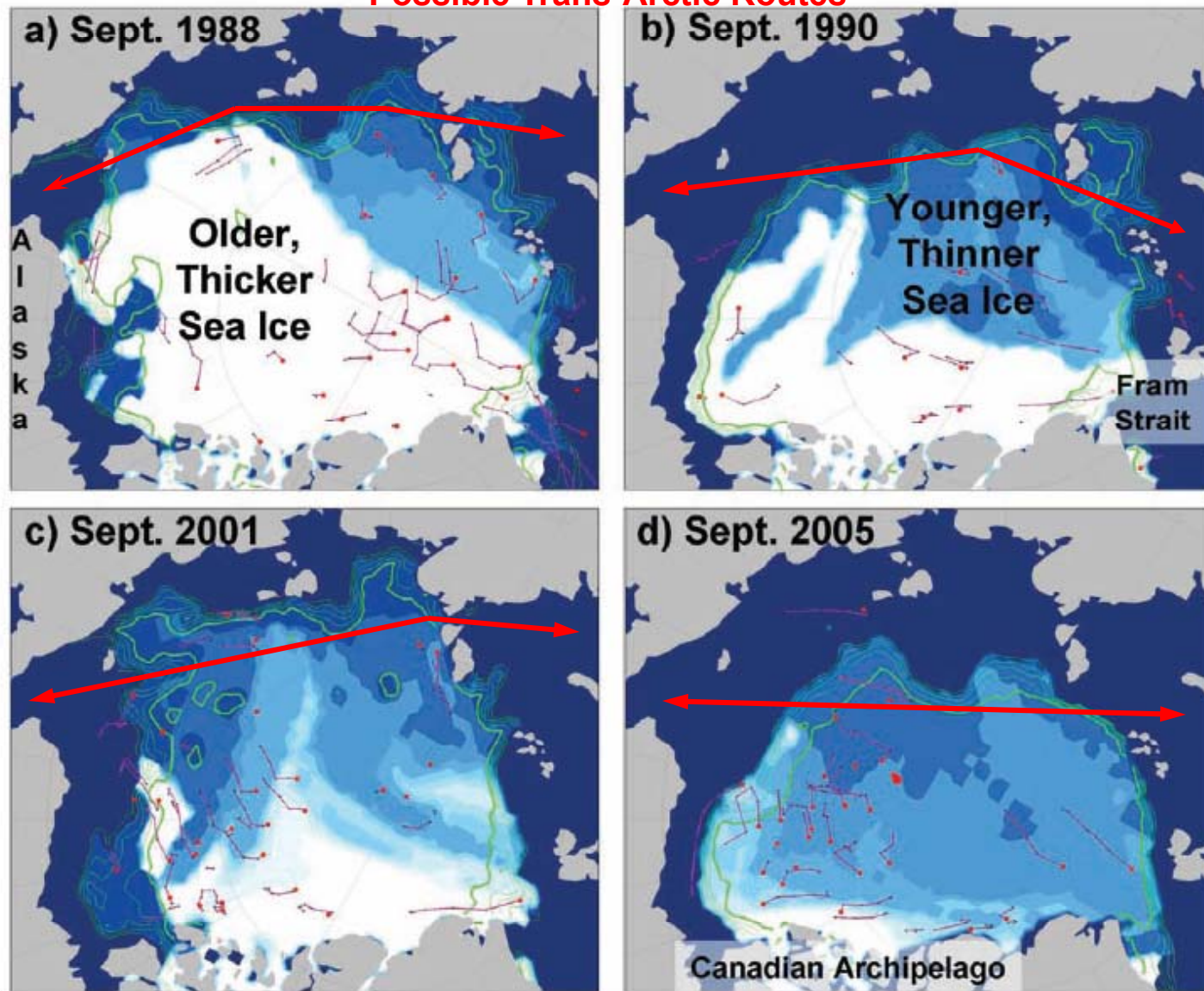


16 September 2006

Sea Ice Interannual Variability in Vilkitskiy Strait

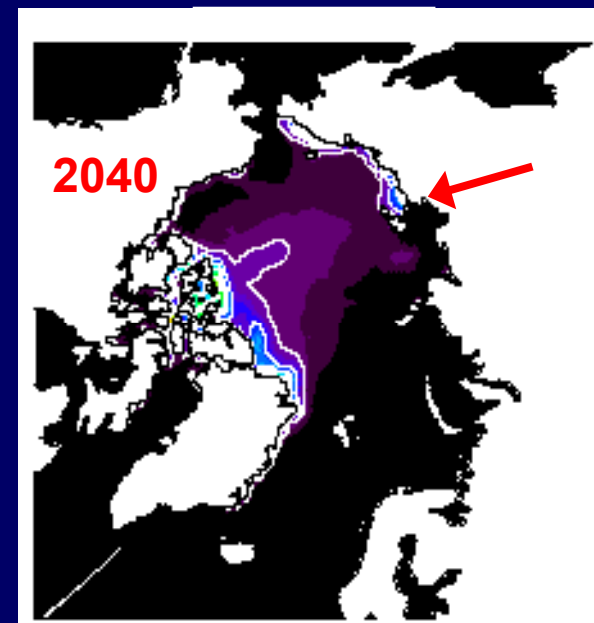
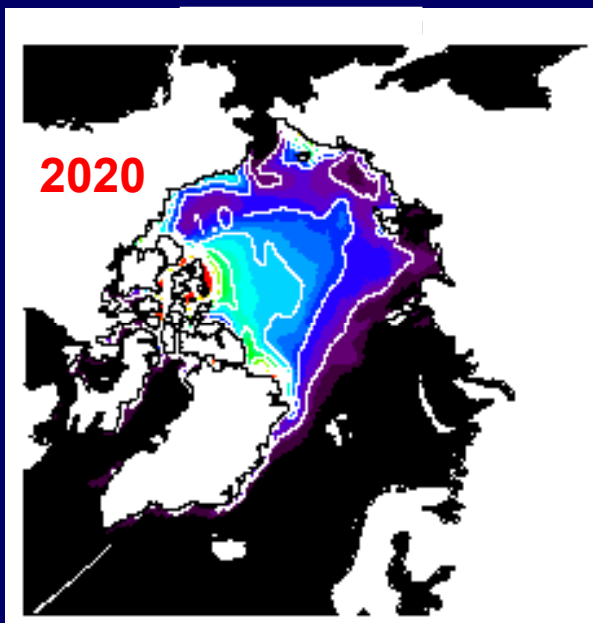
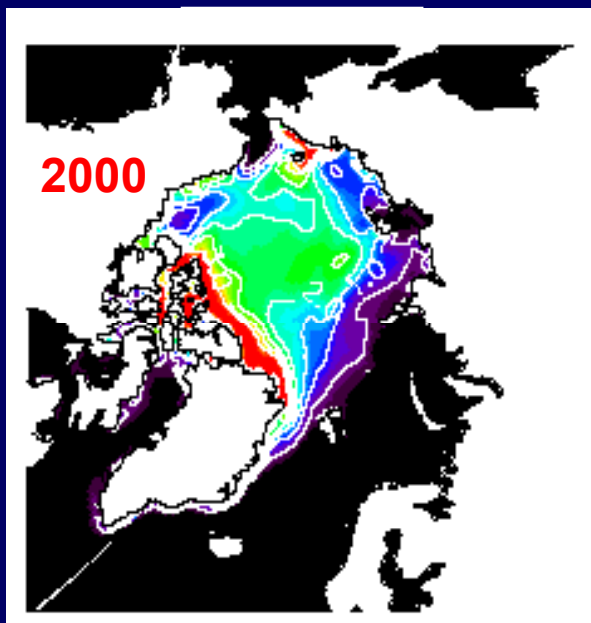
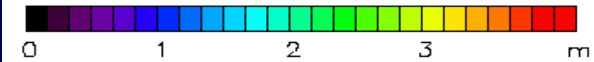
Changing Nature of Multi-year Arctic Sea Ice

Possible Trans-Arctic Routes

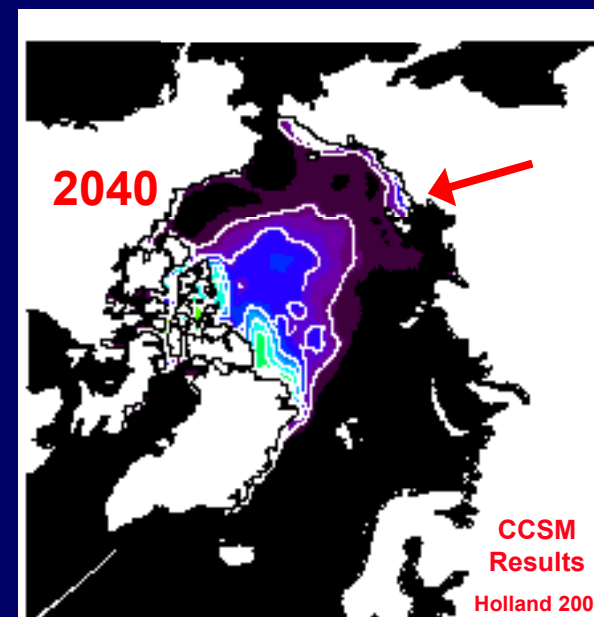
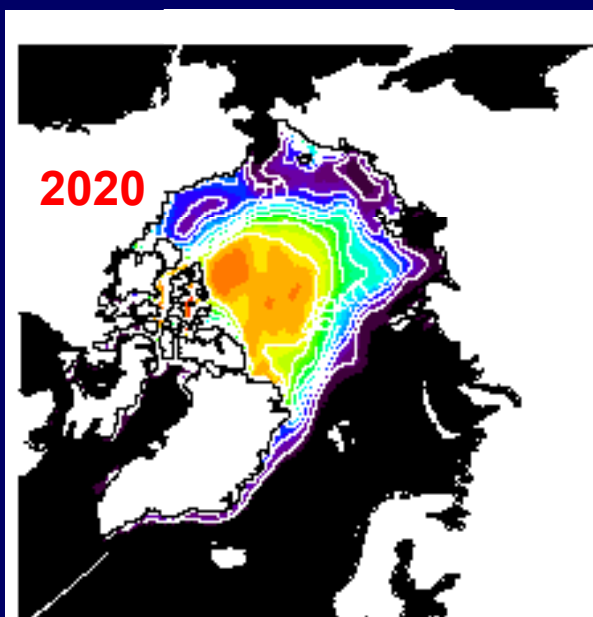
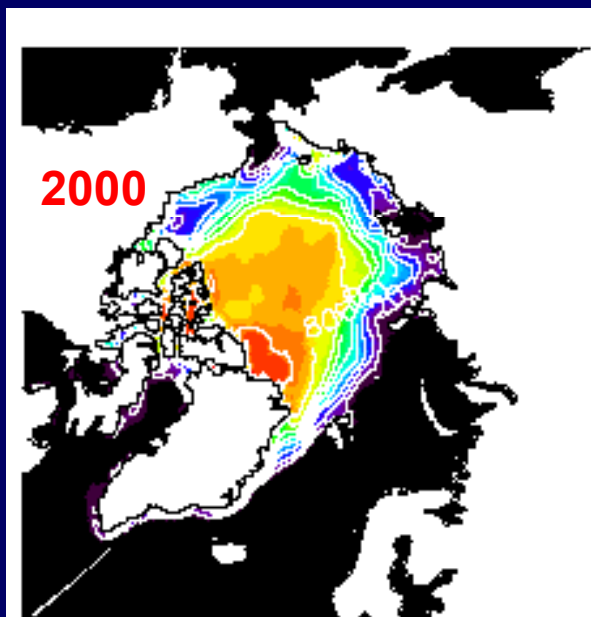


(Open Water) OW 0 1 2 3 4 5 6 8 10+ Years

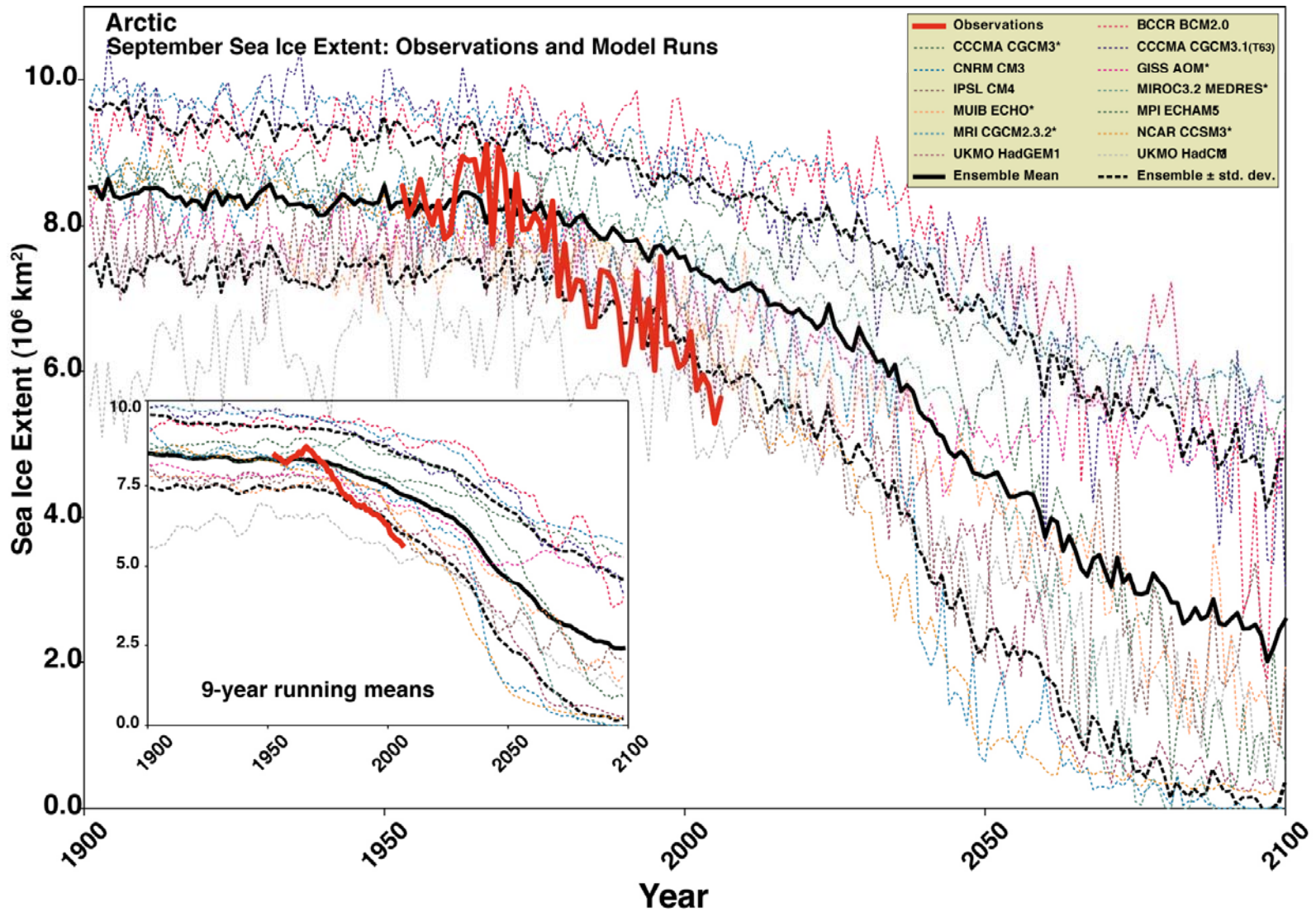
Recent Model Results September Ice Thickness



September Ice Concentration



CCSM
Results
Holland 2005



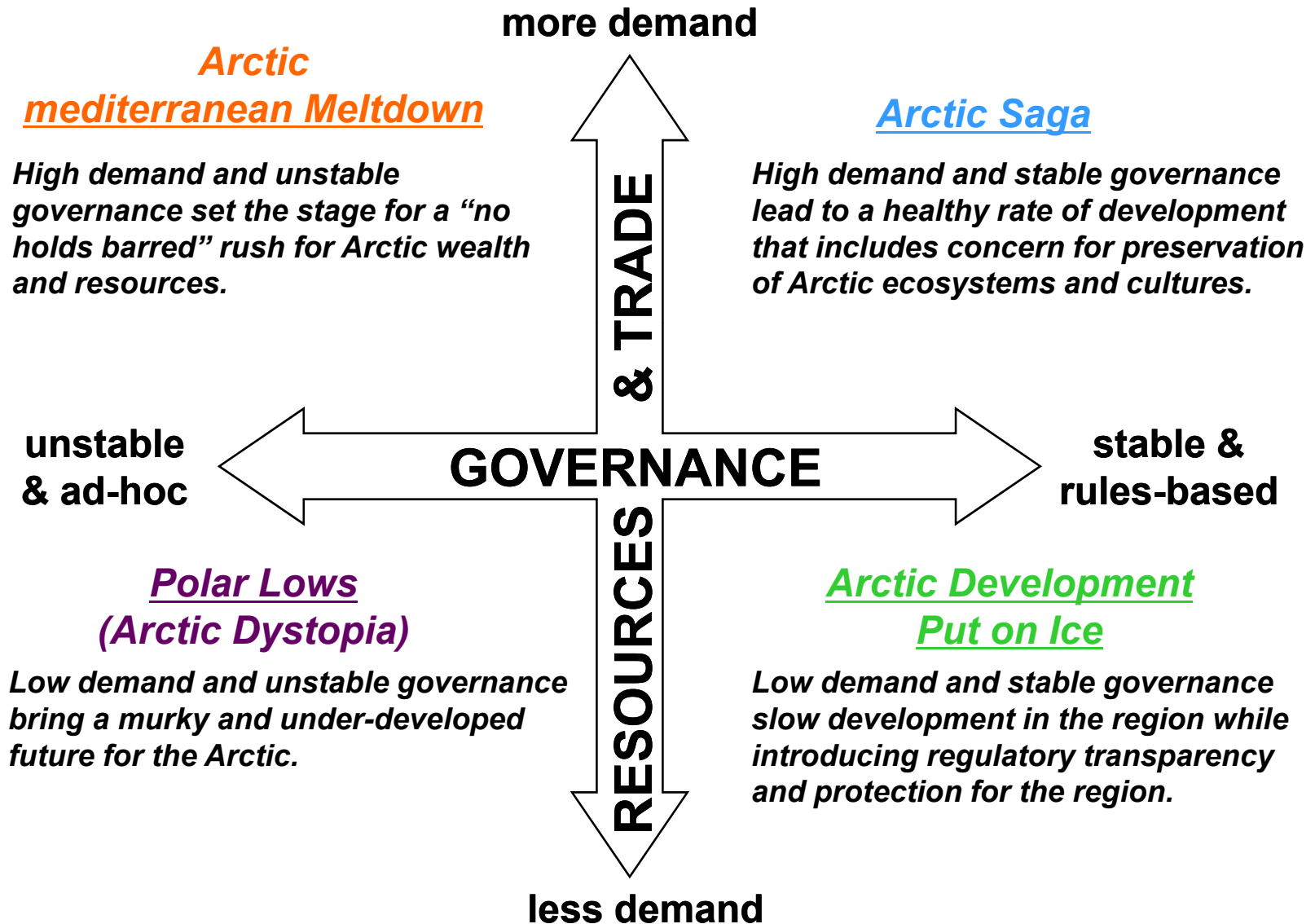
September Arctic Sea Ice Extent ~ Stroeve et al. Fig 1

Arctic Sea Ice Decline: Faster Than Forecast (GRL, 1 May 07)

Summary Points ~ Sea Ice

- **Diminishing Arctic Sea Ice ~ Extent & Thickness**
 - ~ Arctic coastal regions increasingly ice-free, but winter ice remains ~
- **GCM Simulations ~ Show Diminishing Arctic Sea Ice Throughout the Century**
- **Plausible ~ 2040 Ice-free Arctic Ocean (Earlier??)**
 - ~ Potential Disappearance of Multiyear Arctic sea ice ~
- **Plausible ~ More Mobile Sea Ice, More Complex Situation**
- **Russian Arctic ~ Longer Seasons of Navigation**
- **Canadian Arctic ~ Large Sea Ice Variability**
- **Key: Uncertain Future Operating Conditions, Greater Marine Access & Longer Seasons of Navigation**
- **Required: Increased Monitoring for Arctic Changes**

Scenarios on the Future of Arctic Marine Navigation in 2050



Themes to Consider

Broad Context

Indigenous communities

China, Japan, Korea

Maritime Disasters

World Trade Patterns

...Plus and from the list of 19 uncertainties and/or brainstorm

Marine Navigation Modes & Sectors

Regional

Trans-Arctic

Tourism

Oil and Gas

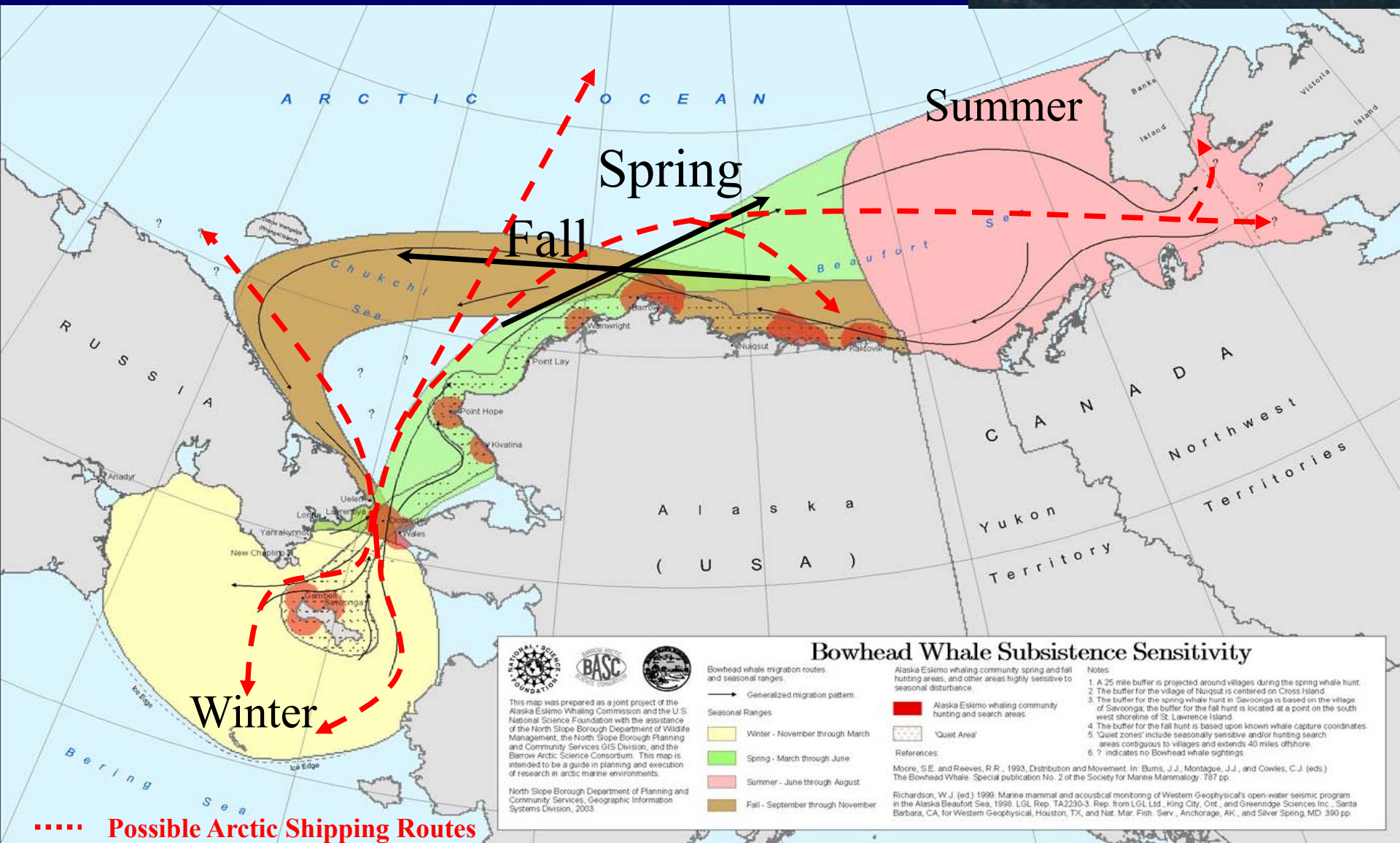
Minerals

Fisheries

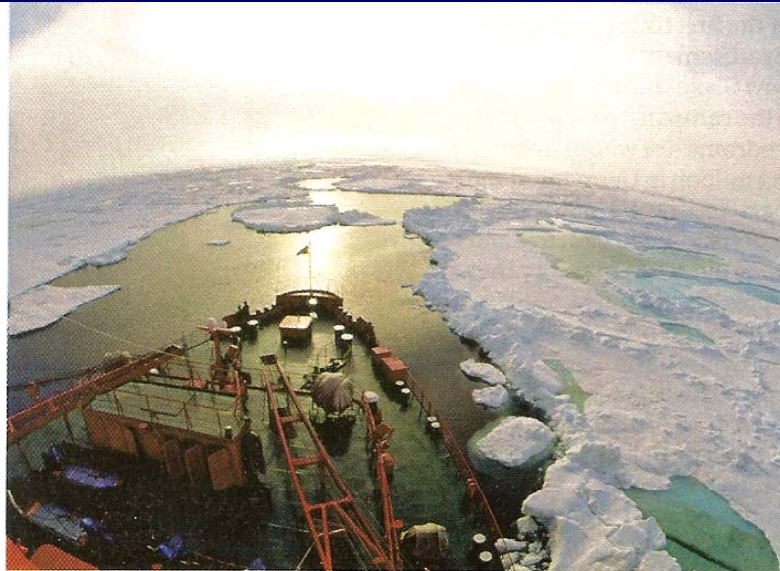


'Wild Card' Issue 1 ~ Multiple Ocean Uses

Bowhead Whale Migrations & Arctic Marine Operations



'Wild Card' Issue ~ Arctic Ship Emissions



PETER GUNNING/ORBIS

New pathway to pollution in Arctic

ONE of the bonuses of global warming is the potential for new shipping routes to open up through the Arctic as ice retreats, shortening journeys by many thousands of miles. There is a downside, however. New northern passages could significantly boost levels of low-lying ozone as ship exhausts pump pollutants into the pristine environment.

Climate models indicate that the northern passages – the north-east coast of Siberia, northern Alaska and around the Canadian archipelago – may be open to shipping during the summer months from around 2050

onwards. Claire Granier, from the University of Pierre and Marie Curie in Paris, France, and her colleagues calculated the likely ozone emissions associated with such a scenario, assuming that the routes would be accessible for six months of the year.

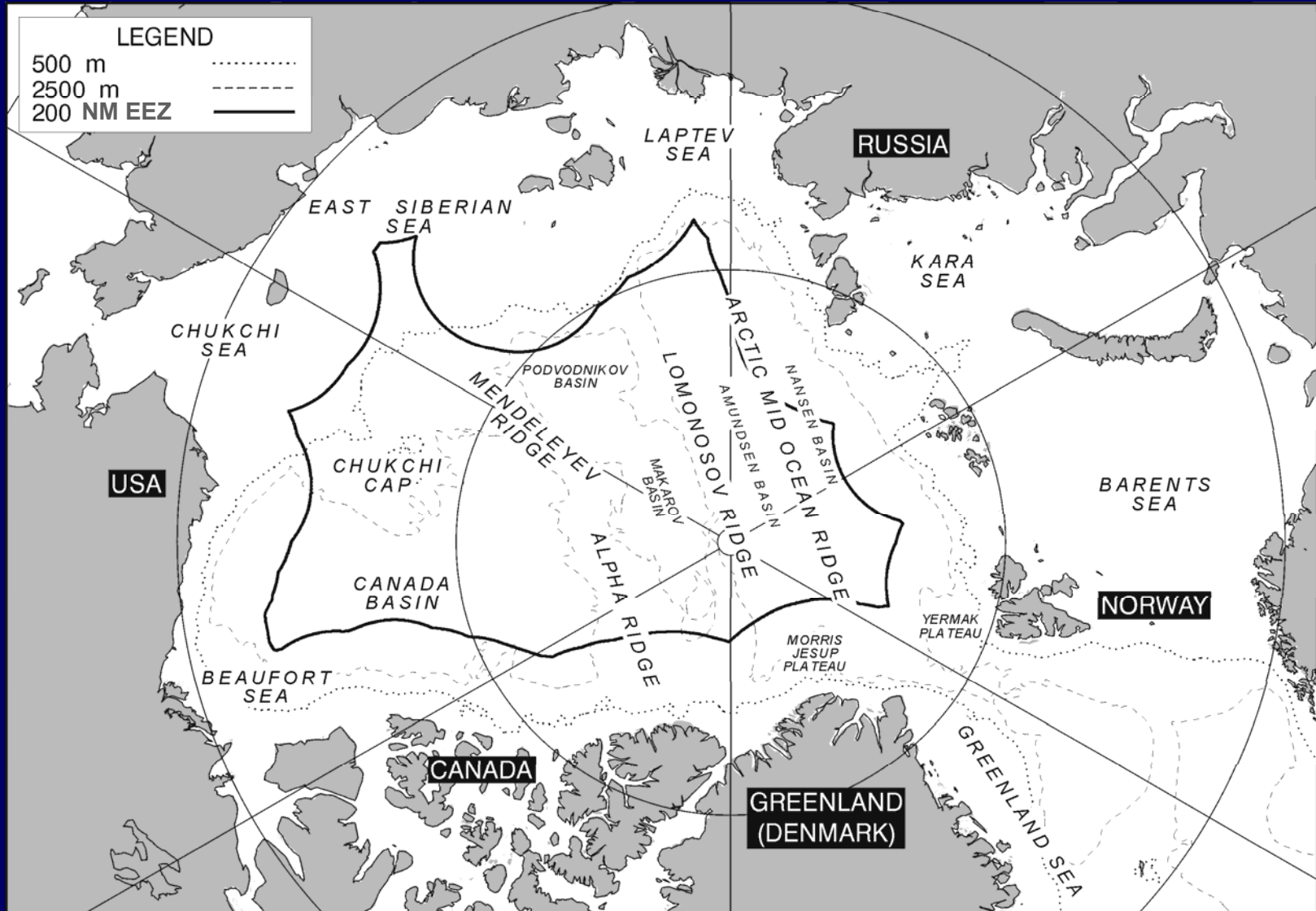
Emissions of nitrogen oxides and carbon monoxide from ships could triple ozone levels, making them comparable to those in industrialised regions today (*Geophysical Research Letters*, DOI: 10.1029/2006GL026180).

"The Arctic is a very sensitive region and these very high ozone levels are likely to have a serious impact on plant life," says Ulrike Niemeier, a co-author from the Max Planck Institute for Meteorology in Hamburg, Germany.

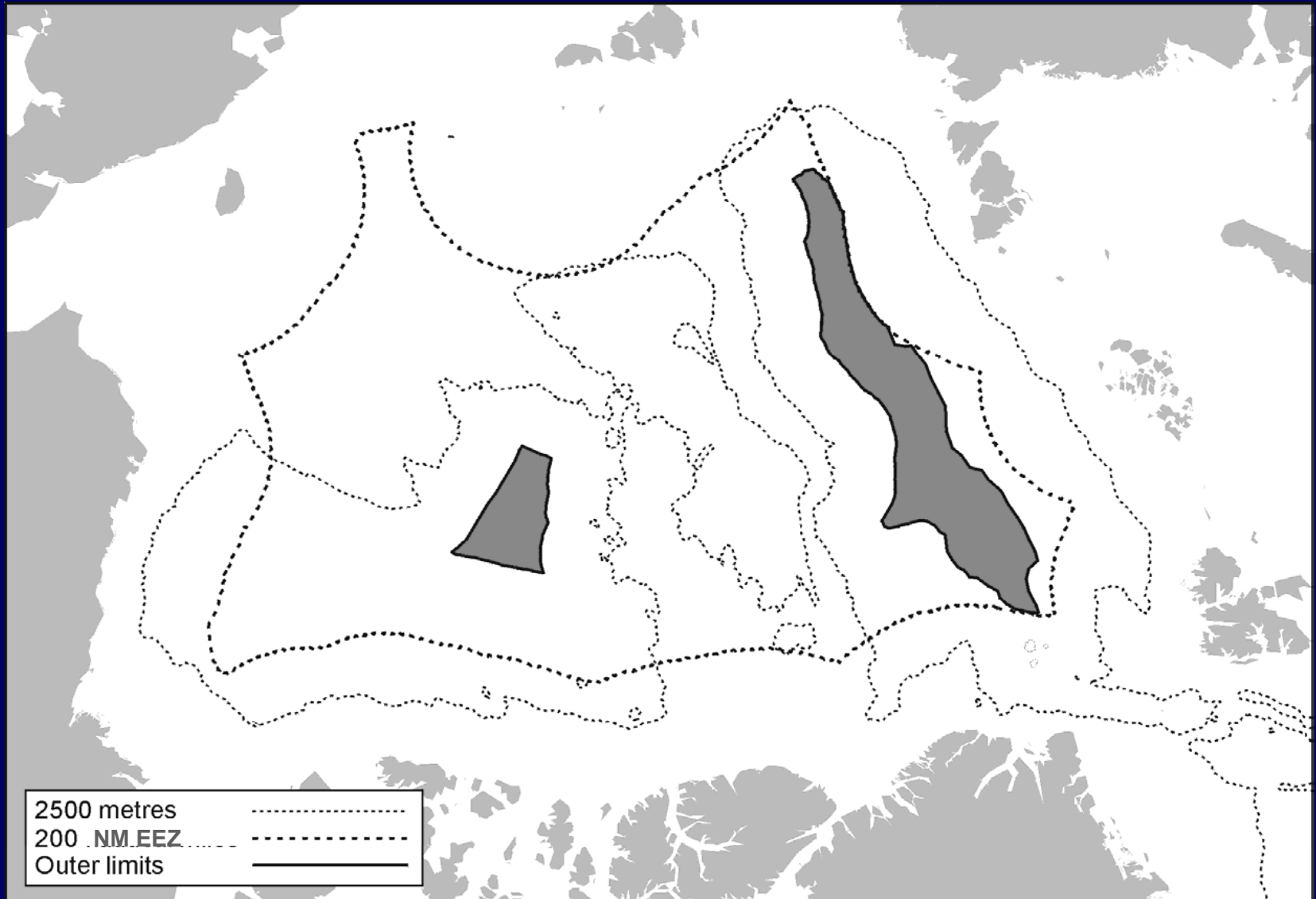
New northern passages could significantly boost levels of low-lying ozone as ship exhausts pump pollutants into the pristine environment.

Emissions of nitrogen oxides and carbon monoxides from ships could triple ozone levels, making them comparable to those in industrialized regions today.

Today's Maritime Arctic (200 NM Exclusive Economic Zone)



Hypothetical - Future Maritime Arctic (After UNCLOS Article 76)



(Macnab 2000)

‘Wild Card’ Issue 3B

'Wild Card' Issue 4 ~ Technology

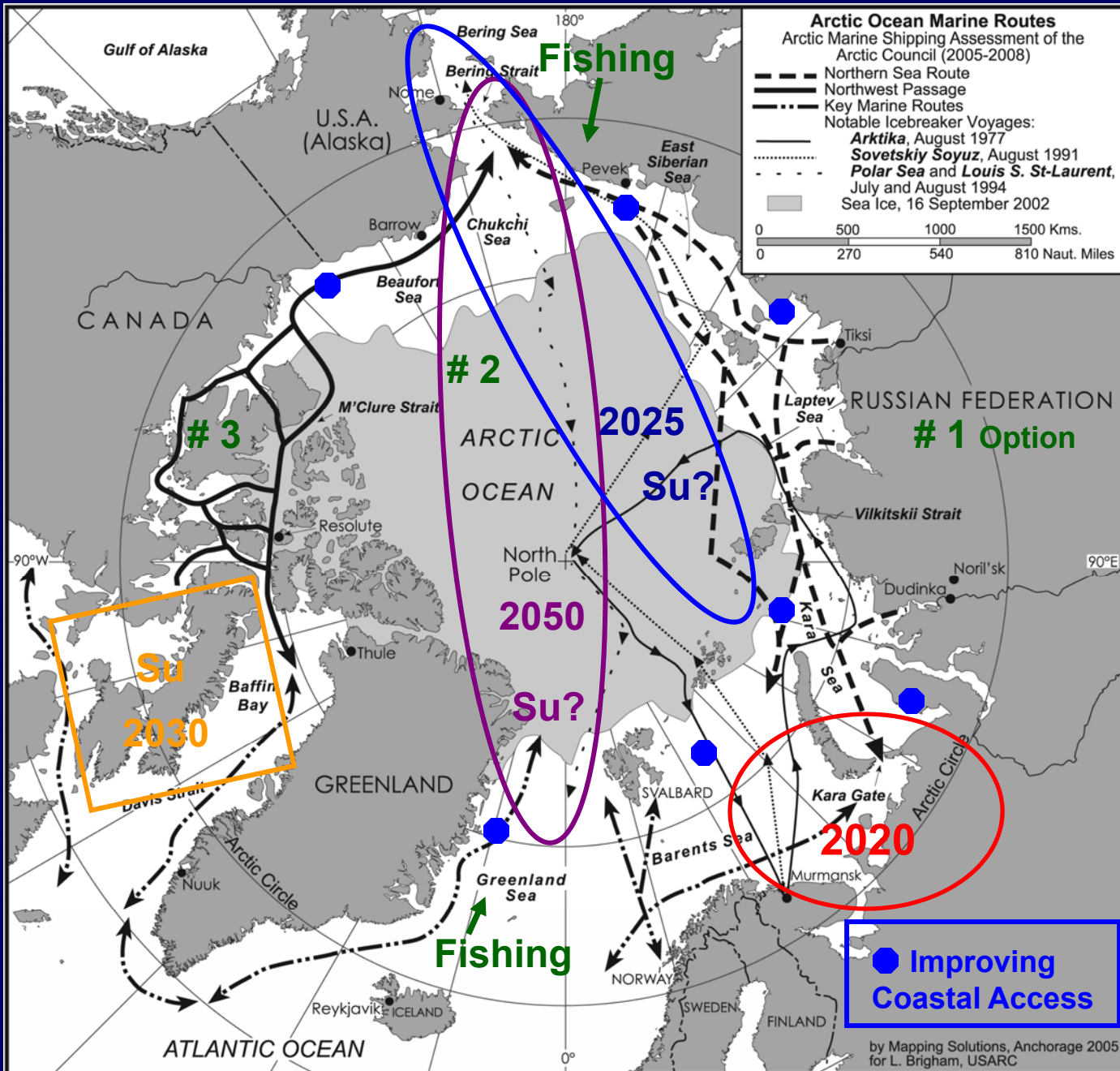
Future Convoy Requirements?



**Icebreaking (Double Acting) Container Ship
Norilskiy Nickel in the Kara Sea
March 2006**

Aker Arctic

The Maritime Arctic of the Future?



Potential AMSA Findings

Primary Driver ~ Regional & Global Natural Resource Development

Lack of Integrated Governance-Regulatory Framework

Continued Sea Ice Retreat ~ Increased Access

Winter Arctic Sea Ice Cover Remains

New Ship Technologies ~ Allow Greater Access & Independent Operations (No Convoys)

Global Maritime Industry ~ Key Stakeholders

Minimal Arctic Infrastructure to Support Expanded Marine Activity

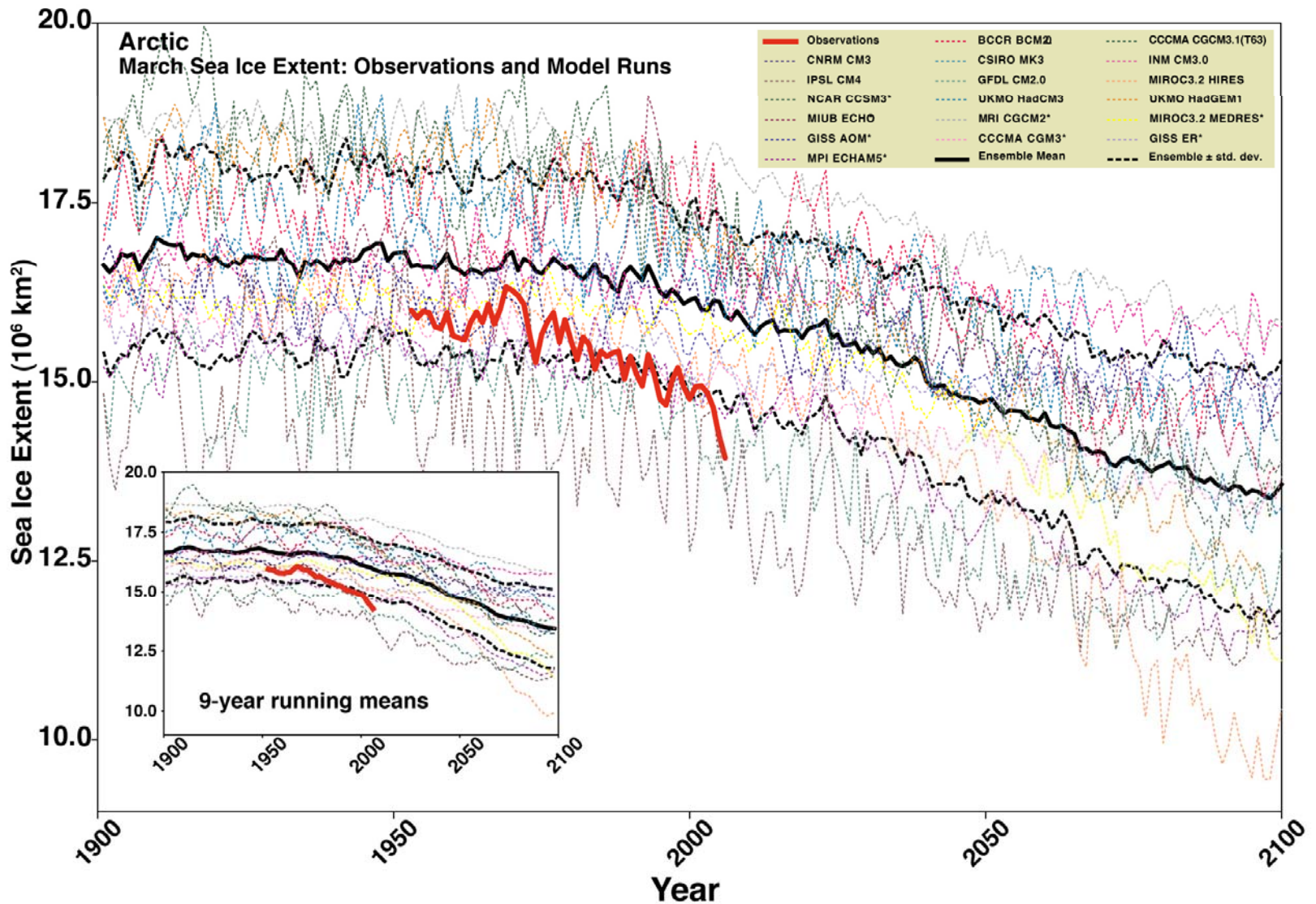
**Sectors: Oil & Gas, Hard Minerals, Tourism & Fishing
~ Future: Timber & Water**

Greatly Enhanced Monitoring Required

Intense Development ~ NW Russia & Norwegian-Barents-Kara Seas

Balance ~ Freedom of Navigation with Coastal State Marine Safety & Environmental Protection Interests

Lack of Experienced Mariners



March Arctic Sea Ice Extent ~ Stoeve et al., Fig 2

Arctic Sea Ice Decline: Faster Than Forecast (GRL, 1 May 07)