Collaborative Research: A Heat Budget Analysis of the Arctic Climate System

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Objectives:

Examine the Arctic climate system from the integrating viewpoint of its large-scale *heat budget*

Synthesize information from:

- ERA-40 and NCEP reanalyses
- Oceanographic obs
- Terrestrial obs
- Satellite obs
- Land surface models
- Coupled ice-ocean models

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Some Products

…(all 2007)

Serreze, M, A Barrett, A Slater, M Steele, J Zhang, K Trenberth (2007)
The large-scale energy budget of the Arctic
J Geophys Res, 112

Serreze, M, A Barrett, J Stroeve, M Holland (2007)
Emerging arctic amplification as seen in the NCEP/NCAR reanalysis ***submitted to Geophys Res Lett***

Steele, M, W Ermold and J Zhang (2007)
Arctic Ocean surface warming trends over the 20th century
submitted to Geophys Res Lett

Stroeve, J, M Holland, W Meier, T Scambos, M Serreze (2007)
Arctic sea ice decline: Faster than forecast
Geophys Res Lett, 34

Polyakov, I, M Steele, lots of et als (2007)
Observational program tracks Arctic Ocean transition to warmer state
EOS, this week

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Linkages to explore

SASS I:

- Perovich: ***albedo & summer ocean warming***
- Rigor: ***air temperature trends vs. ocean trends***
- Miles: ***climate modes' role in warming***
- Walker: ***marine warming → terrestrial ecosystem response?***

SASS II:

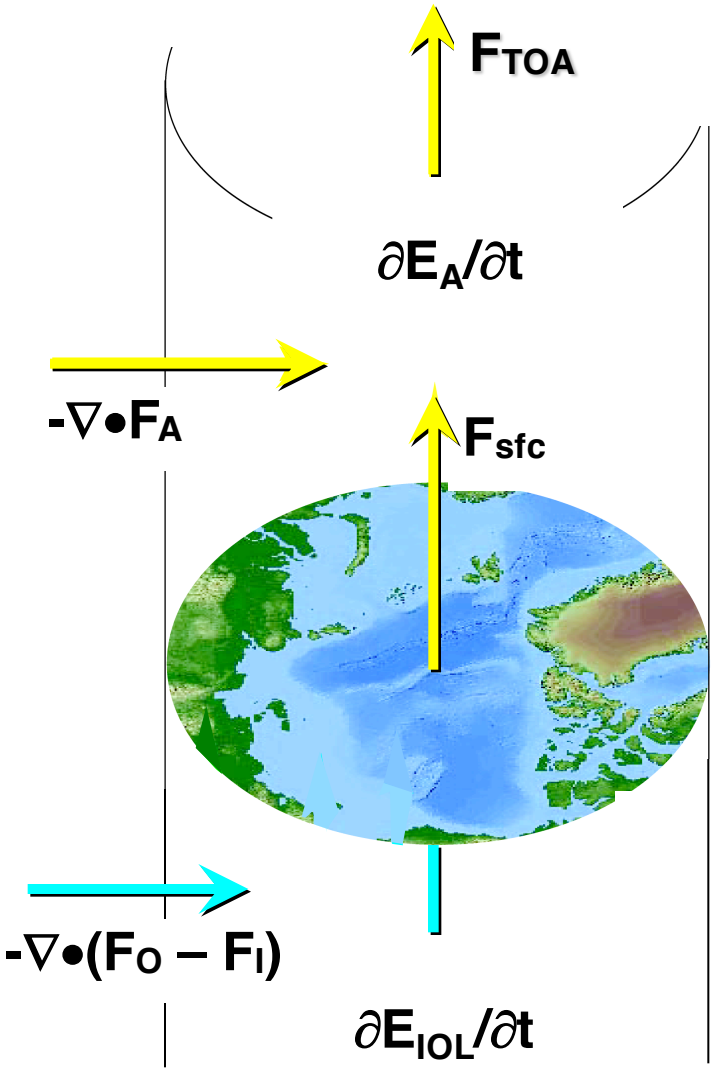
- Zhang: ***ocean warming → plankton response? (modeling)***
- Matrai: ***ocean warming → plankton response? (obs)***

probably others we've missed…

The large-scale energy budget of the Arctic

(annual mean, seasonal cycle)

Serreze, Barrett, Slater, Steele (2007)



Atmospheric Column

- *ERA40*
- *NCEP re-analysis*
- *ERBE*

Ice/Ocean/Land Column

- *Vinje obs.*
- *J. Zhang model*
- *Climatology (PHC)*

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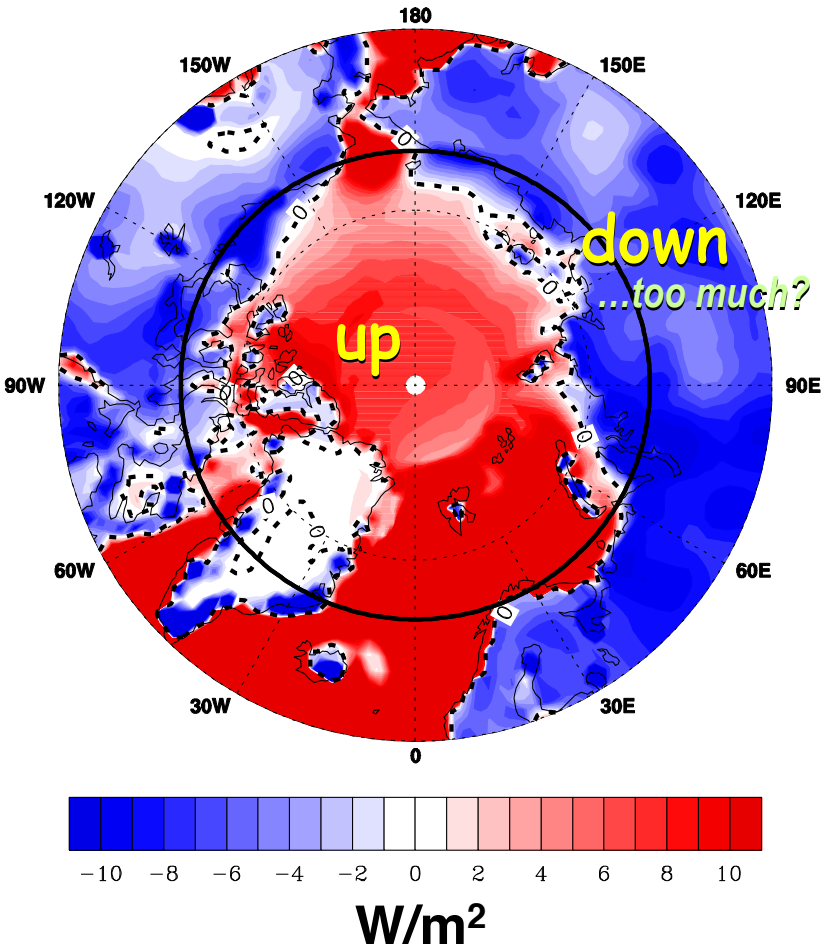
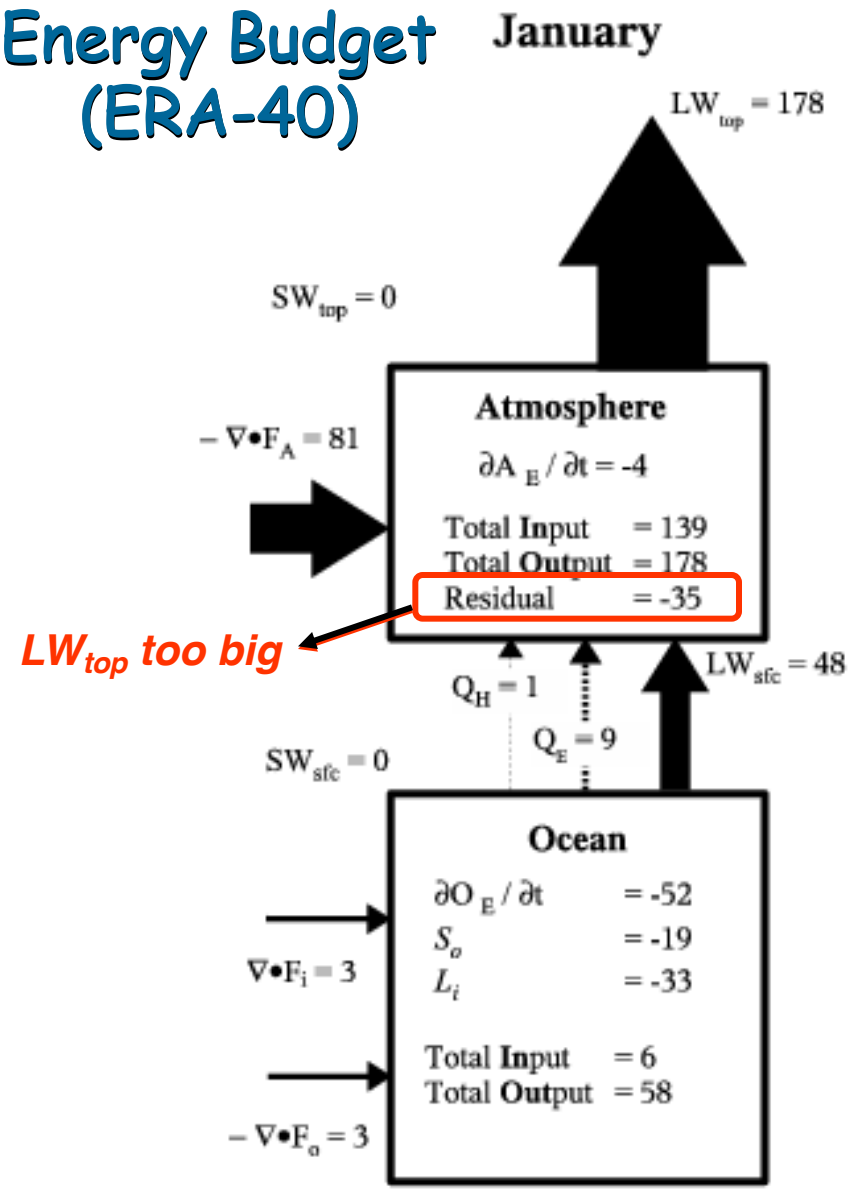
Net Annual Surface Heat Flux (ERA-40)

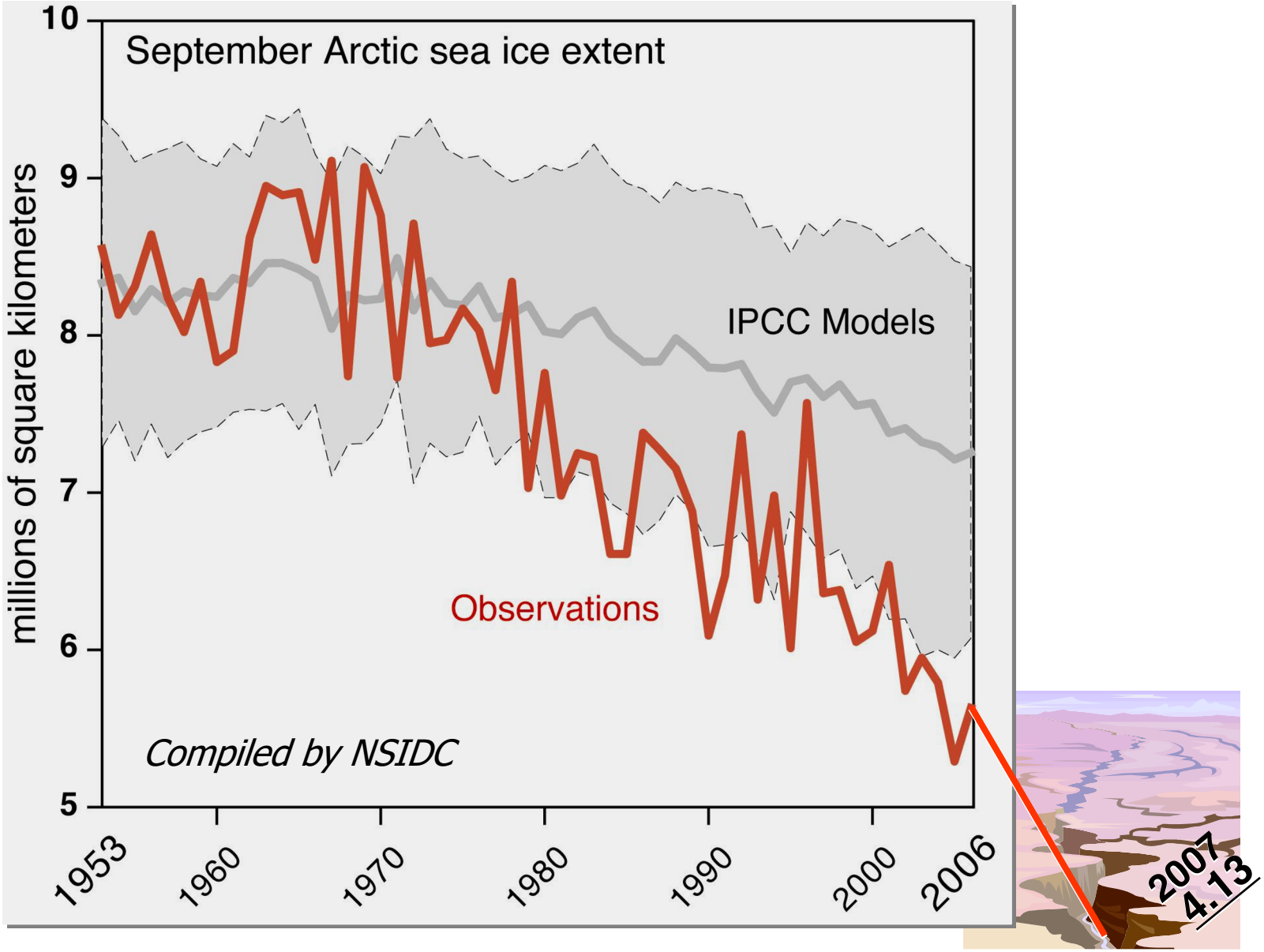


Seasonal Energy Budget (ERA-40)



Observed Sea Ice Decline: Faster than Forecast

Stroeve, Holland, Meier, Scambos, Serreze (2007)



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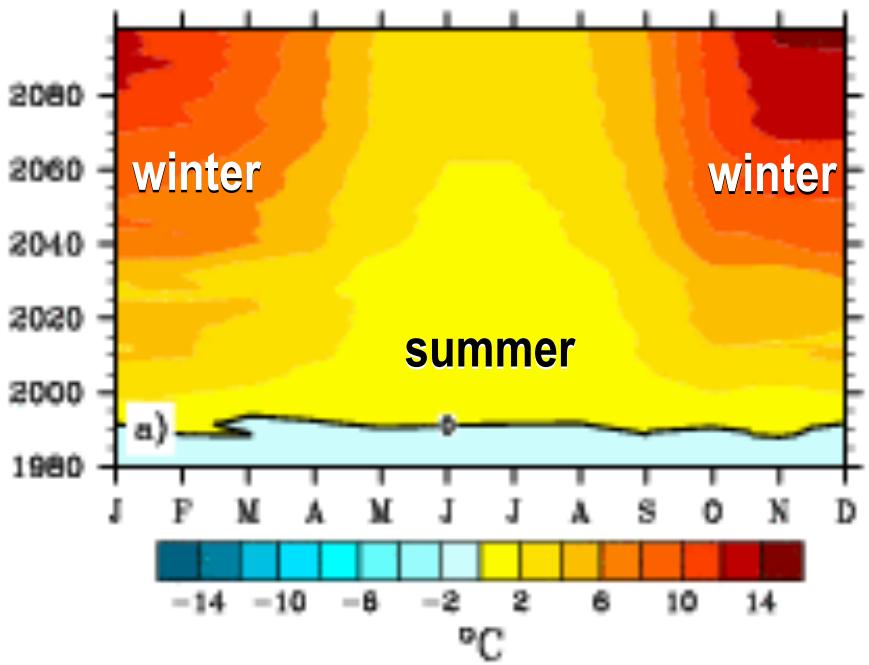
The Emergence of Arctic Amplification

Serreze, Barrett, Stroeve, Holland (2007)

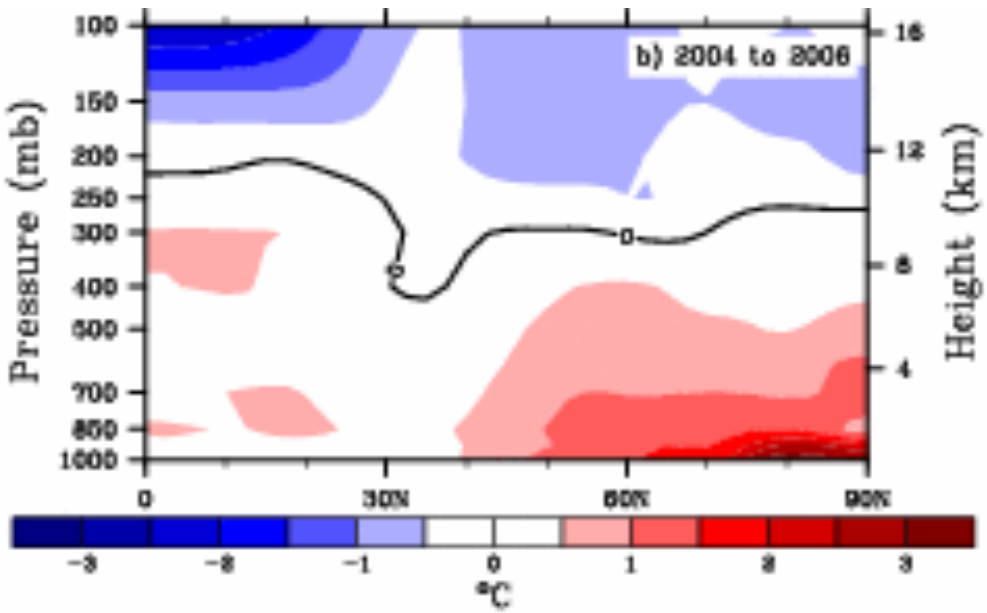
Modeled Future SAT



ice thinning →
winter surface warming

Observed Temperature Anomalies

(NCEP Oct-Dec, rel. to 1979-1999)



It's starting to happen!

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summer (Jul-Aug-Sep)

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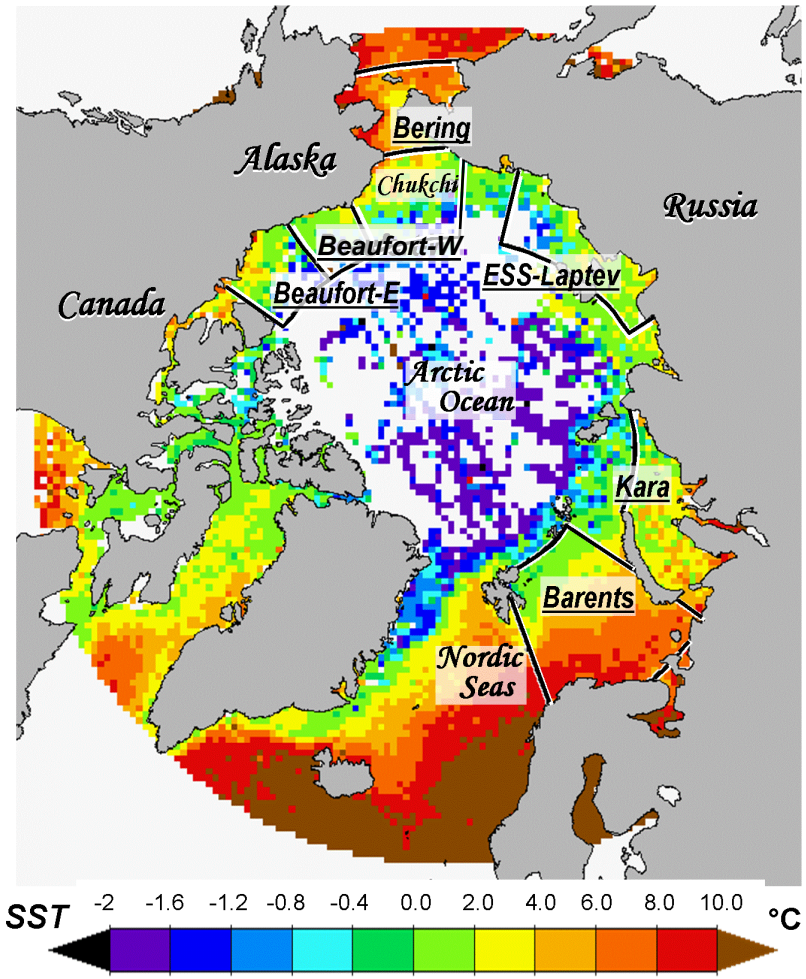
Arctic Seas Ocean Surface Warming

over the 20th century

Steele, Ermold, Zhang
(GRL submitted '07)

summer (JAS)
Sea Surface Temp
(0-10 m)



World Ocean Database '05
(in situ data)

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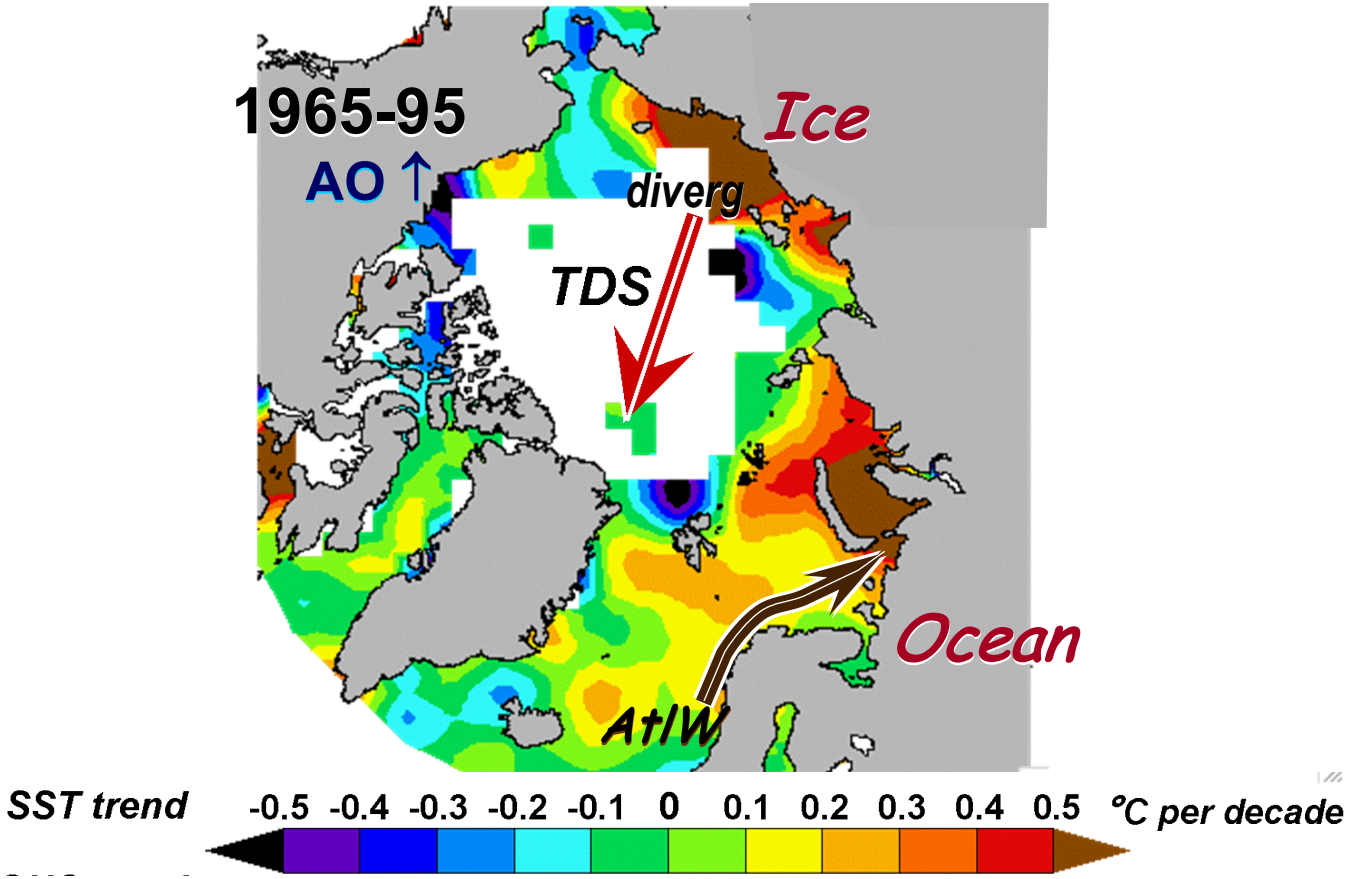
SST trends & the AO



Warming influenced by ocean & ice advection

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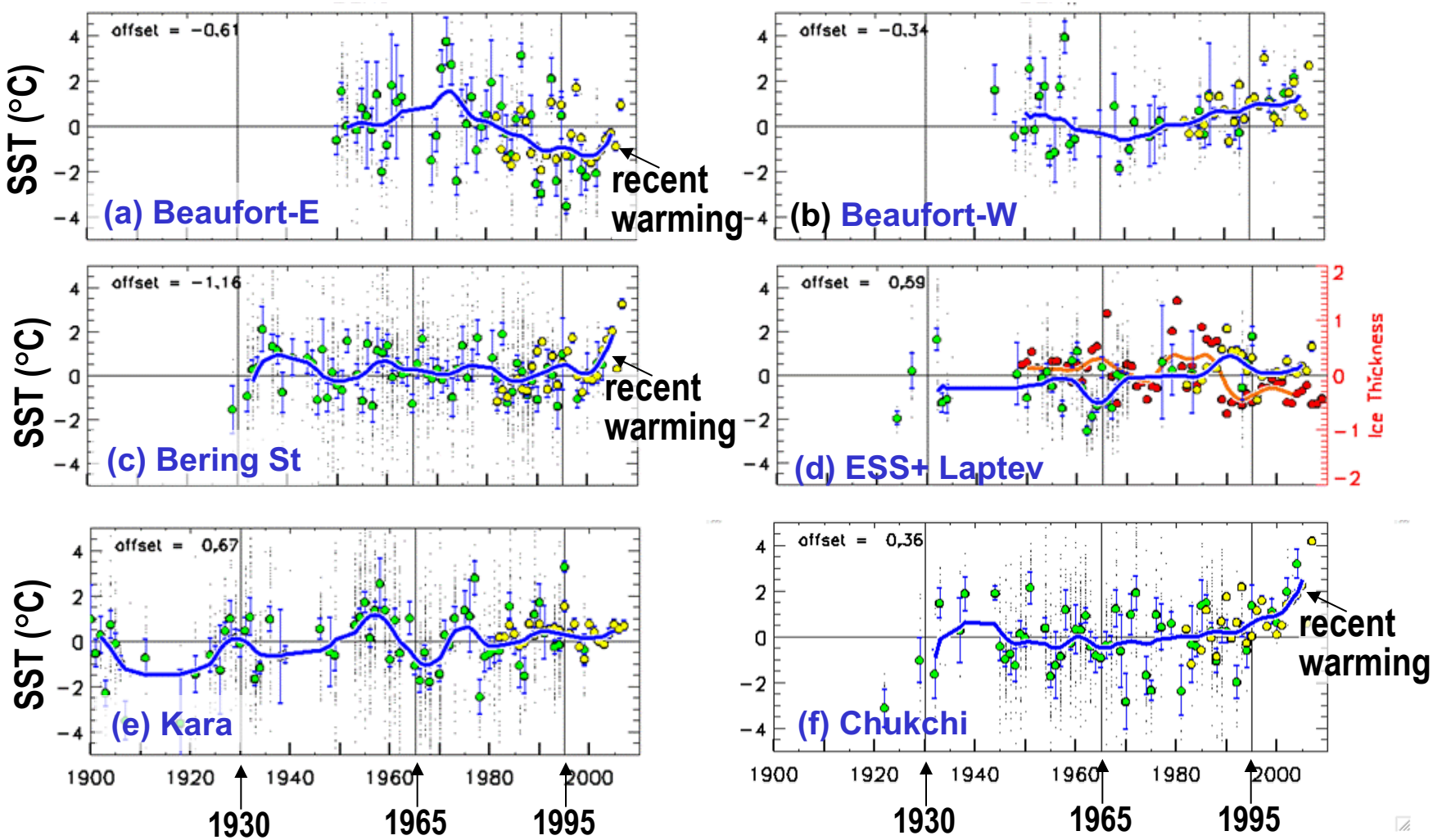
SST trends:
regional anomaly time series

- *in situ* WOD'05
- *satellite* Reynolds et al

National Weather Service
Environmental Modeling Center

smoothed



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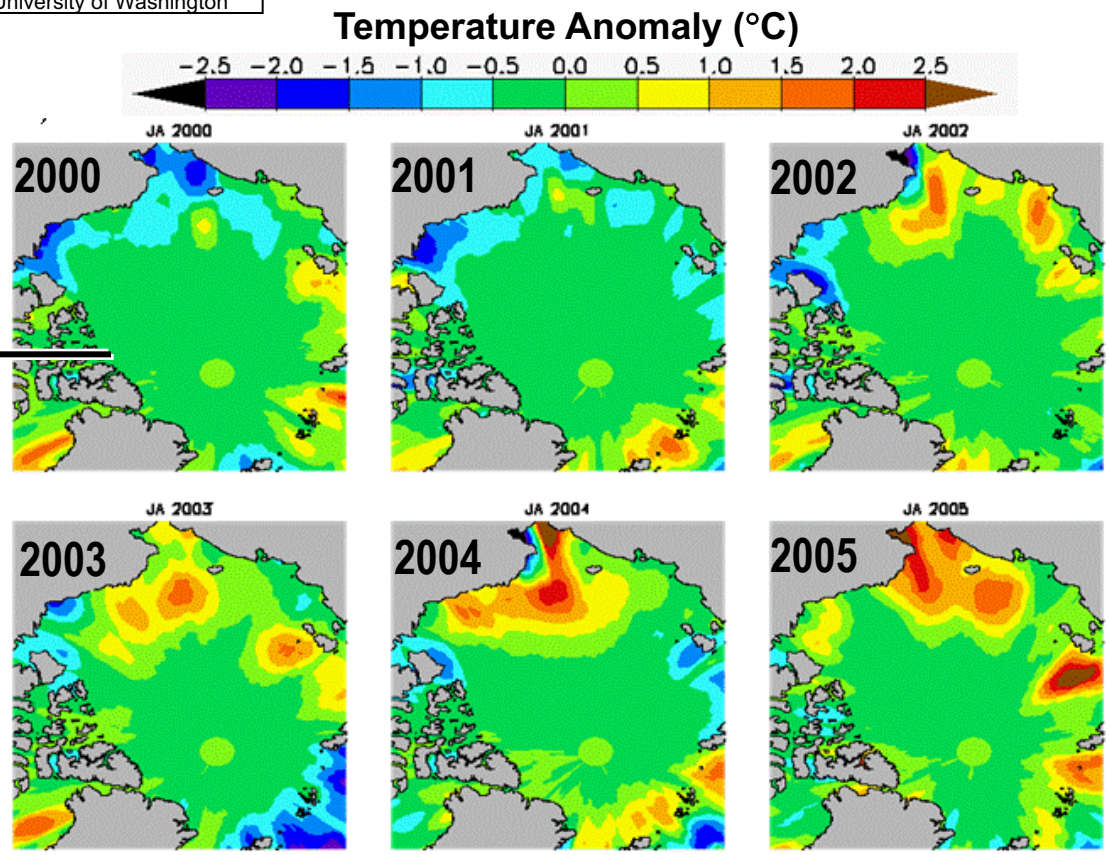
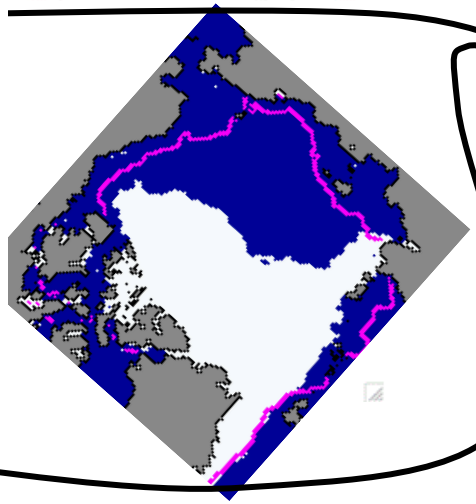
July-Aug SST anomalies (rel to 1982-2007)



ehh



2007: What a year!

Max Anom ≅ 5°C

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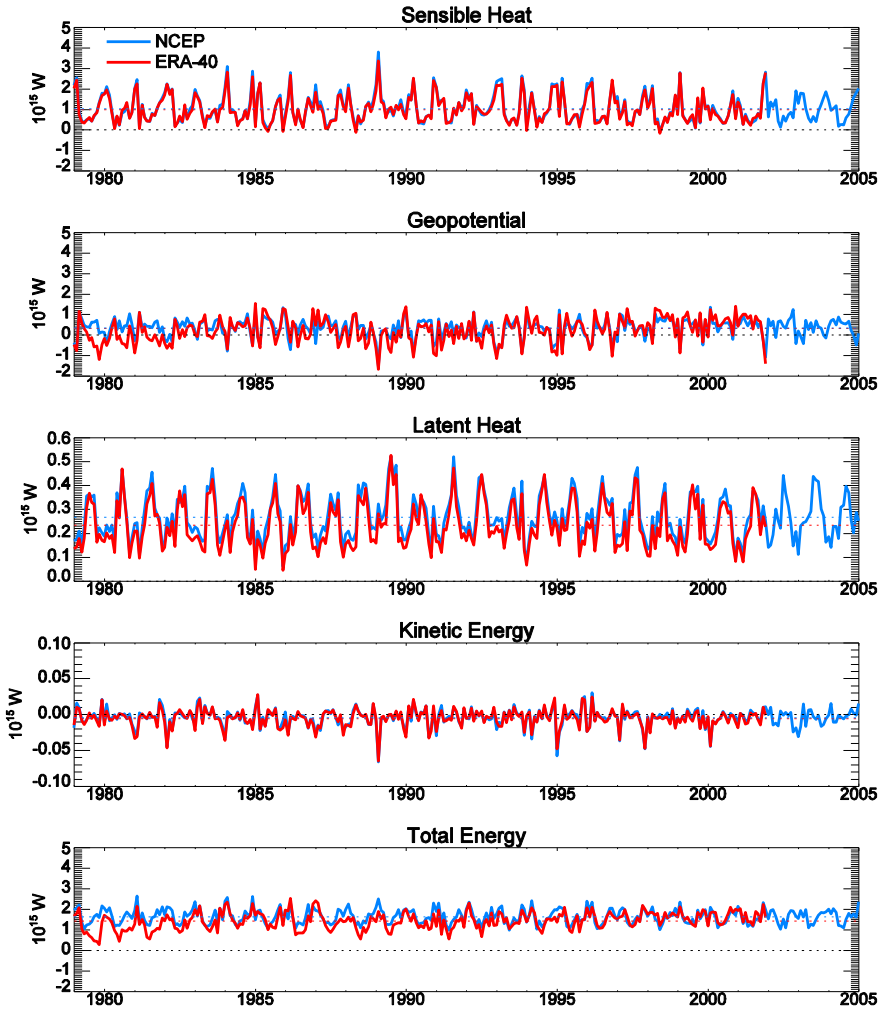
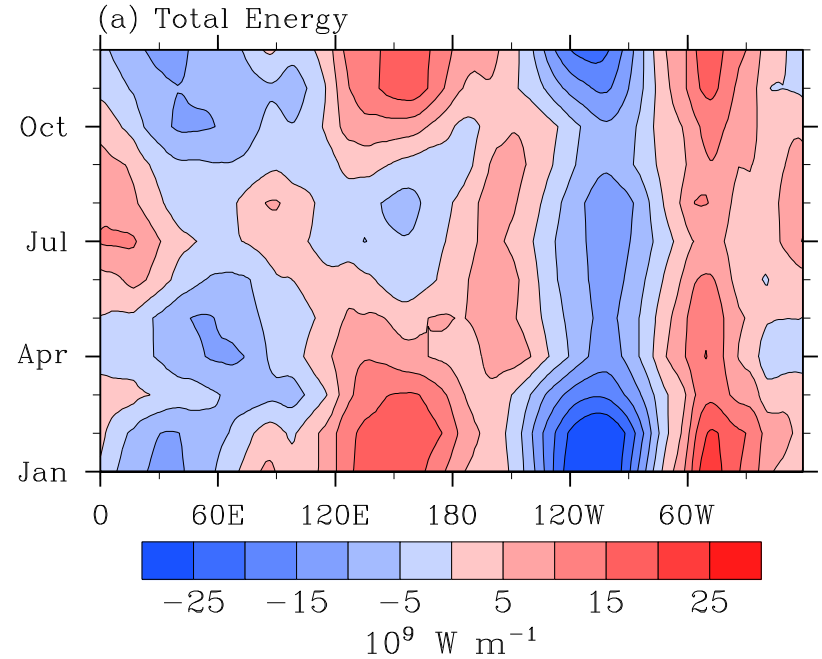
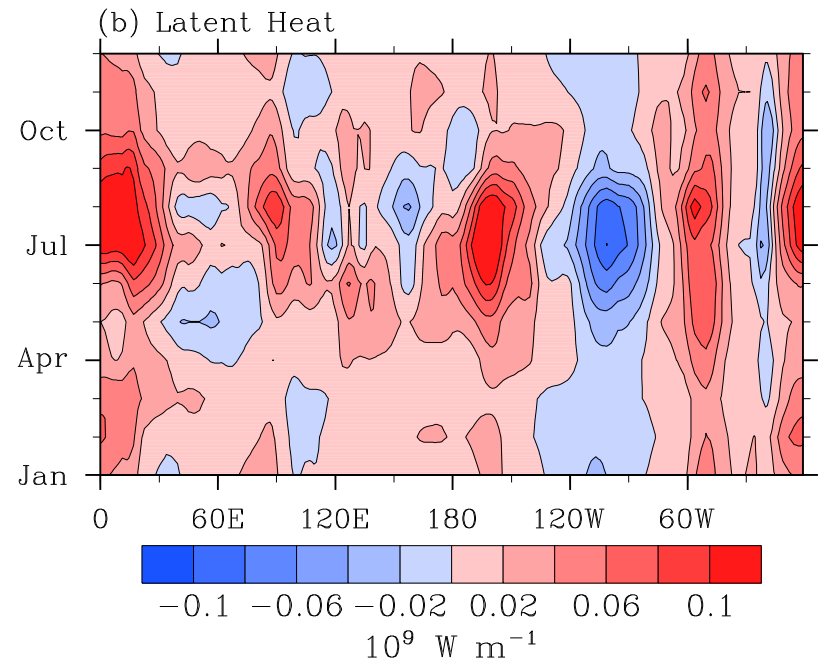
Thank You

Energy Transports across 70 deg N



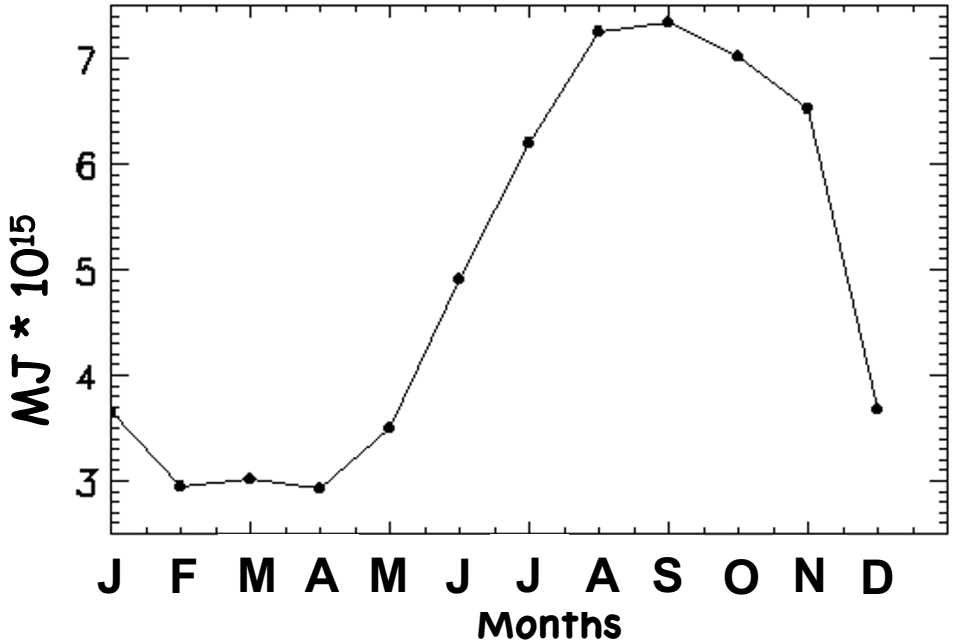


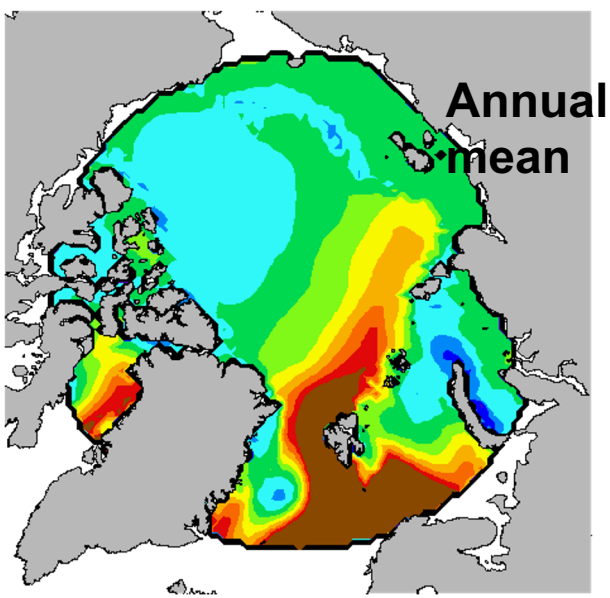


70-90 degN

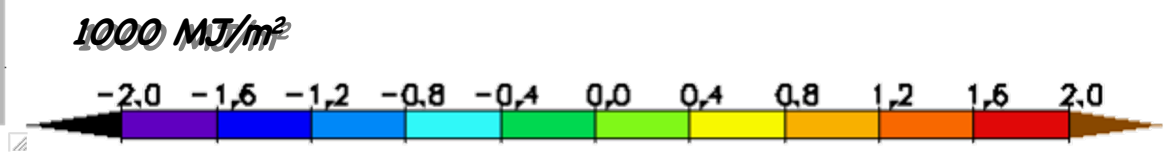
Arctic Ocean Sensible Heat Content

Jan	365633
Feb	295006
Mar	301168
Apr	292278
May	349785
Jun	490397
Jul	620166
Aug	725292
Sep	733829
Oct	701069
Nov	652471
Dec	366975



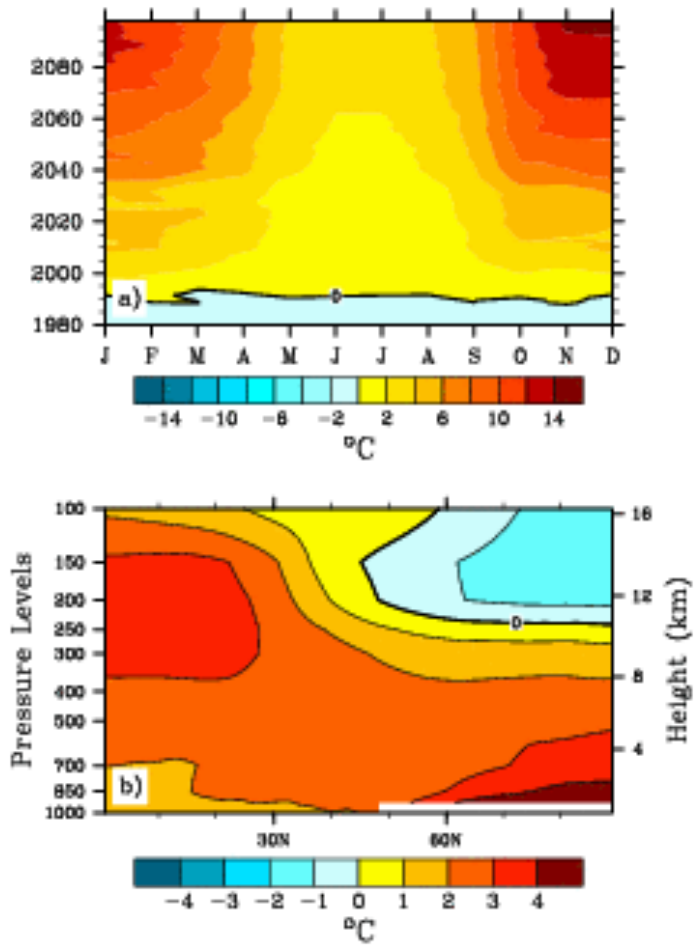


Courtesy M Steele

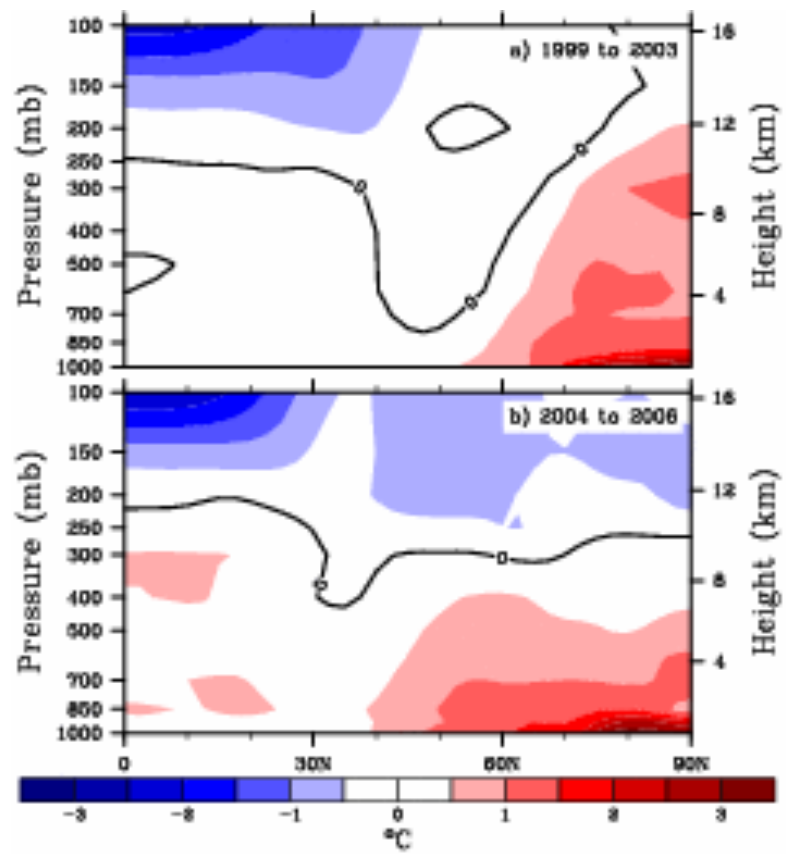


The Emergence of Arctic Amplification

The Signature in CCSM3



Oct-Dec Temperature Anomalies in NCEP, Relative to 1979-1999



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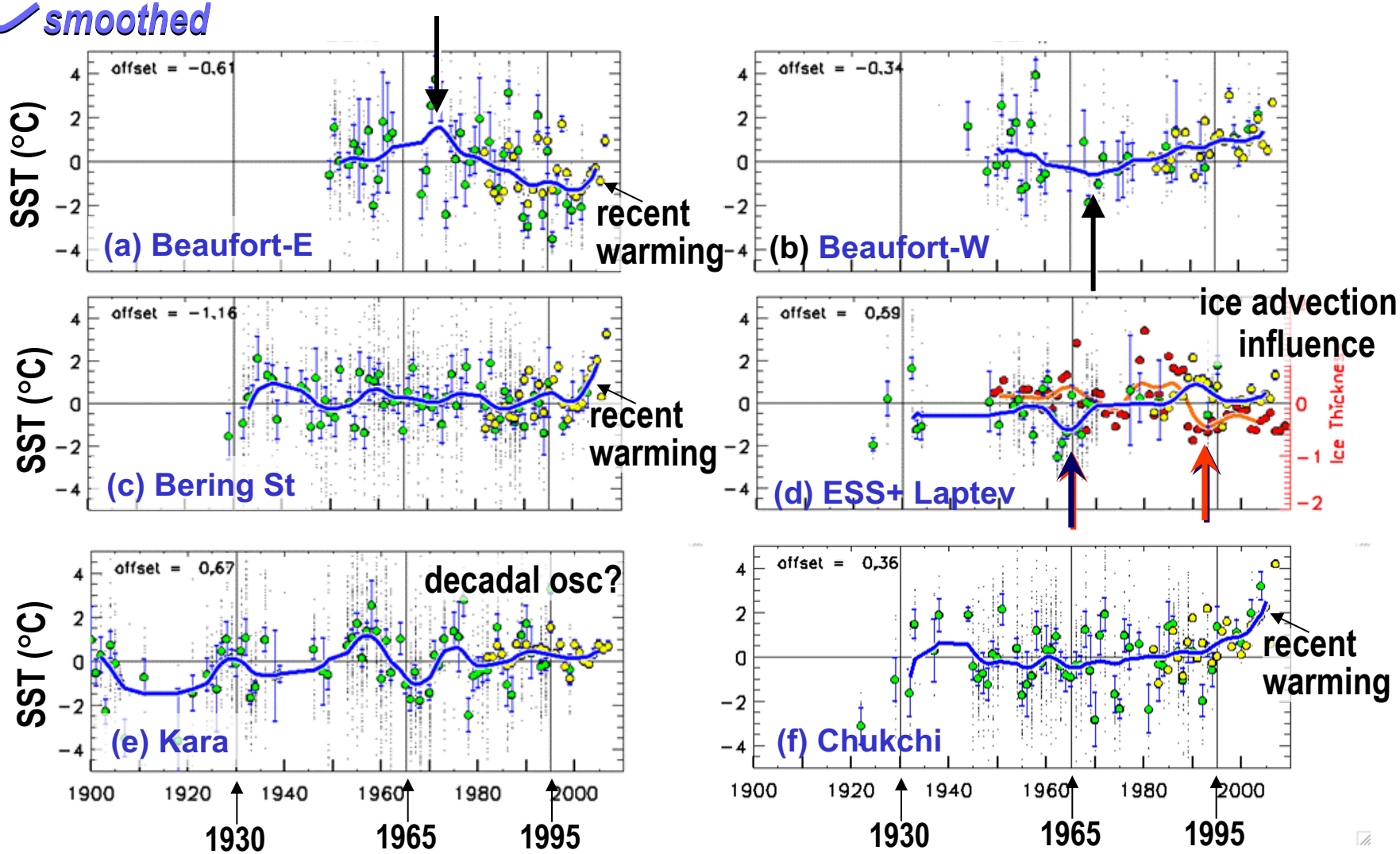

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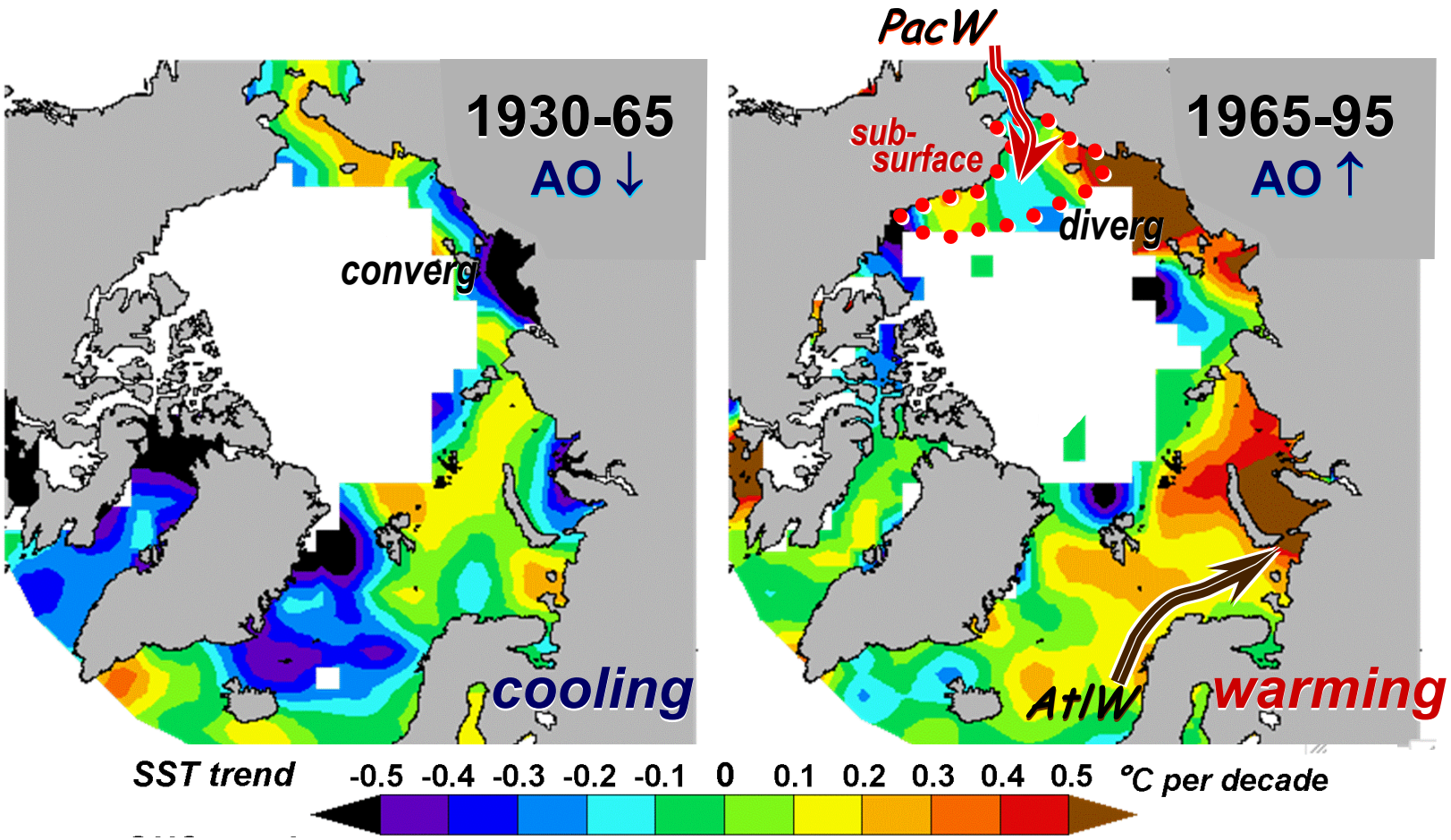

- Ocean advection influence
- Ice advection influence

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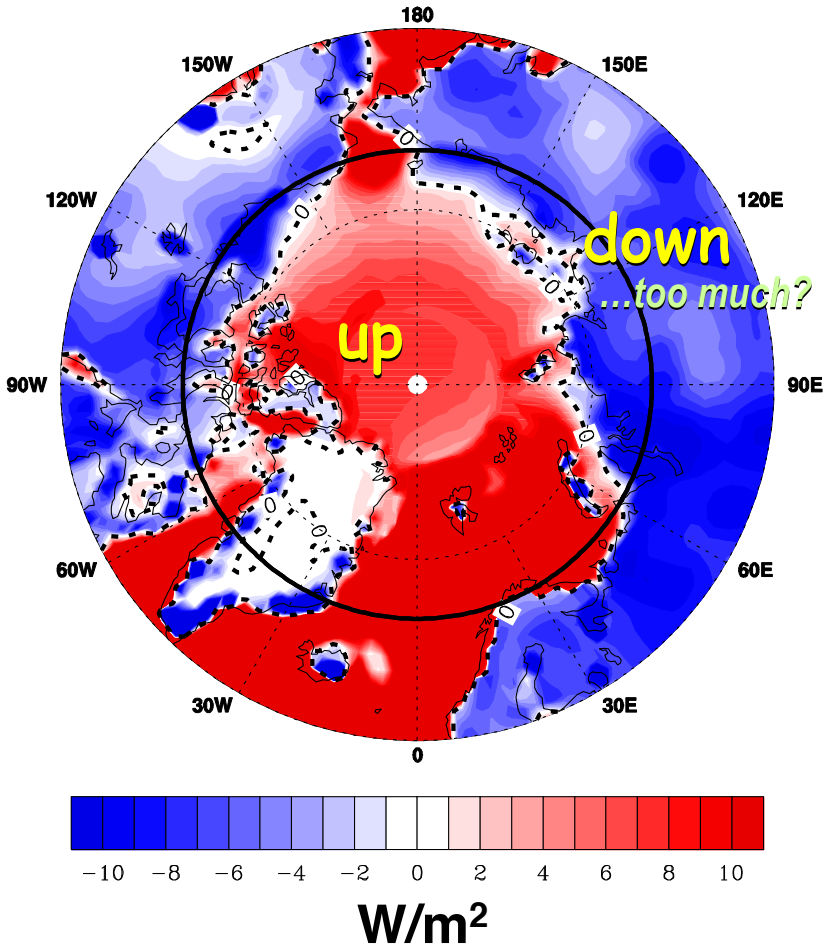
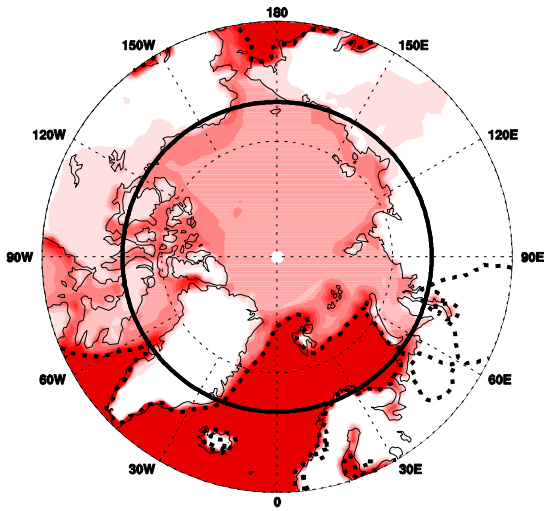
Net Surface Heat Flux from ERA-40

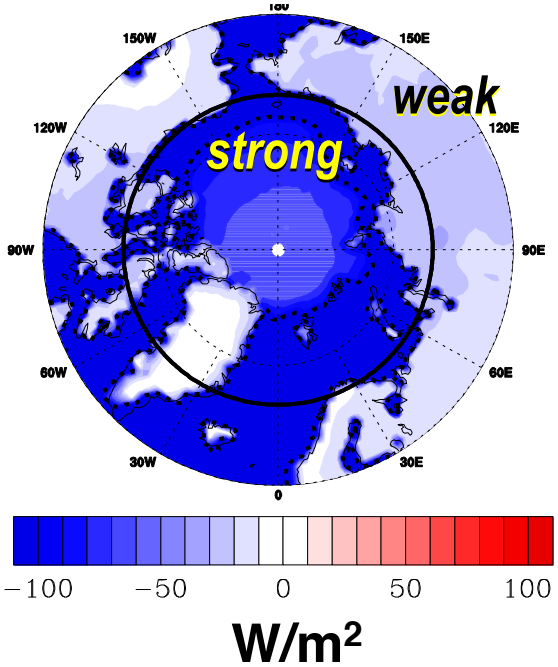
Annual



January



July



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Seasonal Arctic Ocean Energy Budget (ERA-40)