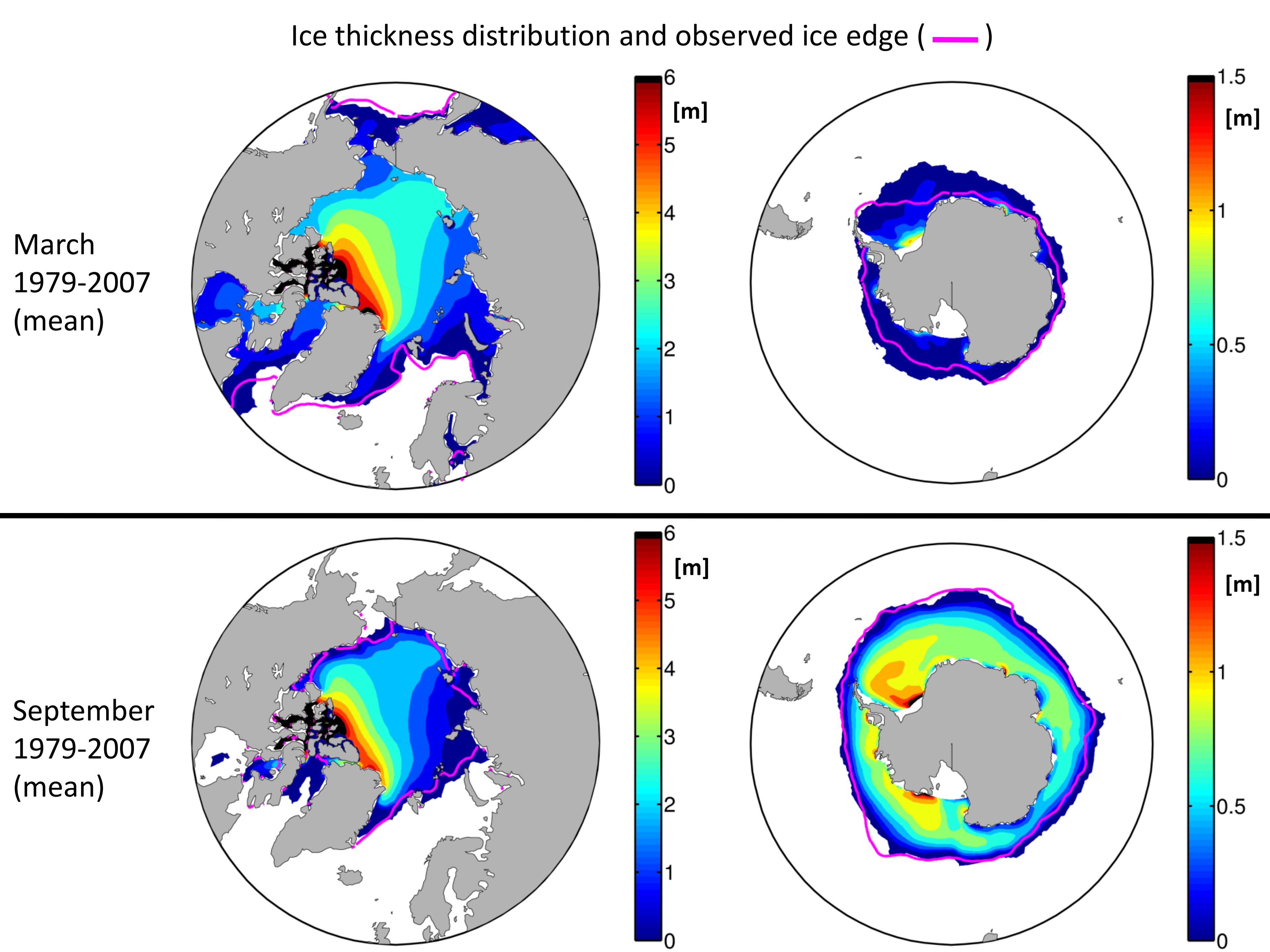


Ice thickness distribution and observed ice edge ( )
March
1979-2007
(mean)
September
1979-2007
(mean)
[m]
6
5
4
3
2
1
0
1.5
1
0.5
0

TECLIM Seminars series on sea ice

UCL, November 17th 2010

Importance of physics, resolution and forcing in hindcast simulations of Arctic and Antarctic sea ice variability and trends

François Massonnet, Thierry Fichefet

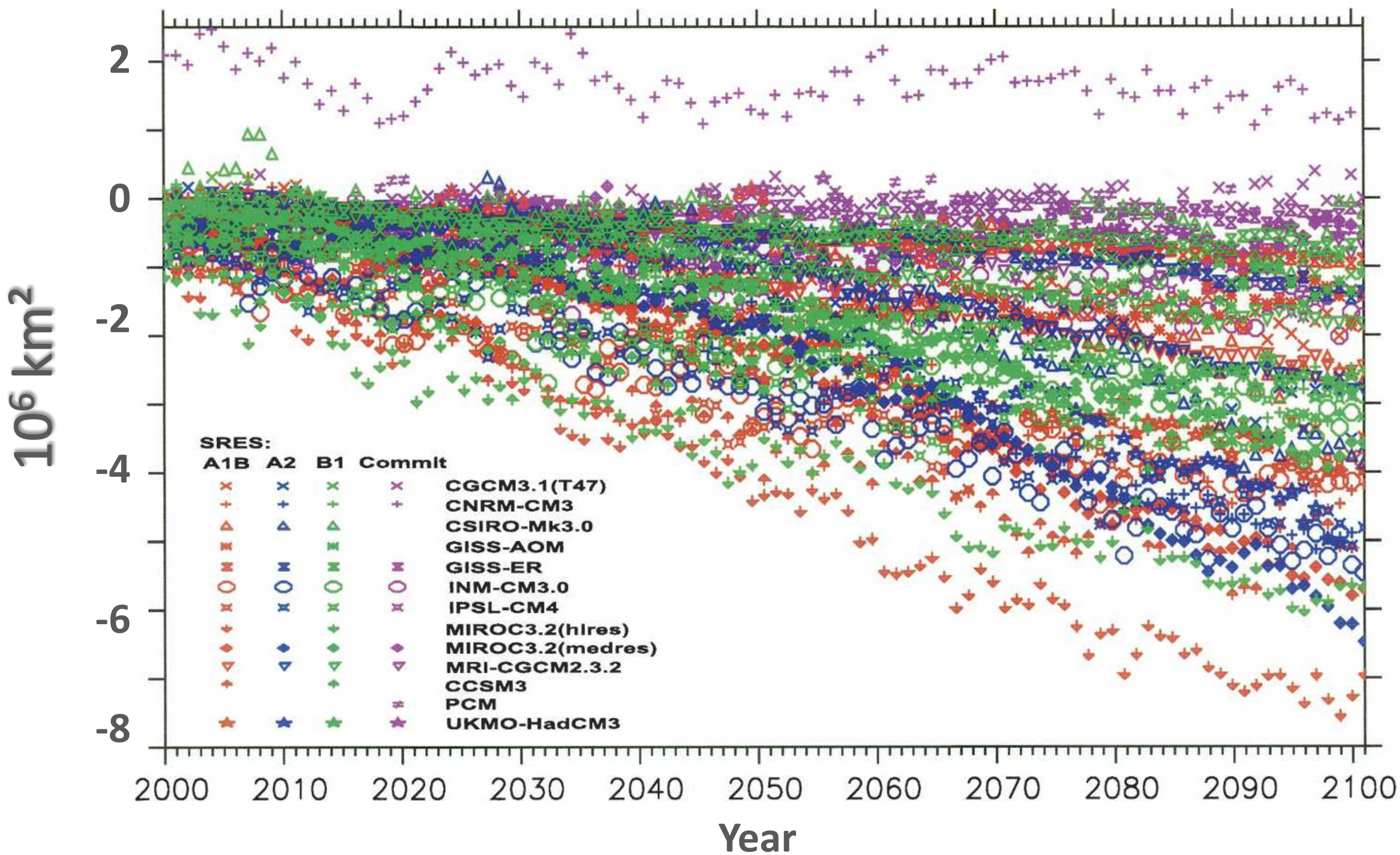
with contributions from H. Goosse, M. Vancoppenolle, C. König Beatty, P. Mathiot

Georges Lemaître Centre for Earth and Climate Research (TECLIM)

Earth and Life Institute (ELI)

UCL Université catholique de Louvain

Uncertainties in sea ice variability

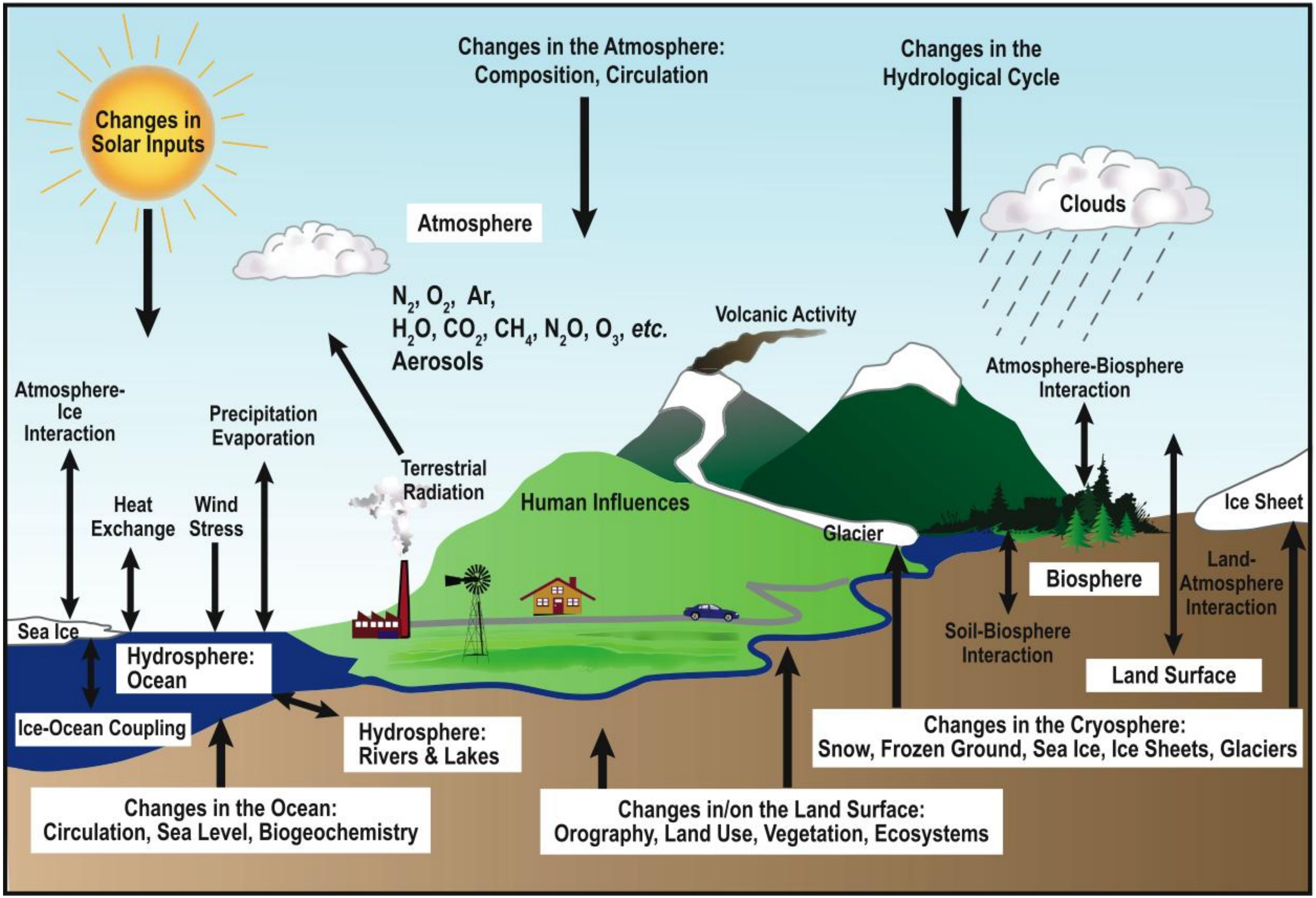


IPCC model projections of annual Arctic mean sea ice area anomalies (under various scenarios). From Zhang and Walsh, 2005

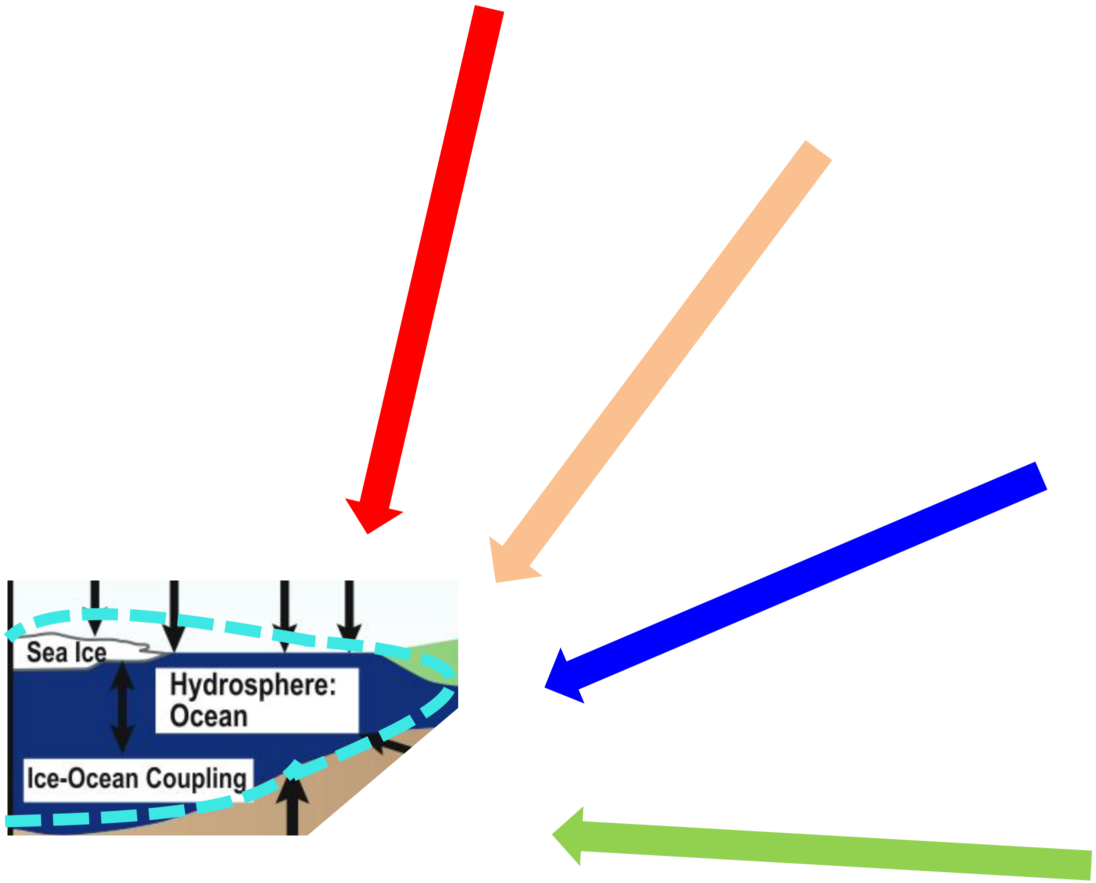
• What are the reasons for this spread?

(Climate) **G**eneral **C**irculation **M**odel

• *Stroeve et al. (2007)* note that GCMs tend to underestimate summer Arctic sea ice losses, but **sophisticated** sea ice models perform better than others


Changes in the Atmosphere:
Composition, Circulation
Changes in the
Hydrological Cycle
Changes in
Solar Inputs
Atmosphere
Clouds
N_2, O_2, Ar,
H_2O, CO_2, CH_4, N_2O, O_3, *etc.*
Aerosols
Volcanic Activity
Atmosphere-Biosphere
Interaction
Atmosphere-
Ice
Interaction
Precipitation
Evaporation
Terrestrial
Radiation
Heat
Exchange
Wind
Stress
Human Influences
Glacier
Ice Sheet
Biosphere
Land-
Atmosphere
Interaction
Sea Ice
Hydrosphere:
Ocean
Soil-Biosphere
Interaction
Land Surface
Ice-Ocean Coupling
Hydrosphere:
Rivers & Lakes
Changes in the Cryosphere:
Snow, Frozen Ground, Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean:
Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface:
Orography, Land Use, Vegetation, Ecosystems

IPCC, 2007


Sea Ice
Hydrosphere:
Ocean
Ice-Ocean Coupling


PS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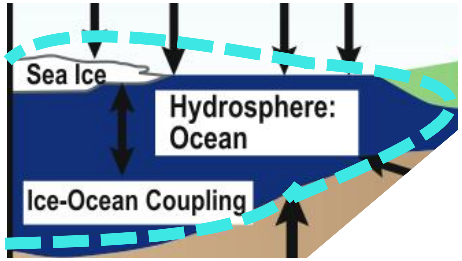
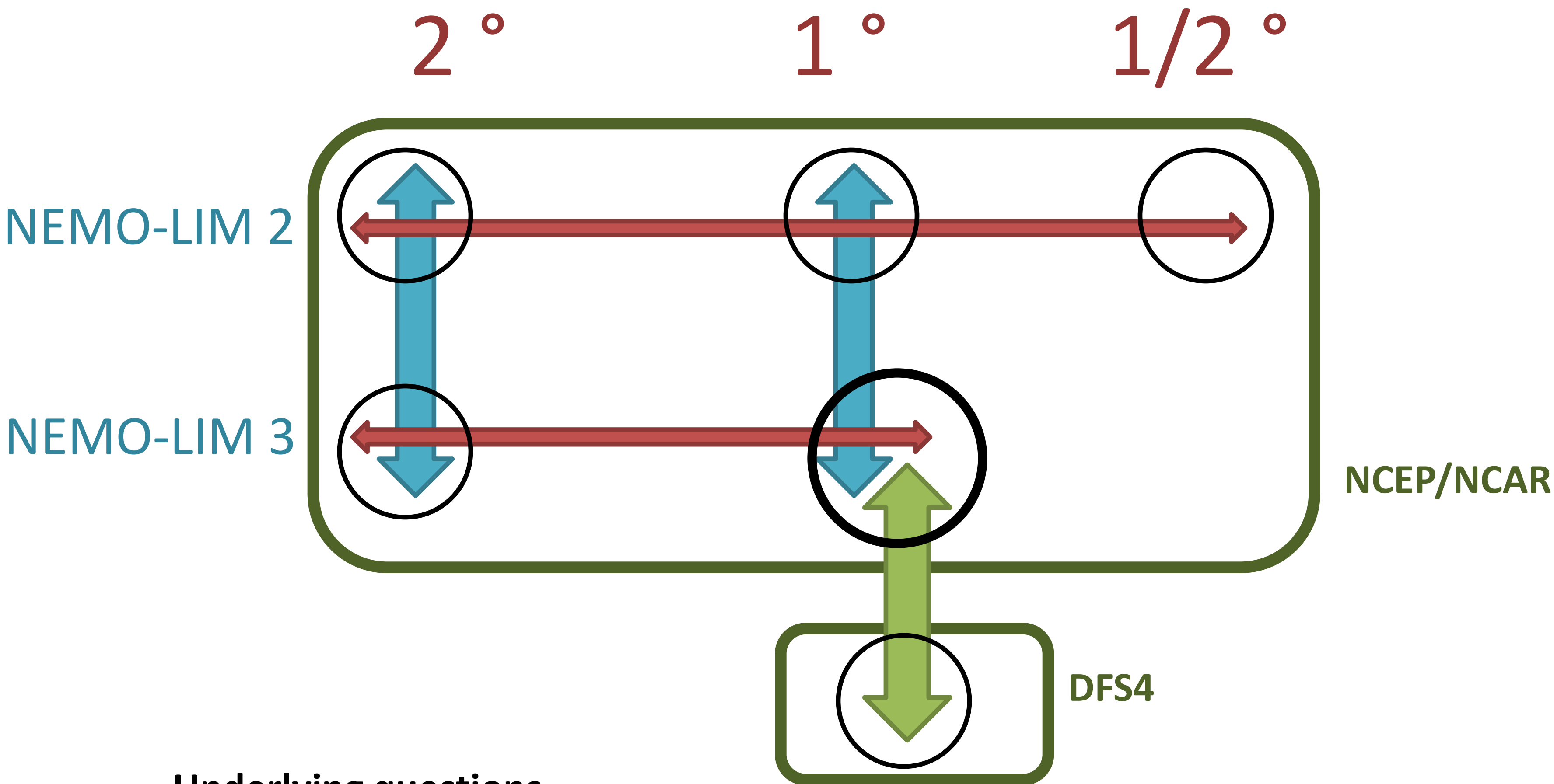
MR


ecolo


Sea Ice
Hydrosphere:
Ocean
Ice-Ocean Coupling

Understanding sea ice variability with an OGCM



<u>Underlying questions</u>

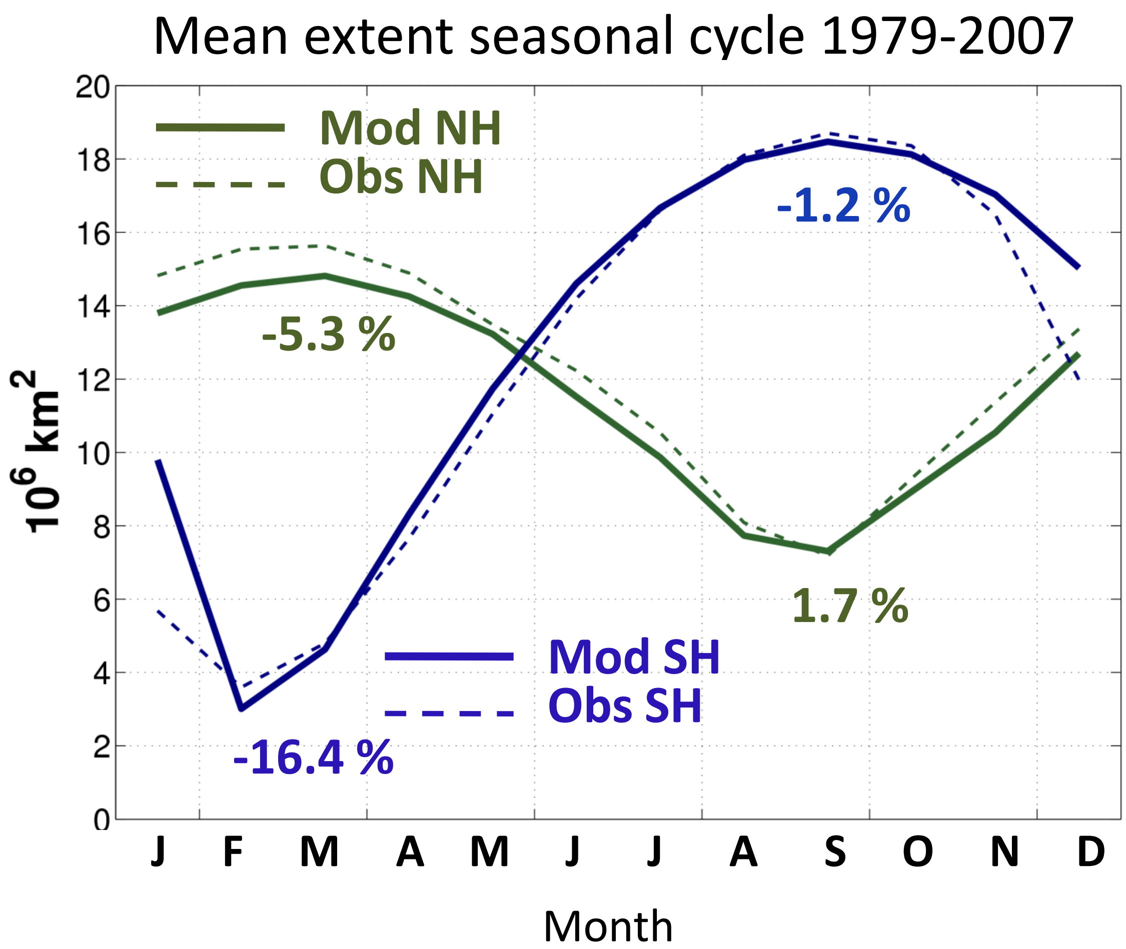
1) **How is** *model's variability performance* **modified along arrows?**

2) **How does** *model variability* **behave along arrows?**

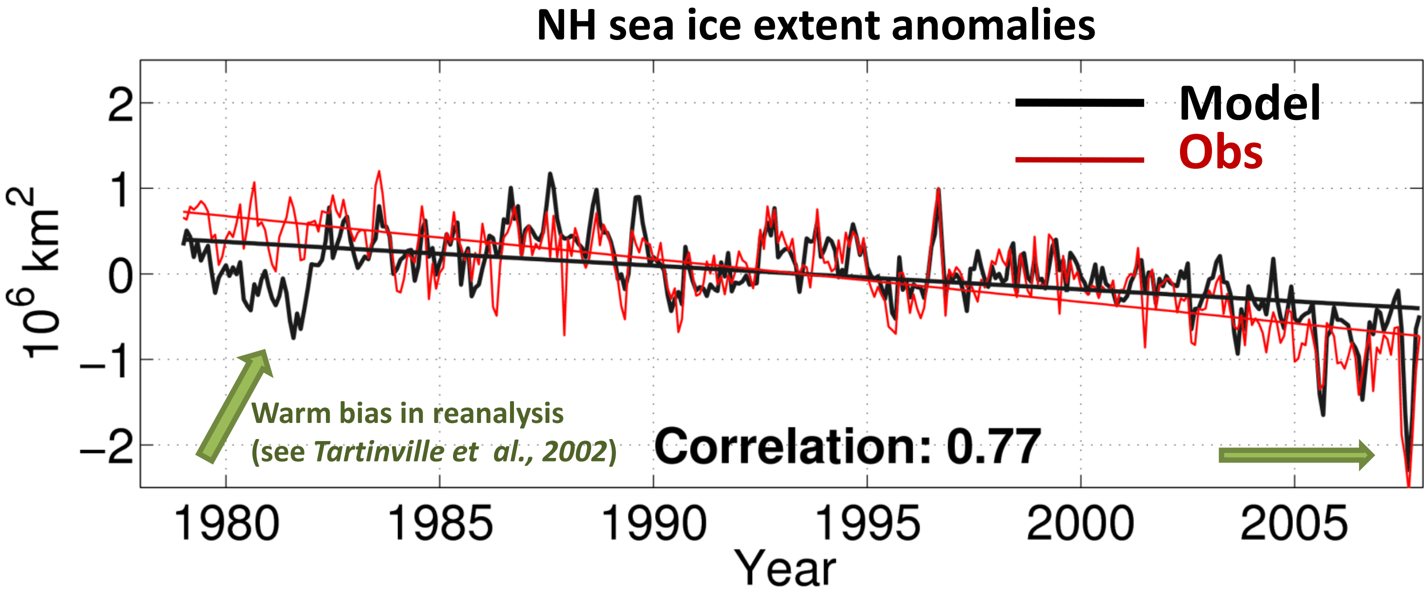
Outline

1. Reference simulation
2. Sensitivity to physics representation
3. Sensitivity to resolution
4. Sensitivity to atmospheric forcing
5. Illustration of sensitivity experiments
6. Conclusions

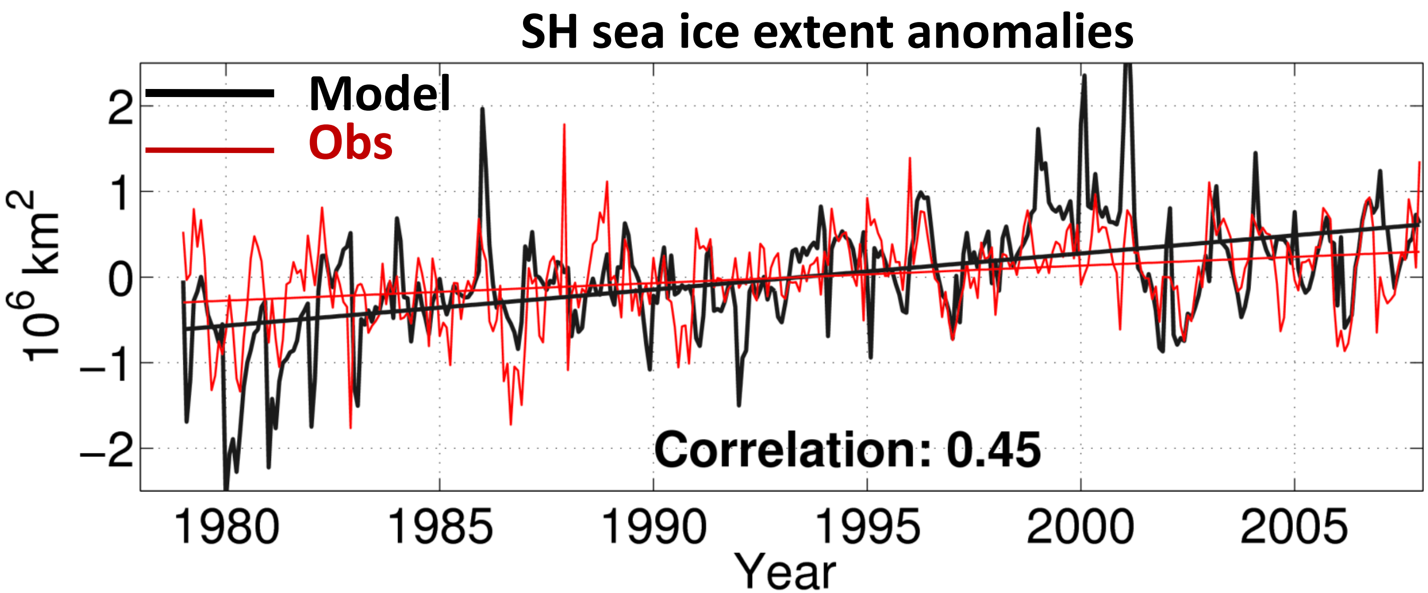
1. Reference Simulation (NEMO-LIM3-1°-NCEP/NCAR)



1. Reference Simulation (NEMO-LIM3-1°-NCEP/NCAR)



Err. Variance: -19.9 %
Err. Trend: -45.7 %



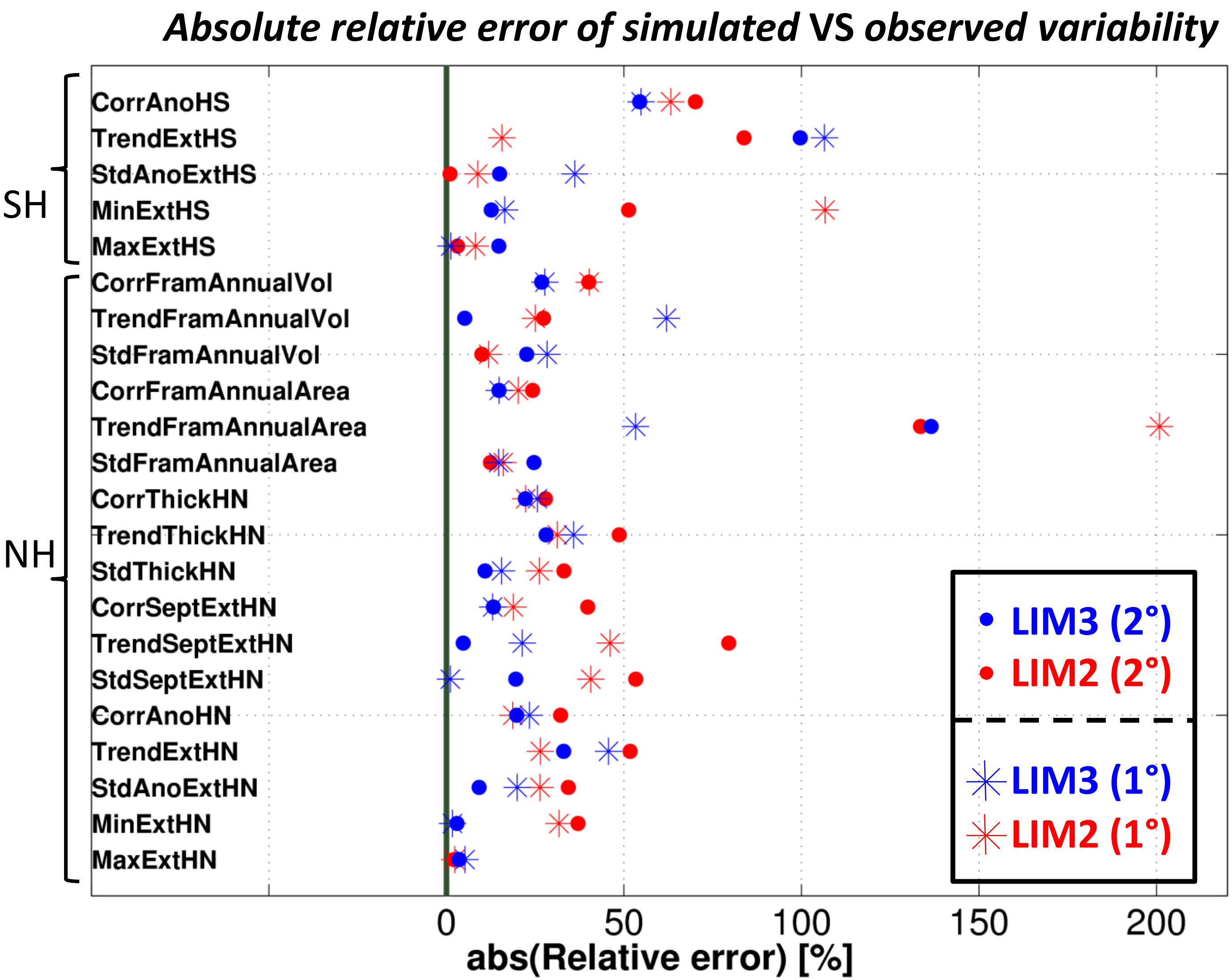
Err. Variance: 36.2 %
Err. Trend: 106.5 %

2. Sensitivity to physics representation

Main differences LIM2 – LIM3

		LIM 2 Fichefet and Morales Maqueda, 1997	LIM 3 Vancoppenolle et al., 2009
1	*Ice thickness representation*	**1-category Ice Thickness Distribution (ITD)**	**5 categories ITD**
2	*Vertical thermodynamics*	**2 + 1 layers** **Effective thermal conductivity** **Basic brine modelling**	**5 + 1 layers** **/** **Explicit brine +drainage**
3	*Rheology*	**Viscous Plastic**	**Elastic Viscous Plastic**

2. Sensitivity to physics representation



Overall:

LIM3 « better » 28 times / 44

Mean abs err: 27.7% - 38.8%

NH:

LIM3 « better » 23 times / 34

Mean abs err: 23.8% - 38.0%

SH:

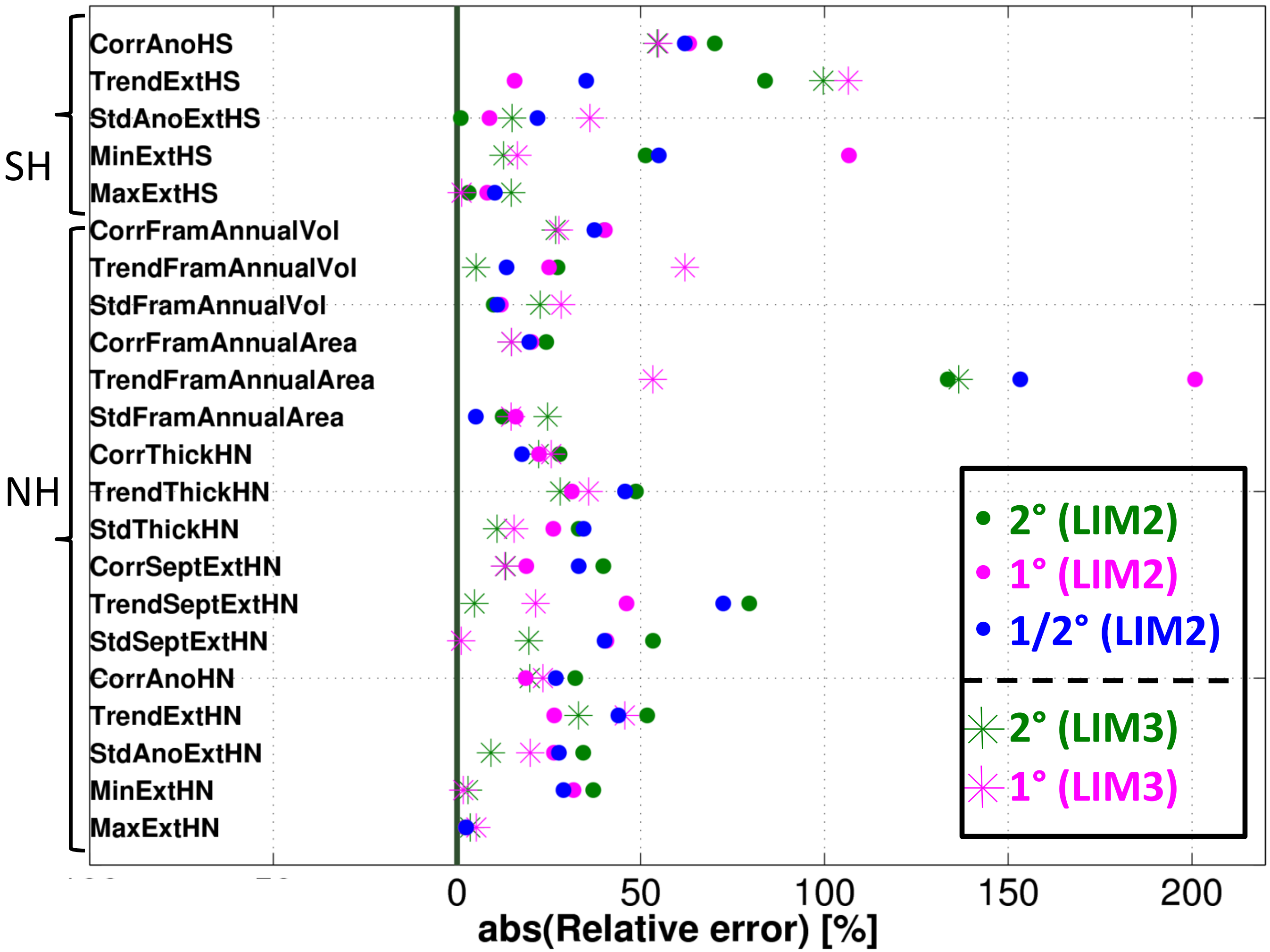
LIM3 « better » 5 times / 10

Mean abs err: 41.2% - 41.2%

- Physics seem to play a key role in governing the skill of models to simulate variability…
- … only in NH

3. Sensitivity to resolution

Absolute relative error of simulated VS observed variability



Overall:

Mean abs err: 33.9% - 32.6% - 36.3%

NH:

Mean abs err: 31.9% - 29.9% - 36.1%

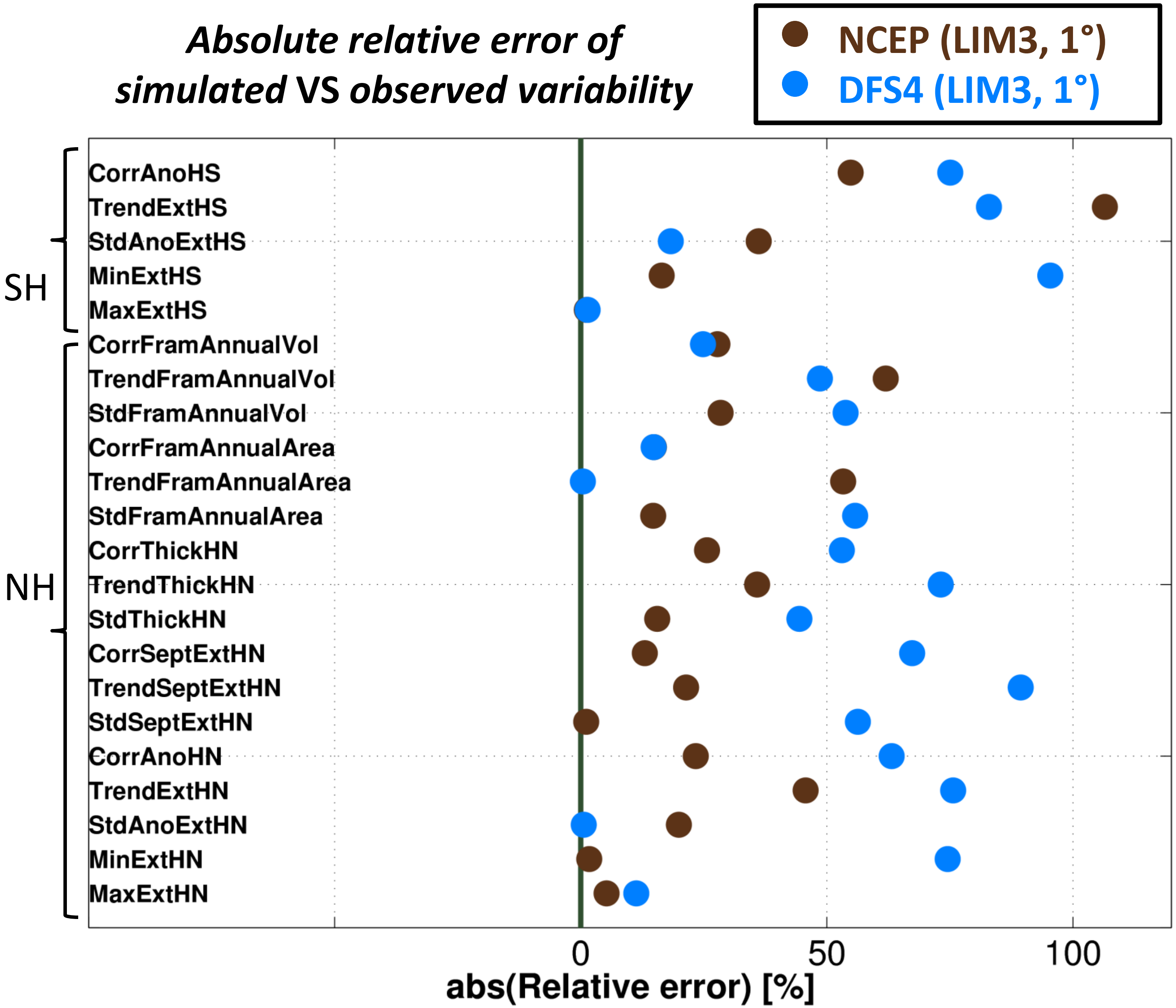
SH:

Mean abs err: 40.6% - 41.8% - 36.9%

- No significant improvement with resolution (for this range)
- But: LIM calibrated for 2°

4. Sensitivity to atmospheric forcing

Absolute relative error of simulated VS observed variability



<u>Overall:</u>
Mean abs err: 28.4% - 49.1%

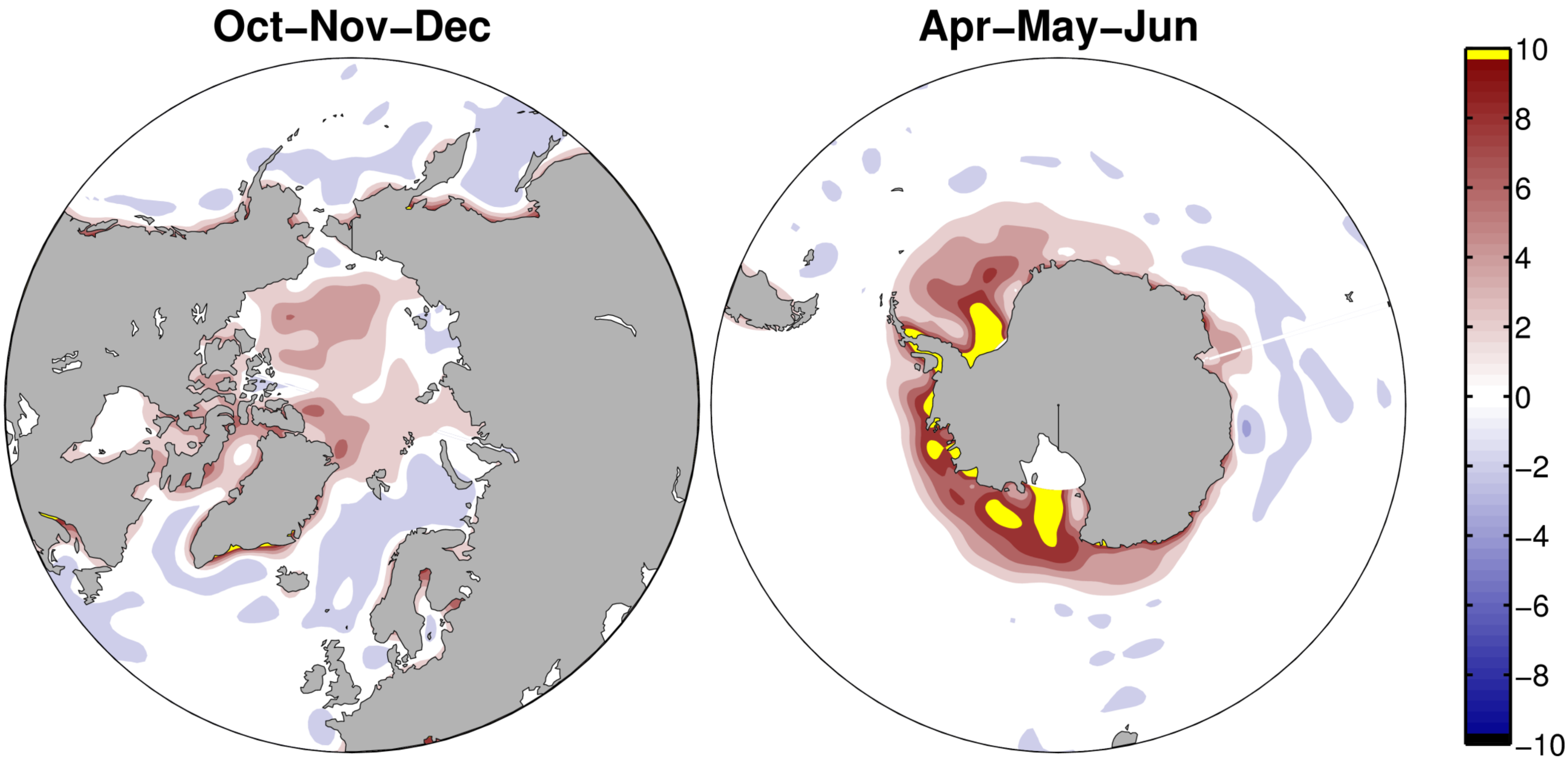
<u>NH:</u>
Mean abs err: 24.1% - 47.5%

<u>SH:</u>
Mean abs err: 43.0% - 54.6%

- DFS4 (Brodeau et al., 2010) is based on ERA-40 fields
- LIM calibrated for NCEP reanalysis

4. Sensitivity to atmospheric forcing

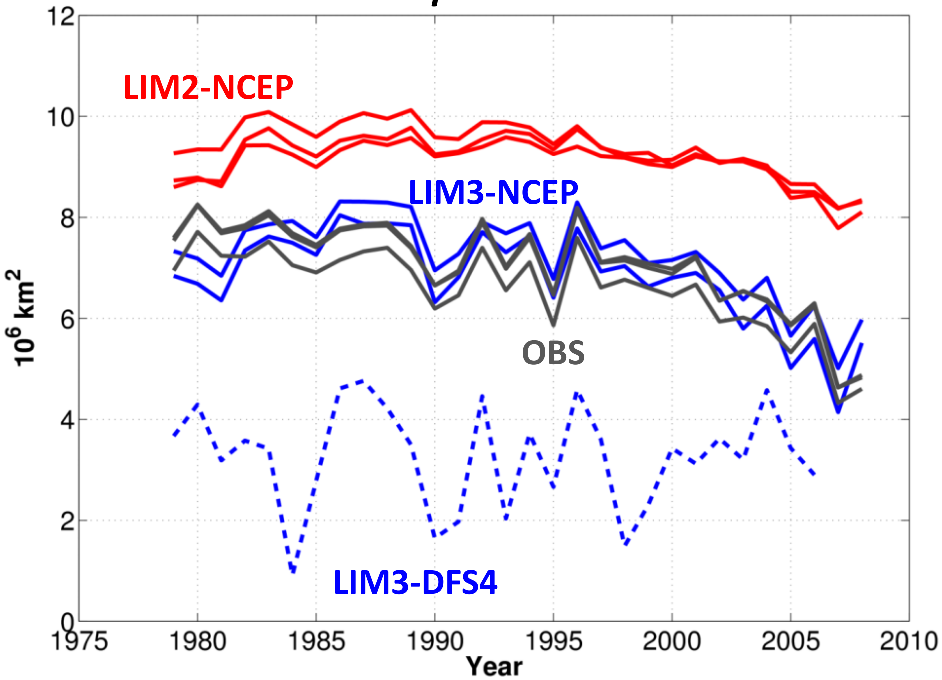
Mean 1979-2006 2m air temperature difference* [K] *« DFS4 » minus « NCEP »



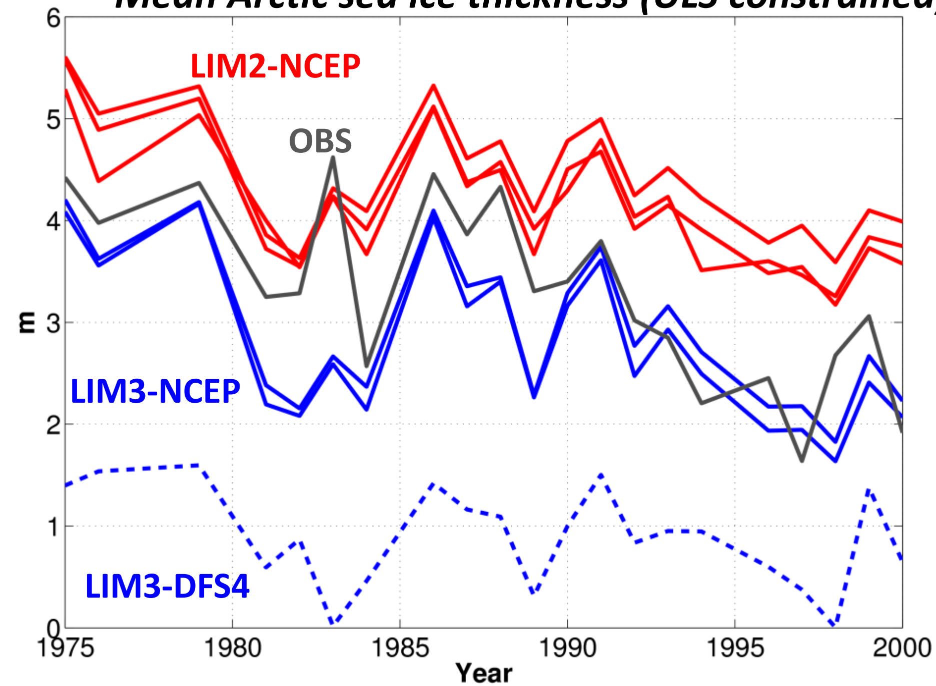
- DFS4 2m air temperatures known to be warmer than NCEP (Bromwich and Wang, 2005)
- Higher winter temperatures ➡ smaller summer ice extents

5. Illustration of sensitivity experiments

Arctic sea ice September mean extent



Mean Arctic sea ice thickness (ULS constrained)



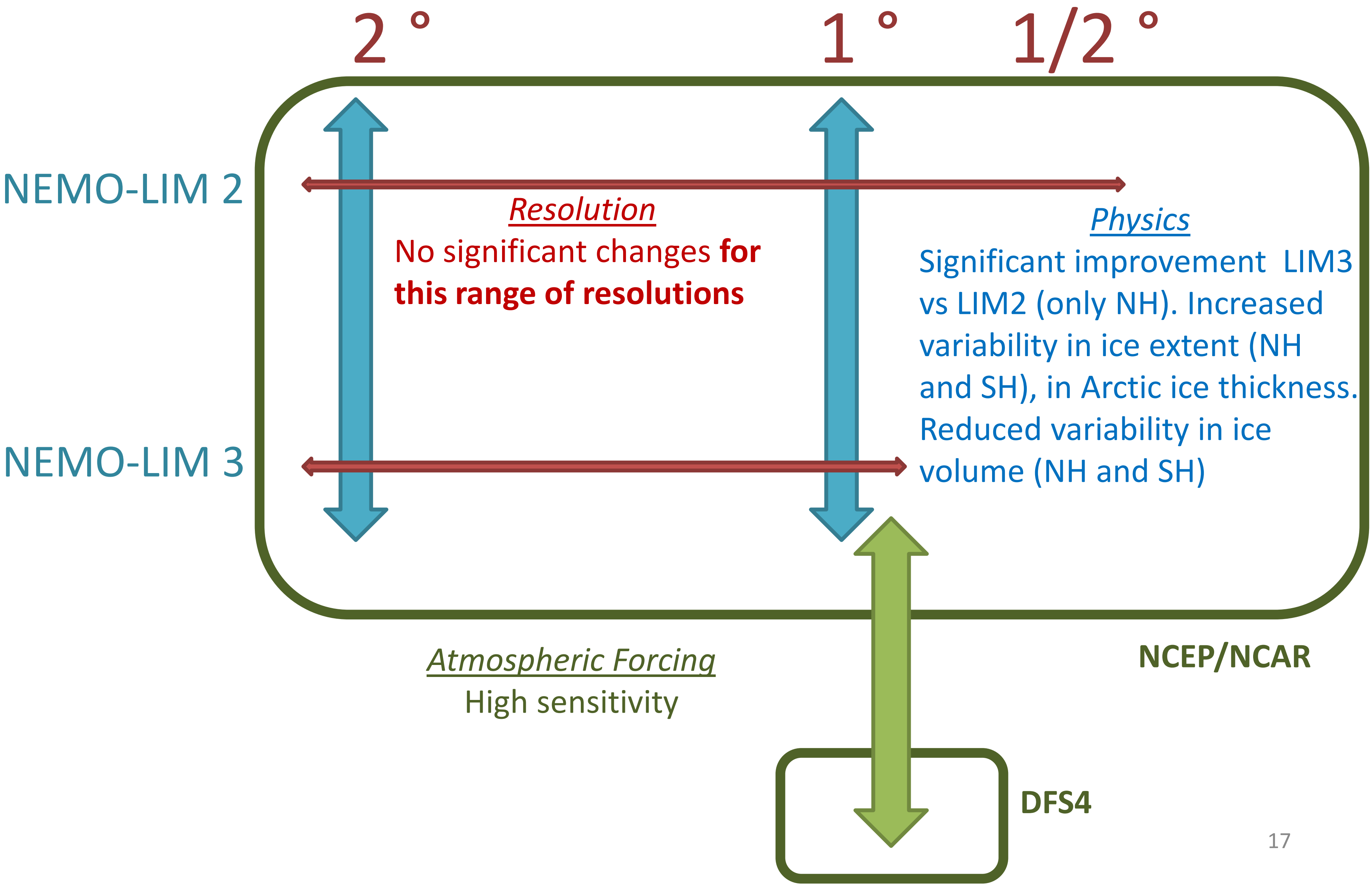
- Higher variability for smaller mean extents (as in *Goosse et al., 2009*)

- Higher variability with ITD representation, through ice-albedo feedback (*Holland et al., 2006*)

- Previous studies (e.g. Bitz et al., 2001): ITD ➡ thicker ice. However…

- Increased ice thickness variability with higher mean ice thickness (as in *Holland and Curry, 1999*)

6. Conclusions



6. Conclusions

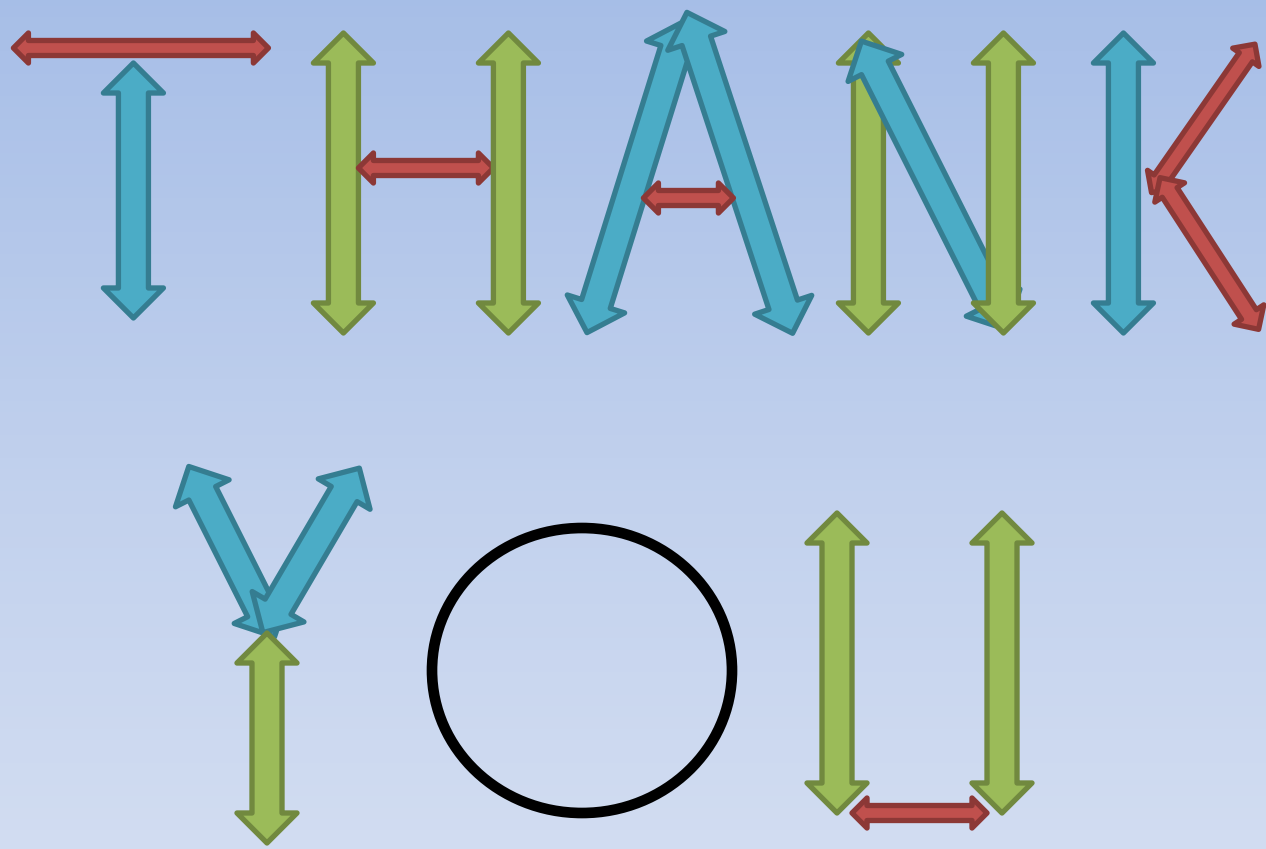
Take home message

• Keep in mind that this study considers sensitivity of sea ice **variability** for **atmosphere-driven OGCMS** at a **decadal time scale**

• Don’t direct your priorities to higher resolutions if you work at ~ 1°. Eddy-permitting resolutions (< ¼ °) have not been tested here. Also, higher resolution for the reanalyses could be important (DeWeaver and Bitz, 2006)

• Include a subgrid parametrization of ice thickness distribution to better simulate observed variability (NH). For GCMs, ITD also allows warmer surface air temperatures above perennial ice (Holland et al., 2006)

• Quality of atmospheric reanalyses are of higher importance. For GCMs, much effort should be directed to atmosphere modelling



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