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

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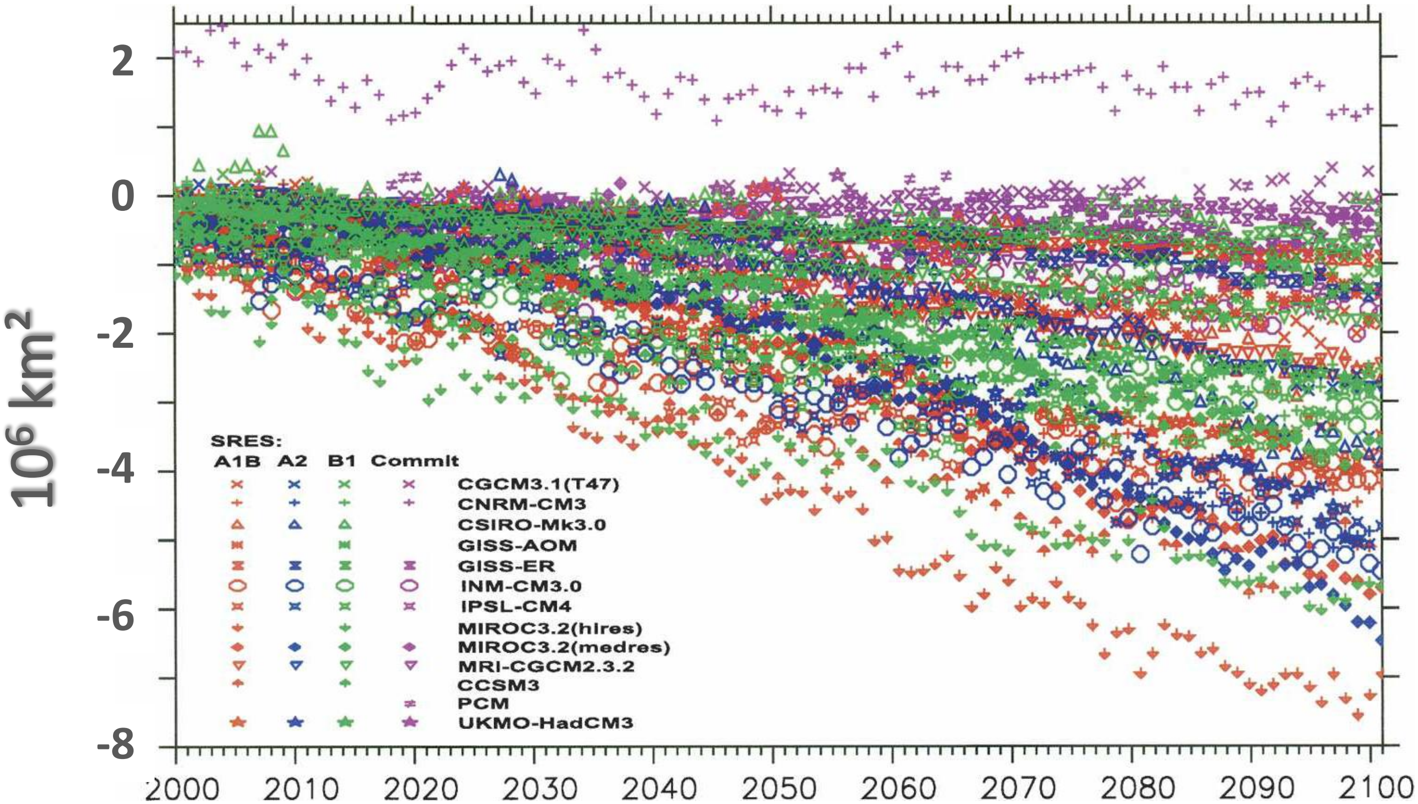
Uncertainties in sea ice variability



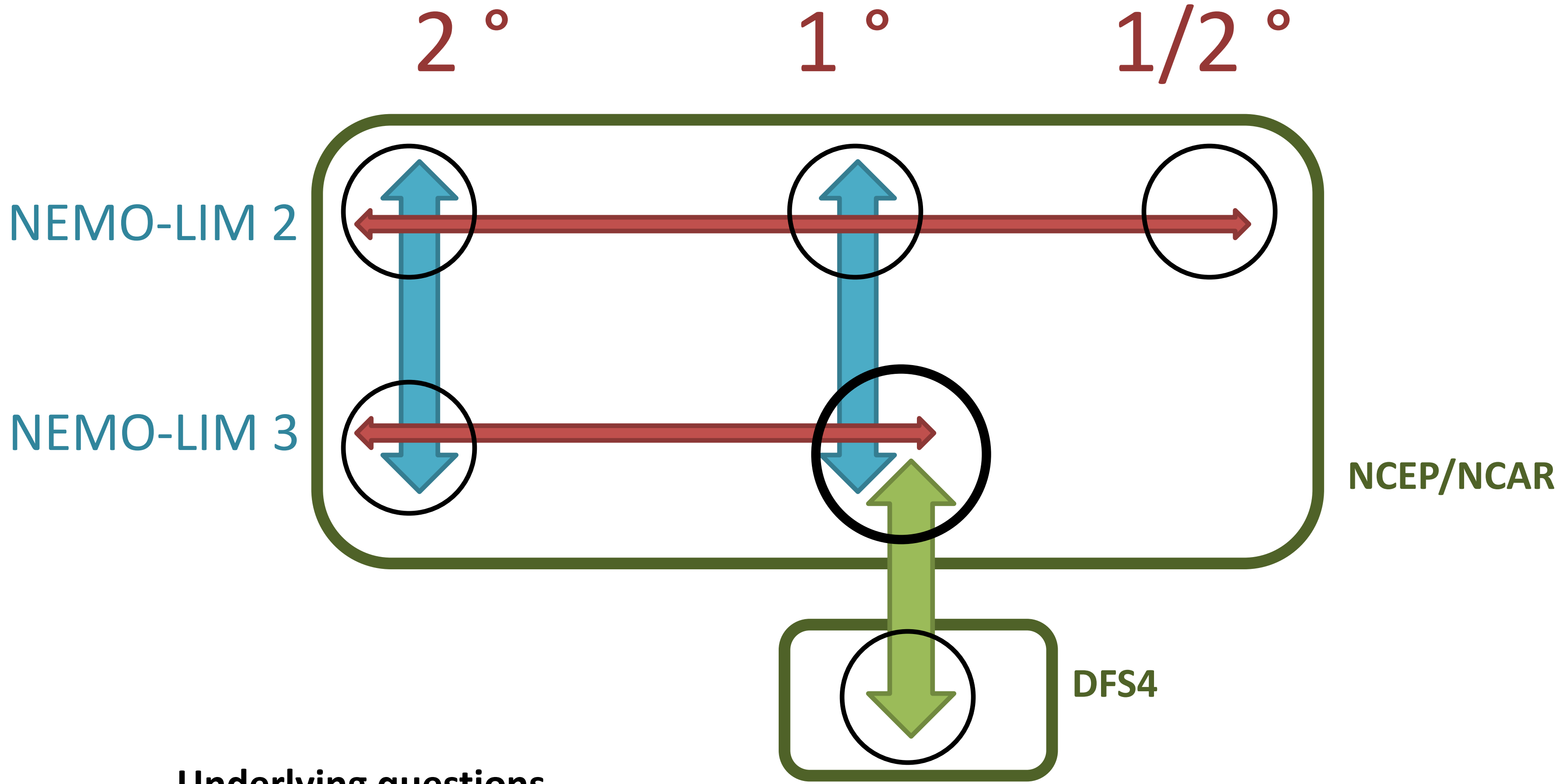
IPCC model projections of annual Arctic mean sea ice area anomalies (under various scenarios). From Zhang and Walsh, 2005

- What are the reasons for this spread?

- None of the 15 GCMs evaluated in *Arzel et al. (2006)* study can simultaneously capture observed mean state, trend and interannual variability with < 10% error for 1981-2000

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

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)

Atmospheric Forcing

NCEP/NCAR daily surface air temperatures and wind speeds (1948-2008) + monthly climatological surface relative humidities, cloud fractions and precipitation rates + monthly climatological river runoffs

Bulk formulas

Surface fluxes of heat, freshwater and momentum (*salinity restoring*)

Tripolar global grid, 1° resolution
1948-2008 runs; analyses for 1979-2007

LIM3 (SEA ICE MODEL)

- Explicit representation of the subgrid-scale ice thickness, enthalpy, salinity and age distributions (5 categories)
- Multi-layer halo-thermodynamic component (1 snow layer + 5 ice layers)
- Mechanical redistribution that takes into account ridging/rafting processes and ridge porosity
- EVP rheology on a C-grid

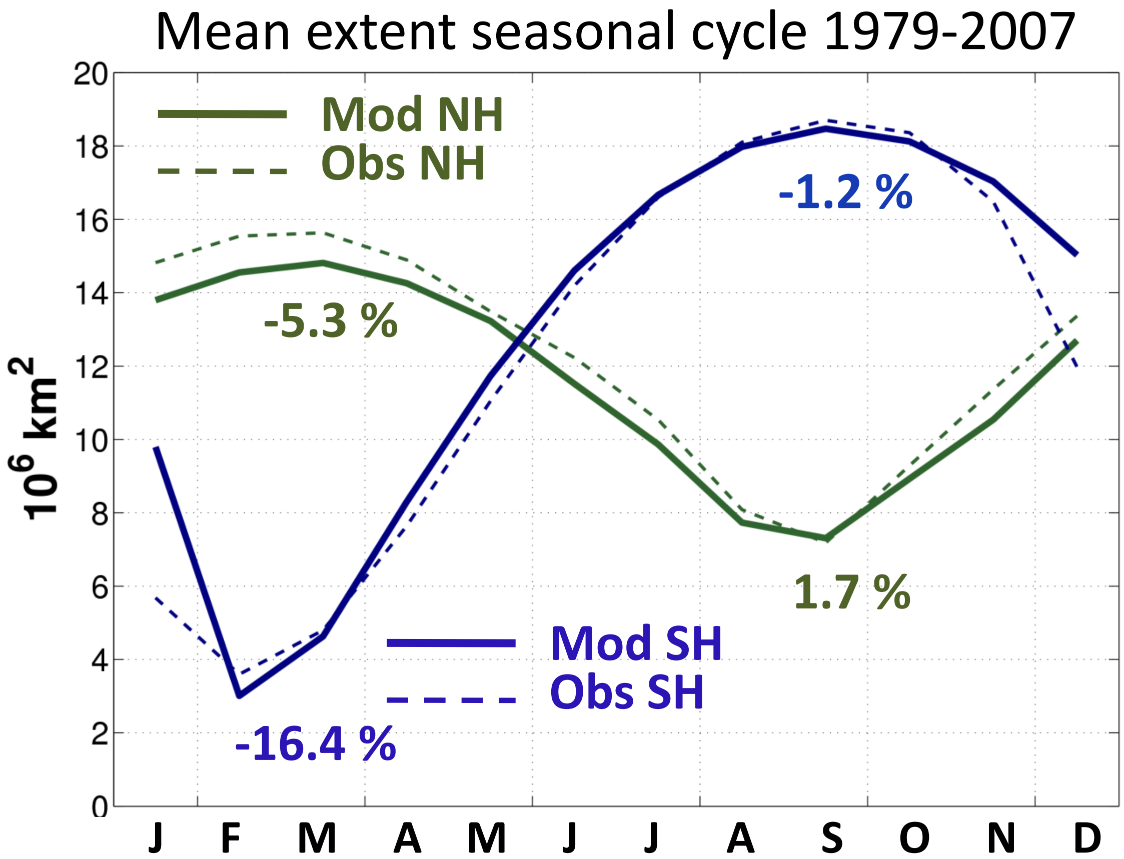
www.climate.be/lim

NEMO (OCEAN MODEL)

- Primitive equation, free surface ocean general circulation model on a C-grid
- Level-1.5 turbulence closure scheme
- Isopycnal mixing + G&M parameterisation of eddy-induced tracer advection
- Bottom boundary layer scheme + partial step topography, 42 levels

www.nemo-ocean.eu

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



About observations

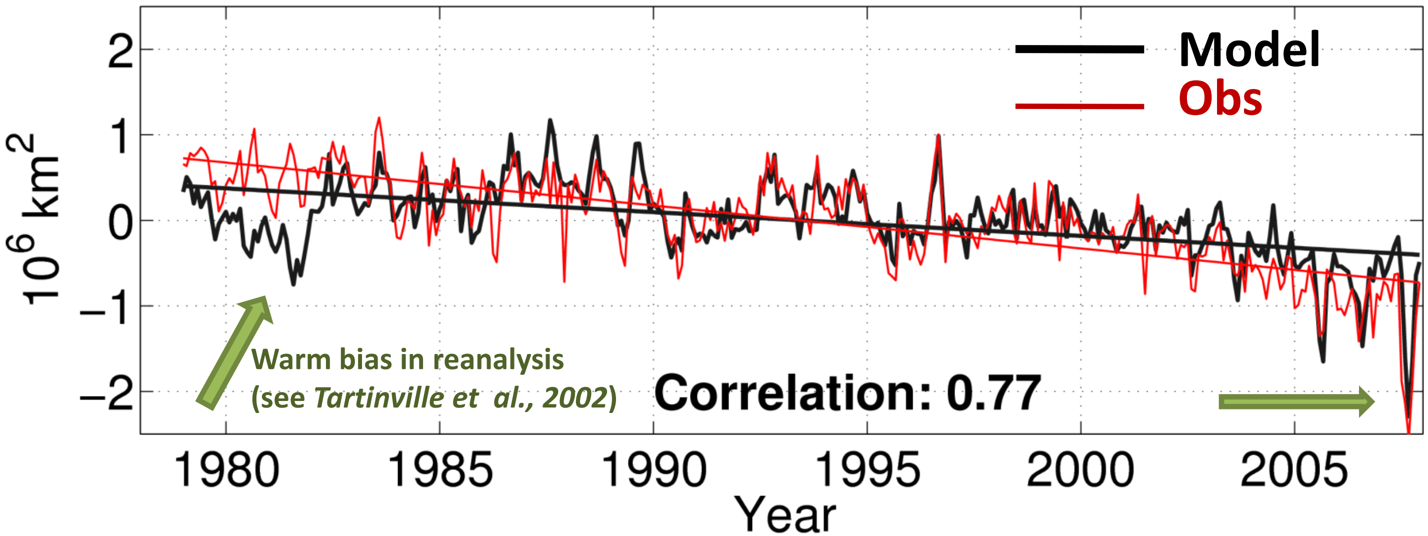
• OSISAF 1979-2007 reprocessed data set for ice concentrations (*EUMETSAT OSISAF, 2010*), interpolated to respective model grids

• ULS for ice thicknesses (*Rothrock et al., 2003*)

• PMW and ULS for Fram Strait outflow (*Kwok et al., 2004*)

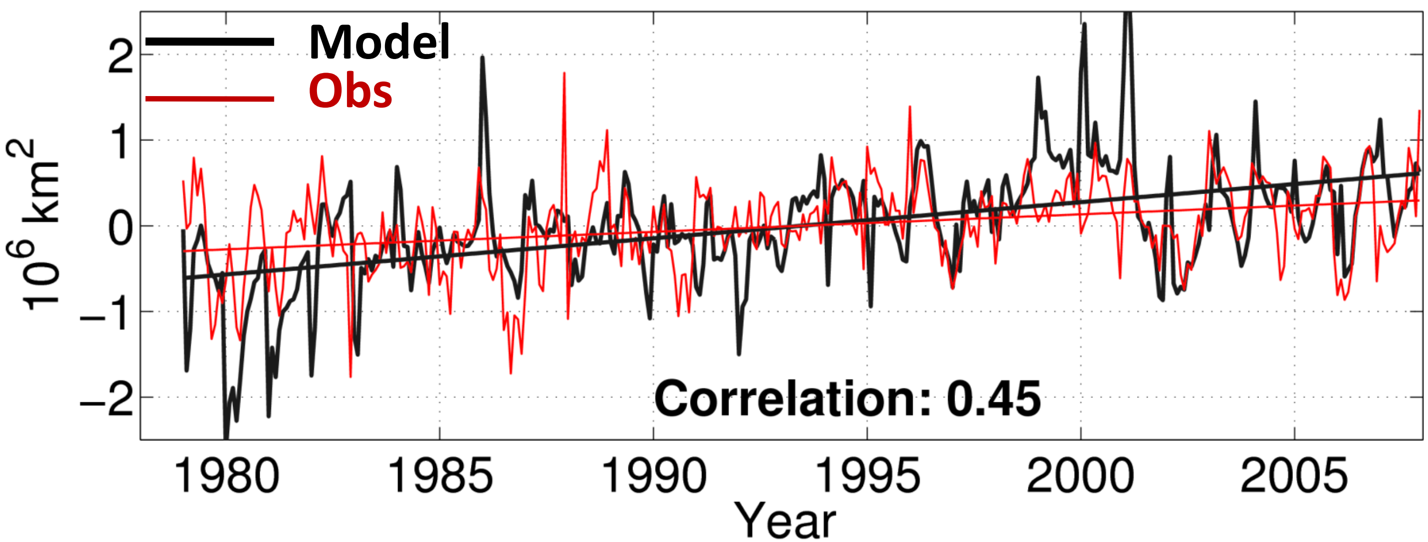
1. Reference Simulation (NEMO-LIM3-1°-NCEP/NCAR)

NH sea ice extent anomalies



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

SH sea ice extent anomalies

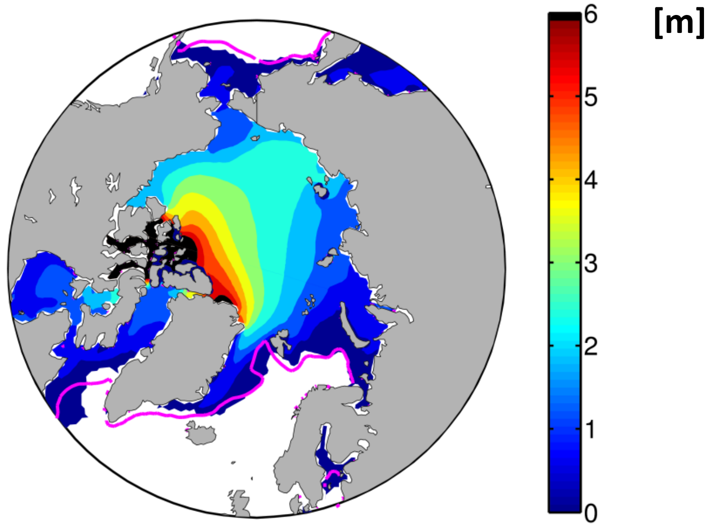


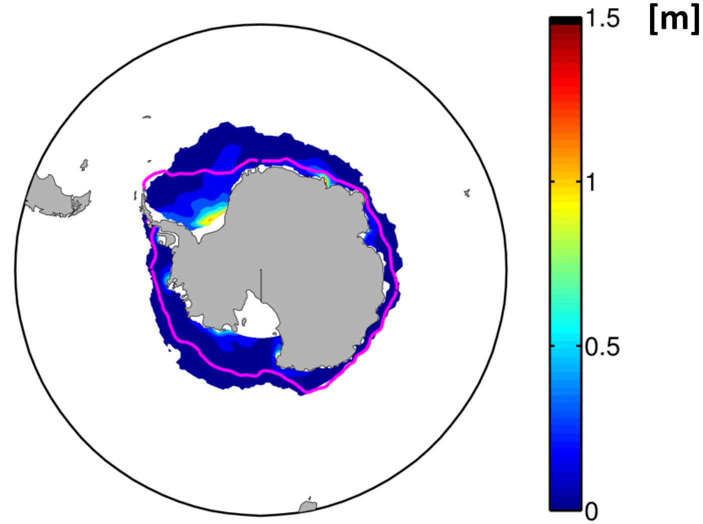
Err. Variance: 36.2 %
Err. Trend: 106.5 %

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

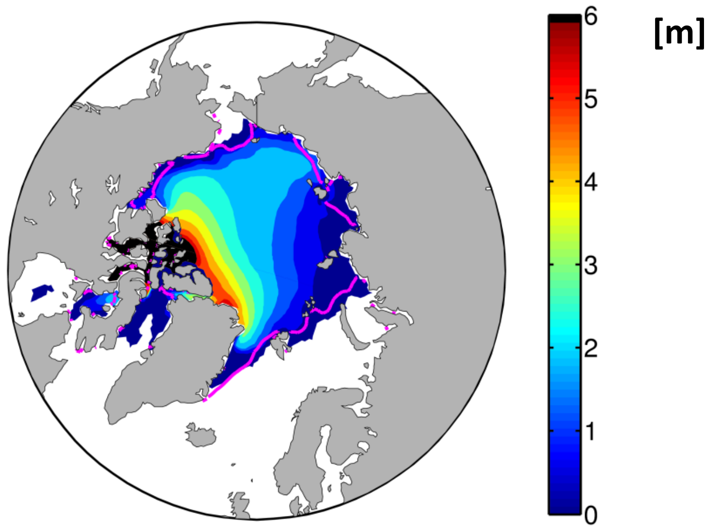
Ice thickness distribution and observed ice edge (—)

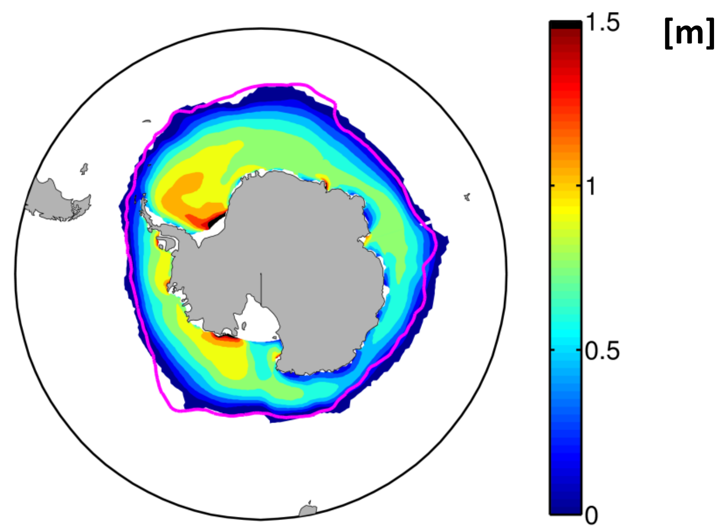
March 1979-2007





Sept. 1979-2007





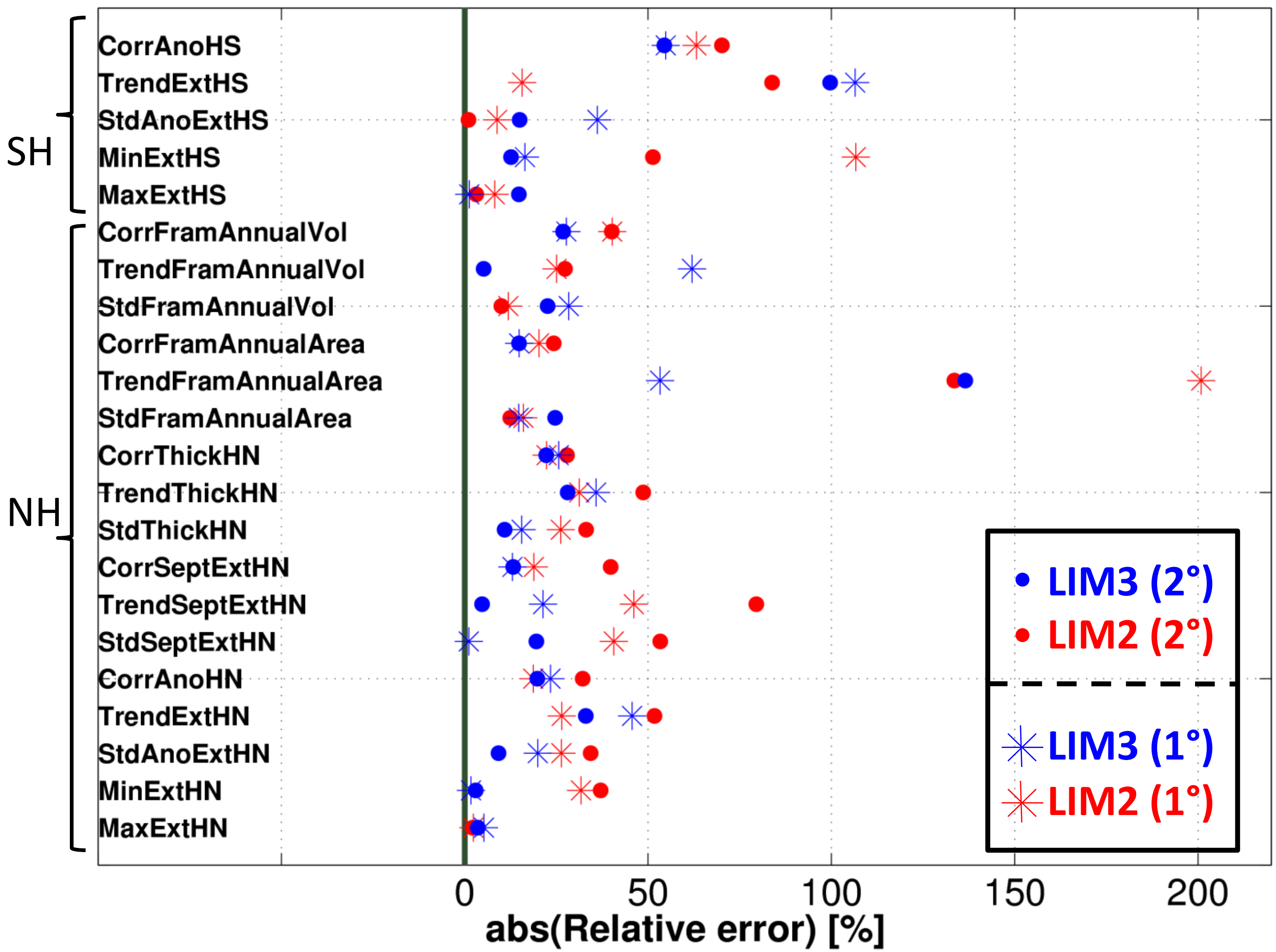
2. Sensitivity to physics representation

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**	**5 + 1 layers**
		Effective thermal conductivity	**/**
		Basic brine modelling	**Explicit brine +drainage**
3	*Rheology*	**Viscous Plastic**	**Elastic Viscous Plastic**

2. Sensitivity to physics representation

Absolute relative error of simulated VS observed variability



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%

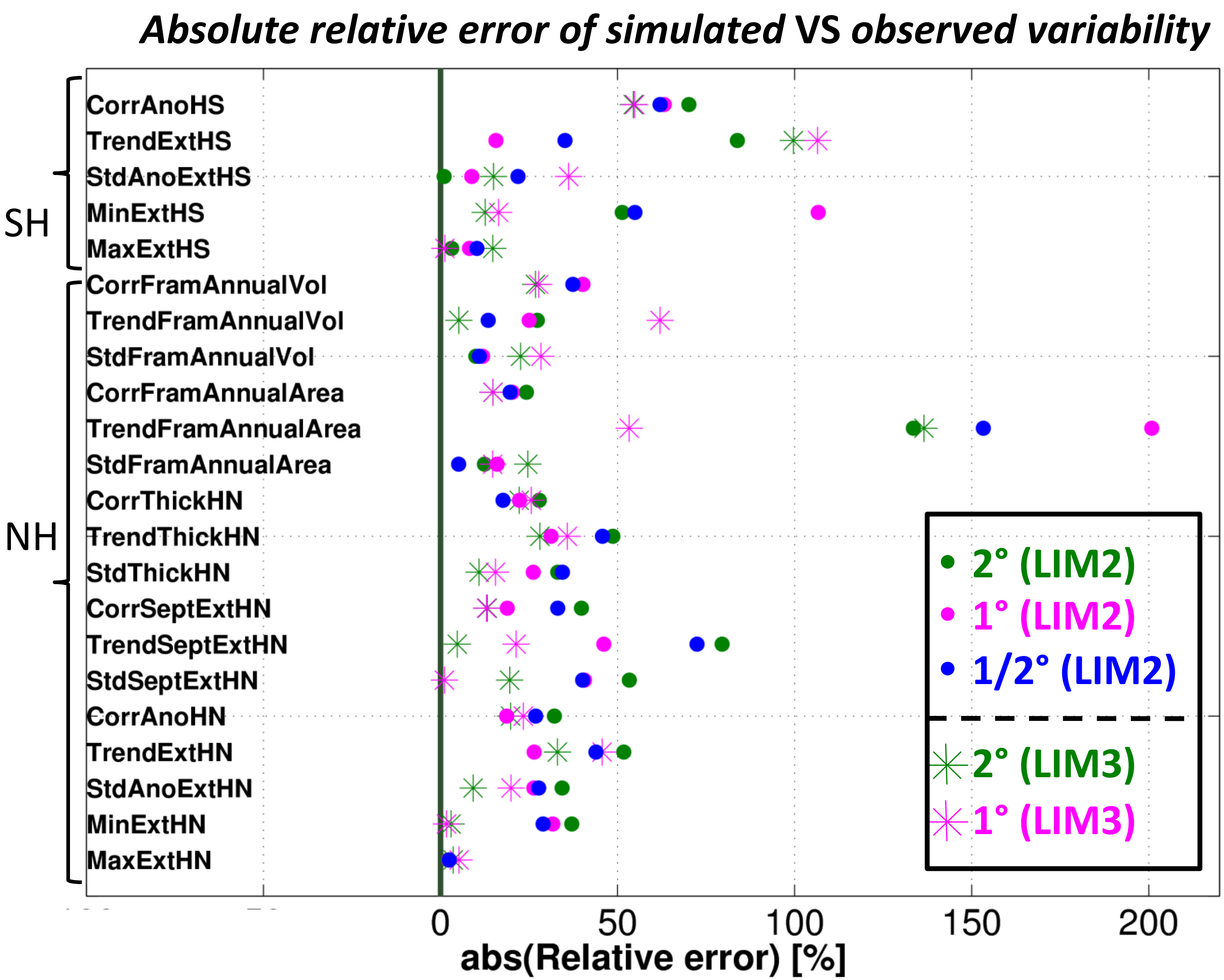
SH:

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



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

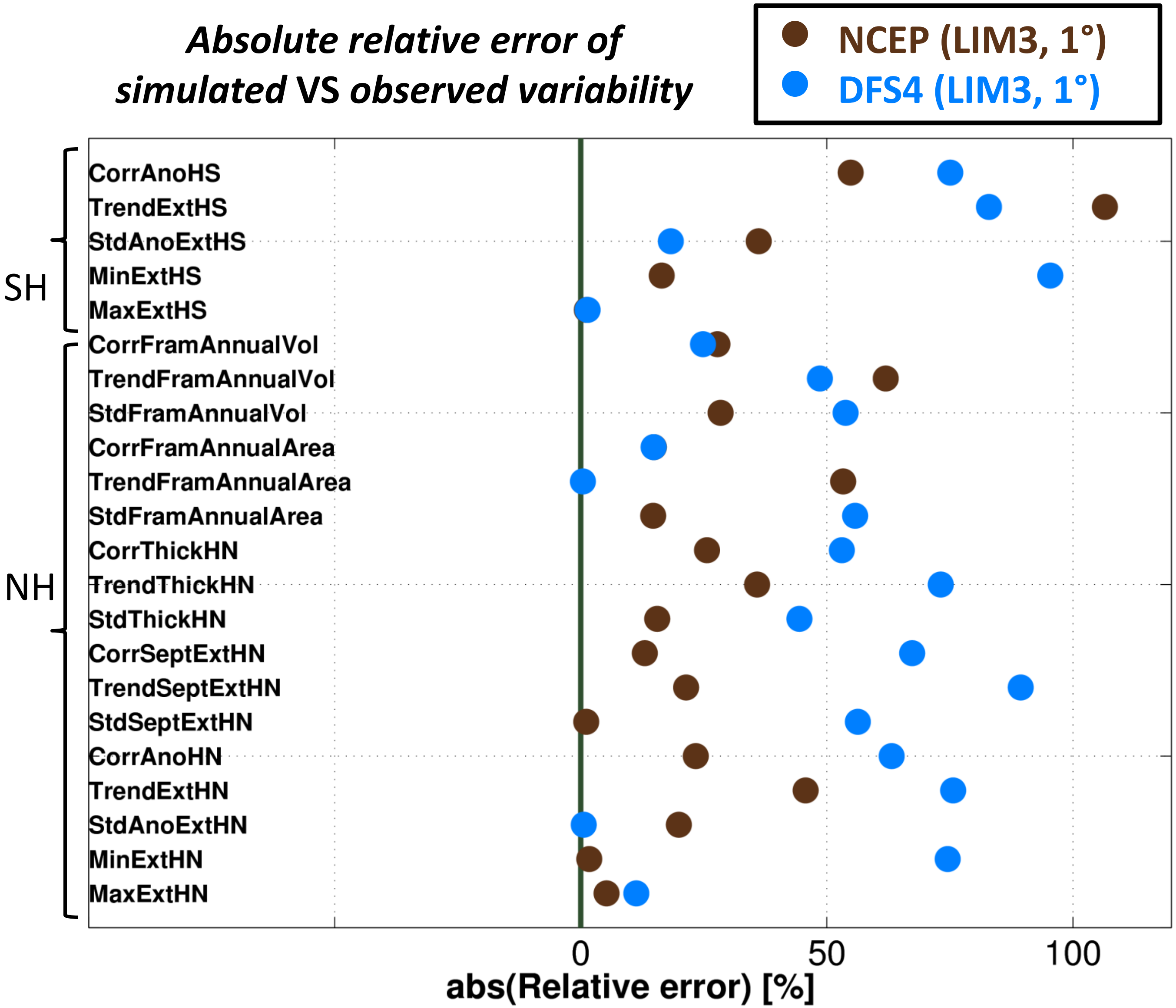
NH:
Mean abs err: 31.9% - 29.9% - 36.1%

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



Overall:
Mean abs err: 28.4% - 49.1%

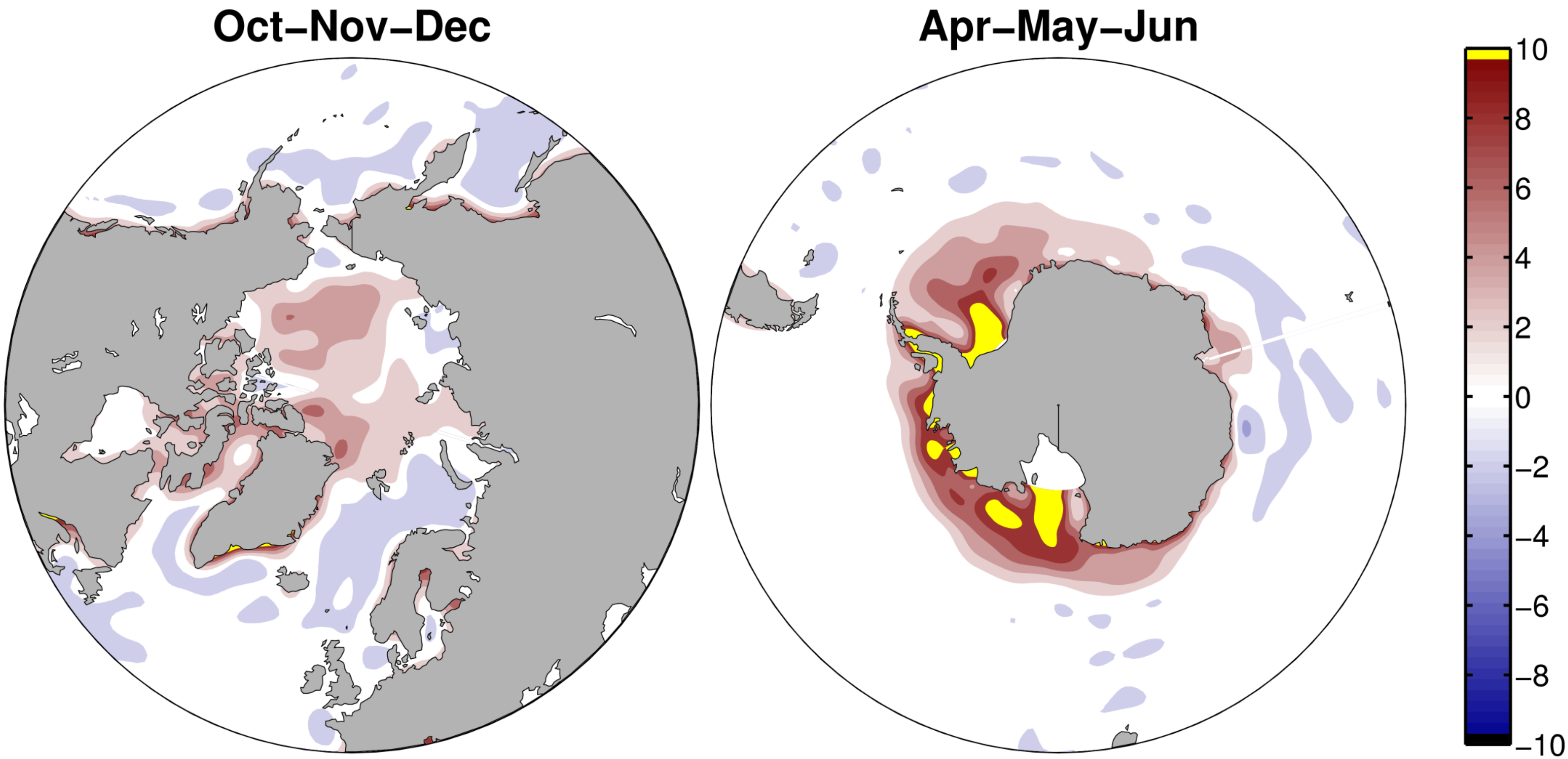
NH:
Mean abs err: 24.1% - 47.5%

SH:
Mean abs err: 43.0% - 54.6%

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

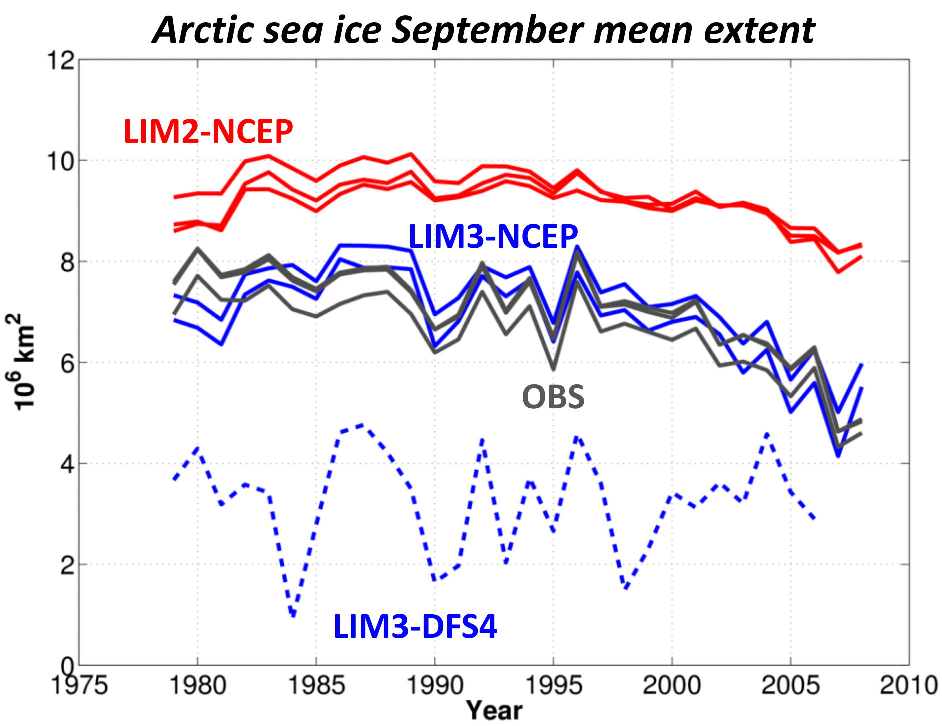
4. Sensitivity to atmospheric forcing

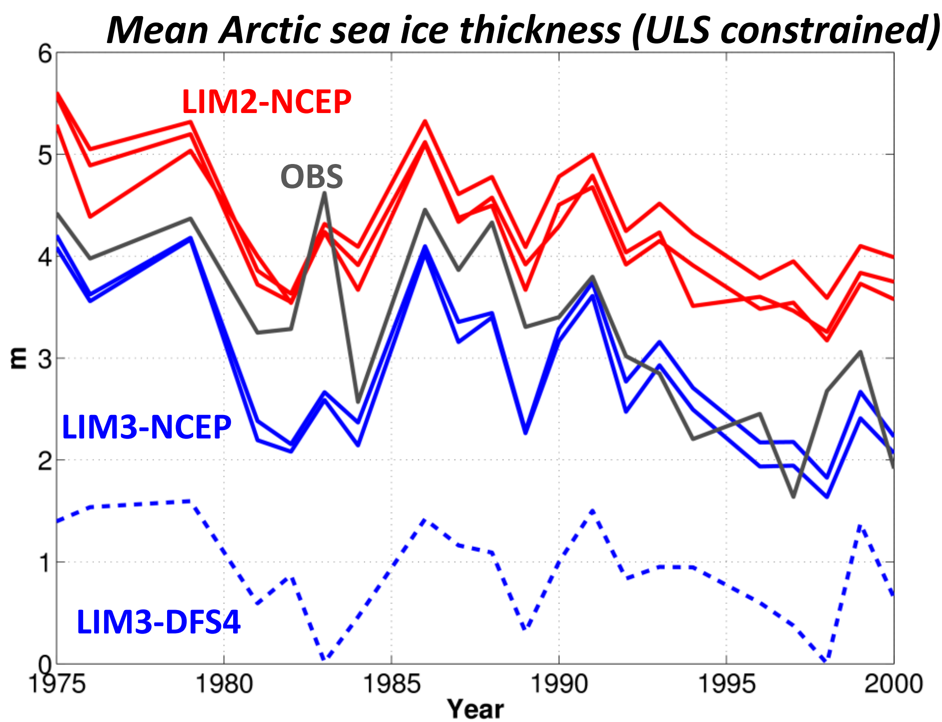
Mean 1979-2006 2m air temperature difference **[K]** ***« DFS4 » minus « NCEP »***



- 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

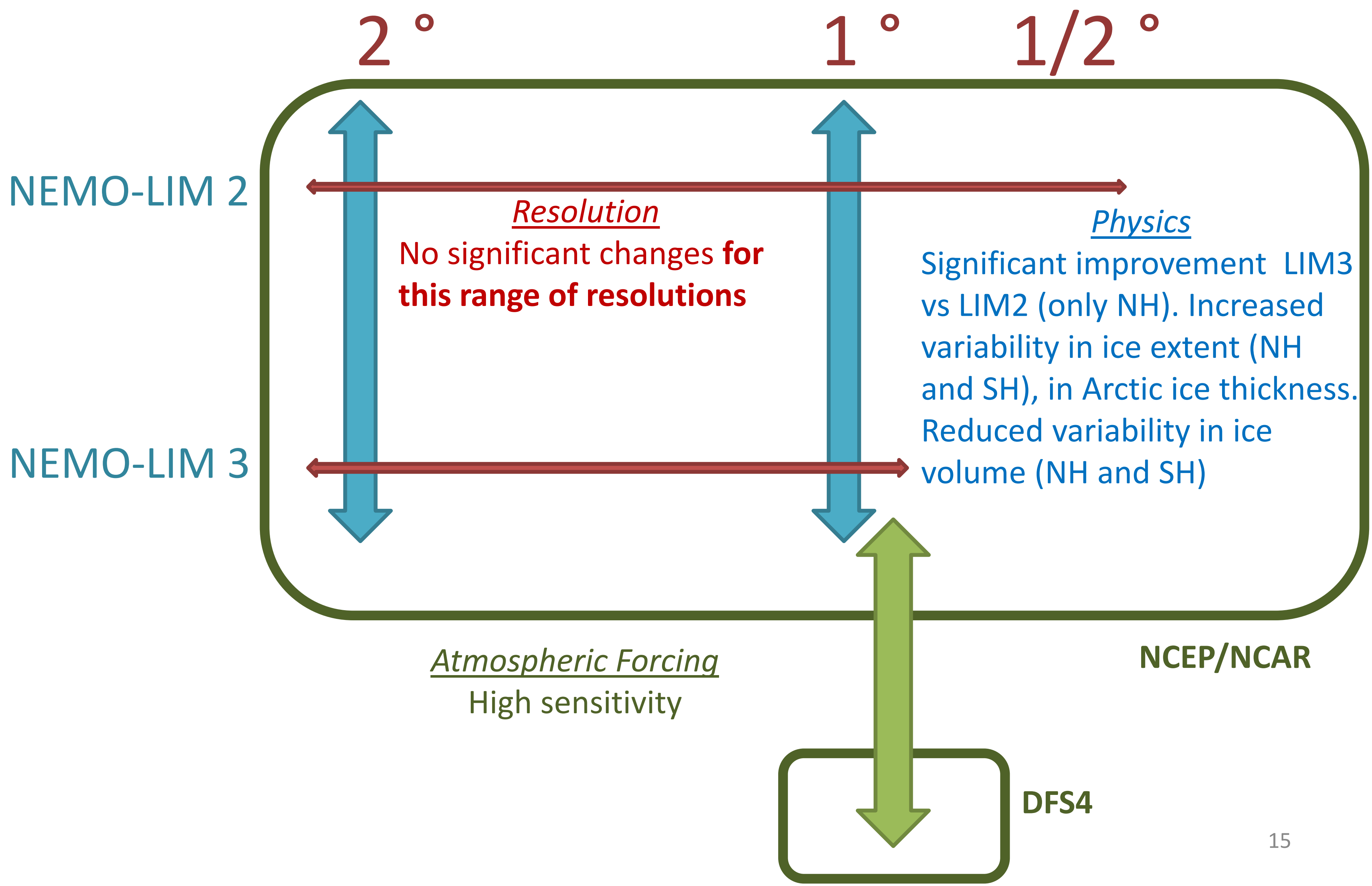




- Higher variability for smaller mean extents (as in *Goosse et al., 2009*)
- Higher variability with ITD representation, through ice-albedo feedback (*Holland et al., 2006*)

- 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

THANK YOU

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