MERCATOR OCEAN INTERNATIONAL

Impact of uncertainties from 7 atmospheric reanalysis surface conditions on Arctic Ocean freshwater budget

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Motivation of the study

- The question : our sea ice biases can be related to the atmospheric forcing?...
- Lindsay et al. (2014)'s paper : evaluation of 7 atmospheric reanalysis dataset in the Arctic (NCEP-R1, NCEP-R2, CFSR, 20CR, MERRA, ERA-Interim & JRA-25) for the 1980-2009 period & forcing PIOMAS with four of them (NCEP-R1, CFSR, MERRA & ERA-I) & evaluation of the trend of the sea ice volume with CDR dataset. Albedo and drag coefficient bias-corrected.
- Our study : Use available reanalysis/operational atmospheric forcing over the 2007-2014 periods to drive the CREG configuration in our NRT protocol context with none assimilation and at ¼° resolution to perform numerous sensitivities tests. No bias correction.

Experimental 2007-2015 set up with the CREG Configuration

- Modelling Experimental set up (none assimilation)
- Same NRT protocol (2007-2015) of global operational systems with an updated modelling platform.

- NEMO 3.6

- LIM3 sea ice model (multi category)

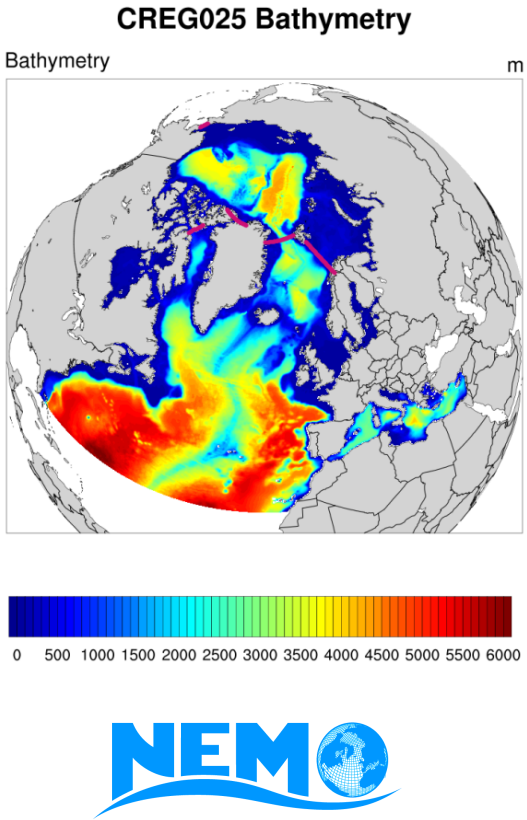
- CREG configuration (1/4°)

- Start run in 10/2006
- T&S initial conditions from WOA13
- Sea ice concentration initial conditions from OSI-SAF
- Sea Ice thickness Initial conditions from ICESat (October 2006

- Seasonal climatology Runoff (+ Greenland and nordic glaciers)

- none restoring

- Boundaries conditions from operational system

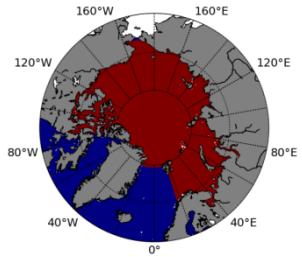


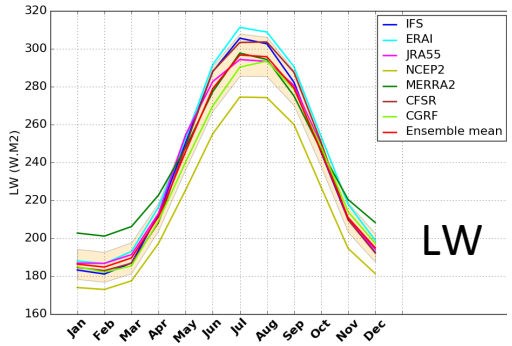
Evaluation of 7 state-of-the-art atmospheric reanalysis in the Arctic Ocean

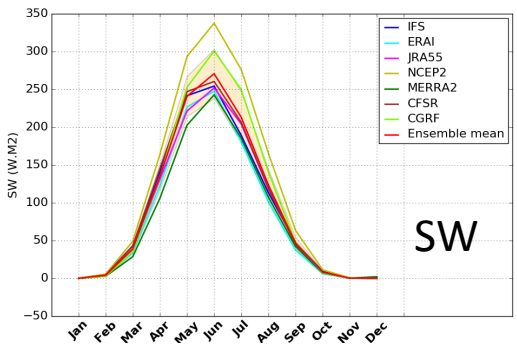
Selection Criteria : Period, Global domain, with assimilation, « High Resolution », no correction.

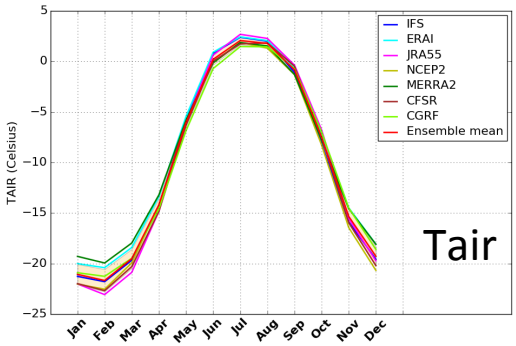
Name	Source	Domain	Period of Record	Available timestep(s)	Available resolution lonXlat
IFS	ECMWF	Global	1985 to present	Sub-daily	…0.35°,0.22°, 0.1°… …50km,25km,16km…
ERA-Interim	ECMWF	Global	1979/01 to 2016/01	Sub-daily	0.75°x0.75°
JRA-55	Japanese Meteorological Agency	Global	1958/01 to 2016/01	Sub-daily	0.56x0.56
NASA MERRA-2	NASA	Global	1979/01 to 2015/11	Sub-daily	0.667° x0.5°
NCEP Reanalysis (R2)	NCEP,DOE	Global	1979/01 to 2015/07	Sub-daily	2.5°x2.5°
Climate Forecast System Reanalysis (CFSR) and Version 2 (CFSv2)	NCEP	Global	1979 to 2010 2011 to 2015/09	Sub-daily	0.5°x0.5° & 2.5°x2.5°
CGRF	ECCC	Global	2002-2015	Sub-daily	0.3°x0.3°

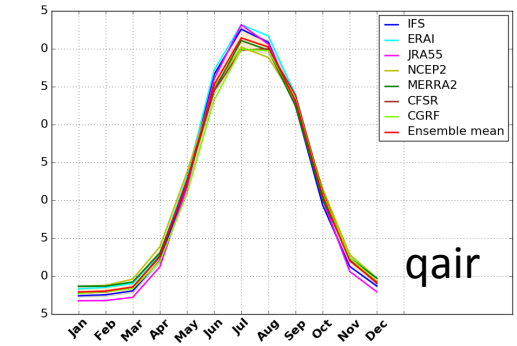
Seasonnal cycle

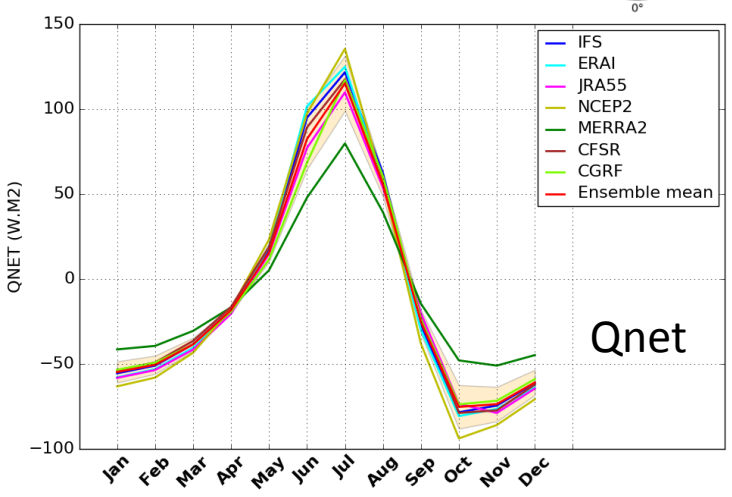






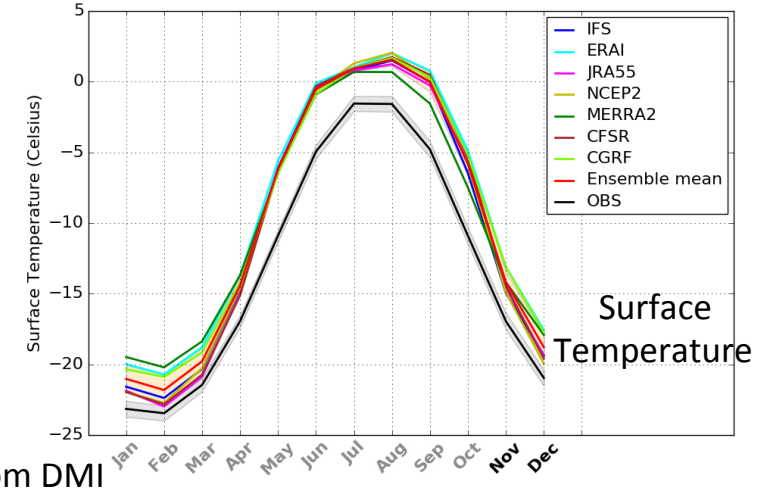






Ensemble runs built with 7 CREG025's experiments driven by the 7 atmospheric "reanalysis" forcing.

2007-2014	LW	SW	Tair	qair	Qnet	Surf. Temp.
σ	9 W.M^2	12 W.M^2	0.7°C	8.25E-05 g/kg	8 W.M^2	0.7°C
Max σ Period	12 W.M^2 June	33 W.M^2 June-July	1.12°C Febr.	1.37 E-04 g/Kg July	17 W.M^2 June-July	1.1°C Febr.



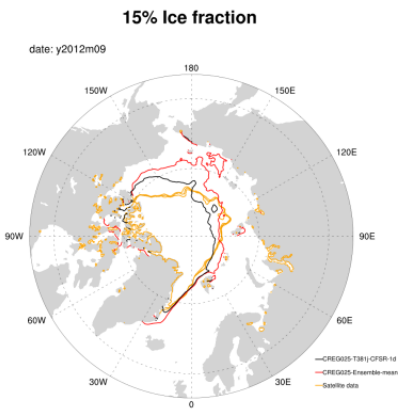
- Ensemble Mean surface temperature = **-10°C**
- Mean Obs surface temperature = **-13.1°C** ± 0.52°C.

Obs = L3 Satellite data from DMI

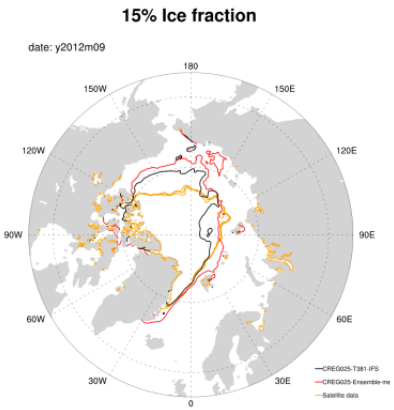
http://marine.copernicus.eu/documents/QUID/CMEMS-OSI-QUID-011-008.pdf

Sea Ice Concentration September 2012

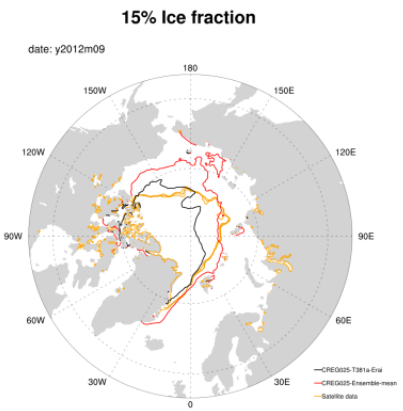
CFSR/CFSv2



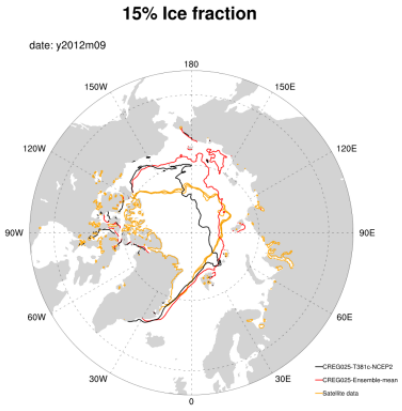
IFS ECMWF



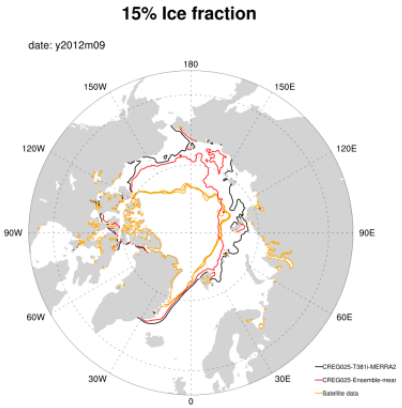
ERA-Interim



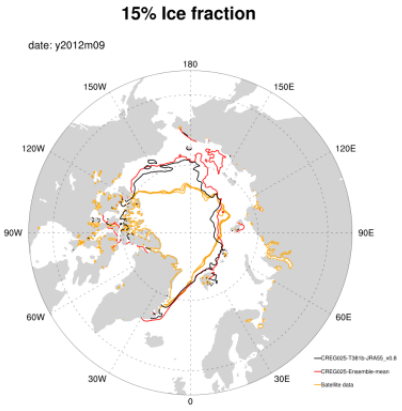
NCEP-R2



MERRA-2



JRA55



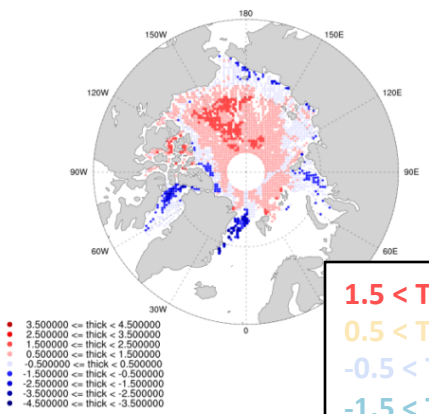
Mean CREG Ensemble
Mean Observations (CERSAT, NSIDC, OSI SAF)

- General Underestimation in Eurasian Basin and overestimation in Canadian Basin.
- Large overestimation with MERRA-2

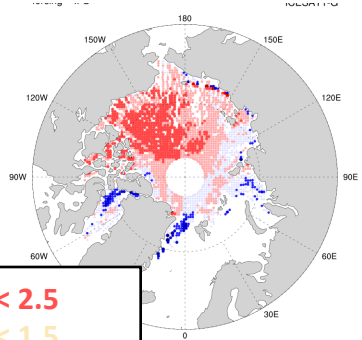
15% Ice Fraction

Sea Ice Thickness – Comparison with ICESat-GSFC - March 2007

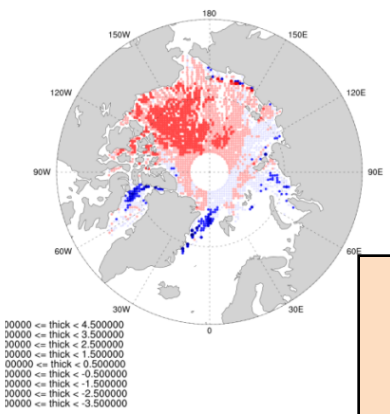
CFSR/CFSv2



IFS ECMWF



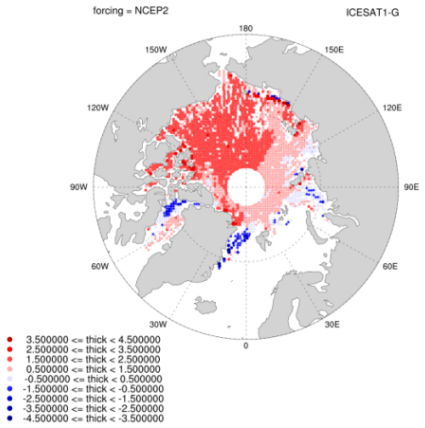
ERA-Interim



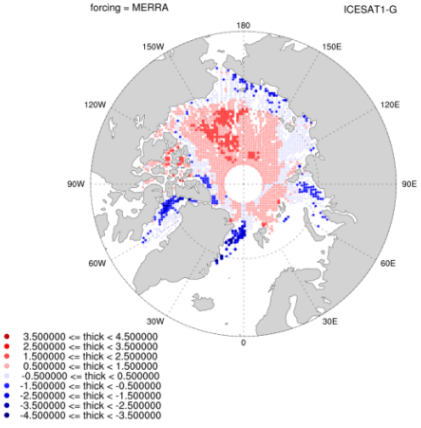
1.5 < THICK < 2.5
0.5 < THICK < 1.5
-0.5 < THICK < 0.5
-1.5 < THICK < -0.5
-2.5 < THICK < -1.5

- Overestimation in Canadian Basin for all experiments.
- No impacts of atmospheric forcings

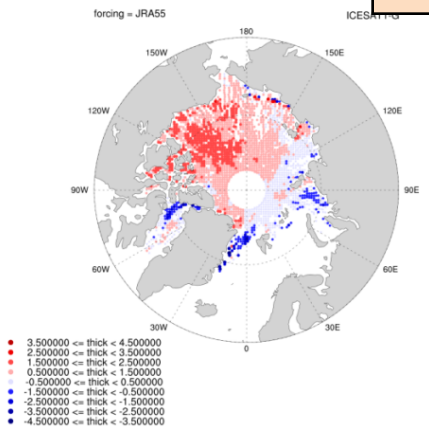
NCEP-R2



MERRA-2



JRA55



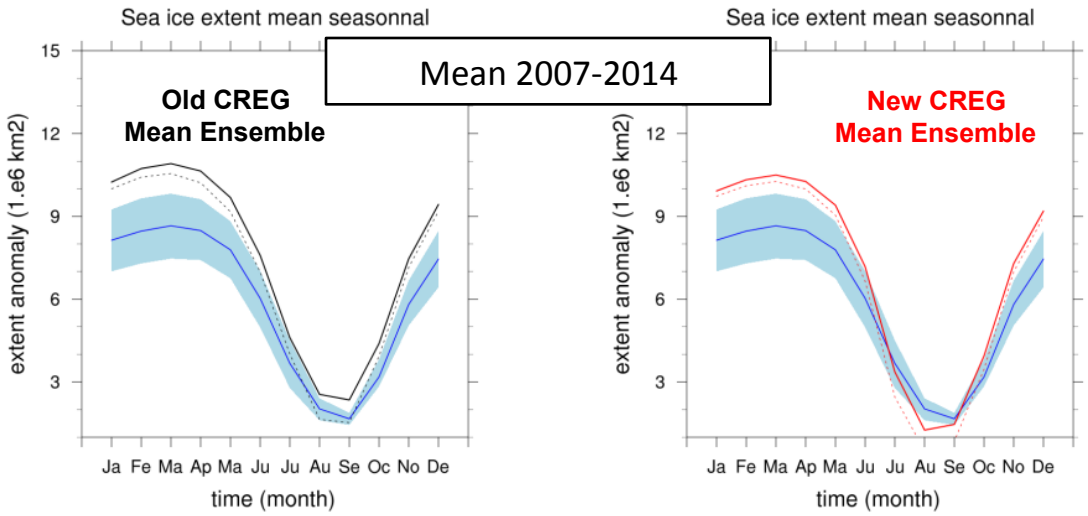
Changed Physics

Biases in ice volume (and liquid FW export at Fram Strait) → CREG New

	CREG Old	CREG New	
Initial conditions for (T, S)	WOA 13	EN.4	Impact on water masses only
Horizontal Diffusion on tracers with GM (Gent,McWilliams, 1990)	ON	OFF	
2nd bulk rheology parameter C*	20	5	
Number of ice categories	5	15	
Ridging	Ridging	Ridging changed	
Snow repartition on ice	66%	100%	Weak impact

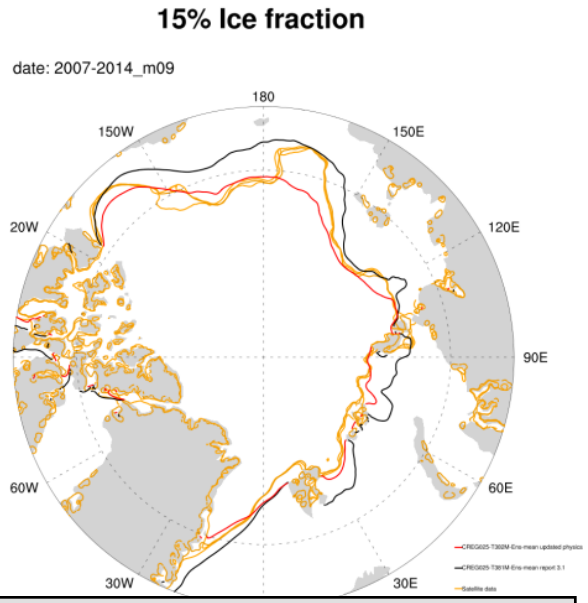
- $P = P^* * h * e^{-c^*(1-A)}$ where P is the ice strength, h the ice thickness, A the ice concentration, P* and c* the first and 2nd rheology parameter. C*: *"… no serious efforts have been published for their (his) quantification." "Range 1 << c* << ∞" (From Lepparänta (2011) !!)*
- Ridging : Change in the fraction of shearing energy contributing to ridging and measure of ridging ice

Results with changed Physics: Old vs New CREG: Sea Ice extent



Mean Observations (CERSAT, NSIDC, OSI SAF)

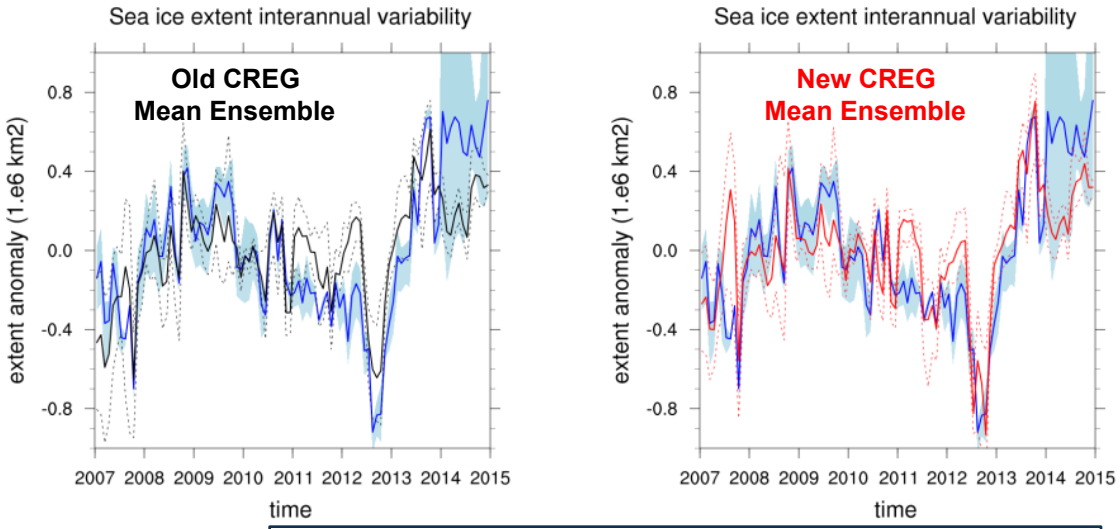
Mean September 2007-2014



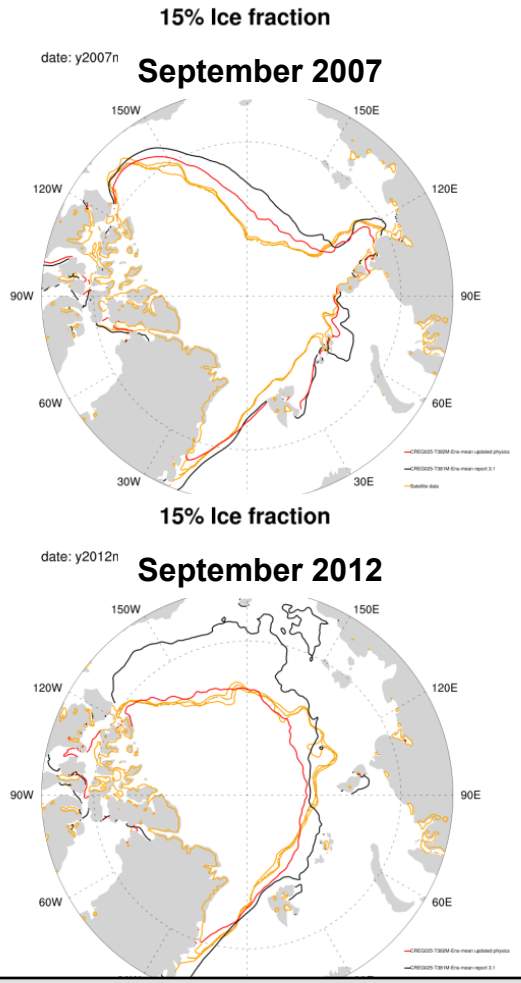
Old CREG Mean Ensemble
New CREG Mean Ensemble
Mean Observations (CERSAT, NSIDC, OSI SAF)

- Less sea ice extent with New CREG, particularly during summer
- Strong sea ice cover reduction in western basin
- New CREG compares better with mean observations

Results with changed Physics: Old vs New CREG: Sea Ice extent



Mean Observations (CERSAT, NSIDC, OSI SAF)

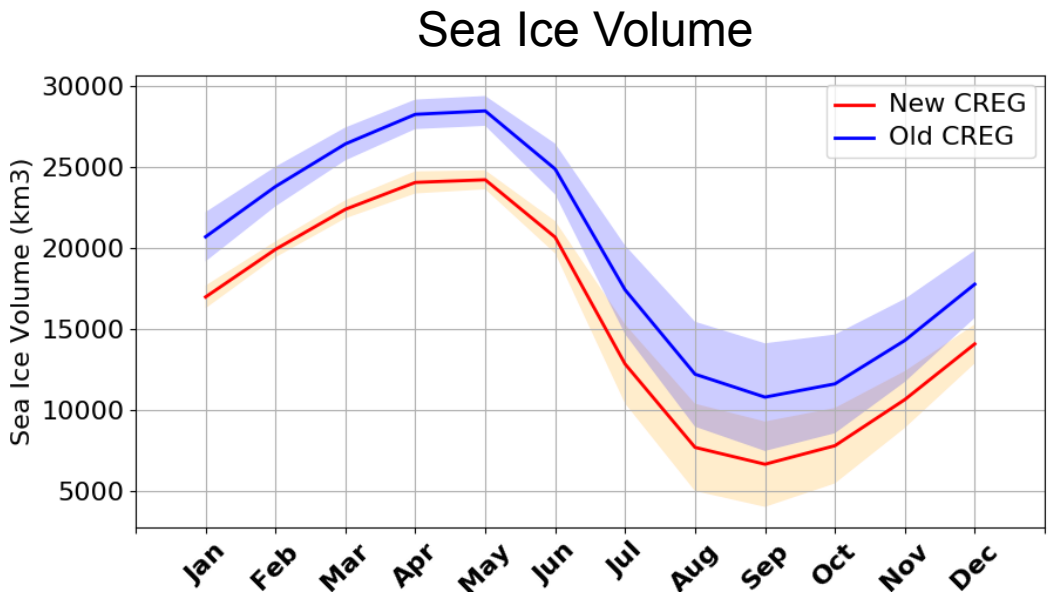


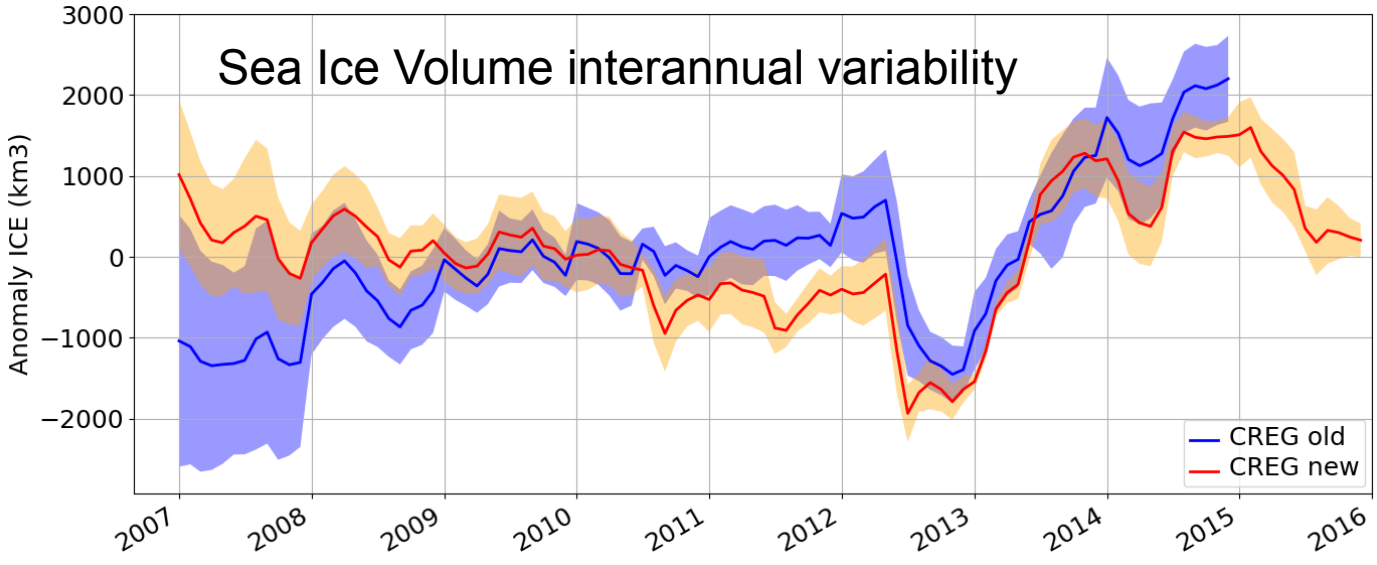
- No change in interannual variability
- Better representation of summers 2007 and 2012
- No change in uncertainties

Old CREG Mean Ensemble
New CREG Mean Ensemble
Mean Observations (CERSAT, NSIDC, OSI SAF)

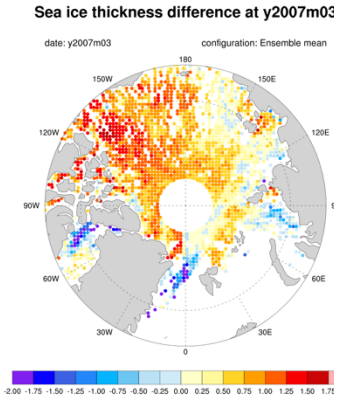
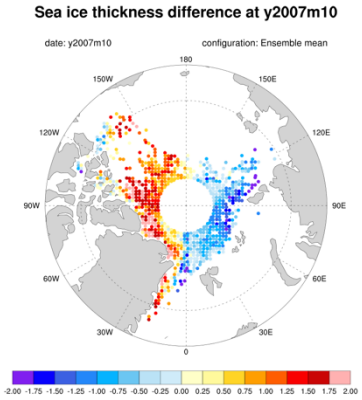
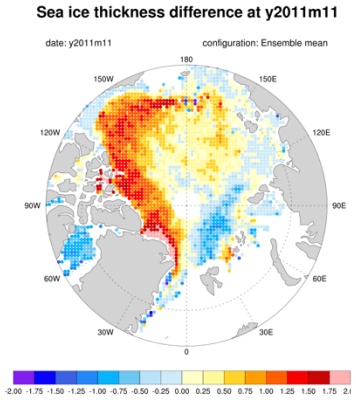
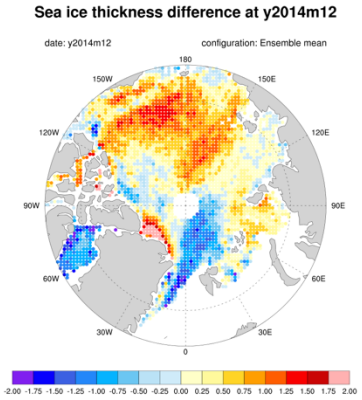
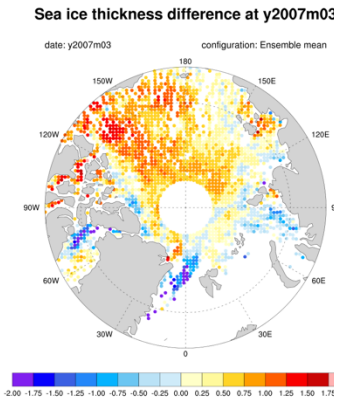
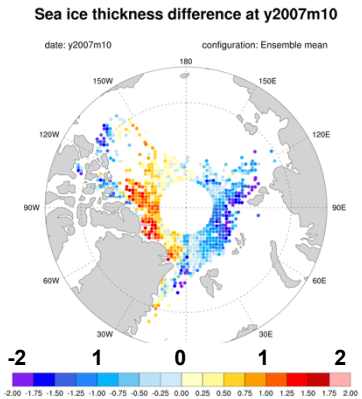
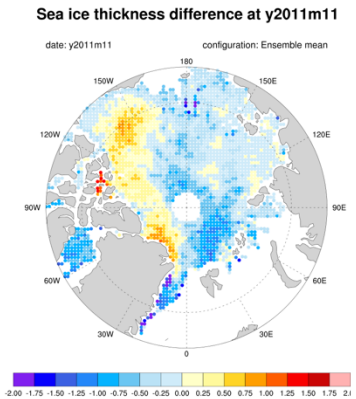
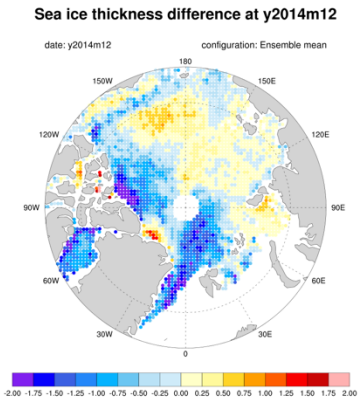
Results with changed Physics: Old vs New CREG: Sea Ice Volume

- Less sea ice volume with New CREG (-4000 km^3)
- « Low frequency » variability has changed
- Still largest uncertainties in summer …
- …But less uncertainties with New CREG



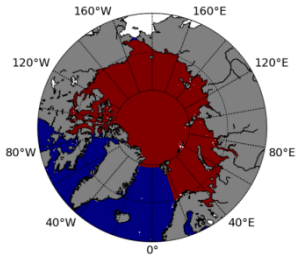


Results with changed Physics: Old vs New CREG: Sea Ice thickness

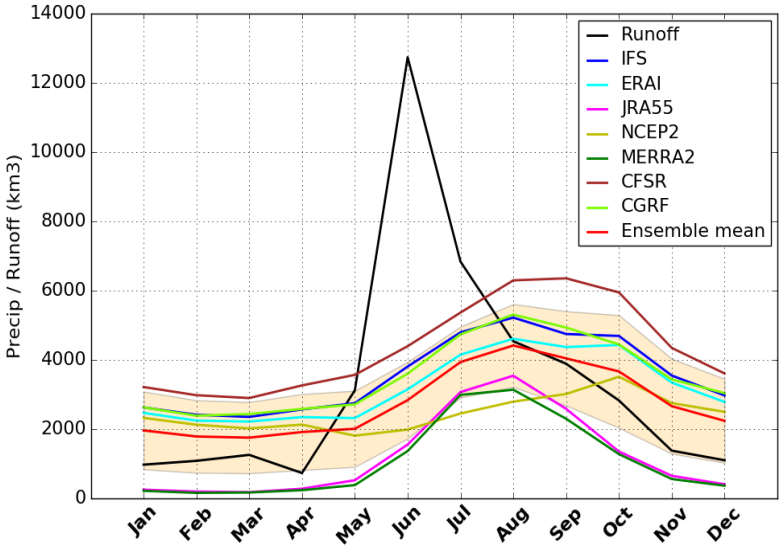
	March 2007	October 2007	November 2011	December 2014
Old CREG Ensemble Mean				
Differences with:	**ICESat-GSFC**		**Cryosat-AWI**	
New CREG Ensemble Mean				

→ Large reduction of thickness in Canadian Basin; Better comparisons with ICESat and Cryosat.

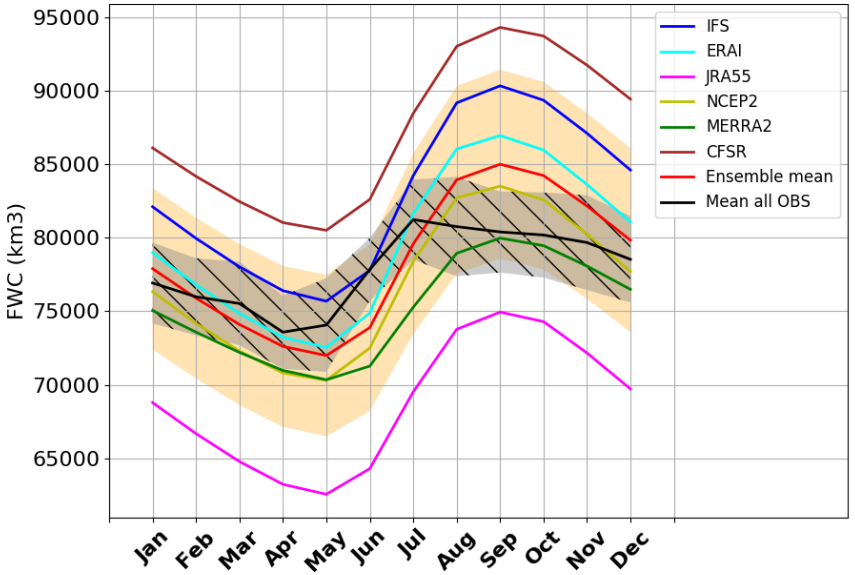
Impact of atmospheric uncertainties
Freshwater Content



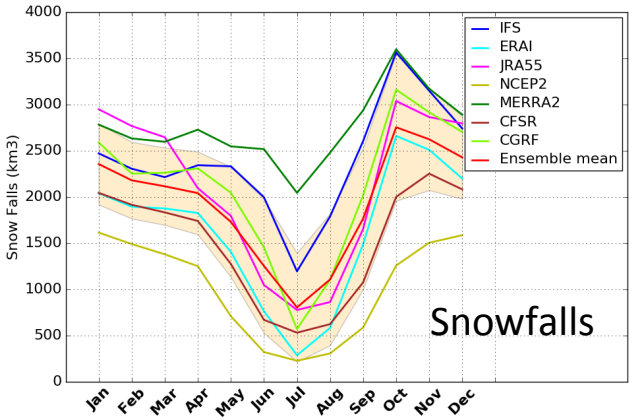
Total precipitation / runoffs
over the Arctic Domain (2011-2014)



Mean FWC (km3)
over the Arctic Domain (2011-2014)

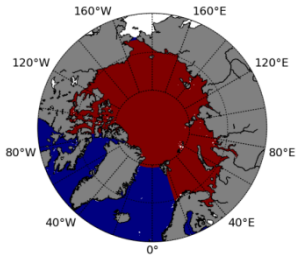


OBS= WOA13+ EN.4 + ISAS + PHC3.0 + Levitus09



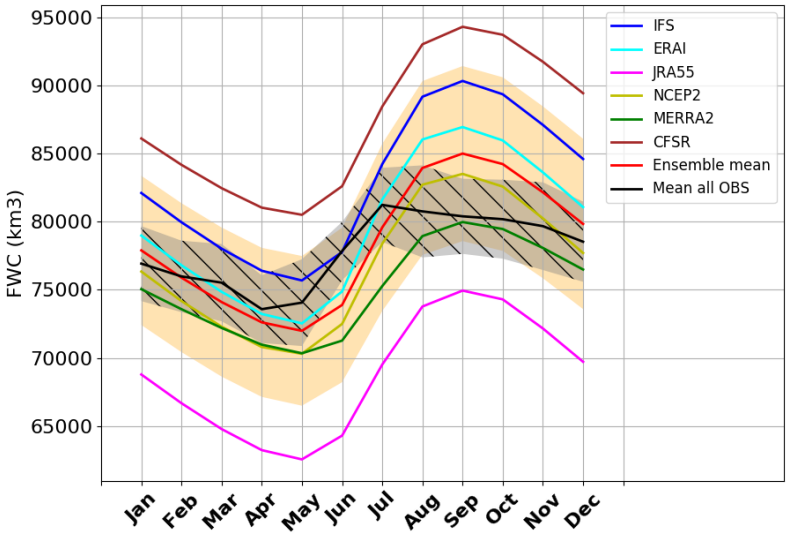
- Large uncertainties in solid and liquid precipitations
  - Mean value MERRA-2 = 1086 km3/year
  - Mean value in CFSR/CFSv2 = 4321 km3/year.
- σ FWC = 10000 km3

Impact of atmospheric uncertainties Freshwater Content



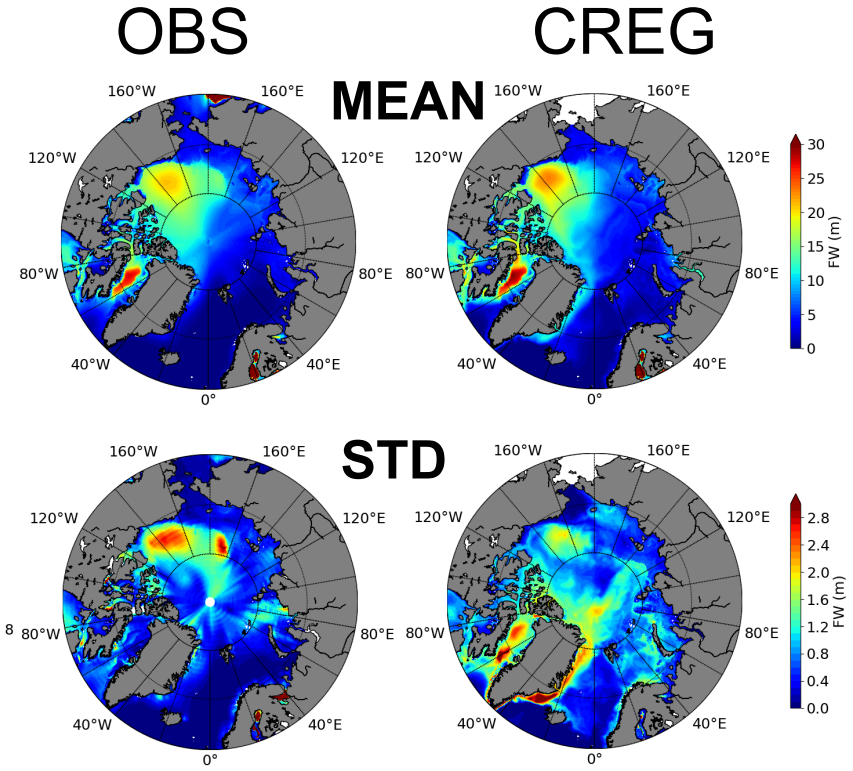
Ensemble runs built with 6 CREG025's experiments driven by 6 atmospheric "reanalysis" forcing : IFS, ERA-Interim, JRA55, NCPR-R2, CFSR/CFSv2 and MERRA-2

Mean FWC (km3)
over the Arctic Domain (2011-2014)



- Good agreement between spatial distribution of Freshwater from the mean ensemble of CREG simulations and the mean ensemble of 6 climatologies (PHC3, EN4, ISAS, LEVITUS ...)
- Higher spread in the Beaufort gyre for the climotologies of observations
- Higher spread in the coast of Groenland for the different CREG simulations.

Mean FW (km3) (2011-2014)



Impact of atmospheric uncertainties
Transport uncertainties

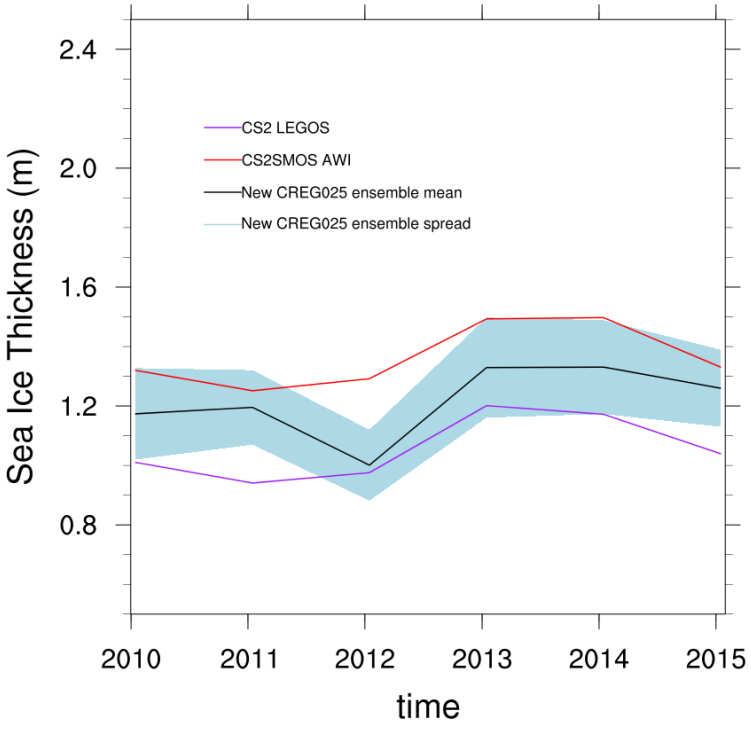
Ensemble mean tranport (2011-2015)

- 55% of the variability of the Freshwater Export at Fram strait is due to differences in atmospheric forcing .
- In terms of ice volume export and volume transport, the variability due to interannual and seasonal variability is higher than the differences in atmospheric forcing .
- Variability of atmospheric forcing has the major impact at Fram strait. In the other straits the interannual and seasonal variability dominate .

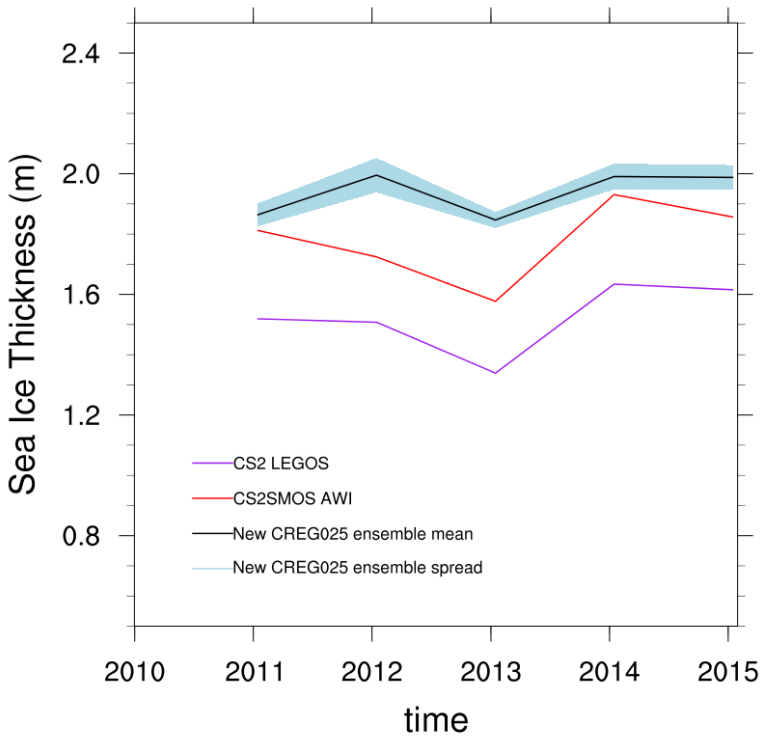
		Freshwater (km^3/year	Ice Volume (km^3/year)	Volume Transport (Sv)
Fram Strait	Mean Ensemble	-1318	-2030	-1,31
	Std ensemble	+/-722	+/-224	+/-0,48
	Std seasonal + interannual	+/-538	+/-1002	+/-0,91
Fram + Bering + Nares + Lancaster + Barents + Jones	Mean Ensemble	-2004	-2224	0,03
	Std ensemble	228	631	0,05
	Std seasonal + interannual	985	1067	1,13

Impact of atmospheric uncertainties
Sea Ice Thickness

Oct-Nov-Dec Mean SIT over AWI/LEGOS merged domain



Jan-Feb-Mar-Apr Mean SIT over AWI/LEGOS merged domain



- Uncertainties from 6 atmospheric reanalysis
  - Proposed set of changed physics largely improves sea ice extent and thickness, particularly during summer and Canadian basin. Weak impact is obtained when only one unique paramater is modified.
  - Impact of atmospheric uncertainties is reduced with a more realistic sea ice cover.
  - The ensemble mean still shows better performance than individual member.
  - The use of GM90 parameterisation largely degrades water masses properties.
  - (The atmospheric forcing represents about 56 % of the uncertainties in the FW sink of the Arctic Ocean with this experimental methodology)

Plans:

- Paper in preparation
- Ensemble model using atmospheric perturbations built from these atmospheric reanalysis.

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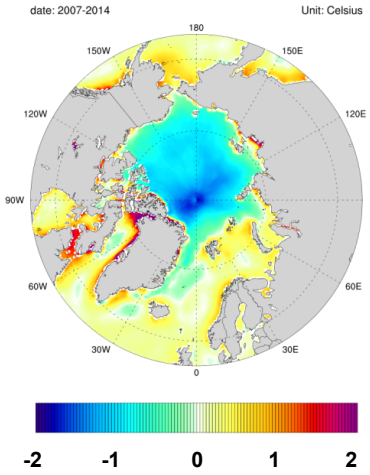
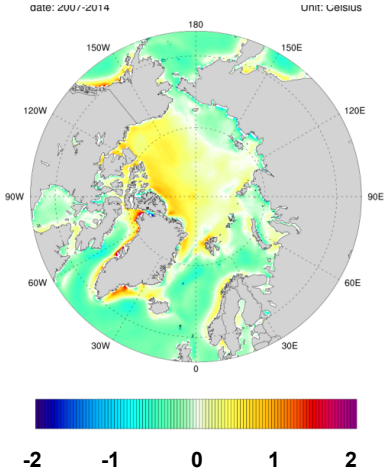
Thank you

Surface Air Temperature at 2m heigh 2007-2014

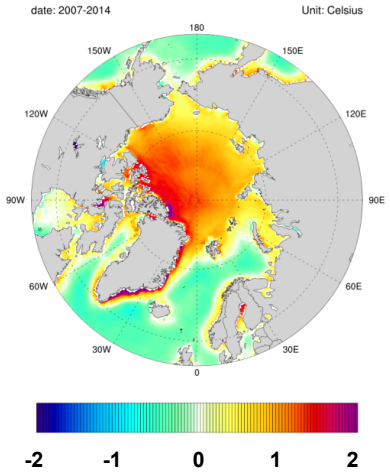
CFSR/CFSv2



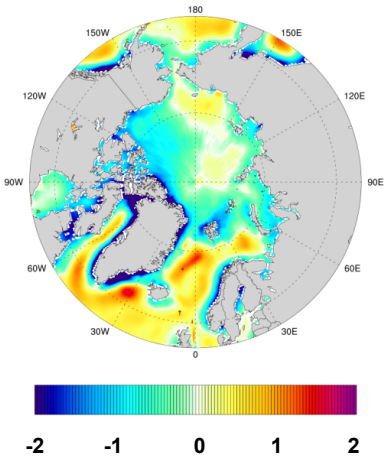
IFS ECMWF



ERA-Interim



NCEP-R2



MERRA-2

T10m

JRA55

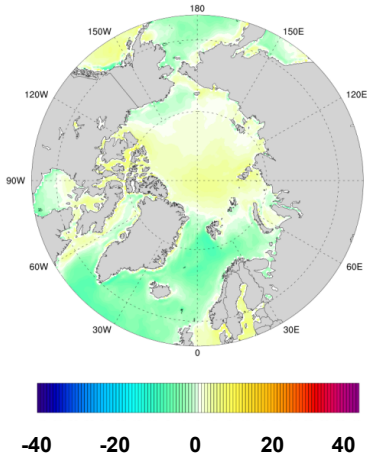
T10m

Anomaly with ensemble mean

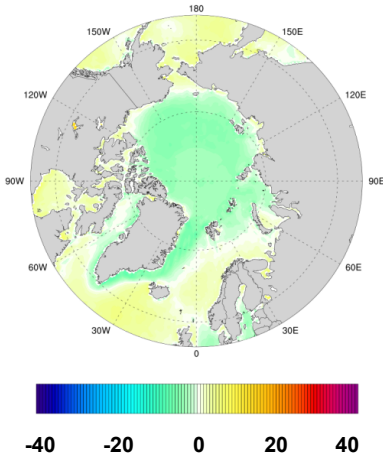
- Warmer icy surfaces with ECMWF's products
- Anomalies Up to 2°C
- In accordance with Jakobson (2012) and Lindsay(2014)
- Largest differences on ice covered areas
- Importance of horizontal resolution around Greenland (NCEP-R2 at 2.5°)

Downward SW at the surface 2007-2014

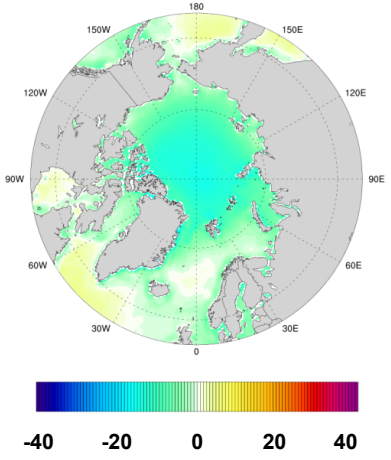
CFSR/CFSv2



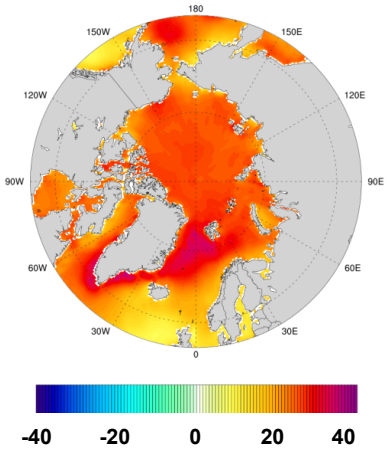
IFS ECMWF



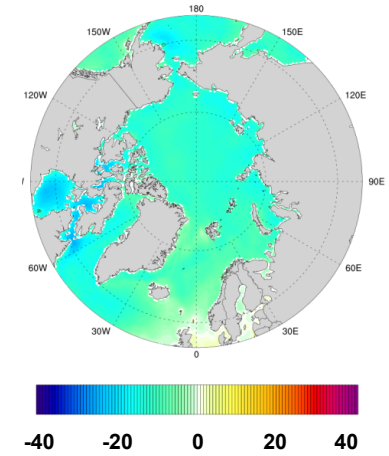
ERA-Interim



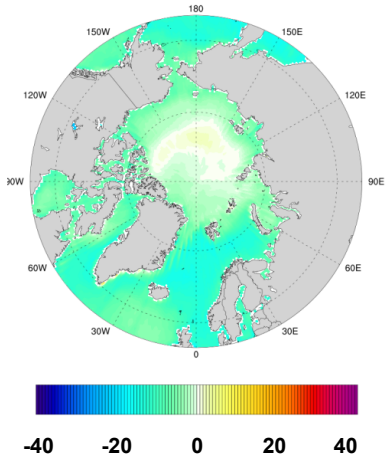
NCEP-R2



MERRA-2



JRA55



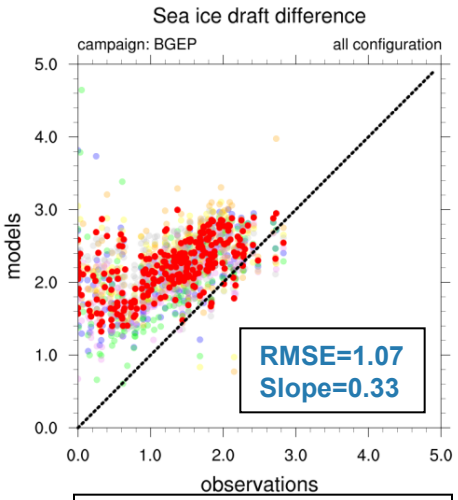
Anomaly with ensemble mean

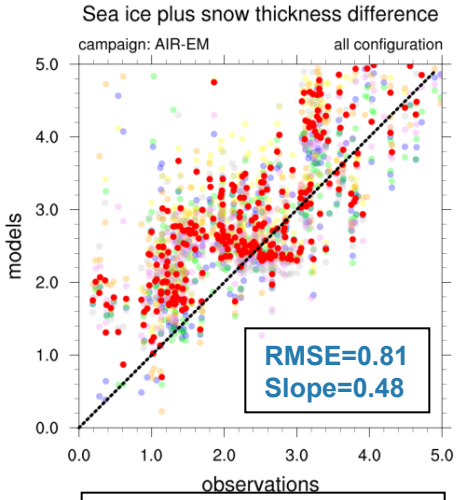
- ERA-Interim and MERRA-2 the coldest (-15W.M^2)
- NCEP-R2 far the warmest
- Anomalies up to **20W.M^2** in Arctic.
- In accordance with Lindsay(2014)

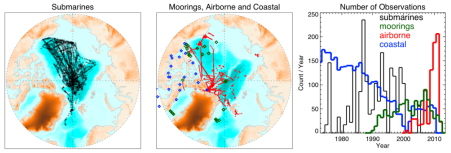
Results with changed Physics: Old vs New CREG: Sea Ice thickness

Comparisons with in situ data from *« Unified Sea Ice Thickness Climate Data Record »*

Old CREG Ensemble Mean



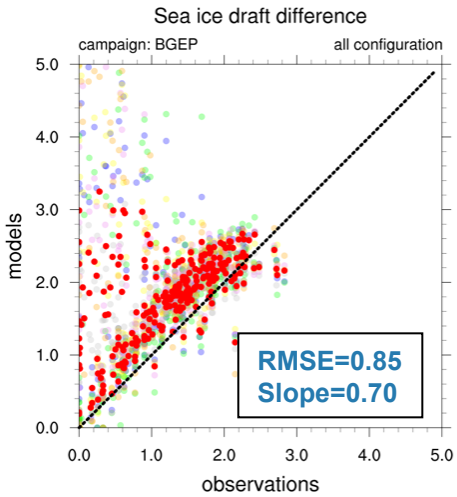


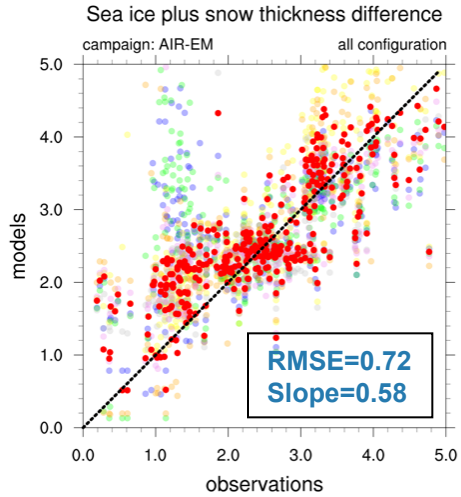


BGEP Campaign

Air-EM campaign

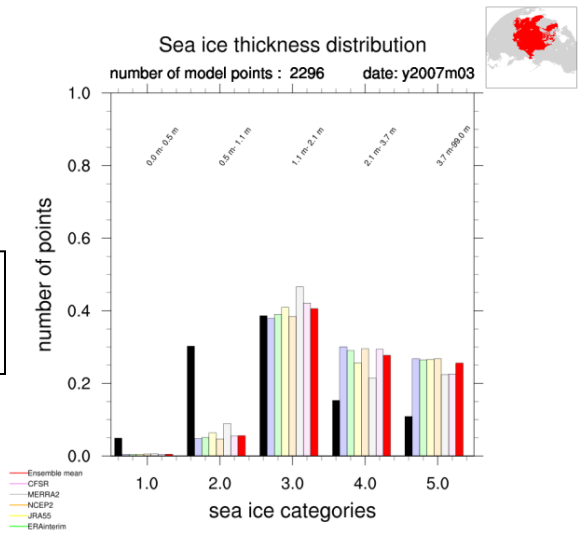
New CREG Ensemble Mean

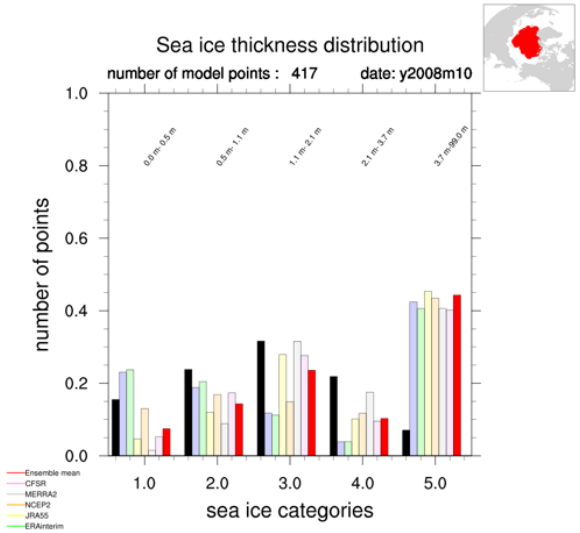




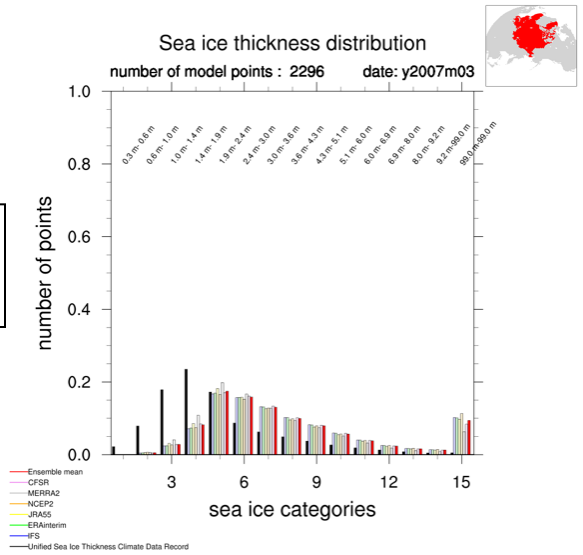
Results with changed Physics: Old vs New CREG: Sea Ice thickness distribution

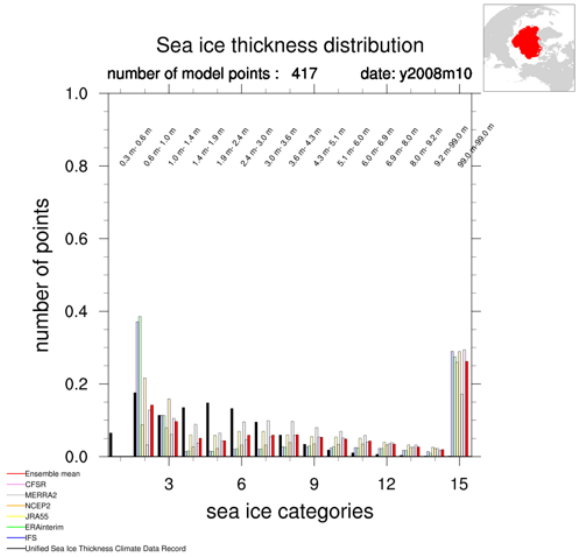
Old CREG





New CREG





- Under representation of thinner ice (<0.6m)
- Over representation of thicker ice
- Peculiar strong peak in the thickest category
- Similar distribution whatever the atmospheric forcing