Identification of the overarching science challenges that the CCI will help to address

Theme: Ocean

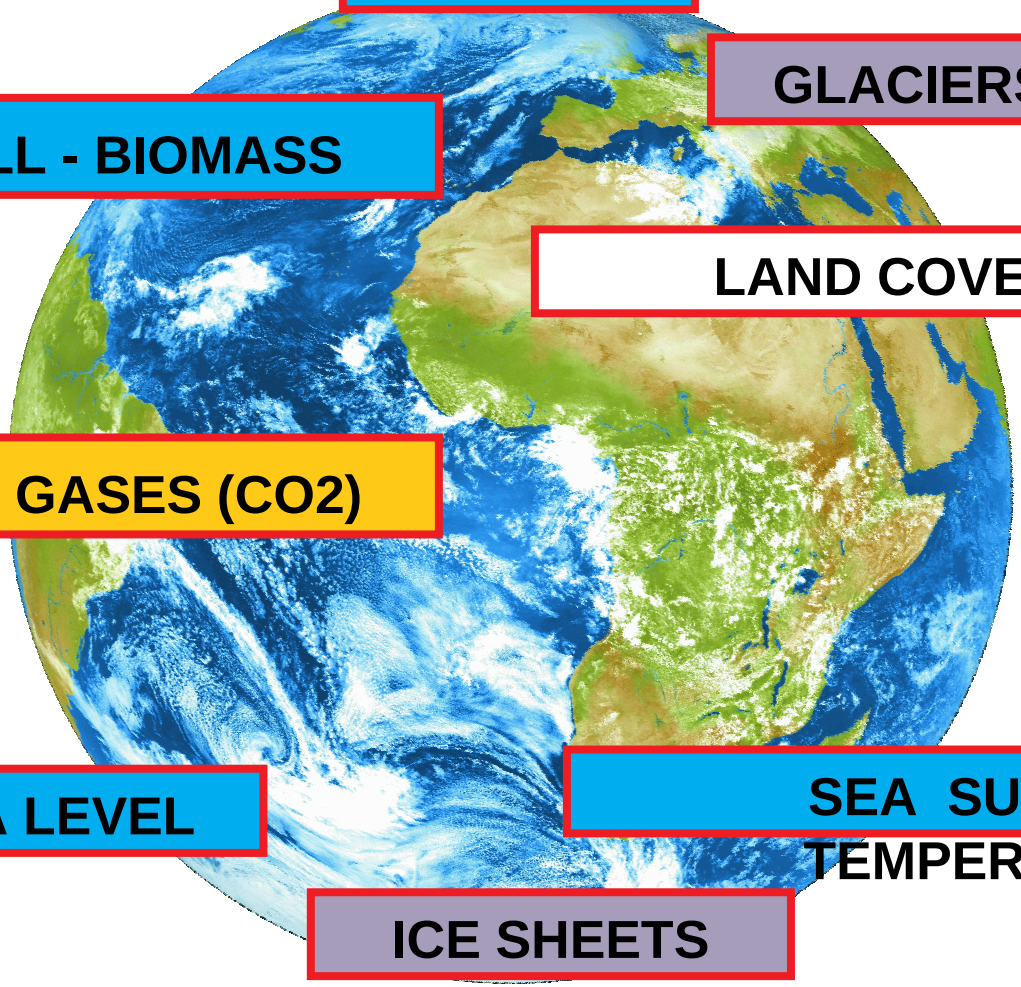
by

Johnny A. Johannessen with support from MONARCH-A team
(Stammer, Cazenave, Andersen, Heinze, …. and many more)

Overarching scientific challenges - Ocean

- eddy dynamics, influence on biogeochemistry
- deep convection
- internal mixing
- ecosystem understanding
- biogeochemistry, CO2 cycle and acidification
- sea ice deformation, volume changes and ice mass fluxes
- mean sea level retrieval in the sea ice covered Arctic Seas
- freshwater fluxes (water cycle)
- accuracy in forward projection of future sea level change
- consistent Earth System Approach; regional & global scales

The Ocean Related ECVs



SEA ICE

GLACIERS

CHLOROPHYLL - BIOMASS

LAND COVER (SNOW)

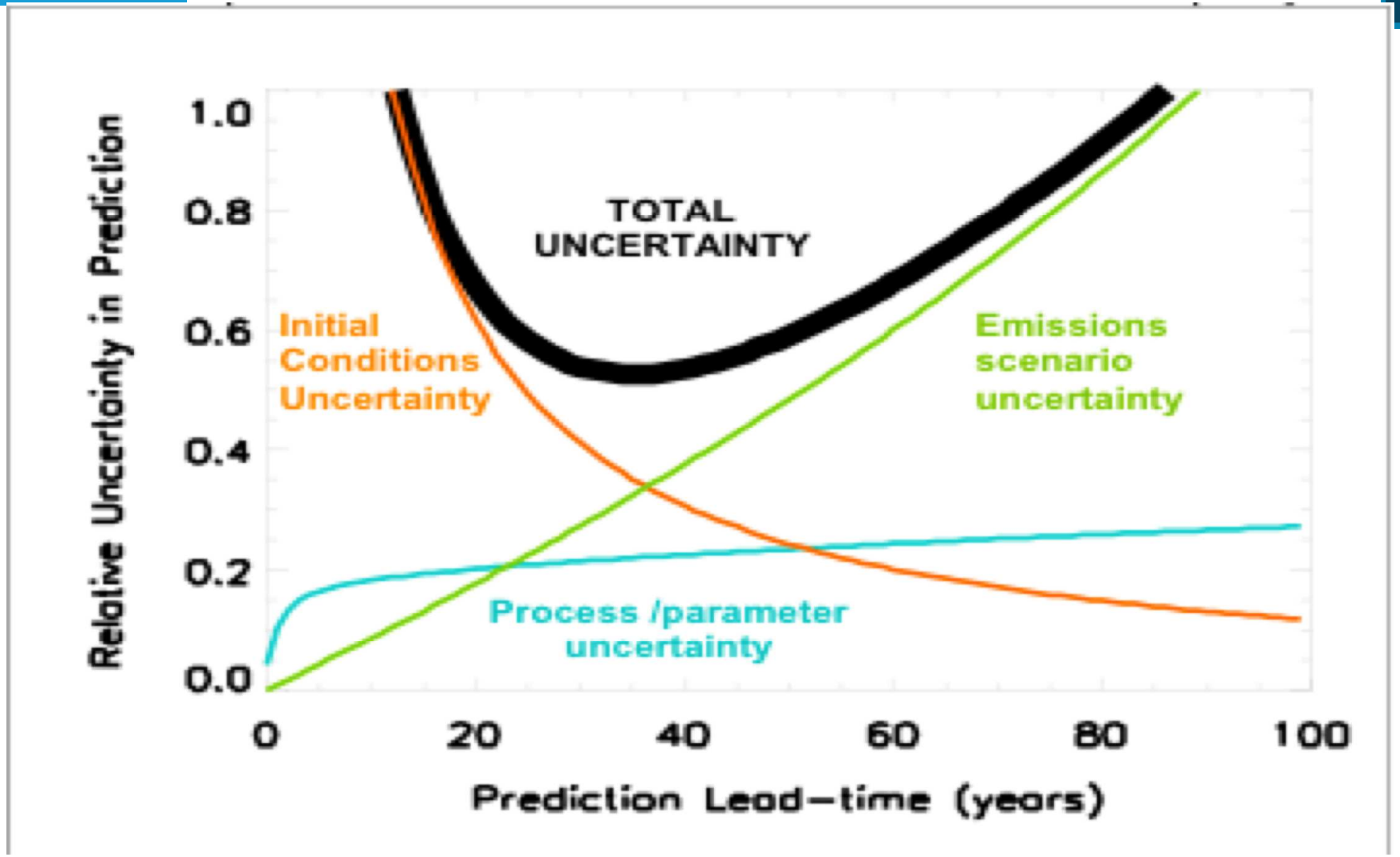
GREENHOUSE GASES (CO2)

SEA LEVEL

SEA SURFACE TEMPERATURE

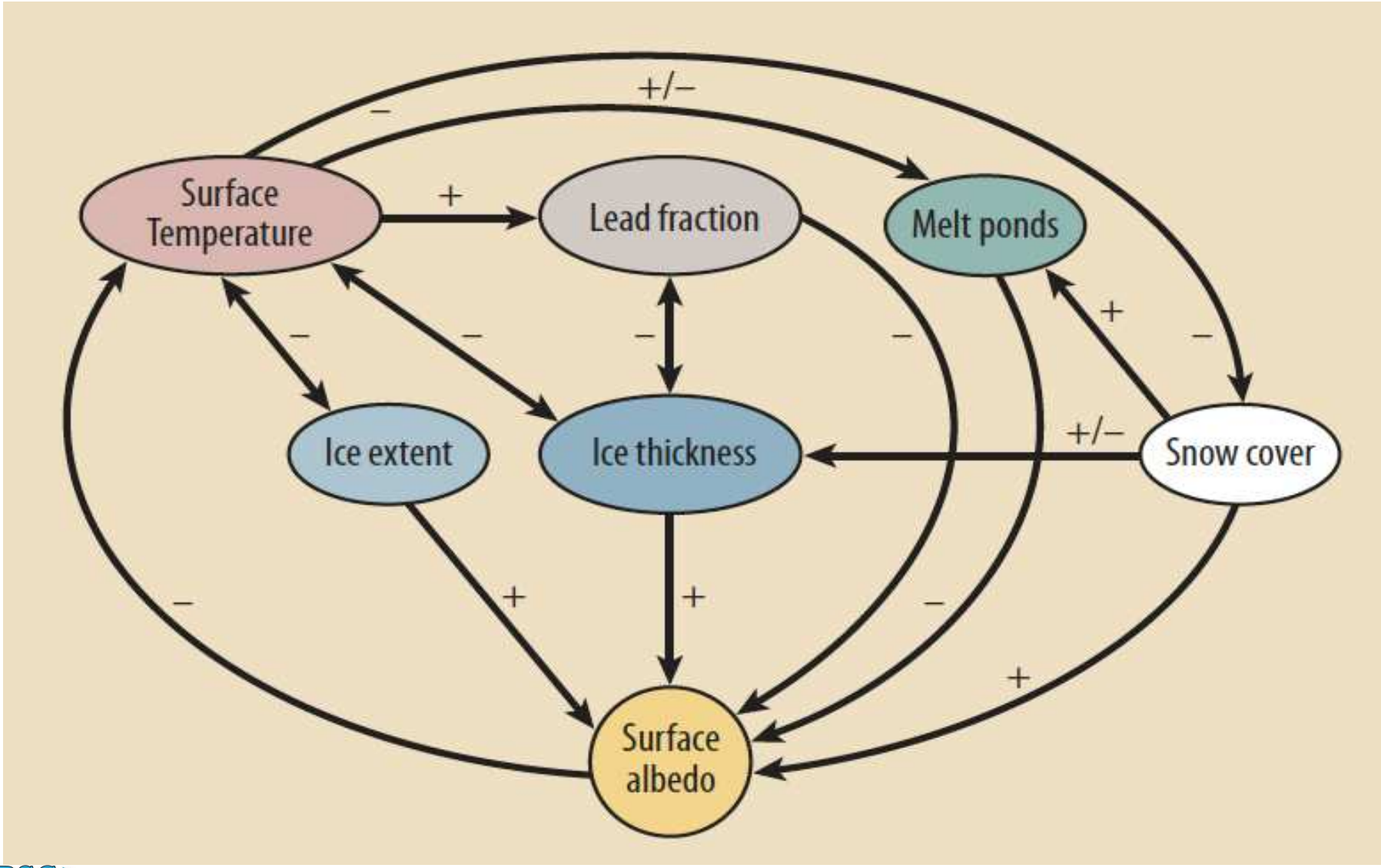
ICE SHEETS

Climate Projection Uncertainties

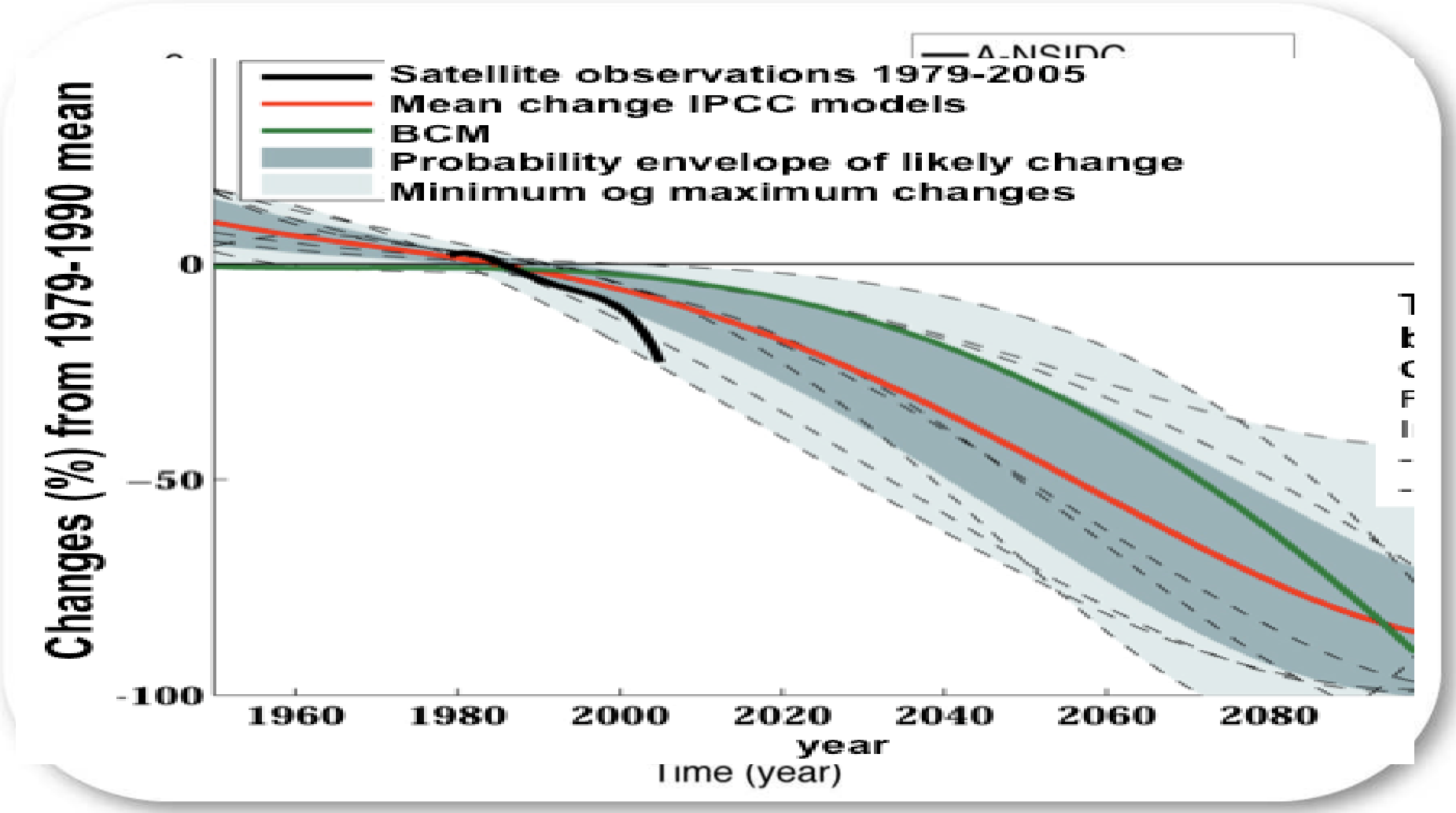


Cox and Stevenson, 2007

Interaction and Mutual Feedback

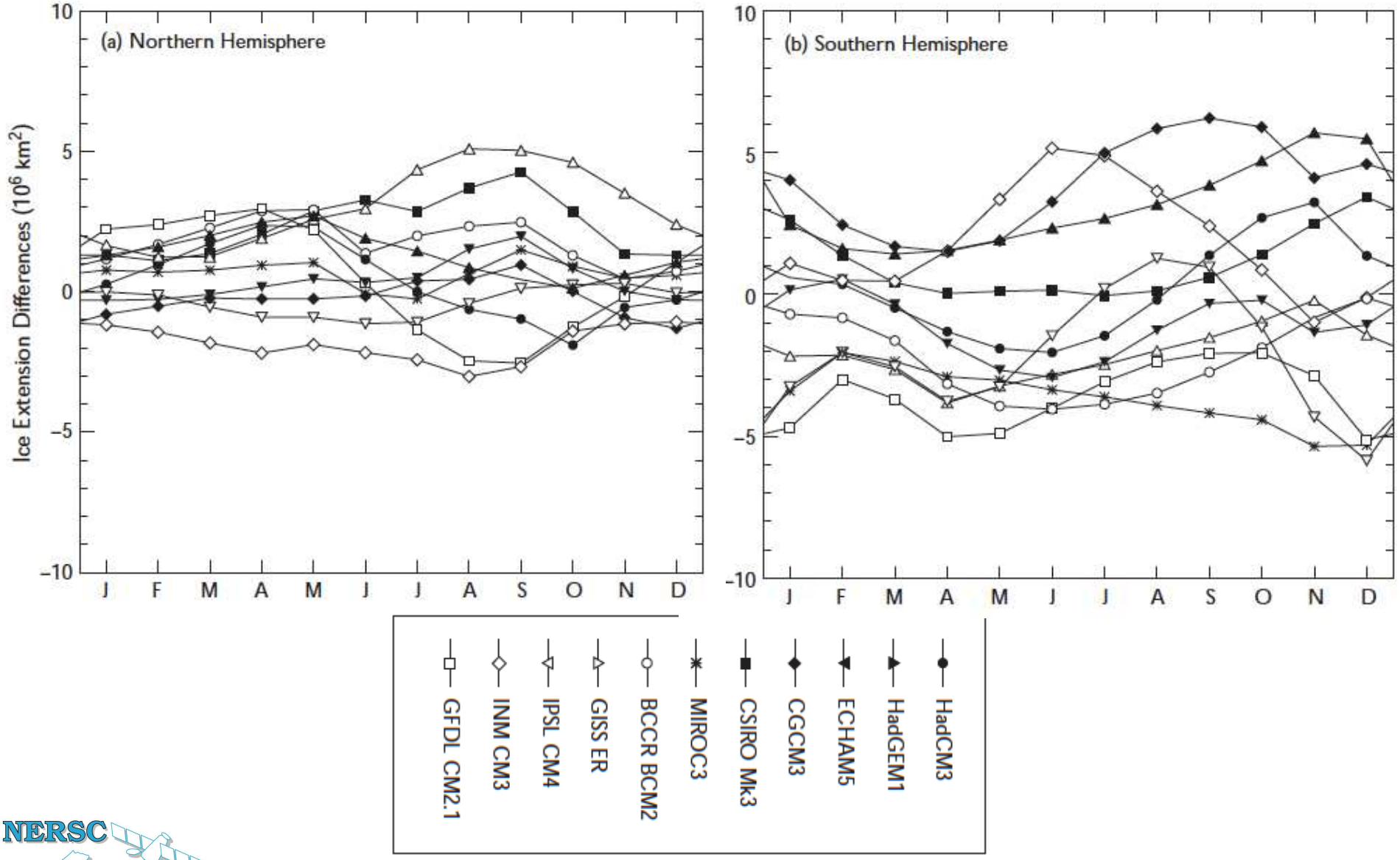


Arctic Sea Ice Area

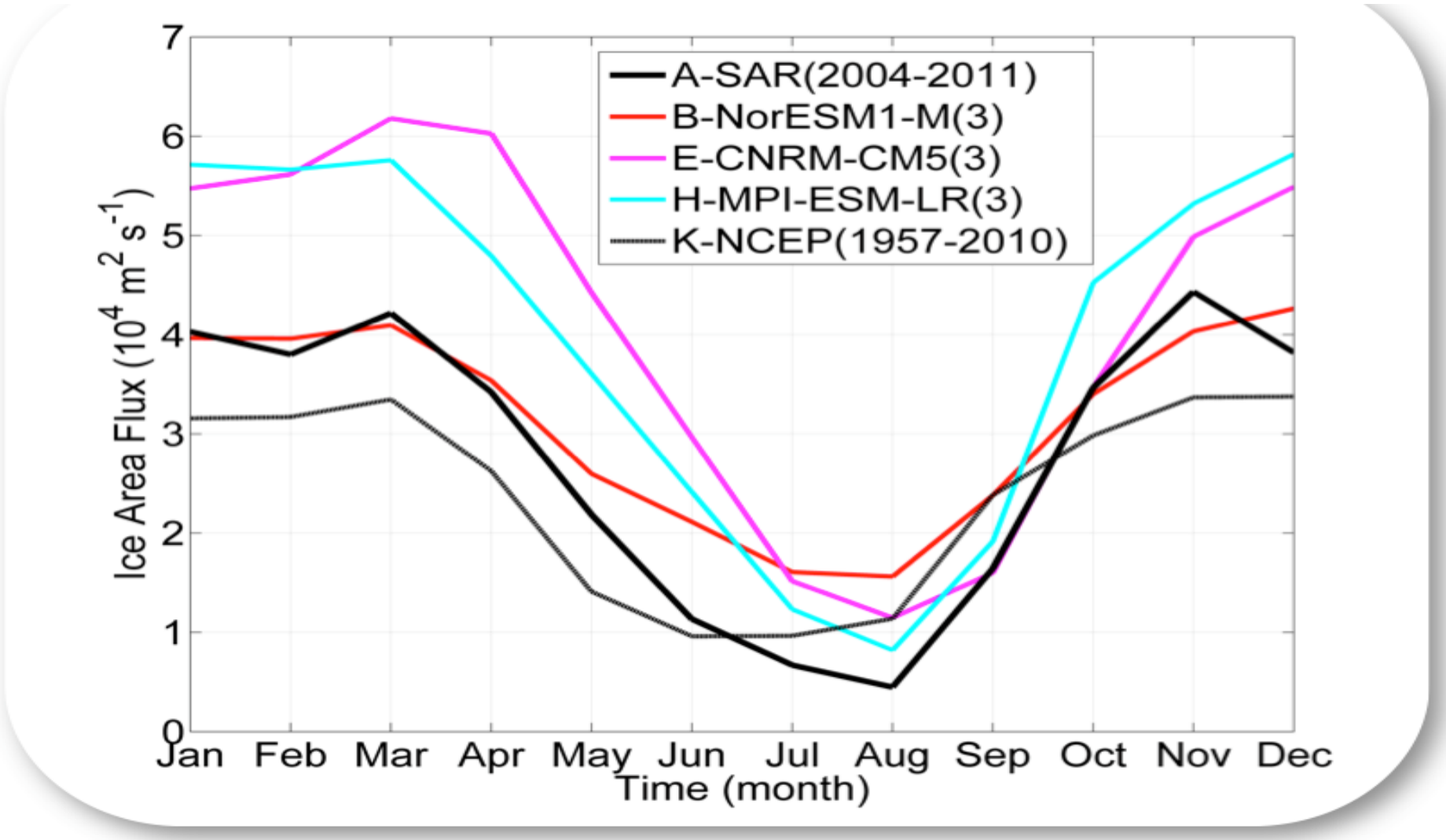


Geyer et al, 2012

Differences in Sea Ice Extent



Arctic Sea Ice Area Flux



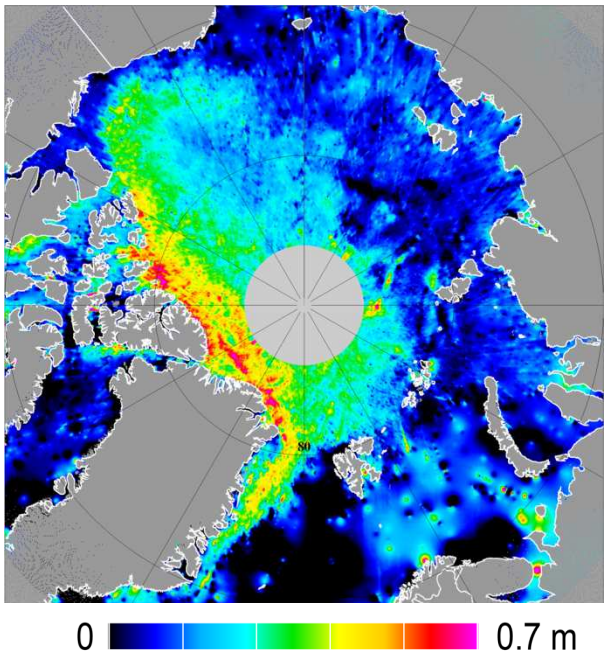
Geyer et al, 2012

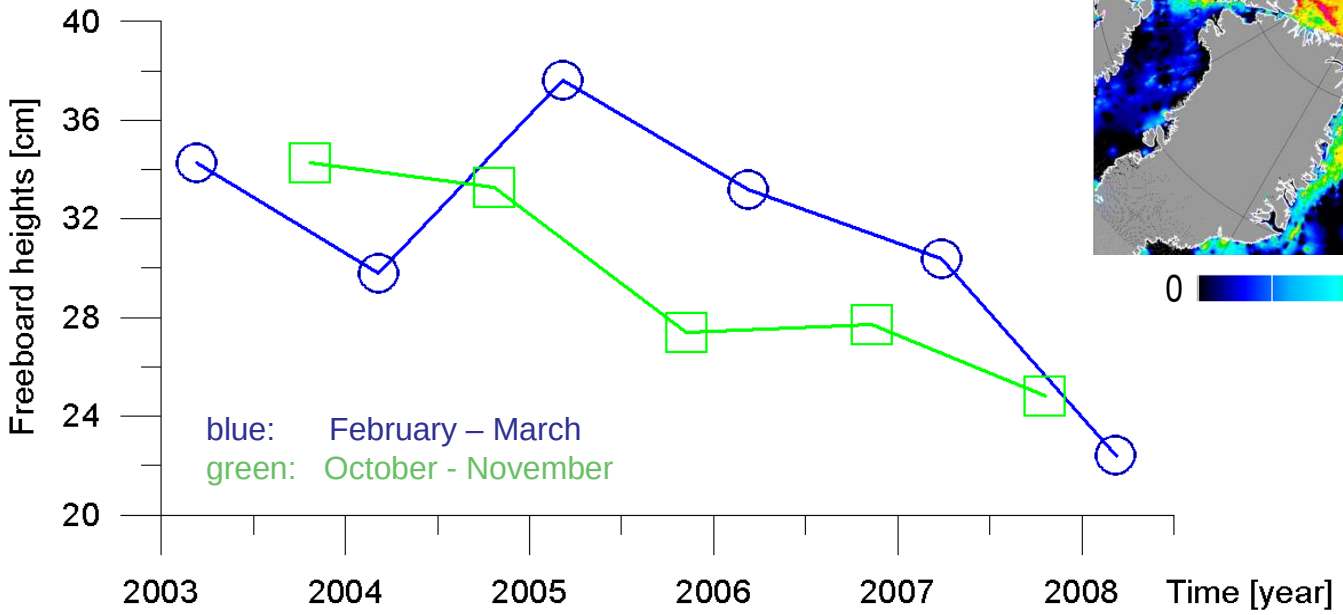
Sea ice freeboard heights

Sea ice freeboard heights and dynamic topography of the Arctic Ocean observed from ICESat altimetry 2003-2008 resolution 0.1°x 0.2°

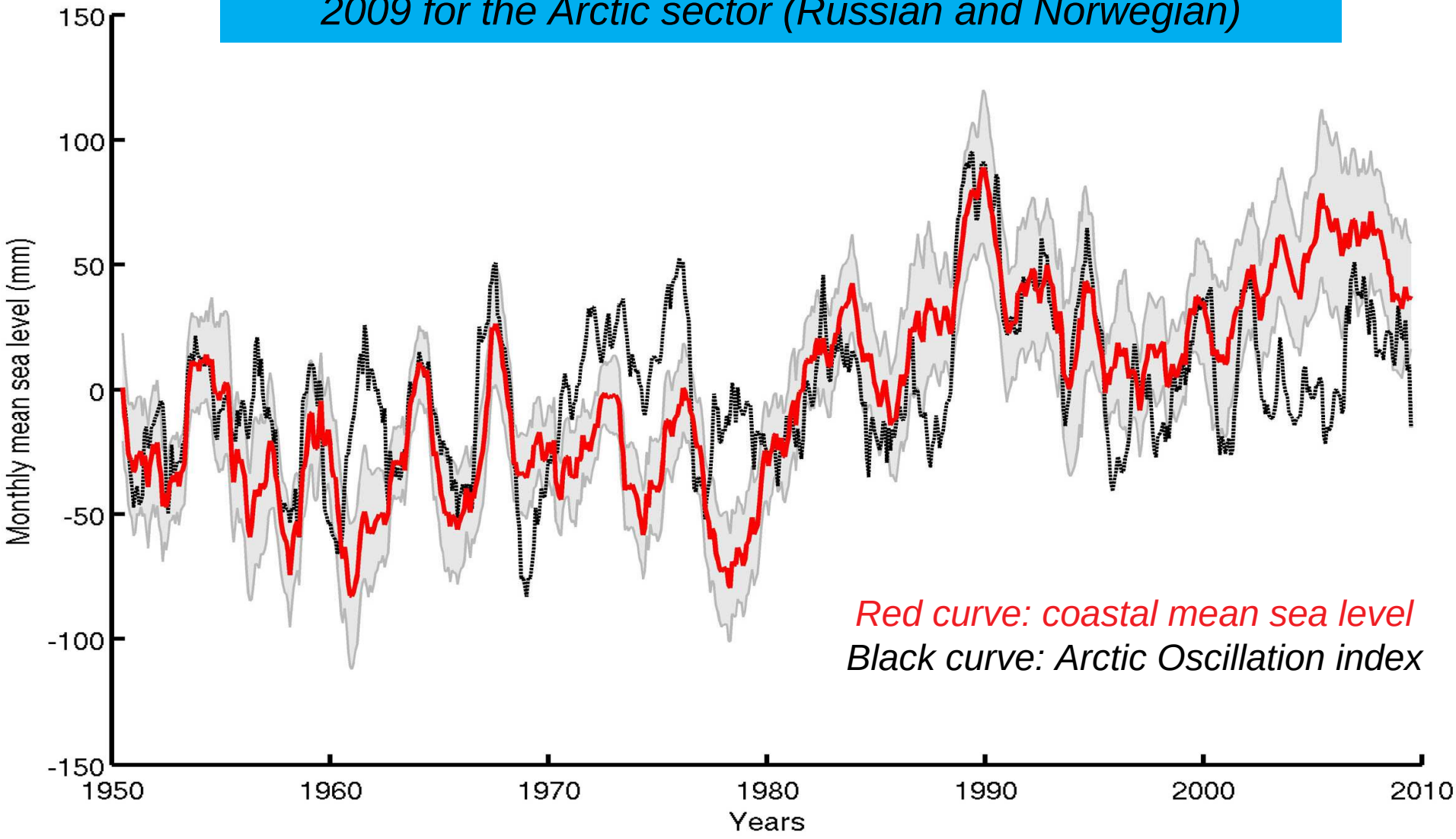
WHAT IS THE ACCURACY?

ICESat freeboard heights
October 2005



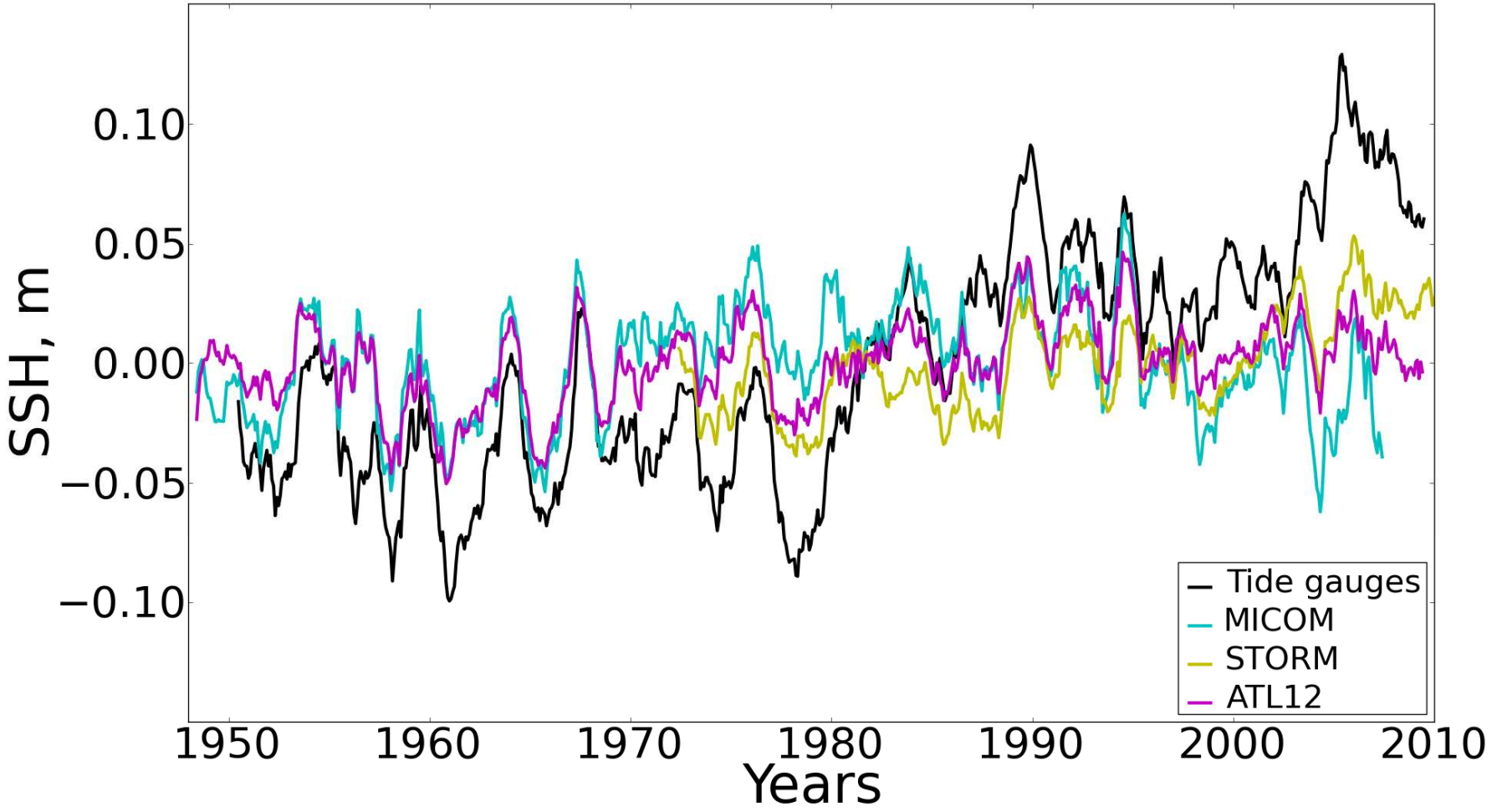


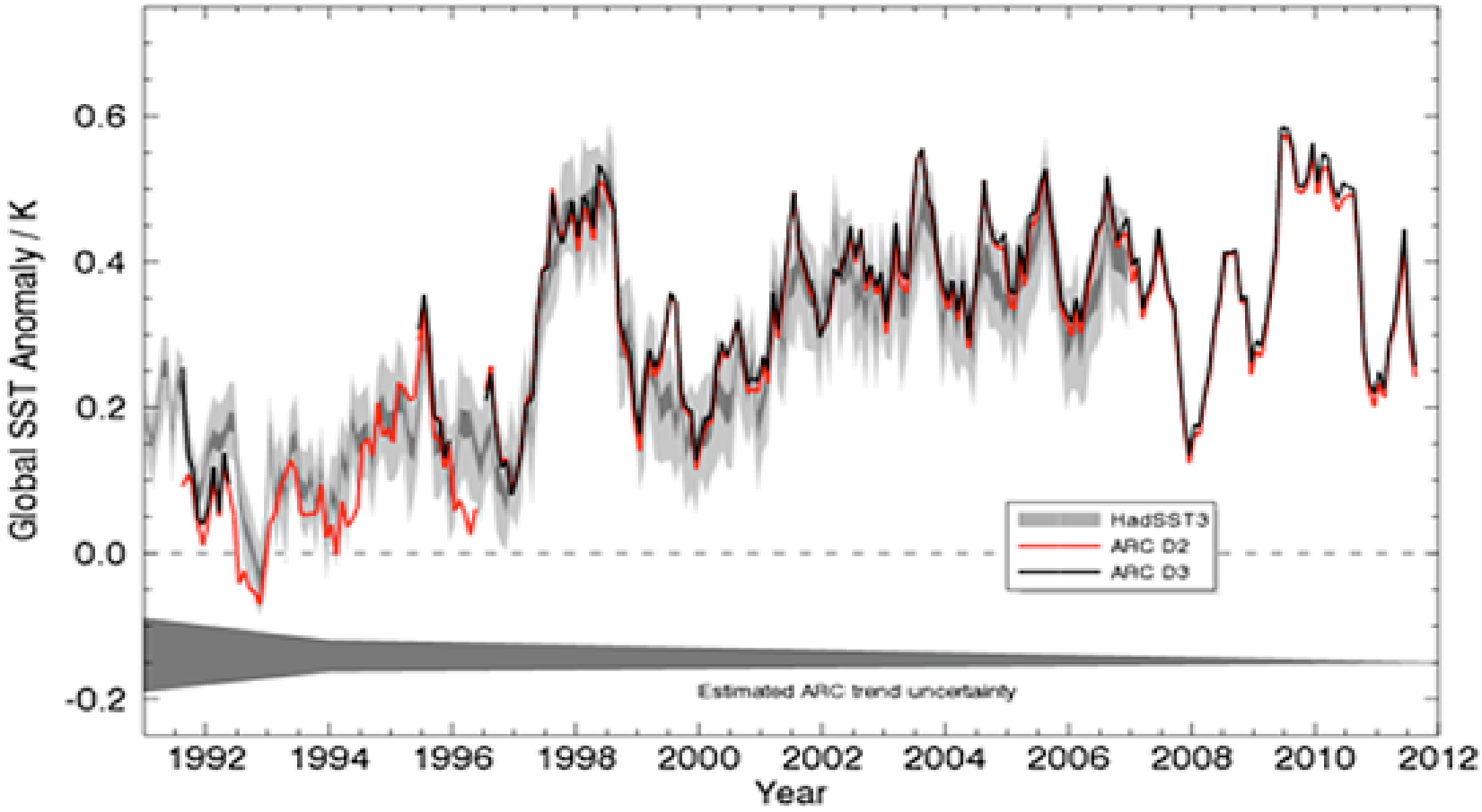
Coastal mean sea level from tide gauge records over 1950-2009 for the Arctic sector (Russian and Norwegian)



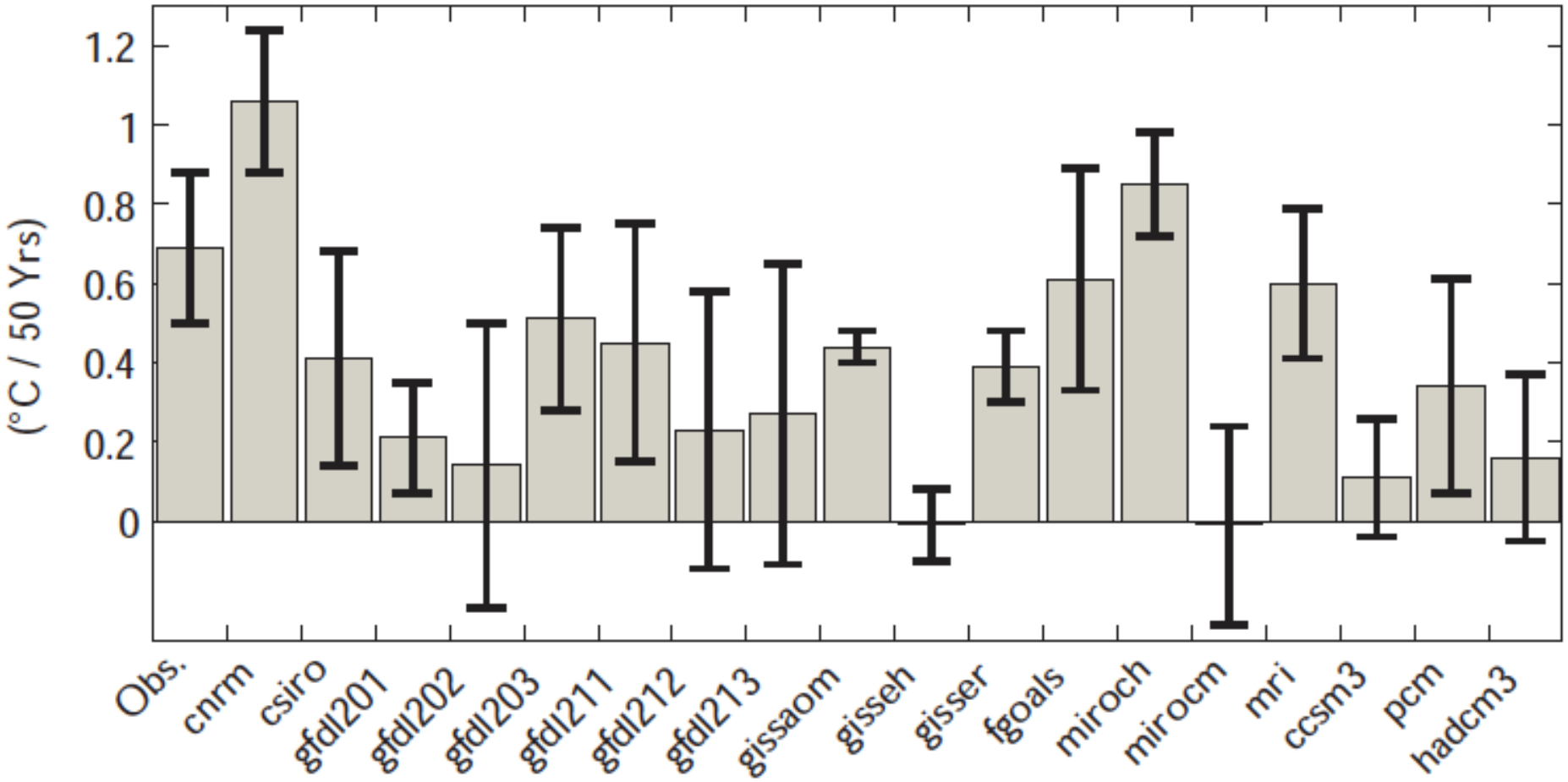
Simulations vs tide gauge observations (Henry, et al., 2012)

MONARCH-A Project

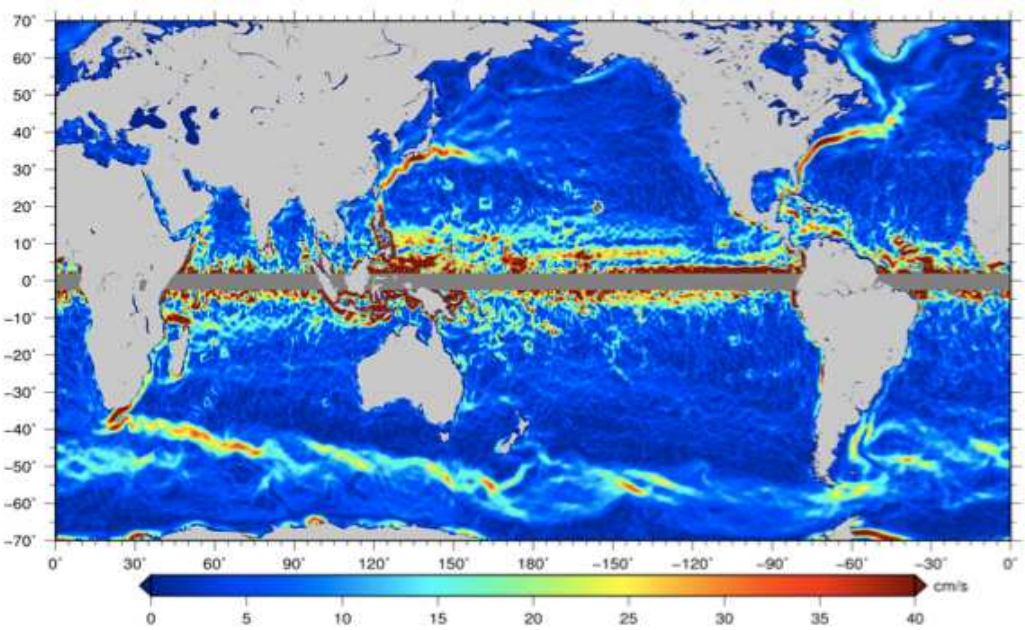


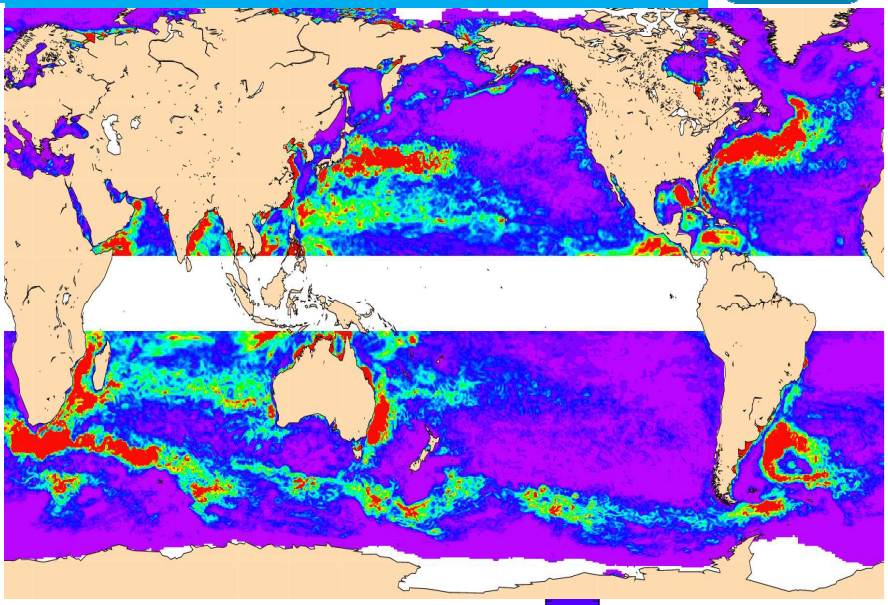

Global SST Anomaly / K
0.6
0.4
0.2
0.0
-0.2
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
HadSST3
ARC D2
ARC D3
Estimated ARC trend uncertainty

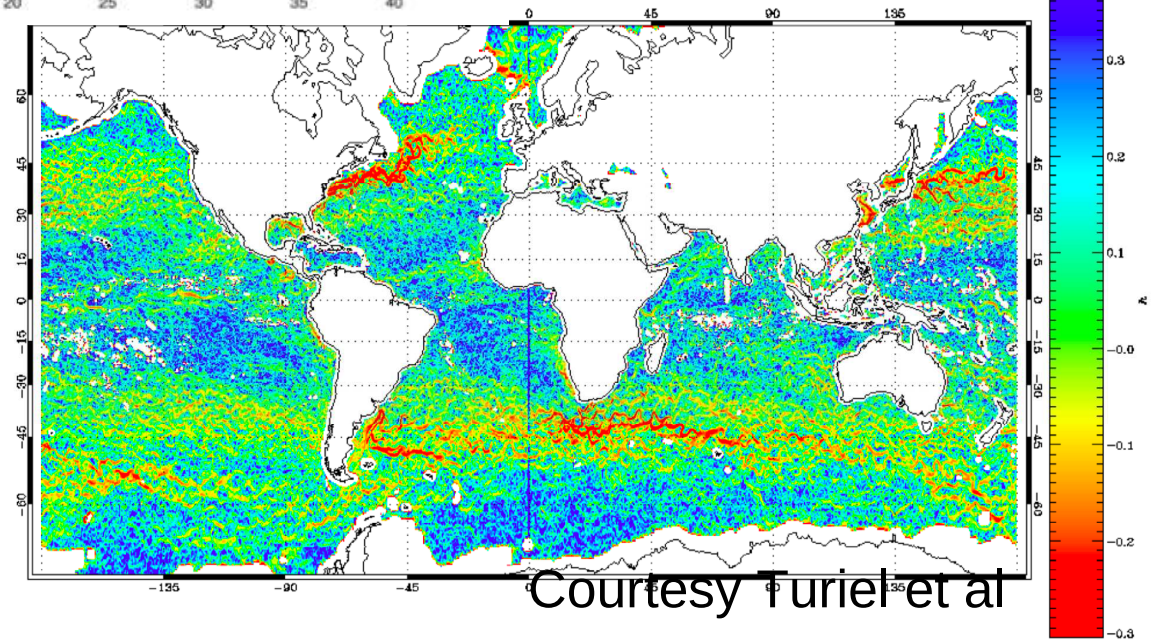
Trends in Tropical SST from 1950 to 2000,
U.S. Climate Change Science Program



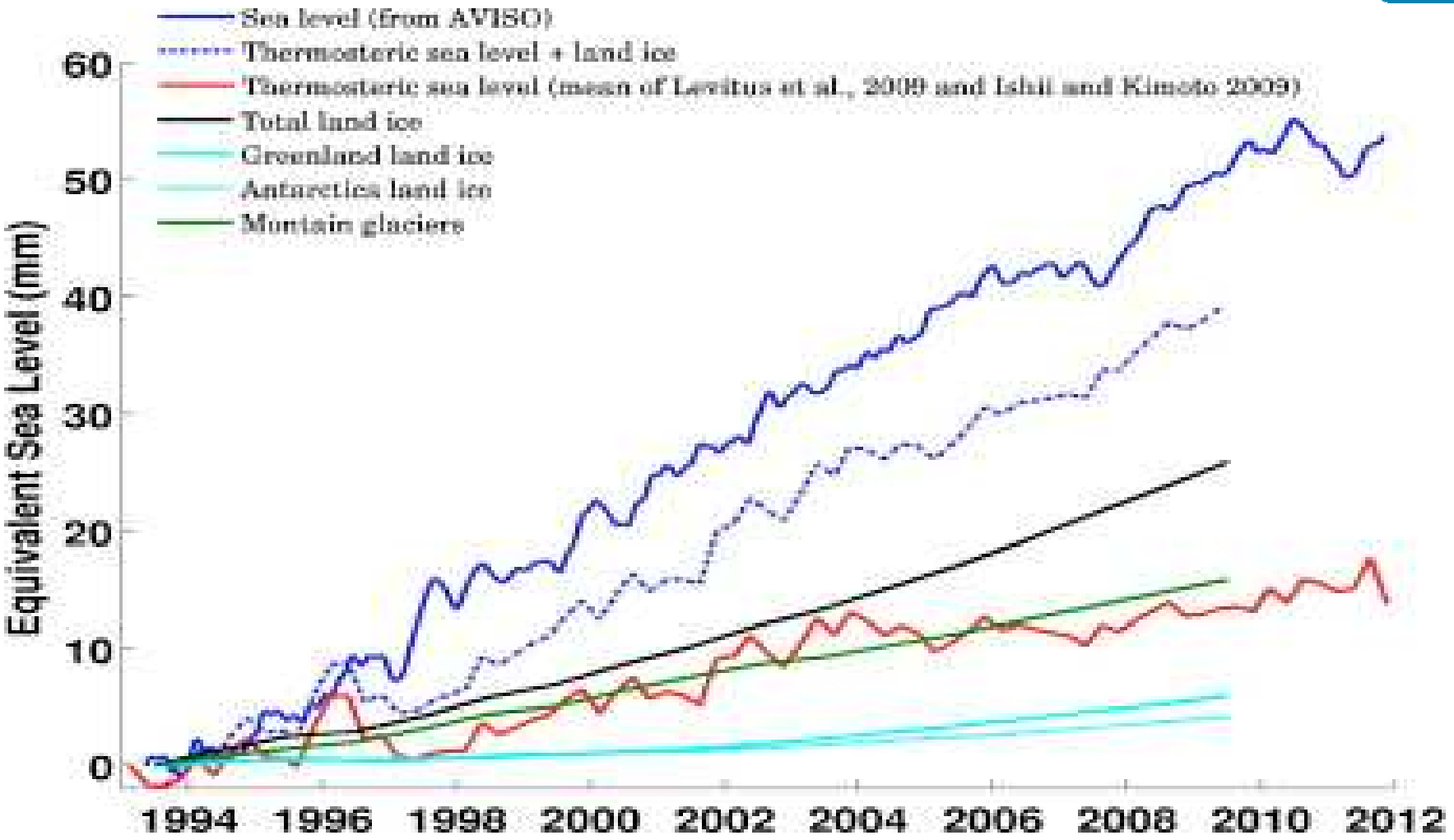
LINKS BETWEEN GOCE MSGC AND SST GRADIENTS and EKE





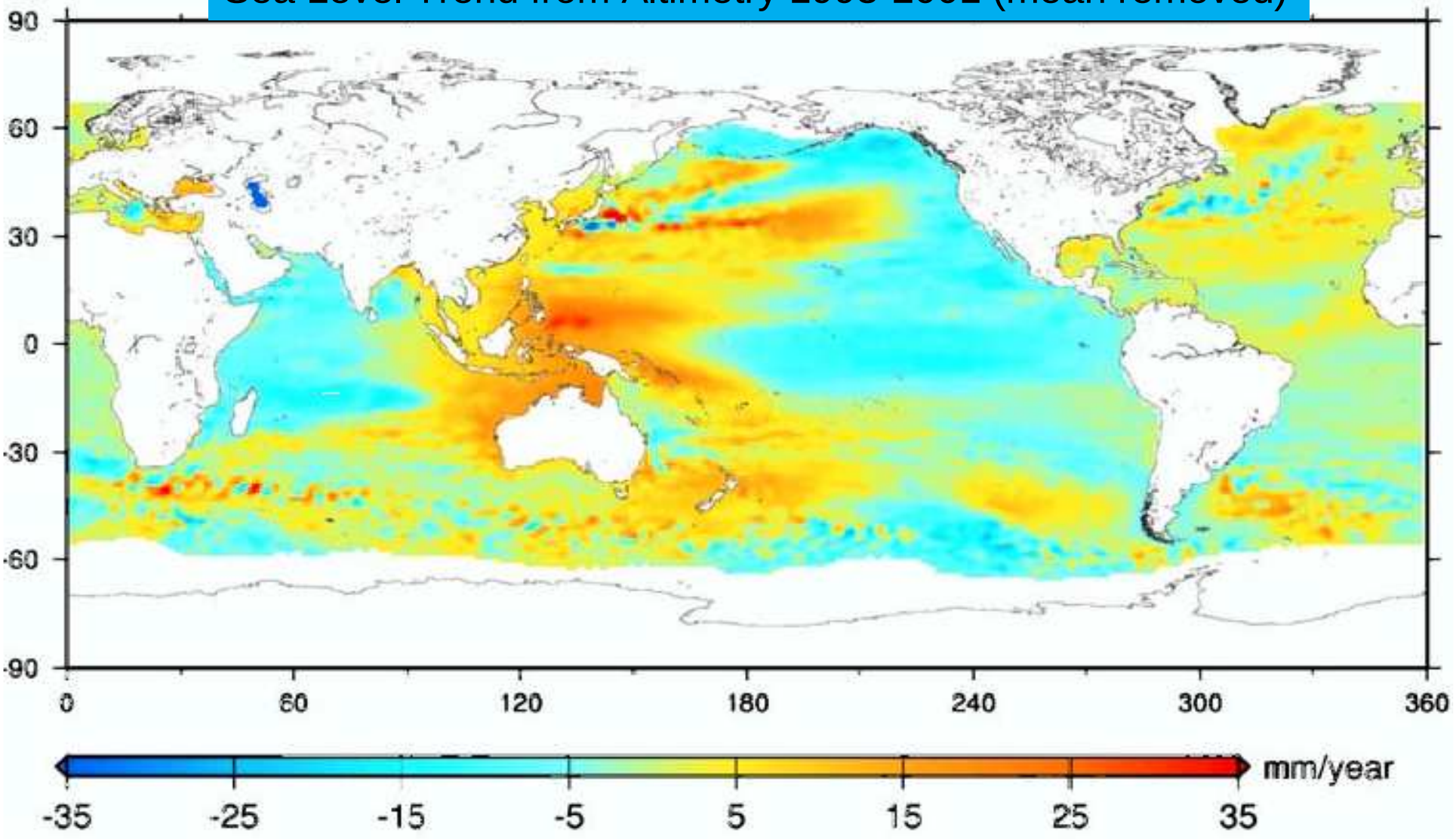


Courtesy Turiel et al



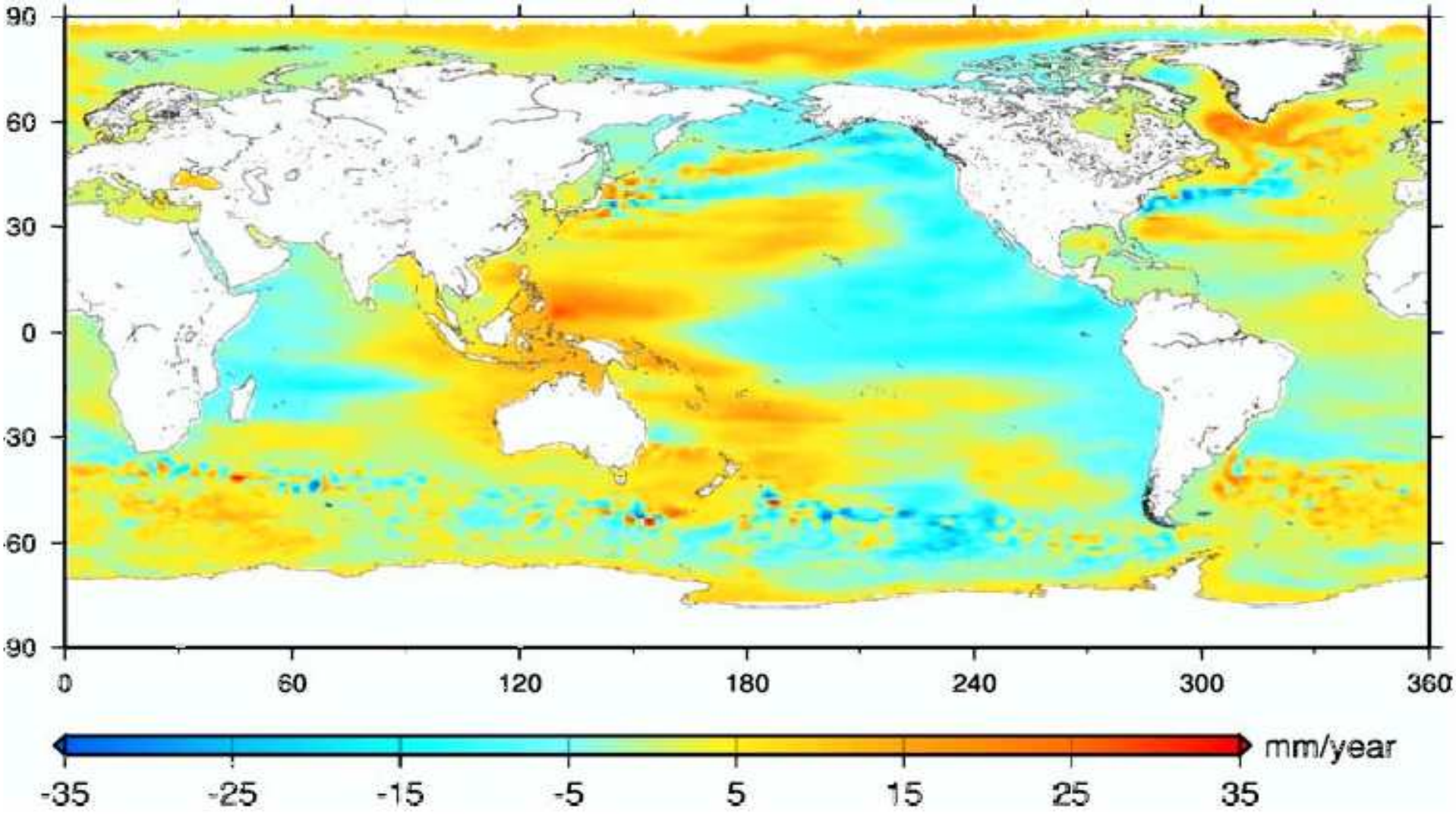
Meyssignac and Cazenave (in press)

Sea Level Trend from Altimetry 1993-2001 (mean removed)



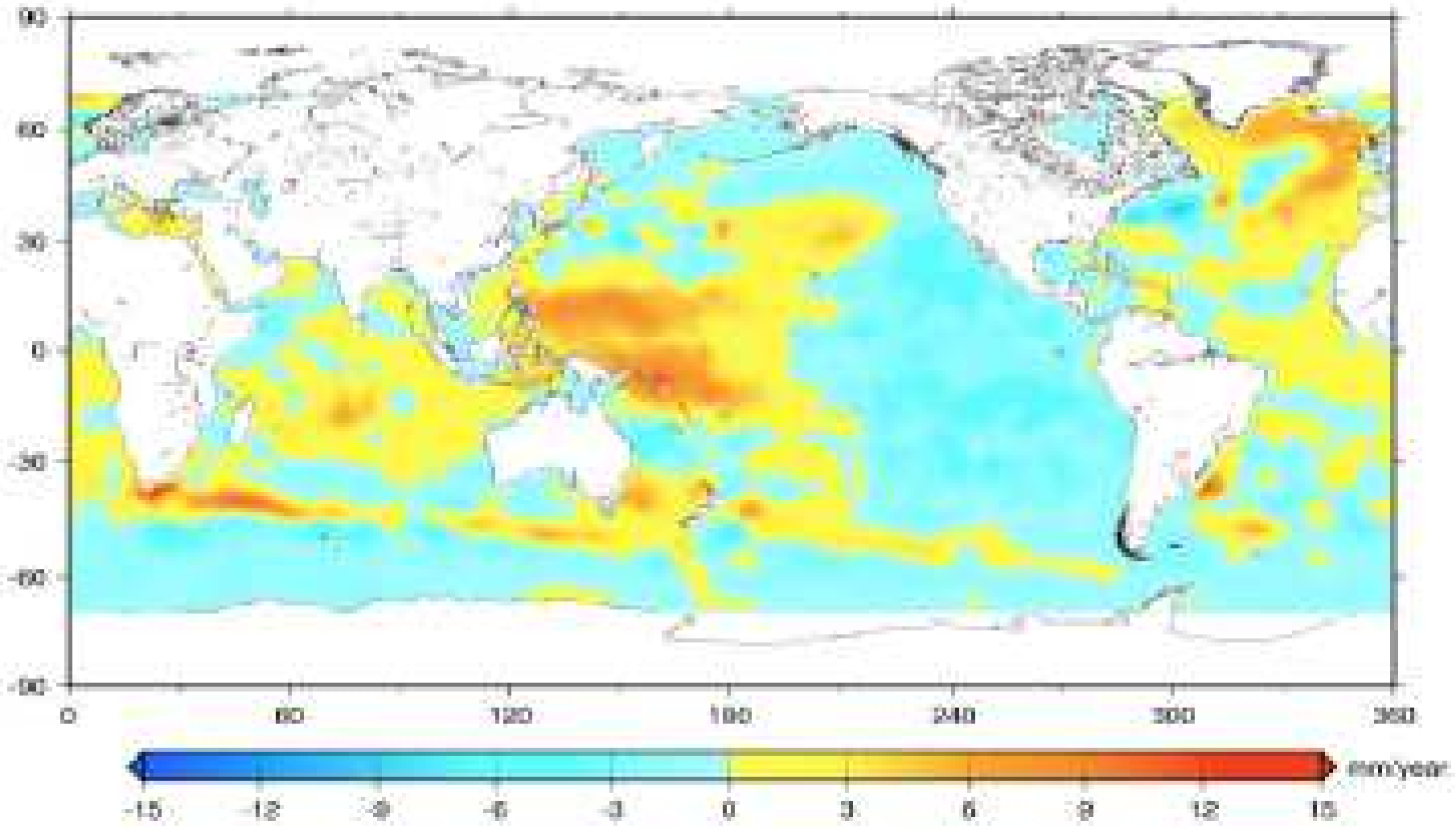
Lombard et al 2009

NEMO Sea Level Trend 1993-2001 (mean removed)



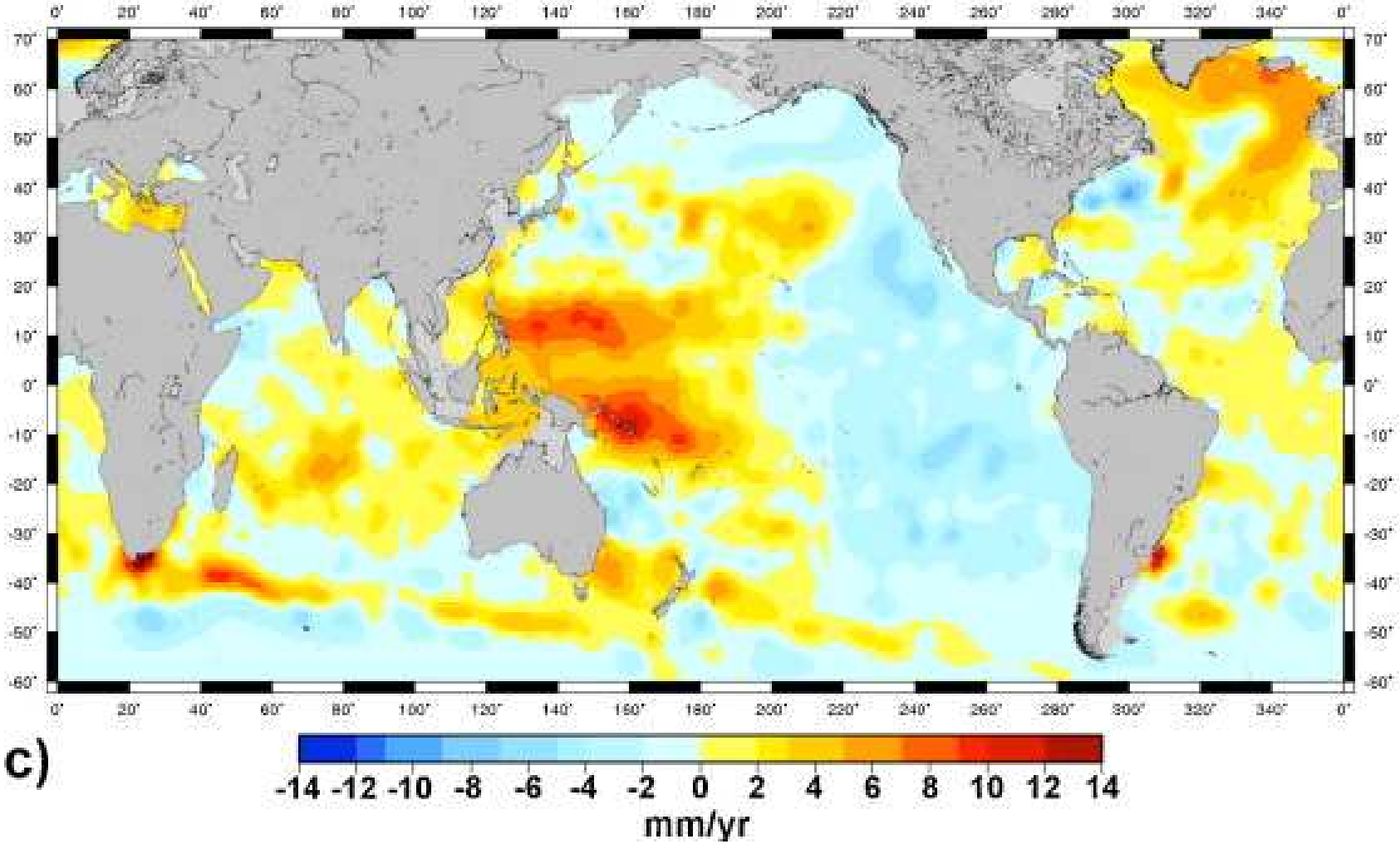
Lombard et al 2009

Observed Thermal Expansion, 1993-2009



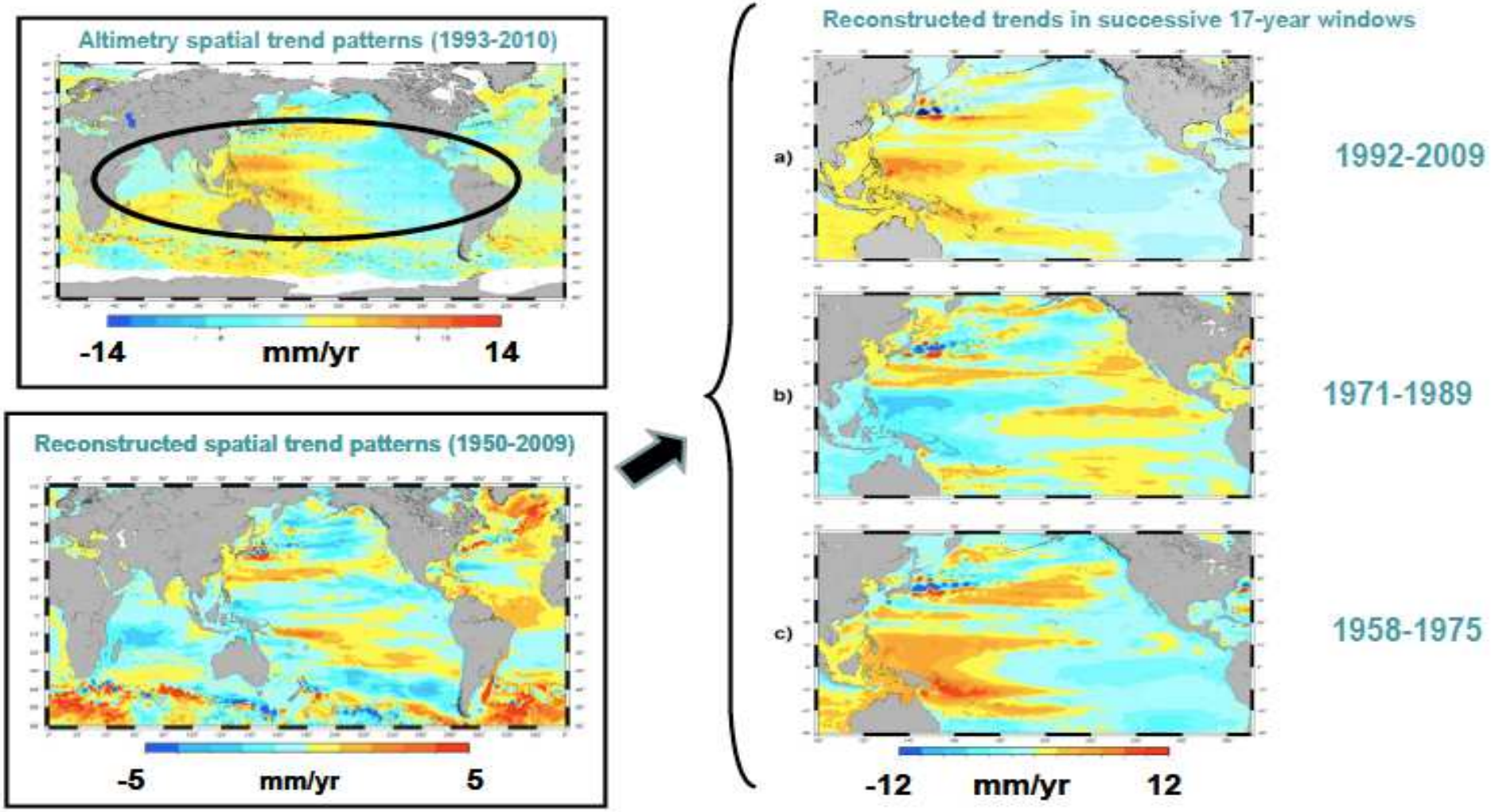
NERSC

Thermosteric Sea Level Trend from Levitus 1950-2009



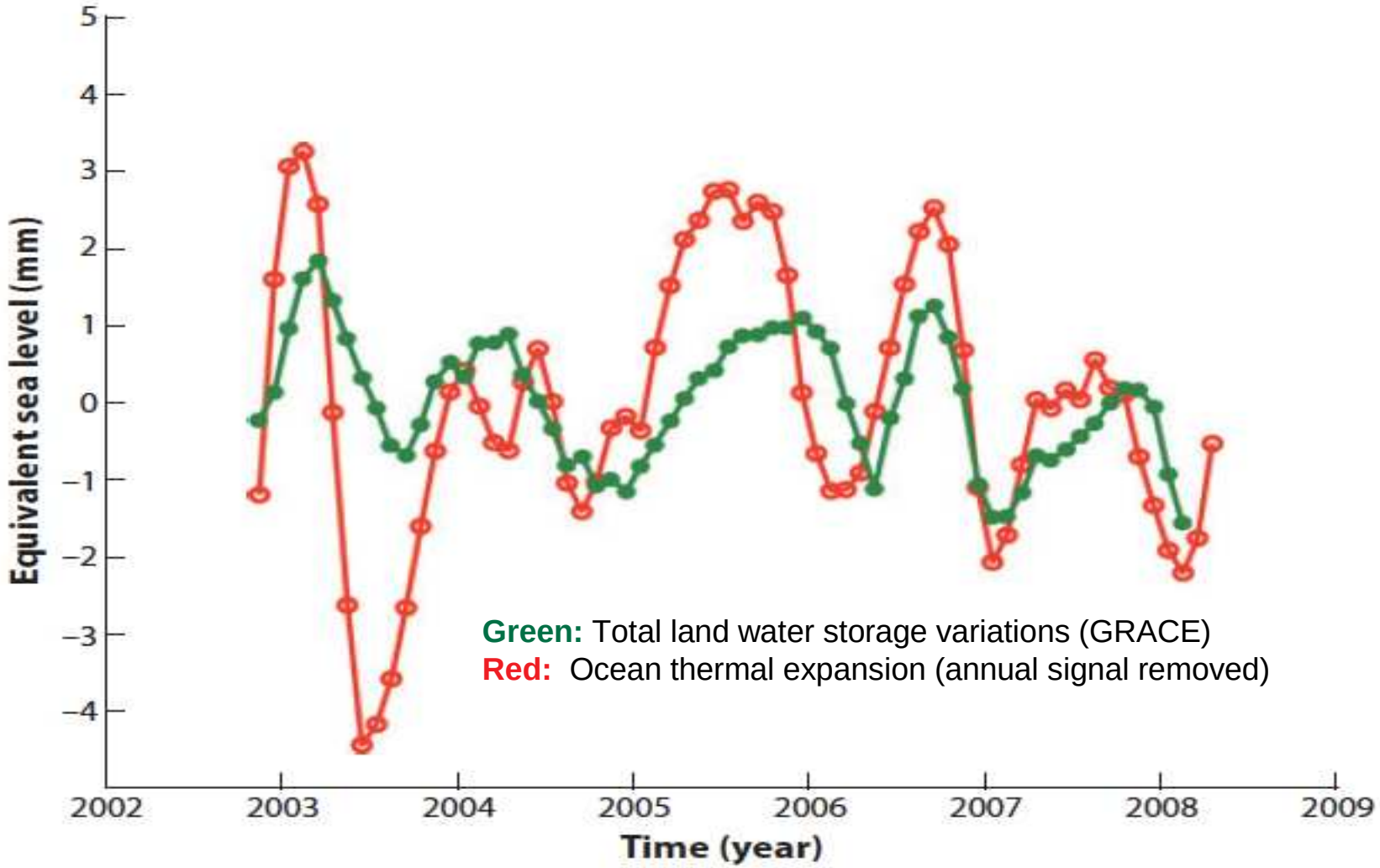
Meyssignac and Cazenave (in press)

Sea Level trends 1993-2010 versus 1950-2009



Meyssignac et al

Sea level variability (freshwater, thermal)



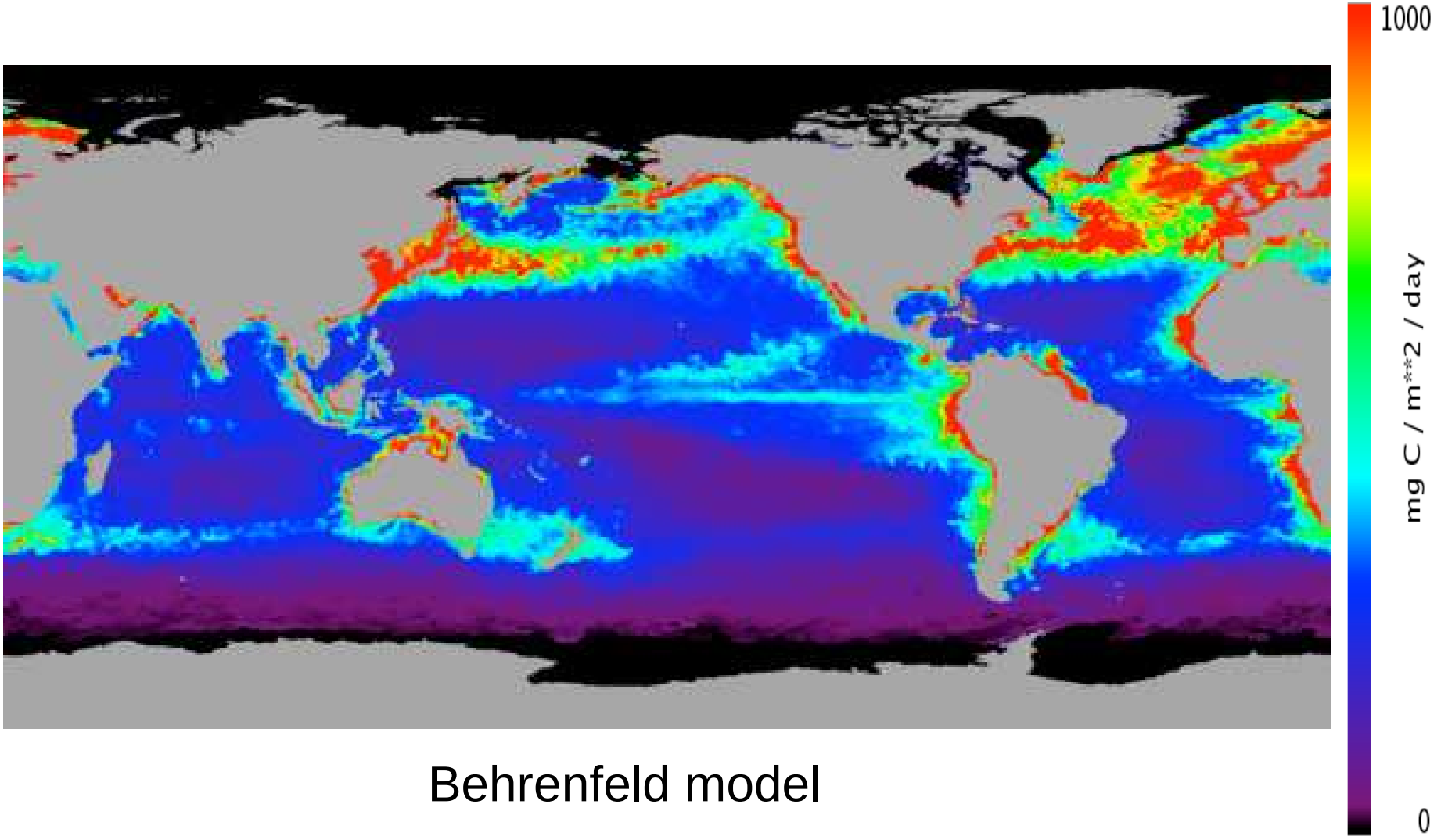
Llovel et al, 2010

Sea level budget for two time spans (1993–2007, 2003–2007)*

Sea level rise (mm year^{-1})	1993–2007	2003–2007
Observed	3.3 ± 0.4	2.5 ± 0.4 (Ablain et al. 2009)
Thermal expansion	1.0 ± 0.3 (mean of Levitus et al. 2009 and Ishii & Kimoto 2009 values)	0.25 ± 0.8 (Argo) (mean of Willis et al. 2008, Cazenave et al. 2009, and Leuliette & Miller 2009 values)
Ocean mass	2.3 ± 0.5 (observed rate minus thermal expansion)	2.1 ± 0.1 (GRACE with a −2 mm year^{-1} GIA correction, Cazenave et al. 2009)
Glaciers	1.1 ± 0.25 (based on Kaser et al. 2006 and Meier et al. 2007)	1.4 ± 0.25 (Cogley 2009)
Total ice sheets (Greenland & Antarctic)	0.7 ± 0.2 0.4 ± 0.15 0.3 ± 0.15 (compilation of published results)	1.0 ± 0.2 0.5 ± 0.15 0.5 ± 0.15 (compilation of published results)
Land waters	—	−0.2 ± 0.1 (W. Llovel, K. DoMinh, A. Cazenave, J.F. Cretaux, M. Becker, unpublished manuscript)
Sum of (2 + 4 + 5 + 6)	2.85 ± 0.35	2.45 ± 0.85
Observed rate minus sum	0.45	−0.05

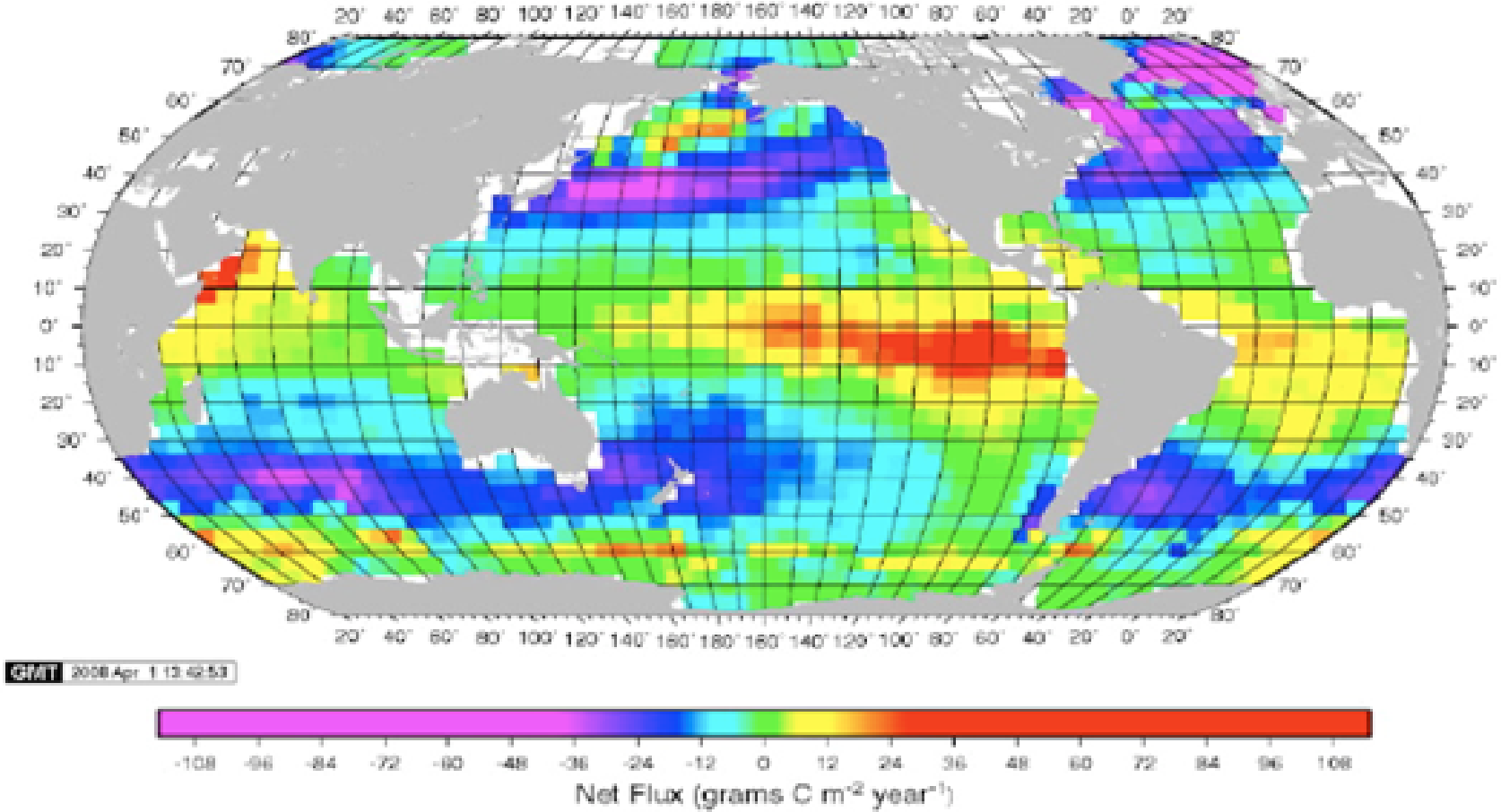
Cazenave and Llovel, 2010

Monthly Net Primary Production: May , 2006



Behrenfeld model

Estimates of Ocean-Atmosphere CO2 Exchange

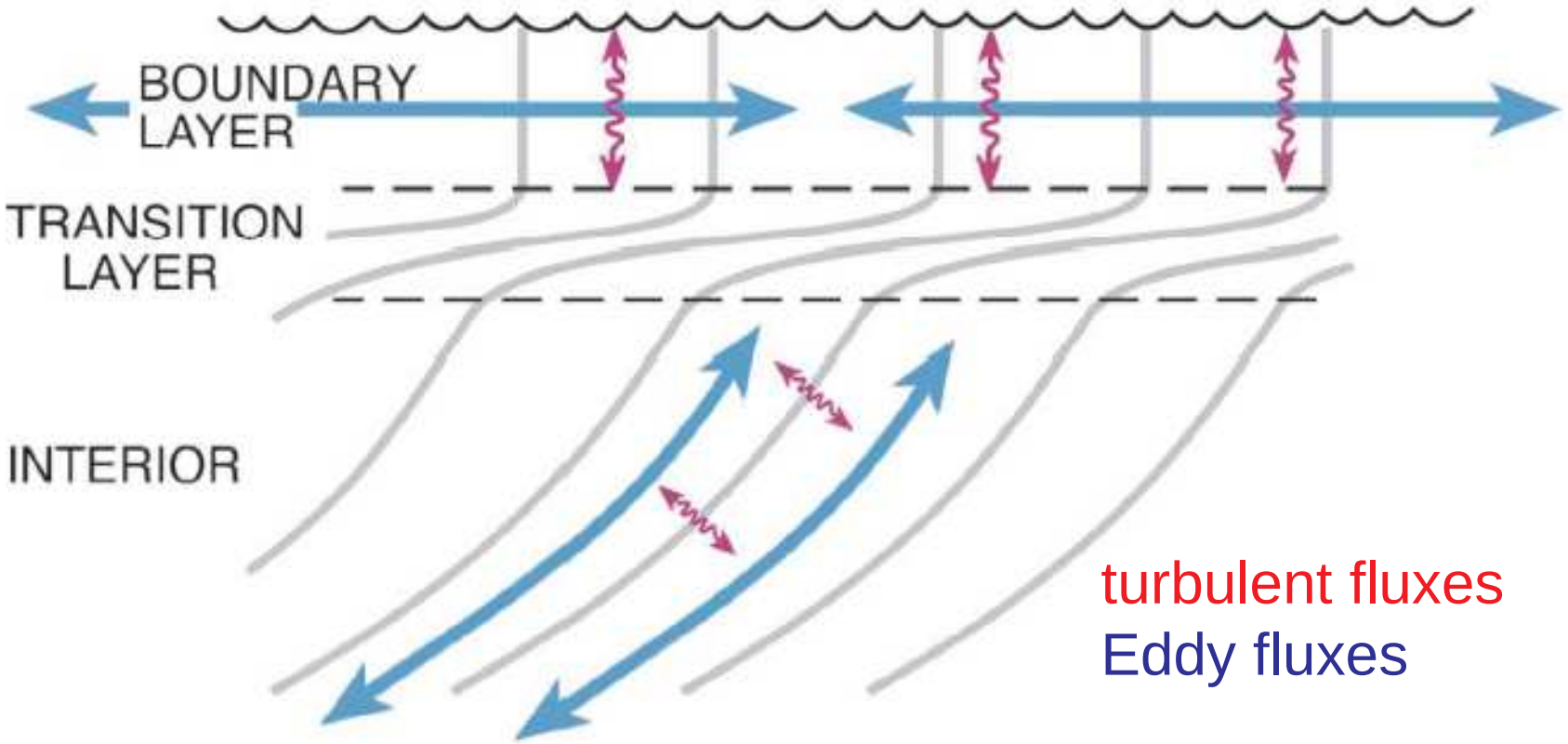


© Takahashi et al. (2009)

NET SINK FOR ATMOSPHERIC CO2 IN HIGH LATITUDES AND ARCTIC:

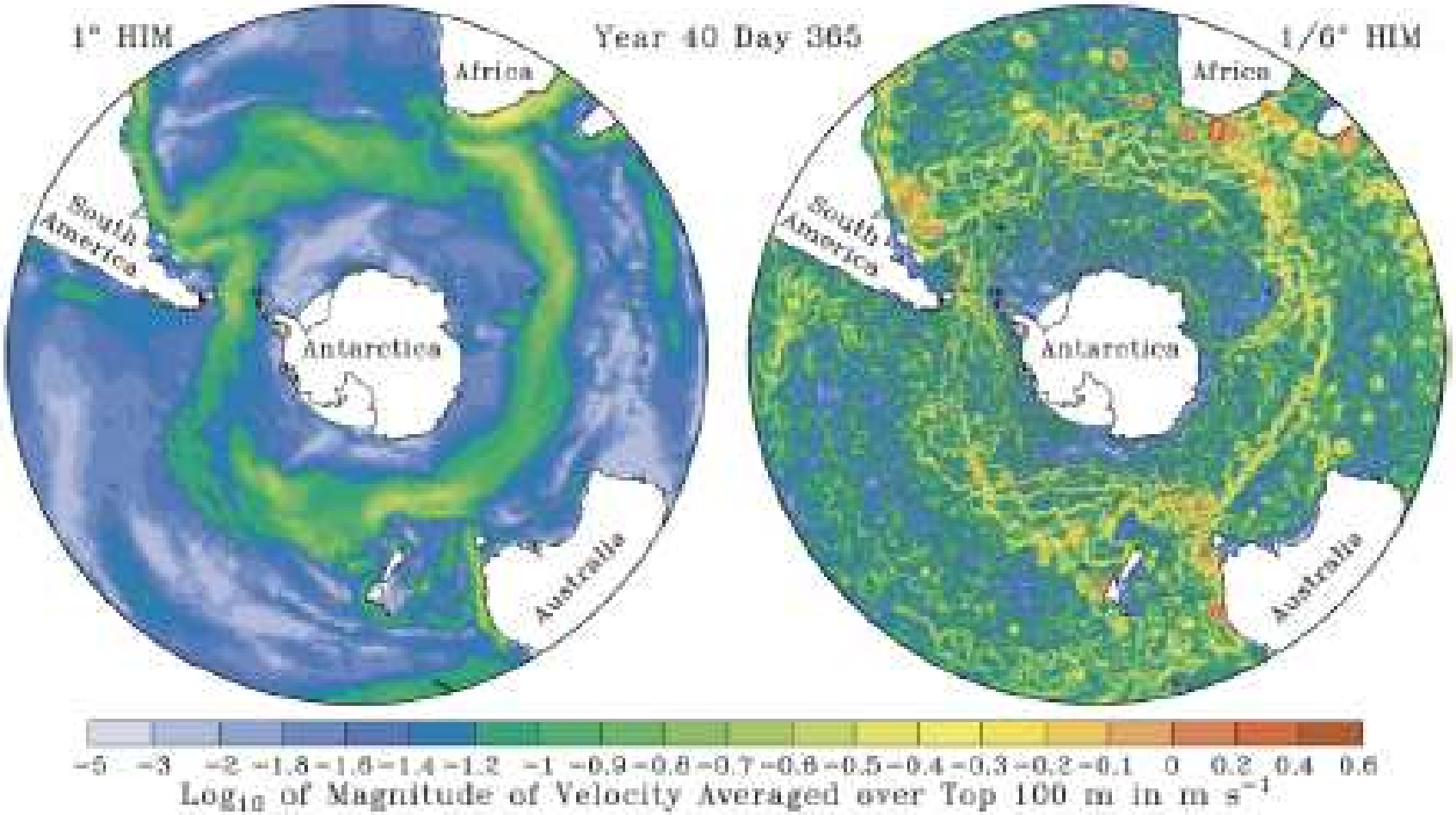
- McGuire et al. (2009): 24-100 Tg C/yr
- Bates and Mathis (2009): ~66-199 Tg C/yr

Role of eddies for ocean mixing



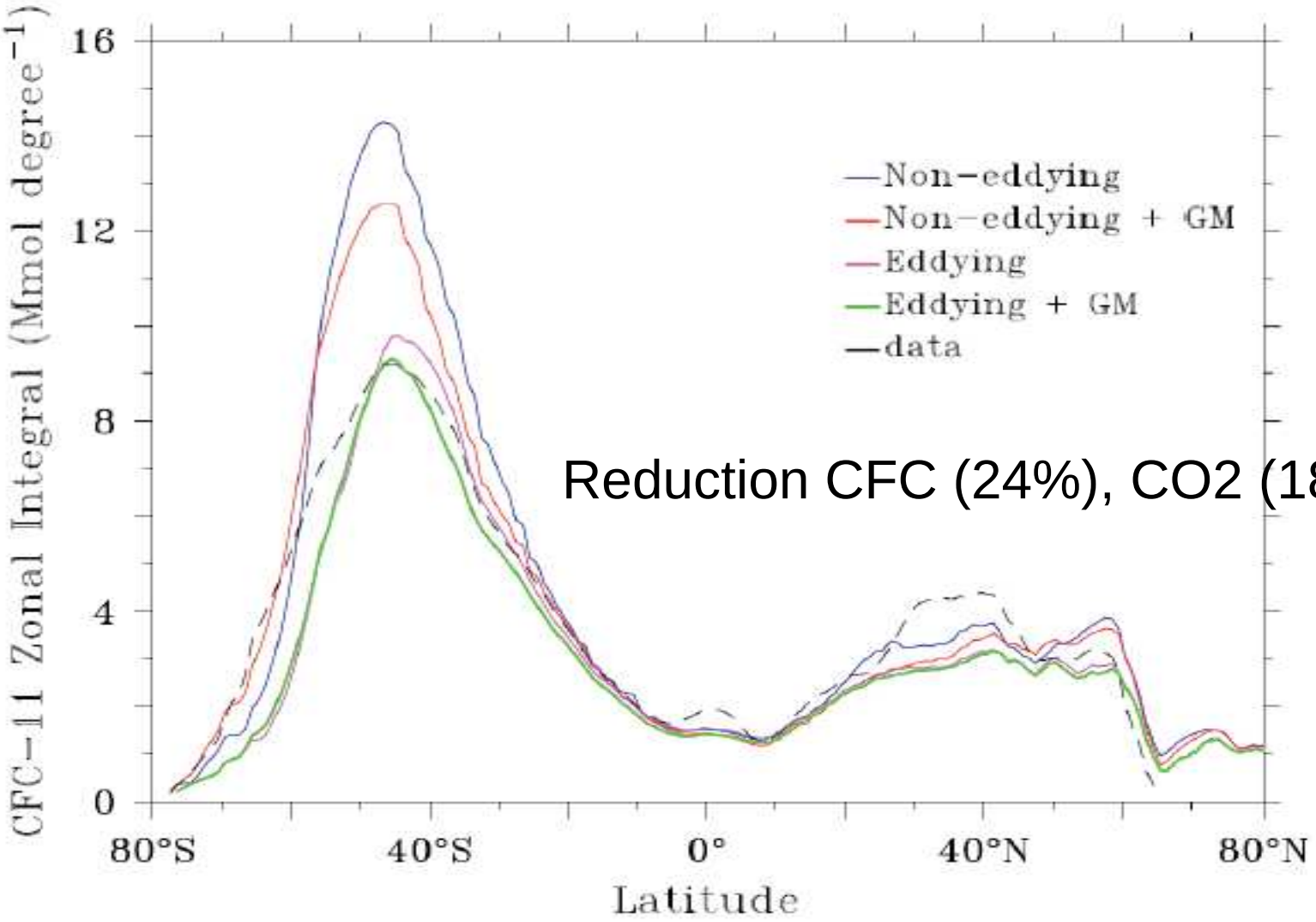
Courtesy SUTER

Surface velocity maps (top 100m)



Hallberg & Gnanadesikan

Oceanic Uptake of CFC and CO2



Reduction CFC (24%), CO2 (18%)

Courtesy SUTER

ECV	Water Cycle	CO2 Cycle	Sea Level
Sea Ice	X	X	X
Sea Surface Temperature	(X)	X	X
Ocean Color		X	(X)
Glaciers/Ice Sheet	X		X
Greenhouse Gas (CO2)	(X)	X	
Land Cover (Snow)	X		X
Clouds	X	X	(X)

Summary

The spatial trends of the ocean ECVs (Sea-level, SST, Sea Ice and Ocean Color) must be co-located with highest possible spatial resolution (10-30 km) and combined with time series of

- **Land Cover** (snow cover **influence freshwater runoff and Sea Level)**
- **Fire Disturbance** (influence soil moisture**, run-off, sea level**)
- **Glaciers/Ice sheets (influence freshwater runoff and Sea Level)**
- Clouds (influence radiation balance and surface albedo)
- Aerosol (influence radiation balance and surface albedo)
- Ozone
- Greenhouse Gases (CO2, CH4) (CO2 cycle and uptake in the ocean)

Piece together the ECVs in a consistent Earth System Approach (Water Cycle, CO2 Cycle, Sea Level, etc.). Make regular comparison to models.

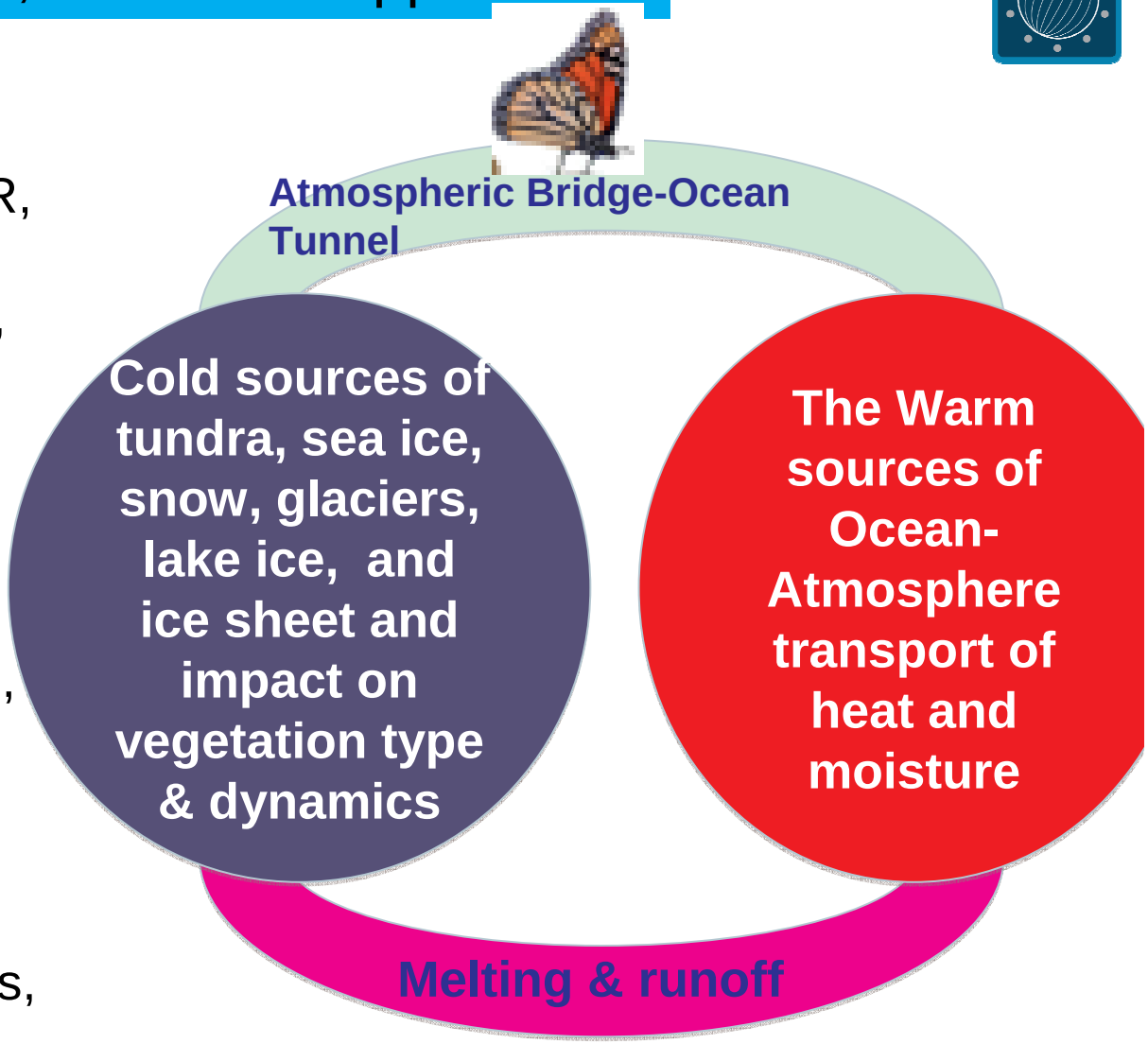
Data assimilation in climate models next.

Data, Tools and Approaches

Satellite data:
altimetry, scatterometer, SAR, imaging spectrometers, AVHRR/AATSR, pass.micro, gravity, etc,..

In-situ data
legacy of IPY, Ice buoys, NISE/IMR data set, Russian permafrost data, tide gauges, vegetation cover, river flux data, snow depth, etc

Models:
Forced ocean-sea ice models, vegetation models, re-analyses, and fields from coupled climate models



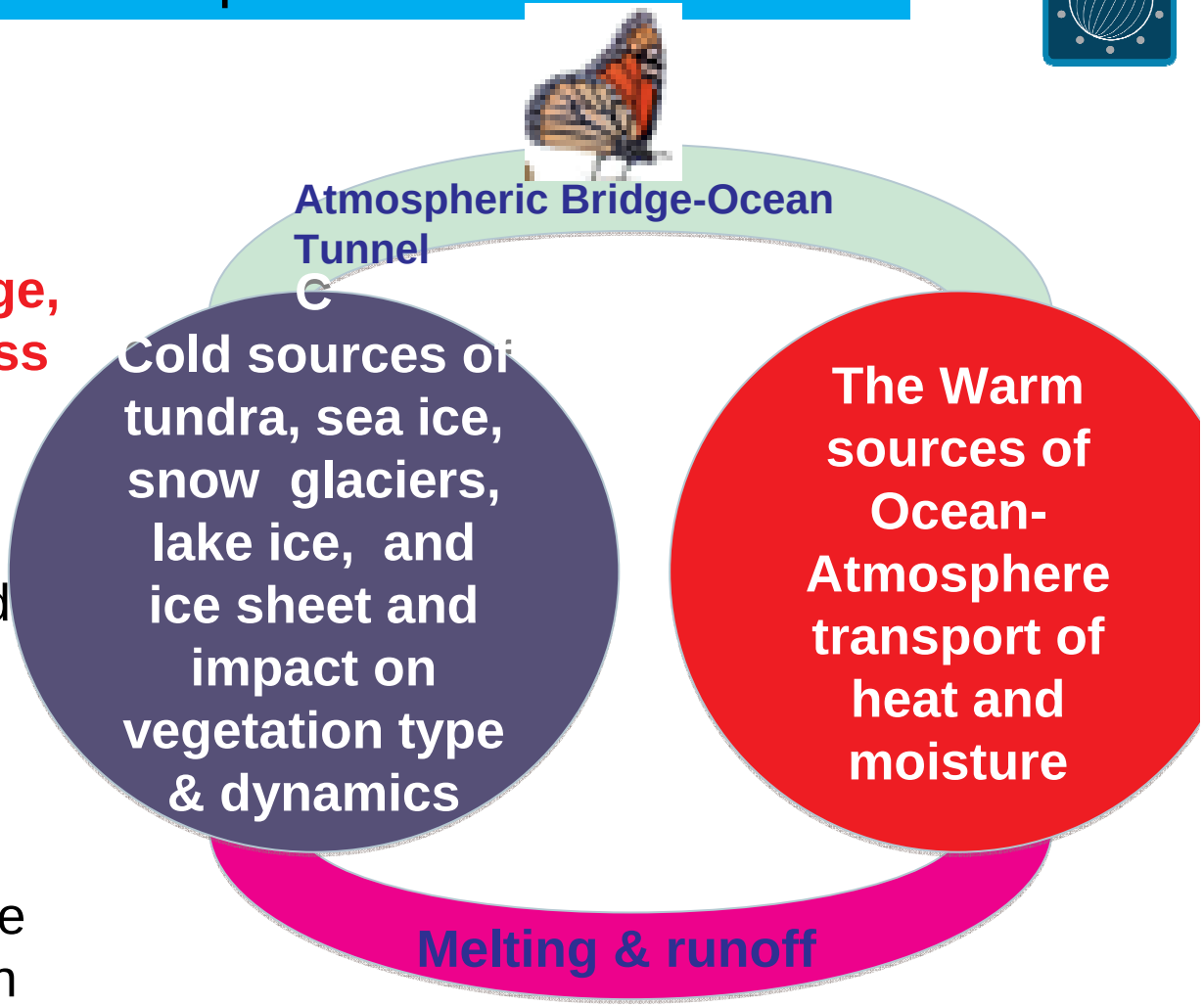
How are changes detected, connected and simulated?

11 ECV trends will be produced and assessed

Terrestrial: **river discharge,** snow cover**, ice sheet mass balance** and permafrost;

Oceanic: **sea ice drift** and sea ice volume, **sea level, current,** ocean color and CO2 partial pressure;

Atmospheric: near surface wind field (related to shift in atmospheric circulation patterns)



SYNTHESIS AND MUTUAL FEEDBACK LOOPS

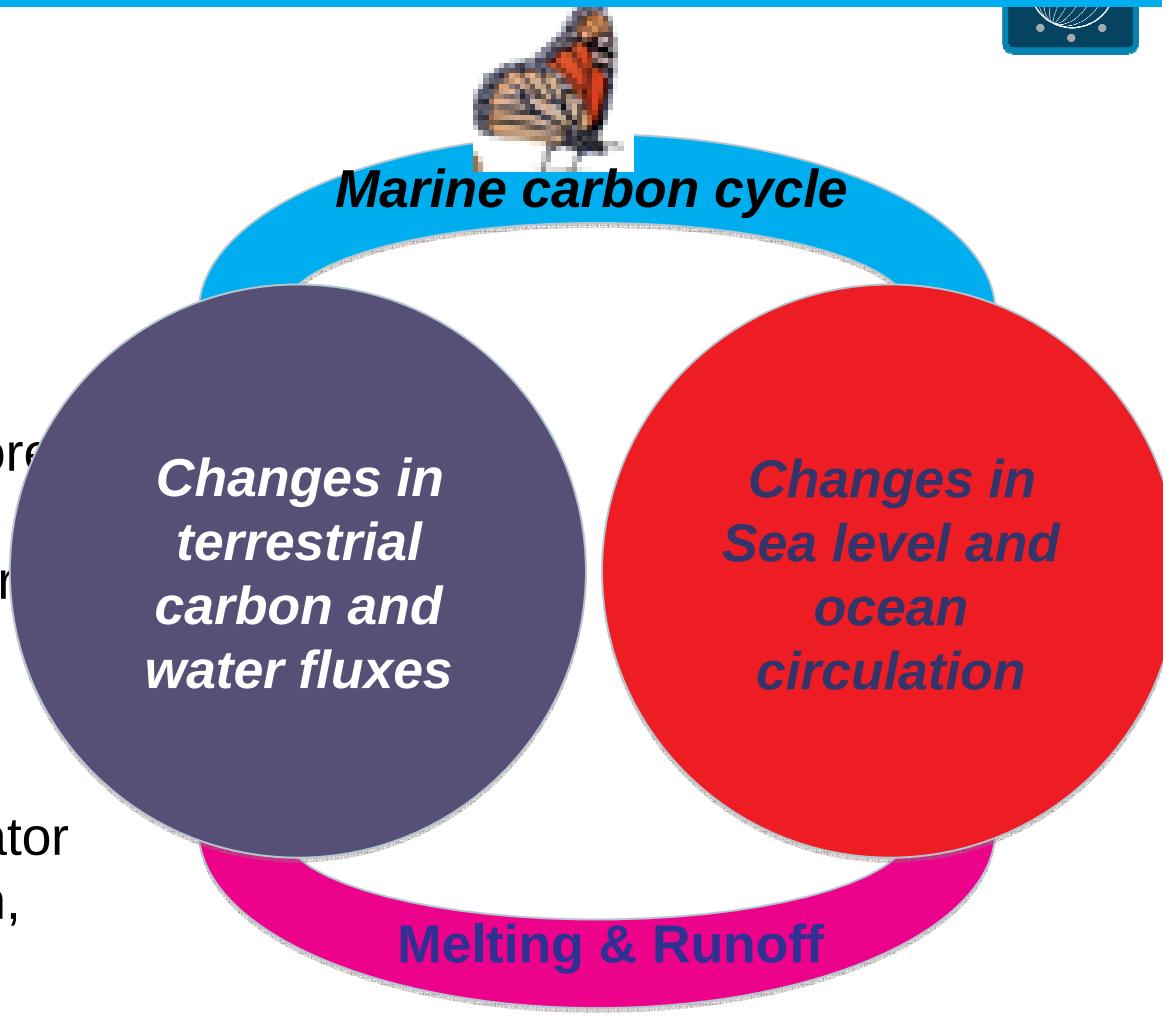
Synthesis and Interaction with the Scientific Community

Interaction and dissemination of results with:

GCOS, CLIVAR, ESA CCIs, Eumetsat SAFs, EC GMES Core Services, Arctic Council and AMAP, Climate Modeling Centr (BCCR, Max Planck, Hadley, ECMWF, ….).

CARBONES, EURO4M (indicator bulletin), ERA-CLIM, MyOcean, MACC2, Geoland2

Support and contribute to priorities and design of high latitude and Arctic monitoring system for climate change.

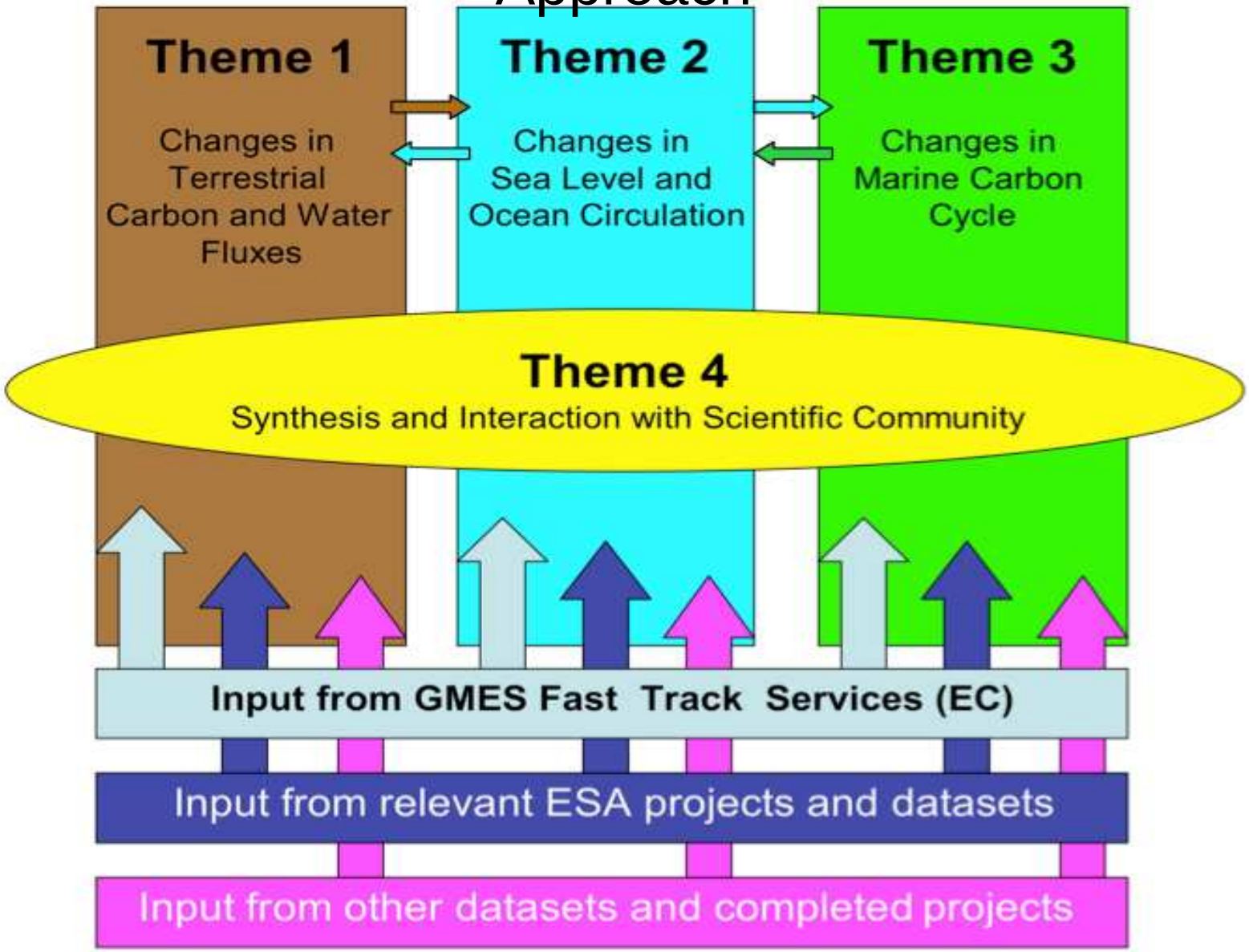


SYNTHESIS AND MUTUAL FEEDBACK LOOPS

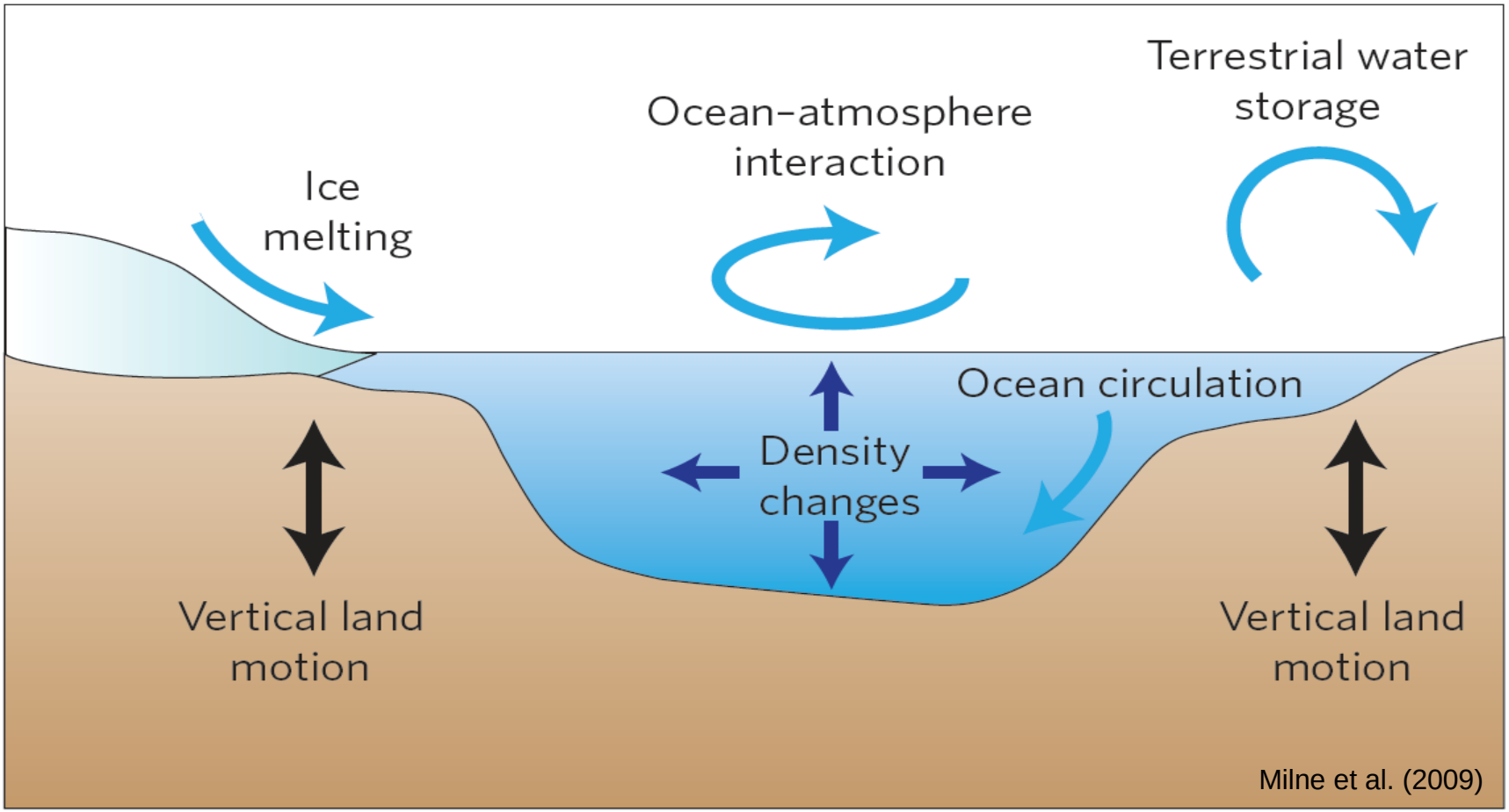
Sea Level ECV

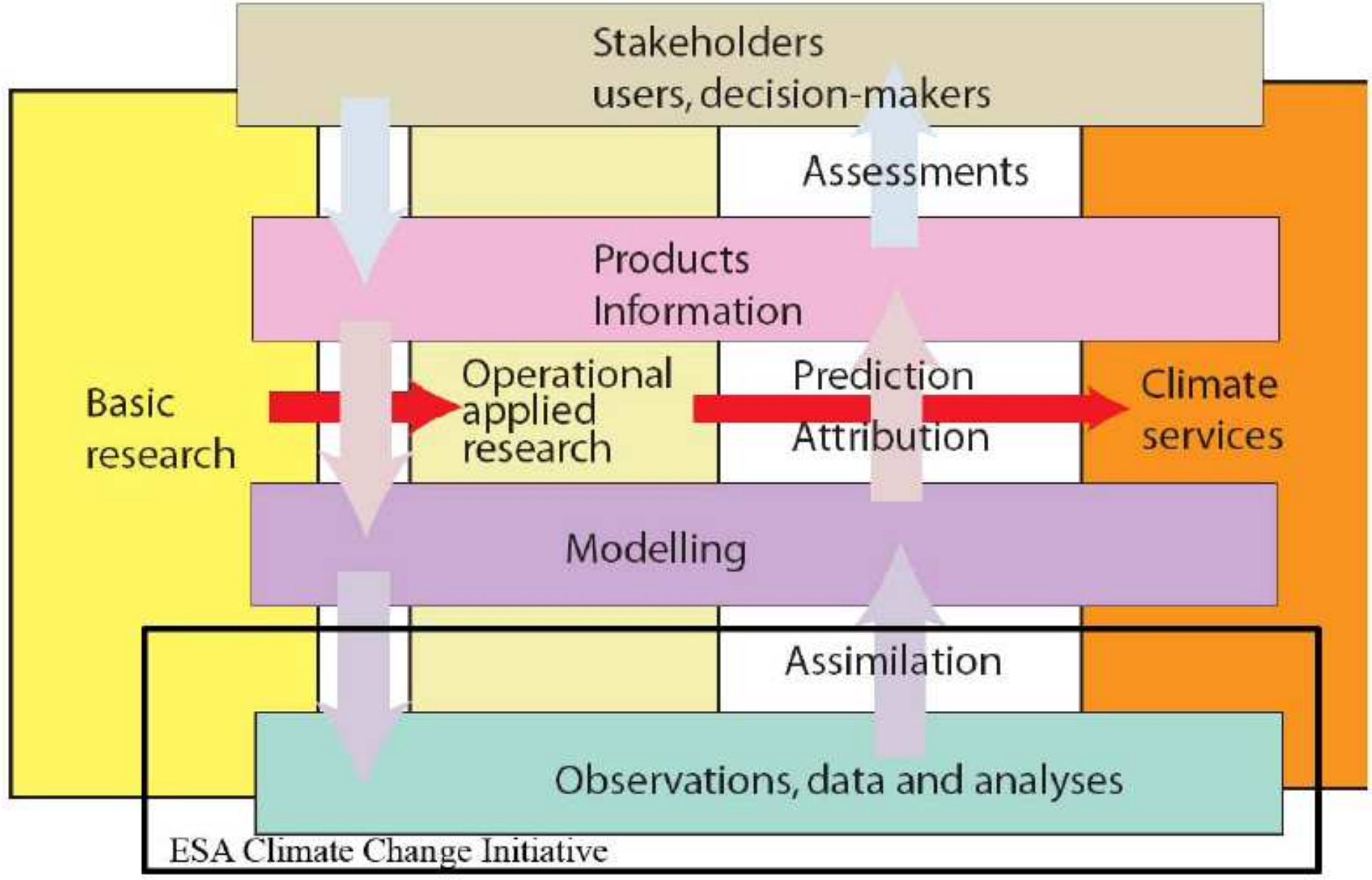
GCOS Requirement		Current Status
• Accuracy: • Spatial resolution: • Temporal resolution: • Stability:	1 cm Horizontal: 25 km Daily 0.5 mm/decade	2 cm Horizontal: 25 km Weekly 10 mm/decade (1 mm/yr)

Work Breakdown – Based on an Earth System Approach

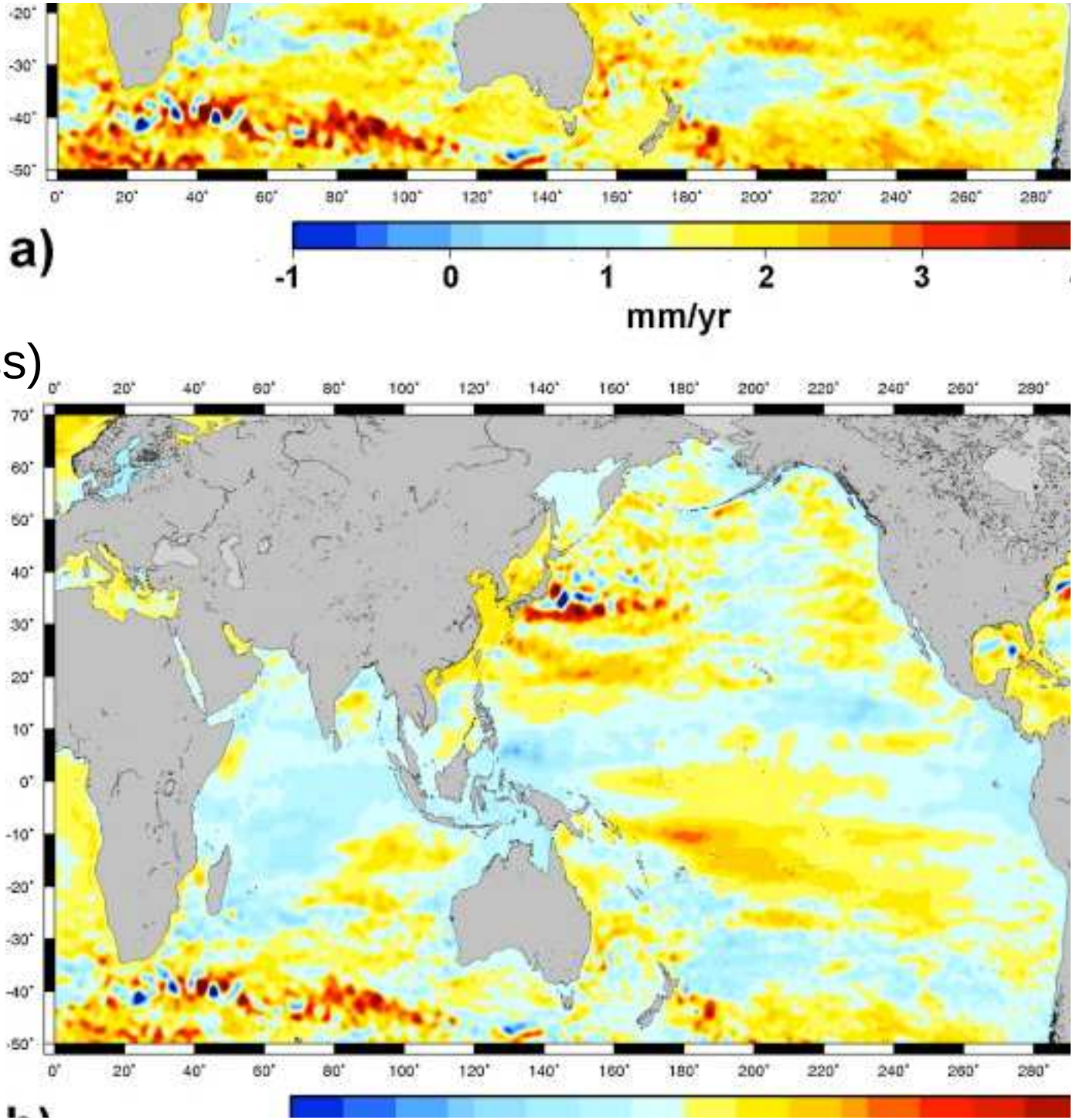


Interaction and mutual feedback – Sea Level

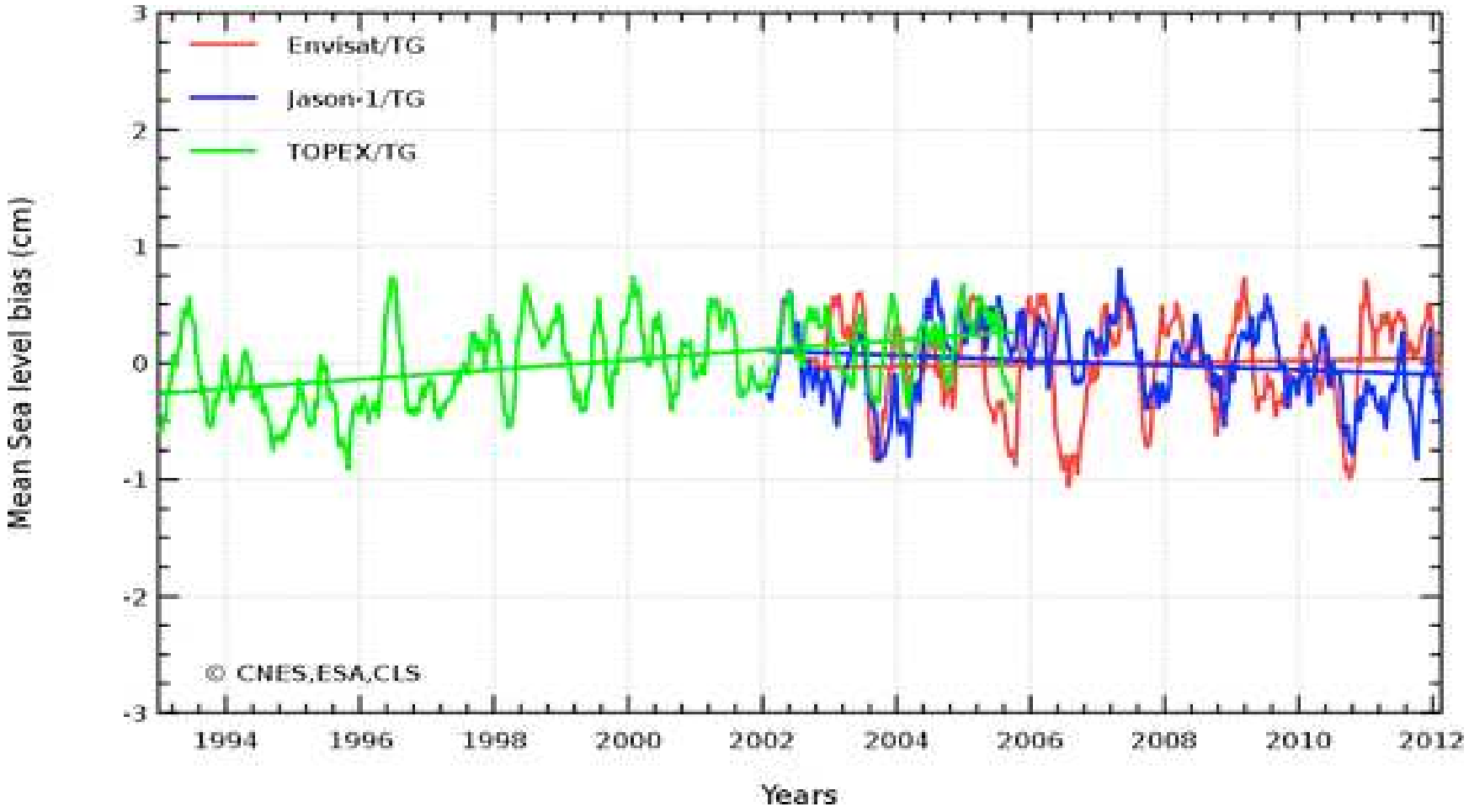



Stakeholders
users, decision-makers
Assessments
Products
Information
Basic
research
Operational
applied
research
Prediction
Attribution
Climate
services
Modelling
Assimilation
Observations, data and analyses
ESA Climate Change Initiative

Meyssignac and Cazenave (in press)
1950-2009



Assessment of accuracy versus tide gauges applied a low-pass filter (two months



September Sea Ice Extent
MONARCH-A project