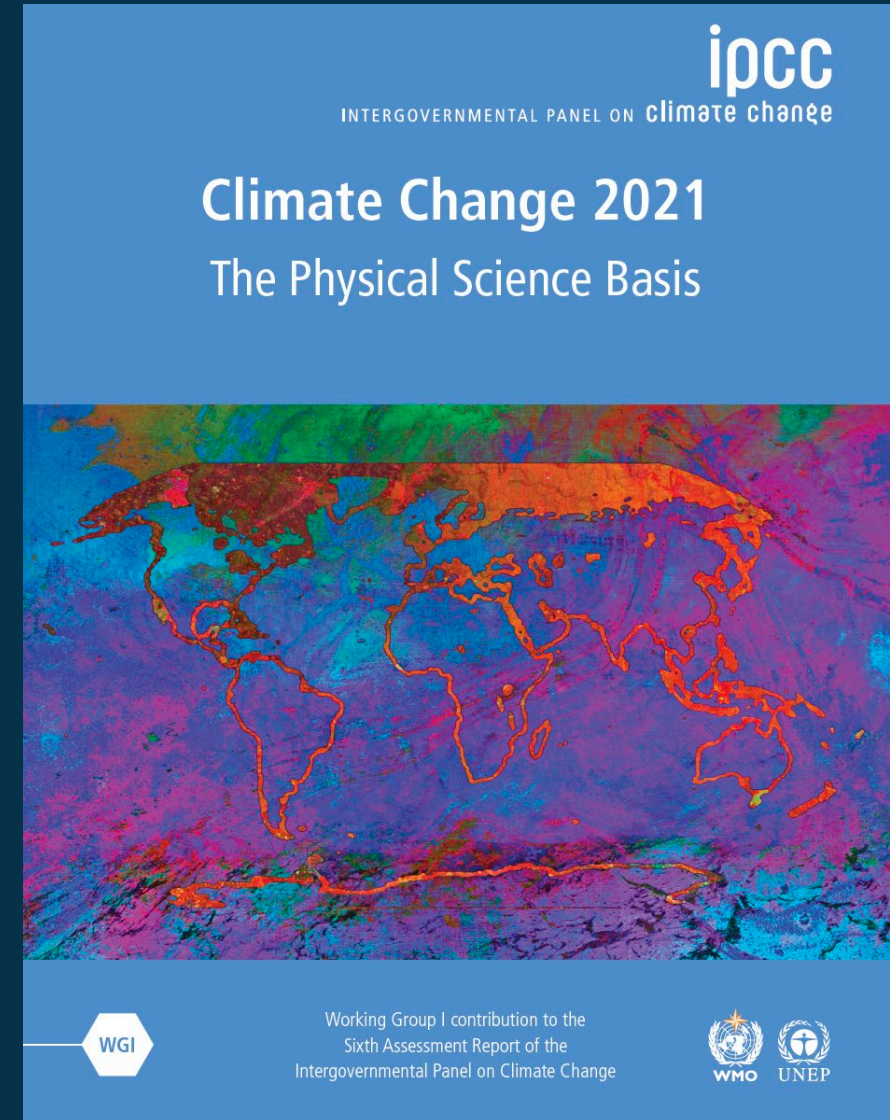


# Earth Observation contributions to the IPCC AR6 WGI

Richard Jones, Met Office Hadley Centre  
CMUG Science Lead

Coordinating Lead Author AR6 WGI Atlas;  
Coordinating Author Technical Summary;  
Lead Author Summary for Policymakers;  
AR6 WGI-II Handshake team member.

- Improved understanding of human influence on all aspects of the climate and in all regions
- Greater focus on:
  - regional climate change,
  - changes in extreme events & linking these to human activity
- Interactive online global and regional atlas for observed & projected climate change information



## Chapter 1 – Framing, Context, Methods:

*“**Cryosat-2** radar altimetry satellite mission has continued to provide measurements of changes in the thickness of sea ice and the elevation of the Greenland and Antarctic ice Sheets....longer timeseries from multiple missions have led to considerable advances in understanding ...”*

*“**SMOS**...filling critical gaps in the observation of hydrological trends and variability over land.”*

## Chapter 10 - Linking Global to Regional Climate Change:

*“Satellite products provide a valuable complement to in situ measurements, particularly over regions where in-situ measurements are unavailable... Their observations are valuable (high confidence) for regional applications since they provide multi-channel images at very high spatiotemporal resolutions.”*

# EO data underpinning headline statements

*"It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean cryosphere and biosphere has occurred."*

**Glacier retreat since the 1990s, with most negative mass balance in last decade:**

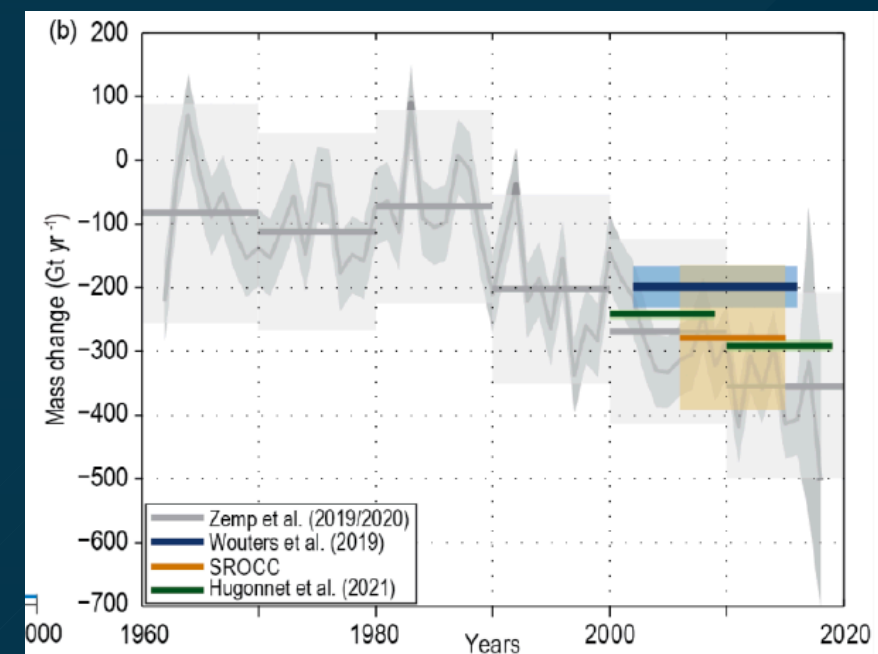
Zemp et al., 2020, Hugonnet et al., 2021

**Sea ice retreat:** Lavergne et al., 2019

**Ocean warming:** Berry et al., 2018

**Sea level rise:** Dieng et al., 2017

**Lake responses:** Woolway et al., 2020



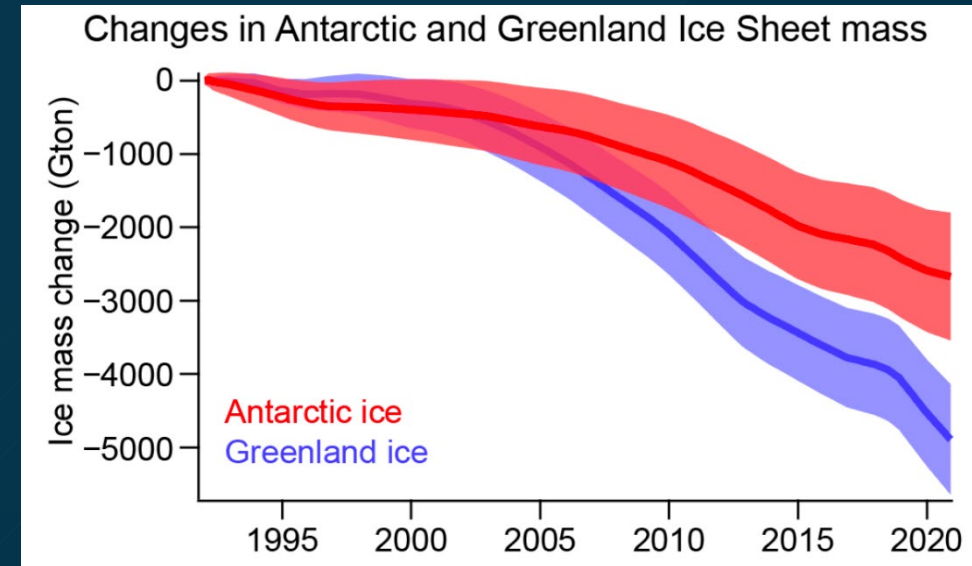
AR6 chapter 2 fig 2.23 Annual and decadal global glacier mass change

# EO data underpinning headline statements

*"The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years."*

*"Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3 degrees with a narrower range compared to AR5."*

- **IMBIE and SLBC and CCI ice sheet** projects (IMBIE, 2021, Slater et al., 2020) support:
  - *"The rate of ice sheet loss increased by a factor of 4 between 1992-1999 and 2010-2019."*
  - *"Together, ice sheet and glacier mass loss were the dominant contributors to global mean sea level rise 2006-2018."*



**AR6 chapter 2 fig 2.24 from IMBIE, 2018, 2020**

**ESMValTool** (Earth System Model (ESM) Evaluation Tool) is an open access diagnostics and performance metrics tool for climate model evaluation. It allows easy access to data and dissemination of results.

- Invaluable for broadening the user base for EO datasets, e.g.
  - Land surface temperature
  - Methane
  - Water Vapour
  - Sea surface salinity
  - Ocean Colour

Chapter 3 (Human Influence on the climate system) states ESMValTool is used to “ensure traceability of the results and provide an additional level of quality control”.

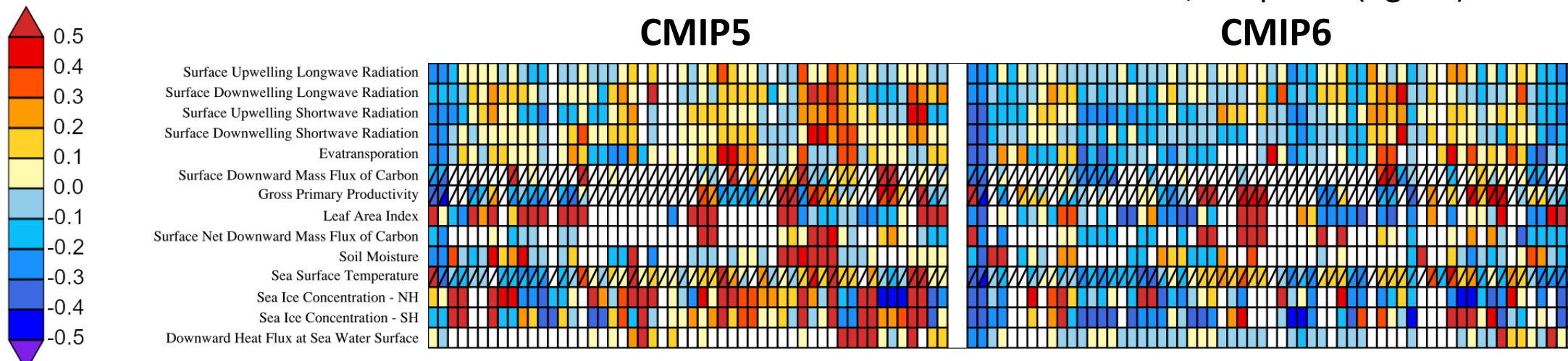
**Obs4MIPs** (Observations for Model Intercomparison Projects) collates and makes available in standard easily accessible formats observational datasets (including many EO datasets) for evaluation in model intercomparison projects (e.g. CMIP, CORDEX), for example used with tools such as ESMValTool.



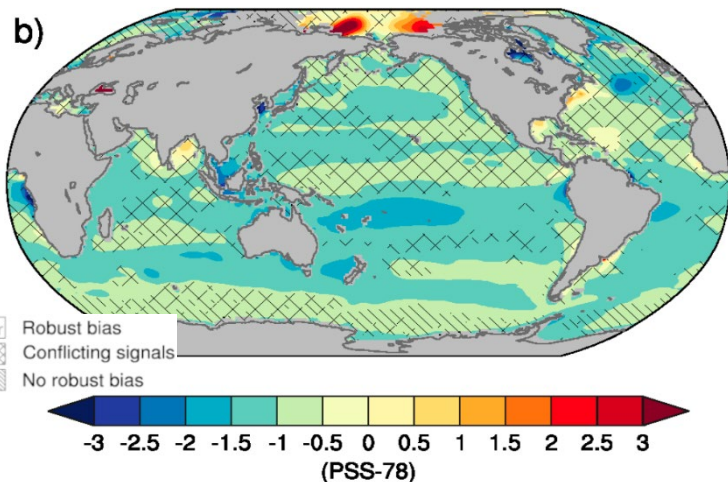
# Evaluation of CMIP6 models with ESMValTool



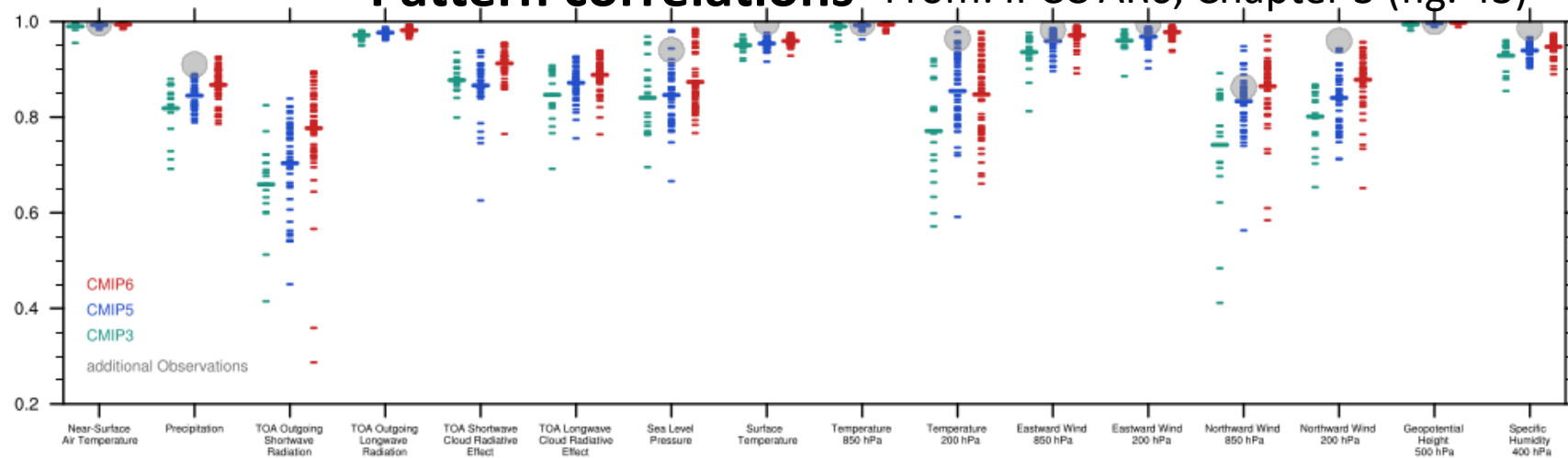
## Relative model performance (RMSD) From: IPCC AR6, Chapter 3 (fig. 42)



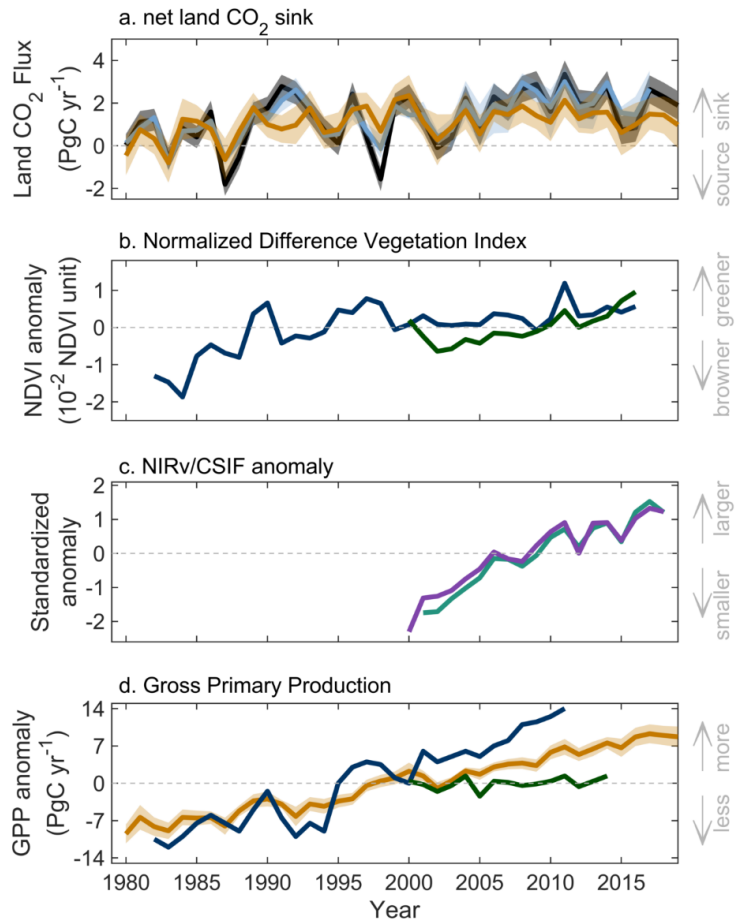
### CMIP6 Sea Surface Salinity Bias



## Pattern correlations From: IPCC AR6, Chapter 3 (fig. 43)



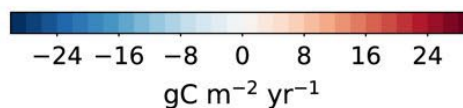
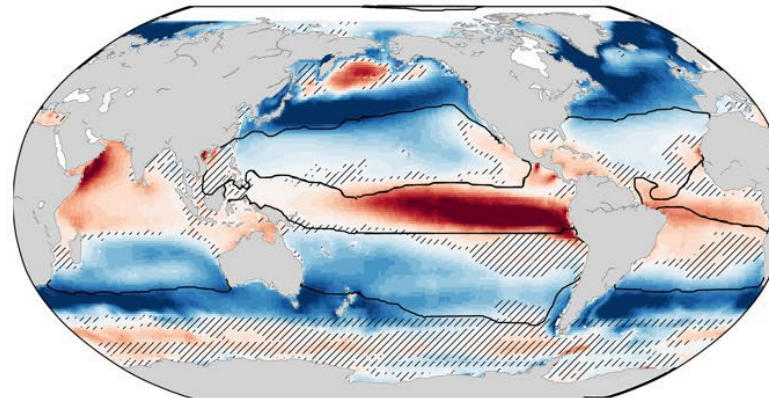
# Carbon cycle observations and model evaluation



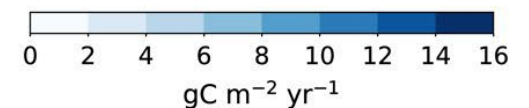
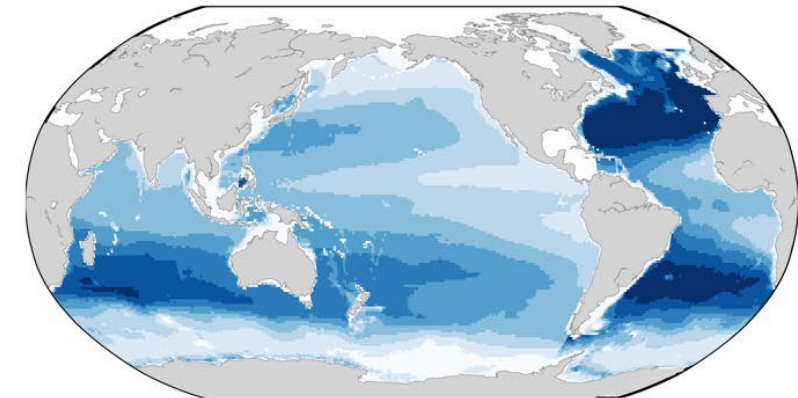
CO <sub>2</sub> mass balance	Model	Satellite(-driven)
residual net land CO <sub>2</sub> sink	Inversion DGVMs	AVHRR NIRv
		MODIS CSIF

Observed and modeled components of the land carbon cycle (left) and observed indices of carbon fluxes at the ocean surface (below)

a) Net air-sea flux ( $F_{net}$ ) of CO<sub>2</sub> (1994-2007)



b) Rate of change in anthropogenic CO<sub>2</sub> inventory (1994-2007)





# Summary

A wide range of observed changes across all major components of the climate system (atmosphere, land, oceans and cryosphere) have been documented from EO data.

EO data have been used to quantify the glacier and ice-sheet contributions to sea level rise and demonstrate they were the dominant factors in the increasing rate of the rise this century.

The use of EO data in community model evaluation tools has significantly broadened the scope of model evaluation to cover all components of the climate system and promoted coordinated efforts to apply this to both global and regional climate models.

Inclusion of key Earth System components such as the carbon cycle in model evaluation enhances models' credibility for mitigation assessments and evaluation of their climate variability (including trends) is relevant to climate adaptation and resilience assessments.