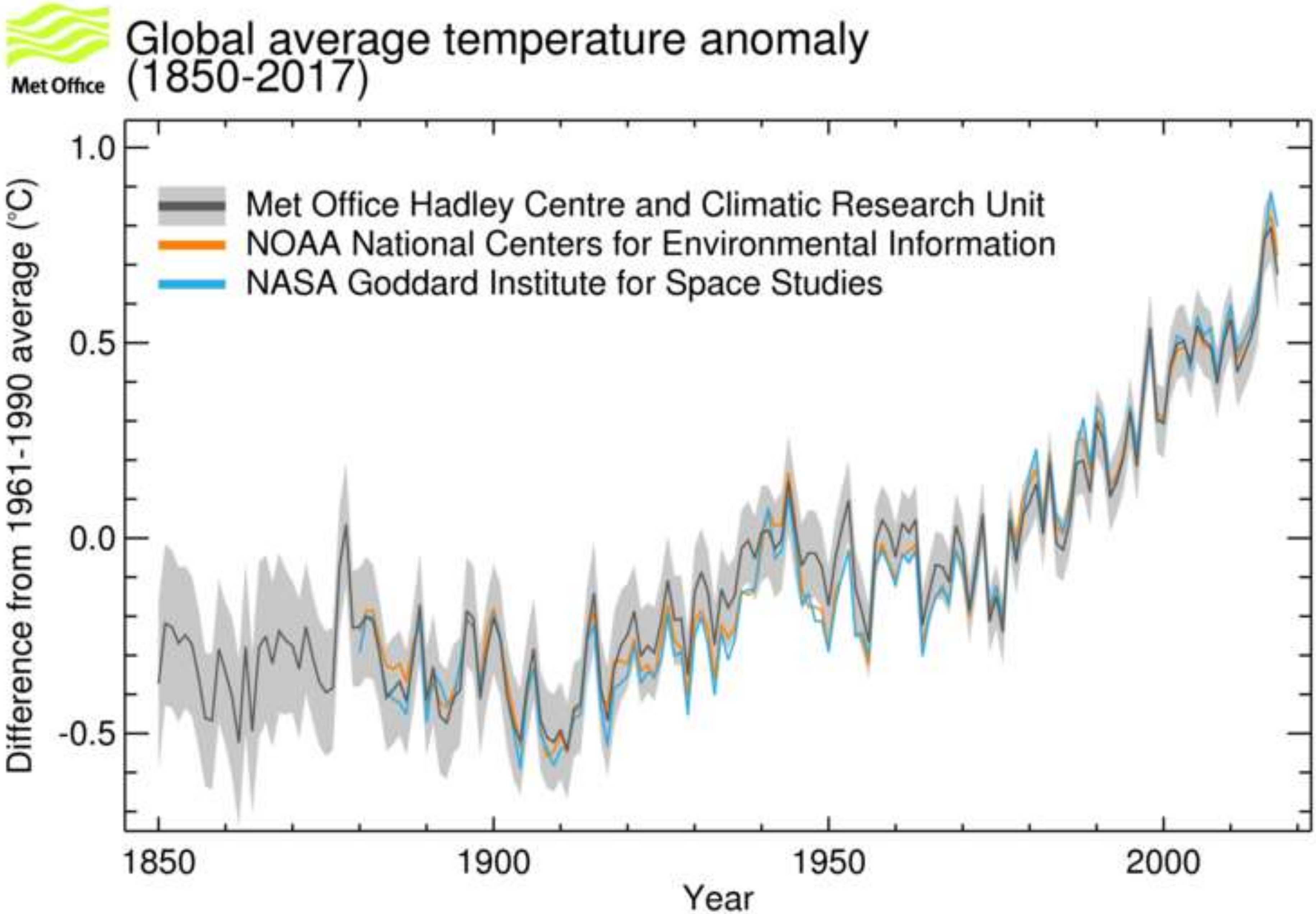
Securing Multidisciplinary UndeRstanding and Prediction of Hiatus and Surge events (SMURPHS) – overview and some Reading activities

Richard Allan & Andrea Dittus

Reading SMURPHS also including: Jonathan Gregory, Jon Robson, Chunlei Liu, Keith Shine, Ramiro Checa-Garcia, Nicolas Bellouin, Michaela Hegglin, Ed Hawkins, Laura Wilcox, Rowan Sutton.

NCAS meeting, Reading, 18 May 2018



Met Office
Global average temperature anomaly
(1850-2017)
Met Office Hadley Centre and Climatic Research Unit
NOAA National Centers for Environmental Information
NASA Goddard Institute for Space Studies
Difference from 1961-1990 average (°C)
1.0
0.5
0.0
-0.5
1850
1900
1950
2000
Year

Did global warming go on holiday?

- Global surface warming rate slowed from 1980s/90s to 2000s
  - Energy imbalance remains positive/strengthens, sea level rise accelerates
  - Ocean heat uptake to deeper levels, distinct Pacific variability pattern
- Unusual climate phenomena
  - Unprecedented Pacific trades, suppressed El Niño, AMOC & ITF ocean changes, Arctic warming, cold northern winters, NAO/PDV/AMV phase
- Warming rate unusually low compared to climate simulations
  - Radiative Forcing & sampling explains some of discrepancy
- Internal variability explains slowdown, SST-pattern suppression of climate sensitivity involving cloud feedbacks important?
  - But unrepresented forced responses can't be discounted

  http://www.met.reading.ac.uk/~sgs02rpa/research/DEEP-C.html#PAPERS
- Multiple factors explain hiatus/surge events: understanding decadal variability advances climate science Cassou et al. 2018 BAMS

Project overview

A. Conceptual Framework

- definitions, energy budget

B. Characterisation

- observed changes, morphology

C. Unforced Variability

- feedbacks/heat uptake mechanisms,

D. Forced Response

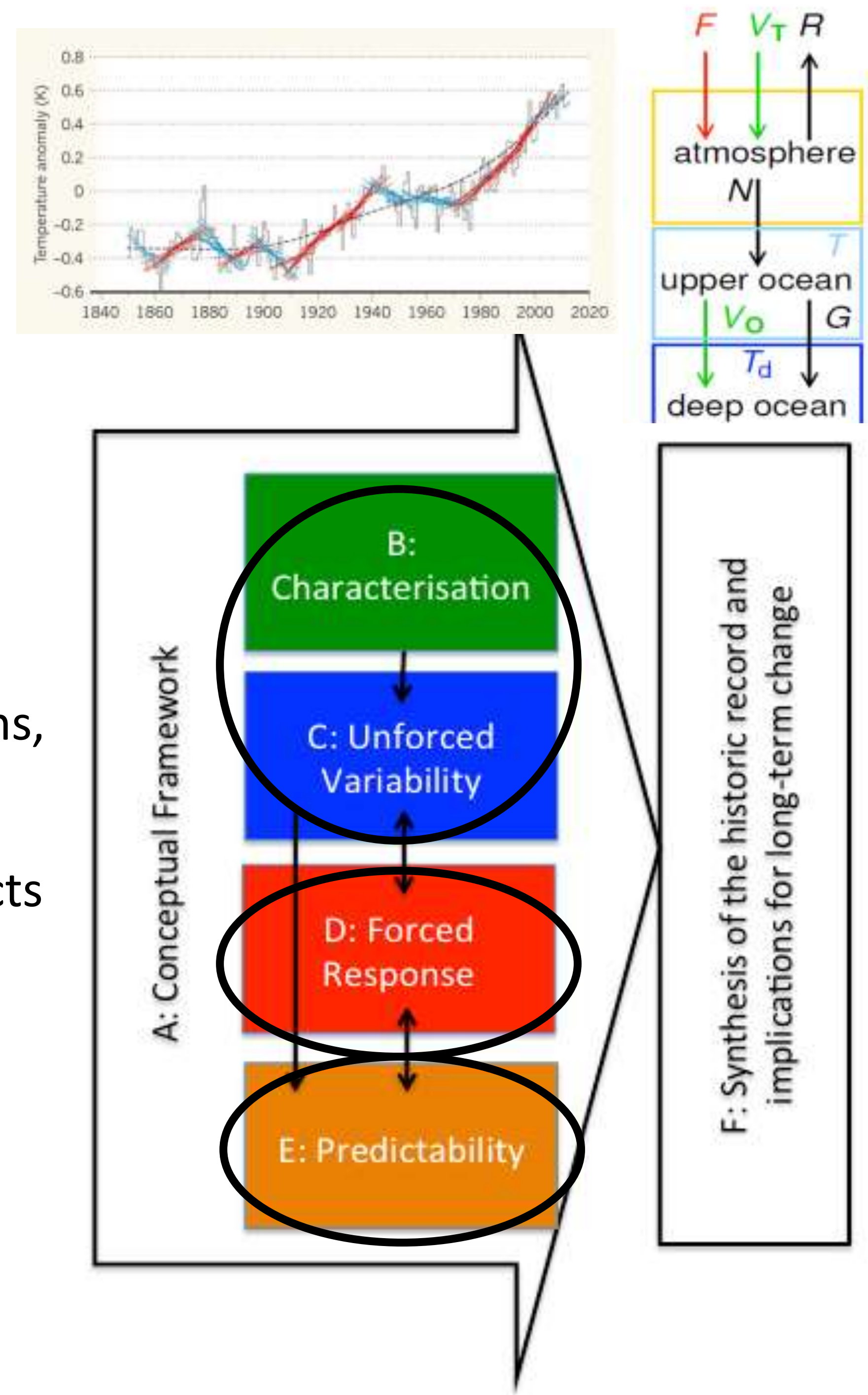
- radiative forcing updates and effects

E. Predictability

- large ensembles, uncertainty

F. Synthesis

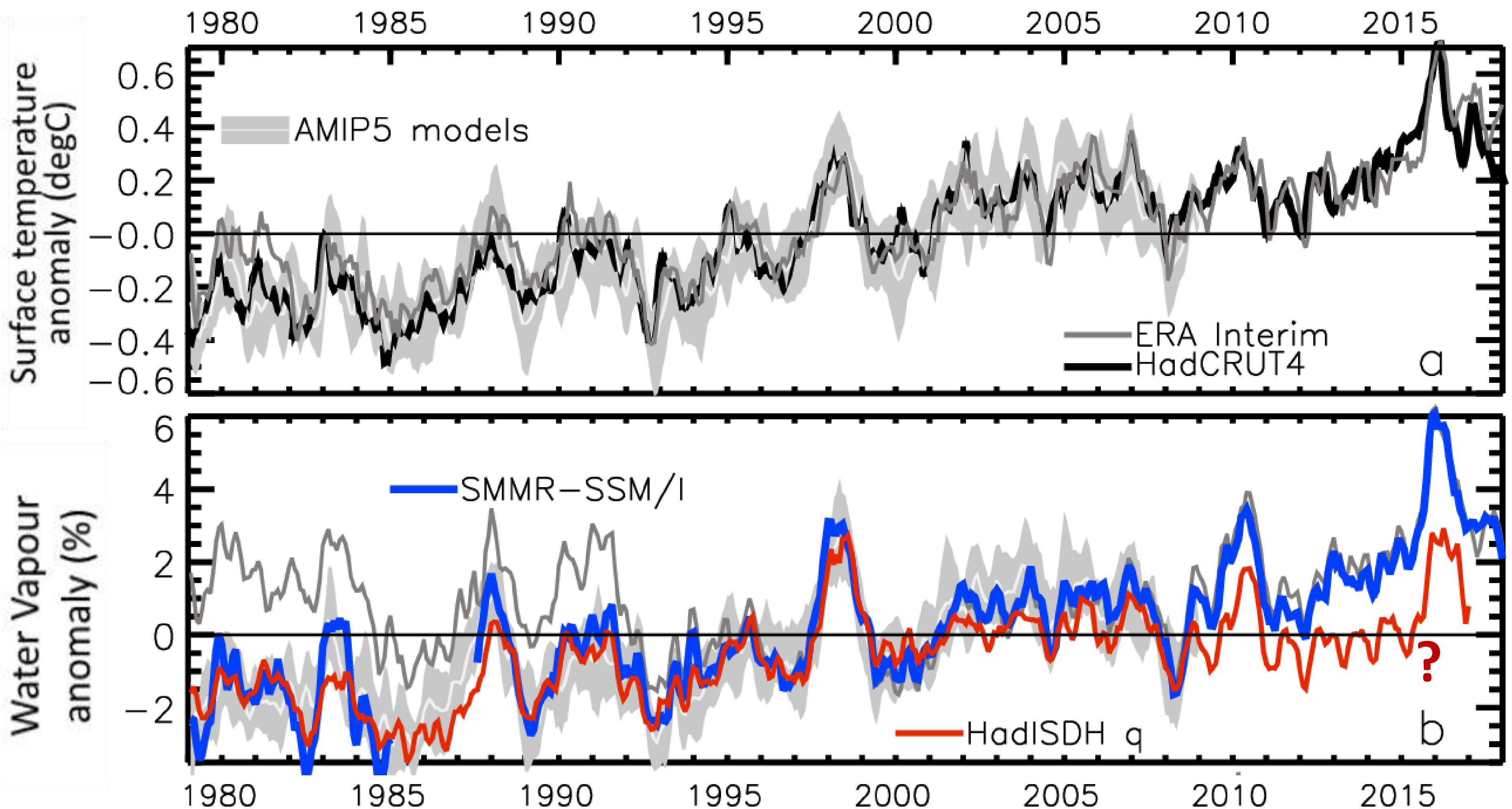
- Interpret historical record/climate response



Some SMURPHS activities (presented at project meeting)

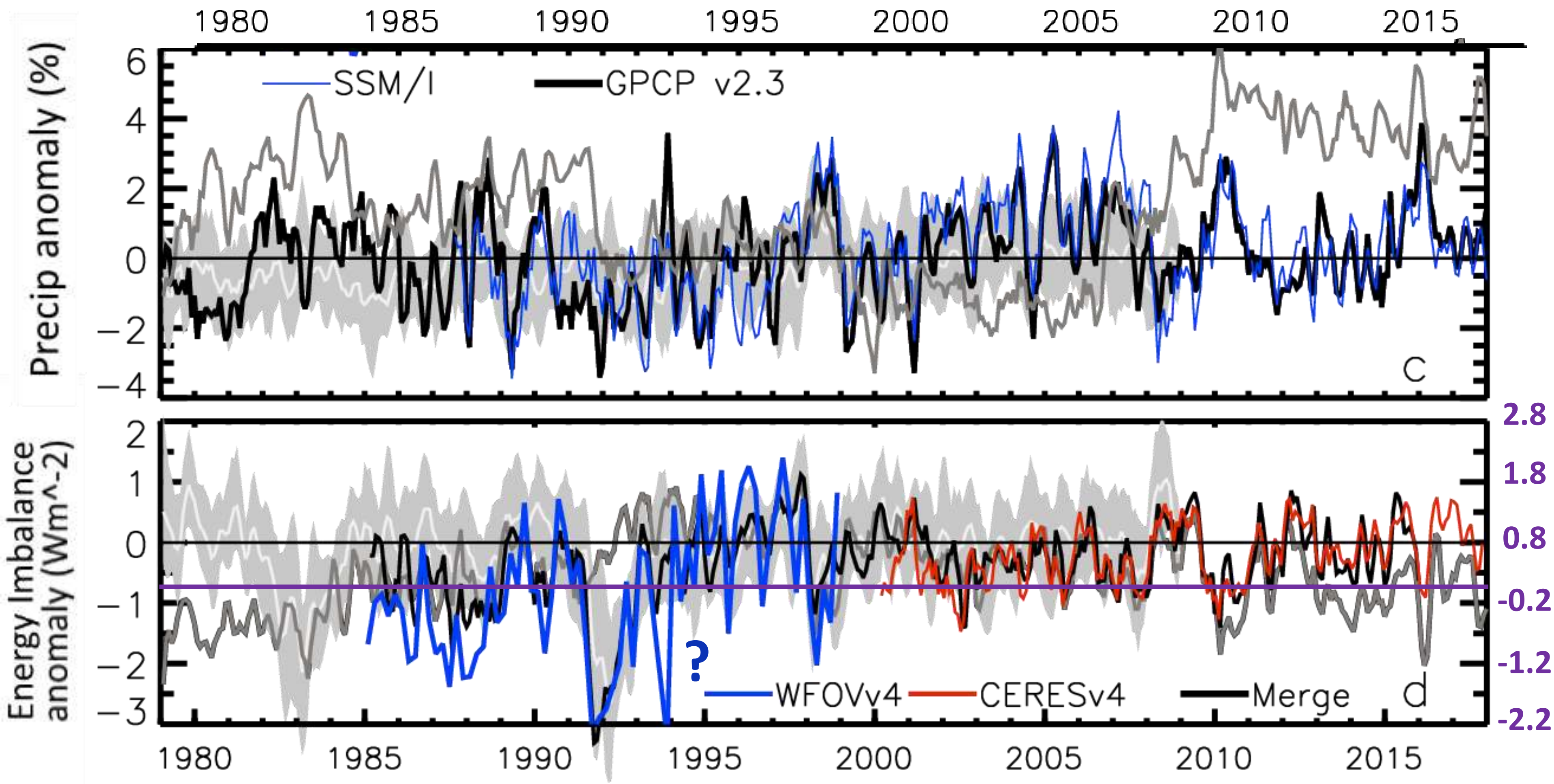
- SST patterns and problems inferring climate sensitivity from observations – Jonathan Gregory/Paulo Ceppi (Reading/→ Imperial ☹); AMOC changes – Jon Robson (Reading)
- Multivariate fingerprints of surge/hiatus at the surface & improvements in temperature record – Tim Osborn (UEA)
- Effect of model bias on Atlantic freshwater transport and implications for AMOC bi-stability - Jennifer Mecking, Sybren Drijfhout, Laura Jackson (Southampton)
- The relation between natural variations in ocean heat uptake and global mean surface temperature anomalies in CMIP5 - Sybren Drijfhout (Southampton)
- Unforced Variability and Mechanisms of Ocean Heat Uptake – Sinha/Josey (NOC); Ocean Adjoint Modelling at BAS - Emma Boland (BAS)
- Efficacy of Climate Forcings in PDRMIP Models & Simple climate model uncertainty from radiative forcing – Tom Richardson/Piers Forster/Chris Smith (Leeds)
- Volcanic radiative forcing from detailed simulations - Graeme Mann (Leeds)
- *The 18.6-year lunar nodal cycle and the global warming hiatus - Manoj Joshi (UEA)*
- Understanding variability of the interhemispheric surface temperature difference / Detection and attribution of hydrological cycle changes using sea surface salinity - Andrew Friedman/Gabi Hegerl (Edinburgh)
- Detection & attribution of anthropogenic signal in ocean heat content & potential to constrain climate sensitivity range - Tokarska/Gabi Hegerl (Edinburgh)
- Global mean surface temperature response to large-scale modes of climate variability - Jules Kajtar/Matt Collins (Exeter)

Recent global climate variability



Update from [Allan et al.(2014) Surv. Geophys]

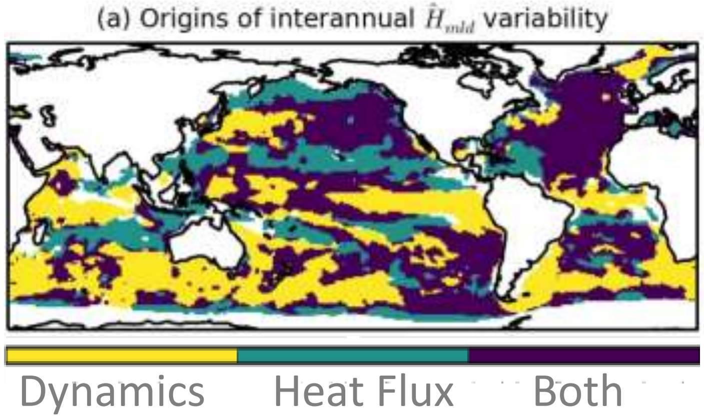
Recent global climate variability



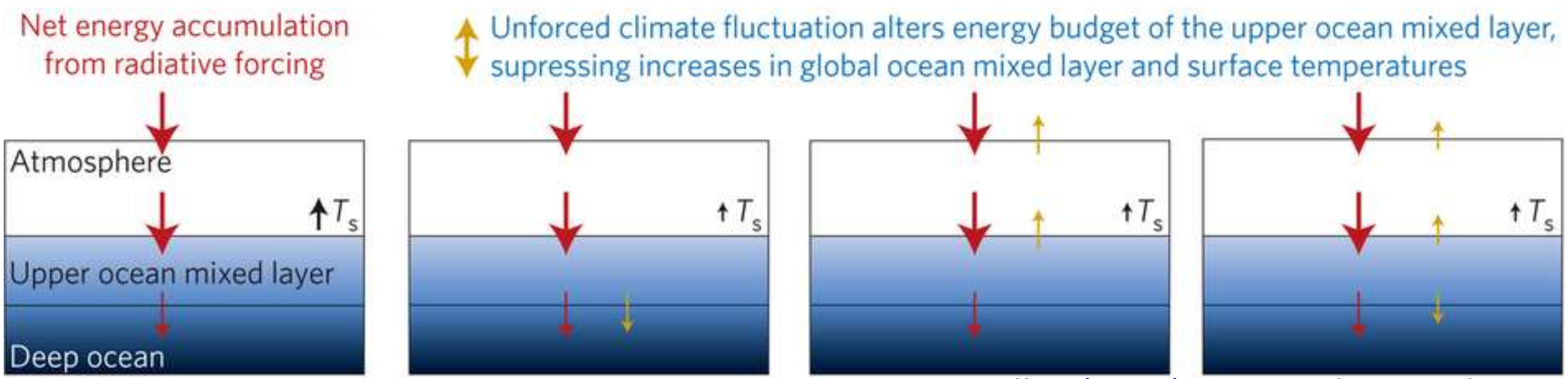
Update from [Allan et al.(2014) Surv. Geophys.](); [Allan et al. (2014) GRL]()

Ocean mixed layer energy budget & framework

- Slowdown events simulated by climate models
  - ↑ocean heat uptake below 300m (Meehl et al. 2011)
- Energy imbalance increase since 1990s, steady in 2000s (Cheng et al. 2017; Allan et al. 2014)
- Upper ocean mixed layer heat budget → global surface temperature Hedemann et al. 2017
  - Small perturbations obfuscate attribution
  - Useful interpretive framework

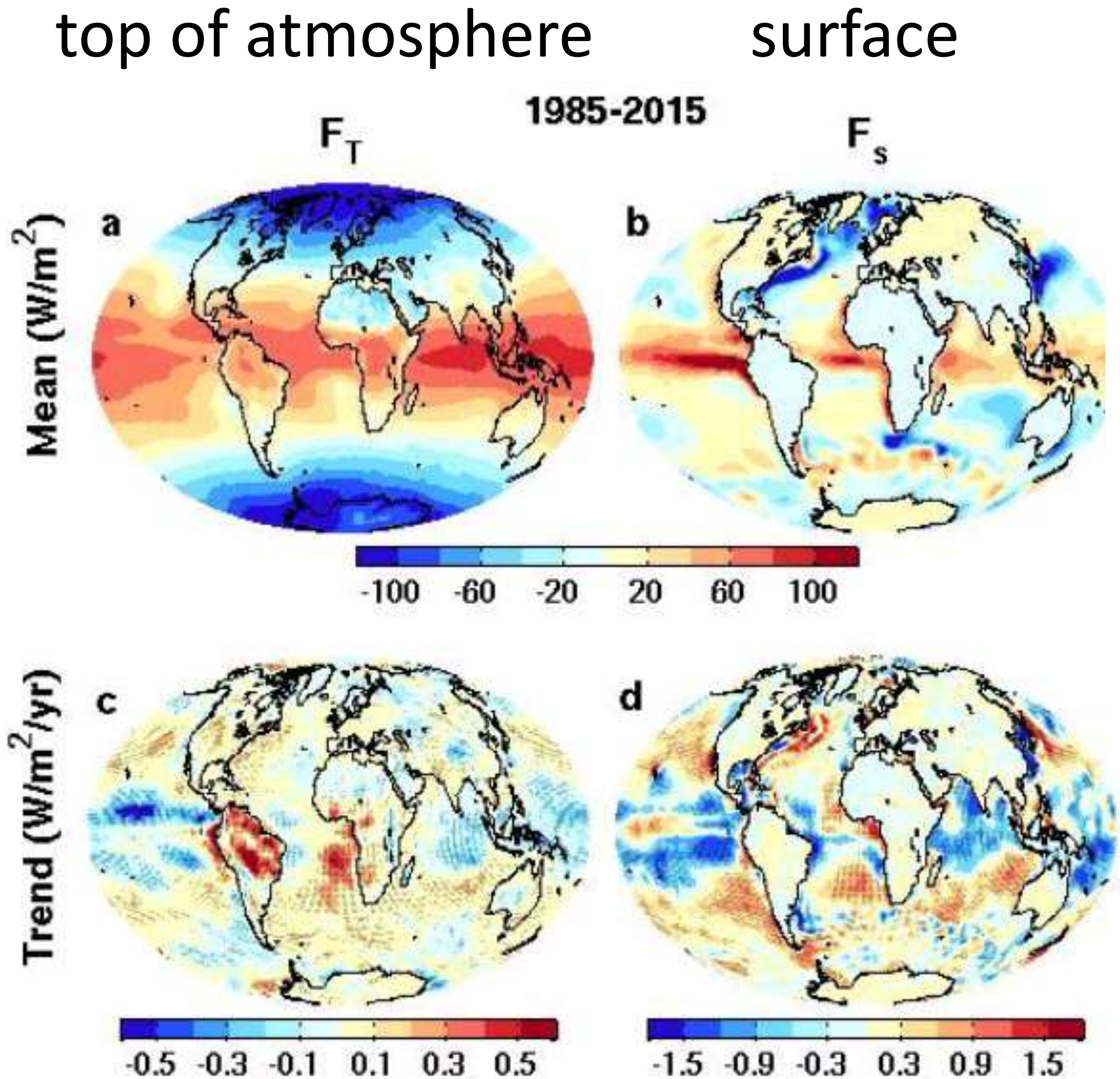


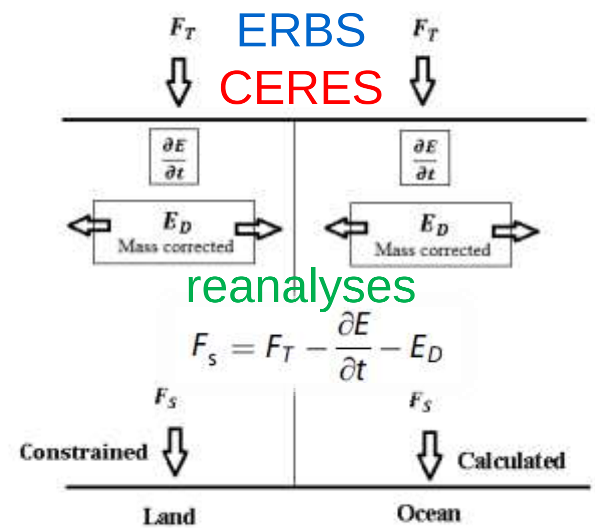
Origins of ocean mixed layer heat content variability Roberts et al. 2017 JGR



Allan (2017) Nature Climate Change

New global surface flux estimates





$$F_s = F_T - \frac{\partial E}{\partial t} - E_D$$

Surface energy flux dataset combining TOA reconstruction with reanalysis energy transports: Liu et al. (2015) JGR

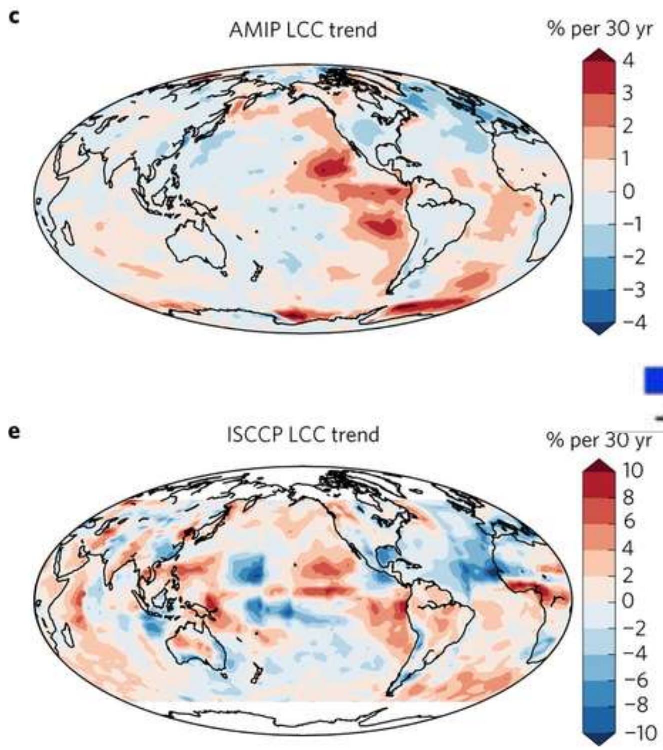
Liu et al. (2017) JGR Data: http://dx.doi.org/10.17864/1947.111

Feedbacks on internal and forced climate change involving regional energy budget

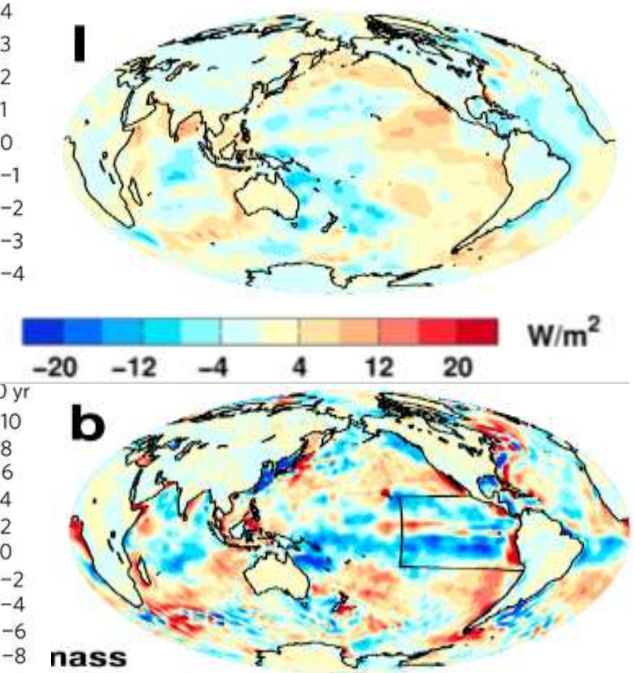
Low Cloud Cover trend **1980s-2000s** Surface energy flux change

AMIP MODELS

OBSERVATIONS



Zhou et al. (2016) Nature Geosci



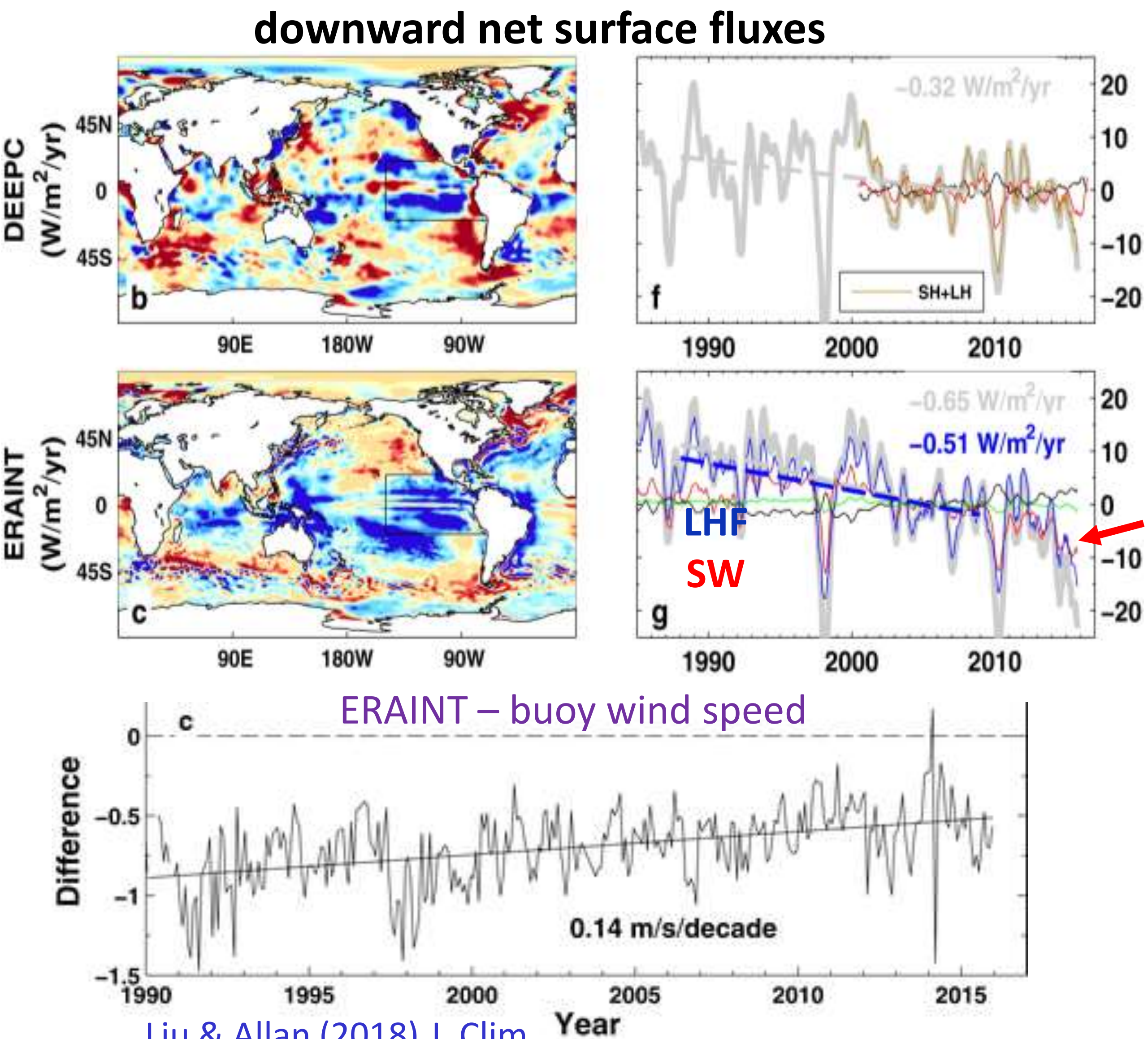
Liu et al. (2015) JGR

Distinct feedbacks on internal variability & forced change e.g. Brown et al. 2016; Xie et al. 2015 ; England et al. (2014)

Spatial patterns of warming crucial for feedbacks & climate sensitivity e.g. He & Soden (2016); Richardson et al. (2016); Ceppi & Gregory (2017); Andrews & Webb (2017)

Do climate models underestimate low cloud amplifying feedbacks, internal variability & climate sensitivity? Marvel et al. (2018); Silvers et al. (2017) ; Yuan et al. (2018)

Has increased evaporation as well as cloud contributed to east Pacific cooling?

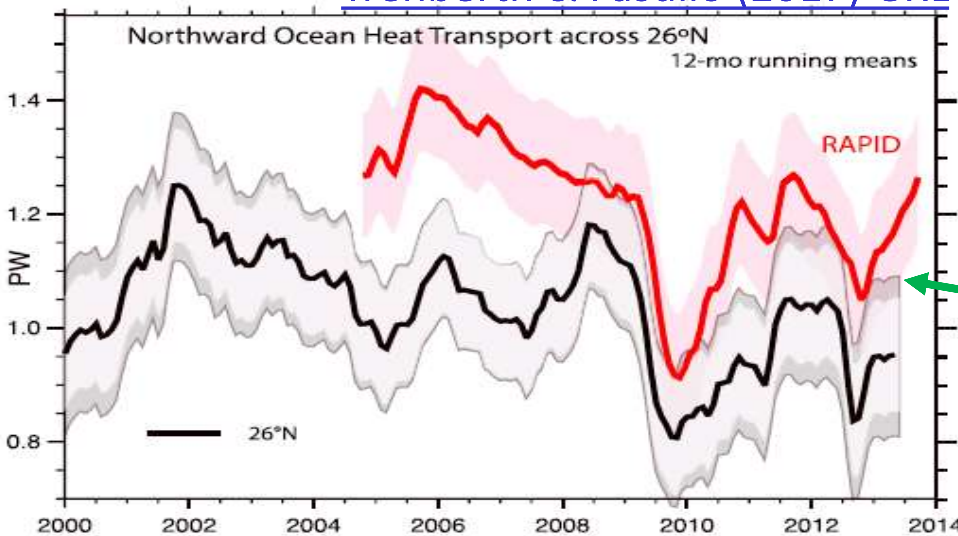


[Liu & Allan (2018) J. Clim]()

- Decreases in East Pacific surface fluxes since 1990s
- Some influence of clouds (SW radiation)
- Is surface evaporation amplifying cooling?
- Spurious trends in reanalysis winds?

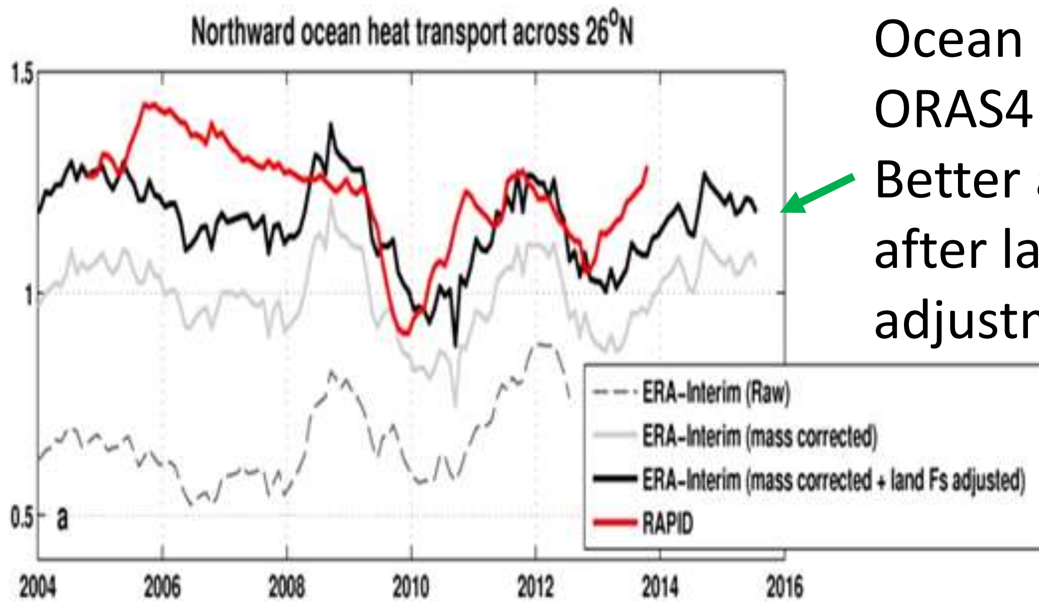
Inferred ocean heat transport@26°N

Trenberth & Fasullo (2017) GRL



Compare indirect method with RAPID observations

Is TF2017 discrepancy due to lack of land F_s adjustment?



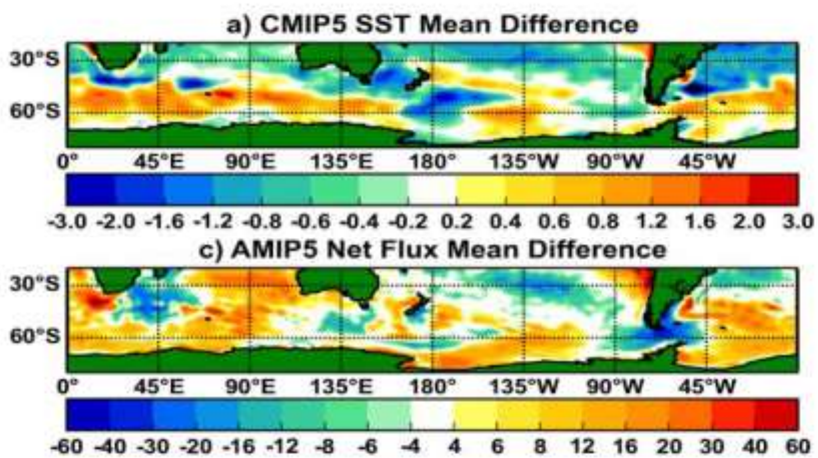
Ocean heating from ORAS4 (0-700m). Better agreement after land Fs adjustment

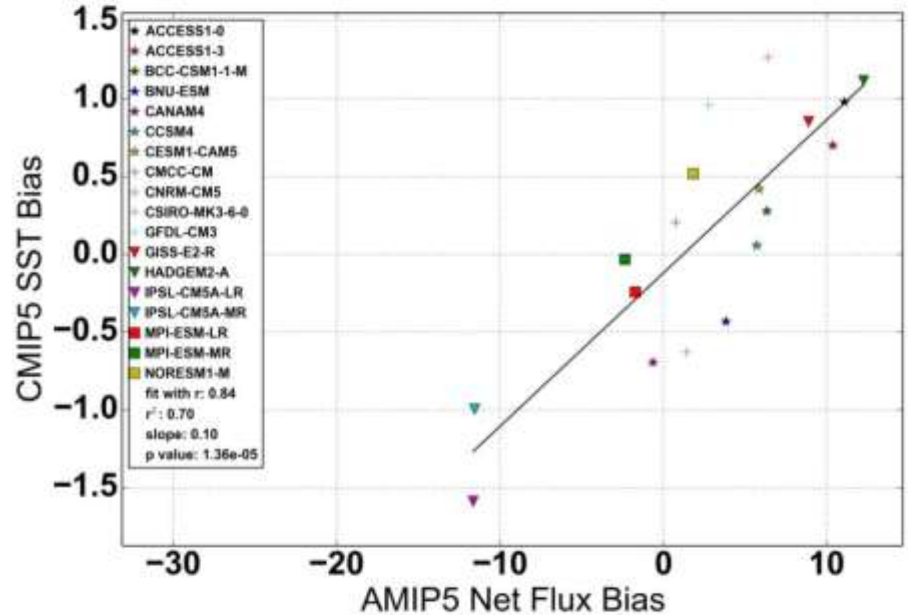
2004-2013
RAPID 1.23 PW
TF2017 1.00 PW
Liu et al: 1.16 PW
large uncertainty

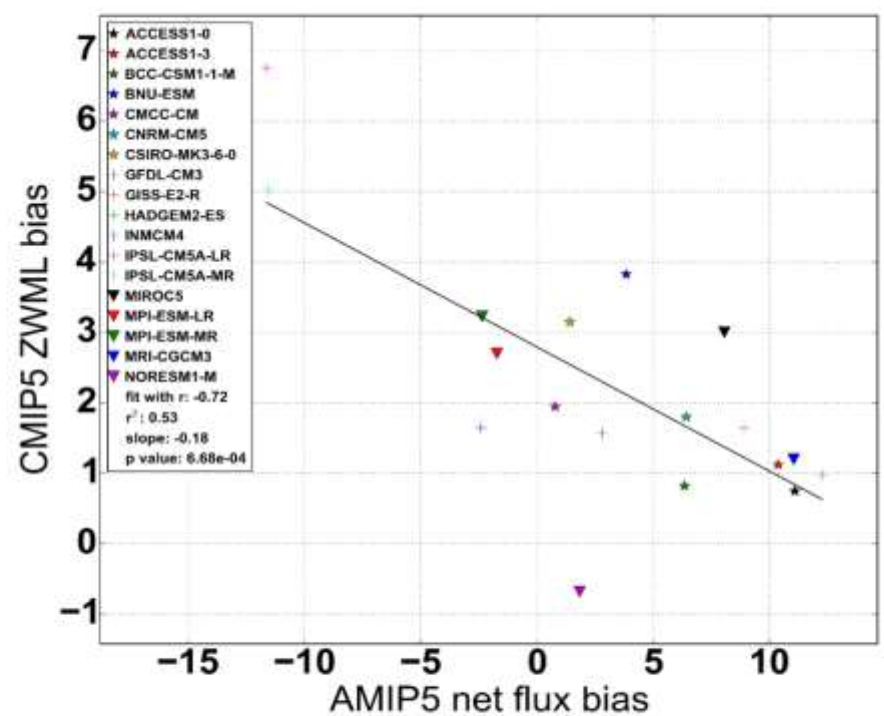
Evaluation of model biases in surface flux

- Use surface flux product in evaluation/development of climate models
- Biases in AMIP5 simulations linked to SST & zonal wind maximum latitude (ZWML) bias

Hyder et al. in prep

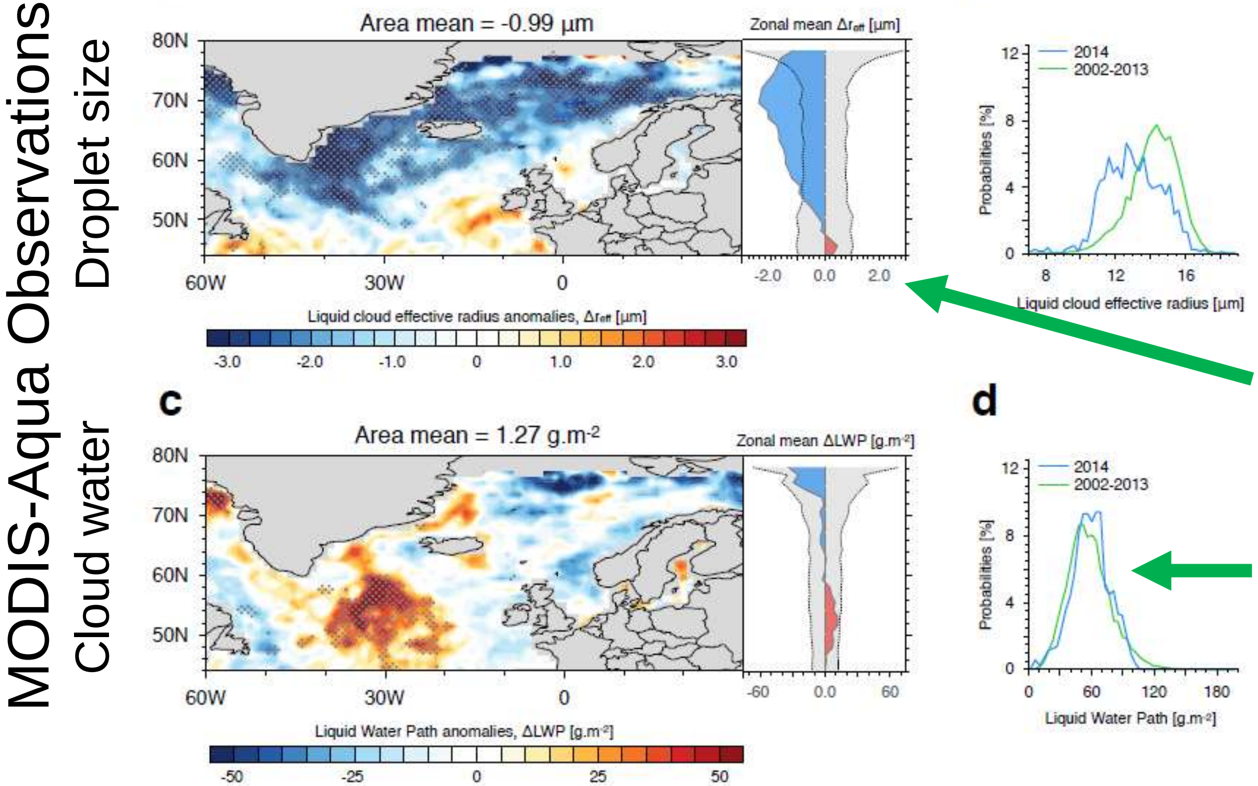




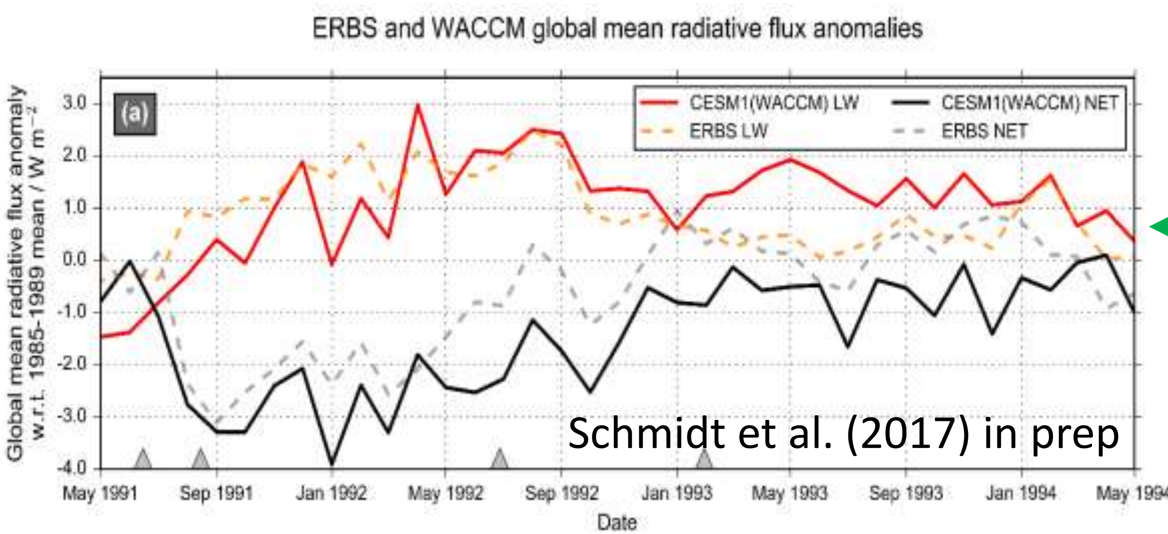


Advancing understanding of volcanic aerosol effects on climate

Malavelle et al. (2017) Nature



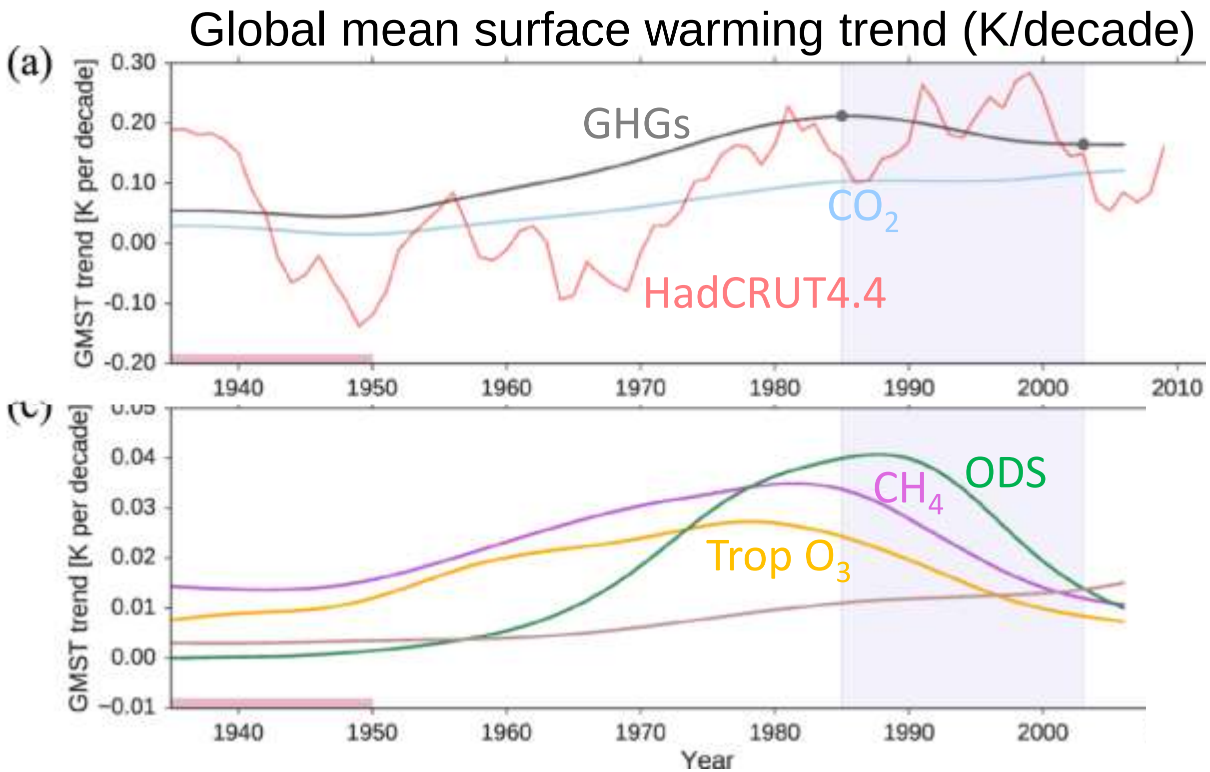
- Volcanic aerosol haze brightens low altitude clouds, cooling climate
- Further indirect effects in cloud water found to be negligible (but see McCoy et al. (2018) ACPD)



Schmidt et al. (2017) in prep

- New assessment of direct volcanic influence on climate combining nudged models & observations

Role of radiative forcings on variability

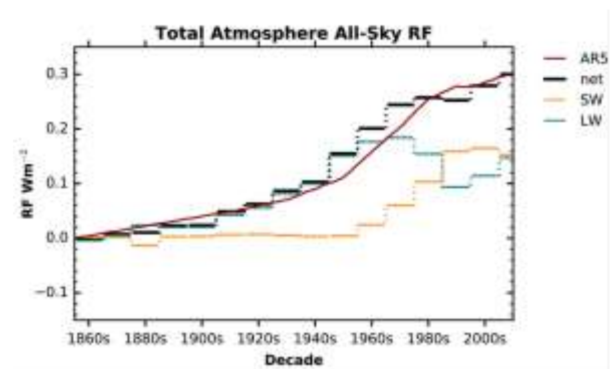


Non-CO_2 GHGs contributed to slower warming rate (CH_4, ozone depleting substances, ODS & tropospheric ozone)

Checa-Garcia et al. 2016 ERL

See also Estrada et al. (2013) Nature Geosci.

Updates to ozone: CMIP6 total ozone RF 0.28±0.17 Wm^{-2} (1850s-2000s), 80% higher than using CMIP5 ozone: grows rapidly until 1970s, slows toward 2000s, renewed growth after: Checa-Garcia et al. 2018 GRL



Random Outstanding Questions

- Can net zero global radiative forcing but with spatial pattern drive temperature change?
- Does the east Pacific control hiatus/surge events? Does the Atlantic drive the Pacific? Do the tropics drive the N Atlantic?
- How does rebound from volcanic eruptions (e.g. Pinatubo) influence the climate system; is this represented by models?
- Is there a missing ocean dynamical feedback on warming?
- Is internal variability adequately represented by models?
- What is the role of aerosol changes/uncertainty in determining observed/simulated warming rate & difference?

Need clever people with big models to address some of these…

SMURPHS large ensemble: Experiment design & preliminary results

Andrea Dittus, Ed Hawkins, Laura Wilcox, Rowan Sutton, Chris Smith, Leighton Regayre

Outline

1. Context
2. Motivation for large ensemble
3. Experiment design & preliminary results
4. Outlook / analysis ideas
5. Future ensemble

SMURPHS: Securing Multidisciplinary UndeRstanding and Prediction of Hiatus and Surge events

- Characterisation of Hiatus and Surge Events, e.g.:
  - Richard and Chunlei's work
  - Updates of obs. datasets to CRUTEM5 (UEA)
- Unforced Variability
  - Ocean processes for H/S events, e.g. OHC (NOC, BAS, U Southampton)
  - Influence of large scale modes of variability on GMST (Exeter)
- Forced Response
  - Forcing datasets (Reading, Leeds)
  - Uncertainties in historical ERF, efficacy of forcings (Leeds)
- Predictability
  - Interaction between variability and forcing, especially aerosols using large ensemble
- Interpreting the historical record
  - Separating forced and unforced contributions, D&A OHC (Reading, Edinburgh)
  - Estimates of ECS and TCR (Reading, Edinburgh)

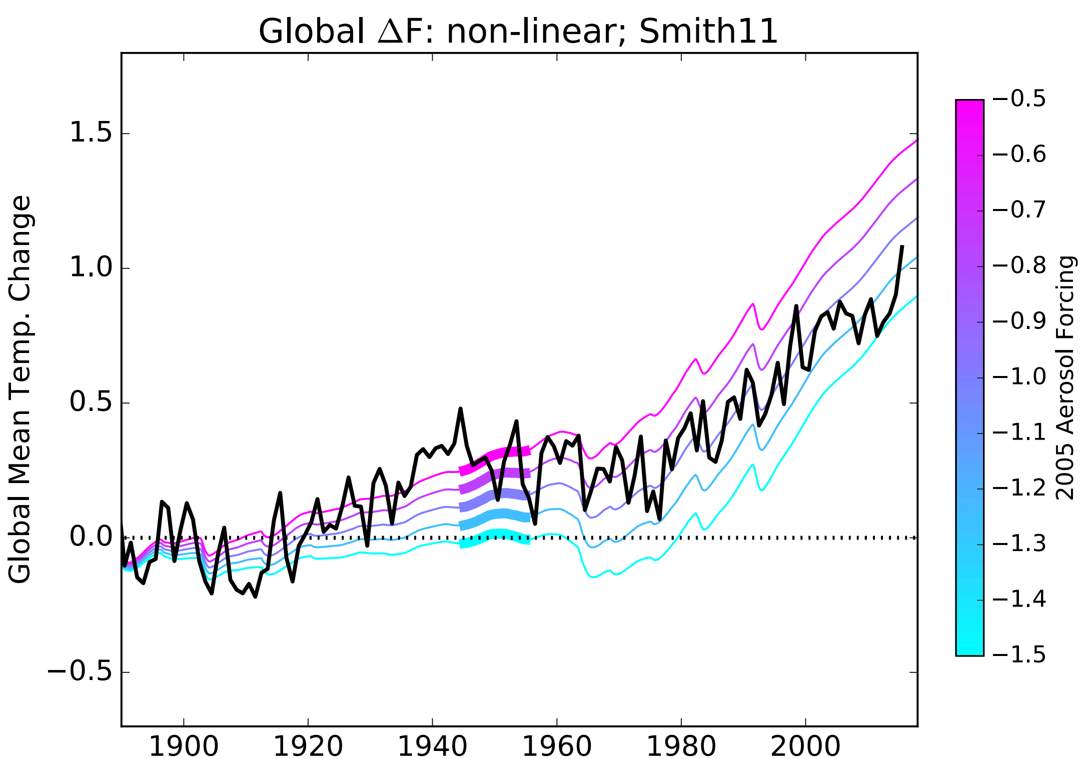
Context & motivation: variability & forcing interactions

- Produce a large ensemble with HadGEM3-GC3.1 with scaled historical aerosol emissions, to look at:

➢ Implications of **uncertainties in historical aerosol forcing** for historical global mean surface temperature, hiatus and surge events and climate sensitivity

➢ Understanding the interaction between natural climate variability and forcing, especially due to aerosol forcing

Uncertainties in aerosol radiative forcing

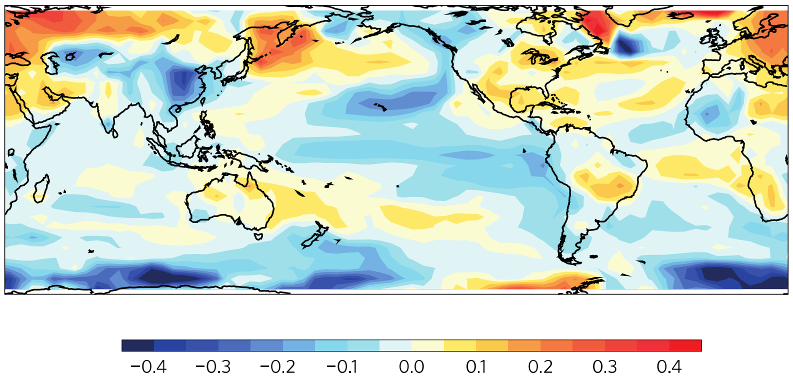


Booth et al., 2018 under review

- Magnitude of historical aerosol forcing highly uncertain
- Large spread in CMIP5 models (-0.4 to -1.6 W/m^2)
- Likely important aerosol role for 1950-1970 hiatus - less certain for recent hiatus

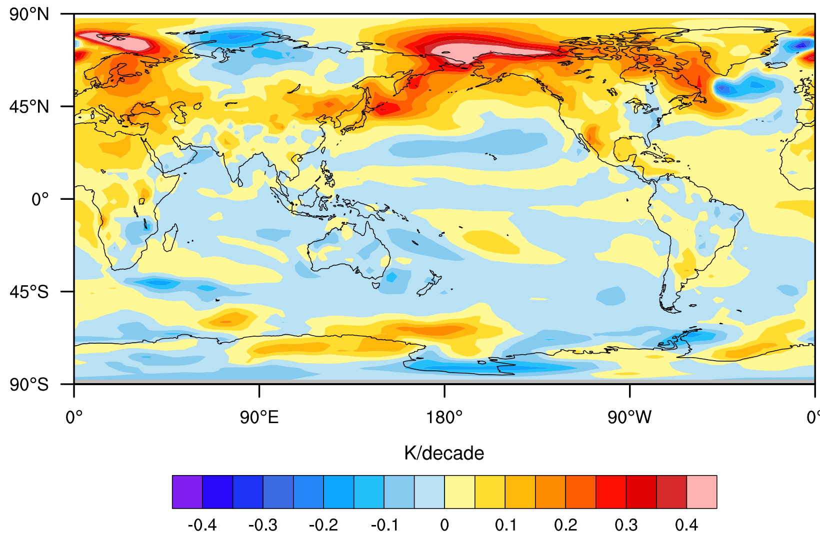
Climate variability and forcing

CMIP5 aero-only TAS trends 1998 - 2012



Smith et al., 2016 *Nat. Clim. Change*

CanESM2 aero-only TAS trends 1998 - 2012



Climate variability and forcing

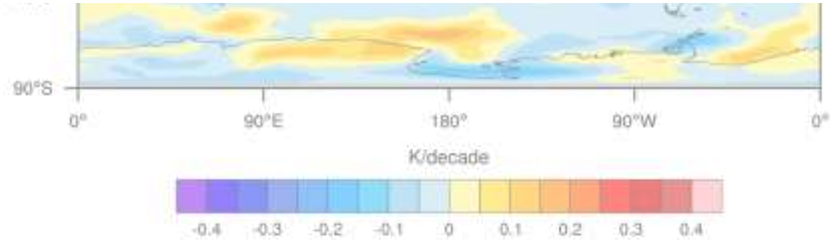
CMIP5 aero-only TAS trends 1998 - 2012

Many open questions!

Possible aerosol influences on

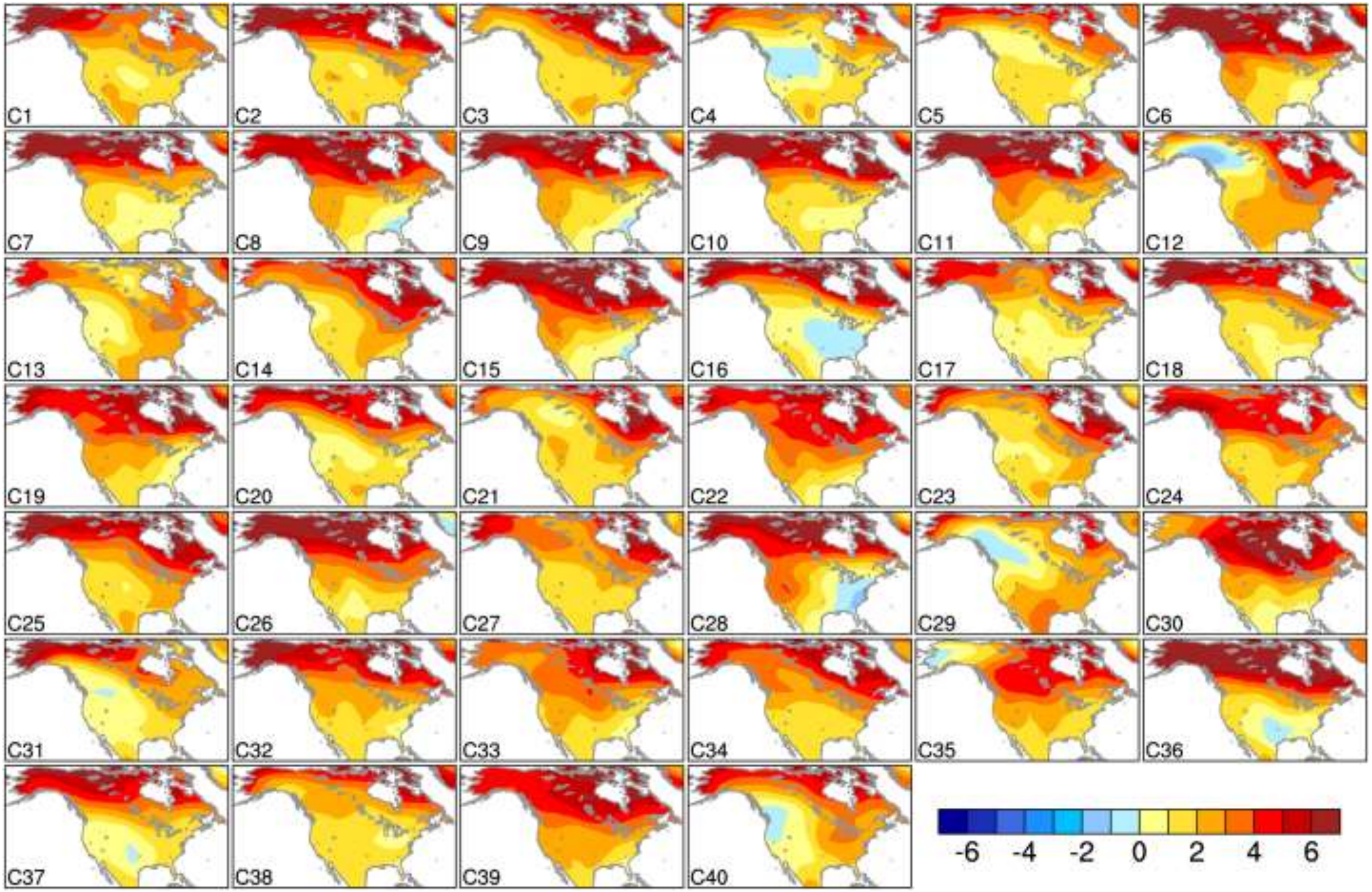
- Pacific variability (e.g. Smith et al., 2016)
- Atlantic variability (e.g. Booth et al., 2012)

Is it model dependent?
Dependent on ensemble size (noise)?
Dependent on magnitude of aerosol forcing (indirect effect)?



Large ensemble

CCSM3 large ensemble 2010-2060



Deser et al., 2014

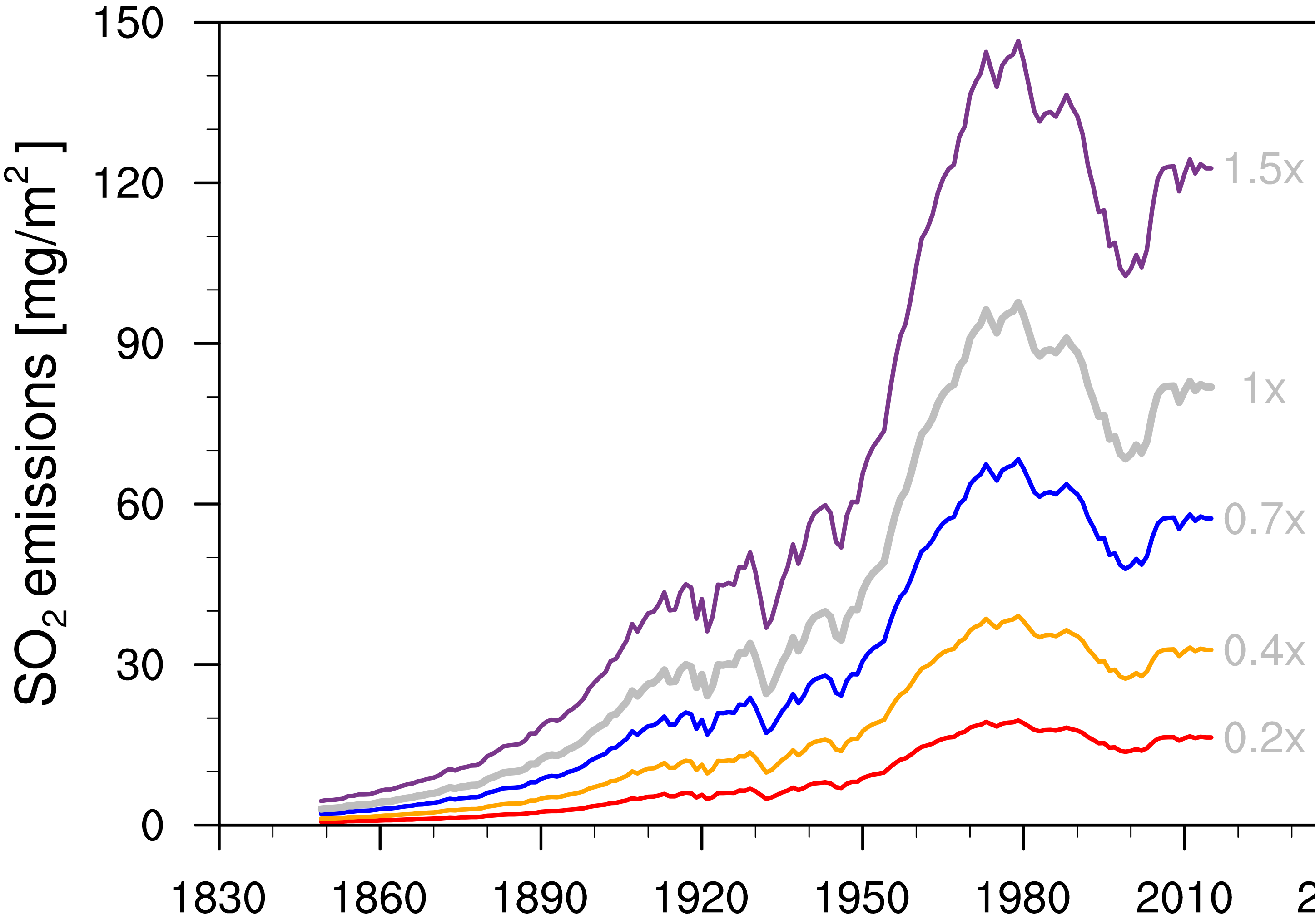
HadGEM3.1 historical large ensemble

Experiment design

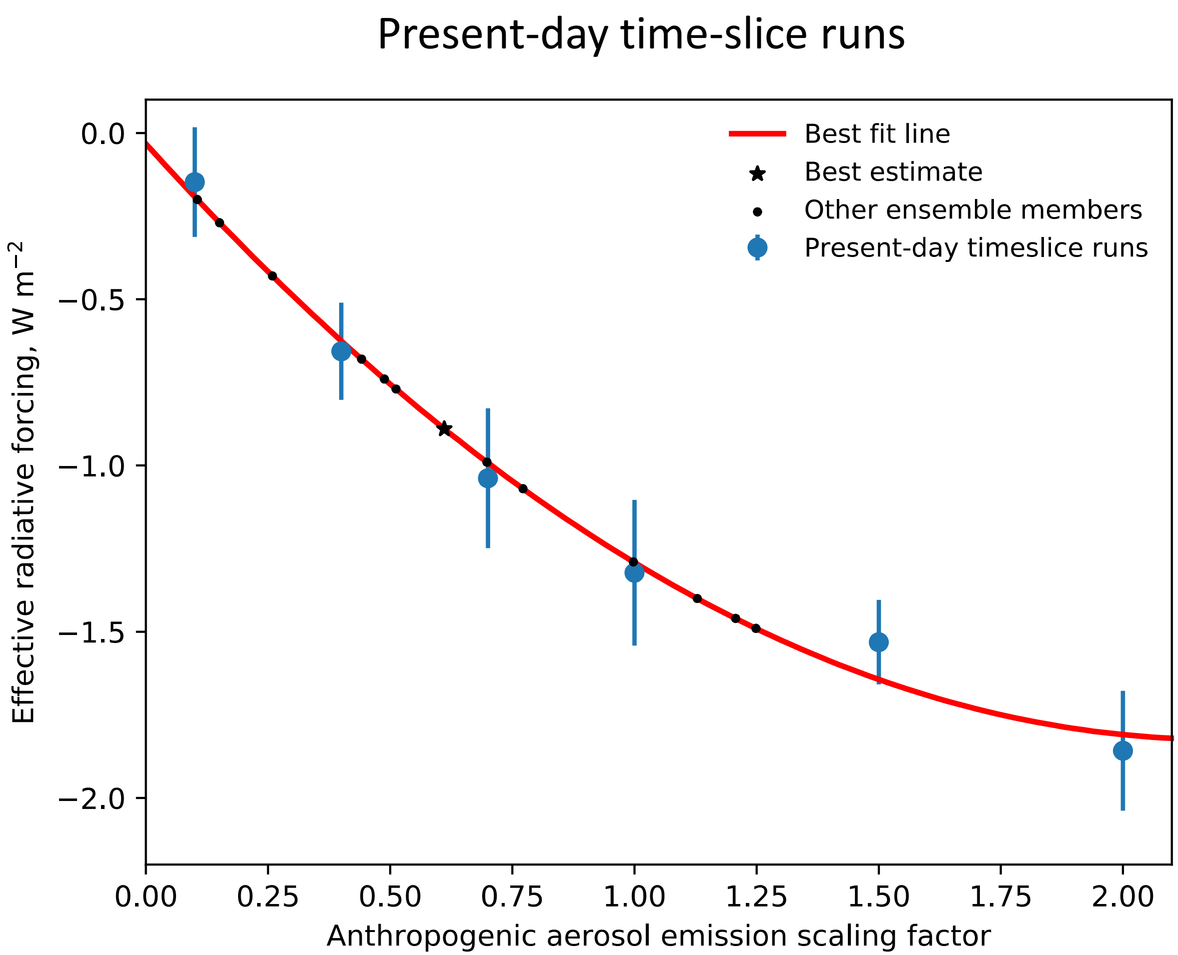
- Large ensemble (~32 members, 1850-2014) of simulations with HadGEM3-GC3.1 (N96-ORCA1), GLOMAP-mode
  - +4 standard aerosol emissions CMIP6 simulations from MetO
- Goal: sample uncertainties in historical aerosol radiative forcing and different ocean initial conditions
- 4 different scalings for historical anthropogenic aerosol emissions and 8 ocean states:

8 intial conditions x 4 scalings

Aerosol scalings



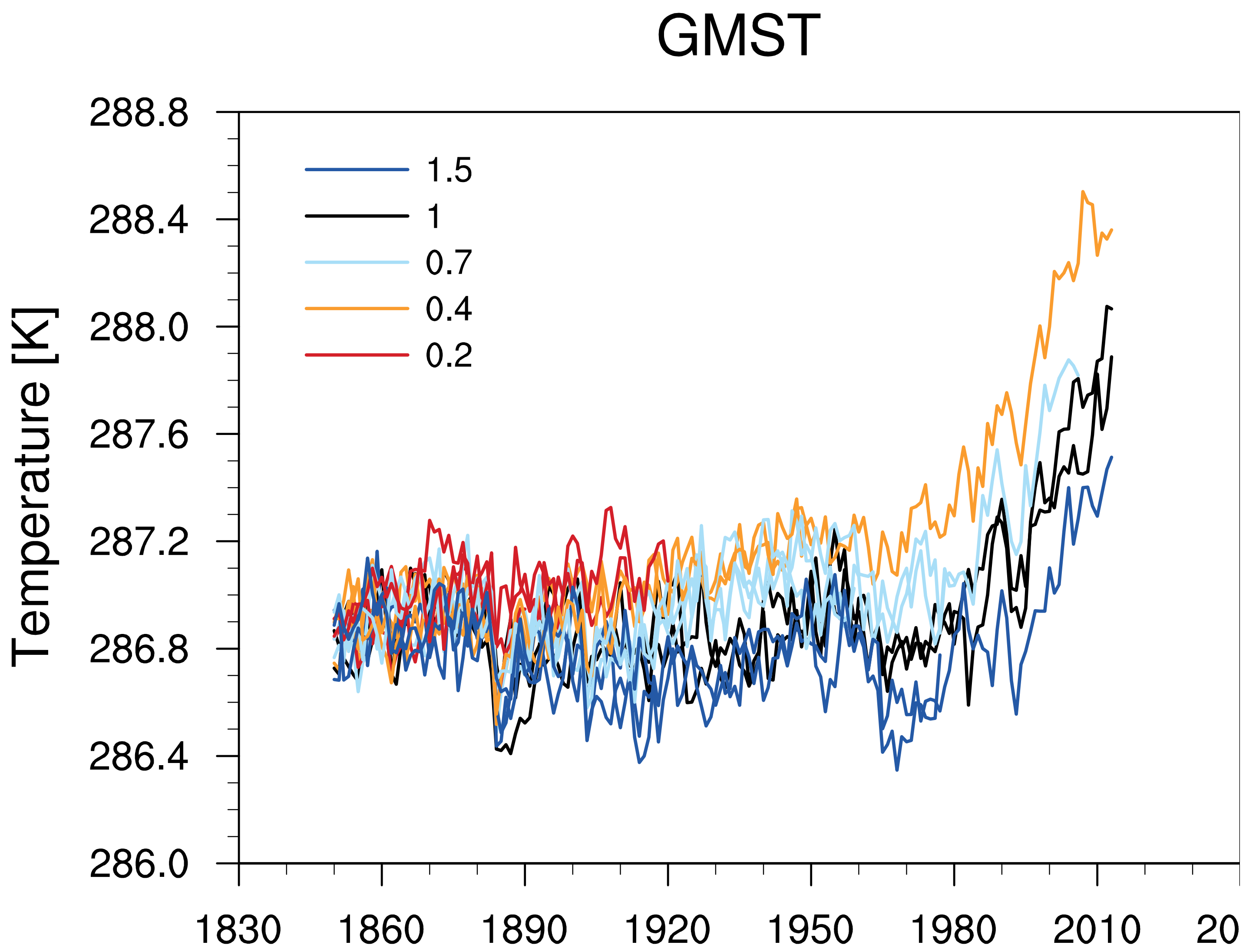
Aerosol scalings



- **0.2**x scaling to give -0.35W/m2
- **0.4**x scaling to give -0.63W/m2
- **0.7**x scaling to give -1W/m2
- (1x scaling to give -1.3W/m2)
- **1.5**x scaling to give -1.6W/m2

Figure Chris Smith, Leeds

Preliminary results



Analysis plans/ ideas for this ensemble

- Role for anthropogenic aerosol forcing in Atlantic and Pacific multi-decadal variability?
- Is the response to aerosol different depending on ocean base state?
- Differences in amplitude of variability?
- Role of aerosols in historical temperature record

REAL Projections

Future experiments planned

Projections (SMURPHS & REAL)

- To 2035/2100: multiple forcing scenarios, uncertainties in future aerosol emissions

- Future “control experiment” using 2080 forcings

➢ Look at changes in variability

Thanks!

Any questions or comments?

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