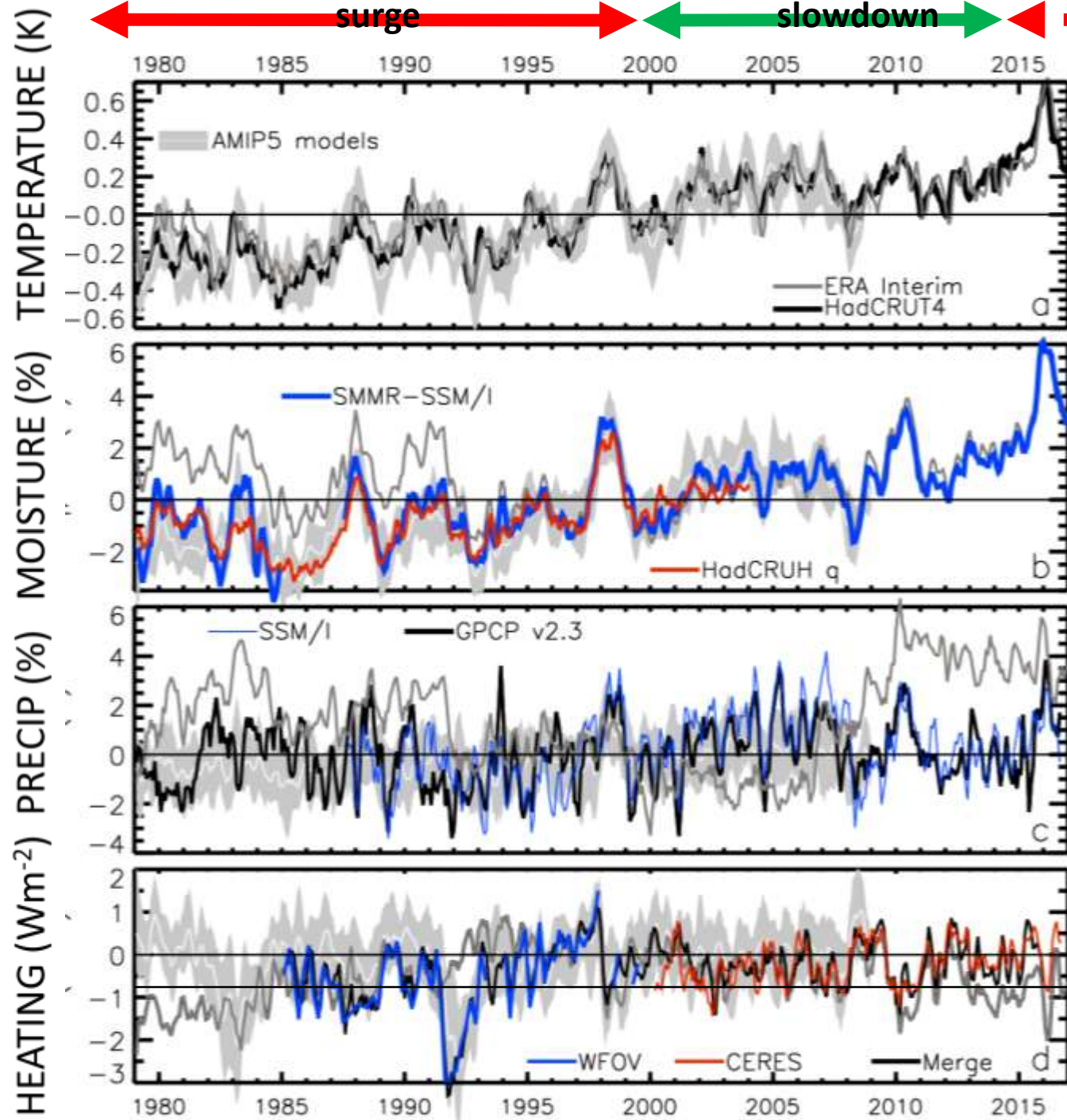


WP1 highlights - Observed TOA imbalance & atmospheric energy transports

Richard Allan - University of Reading

DEEP-C wrap-up meeting, Met Office, 31 March 2017




Changes in Temperature, moisture, precipitation & net radiation through surge & slowdown

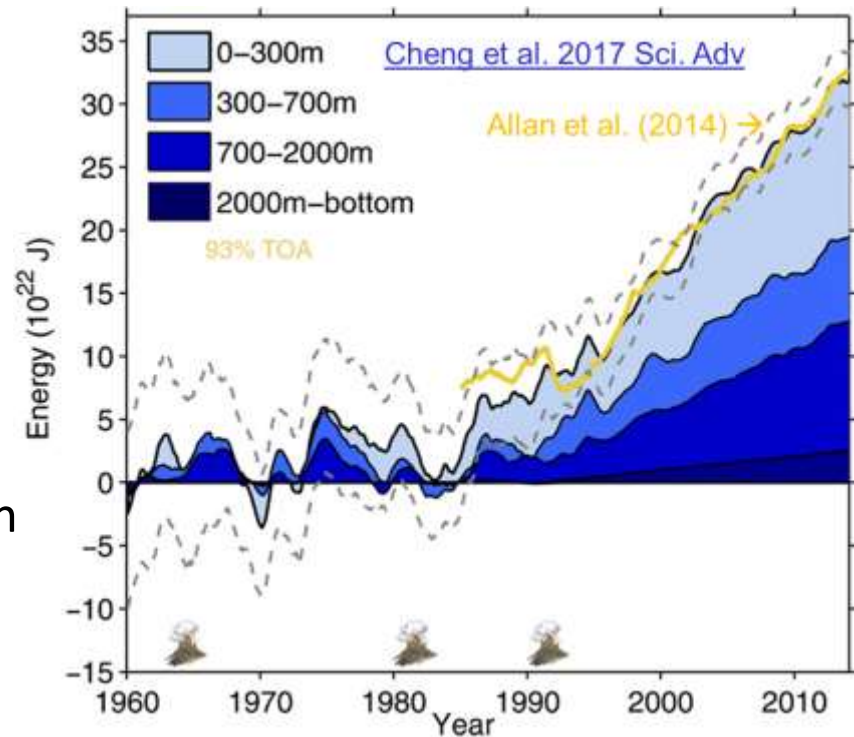
Update from:
[Allan et al. \(2014\) Surv. Geophys](#) &
[Allan et al. \(2014\) GRL](#)


2.8
 1.8 Earth's
 0.8 energy
 -0.2 imbalance
 -1.2 (Wm^{-2})
 -2.2

Top of atmosphere radiation dataset

[Allan et al. \(2014\) GRL](#)  110

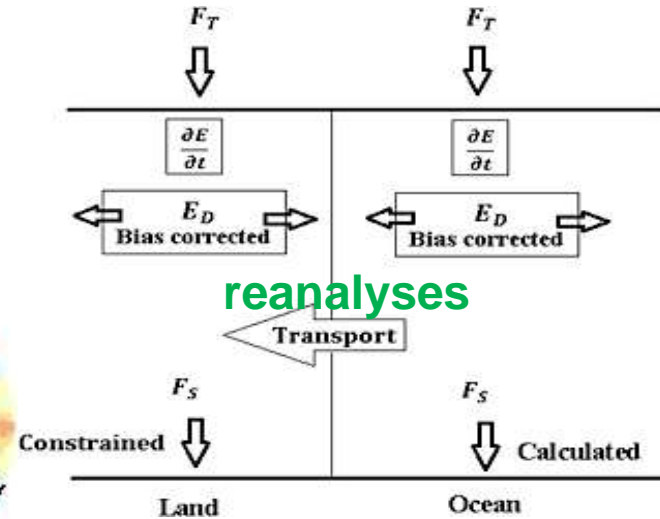
- 1985-present [dataset](#) (NetCDF)
- Steady heating of planet despite temporary surface warming slowdown
- Increase in net imbalance: late 1980s $\sim 0.2 \text{ Wm}^{-2}$; 2000s $\sim 0.6 \text{ Wm}^{-2}$



- Confirmed recently by updated ocean data (above, [Cheng et al. 2017 Sci. Adv](#))
- Slight drop in net imbalance late 1990s-2000s may have influenced slowdown (e.g. [Smith et al. 2015 GRL](#))  42
- Distinct energy budget/temperature relations for internal variability: [Xie et al. \(2015\) Nature Geosci](#)
- Well cited (43), dataset used (e.g. Cheng et al., Xie et al., Williams et al., Hyder et al. & [Roberts et al.](#) see talks) & disseminated via media/social media/blogs

Net downward energy flux/trends top of atmosphere surface

CERES/ERBS/ERAINT

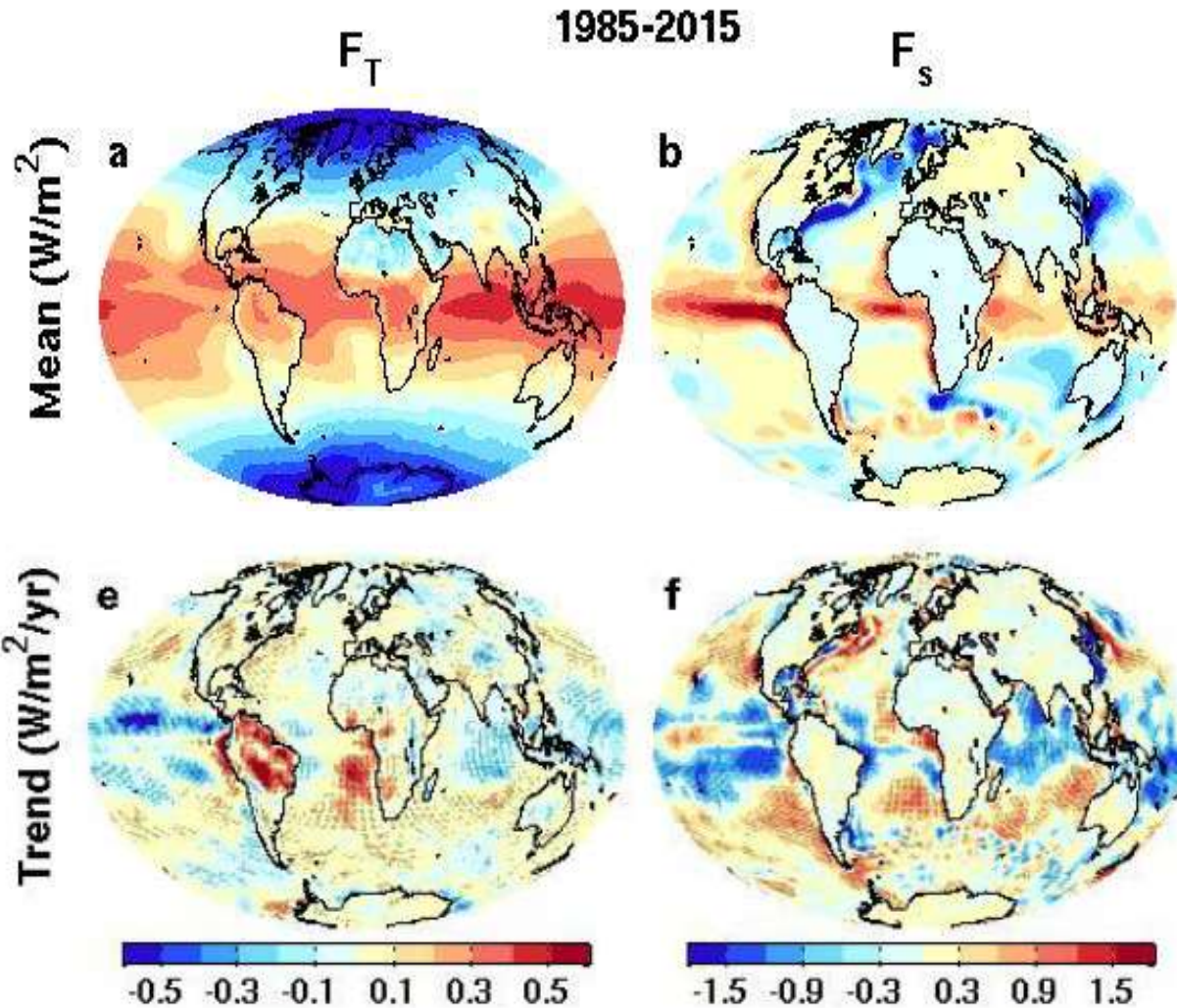


JULES/ERAINT

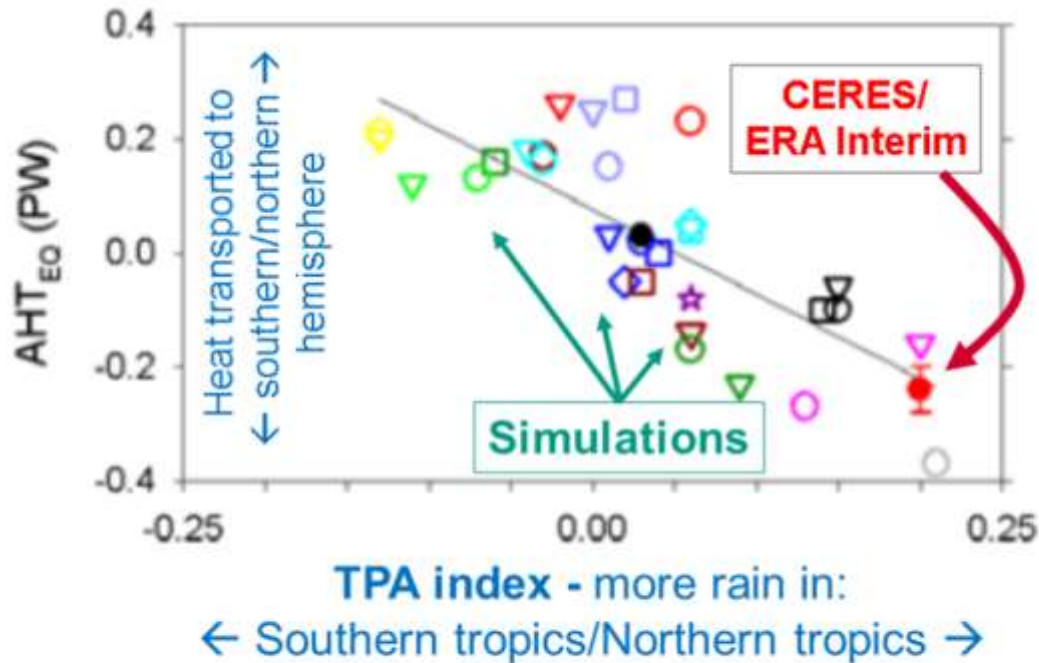
Surface energy flux
[dataset](#) combining
TOA reconstruction
with reanalysis energy
transports: [Liu et al. \(2015\) JGR](#)



More in Chunlei's talk



Cross-Equatorial heat transport linked to model precipitation bias



Estimated cross equatorial atmospheric heat transport in peta Watts (AHT_{EQ}) against an index of tropical precipitation asymmetry (TPA) between hemispheres in simulations and observations

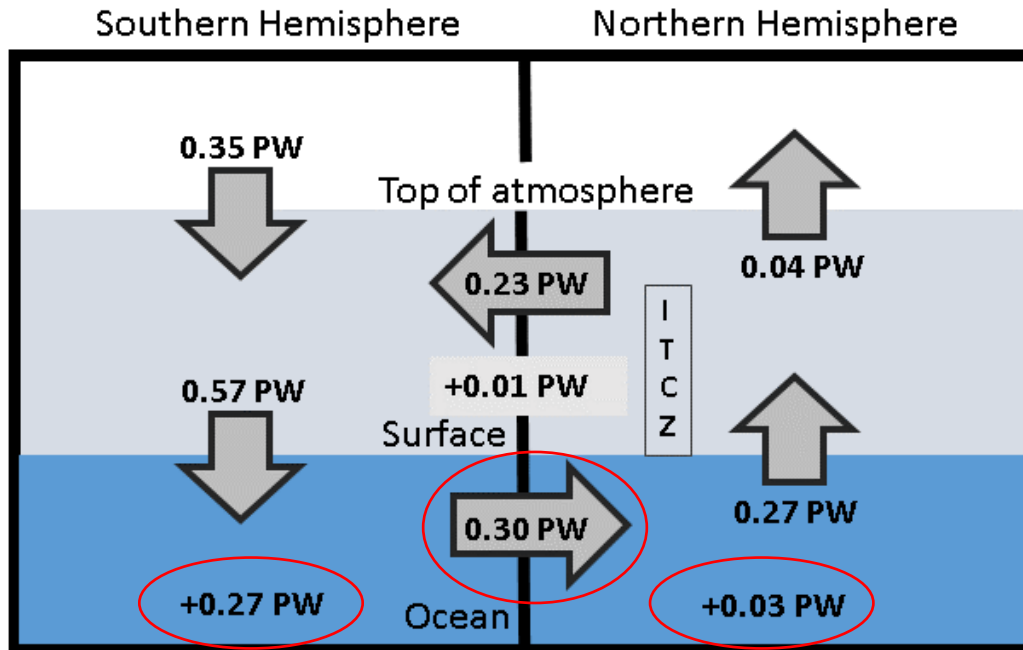
- Clear link between bias in cross-equatorial heat transport by atmosphere and inter-hemispheric precipitation asymmetry

[Loeb et al. \(2016\) Clim. Dyn](#)

Altmetric 14

Also: [Haywood et al. \(2016\) GRL](#)
[Hawcroft et al. \(2016\) Clim. Dyn.](#)

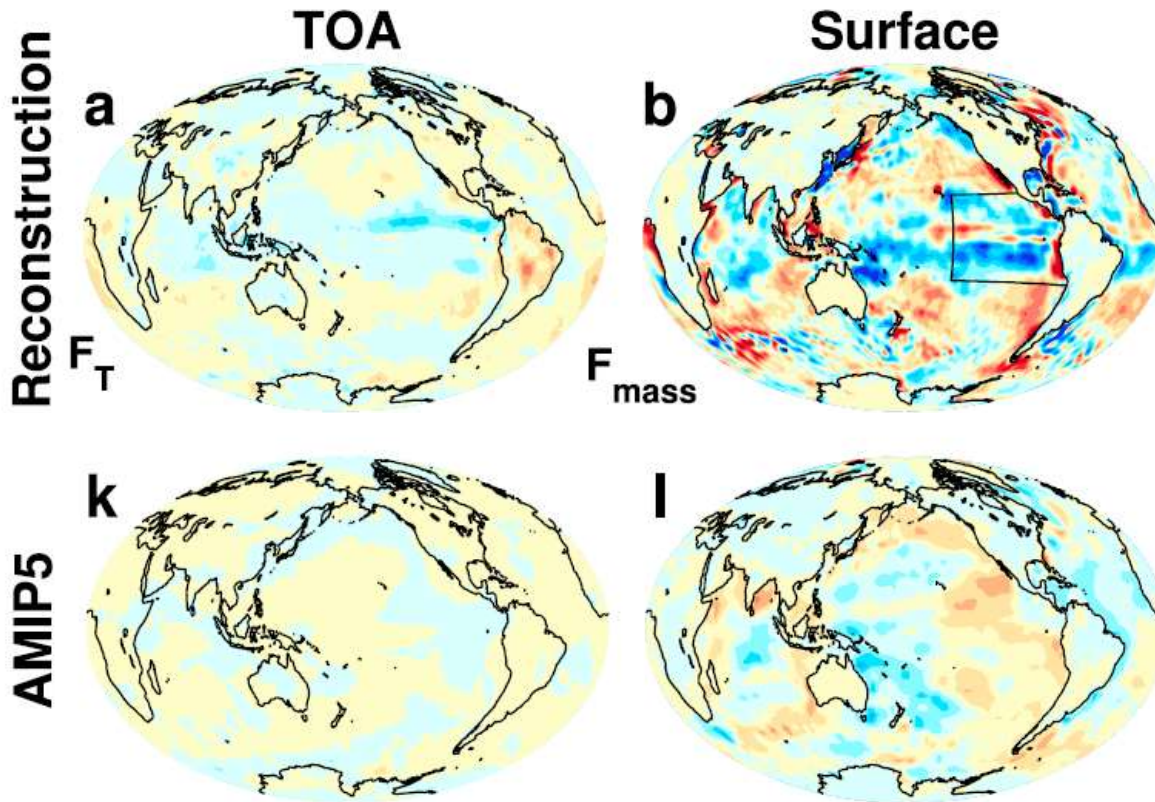
Updated observed energy budget asymmetry



Updated from [Loeb et al. \(2016\)](#) for 2000-2015 based on [Liu et al. \(2015\) JGR](#) (Liu et al. 2017 JGR in review)

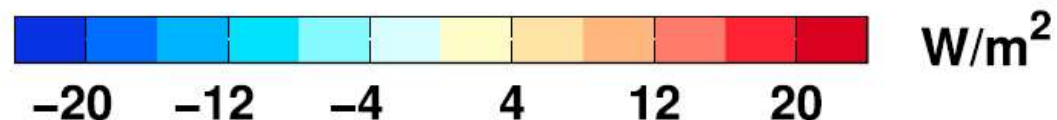
- Observed inter-hemispheric imbalance in Earth's energy budget
- Use asymmetric ocean heating observed by [Roemmich et al. \(2015\) Nature Climate](#) and [Purkey & Johnson \(2010\)](#)
- Derive implied ocean heat transport: smaller than [Loeb et al. \(2015\)](#) and [Frierson et al. 2013](#) (0.44 PW) – unrealistically so?

Surface energy flux changes: discrepancy between models/reconstruction



- Changes in energy fluxes 1986-2000 to 2001-2008
- Surface energy flux dominated by atmospheric transports
- Contrasting model pattern of change, realistic? e.g. [He & Soden \(2016\) J. Clim](#)
- Are reanalysis transports reliable?

[Liu et al. \(2015\) JGR](#)



Dissemination Activities

Activities listed on researchfish, including:





- **Media:** BBC Breakfast (COP), BBC Radio 4 (comment on Nieves et al.), Science Media Centre (briefings & comments), BBC news/Independent/Sky/Telegraph/Voice of Russia, etc (e.g. IPCC & comments on papers)
- **Blogs:** NASA sensing our planet, Climate Lab Book, Weather@Reading, Carbon Brief, Conversation, NCAS and NCEO highlights
- **Outreach:** U3A, RMetS, local interest groups, schools, twitter
- **Workshops:** CLIVAR, decision analysis workshop, GEWEX, CERES/GERB
- **Datasets:** DEEP-C TOA and surface energy flux; NOC ocean heat content
- **Special Issues:** Current Climate Change Reports [Energy Budget Section](#)
- **Website:** resource for journal papers -

<http://www.met.reading.ac.uk/~sgs02rpa/research/DEEP-C.html#PAPERS>

Recent Literature (from DEEP-C website)

- [Cheng et al. \(2017\) Sci. Adv.](#): 200 billion kilowatt heating of Earth since 1960 mostly after 1980, affecting deeper ocean since 1990s, variation close to [Allan et al. \(2014\)](#)
- [Johnson and Birnbaum \(2017\) GRL](#): building El Nino increases ocean heat uptake (1°C warming in Nino3.4 over a year increases Earth's energy uptake by 0.2 Wm⁻²)
- [Johnson et al. \(2016\) Nature Climate Change](#): improved estimate of Earth's energy imbalance of +0.6 to +0.8 Wm⁻² due to better ocean sampling
- [Burgman et al. \(2017\) GRL](#): shortwave low cloud feedbacks in E. Pacific explain much of SST/circulation variability of last 16 years
- [Dong & McPhaden \(2017\) ERL](#): radiative forcing dominates decadal temperature trends apart from during extreme phases of internal variability
- [Desbruyères, et al. \(2017\) J Clim.](#): global heat uptake of 0.62-0.80 Wm⁻², 90% above 2000-m depth, large part in S. Ocean.
- [Trenberth and Fasullo \(2017\) GRL](#): satellite/reanalysis-based 26°N heat transports 1PW close to RAPID *in situ* but without negative trend
- [Hu & Sprintall \(2017\) GRL](#): Strengthened Indonesian throughflow 2004-2014 from increased precipitation & freshening
- [Roberts et al. \(2017\) JGR-Oceans](#): Non-Ekman ocean heat transport processes dominate mixed layer ocean heat content in equatorial oceans & regions of strong ocean currents/eddy activity & force atmospheric response.
- [Llovel & Terray \(2016\)](#): ocean heat uptake peaks ~40°S; rapid upper ocean warming linked to poleward shift of mean wind stress curl enhances Ekman pumping 45-60°S

WP1 - Primary Outputs

- **Allan, R. P., C. Liu, N. G. Loeb, M. D. Palmer, M. Roberts, D. Smith** and P.-L. Vidale (2014) Changes in global net radiative imbalance 1985-2012, Geophysical Research Letters, 41, [10.1002/2014GL060962](https://doi.org/10.1002/2014GL060962).  110 [DATASET](#)
- **Liu, C. Allan, R. P., P. Berrisford, M. Mayer, P. Hyder, N. Loeb, D. Smith, P.-L. Vidale, J. Edwards** (2015) Combining satellite observations and reanalysis energy transports to estimate global net surface energy fluxes 1985-2012, J. Geophysical Research, [doi: 10.1002/2015JD023264](https://doi.org/10.1002/2015JD023264)  9 Datasets: <http://dx.doi.org/10.17864/1947.111>
- **Loeb, N. G., H. Wang, A. Cheng, S. Kato, J. T. Fasullo, K.-M. Xu and R. P. Allan** (2015) Observational Constraints on Atmospheric and Oceanic Cross-Equatorial Heat Transports: Revisiting the Precipitation Asymmetry Problem in Climate Models, Climate Dynamics, [10.1007/s00382-015-2766-z](https://doi.org/10.1007/s00382-015-2766-z)  14
- **Smith, D., R. P. Allan, A. C. Coward, R. Eade, P. Hyder, C. Liu, N. G. Loeb, M. D. Palmer, M. Roberts, & A. A. Scaif** (2015) Earth's energy imbalance since 1960 in observations and CMIP5 models, GRL, [10.1002/2014GL062669](https://doi.org/10.1002/2014GL062669),  42

In prep:

- **Liu et al.** (2017) Evaluation of satellite and reanalysis-based global net surface energy flux and uncertainty estimates, JGR in review
- Schmidt et al. (2017) Current and near-future volcanic forcing of global climate change, in prep.

Chris Roberts' Nature Climate paper →

