

# DEEP-C 8<sup>th</sup> project meeting: Introduction

**Richard Allan - University of Reading**

*DEEP-C project meeting, University of Reading, 10 October 2016*

# Agenda

- 11:20-11:40 Evaluation of satellite and reanalysis-based global net surface energy flux - Chunlei Liu
- 11:40-12:00 Deep and abyssal ocean warming from 35 years of repeat hydrography - Damien Desbruyeres
- 12:00-12:20 Did hydrography sampling capture global and regional deep ocean heat content trends accurately between 1990-2010? - Freya Gary
- 12:20-12:40 Surface flux and ocean heat transport convergence contributions to seasonal and interannual variations of ocean heat content - Chris Roberts

## **12:40-13:20 LUNCH**

- 13:30-13:50 Rationalising the impact of ocean mixing parameterisations on simulations of ocean heat uptake - Remi Tailleux, INSPECT project
- 13:50-14:00 ESA SST Climate Change Initiative project/dataset - Claire MacIntosh
- 14:00-14:10 Plans for synthetic profiling and sea level - Lesley Allison
- 14:10-14:30 Southern Ocean heat flux errors - Pat Hyder
- 14:30-14:40 Impact of choice of climatology on results from OI mapping of float data - Brian King
- 14:40-15:30 Discussion/Wrap up **& TEA**

# DEEP-C Introduction

- Diagnosing Earth's Energy Pathways in the Climate system
  - WP1 Radiative imbalance & transports (Allan, et al. Reading)
  - WP2 Ocean heat content & observations (McDonagh et al., NOC)
  - WP3 Simulations/process understanding (Palmer et al., Met Office)
  - WP4 Synthesis (All)
- Original aims to explain and understand:
  - “missing” energy in the climate system
  - Slower rates of surface warming in early 2000s
- Methods: combine satellite data, reanalyses and ocean measurements with modelling

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

# DEEP-C Work Plan

Start date: March 2013; Project Ends February 2017

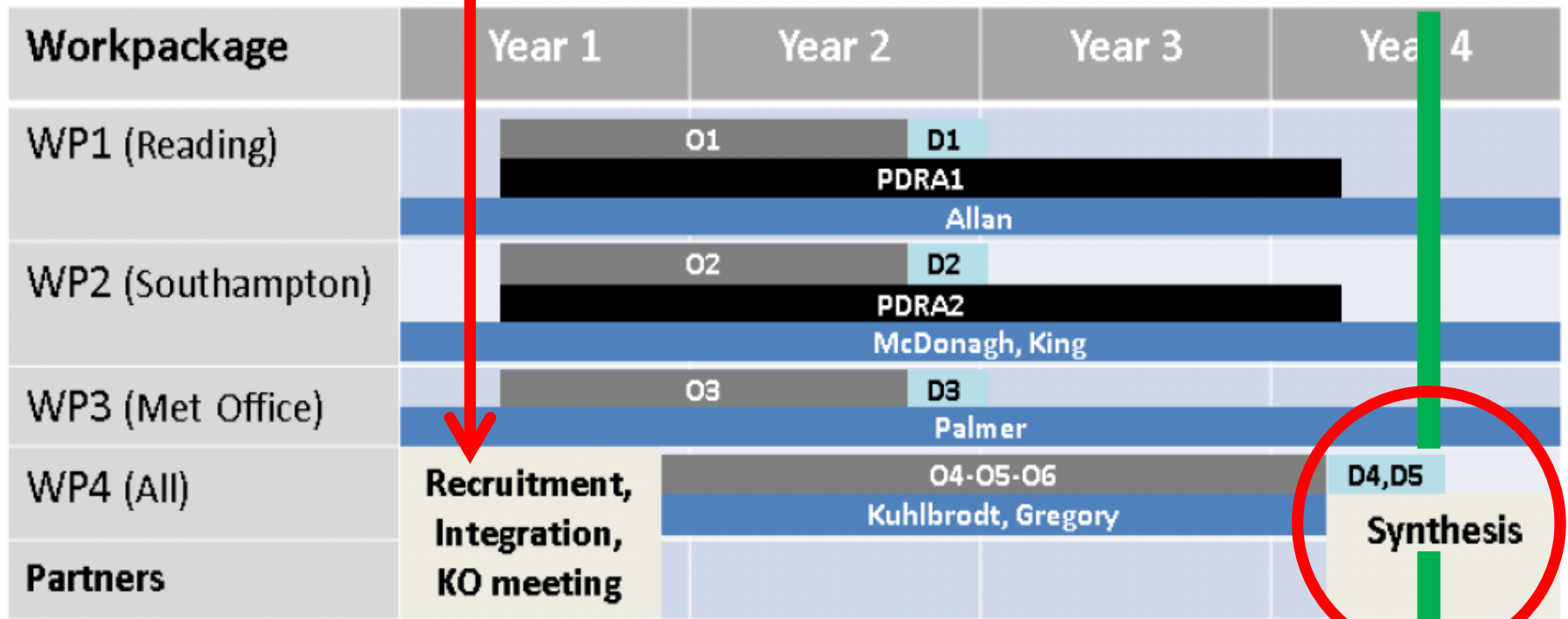


Table 2 - Management timeline for DEEP-C.

# Project Objectives

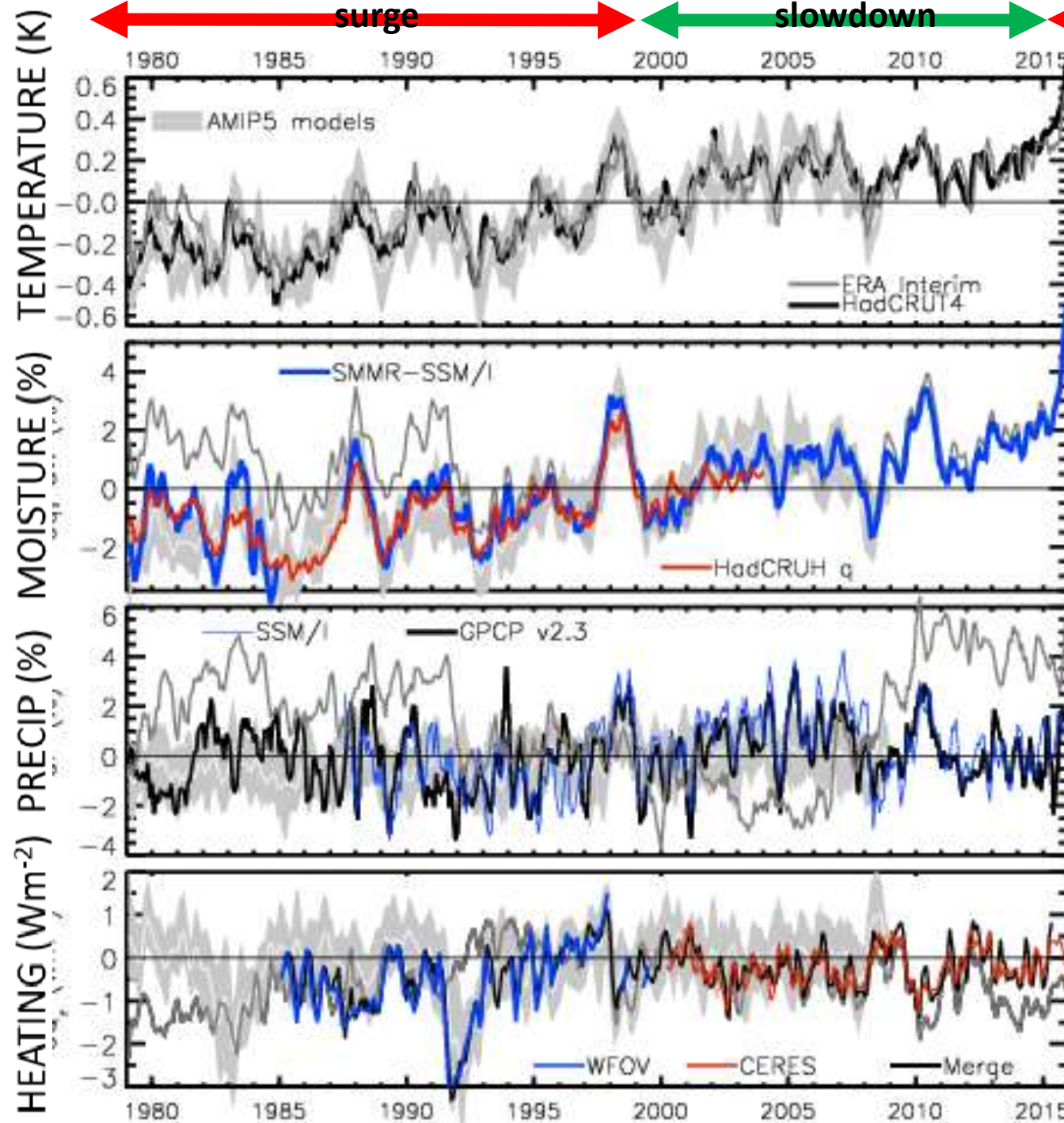
- O1.** Combine satellite radiation budget measurements with atmospheric reanalyses, providing improved 2D estimates of surface heat fluxes across the ocean surface (WP1)
- O2.** Calculate global 3D ocean heat content and its changes since 2003 using ARGO and ship-based observations, leading to improved understanding of energy propagation through the climate system (WP2)
- O3.** Investigate spatial patterns of surface and sub-surface temperature changes in distinct hiatus decades using simulations and observations (e.g. Fig. 4); evaluate the processes fundamental for ocean heat uptake and redistribution (WP3)
- O4.** Combine ocean and satellite data (from O1-2) to provide new estimate of Earth's net radiative energy balance (2000-2015) and compare with CMIP5 climate simulations (from O3) (WP1-4)
- O5.** Monitor co-variations in net radiative energy imbalance and ocean heating (from O1,O2,O4); quantify and understand lags between OHC and TOA radiation (WP1-4)
- O6.** Characterise spatial signatures and mechanisms of ocean and atmospheric heat re-distribution (from O4-5) during the hiatus period 2000-2015 using observations and simulations (WP1-4)

# 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).
- Cheng, L., K. E. Trenberth, **M. D. Palmer**, J. Zhu and J. P. Abraham (2016) Observed and simulated full-depth ocean heat-content changes for 1970-2005, Ocean Science, 12, doi:[10.5194/os-12-925-2016](https://doi.org/10.5194/os-12-925-2016)
- **Desbruyères, D. G.**, S. Purkey, G. J. Johnson, **E. L. McDonagh** and **B. A. King** (2016), Deep and Abyssal Ocean Warming from 35 years of Repeat Hydrography, GRL, in press, DOI: [doi: 10.1002/2016GL070413](https://doi.org/10.1002/2016GL070413)
- **Desbruyères, D. G., E. L. McDonagh, B. A. King, F. K. Garry**, A. T. Blaker, B. Moat and H. Mercier (2014) Full-depth temperature trends in the NE Atlantic through the early 21st century, GRL, doi:[10.1002/2014GL061844](https://doi.org/10.1002/2014GL061844)
- **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)
- **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)
- **Palmer, M.D.** and D.J. McNeall (2014) Internal variability of Earth's energy budget simulated by CMIP5 climate models, Environ. Res. Lett. 9, 034016, [doi:10.1088/1748-9326/9/3/034016](https://doi.org/10.1088/1748-9326/9/3/034016)
- **Palmer, M.D., C. D. Roberts**, et al. (2015) Ocean heat content variability and change in an ensemble of ocean reanalyses, Climate Dynamics, doi: [10.1007/s00382-015-2801-0](https://doi.org/10.1007/s00382-015-2801-0)
- **Roberts, C.D., M.D. Palmer**, D. McNeall and M. Collins (2014) Quantifying the likelihood of a continued hiatus in global warming, Nature Climate Change [doi:10.1038/nclimate2531](https://doi.org/10.1038/nclimate2531)
- Roberts, M. J. and co-authors inc. **P Hyder** (2016) Impact of ocean resolution on coupled air-sea fluxes and large-scale climate, GRL, [doi:10.1002/2016GL070559](https://doi.org/10.1002/2016GL070559)
- **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),
- von Schuckmann, K. et al. inc. **M. D. Palmer** (2016) An imperative to monitor Earth's energy imbalance, Nature Climate Change [doi: 10.1038/nclimate2876](https://doi.org/10.1038/nclimate2876)

# Some Dissemination Activities

- **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 England et al and Kosaka and Xie)
- **Blogs:** NASA sensing our planet, Climate Lab Book, Weather@Reading, Carbon Brief, Conversation, NCAS and NCEO highlights
- **Workshops:** CLIVAR, decision analysis workshop, GEWEX, CERES/ScaRaB/GERB
- **Outreach:** U3A, RMetS, local interest groups, schools, twitter
- **Datasets:** DEEP-C TOA and surface energy flux; NOC ocean heat content



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

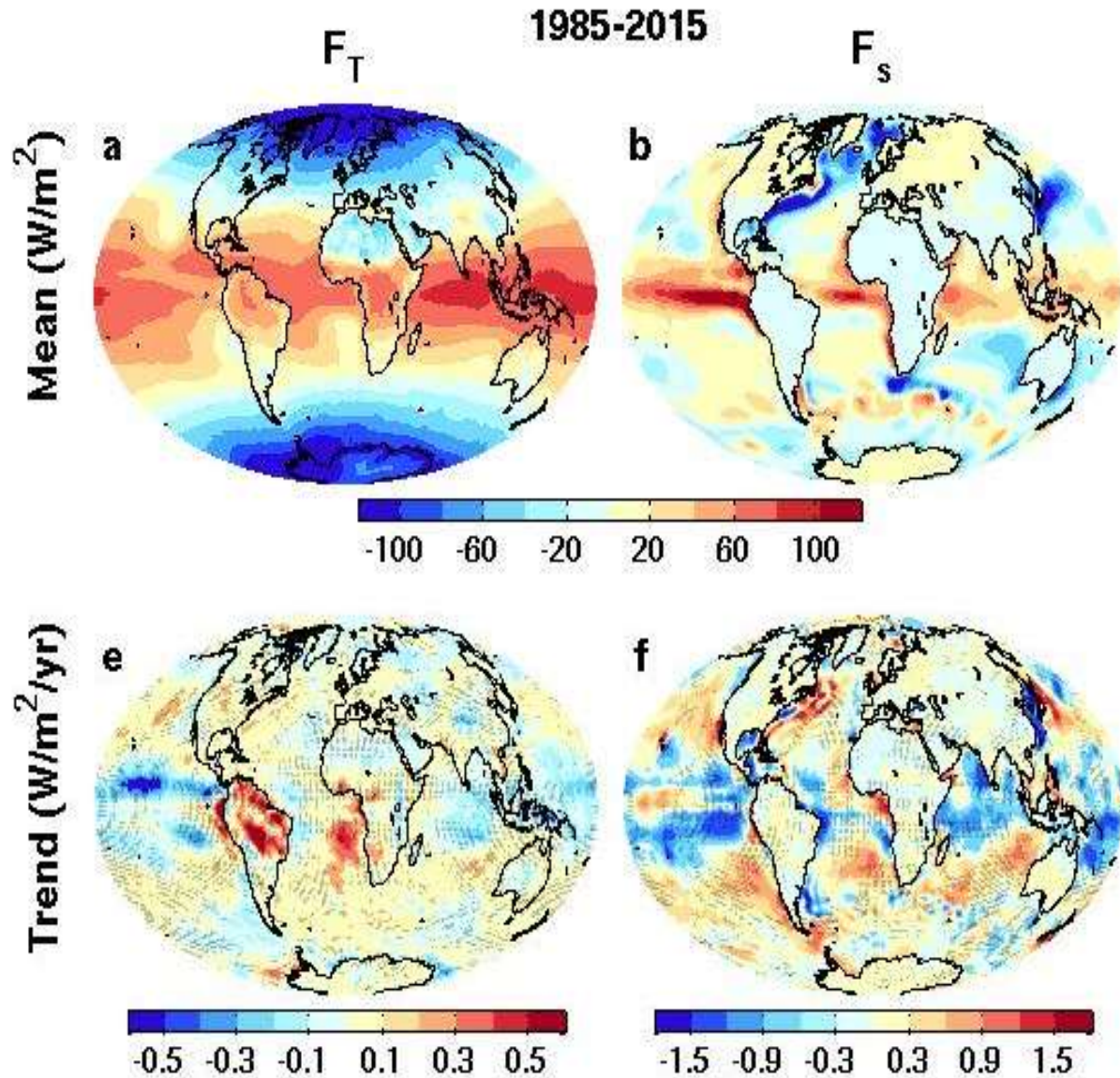
Update from [Allan et al. \(2014\) Surv. Geophys](#) & [Allan et al. \(2014\) GRL](#)

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



# Net downward energy flux & trends

top of atmosphere      surface



# Recent Literature

- [Johnson et al. \(2016\) Nature Climate Change](#): improved estimate of Earth's energy imbalance of +0.6 to +0.8 Wm<sup>-2</sup> due to better ocean sampling
- [Richardson et al. \(2016\) Nature Climate](#): reconciling obs-based/simulated TCS through consistent sampling of surface temperature (TCR~1.7°C at 2xCO<sub>2</sub>)
- [Medhaug and Drange \(2016\) Clim. Dyn.](#): Decadal-scale upper 700m ocean heat anomalies of  $\sim 7.5 \times 10^{21}$  J comparable to that needed to maintain global warming.
- [Kosaka and Xie \(2016\) Nature Geosci.](#): model simulations of global warming "staircase" used to remove internal variability from observational record
- [Sevellec et al. \(2016\) GRL](#): hiatus of the early 21st Century was extremely unlikely
- [Mann et al. \(2016\) GRL](#): N. Pacific played critical role in the slowdown but was not predictable; minor contribution from N. Atlantic exhibits some predictability
- [Bellamo et al. \(2016\) GRL](#) & [Brown et al. \(2016\) GRL](#): basin-scale Atlantic Multidecadal Oscillation amplified by cloud feedback
- [Checa-Garcia et al. \(2016\) ERL](#): CFC decline + less growth in methane & low-level ozone pollution contributed to slower surface warming
- [Takahashi and Watanabe \(2016\)](#) & [Smith et al. \(2016\) Nature Climate](#): Aerosol forcing linked to hiatus through influence on Pacific trade winds/ocean circulation

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

# Role of Atlantic/Pacific Variability?

Radiative Forcing/Imbalance  
[Johnson et al. \(2016\)](#) ; [Checa-Garcia et al. \(2016\)](#) ; [Huber & Knutti \(2014\)](#) ; [Santer et al. \(2015\)](#)

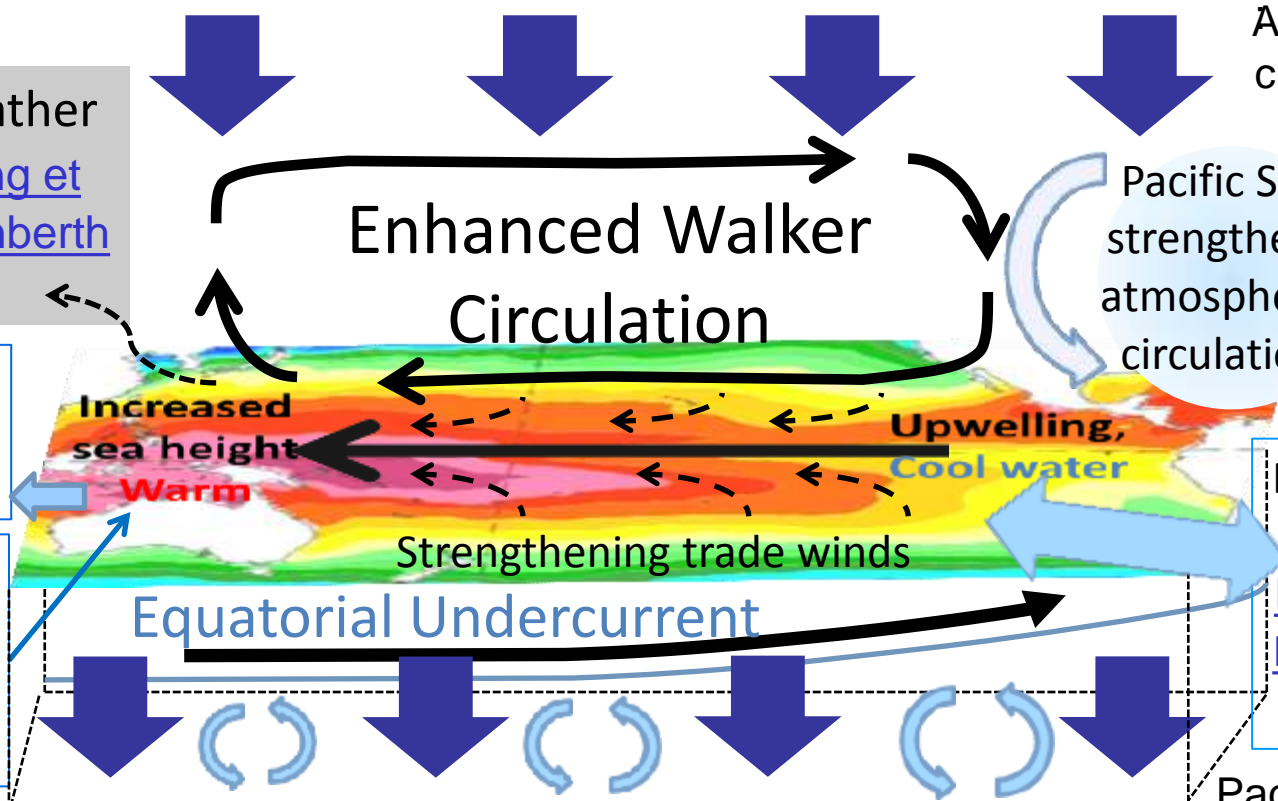
Aerosol forcing of circulation ([Smith et al. 2016](#))

**Continued heating from greenhouse gases**

Unusual weather patterns ([Ding et al. 2014](#); [Trenberth et al. 2014b](#))

? Heat flux to Indian ocean  
[Lee et al 2015](#)

Increased precipitation  
 Decreased salinity



Pacific SST strengthens atmospheric circulation

**Remote forcing from Atlantic:**  
[Li et al. \(2016\)](#) ; [McGregor et al. \(2014\)](#)

Enhanced mixing of heat below 100 metres depth by accelerating shallow overturning cells and equatorial undercurrent

Pacific dominates?  
[Mann et al. \(2016\)](#)  
[Kosaka & Xie \(2013\)](#)  
[England et al. \(2014\)](#)

See also: [Merrifield \(2010\)](#).; [Sohn et al. \(2013\)](#) .; [L'Heureux et al. \(2013\)](#) . Change; [Watanabe et al. \(2014\)](#) ; [Balmaseda et al. \(2013\)](#) ; [Trenberth et al. \(2014\)](#) .; [Llovel et al. \(2014\)](#) ; [Durack et al. \(2014\)](#) ; [Nieves et al. \(2015\)](#) ; [Brown et al. \(2015\) JGR](#) ; [Somavilla et al. \(2016\)](#) ; [Liu et al. \(2016\)](#)

# Final WP1 outputs/conclusions

- Finalised energy flux dataset version and uncertainty estimates (Liu et al.)
- Cross equatorial heat transport (NERC highlight topic?)
- Heat flux bias in southern ocean (Pat et al.)
- Basin-scale changes in heat flux (Damien et al.) & heat flux/transport contributions to heat content (Chris et al.)
- SMURPHS work
  - spatial signatures/morphology,
  - links to water cycle,
  - Understanding Pacific discrepancy in heat flux changes
  - quantify/understand lags between OHC and TOA radiation
  - mechanisms for feedbacks on internal variability)

