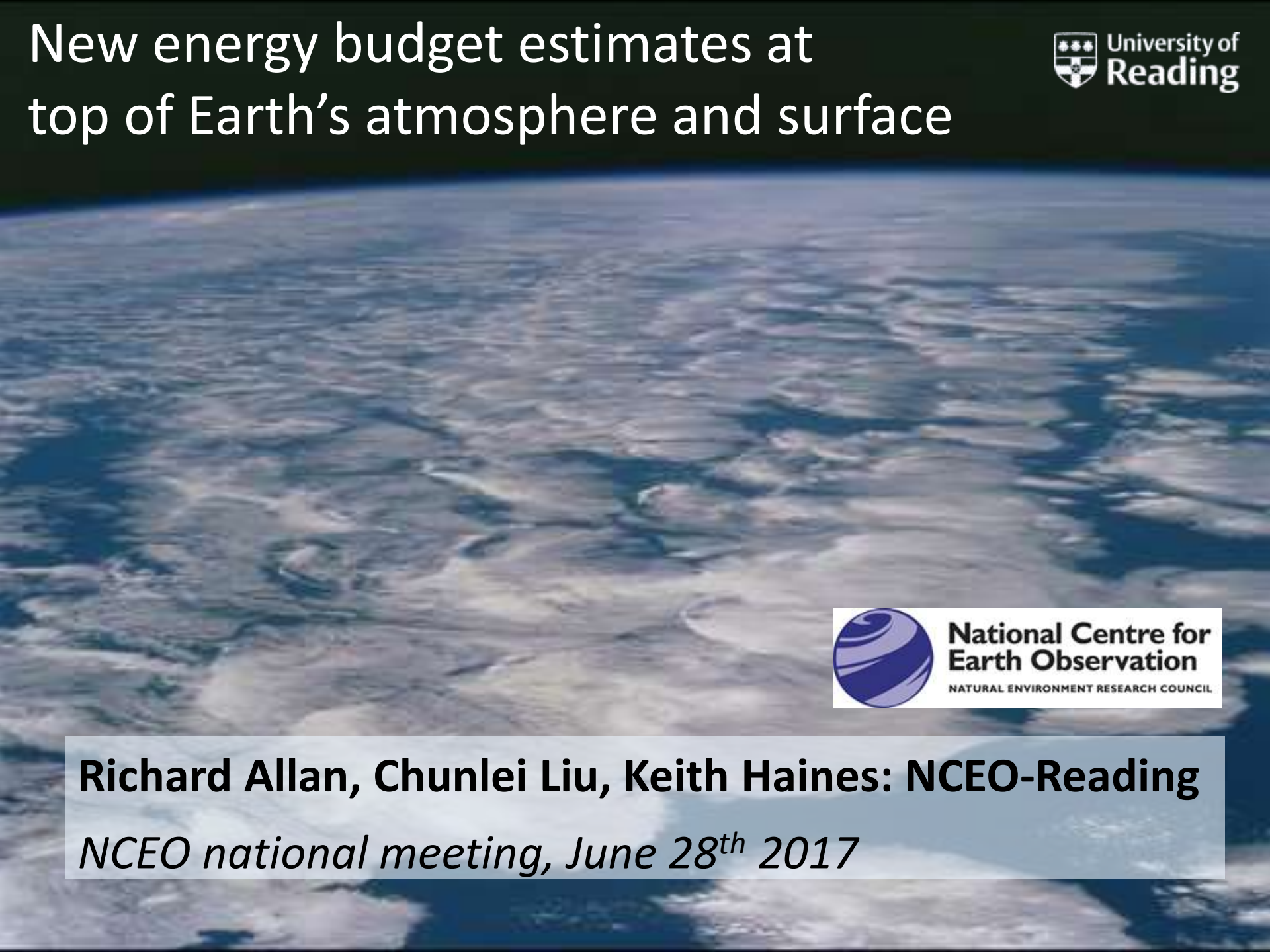
New energy budget estimates at top of Earth's atmosphere and surface



Richard Allan, Chunlei Liu, Keith Haines: NCEO-Reading

NCEO national meeting, June 28th 2017

Variation in Earth's global energy imbalance since the 1980s

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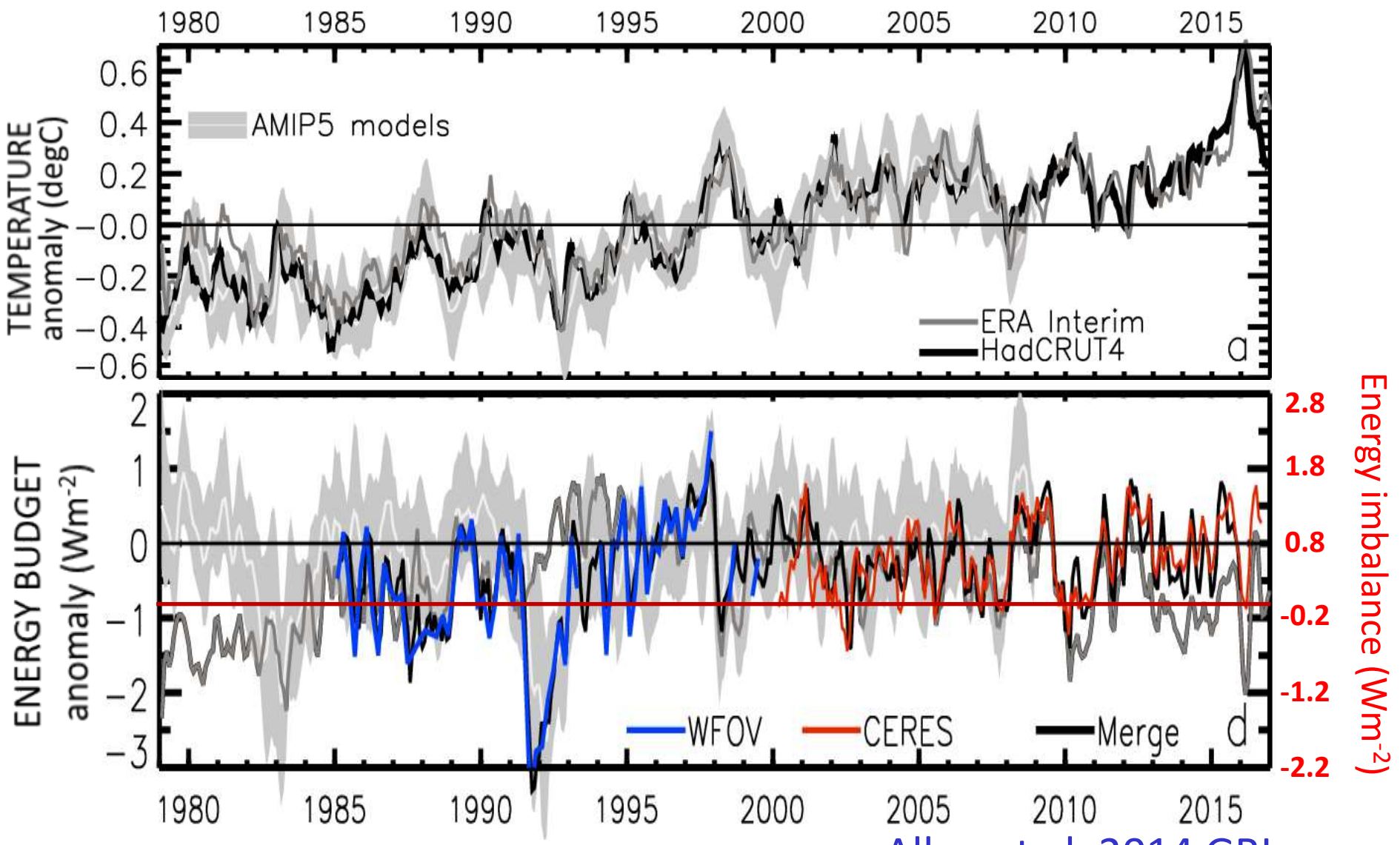
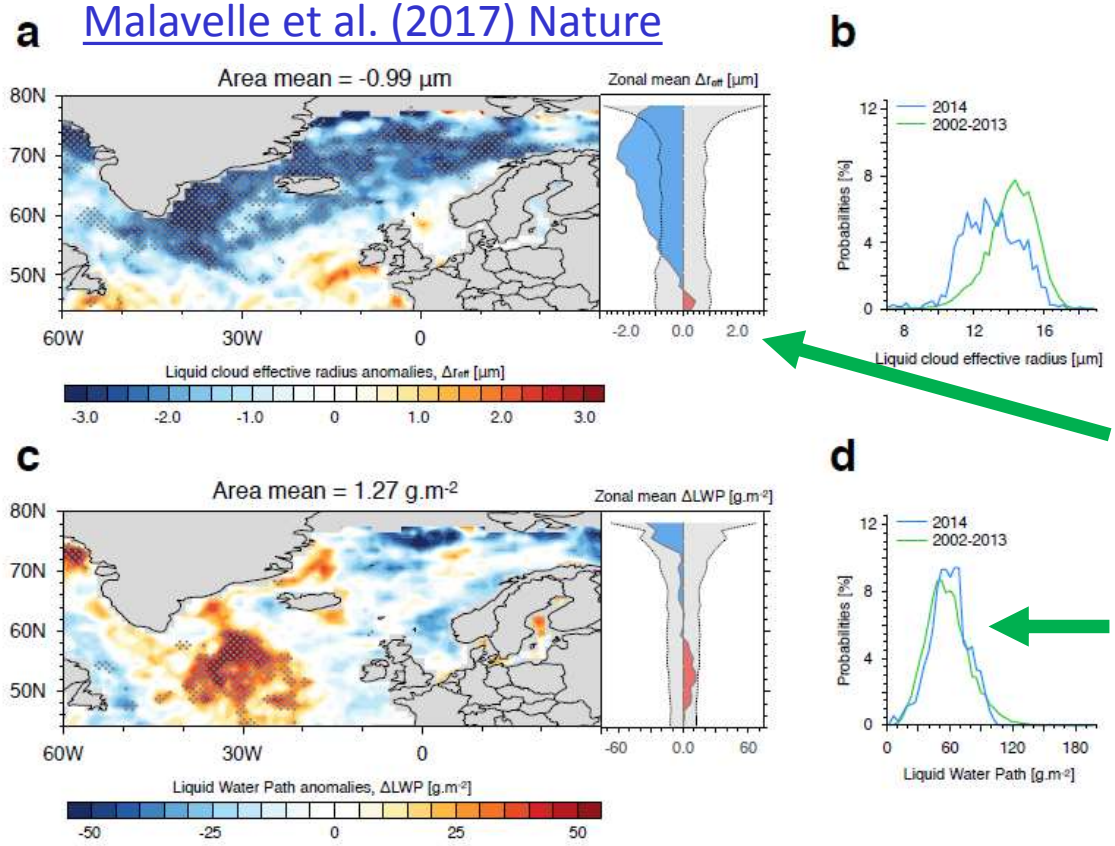


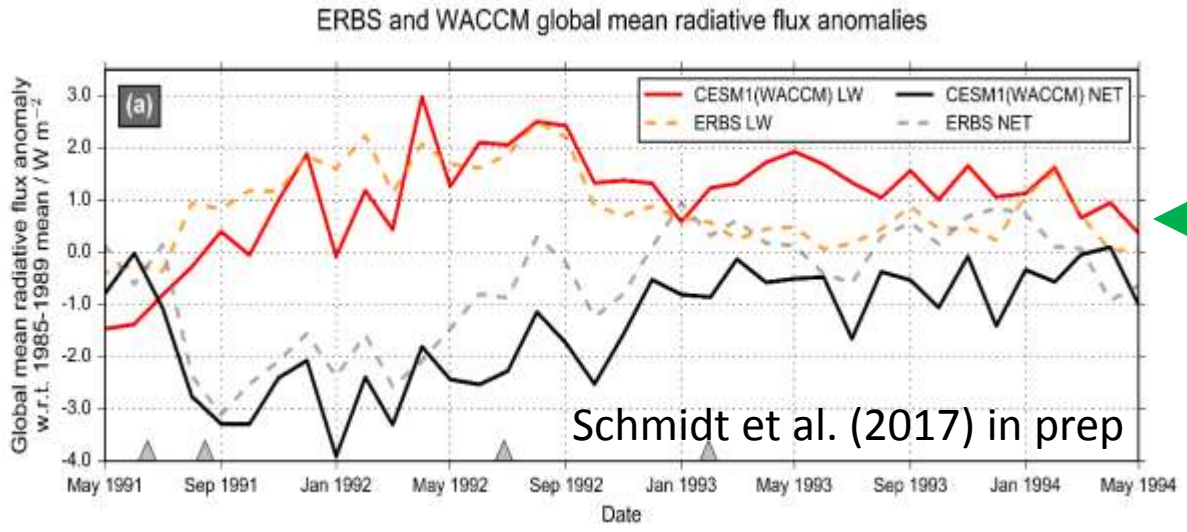
Allan et al. 2014 GRL

MODIS-Aqua Observations

Droplet size

Cloud water





Advancing understanding of volcanic aerosol effects on climate

- Volcanic aerosol haze brightens low altitude clouds, cooling climate
- Further indirect effects in cloud water found to be negligible
- Results will help to improve climate change projections
- New assessment of direct volcanic influence on climate combining nudged models & observations

New global surface flux estimates

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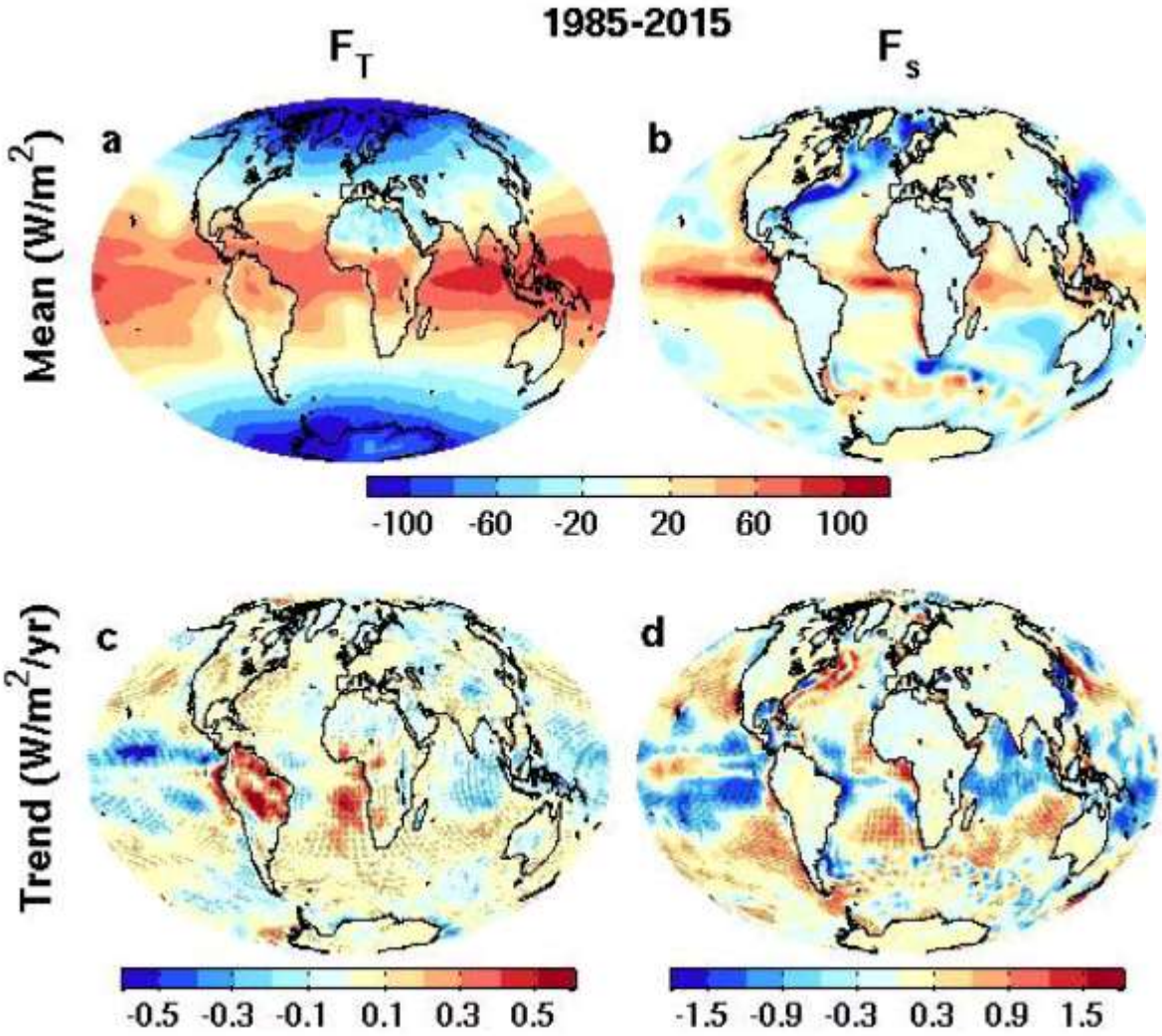
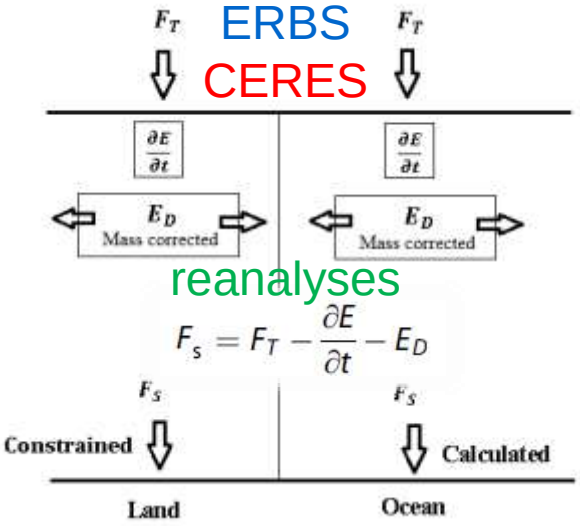
top of atmosphere surface





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

Has increased evaporation driven East Pacific cooling?

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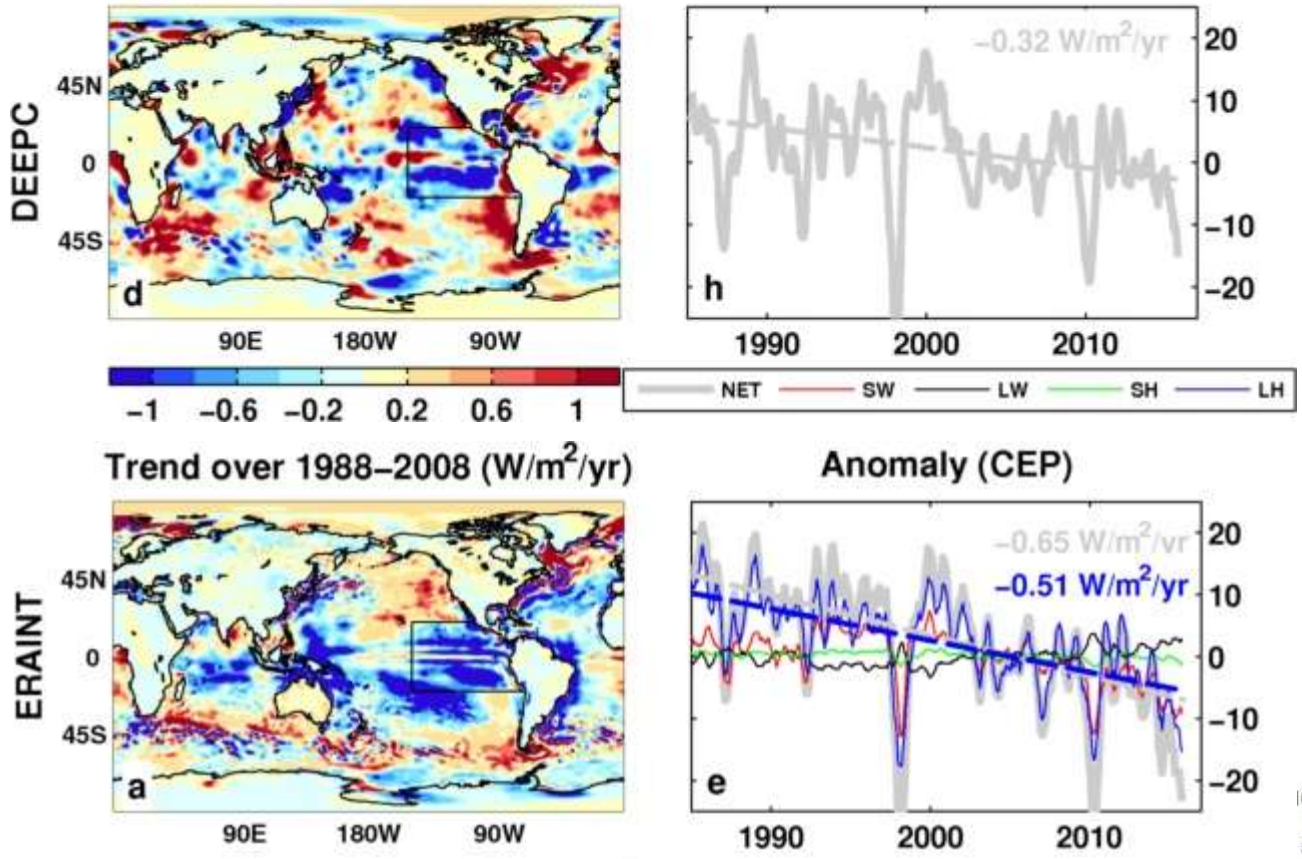
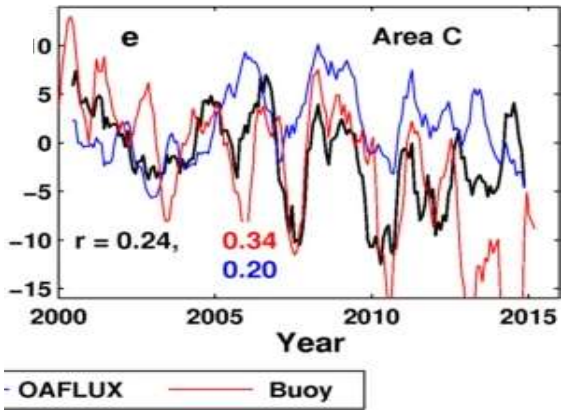


downward LHF



- Decreases in East Pacific surface fluxes since 1990s
- Discrepancy to simulations without coupled feedbacks
- Is surface evaporation amplifying cooling?

Cross-hemispheric energy transport & precipitation biases

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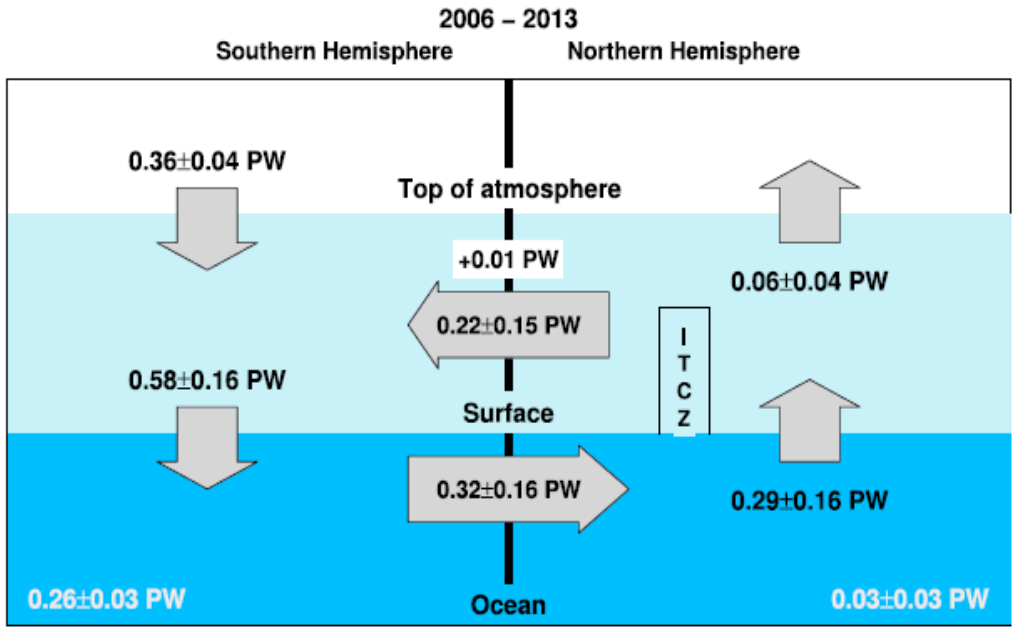
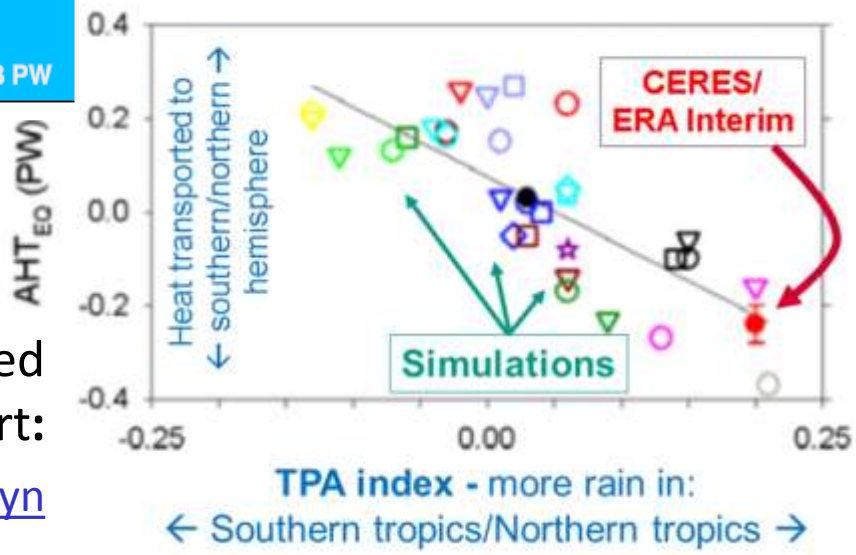


Left: New observational estimates of inter-hemispheric energy budget (peta watts):

Liu et al. (2017) JGR



Right: Model precipitation biases linked to cross-equatorial heat transport**:**

Loeb et al. (2016) Clim. Dyn

Meridional Heat Transport Estimate

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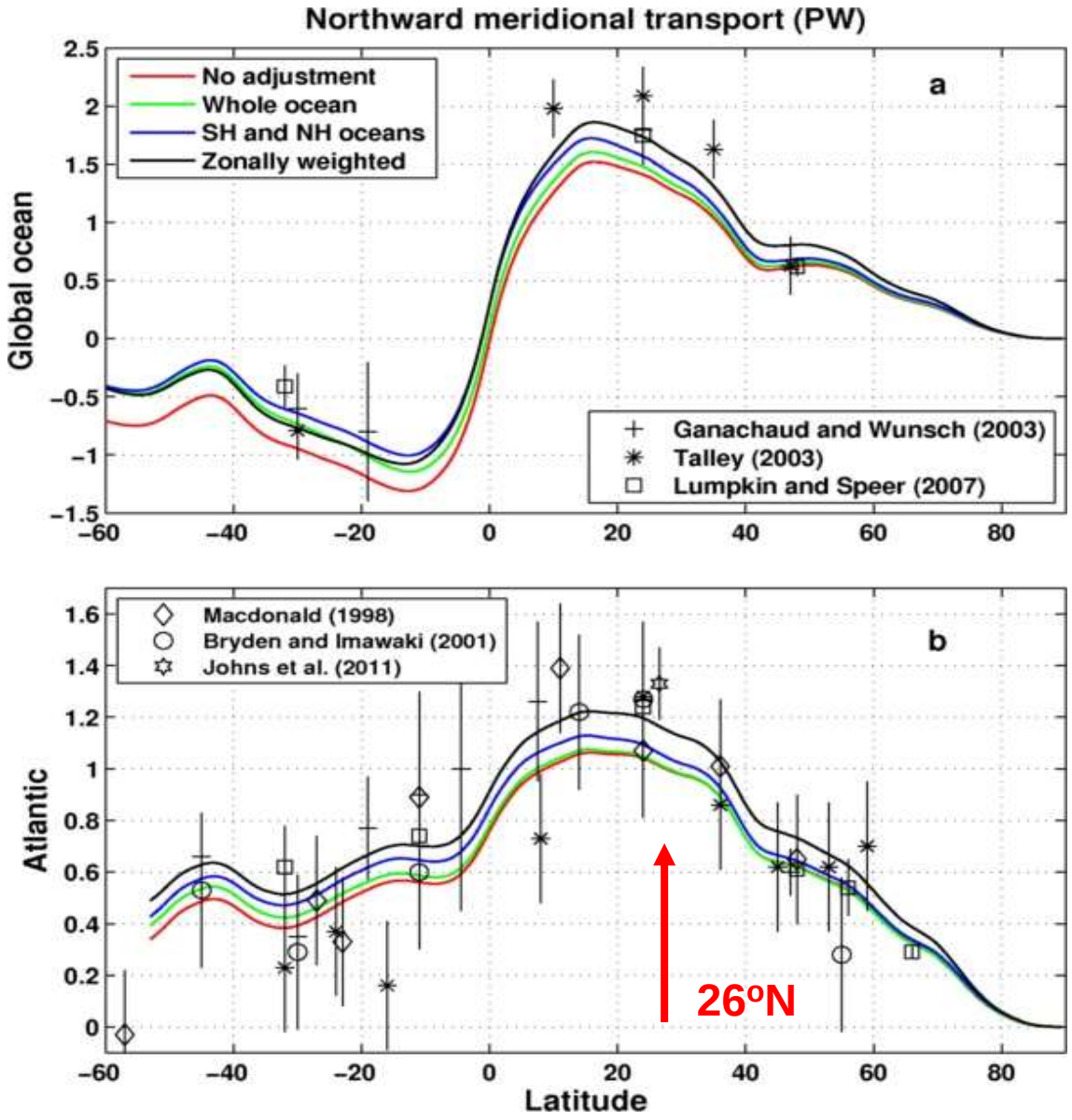
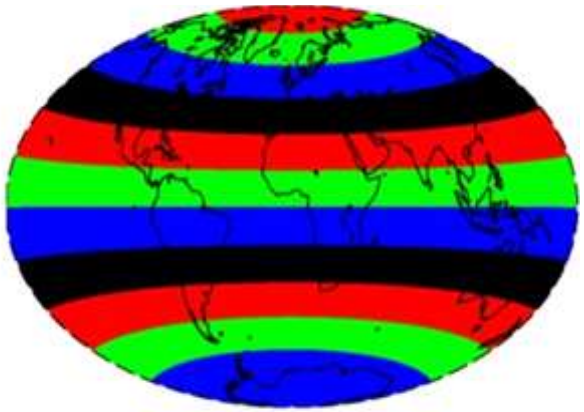


- Inferred from DEEP-C surface energy flux data (Liu et al. 2017 JGR) & ocean heating (Roemmich et al 2015) 2006-2013
- Sensitivity of method to land flux correction

Zonal land correction



Inferred ocean heat transport@26°N

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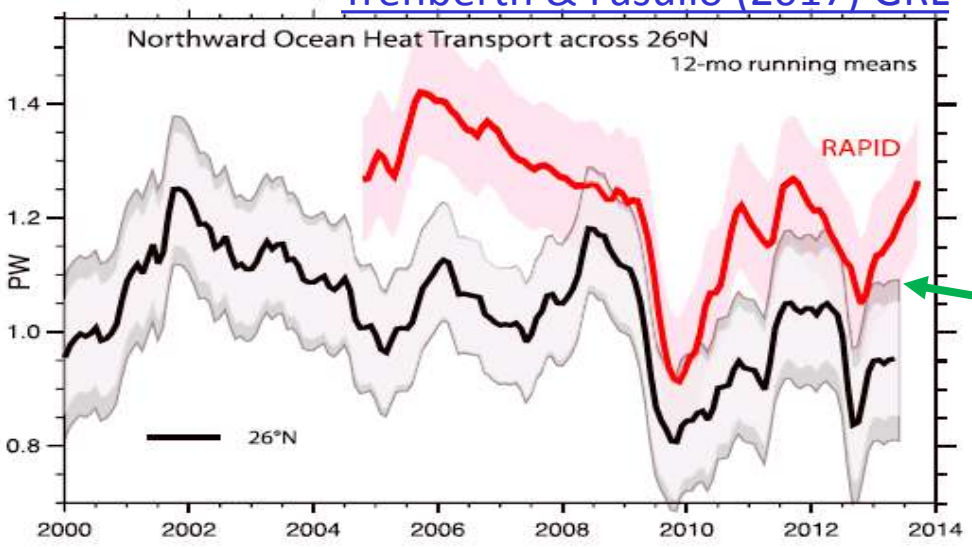
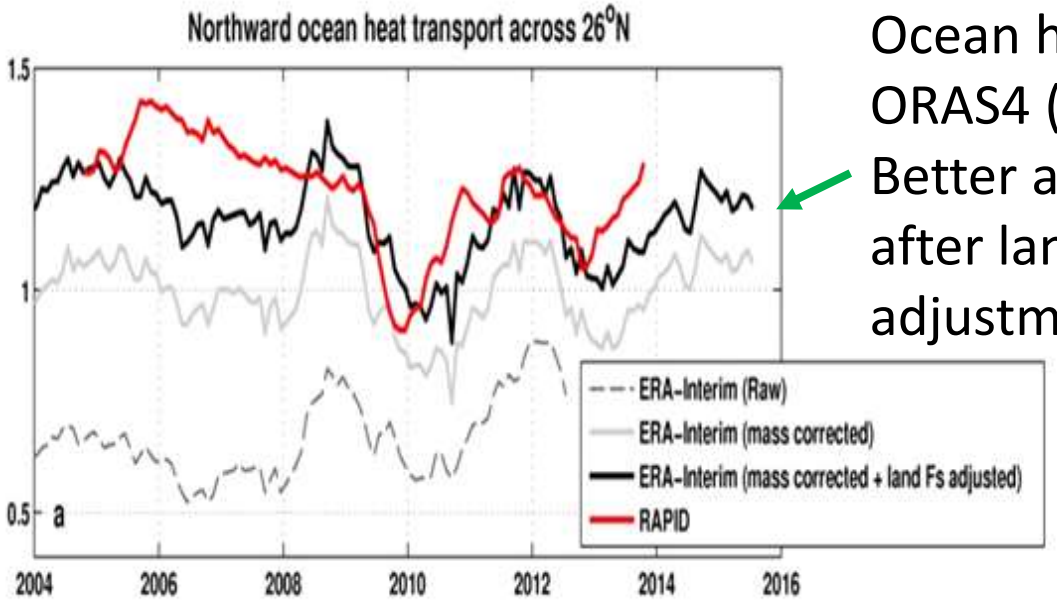
Trenberth & Fasullo (2017) GRL



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

Coupled Energy and Water Cycle

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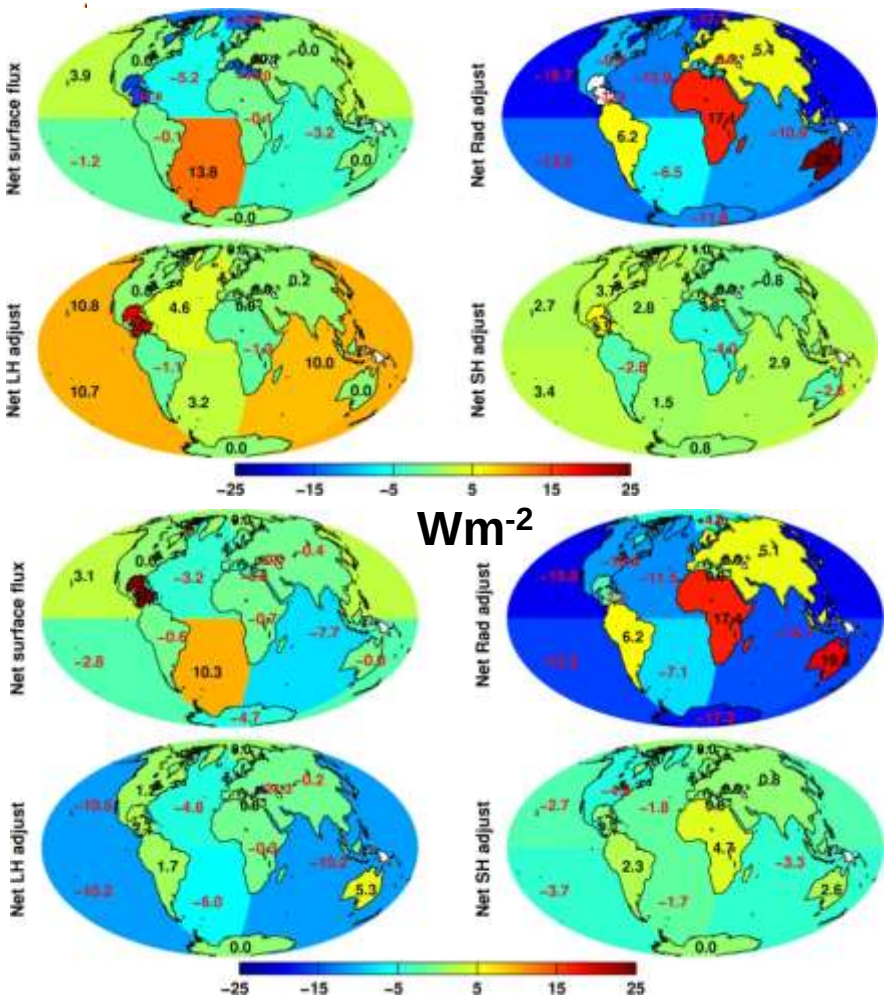
- Variational analysis of TOA and Surface Energy and Water cycles

$$J = (\mathbf{F} - \mathbf{F}_{\text{obs}})^{\mathrm{T}} \mathbf{S}_{\text{obs}}^{-1} (\mathbf{F} - \mathbf{F}_{\text{obs}}) + \frac{(R - R_{\text{obs}})^2}{\sigma_R^2}.$$

- Follows work by L'Ecuyer et al (2015) J. Clim, Liu et al (2015) JGR
- Uses CERES + Multi-EO products (from L'Ecuyer) and ERA Interim transports + N Atlantic/Arctic ocean transport constraint + Land surface heat flux constraint.
- Treats Radiation (SW/LW) and Latent/ Sensible fluxes separately
- Solve over 7 Land areas, 9 Ocean areas with 14 d.o.f. (fluxes) for each region = *224 degrees of freedom*
- Excellent preliminary balanced adjustments to all fluxes
- Could apply these as low resolution adjustments to higher resolution product eg as in Liu et al (2017) JGR

New Results - **See poster by Keith Haines/Chris Thomas**



L'Ecuyer et al Results

Conclusions

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- Extended Top of atmosphere radiation dataset (Allan et al. 2014 GRL)
  - Links between radiative forcing, feedbacks and climate response
  - Understanding volcanic aerosol climate effects (e.g. Malavelle et al. 2017 Nature)
- New method for deriving surface energy flux (Liu et al. 2017 JGR)
  - Combine satellite data with reanalysis energy transports
  - New estimates of hemispheric energy imbalance and ocean heat transports
  - Has increased evaporation in East Pacific contributed to decadal cooling?
- Future work
  - Basin-scale combined energy and water cycle budgets through using variational data assimilation inverse techniques: **see Keith Haines' poster**
  - Tracking changes in ocean heat transports (e.g. vs RAPID array)
  - Understand feedbacks in East Pacific determining decadal climate variability
  - Exploitation of surface energy flux in diagnosing systematic model biases in the Southern Ocean and monsoon regions