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

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

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

Allan et al. 2014 GRL
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

MODIS-Aqua Observations
Cloud water
Droplet size

Malavelle et al. (2017) Nature

Schmidt et al. (2017) in prep
New global surface flux estimates
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?

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

downward LHF
Cross-hemispheric energy transport & precipitation biases

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

- 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
Inferred ocean heat transport@26°N

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 $F_s$ adjustment

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

large uncertainty
Coupled Energy and Water Cycle

- Variational analysis of TOA and Surface Energy and Water cycles

\[ J = (F - F_{\text{obs}})^T S^{-1}_{\text{obs}} (F - F_{\text{obs}}) + \frac{(R - R_{\text{obs}})^2}{\sigma^2_R} \]


- 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
Conclusions

• 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