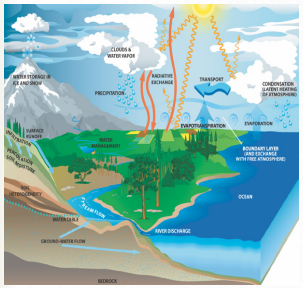
NEWS Climatology Project: The State of the Energy Budget at Continental to Global Scales

Tristan L'Ecuyer[1], Matthew Rodell[2], Hiroko Beaudoing[3], William Olson[4], Bing Lin[5], Seiji Kato[5], Carol Anne Clayson[6], Eric Wood[7]

1: University of Wisconsin-Madison (tristan@aos.wisc.edu); 2: NASA Goddard Space Flight Center; 3: Earth System Science Interdisciplinary Center/Univ. of Maryland; 4: Joint Center for Earth Systems Technology/Univ. Maryland Baltimore County; 5: NASA Langley Research Center; 6: Florida State University; 7: Princeton University

What is the NEWS Energy and Water Cycle Climatology Project?



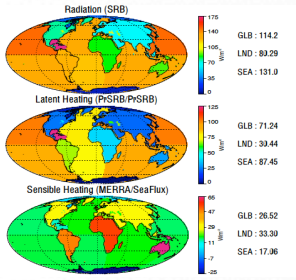
Why? Our ability to predict climate change fundamentally depends on our ability to model the processes that govern exchanges between key reservoirs in the global energy budget and their coupling to corresponding changes in the water cycle.

What? The goal of the NEWS Climatology Project is to compile benchmark estimates of water and energy fluxes in the present day climate providing the science community with a critical resource for evaluating energy balance and water cycles in climate models.

How? Combine state-of-the-art estimates of component fluxes from contemporary Earth-observing satellites to document the energy and water cycles on continental and monthly scales. Use rigorous estimates of uncertainties in each flux to establish optimal budgets that satisfy global energy and water balance constraints.

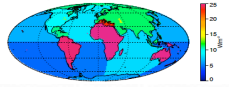
Underpinning NEWS Datasets

Datasets employed in this study were primarily developed by investigators in the NASA Energy and Water cycle Study (NEWS) and many can be accessed through the NEWS website, http://www.nasa-news.org. To document the current state of the climate system while minimizing the impact of interannual variability on ENSO time-scales the analysis targets the most up-to-date observational datasets from the 10 year period from 1998-2007. Surface radiative fluxes are defined based on the GEWEX SRB and ISSCP FD products. Latent and sensible heating estimates over the ocean are obtained from the SeaFlux dataset while Princeton University latent heat products are used over land. The MERRA and GLDAS reanalysis products are also used to fill gaps in observational datasets and establish error bounds.



Examples of surface flux datasets: (a) net surface radiation from the GEWEX SRB product, (b) latent heating from the Princeton SRB dataset, and (c) sensible heating from MERRA (land) and SeaFlux (ocean).

Combined SFC Flux Uncertainties

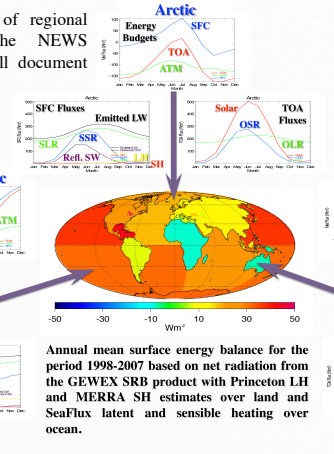


A concerted effort has been made to assess the uncertainties in each product through a combination of product inter-comparisons, external validation, and rigorous sensitivity studies.

This study was made possible through the efforts of the NASA Energy- and Water- cycle Study that has been focusing for over five years on the difficult task of *Integration* of disparate, though connected through the water and energy cycle, NASA satellite and model data.

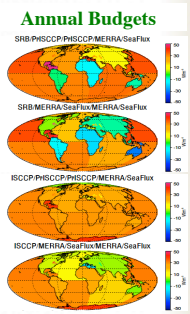
Continental Energy Budgets and their Annual Cycle

Given the importance of regional climate variability, the NEWS Climatology Project will document all components of the energy and water cycle on continental and monthly scales.



Annual mean surface energy balance for the period 1998-2007 based on net radiation from the GEWEX SRB product with Princeton LH and MERRA SH estimates over land and SeaFlux latent and sensible heating over ocean.

Annual Budgets: Surface radiative fluxes often exceed latent and sensible heat fluxes at the surface regardless of the combination of datasets chosen but the resulting bias is within the cumulative uncertainties in the component datasets.



Constrained Optimization of the Global Energy and Water Cycles

A variational framework makes it possible to test the extent to which balance can be achieved within derived uncertainties. By optimally adjusting component fluxes based on rigorous uncertainty estimates it is possible to supply the modeling community with products that satisfy global balance constraints.

General budget equation:

$$R = \sum_{i=1}^{M} F_i - \sum_{o=1}^{N} F_o$$

"Optimal" solution minimizes the cost function:

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

Minimum occurs when:

$$\mathbf{F} = \mathbf{F}_{obs} - \mathbf{S}_{\mathbf{F}} \mathbf{K}^{\mathrm{T}} \mathbf{S}_{\mathbf{y}}^{-1} \left(R_{obs} - \mathbf{K}\mathbf{F}_{obs}\right)$$

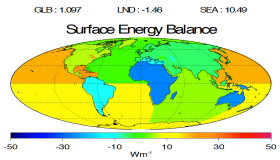
$$\mathbf{S}_{\mathbf{F}} = \left(\mathbf{K}^{\mathrm{T}} \mathbf{S}_{\mathbf{y}}^{-1} \mathbf{K} + \mathbf{S}_{obs}^{-1}\right)^{-1}$$

Application to Surface Energy Balance

$$S = F_{LW}^{\downarrow} + F_{SW}^{\downarrow} - F_{LW}^{\uparrow} - LH - SH$$

	Solar Radiation	Thermal Radiation	Latent Heat	Sensible Heat	Residual
Original	171 (15)	343 (9)	71 (15)	25 (7)	19
Optimal	160 (12)	341 (8)	74 (12)	27 (7)	1

Optimal observational estimates of surface energy balance (uncertainties in parentheses). Raw observations and errors are also presented – both have value for model comparisons.



Annual mean surface energy balance after optimization. Here all fluxes have been simply scaled by the magnitudes of the global adjustments. A more comprehensive regional-scale budget optimization is currently underway.

Summary

- The NEWS Energy and Water Cycle Climatology Project will provide new estimates of the state of the energy and water cycles on continental and monthly scales.
- With rigorous uncertainty estimates and the novel optimization approach adopted for applying budget constraint, these products are ideal for evaluating the representation of present day climate in GCMs.
- Ongoing work seeks to expand the optimization procedure to exploit the strong coupling between the energy and water cycles.
- Results will be published in a manuscript in preparation for BAMS: L'Ecuyer, T. S, M. Rodell, H. Beaudoing, W. Olson, B. Lin, S. Kato and the NEWS Energy and Water Cycle Climatology Working Group, 2011: "Observational Constraints on the Earth's Energy Balance".