Anticipated Improvements to Net Surface Freshwater Fluxes from GPM

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Abstract

Evaporation and precipitation over the oceans play very important roles in the global water cycle, upper-ocean heat budget, ocean dynamics, and coupled ocean-atmosphere dynamics. In the conventional representation of the terrestrial water cycle, the assumed role of the oceans is to act as near-infinite reservoirs of water with the main drivers of the water cycle being land-atmosphere interactions in which excess precipitation (P) over evaporation (E) is returned to the oceans as surface runoff and baseflow. Whereas this perspective is valid for short space and time scales -- fundamental principles, available observed estimates, and results from models indicate that the oceans play a far more important role in the large-scale water cycle at seasonal and longer timescales. Approximately 70-80% of the total global evaporation and precipitation occurs over oceans. Moreover, latent heat release into the atmosphere over the oceans is the major heat source driving global atmospheric circulations, with the moisture transported by circulations from oceans to continents being the major source of water precipitating over land. Notably, the major impediment in understanding and modeling the oceans' role in the global water cycle is the lack of reliable net surface freshwater flux estimates (E - P fluxes) at the salient spatial and temporal resolutions, i.e., consistent coupled weekly to monthly E - P gridded datasets.

Although there are a number of research and operational groups which produce observational and simulated P and E datasets, there has been no systematic effort devoted to producing consistent and carefully quality controlled E - P flux datasets, particularly lengthy observational time series based on imposing physical constraints derived from known properties of the atmospheric boundary layer and oceanic mixed layer. The main problem with using current observational datasets directly for freshwater flux estimates, is that E - P is a differential term, arithmetically derived from two separate quantities, each with its own unique variance and uncertainty properties. The foremost attributes of P, in terms of its spatial and temporal field characteristics, are its large variational properties -- i.e., its fields contain high-amplitude peaks and valleys in both space and time. On the other hand, E tends to contain low-amplitude spatial and temporal variations. Therefore, to avoid producing an E - P difference quantity whose inherent property is simply that of noise uncertainty passed on from the two independent E and P terms, each with its own distinct properties, it is essential to eliminate first-order spatial-temporal discontinuities in the E and P estimates separately, and then to remove the non-concomitant systematic errors -- to the extent possible. There are a number of sources for discontinuities in compiling E and P time series, ranging from satellite-instrument changes, sensor sensitivity

degradation (calibration drift), algorithm-to-algorithm differences, inconsistencies in rain existence tests, differences in light rain thresholds, differences in maximum allowable rainrate thresholds, imprecise averaging schemes, etc.

In order to quantitatively study the oceans' role in the context of global and regional water cycles, not only do consistent, high quality P, E, and E - P flux observations need to be made available, but also numerical experiments need to be conducted with coupled atmosphere-ocean models capable of reproducing the salient 4-dimensional freshwater flux structures. It should be recognized that there are existing major problems in using even state-of-the-art models in studying global and regional water cycle processes. A lack of balance in E - P fluxes at the ocean surface is a current shortcoming in global coupled ocean-atmosphere models. When E - P flux corrections are applied to stabilize the ocean model state, the corrections are often as large as the average E - P flux itself -- while the uncertainty of E - P fluxes at the ocean-atmosphere interface approach 100% of the variance. Partitioning this uncertainty between atmospheric and oceanic sources is currently a matter of guesswork, and thus remains an important research topic in itself. Therefore, reliable and accurate P, E, and E - P flux observations, whether based on *in situ* or remotely sensed measuring systems, in conjunction with appropriate quality-control procedures, would provide a tremendous enhancement to improving coupled atmosphere-ocean models.

The research implicit in this topic is an important element of the Science Implementation Plan of the Global Precipitation Measurement (GPM) Mission. The foremost elements of this plan are improving P and E measurement requirements, and developing adequate data quality checks, error reduction, and error analysis (quantifying uncertainty) so as to enable improved P, E, and E - P flux information. The GPM Mission will expand the scope of precipitation measurement through use of a constellation of 9 satellites provided by an international consortium of space agencies, the main satellite being the "GPM Core Satellite" carrying a new dual-frequency Ku-Ka band precipitation radar and an advanced, multifrequency passive microwave radiometer. The eight other constellation satellites will consist of: (1) a set of dedicated satellites with specialized rain-detection capabilities flying in a mix of sun-synchronous and non-sun-synchronous orbits, (2) a set of operational/experimental satellites carrying similar passive microwave radiometers equipped with rain-detection frequencies, and (3) a set of backup operational satellites, to be used in case any frontrunner constellation member(s) is(are) lost, and carrying passive microwave radiometers equipped with frequencies specialized for temperature/moisture sounding but adequate for rain-detection, albeit with greater precipitation retrieval uncertainties.

The purpose of the constellation approach is to achieve 3-hour sampling at any point on the globe continuously, noting that the Core Satellite's primary roles are (1) to establish an observational database enabling a relatively complete understanding of the physical/microphysical nature of precipitation life cycles, the generation of latent heating, and the acquisition of space-time variations in rain microphysics, and (2) stemming from improvements in the physical retrieval of rainrates, serve as a calibration reference to the other constellation satellites, thus ensuring bias-free global precipitation measurements. With this new observational capability and the use of physical constraints to reduce errors in E - P quantities, improvements in the estimation of freshwater fluxes will be made possible.

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