J2.6 EVALUATIONS OF ESTIMATES OF FRESHWATER DISCHARGE FROM CONTINENTS

Kevin E. Trenberth and Aiguo Dai
National Center for Atmospheric Research*, Boulder, CO

1. INTRODUCTION

Four new estimates of annual and monthly mean values of continental freshwater discharge into the individual and global oceans at 1°resolution are compared. The most accurate estimate is based on stream-flow data from the world's largest 921 rivers, supplemented with estimates of discharge from unmonitored areas based on the ratios of drainage areas. Simulations using a river transport model (RTM) from the NCAR Community Climate System Model, forced by a runoff field, were used to derive the river mouth outflow from the farthest downstream gauge records.

The other estimates utilize RTM simulations forced by different runoff fields (i) based on observed stream-flow and a water balance model (Fekete et al. 2000); (ii) based on estimates of precipitation P minus evaporation E computed as residuals from the atmospheric moisture budget using atmospheric reanalyses from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP) and iii) the European Centre for Medium Range Weather Forecasts (ECMWF) (Trenberth et al. 2001).

While $P - E$ is a good proxy of runoff over land in a steady state, it may differ because of changes in storage and, in particular, snow accumulation and melt and infiltration of water into the ground. We adopted a simple scheme that melts snow at a fixed rate whenever the climatological mean surface temperature is above 0°C. On a day-to-day basis, runoff depends upon the frequency, sequence and intensity of precipitation and not just amount, as these factors alter the extent to which soils can soak up rain. Changes in soil moisture can be important, and it is only on annual and longer time scales that conditions may approximate a steady state. Here we present only long-term means, for 1979-1993 for ECMWF and 1979-1995 for NCEP.

Tests are made using independent estimates of P to infer E and this can be used as a test of the results, since E should be positive. Similarly, there is a requirement that P should exceed E over land except where surface flow allows otherwise, such as in Southern California (owing to irrigation). These results show that the main problems are in regions where the atmospheric data are less reliable, such as Africa, parts of Asia, and South America.

*The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Corresponding author address: Dr. Kevin E. Trenberth, NCAR, P.O. Box 3000, Boulder CO 80307.
E-mail: trenbert@ucar.edu

2. COMPARISON OF DISCHARGE INTO OCEAN

When the RTM is forced by the $P - E$ fields derived from the NCEP and ECMWF reanalyses, the simulated station flow rate generally agrees with the observed at most of the major rivers. Substantial differences exist, however, for the world's largest rivers. For example, the simulated flow rate is 3063 and 3833 km^3 yr^{-1} for the Amazon at Obidos in the NCEP and ECMWF cases, and 5083 km^3 yr^{-1} for the Fekete et al. runoff, while the observed rate is 5330 km^3 yr^{-1}. In general, the Fekete et al. runoff resulted in better simulated station flow rates, especially for the world's largest rivers. However, the basin-integrated $P - E$ from the reanalyses generally agree with the Fekete et al. runoff provided that we include the effects of snow accumulation and melt, which are important in middle and high latitudes. The results suggest that the monthly $P - E$ fields are reasonable proxies of monthly runoff as long as the areas are large enough.

The full results will be published (Dai and Trenberth 2003) and only one figure is shown here. We compare the meridional profiles of discharge into the oceans from the four estimates at 1° resolution with the previously widely used values of Baumgartner and Reichel (1975) (BR75). The latter derived global maps of annual runoff and made estimates of annual freshwater discharge largely based on stream-flow data from the early 1960s with rather limited station coverage, and areal integration over 5° latitude zones. The comparison (Fig. 1) shows the 1° values along with their accumulated value integrated from the north southwards.

As expected, the continental discharge is dominated by the peak outflows from the world's largest rivers such as the Amazon (∼0.21 Sv at 0.75°S, 1 Sv = 10^6 m^3 s^{-1}), Congo (0.041 Sv at 5.75°S), Orinoco (0.036 Sv at 9.25°N), Changjiang (0.030 Sv at 32.25°N), Brahmaputra/Ganges (0.033 Sv at 24.25°N), Mississippi (0.019 Sv at 30.25°N), and Paraná (0.018 at 34.75°S). The northern mid- to high-latitudes (45–75°N) encompass the largest landmass and many large rivers, such as the Yenisey, Lena, Ob, Amur in Russia, Mackenzie and St. Lawrence in Canada, and Yukon in Alaska. Many of the Russian and Canadian rivers run from south to north and enter the Arctic Ocean. Collectively, these rivers provide a large freshwater discharge into the Arctic, North Atlantic and North Pacific Oceans, thereby affecting the oceanic water budget and circulation, both locally and globally, especially through the thermohaline circulation.

The accumulated discharge for the NCEP $P - E$ case is considerably lower than the others, whereas the BR75 case agrees remarkably well with our estimates based on the stream-flow data, Fekete et al. runoff and ECMWF $P - E$. However, the latitudinal distribution from BR75 at 5° resolution is too smooth and quite unrealistic, as even after smoothing the 1°discharge data using 5°lat running-mean, large differences still exist between the BR75 and our estimates, whereas the agreement among our four different estimates is improved. Further the distribution of BR75 among ocean basins also differs considerably.

3. CONCLUSIONS

The continental discharges into the oceans within each 1°latitude band implied by the Fekete et al. runoff and reanalysis $P-E$ fields agree reasonably well with the river-based estimates, which we regard as the closest to the truth. This is particularly true for the Fekete et al. runoff and ECMWF $P-E$ cases and for the global oceans and the Atlantic Ocean. In general, the NCEP $P-E$ underestimates continental discharge at many latitudes for all the ocean basins except for the Arctic Ocean. Snow accumulation and melt have large effects on the annual cycle of discharge into all the ocean basins except for the Indian Ocean and the Mediterranean and Black Seas. Results suggest that the $P-E$ data from reanalyses may be used to study the interannual to decadal variations in continental discharge.

Acknowledgments. This research was sponsored by NOAA Office of Global Programs grant NA56GP0247, the joint NOAA/NASA grant NA87GP0105 and the NCAR Water Cycle Across Scales Initiative.

References

Baumgartner, A. and E. Reichel, 1975: *The World Water Balance.* Elsevier Scientific Publ. Co., New York, 179pp.+ 31 maps.

Dai, A., and K. E. Trenberth, 2002: Estimates of freshwater discharge from continents: Latitudinal and seasonal variations. *J. Hydrometeor.*, in press.

Fekete, B. M., C. J. Vörösmarty, and W. Grabs, 2000: Global composite runoff fields based on observed river discharge and simulated water balances. Global Runoff Data Centre (GRDC) Rep. No. 22, Germany, 39 pp. + annex 77 pp. [Available on-line from http://www.bafg.de/grdc.htm]

Trenberth, K. E., J. M. Caron and D. P. Stepaniak, 2001: The atmospheric energy budget and implications for surface fluxes and ocean heat transports. *Clim. Dyn.*, **17**, 259–276.

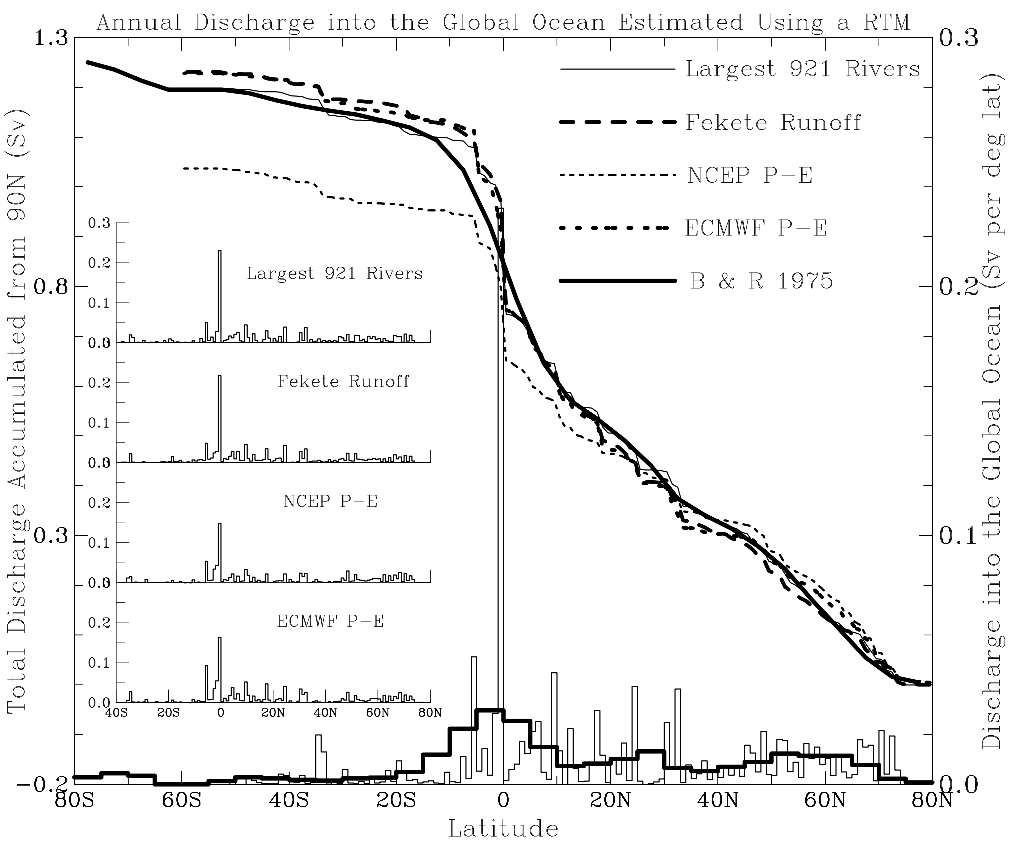

Fig. 1. Estimates of annual mean continental freshwater discharge into the global oceans for each 1°latitude zone (right ordinate and lower stepwise lines, and the insert) and the cumulated discharge starting from 90°N (upper curves). Each line pattern represents an estimate based either on the largest 921 rivers (thin solid line) or on a runoff field (dashed lines), which was used to force a river transport model to derive the discharge. Also shown is an estimate from Baumgartner and Reichel (1975, thick solid line).