An enhanced river routing scheme for the closure of global water budget

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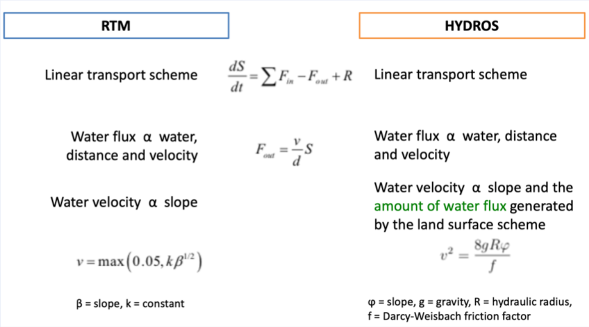
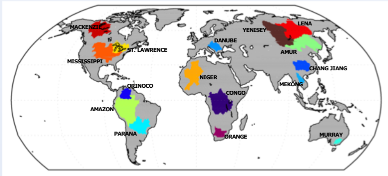
The availability of a realistic water flow in coupled Earth System Models is a powerful instrument to evaluate modeled land surface, a crucial component of the global climate whose properties are often simplified by heavy parameterization. HYDROS (HYdro-Dynamic ROuting Scheme) is a new concept of river routing model, that uses time-varying flow velocity associated with the amount of lateral runoff generated by the ESM's land component and the flow through the river system. Compared to the scheme currently in place, HYDROS show improvements in the simulation of mean annual discharge phase, especially for the Arctic rivers and the Amazon. In the Mississippi case, an extreme flood episode is better caught by the new representation, indicating that the improved flow velocity better catches the discharge peaks after extreme rainfalls. The new routing model is not able to improve the volumes of simulated river discharge, whose magnitude depends on the ability of the ESM land surface scheme to generate correct surface and sub-surface runoff. Once implemented in coupled mode, HYDROS will guarantee a plausible amount and timing of freshwater discharge into the global ocean, unveiling possible unresolved feedback mechanisms occurring in proximity of river mouths.

The old and the new routing schemes



The new scheme aims at overcoming one of the current major limitations of global river routing models, that is the use of time-independent flow velocities parameterized as a function of topography. Through the imposition of hydraulic equations, HYDROS defines a time-varying flow velocity associated with the amount of lateral runoff generated by the ESM's land component and the flow through the river system.

Drainage Basins



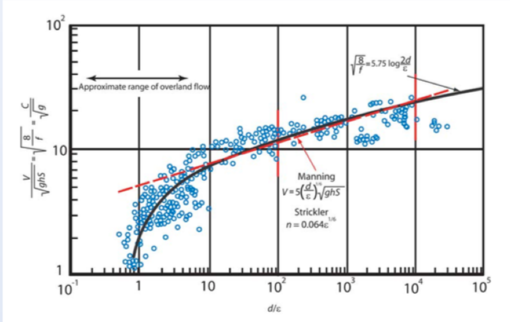
HYDROS calculates time-dependent flow velocities through the hydraulic Darcy-Weisbach equation.

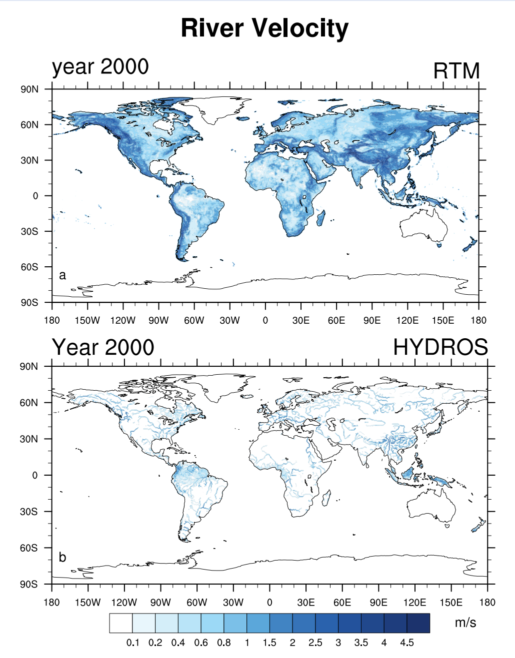
$$v^2 = \frac{8gR\varphi}{f}$$

Two main reasons drove this approach:
- differently from some empirical approaches (i.e. Manning formula), the equation is thoretically based;
- Resistance to flow given by Darcy-Weisbach is demonstrated to be appropriate both for overland and river flow.

f is the so-called friction factor (see figure), obtained by the Chezy resistance factor
R is the hydraulic radius ($\frac{Section}{Wet\ Perimeter} = \frac{d*w}{2d+w}$), where d (depth) is calculated, and depends on the amount of inflow, while w (width) is parameterized.
ε is the roughness height, which depends on the type of soil and vegetation found in the region where the river flows.

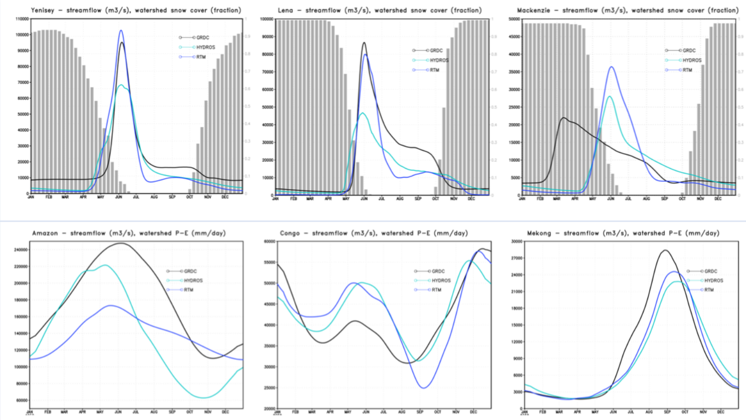
The friction factor





In the new scheme, the overland flow velocity is much slower than in-bed velocity. In this way it is possible to recognize river beds in a global map of flow velocity

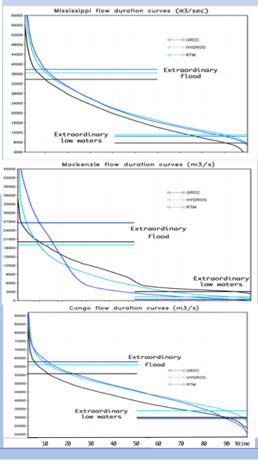
Annual cycle of river discharge



The amount of accumulated snow and the timing of its melt is crucial for Arctic river discharges.
Both RTM and HYDROS
-> realistic peak timing for the Siberian rivers;
-> delayed peaks for Alaskan rivers.
RTM realistic peak amounts
HYDROS more realistic delayed water release.

Tropical and Monsoon rivers are rather realistic in both routing schemes.
Major differences in the Amazon river: the annual cycle is reduced in RTM, while HYDROS is able to catch the sinusoidal annual trend.

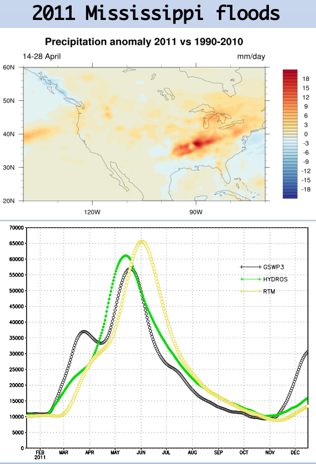
Flow duration curves



A flow duration curve is a plot of discharge vs. percent of time that a particular discharge was equaled or exceeded. The area under the FDC gives the average daily flow, and the median daily flow is the 50% value. This diagnostic is key in hydraulic applications since allows to graph flood and drought probability. FDC simulated by HYDROS are considerably improved for Arctic rivers, in other regions both models have reasonable performances.

2011 Mississippi floods

The Mississippi floods in May 2011 were among the largest and most damaging ever recorded. In April 2011, two major storm systems discharged record rainfalls on the Mississippi River watershed. When that additional water combined with the springtime snowmelt, the river and many of its tributaries began to swell to record levels by the beginning of May. On May 17-18, the Vicksburg station set an all-time discharge record of over **65000 m3/s.**



MAIN CONCLUSIONS

HYDROS operates on river velocity computation;
Differently from RTM, HYDROS accounts for friction and hydraulic radius in the velocity computation;
HYDROS presents a velocity pattern more similar to rivers pattern compared to RTM;
HYDROS has improved representation of river discharge seasonal cycle in tropical regions;
RTM better catches peaks at high latitudes, but HYDROS shows more realistic water release;
HYDROS improves the timing of flood peaks in mid-latitudes.

References:
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