HyMAP routing model and its performance in the Land Information System framework

Augusto Getirana

Hydrological Sciences Laboratory, NASA Goddard Space Flight Center
ESSIC, University of Maryland

Contributors
David Mocko, Sujay Kumar, Hahn Jung, Amy McNally

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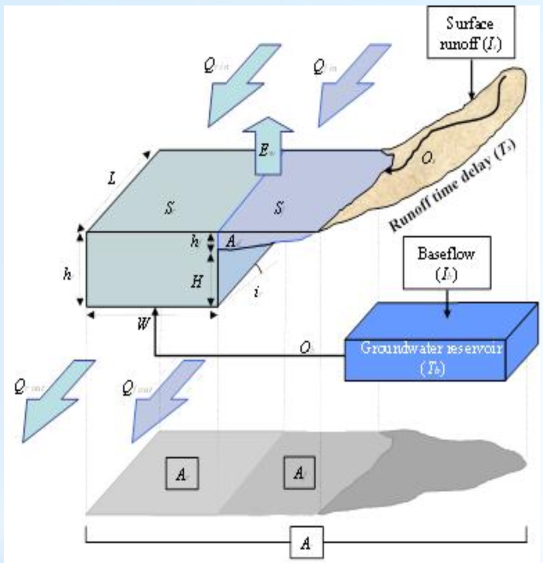
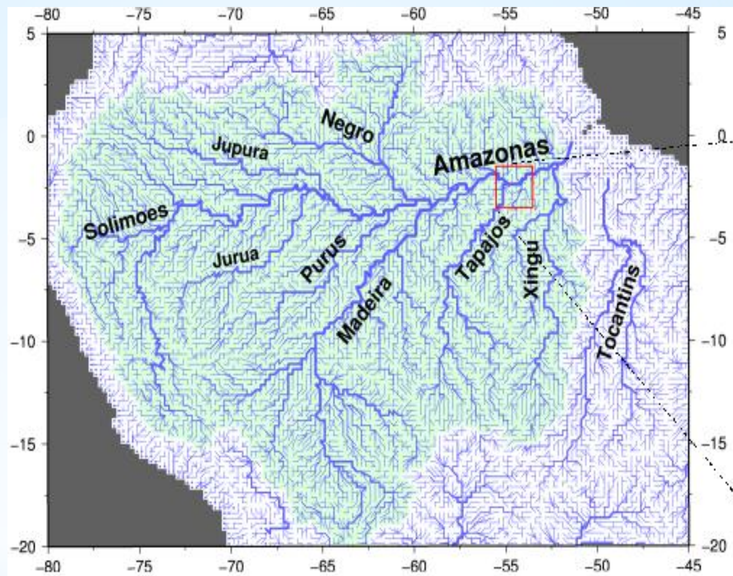
PRESENTATION SUMMARY

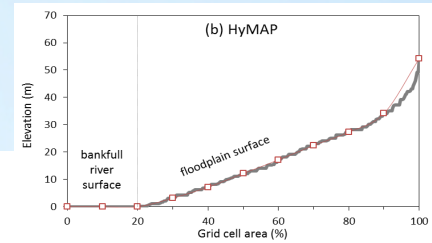
1. Brief description of HyMAP
2. HyMAP in LIS
3. Recent applications of LIS-HyMAP (public release)
4. HyMAP2 (in development) and applications

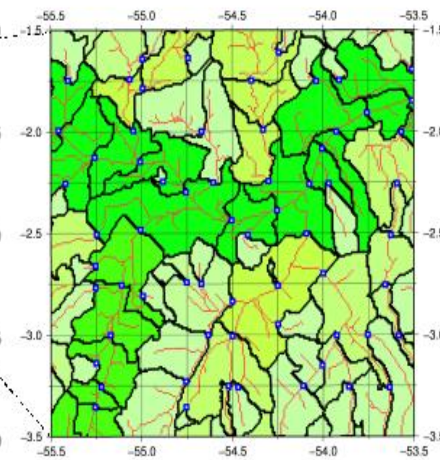
* Brief description of HyMAP

THE HYMAP MODEL









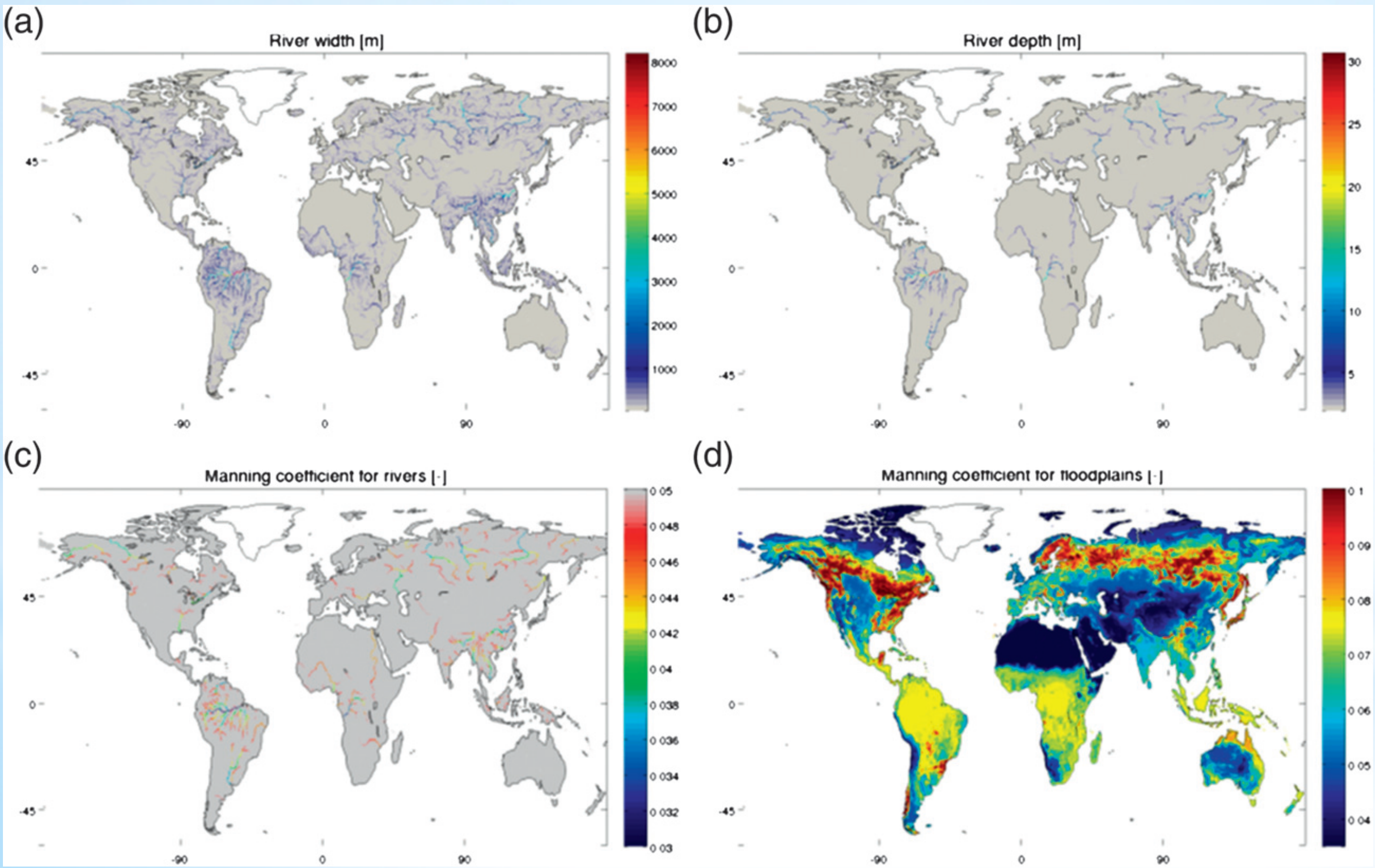
- Global scale;
- Adjustable spatial and temporal resolutions;
- Composed of four modules accounting for:

(1) the surface runoff and baseflow time delays;
(2) a river-floodplain interface;
(3) flow routing in river channels and floodplains; and
(4) evaporation from open water surfaces.

Model outputs:

- **Surface water storage** (rivers and floodplains);
- **Water depth (**rivers and floodplains);
- **Discharge** (rivers and floodplains);
- **Flow velocity (**rivers and floodplains);
- **Flooded area**;
- **Evaporation** from open water surfaces.

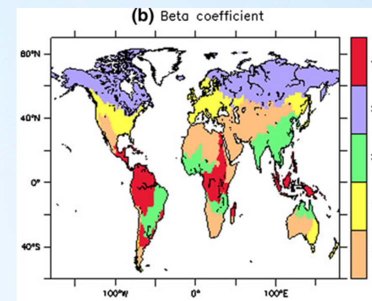
HYMAP PRAMETERS



River width and depth vary as a function of the mean discharge Qmed

$$W = \max(10, \quad \beta \times Q_{med}^{0.5})$$

$$H = \max(2.0, \quad \alpha \times W) \quad \alpha = 3.73 \times 10^{-3}$$



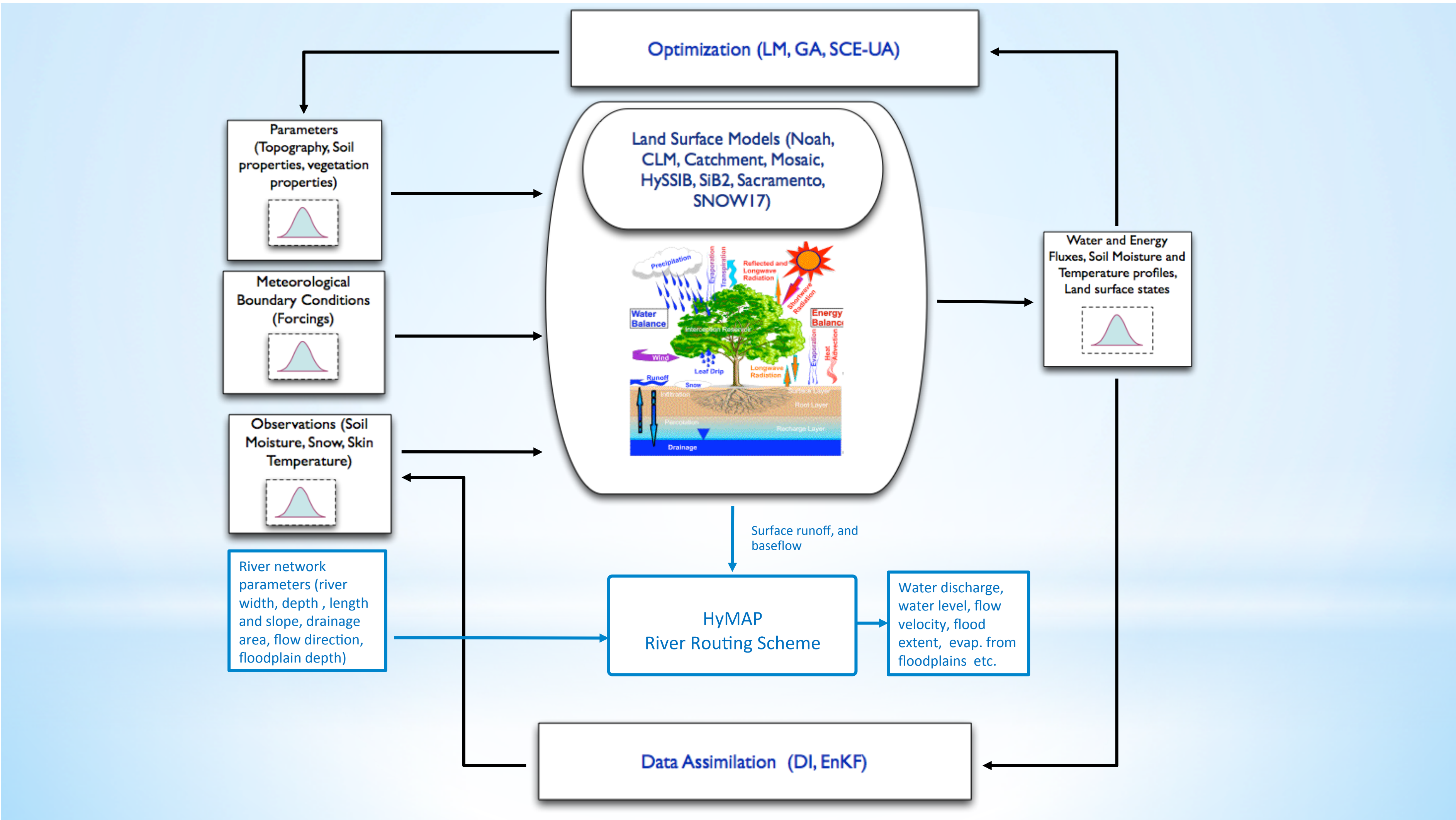
Decharme et al. (2012, ClimDyn)

The **Manning coefficient for river channels** varies as a function of the river depth;

The **Manning coefficient for floodplains** is spatially distributed as a function of a static land cover types as defined in ECOCLIMAP (Meteo-France).

Draining area, elevation profile, river slope and length are derived from the 1-km HydroSHEDS using the FLOW upscaling algorithm (Yamazaki et al., 2009, WRR).

* HyMAP in LIS


Optimization (LM, GA, SCE-UA)
Parameters (Topography, Soil properties, vegetation properties)
Meteorological Boundary Conditions (Forcings)
Observations (Soil Moisture, Snow, Skin Temperature)
Land Surface Models (Noah, CLM, Catchment, Mosaic, HySSIB, SiB2, Sacramento, SNOW17)
Water and Energy Fluxes, Soil Moisture and Temperature profiles, Land surface states
Surface runoff, and baseflow
River network parameters (river width, depth , length and slope, drainage area, flow direction, floodplain depth)
HyMAP River Routing Scheme
Water discharge, water level, flow velocity, flood extent, evap. from floodplains etc.
Data Assimilation (DI, EnKF)

FEATURES IN LIS-HYMAP PUBLIC RELEASE

- ✓ Global parameters available at numerous spatial resolutions (from 0.05 to 0.25 degrees);
- ✓ HyMAP runs in either online (simultaneously with LSM) or offline (forced with LSM outputs) modes;
- ✓ Coupled with all LSMs (recently included LSMs might not have been coupled yet);
- ✓ Offline runs adapted to LIS, NLDAS, GLDAS and ECMWF outputs;
- ✓ Forecast and ensemble modes;
- ✓ Grid-based computation;
- ✓ Runs are currently performed using a single processor.

LIS-HYMAP OPTIONS

HyMAP options in the lis.config file (public release)

```
#HYMAP router
Routing model:             "HYMAP router"


HYMAP routing model time step:               "30mn"
HYMAP routing model output interval:         "1da"
HYMAP routing model restart interval:        "1mo"

HYMAP routing method:                       kinematic
HYMAP run in ensemble mode:                 0
HYMAP routing model linear reservoir flag:  1
HYMAP routing model evaporation option:     1  #1=do not compute, 2=compute
HYMAP routing model restart file:     none
HYMAP routing model start mode:              colstart
```

LSM/Met forcing options for HyMAP offline mode

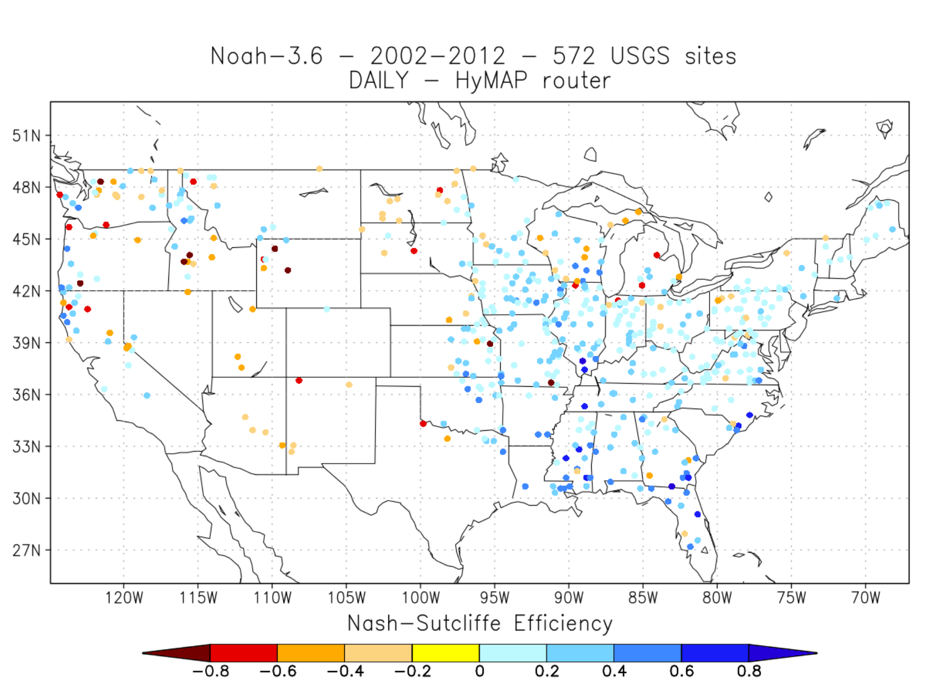
```
Land surface model:                         none #"CLSM F2.5"
Met forcing sources:                        none  #"MERRA2"

TEMPLATE model timestep:                         "30mn"

External runoff data source:   "LIS runoff output"
LIS runoff output directory:   './CLSM/005/SPINUP/'
LIS runoff output interval:    '1da'
```

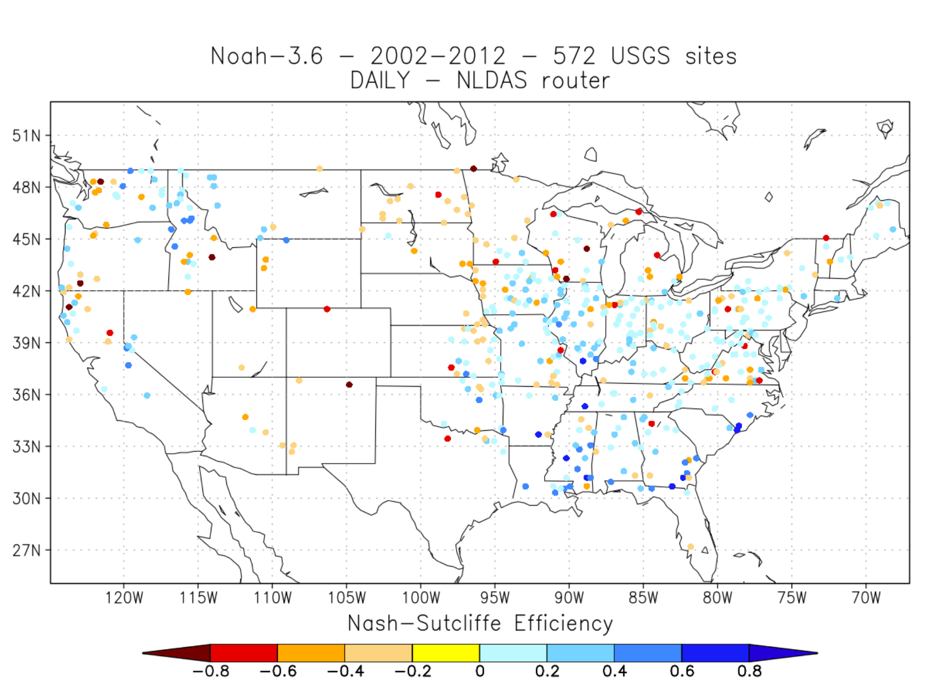
CURRENT PROJECTS USING LIS-HYMAP

1. GLDAS (M. Rodell, GSFC)
2. NLDAS (Multi-agency)
3. NCA-LDAS (M. Jasinski, GSFC)
4. FLDAS (C. Peters-Lidard, GSFC; J. Verdin, USGS)
5. WELDAS (A. Getirana, GSFC)
6. SALDAS (B. Zaitchik, JHU)
7. Peru/Ecuador Malaria Early Warning System (B. Zaitchik, JHU)
8. HMA (High Mountain Asia: S. Kumar, GSFC)
9. FAME (C. Peters-Lidard, GSFC)
10. SWOT MIP (C. David, JPL)

* Recent applications of LIS-HyMAP - public release

OPERATIONAL TRANSITION FOR THE NEXT PHASE OF NLDAS

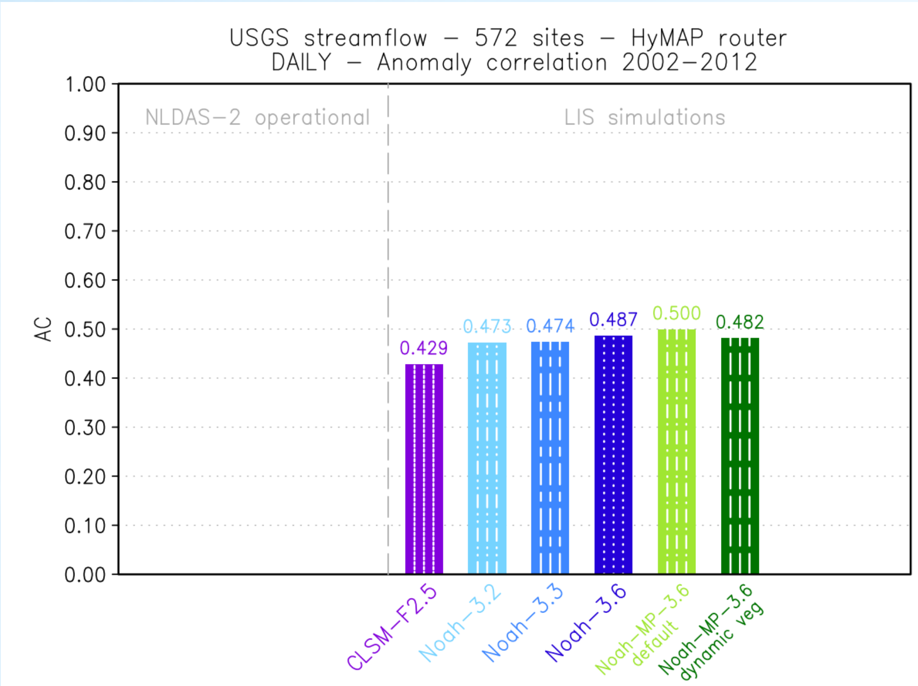


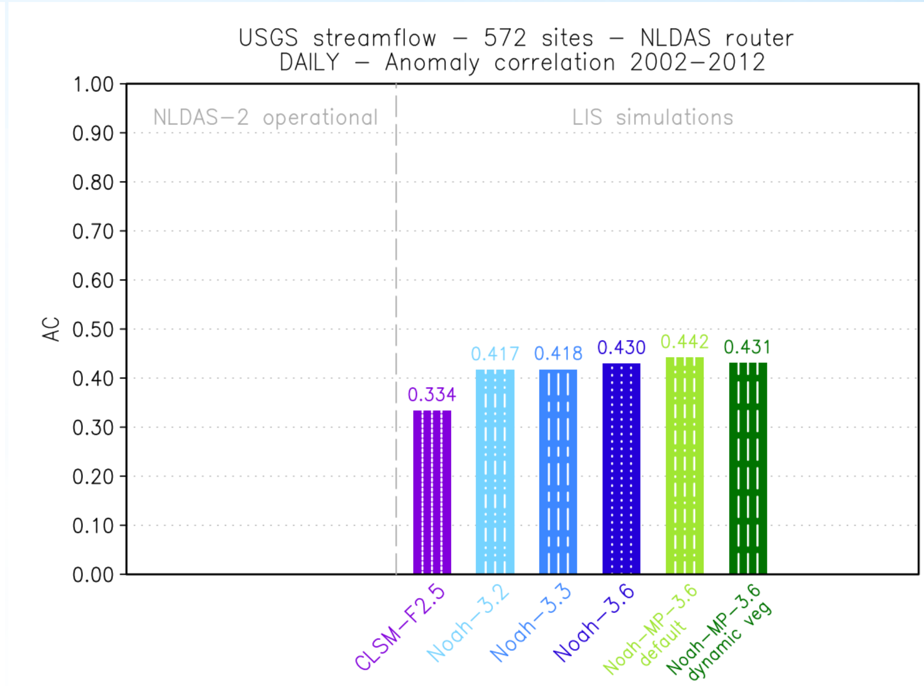


NSE values tend to be higher with the HyMAP router, especially in the Midwest and Mid-Atlantic.
We expect further improvement with HyMAP after additional parameter/physics refinement.

Courtesy: D. Mocko

OPERATIONAL TRANSITION FOR THE NEXT PHASE OF NLDAS

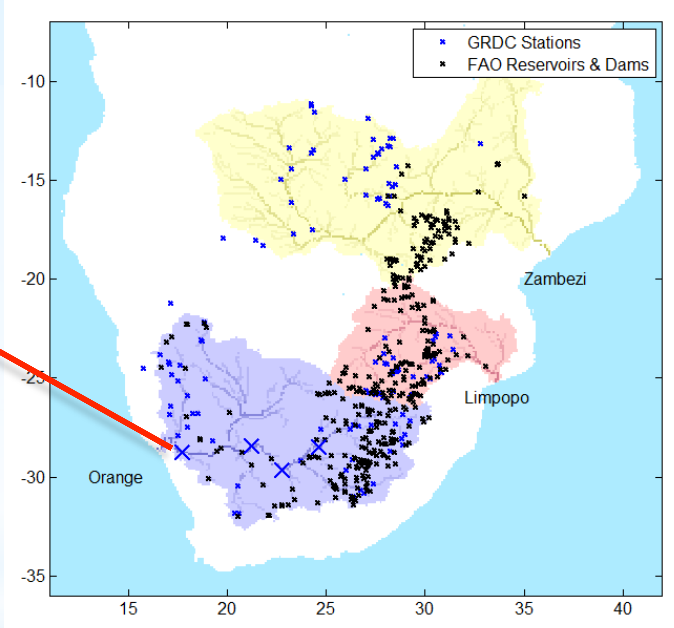


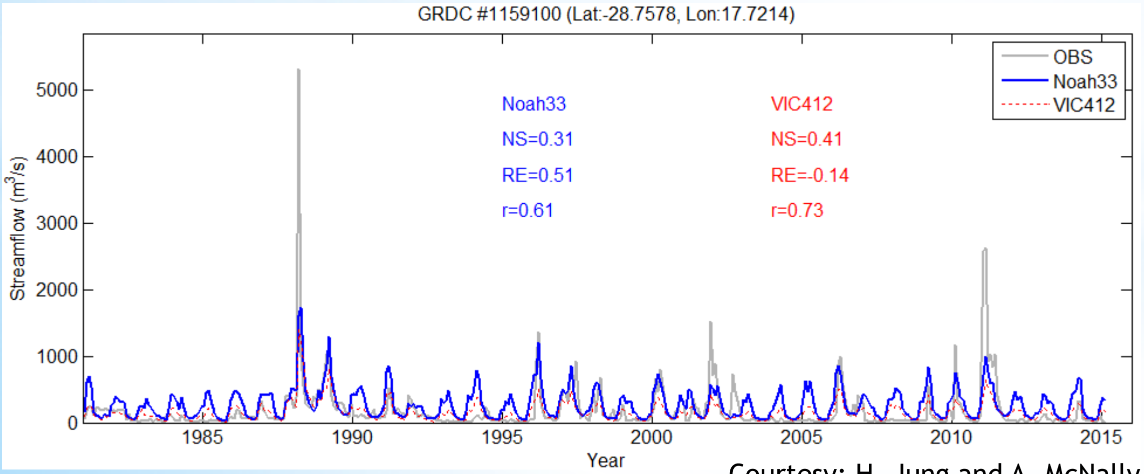


The daily AC values are higher using the HyMAP router for all LSMs.
Noah-3.6 and Noah-MP default tend to have the highest AC values.

Courtesy: D. Mocko

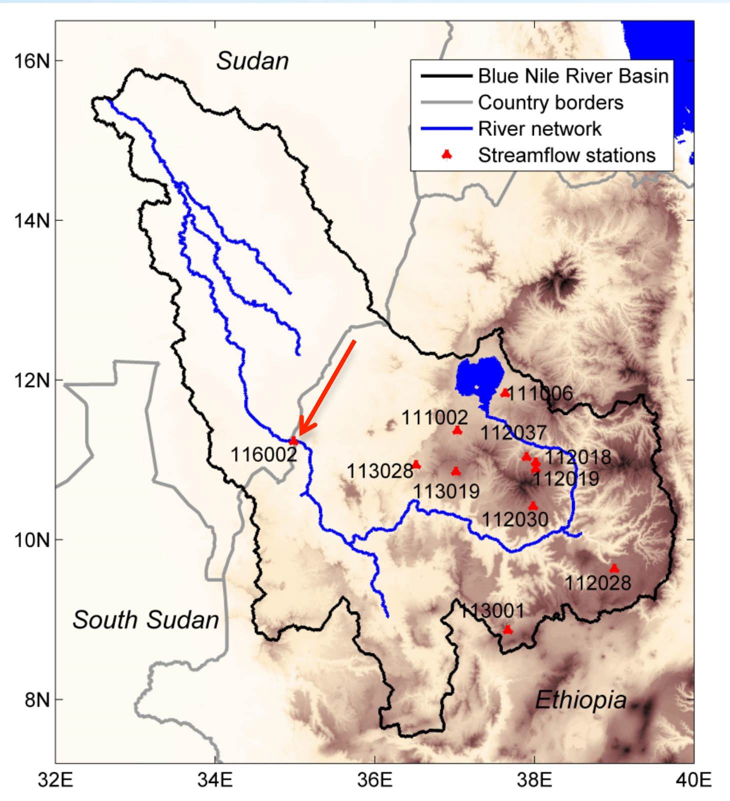
STREAMFLOW SIMULATIONS IN SOUTHERN AFRICA (FLDAS)



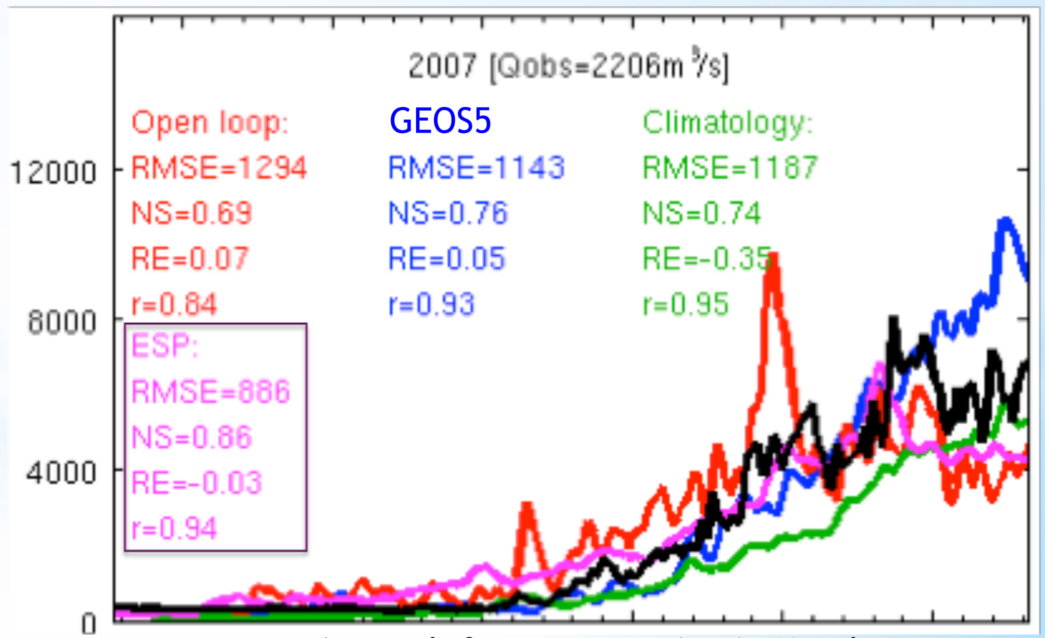


Courtesy: H. Jung and A. McNally

STREAMFLOW FORECAST OVER THE BLUE NILE RIVER (FAME)



Diem station (~175,000km2)
Catchment LSM
HyMAP kinematic wave
MERRA2+CHIRPS
15-min time step
0.10-degree



6-month forecast starting in March

* HyMAP2 (in development) and applications

LATEST IMPROVEMENTS

- ✓ Inclusion of the local inertia formulation and adaptive time steps (Bates et al., 2010);
- ✓ Hybrid runs, spatially combining both the kinematic wave and local inertia using flow type maps;
- ✓ Reservoir operation module using radar altimetry data;
- ✓ Vector-based computation.

LIS-HYMAP2 OPTIONS

HyMAP options in the lis.config file (in development)

```
HYMAP2 routing method:                               "local inertia"
HYMAP2 routing model time step method:     "constant" # "adaptive" #
HYMAP2 routing model adaptive time step alfa coefficient: 0.5

HYMAP2 reservoir operation option: 0
HYMAP2 number of reservoirs: 1
HYMAP2 reservoir operation input time series size: 2
HYMAP2 reservoir operation input directory: ./
HYMAP2 reservoir operation header filename: ./header_test.txt
HYMAP2 reservoir operation input data type: "water level"

HYMAP2 floodplain dynamics: 1
```

EVALUATION OF THE LOCAL INERTIA FORMULATION AND HYBRID RUNS OVER THE AMAZON BASIN

Saint Venant equations:

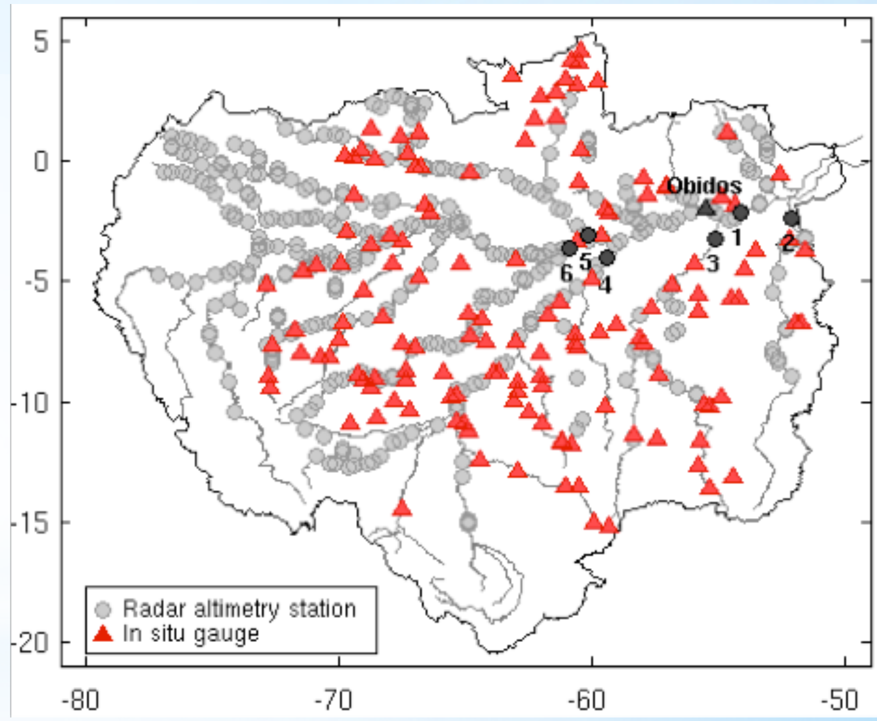
$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

$$\frac{\partial}{\partial x}\left[\frac{Q^2}{A}\right] + \frac{\partial Q}{\partial t} + gA\frac{\partial h}{\partial x} = gAS_o - gAS_f$$

(i) (ii) (iii) (iv) (v)

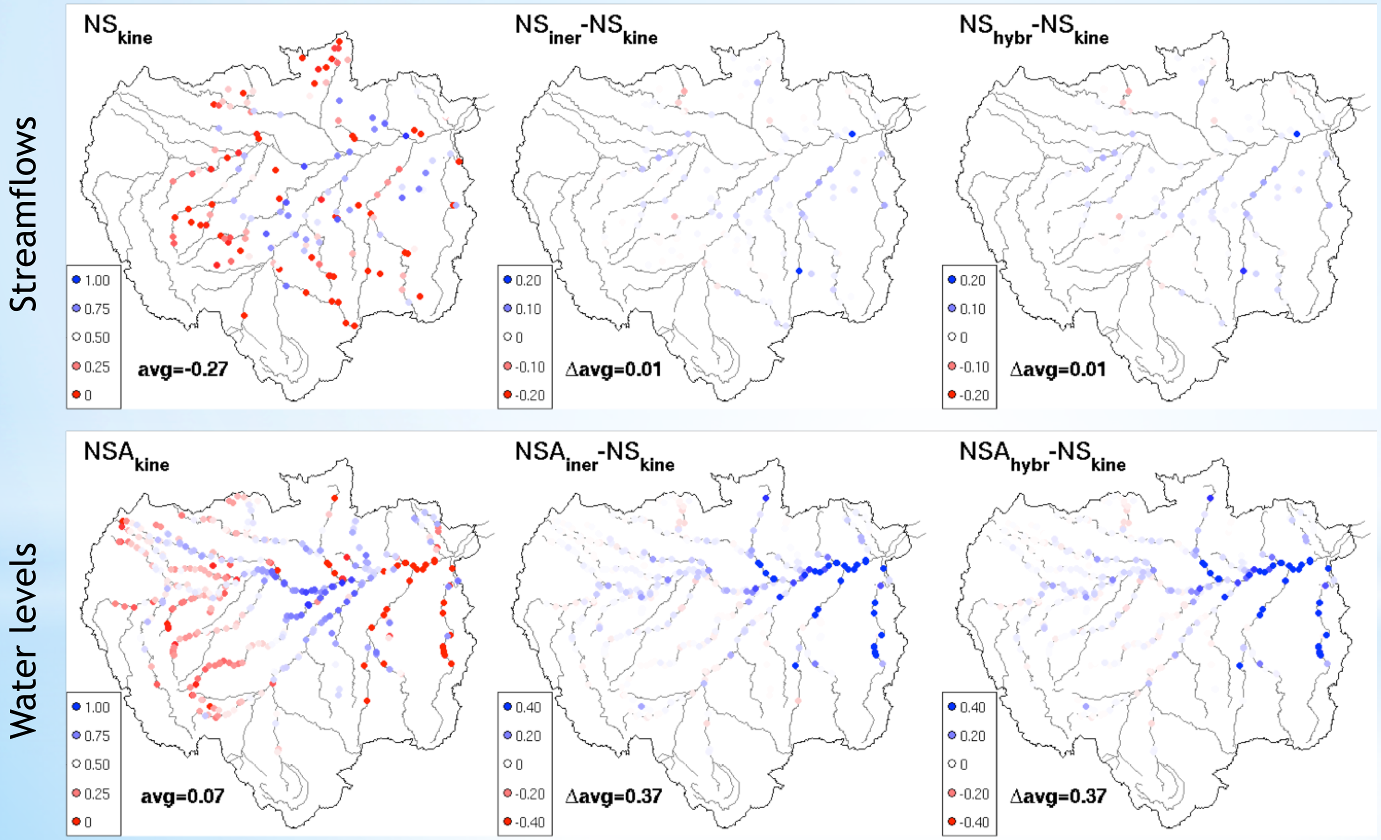
(i) convective and (ii) local inertia with (iii) pressure, (iv) gravity and (v) friction forces

- ➢ Kinematic wave equation: terms (iv) and (v)
- ➢ Local inertia formulation: terms (ii)-(v)
  - ✓ backwater effects; and
  - ✓ numerical stability at longer time steps compared to the diffusive wave equation: terms (iii)-(v)



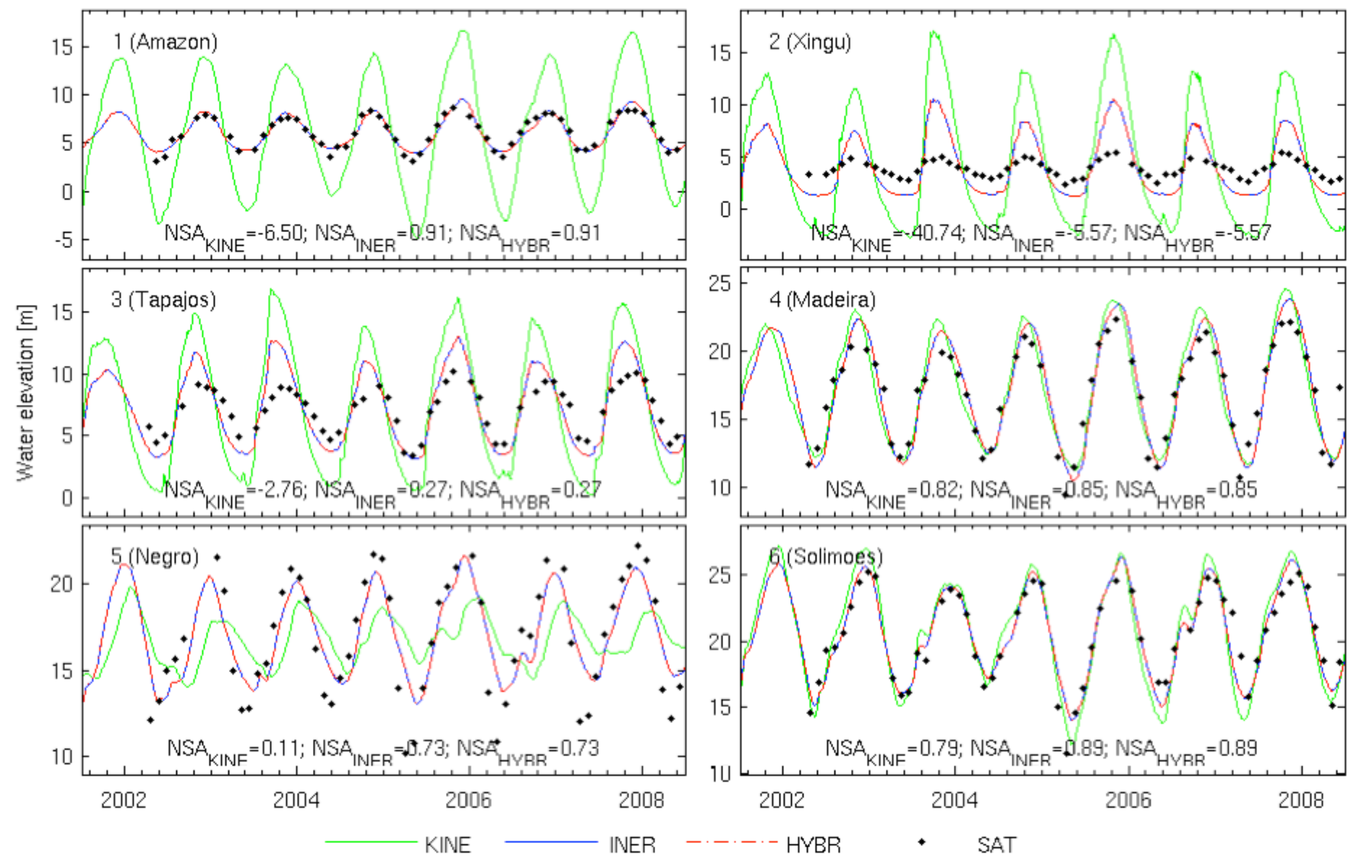
144 stream gauges and 396 locations with satellite-based water elevations

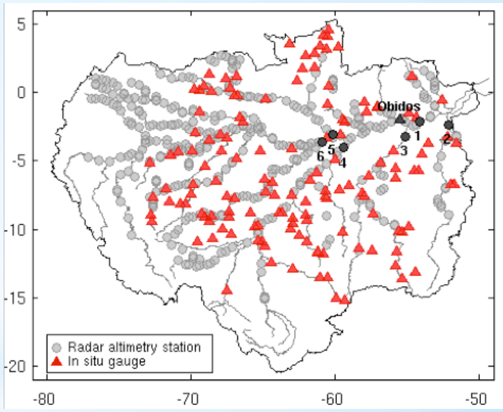
NASH-SUTCLIFFE FOR STREAMFLOWS AND WATER LEVELS OVER THE AMAZON BASIN



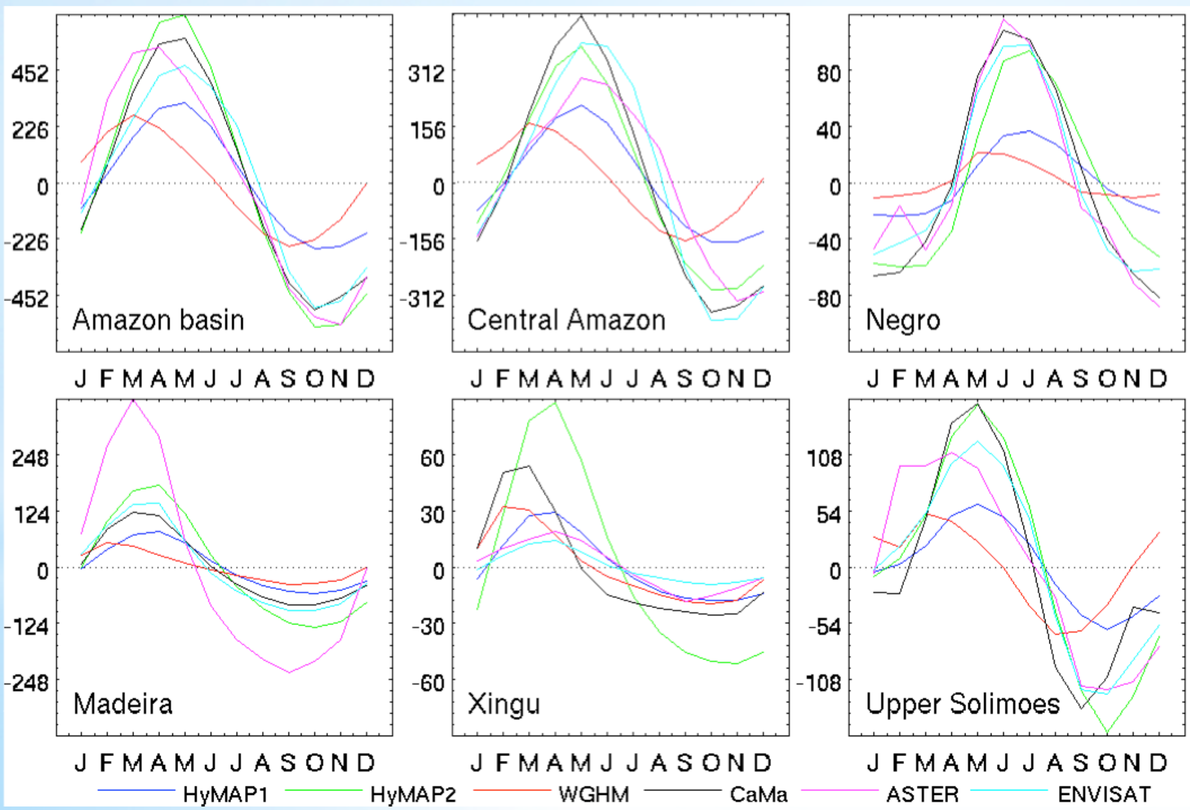
Noah33 LSM
HyMAP2 (KINE, INER,HYBR)
Princeton met. forcing
15-min time step
0.25-degree
2002-2008 period

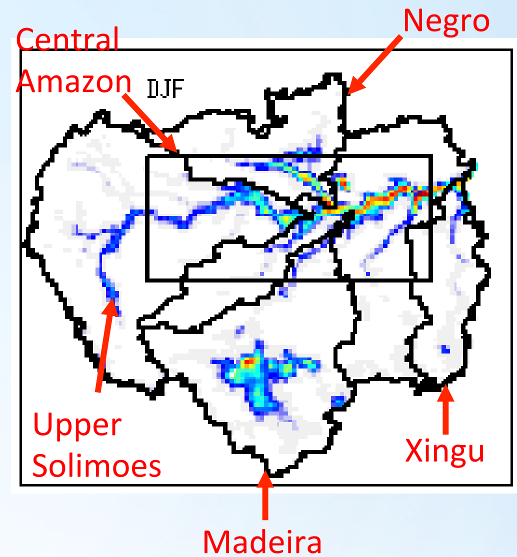
WATER ELEVATION TIME SERIES AT RIVER CONFLUENCES AND BASIN OUTLET





SURFACE WATER STORAGE CHANGE IN THE AMAZON BASIN

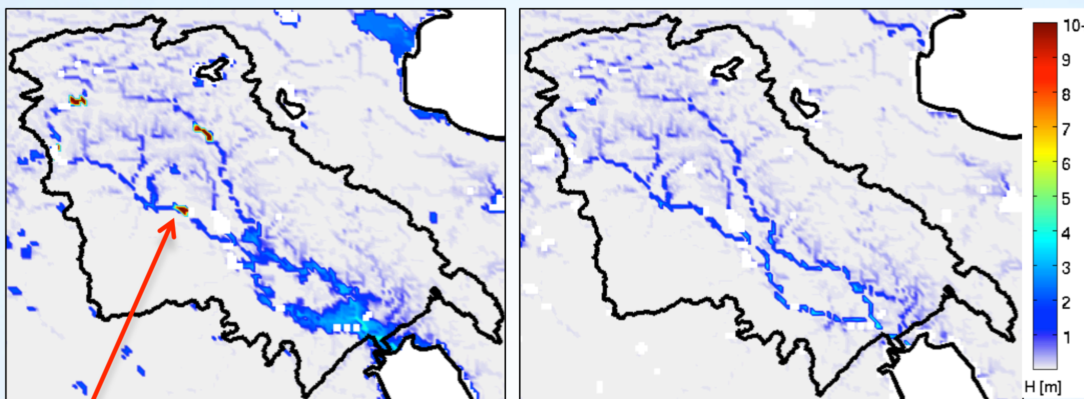




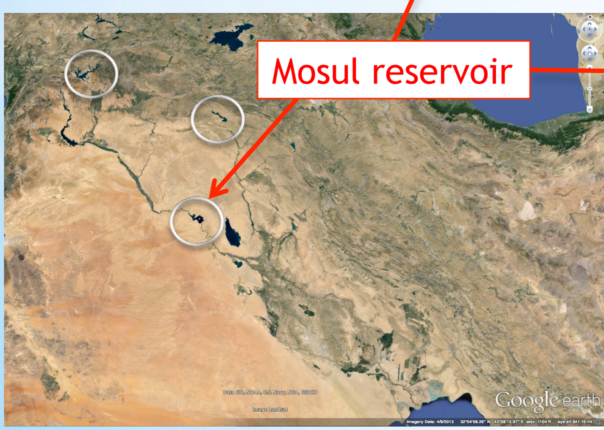
- In these plots, HyMAP1 and HyMAP2 indicate runs with and without linear reservoirs accounting for time delays;
- HyMAP was forced with an ensemble of 14 LSM outputs (see Getirana et al., 2014, JHM);
- ASTER and ENVISAT are satellite-based products (see Papa et al., 2013, JGR)

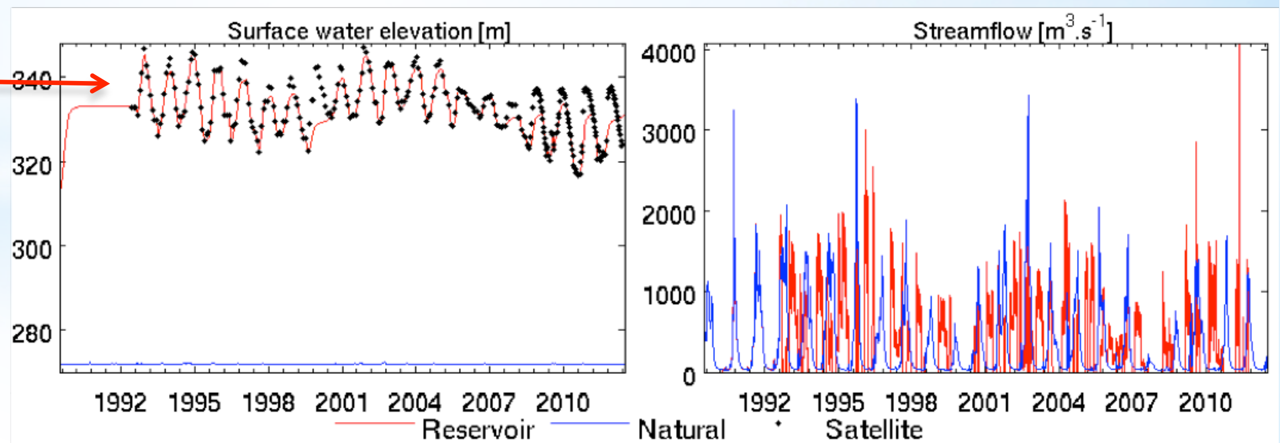
STREAMFLOW, WATER LEVEL AND RESERVOIR OPERATION OVER THE TIGRIS-EUPHRATES RIVER BASIN

Local Inertia + reservoirs | Kinematic wave

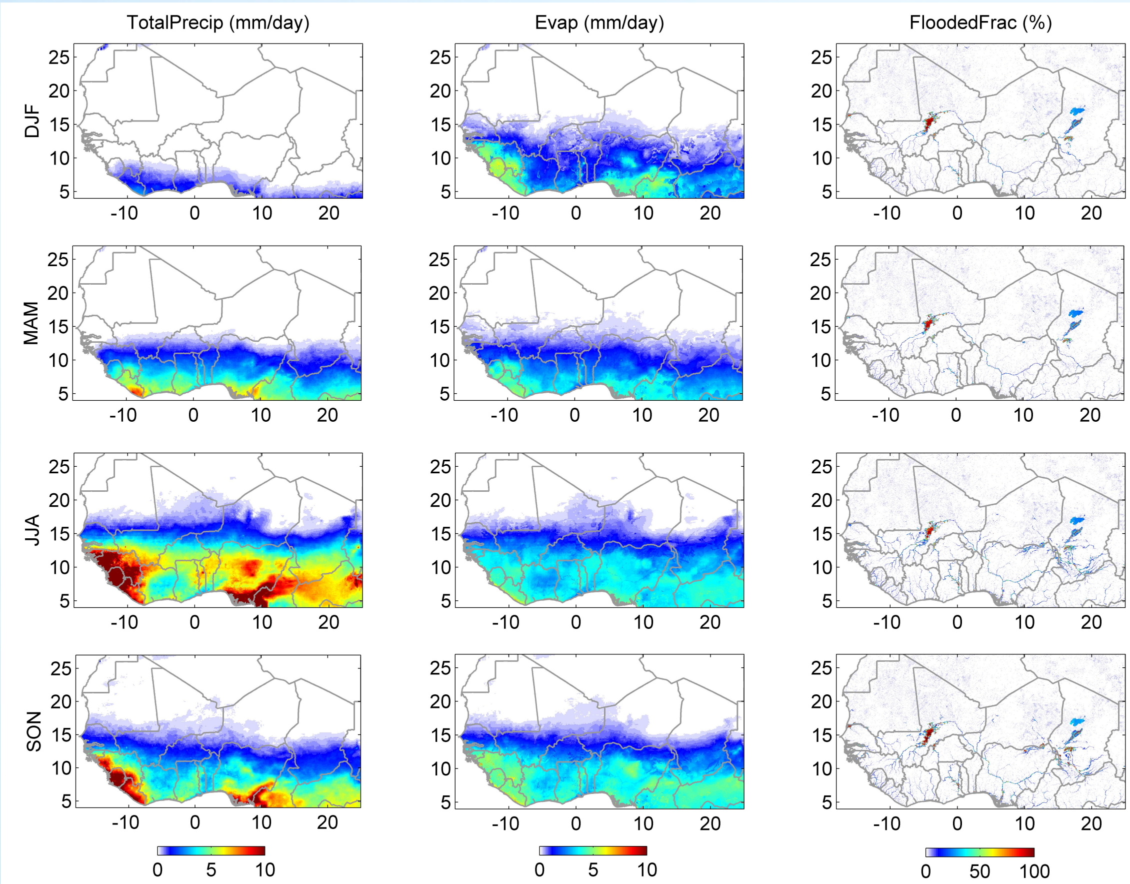


Noah33 LSM
HyMAP2
Princeton met forcing
Adaptive time step
0.10-degree
1990-2012 period



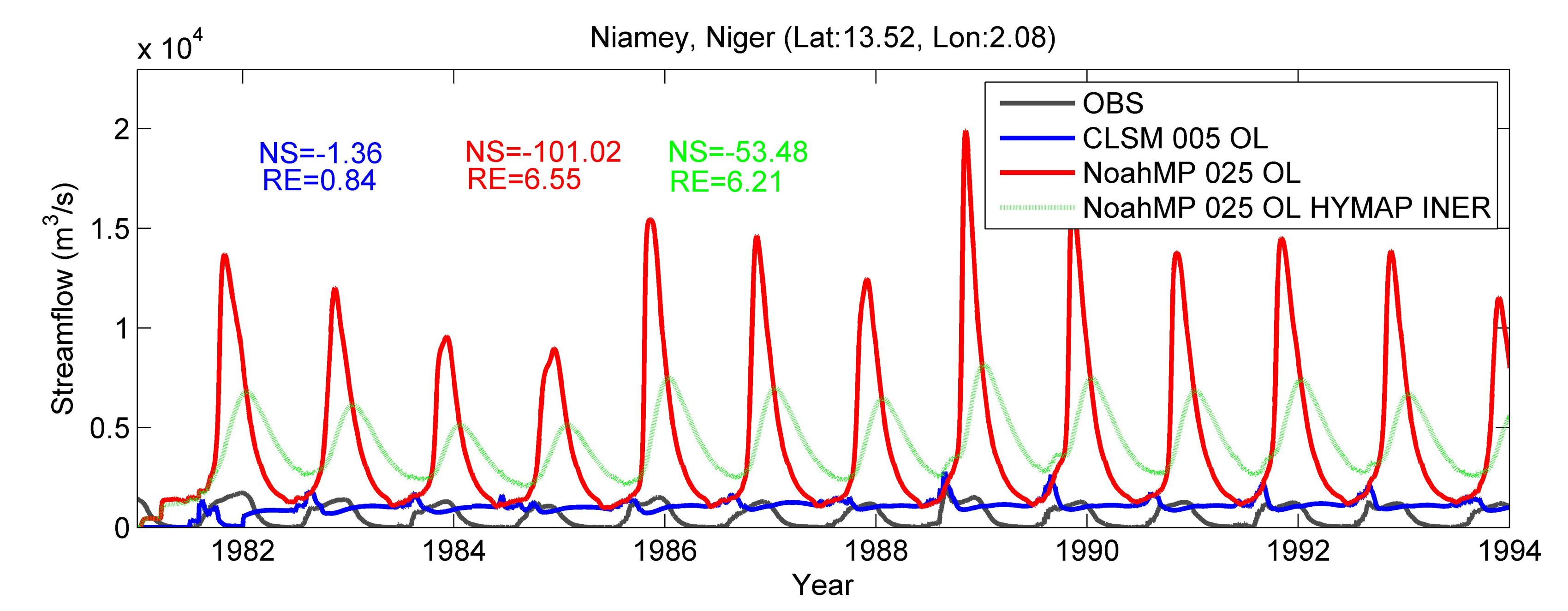


STREAMFLOW AND FLOODPLAIN EXTENT OVER WEST AFRICA (WELDAS)



Catchment LSM
HyMAP2
MERRA2 CHIRPS met forcing
Adaptive time step
0.05-degree
1981-1994 period

STREAMFLOW AND FLOODPLAIN EXTENT OVER WEST AFRICA (WELDAS)



UNDER DEVELOPMENT

- Upscaling algorithm capable of processing numerous databases (e.g. HydroSHEDS, Hydro1k, etc.) at any spatial resolution (30+meters) and given domains;
- Parallelization, allowing faster HyMAP runs with multiple processors;
- Re-inclusion of evaporation from open waters.

* Questions?