Isotope-enabled Coupled Catchment-Lake Water Balance Model: Description and Validation

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Water
Resources
Programme

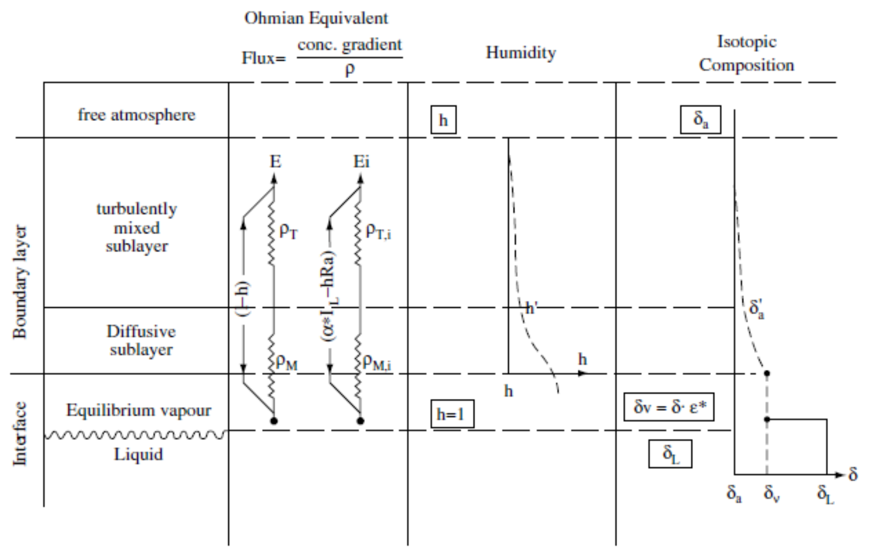

Fig. 4.2. The Craig–Gordon model of isotope fractionation during the evaporation from a free water surface.

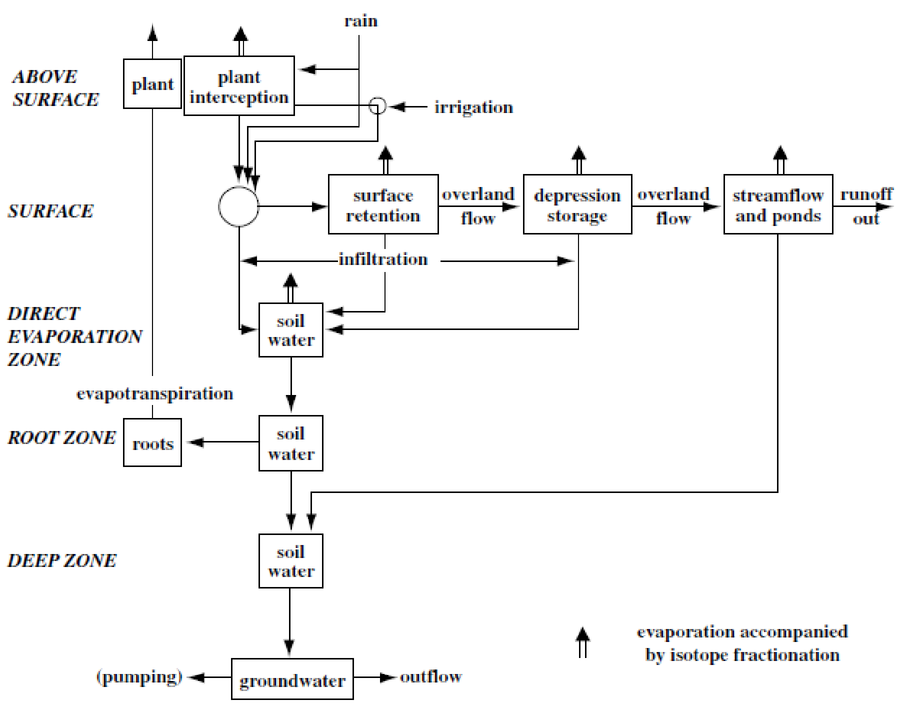

Fig. 1.4. Scheme of the water fluxes at the atmosphere/land-surface interface (adapted from Gat and Tzur, 1976).

Gat, 2010

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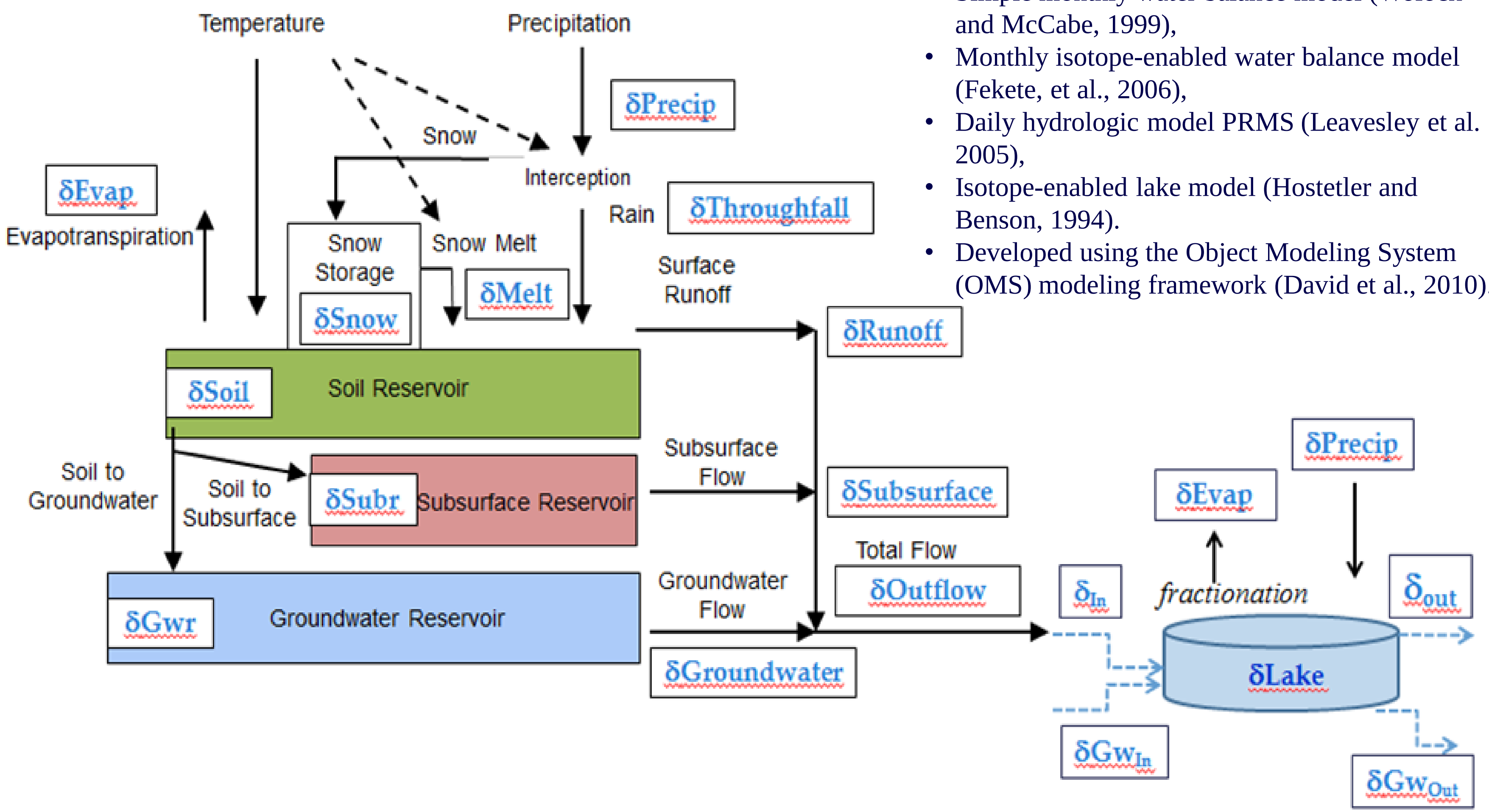
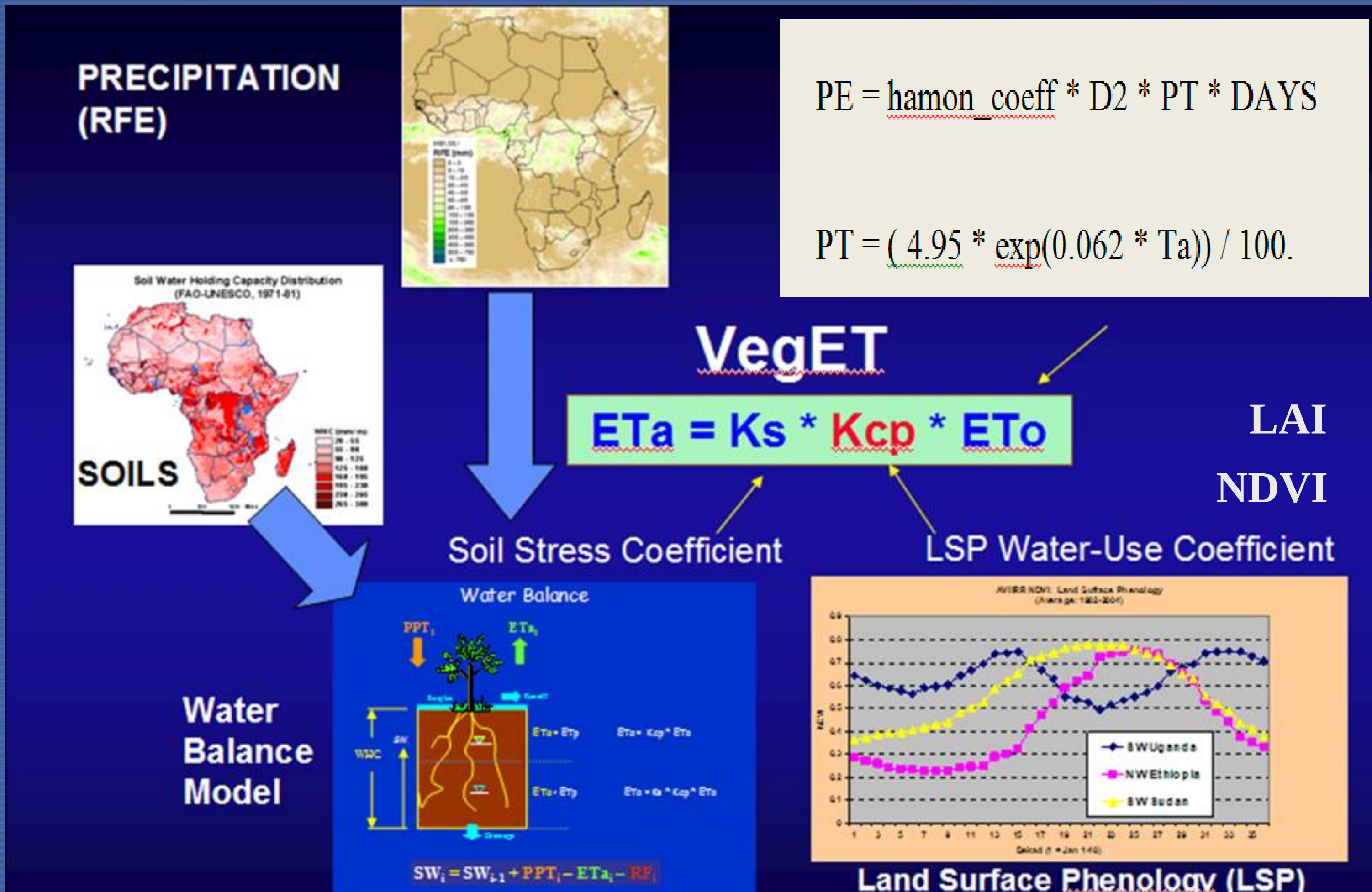
IAEA Water Balance Model with Isotopes



- Simple monthly water balance model (Wolock and McCabe, 1999),
- Monthly isotope-enabled water balance model (Fekete, et al., 2006),
- Daily hydrologic model PRMS (Leavesley et al. 2005),
- Isotope-enabled lake model (Hostetler and Benson, 1994).
- Developed using the Object Modeling System (OMS) modeling framework (David et al., 2010).

Actual Evapotranspiration (VegET)



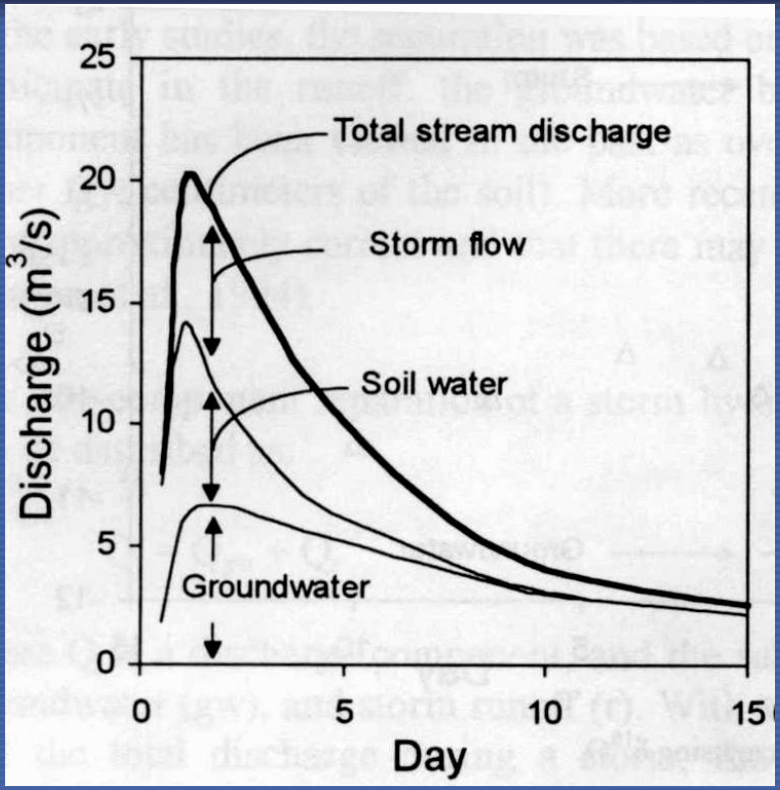
Senay et al., 2008

Flow Components

$$rodirect = Prain \times directfac$$

$$ssflow = ssflow\_coef * ssres\_stor$$

$$gwflow = gwflow\_coef * gwres\_stor$$



$$Q(t) = Q(t_o)e^{-k(t-t_o)}$$

Boussinesq equation

δR = ((Rodirect * δRodirect) + (Ssflow * δSsflow) + (Gwflow * δGwflow)) / R

Soil Moisture Fractionation

$$\delta E = [\delta L/\alpha - h \,.\, \delta a - (\varepsilon^* + \Delta\varepsilon)] \,/\, [(1 - h) + \Delta\varepsilon/1000]$$

Modelled as a drying water body from which water is removed only by evaporation

Vapour flux equations

$$\frac{dN_i}{dN} = \frac{\frac{R}{\alpha} - hRa}{(1-h)\,\rho_i/\rho}$$

$$\delta = (\delta_o - A/B)\, f^{\,B} + A/B$$

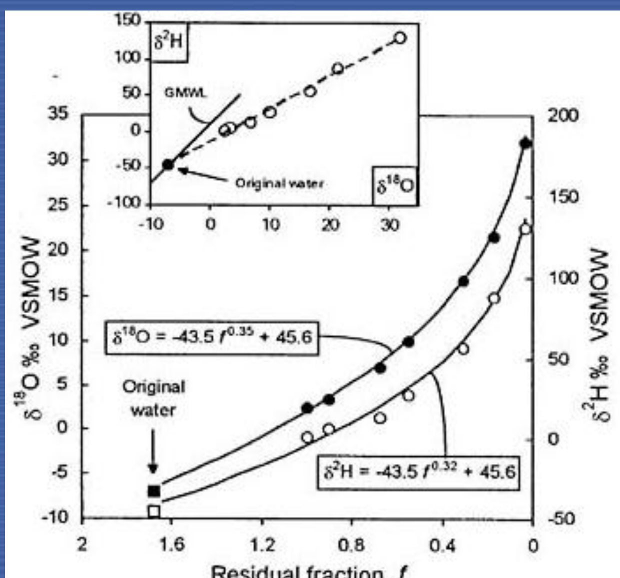
Assuming Const. Evapo. Cond.

$$A = (h\delta_a + \Delta\varepsilon + \varepsilon/\alpha) \,/\, (1 - h + \Delta\varepsilon)$$

$$B = (h - \Delta\varepsilon - \varepsilon/\alpha) \,/\, (1 - h + \Delta\varepsilon)$$

$$\alpha_{l\text{-}v} = e^{(C2/T2 + C1/T + C0)}$$

$$\delta_a = \delta_{ppt} / \alpha - (1 - 1/\alpha)$$



Gonfiantini & Fontes, 1963

$$\Delta\varepsilon = \theta\cdot n.Ck.\,(1 - h)$$

$$\Delta\varepsilon\,^{18}O\,‰ = 14.2\,(1 - h)$$

$$\Delta\varepsilon\,^{2}H\,‰ = 12.5\,(1 - h)$$

Ck = ((D/Di)^n - 1).1000

(Ck=Kinetic constant: 25.1 and 28.5 for O &D)

$$\varepsilon = (\alpha - 1)$$

$$\alpha_{l\text{-}v} = e^{(C2/T2 + C1/T + C0)}$$

Majoube, 1971

n = 1 for stagnant, and
n = ½, for fully turbulent wind conditions

Gonfiantini, 1986

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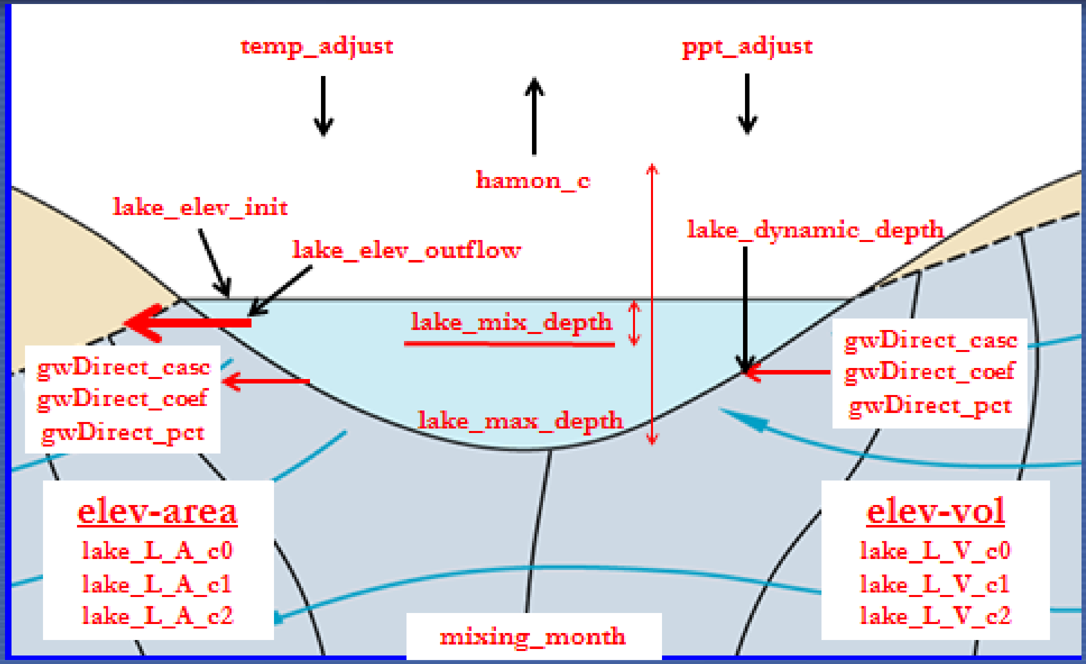
Water Resources Programme

IWBMIso Lake Parameters



$$\delta_L \frac{dV_L}{dt} + V_L \frac{d\delta}{dt} = \delta_{IS} I_S + \delta_{IG} I_G + \delta_P P - \delta_{OS} O_S - \delta_{OG} O_G - \delta_E E$$

Where

x=E/I (fraction of inflow water lost by evaporation)

y=Q/I (fraction lost by isotopically non-fractionating outflows)

If I=Q=0, lake drying up due to Evap. only

$$\delta = \left(\delta_o - \frac{\delta_I + A*x}{1+B*x}\right) * f^{-\frac{1+B*x}{1-x-y}} + \frac{\delta_I + A*x}{1+B*x}$$

$$\delta = (\delta_o - A/B)\, f^{B} + A/B$$

If I=0, but Q <>0

E and infiltration, e.g. pond

$$\delta = (\delta_o - A/B)\, f^{BZ} + A/B$$

Z= E/(E+Q)

Gonfiantini, 1986

IWBMIso Model Components

Developed in the Object Modeling System (OMS) Framework on Java

StationUpdater
ObsIso
Climate

Reads parameter and data files.

Estimates and assigns climate variables to HRUs.

WbHruIso

Calculates water & isotope balances for each HRU.

WbSubbasinIso

Computes water & isotope balances for each subbasin by aggregating associated HRU water and isotope balances.

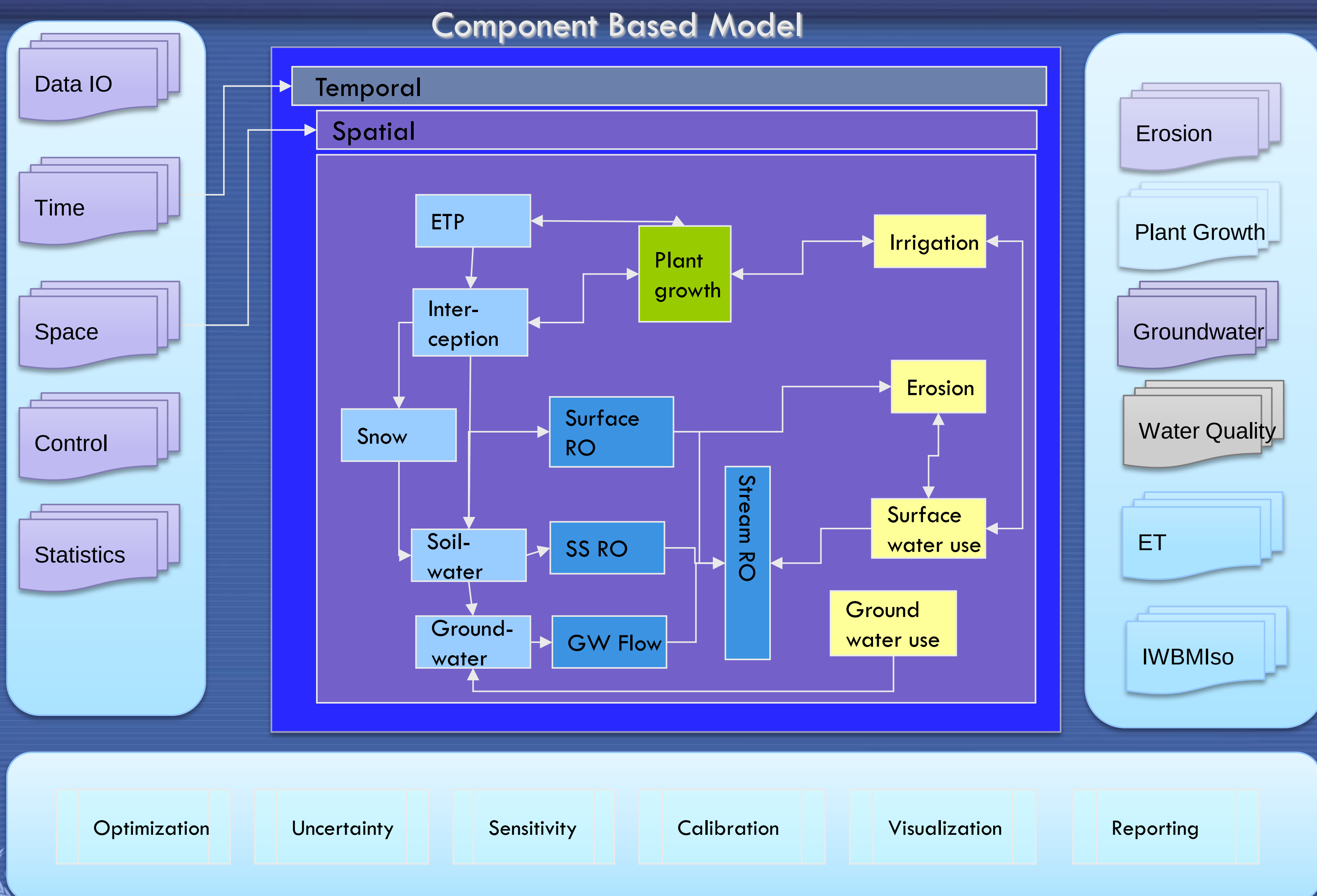
WbSummaryIso

Controls outputs.

OMS Principal Architecture

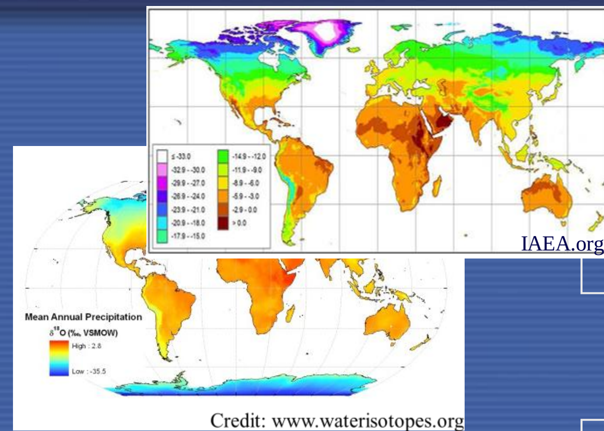
System Components

Science Components



Model Components and Basic Information Flow

Model Monthly Input Data File Generation



Remotely Sensed and Atmospheric Model Data

CRU: P, T, RH, WET

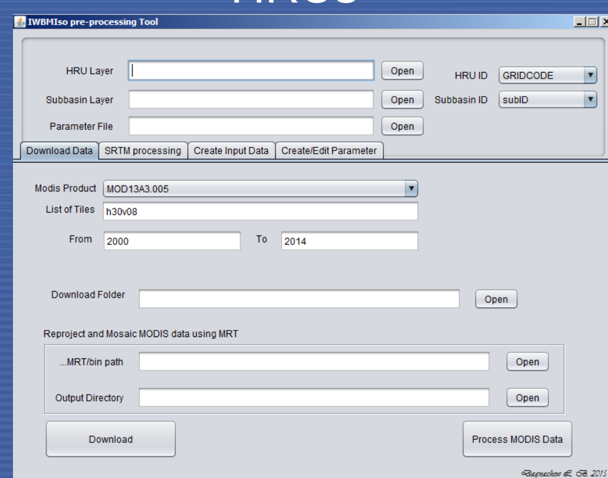
MODIS: NDVI, LAI, VCF

FAO Soil

Global Precip. Isotope

- *WATERISOTOPES.ORG*
- *IAEA*

Assimilated to create monthly time-series values for HRUs



Field Data Measurements

Streamflow

- Discharge
- Diversions

Meteorological

- Temperature
- Precipitation
- R Humidity

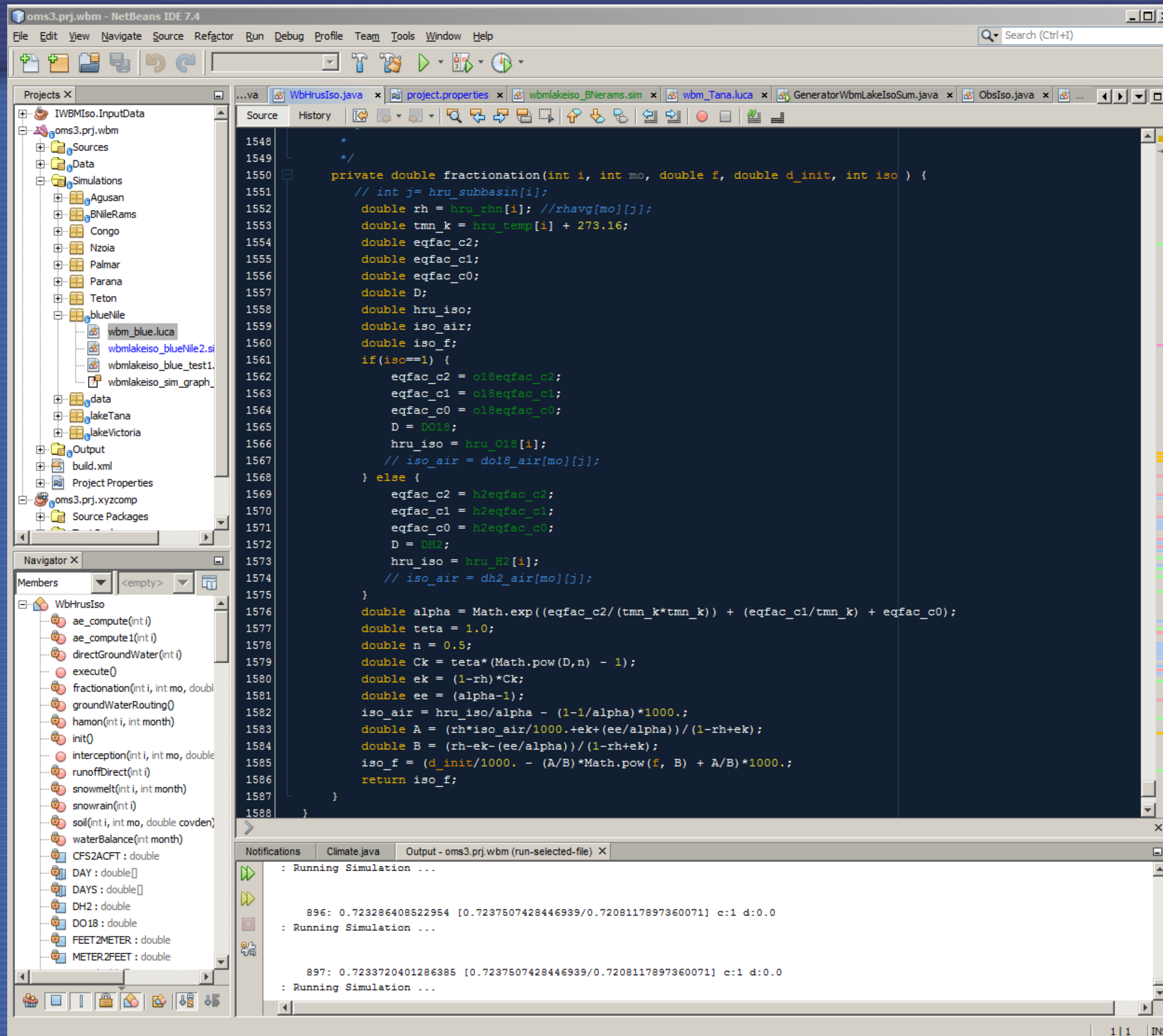
Water Bodies / Wetlands

- Surface Elevations
- Temperature
- Isotopes

Isotopes

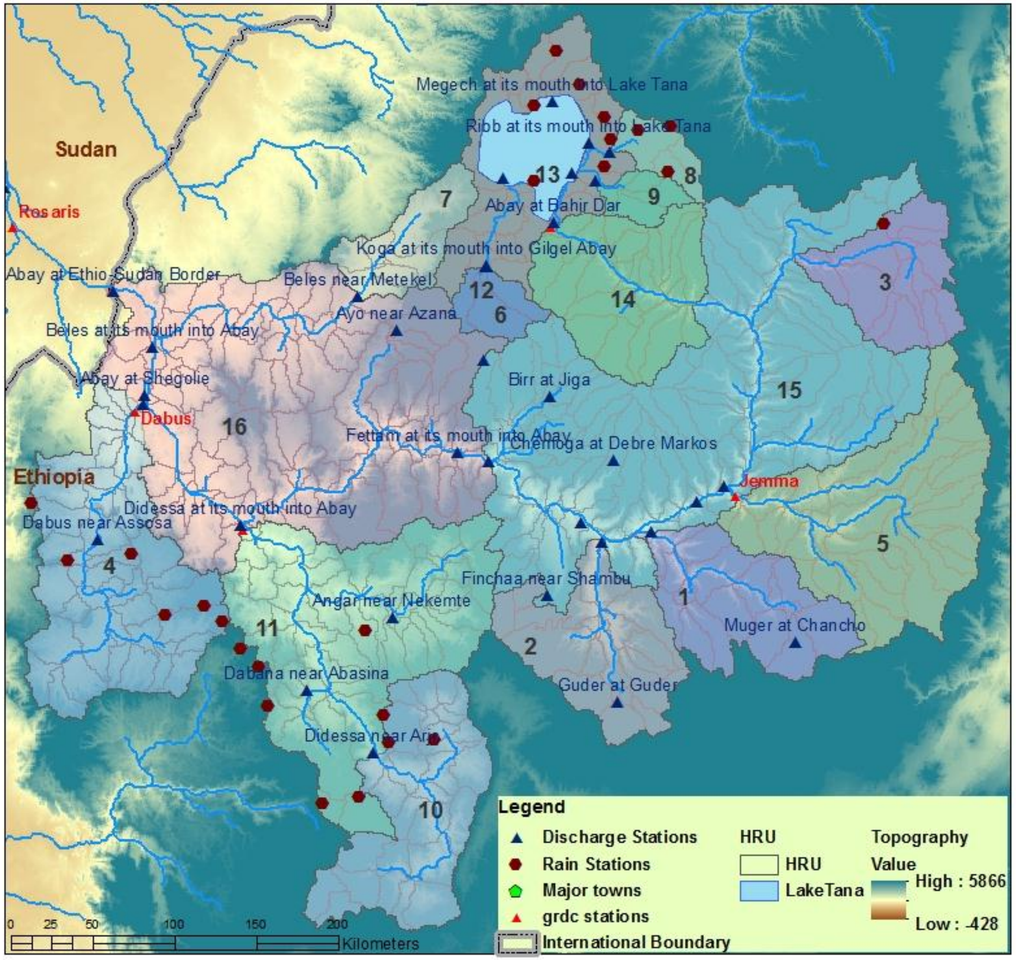
- River and Tribs
- GW Wells
- Precipitation

IWBMIso Code Snippet



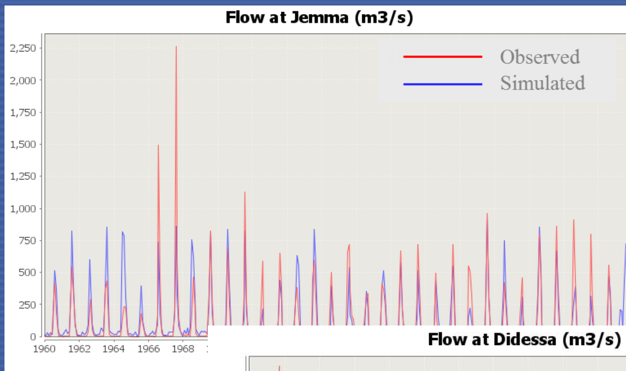
Case Study 1

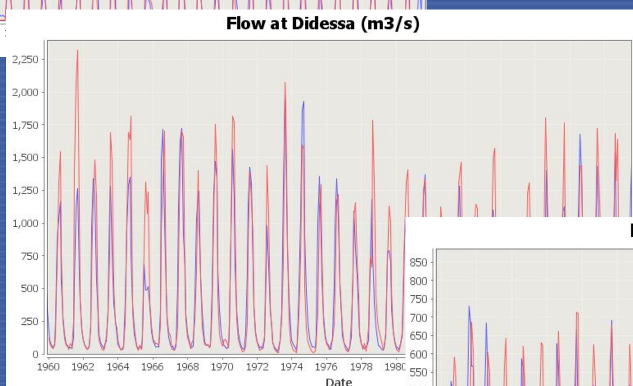
Upper Blue Nile Basin, Ethiopia

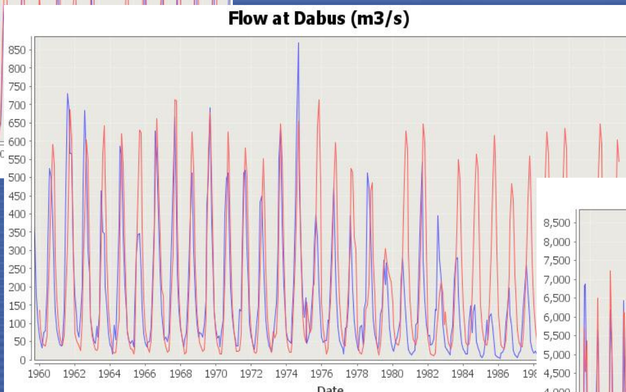


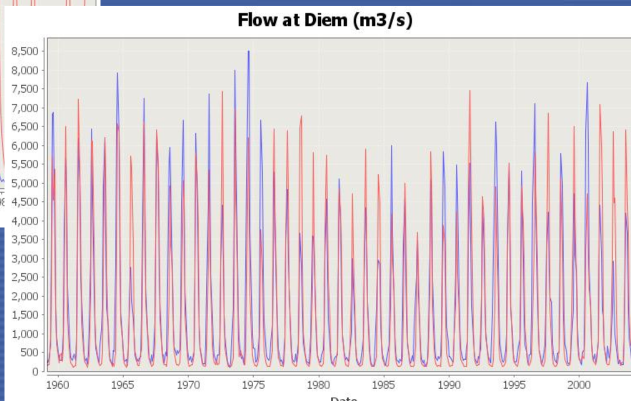
16 Subbasins
438 HRUs
Catch. 174,800 km^2
Lake: 3280 km^2

Selected Model Calibration and Evaluation Results





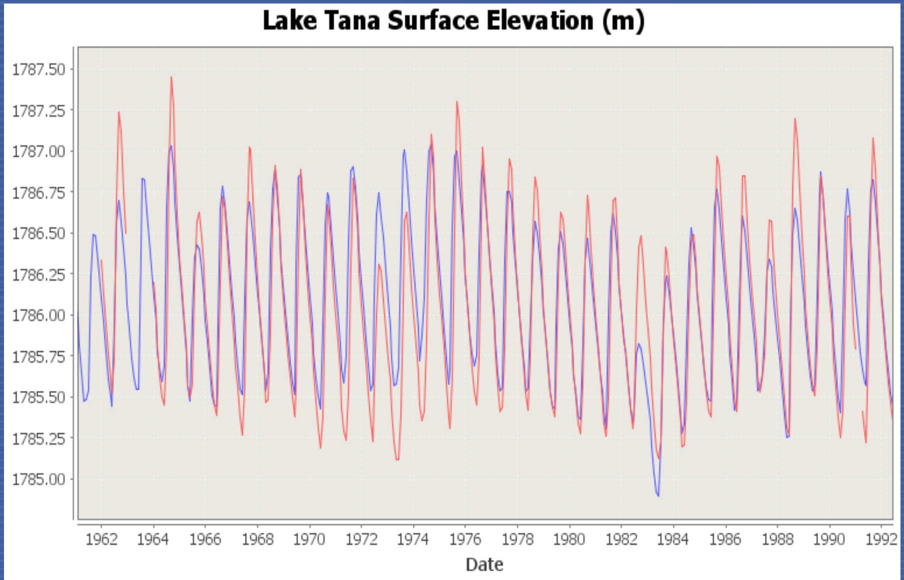


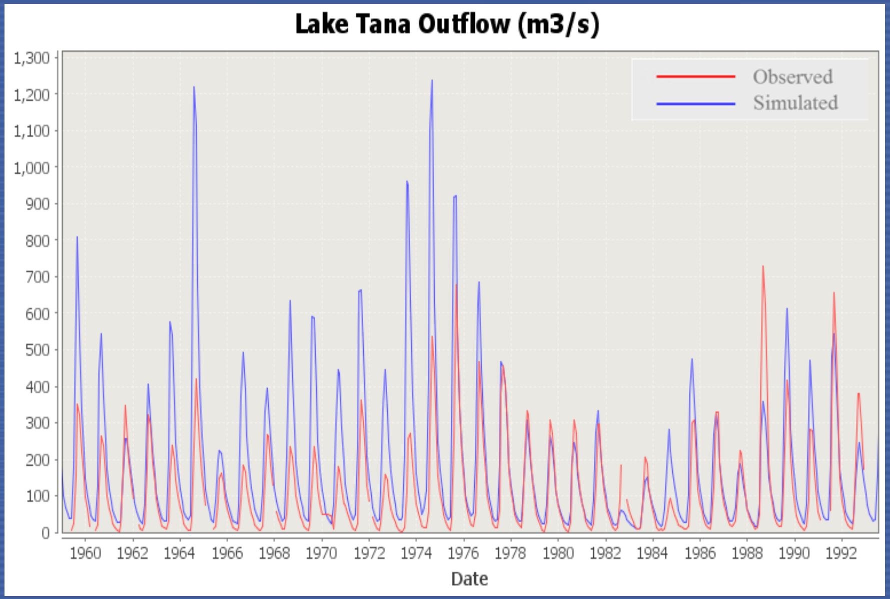


Station	NSE Calibration (Period)	NSE Evaluation (Period)
Jemma	**0.74** (1975-1990)	**0.56** (1960-1974) **0.64** (1960-1992)
Mugher	**0.85** (1975-1990)	**0.55** (1960-1974) **0.68** (1960-1992)
Didessa	**0.77** (1975-1990)	**0.80** (1960-1974) **0.79** (1960-1992)
Dabus	**0.64** (1960-1974)	**-0.07** (1975-1992) **0.31** (1960-1992)
Diem	**0.76** (1975-1990)	**0.75** (1960-1974) **0.72** (1960-2003)

Selected Model Calibration and Evaluation Results

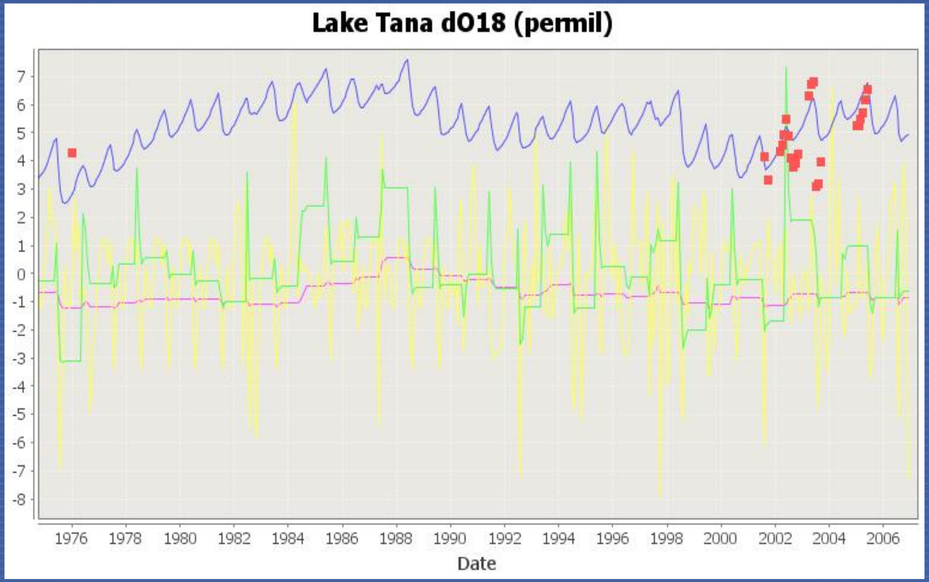
Lake Tana



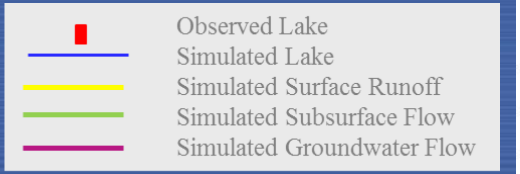


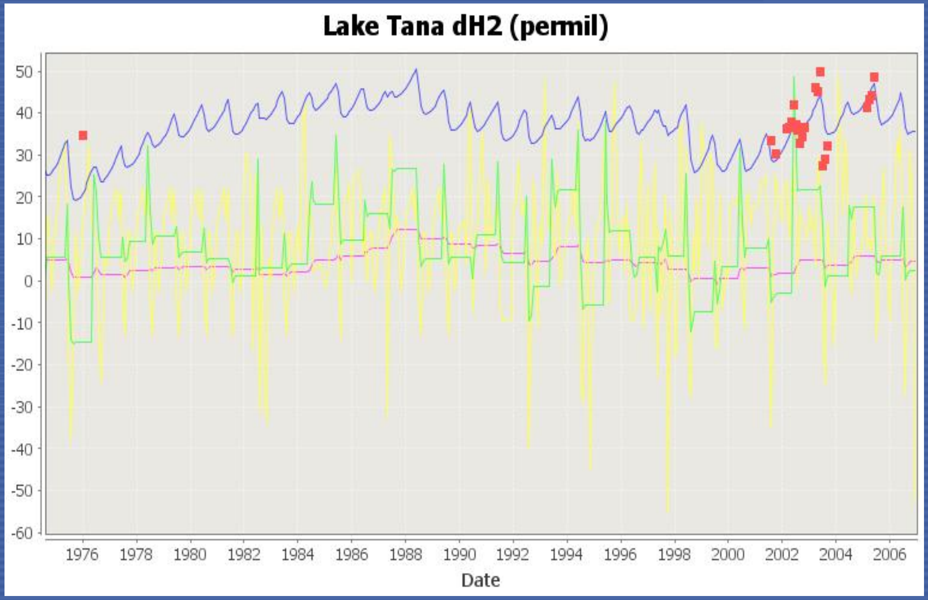
Selected Model Calibration and Evaluation Results

Lake Tana



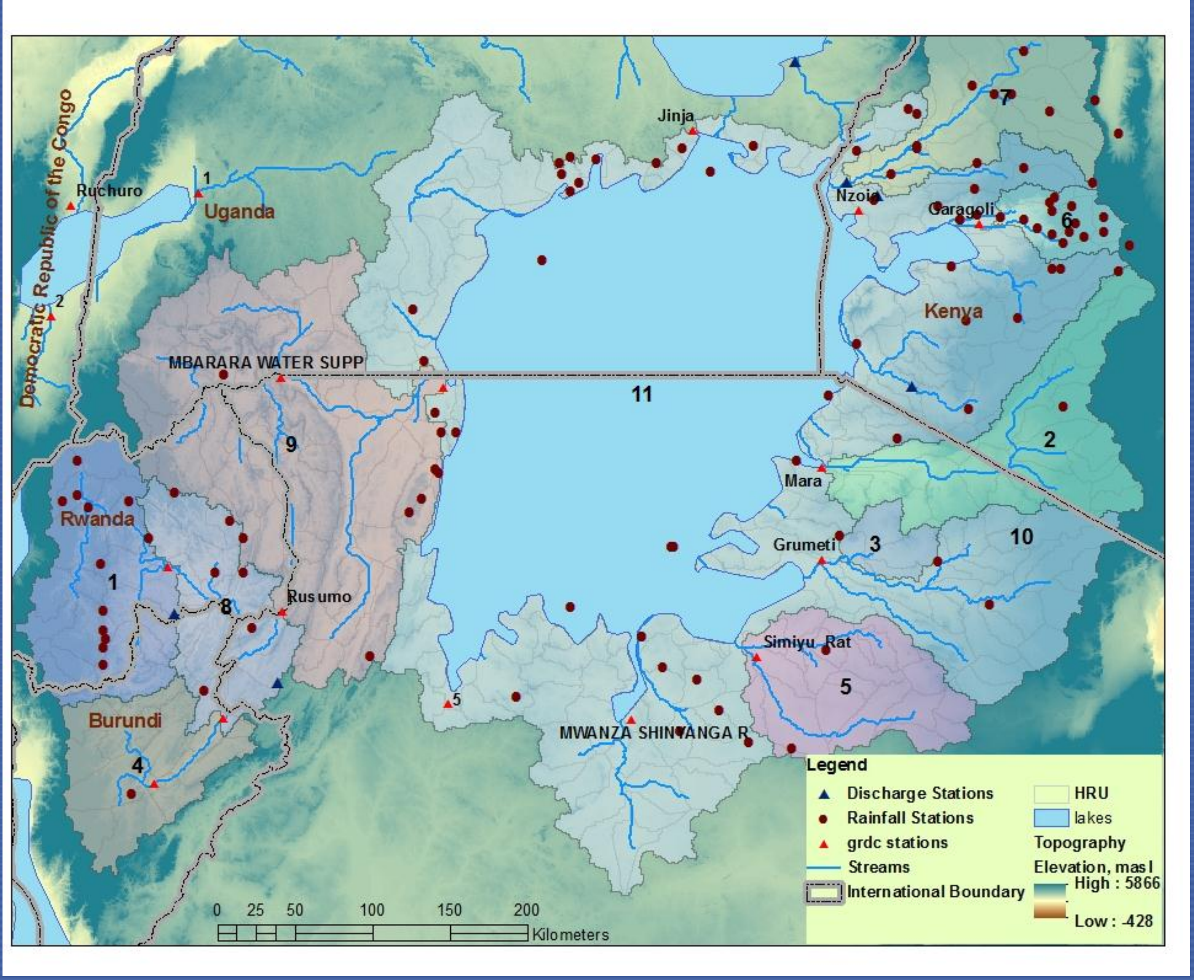
isotope for





Case Study 2

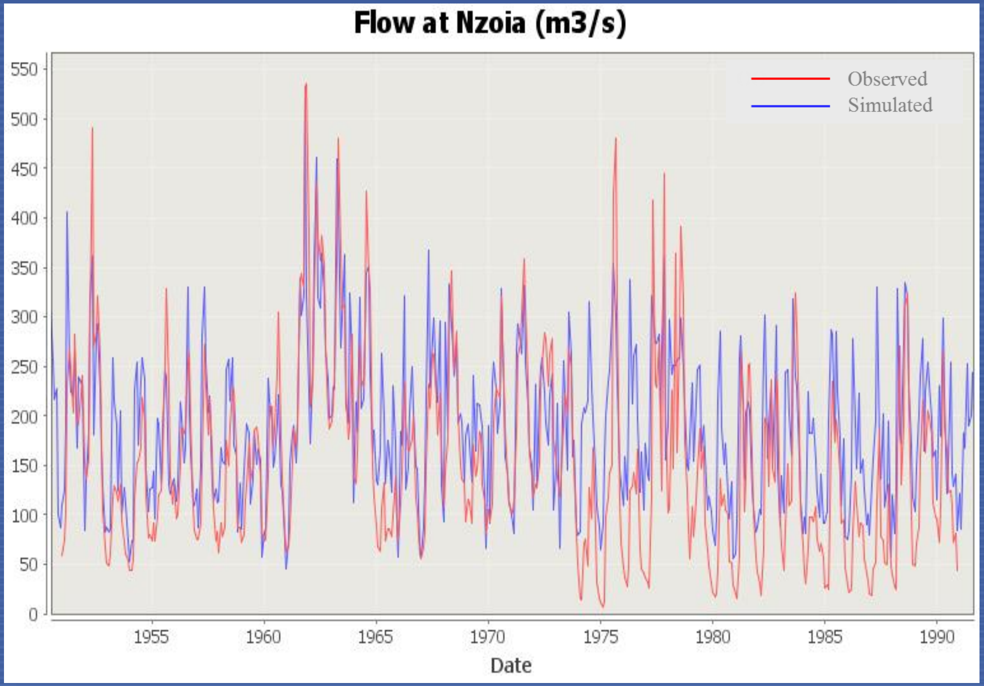
Lake Victoria, East Africa

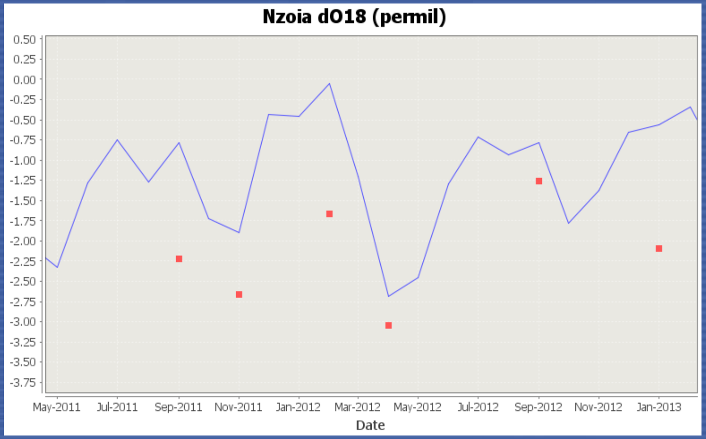


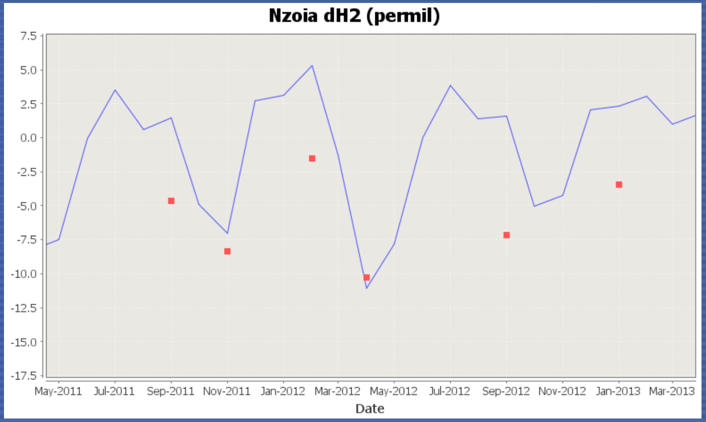
11 Subbasins
368 HRUs
Catch.: 252,000 km^2
Lake: 68,800 km^2

Selected Model Calibration and Evaluation Results

Nzoia Rive, tributary to L. Victoria, Kenya

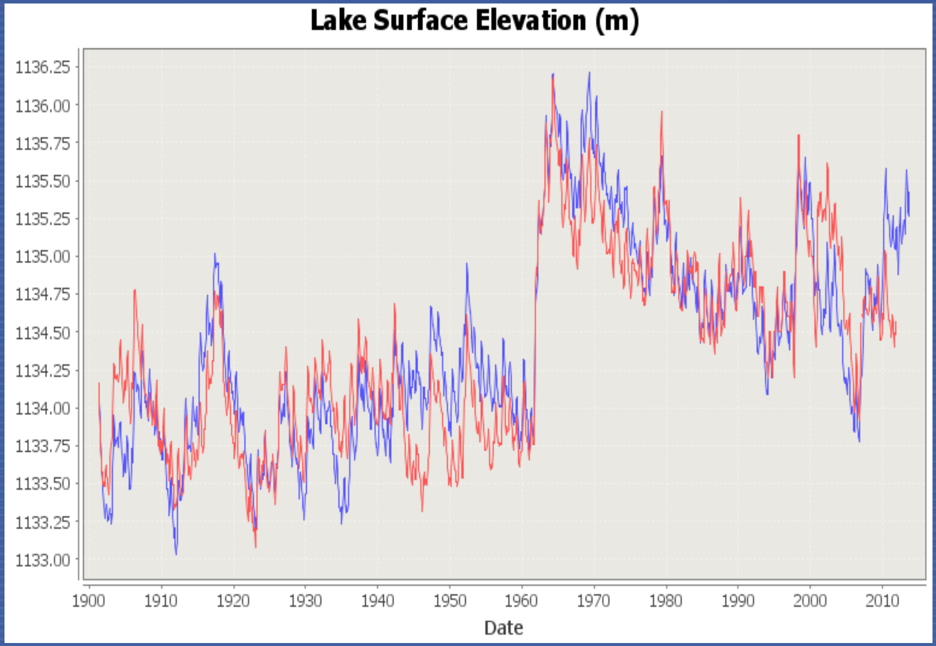


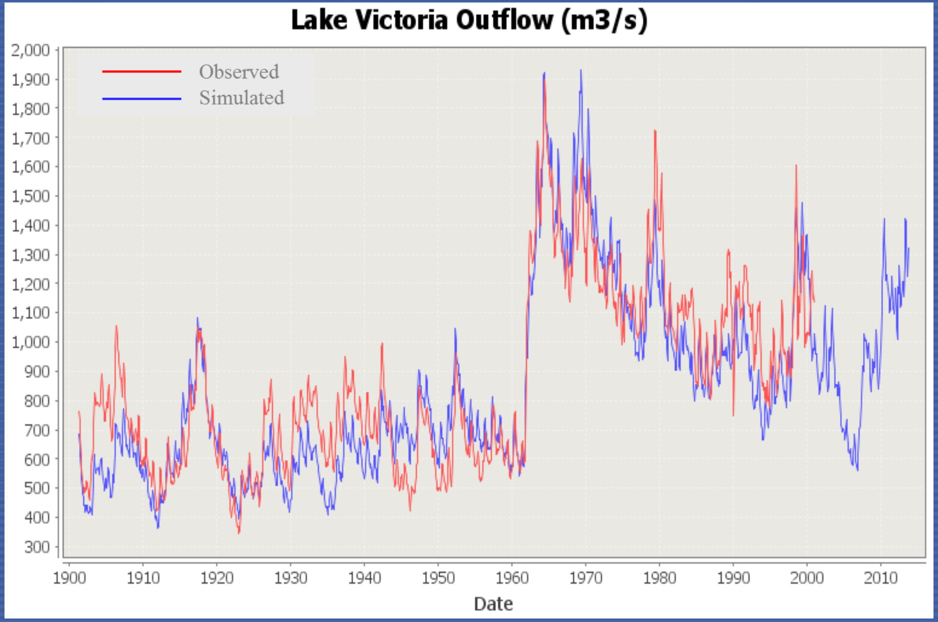




Selected Model Calibration and Evaluation Results

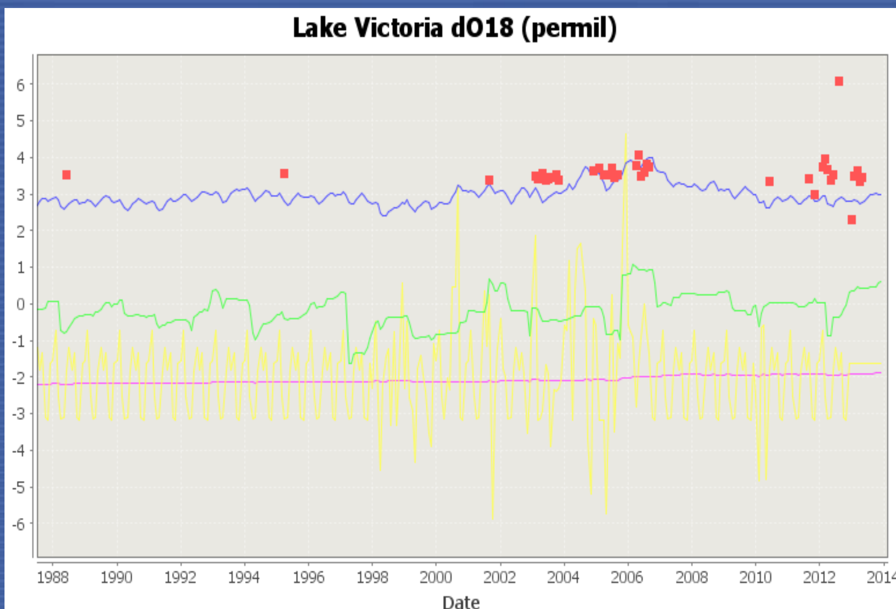
Lake Victoria

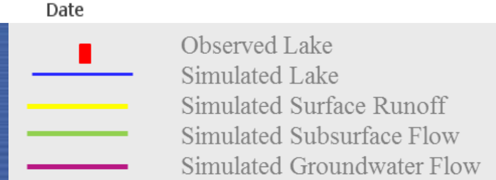




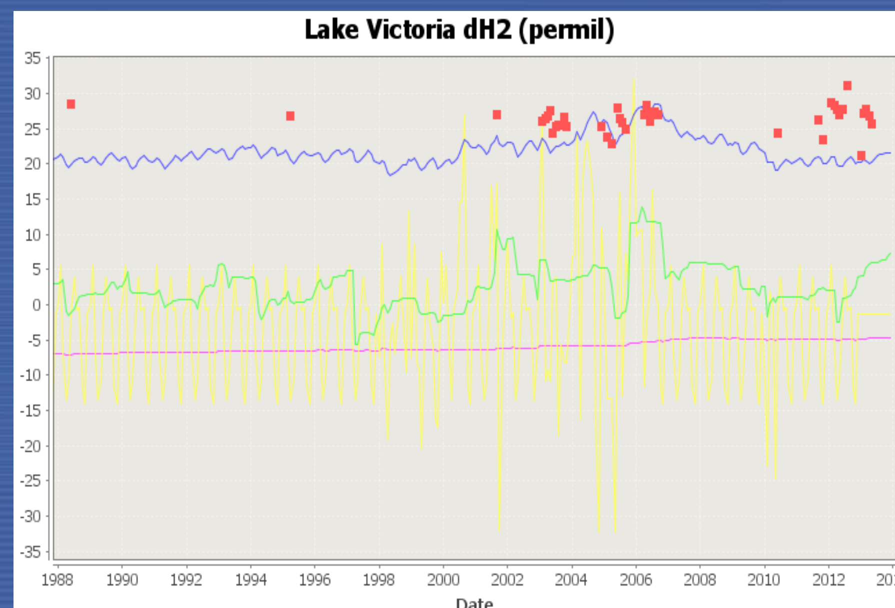
Selected Model Calibration and Evaluation Results

Lake Victoria

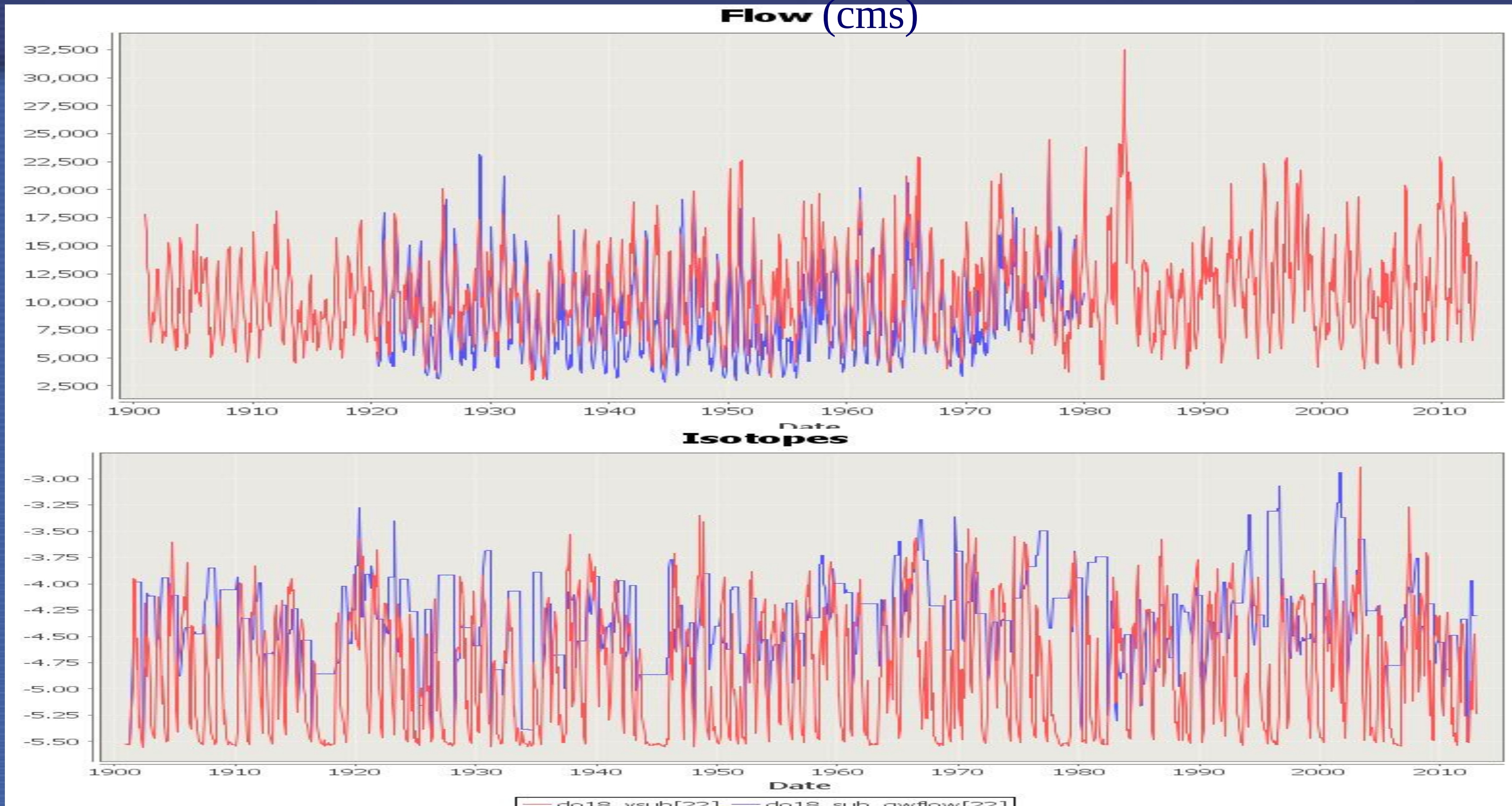


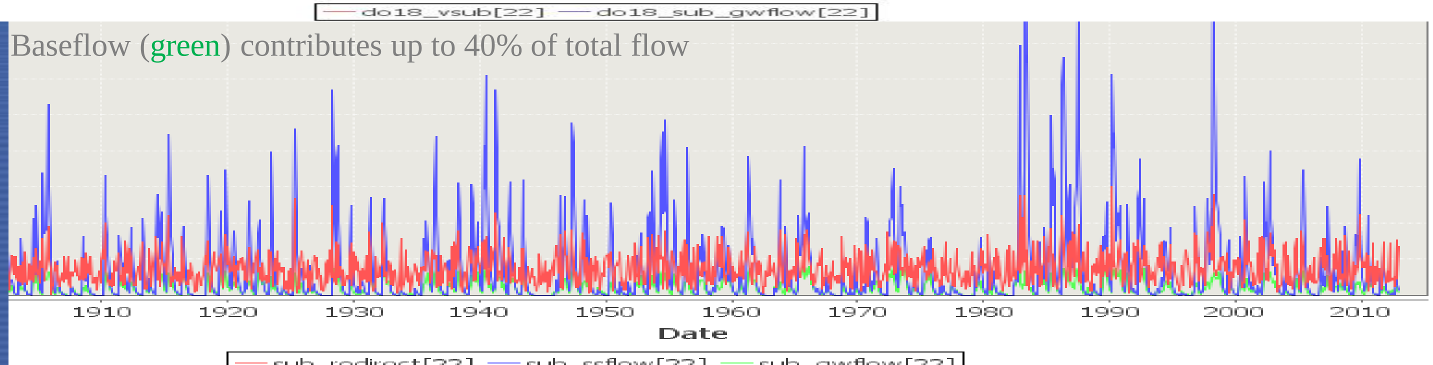


isotope for



Parana River @ Corrientes, Argentina

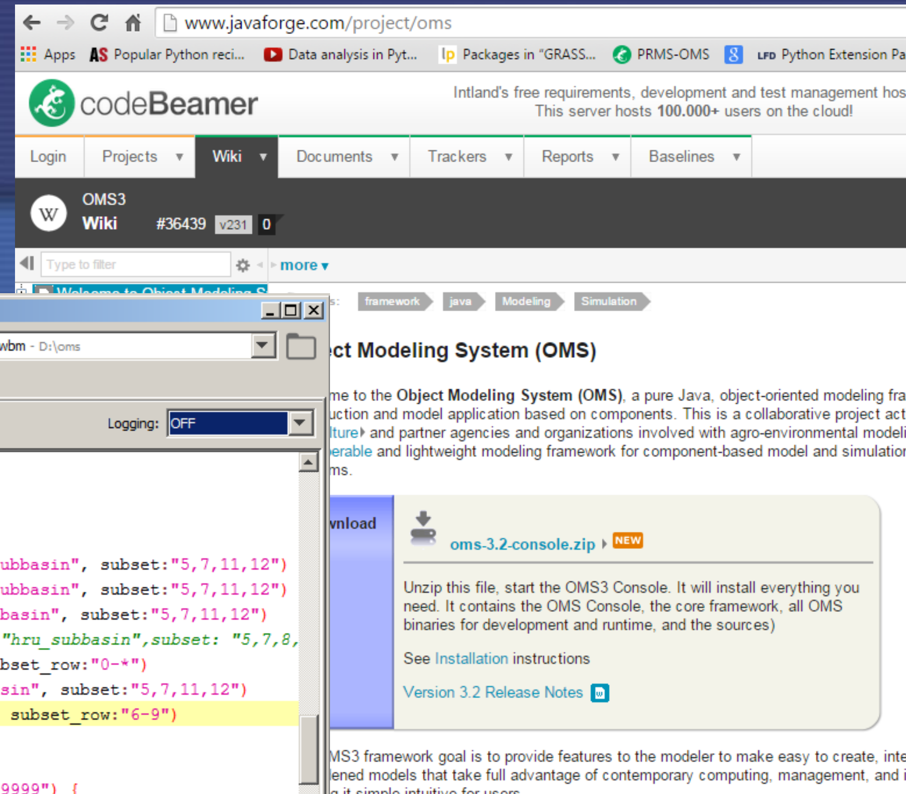


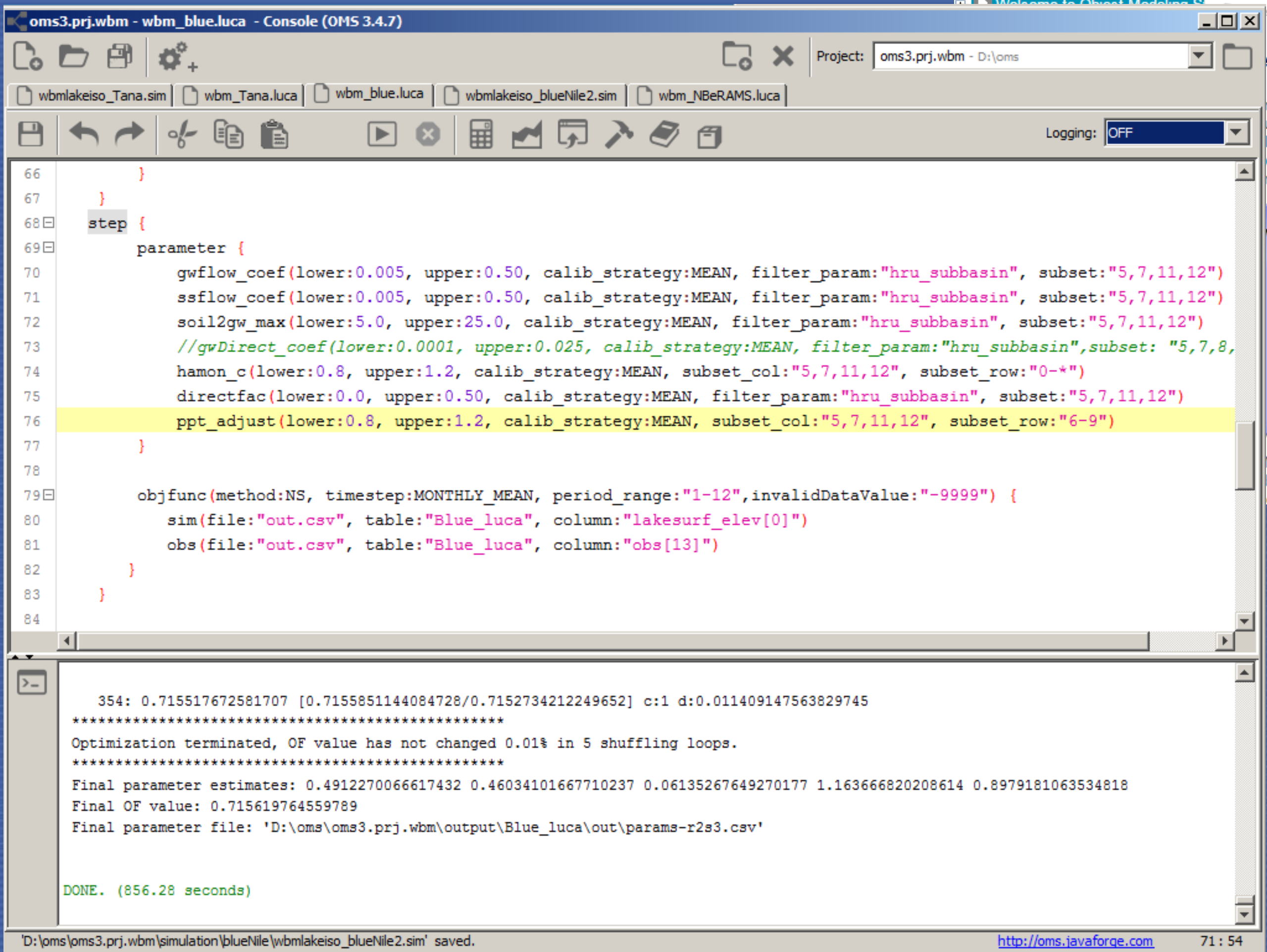


Baseflow (green) contributes up to 40% of total flow

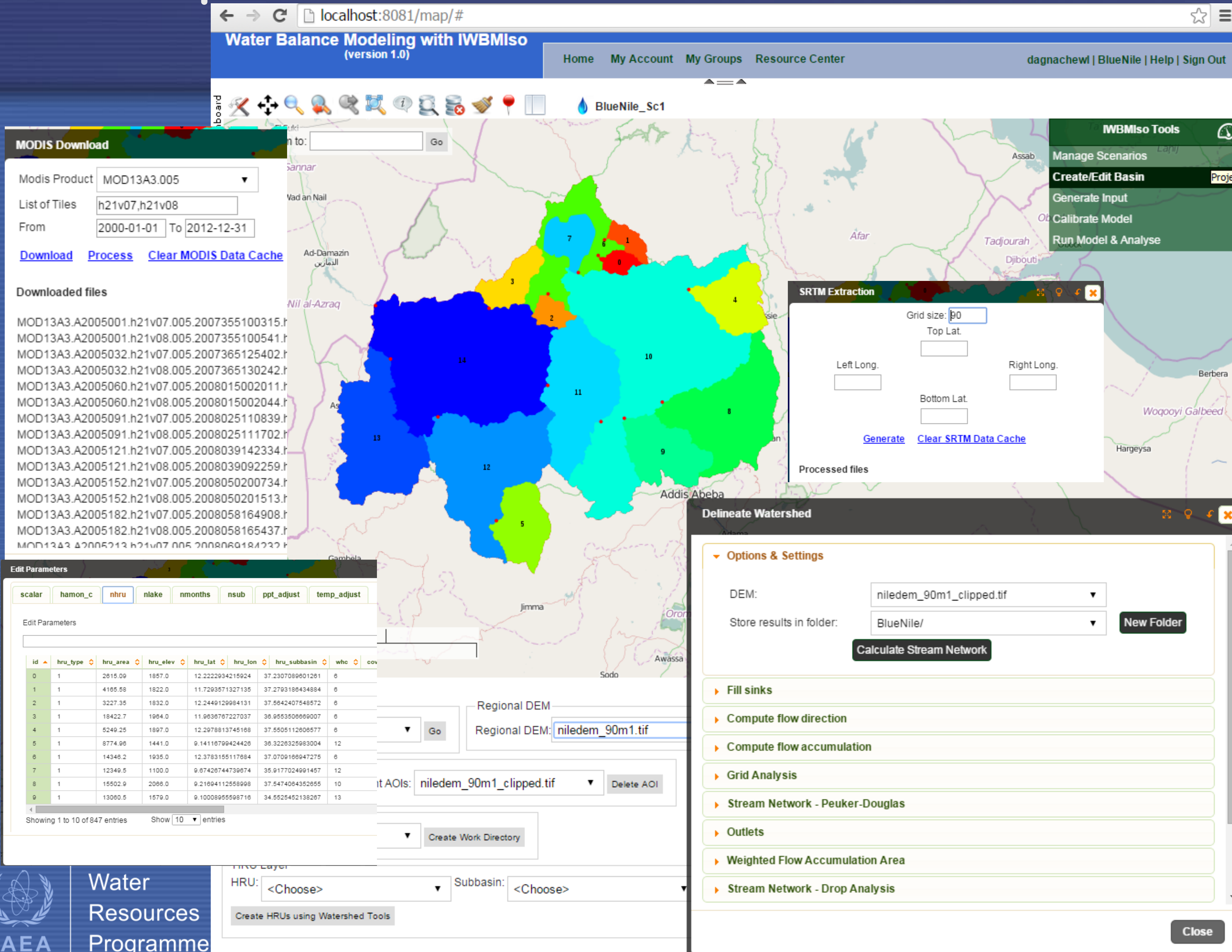
Model Deployment

OMS Console





eRAMS Implementation of IWBMIso



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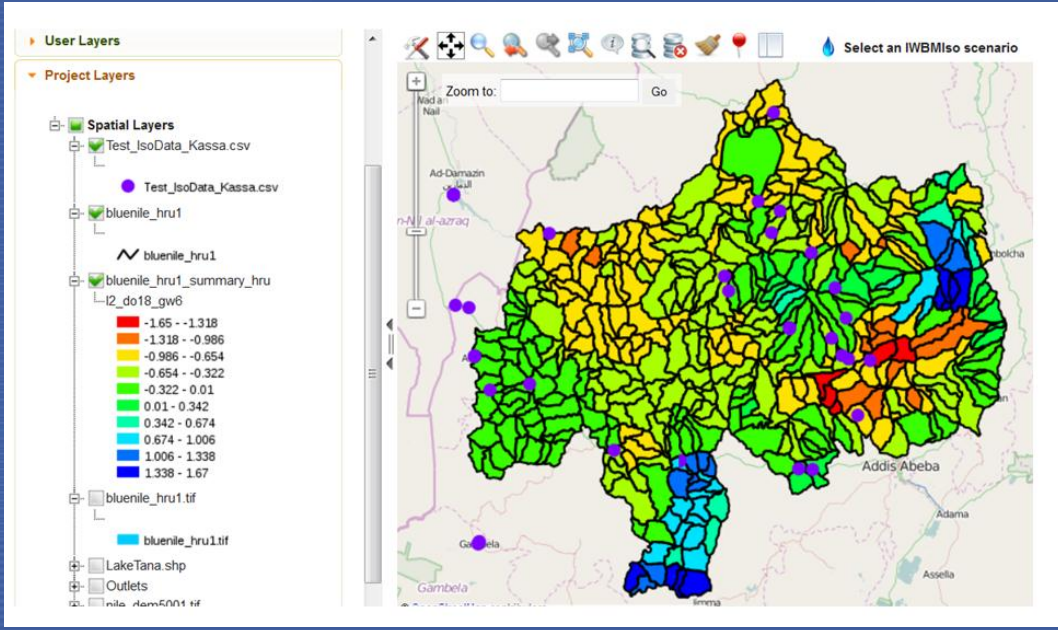
Water Resources Programme

eRAMS Implementation of IWBMIso

- HRU & Sub basin Delineation
- Data Downloading tools
- Global data pre-processing tools
- Simulation and Calibration
- Plotting and Comparison
- Map Generation
- Online and Offline versions
- …



Water Resources Programme

Conclusions

IWBMIso:

Provides a quick and easy method for regional to global water balance assessment, especially in data scarce areas

Water stable isotopes used to constrain model calibration and to better estimate water balance components

Freely available, well-integrated with globally available free datasets

Cross-platform: Windows, OSX, Linux, smart phone, Browser

Modular and dynamic

How to Get a copy

IWBMIso can be obtained via

- http://www-naweb.iaea.org/napc/ih
- Contact: D.Belachew@iaea.org