PyHSPF: Data Integration Software for Hydrologic and Water Quality Modeling

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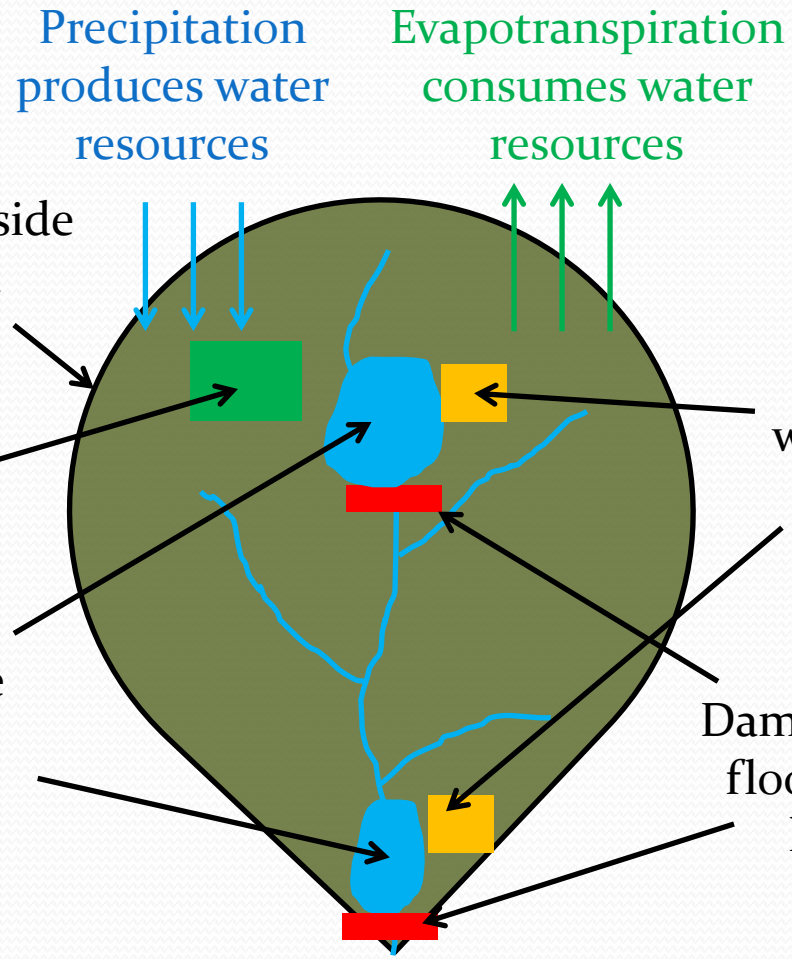
Outline

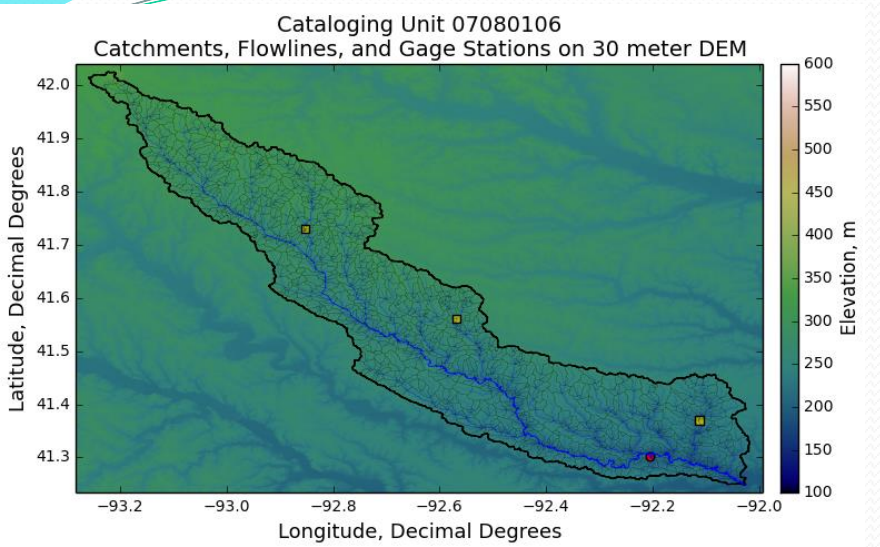
- Hydrology/watershed modeling background
- PyHSPF overview and important classes
- Software example application
- Future ideas

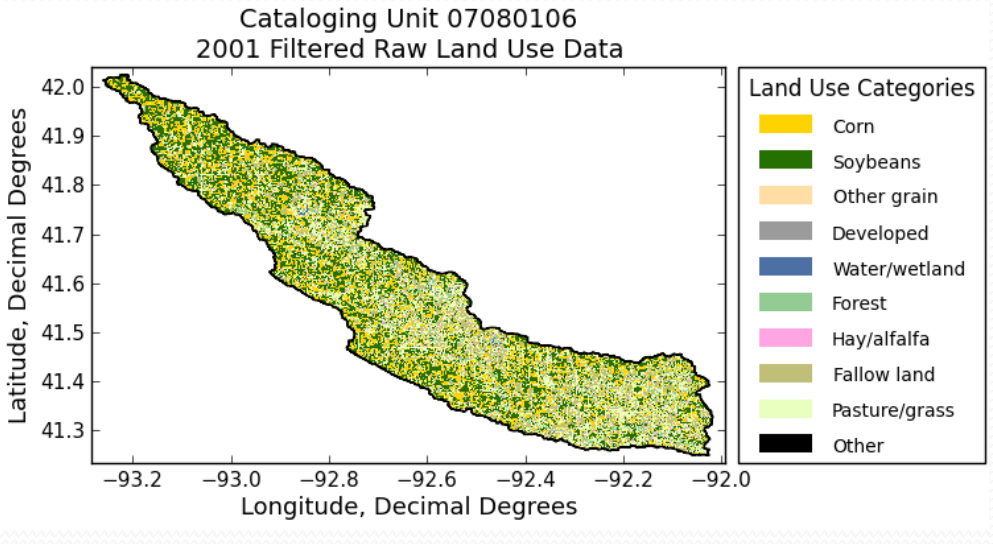
Water Movement on Land Surfaces/Watersheds



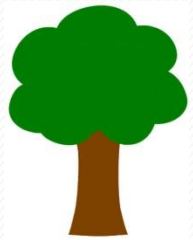
Human activities alter hydrologic cycle and water quality:
Need Data/Models to Predict Downstream Implications

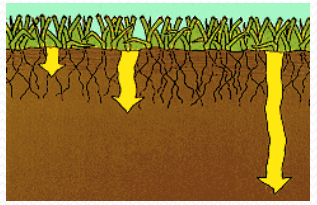
Basic Equation for Hydrologic Modeling





Physical Hydrography + Land Use +





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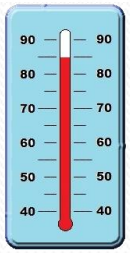
Hydrology Parameters

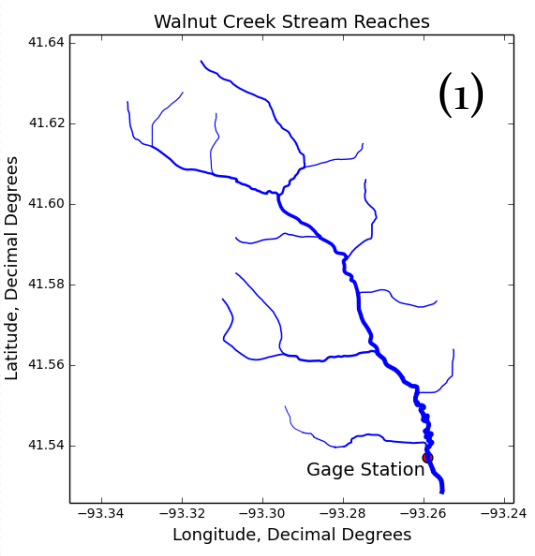


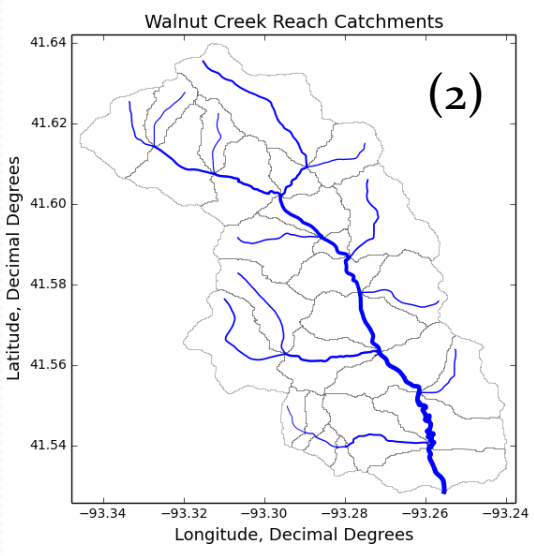
Climate

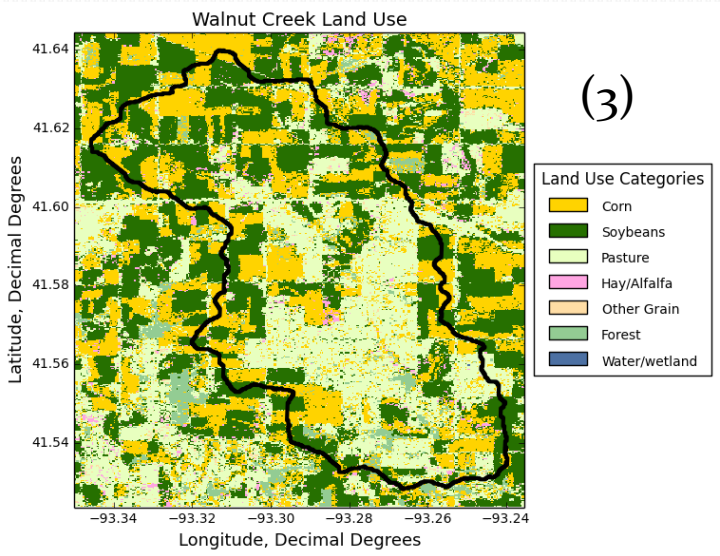
Surface Water flow/quality

Hydrological Simulation Program in Fortran (HSPF)

- Developed by EPA and USGS from Stanford Watershed Model
- Flexible and adaptable (good and bad)
- Model development process
  1. Divide watershed into reach network
  2. Define catchment areas for reaches (subbasins)
  3. Divide subbasins into homogeneous land segments by category (corn, forest, pasture, developed, etc.)
  4. Supply climate forcing time series
  5. Calibrate hydrology process parameters using observed flows



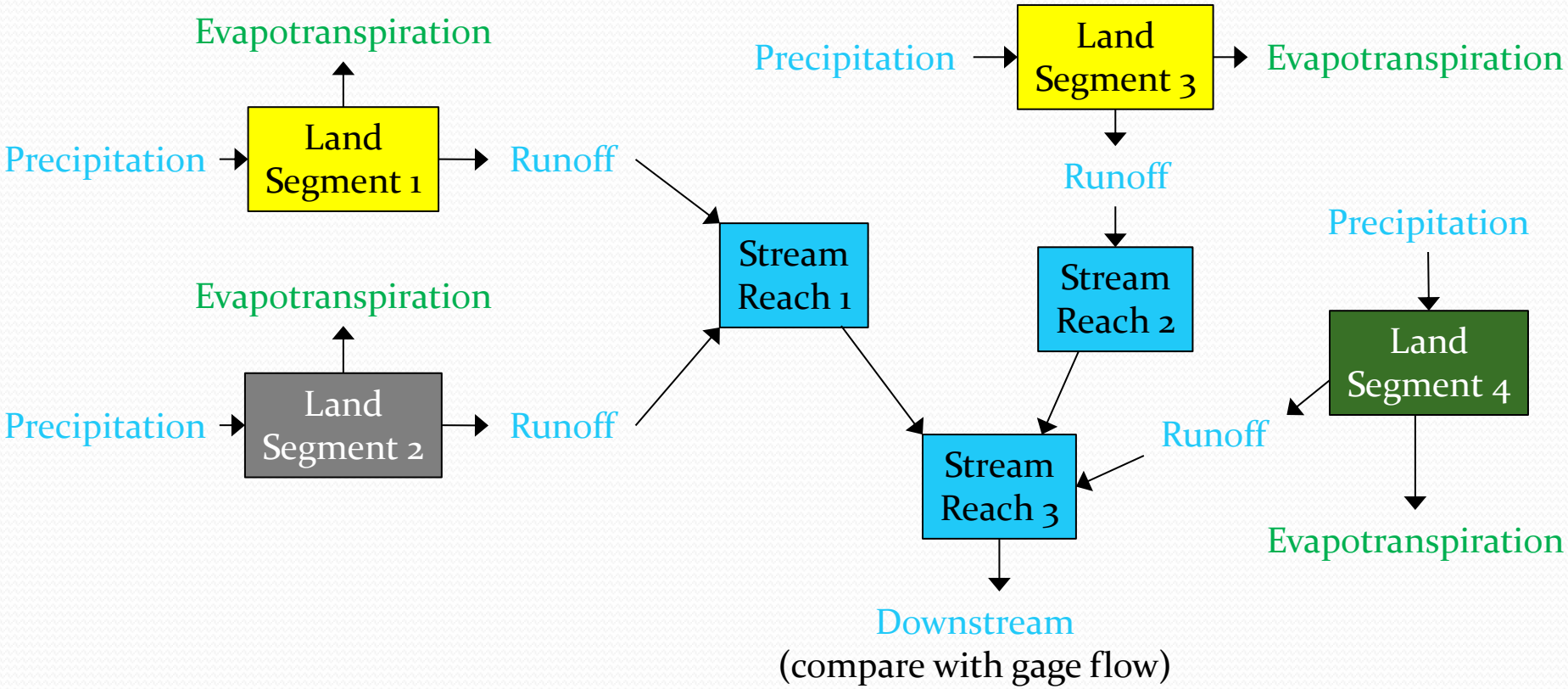




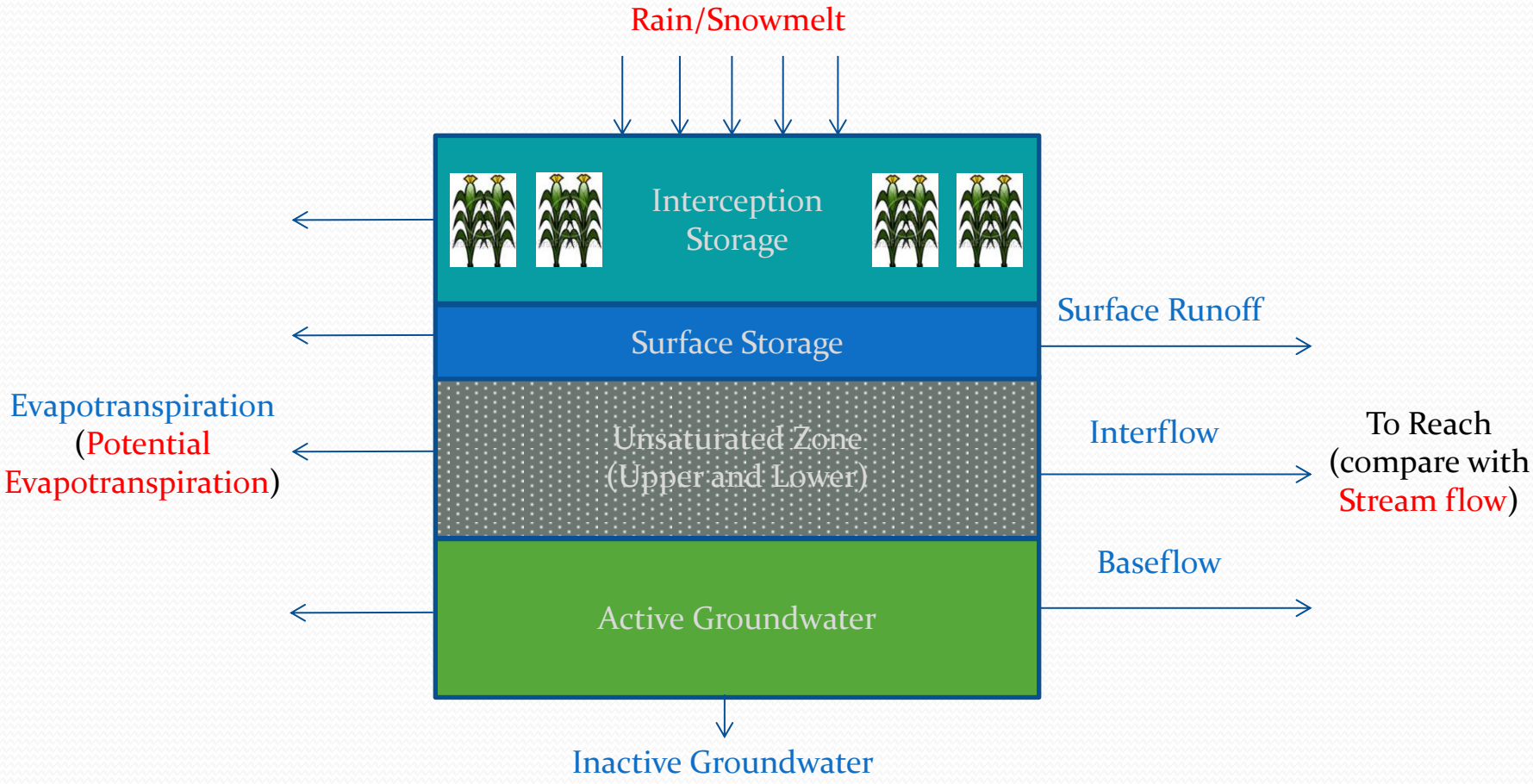
Calculation Logic Example

"Water flows down hill" (water on land surface)

1. Perform water budget on each land segment at each time step
2. Route runoff from land segments to streams
3. Perform water budget on stream reaches
4. Go to the next time step

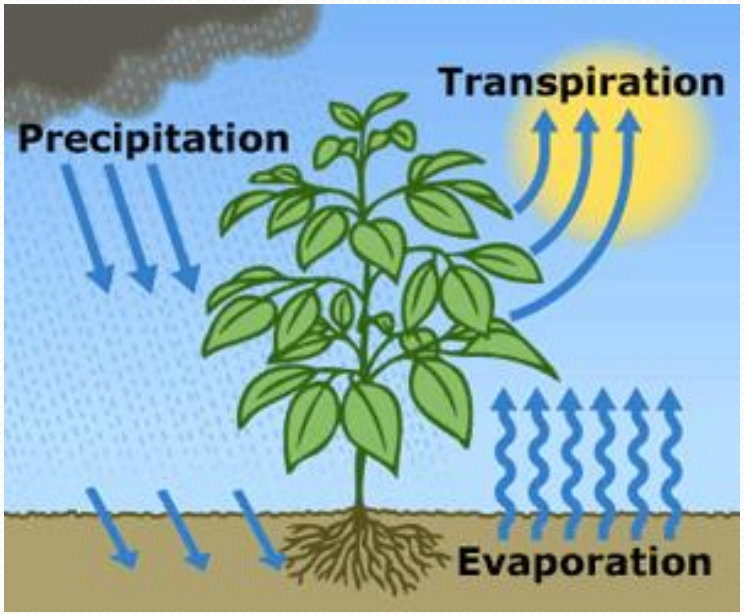


HPSF Pervious Land Segment (PERLND) Water Budget (External Time Series, Fluxes, State Variables)



Evapotranspiration (ET)

- Combined evaporation and plant transpiration
- Function of:
  - Climate
    - Temperature (hot = more evaporation)
    - Humidity (dry = more evaporation)
    - Wind (windy = more evaporation)
    - Sunlight (sunny = more evaporation)
  - Vegetation
    - Leaf area index of vegetation
    - Stomatal resistance of vegetation
  - Soil moisture

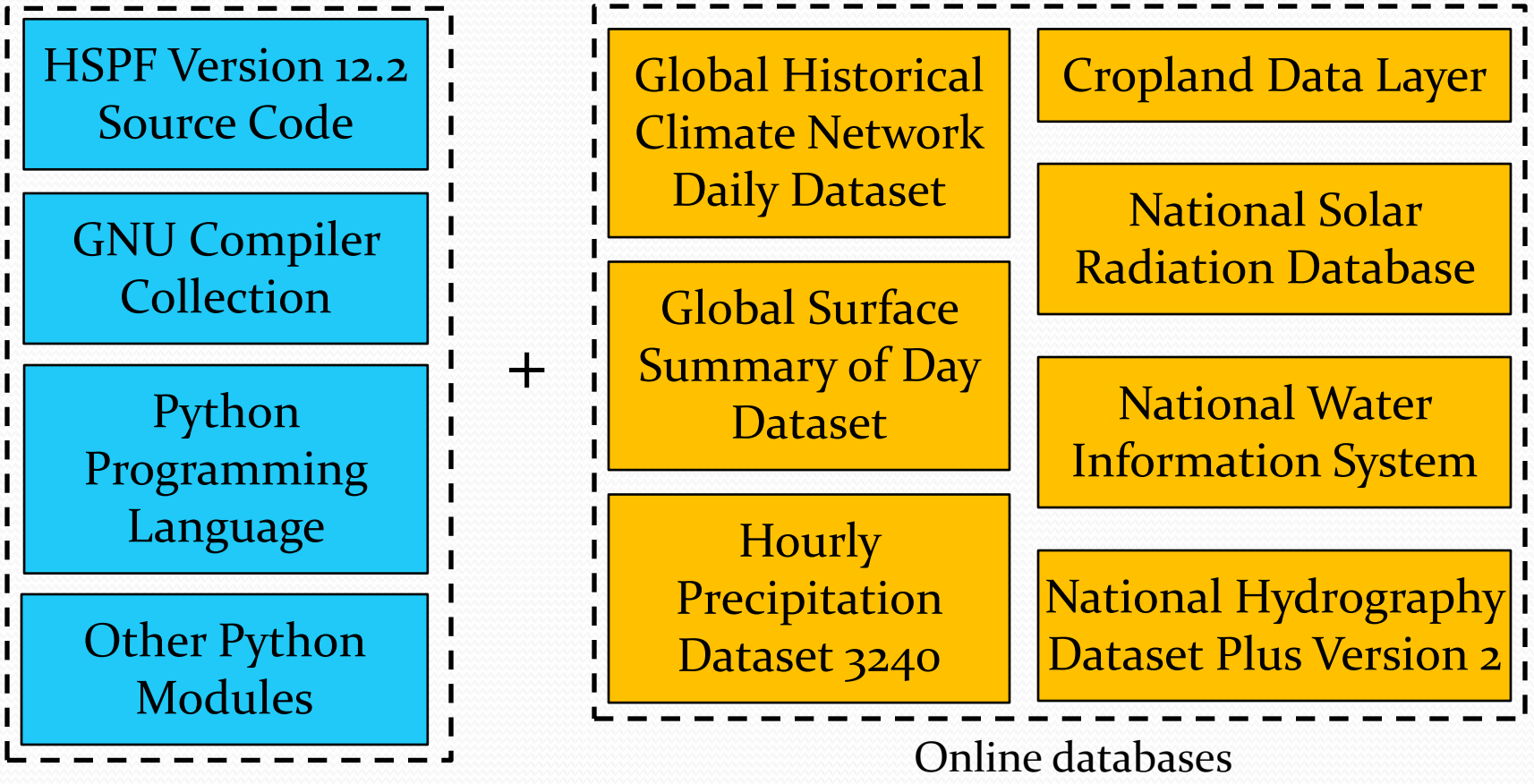


1. Penman-Monteith Equation (energy balance) = climate
2. Empirical crop coefficient = vegetation
3. Watershed model + (1) + (2) = soil moisture accounting

Summary of HSPF Data Needs

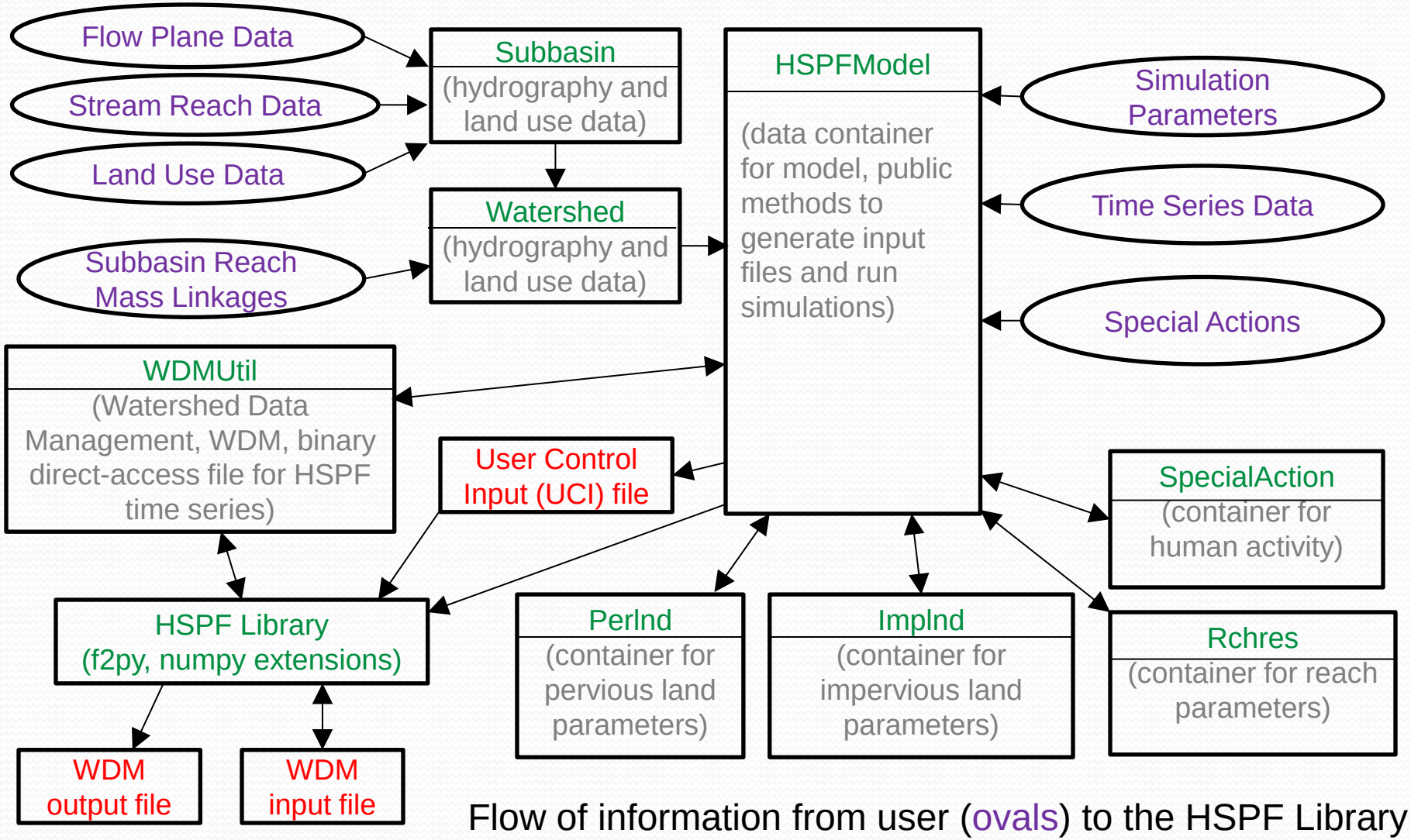
- Hydrography
  - Stream reach network/connectivity
  - Stream reach catchment areas/geometry (subbasins)
  - Dams/diversions/withdrawals
- Land use
  - Subbasin land use category fractions
  - Crop-specific information (plant, till dates)
- Climate time series
  - Precipitation, temperature, humidity, wind, sunlight
  - Evapotranspiration demand (depends on vegetation)
- Hydrology
  - Stream flow and water quality
  - Hydrology process parameters (inversion)

PyHSPF: Python extensions for utilizing HSPF



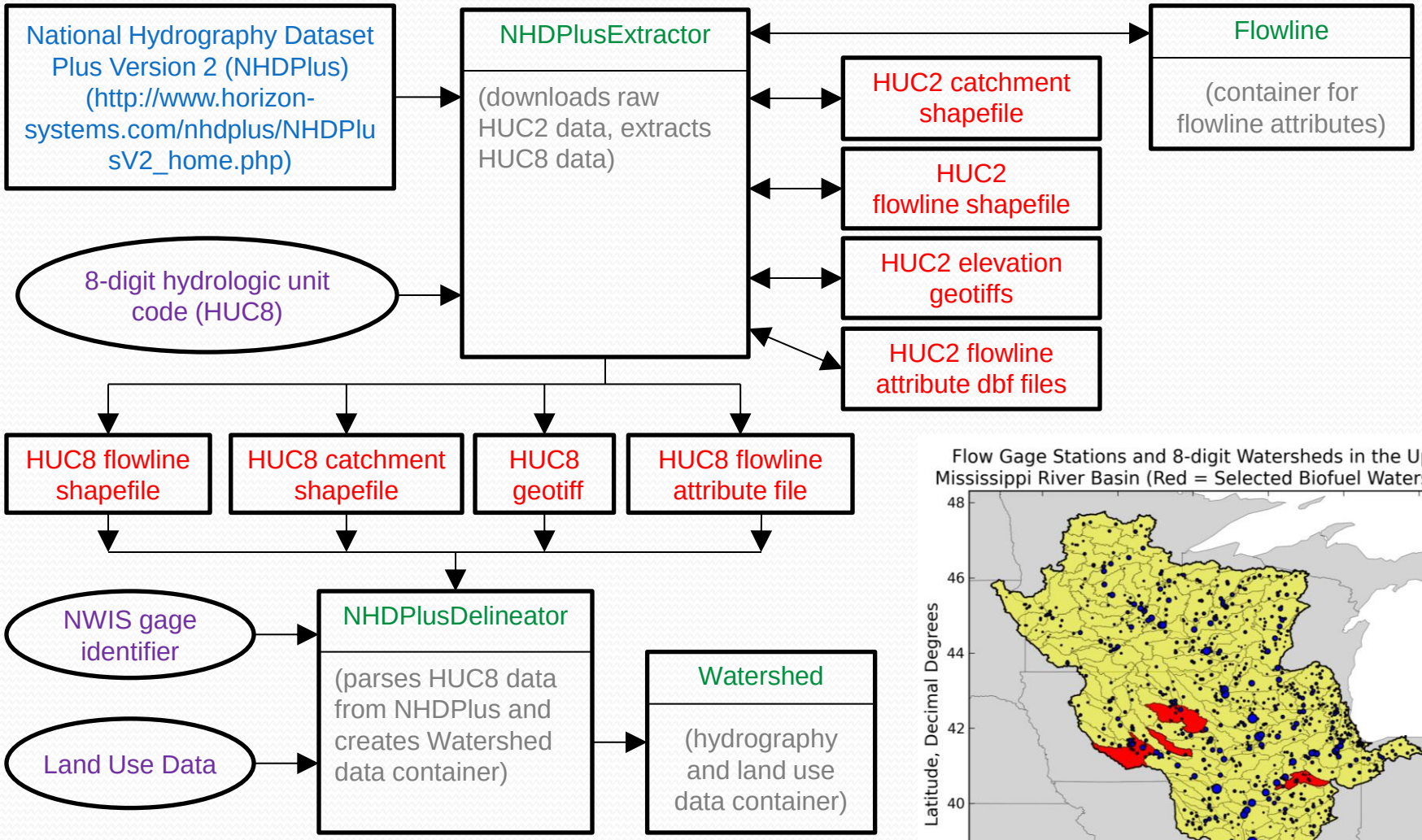
Automates data extraction, aggregation, calibration to develop model in ~1 hour

“Core” Module Classes/Data Structures



Flow of information from user (ovals) to the HSPF Library to generate input/output files (red) and run a simulation

National Hydrography Dataset Plus Tools

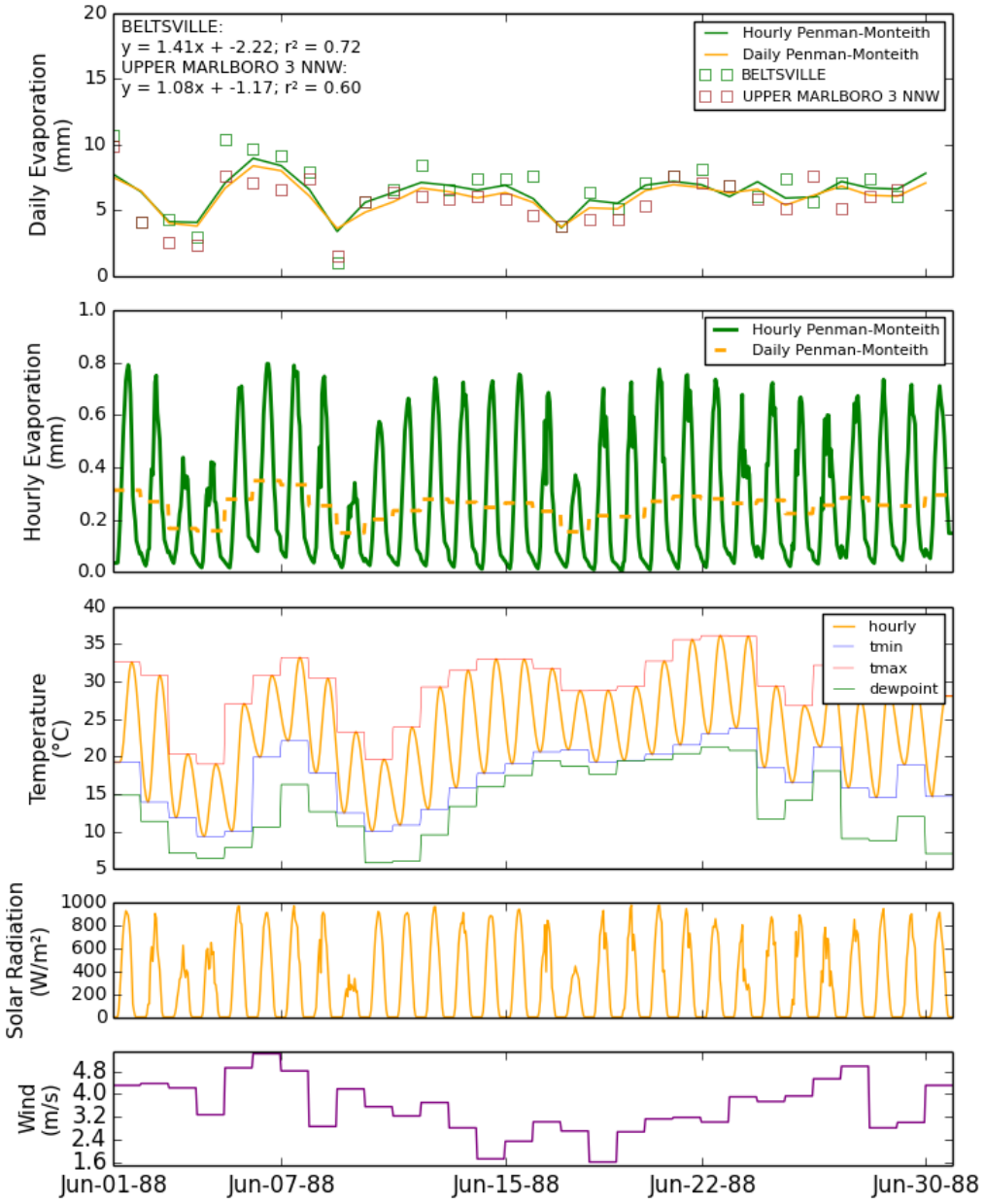


Flow of information from user (ovals) and the WWW (NHDPlus) to local files (red) and the Watershed class

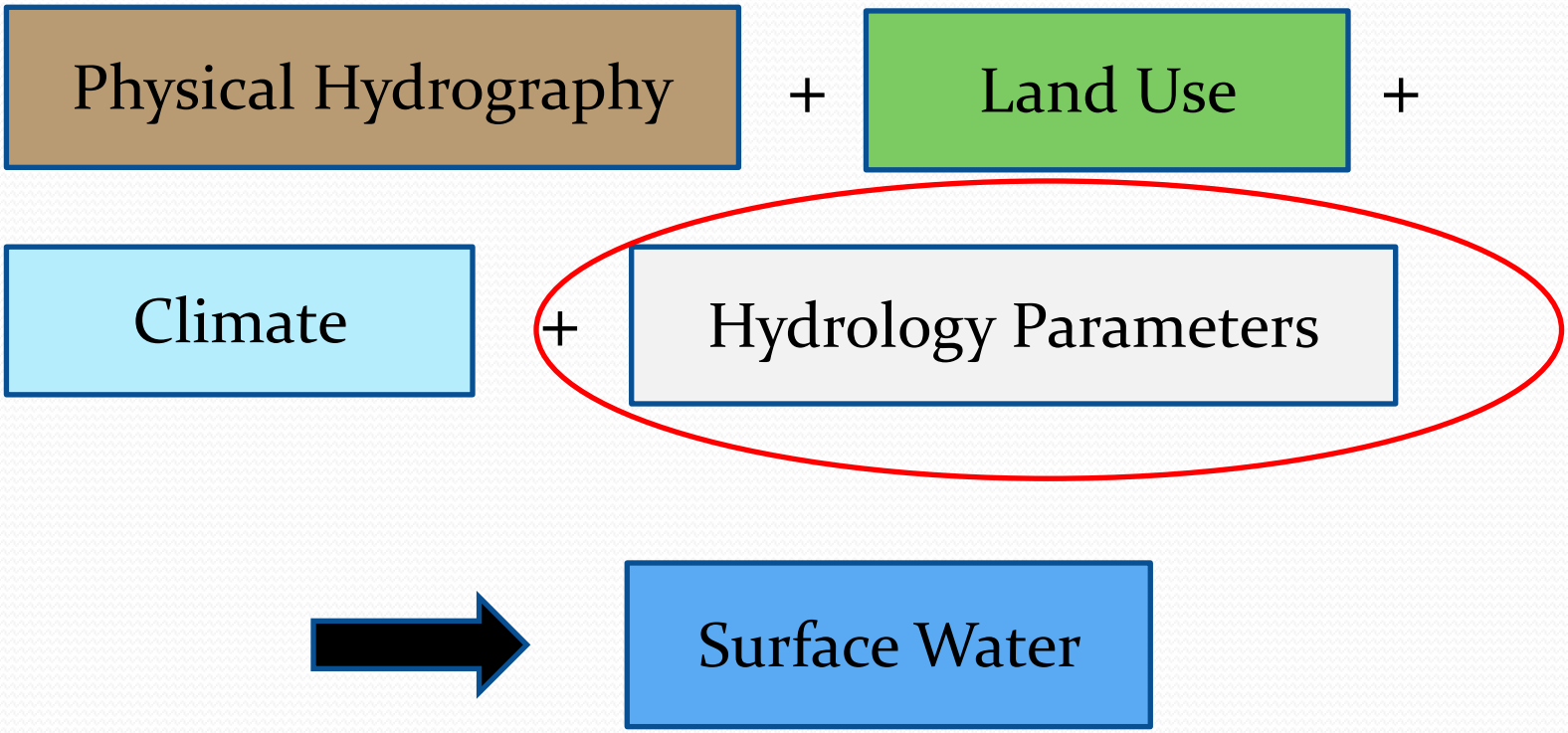
Climate Data – Reference Evapotranspiration

Automated extraction of temperature, dew point, wind speed, solar radiation, pan evaporation

Computation of hourly reference evapotranspiration (ET_o) time series (demand by well-watered grass)

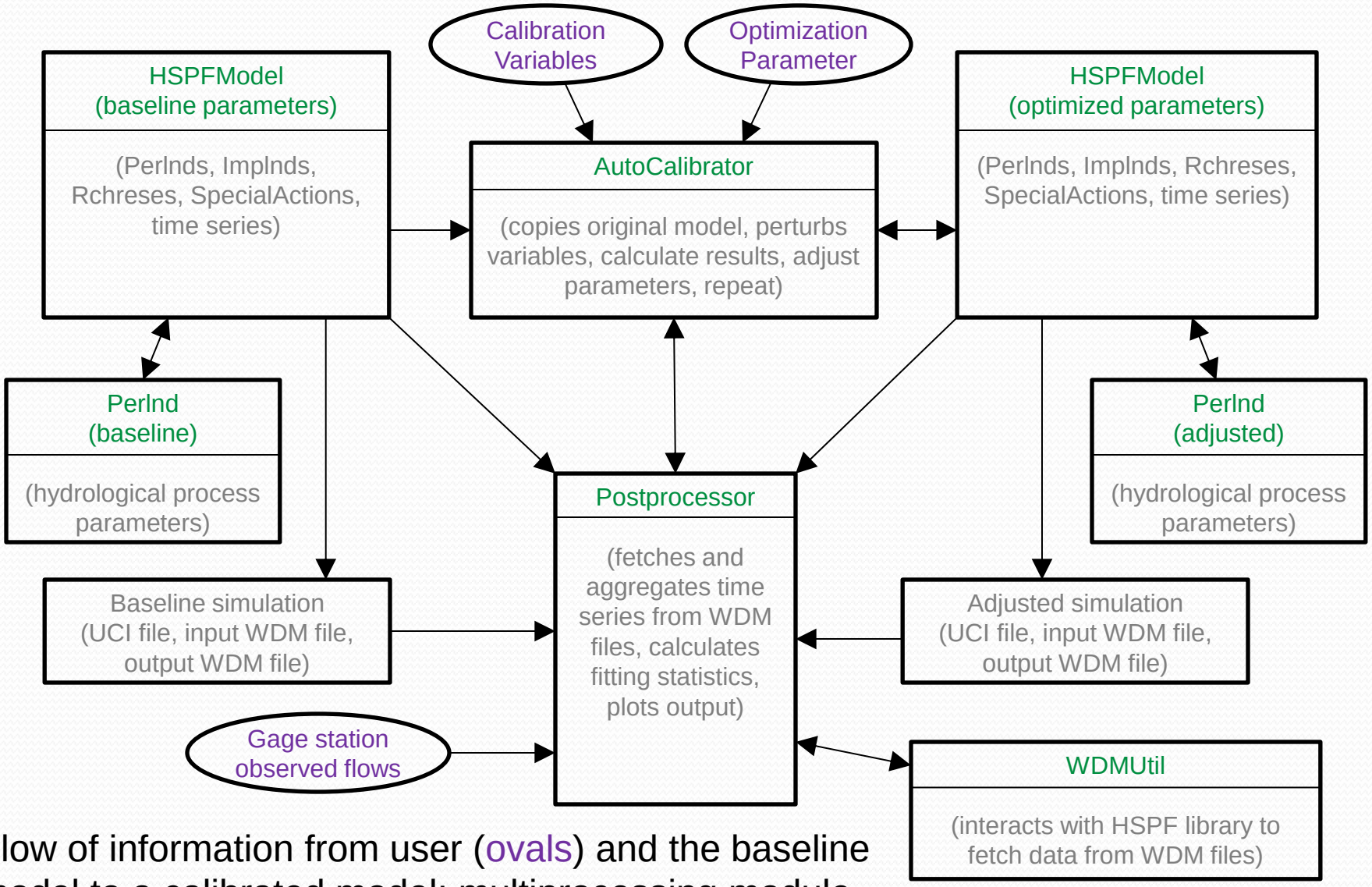


Basic Equation for Hydrologic Modeling



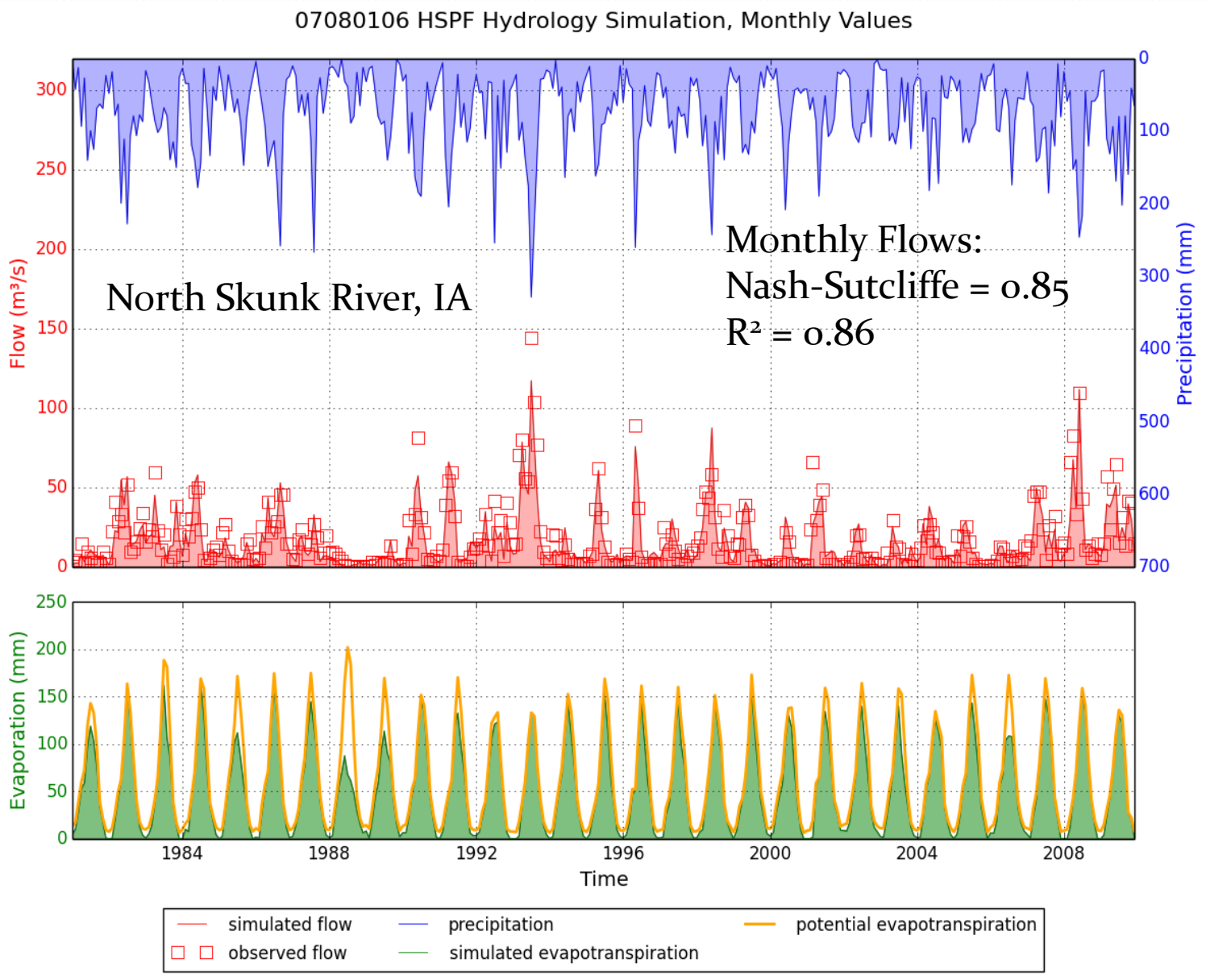
Not measurable, requires calibration/inversion

Postprocessor and AutoCalibrator Classes

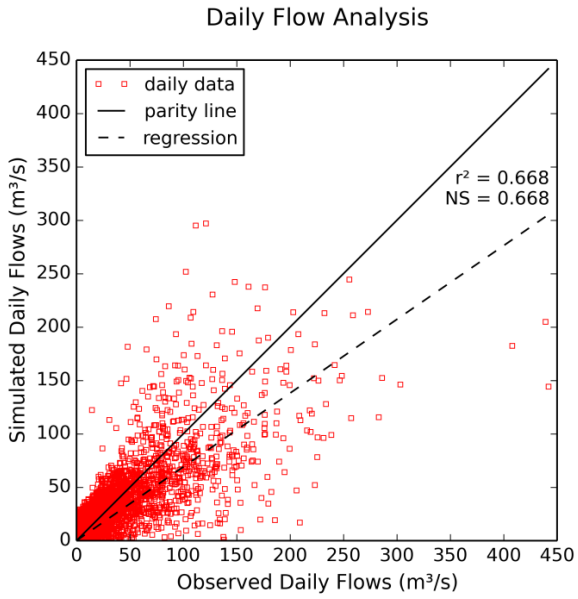


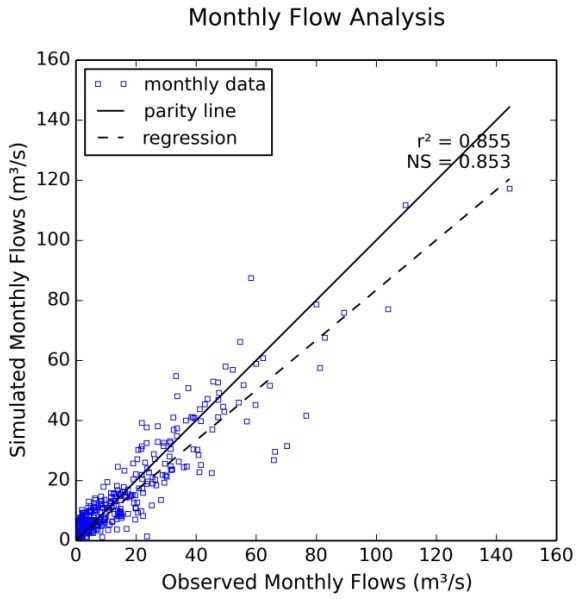
Flow of information from user (ovals) and the baseline model to a calibrated model; multiprocessing module

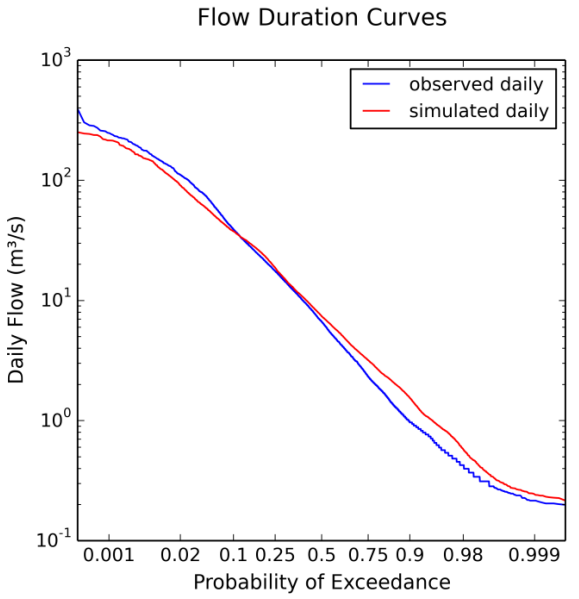
Monthly Hydrograph

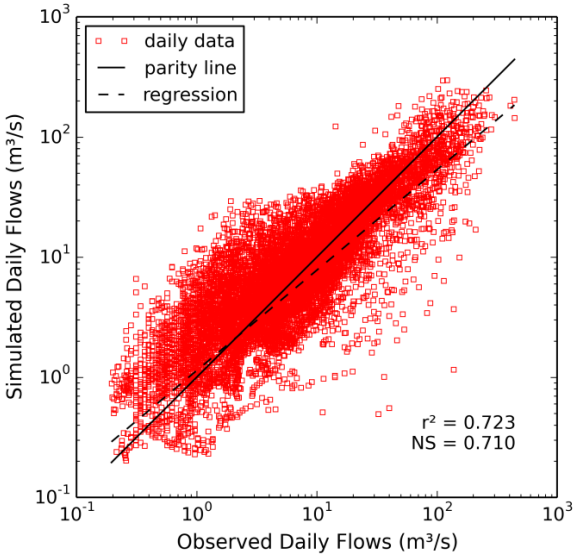


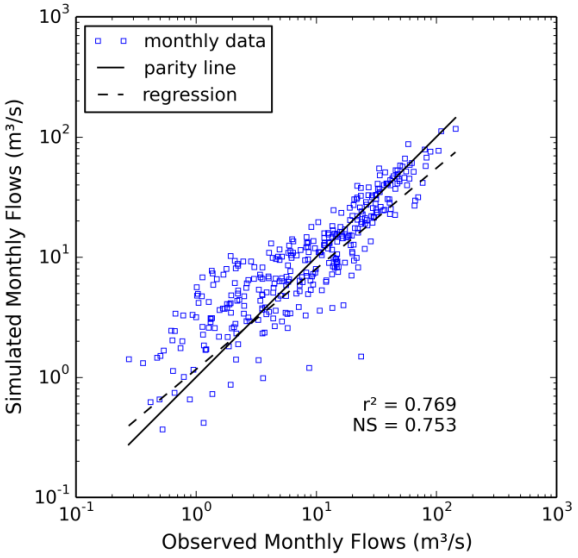
Statistical Plots

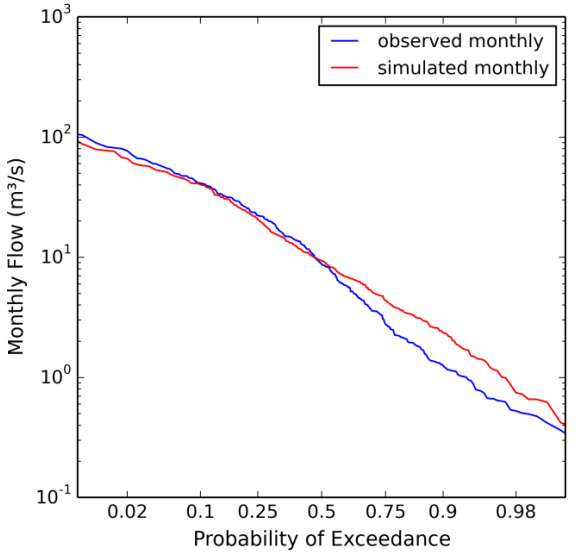




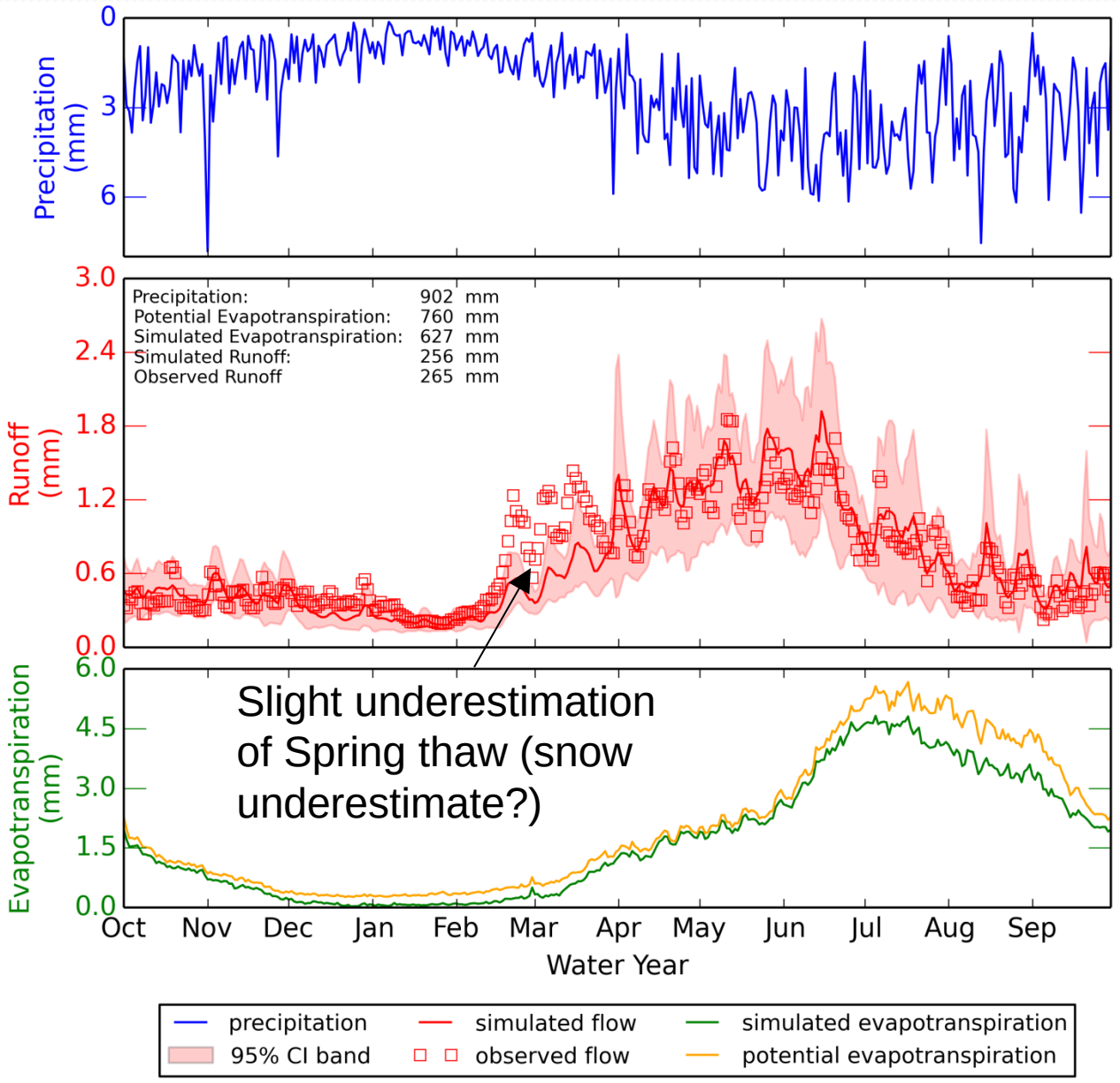




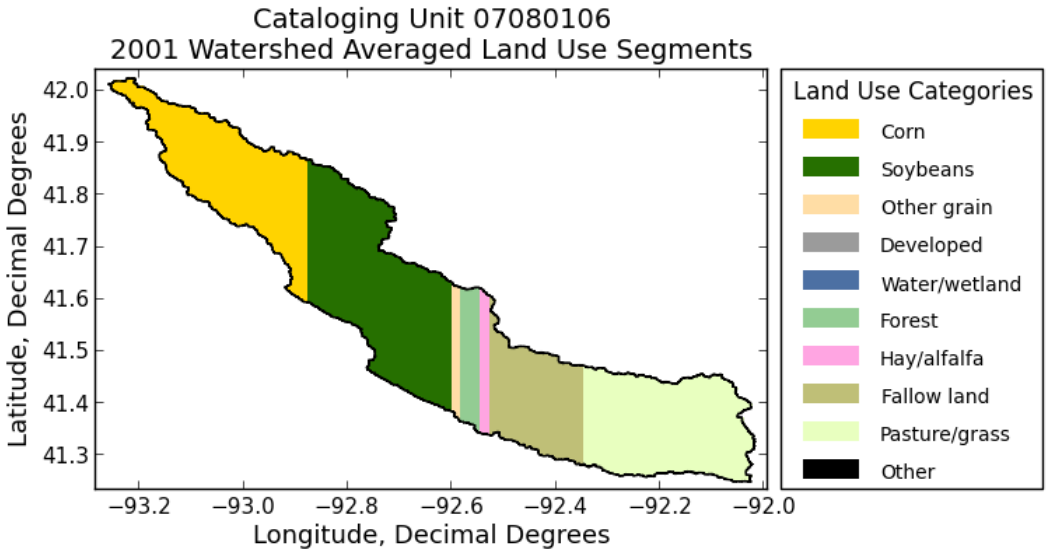


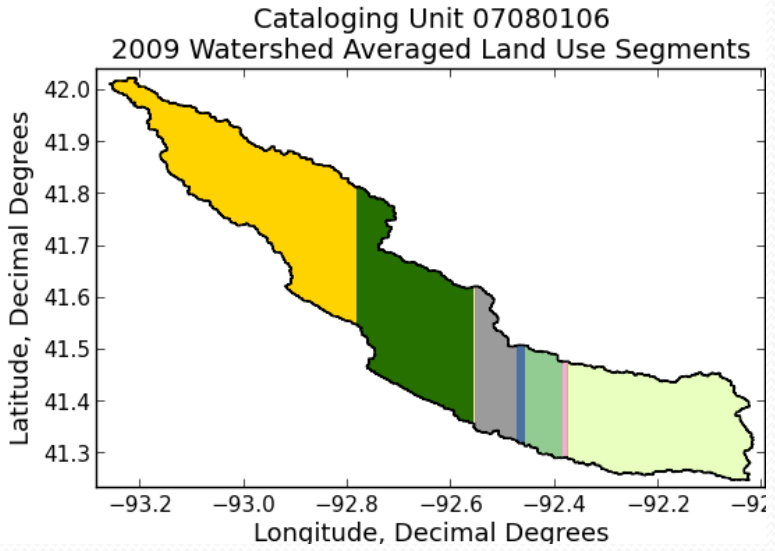


“Day of the Year” Hydrograph



Land Use Change Application (2001 vs 2009)



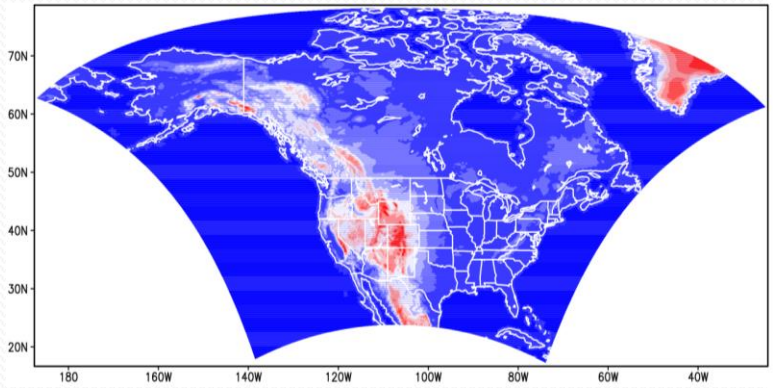


Corn fraction increased ~10%
Evapotranspiration increased 30 mm/yr (5%)

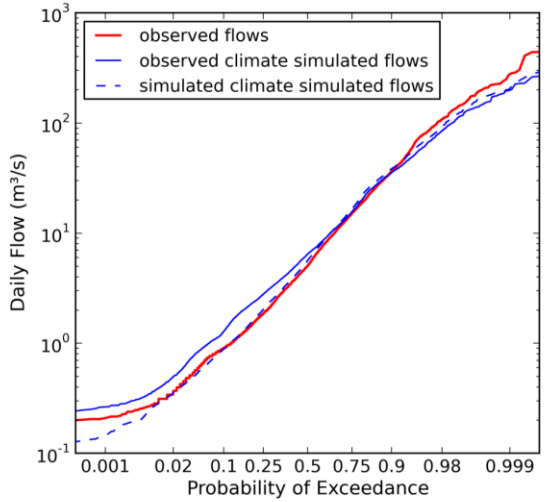
Parameter	2001 Land use Scenario Mass Balance (mm/yr)	2009 Land use Scenario Mass Balance (mm/yr)
Precipitation	898	898
Runoff	251	221
Evapotranspiration	630	661
Annual Max Daily Flow (ft3/s)	93.6	78.5

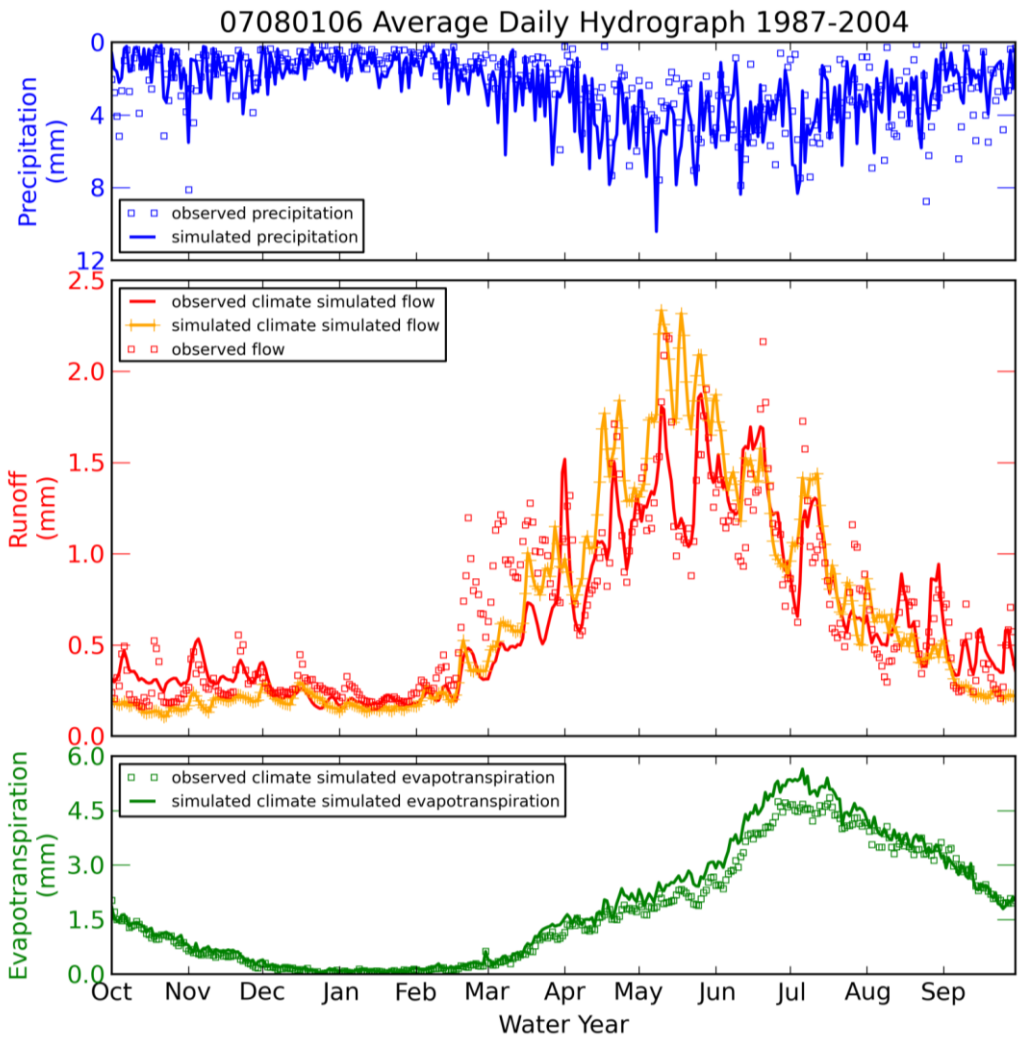
Climate Change Application (downscaled climate model)

- Standard Weather Research and Forecasting (WRF) Model
- Observed versus simulated climate in calibrated HSPF model



Daily Flow-Duration Curve





Future Ideas for PyHSPF

- Nationwide-application
  - Larger-scale models
  - Data mining (correlations between hydrological processes and human activities)
- Time-variable land use
- Water quality modules
  - Pesticides
  - Nutrients
- Different data sources
  - Radar precipitation
  - Climate models
  - Different countries
- Modified hydrological process representation

Thank You!

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https://github.com/djlampert/PyHSPF