Update on rSAS implementation and parameterization

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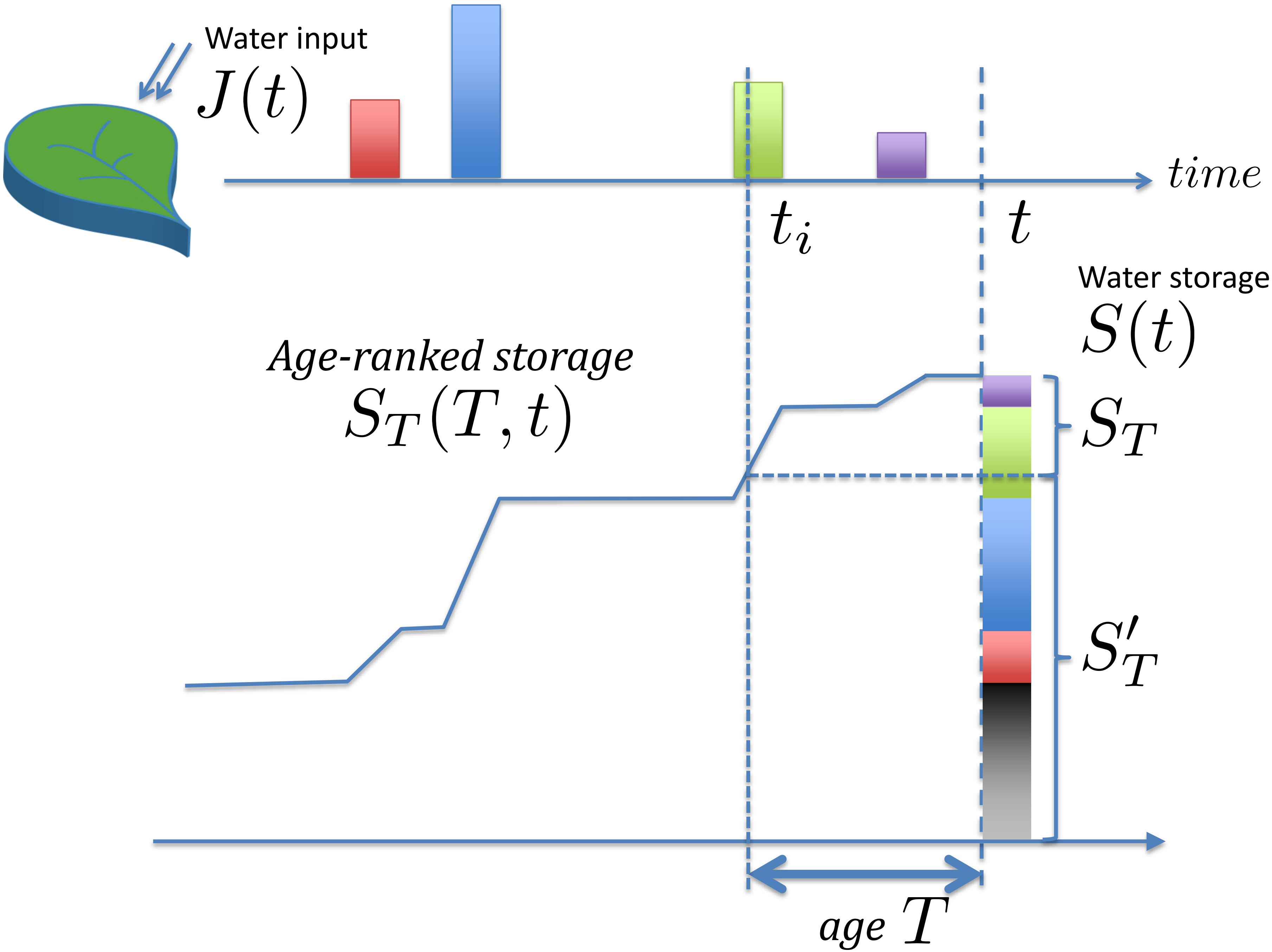
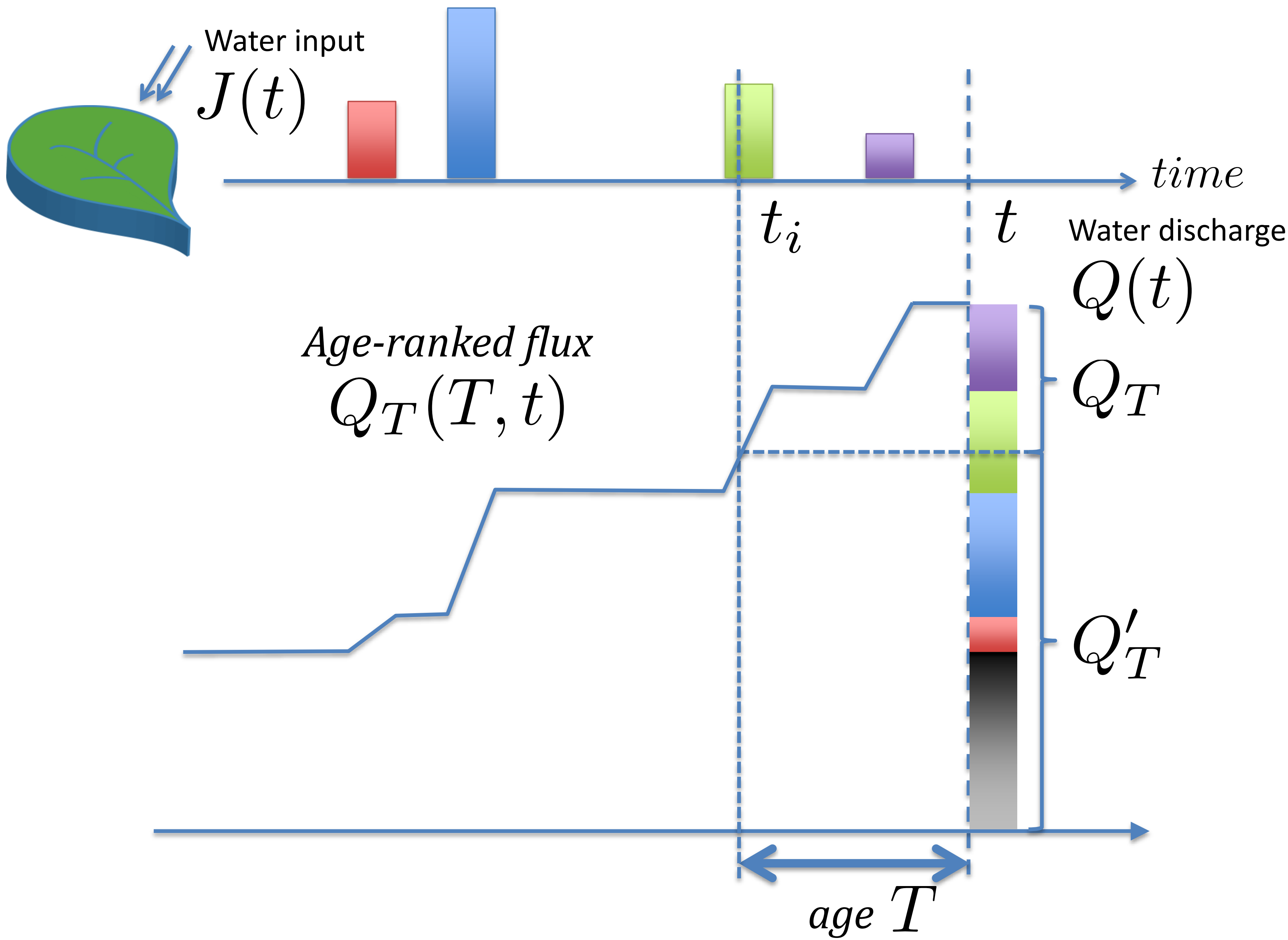
What is rSAS and what is it for?

- rSAS : rank StorAge Selection
  - Technique for modeling time-variable transit time distributions
- Here it is being used to account for **groundwater lag times** in watershed model
  - Only used to route recharge N load through groundwater
  - Not used for other species, or other pathways
- Parameterized by a mix of
  - USGS MODFLOW modeling
  - “best estimates”, to be replaced by…
  - Statistical regionalization model

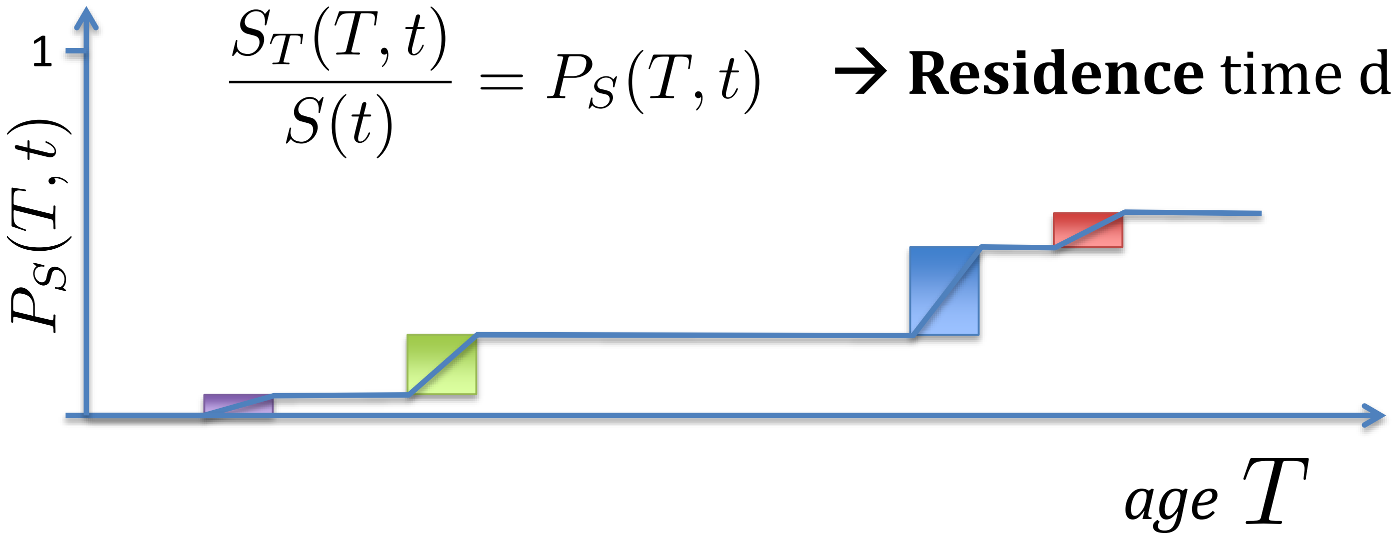


Water input
$J(t)$
$time$
t_i
t
Water storage
$S(t)$
Age-ranked storage
$S_T(T,t)$
S_T
S'_T
age T

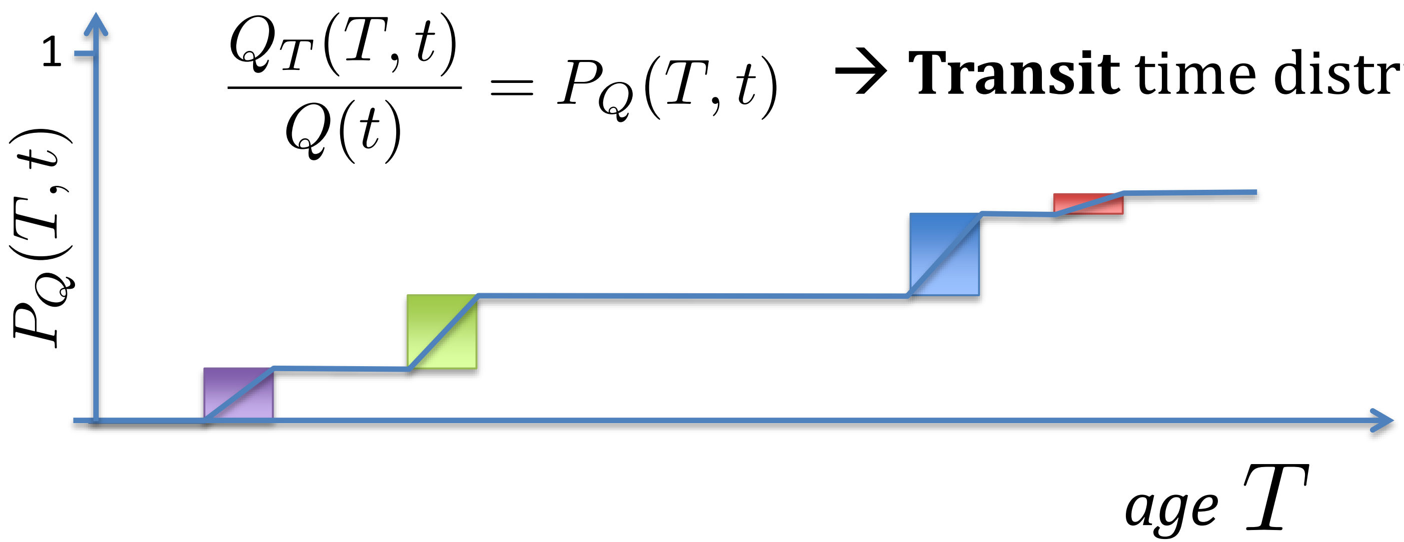


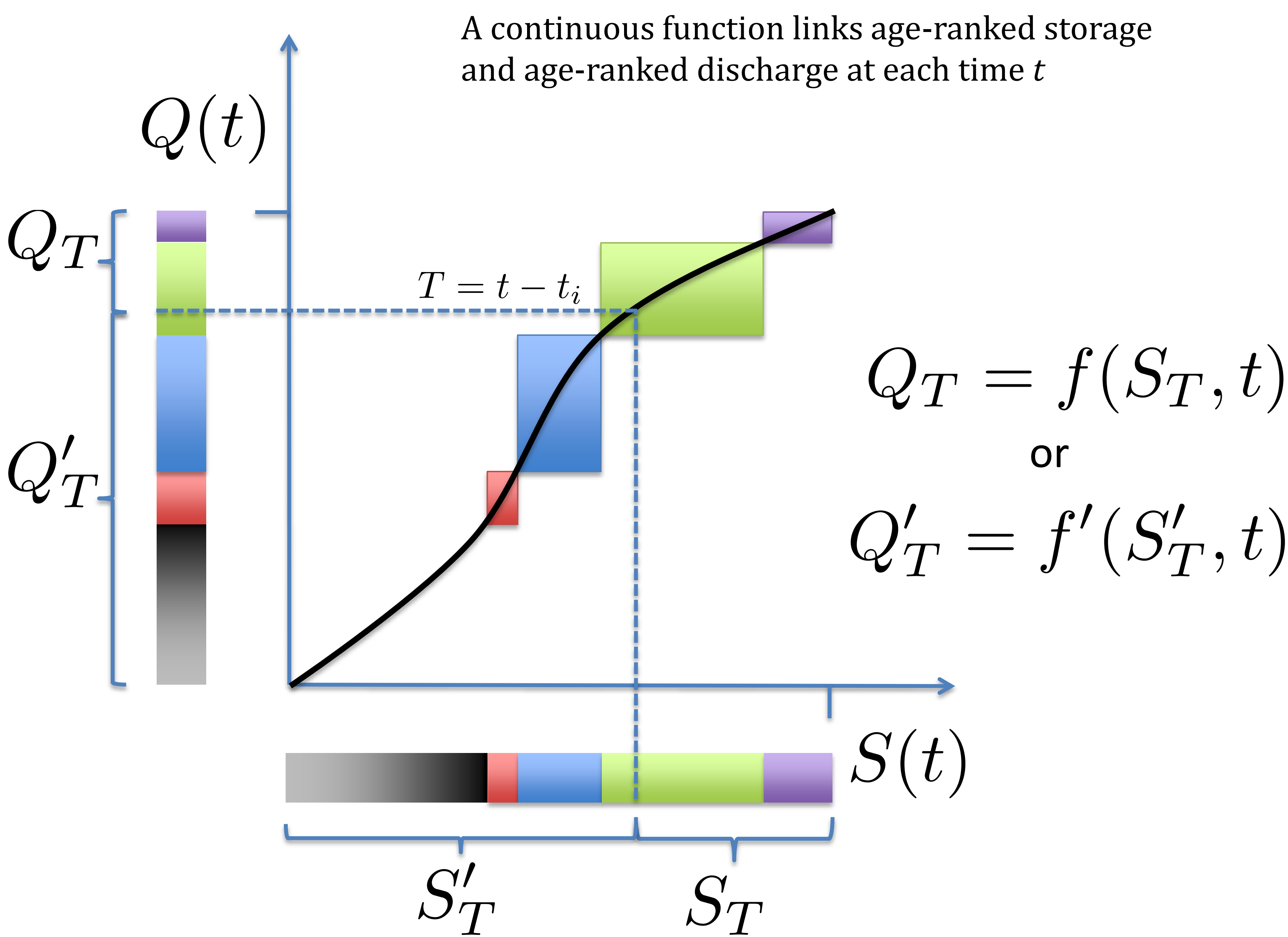
Water input
$J(t)$
$time$
t_i
t
Water discharge
$Q(t)$
Age-ranked flux
$Q_T(T,t)$
Q_T
Q'_T
age T

$$\frac{S_T(T,t)}{S(t)} = P_S(T,t)$$ → **Residence** time distribution



$$\frac{Q_T(T,t)}{Q(t)} = P_Q(T,t)$$ → **Transit** time distribution




A continuous function links age-ranked storage
and age-ranked discharge at each time t
$Q(t)$
Q_T
Q'_T
$T = t - t_i$
$Q_T = f(S_T, t)$
or
$Q'_T = f'(S'_T, t)$
$S(t)$
S'_T
S_T

$$\frac{Q_T(T,t)}{Q(t)} = \frac{f(S_T,t)}{Q(t)}$$

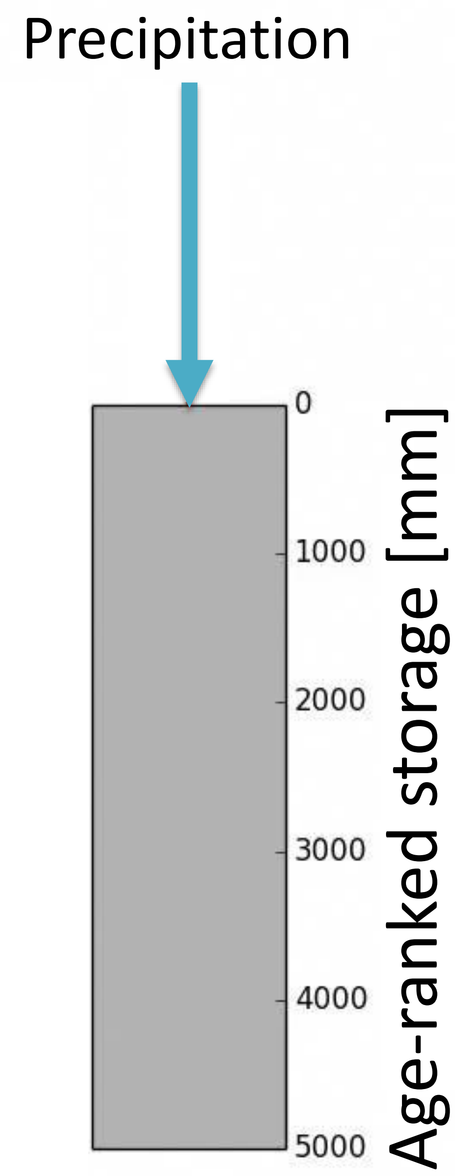
$$P_Q(T,t) = \Omega_Q(S_T,t)$$

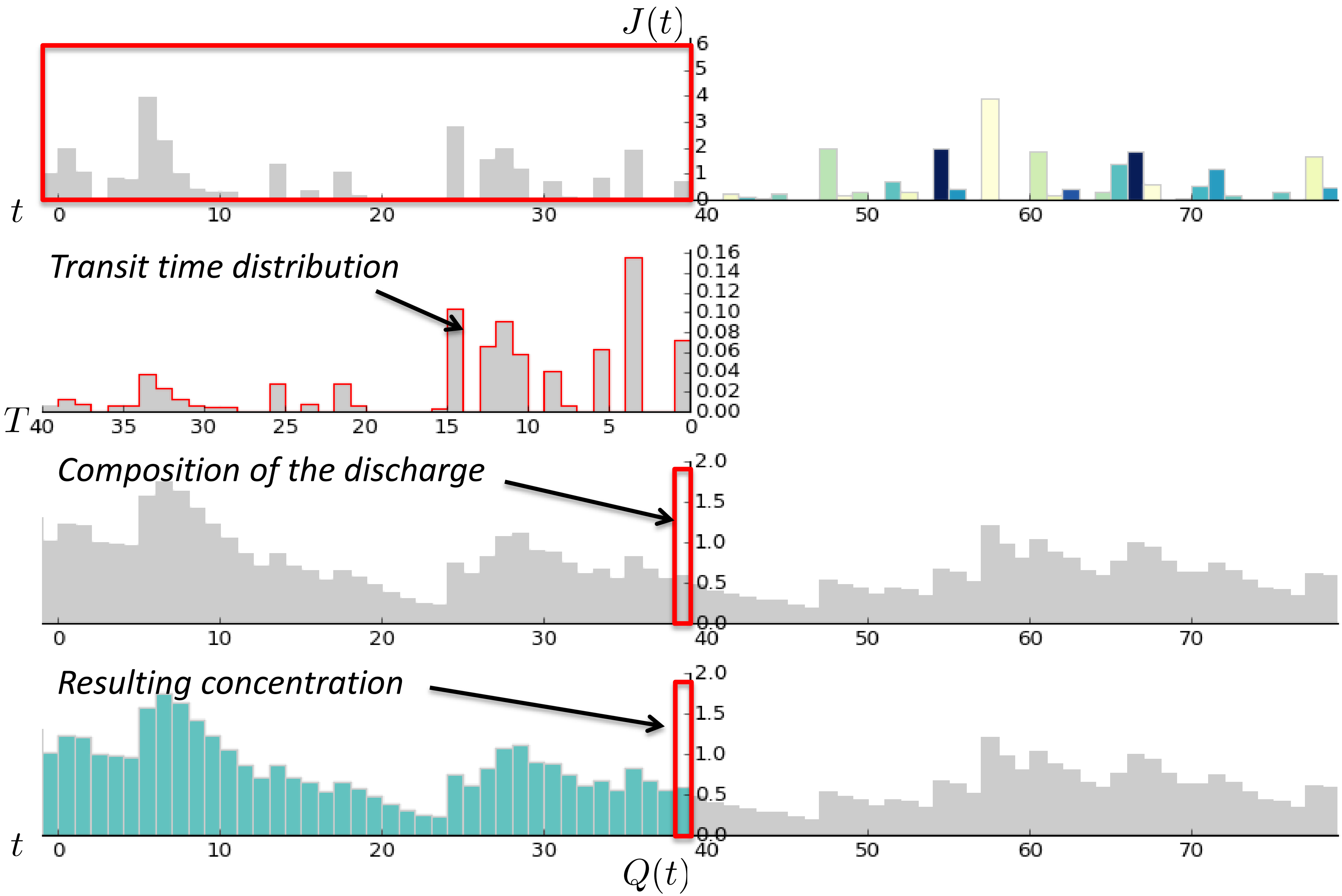
Transit time distribution (TTD)

rank StorAge Selection (rSAS) function

The rSAS function is a (possibly time-varying) probability distribution over storage.

Present model assumes rSAS is time-invariant but TTD varies because recharge rate varies


Precipitation
0
1000
2000
3000
4000
5000
Age-ranked storage [mm]



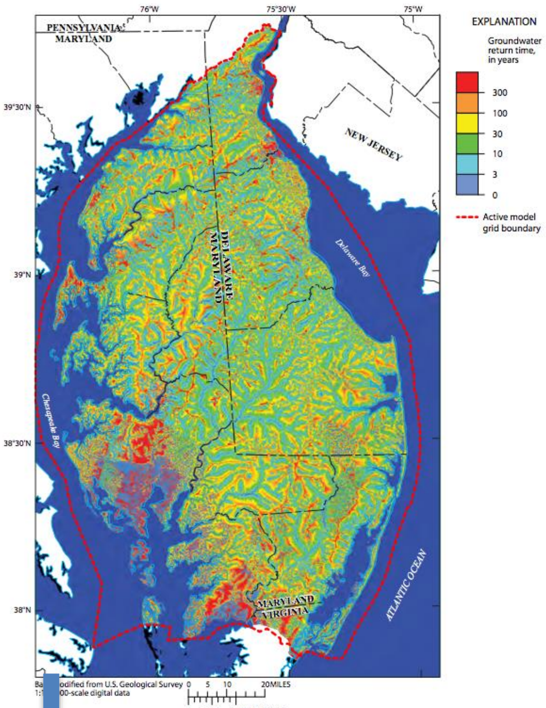
$J(t)$
t
Transit time distribution
T
Composition of the discharge
Resulting concentration
t
$Q(t)$

Overview

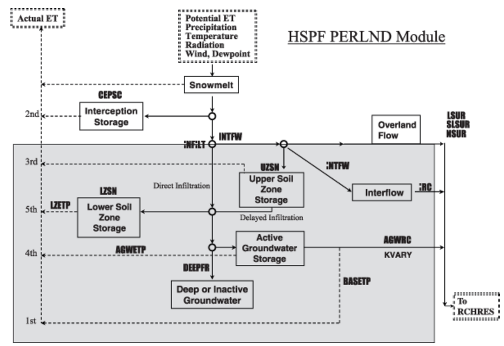
Linking groundwater and surface water models

USGS MODFLOW

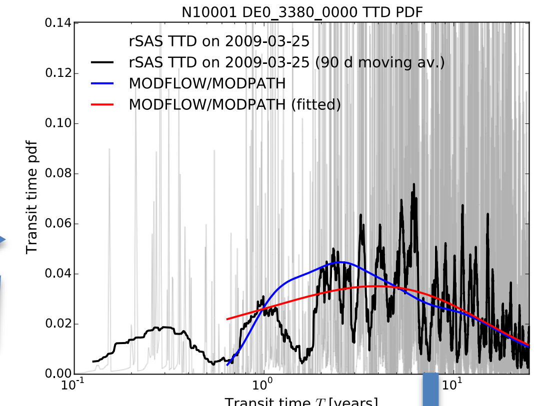
Ward Sanford et al



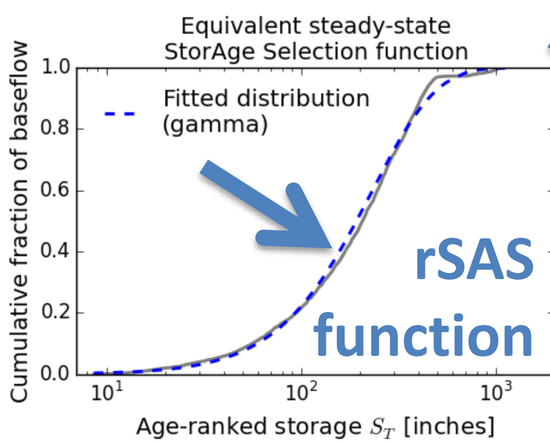
CBP watershed model

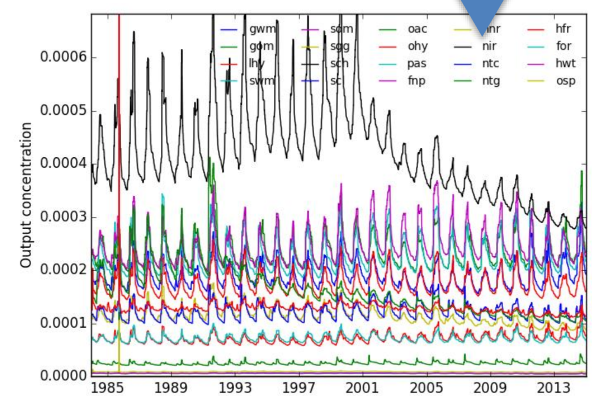


Time-varying transit time distributions



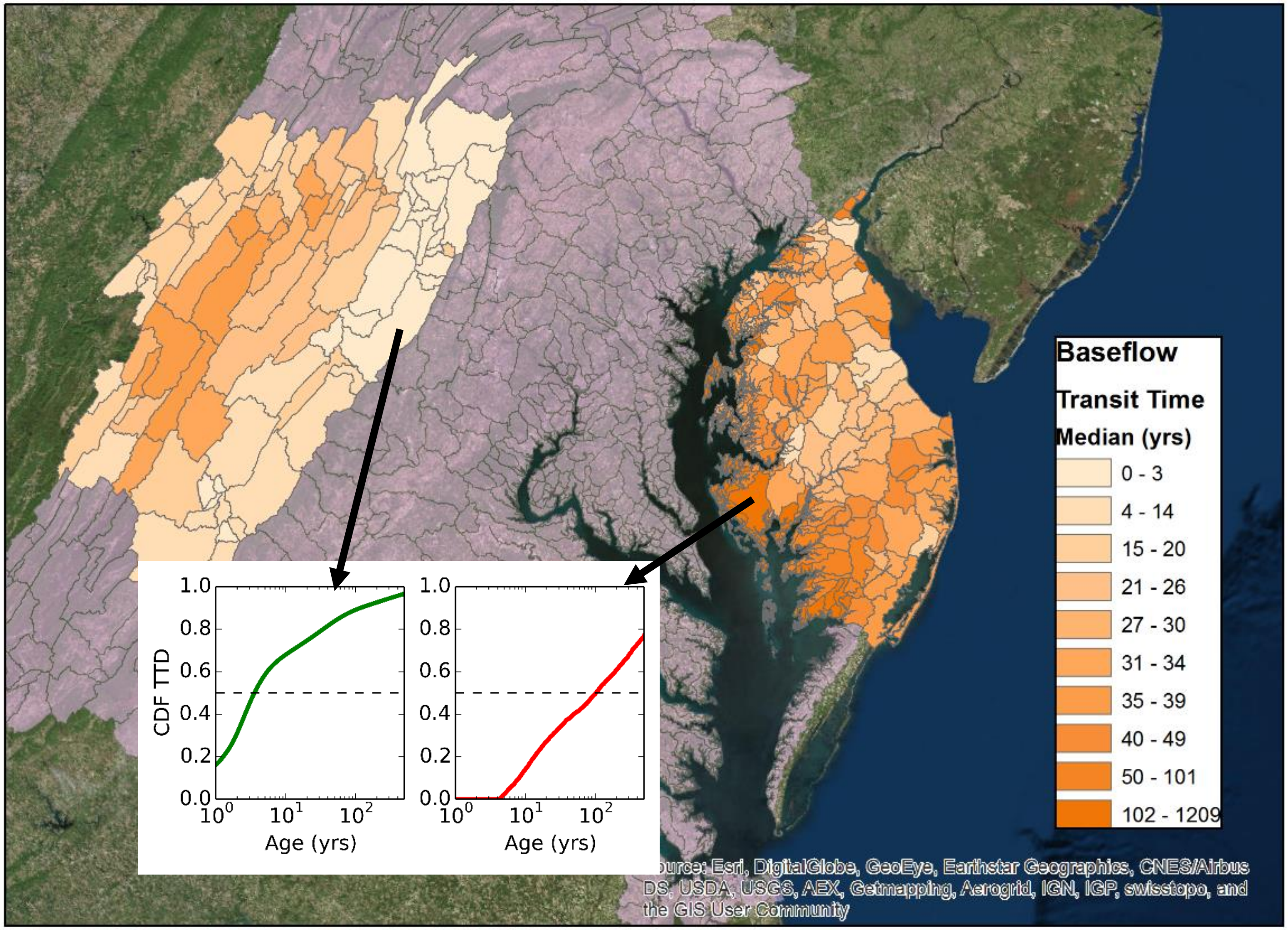
Steady-state transit time distributions





Nitrate loading scenarios

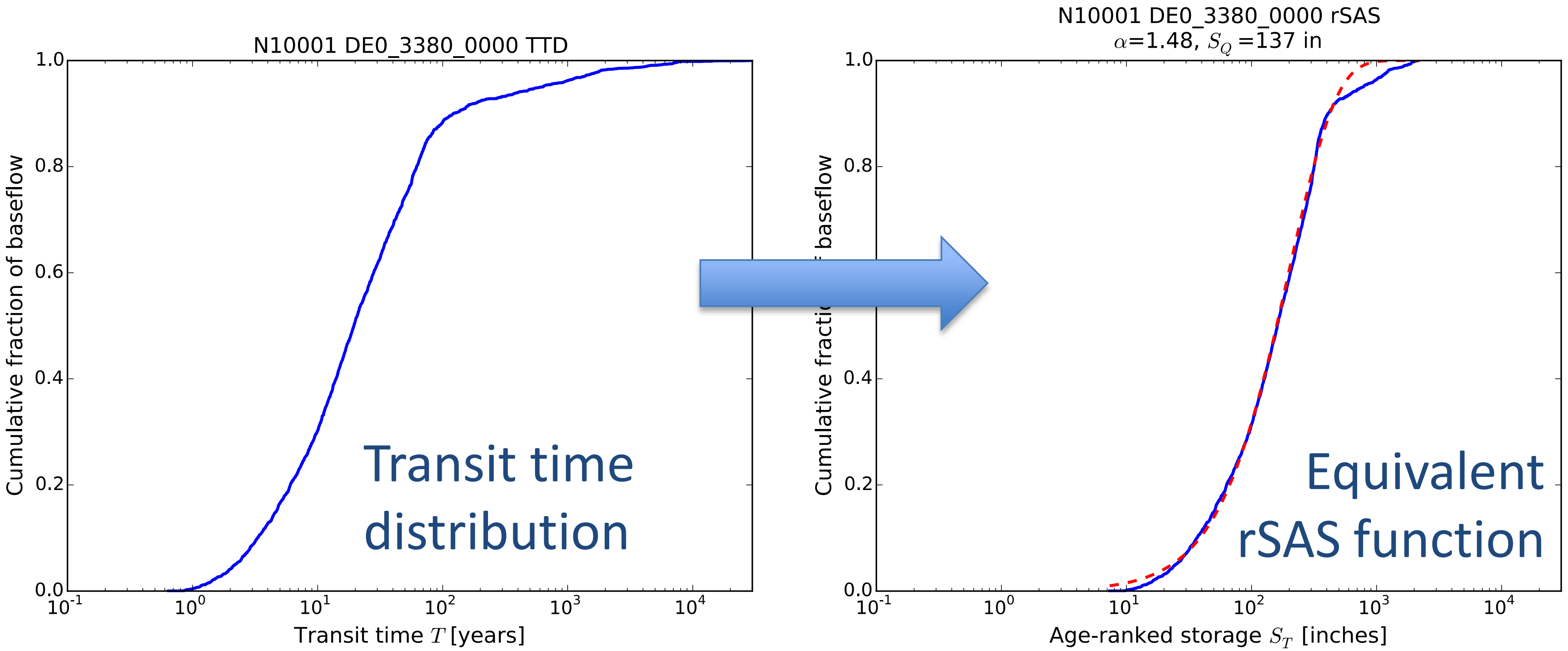
TTD for each LRS
from USGS MODFLOW modeling



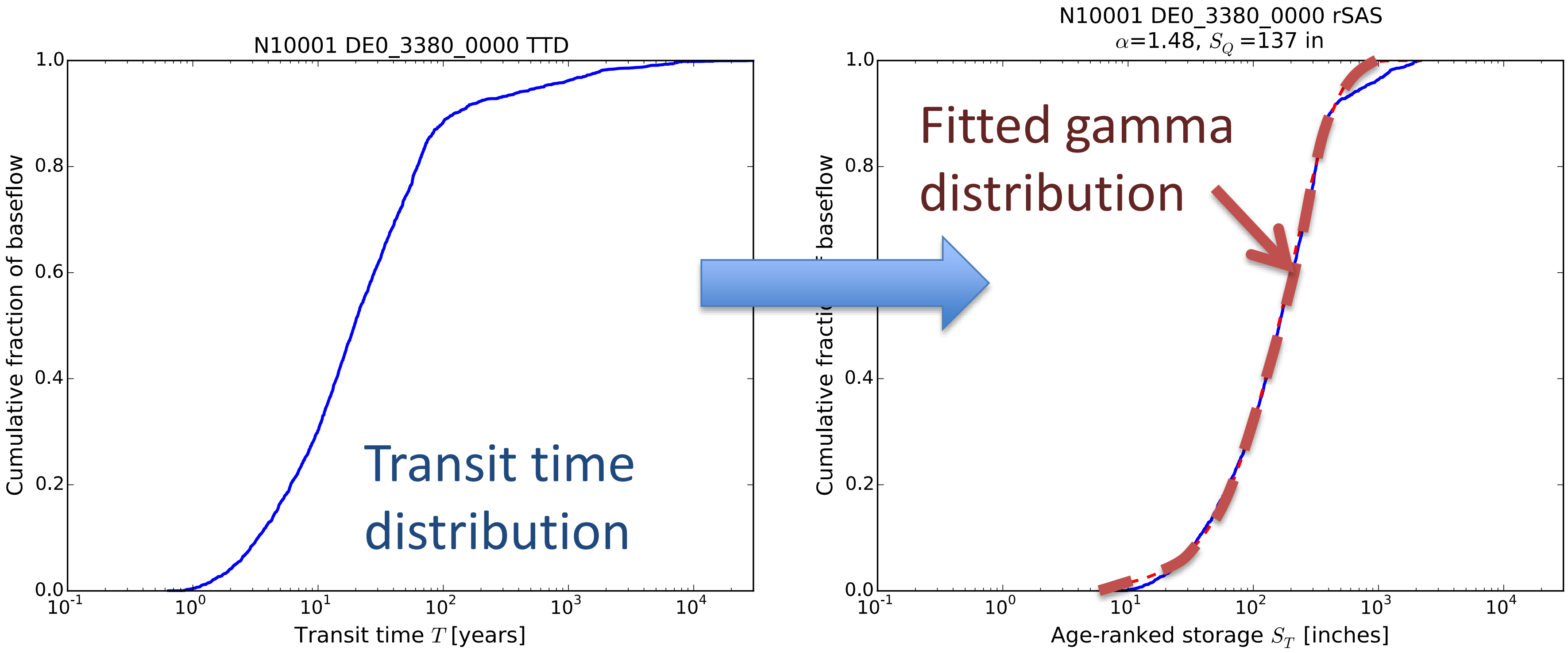
3 (or 4) sets of steps

- Part 1 – rSAS parameterization
  - conducted by JHU
  - parameters handed off to CBPO
- Part 2 – Calibration phase
  - run by CBPO using calibration hydrology
  - sets flux normalization factors
- Part 2a – Landuse/Hydrology phase
  - run by CBPO for landuse/hydrologic scenario
- Part 3 – Loading scenario
  - run by CBPO for N loading scenarios

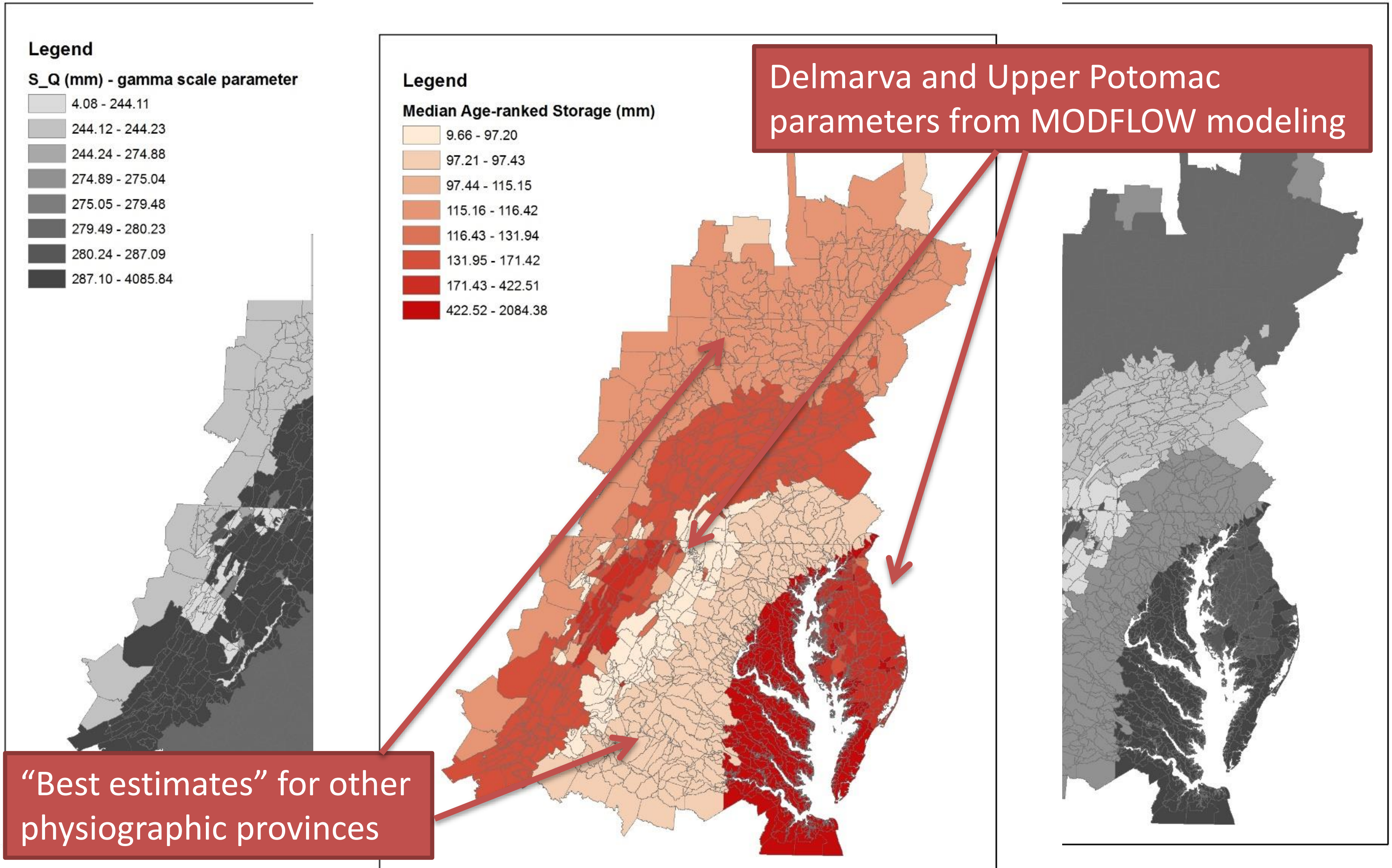
Step 1.1 TTD + recharge rate converted to equivalent rSAS



Step 1.2 Fit 2-parameter gamma distribution to rSAS



Step 1.3 Estimate parameters in remainder of the watersheds



Step 2.1 Determine LRS recharge rate from WM landuse and daily hydrology

- Each land-use in land-river segment has own hydrologic simulation
- Need a single recharge rate for rSAS
- Single rate determined from area-weighted mean recharge timeseries

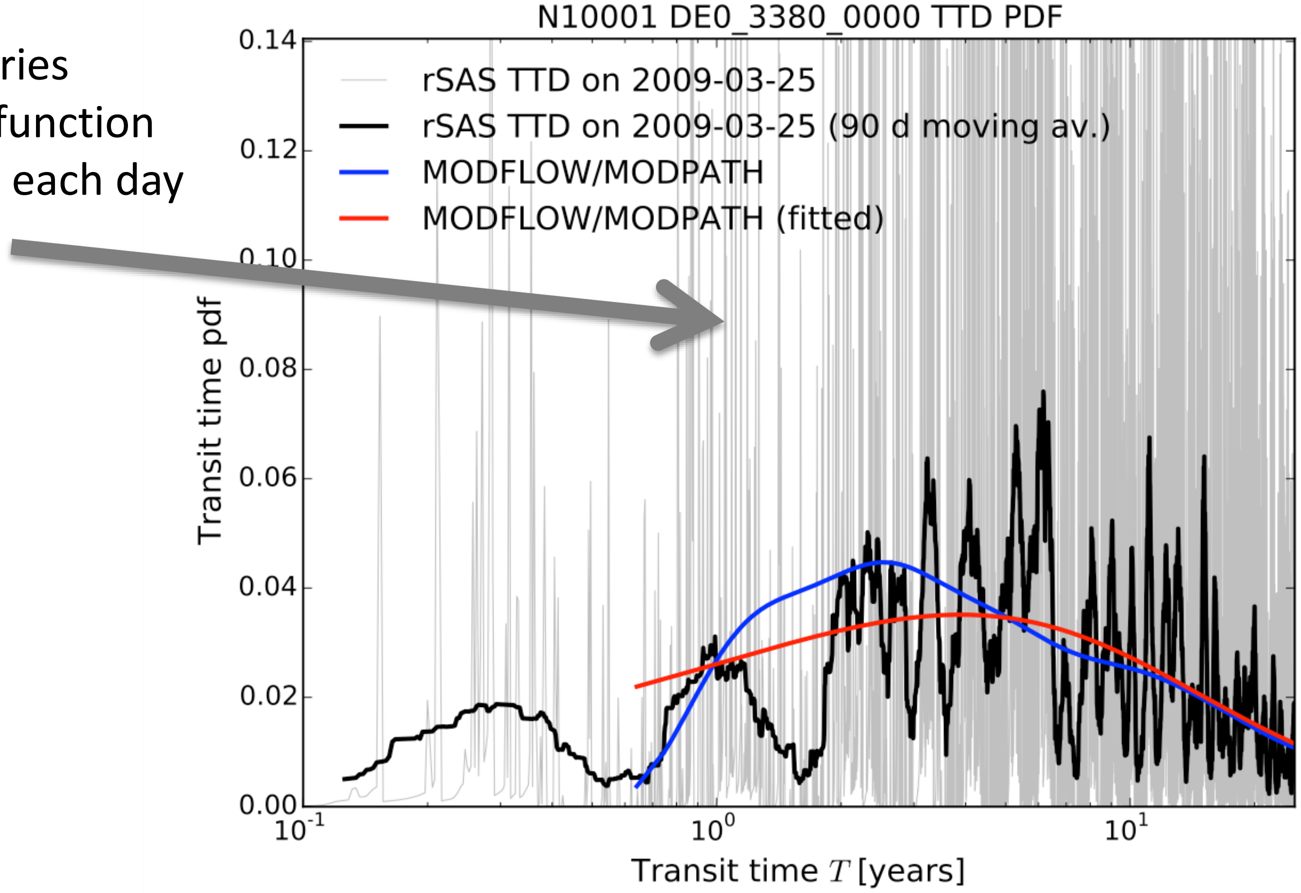
Step 2.2 Calculate *flux correction factor* (FCF) for calibration scenario

- FCF forces the CBP and MODFLOW models to agree about transit time distribution at mean baseflow, even though they have different values for mean baseflow

- Calculated for calibration hydrology scenario, fixed after that.

Step 2.3 Calculate time-varying TTD

WM recharge timeseries combined with rSAS function to determine TTD for each day



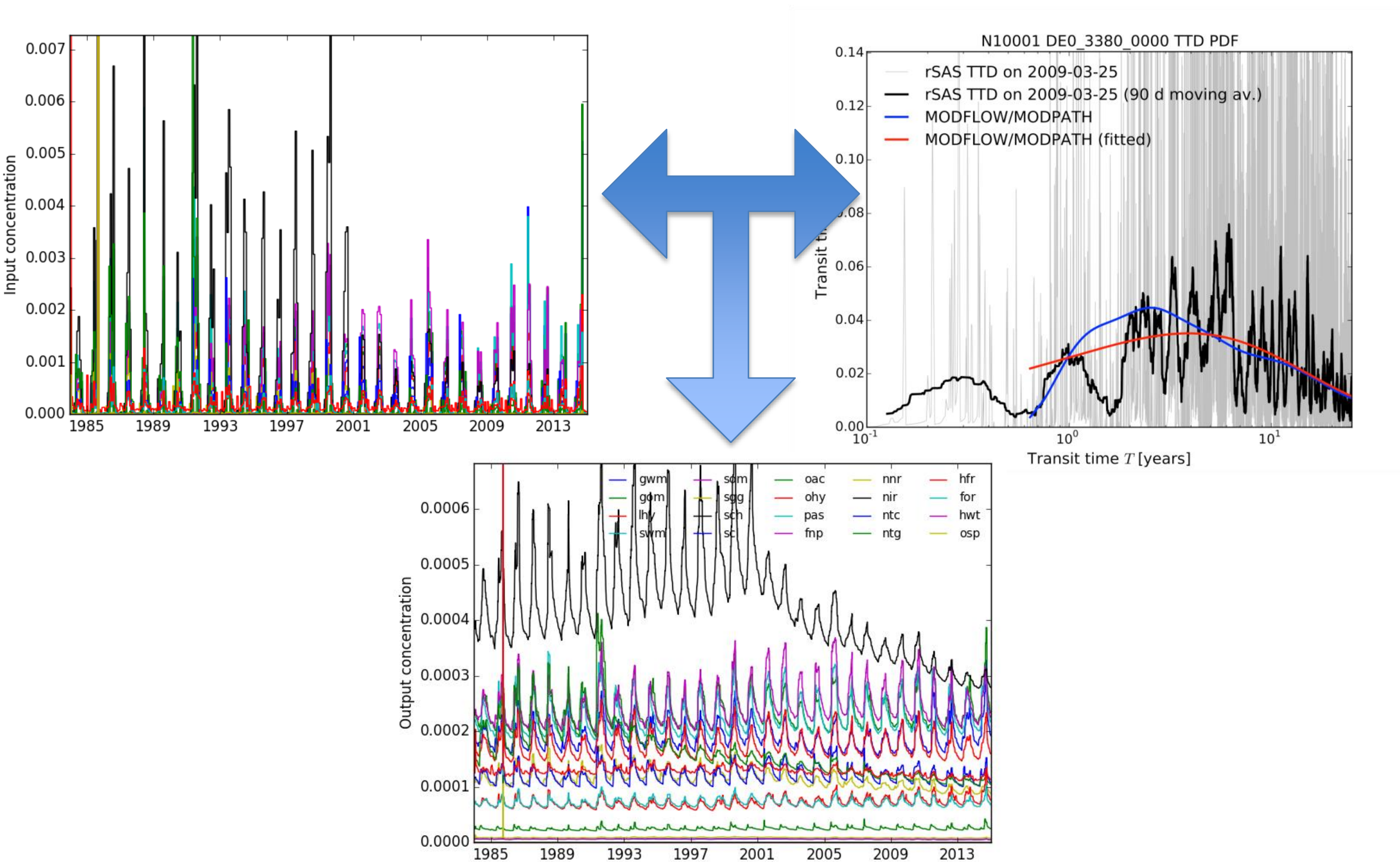
Step 2a Hydrologic/landuse scenarios

- When hydrology or landuse composition changes:
  – Repeat steps 2.1 and 2.3
  – Don’t adjust flux correction factor

Step 3.1 Construct LRS target loading timeseries

- Loading from each source in each land use in LRS combined into a single monthly loading timeseries
- Target loading used to rescale loading timeseries to give expected mean loading rate long term
- Daily concentration timeseries constructed with constant values within each month to give desired loading
- Background concentration set from mean values
  - can be altered to look at change scenarios

Step 3.2 Convolve to get baseflow concentration timeseries



Outlook:
Improving parameter estimates

- Current parameters are best we can do for now, but currently working on better values
- Dano Wilusz (PhD student at JHU) is working to develop a statistical model of rSAS parameters using a range of data sources
  - Topographic data
  - Groundwater modeling by U. Maryland (Alimatou Seck and Claire Welty)
  - Soils and geology databases

Outlook: Improving recharge sensitivity

- Current assumption of time-invariant rSAS could be improved to better account for effect of climate variability
  - Likely that current approach overestimates sensitivity to increased recharge of long flow paths, and underestimates sensitivity of short flow paths
  - Planned seasonal modeling by USGS could be used to develop improved methods with minimal effect on CBPO workflow