ECOLOGICAL & ECONOMIC IMPACTS OF LAND USE AND CLIMATE CHANGE ON COASTAL FOOD WEBS & FISHERIES

FACETS
Floridan Aquifer Collaborative Engagement for Sustainability

Simulating nitrate concentrations at the outlet of the Suwannee River by combining SWAT-MODFLOW with MODPATH

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The bigger picture

Part of research project:

Ecological and Economic Impacts of Land Use and Climate Change on Coastal Food Webs and Fisheries

Focused on the Suwannee River estuary

One of the objectives:

Simulate changes in quantity and quality of river water to the estuary for future scenarios (land use, water use, climate)

Results feed into ecosystem model for estuary

Modeling wise strongly related to another project we worked on:

Floridan Aquifer Collaborative Engagement for Sustainability

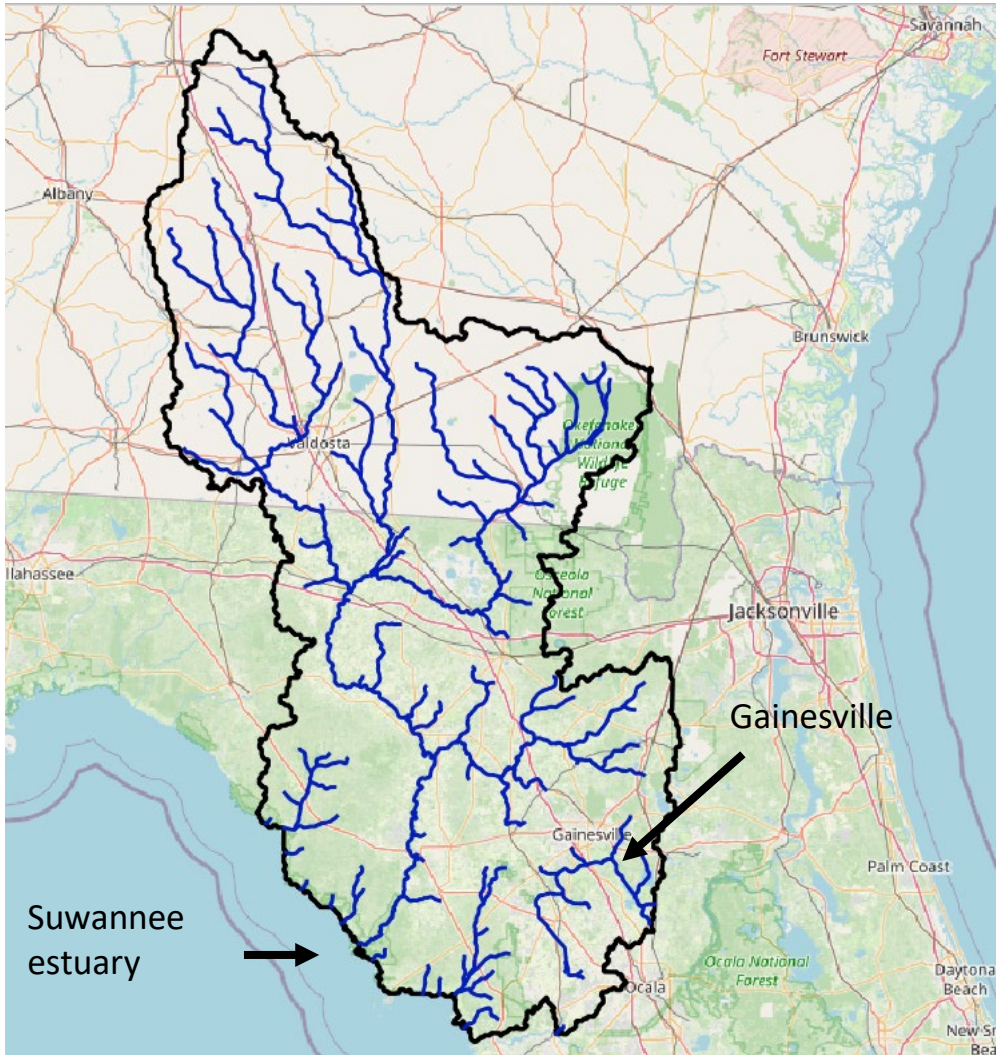
ECOLOGICAL & ECONOMIC IMPACTS OF LAND USE AND CLIMATE CHANGE ON COASTAL FOOD WEBS & FISHERIES

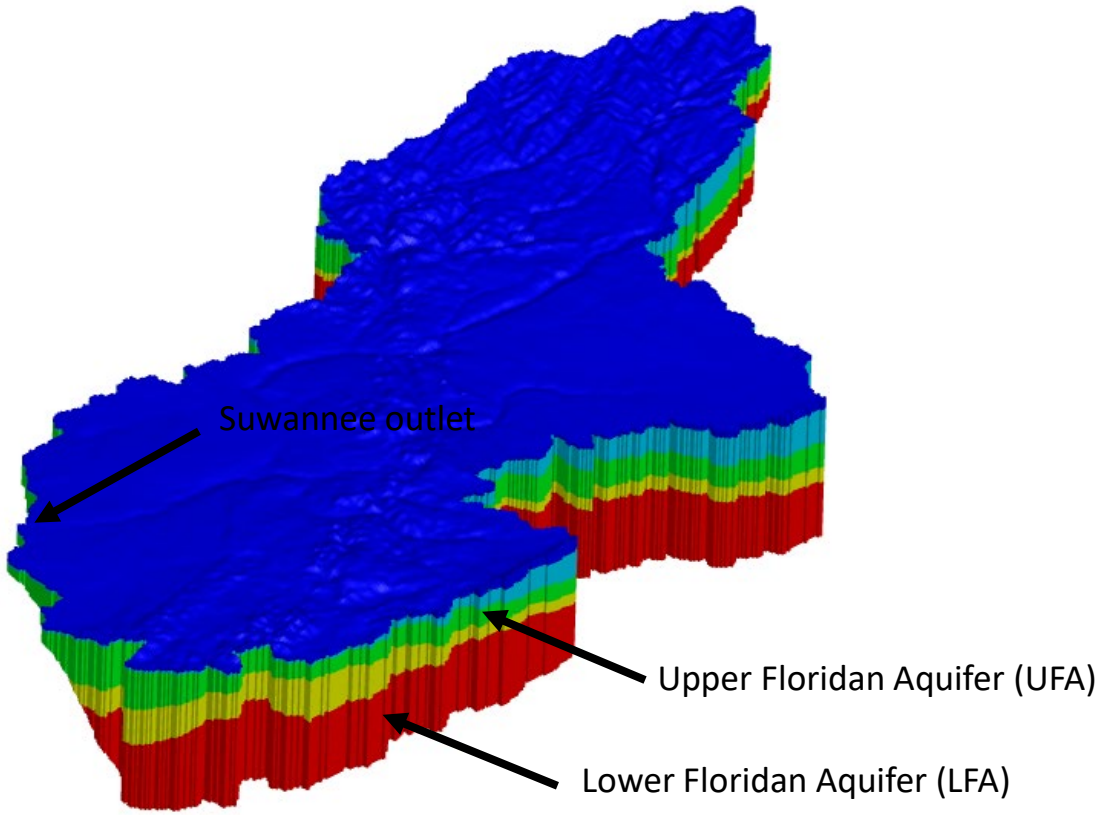
FACETS
Floridan Aquifer Collaborative Engagement for Sustainability

NATIONAL ACADEMIES Sciences Engineering Medicine
GULF RESEARCH PROGRAM

USDA United States Department of Agriculture National Institute of Food and Agriculture

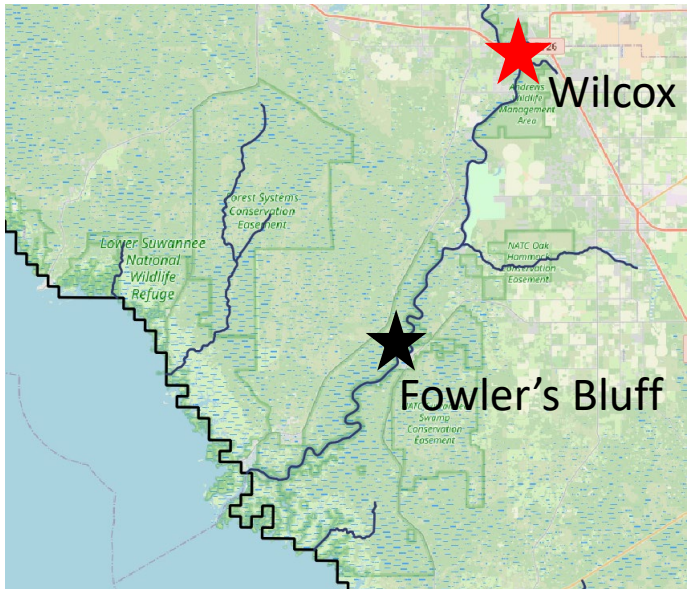
Model area

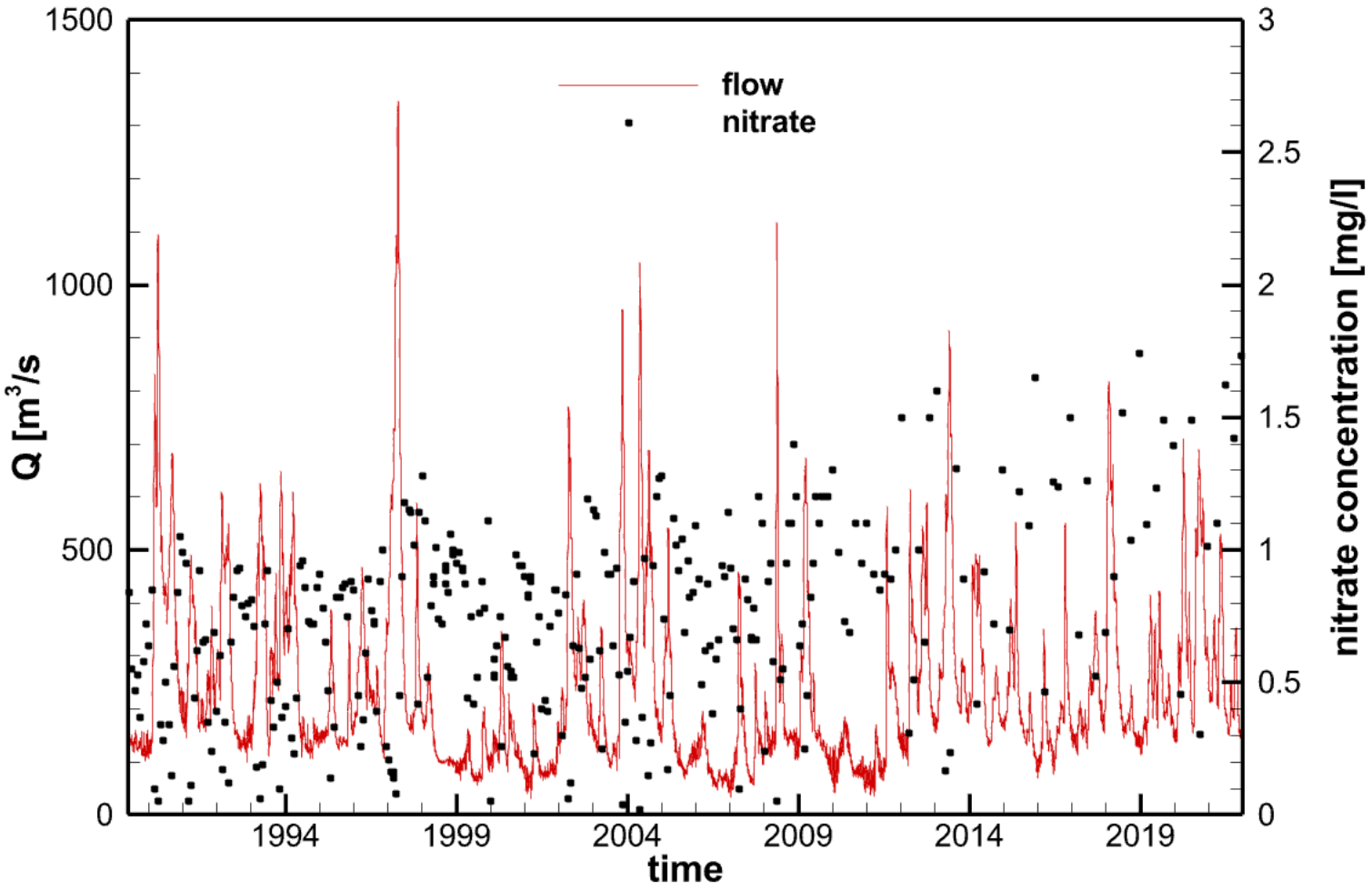




Subsurface domain clipped from NFSEG model (North Florida Southeast Georgia Model)

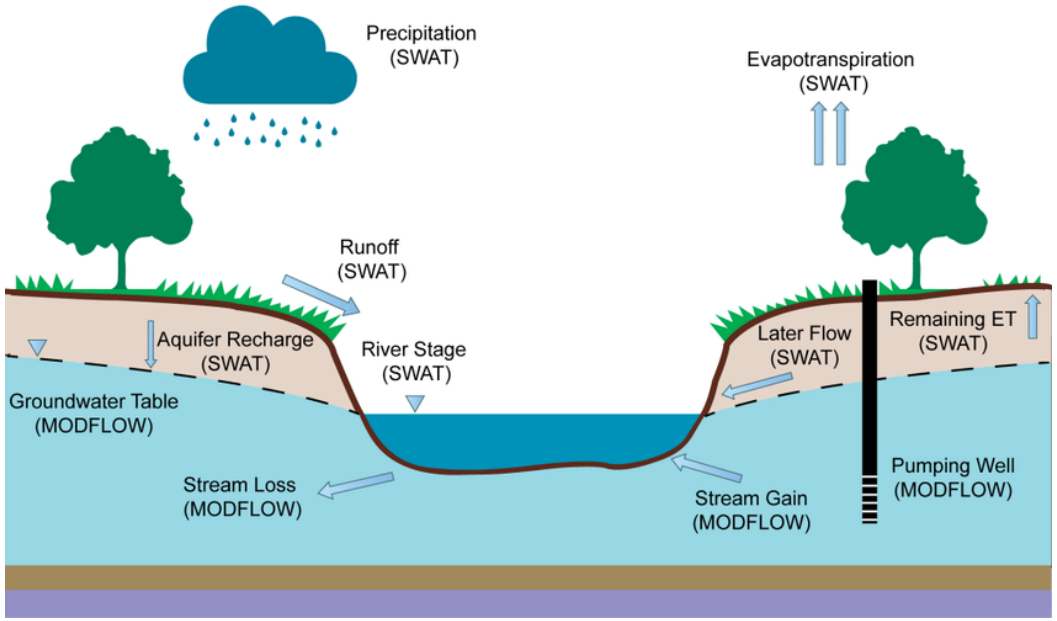
Measured data





SWAT-MODFLOW

Inputs:
Topography, soils and land use
Weather
Land management
Hydrostratigraphy (NFSEG)



Outputs:
Crop yields
Stream flow
Groundwater levels
Nitrate leaching

We can simulate different land use and climate scenarios!

SWAT accounts for nitrate
BUT:
MODFLOW does not simulate nitrate transport!
(In SWAT-MODFLOW nitrate contribution from groundwater is zero by default)

MODPATH

Particle-tracking code for MODFLOW
(a post-processor to MODFLOW, need to run MODFLOW first)

Works like dye tracer
Particles are advected in a simulated flow field
Attach positions and travel times to particles
We can also attach water volumes and contaminant masses to particles

Useful for:
age and source components
visualization of flow fields
contaminant transport
delineating capture zones
Gaining additional insights into flow model!

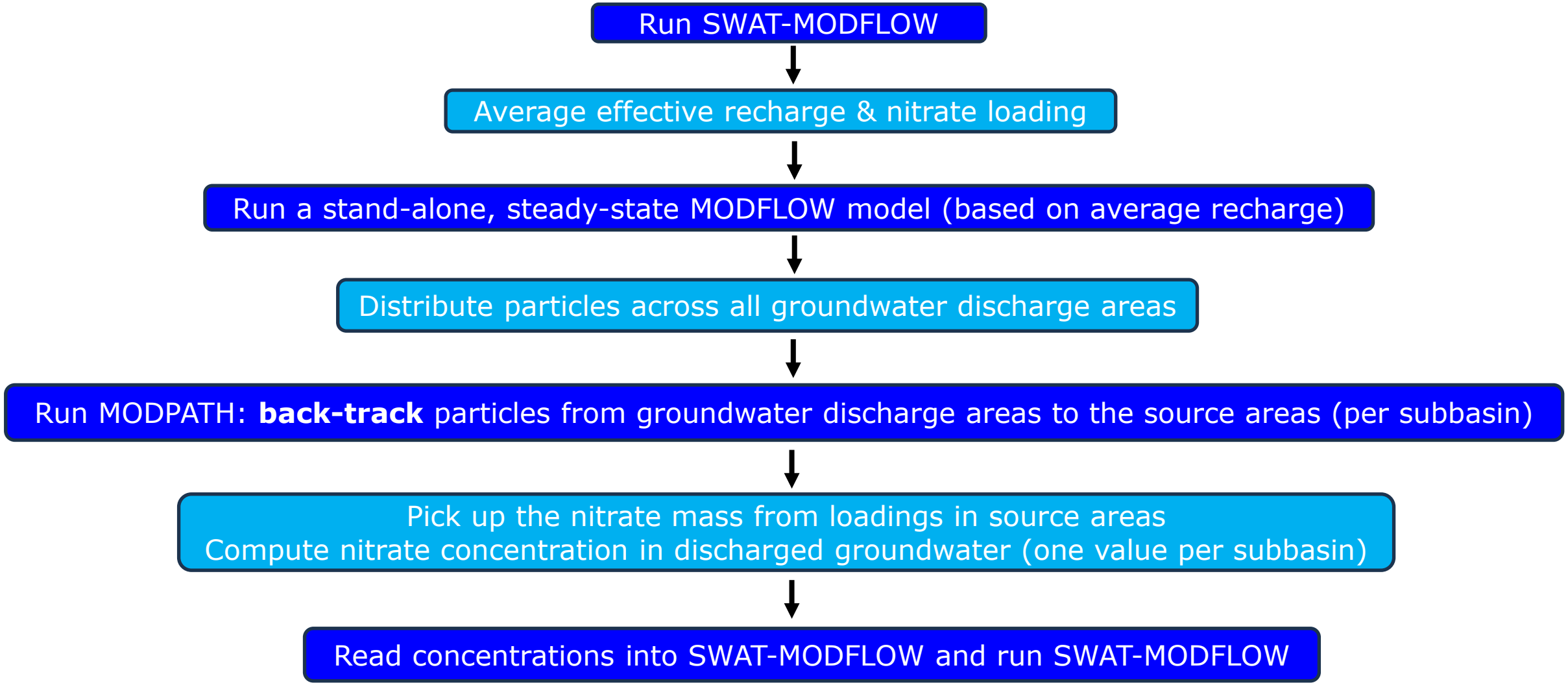
Back-tracking: Reverse flow field and track particles from discharge areas to source areas

Key idea: Combine MODPATH with SWAT-MODFLOW to simulate nitrate transport.

Some design considerations

- Particles can pick up the mass associated with nitrate loading as simulated by SWAT (using particles positions and nitrate loading to groundwater per HRU).
- Particle-tracking becomes very **expensive** if the flow fields change on a daily basis.
- **Long travel times**. We need MODFLOW solutions for flow fields that date back hundreds if not thousands of years.
- For particles with long travel times, we may need to account for **historical land use changes**.
- If nitrate loading changes over time, then the particle-tracking results depend on the time of release!

Combining SWAT-MODFLOW and MODPATH



What about SWAT-MODFLOW-RT3D?

Computes concentrations everywhere using the advection-dispersion equation

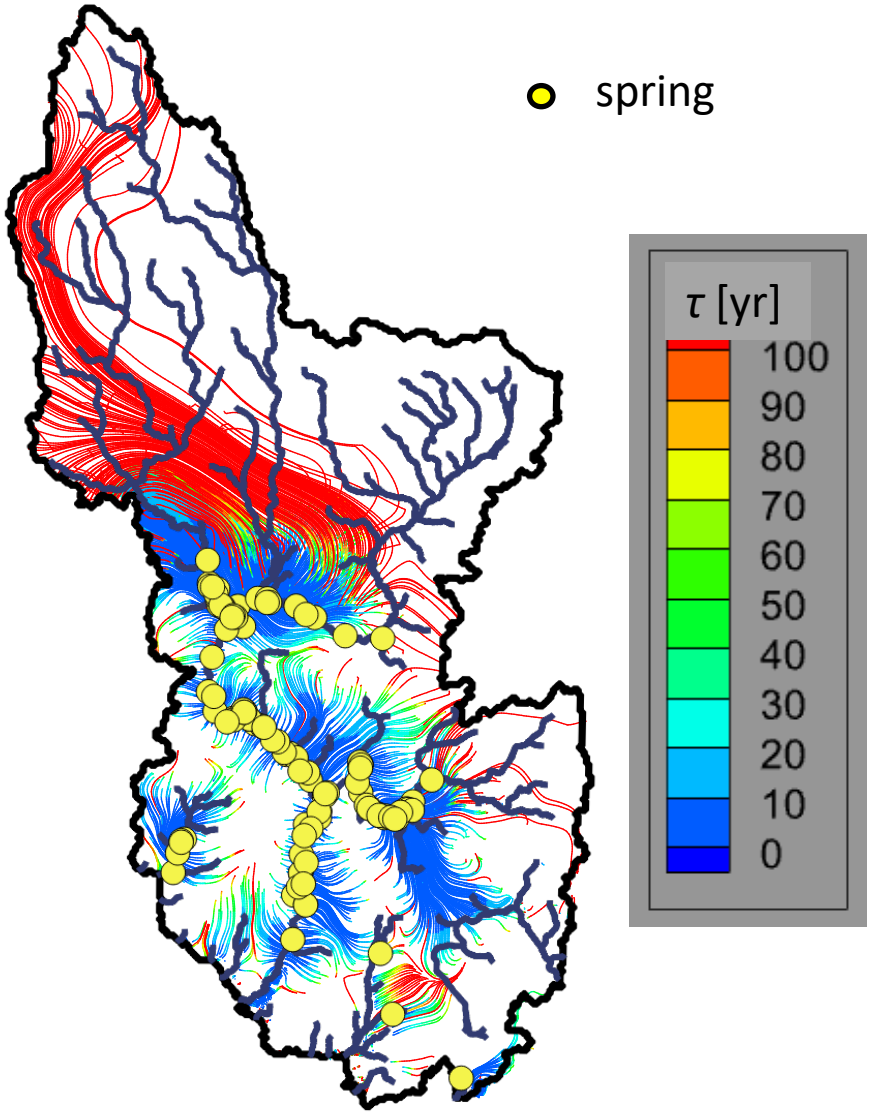
Courant and Peclet numbers
(restrictions on space and time discretization!)

Also difficult to handle old groundwater
Need initial nitrate concentrations…

No indication of age and source components!

MODPATH more useful to gain insights into flow model!
(Start with MODPATH before using SWAT-MODFLOW-RT3D)

Path lines in Suwannee River basin (10000 particles, 2D projection)



Observations:

- Most particles released from reaches with springs
- Some particles have long travel times (> 100 yr)
- We can construct a TTD for each subbasin (should use more particles)
- We can figure out the source areas

Important notes on travel times

With original NFSEG parameters, the mean travel times are very high!
Most of particles travel through the Lower Floridan Aquifer.

We decrease the horizontal hydraulic conductivity of the LFA and increase the horizontal hydraulic conductivity of the UFA such that the effective horizontal conductivity of the two layers remain the same.

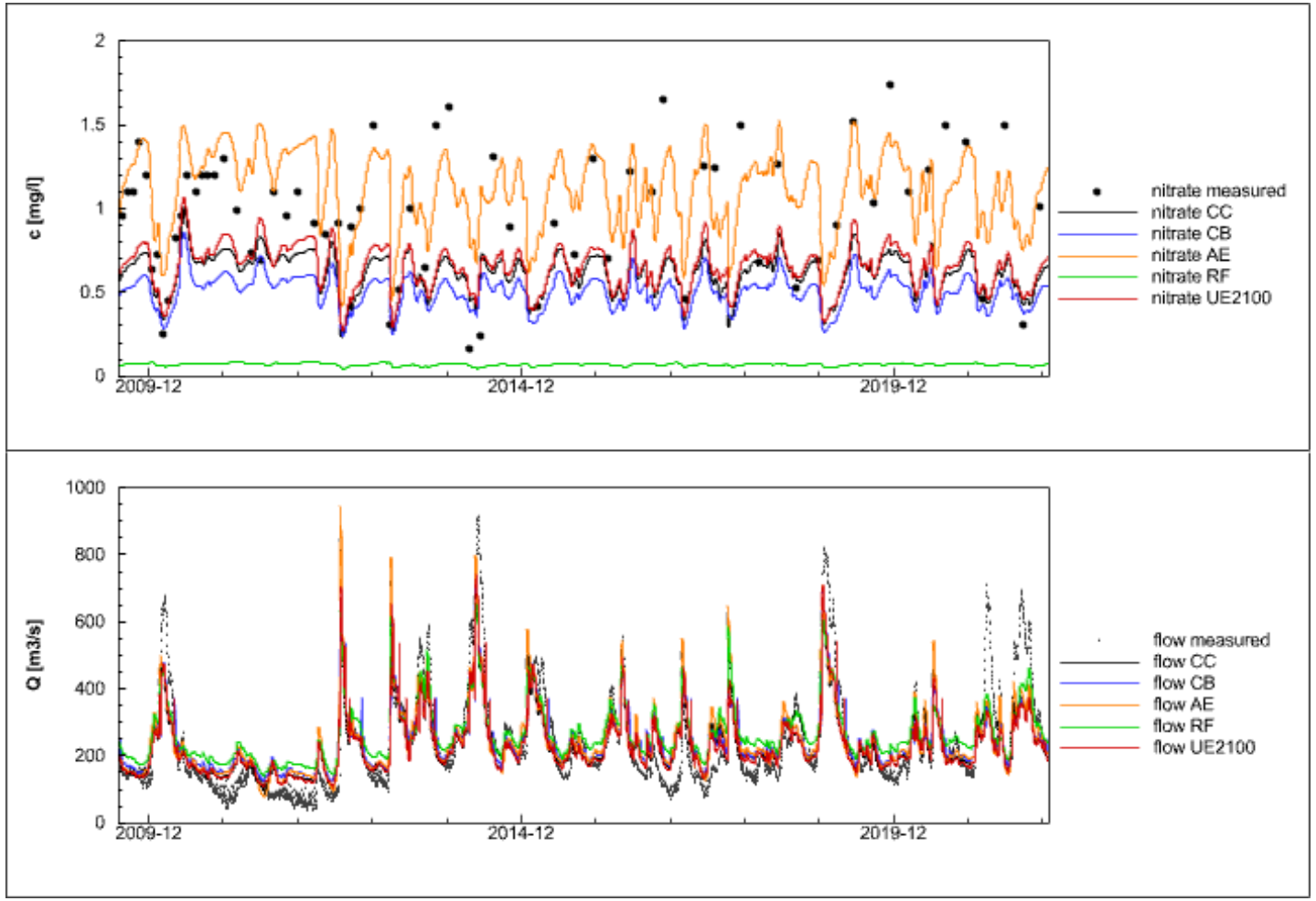
→

Better agreement with travel times inferred from measurements (isotopes, CFK's, etc.).

General important remarks:

Particle-tracking results can indicate problems with the underlying flow model!
Particle-tracking helps to understand the flow model better!

Nitrate concentrations at Wilcox (using 100.000.000 particles)

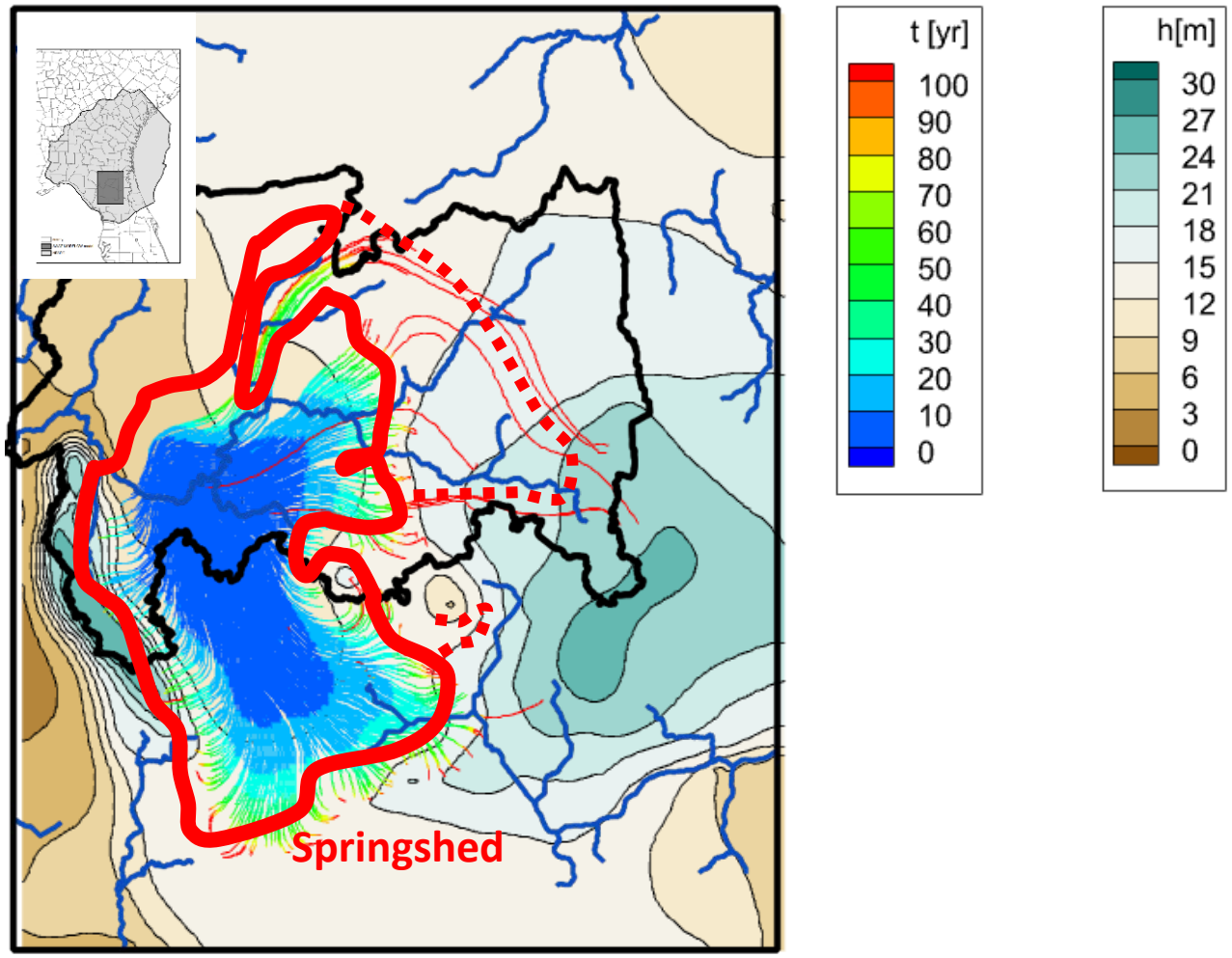


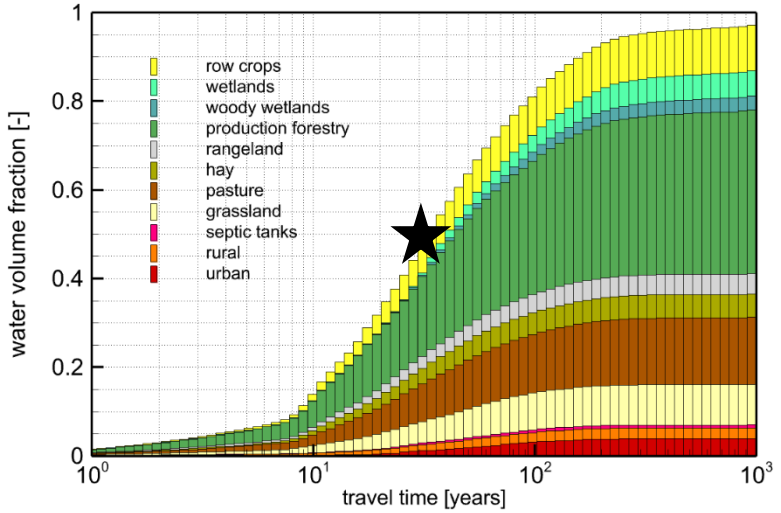
CC	current conditions
CB	Southeast Conservation Blueprint (all non-irrigated agricultural lands in blueprint to restoration forestry)
AE	agricultural expansion (all forests on soil A)
RF	restoration forestry (all agricultural lands)
UE2100	urban expansion 2100 (EPA ICLUS SSP2)

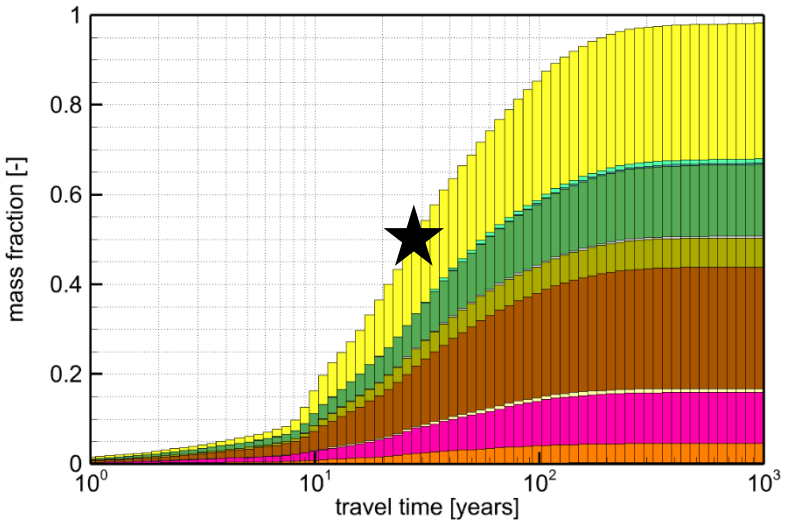
Remarks:

- High flow corresponds to low nitrate
- Relative differences are reasonable
- High concentrations are not reproduced

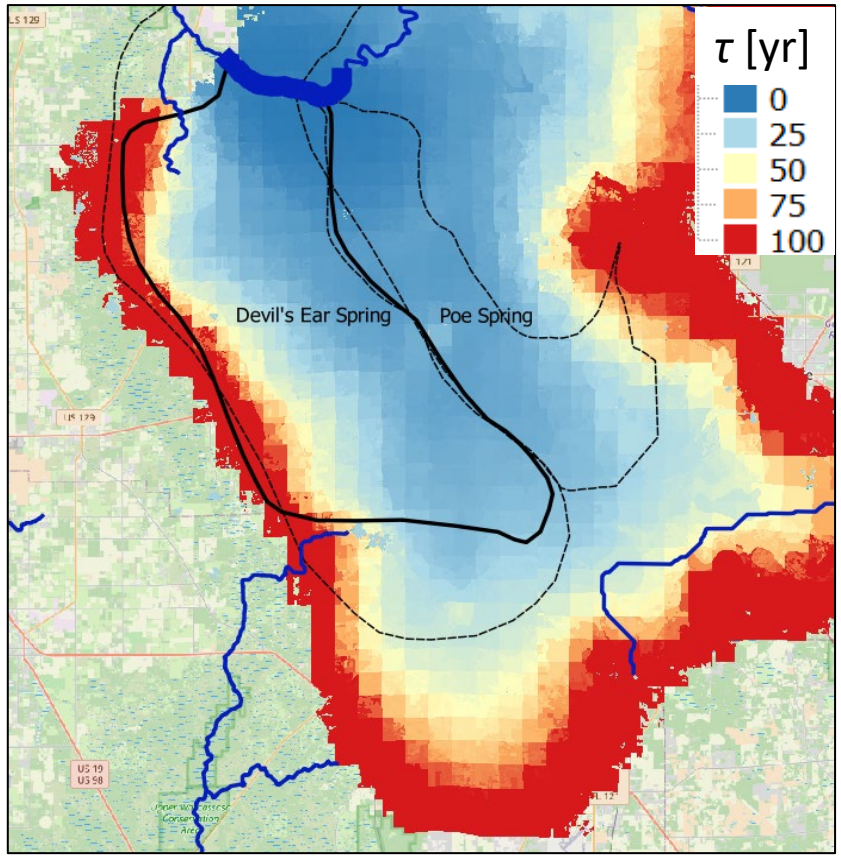
Age and source components (from FACETS project)

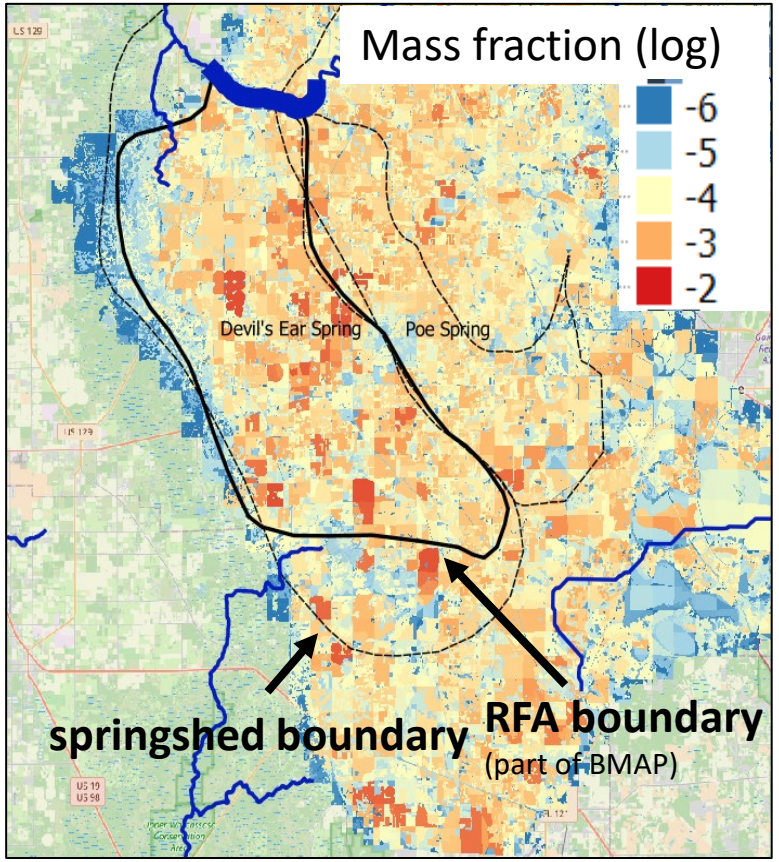






Age and source components → mitigation strategies?





Could target areas with shortest travel times and highest mass fractions.
Quickest and most substantial results!

Remarks

- We assume that nitrate concentrations in groundwater are fairly constant. According to nitrate measurements in springs this is reasonable over relatively short time spans (years).
- We could account for historical land use (important for old groundwater). Use SWAT-MODFLOW models for RF and CC. Build MODFLOW model with 2 stress periods: One steady-state period based on RF(historic) and a transient period based on CC. Then we need to release particles at multiple time intervals as concentration in groundwater will change with time.
- Novel model framework assumes that the flow model is correct. A calibrated flow model is not guaranteed to be correct. Levels and fluxes may look correct for the wrong reasons.
- Our modeling framework provides insights into such problems! May need to adapt flow model.
- Need to keep in mind that nitrate transport is a rather complex problem.
- Also need to keep in mind that flow model does not accurately account for karst features.

Conclusions and outlook

- Novel modeling framework can simulate the effect of a change in land use on the nitrate concentrations at the Suwannee River outlet.
- MODPATH helps to extract additional insights into the flow model.
- Novel framework provides insights into age and source components that may be helpful in designing mitigation strategies.
- Model behaves reasonably well but is not perfect.
- Model simplifications (assumptions) affect the accuracy. This can be improved.
- Simulations for different future climate projections.
- We have not looked in detail to the model parameters that affect denitrification.
- Will work on a SWAT-MODFLOW-RT3D model.