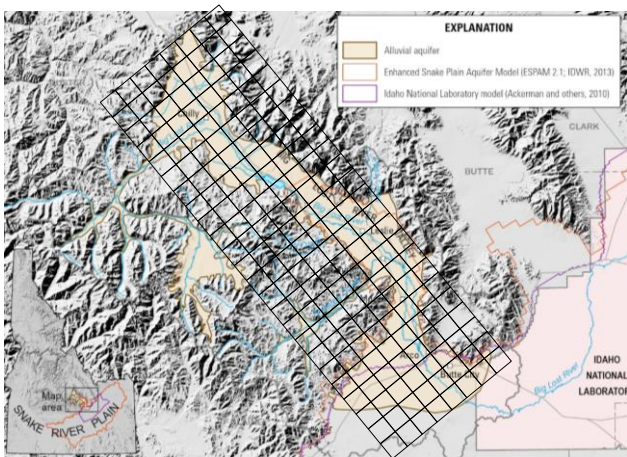
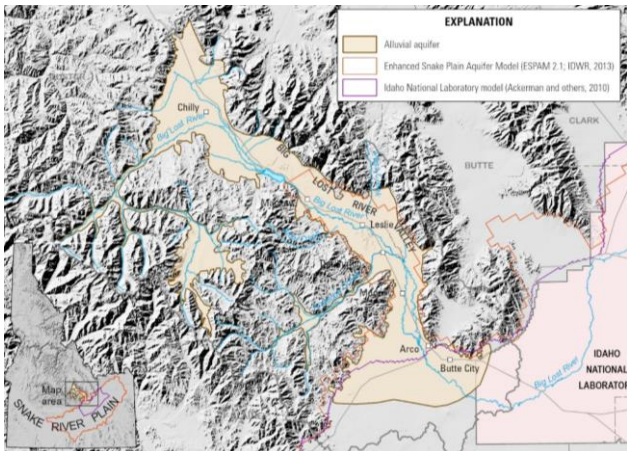


# Model Development Process

Stephen Hundt & Jacob Knight  
USGS  
November 16, 2022



# Goal of this talk

Explain how we intend to work on the model and how we hope to interact with the MTAC

Demonstrate a 'model status' presentation that we hope to use in future MTAC meetings

Get your feedback

# Contents

Different approaches

Proposed approach

Example model status update

Discussion

# Model Development Approaches



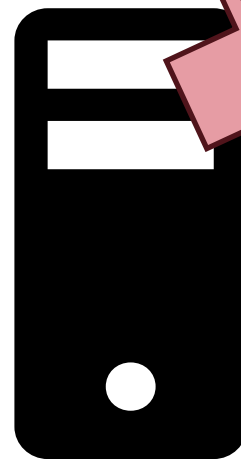
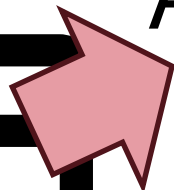
# We want to build a model, but how?

We have a strategy

**For now:** how you come in because, surprise, you're helping.

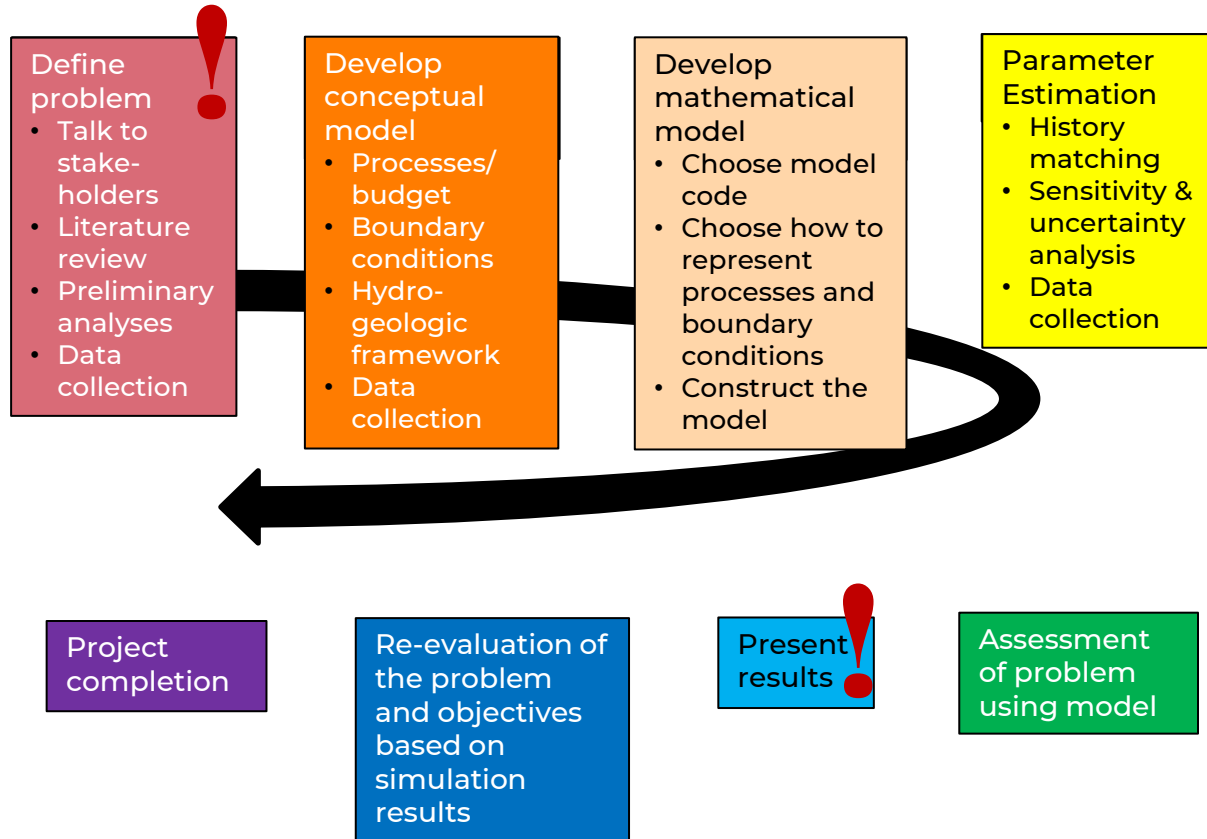
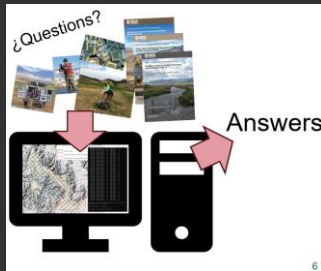
**Future meetings:** hydrology and model details.

¿Questions?



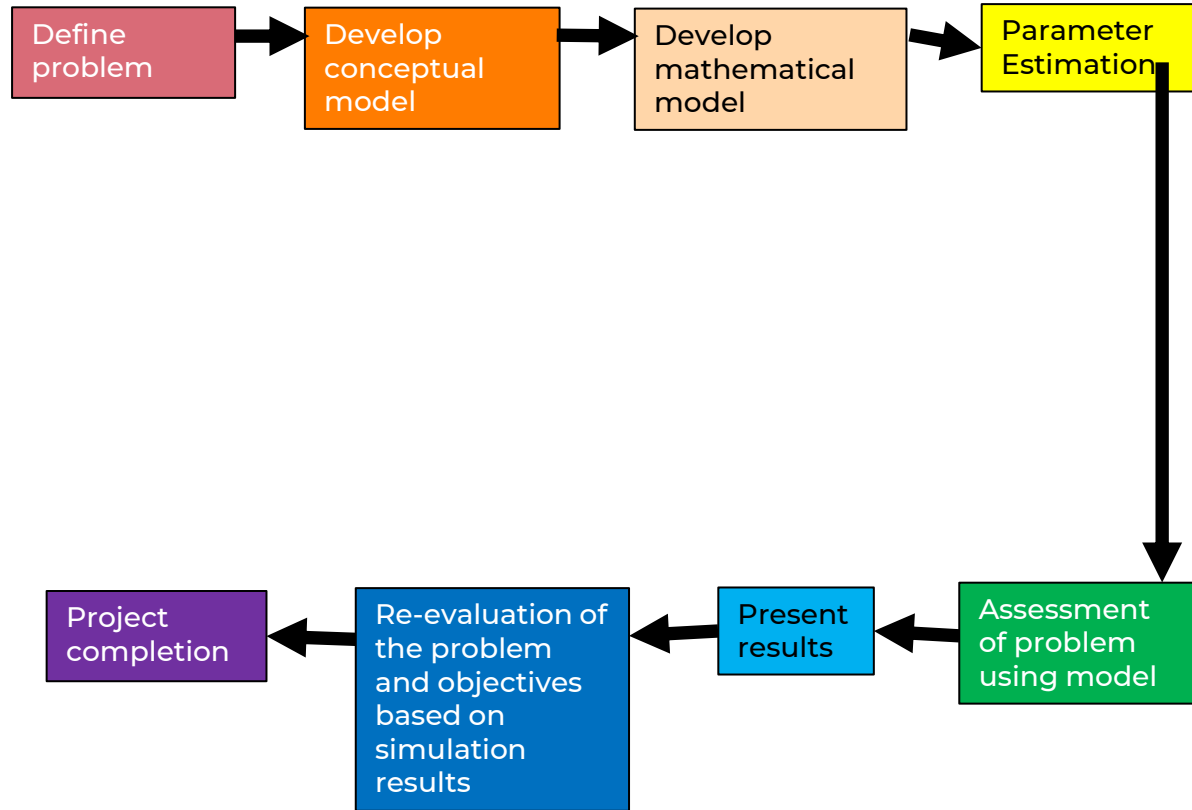
Answers

# The modeling process



After Reilly (2001) TWRI 3,B8

# Sequential Development



After Reilly (2001) TWRI 3,B8



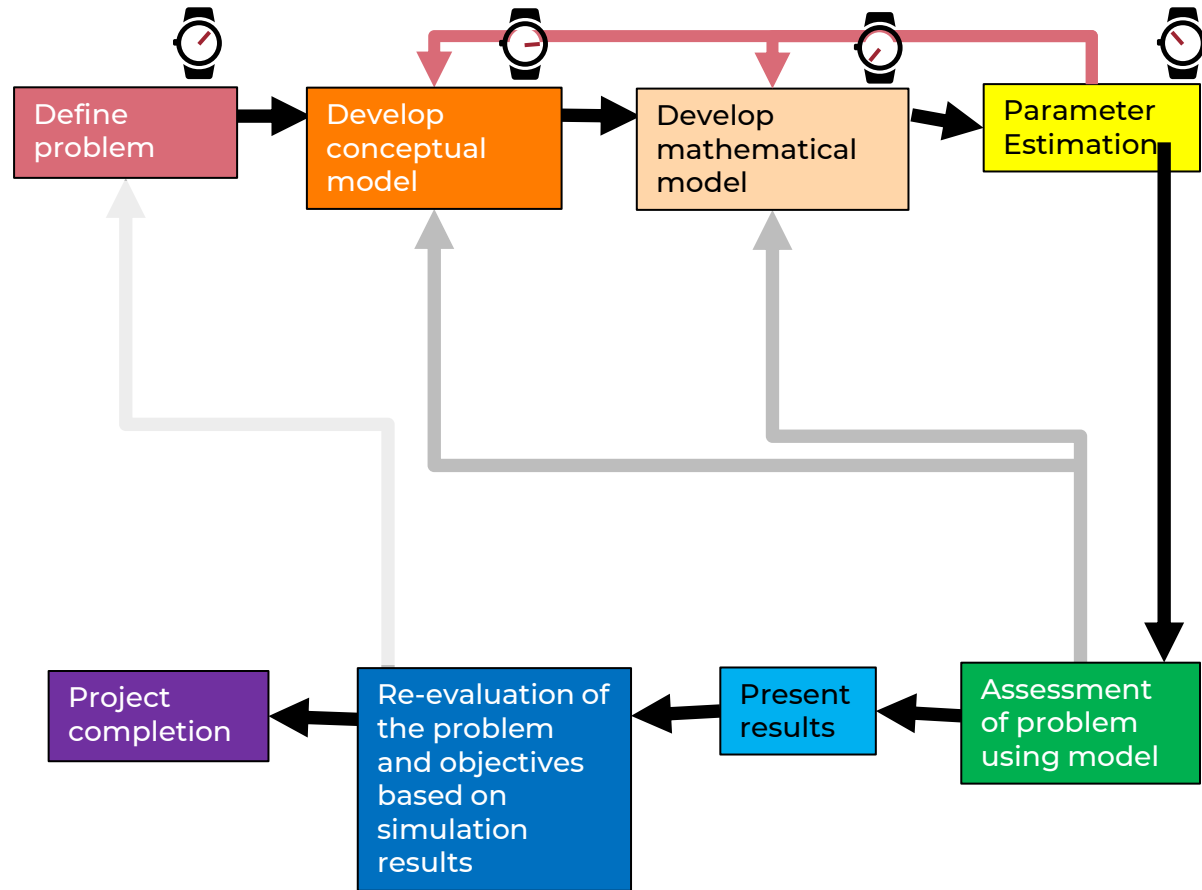
# Sorta - Iterative Development

Run out of time to reevaluate problem and adjust conceptual and mathematical model

Difficult to notice and track down errors

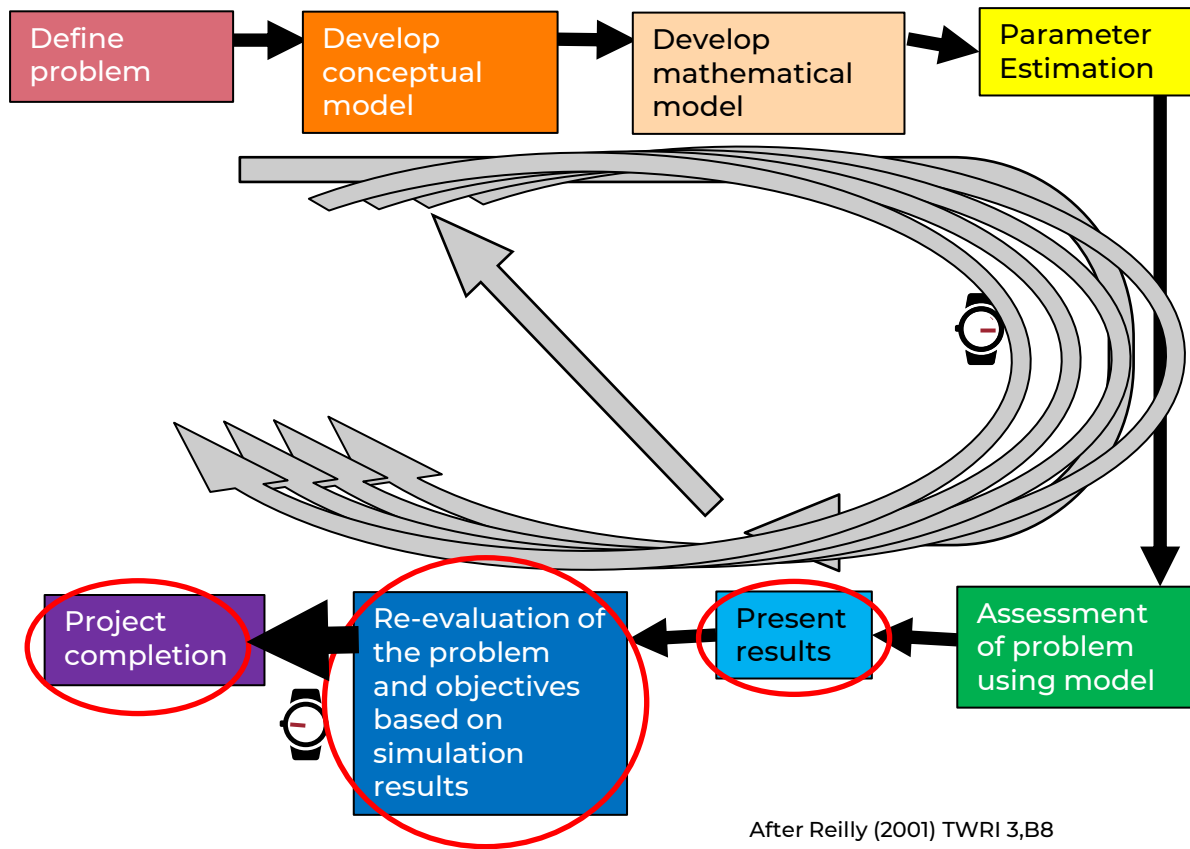
Hard to assess the importance of different model features (especially if they don't include parameters for sensitivity analysis)

Less familiar with 'results' -> less insightful documentation



After Reilly (2001) TWRI 3,B8

# How to get to truly iterative model development?



# Our Proposed Approach

Including how we'll involve the  
MTAC

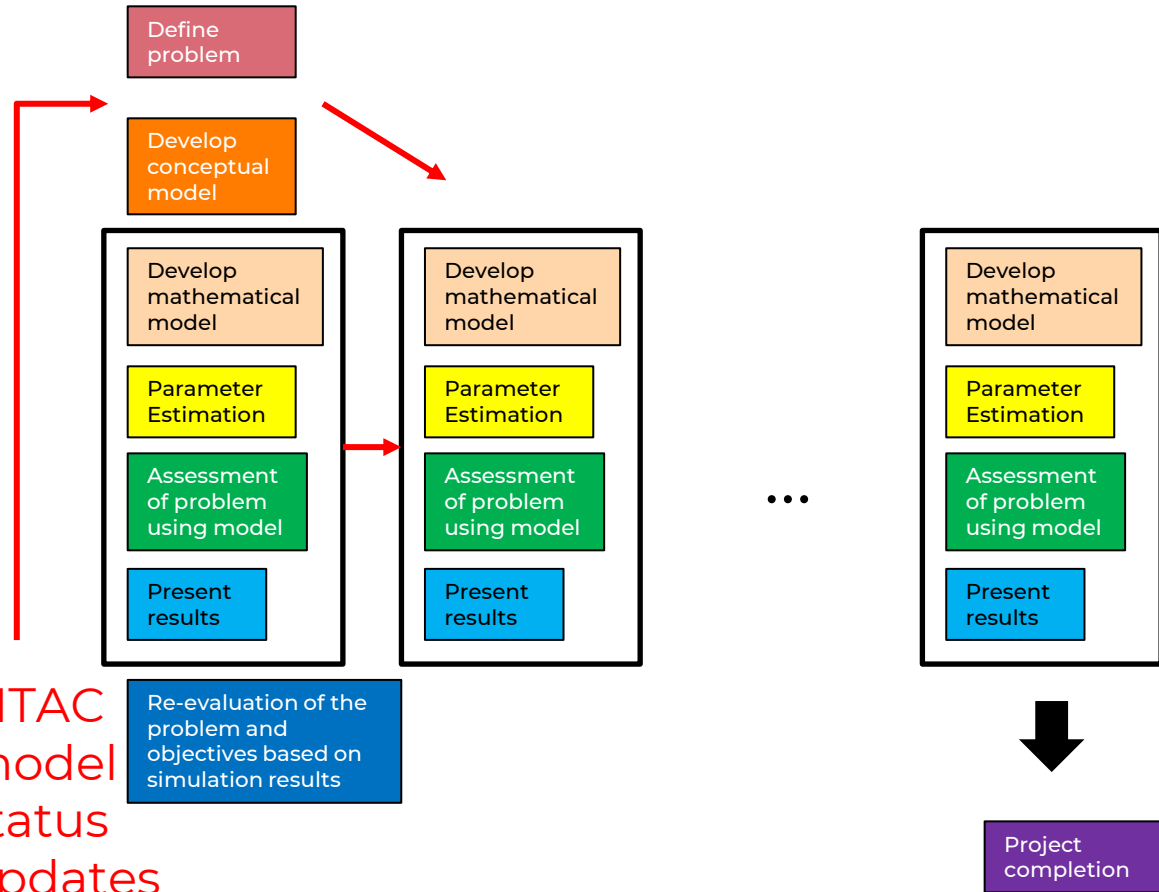
# Approach in summary

Build scripts that automatically complete all steps from data retrieval through running and plotting scenario output

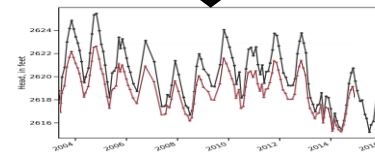
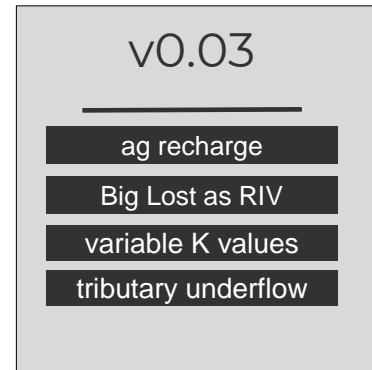
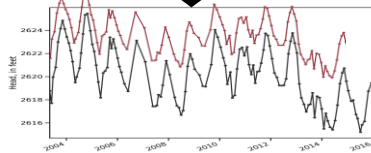
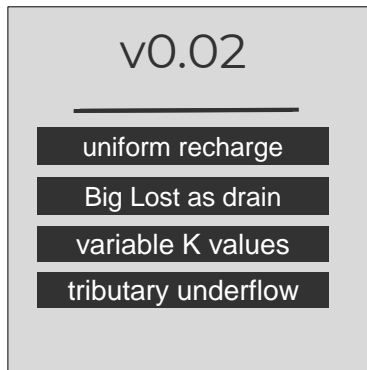
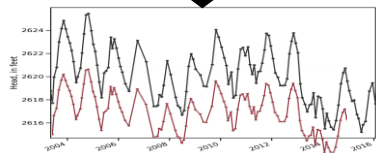
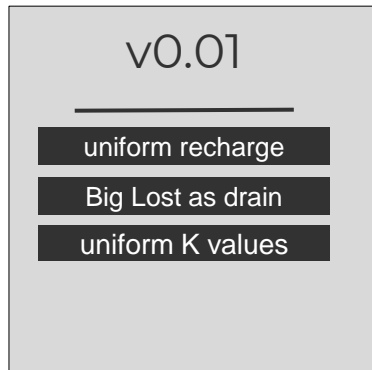
Get rudimentary version working and incrementally step through working versions from there

The “results” will include history-matching, parameter estimates, scenario output, and other model metrics **and will be presented at every MTAC**

MTAC  
model  
status  
updates



# We'll build fully working versions as we go



...

# Communication with MTAC

Show newest working version

Specific results to facilitate  
feedback

Act on MTAC feedback

## Proposed format

- Review objectives
- What you told us last time
- What we've done since last time
- What the model does
- RESULTS
- What the model doesn't do
- What the model should do next

# Case Study and Example Model Status Update

Version 0.0.1:

A pure fantasy starting point

# Jake's Turn...





*Reproducible Model Development, Rapid Deployment, and the ‘Workmanship of Certainty’*

**Jake Knight**

**Hydrologist**

**Arizona Water Science Center**

# INTRODUCTION

The following presentation contains a worked example of RRR modeling, a sales pitch for scripted model development, and a first attempt at conducting a model review session

## Presentation Outline

- The GULF model experience
- Script-based model development
- Getting started with BLRM

# The GULF Model

*Contentious, Complex, Compressed*

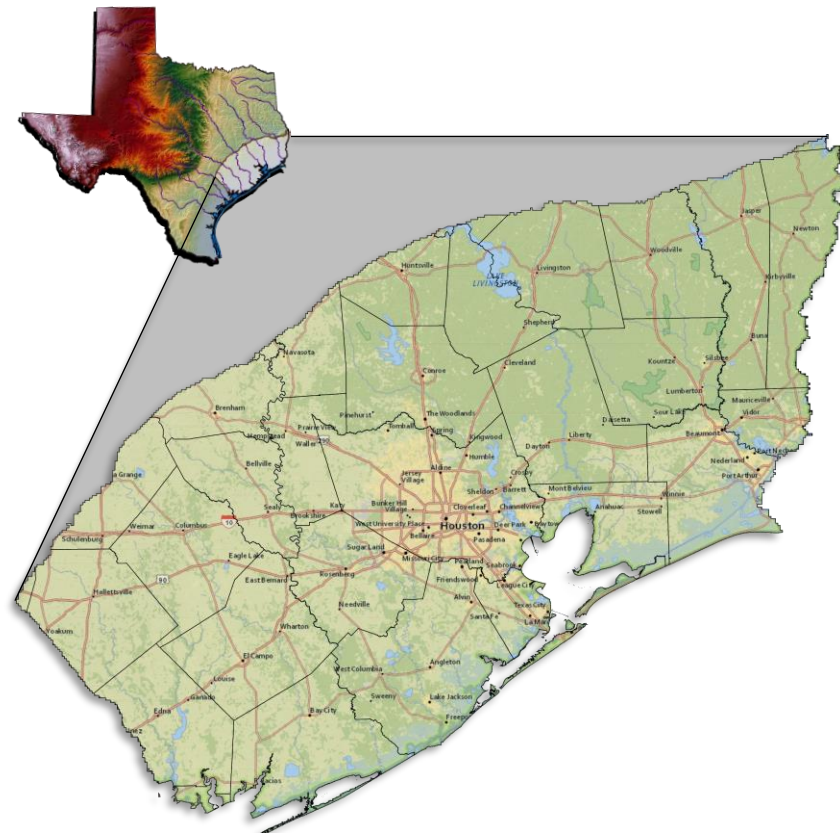
**Next “Model of Record” for determining allowable groundwater extraction rates in Houston area.**

**Multi-objective model that must adequately simulate widespread historical groundwater-level declines in multiple aquifer systems, and associated land-surface subsidence**

**Substantial uncertainty of historical groundwater pumping rates**

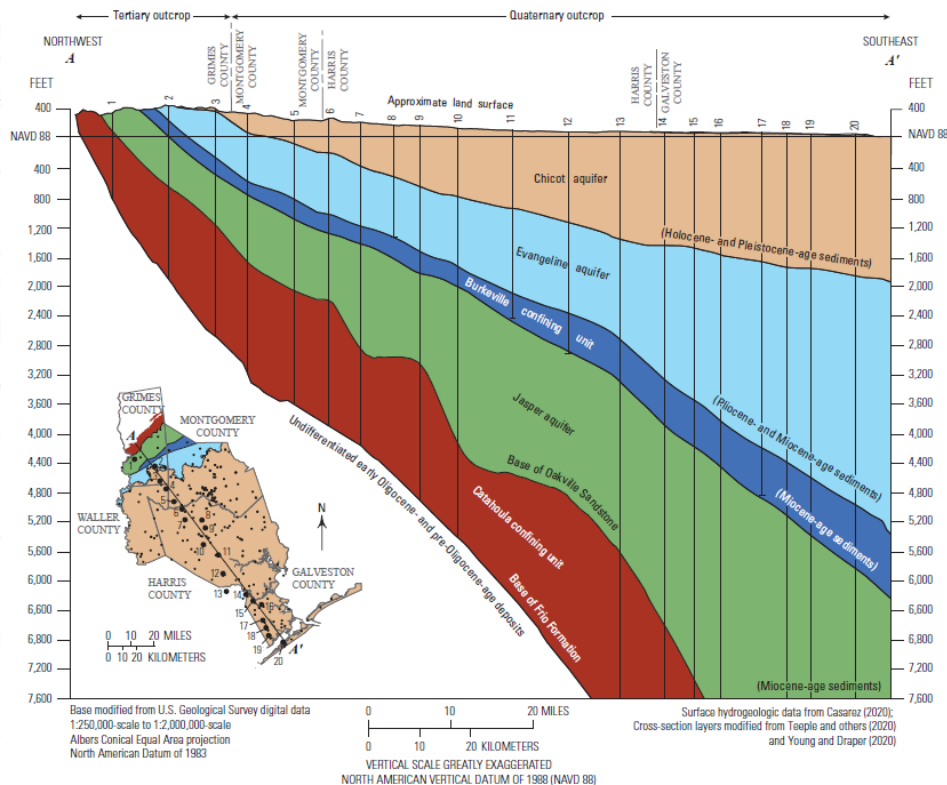
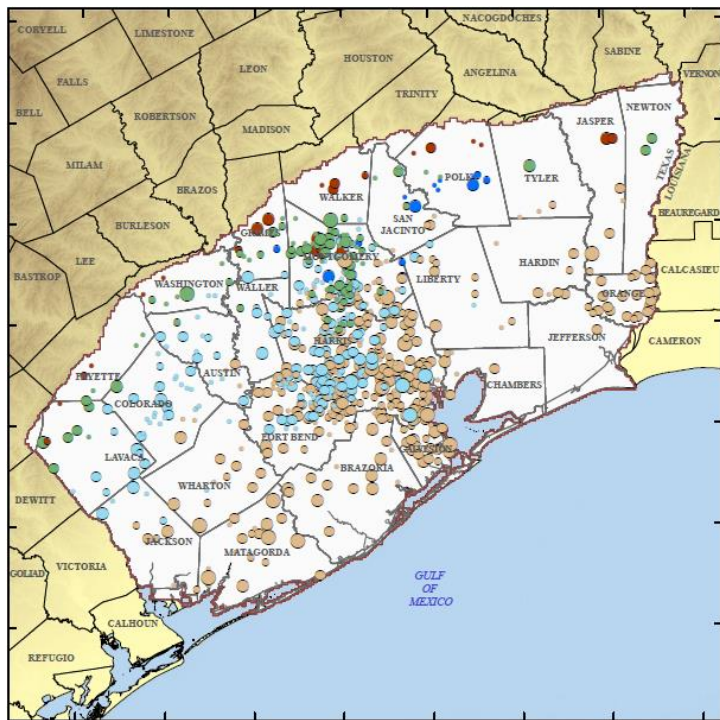
**1<sup>st</sup> large-scale implementation of CSUB package in MODFLOW 6**

**Quick turnaround time**



# The GULF Model

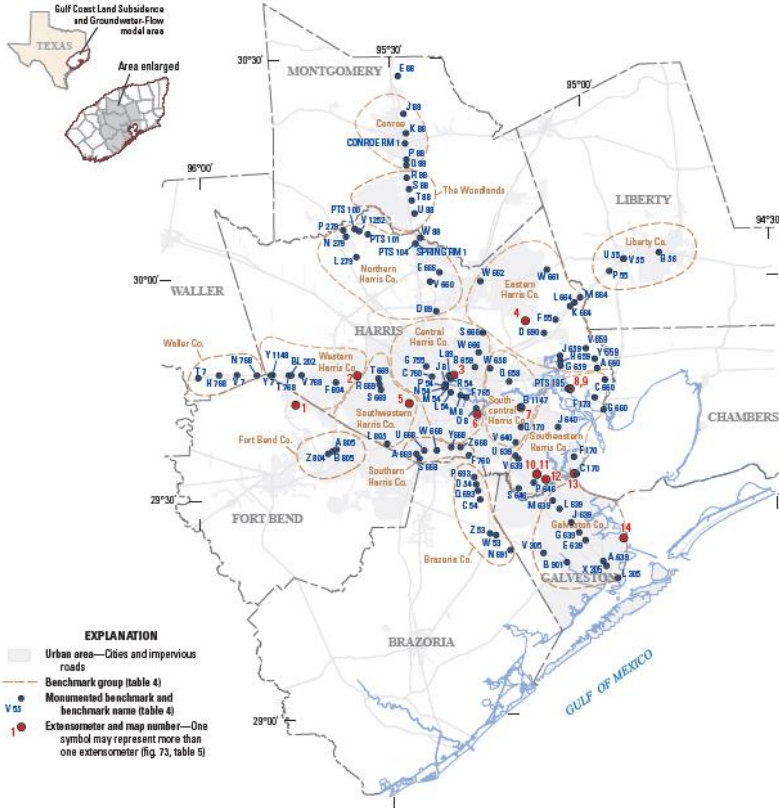
## Observation Data – GW Levels



- EXPLANATION**
- Hydrogeologic unit
  - Chicot aquifer
  - Evangeline aquifer
  - Burkeville confining unit
  - Jasper aquifer
  - Catahoula confining unit
  - Hydrogeologic unit contact
  - Well and map number
  - Line of section
  - Well used to determine hydrogeologic contact and map number
  - Well used to create hydrogeologic unit surface

# The GULF Model

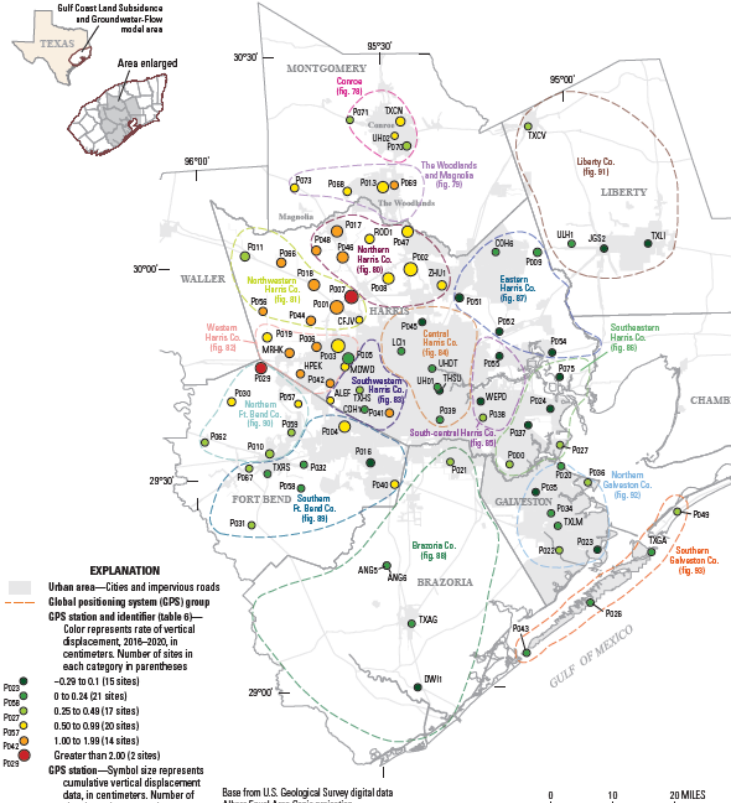
## Observation Data - Subsidence



**EXPLANATION**

- Urban area—Cities and impervious roads
- Benchmark group (table 4)
- Monumented benchmark and benchmark name (table 4)
- Extensometer and map number—One symbol may represent more than one extensometer (fig. 73, table 5)

Base from U.S. Geological Survey digital data  
 Albers Equal Area Conic projection  
 Standard parallels 29°30' N. and 45°30' N.  
 Central meridian 96°00' W.  
 North American Datum of 1983



**EXPLANATION**

- Urban area—Cities and impervious roads
- Global positioning system (GPS) group
- GPS station and identifier (table 6)
- Color represents rate of vertical displacement, 2016–2020, in centimeters. Number of sites in each category in parentheses
- GPS station—Symbol size represents cumulative vertical displacement data, in centimeters. Number of sites in each category in parentheses

●	0–0.29 (15 sites)
●	0 to 0.24 (21 sites)
●	0.25 to 0.40 (17 sites)
●	0.50 to 0.99 (20 sites)
●	1.00 to 1.99 (14 sites)
●	Greater than 2.00 (2 sites)

○	–2.8 to 4.9 (38 sites)
○	5.0 to 9.9 (14 sites)
○	10.0 to 19.9 (12 sites)
○	20.0 to 39.9 (6 sites)
○	Greater than 40.0 (6 sites)

Base from U.S. Geological Survey digital data  
 Albers Equal Area Conic projection  
 Standard parallels 29°30' N. and 45°30' N.  
 Central meridian 96°00' W.  
 North American Datum of 1983



Note: GPS stations ANG5 and ANG6 have the same geographic coordinates

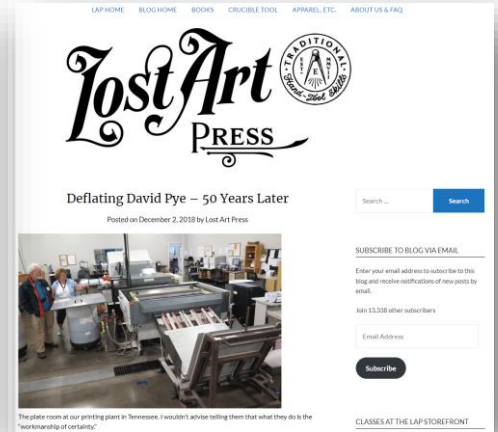
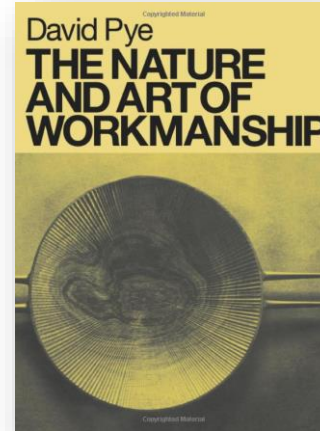
# Script-based model development

## *Risk vs. Certainty*

### From “The Nature and Art of Workmanship” - David Pye (1968)

*The most typical and familiar example of the workmanship of risk is writing with a pen, and of the workmanship of certainty, modern printing...*

*...But all this judgment, dexterity and care has been concentrated and stored up before the actual printing starts. Once it does start, the stored up capital is drawn on and the newspapers come pouring out in an absolutely predetermined form with no possibility of variation between them...*

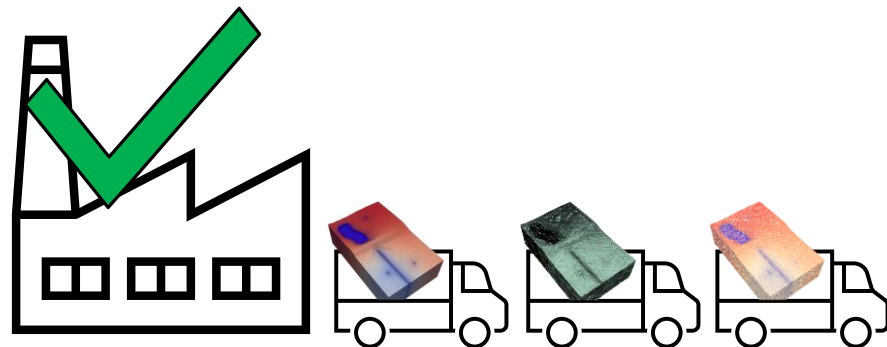
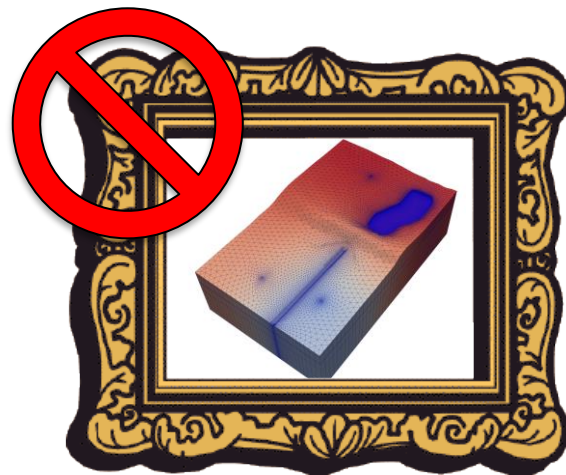


# Script-based model development

*Don't build a model, build a model factory.*

Leverage scripts to:

- Survive in the realm of “the ubiquity of error”
- “Concentrate and store up” your modeling “judgement, dexterity, and care.”
- Automate input/output generation
- Execute *Plan-Do-Check-Act* cycles to move forward in short, quick steps
- Maintain flexibility to change decisions



# The GULF Model

## Project Workflow

### Plan-Do-Check-Act Cycle (Scrum-“ish”)

- **Build or deploy** a model/ensemble variation by modifying and executing scripts `build_model.py` and/or `build_pst.py`

`./model_files/build_model.py`

```
1523 if __name__ == "__main__":
1524     mod_dir = "model_test"
1525
1526     #process_intera_wel()
1527
1528     #shape_to_arrays(shp_dir = os.path.join("../", "gulf_grid"), shp_f = "gulf_grid_20210602.shp")
1529
1530     build_history_simulation(mod_name="gulf_history", mod_dir=mod_dir, sp_info="history_model_timestepping.csv",
1531                             ss_sim=False, sp_short=None, sub=True, build_prep=True)
1532
1533     run_history_simulation(mod_name="gulf_history", mod_dir=mod_dir, exe_file='mf6.exe', prev_strt=None)
1534
1535     run_zonebudget(exe_file='zbud6.exe', mod_dir=mod_dir, mod_name='gulf_history')
1536
1537     #plot_output(ifpdir=mod_dir, ofpdir='history_plots', mod_name='gulf_history',
1538                 # sp=19, sp_info="history_model_timestepping.csv", shp_f="gulf_grid_20210324_active_area.shp" sub=True)
1539
1540     #grab_strt(mod_name="gulf_history", mod_dir="model_base", nlay=6, ofpdir="strt_heads")
1541
1542     #shutil.copy2("build_model.py", os.path.join(mod_dir, "build_model_{0}.py".format(mod_dir)))
```

`./model_files/build_pst.py`

```
3400
3401 if __name__ == "__main__":
3402
3403     org_dir = "model_base_gm"
3404     pri_dir = "model_prior_gm"
3405     ies_dir = "model_ies_gm"
3406     noptmax = 3
3407
3408
3409     # CHOOSE LOCAL TEST OR SERVER RUN
3410     if multiprocessing.cpu_count() < 13:
3411         local = True
3412         nreal = 10
3413     else:
3414         local = False
3415         nreal = 600
3416
3417     ## RUN MODEL
3418     # run_history_simulation(mod_name="gulf_history", mod_dir=org_dir, exe_file=exe_name)
3419
3420     ## BUILD PEST INTERFACE
3421
3422     # setup_control_file(mod_name="gulf_history", org_dir=org_dir, template_dir="model_template", quick=False, sub=True, ies_num_reals=nreal)
3423
3424     # ## ASSIGN STANDARD DEVIATION TO OBS
3425     # assign_stddev_obs(mod_name="gulf_history", m_d="model_template", pst_name="gulf_history.pst", draw_ensemble=False, num_reals=nreal)
3426
3427     # ## FREEZE SOME PARS
3428     # freeze_pars(mod_name="gulf_history", m_d="model_template", pst_name="gulf_history.pst")
3429
3430     ## RUN BASE MODEL
3431     # run_pst_model(mod_name="gulf_history", template_dir="model_template")
3432
3433     # ## PRIOR MONTE CARLO
3434     # if os.path.exists(pri_dir):
3435         #     shutil.rmtree(pri_dir)
3436
3437     # prep_for_parallel(b_d="model_template", pst_name="gulf_history.pst",
3438                       # m_d=pri_dir, mod_name="gulf_history", noptmax=1, ies_num_reals=nreal, overdue_giveup_fac=1.5, overdue_giveup_time=480.0, make_zip=True, sen=False)
3439
3440     ## RUN PRIOR
3441     # if local:
3442         #     run_local(b_d="model_template_parallel", m_d=pri_dir, pst_name="gulf_history.pst", num_workers=5)
3443     # else:
3444         #     run_condor(pst_name="gulf_history.pst", m_d=pri_dir, port=4044, sub_file="gulf_workers.sub")
3445
3446     # ## REWEIGHT BASED ON MEAN RESIDUALS IN PRIOR
3447     # reweight_obs(mod_name="gulf_history", t_d="model_template", m_d=pri_dir, pst_name="gulf_history.pst", run=True, sub=True)
3448
3449     # ## APPLY SOME COMMON SENSE LOCALIZATION
3450     # build_localizer(t_dir="model_template_reweight", pst_name="gulf_history.pst", mod_name="gulf_history", save=True)
3451
3452     # ## APPLY SOME HEAVY HANDED LOCALIZATION
3453     # build_localizer_no_forcing(t_dir="model_template_reweight", pst_name="gulf_history.pst", mod_name="gulf_history", save=True)
3454
3455     # ## IES RUN
3456     # prep_for_parallel(b_d="model_template_reweight", pst_name="gulf_history.pst",
3457                       # m_d=ies_dir, mod_name="gulf_history", noptmax=noptmax, ies_num_reals=nreal, overdue_giveup_fac=1.5, overdue_giveup_time=480.0, make_zip=True,
3458                       # sen=False, restart=pri_dir, with_loc=True, max_ies_reals=999)
3459
3460     # prep_for_parallel(b_d="model_template_reweight", pst_name="gulf_history.pst",
3461                       # m_d=ies_dir, mod_name="gulf_history", noptmax=noptmax, ies_num_reals=nreal, overdue_giveup_fac=1.5, overdue_giveup_time=600.0, make_zip=True,
3462                       # sen=False, restart=pri_dir, with_loc=False, max_ies_reals=999)
3463
3464     ## RUN IES
3465     # if local:
3466         #     run_local(b_d="model_template_reweight_parallel", m_d=ies_dir, pst_name="gulf_history.pst", num_workers=5)
3467     # else:
3468         #     run_condor(pst_name="gulf_history.pst", m_d=ies_dir, port=4044, sub_file="gulf_workers.sub")
3469
3470     # CONDITION POSTERIOR
3471     condition_posterior(pst_name="gulf_history.pst", m_d=ies_dir, noptmax=1, threshold=0.95)
3472     # ## MISCELLANY
3473     # initialize_bm_obs(template_dir="model_template")
3474
```



# The GULF Model

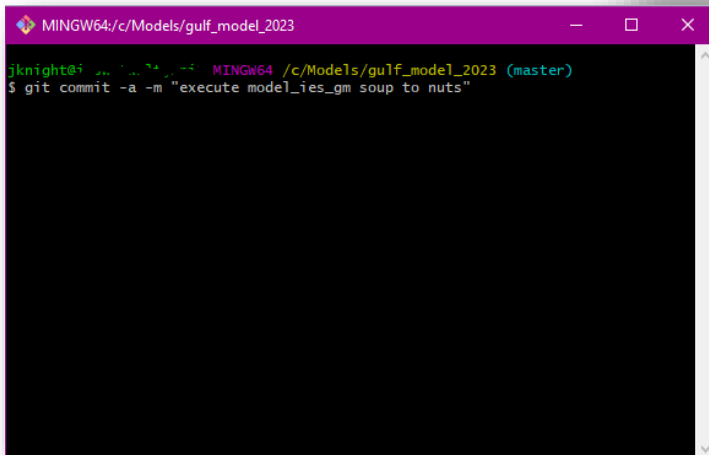
## Project Workflow

### Plan-Do-Check-Act Cycle (Scrum-“ish”)

- Build or deploy a model/ensemble variation by modifying and executing scripts `build_model.py` and/or `build_pst.py`
- **Document** changes and expectations.
- **Commit** changes to GIT repository.

./model\_files/gulf\_ies\_run\_notes.txt

```
8 model_ies_gm:
9 estimate coarse grain properties (ske and theta) independently by layer, no more cascading down from top layer
10 fix bug in build_pst that quintuples number of clay_frac mfinput obs because ib in par name
11 last call for parameterhol
12 SY seems to be maxing out at 0.20?
13 decrease ssv ult lower bound from 5e-5 to 1e-5
14
15 model_base_bm5:
16 stop tracking sk at submap obs locs
17
18
19
20 model_ies_bm4 (bm4a after correcting weight scheme bug:
21 new pest exe 5.1.0
22 weighted cmp obs > 0 for 1943 and 1978 maps
23 removed bm obs minimum value filter for weighting
24 theta mult range back to larger distributions of fc2 era, sacrificial par
25 clay_frac parameterized, used to change thick_frac values in csub pkgdata
26 rch pars fixed
27 twel pars fixed
28 wel and irr grid pars adjustable
29
30 RESULTS: pretty good. considering de-weighting burkeville obs, might be messing with updip evg and jsp heads
31
32
33 model_base_bm4:
```



```
MINGW64:/c/Models/gulf_model_2023
jknights@jknights:~/c/Models/gulf_model_2023 (master)
$ git commit -a -m "execute model_ies_gm soup to nuts"
```

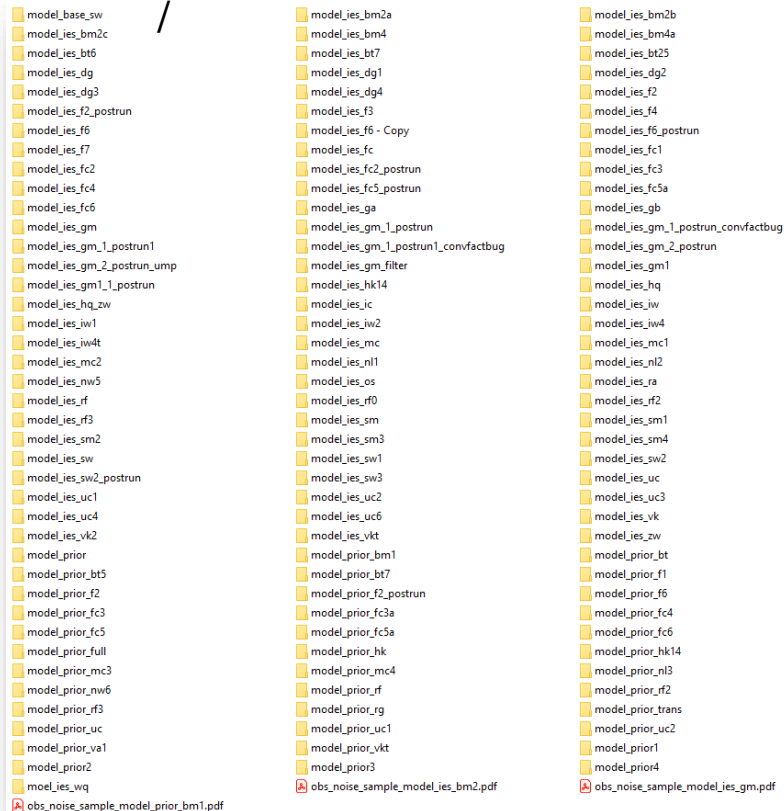
# The GULF Model

## Project Workflow

### Plan-Do-Check-Act Cycle (Scrum-“ish”)

- Build or deploy a model/ensemble variation by modifying and executing scripts `build_model.py` and/or `build_pst.py`
- Document changes and expectations.
- Commit changes to GIT repository.
- **Review** results `plot_results.py`
- **Decide** next course of action.
- Repeat, Repeat, Repeat, until...?

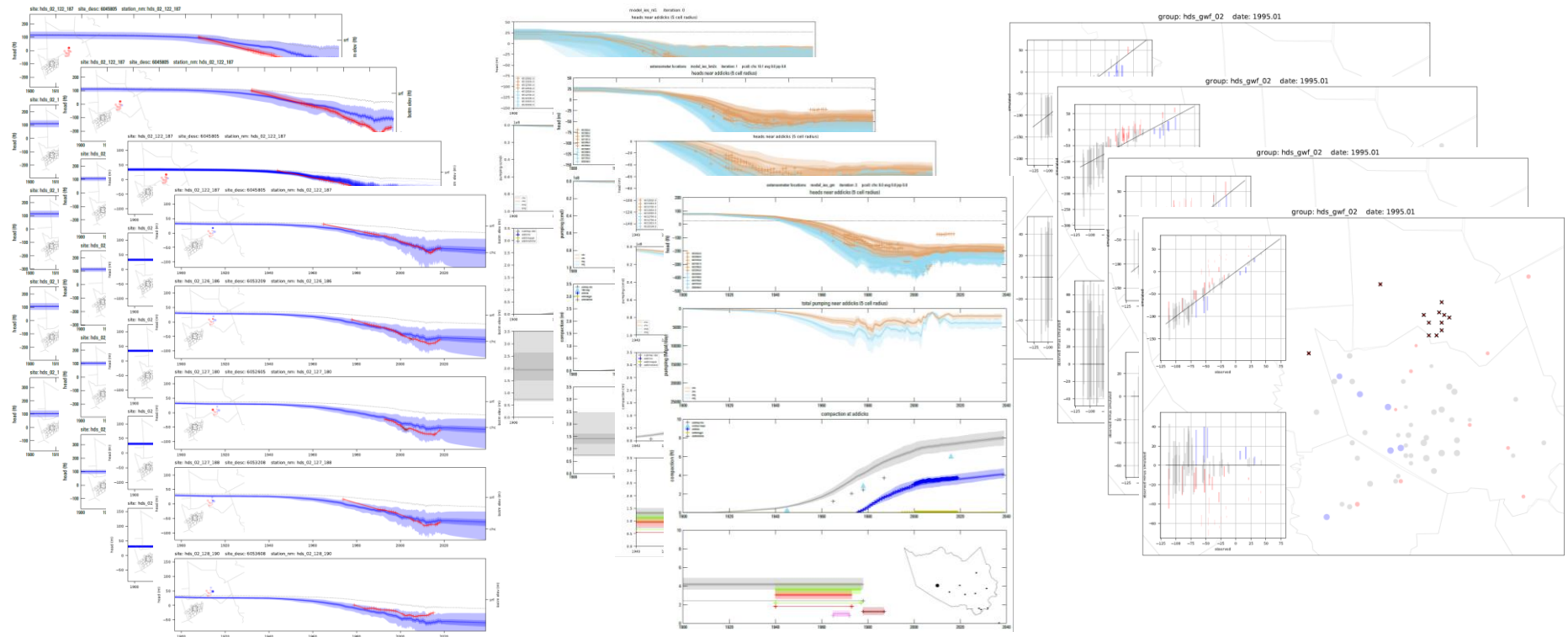
./model\_files/model\_plots



The screenshot displays a file explorer window titled './model\_files/model\_plots'. It shows a directory structure with numerous files, each represented by a yellow folder icon. The files are organized into three columns. The first column contains files such as 'model\_base\_sw', 'model\_ies\_bm2c', 'model\_ies\_bt6', 'model\_ies\_bt7', 'model\_ies\_bt8', 'model\_ies\_bt9', 'model\_ies\_bt10', 'model\_ies\_bt11', 'model\_ies\_bt12', 'model\_ies\_bt13', 'model\_ies\_bt14', 'model\_ies\_bt15', 'model\_ies\_bt16', 'model\_ies\_bt17', 'model\_ies\_bt18', 'model\_ies\_bt19', 'model\_ies\_bt20', 'model\_ies\_bt21', 'model\_ies\_bt22', 'model\_ies\_bt23', 'model\_ies\_bt24', 'model\_ies\_bt25', 'model\_ies\_bt26', 'model\_ies\_bt27', 'model\_ies\_bt28', 'model\_ies\_bt29', 'model\_ies\_bt30', 'model\_ies\_bt31', 'model\_ies\_bt32', 'model\_ies\_bt33', 'model\_ies\_bt34', 'model\_ies\_bt35', 'model\_ies\_bt36', 'model\_ies\_bt37', 'model\_ies\_bt38', 'model\_ies\_bt39', 'model\_ies\_bt40', 'model\_ies\_bt41', 'model\_ies\_bt42', 'model\_ies\_bt43', 'model\_ies\_bt44', 'model\_ies\_bt45', 'model\_ies\_bt46', 'model\_ies\_bt47', 'model\_ies\_bt48', 'model\_ies\_bt49', 'model\_ies\_bt50', 'model\_ies\_bt51', 'model\_ies\_bt52', 'model\_ies\_bt53', 'model\_ies\_bt54', 'model\_ies\_bt55', 'model\_ies\_bt56', 'model\_ies\_bt57', 'model\_ies\_bt58', 'model\_ies\_bt59', 'model\_ies\_bt60', 'model\_ies\_bt61', 'model\_ies\_bt62', 'model\_ies\_bt63', 'model\_ies\_bt64', 'model\_ies\_bt65', 'model\_ies\_bt66', 'model\_ies\_bt67', 'model\_ies\_bt68', 'model\_ies\_bt69', 'model\_ies\_bt70', 'model\_ies\_bt71', 'model\_ies\_bt72', 'model\_ies\_bt73', 'model\_ies\_bt74', 'model\_ies\_bt75', 'model\_ies\_bt76', 'model\_ies\_bt77', 'model\_ies\_bt78', 'model\_ies\_bt79', 'model\_ies\_bt80', 'model\_ies\_bt81', 'model\_ies\_bt82', 'model\_ies\_bt83', 'model\_ies\_bt84', 'model\_ies\_bt85', 'model\_ies\_bt86', 'model\_ies\_bt87', 'model\_ies\_bt88', 'model\_ies\_bt89', 'model\_ies\_bt90', 'model\_ies\_bt91', 'model\_ies\_bt92', 'model\_ies\_bt93', 'model\_ies\_bt94', 'model\_ies\_bt95', 'model\_ies\_bt96', 'model\_ies\_bt97', 'model\_ies\_bt98', 'model\_ies\_bt99', 'model\_ies\_bt100'. The second column contains files such as 'model\_ies\_bm2a', 'model\_ies\_bm4', 'model\_ies\_bt7', 'model\_ies\_dg1', 'model\_ies\_dg2', 'model\_ies\_dg3', 'model\_ies\_dg4', 'model\_ies\_f3', 'model\_ies\_f6 - Copy', 'model\_ies\_fc', 'model\_ies\_fc2\_postrun', 'model\_ies\_fc5\_postrun', 'model\_ies\_ga', 'model\_ies\_gm1\_postrun', 'model\_ies\_gm1\_postrun1', 'model\_ies\_gm1\_postrun2', 'model\_ies\_gm1\_postrun3', 'model\_ies\_gm1\_postrun4', 'model\_ies\_gm1\_postrun5', 'model\_ies\_gm1\_postrun6', 'model\_ies\_gm1\_postrun7', 'model\_ies\_gm1\_postrun8', 'model\_ies\_gm1\_postrun9', 'model\_ies\_gm1\_postrun10', 'model\_ies\_gm1\_postrun11', 'model\_ies\_gm1\_postrun12', 'model\_ies\_gm1\_postrun13', 'model\_ies\_gm1\_postrun14', 'model\_ies\_gm1\_postrun15', 'model\_ies\_gm1\_postrun16', 'model\_ies\_gm1\_postrun17', 'model\_ies\_gm1\_postrun18', 'model\_ies\_gm1\_postrun19', 'model\_ies\_gm1\_postrun20', 'model\_ies\_gm1\_postrun21', 'model\_ies\_gm1\_postrun22', 'model\_ies\_gm1\_postrun23', 'model\_ies\_gm1\_postrun24', 'model\_ies\_gm1\_postrun25', 'model\_ies\_gm1\_postrun26', 'model\_ies\_gm1\_postrun27', 'model\_ies\_gm1\_postrun28', 'model\_ies\_gm1\_postrun29', 'model\_ies\_gm1\_postrun30', 'model\_ies\_gm1\_postrun31', 'model\_ies\_gm1\_postrun32', 'model\_ies\_gm1\_postrun33', 'model\_ies\_gm1\_postrun34', 'model\_ies\_gm1\_postrun35', 'model\_ies\_gm1\_postrun36', 'model\_ies\_gm1\_postrun37', 'model\_ies\_gm1\_postrun38', 'model\_ies\_gm1\_postrun39', 'model\_ies\_gm1\_postrun40', 'model\_ies\_gm1\_postrun41', 'model\_ies\_gm1\_postrun42', 'model\_ies\_gm1\_postrun43', 'model\_ies\_gm1\_postrun44', 'model\_ies\_gm1\_postrun45', 'model\_ies\_gm1\_postrun46', 'model\_ies\_gm1\_postrun47', 'model\_ies\_gm1\_postrun48', 'model\_ies\_gm1\_postrun49', 'model\_ies\_gm1\_postrun50', 'model\_ies\_gm1\_postrun51', 'model\_ies\_gm1\_postrun52', 'model\_ies\_gm1\_postrun53', 'model\_ies\_gm1\_postrun54', 'model\_ies\_gm1\_postrun55', 'model\_ies\_gm1\_postrun56', 'model\_ies\_gm1\_postrun57', 'model\_ies\_gm1\_postrun58', 'model\_ies\_gm1\_postrun59', 'model\_ies\_gm1\_postrun60', 'model\_ies\_gm1\_postrun61', 'model\_ies\_gm1\_postrun62', 'model\_ies\_gm1\_postrun63', 'model\_ies\_gm1\_postrun64', 'model\_ies\_gm1\_postrun65', 'model\_ies\_gm1\_postrun66', 'model\_ies\_gm1\_postrun67', 'model\_ies\_gm1\_postrun68', 'model\_ies\_gm1\_postrun69', 'model\_ies\_gm1\_postrun70', 'model\_ies\_gm1\_postrun71', 'model\_ies\_gm1\_postrun72', 'model\_ies\_gm1\_postrun73', 'model\_ies\_gm1\_postrun74', 'model\_ies\_gm1\_postrun75', 'model\_ies\_gm1\_postrun76', 'model\_ies\_gm1\_postrun77', 'model\_ies\_gm1\_postrun78', 'model\_ies\_gm1\_postrun79', 'model\_ies\_gm1\_postrun80', 'model\_ies\_gm1\_postrun81', 'model\_ies\_gm1\_postrun82', 'model\_ies\_gm1\_postrun83', 'model\_ies\_gm1\_postrun84', 'model\_ies\_gm1\_postrun85', 'model\_ies\_gm1\_postrun86', 'model\_ies\_gm1\_postrun87', 'model\_ies\_gm1\_postrun88', 'model\_ies\_gm1\_postrun89', 'model\_ies\_gm1\_postrun90', 'model\_ies\_gm1\_postrun91', 'model\_ies\_gm1\_postrun92', 'model\_ies\_gm1\_postrun93', 'model\_ies\_gm1\_postrun94', 'model\_ies\_gm1\_postrun95', 'model\_ies\_gm1\_postrun96', 'model\_ies\_gm1\_postrun97', 'model\_ies\_gm1\_postrun98', 'model\_ies\_gm1\_postrun99', 'model\_ies\_gm1\_postrun100'. The third column contains files such as 'model\_ies\_bm2b', 'model\_ies\_bm4a', 'model\_ies\_bt25', 'model\_ies\_dg2', 'model\_ies\_f2', 'model\_ies\_f4', 'model\_ies\_f2\_postrun', 'model\_ies\_f6\_postrun', 'model\_ies\_fc1', 'model\_ies\_fc3', 'model\_ies\_fc5a', 'model\_ies\_gb', 'model\_ies\_gm1\_postrun\_convfactbug', 'model\_ies\_gm2\_postrun', 'model\_ies\_gm1', 'model\_ies\_hq', 'model\_ies\_ic', 'model\_ies\_iv', 'model\_ies\_iv4', 'model\_ies\_mc1', 'model\_ies\_n2', 'model\_ies\_ra', 'model\_ies\_rf2', 'model\_ies\_sm1', 'model\_ies\_sm4', 'model\_ies\_sw2', 'model\_ies\_uc', 'model\_ies\_uc3', 'model\_ies\_vk', 'model\_ies\_zw', 'model\_prior\_bt', 'model\_prior\_f1', 'model\_prior\_f6', 'model\_prior\_fc4', 'model\_prior\_fc6', 'model\_prior\_hk14', 'model\_prior\_n13', 'model\_prior\_rf2', 'model\_prior\_trans', 'model\_prior\_uc2', 'model\_prior1', 'model\_prior4', 'obs\_noise\_sample\_model\_ies\_bm2.pdf', 'obs\_noise\_sample\_model\_ies\_gm.pdf'. The first file in the first column is selected.

# The GULF Model

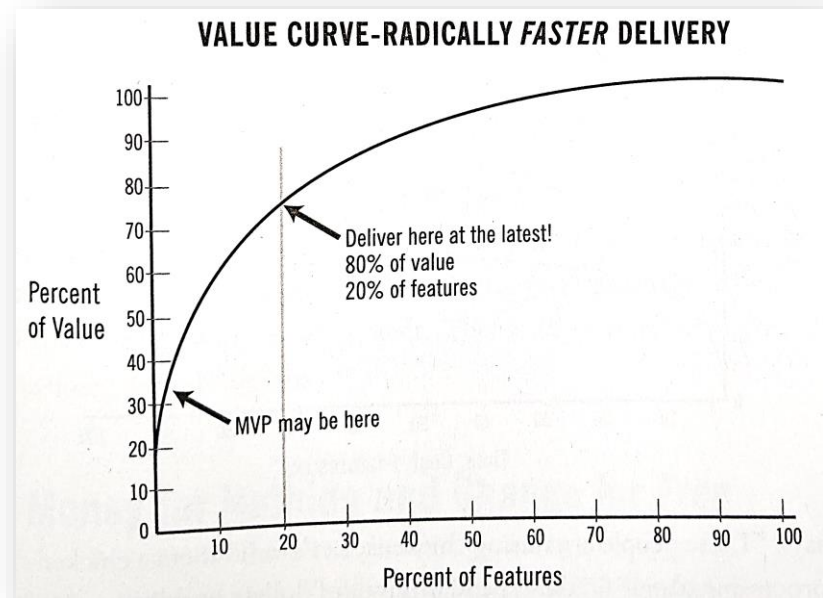
## Project Workflow



# The BLRM Model

## Getting Started

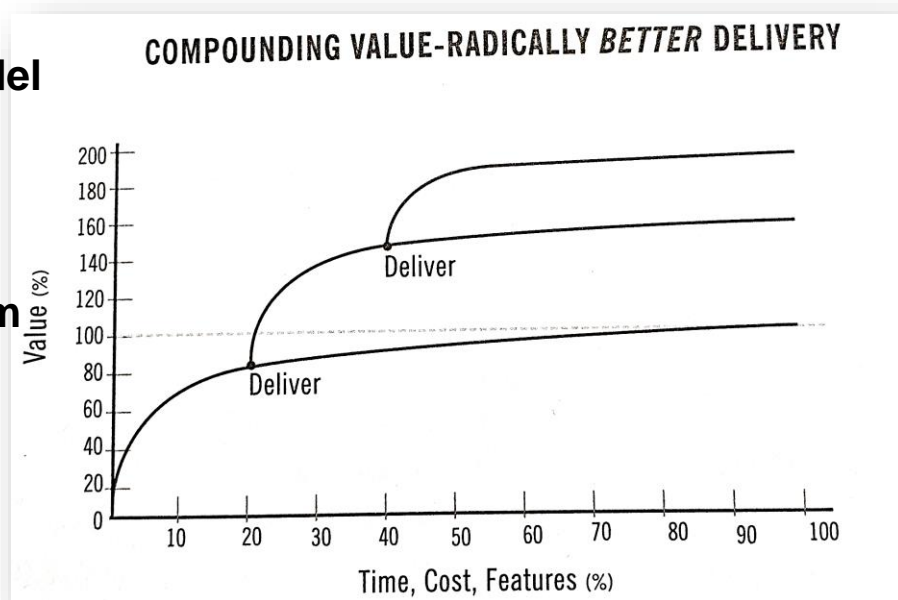
- “Minimum Viable Product” model running
  - Embarrassingly simple, far from complete, but it “works.”
- Many useful scripts inherited and adapted from GULF project
- Executing PDCA cycles with each added feature
- Repeat, Repeat, Repeat, until...?



# The BLRM Model

## Getting Started

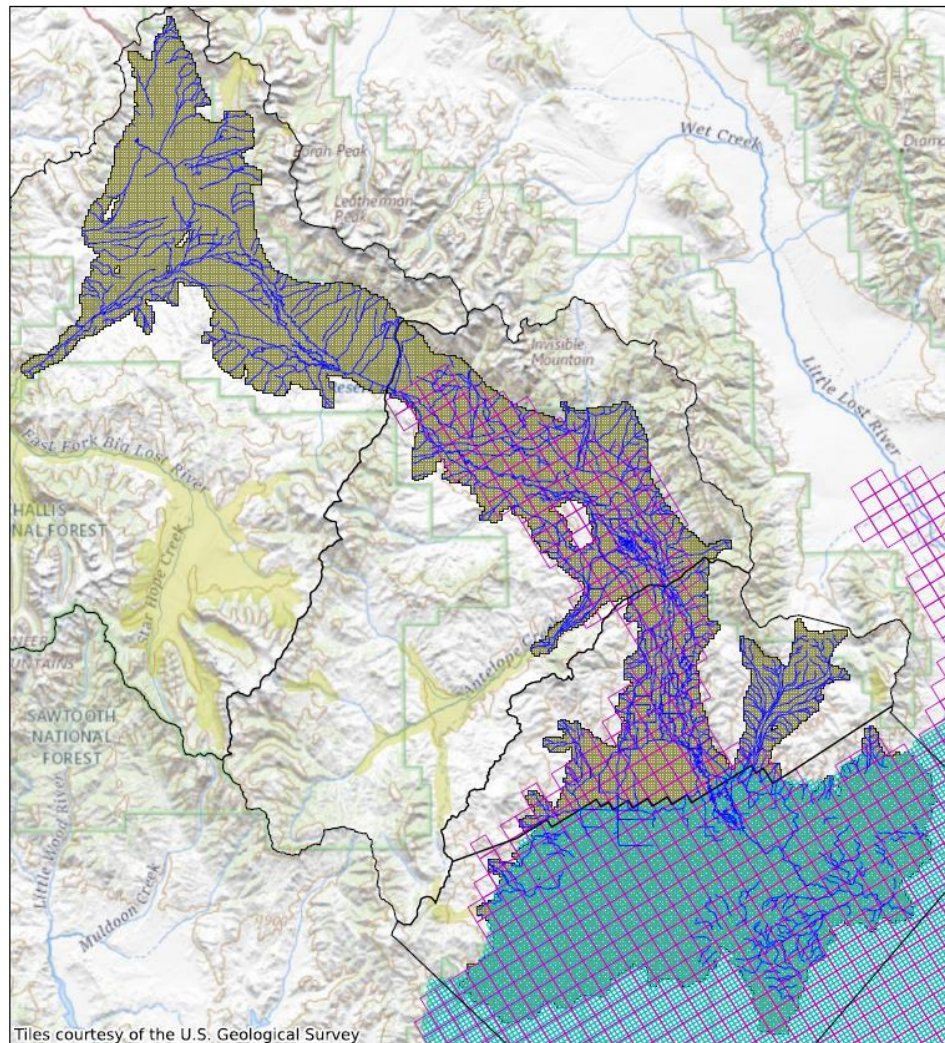
- Each MTAC meeting is an opportunity for a “product delivery”
  - Review added features, improved model performance w.r.t. objectives
  - Discuss model shortcomings, challenges
- Feedback at each MTAC meeting will inform a refreshed list of target features and abilities to aim for before the next MTAC meeting
- Repeat, Repeat, Repeat, until...?



# The BLRM Model

*minimum viable product (MVP) model*

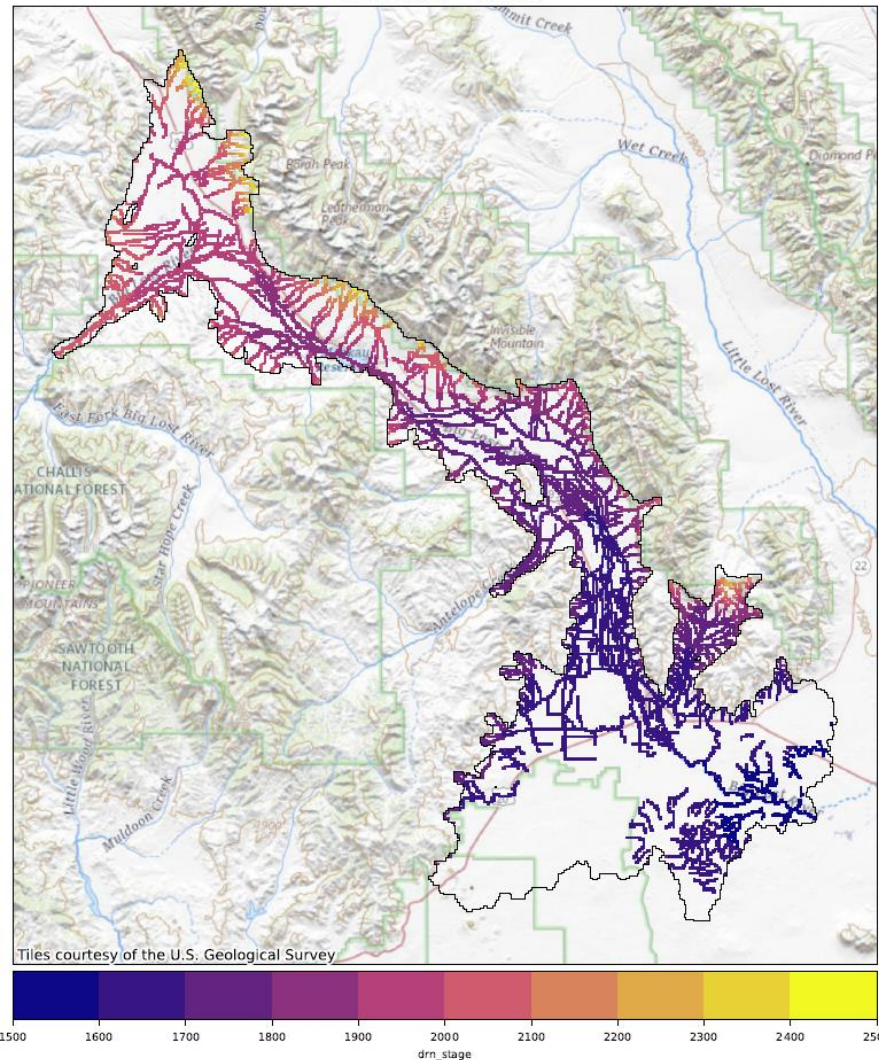
- **Model build from raw data through parameterization and prior MC evaluation**
- **Script-based and fully automated (so far)**
  - Python + FloPy, PyEmu, mfsetup, sfrmaker
- **Arbitrary cell size (100m, 200m, 250m tested)**
- **Drain network from NHD+ streamlines**
- **General Head Boundary condition at southern extent set to ESPAM-simulated steady-state heads**
- **Constant RCH rates and HK**
- **Crude basement surface elevation**



# The BLRM Model

*minimum viable product (MVP) model*

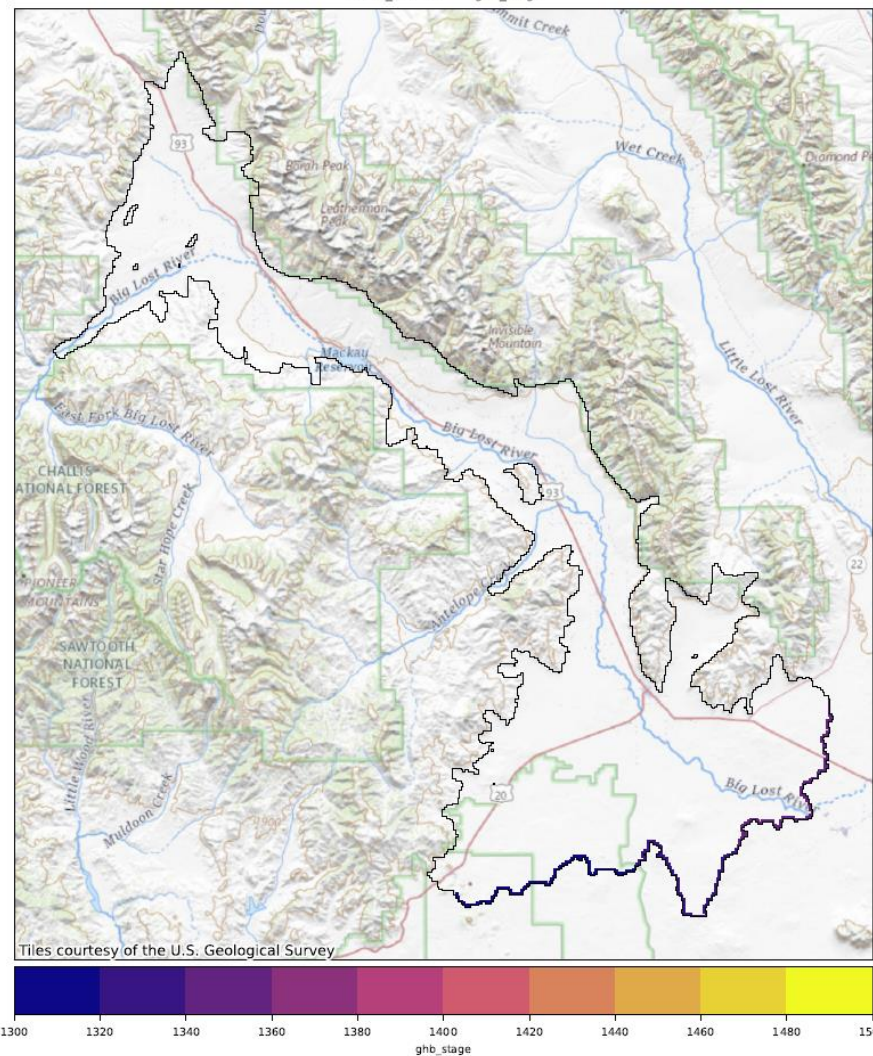
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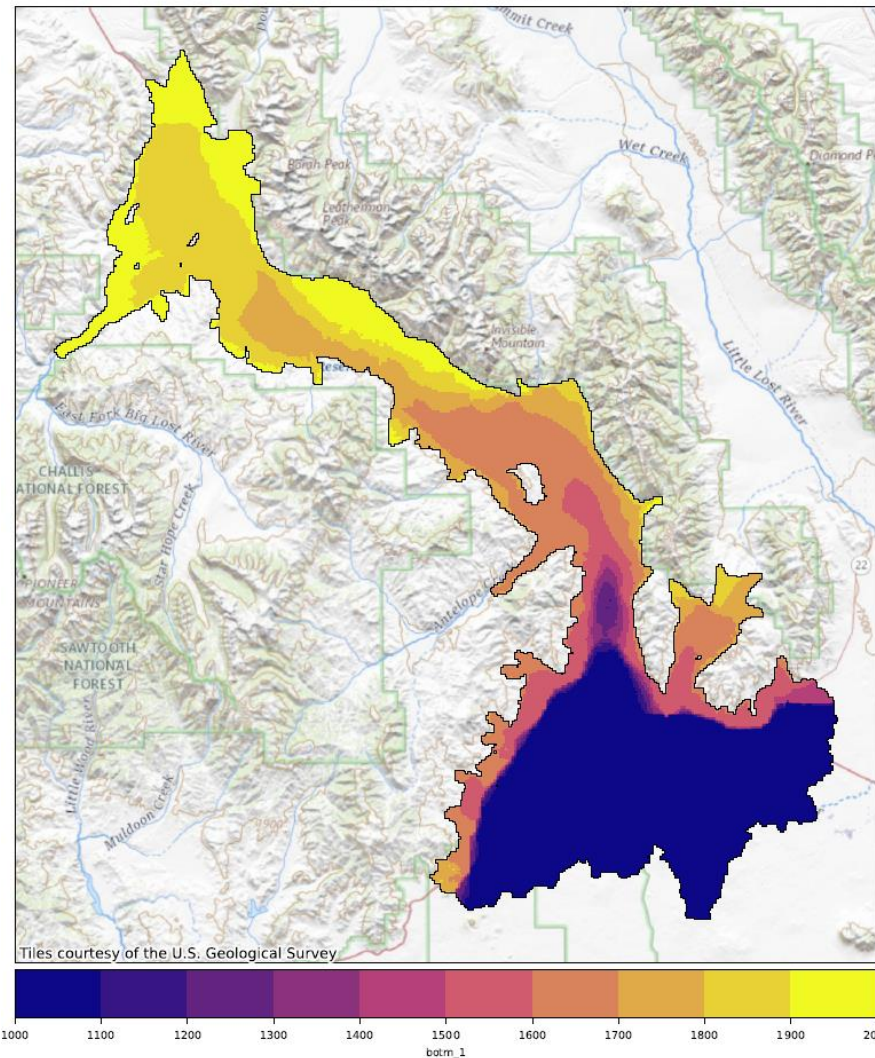




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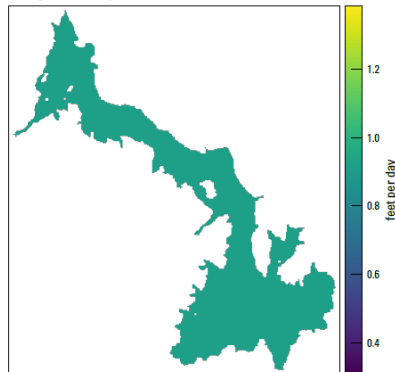
# The BLRM Model

*minimum viable product (MVP) model*

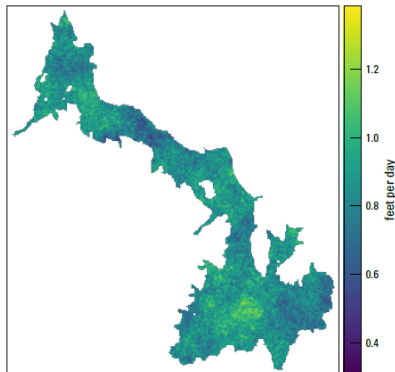
- HK and RCH parameterization via multipliers deployed at 3 spatial scales:

- Global
- Pilot Point
- Indv. Cell

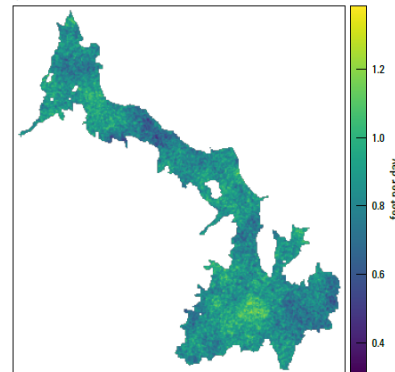
A) Original model input



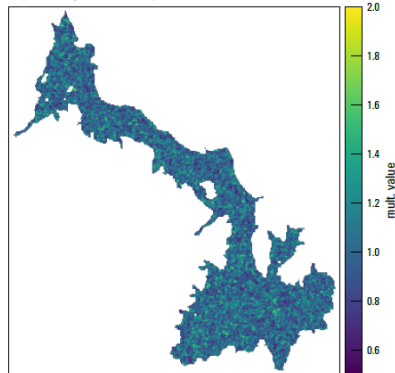
Property: HK Layer 0 Realization: 0 phi rank: 0  
B) prior HK model input  
 $\phi: 0.00E+00$



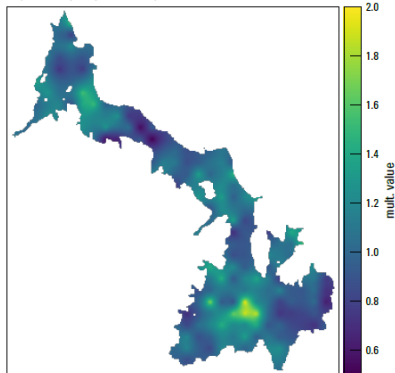
C) posterior HK model input  
 $\phi: 0.00E+00$



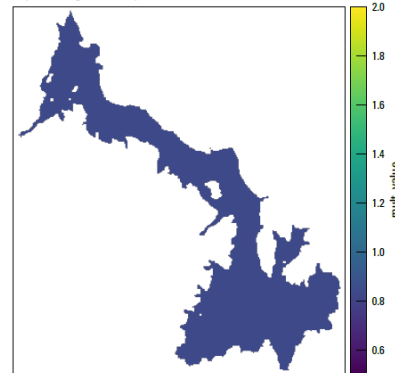
D) posterior grid-scale multiplier



E) posterior pilot points multiplier



F) posterior global multiplier

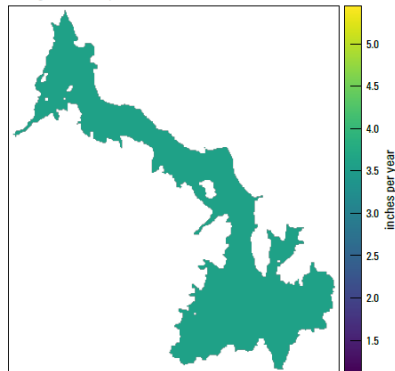


# The BLRM Model

*minimum viable product (MVP) model*

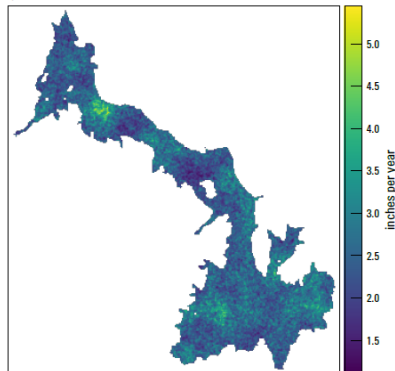
- HK and RCH parameterization via multipliers deployed at 3 spatial scales:
  - Global
  - Pilot Point
  - Indv. Cell

A) Original model input

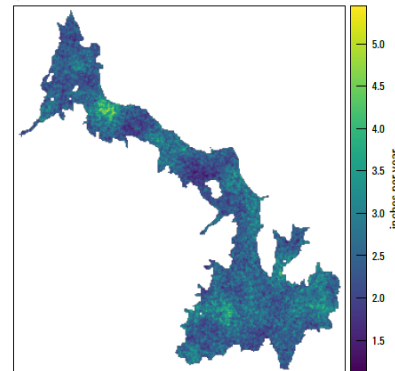


Property: RCH Layer 0 Realization: 0 phi rank: 0

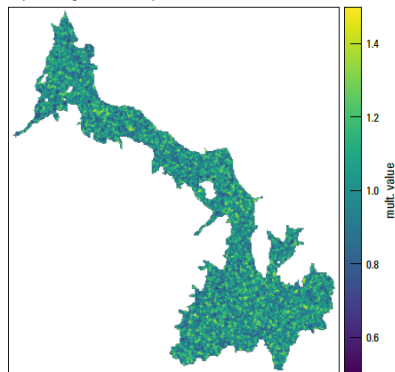
B) prior RCH model input  
 $\phi: 0.00E+00$



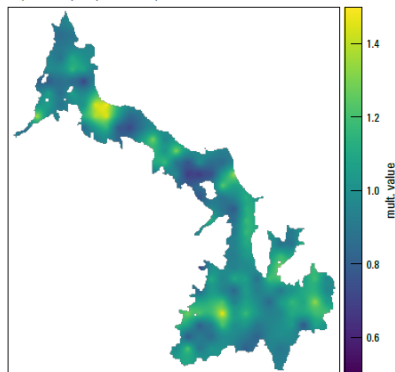
C) posterior RCH model input  
 $\phi: 0.00E+00$



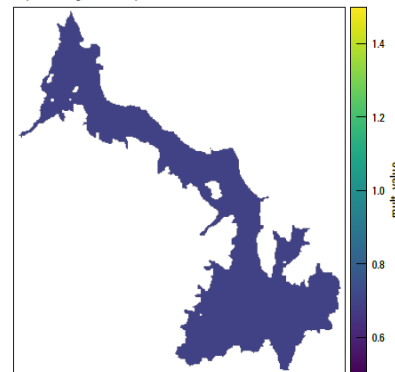
D) posterior grid-scale multiplier



E) posterior pilot points multiplier



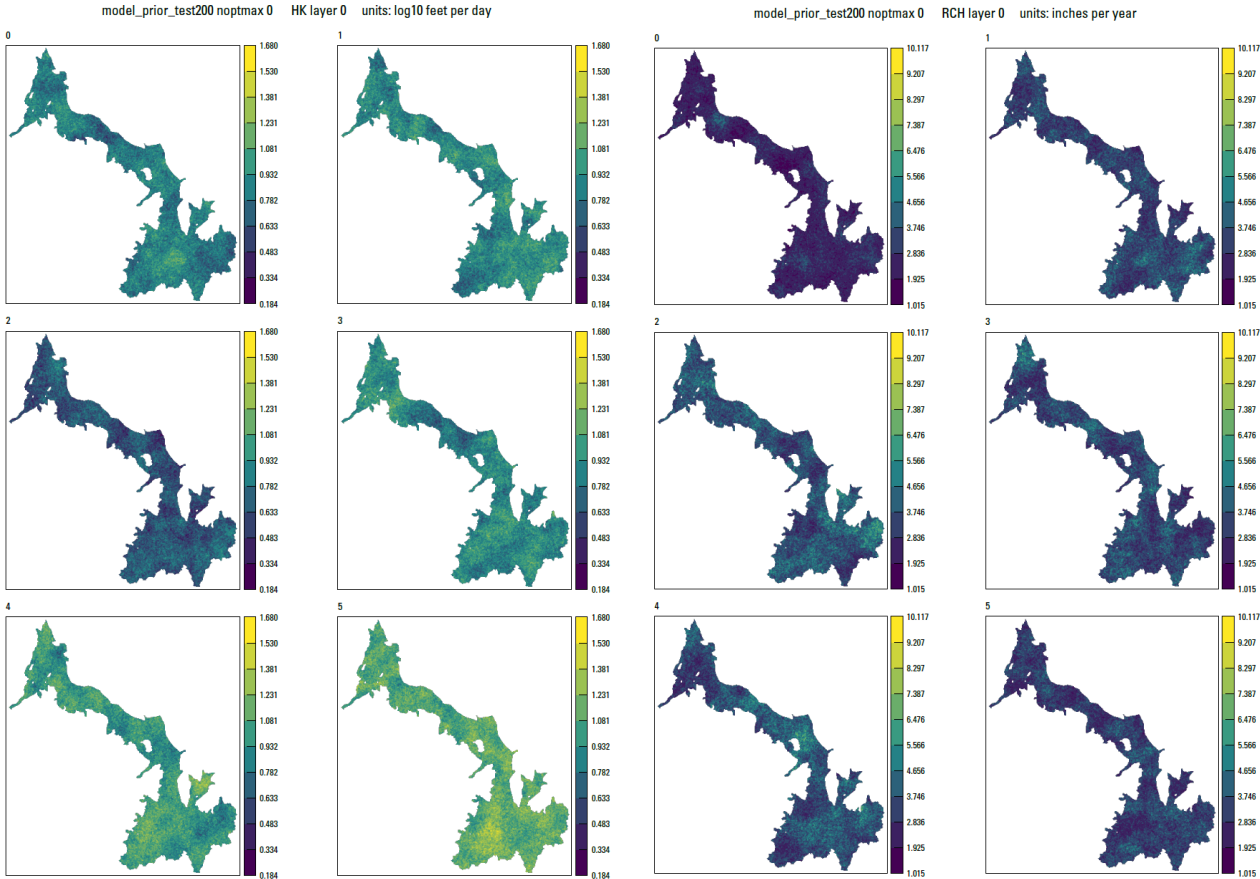
F) posterior global multiplier



# The BLRM Model

*minimum viable product (MVP) model*

- Randomly draw values from Prior Parameter Distribution to build Prior ensemble of model realizations

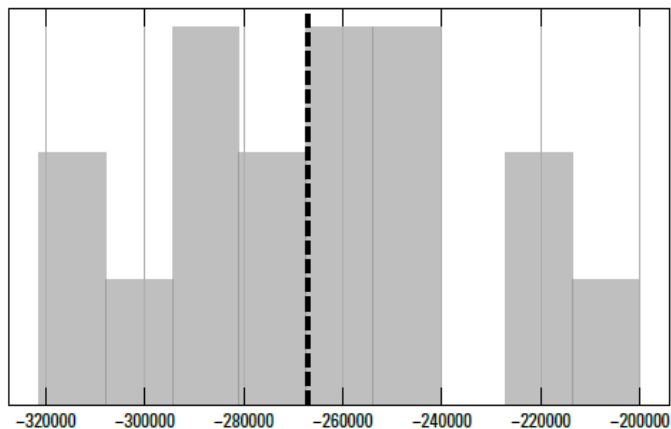


# The BLRM Model

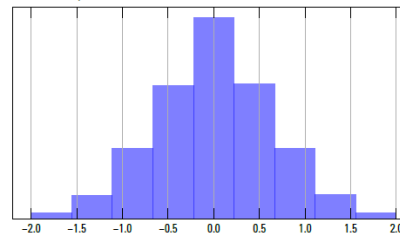
*minimum viable product (MVP) model*

- Prior Monte Carlo evaluates range of outputs resulting from range of inputs
  - Currently tracking underflow into ESPAM domain (est. 267k afyr)

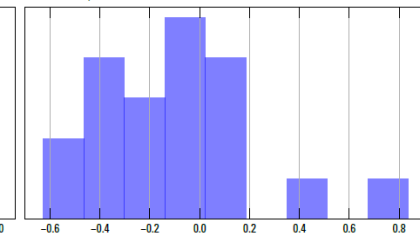
A) oname:zbd\_otype:lst\_usecol:net\_zone\_03\_zone:zone04\_datetime:19790104, count:1  
min:-3.2E+05, max:-2.0E+05



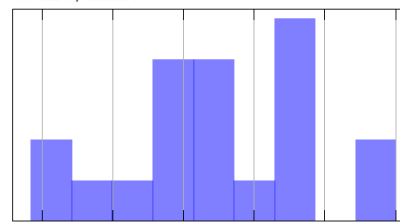
A) drn\_cond, count:11128  
min:-2.0E+00, max:2.0E+00



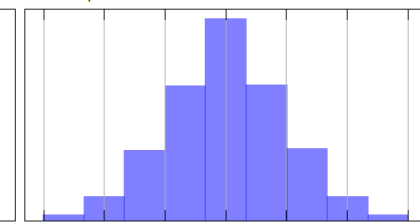
B) ghb\_cond, count:1  
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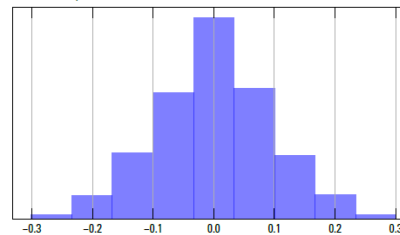
C) npf\_k33\_cn, count:1  
min:-2.2E-01, max:3.0E-01



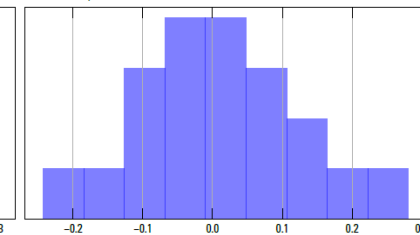
D) npf\_k33\_gr, count:43205  
min:-3.0E-01, max:3.0E-01



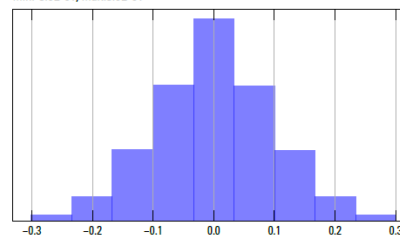
E) npf\_k33\_pp, count:197  
min:-3.0E-01, max:3.0E-01



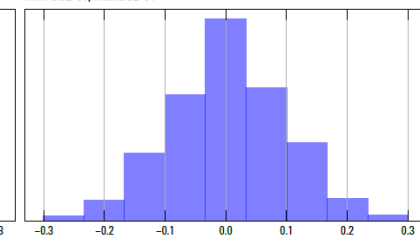
F) npf\_k\_cn, count:1  
min:-2.4E-01, max:2.8E-01



G) npf\_k\_gr, count:43205  
min:-3.0E-01, max:3.0E-01



H) npf\_k\_pp, count:197  
min:-3.0E-01, max:3.0E-01



# Stephen's Turn...



# Discussion

# Summary and Questions

- How does this communication format sound?
- What should we include in model status update presentations?
  - Figures
  - Topics
- What should the model do next?
- What else do you want to tell us?
- Questions?



# Thanks!

Stephen Hundt

[shundt@usgs.gov](mailto:shundt@usgs.gov)

208-387-1390

Jacob Knight

[jknight@usgs.gov](mailto:jknight@usgs.gov)

520-670-3336