“Mommas don’t let your babies grow up to be modeling cowboys”

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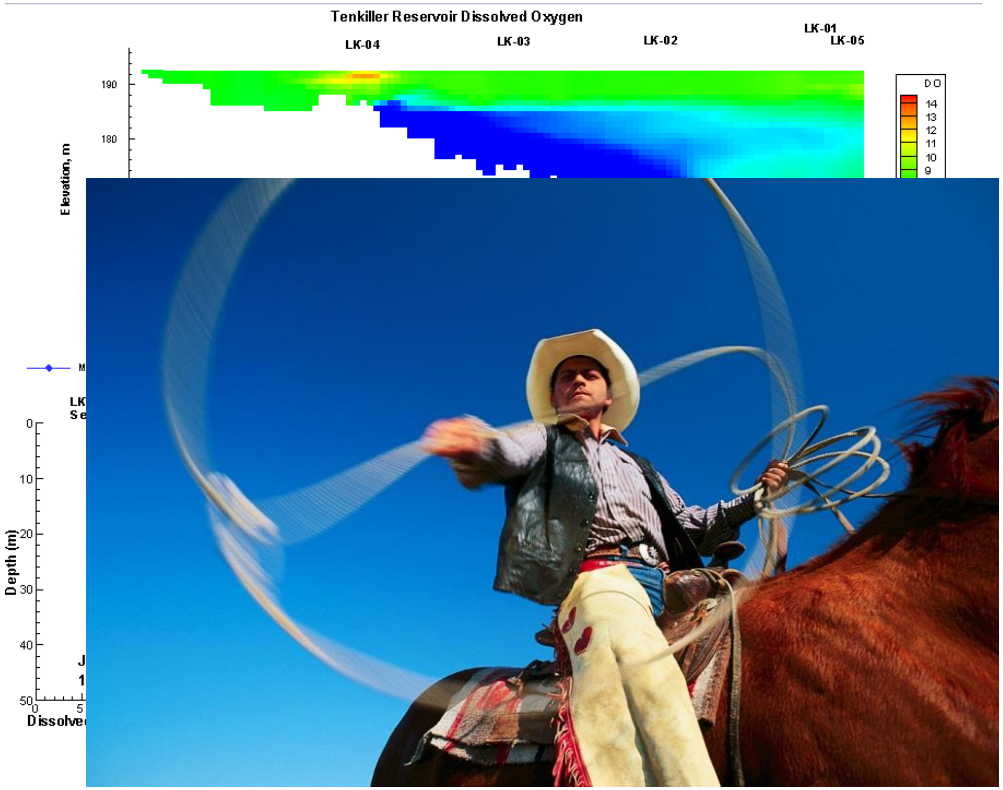
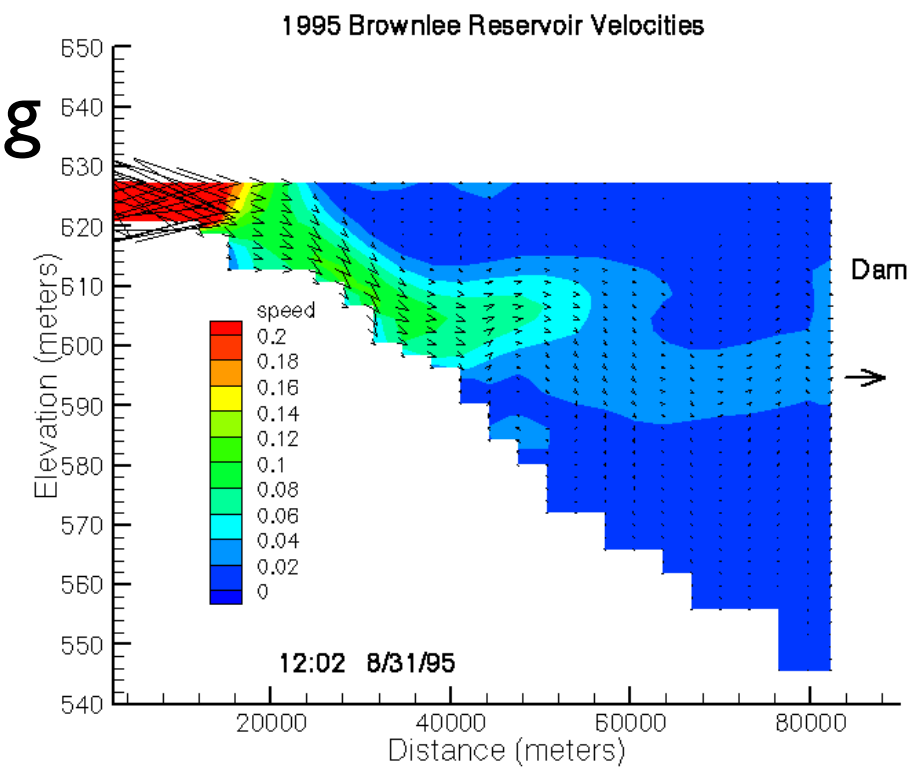
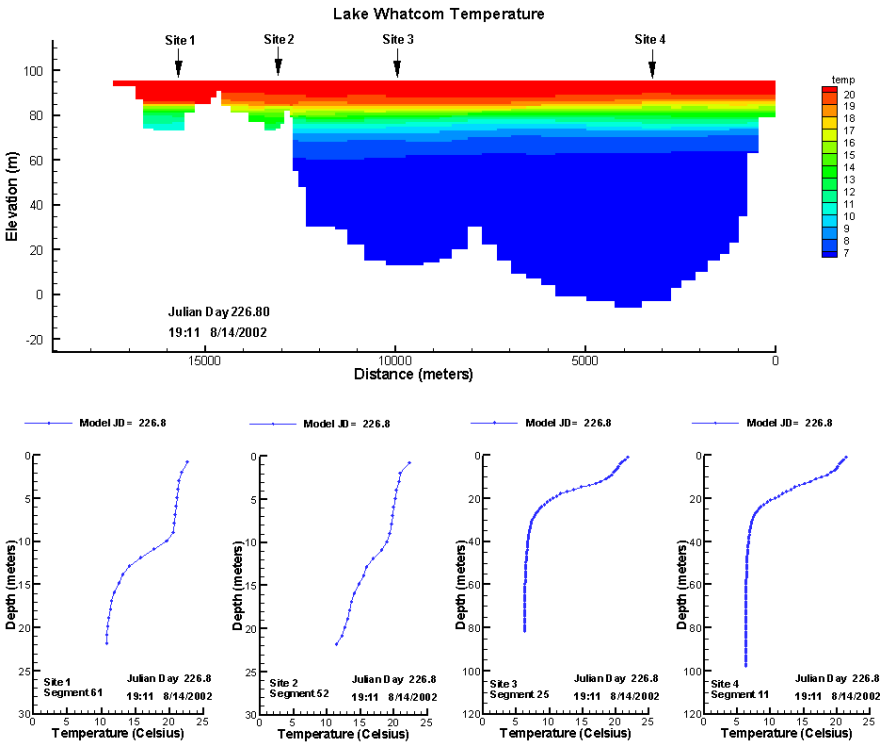


Keeping modeling and modelers 'honest'

- Why use a model?
- Modeling trends
- Lies of modelers
- History of modeling
- Use and abuse of models
- Final Thoughts



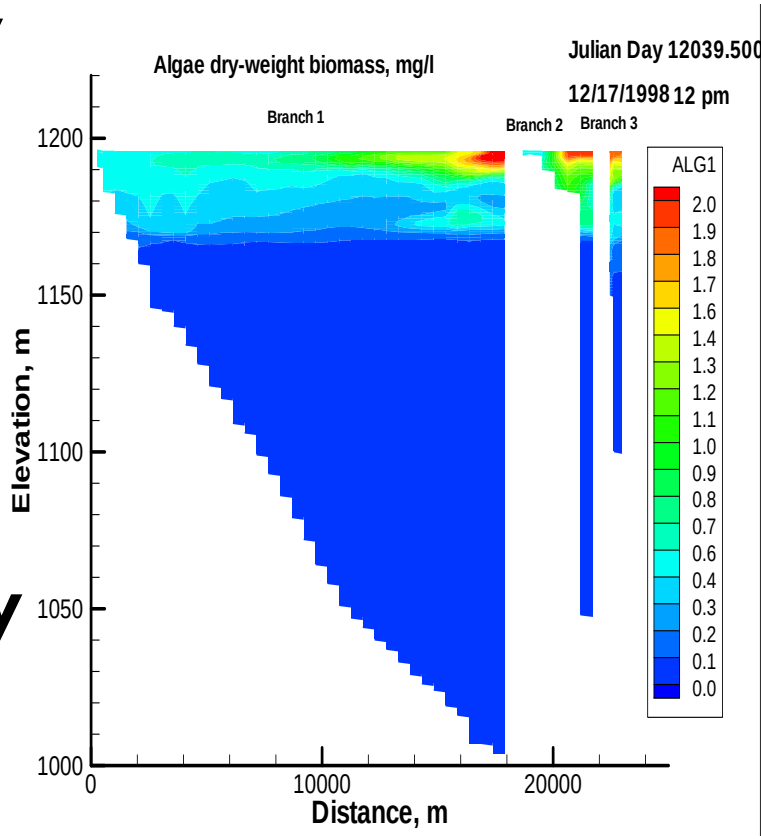
Why use a model?



- Mathematical equations are too complex for our intuition
- Often required as part of a regulatory requirement
- Models allow one to utilize and organize existing data into a framework to understand the system

Modeling Trends

- "As models are increasingly used to support decisions that result in significant financial investment for restoration and infrastructure, ***the defensibility and accuracy of models will be challenged***." (EPA 2005)



Useless Arithmetic: Why Environmental Scientists Can't Predict the Future, 2006.

- One review: "The book is a welcome antidote to the blind use of supposedly quantitative models……. which are not yet capable of producing useful information…"

Remember

- There are no bad models just bad modelers

"…Cowboys ain't easy to love…."

Top 10 lies of modelers and their models

- This model is “user-friendly”
- The techniques in this model were first developed here
- You can easily run the code without the user manual
- The model can model anything

(adapted and enhanced from Ralph Cheng, USGS)

Top 10 lies of modelers and their models (continued)

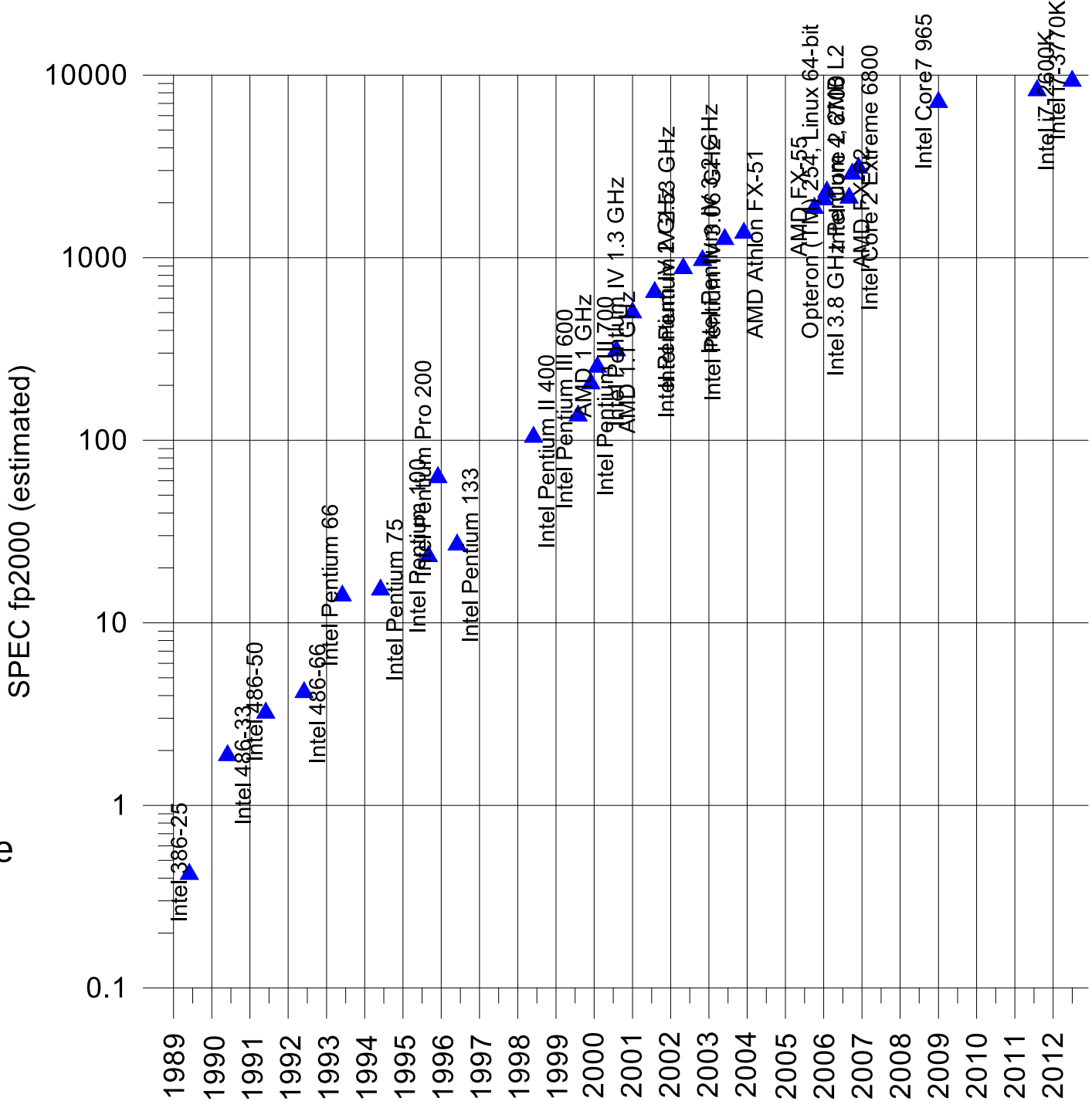
- This model is "robust [robusto]"* and "accurate [precisa]"
- This model can be run on any computational platform (UNIX, LINUX, PC, Mac) with little or no modifications
- There are no more "bugs" in the model, just undocumented features

* strong and healthy, capable of performing without failure under a wide range of conditions

Top 10 lies of modelers and their models (continued)

- You won't need to hire the model developer to run the model once you get in trouble since the model is so easy to use.
- The user manual has everything you need to run the model
- As you know, the model is right and the data are wrong, i.e., never trust data, never ever trust data.

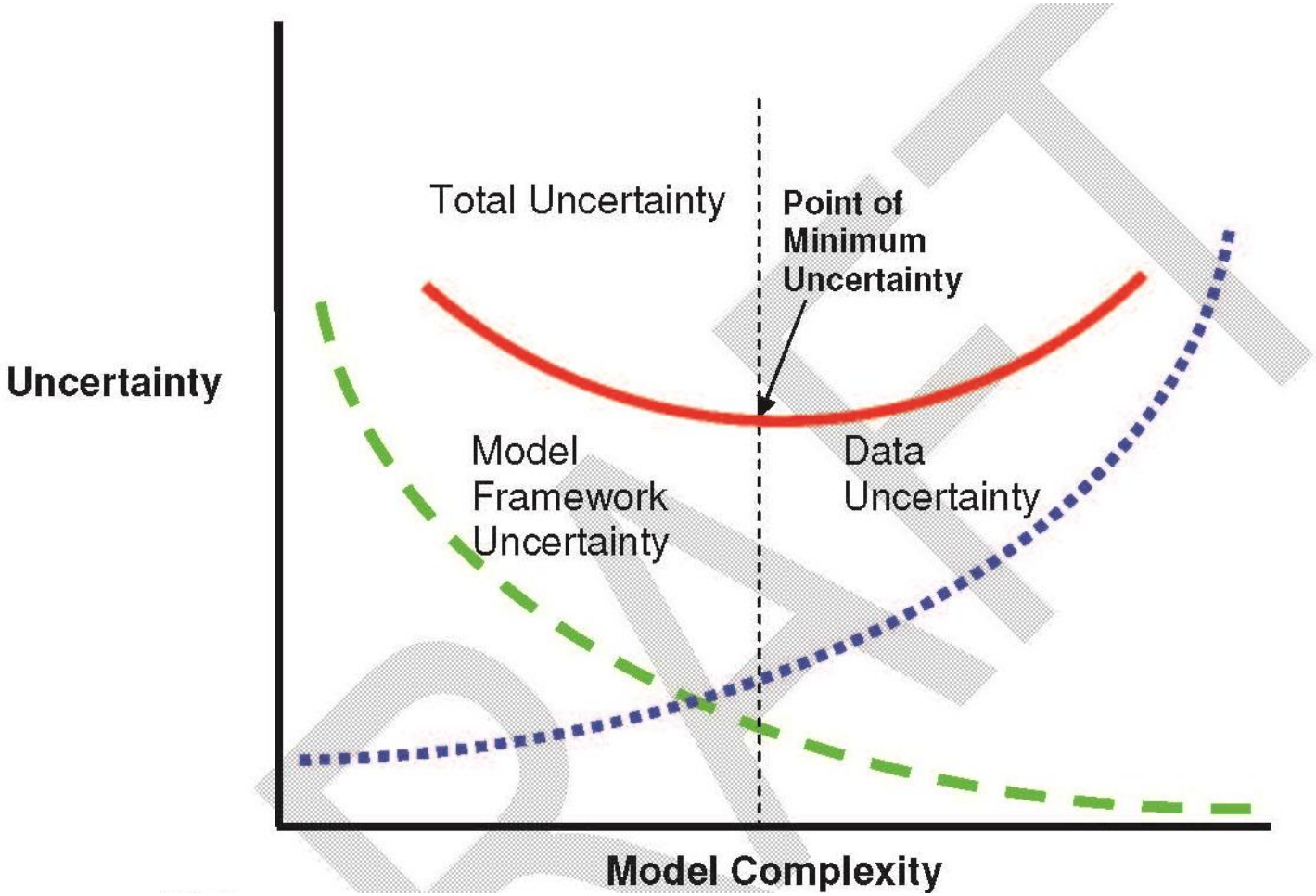
Floating point performance has increased > 10^4 in 20 years



Computer Power Has Increased

- Easier to get the wrong answer *faster*!

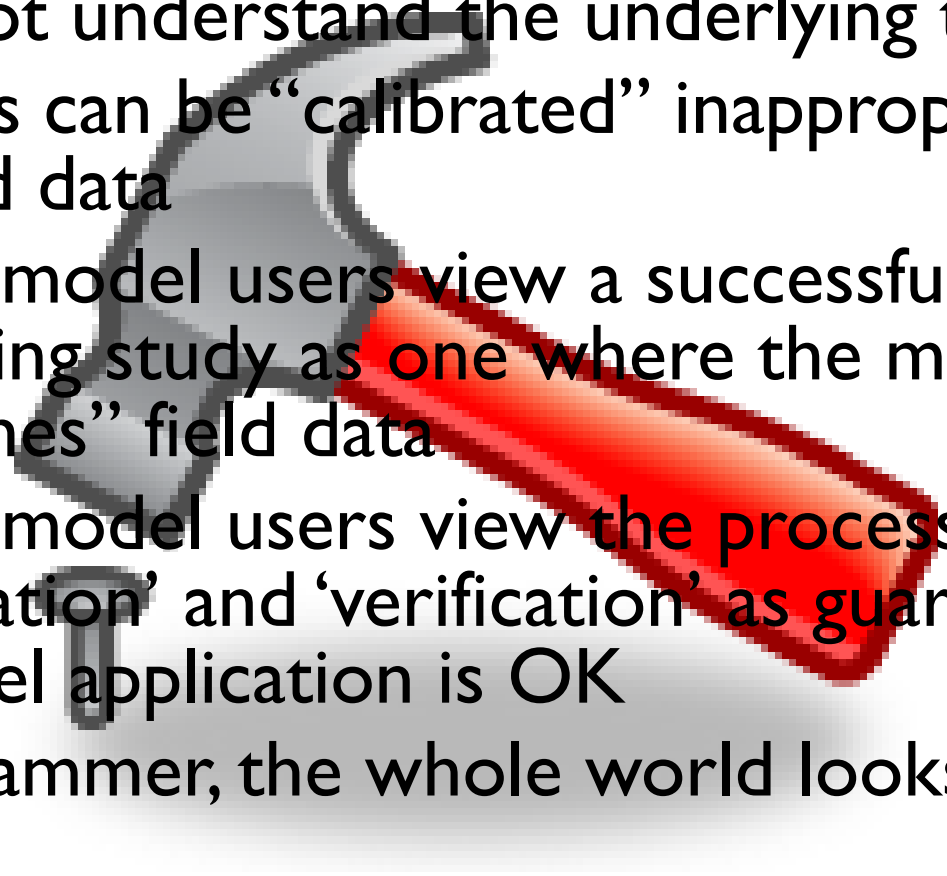
An optimum level of complexity exists for every model



EPA Guidance on Modeling 2008

Why are models be misused?

- Models are complex tools and model users may not understand the underlying theory
- Models can be "calibrated" inappropriately to field data
- Often model users view a successful modeling study as one where the model "matches" field data
- Often model users view the process of 'calibration' and 'verification' as guaranteeing a model application is OK
- To a hammer, the whole world looks like a nail



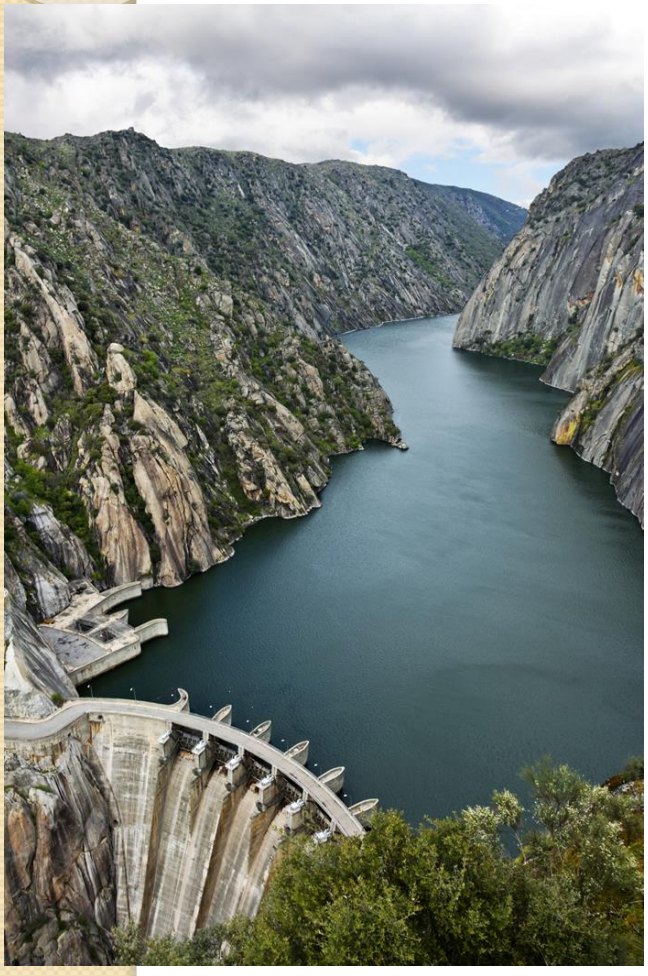
Lessons Learned in Water Quality Modeling (or How to avoid model misuse and abuse!)

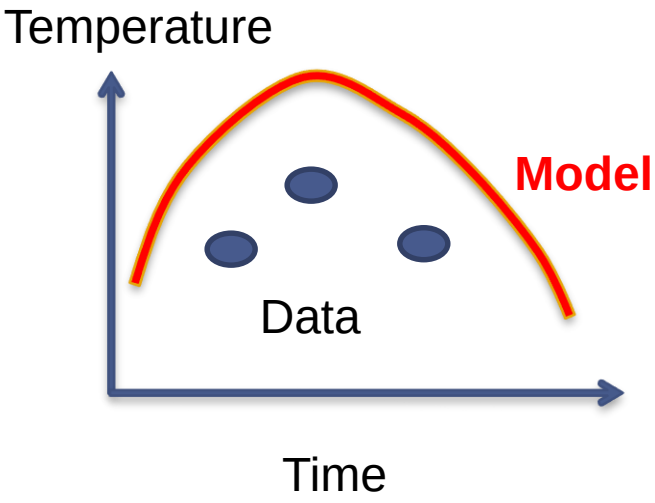
- OK not to match data
- Do not say 'all is fine' without clear documentation
- Show all model-data comparisons
- Do not over-average data or model results
- What is calibration? Model validation?
- Listen – pay attention to the big picture [Do not ignore hydrodynamics]
- Is more complicated always better?

It is OK not to match data

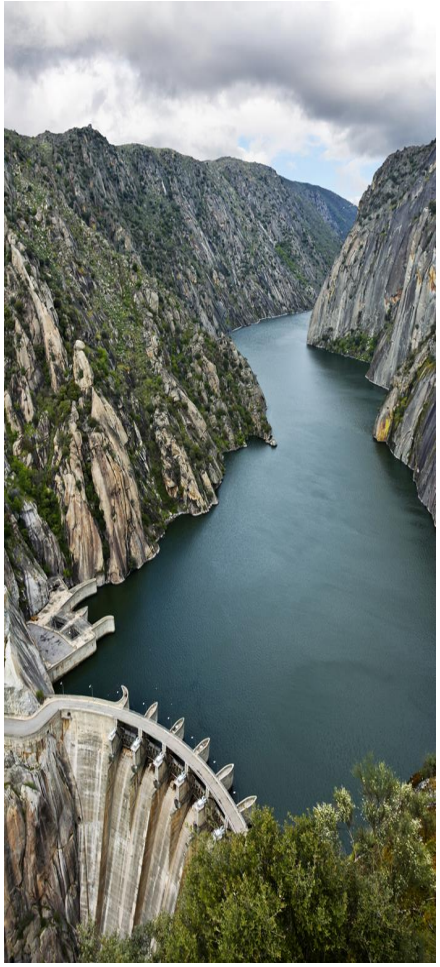
- Physical data are ignored or purposely changed to obtain better model-data agreement

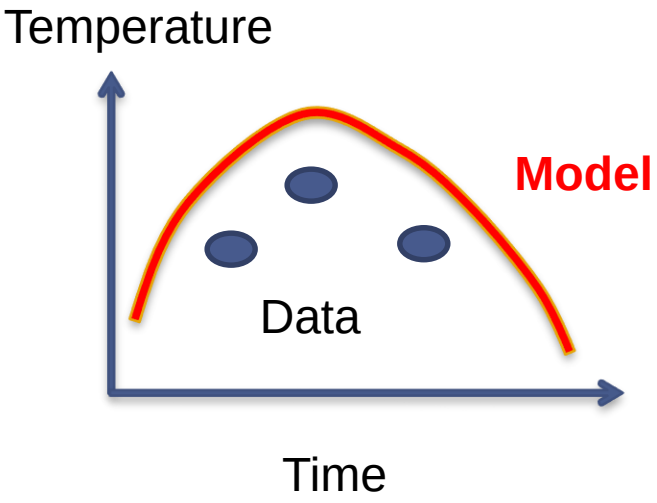
Model predicted temperature too high?



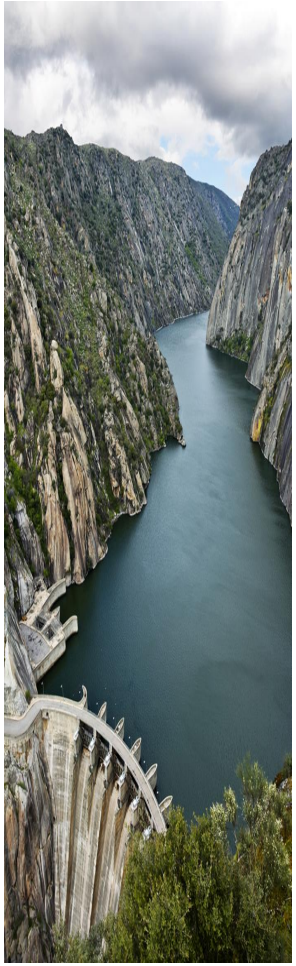


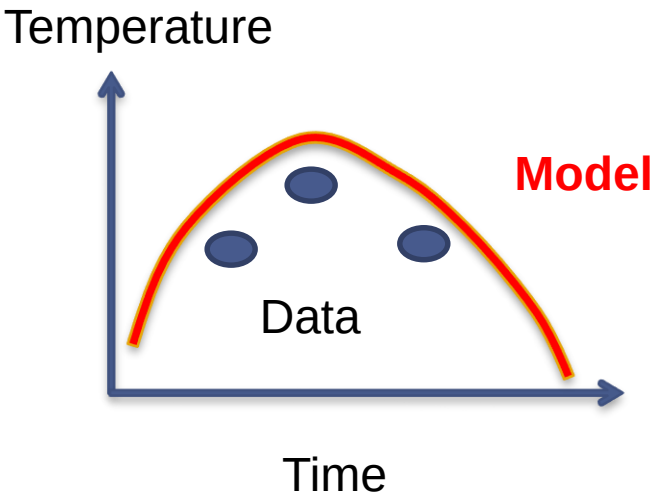
Model predicted temperature too high?



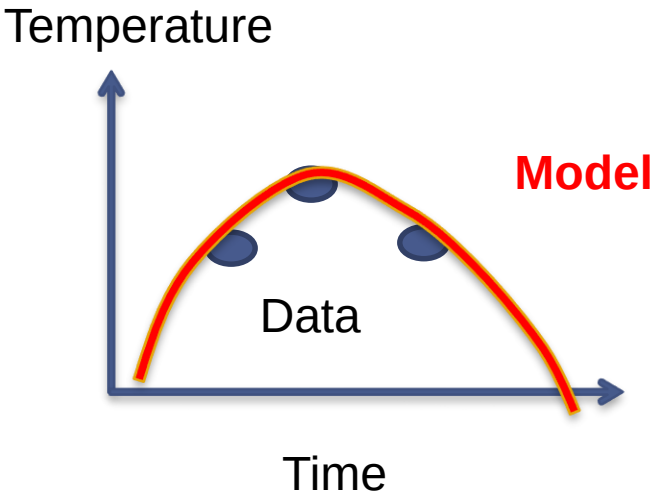


Model predicted temperature too high?





Model predicted temperature too high?

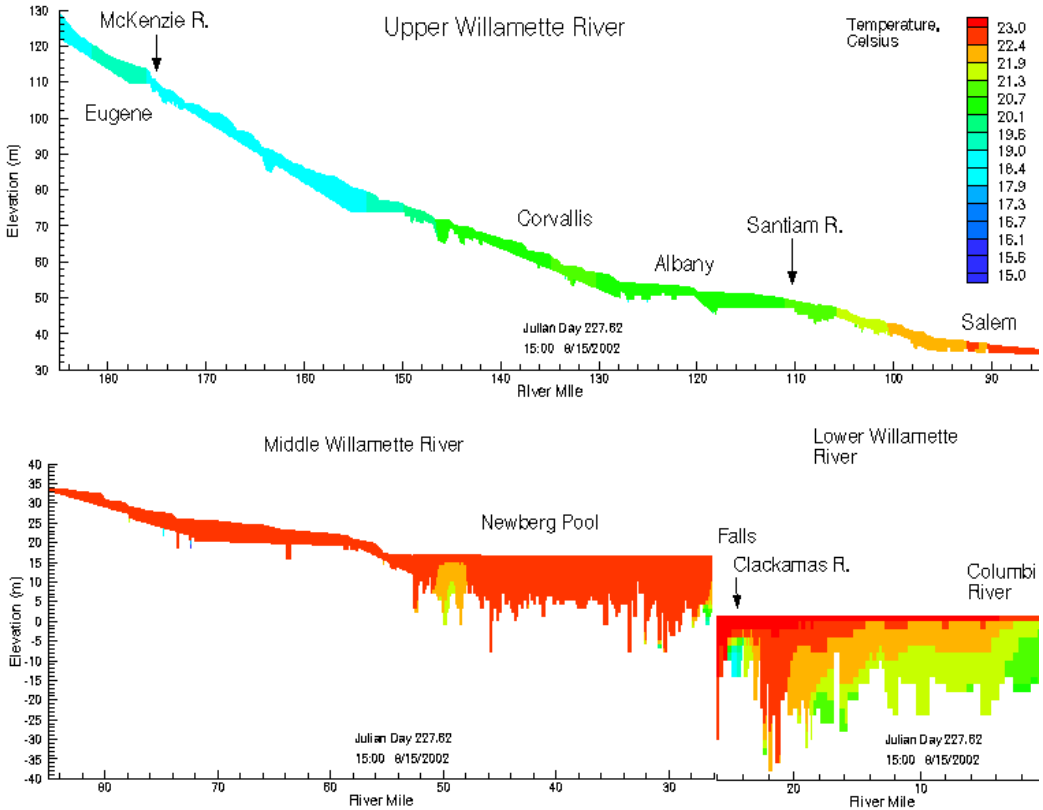


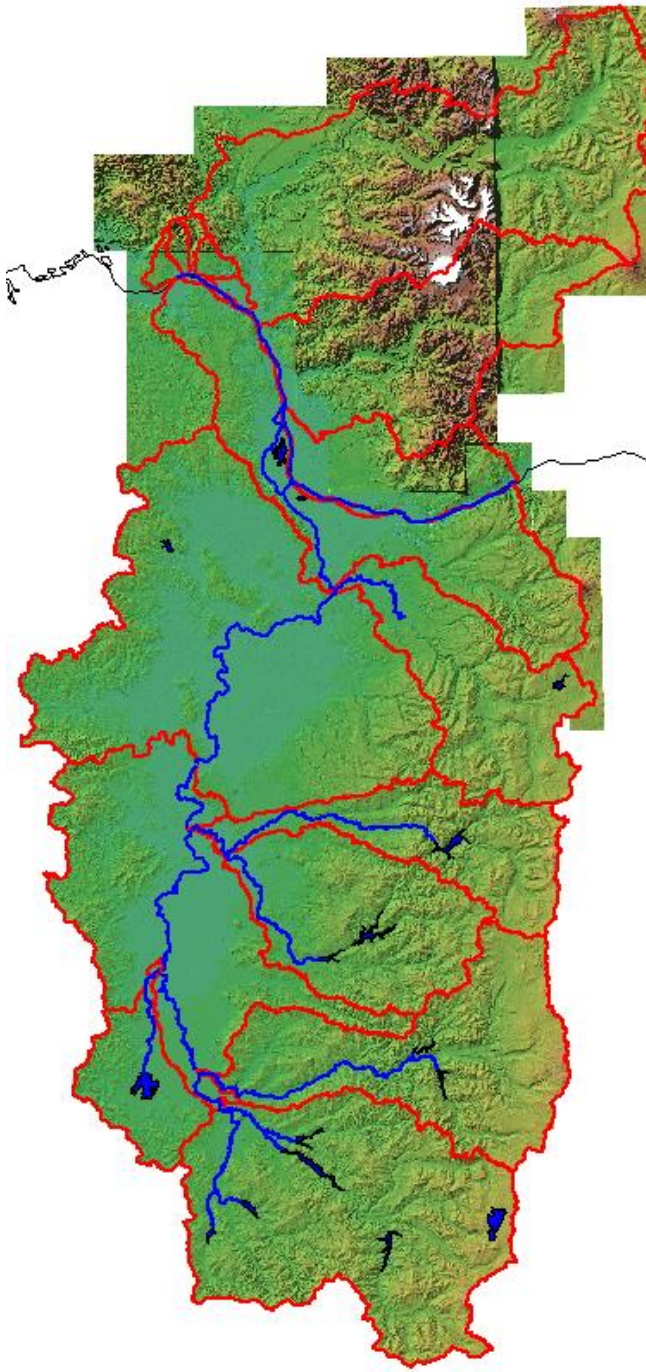
Calibrate for the right reasons!

- Shading used as a calibration parameter?

Columbia River – Rocky Reach Dam

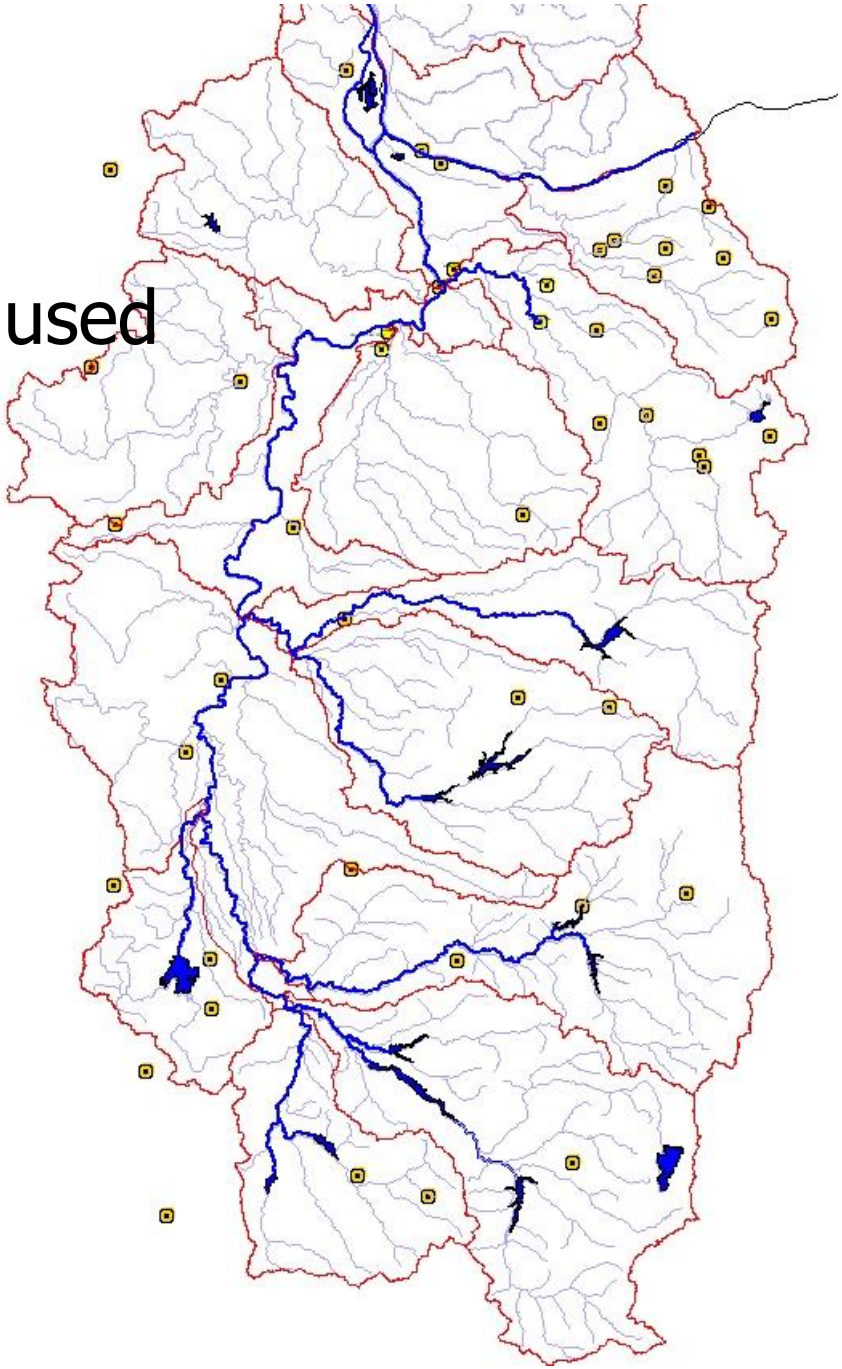
Model Calibration - Willamette River Basin Example





Data: Meteorological Sites

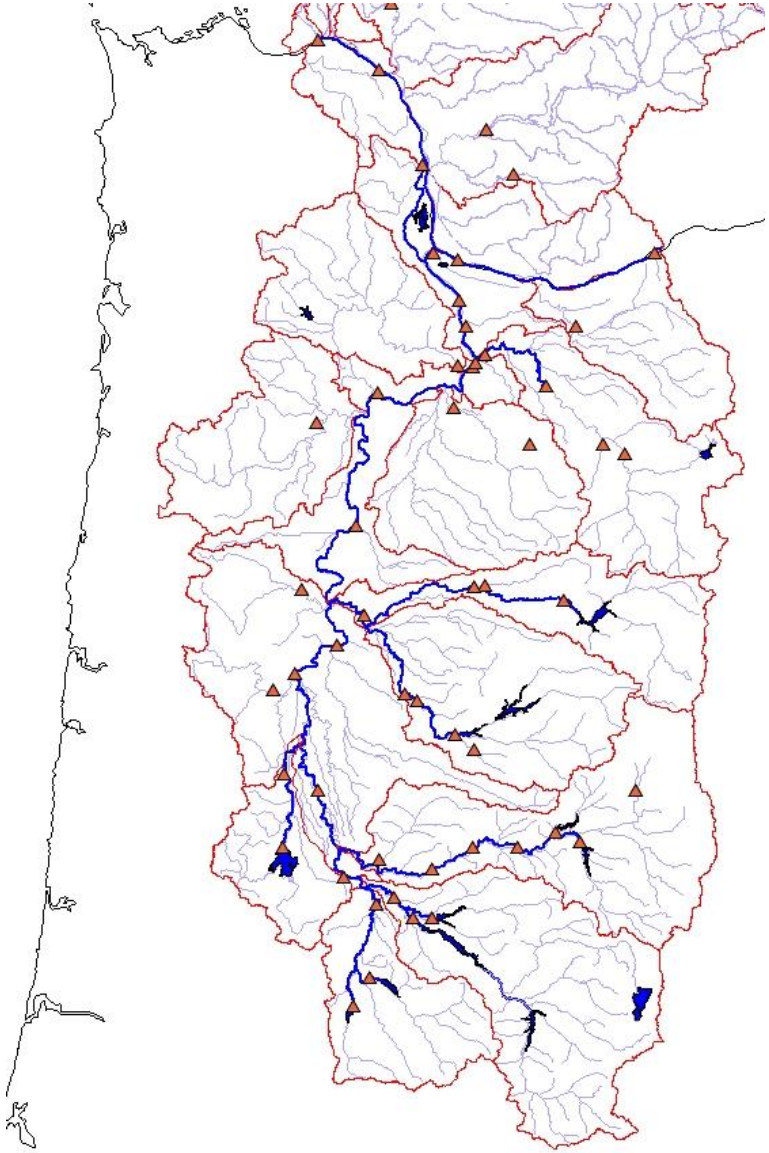
Data from 14 sites were used



National Weather Service
Oregon Dept. of Forestry, RAWS
U.S. Forest Service, RAWS
Bureau of Reclamation, AgriMet

Air temperature
Relative humidity or
    Dew point temperature
Wind speed
Wind direction
Solar radiation

Data: Discharge and Water Level Sites

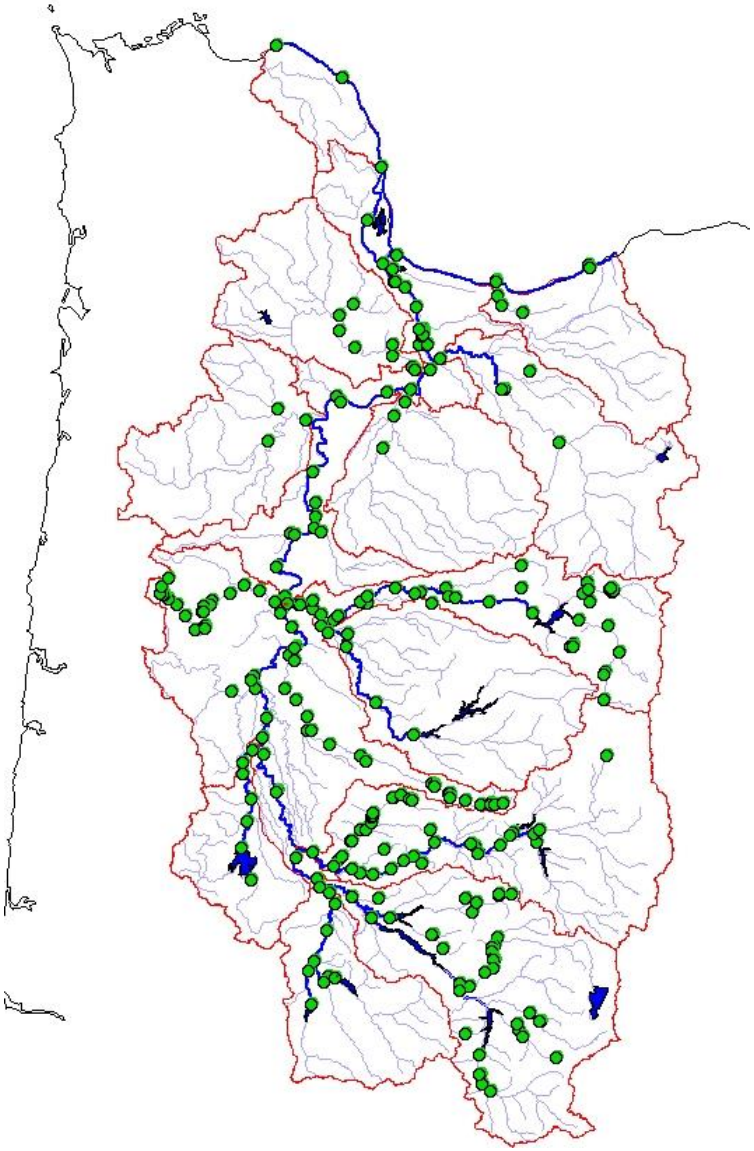


Total of 53 sites were monitored
for stage and flow

Data: Temperature Monitoring Sites

Monitored in 2001 & 2002

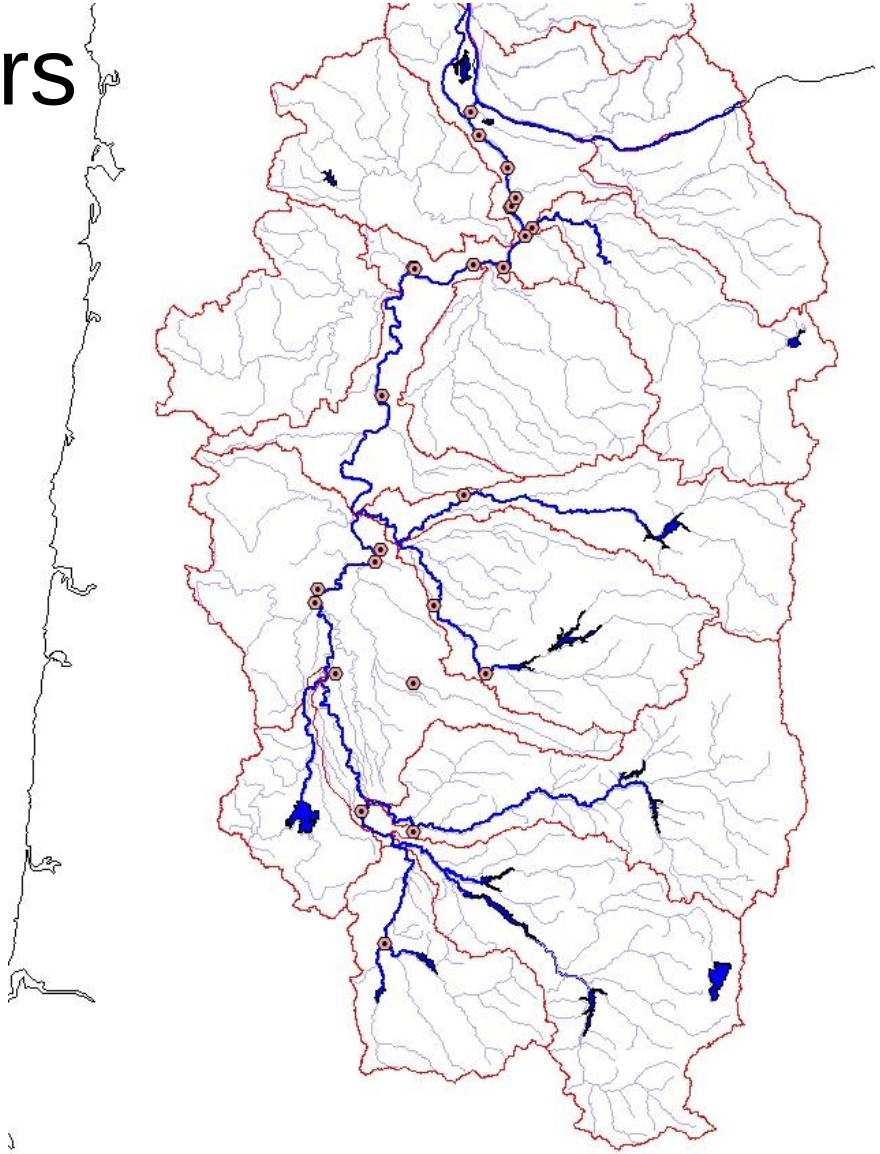
Total of 274 temperature sites were monitored – several dozen were continuous



Data: Major Point Source Dischargers

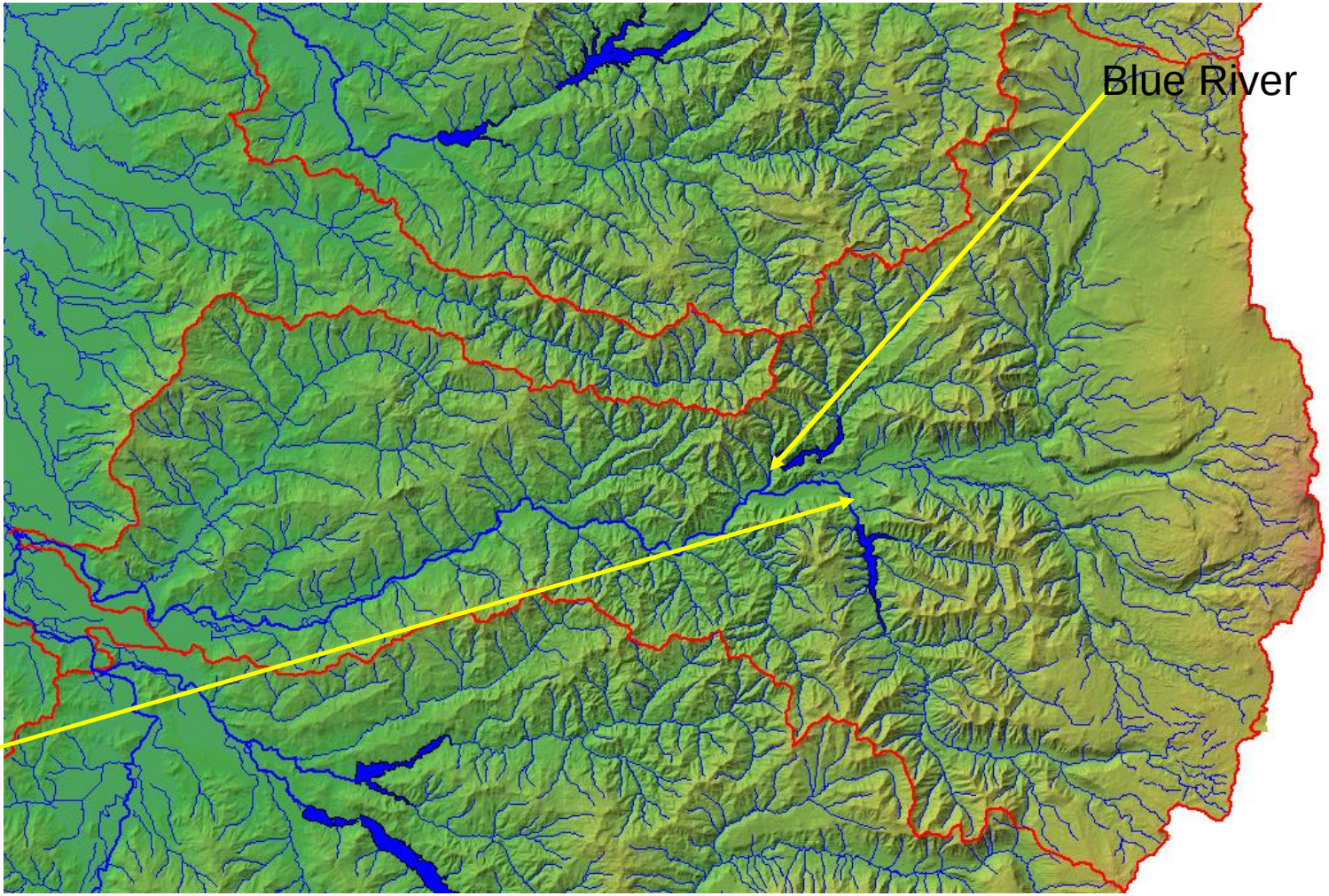
26 Point Source Dischargers

15 Municipal Dischargers
11 Industrial Dischargers

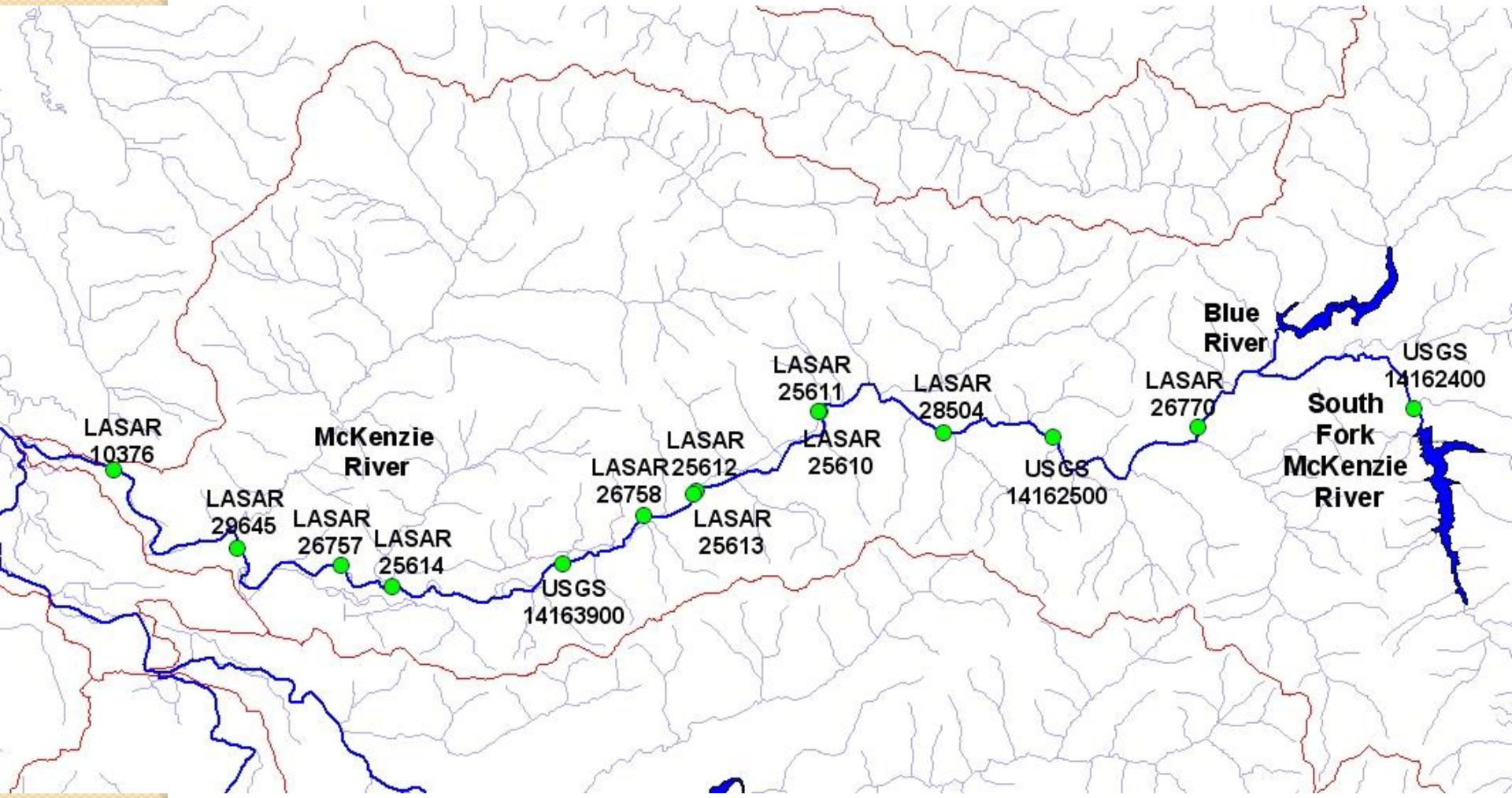


McKenzie River

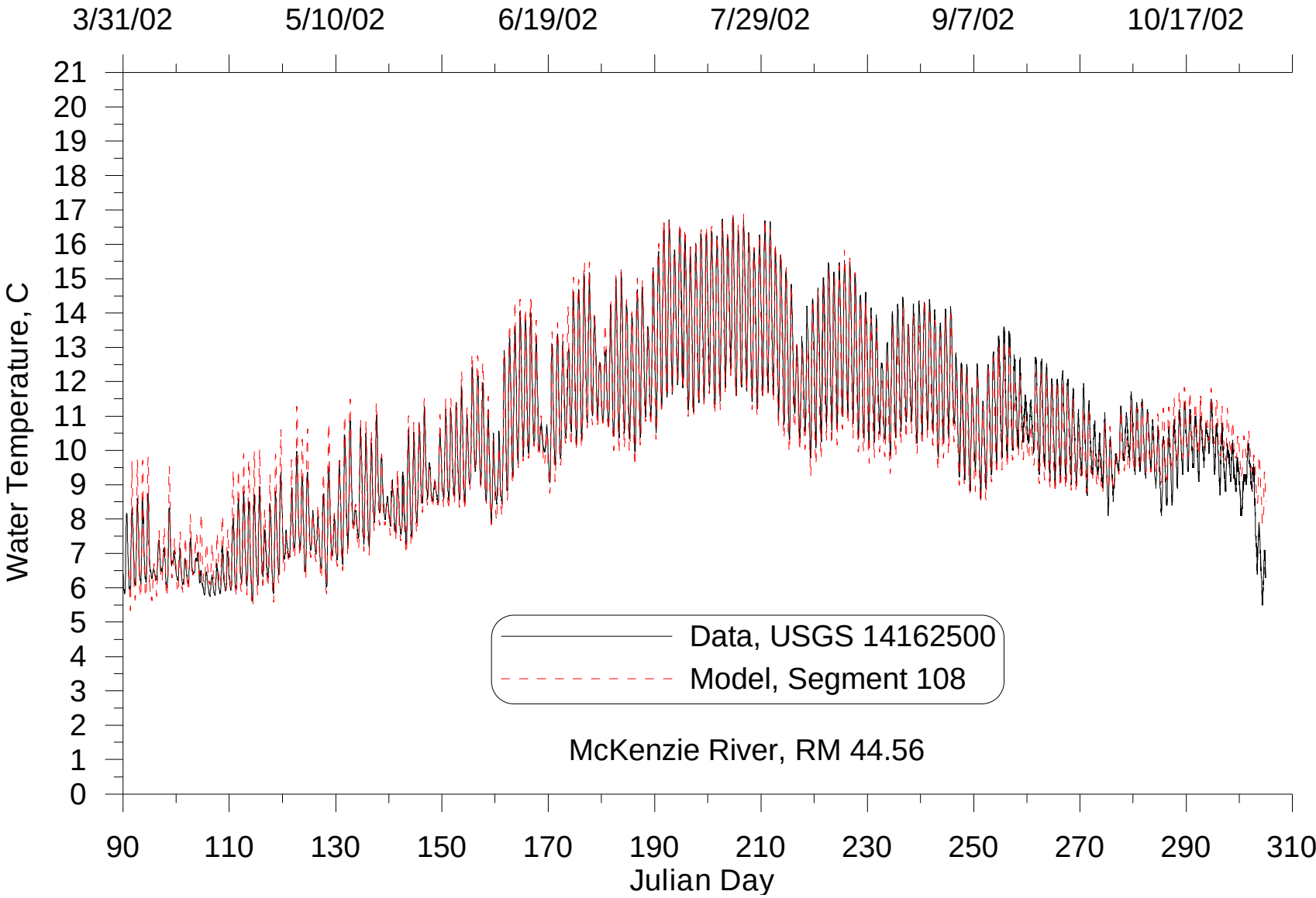
McKenzie River , RM 0 to RM 61
(includes South Fork McKenzie and Blue River)



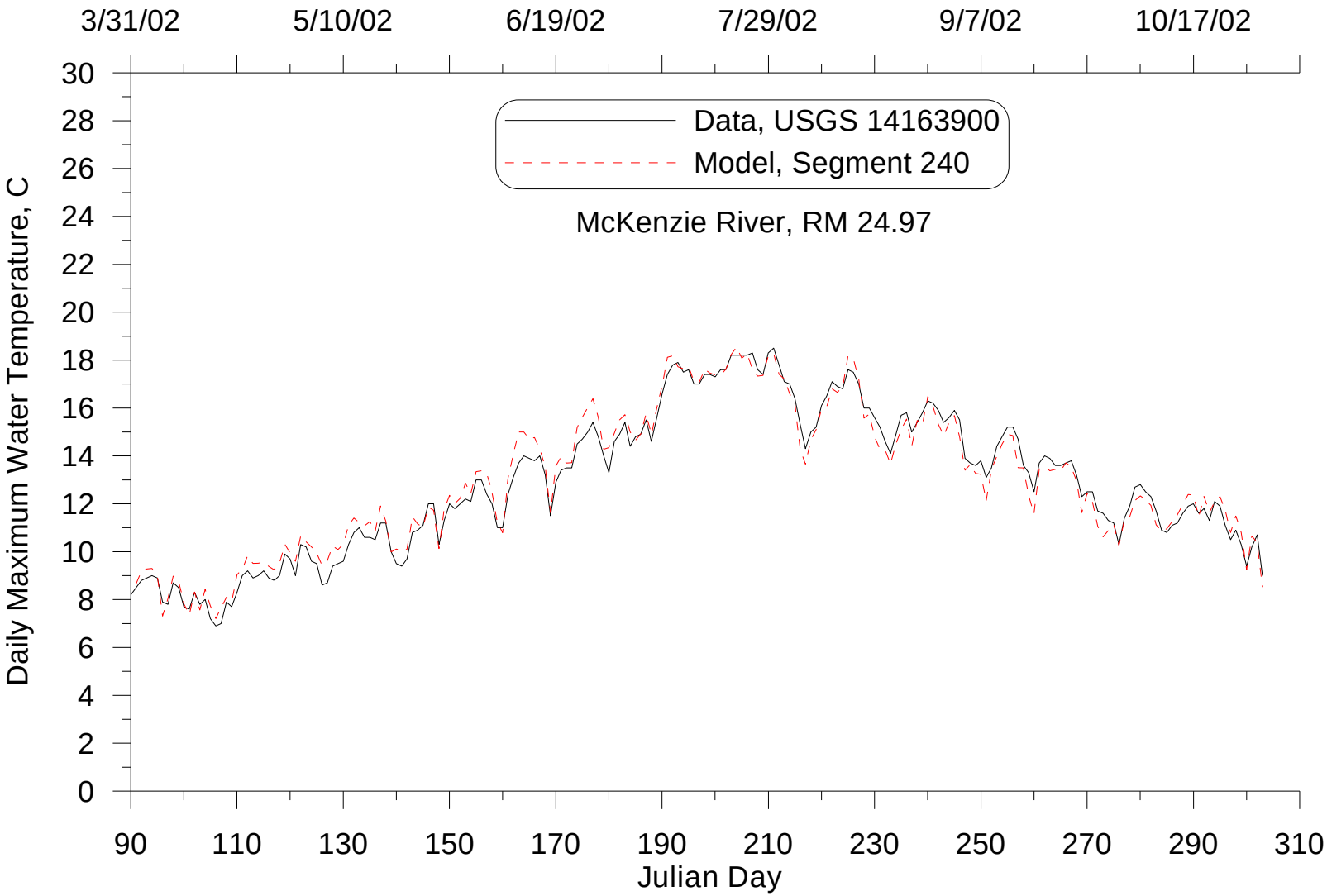
McKenzie River



McKenzie River



McKenzie River Daily Maximum Temperature

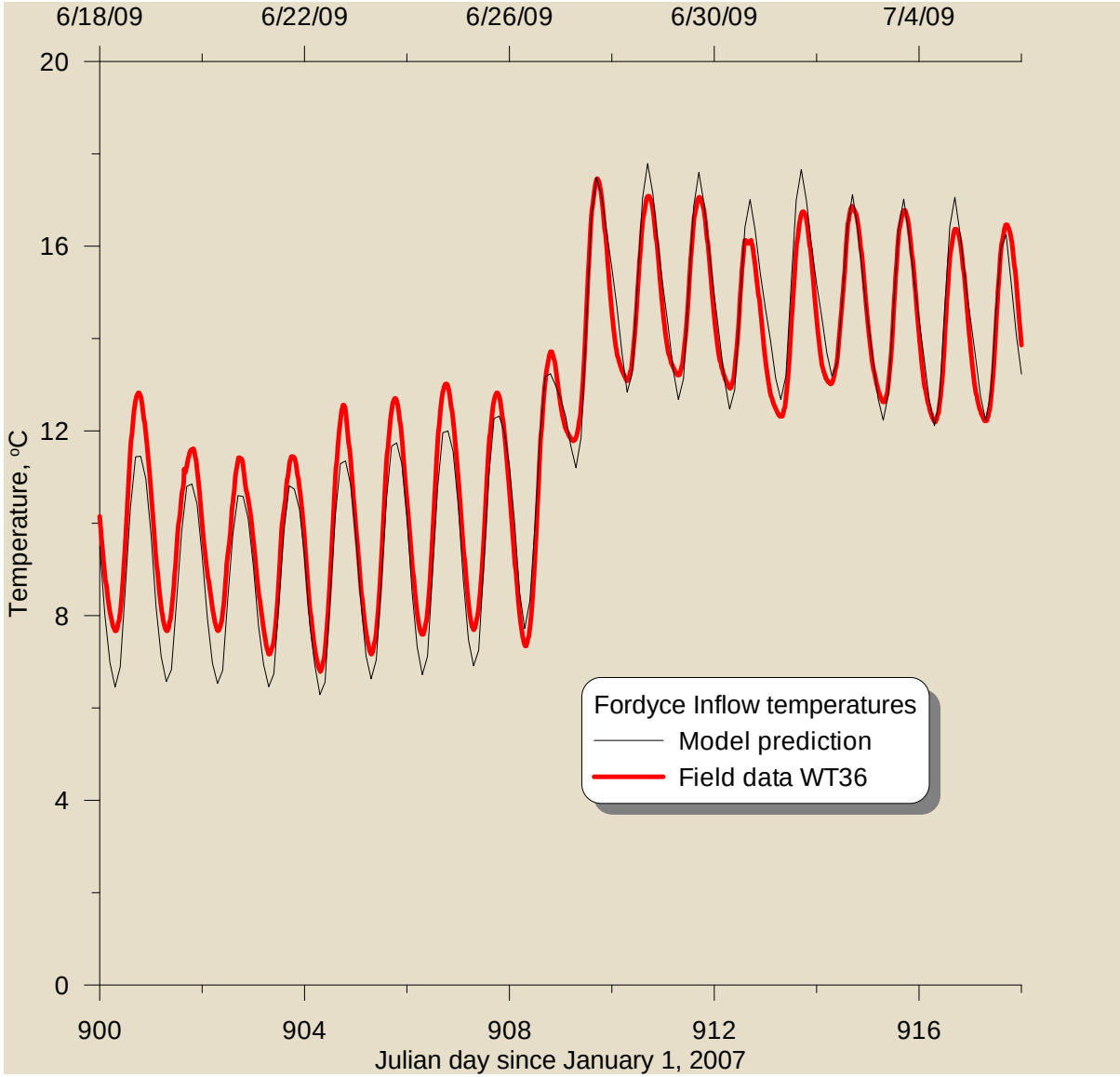


McKenzie River Temperature Statistics

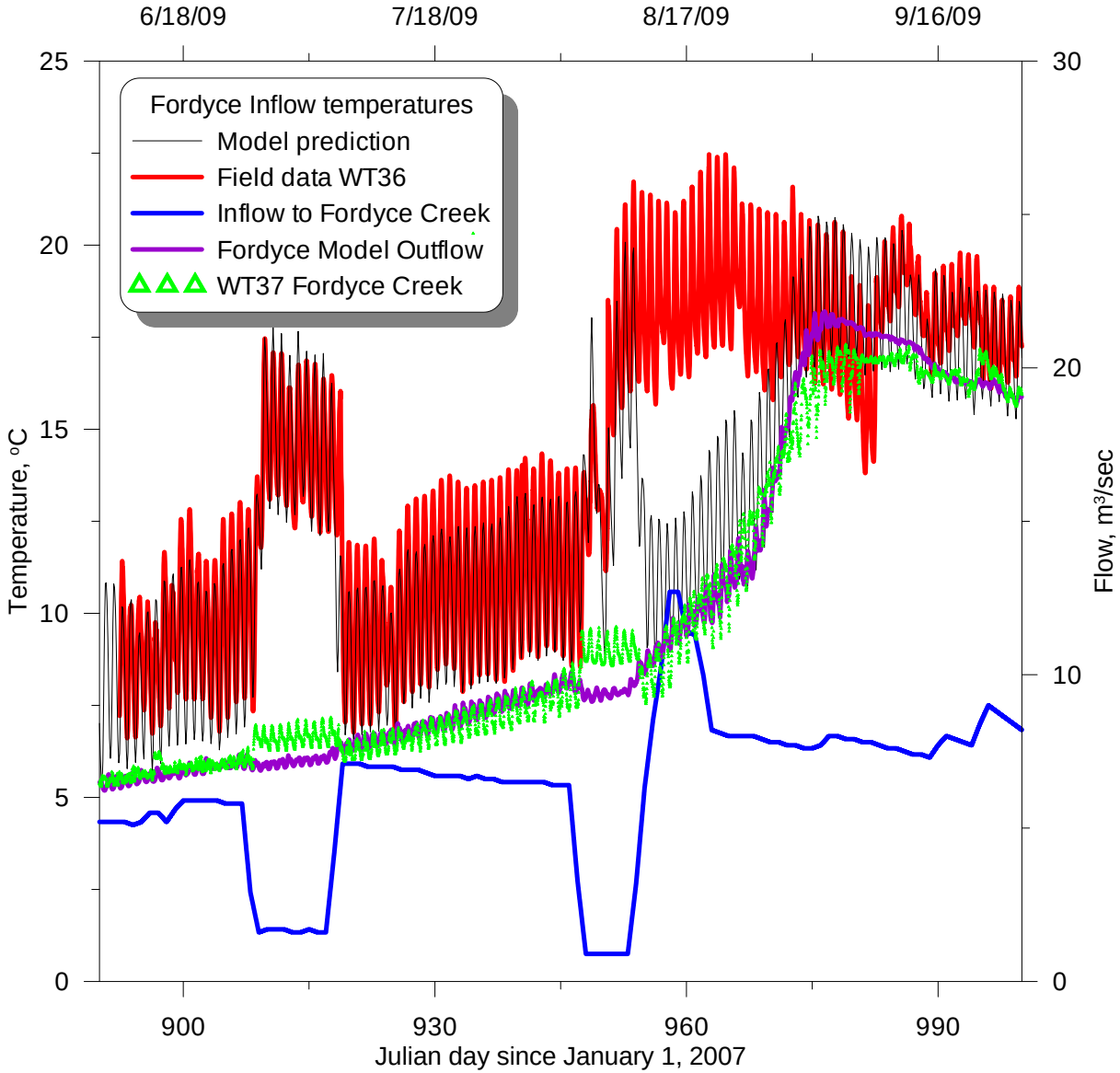
River Mile	Model Segment	Temperature 2002			
		Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
60.39	4	10271	0.05	0.13	0.20
50.99	65	5856	-0.35	0.42	0.50
44.56	108	10270	-0.09	0.39	0.50
40.74	132	3385	-0.13	0.37	0.45
35.72	167	5668	-0.21	0.74	0.88
30.38	203	NA			
28.45	215	5666	-0.34	0.78	0.91
24.97	240	10270	-0.15	0.55	0.68
17.90	285	NA			
15.61	299	5669	1.81	1.86	2.40
10.40	333	5857	-0.25	0.57	0.73
3.38	378	5715	-0.07	0.55	0.71

Another example – Fordyce Creek, CA

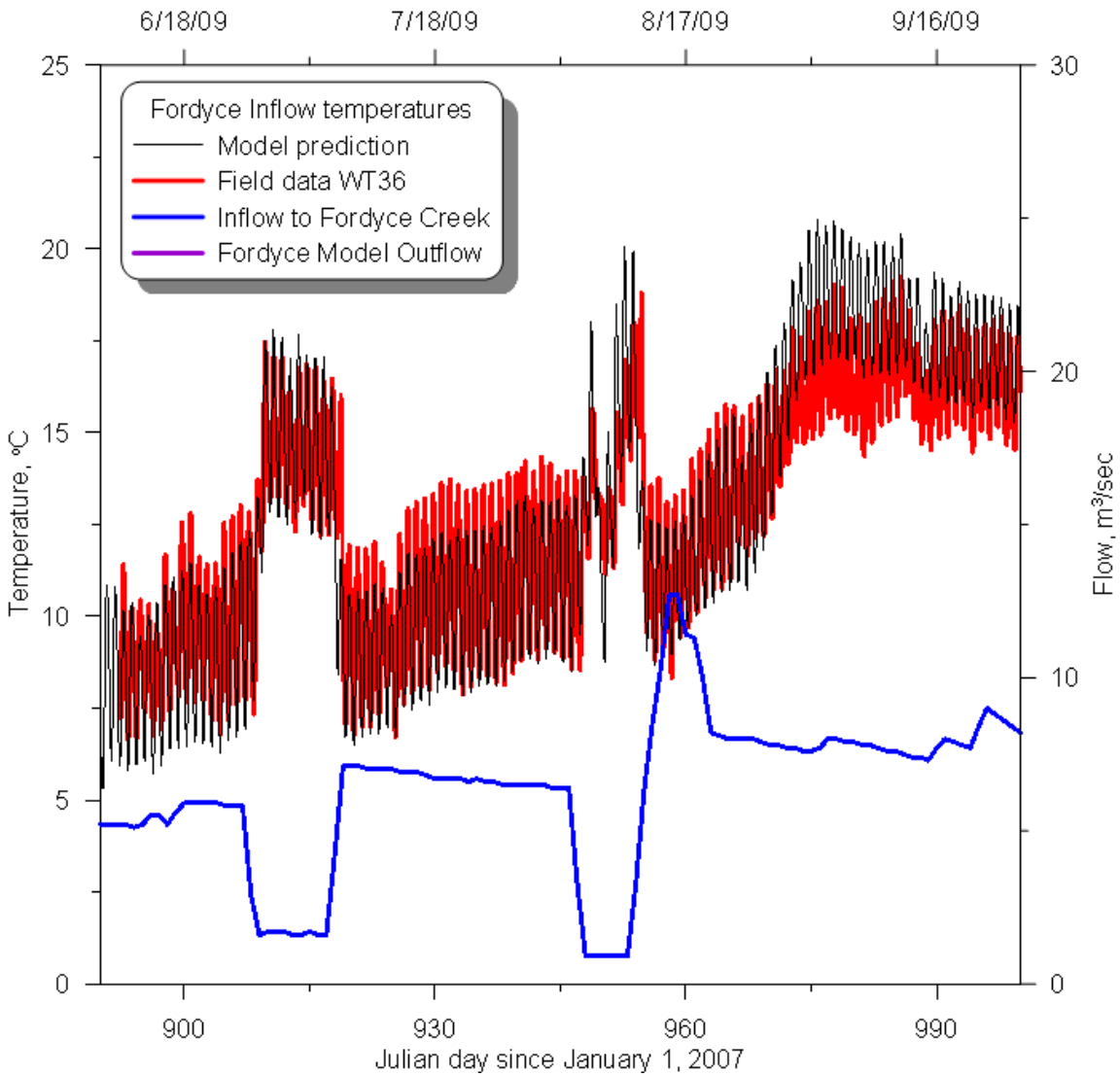
Fordyce Creek Model Results



Fordyce Creek Model Results



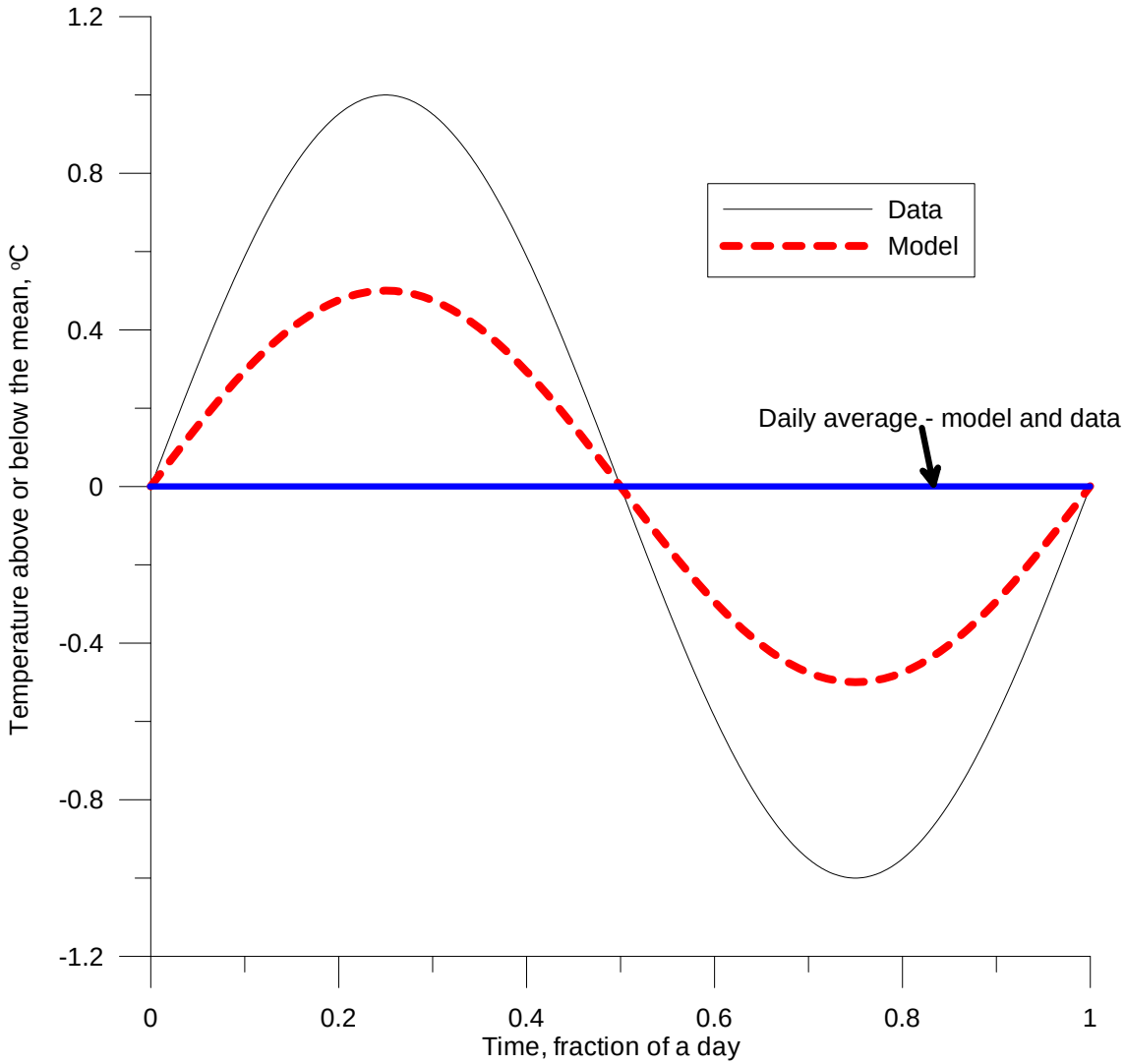
Fordyce Creek Model Results



Not perfect but a better starting point

Show all model vs data comparisons, avoid over-averaging

- Do not average all the data and then average all the model results to show good model-data agreement



"Over-averaging"

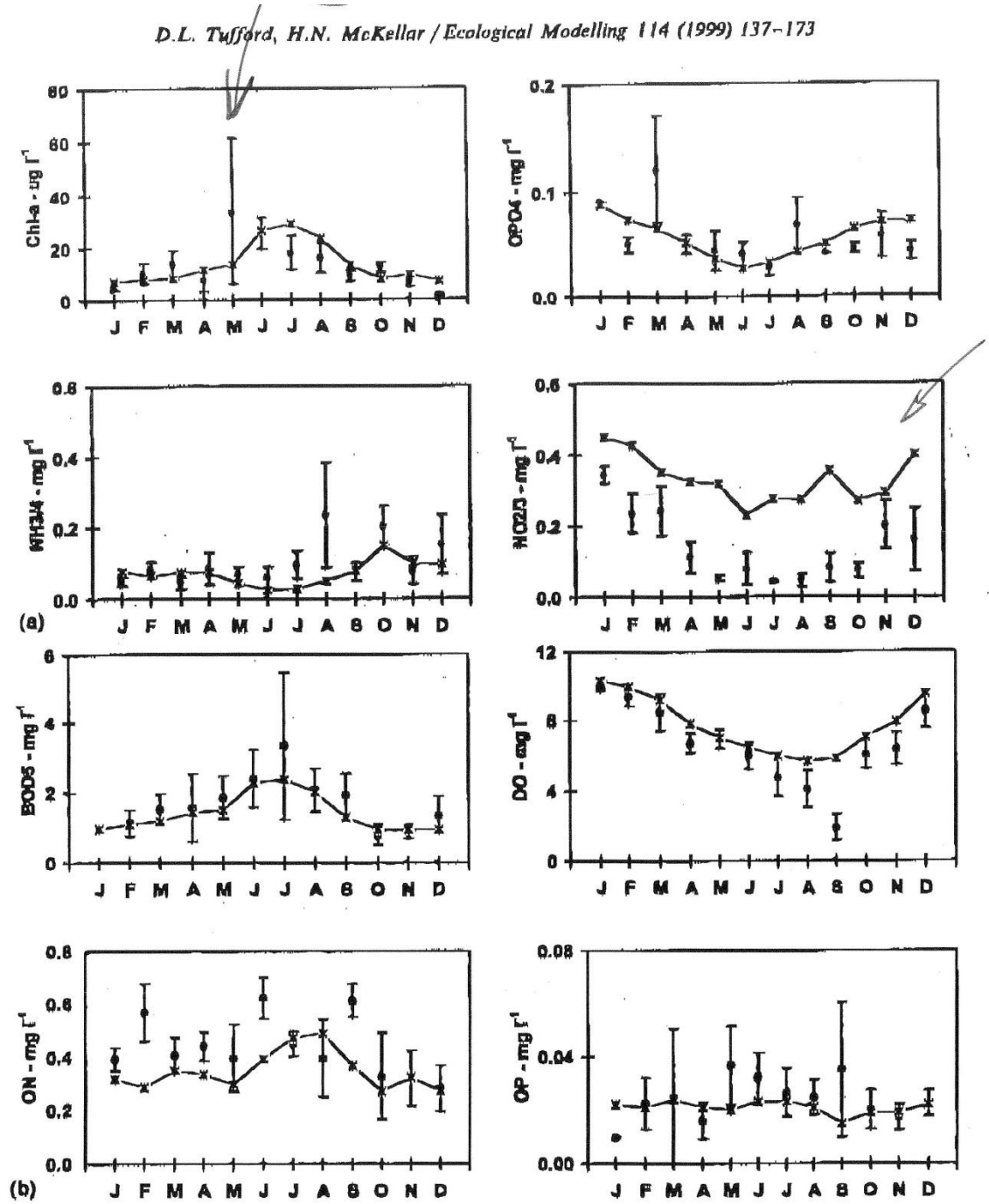
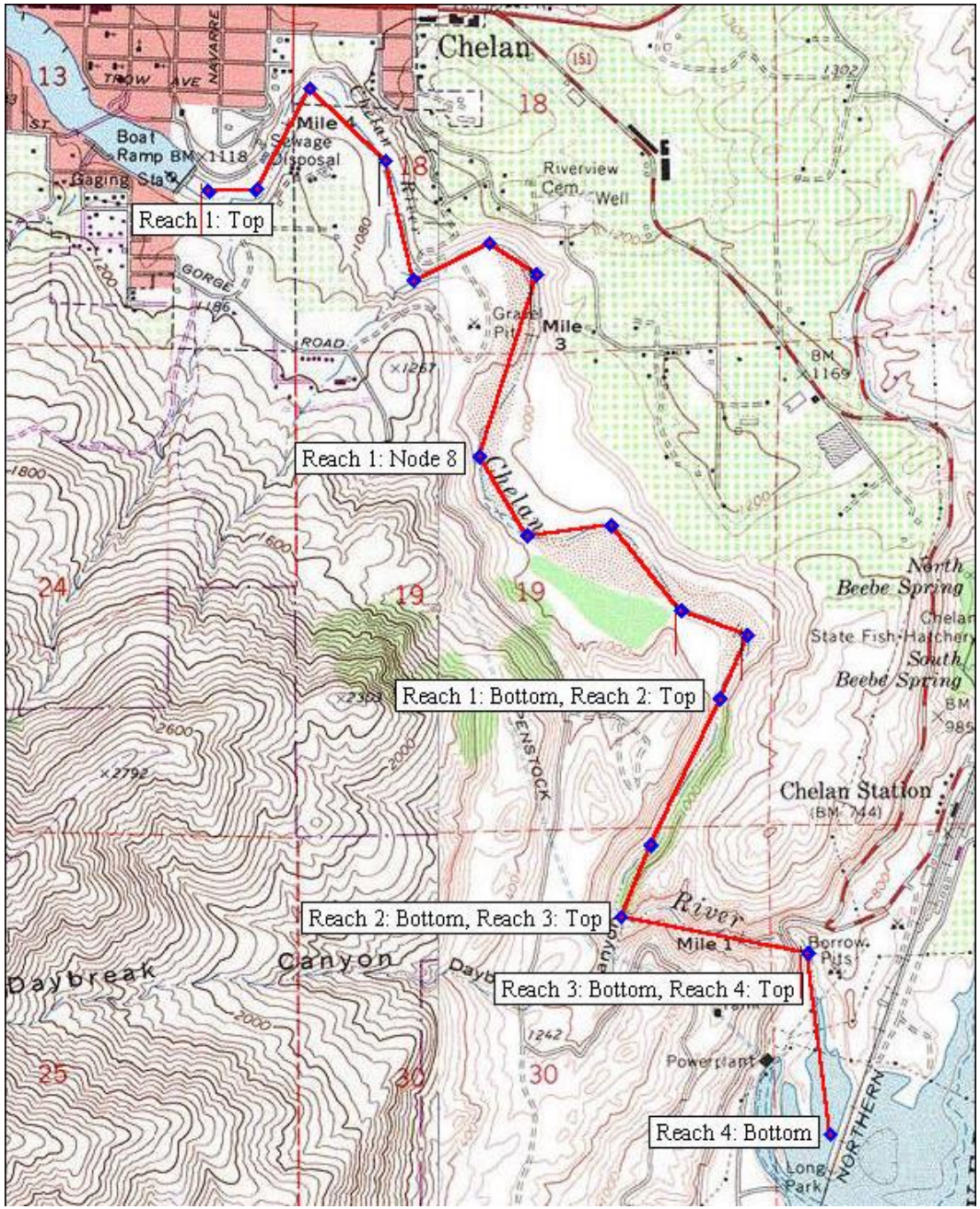


Fig. 15. Segment 02 calibration charts. Monthly monitoring data (5-year mean ± 1 S.E.) and monthly mean model results.

Choose the right model

- Wrong model chosen because firm always used this model

Chelan River – between Chelan Lake and Columbia River



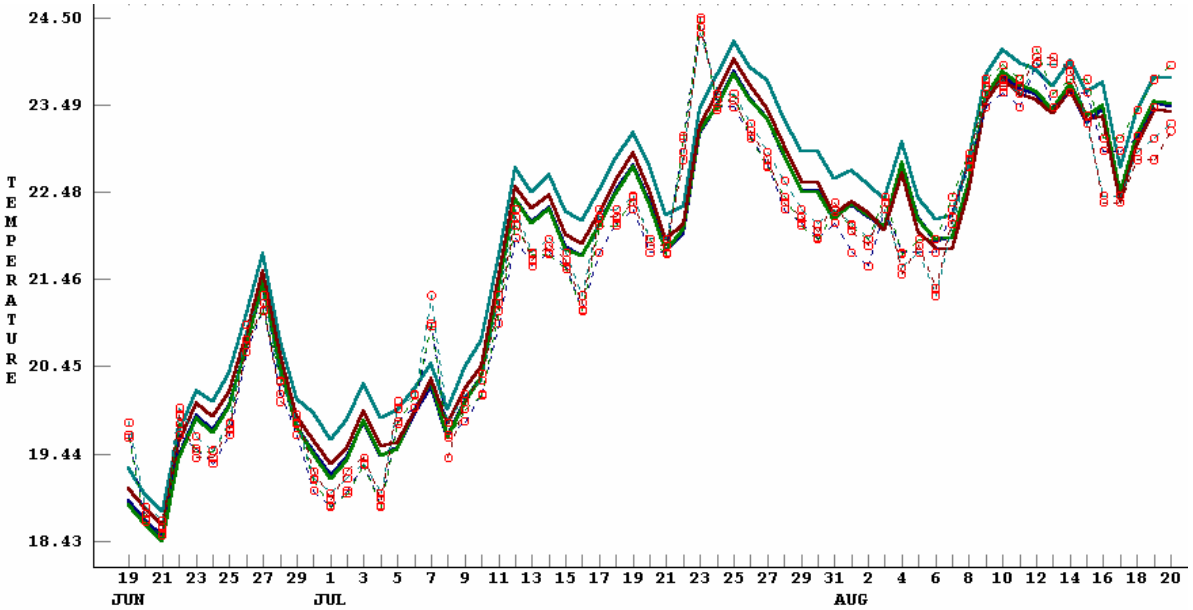
6.1 km study area or about 4 miles

What is travel time?

Use of a daily average temperature model?

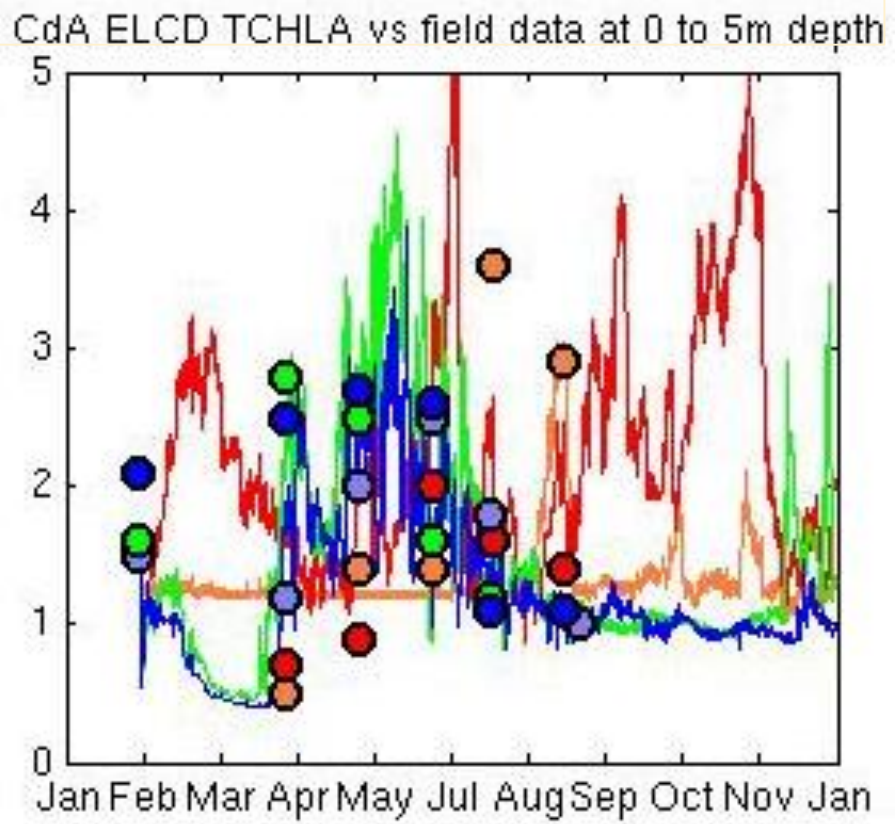
Explaining that all is OK – must provide evidence

- "Although the predicted maximum temperatures do not exactly fit the observed stream temperatures, the overall pattern follows and the maximum temperature calibration is judged acceptable within its acknowledged limits."



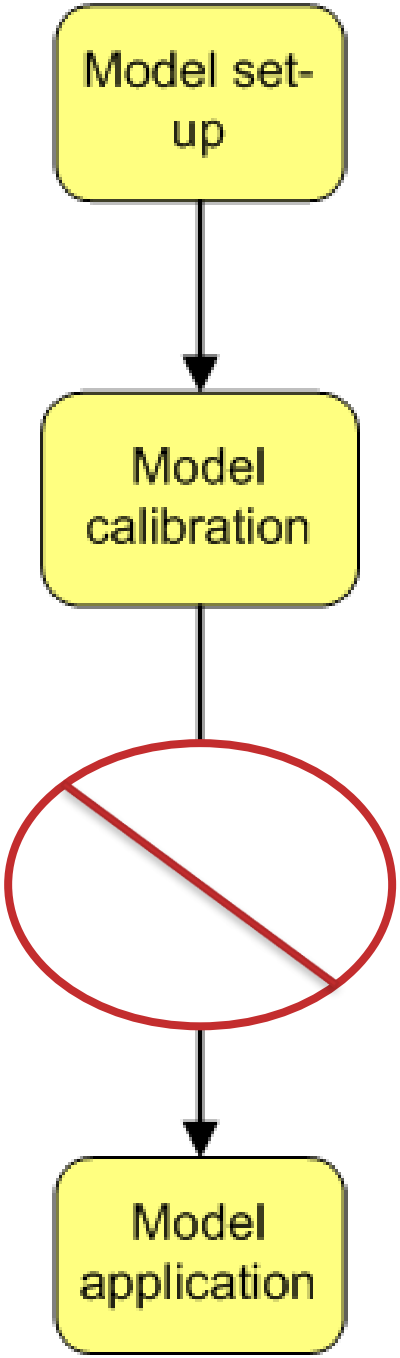
Broad sweeping conclusions

Without any adjustments to the phytoplankton parameter values estimated form the literature review, *[model name]* ***confidently reproduces the observed biomass. …***From this comparison, we may conclude that the ***model is predicting not only the correct amount of algal biomass, but also that it is reproducing the dynamics leading to the observed spatial and seasonal variability.***



"…and if you don't understand him and he don't die young you'll probably just ride away…"

Typical Steps in Model Development



Tom Cole's refrain: "It is all calibration"

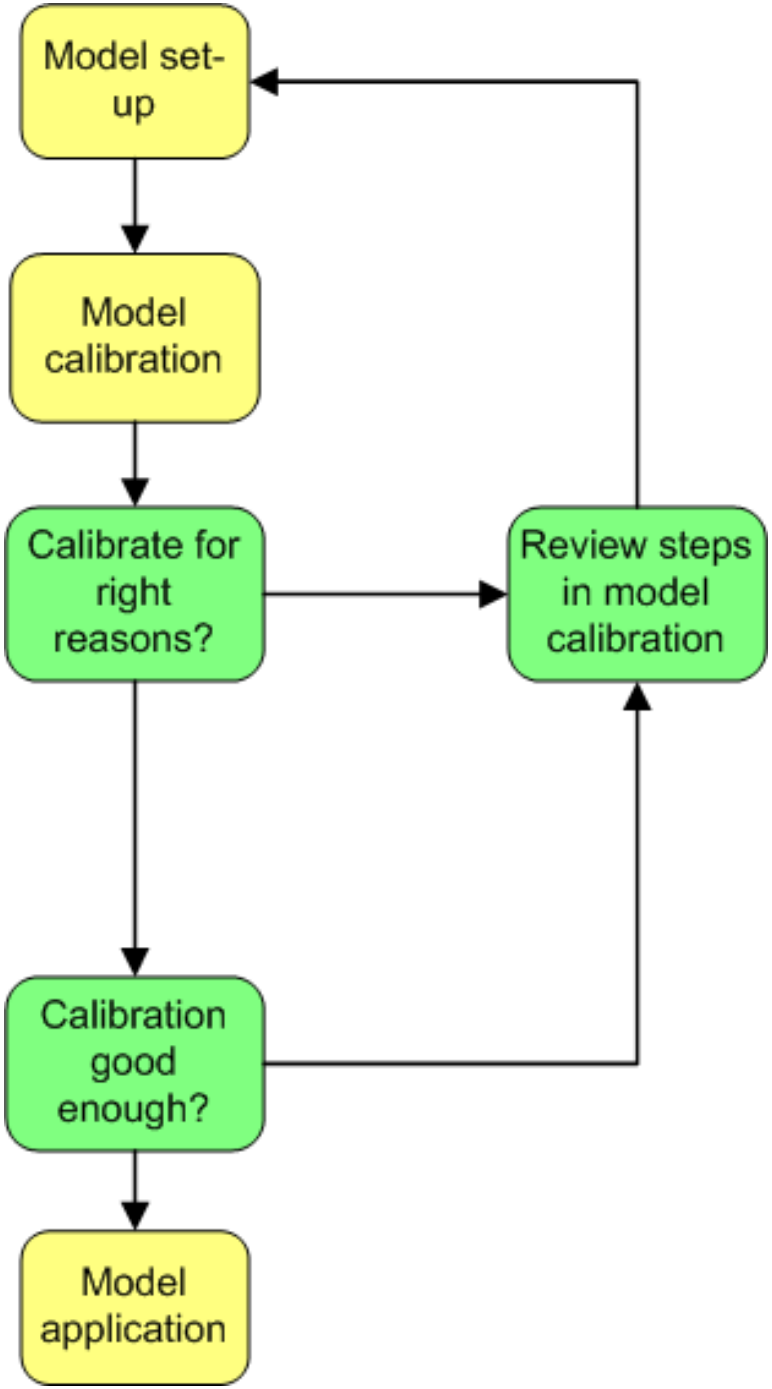
Validation, verification, confirmation, corroboration, substantiation?

"Validation tests against independent data that have not also been used for calibration are necessary in order to be able to document the predictive capability of a model."

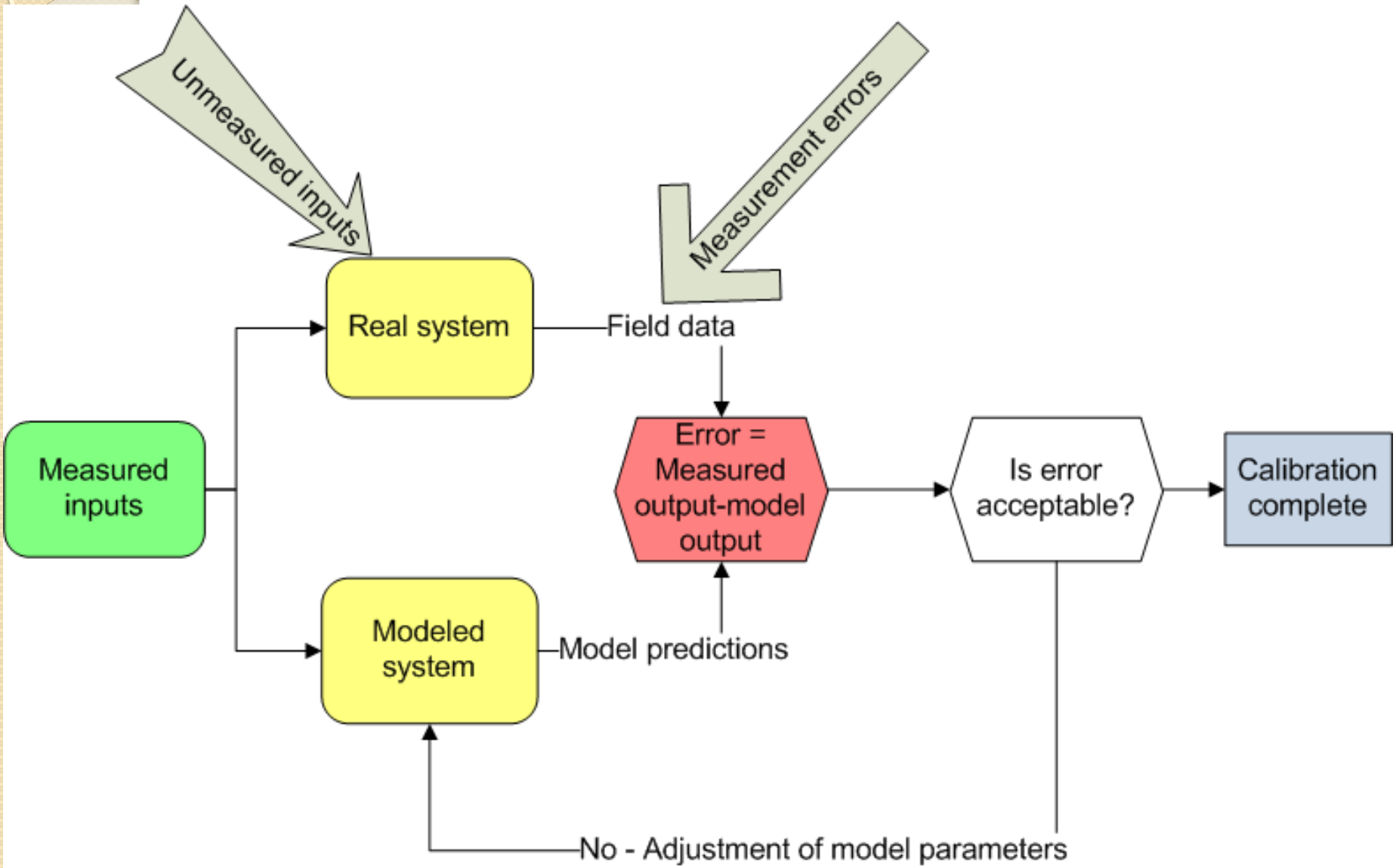
Validation

- Typically, ***to have confidence*** that a calibrated stream temperature model will predict accurately over a wide range of flows and climate conditions, ***the model will be validated***. Validation is generally accomplished by applying the global calibration factors ***to another independent set of data, or by splitting the available data set into two equal-sized sets, and running the model as a test of the calibration***.

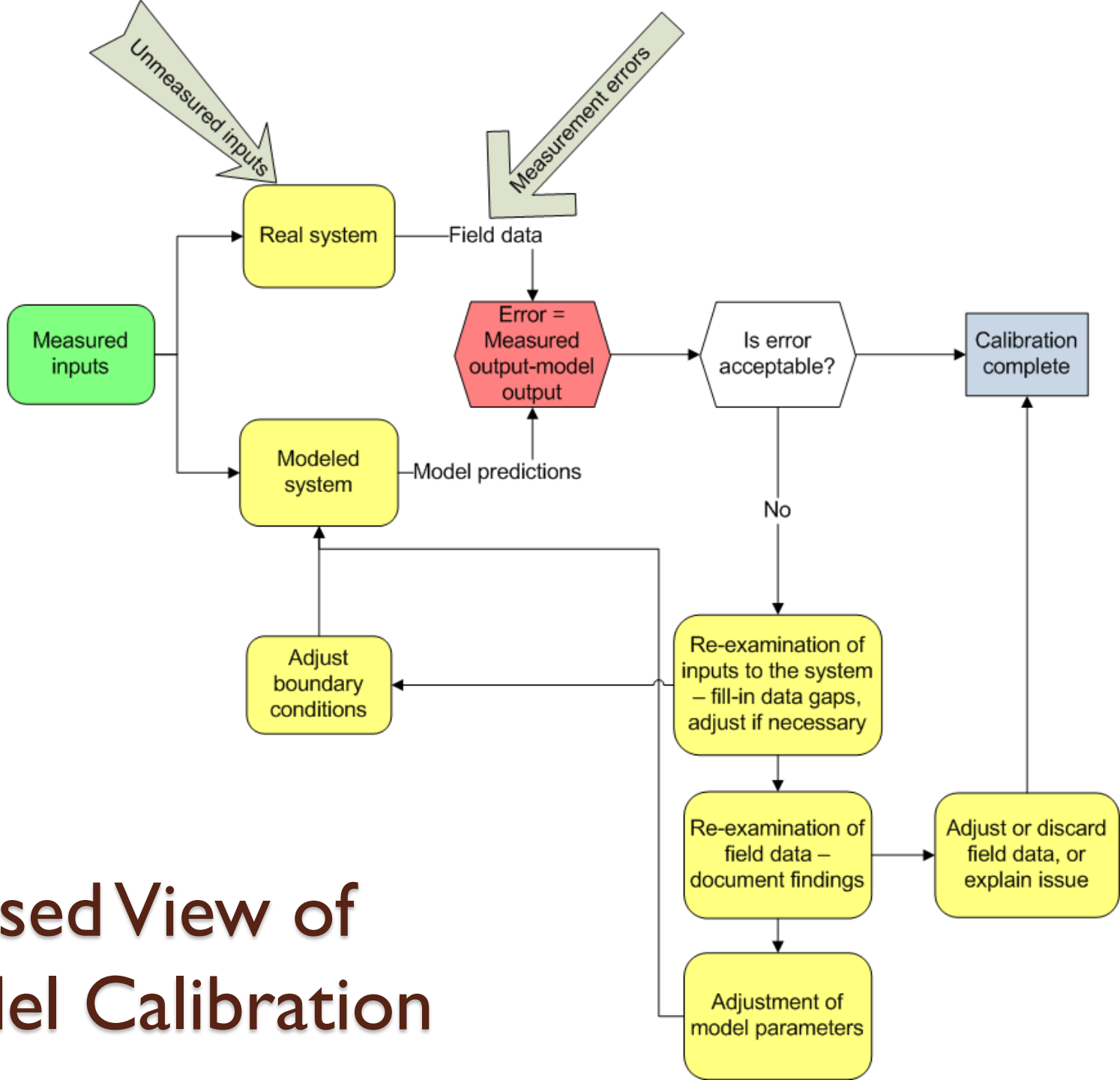
Revised Steps in Model Development



Traditional View of Model Calibration



Revised View of Model Calibration

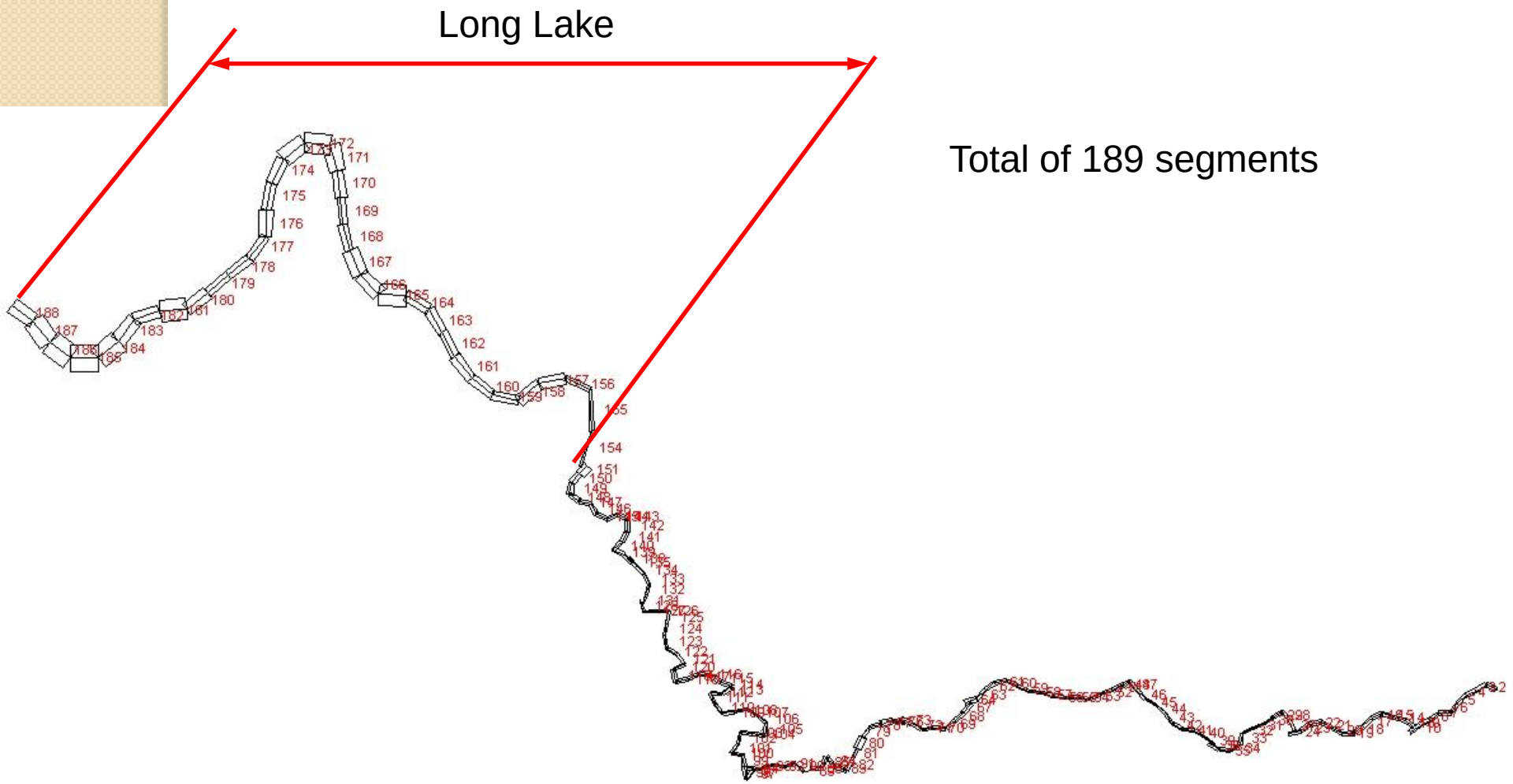


Listen – look at the big picture

The Spokane River – Long Lake System Model

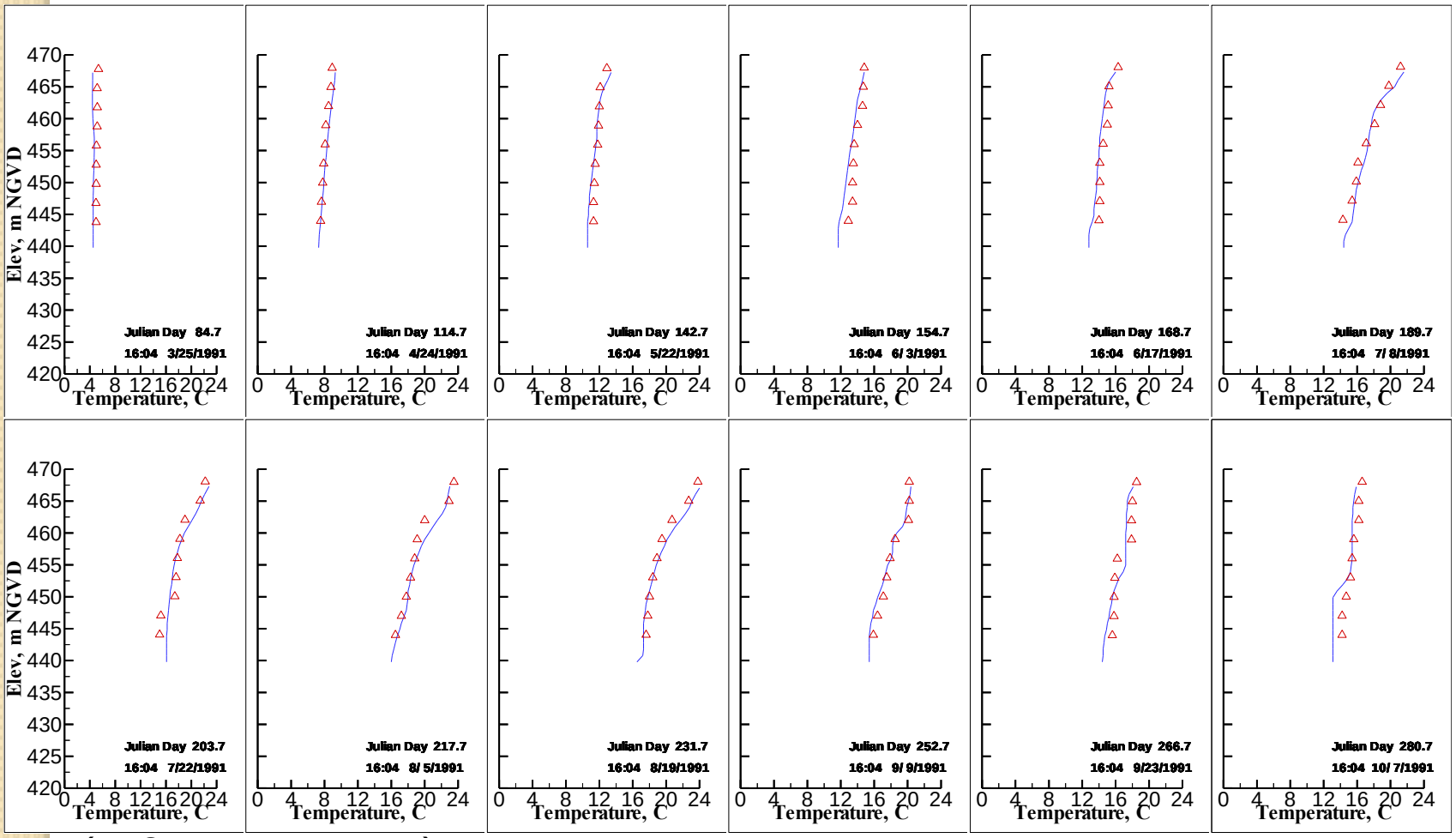
Wind data uncertainty

Model grid



Total of 189 segments

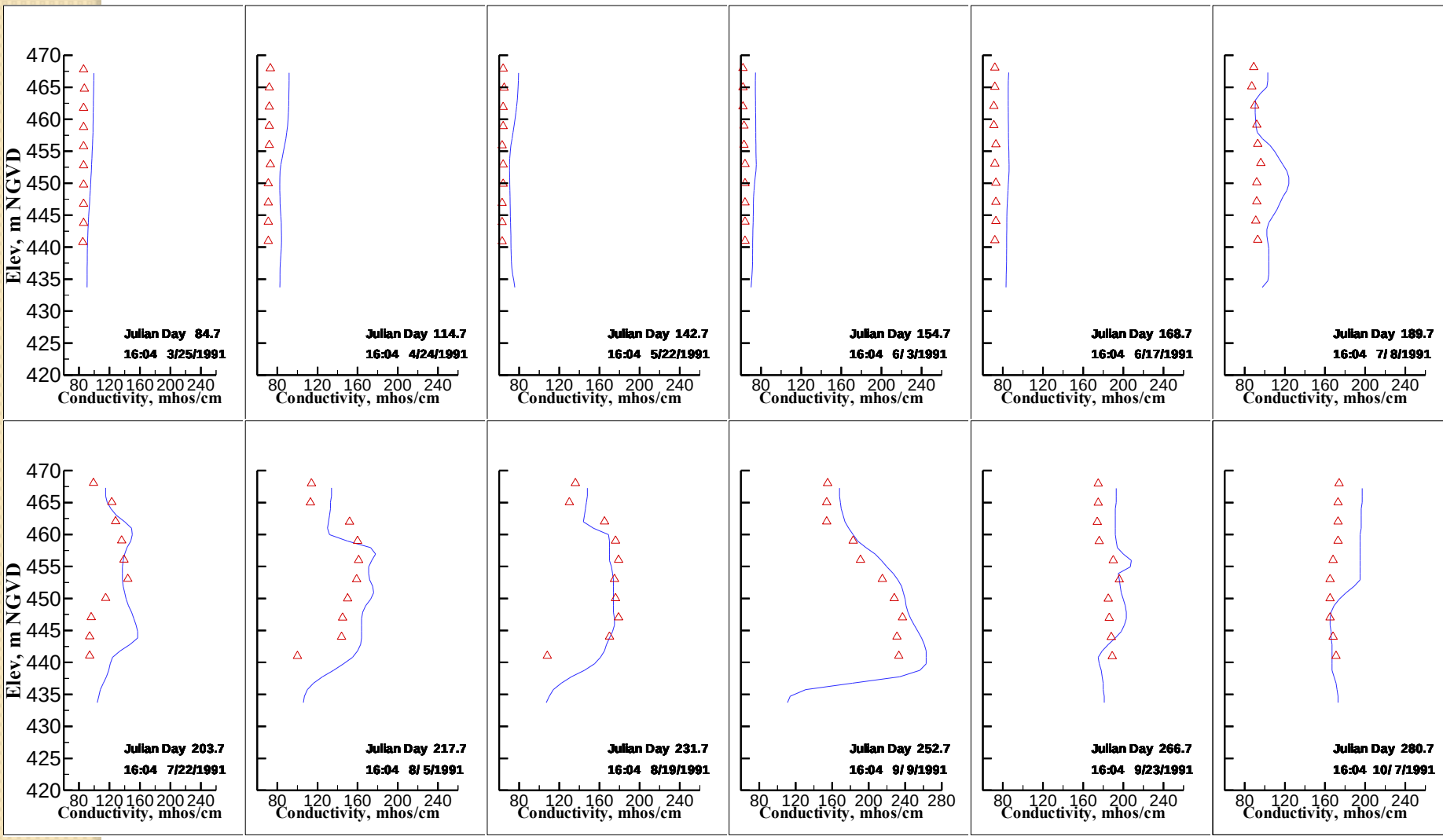
Temperature Prediction – Long Lake, 1991



(LL2, segment 174)

Open triangles are data and the line is the model

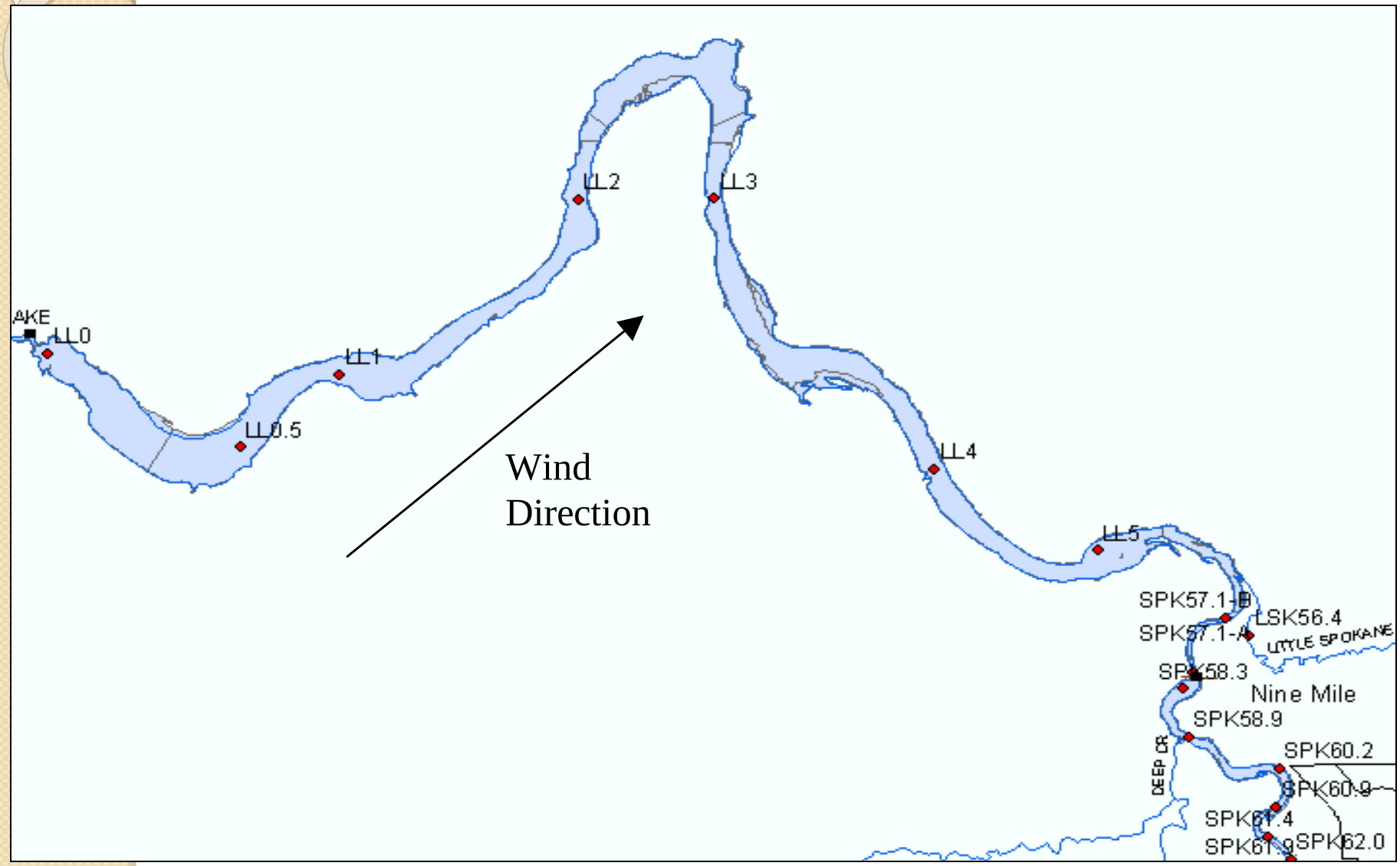
Conductivity Prediction – Long Lake, 1991



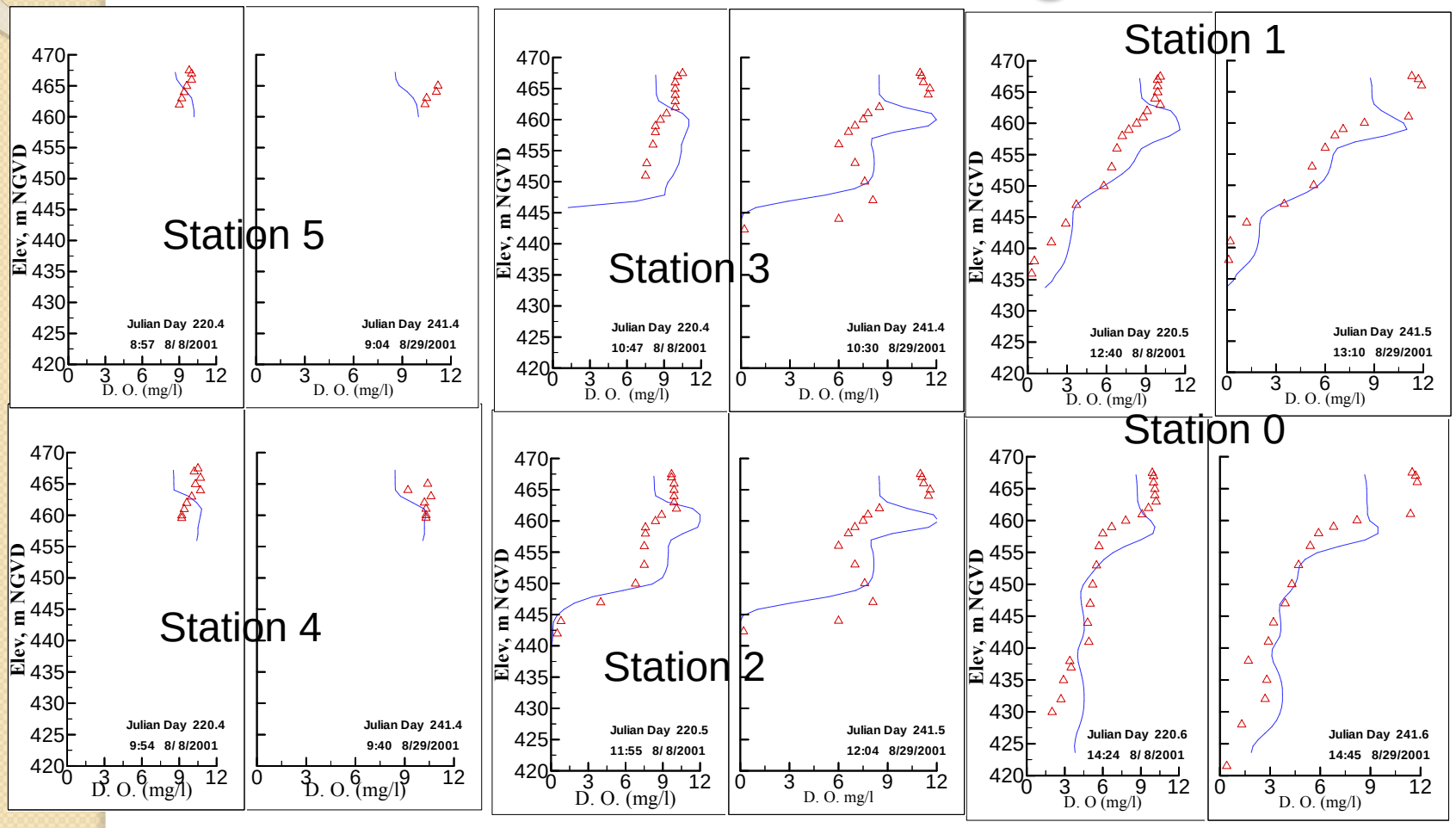
(Site LL1, segment 180)

AME: 14.7 mhos/cm RMS: 17.2 mhos/cm

Adjustment of wind direction

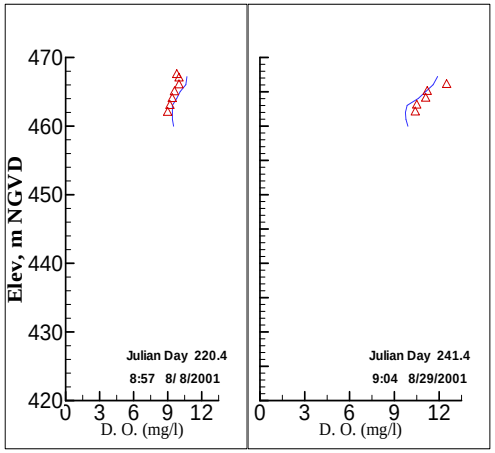


Dissolved Oxygen Long Lake 2001- before wind direction change

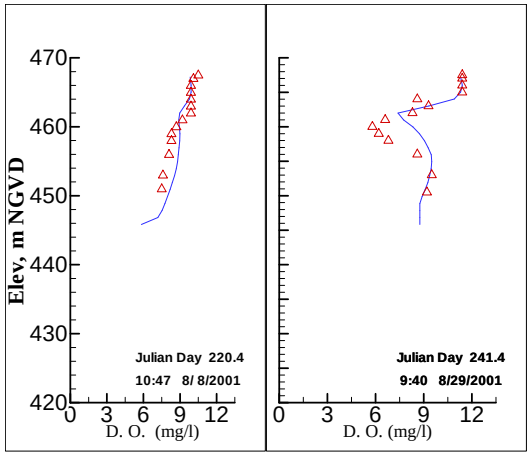


Dissolved Oxygen Long Lake 2001- after wind direction change

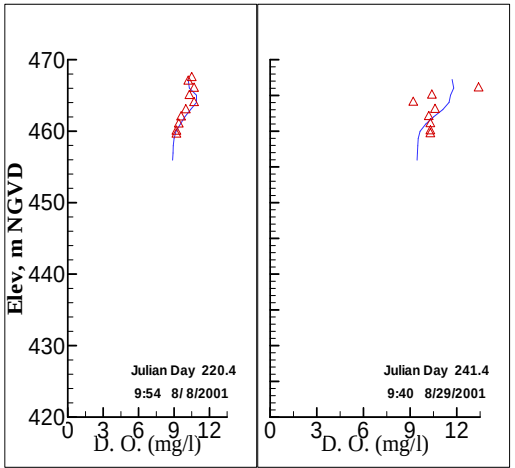
Station 1



Station 2

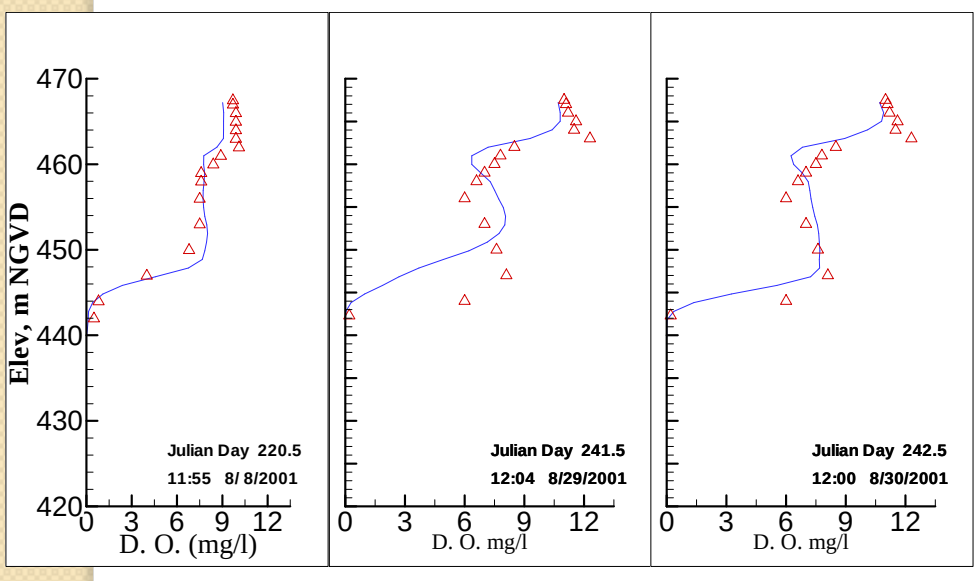


Station 3

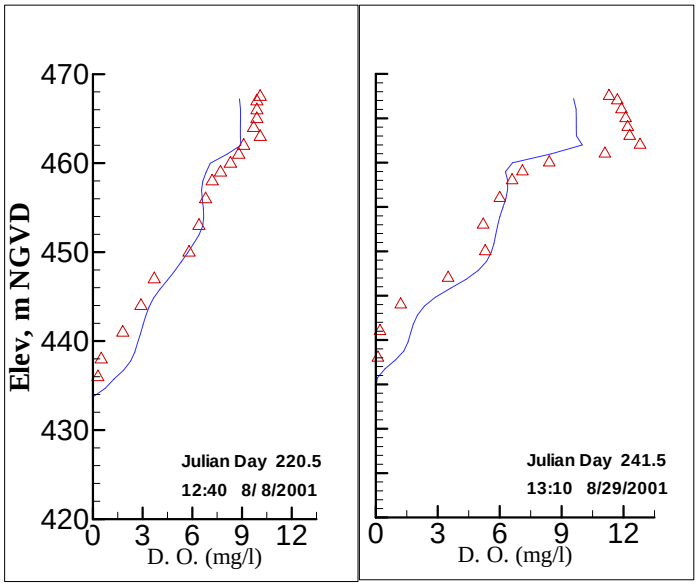


Dissolved Oxygen Long Lake 2001-after wind direction change

Station LL2

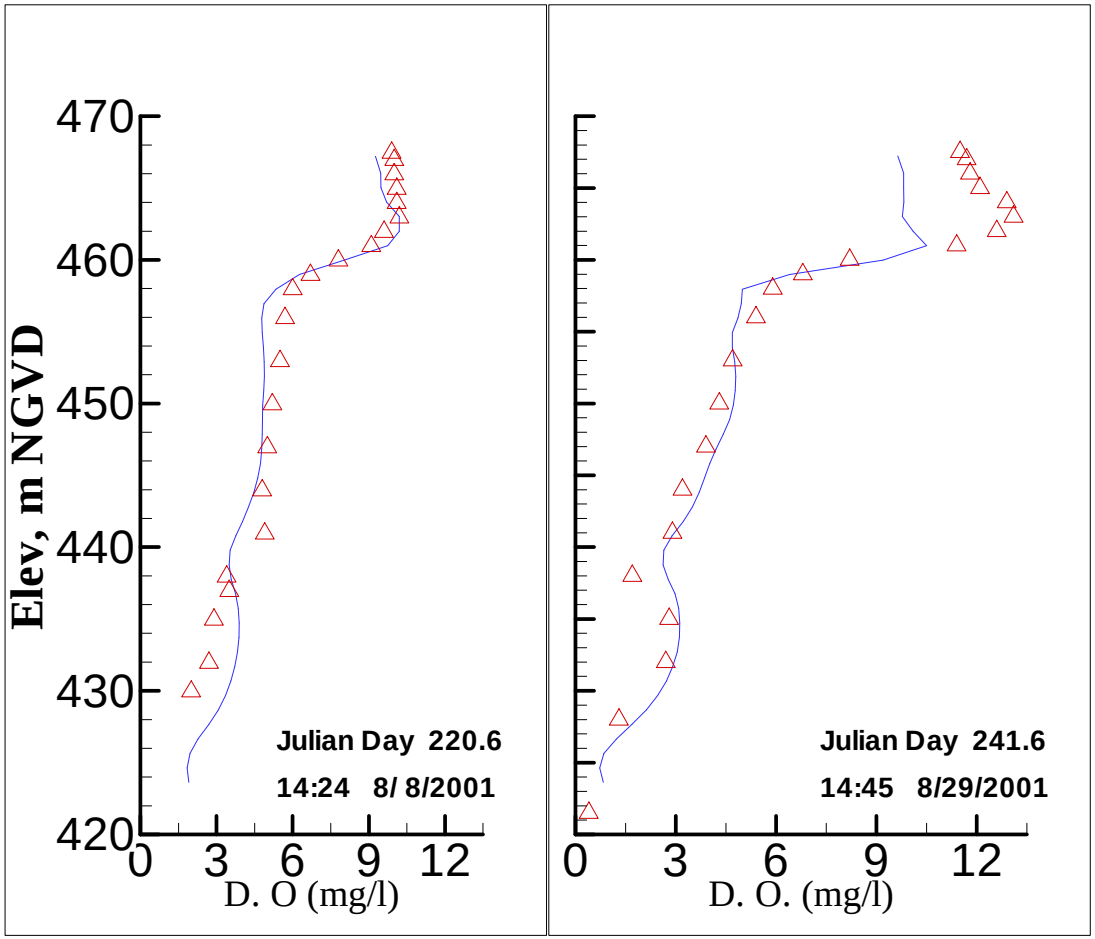


LL1

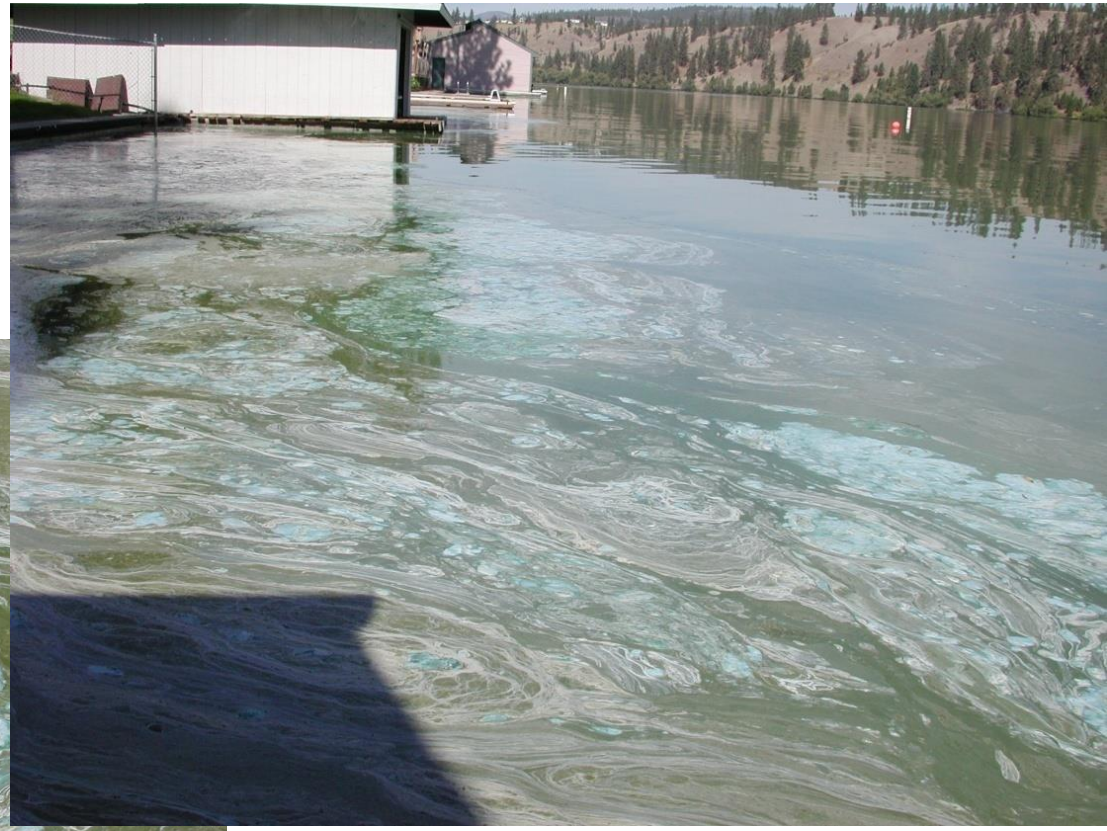


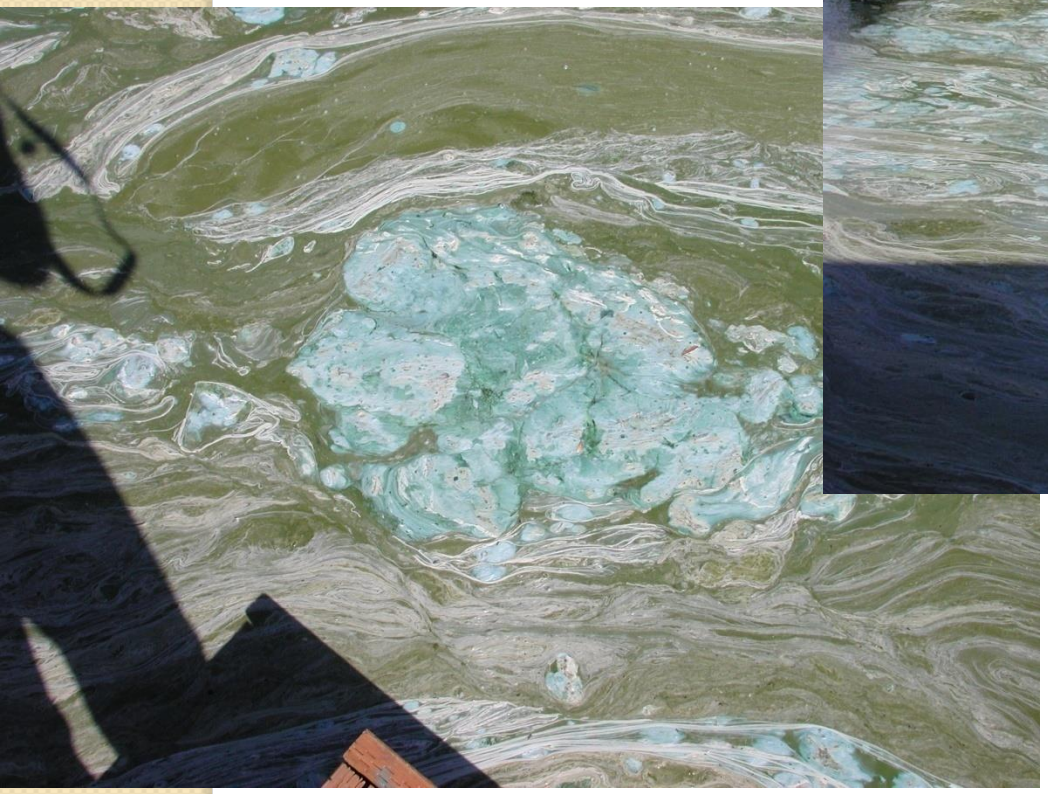
Dissolved Oxygen Long Lake 2001-after wind direction change

Station LL0

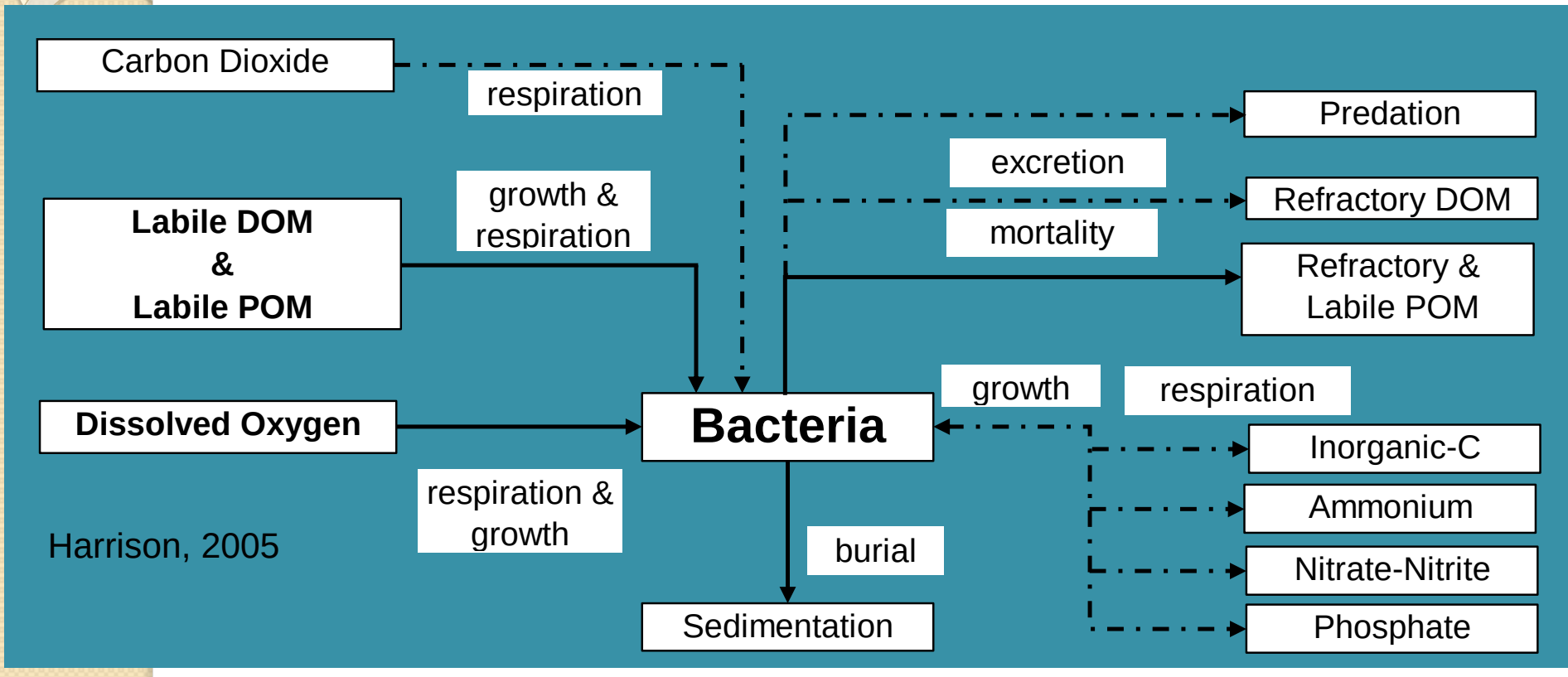


Cyanobacteria bloom in Long Lake



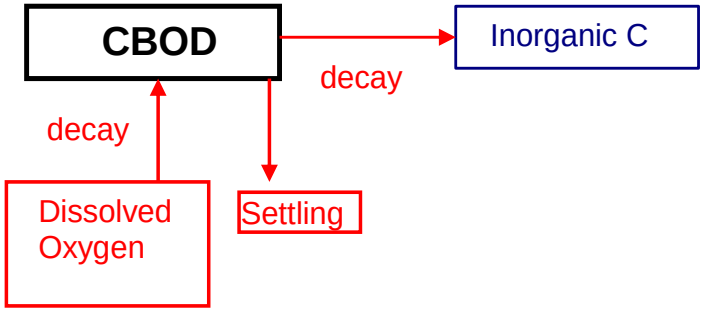


Additional model complexity - a better bacterial model?



Harrison, 2005

vs simple model →

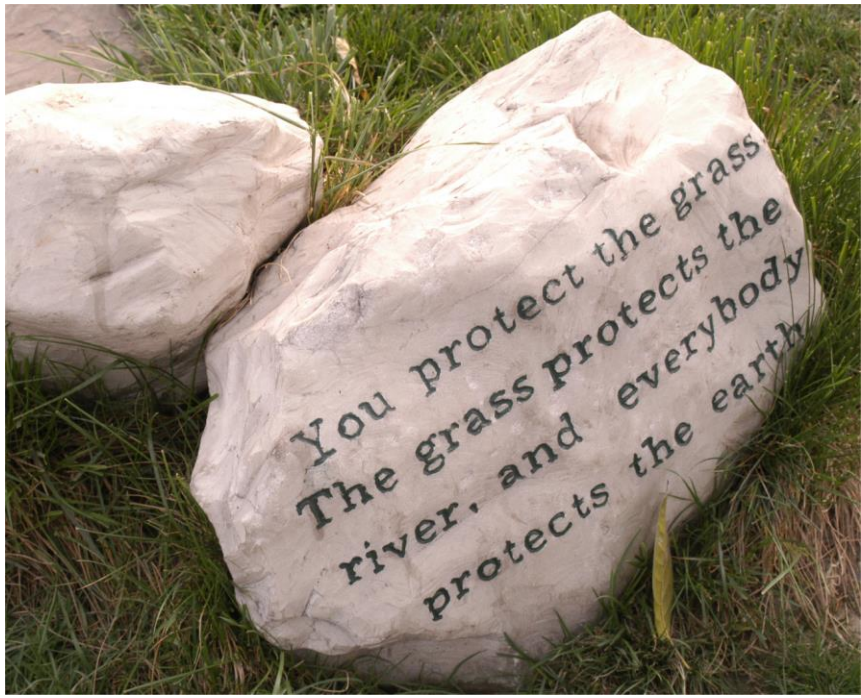


Current and Future Trends for Hydrodynamic and Water Quality Modeling

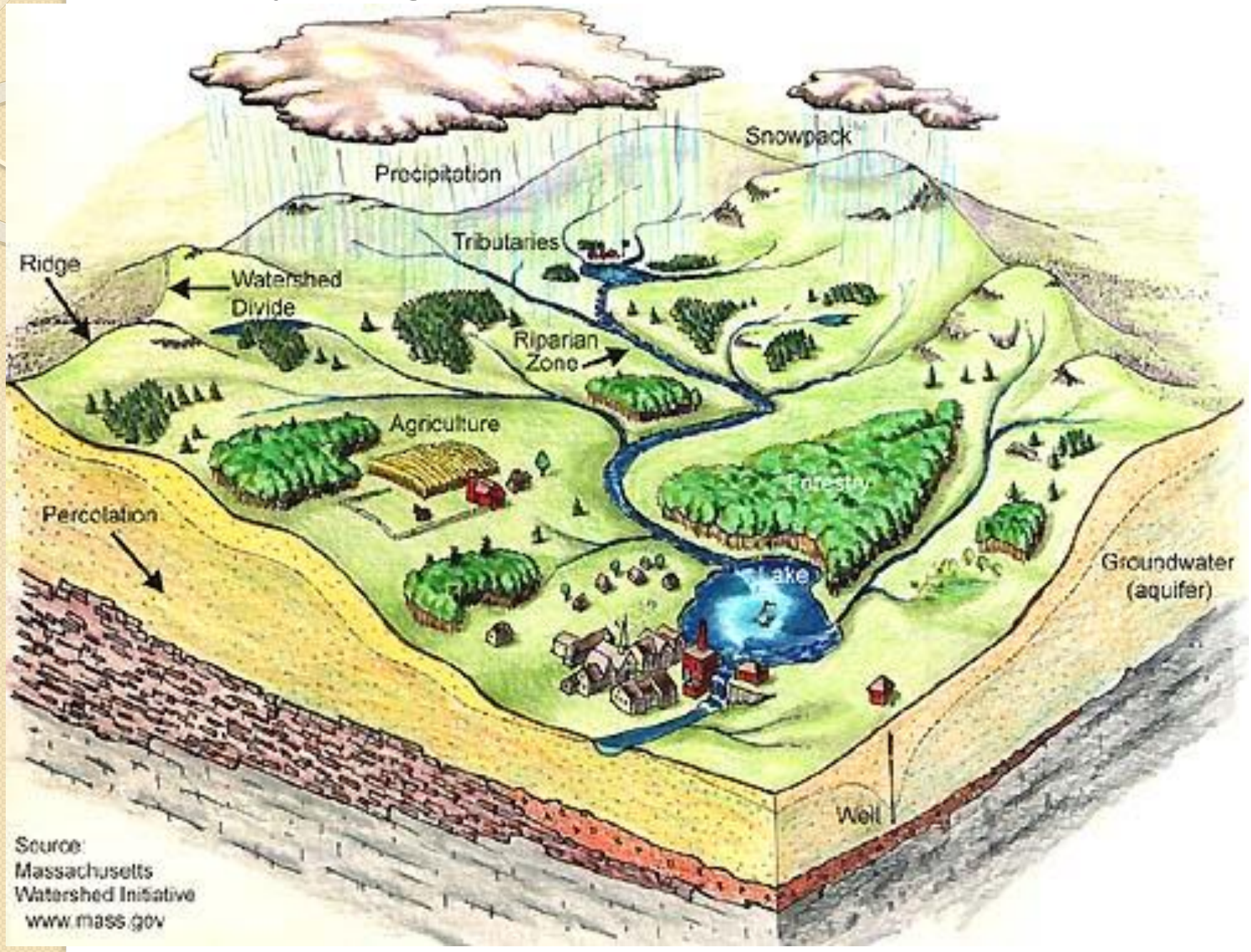
- Management and research model goals merging
- Coupling of models:
  - groundwater and hydrologic models with in-stream models
  - Coupling of reservoir simulation models for flow only, such as RESSIM, with water quality models
  - Coupling atmospheric models with in-stream models
  - Coupling of fish transport and bioenergetics with hydrodynamic and water quality models
  - The "everything" model – couple with social-economic models

Research vs Management Models

- Research context: immediate use of the model not necessary, use model for further investigations
- Management context: immediate application known and carefully specified



“Everything” model



Modeling Framework

Climate Trajectories

- Temperature
- Precipitation

Climate Scenario Assessment and Downscaling

Hydrologic System

- Snowpack Modeling
- Upper Basin Hydrology
- Dams and Reservoirs
- Mainstem Water Quantity/ Quality
- Aquifer Storage/Recharge

Ecosystem

- Vegetative Succession
- Land Cover Change
- Aquatic Habitat Provisioning
- T&E Aquatic Species

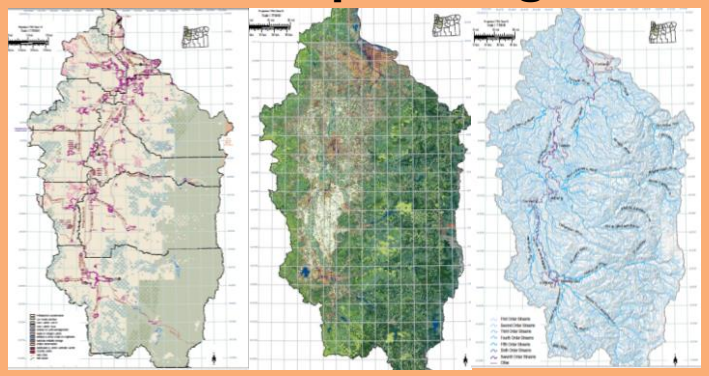
Multi-agent Decision Modeling

Landscape Feedbacks

Landscape Feedbacks

Landscape Feedbacks

Landscape Change



- Human Landscape
- Biophysical Landscape
- Hydrologic Landscape

Human Trajectories

- Population
- Income

Human System

- Land use regulations, policies
- Property rights and other institutions
- External economy influences
- Markets and prices

Public Water Mgmt

Water Use

Land Use

Analysis and Evaluation of Adaptation and Mitigation Responses: Policy, Management and Other Interventions

Final comments/reminders

- Don't average data and model results – unless you realize the implications
- It is OK to not match data
- Visualize model predictions – hard part is explaining what the model is saying
- It is all calibration – beware of claims of "validation"
- Models are complex tools and can be "calibrated" inappropriately to field data
- Key challenge – do model users understand the theory behind the model?

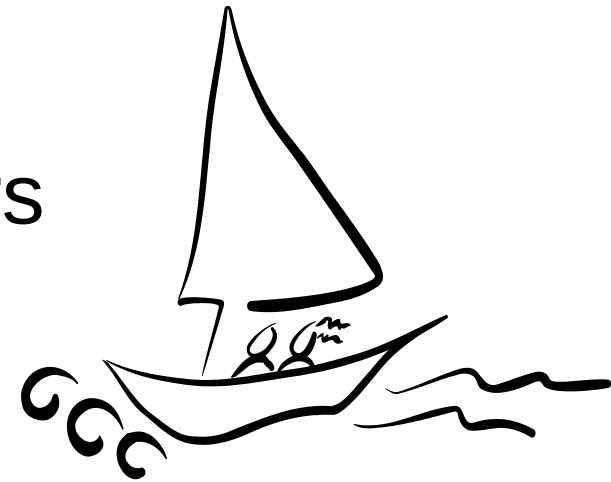
Final

- Wa … odeling of a wa … n managing a riv …
- Ha … - not just in-res … conditions
- Re … atching data – t … should guide fut … s
- Lin … odels tog …
- Do … e modeling pro … picture
- Ha …

Final thoughts

http://www.youtube.com/watch?v=UhDoJtNpL3s

- ….”sometimes won’t know how to take him.

He ain’t wrong, he’s just different but his pride won’t let him, Do things to make you think he is right…”

As Waylon and Willie say: “…make ‘em be doctors and lawyers and such”…