The WRF-Hydro Modeling System: Implementation and Calibration Approaches

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WRF-Hydro Development Team

Model Evaluation: Multi-scale model analysis over intensive observational testbeds

3 legs of the model 'fidelity' stool:

- 1. Temporal Domain:
  - Assessing high and low frequency behavior in model simulated flow responses
  - Diagnosing extremes in hydrological models
- 2. Spatial Domain:
  - Capturing patterns of heterogeneity and organization in hydrologic states (GW, snow, S.M.)
  - Representing changes in runoff productivity across climate-topographic gradients
  - Reproducing the appropriate upscale behavior of runoff and streamflow from headwater to large river systems
- 3. Multi-variate model characterization:
  - Energy and Radiation fluxes
  - Inundation
  - Groundwater-critical zone interactions
  - Shallow soil moisture

Suggested WRF-Hydro Implementation Steps

This procedure will help isolate problems which may otherwise be difficult and/or time-consuming to diagnose in many implementations:

1. Derive *and QC all inputs*…(time mean fields, accumulation fields, screen for anomalies…)
2. Conduct offline simulations…
3. Start with 'idealized' forcing (FORC_TYP = 4)
4. Run WRF_Hydro with no routing
5. Then sequentially add routing components:
    1. Sfc/subsfc
    2. GW/baseflow
    3. Channel flow
    4. Reservoirs
6. If all above works, then non-forcing input grids and components are functional (though not guaranteed accurate!)
7. Do offline runs with FORC_TYP set to data input format
8. After all that and calibration, then run coupled WRF-Hydro

Integrated Land/Hydrology Model Evaluation & Calibration Steps (1)

This procedure is incremental to help isolate key sensitivities and maximize opportunity for obtaining 'right answers for the right reasons':

1. Land model only long term water budget (local, gridded and basin averaged/ integrated as appropriate:
    1. Annual and seasonal runoff vs. observed flows
    2. Land atmosphere fluxes
    3. Groundwater storage/soil moisture (primarily correlative analysis)
    4. Snowpack

2. Calibration Methods:
    1. SCE, PEST, Manual

3. Key is to obtain a reasonable annual and seasonal water budget partitioning that properly reflects climate forcing

Integrated Land/Hydrology Model Evaluation & Calibration Steps (2)

This procedure is incremental to help isolate key sensitivities and maximize opportunity for obtaining ‘right answers for the right reasons’:

1. Land model plus ‘terrain routing’ (and bucket model) and evaluate against long term water budget (local, gridded and basin averaged/integrated as appropriate):
    1. Annual and seasonal runoff vs. observed flows
    2. Land atmosphere fluxes
    3. Groundwater storage/soil moisture (primarily correlative analysis)
    4. Snowpack

2. Calibration Methods:
    1. SCE, PEST, Manual

3. Key is to re-tune land model and terrestrial routing parameters *to maintain* a reasonable annual and seasonal water budget partitioning that properly reflects climate forcing.

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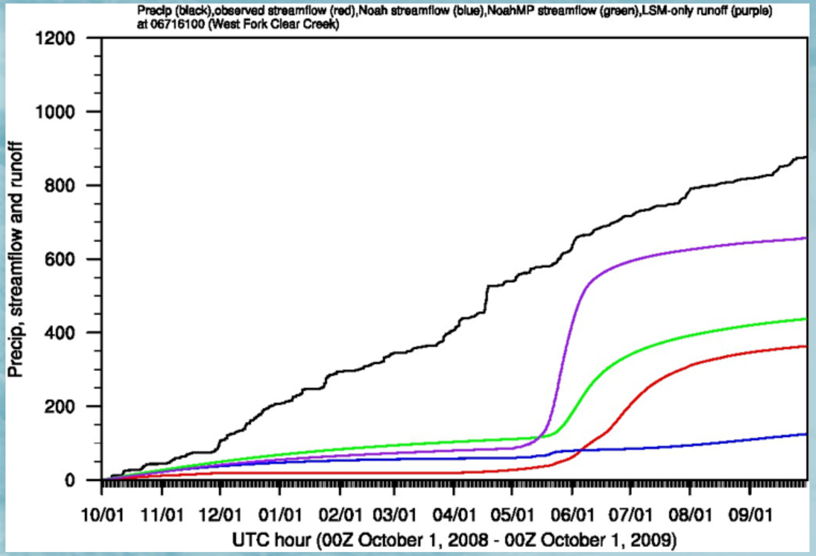
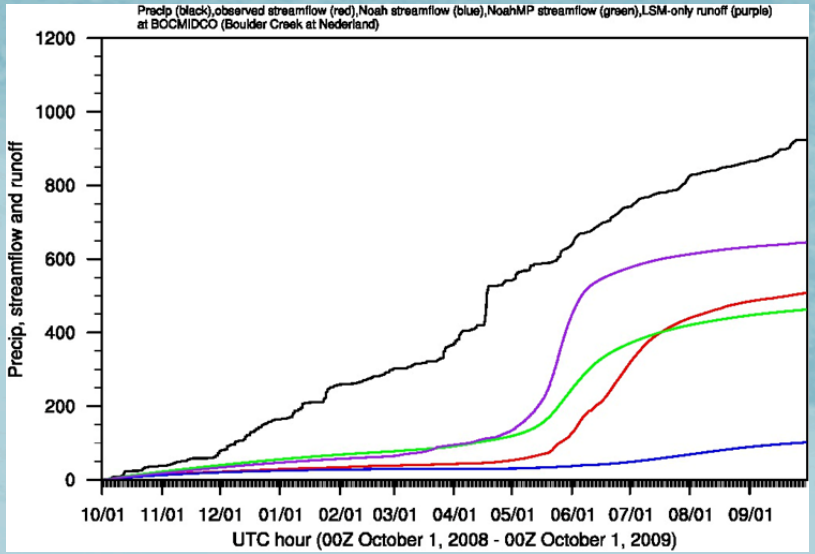
Integrated Land/Hydrology Model Evaluation & Calibration Steps (2)

- NoahMP yielding markedly better snowpack estimates and runoff simulations than original Noah in headwaters
- Routed flows in WRF-Hydro (uncalibrated) producing improved runoff with respect to observations than simply land model only. Suggests re-infiltration and en route ET ‘losses’ are important.

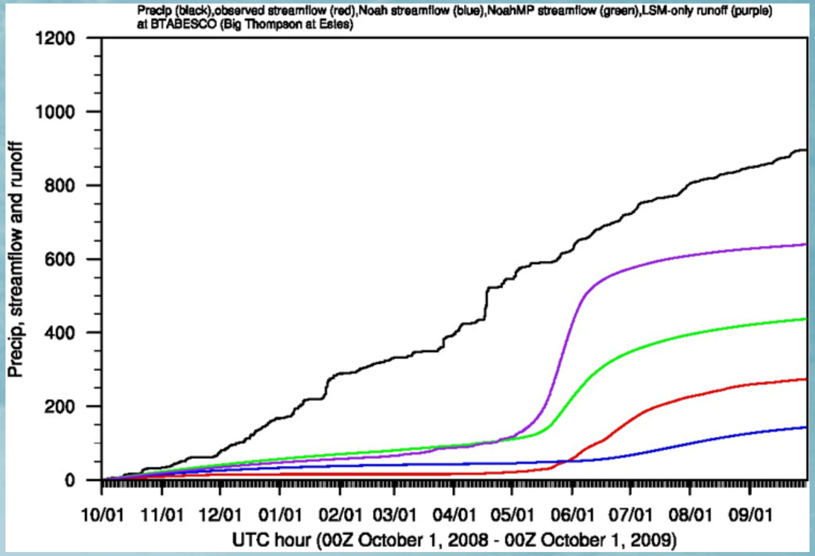
West Fork Clear Creek



Boulder Creek at Nederland



Big Thompson at Estes



Integrated Land/Hydrology Model Evaluation & Calibration Steps (3)

This procedure is incremental to help isolate key sensitivities and maximize opportunity for obtaining 'right answers for the right reasons':

1. Streamflow calibration with active channel routing: (can be done with full system or just prescribed 'channel inflows/channel model only':
    1. Continuous timeseries analysis
    2. N-S, RMSE, Bias, MAE
    3. *Flow duration curve (total integral of area between observed and modeled flow duration curves)*
    4. Peak flows
    5. Flood wave celerity

2. Calibration Methods:
    1. SCE, PEST, Manual

3. Goal is to build upon prior 'land routing' calibration for water budget and focus here on flood wave propagation

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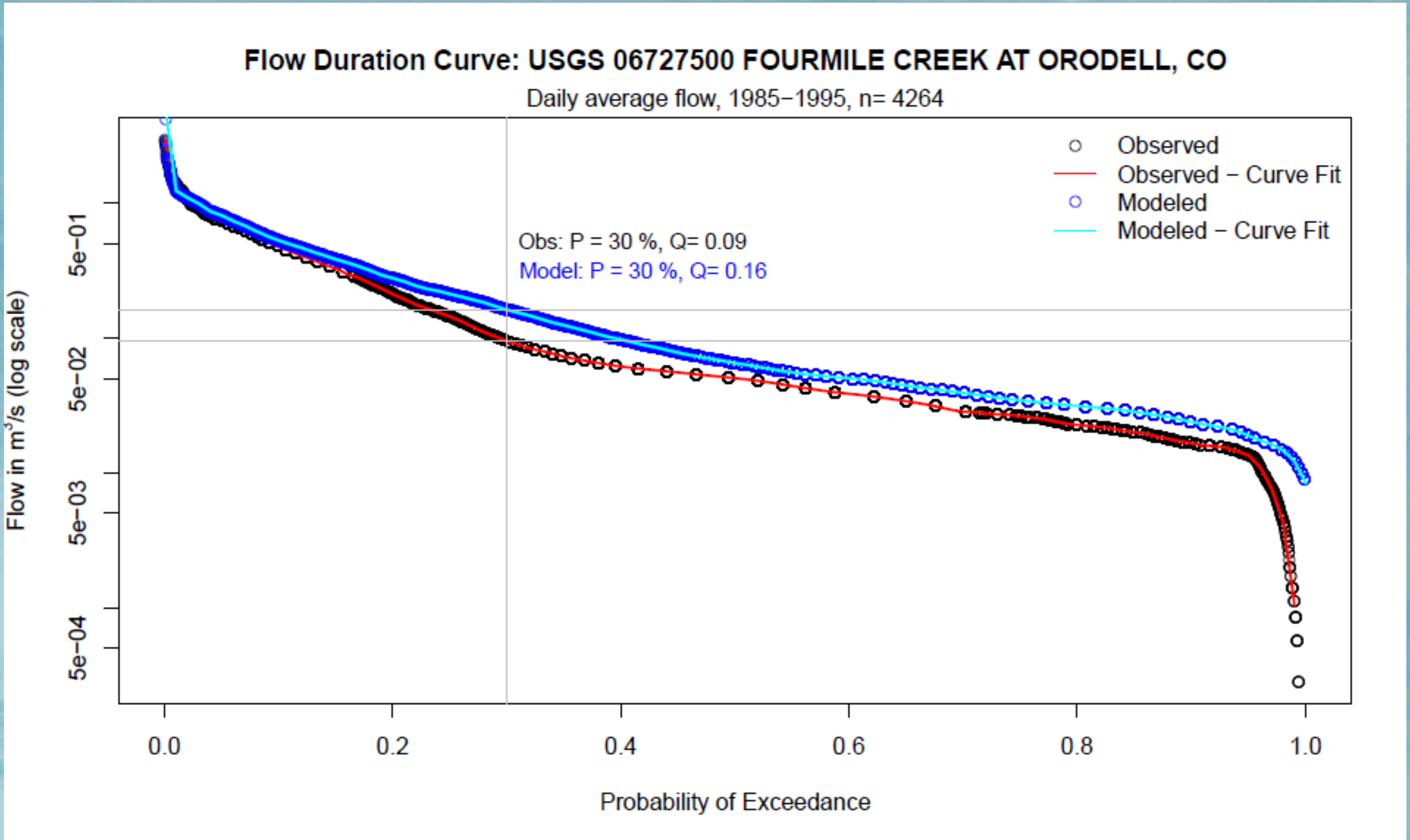
Integrated Land/Hydrology Model Evaluation & Calibration Steps (3)

R-script



Integrated Land/Hydrology Model Evaluation & Calibration Final Comments

- Paradigm is shifting from model calibration to model evaluation and diagnosis
- With process-based hydrologic models there are multiple evaluation metrics (beyond streamflow) that can be brought to bear
- Data requirements increase correspondingly and ‘PUB’ is still fraught with uncertainties
- Need a structured approach to isolate primary sources of uncertainty, sensitivity and opportunity for calibration
- Will still be some classic calibration artifacts in parameter estimates