State Updating of Distributed Hydrologic Model via Variational Data Assimilation for Real-time Analysis and Prediction of Streamflow

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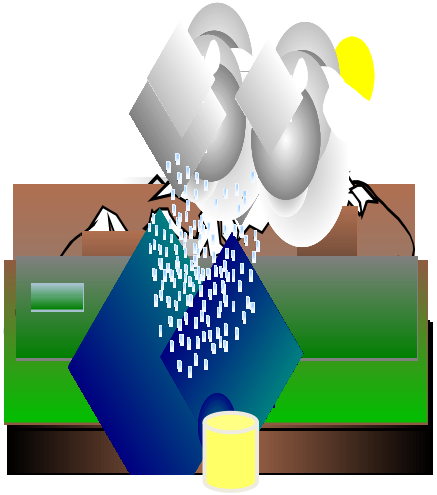
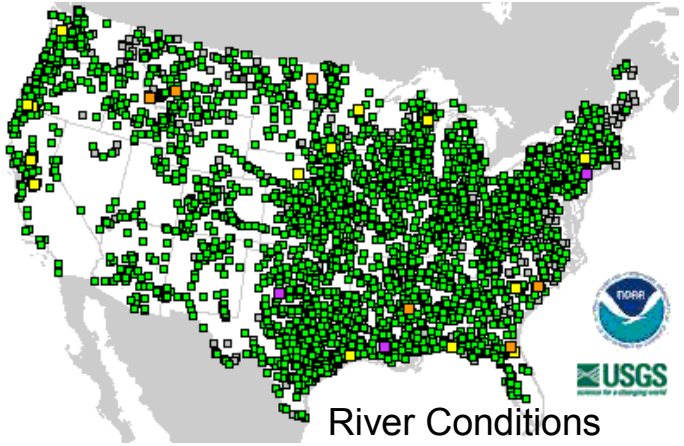
Predicting Floods to Droughts In Your Neighborhood

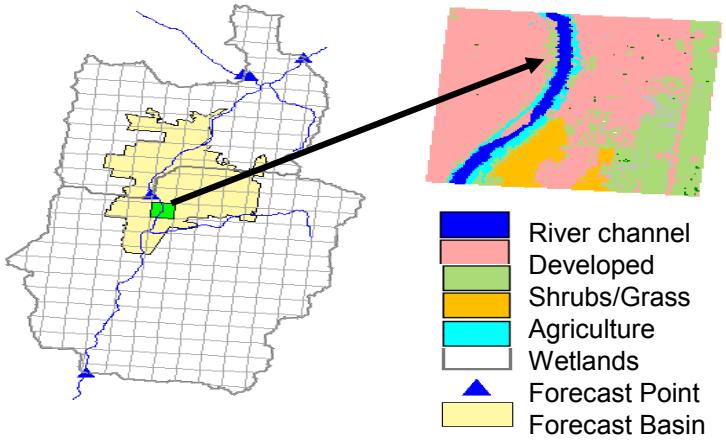


River Services

(1000 kilometers per forecast point)

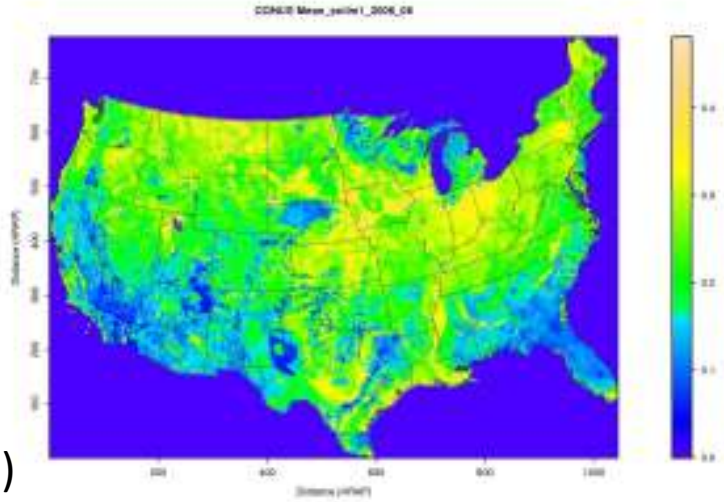


River Conditions



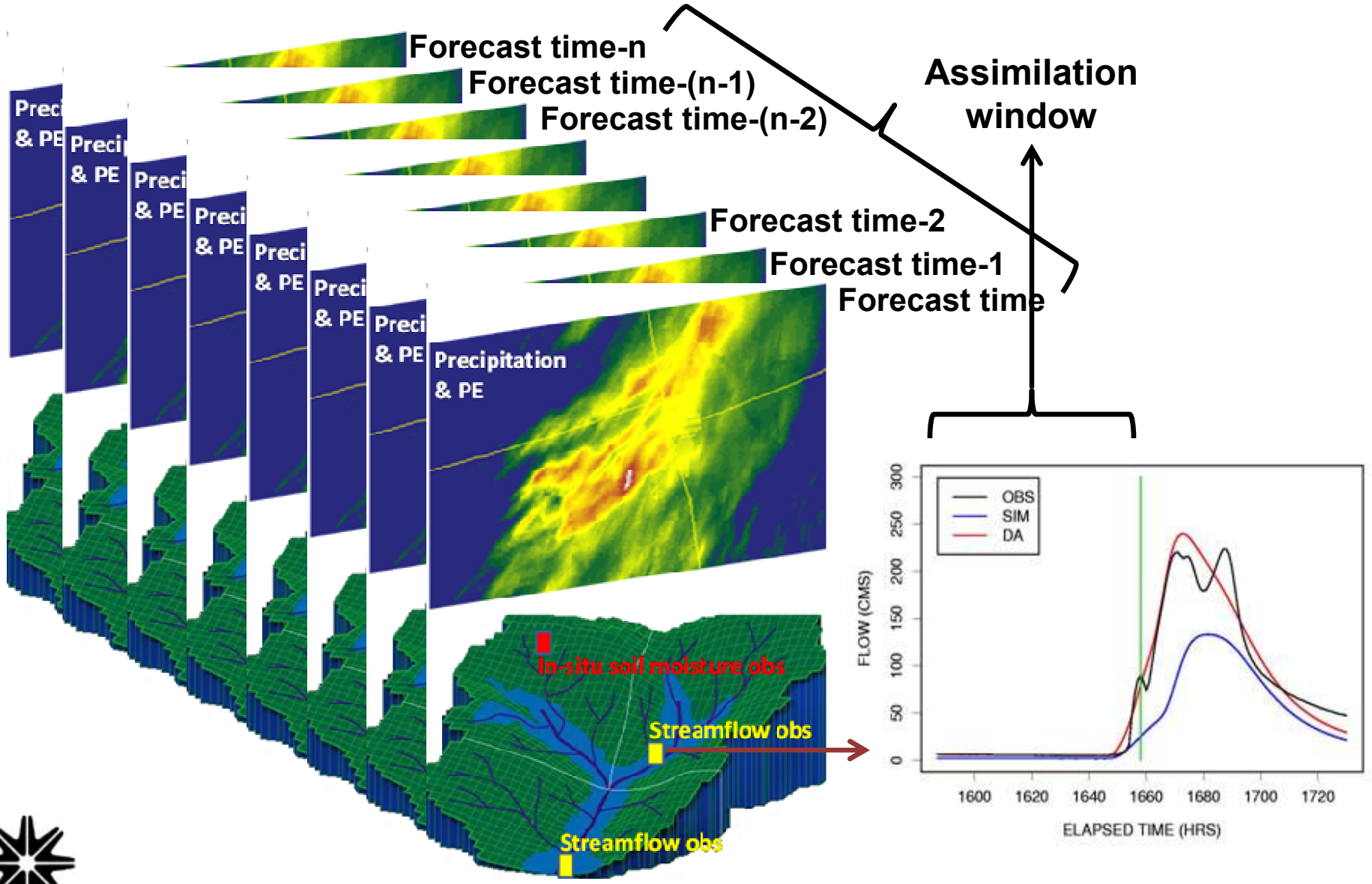
Water Resource Services

(16 square kilometer forecast basins)



From Carter (2006)

Improve streamflow analysis and prediction by assimilating hydrologic and hydrometeorological data into distributed models



Models used

- Hydrology Laboratory's Research Distributed Hydrologic Model (HL-RDHM, Koren et al. 2004)
  - Gridded (~4x4 km^2) soil moisture accounting models (SAC)
  - Kinematic-wave routing

- The prototype DA assimilates (Seo et al. 2003, Lee et al. 2010[1]):
  - Streamflow (outlet, interior)
  - In-situ soil moisture
  - Precipitation
  - Potential evaporation (PE)

[1]Submitted to the Journal of Hydrology

Control vector

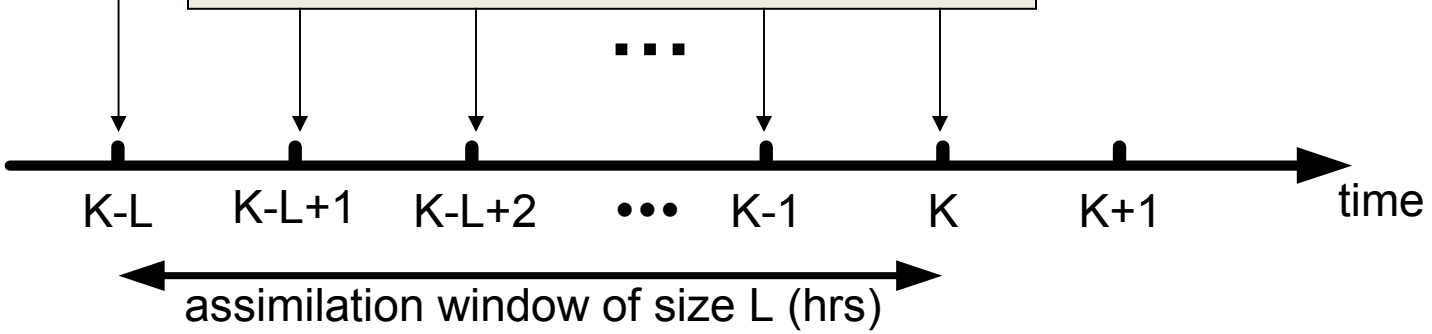
Background SAC states

$UZTWC_{i,K-L}$
$UZFWC_{i,K-L}$
$LZTWC_{i,K-L}$
$LZFSC_{i,K-L}$
$LZFPC_{i,K-L}$ $(i=1, \ldots, n_G)$

n_G: Number of grid boxes in the basin

Adjustment factors to precipitation and PE

$X_{P,k}$ and $X_{E,k}$ $(k=K-L+1, \ldots, K)$



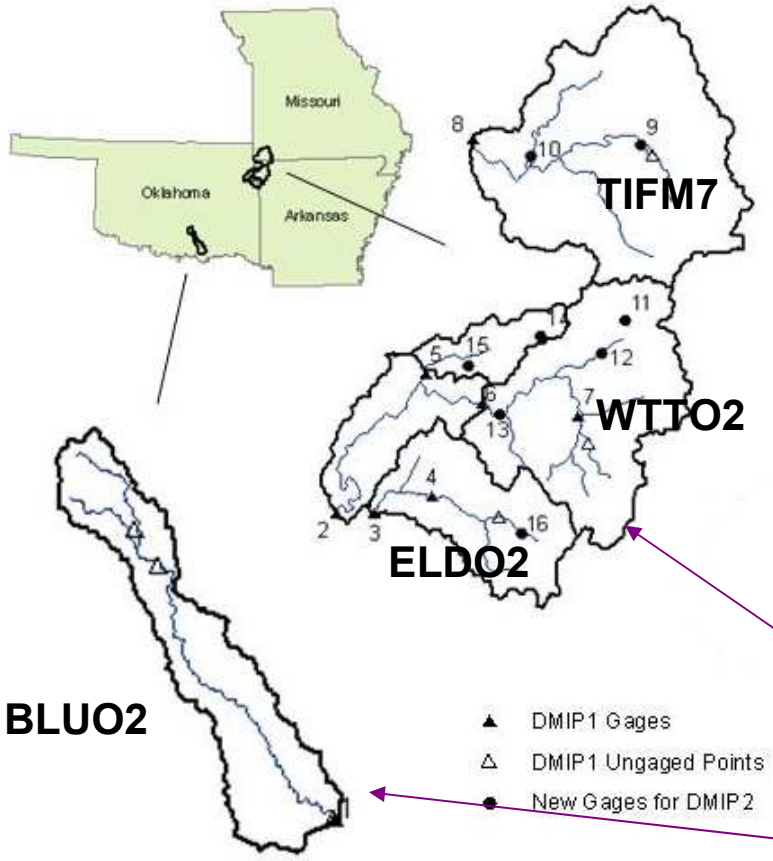
Approach

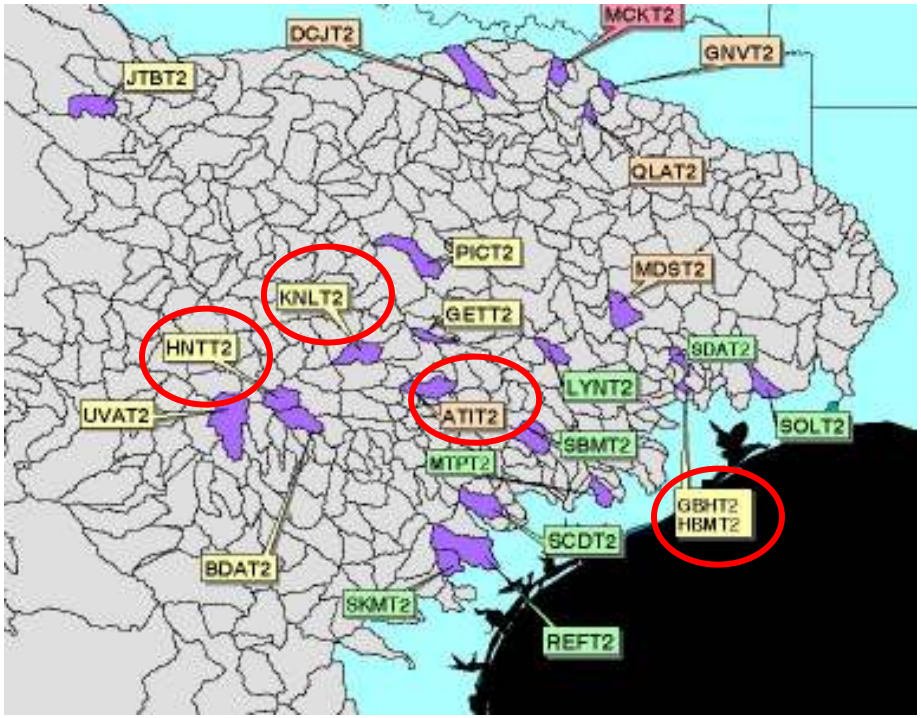
- 3 cases
  - Case 1: Assimilate outlet flow only
  - Case 2: Assimilate interior flow only
  - Case 3: Assimilate streamflow at both outlet and interior locations
- Varying size of control vector
  - Spatial discretization : Grid, sub-basin, basin
  - temporal discretization: 1hr, 6hr, length of the assimilation window
- High flow events only

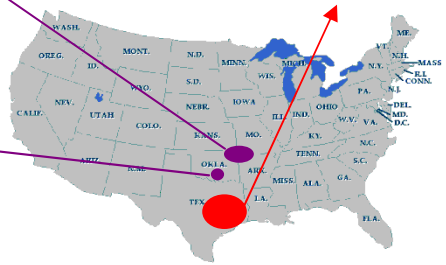
Study basins

4 basins in Arkansas-Red Basin River Forecast Center(ABRFC) service area: TIFM7, WTTO2, ELDO2, BLUO2

5 basins in West Gulf River Forecast Center(WGRFC) service area: HNTT2, KNLT2, ATIT2, GBHT2, HBMT2







(Seo et al. 2006)

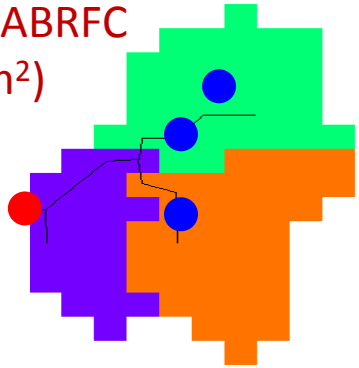
(source: http://www.nws.noaa.gov/oh/hrl/dmip/2/images/dmip%202%20test%20basins%20web%20page_Slide2.JPG)

	Area (km^2)	Interior gauges	Sub-basins	Assimilation window (hr)	Simulation period	No. Events (streamflow threshold (m^3/s))
ELDO2	795	2	3	36	**8 yrs** 1996/1–2004/1	17 (200)
WTTO2	1645	3	3	48	**2 yrs** 2000/4–2002/1	7 (200)
TIFM7	2258	2	5	60	**6 yrs** 2000/5–2006/9	15 (200)
BLUO2	1232	1	5	60	**3 yrs** 2003/10– 2006/9	7 (100)
HBMT2	246	1	3	42	**13 yrs** 1997/1–2009/7	20 (400)
GBHT2	137	1	3	48	**10 yrs** 2000/1–2009/7	16 (150)
ATIT2	844	11	3	36	**13 yrs** 1997/1–2009/6	23 (100)
KNLT2	904	2	5	36	**11 yrs** 1997/10–2008/9	15 (200)
HNTT2	769	1	3	30	**12 yrs** 1998/1–2009/6	9 (200)

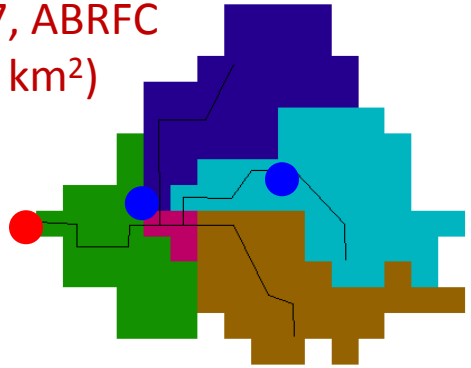
ABRFC WGRFC

Sub-basin Delineation

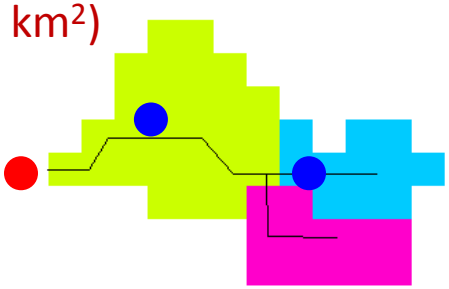
WTTO2, ABRFC (1645 km²)



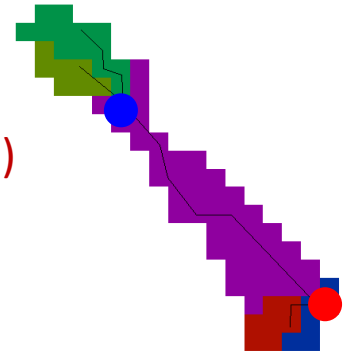
TIFM7, ABRFC (2258 km²)



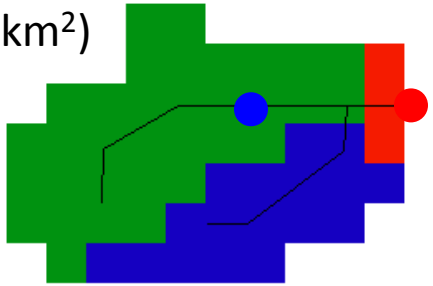
ELDO2, ABRFC (795 km²)



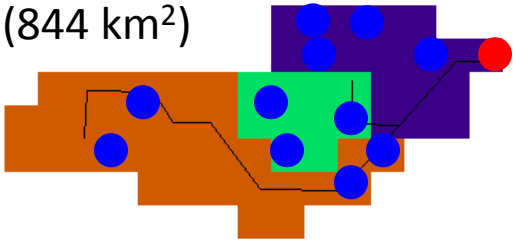
BLUO2, ABRFC (1232 km²)



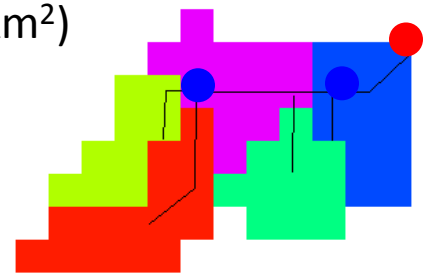
HNTT2, WGRFC (769 km²)



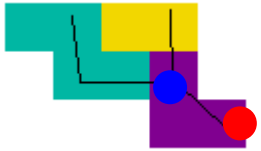
ATIT2, WGRFC (844 km²)



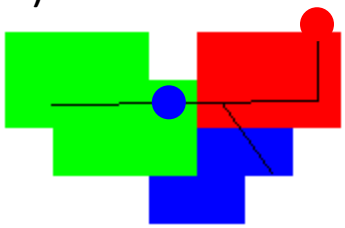
KNLT2, WGRFC (904 km²)



GBHT2, WGRFC (137 km²)



HBMT2, WGRFC (246 km²)



● outlet ● Interior stream gauges —— channel network

Scale of adjustment associated with the largest percent reduction in RMSE in streamflow analysis

Blue: Outlet flow results **Red: Interior flow results**

Outlet flow assim'ed

	Dist	Semi-dist	Lumped
win			
6hr	B,W W		E
1hr	A,E,Hb,Hn,K,T A,B,G,T	G Hn,K	Hb

Interior flow assim'ed

	Dist	Semi-dist	Lumped
win	T		
6hr		W	
1hr	B,E,K A,B,E,Hb,Hn,K,T,W	A,G,Hn G	Hb

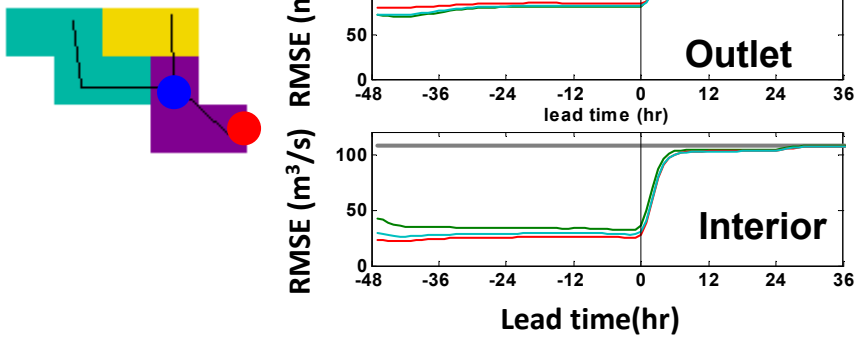
Outlet & interior flow assim'ed

	Dist	Semi-dist	Lumped
win			
6hr		K	
1hr	A,B,E,Hb,Hn,T,W A,B,E,G,Hb,K,T,W	G Hn	

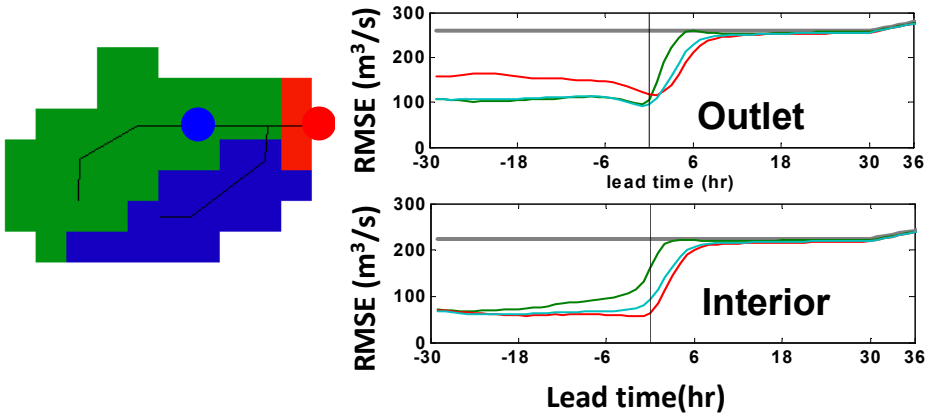
A: ATIT2 B: BLUO2 E: ELDO2 G: GBHT2 Hb: HBMT2 Hn: HNTT2 K: KNLT2 T: TIFM7 W: WTTO2

RMSE of simulated streamflow vs. lead time (hrs)

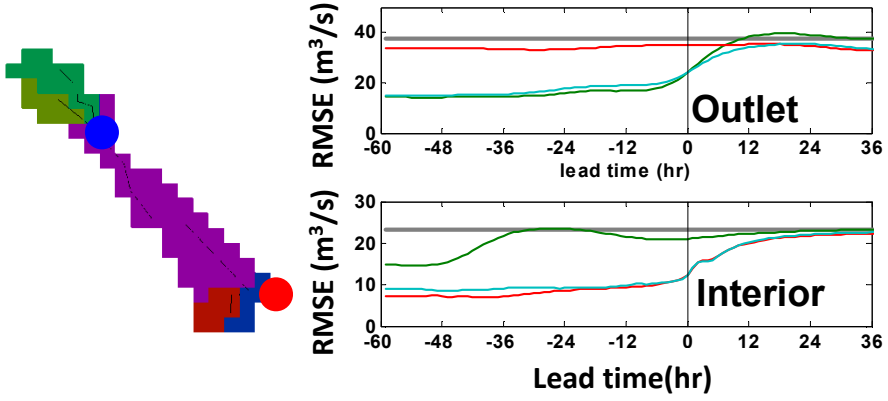
GBHT2 (137 km²)



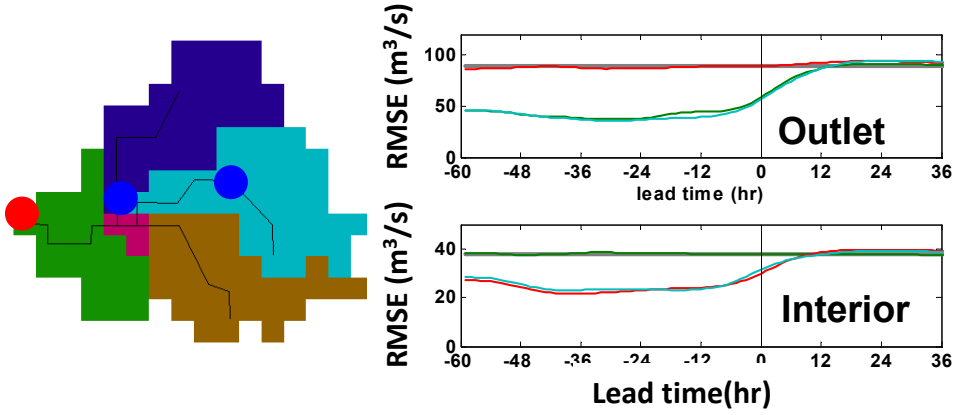
HNTT2 (769 km²)



BLUO2 (1232 km²)



TIFM7 (2258 km²)



No DA Outlet flow DA Interior flow DA Outlet & interior flow DA

Percent reduction in RMSE of simulated hourly streamflow

- Simulation is w/ and w/o DA for each high-flow event for all 9 basins.
- The results are over the entire assimilation window (i.e. the analysis period).

	Assim. outlet flow only	Assim. interior flow only	Assim. outlet & interior flow
Verified at outlet	48 %	**19 %**	46 %
Verified at interior	**16 %**	43 %	36 %

Conclusions

- Assimilating outlet flow improved analysis of interior flow approximately 16% in terms of RMSE
- Assimilating interior flow improved outlet flow analysis approximately 19% in terms of RMSE
- Improvement in prediction is smaller than in analysis, and dissipates rather quickly as the lead time increases
- No clear optimum spatio-temporal scale for adjustment was found
  - Varies from basin to basin and depends on the location of the stream gauges
- For events with timing errors, the assimilation results have limited skill

Thank you