A hydrologic model of a data-scarce, mountainous basin to assess passive microwave estimates of SWE;
A case study of the Upper Helmand Watershed, Afghanistan

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Objectives

1. To better understand the water resources in the Upper Helmand Watershed, Afghanistan.

2. To develop a snow hydrology model of the basin using available ground and remotely sensed data.

3. To compare results of the snow model to passive microwave estimates of snow water equivalent (SWE).

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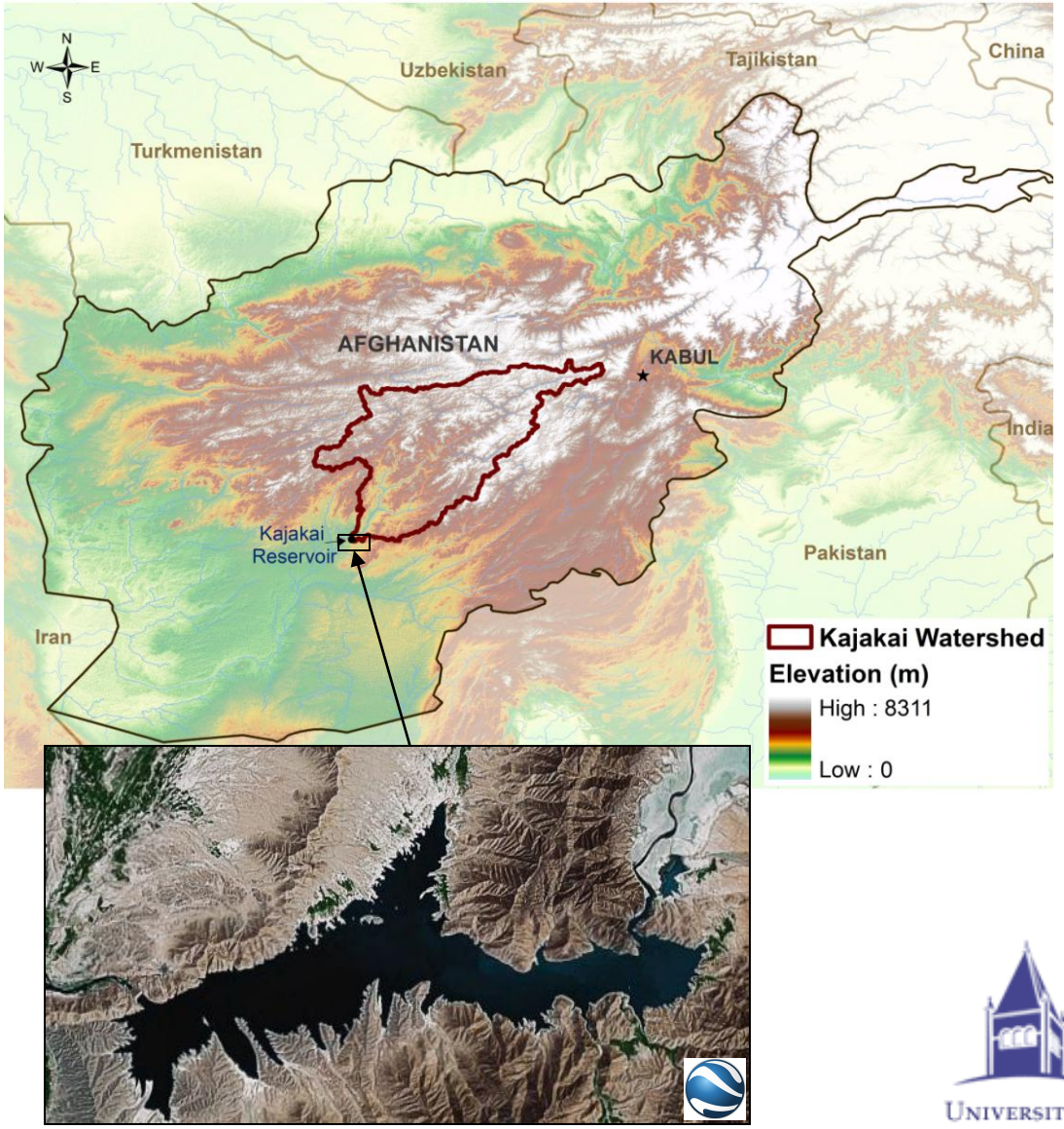
Study Location

Upper Helmand Watershed, Afghanistan

- Irrigation
- Water supply
- Flood reduction
- Power generation



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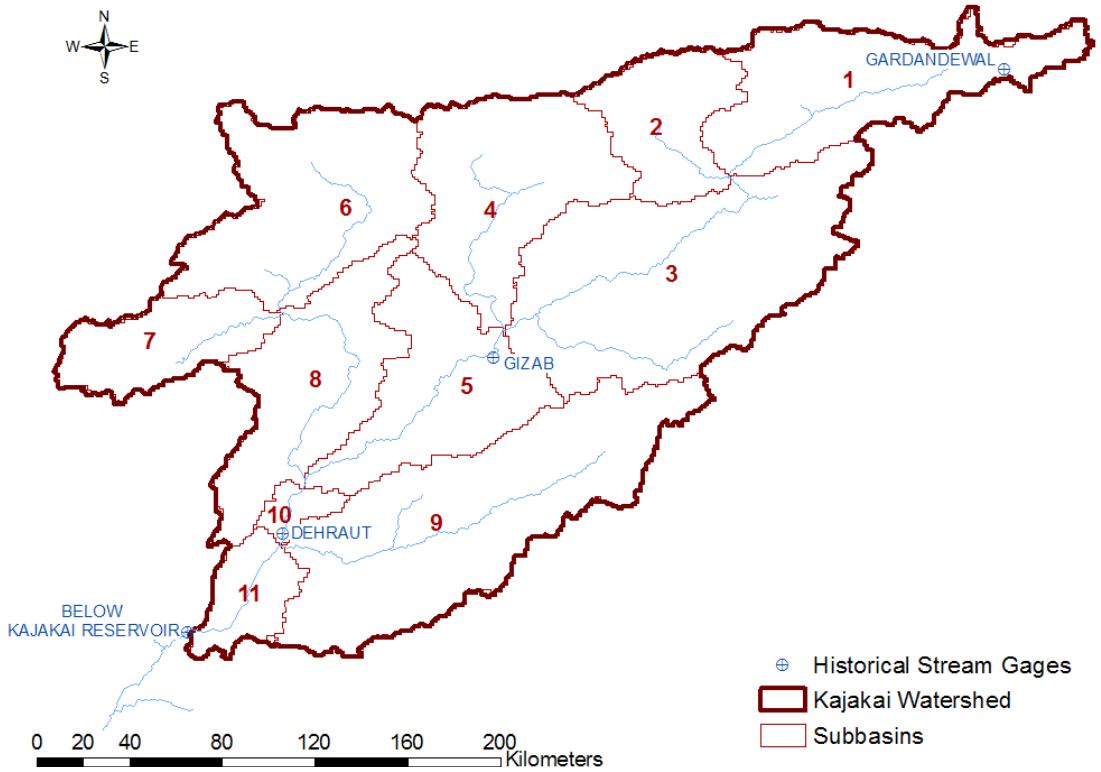
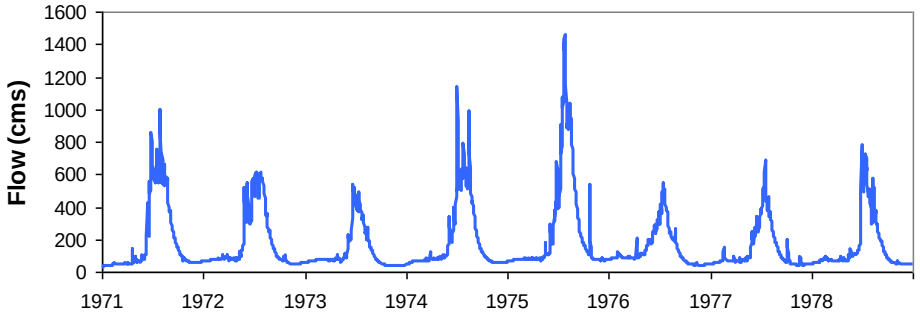
Study Location

- Spring runoff results from snowmelt and increased rainfall
- Arid country
- Limited data sources
- Floods/Droughts occur with little warning



Helmand River at Dehraut



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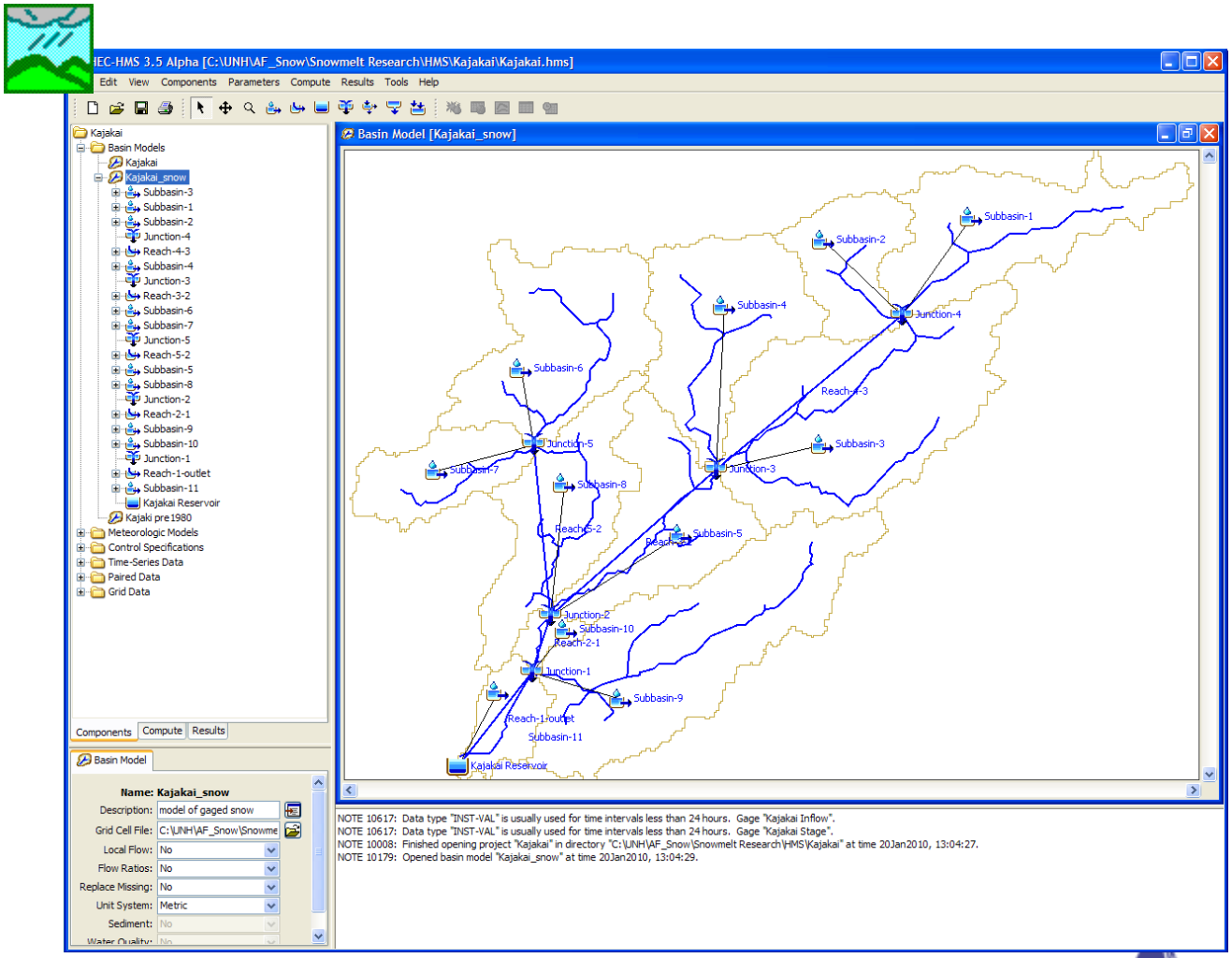
Snow Hydrology Model

- HEC Hydrologic Modeling System (HMS)
  - Distributed
  - Temperature index snow model
- 6 winter seasons
  - 01 OCT – 30 JUN
  - 2004 – 2009



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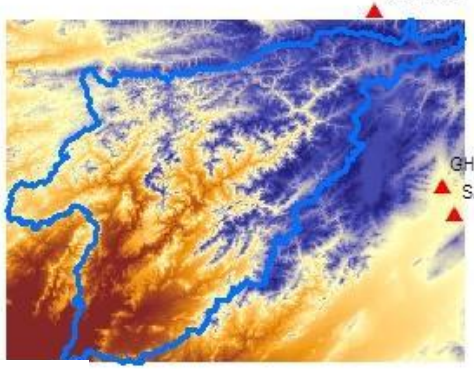
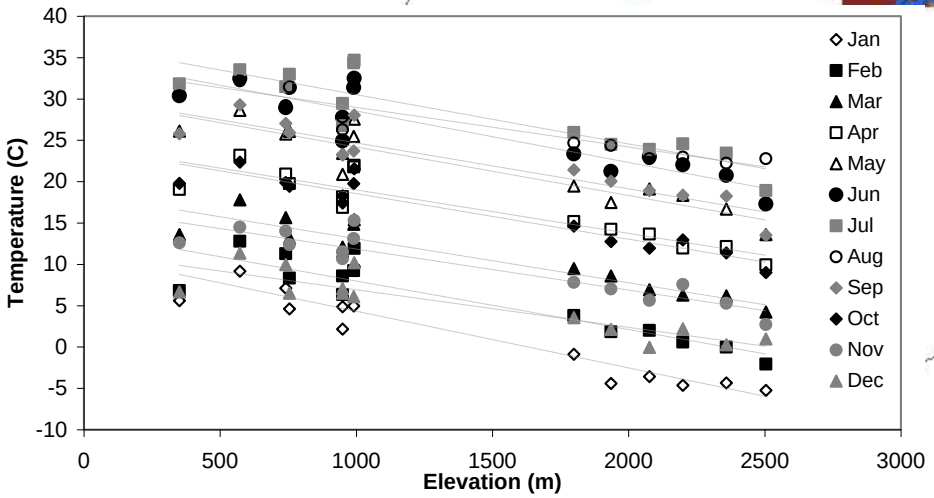
Snow Hydrology Model

Temperature Data

- Lapse rate = 5.6°C/km
- 1km^2 grid size
- 14 stations





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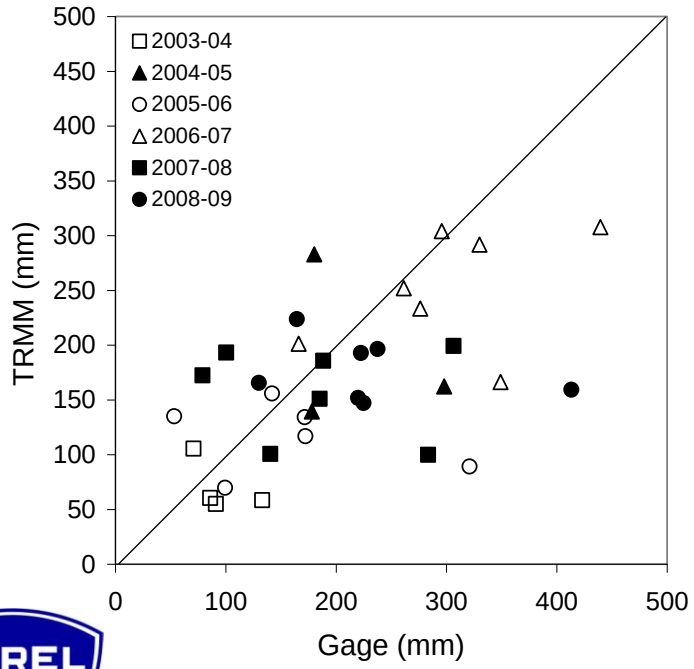
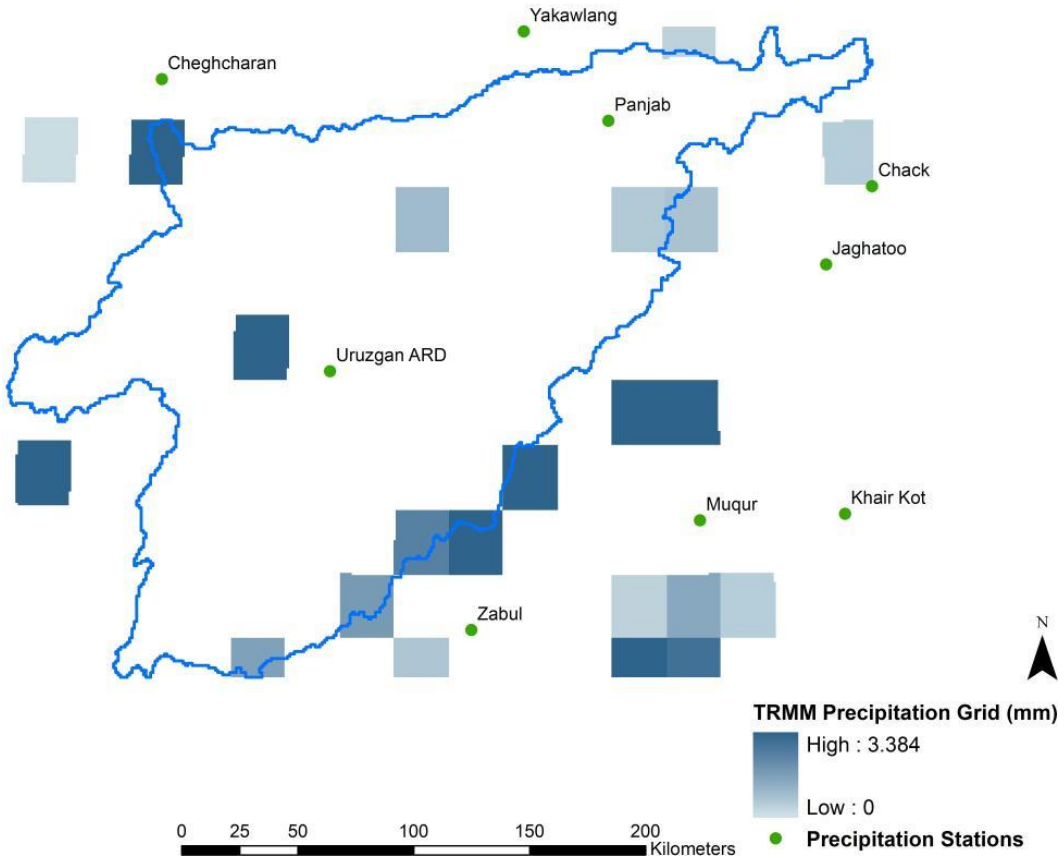
Snow Hydrology Model

- Precipitation Data
  - Limited gage data
  - TRMM 3B42 precipitation
  - Resampled to 1km^2 grids





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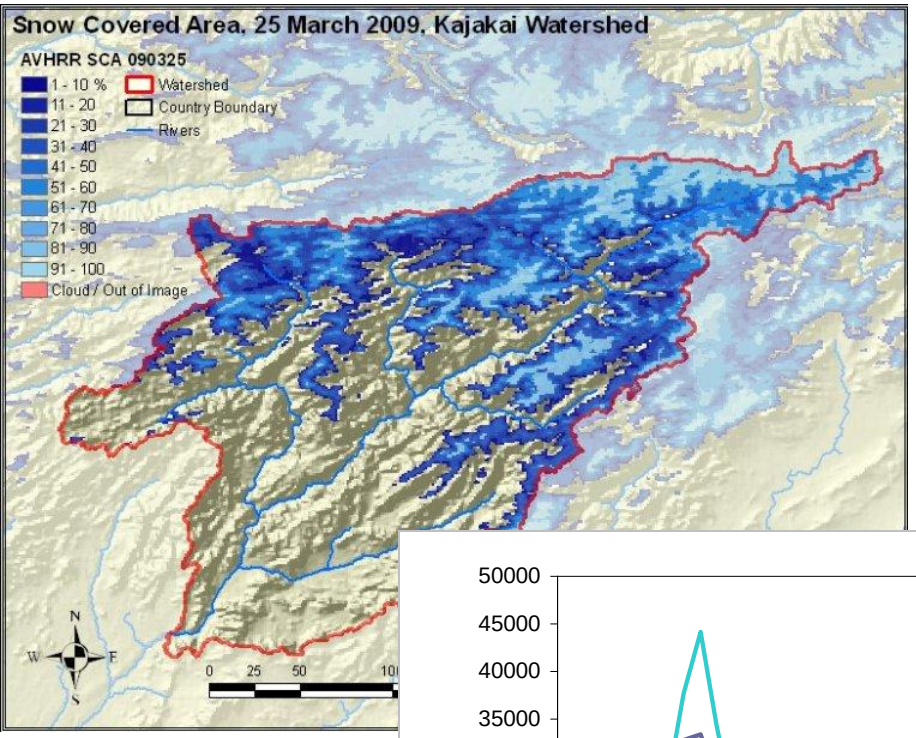
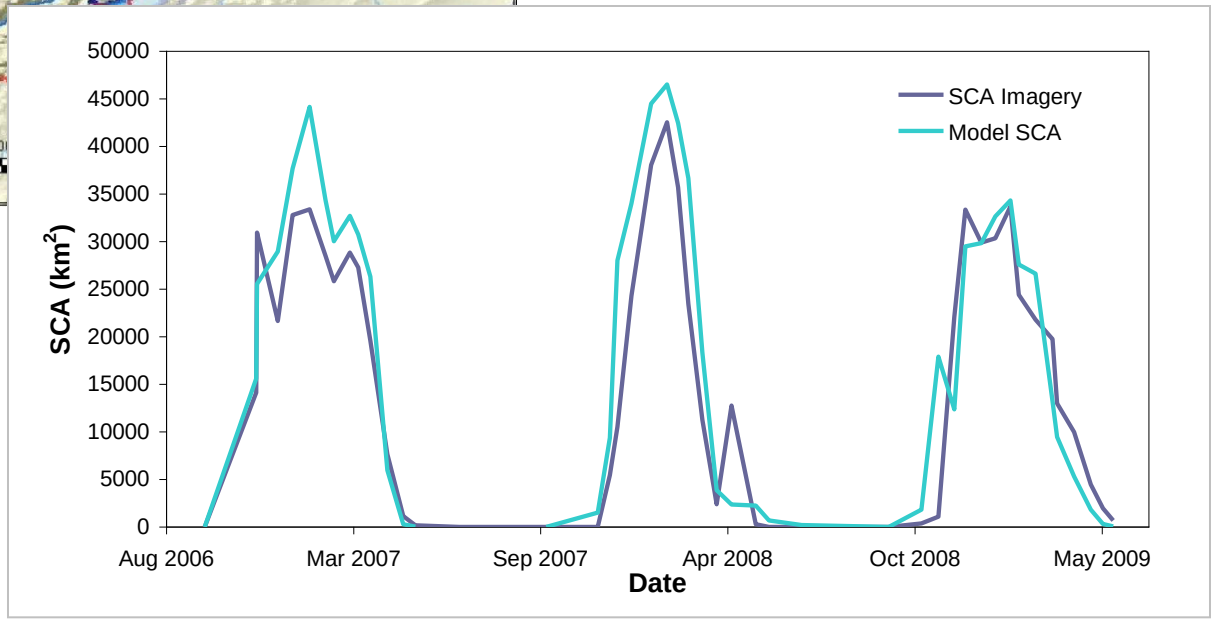
Snow Hydrology Model



Snow model calibration

- High-resolution SCA imagery available from 2006-2009
- Developed using AVHRR, MODIS
- $R^2 = 0.86$



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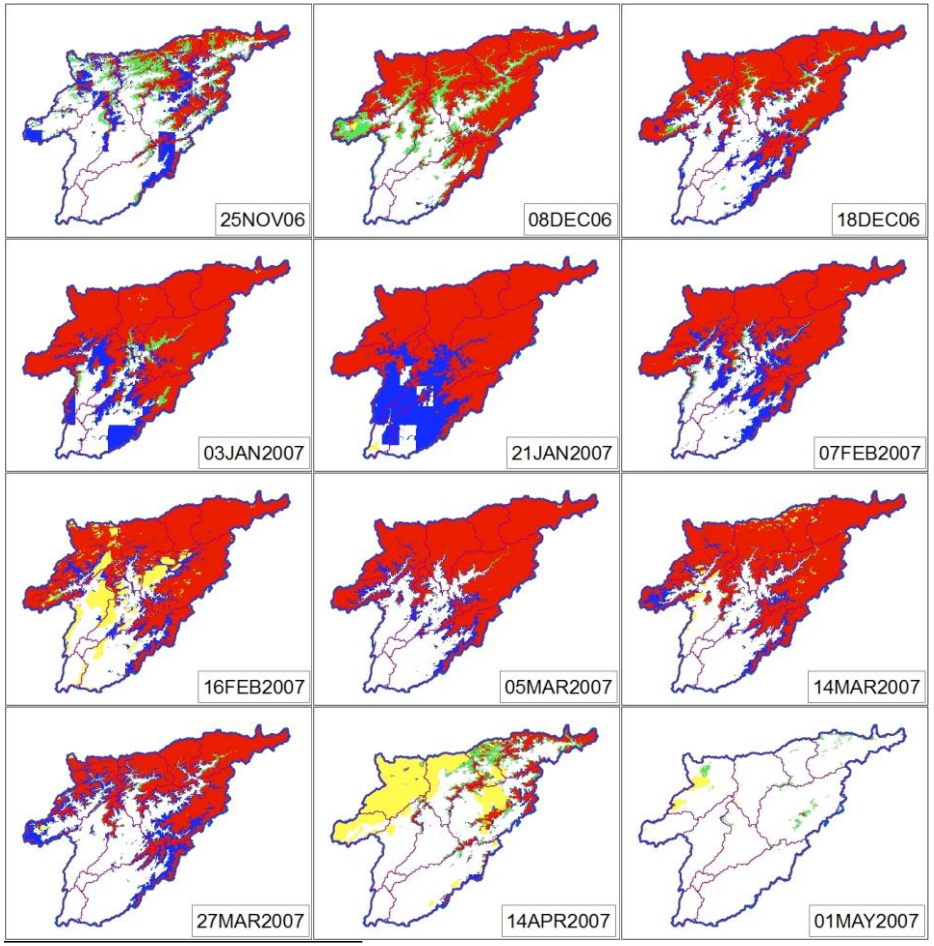
Snow Hydrology Model

2006-07

2006-07	Snow	No Snow	
Snow	257609	54672	312281
No Snow	19508	256006	275514
	277117	310678	587795

overall accuracy: 87.4%



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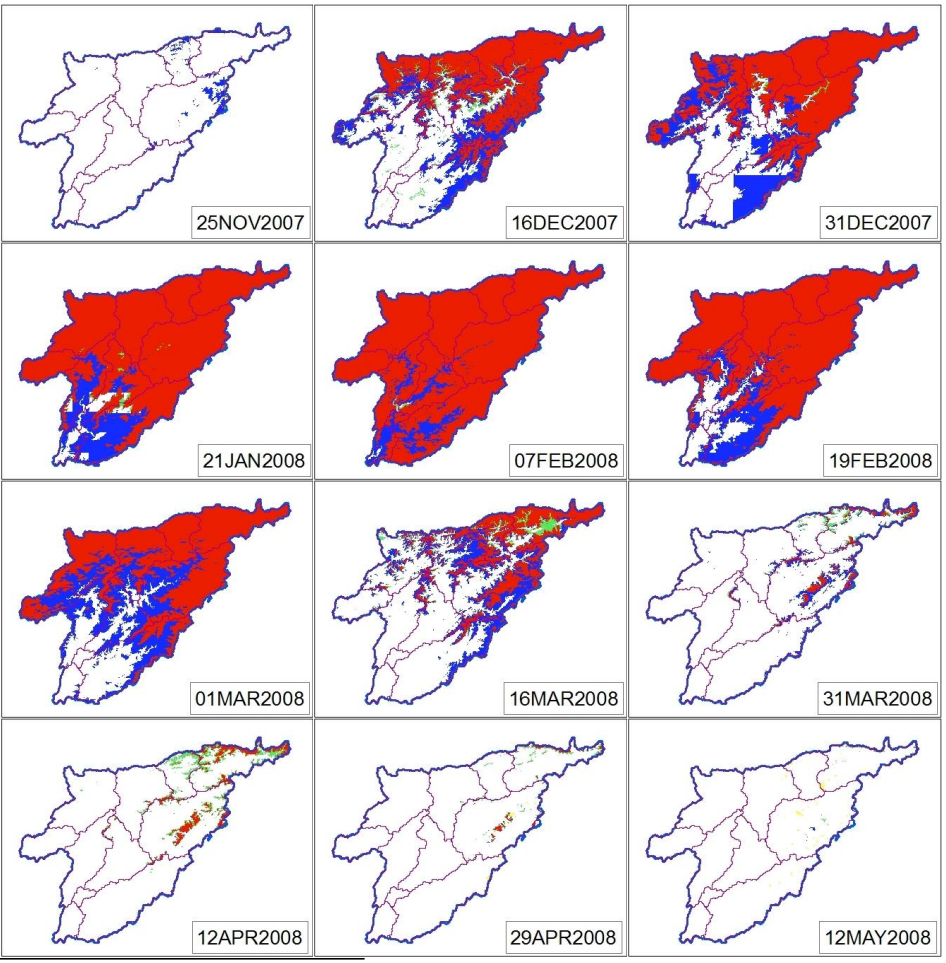
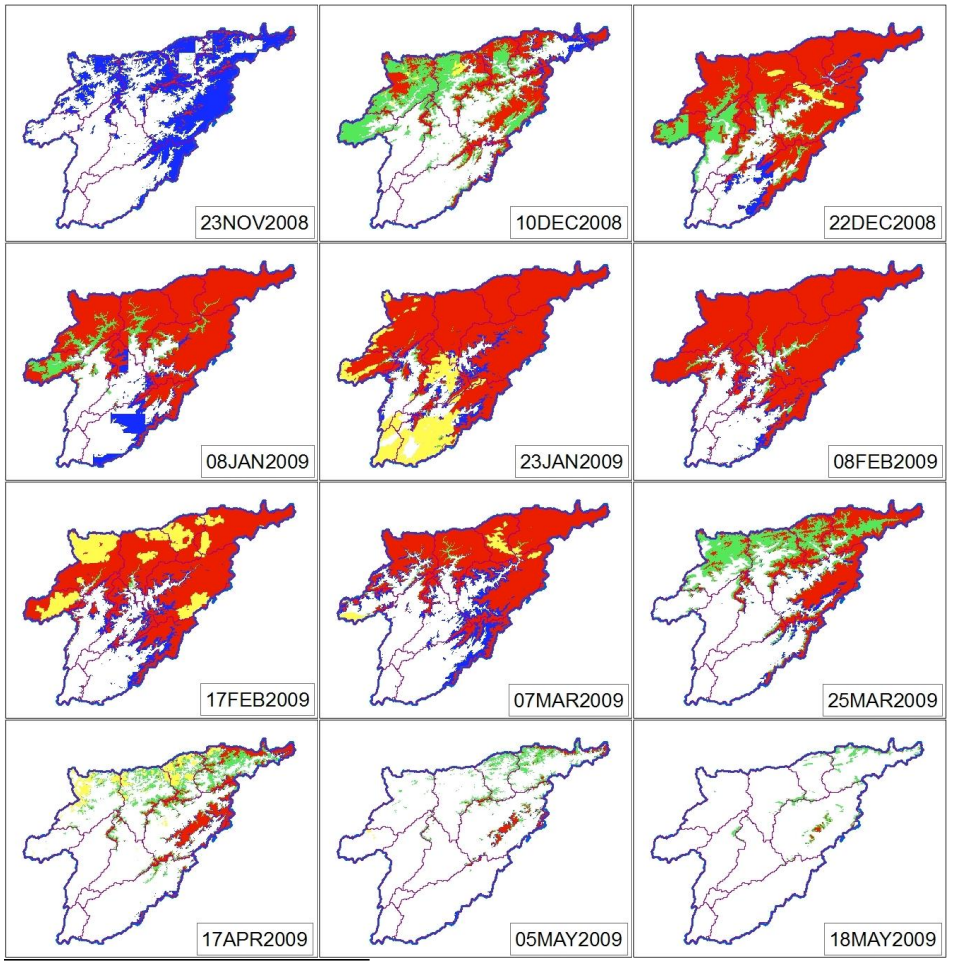
Snow Hydrology Model

2007-08



2008-09



2007-08	Snow	No Snow	
Snow	232353	69025	301378
No Snow	17948	347751	365699
	250301	416776	667077

overall accuracy: 86.96%

2008-09	Snow	No Snow	
Snow	220691	45613	266304
No Snow	48229	407097	455326
	268920	452710	721630

overall accuracy: 87.0%

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Hydrologic Model

- Model runoff was calibrated to reservoir inflows
- Reservoir Data available:
  - Monthly reservoir levels, 1998 through present
  - Daily reservoir levels, 2006-2007
  - Elevation-Discharge relationship
  - Elevation – Area – Storage relationship

$$I(t) = \Delta S + O(t) - P(t) + E(t)$$

- *O(t)* = outflow (cms), estimated from Elevation-Discharge relationship, based on unit capacity for Kajakai Dam
- *ΔS(t)* = Change in storage, based on Elevation-Area-Storage relationship, (USACE 2007, USGS 2007)
- *P(t)* = Precipitation (mm), TRMM
- *E(t)* = Evaporation (mm), estimated using Hargreaves method

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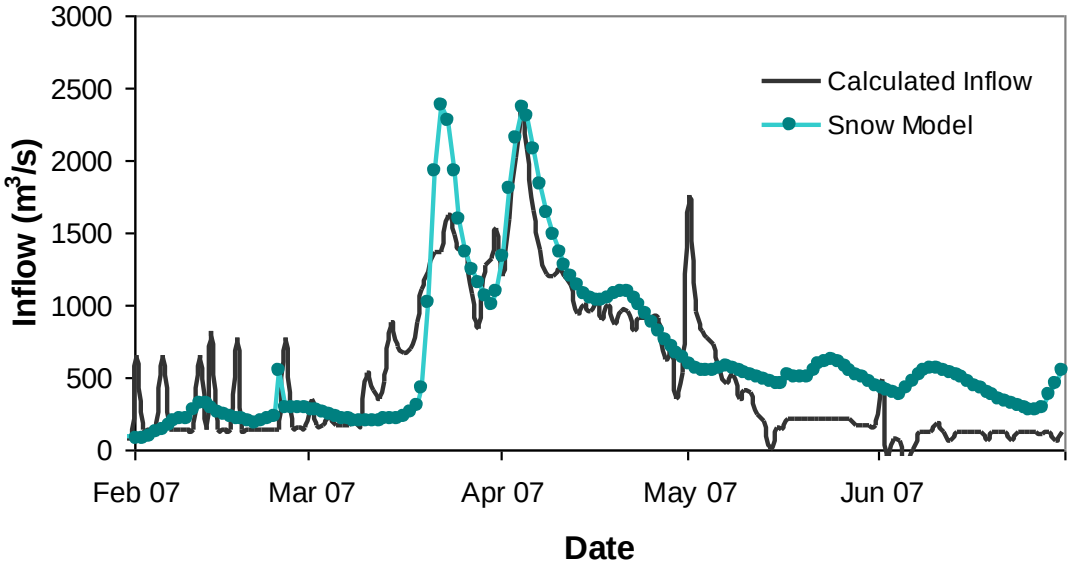
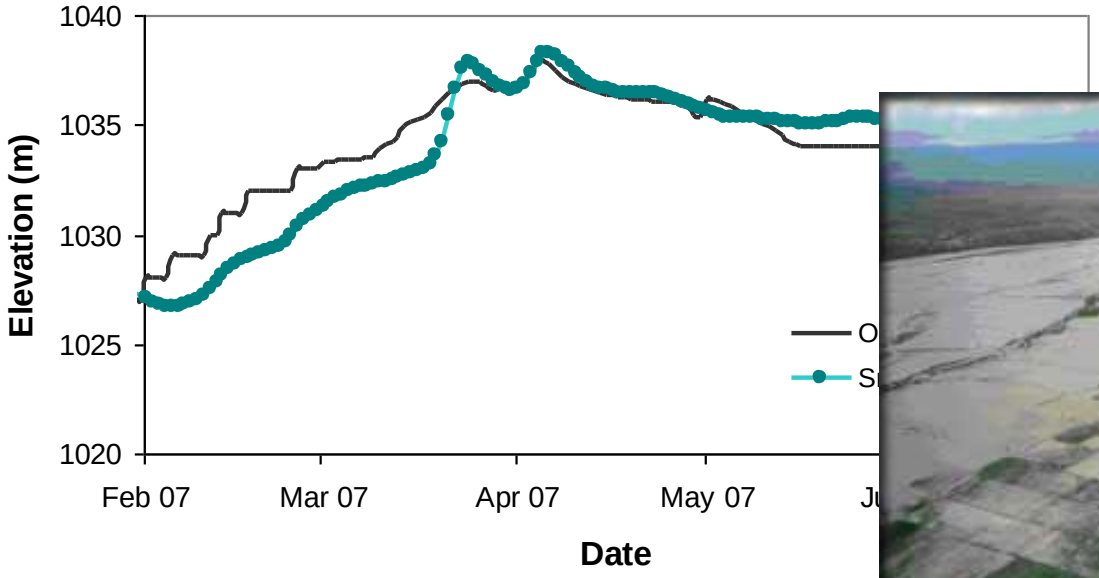
Hydrologic Model

2006-07



Reservoir Inflow (cms)



Water Level (m)

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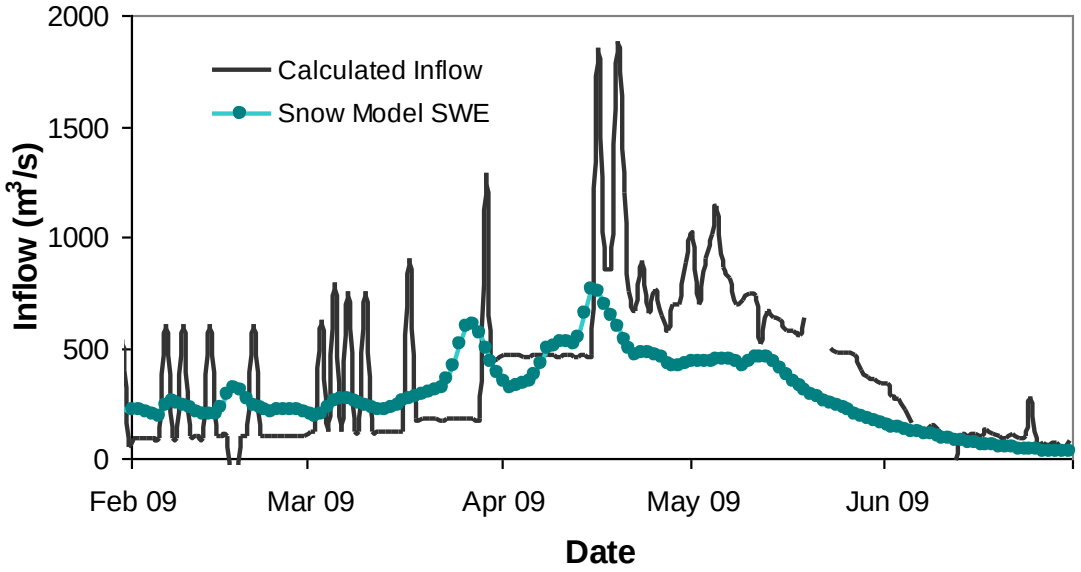
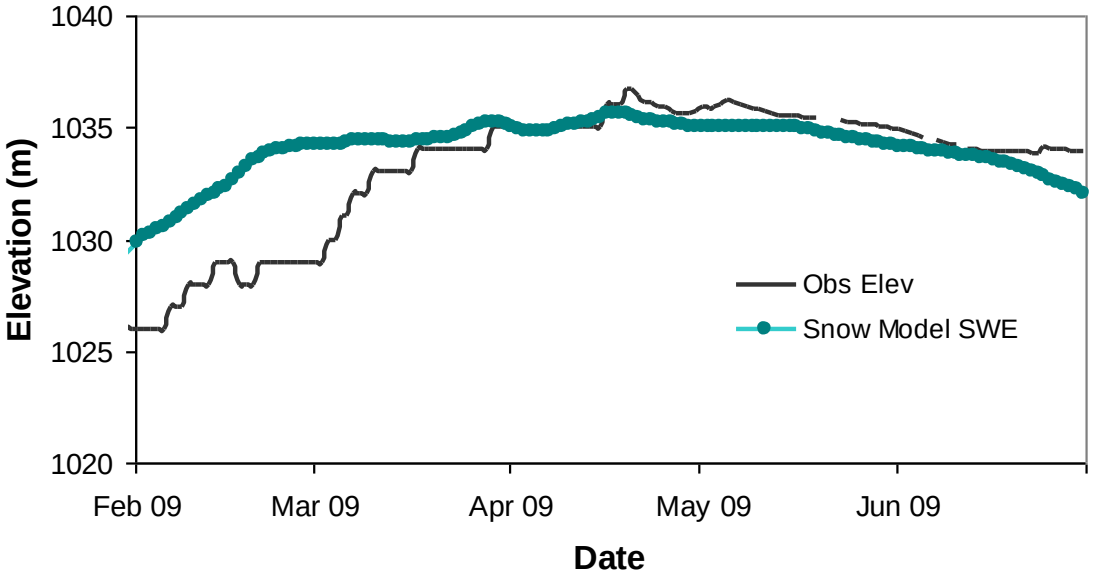
Hydrologic Model

2008-09



Reservoir Inflow (cms)



Water Level (m)

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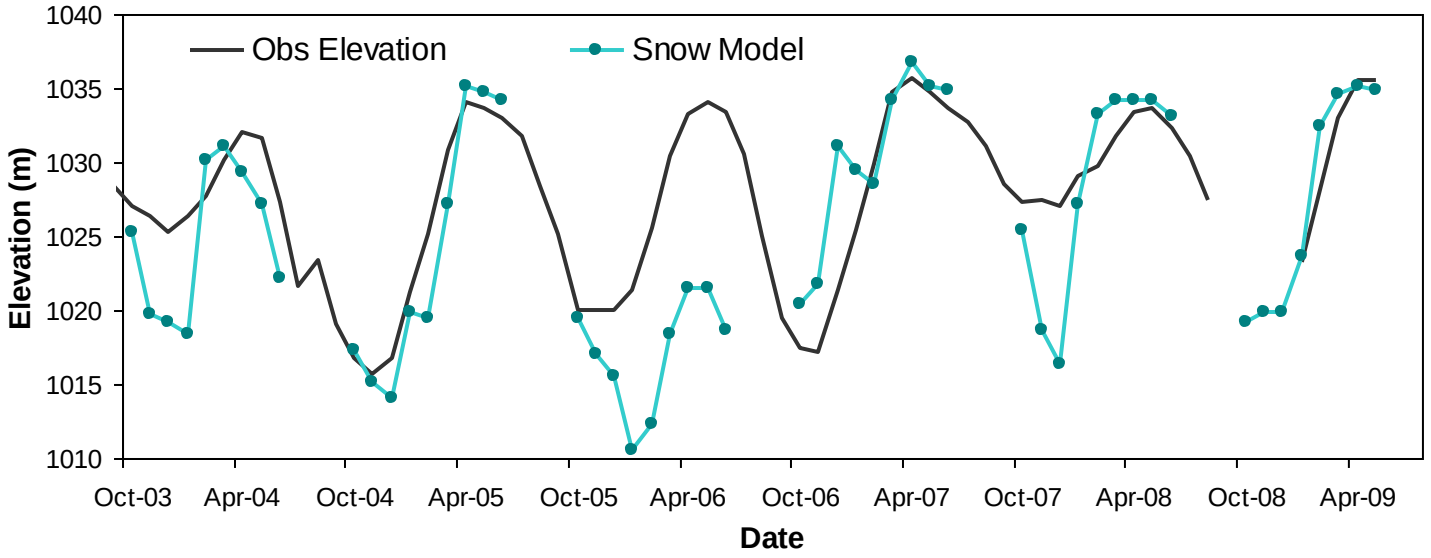
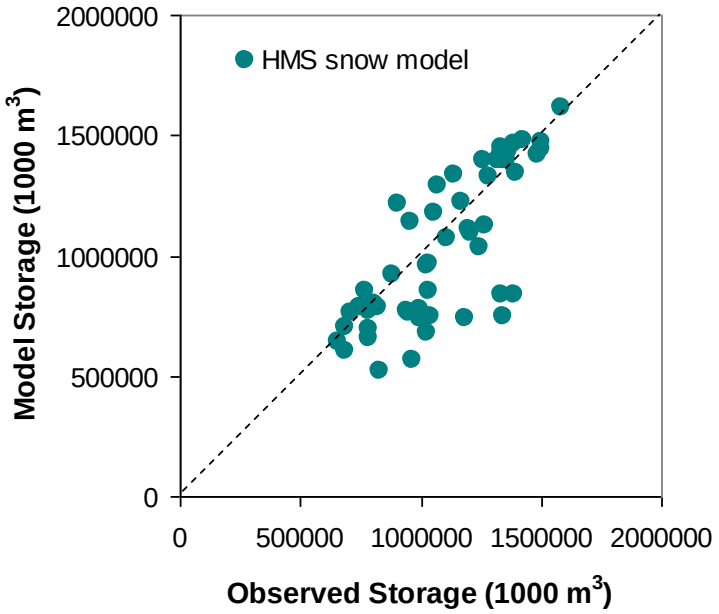
Hydrologic Model





Monthly average storage

$R^2 = 0.612$

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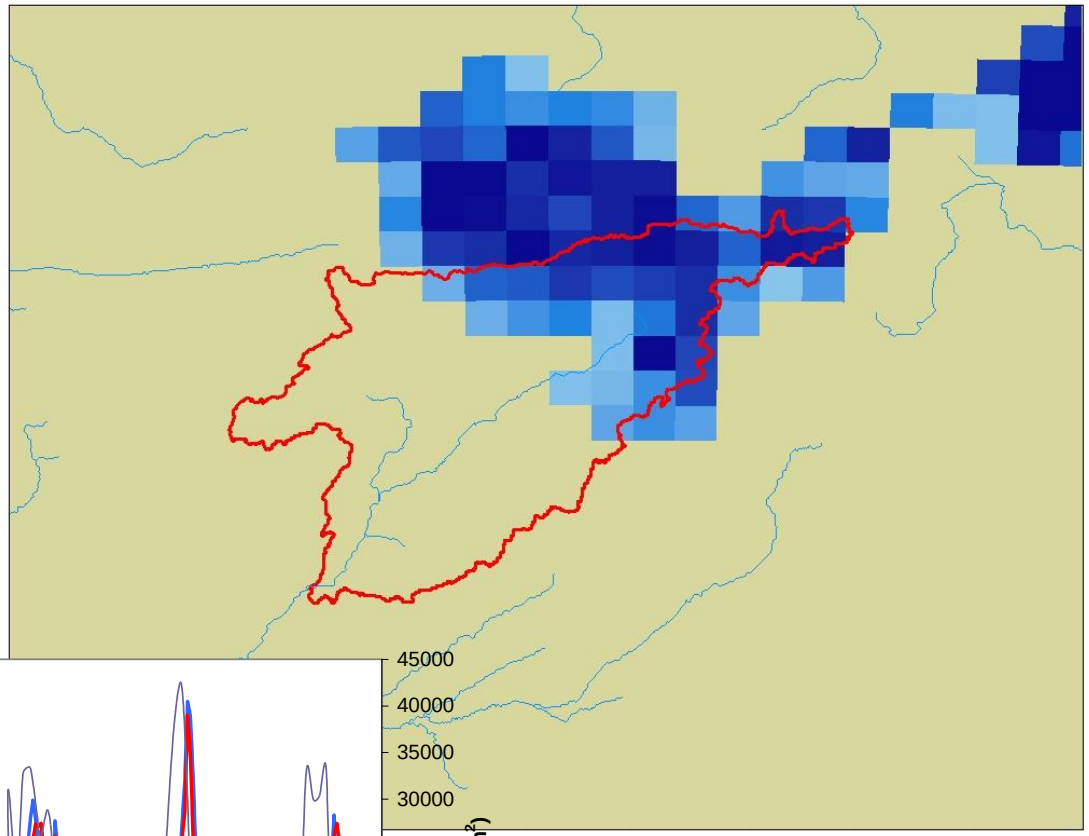
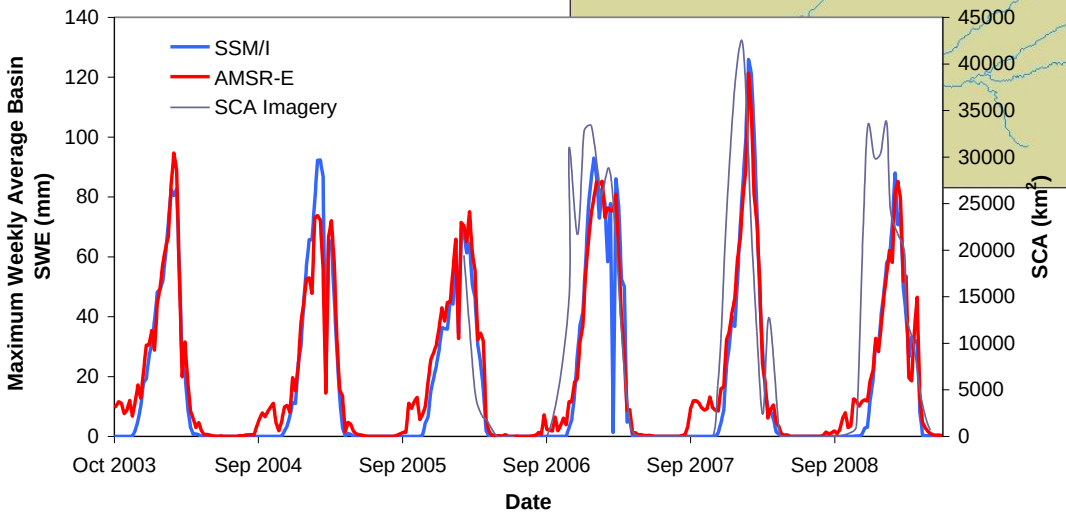
Passive Microwave SWE

- Sources of error
  - Snow metamorphosis
  - Wet snow
  - Saturation depth
  - Topology
  - Vegetation
  - Resolution – 25 km^2
- AMSR-E daily SWE product
  - NSIDC EASE Grid





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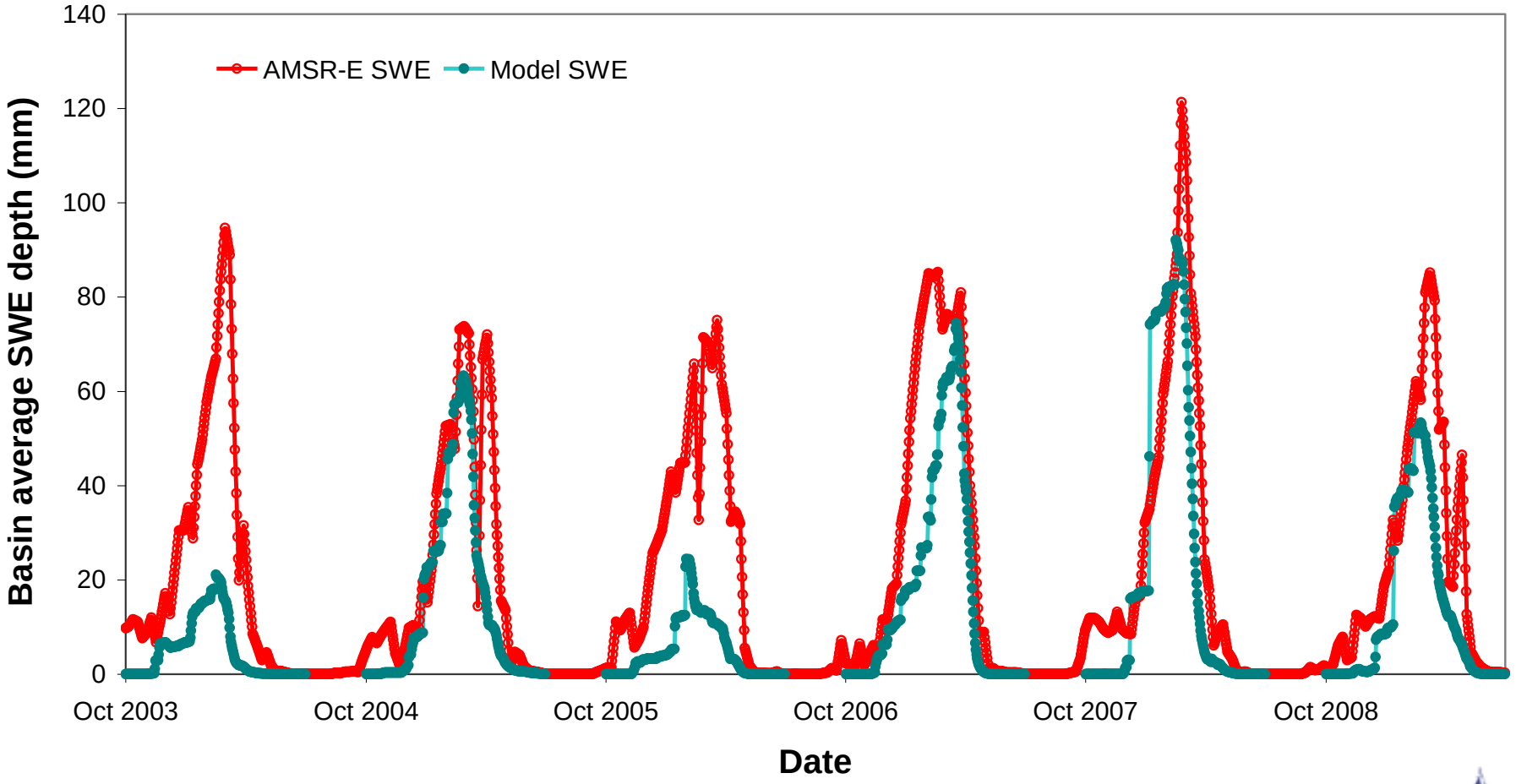
Passive Microwave SWE



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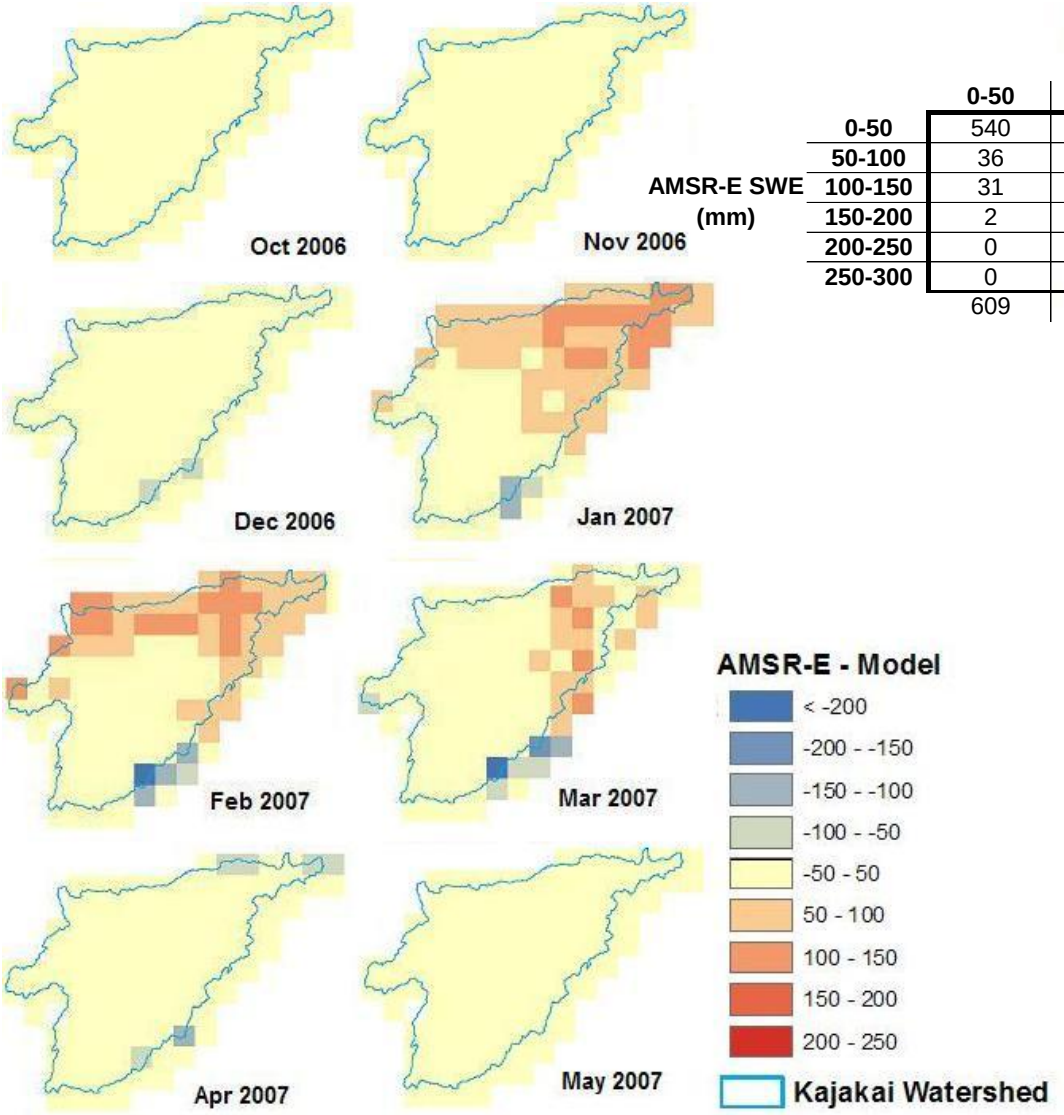
Passive Microwave SWE



AMSR-E SWE (mm)	Model SWE (mm) 0-50	50-100	100-150	150-200	200-250	250-300	
0-50	540	13	1	1	2	0	557
50-100	36	9	7	0	1	0	53
100-150	31	27	10	0	0	1	69
150-200	2	20	1	0	0	0	23
200-250	0	0	0	0	0	0	0
250-300	0	0	0	0	0	0	0
	609	69	19	1	3	1	702

Overall match: 79.6%

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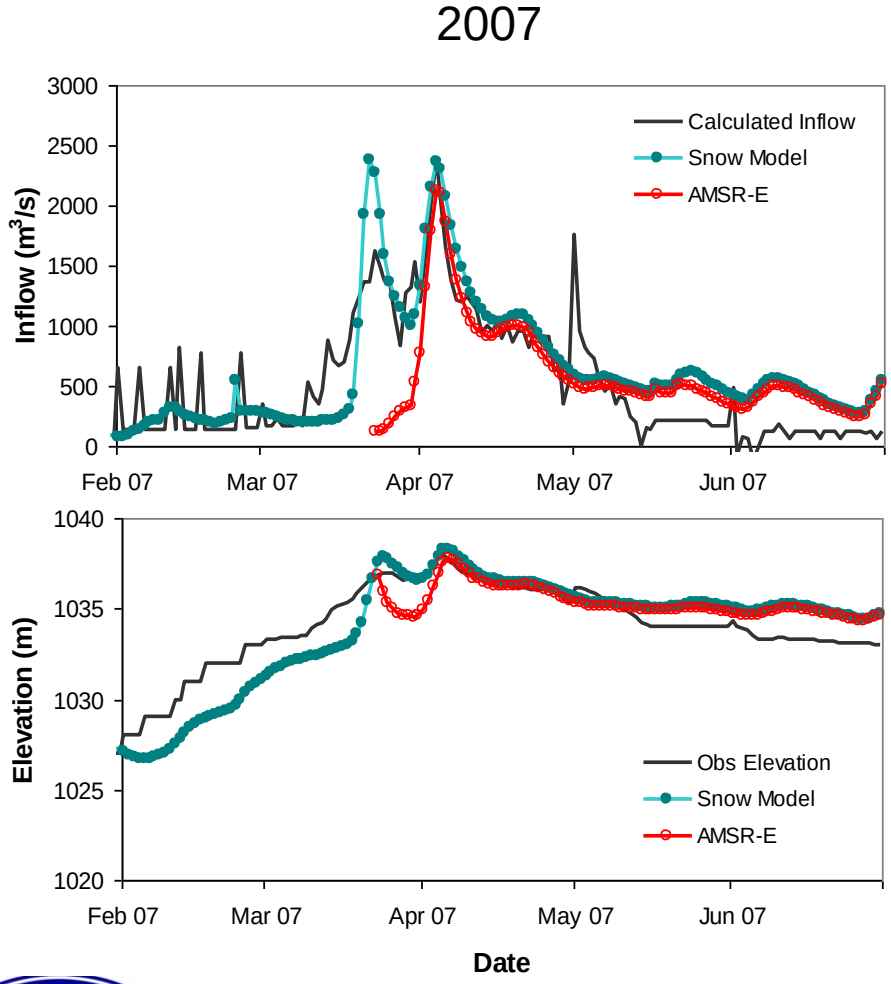
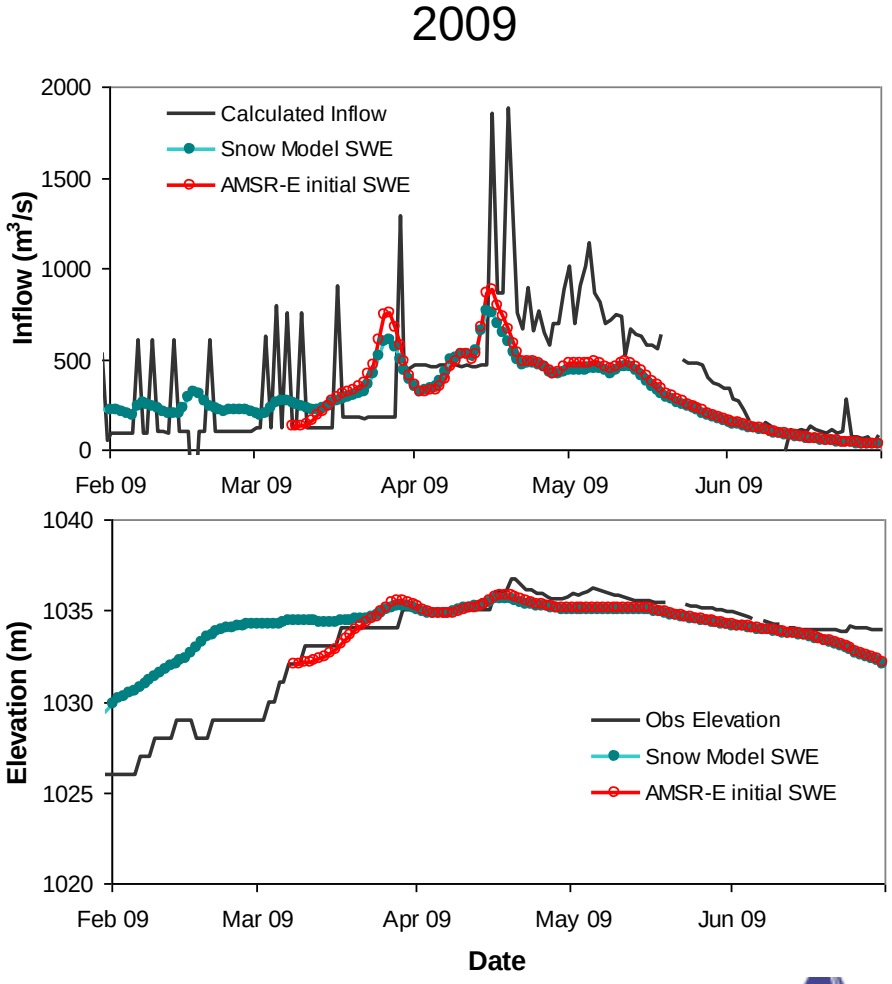
Using AMSR-E as initial conditions





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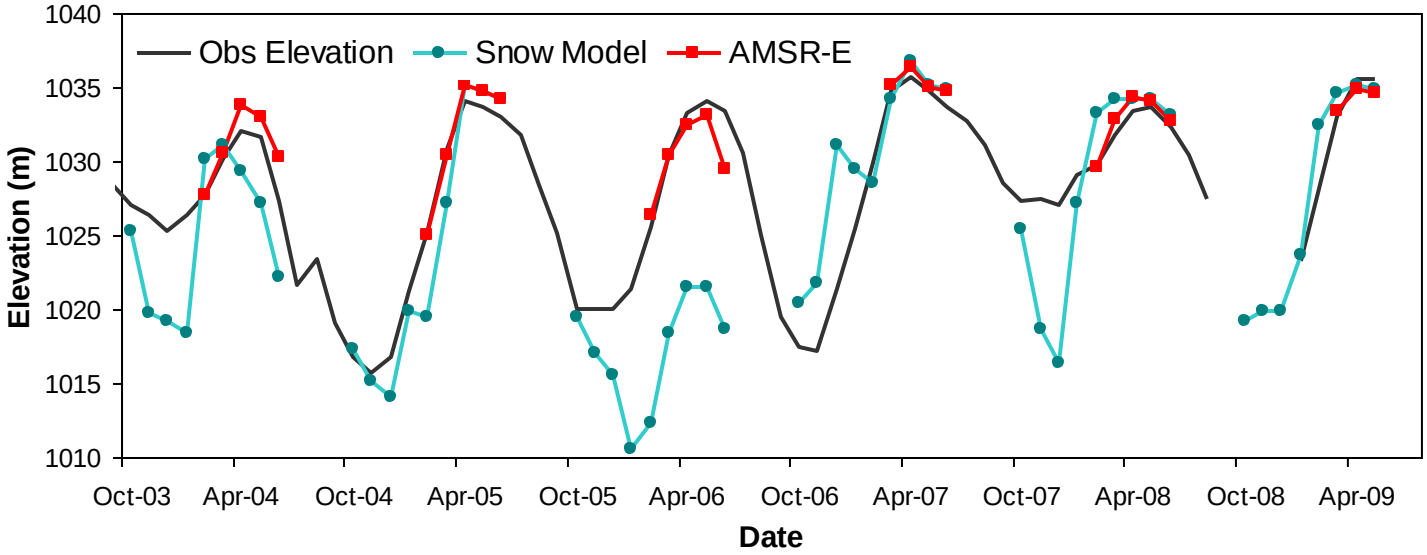
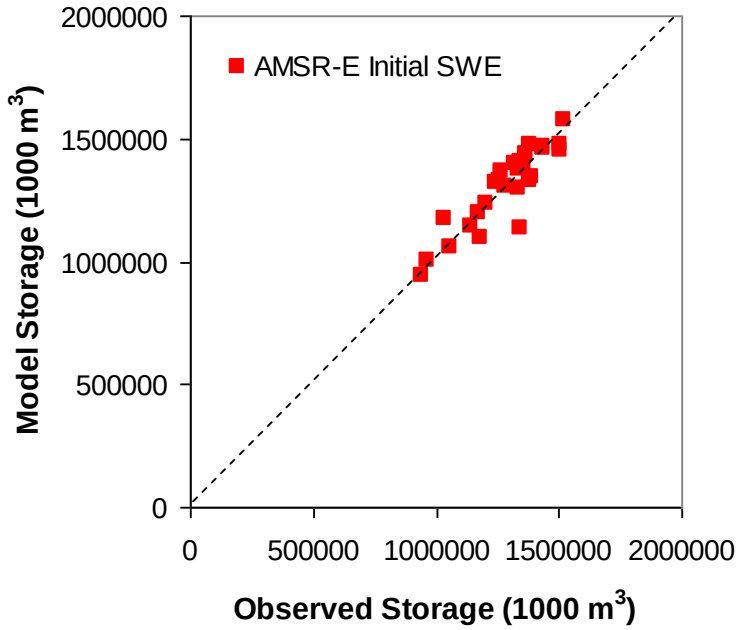
Using AMSR-E as initial conditions





Monthly average storage

Original model, $R^2 = 0.612$

Initial AMSR-E SWE, $R^2 = 0.814$

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Conclusions

- A hydrologic model of the Upper Helmand watershed is sensitive to input precipitation
  - Additional gages, improvements to satellites estimates, analyses of orographic effects will help improve model results
- The snow model accurately models snow accumulation and melt and can provide useful information about the snow hydrology of the region.
- Passive microwave SWE data provides a reasonable estimate of the water volume in the snow.
- Reservoir managers can use this information in operating decisions, both to maximize water supply and reduce flood risk.
- Passive microwave SWE can also be used to initialize the hydrologic model for use in forecasting and design.

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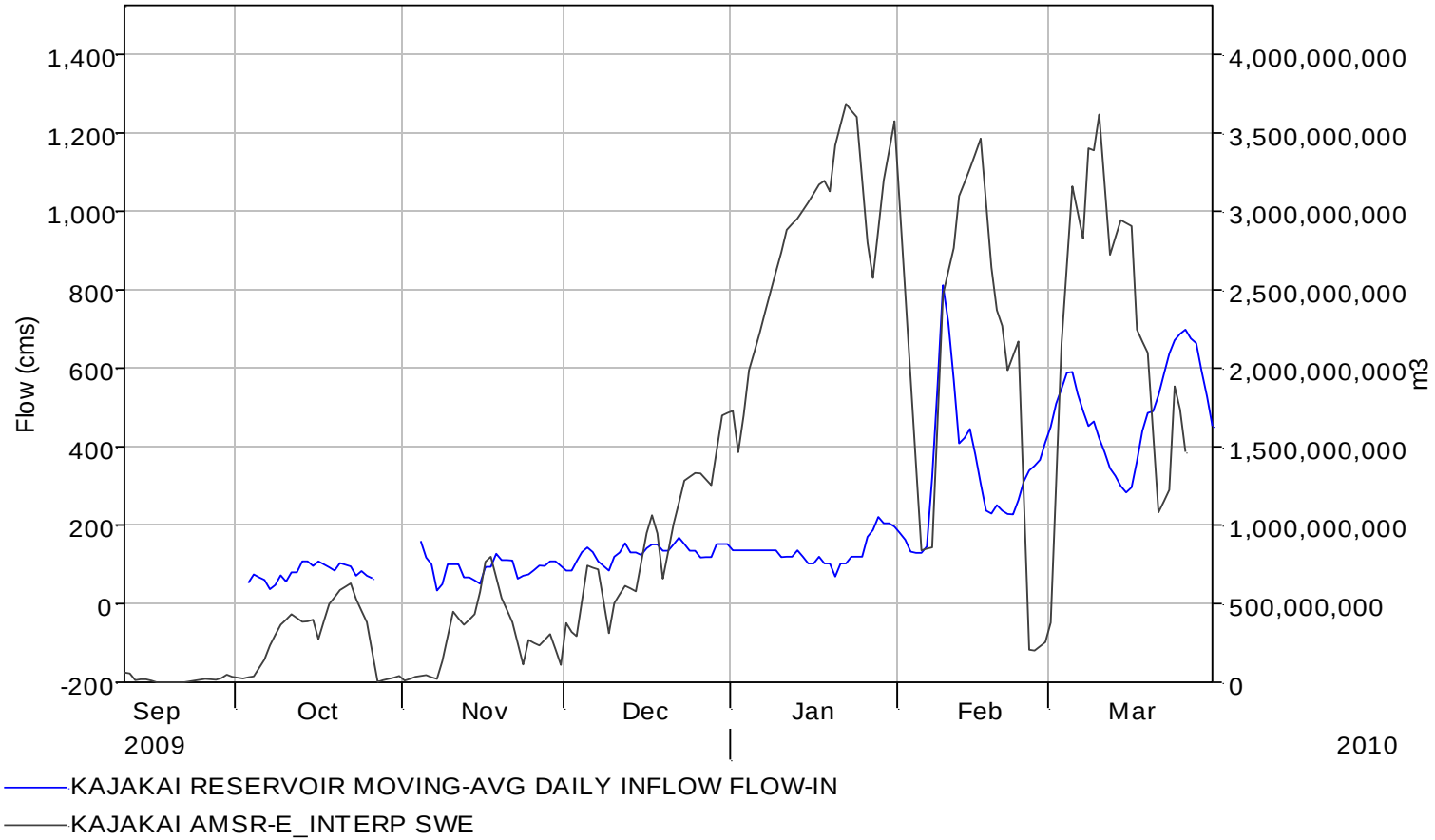
Thank you



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