



a place of mind



Member-to-Member Ensemble Hydrometeorological Modeling

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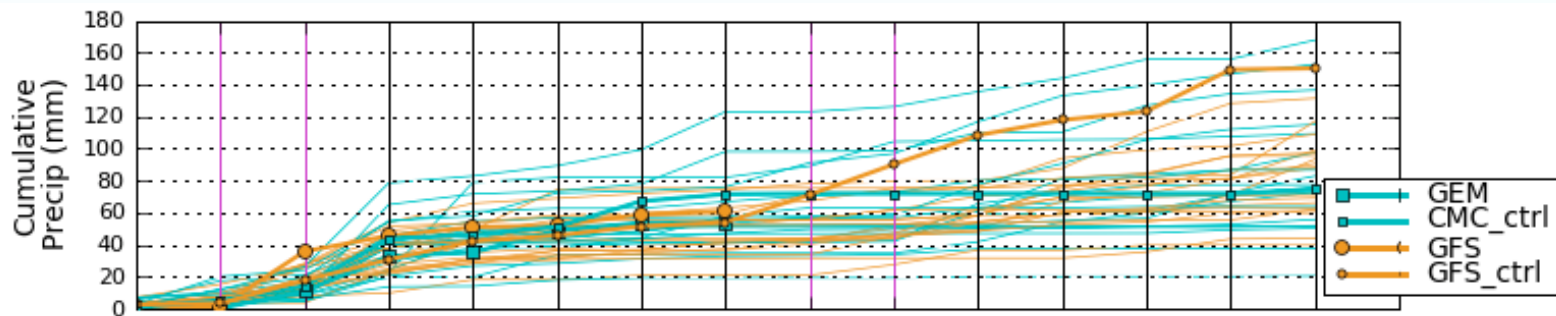
October 6, 2011
CSHS Workshop

Outline

- Ensemble and Probabilistic Forecasting
- Capturing Model Uncertainty with Ensembles
- Member-to-Member Ensemble
- Case Study

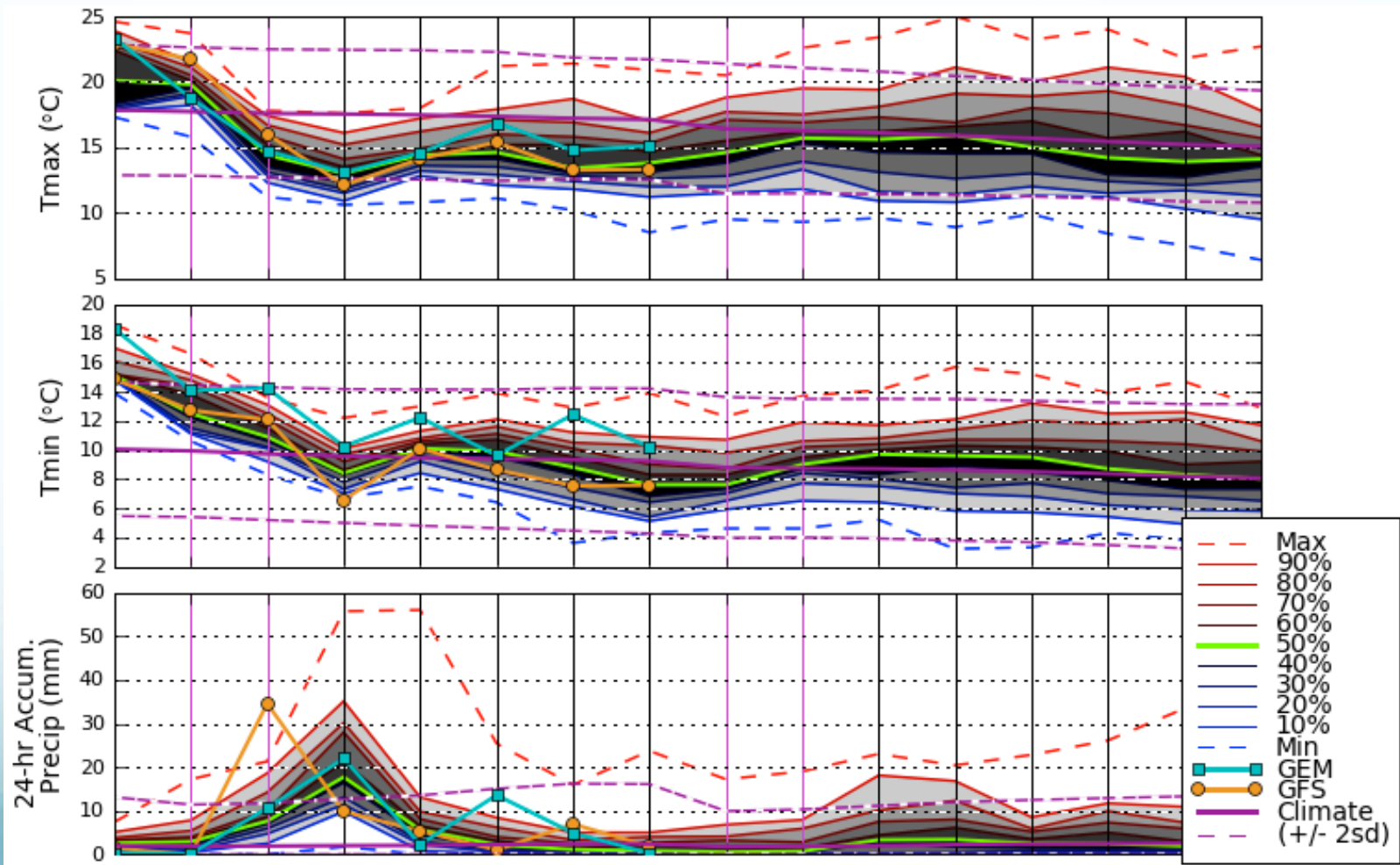
Ensemble and Probabilistic Forecasting

- Make a number of forecasts designed to sample the range of forecast uncertainty



- Ensemble mean has been shown to outperform any one deterministic model
- True value lies in ability to provide probabilistic forecasts, measure of (total) forecast uncertainty

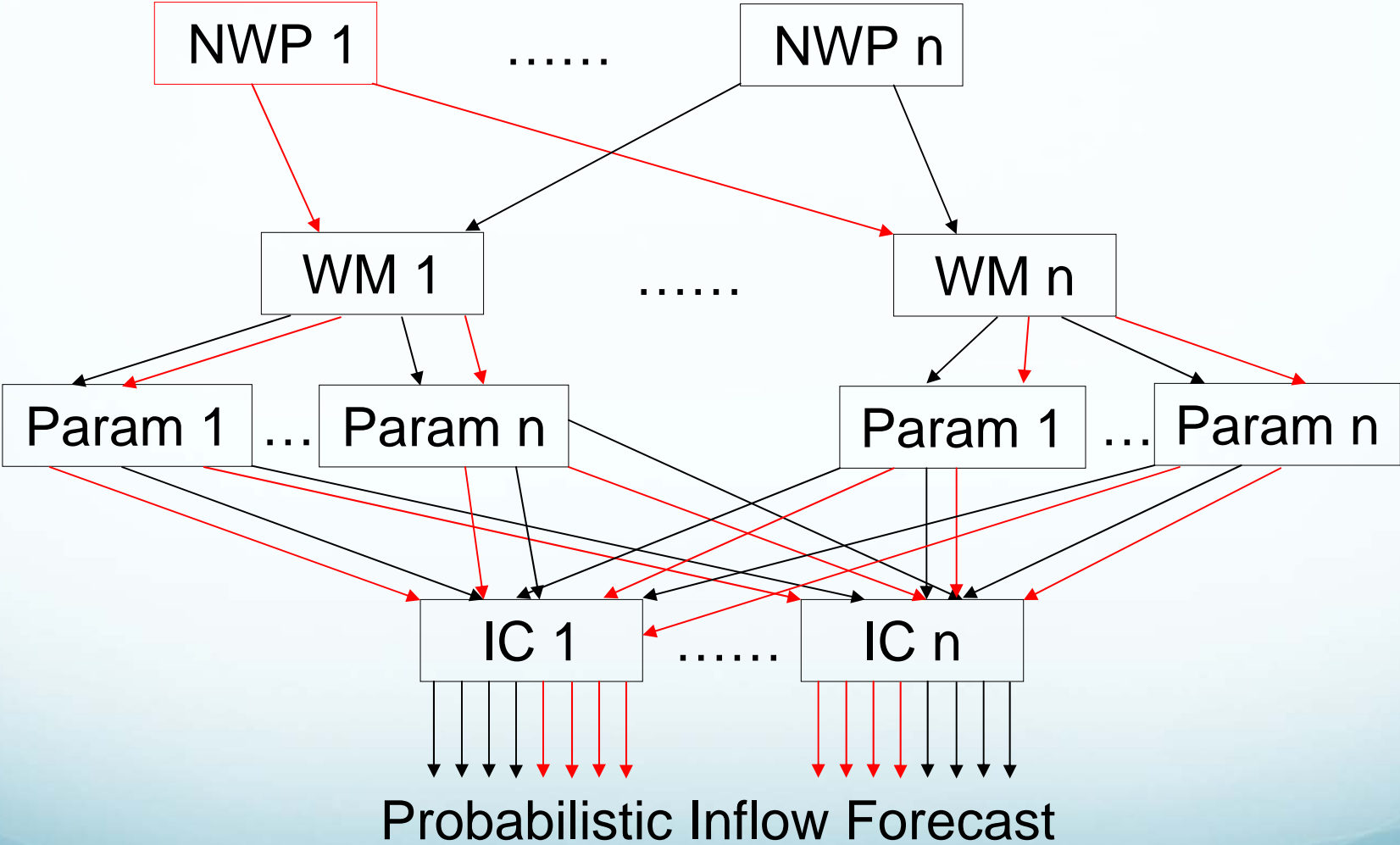
Ensemble and Probabilistic Forecasting



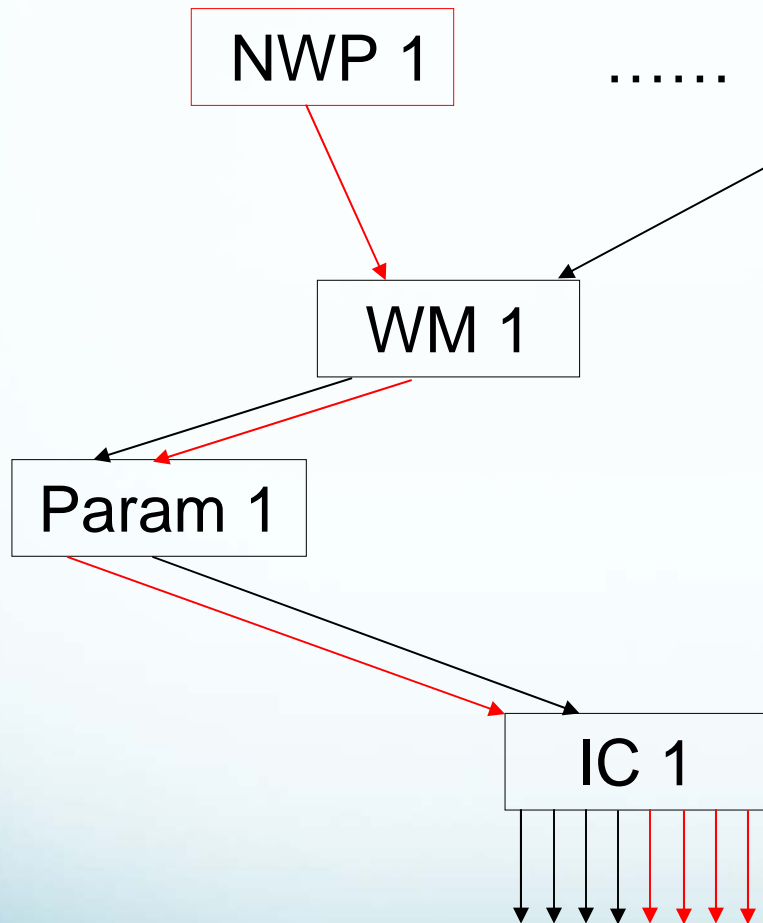
Capturing Uncertainty

Source of Uncertainty	Ensemble Approach
Initial conditions	Multi-analysis
Parameterization	Varied-model
Model Structure	Multi-model
Boundary conditions	Multiple meteorological inputs
All	NWP: Super-ensembles Hydro: M2M

Member-to-Member Ensemble

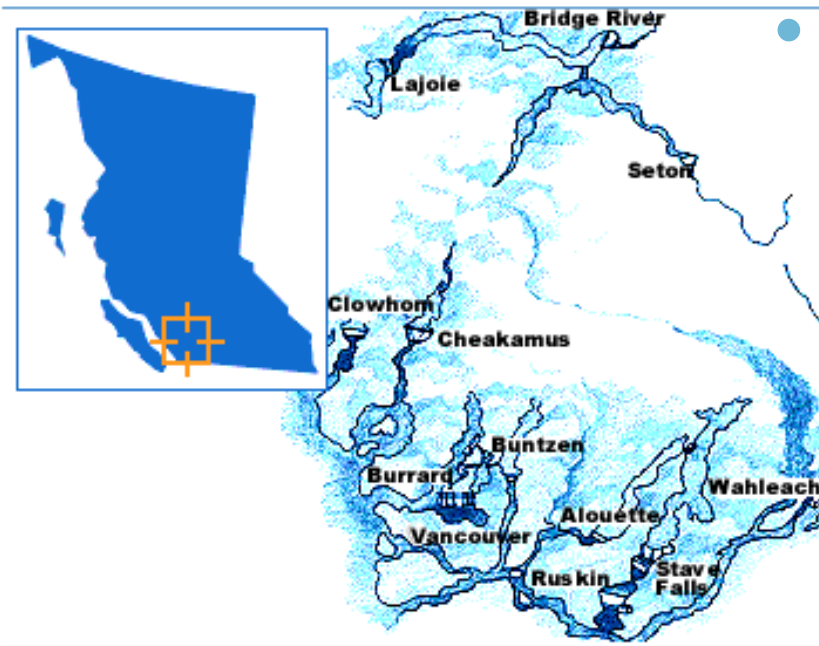


Case Study



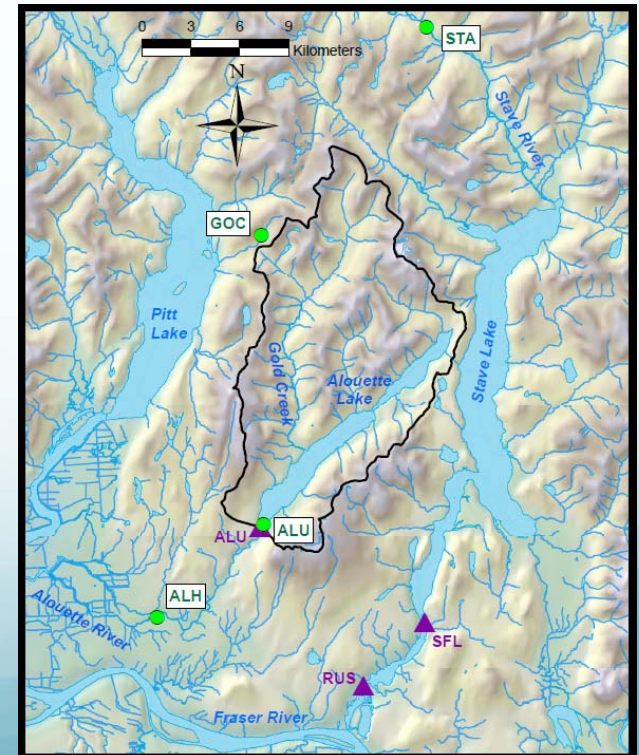
- Test the feasibility of using high-resolution NWP output to drive a distributed watershed model in complex terrain
 - Are any of the modeling systems skillful? At what lead-times?
 - Do the models have the potential to contribute skill to an ensemble inflow forecast?

Case Study



- Alouette Watershed
 - Drainage area 200 km²
 - Steep terrain on north shore of Fraser River
 - Driven primarily by rainfall from Pacific storms

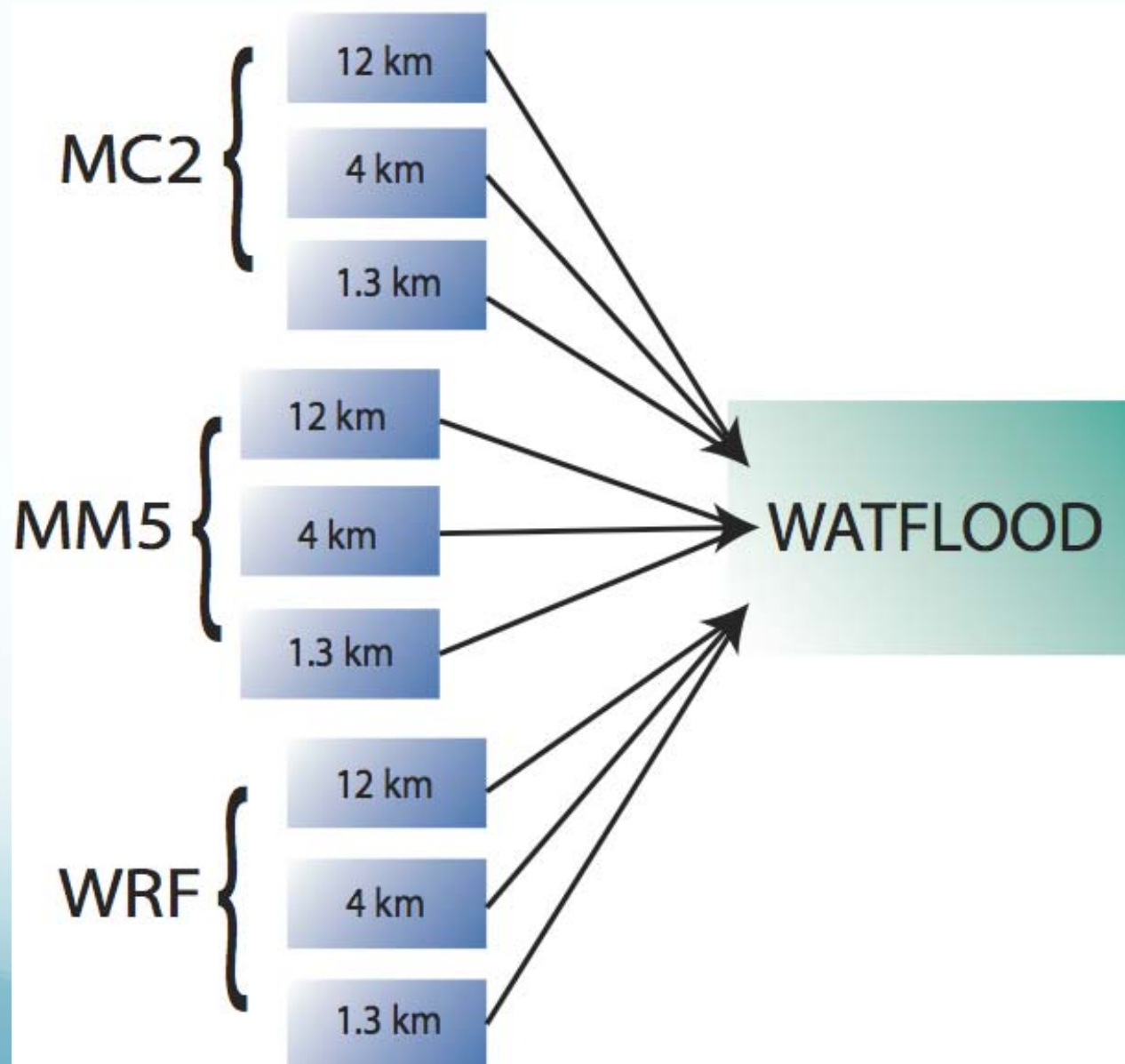
- 22-26 October, 2010
 - Series of Pacific frontal systems
 - 100 mm precip at Alouette Dam (125 m)
 - 200 mm precip at Gold Creek (794 m)
 - Daily mean inflow peak ~ 140 cms on 25 Oct



Models Employed

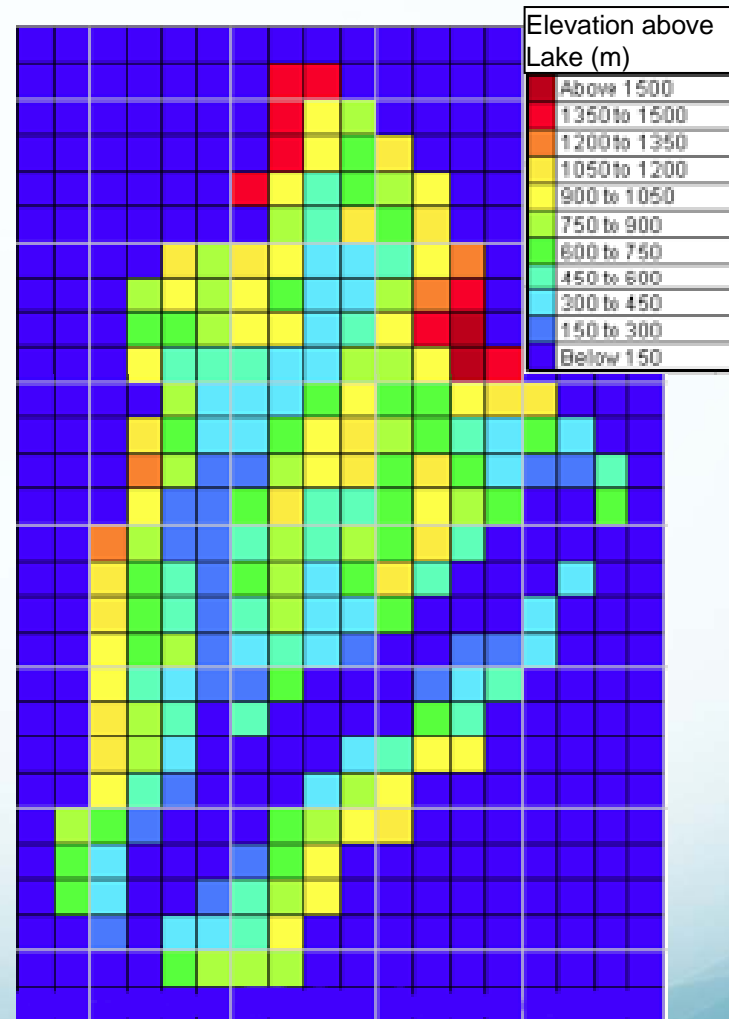
- Weather Models
 - Mesoscale Compressible Community Model (MC2)
 - 5th Generation Pennsylvania State University - National Center for Atmospheric Research Mesoscale Model (MM5)
 - Weather Research and Forecasting Model (WRF3)
 - Nested grids of 108, 36, 12, 4 and 1.3 km grid spacing
- Hydrologic Model
 - WATFLOOD/SPL9
 - Physically-based, distributed
 - Requires Temperature and Precipitation

Models Employed



Model Setup

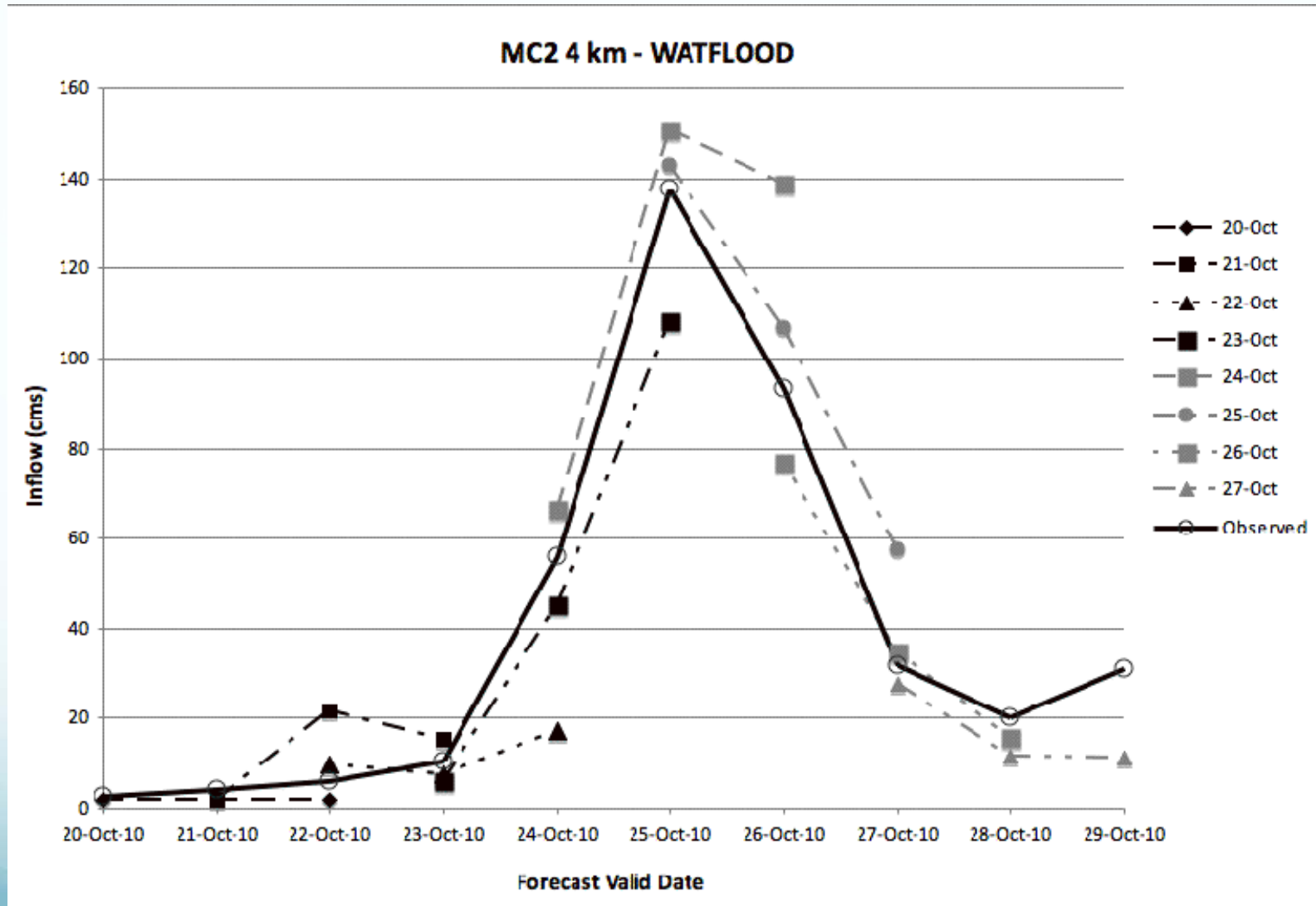
- Watershed files set up and calibrated by Nick Kouwen
- Meteorological quantities downscaled to 1x1 km watershed grid using built-in methods (RAGMET, TMP)
- WATFLOOD spun up using quality-controlled observations from 1 Oct, 2009 to 31 Aug, 2010
- NWP models were used to continue spin-up until beginning of inflow event (1 Sept - 19 Oct, 2010)
 - Nine different initial model states



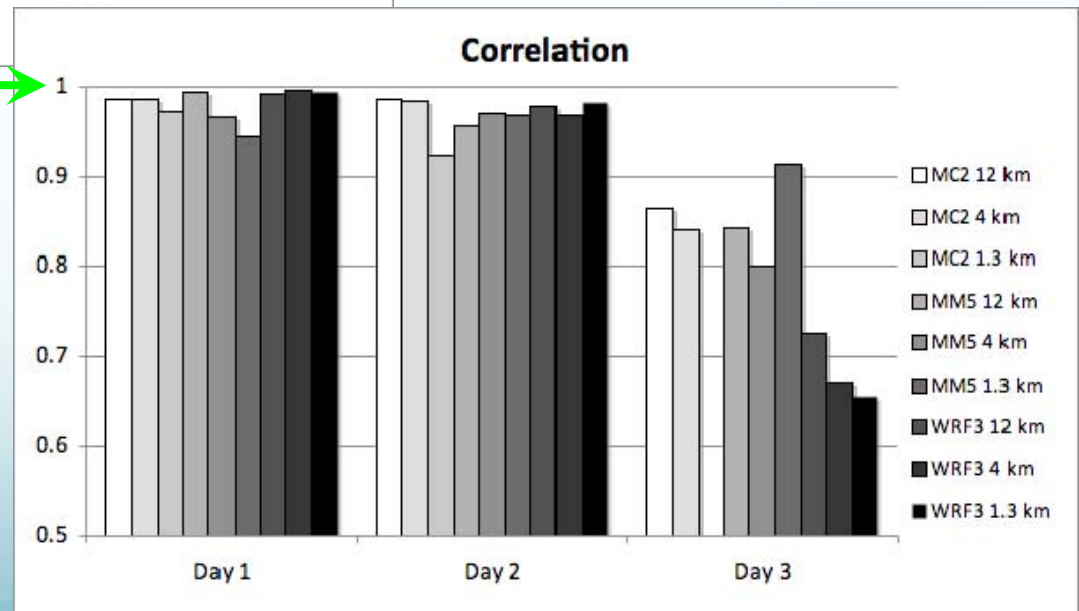
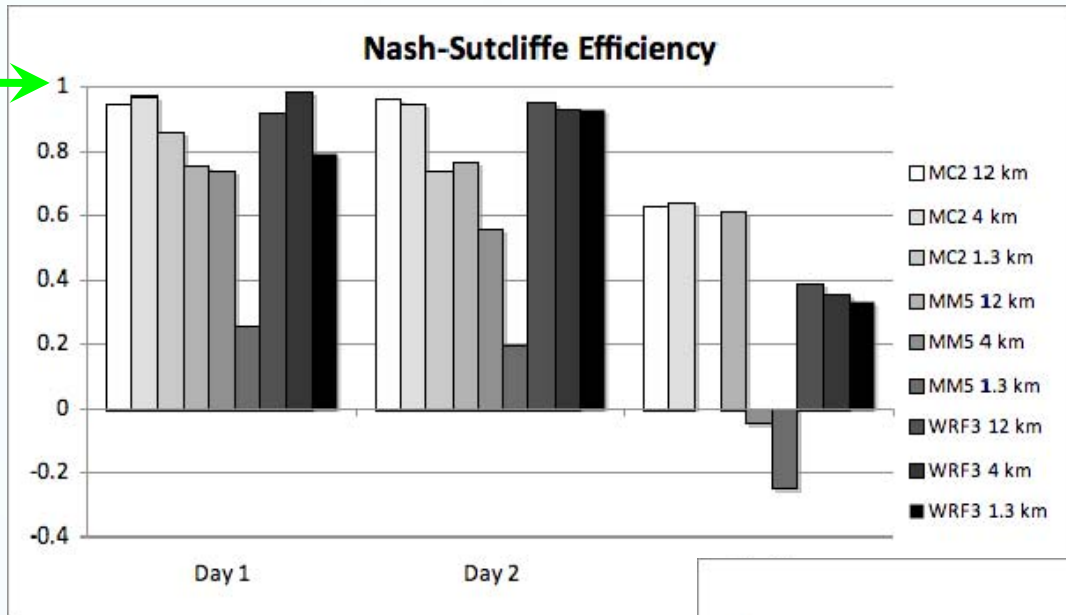
Methods

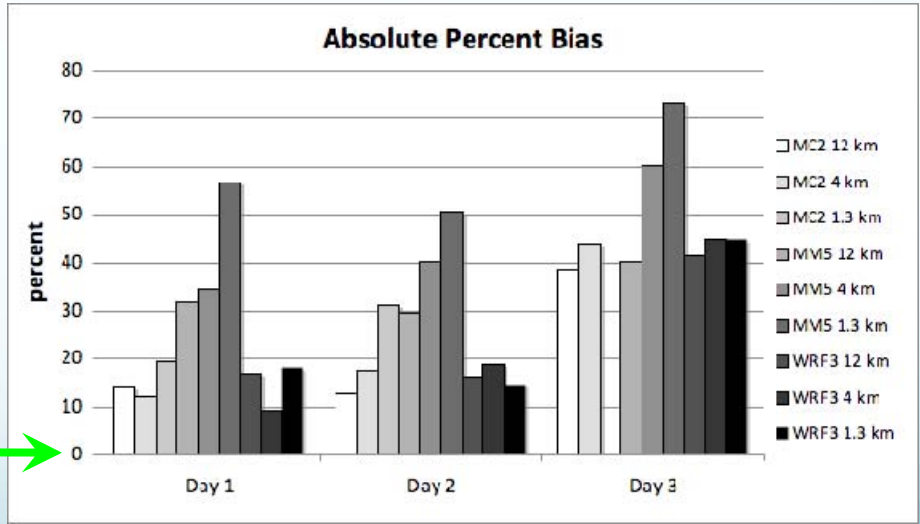
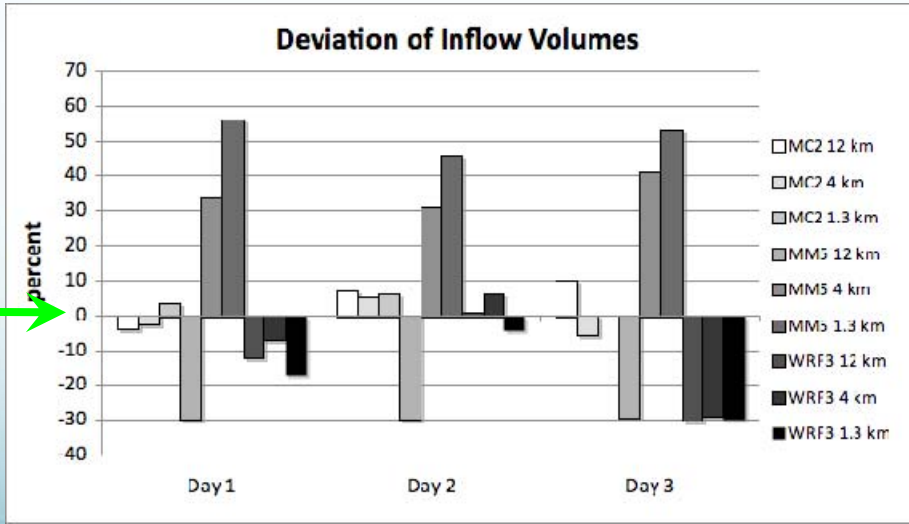
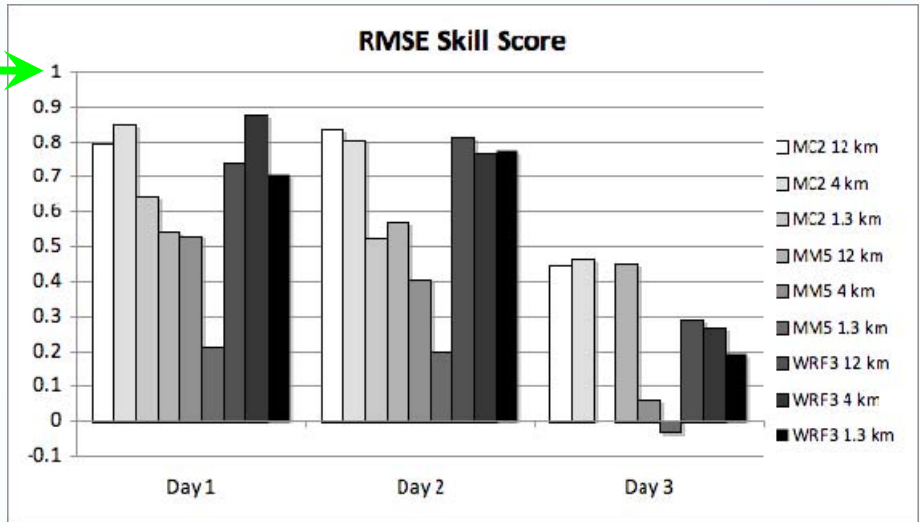
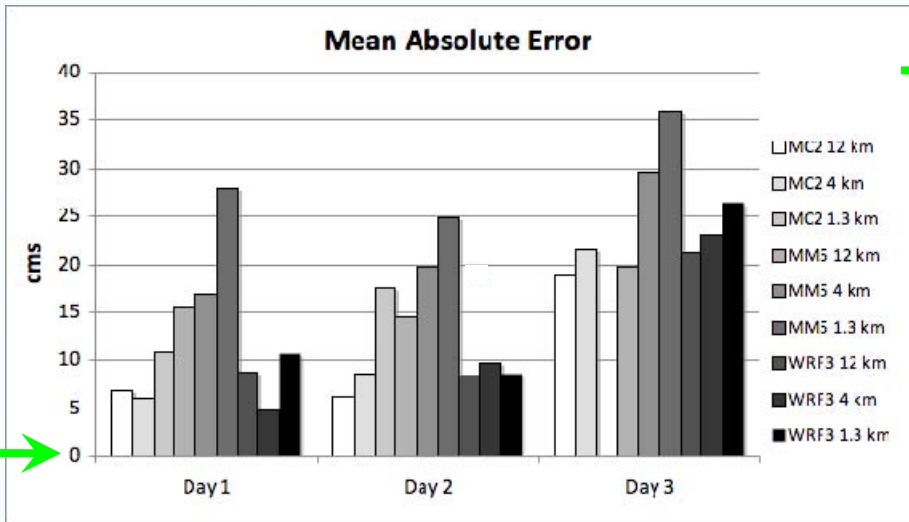
- WATFLOOD output of hourly inflows combined into mean daily inflow rates
- Inflow forecasts compared with mean daily inflow rates calculated by BC Hydro (“observations”)
- Evaluation based on WATFLOOD statistics
 - Nash-Sutcliffe Efficiency (NSE)
 - Correlation coefficient (r)
 - Mean Absolute Error (MAE)
 - Deviation of runoff volumes (D_v)
 - Absolute Percent Bias (APB)
- RMSE Skill Score (RMSESS) relative to zero-skill persistence forecast

Case Study Results

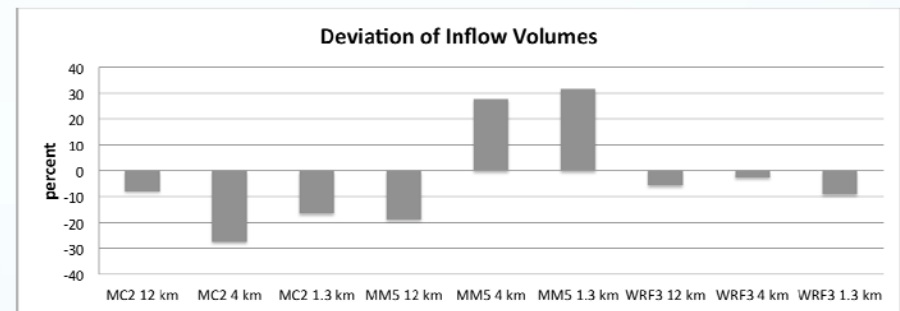
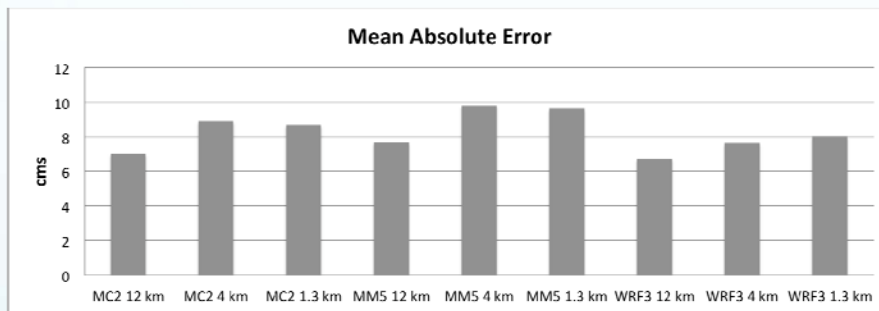
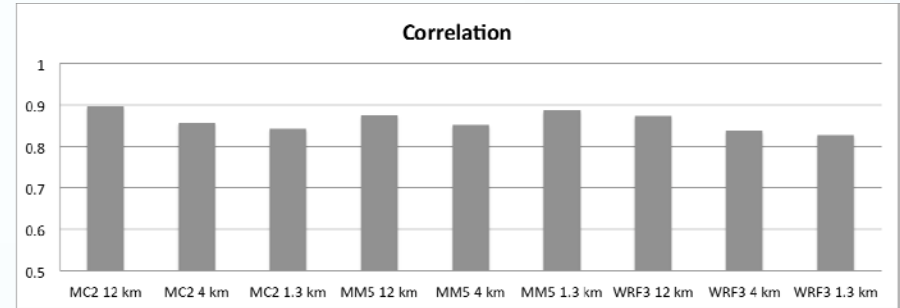
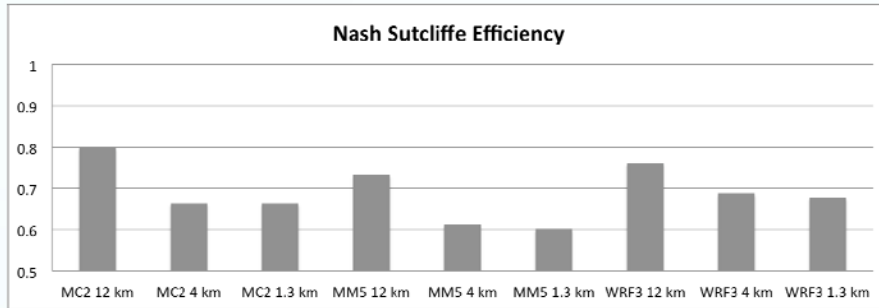


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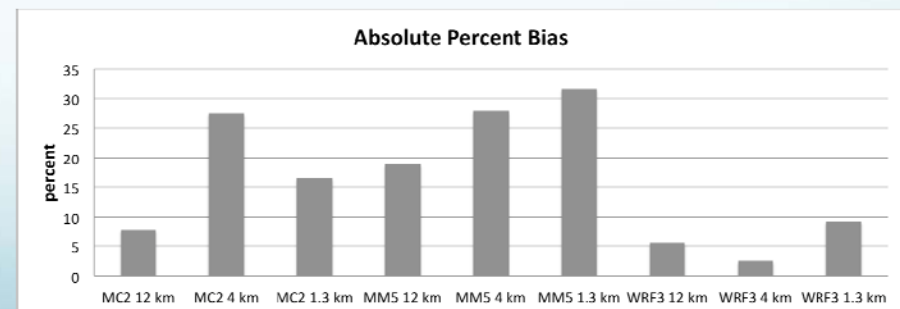




NWP Spin-Up Results



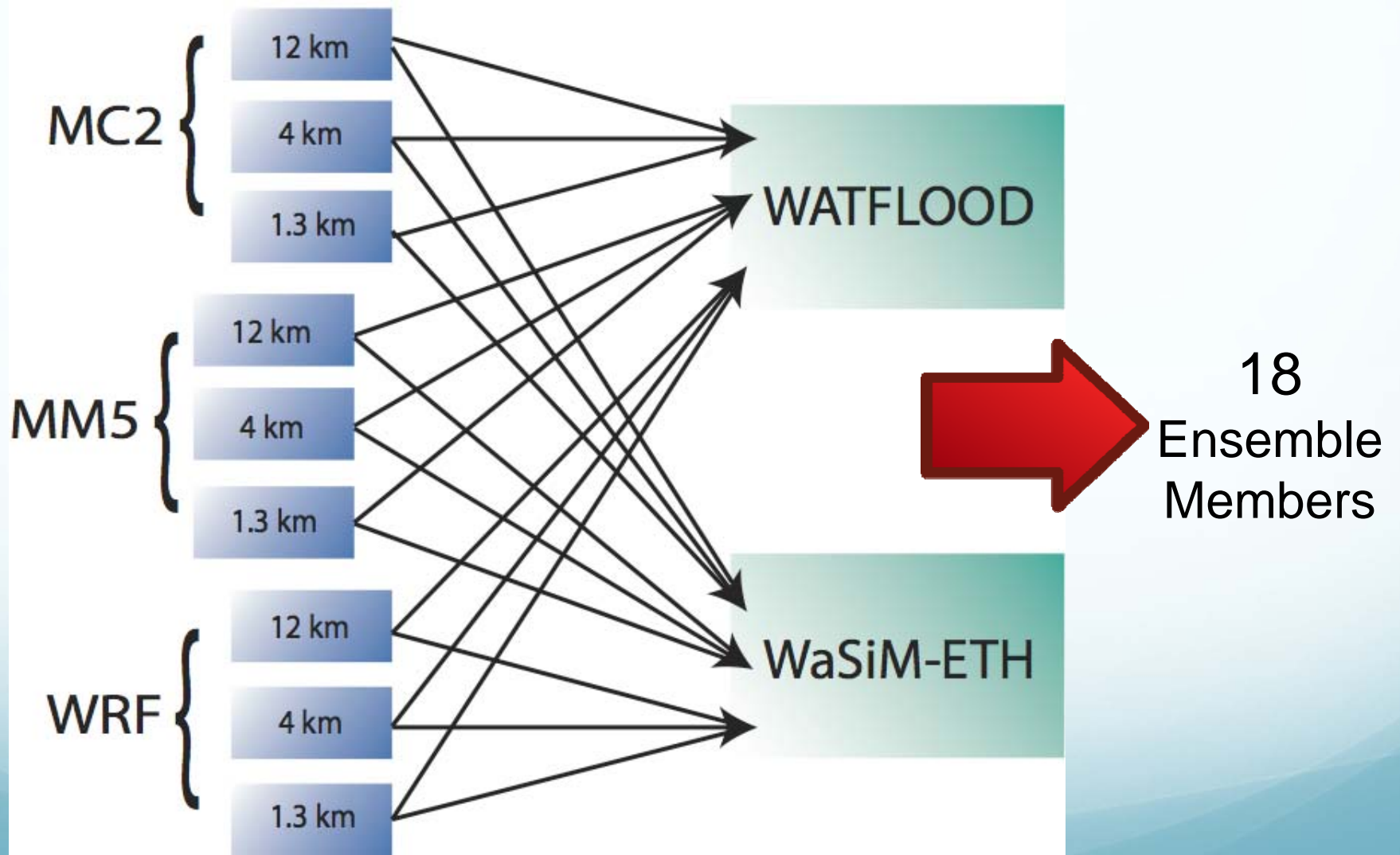
- Day 1 forecasts
- Sept 1 - Oct 19, 2010



Discussion

- Differences in performance metrics across models and grid spacings suggest use of ensemble forecast
- Most models skillful at all lead times for case study
- Better performance at shorter lead times
- Low-resolution (12 km) models perform best
- Future Work: Member-to-Member (M2M) Ensemble

M2M Ensemble



Questions/Comments?

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