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Floods and snow mass estimations using GRACE observations

Shusen Wang¹, Hazen Russell²

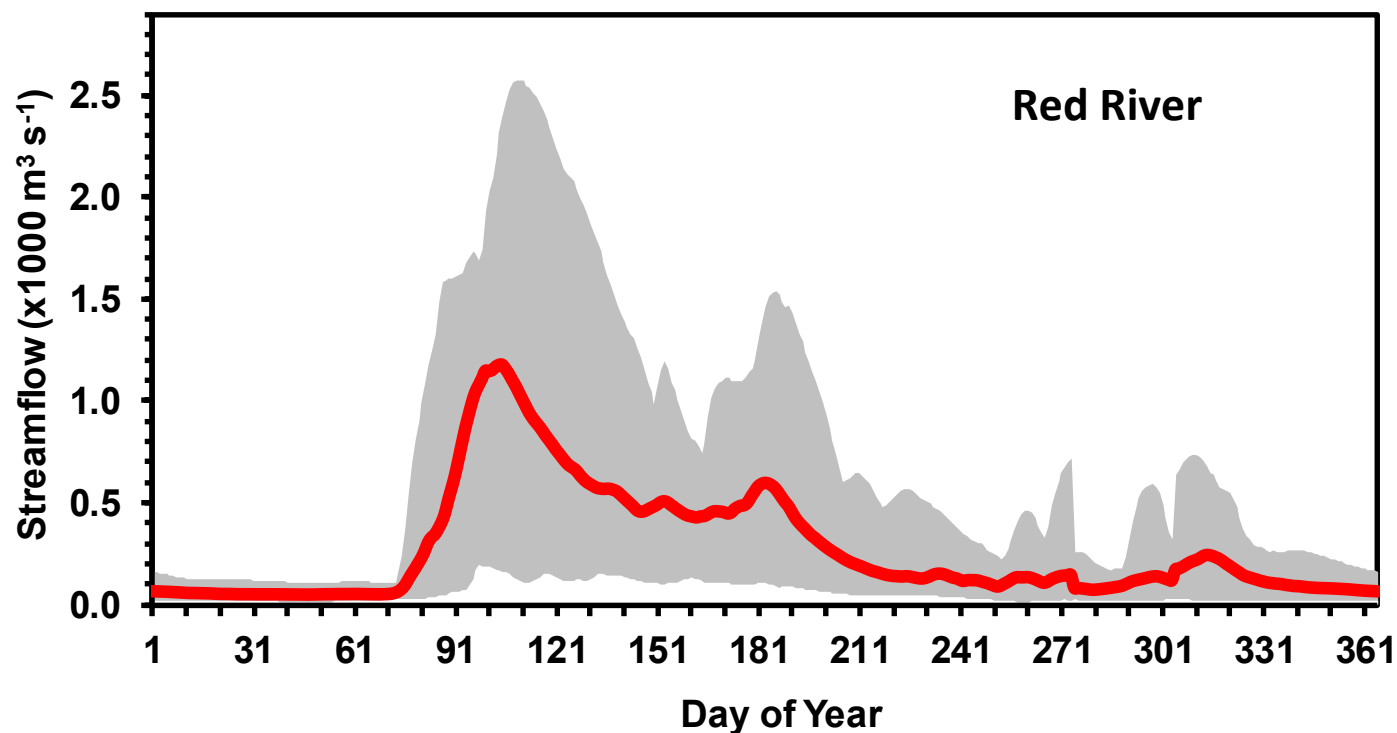
¹*Canada Centre for Remote Sensing*

²*Geological Survey of Canada*



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River flows over cold regions



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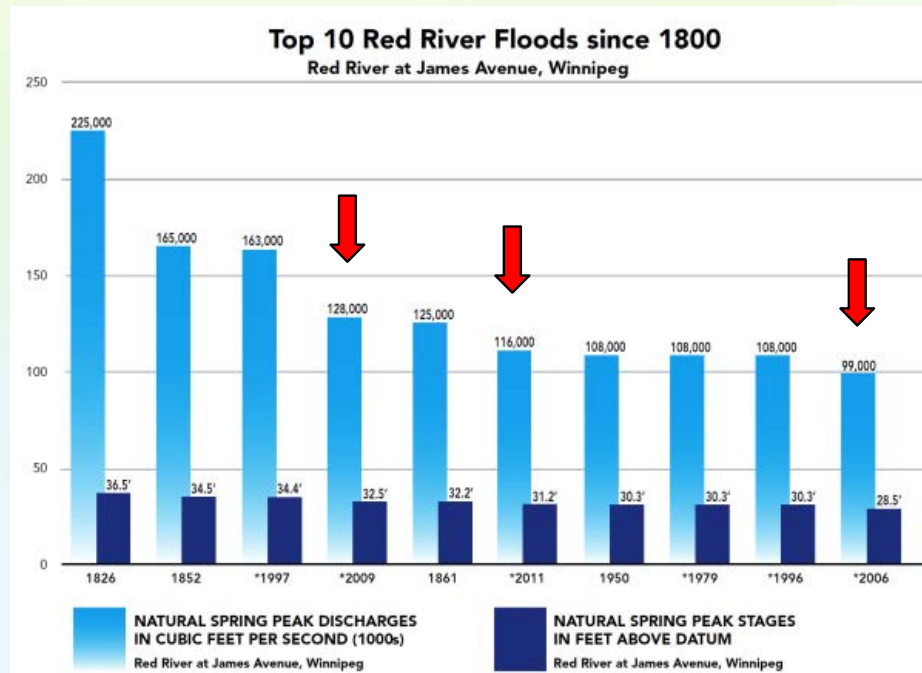
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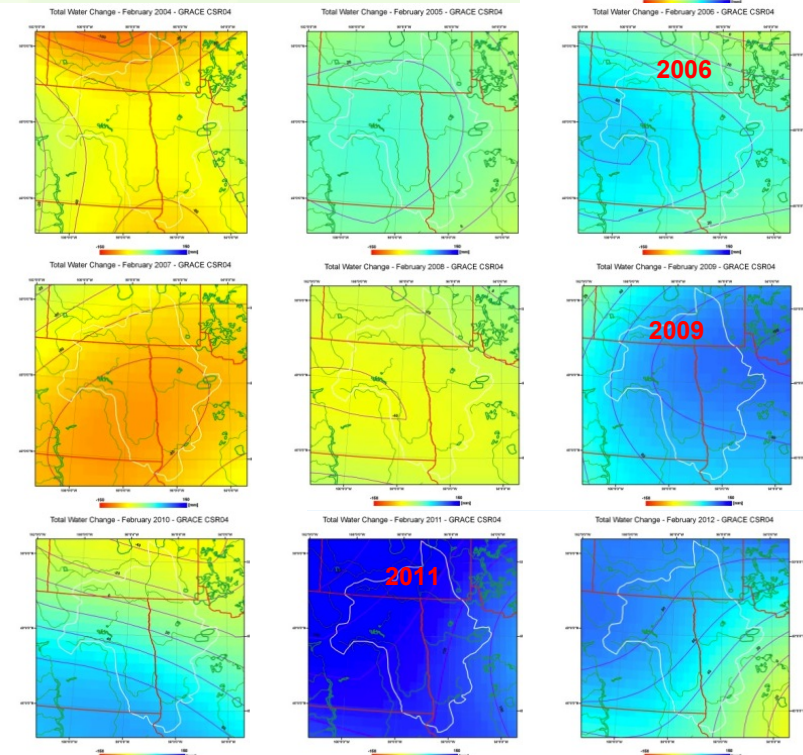
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Floods vs. GRACE TWS

– Observations for the Red River



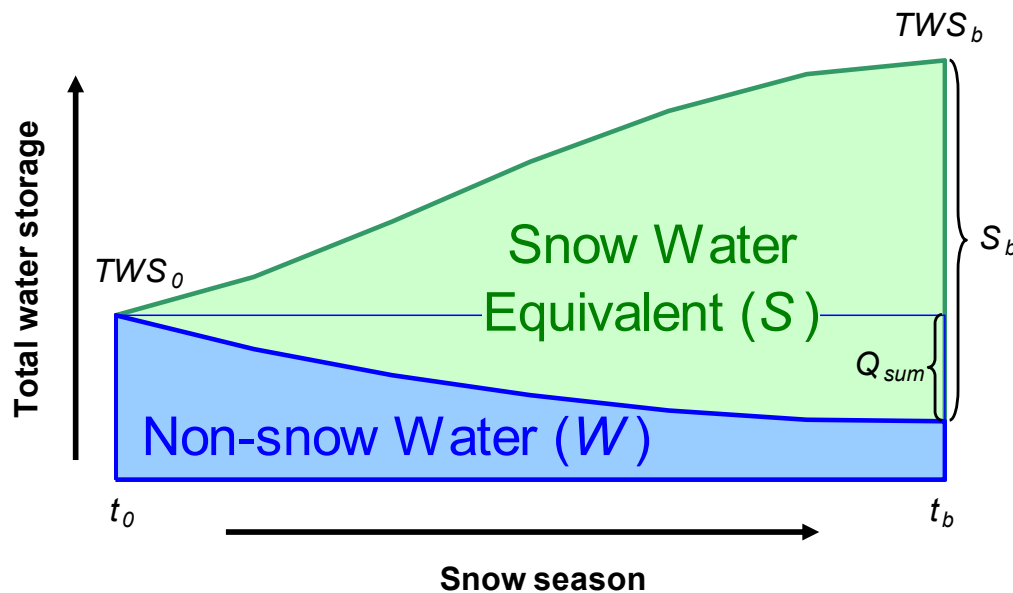
TWS anomaly in February, 2003-2012



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A GRACE-based flood forecasting model



$$Q_{base}(t) = -dW(t)/dt = a(W(t) - b)$$

$$Q_{sum} = \int_{t_0}^{t_b} Q_{base}(t) dt = TWS_0 - (TWS_0 - b)e^{-a(t_b - t_0)} - b$$

a : basin dischargeability

b : TWS when discharge=0

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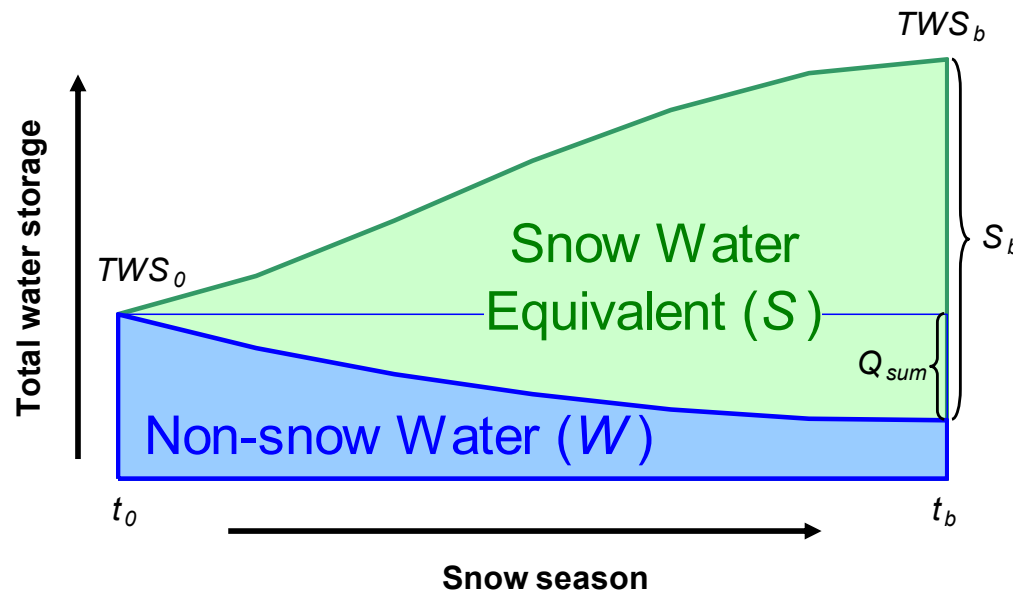


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A GRACE-based flood forecasting model



$$S_{melt}(t) = \min(S_{mass}(t-1), \alpha(T_a(t) - \beta))$$

α : snowmelt rate per unit of T_a above β

β : base temperature for snowmelt

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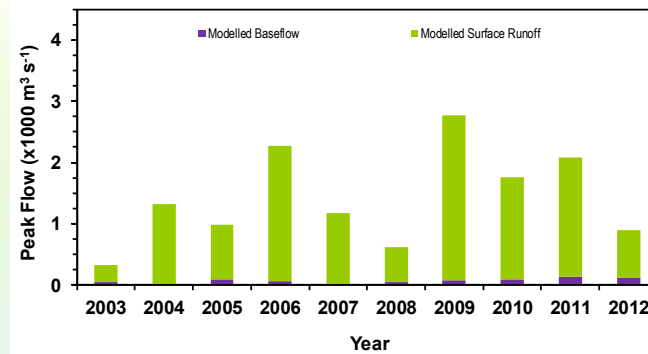
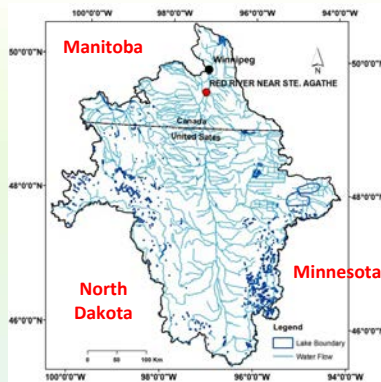


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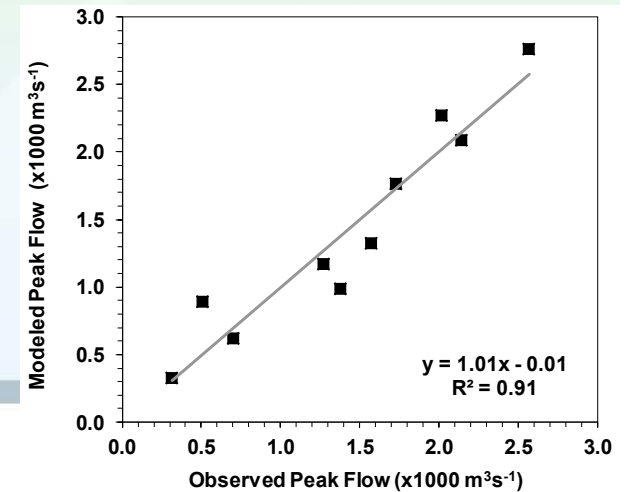
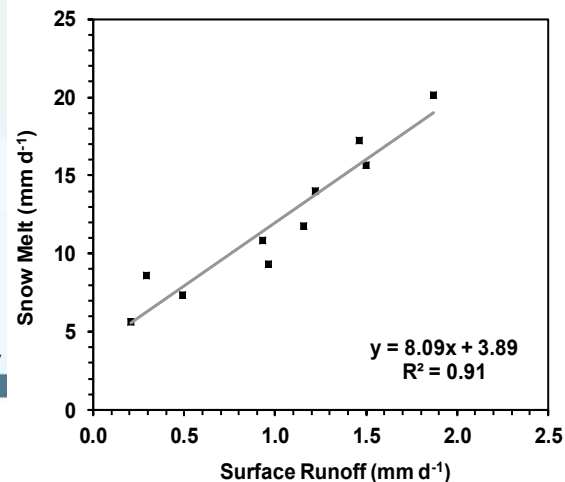
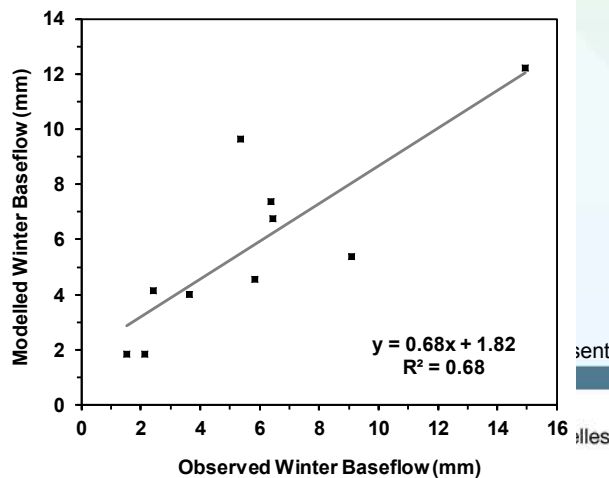
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Test for the Red River basin



Baseflow contribution to floods is <5%

Wang, S. et al., 2016, Can. J. Rem. Sens.



Potential issues?

- Impact of GIA
- Limitation in the basin area

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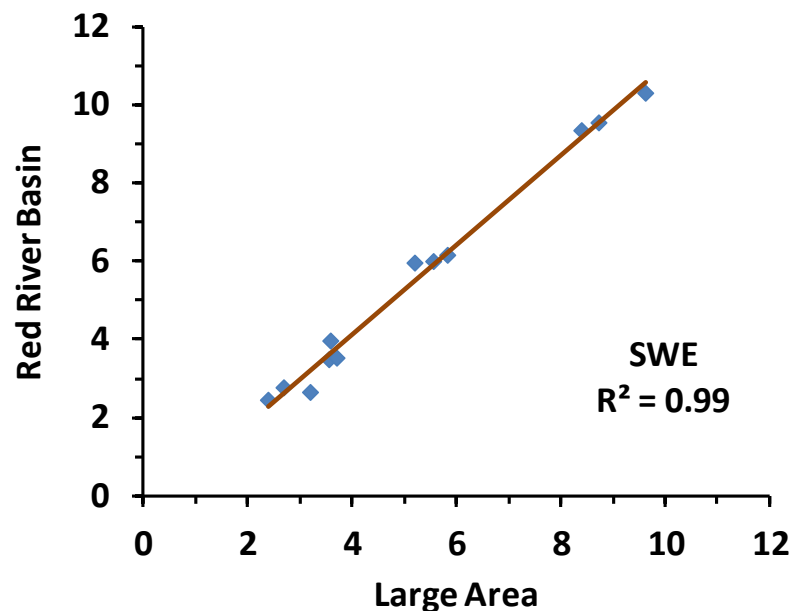
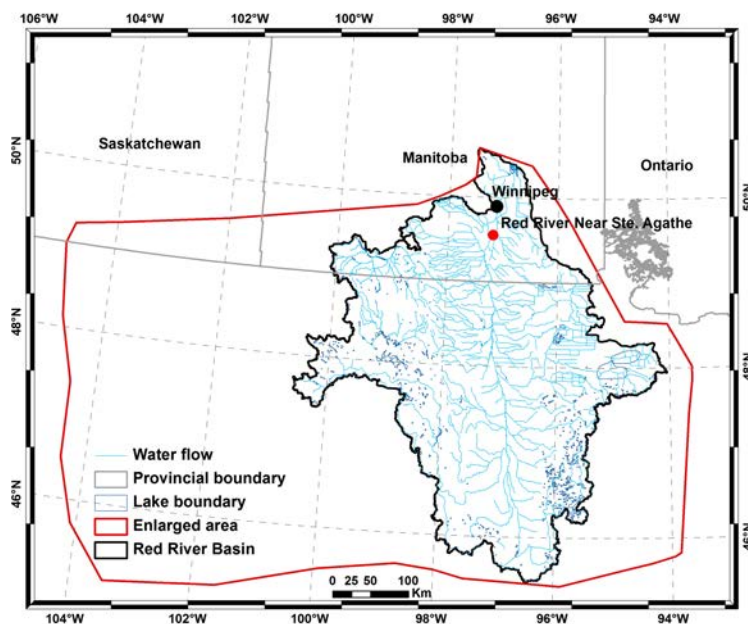


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SWE: Red River vs. a larger region



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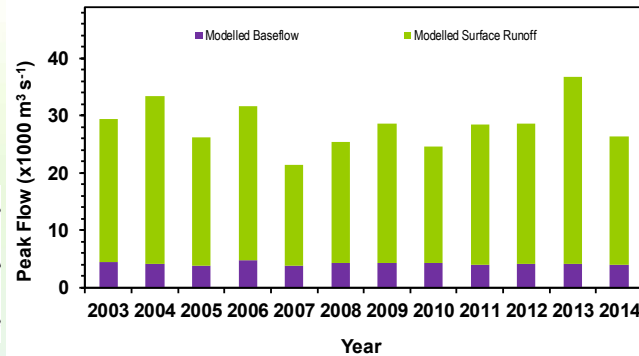
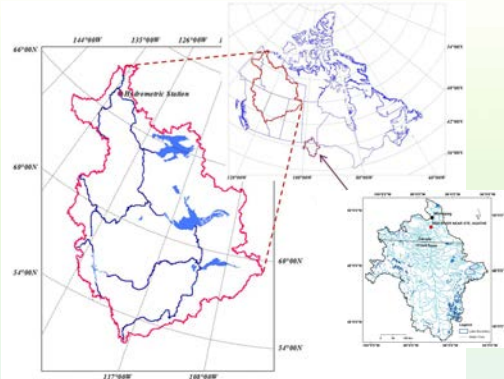


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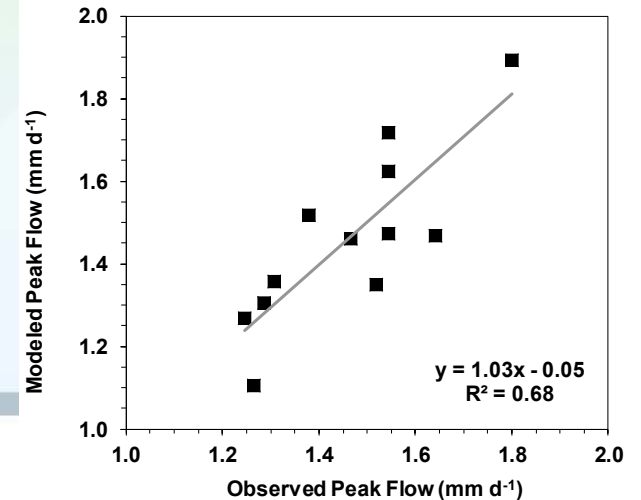
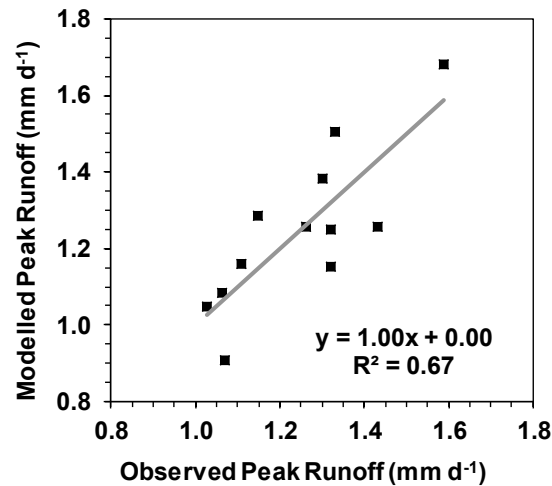
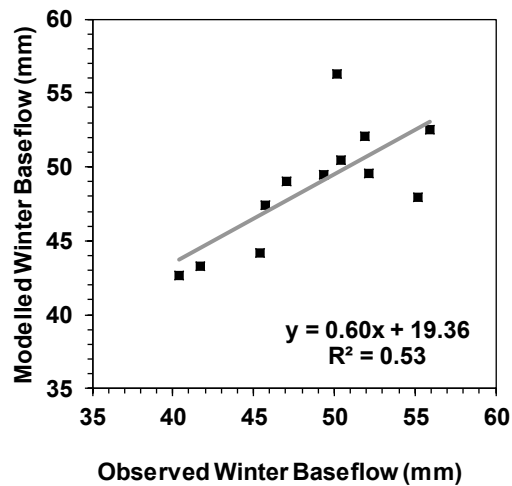
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Test for the Mackenzie River basin

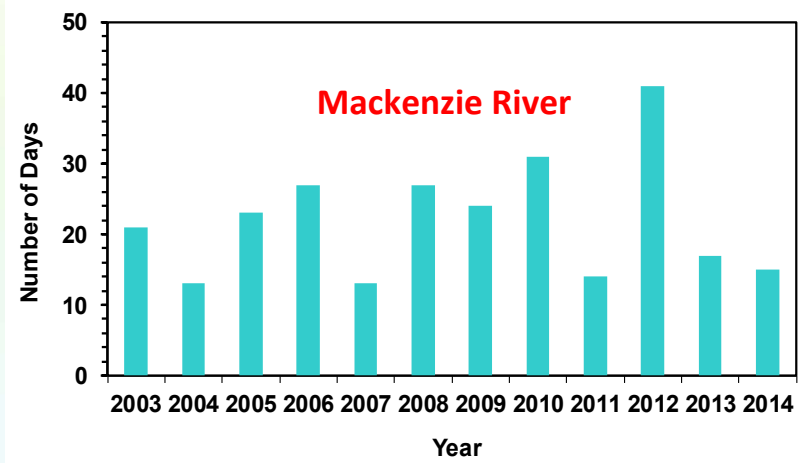
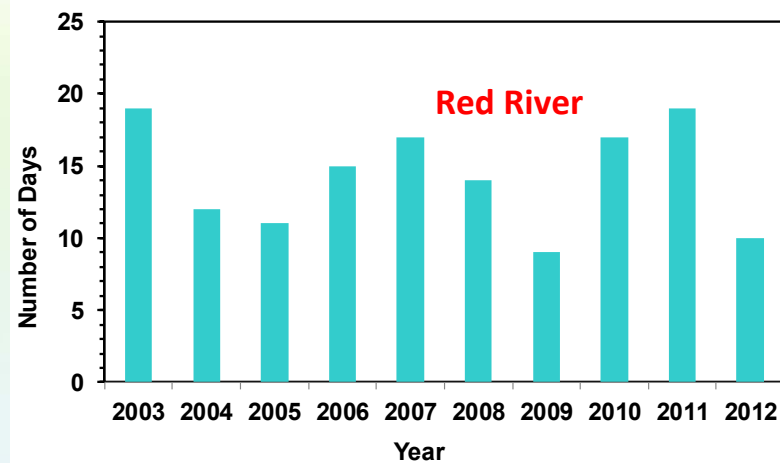


15% of the floods is contributed by baseflow, 85% by surface runoff.

Wang, S. et al., 2017., Rem. Sen.



Peak flow travel time



Average travel time for the peak snowmelt water to flow out of the basin is ~14 days for Red River, and ~22 days for Mackenzie River.

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Differences in major drivers for floods

- Major driver for floods is snow mass for the Red River, and air temperature for Mackenzie River:
 - Red River: Snow mass anomaly explained 67.3% of the interannual variations in peak flows;
 - Mackenzie River: Rising temperature patterns in snowmelt season determined the peak flows. Snow mass contributed <10%;
 - The Lower Fraser River (*BC Water Management Branch, 2012*): Snow mass contributes 20%–40%, weather factors (mainly temperature) contribute about 60%–80% to the flood risk.

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Snow mass and Snowmelt

- GRACE-based snow mass was found 20% higher than that from GLDAS;
- Mackenzie River basin has lower snowmelt efficiency per unit heat and higher base temperature for snowmelt than Red River basin.

	Mackenzie River	Red River
a (mm/°C) :	17.0	18.2
b (°C) :	2.1	1.0

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Basin hydrological features

- Mackenzie River basin has higher water state and higher dischargeability than Red River basin

	Mackenzie River	Red River
Conductivity (10^{-3} day^{-1})	1.07	0.49
Water state (mm) (TWS at Q=0)	- 195.9	9.2

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Summary

- The model provides a practical tool for flood early warning by using only GRACE and temperature data.
- The improved (proposed) GRACE-FO data latency and update frequency is of great value to cold region hydrological studies, public safety, and water resources management.

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