Satellite Enhanced Snowmelt Flood Predictions in the Red River of the North Basin

Earth Science Applications: Water Resources
January 2015 - 2018

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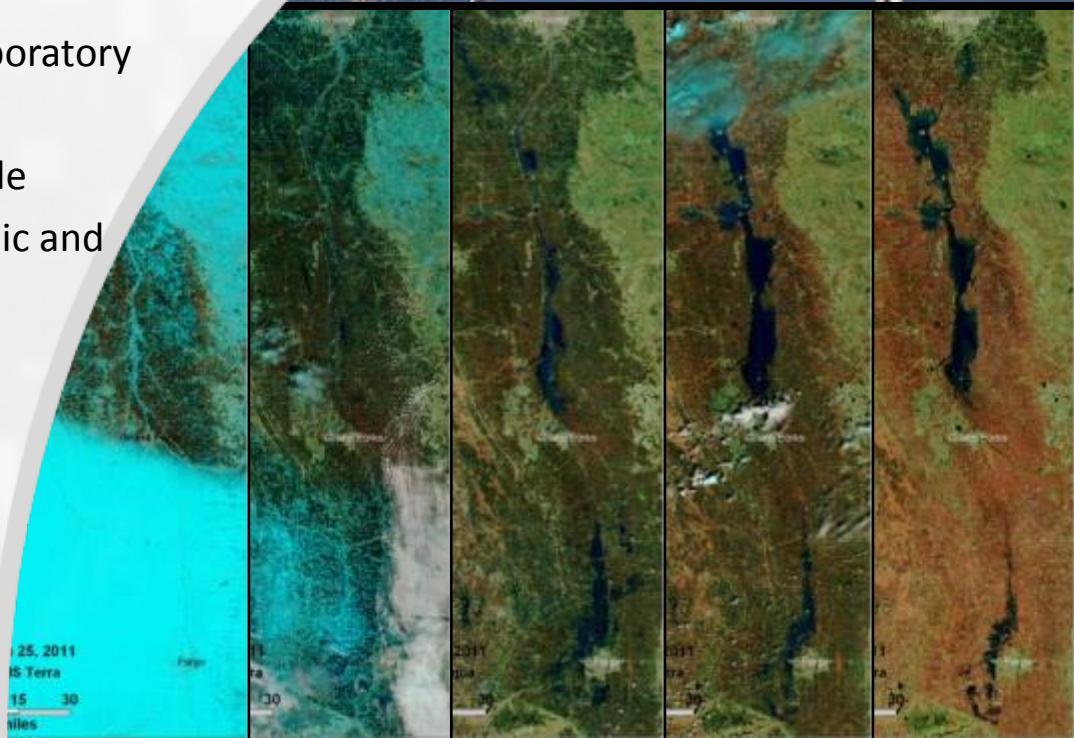
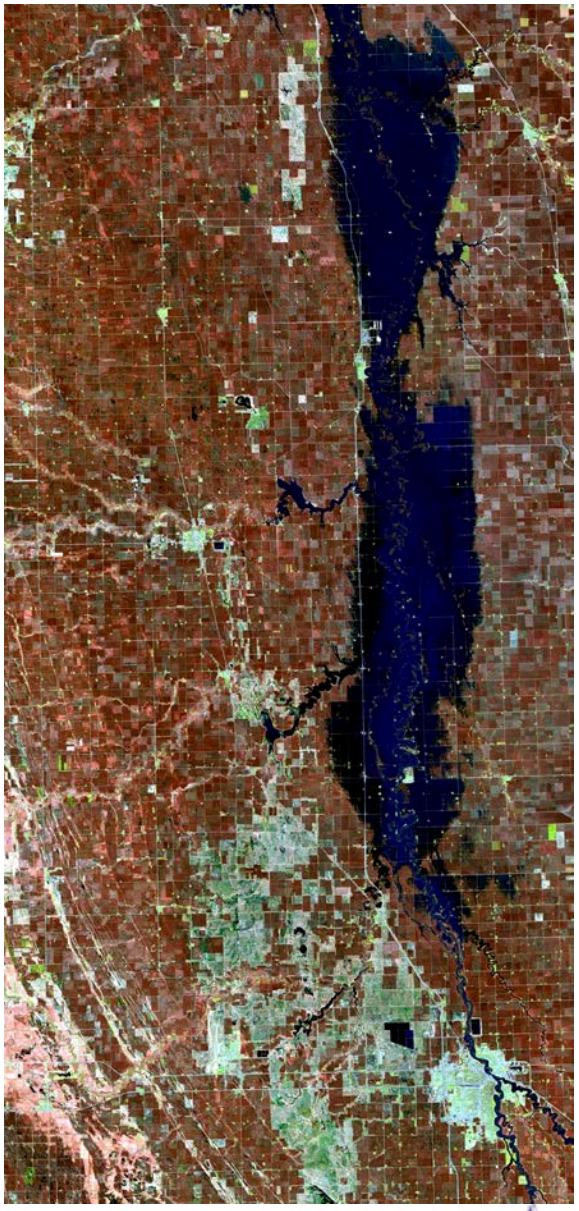
[4]Agricultural Research Service, Beltsville
[5]National Weather Service, National Oceanic and Atmospheric Administration (NOAA)



Overview

- Decision-Making Activity
- Stakeholder Background
  - The NCRFC
  - Red River of the North Basin
  - CHPS Model
- Remote Sensing Products
  - Microwave SWE and Melt
  - Antecedent Moisture
  - Freeze/Thaw
- Approach



RRB Flooding at Grand Forks
2011-04-25
Photos Courtesy of NOHRSC

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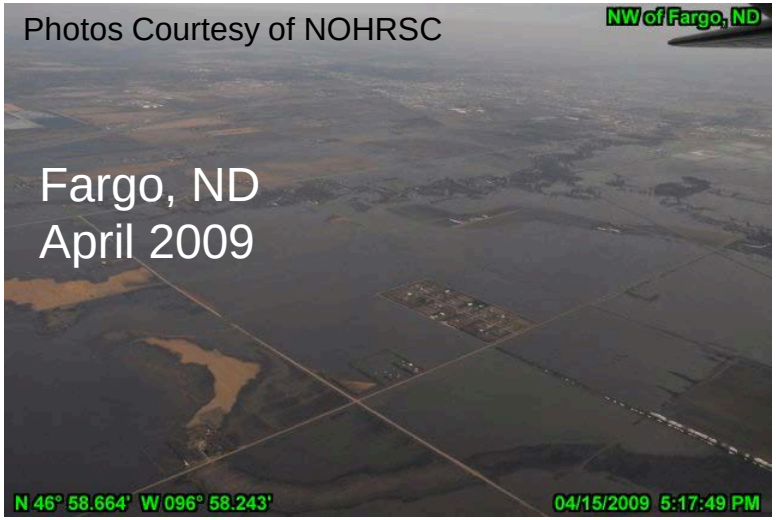
Decision-Making Activity

Enhance the National Oceanic and Atmospheric Administration (NOAA) National Weather Service's (NWS) North Central River Forecast Center's (NCRFC) snowmelt flood predictions capacity in the Red River of the North Basin (RRB) through the inclusion of remotely sensed snow and soil moisture products in the NCRFC's river forecast system.



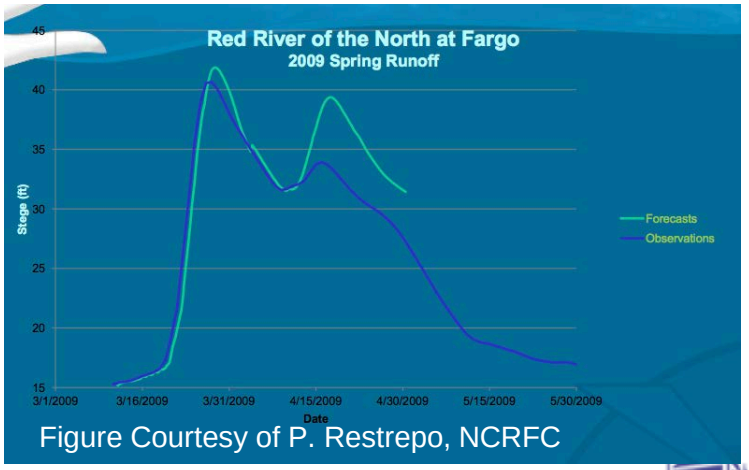


Figure Courtesy of P. Restrepo, NCRFC

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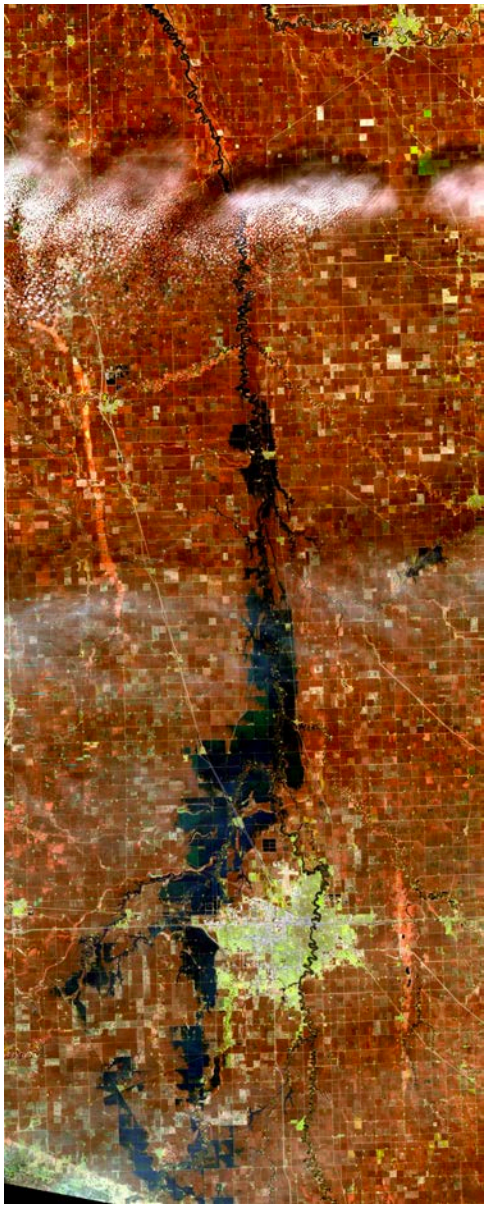

RRB Flooding from Fargo to South Of Grand Forks; 2011-04-25
Photos Courtesy of NOHRSC

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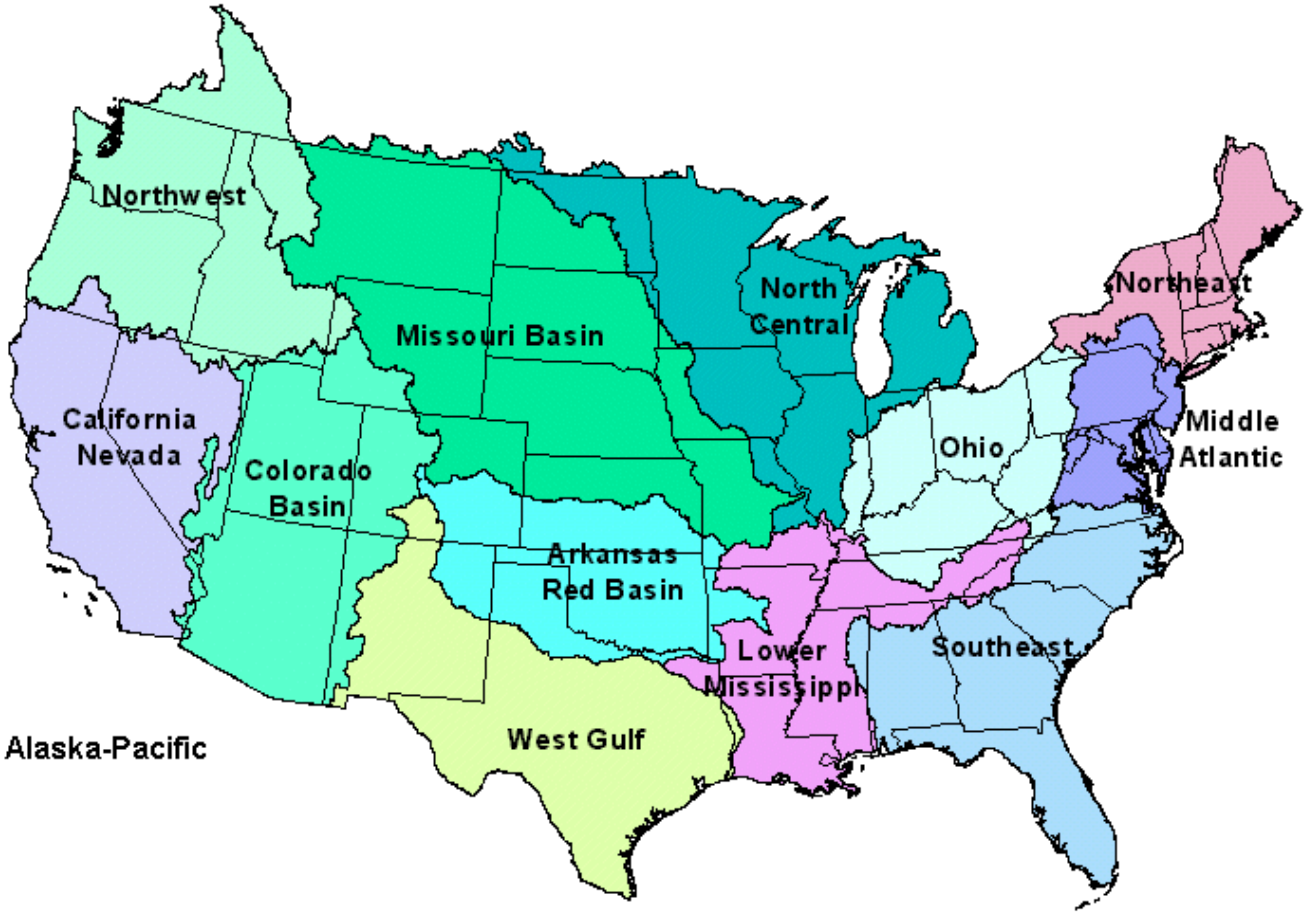
Stakeholder:
NOAA River Forecast Centers



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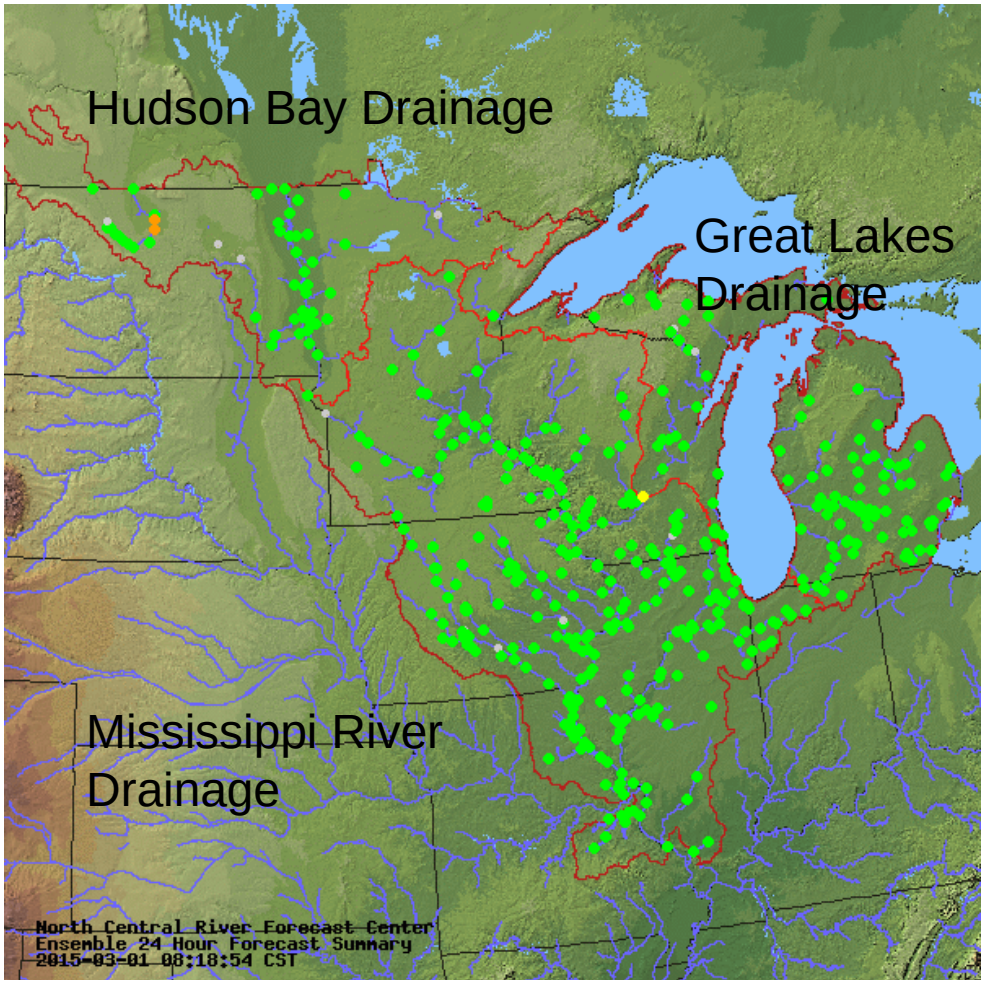
North Central River Forecast Center (NCRFC) Drainage Areas



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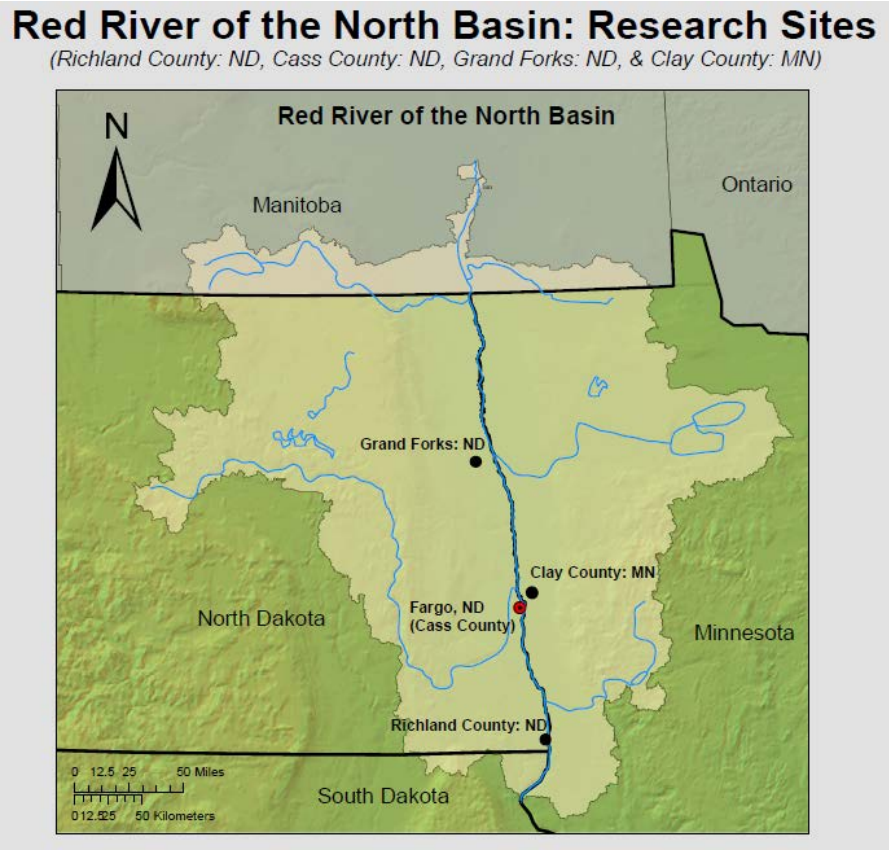
The Red River of the North Basin (RRB)

- Basin Area: 103,600 km^2
- Flow from north to south
- The RRB main stem drops only about 61 m in a 634 km course from its beginning to the U.S.-Canada border.



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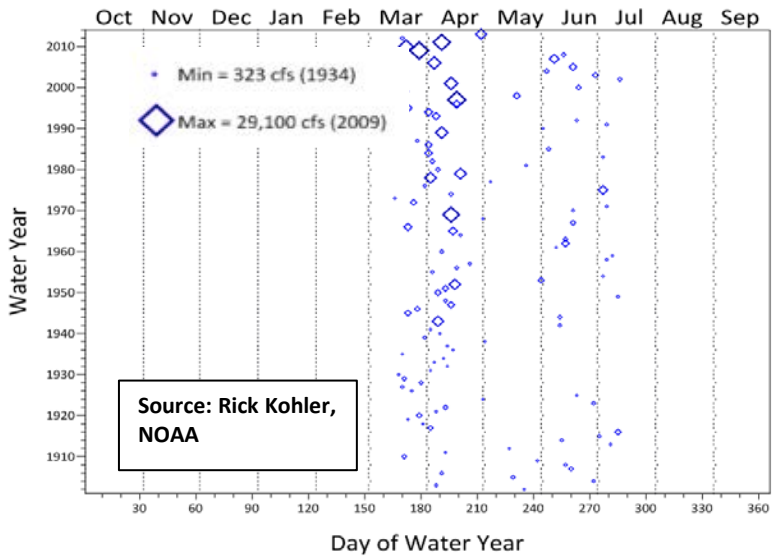
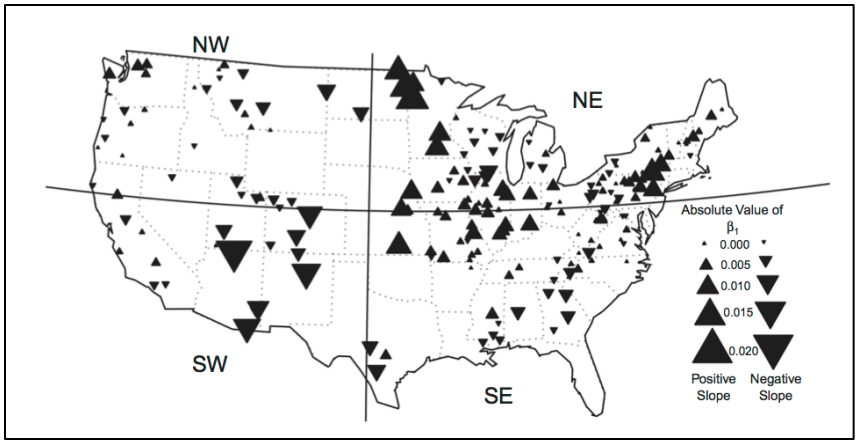
The Red River of the North Basin (RRB)



RRB annual maximum discharge at Fargo by year and day of year. Symbol size is proportional to flow (cfs).



Triangles indicate the magnitude and sign of the regression slopes for annual peak discharge versus global mean carbon dioxide conc. (Hirsch and Ryberg, 2012)

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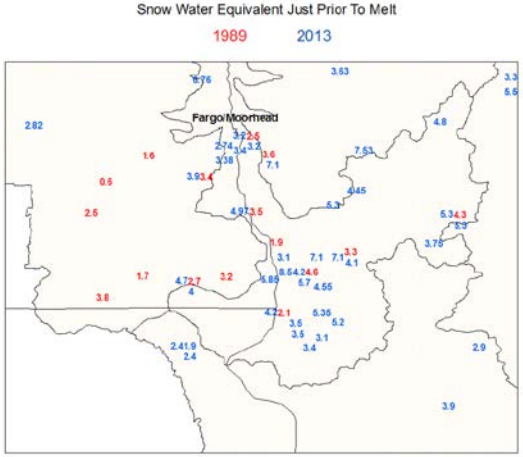
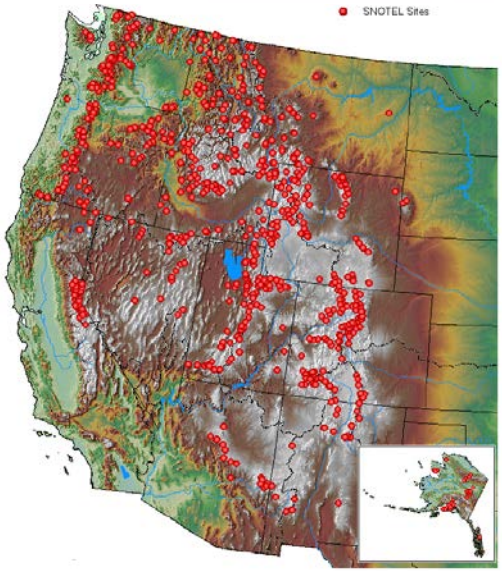
The Red River of the North Basin (RRB)

Lack of Ground Observations





Exponential Increase in Tile Drains

Photo: D. Hopkins, NDSU

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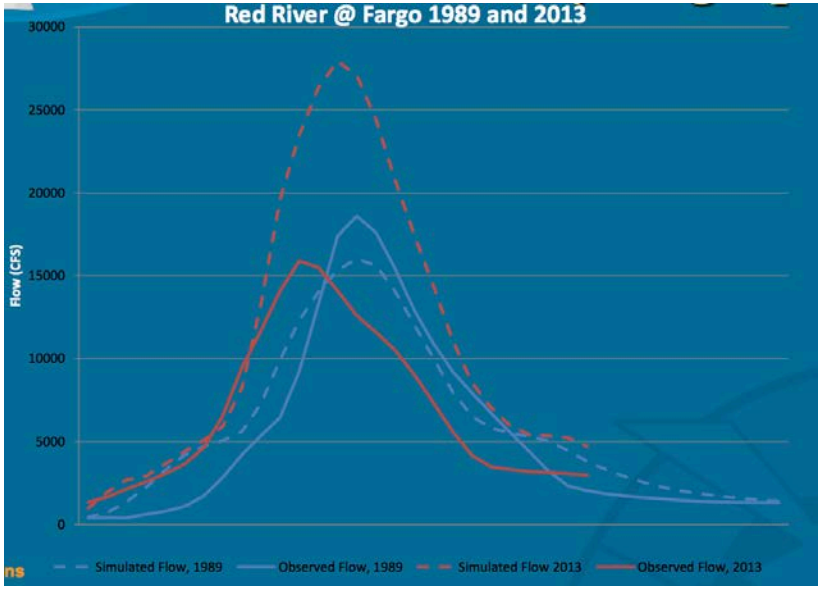
NCRFC RRB Flood Forecasting

- The Community Hydrologic Prediction System (CHPS) with the SNOW-17 snow model is used to estimate flow volume and stage.
- Requires initial state variables (e.g., snowpack, snow covered area, soil moisture, etc.)
- Uses observed and forecast precipitation and temperature to predict the river levels.
- Challenges:
  - Lack of accurate measurements of snow depth and snow equivalent water,
  - Lack of understanding of snowmelt processes and soil infiltration during soil freeze and thaw



Model and observed snowmelt flood flows for similar snow conditions in 1989 and 2013. Courtesy of P. Restrepo

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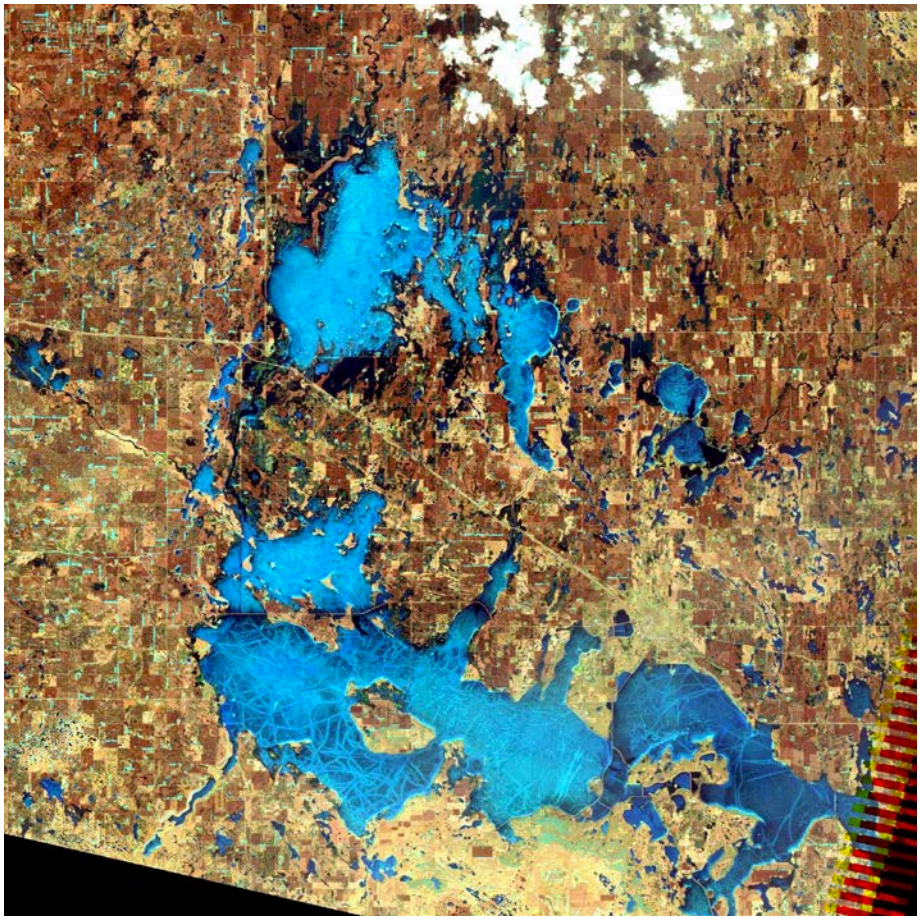
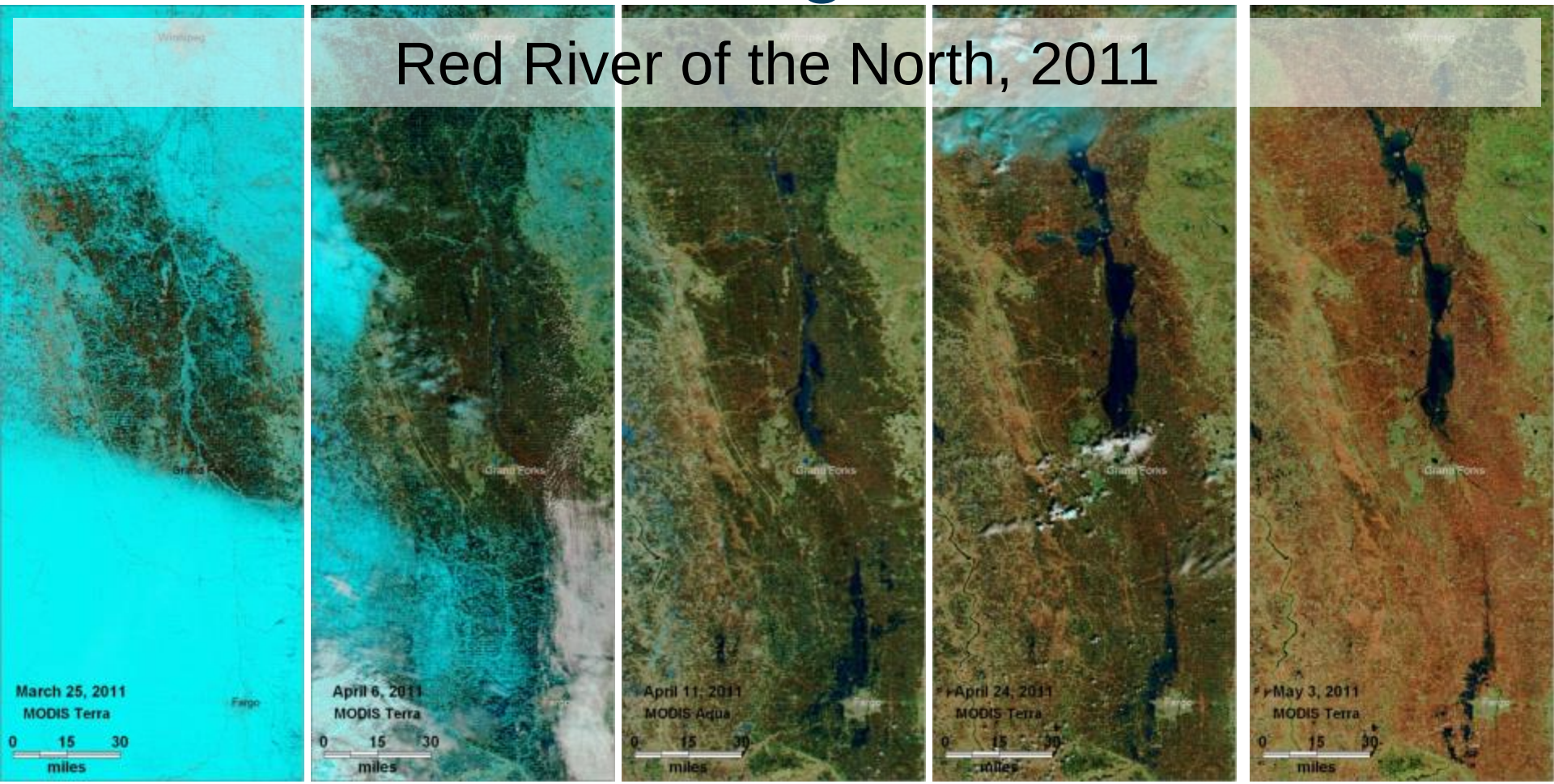


Devils Lake is the large lake to the south, with Pelican Lake just north divided by the east-west County Road 19. Above are the once-separated Lake Irvine, Lake Alice, Chain Lake, Mikes Lake, and Dry Lake. 2011-04-23
Image Courtesy of NOHRSC

Snow Observations Available from Space

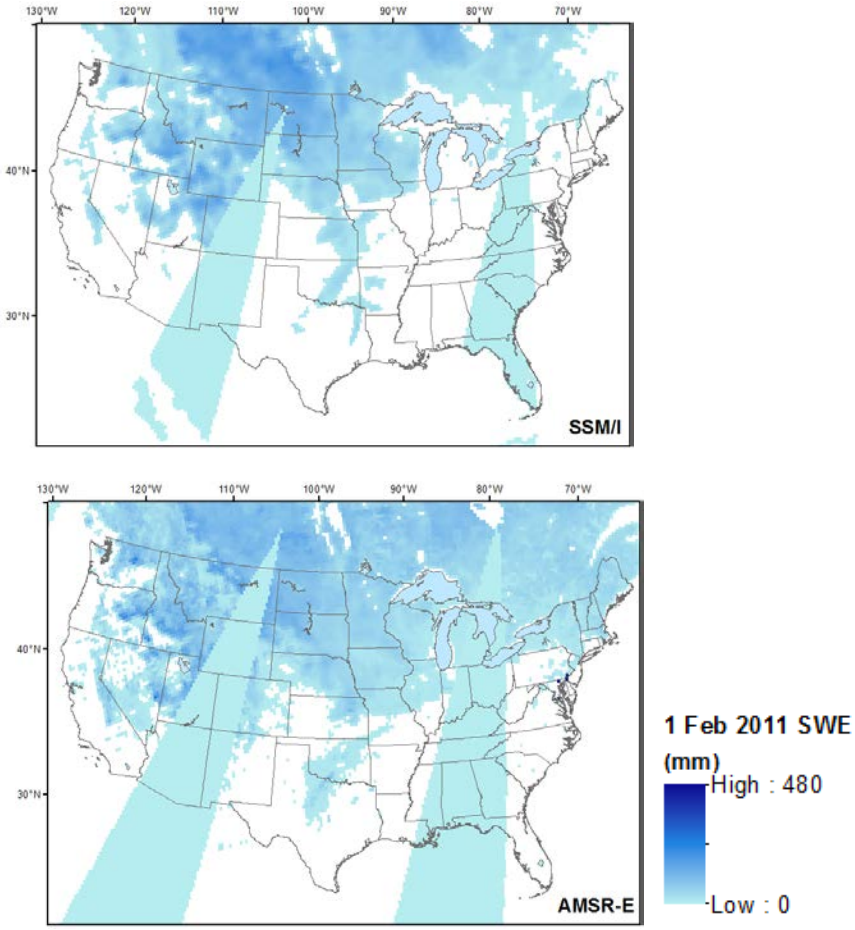
Product	Instrument/ Source	Date	Platform/ Agency	Spatial Resolution	Temporal Resolution
Fractional SCA	MODIS	2000- present	Terra/Aqua	500 m	Daily
SWE	SSM/I	1988-present	DMSP	25 km	Twice daily
SWE	AMSR-E	2003-2011	Aqua	25 km	Twice daily
SWE	AMSR2	2012-present	GCOM-W1	25km	Twice daily
Tb (36.5 GHz V)	AMSR-E	2003-2011	Aqua	25 km	Twice daily
Tb (37 GHz V)	SSM/I	1988-present	DMSP	25 km	Twice daily
Soil Moisture	AMSR-E	2003-2011	Aqua	25 km	Twice daily
Soil Moisture	SMAP	2015-present	SMAP	3 km	3-day
Freeze-Thaw	SMAP	2015-present	SMAP	3 km	3-day

MODIS SCA Imagery and Fraction Snow Coverage Products



Distributed Snow Data in the U.S.

- Passive Microwave SWE
- SSM/I
  - POR: July 1987 – Present
  - Algorithm: $SWE = C(T_{B,19} - T_{B,37})$
- AMSR-E
  - POR: June 2002 – July 2011
  - Algorithm accounts for forest cover, shallow/deep snow
- Sources of Error
  - Wet snow
  - Vegetation
  - Saturation depth
  - Topography
  - Snow metamorphosis
- Available at 25x25 km resolution



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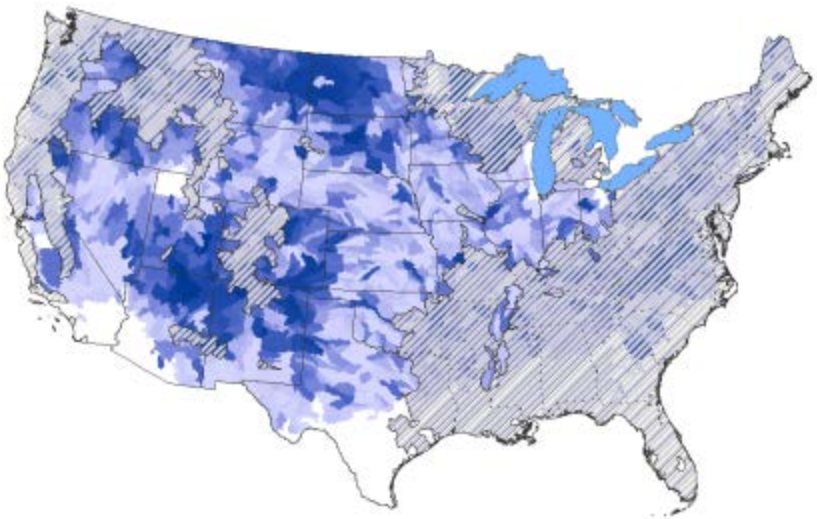
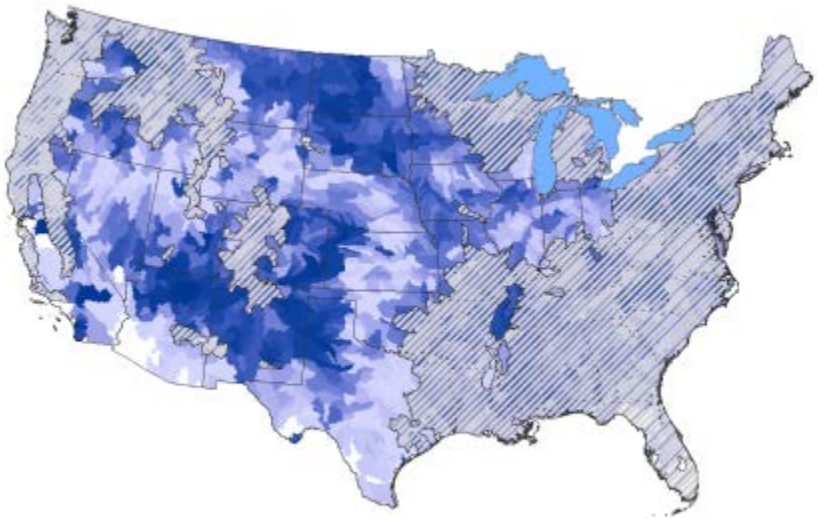
Comparison of passive microwave and SNODAS SWE by HUC8

SNODAS - AMSR-E



SNODAS - SSM/I



Correlations of annual maximum SWE for each HUC8. Hatched area shows regions with >20% forest fraction or > 200 mm annual maximum SWE.

Conclusions:

- **Best comparison in areas with < 20% forest cover with an average annual maximum SWE < 200 mm**
- Good agreement in the northern Great Plains and southern Rockies regions

Vuyovich et al. 2014

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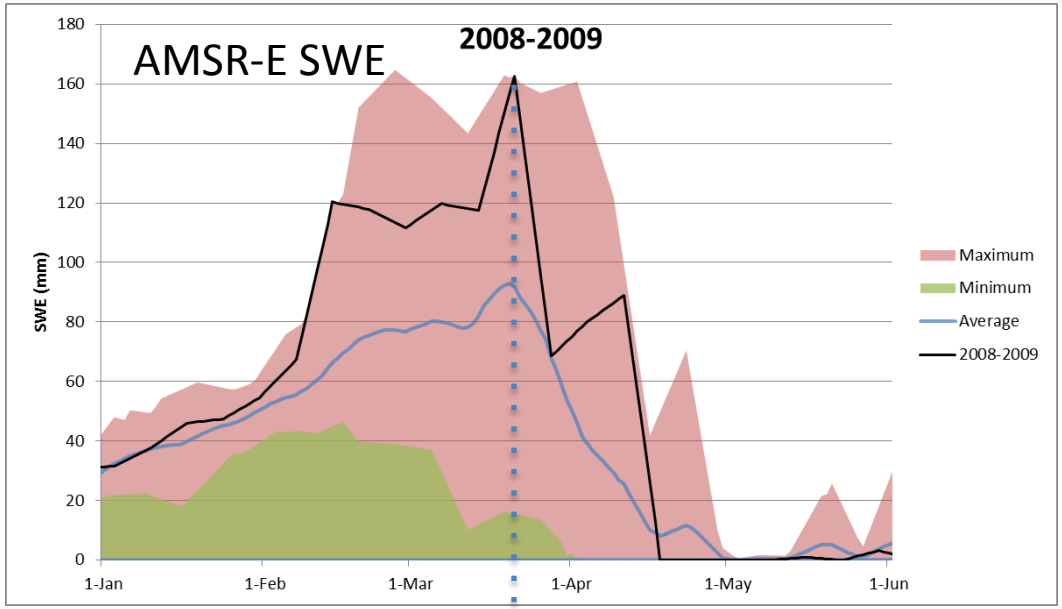
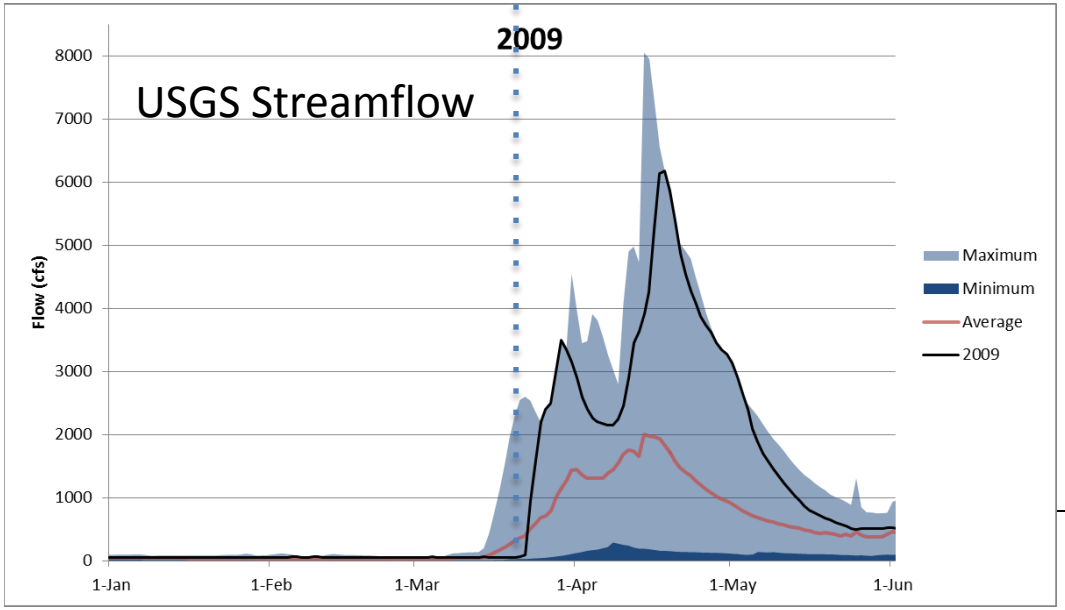
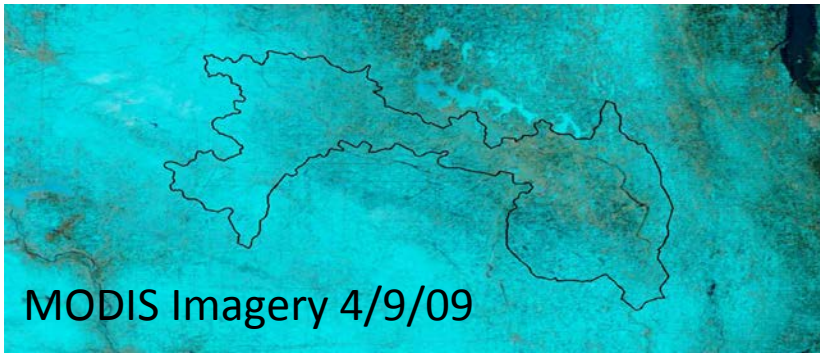
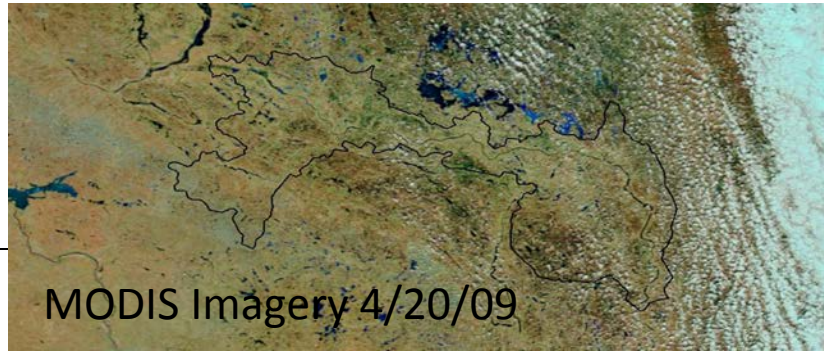
HUC8 Sheyenne Subbasin of the Red River of the North









Melt Detection via Passive Microwave Diurnal Amplitude Variation (DAV) in the RRB

Sheyenne Subbasin: Look for DAV > 200

Daily differences in Tb

DAV= abs(T36.5 GHz V A –T36.5 GHz V D)

Criteria for melt onset

$DAV > DAV_{crit}$ and $Tb > Tb_{crit}$

Applications

Ice Sheets (Ramage et al. 2002, 2006, 2007; Tedesco 2007)

Subartic (Li et al. 2012; Ramage & Semmens 2012; Semmens &Ramage, 2013)

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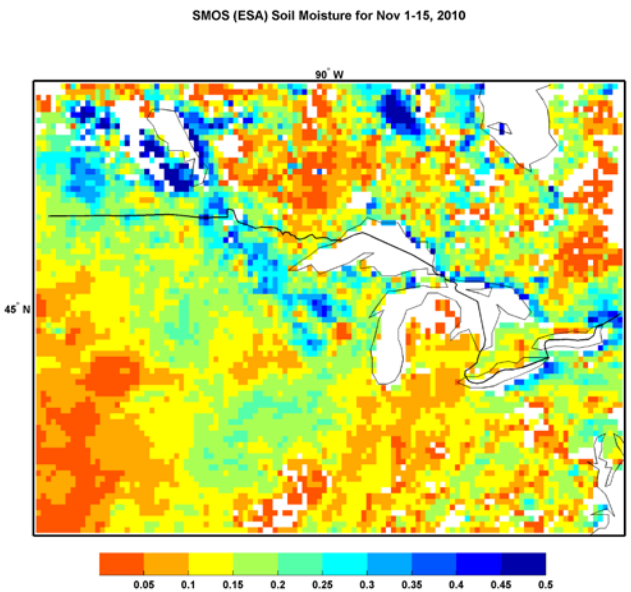
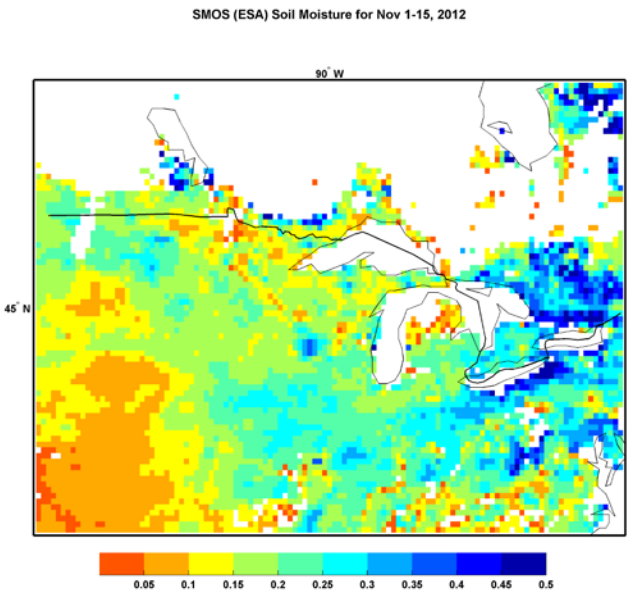
Antecedent soil moisture conditions in the North Central plains region from SMOS



Winter 2011



Winter 2013

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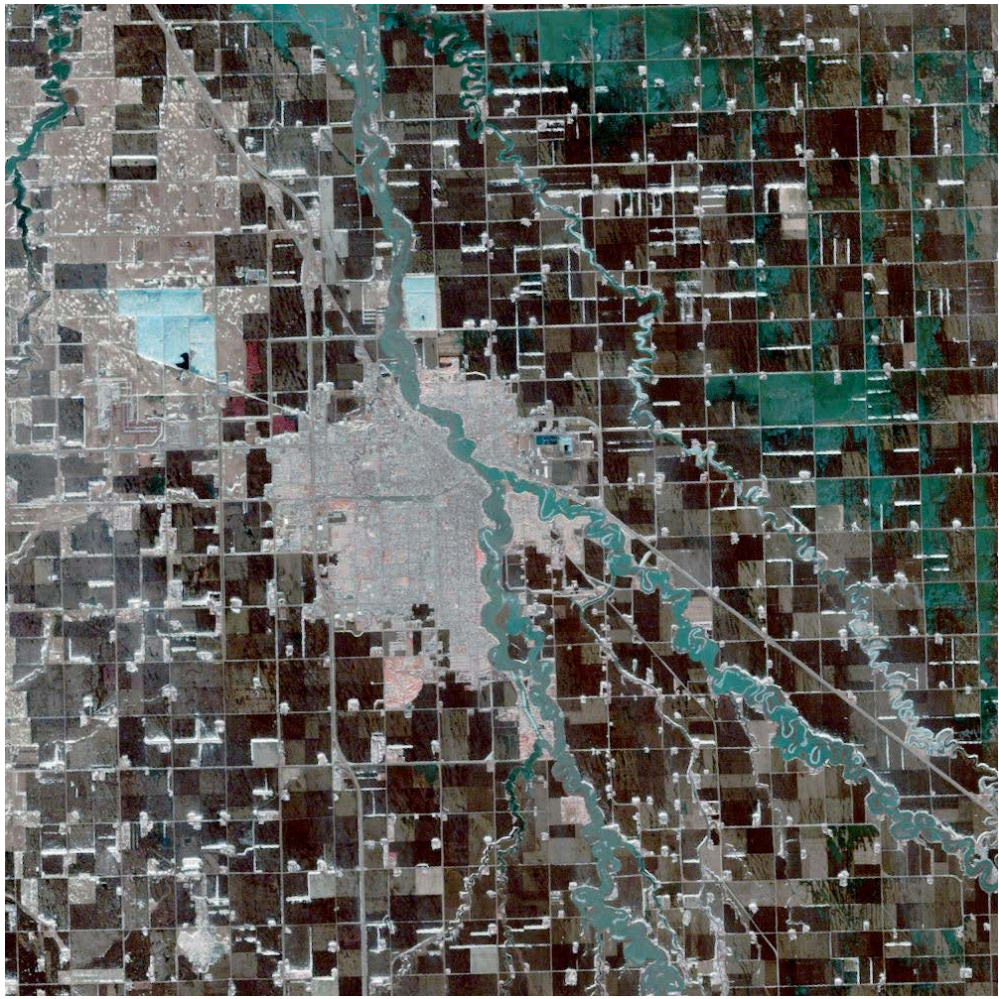

Red River at Grand Forks, ND. Flowing northwest, the Red Lake River joins the Red River of the North. The faint light blue squiggles in the Red Lake River are the ice remaining over the river's usual ox-bow path. The increased water volume is impeded by this ice and it jumps the banks to flow around it. 2010-03-21
Image Courtesy of NOHRSC

Schedule and Milestones

Schedule	Y1	Y2	Y3	Y4	Leads
Task 1. Develop the datasets. (ARL 3)	X	X			TM, WK, JJ
Remote sensing products	X	X			CV, JJ, MC
In situ products	X	X	X	X	XJ, MC
Task 2. Demonstrate satellite value in CHPS. (ARL 3 to 7)	X	X	X	X	JJ, PR, CV
Proof of Concept	X				
Integration and Validation	X	X	X		
Demonstration and Integration			X	X	
Task 3. End-user engagement (ARL3 to 7)	X	X	X	X	All
Communication	X	X	X	X	JJ, PR
Snow Forecast Working Group	X	X	X	X	PR, JJ
Annual Meetings		X			All
SMAP App Working Group	X		X		MC, JJ
ARL Completion Milestones	3	4	5/6	7	All

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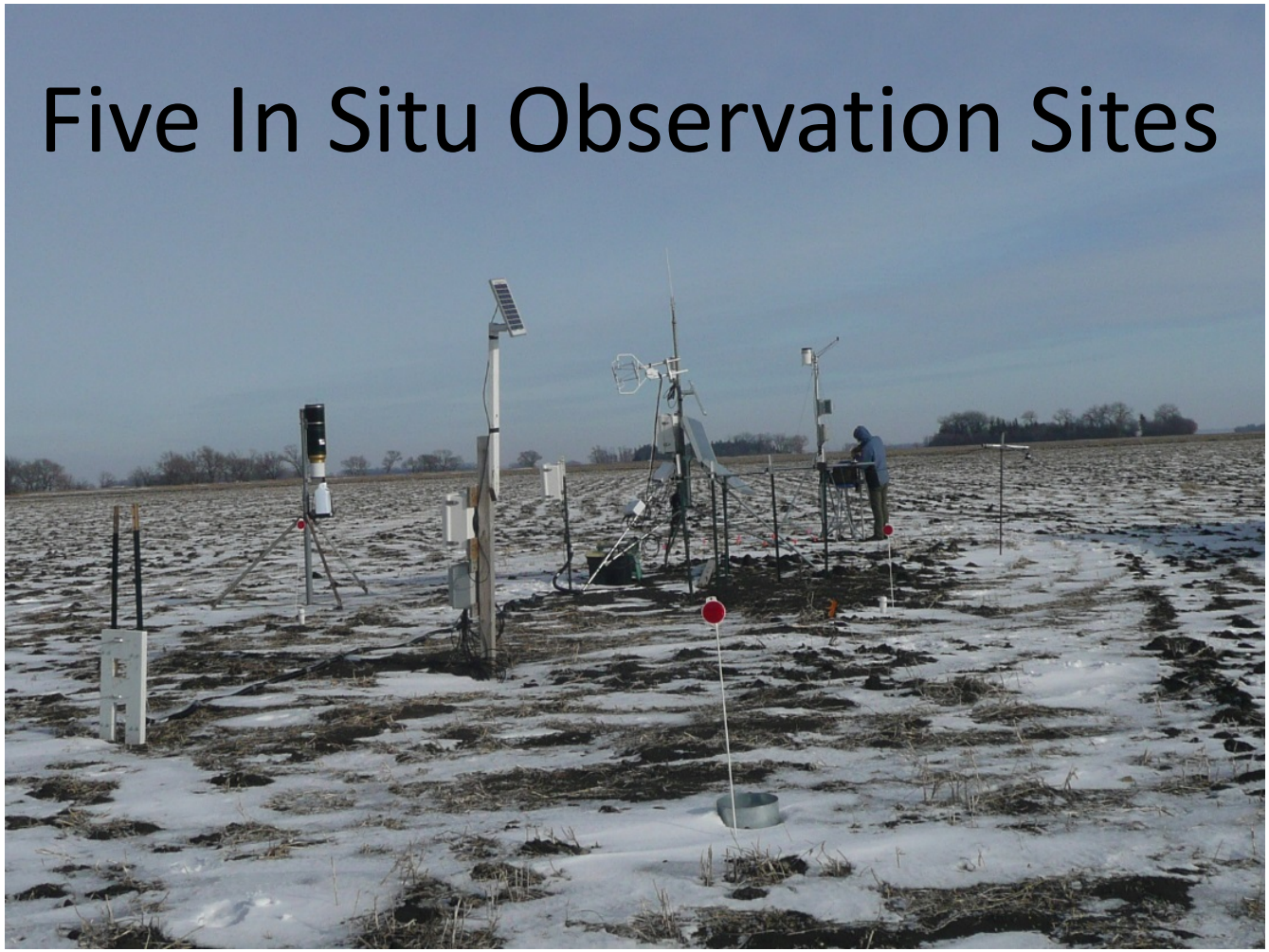
Five In Situ Observation Sites



Weather station on January 27, 2015. Photo was facing to the east of the field. From the front to the back: (1) infiltrometer ring for infiltration measurement, (2) snow pack measurement sensors, (3) hydra probe II soil moisture/temperature profiles measurement, (4) snow equivalent measurement instrument, (5) observation wells, (6) eddy covariance system, and (7) wireless weather station.

End User Engagement

Working group list and contact information:

1. Jeff Lewis, Director, Red River Basin Commission, 1120 28th Ave. N., Suite B., Fargo, ND 58102. Phone: 218-291-0422, Email: jeff@redriverbasincommission.org, Web: www.redriverbasincommission.org,
2. Randy Gjestvang, Engineer, ND State Water Commission at Red River Office, 623 East Main, #103, West Fargo, ND 58078. Phone and Fax: 701-282-2318. Email: rgjestvang@nd.gov. Web: http://swc.nd.gov.
3. Charles Fritz, Director, International Water Institute, 650 NP Ave., Suite 110, Fargo, ND 58102. Phone: 701-388-0861, Fax: 701-231-7205. Email: charles@iwinst.org, Web: www.iwinst.org.
4. Gregg J. Wiche, Director, 821 E. Interstate Ave., Bismarck, ND 58501-1199. Phone: 701-250-7401. Email: gjwiche@usgs.gov, Web: http://geology.cr.usgs.gov/states/ND.html.
5. William Bill Schuh, Hydrologist, 900 E. Blvd. Ave., Bismarck, ND, 58505. Phone: 701-328-2739. Email: bschuh@nd.gov. Web: www.swc.nd.gov.
6. Adnan Akyuz, State Climatologist, NDSU Dept. 7680, PO Box 6050, Fargo, ND 58108. Phone: 701-231-6577. Email: adnan.akyuz@ndsu.edu. Web: e,
7. Eakalak Khan, Director, ND Water Resource Research Institute, Dept. 2470, PO box 6050, Fargo, ND. Phone: 701-231-7717, Email: Eakalak.khan@ndsu.edu. Web: http://www.ndsu.edu/ndsco/.
8. Al Kean, PE, Chief Engineer, MN Board of Water and Soil Resources, 520 Lafayette Rd. N., St. Paul, MN 55155. Office: 651-297-2907. Mobile: 651-245-6531. Email: al.kean@state.mn.us.
9. Xiaodong Zhang, Associate Professor, Department of Earth Systems Science and Policy, Clifford Hall Room 326, 4149 University Ave Stop 9011, Grand Forks, ND 58202-9011. Phone: 701-777-6087. Email: zhang@aero.und.edu. Web: http://www.und.edu/instruct/zhang/.
10. James Stark, Director, Minnesota Water Science Center, 2280 Woodale Drive Mounds View, MN 5112 Phone: (763) 783-3100. Email: stark@usgs.gov. Web: http://mn.water.usgs.gov/
11. Greg Spoden or Pete Boulay, MN State Climatology Office, 439 Borlaug Hall, University of Minnesota 1991 Upper Buford Circle, St. Paul, MN 55108-6028. Phone: 651-296-4214 e-mail: climate@umn.edu
12. Greg Kruse, MN DNR Surface Water Monitoring, 325 Randolph Ave., St Paul, MN 55102. Phone: 651-539-2108 Email: greg.kruse@state.mn.us
13. April Walker, Engineer, City Engineer Fargo, ND, 200 3rd St. N., Fargo, ND 58102. Phone: 701-241-1545, Email: awalker@cityoffargo.com
14. Al Grasser, Engineer, City Engineer Grand Forks, ND, 255 N. 4th St, PO Box 5200, Grand Forks, ND 58201, Phone: 701-746-2640, Email: Agrasser@grandforksgov.com
15. Chris Laveau, USGS Grand Forks, 102 N. 4th St. Room 322, Grand Forks, ND 58203, Phone: 701-775-7221, Email: cdlaveau@usgs.gov
16. Michael Knoff, U.S. Army Corps of Engineers St. Paul District, 180 5th St. E., Suite 700 St. Paul, MN 55101. Phone: (651) 290-5200, Email: michael.r.knoff@usace.army.mil

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Thank You

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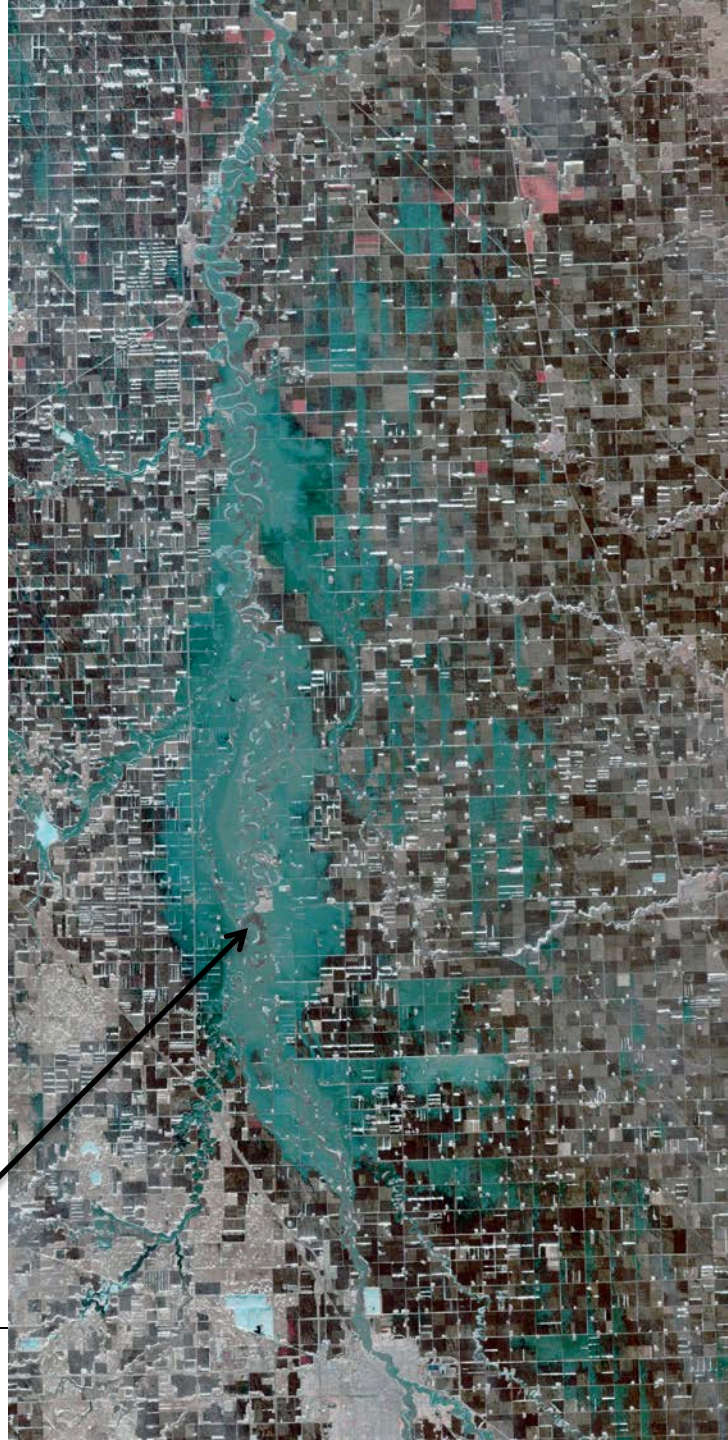

North of Grand Forks, ND, the RRB floods for 45 miles. To the north is the city of Drayton, ND, expected to grow from "moderate stage" flooding to "major stage" on Thursday, March 26. To the west are Grafton and Minto, relatively safe from damage.

Around two-thirds down the image, a small grey square in the center of all that green, is the city of Oslo, MN, completely surrounded by water.2010-03-21. Image Courtesy of NOHRSC

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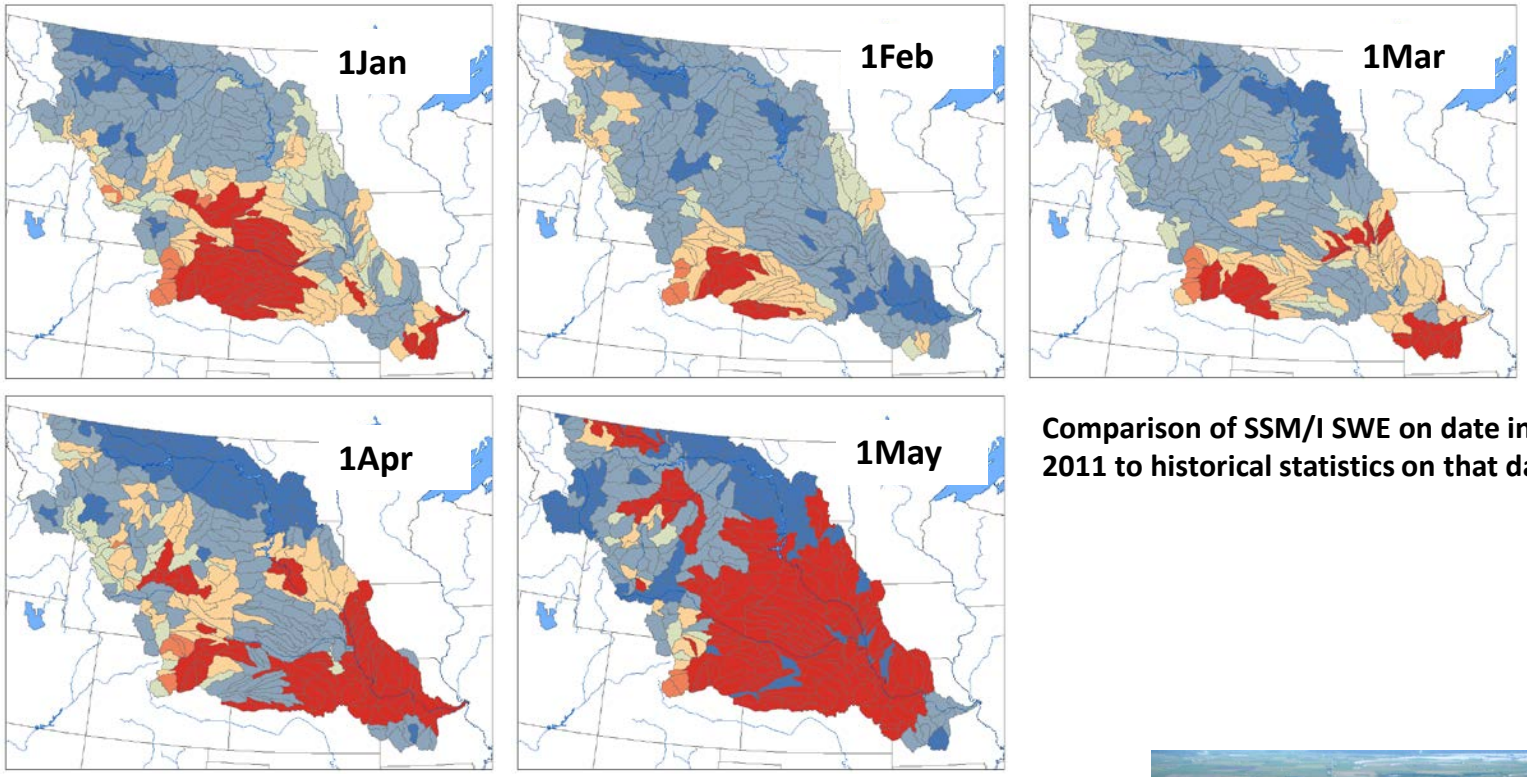
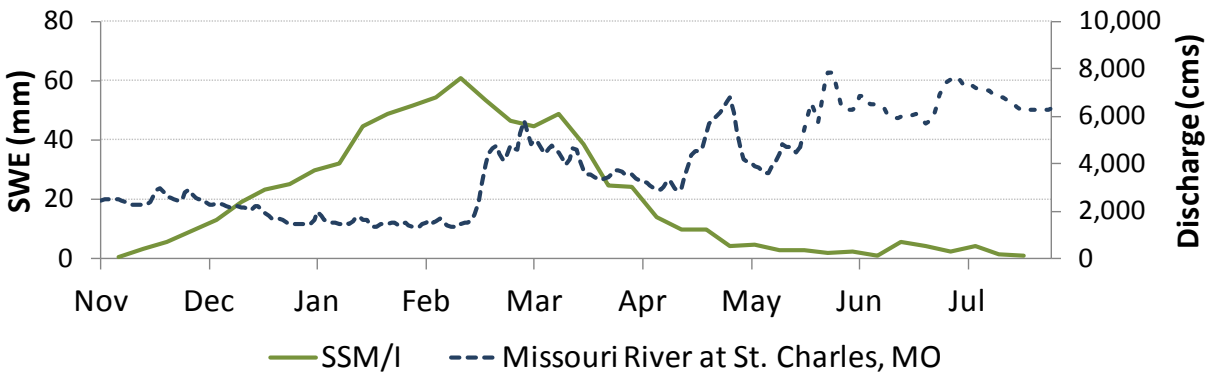
2011 Missouri River Flood



Comparison of SSM/I SWE on date in 2011 to historical statistics on that date



US Army Corps of Engineers, 2011

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