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Evaluating the WRF-Hydro Modeling System in Alaska

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1. Introduction

- National Water Model (NWM) implemented operationally in August 2016 to improve hydrological prediction (OWP, 2017)
  - Four operational configurations (Table 1)
  - Only covers contiguous United States (US)
- NWM is instantiation of Weather Research and Forecasting model hydrological extension package (WRF-Hydro)(Gochis et al., 2013) coupled with Noah Land Surface Model with Multi-Parameterization options (Noah-MP)(Niu et al., 2011)
- WRF-Hydro is extensible, high-resolution hydrologic routing and streamflow modeling framework, coupling column land surface, terrain routing, and channel routing modules (Figure 1) (NCAR, 2017)

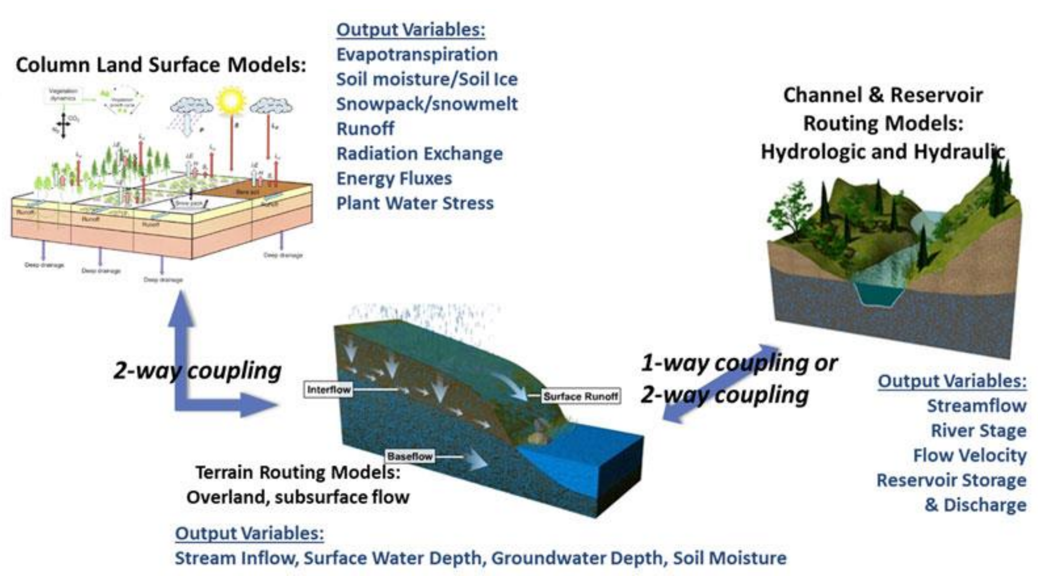

Figure 1. WRF-Hydro modules and output variables (NCAR 2017)

- This project uses experimental version of WRF-Hydro in Alaska mimicking the NWM to:
  - Identify modeling challenges for NWM development in Alaska
  - Assess WRF-Hydro and NWM ability to represent unique hydrological processes of arctic regions and accurately predict high and low flow events
  - Examine impacts of assimilating Surface Water Ocean Topography (SWOT) (Biancamaria et al., 2016) observations to improve model initialization

	Analysis & Assimilation	Short-Range	Medium-Range	Long-Range
Cycling Frequency	Hourly	Hourly	0600 UTC Daily	Daily Ens. (16 mem.)
Forecast Duration	-3 hours	0-15 hours	0-10 days	0-30 days
Resolution	1-km/250-m/ NHDPlus	1-km/250-m/ NHDPlus	1-km/250-m/ NHDPlus	1-km/1-km/ NHDPlus
Meteor. Forcing	MRMS/ HRRR/RAP	HRRR/RAP	GFS	CFS

Table 1. NWM forecast configurations (OWP, 2017) for CONUS domain. Resolution order indicates column land surface, terrain routing, and channel routing resolutions, respectively.

2. Challenges of Hydrological Modeling in Alaska

- Large remote areas with severe lack of in situ observations for model initialization
- Rivers and soils are frozen for many months of the year
- Frequent ice jams
- Rapid snowmelt
- Braided rivers with variable width/geometry

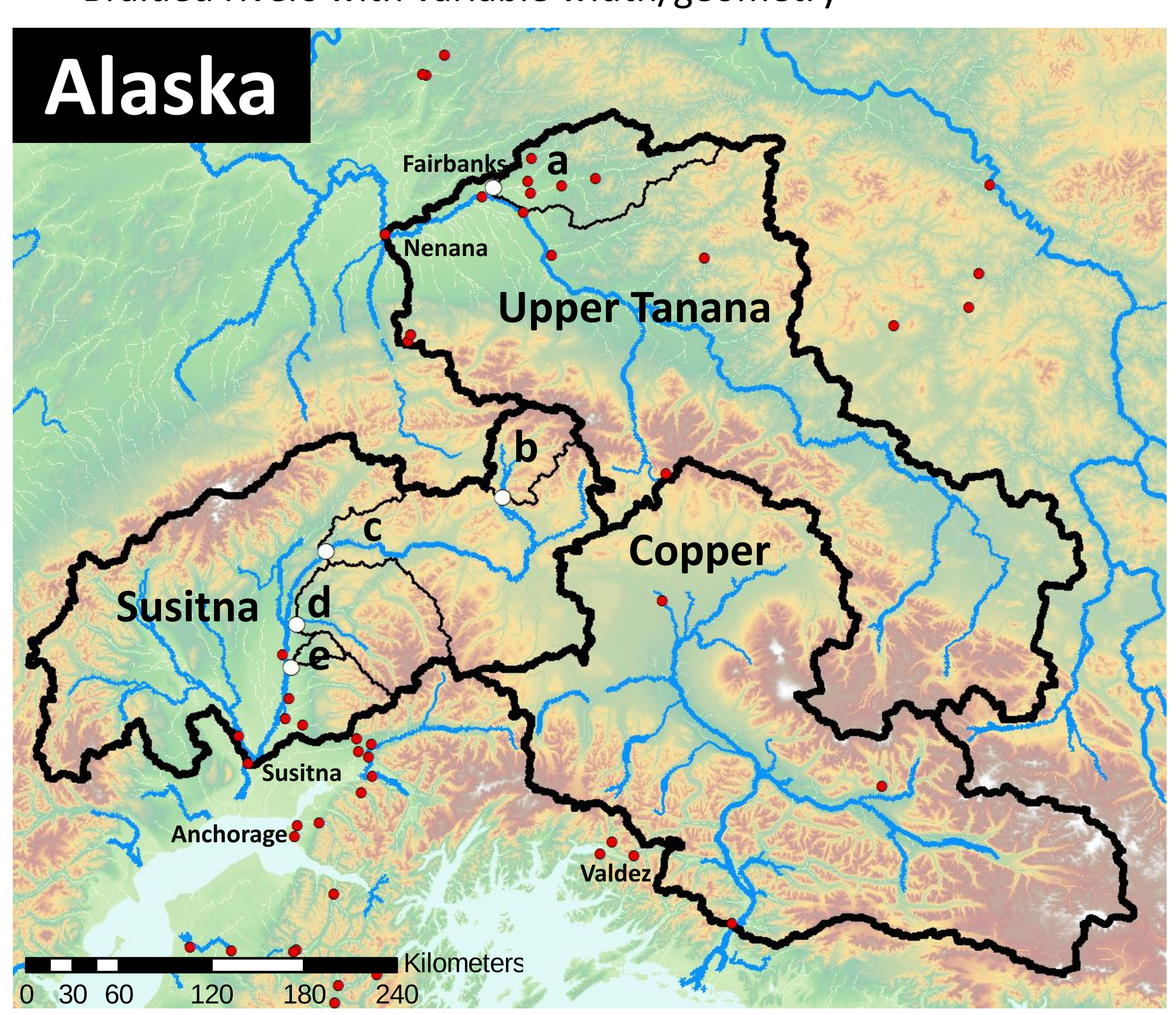

Figure 2. Major basins of South-central Alaska (thick black outlines; large black labels) and the modeled watersheds for this study (thin black outlines; see Table 2). USGS stream gauge sites corresponding to the modeled watersheds are indicted by the white dots. Other Alaskan USGS stream gauge sites (red dots) and SWOT observable rivers (blue lines)(Allen and Pavelsky, 2015) are also shown.

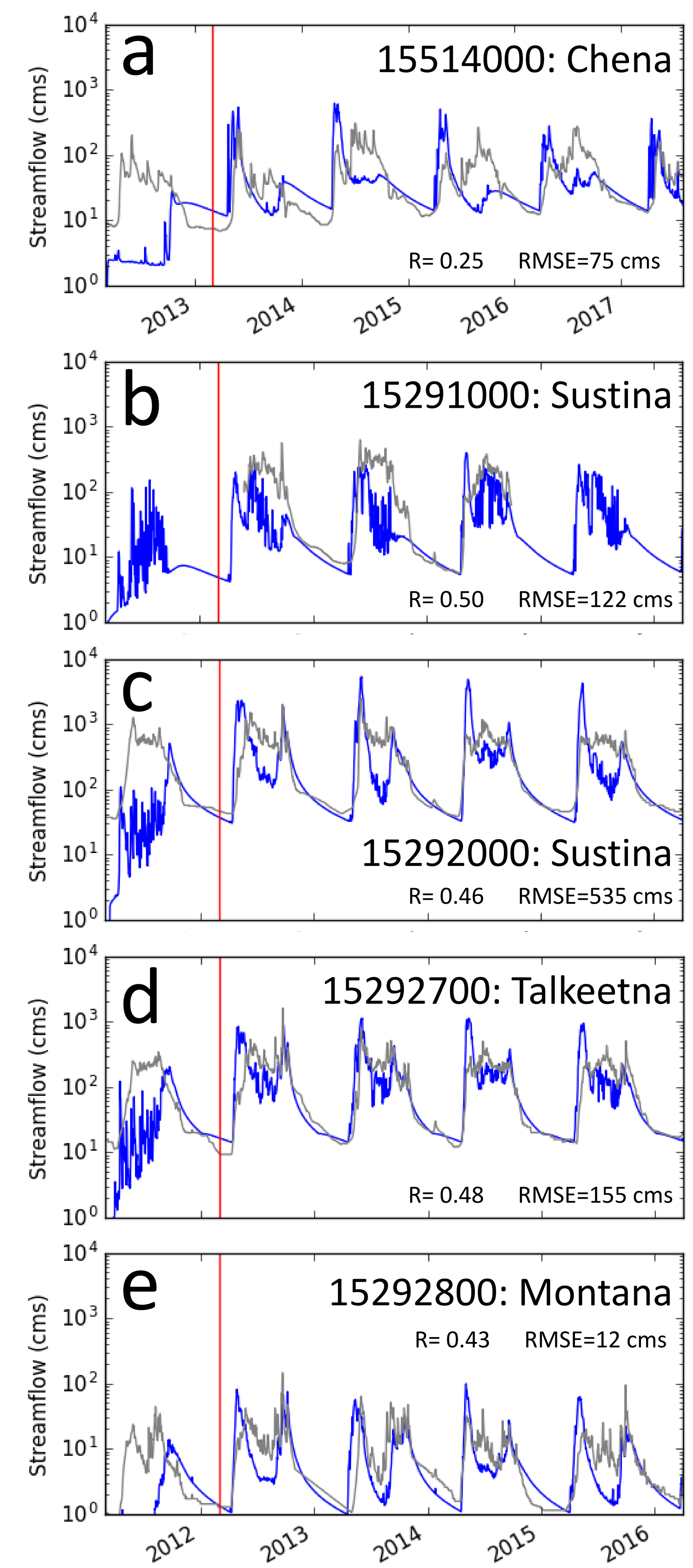

Figure 3. Hydrographs showing WRF-Hydro modeled streamflow (blue) and USGS gauge observations (gray) for five USGS gauge locations (see Figure 2 and Table 2). The one year spin-up period is shown to the left of the red line.

Modeled Watershed	USGS Station ID	USGS Station Name
a	15514000	Chena River at Fairbanks, AK
b	15291000	Susitna River near Denali, AK
c	15292000	Sustina River at Gold Creek, AK
d	15292700	Talkeetna River near Talkeetna, AK
e	15292800	Montana Creek near Montana, AK

Table 2. USGS stream gauges corresponding to the modeled watersheds indicated in Figures 2 and 3).

3. Model Configuration

- Uncalibrated, offline WRF-Hydro (version 4.0) coupled with Noah-MP
- 2 arc-second National Elevation Dataset (NED)(USGS, 2017) regridded to 250 m for WRF-Hydro subsurface flow, overland flow, and diffusive wave channel routing
- 1 km resolution land surface model (grids created using WRF Preprocessing System)
- Baseflow bucket model
- Global Land Data Assimilation System Version 2 (GLDAS-2) meteorological forcing (Rodell et al., 2004).
- 1 year spin-up followed by 4 year simulation
- Examined 5 watersheds (Chena River, upper Susitna River, middle Susitna River, Talkeetna River, Montana Creek) of varying topography and drainage area (Figure 2)

4. Results

- For all 5 watersheds, WRF-Hydro correctly captures rapid increase in discharge in spring due to snowmelt (Figure 3)
- Decrease in discharge during transition from fall to winter also well represented
- Underrepresents discharge in summer months, likely a result of the short spin-up which prevents adequate snowpack and glacier development
- Correctly models annual range of discharge
- Calibration and longer spin-up duration expected to improve results during summer months

5. Next Steps and Future Work

- Calibrate and expand analysis to full South-central Alaska domain
- Perform retrospective forecasts with meteorological forcing generated from offline WRF simulation
- Assess impacts of assimilating SWOT observations into WRF-Hydro to improve initialization

6. SWOT Data Assimilation

- SWOT is a wide-swath (120 km) radar altimeter (10 m spatial resolution, <10 cm elevation error) (Biancamaria et al., 2016)
  - Ka-band (35.75 GHz)
  - 21-day repeat cycle with orbit inclination of 77.6° (~4 observations per repeat cycle over Alaska for any given point)
- Global coverage of rivers with widths greater than 50-100 meters, including major rivers in Alaska (Figure 2)
- Provide measurements of channel water surface elevation (WSE), width, and slope
- Complement USGS stream gauges and provide observations in remote areas where no gauges are present
- Observing System Simulation Experiment (OSSE) for DA impact study until launch in 2021

Acknowledgements

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References

Allen, G. H., and T. M. Pavelsky (2015), Patterns of river width and surface area revealed by satellite-derived North American river width data set, Geophys. Res. Lett., 42, 395-402, doi:10.1002/2014GL062764.Biancamaria et al 2016

Biancamaria, S., D. P. Lettenmaier, and T. M. Pavelsky (2016), The SWOT mission and its capabilities for land hydrology, Surv. Geophys., 37(2), 307-337, doi:10.1007/s10712-015-9346-y.

Brown, M. E., V. Escobar, S. Moran, D. Entekhabi, P. E. O'Neill, E. G. Njoku, B. Doorn, and J. K. Entin (2013), NASA's Soil Moisture Active Passive (SMAP) mission and opportunities for applications users, Bull. Amer. Meteor. Soc., 94, 1125-1128, doi:10.1175/BAMS-D-11-00049.1.

Gochis, D. J., W. Yu, and D. N. Yates (2013), The WRF-Hydro Model Technical Description and User's Guide, Version 1.0, NCAR Technical Document, 120 pp., NCAR, Boulder, Colo. [Available at http://www.ral.ucar.edu/projects/wrf_hydro/.]

Jacobs, A., E. Holloway, and A. Dixon (2016), Atmospheric Rivers in Alaska – Yes they do exist, and are usually ties to the biggest and most damaging rain-generated floods in Alaska, 2016 International Atmospheric River Conference, San Diego, Calif.

NCAR (2017), WRF-Hydro modeling system, National Center for Atmospheric Research Research Applications Laboratory, https://www.ral.ucar.edu/projects/wrf_hydro.

Niu, G.-Y., et al. (2011), The community Noah land surface model with multiparameterization options (Noah-MP): 1. Model description and evaluation with local-scale measurements, J. Geophys. Res., 116, D12109, doi:10.1029/2010JD015139.

OWP (cited 2017), The National Water Model, http://water.noaa.gov/about/nwm.

Plumb, E., and L. Rundquist (2009), The 2008 Tanana River Flood: Where did all the water come from?, AWRA Spring Specialty Conference, Anchorage, Alaska, May 4-6, 27.2.

Rafieeinasab, A. (2017), WRF-Hydro calibration, *Personal communication*, Boulder, Colorado, 19 July.

Rodell, M., P. R. Houser, U. Jambor, J. Gottschalck, K. Mitchell, C.-J. Meng, K. Arsenault, B. Cosgrove, J. Radakovich, M. Bosilovich, J. K. Entin, J. P. Walker, D. Lohmann, and D. Toll (2004), The Global Land Data Assimilation System, Bull. Amer. Meteor. Soc., 85(3), 381-394.

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. G. Duda, X.-Y. Huang, W. Wang, and J. G. Powers (2008), A description of the Advanced Research WRF version 3, NCAR Technical Note, 475, 113 pp., http://www2.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf.

USGS (cited 2017), National Elevation Dataset (NED), https://nationalmap.gov/elevation.html.