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Hydrological Modeling in Alaska with WRF-Hydro

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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)

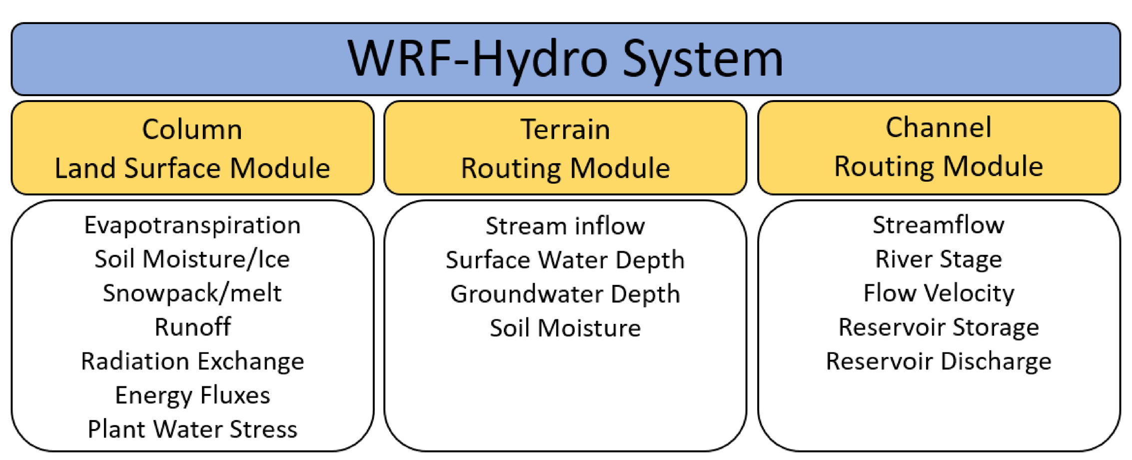

Figure 1. WRF-Hydro modules and output variables.

- This project uses experimental version of WRF-Hydro in Alaska mimicking the NWM to gauge ability of WRF-Hydro to:
    - Represent unique hydrological processes of arctic regions
    - Identify model calibration and initialization challenges associated with limited in-situ observations
    - Investigate potential of assimilating hydrology-focused NASA satellite datasets (e.g., Surface Water Ocean Topography (SWOT)(Biancamaria et al., 2016)) 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). Resolutions indicate column land surface, terrain routing, and channel routing resolutions, respectively. Meteorological forcing acronyms: Multi-Radar Multi-Sensor (MRMS), Rapid Refresh (RAP), High-Resolution Rapid Refresh (HRRR), Global/Climate Forecast System (GFS/CFS).

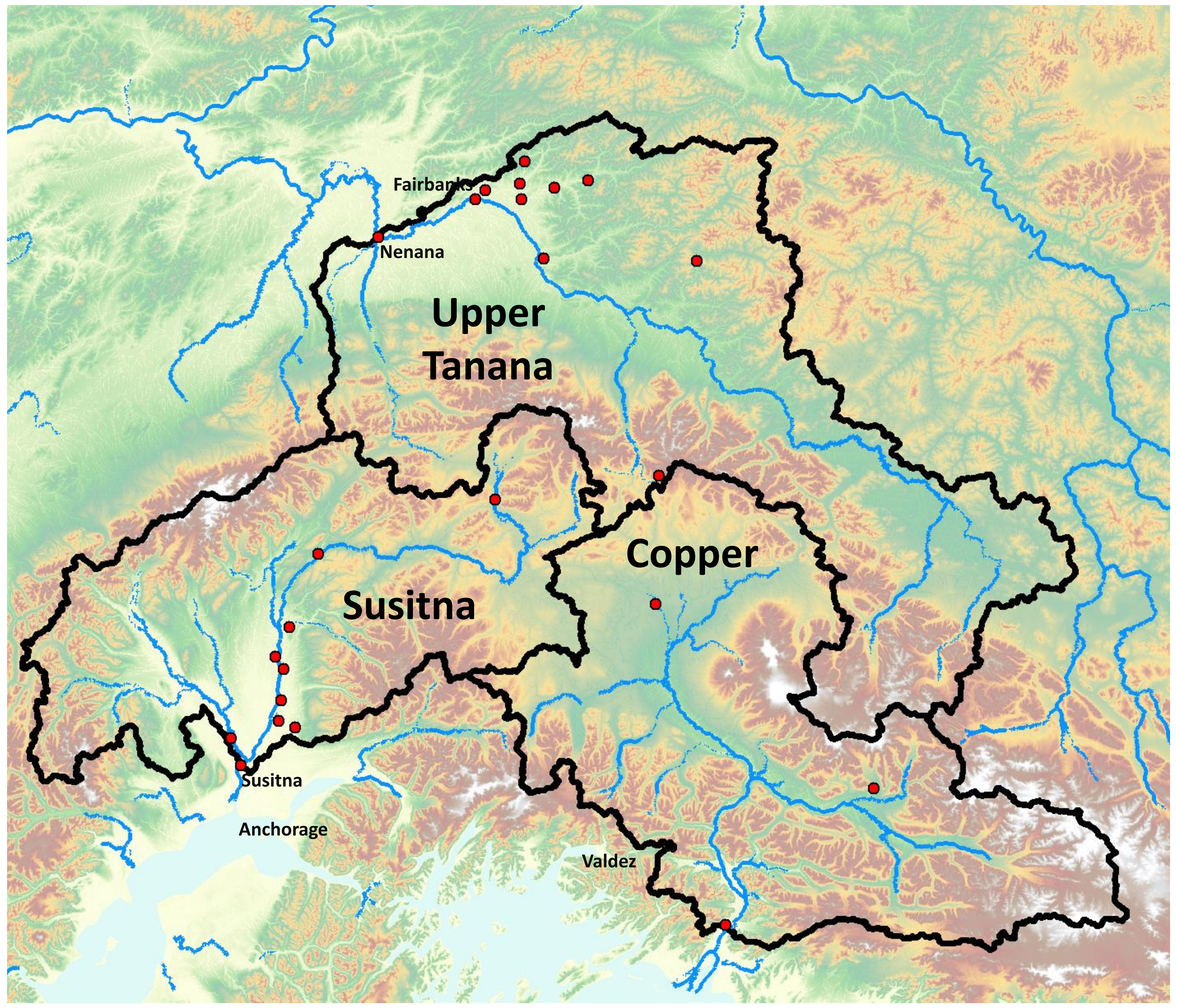

Figure 2. Model domain extent showing current USGS stream gauge sites (red dots) and SWOT observable rivers (blue)(Allen and Pavelsky, 2015).

2. Challenges of Hydrological Modeling in Alaska

- Large remote areas with severe lack of in-situ observations (e.g., soil moisture and streamflow) 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

3. Model Configuration and Calibration

- South-central Alaska domain includes upper Tanana, Susitna, and Copper River basins (Figure 2)
- 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 channel routing
    - 1 km resolution land surface model (grids created using WRF Preprocessing System)
    - Diffusive wave gridded routing
    - Baseflow bucket model
- Case studies:
    - Tanana Valley Flood (July-August 2008)(Plumb and Rundquist, 2009)
    - South-Central Alaska Flood (September 2012)(Jacobs et al., 2016)
    - Susitna Valley Flood (November 2015)(Jacobs et al., 2016)
- Calibrate most sensitive parameters (Rafieeinasab, 2017) using National Center for Atmospheric Research (NCAR) NWM calibration scripts (negative weighted mean Nash-Sutcliffe Efficiency (NSE) and log NSE):
    - Clapp-Hornberger B exponent (bexp)
    - Soil moisture maximum (smcmax)
    - Saturated soil conductivity (dksat)
    - Soil infiltration parameter (refkdt)
    - Soil drainage parameter (slope)
    - Retention depth (RETDEPRTFAC)
    - Saturated soil lateral conductivity (LKSATFAC)
    - Groundwater bucket model max depth (Zmax)
    - Groundwater bucket model exponent (Expon)
    - Canopy wind parameter (cwpvt)
    - Maximum carboxylation at 25C (vcmx25)
    - Ball-Berry conductance relationship slope (mp)

4. Surface Water Ocean Topography (SWOT) Mission

- 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° (Figure 3)
- 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

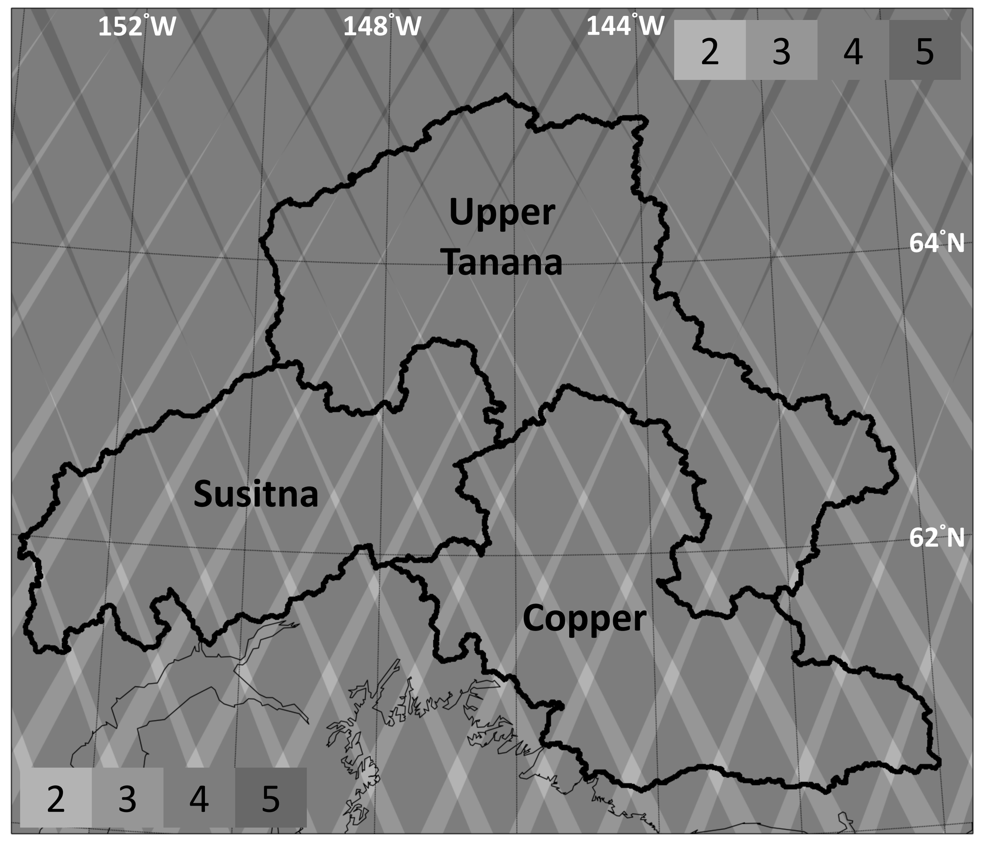

Figure 3. Number of SWOT observations per 21-day repeat cycle over the model domain.

5. Next Steps and Future Work

- Spin-up and calibration using Global Land Data Assimilation System Version 2 (GLDAS-2) meteorological forcing (Rodell et al., 2004).
- Perform case study retrospective forecasts
    - Forcing generated from offline WRF (Skamarock et al., 2008) simulation
    - Driven by Global Data Assimilation System (GDAS) atmospheric reanalysis (NOAA NCEP, 2017)
- Assimilate SWOT WSE into WRF-Hydro and identify impacts

Acknowledgements

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