Streamflow Sensitivity to High-Resolution Precipitation Patterns

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FIRO Science Task Group Meeting
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Outline

• Need for accurate streamflow simulations for reservoir operations
• Distributed hydrologic modeling forcing data challenges
• Linkage between atmospheric and hydrologic models
• High-resolution modeling framework: West-WRF ensemble forcing data for GSSHA
• Spatially robust hydro-meteorological verification data
• Lake Mendocino hydrometeorology testbed
Acknowledgements

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  – Alan Snow
  – Cary Talbot

• SCWA:
  – Chris Delaney
  – Jay Jasperse

• PVID:
  – Janet Pauli
Skillful streamflow forecasts needed for FIRO viability

Streamflow uncertainty = QPF uncertainty + hydrologic uncertainty

Need to understand distributed hydrologic processes and sensitivities to precipitation
Forcing data in distributed hydrology models

- High spatial variability of precipitation over topography
- AR-driven precipitation particularly sensitive to topography due to moist-neutral LLJ (e.g., Ralph et al. 2005)
- Upslope flow shown to explain precipitation rates (Ralph et al. 2013)
Forcing data in distributed hydrology models

- What is the appropriate scale to represent AR-driven precipitation over the 270 km² Lake Mendocino watershed?
  - 25 km GFS
  - 3 km West-WRF/3 km HRRR
  - 800 m PRISM statistical downscaling
  - Something else?
West-WRF/GSSHA Linkage

- Goal of automating coupled West-WRF/GSSHA streamflow forecasts
- Utilization of gsshapy scripts and ftp to allow automated streamflow forecasts
- Methods in development
West-WRF Ensemble Forecast Example

• Multiple 10-day reforecasts of February 6-9, 2015 streamflow event
• GFS boundary and initial conditions for each simulation
• Sea surface temperature boundary conditions varied
• All other West-WRF aspects identical
• **SST product ensemble:**
  
  – **GFS:** Only using GFS deterministic forecast data
    - SST is held constant throughout simulation, using Real-Time Global Analysis (RTG) (NCEP/MMAB)
  
  – **SKTM:** GFS forecast + SST variability within GFS
    - RTG relaxed to climatology
  
  – **cSST:** GFS forecast + constant Hi-Res SST
    - Global 1 km SST (G1SST) satellite and in situ blended product (NASA/JPL) held constant throughout simulation
  
  – **SST:** GFS forecast + Hi-Res SST
    - G1SST varies daily (natural weekly/seasonal variability on daily time scales)

• **West-WRF precipitation drives 270 m GSSHA model (ERDC-CHL) of Lake Mendocino watershed, as a conceptual example**

Slide courtesy Rachel Weihs and Xin Zhang
West-WRF Ensemble Forecast Example

a) GFS

b) cSST

c) SKTM

d) SST

3-hour Precipitation [mm]

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5 25

e) Lake Mendocino Watershed Cumulative Precipitation and Streamflow

Cumulative Precipitation [mm]

0 25 50 75 100 125

Streamflow [cms]

0 10 20 30 40 50

Feb 06, 00:00  Feb 06, 12:00  Feb 07, 00:00  Feb 07, 12:00  Feb 08, 00:00  Feb 08, 12:00  Feb 09, 00:00  Feb 09, 12:00

Legend:
- GFS
- cSST
- SKTM
- SST
West-WRF Ensemble Forecast Example

e) Lake Mendocino Watershed Cumulative Precipitation and Streamflow
West-WRF Ensemble Forecast Example

The images depict ensemble forecast examples for precipitation and streamflow in the West region. The ensemble members include:

- **a) GFS**: A conventional Global Forecast System forecast.
- **a) cSST**: A forecast using coupled sea-surface temperature data.
- **c) SKTM**: A forecast using a coupled sea-land interaction model.
- **d) SST**: A forecast using ocean-only data.

The plots show cumulative precipitation and streamflow for Lake Mendocino Watershed over a period from February 6 to February 9, with detailed time series for each ensemble member, indicating variability and uncertainty in the forecast predictions.
West-WRF Ensemble Forecast Example

e) Lake Mendocino Watershed Cumulative Precipitation and Streamflow

- **GFS**
- **cSST**
- **SKTM**
- **SST**

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<th>Cumulative Precipitation [mm]</th>
<th>Streamflow [cmsg]</th>
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West-WRF Ensemble Forecast Example

• Forecasts produce similar larger-scale synoptic pattern but differing precipitation patterns at watershed scale
• Streamflow sensitive to precipitation pattern:
  – Intensity
  – Intra-watershed variability
Hydrometeorological Verification Data

• How to assess intra-watershed patterns of precipitation, soil moisture and streamflow variability?

• Expansion of observational network will allow for better observations of ARs and inform development of GSSHA modeling
  – Distributed streamflow response
  – Soil moisture across variable topographic characteristics
  – Spatial distributions of precipitation
Hydrometeorological Verification Data

• NOAA HMT network:
  – 3 existing stations within Lake Mendocino watershed providing 2-minute precipitation and soil moisture observations since 2015
• USGS Calpella gauge
• Lake Mendocino estimated inflows

*High temporal resolution precipitation observations from NOAA HMT stations*
Lake Mendocino Hydrometeorology Testbed

- Stroh Pauli/Boyes Cr.
- Pauli/Upland
- Frost Pauli
- Delbar/Mewhinney Cr.
- USACE/Deerwood
- BLM/North Cow Mtn.

Icons:
- ▲ HMT P/SM
- ○ USGS Q
- ★ CW3E P/SM
Lake Mendocino Hydrometeorology Testbed

- Stroh
- Delbar
- CW3E P/SM
- USACE/Deerwood
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- Pauli/Upland
- Frost Pauli
- USGS Q
- BLM/North Cow Mtn.
- Mewhinney Cr.
Lake Mendocino Hydrometeorology Testbed

- Stroh
- Pauli/Hawn Cr.
- Pauli/Boyes Cr.
- Pauli/Upland
- Pauli/Upland
- Delbar/Mewhinney Cr.
- Frost Pauli
- Bridges
- Cold Cr.
- USACE/Deerwood
- BLM/North Cow Mtn.

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<th>Symbol</th>
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Lake Mendocino Hydrometeorology Testbed

- USACE / Deerwood
- Cold Cr. Bridges
- BLM / North Cow Mtn.
- Delbar / Mewhinney Cr.
- USGS Q
- CW3E P/SM
- CW3E Q
- HMT P/SM
Lake Mendocino Hydrometeorology Testbed

- HMT P/SM
- USGS Q
- CW3E P/SM
- CW3E Q

Locations:
- Stroh
- Pauli/Hawn Cr.
- Pauli/Boyes Cr.
- Pauli/Upland
- Delbar/Mewhinney Cr.
- Bridges
- Pauli/Upland
- Magruder?
- USACE/Campground?
- USACE/Deerwood
- USGS Q
- Cold Cr.
- BLM/North Cow Mtn.
Goals

• Installation of instruments in summer 2017
• 2017-2018 AR season intensive observation
• Assessment of high-resolution precipitation patterns within watershed and sensitivity of streamflow to precipitation and soil moisture