Rio Grande Basin Forecasting Project

Workshop on snowpack monitoring for streamflow forecasting and drought planning
Sep. 9, 2015
Rio Grande Compact Delivery Requirements as a Percentage of Annual Index Flows

0% 10% 20% 30% 40% 50% 60% 70% 80%
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600
Annual Index Flow (Acre Feet X 1000)
Percent of Index Required for Delivery
Rio Grande River
Conejos River

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Rio Grande River
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Project Motivation and Goals

• Project Motivation:
  – Need better skill in water supply forecasts to better meet Compact requirements
  – Build on demonstrated capabilities of ‘radar in the mountains’ (6 years)
  – Limited information on snowpack, snowmelt and tributary streamflow conditions leads to uncertainty in snowpack conditions
    • SNODAS
    • Hydro models
    • Other snowpack analyses
Overarching Questions:

• What are the biases in operational precipitation, temperature, humidity, wind and insolation forcing?
• Can operational forcing data errors be corrected with local data?
• How are model biases in simulated snowpack (accumulation and depletion phases) related to errors in forcing data?
• How are the model biases in simulated streamflow (timing and total seasonal volume) related to forcing data and simulated snowpack errors?
Project Motivation and Goals

• Project Goals:
  – Strategic enhancement of precipitation and snowpack observations
  – Evaluate value of new measurements compared to existing analyses
  – Use enhanced observations to evaluate distributed modeling system (WRF-Hydro)
  – Develop new experimental water supply forecast methodologies
Hydrologic Monitoring and Seasonal Streamflow Prediction in the Upper Rio Grande River Basin

- NSSL - NOXP (Xband) radar
  - Snowfall retrieval based on past radar in mountains experiments
- NCAR met. stations (6 stations in Conejos Basin)
- NCAR streamflow (4 sites in the Conejos basin)
- NASA Airborne Snow Observatory
- Operational: NRCS/SNOTEL, CDWR, NWS/SNODAS, MODIS/SCA
Community Engagement in the San Luis Valley and State of Colorado

• Project participants:
  – U. Oklahoma (radar)
  – Adams State U. (radar)
  – Colorado State U. (survey)
  – U. of Colorado (snow pits)
  – Conejos Water Conservancy (site maint.)
  – NRCS, CWCB, NSSL, NASA, NCAR
NSSL Radar Products: Filling the gap

• No quality coverage in upper Rio Grande
• NSSL radar in Alamosa provides 360 deg coverage out to 100km radius
• Estimates of precipitation rate and rain/snow partition
• Operated during all major events Dec.-Apr.
Operational National Radar Mosaic

NOXP-Alamosa

NOXP Comp_Rain 00.00 [2015 02/23 12:59:33 UTC]
On-the-ground Measurements in the Conejos

- 6 stations:
  - Temperature
  - Humidity
  - Wind
  - Incoming solar radiation
  - Snow depth
  - Soil moisture/temperature

- 3 stations
  - Precipitation
Results from Year 1 Monitoring
On-the-ground Measurements in the Conejos

- Comparing operational NLDAS met. data vs. local stations:
  - Downscaled NLDAS lacks daily temperature range vs. local observations
  - NLDAS has warm bias for valley stations
  - NLDAS overestimates total daily insolation
On-the-ground Measurements in the Conejos

Percent Bias in NLDAS Forcing Variables

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- Comparison between operational NLDAS and local met station forcing *suggests too much ‘available energy’* (temperature, radiation, humidity and wind) compared to station data
Summary of Findings to Date: Snowpack-streamflow relationships

1. Despite well below median snowpack at SNOTEL sites streamflow was reasonable. So where did runoff come from?...likely higher elevations than most current SNOTEL sites and late season precipitation

   - Melt out at SNOTEL sites (Lilly Pond) is 2 months earlier than peak flow...longer than channel travel time...
   - Additional work looking at SNODAS and NASA/ASO snowpack products is in progress....
Summary of Findings to Date: Streamflow variability

1. Tributary flows into Conejos River from ungauged Elk Fork, S. Fork branches form very significant fraction of total flow. **Unknown how fractional contribution varies from year to year.** This fact complicates management and suggests better monitoring of tributary flows is needed.

Dates of peak flow:

- S. Fork Conejos: June 11
- Elk Fork: June 12
- Lake Fork: June 7
- Saddle Creek: June 10
On-the-ground Snowpack Monitoring

- Lilly Pond consistent with mid-elevation Conejos sites with late April melt out
- High elevation/north aspect sites (e.g. Forest King) holds snow much longer
- Forest King, Wolf Creek and Cumbres Trestle SNOTEL sites has many ‘plus-ups’ during spring
NASA Airborne Snowpack Monitoring

- 2 flights conducted so far
- April 8, 2015
- May 16, 2015
- Final ‘snow-off’ flight forthcoming (September)

Upper Uncompahgre Watershed
Banded SWE Report- April 30th, 2015
Total SWE: 66,597 Acre Feet
5% below 7,000 ft
7% between 7,000 and 8,000 ft
13% between 8,000 and 9,000 ft
19% between 9,000 and 10,000 ft
23% between 10,000 and 11,000 ft
32% above 11,000
Results from Year 1 Model Evaluation
Seasonal Streamflow Prediction in the Upper Rio Grande River Basin: WRF-Hydro Modeling System

- High resolution (1km/100m) spatially-distributed physics
- Energy balance snowpack and physics-based runoff modeling
- In transition to become national streamflow prediction system with NWS

WRF-Hydro Website: http://www.ral.ucar.edu/projects/wrf_hydro
Impact of NSSL Radar Data:

- NSSL-NOXP radar tends to reduce area-wide precipitation vs. operational product
- More SLV precip. with NOXP product
- Exception is in Upper Conejos River Basin
  - NLDAS +54% bias
  - NOXP +24% bias
Impact of NSSL Radar Data: Basin averaged snowpack

- Most basins show better agreement between NOXP and SNODAS

- Problem basins:
  - Trinchera (accum. error)
  - Los Pinos (early melt)
  - S. Fork Rio (blockage?)
Hydrologic Modeling: Impact of Radar Data

- Radar precipitation product generally improves hydrologic simulation in URG
- Main impact is to reduce positive streamflow bias in operational forcing
- Rio Grande flows well simulated with NOXP radar data
- Conejos River shows early low bias error using radar…why?
Runoff timing and relative magnitude of runoff is reasonable…
Hydrologic Modeling: Why is Conejos Runoff early?

- Low elevation stations in Conejos basin show strong *POSITIVE* temperature bias (+2-4 deg C) in operational forcing data
- NLDAS *overestimates* daily insolation
- Contributes excess basin sublimation and evaporation
- Not previously diagnosed due to lack of observations
- Other variables still being evaluated...
Hydrologic Modeling: Forecast Evaluation

- Forecast research is ongoing
- Incorporating new observations
- Initial Apr. 1 ESP forecasts were low, mostly due to biases in ESP forcings
- Additional model enhancements and bias corrections to forcings developed in WY2015
- New climate forecast method being evaluated (operational in WY2016)
Take Home Points:

• Research radar adds value by reducing some strong forcing biases in model simulated runoff and providing *more local information in non-SNOTEL* areas (e.g. Conejos)
  – Significant potential for better representing spring rain vs. snow

• Additional snowpack monitoring revealed issue of out of phase timing between SNOTEL snow depletion and major runoff periods
  – More/better monitoring is needed at elevations above 11,000 ft. and in areas with greater/persistent snowpack
  – *Excellent opportunity for ASO and satellite data input*
Take Home Points:

• In-situ data identified *significant biases* in operational meteorological forcing datasets…correction methods now being developed

• Tributary flows into Conejos River form very significant fraction (+40%) of total flow suggests better monitoring of tributary flows is needed

• High resolution hydrologic modeling showing good simulation skill in snowpack conditions and in capturing relative contributions of tributary (non-gauged) flows…good flow timing in all basins

• Comparison and use of NASA ASO snowpack and albedo is forthcoming
Ongoing work

- Real-time monitoring/forecast web mapping service for Conejos and Upper Rio Grande basin for experimental products

Real-time display of station observations & model output
Ongoing work

• Expanded experimental WRF-Hydro water supply forecasting:
  – Bias-corrected, downscaled ESP-based forcings
  – Assimilation of real-time CDWR beginning in March 2016
  – Addition of 30-day downscaled NOAA Climate Forecast System forecast data (operational from NWS/NWC starting in May 2016)

• Opportunities for broader interaction:
  – Evaluation of past snowpack conditions (MODIS, MODSCAG)
  – ASO data comparisons against modeled snowpack and albedo
  – Addition of monitoring data to NCAR Web Mapping Service
  – El Nino event coming in 2016…???
End – Thank you.

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