DMIP 2: First Results from North Fork American River

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Pete Fickenscher², Eric Strem²

NOAA/NWS Office of Hydrologic Development
Distributed Model Intercomparison Project (DMIP)
North Fork American River
Near Iowa Hill Bridge
DMIP 2 Western Basins: Gauge Network for ‘Basic’ Data (mimic RFC operations)

- H: Hourly gauges
- D: Daily gauges
- SD: SNOTEL daily gauges

Center of HRAP grids

Precipitation
And
Temperature
DMIP 2 Western Basins: Leverage HydroMet Testbed Radar QPE

Forest Hill Smart R (NSSL)
Auburn X-POL (ESRL)

Two Radars in 2005-2006
QPE Data Processing for Use in DMIP 2

‘Advanced’ DMIP 2 Data: Multi-year time series of gridded data comprised of
1) ‘Basic’ data and 2) Processed and gridded HMT data for each IOP

Step 1:
‘Basic’ DMIP 2 Data: Time series of gridded precipitation
and temperature from NCDC, Snotel sites to Dec. 2002;

-Represent what the RFC uses for current
Forecast operations.
-Used for the initial lumped and distributed
DMIP 2 simulations in the western basins.

Step 2:
Extend ‘Basic’ Data: gridded precip. and temp. from NCDC, Snotel sites

Gridded Precipitation
for each IOP
replaces Basic Data

Analysis of Data
ESRL, NSSL, OHD

Step 3
HMT-West
Observations
Gathered
1 2 3

Note: the time scale describes the attributes of the time series,
not the schedule for processing the HMT data. The HMT observations
will be processed after each campaign and inserted into
the Basic Data time series.
### STATUS: Use of HMT Data and DMIP 2 Science Questions

<table>
<thead>
<tr>
<th></th>
<th>1 Data</th>
<th>2 Type</th>
<th>3 Processing</th>
<th>4 Status</th>
<th>5 DMIP 2 Modeling Experiment</th>
<th>6 DMIP 2 Science Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NCDC, Snotel precip and temperature</td>
<td>‘Basic Data’ represents RFC current data</td>
<td>Process into grids</td>
<td>Complete through 2006; being used by DMIP 2 participants through 2002</td>
<td>Run lumped and dist. models with data currently available</td>
<td>Can we run dist. models now with current data in mountains? Is there gain over lumped models? DMIP 2 Science Plan question VIII, pg. 9</td>
</tr>
<tr>
<td>2</td>
<td>HMT gap filling radar QPE for IOPs</td>
<td>HMT ‘value added’ QPE; corrected for mean field bias</td>
<td>1. Replace ‘basic’ grids with HMT value added</td>
<td>Delivered to OHD; tested cases</td>
<td>Run lumped, dist. models with HMT ‘value added’ QPE</td>
<td>Can we run advanced distributed models using emerging data? Is there gain over lumped models? DMIP 2 Science Plan question IX, pg. 9</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>2. Use MPE, gauge data for correction</td>
<td>Processed all ’05/’06 cases</td>
<td>Run lumped, dist. Models with HMT ‘value added QPE</td>
<td>Same as above</td>
</tr>
<tr>
<td>4</td>
<td>HMT estimates of freezing level for IOPs</td>
<td>HMT ‘value added’ freezing level</td>
<td>Flag grids as rain/snow given freezing level</td>
<td>Data collected; approach identified from 2 journal papers</td>
<td>Run models with new freezing level data; compare to current RFC approach</td>
<td>Art Henkel thinks the greatest improvements may be from better rain/snow level detection. DMIP 2 Science Plan question X, pg. 10</td>
</tr>
<tr>
<td>5</td>
<td>HMT additional in situ rain, temp gauge data</td>
<td>Denser in situ network</td>
<td>Process into grids using MPE or Schake’s program</td>
<td>Data from CDEC delivered to OHD by Dave Kingsmill;</td>
<td>Lumped, distributed model runs with forcings from networks of various densities.</td>
<td>What is required gauge density in mountainous areas? DMIP 2 Science Plan question IX, pg. 9</td>
</tr>
<tr>
<td>6</td>
<td>HMT Soil Moisture</td>
<td>HMT value added</td>
<td>QC, process into point time series</td>
<td>Some data collected; new sensors to be installed</td>
<td>Validate distributed models:</td>
<td>Using soil moisture obs., can we understand if we’re getting the right answer for right reason? DMIP 2 Science Plan question IX, pg. 9</td>
</tr>
</tbody>
</table>

### DMIP 2 Science Plan Questions

1. Can we run advanced distributed models using emerging data? Is there gain over lumped models? DMIP 2 Science Plan question IX, pg. 9
2. What is required gauge density in mountainous areas? DMIP 2 Science Plan question IX, pg. 9
3. Using soil moisture obs., can we understand if we’re getting the right answer for right reason? DMIP 2 Science Plan question IX, pg. 9
DMIP 2 Participants for Western Basins with ‘Basic’ Data

- OHD
- U. Illinois
- Hydrologic Research Center
- U. Bologna
- U. California at Irvine
- U. Nebraska at Lincoln
- U. Arizona

Note: Results not yet analyzed
OHD DMIP 2 North Fork Streamflow Simulations Using Basic Data

- **OHD Lumped model (standard)**
  - Two elevation zones; 5000 ft.
  - Calibrated

- **OHD distributed model**
  - 48 grid cells, ~4km x 4km
  - Calibrated:
    - Started with calibrated lumped parameters
    - Manual calibration of parameters (scalars)
    - Maintain elevation zone relationships
    - Basic scripts developed to generate zone parameters
DMIP 2: North Fork American River
OHD Streamflow Simulations with ‘Basic Data’

March 5, 1991

Observed

OHD Distributed

Lumped
DMIP 2: North Fork American River
OHD Streamflow Simulations with ‘Basic Data’

March 10, 1995

Lumped

OHD Distributed

Observed

March 10, 1995
DMIP 2: North Fork American River
OHD Streamflow Simulations with ‘Basic Data’

March 25, 1998

Flow (cms)

- OHD Distributed
- Lumped
- Observed
DMIP 2: North Fork American River
OHD Streamflow Simulations with ‘Basic Data’

Captures diurnal snowmelt
June, 1999
QPE Data Processing for Use in DMIP 2

‘Advanced’ DMIP 2 Data: Multi-year time series of gridded data comprised of 1) ‘Basic’ data and 2) Processed and gridded HMT data for each IOP

**Step 1:**
‘Basic’ DMIP 2 Data: Time series of gridded precipitation and temperature from NCDC, Snotel sites to Dec. 2002;
- Represent what the RFC uses for current Forecast operations.
- Used for the initial lumped and distributed DMIP 2 simulations in the western basins.

**Step 2:**
Extend ‘Basic’ Data: gridded precip. and temp. from NCDC, Snotel sites

**Step 3**
Gridded Precipitation for each IOP replaces Basic Data
Analysis of Data
ESRL, NSSL, OHD
HMT-West Observations Gathered 1 2 3

Note: the time scale describes the attributes of the time series, not the schedule for processing the HMT data. The HMT observations will be processed after each campaign and inserted into the Basic Data time series.
Initial Distributed Model Analysis of Gridded Precipitation Data: 4 QPE Cases for HMT

• OHD gauge only
  – NCDC hourly/daily and SNOTEL
  – PRISM, 1/d^{1/2}
• MPE gauge only
  – 12 Hourly NCDC gauges
  – No PRISM, 1/d^2
• KDAX/gauge (MPE)
  – 12 Hourly NCDC gauges
• NSSL/ESRL/gauge (MPE)
  – 12 NCDC hourly gauges
  – Uses KDAX/MPE as ‘fill’ between IOPs
Initial Distributed Model Analysis of Gridded Precipitation Data: 4 QPE Cases for HMT

- Run distributed model to Dec 1, 2005 using OHD Basic data
- Save internal states.
- Use saved states as initial conditions for 4 distributed model simulations
North Fork American River
Streamflow Simulations: 4 Cases

Nov 30 – Dec 5, 2005

OHD Basic
Observed

MPE gauge only

KDAX MPE

NSSL/ESRL MPE
North Fork American River
Streamflow Simulations: 4 Cases

Dec 19-26, 2005

Flow (cms)

OHD Basic
Observed
MPE gauge only
KDAX MPE
NSSSL/ESRL MPE
North Fork American River Streamflow Simulations: 4 Cases

Dec 28 – Jan 4, 2006

- Observed
- OHD Basic
- MPE gauge only
- NSSL/ESRL MPE
- KDAX MPE
An example of azimuthal artifacts in SMARTR data

North Fork American River Basin

Radar-derived QPE [mm] SMART-R1 051201/20:00:08-051201/20:55:07 UTC

Merged QPE for 1 Dec 2005 20-21 UTC

-Note the pattern of QPE that emanates radially from the SMARTR radar site.
-ESRL had artifacts in data too.
Detection of Rain/Snow Elevation Using Radar Data

- Snow
- Melting level (0°C)
- Melting layer
- Bright band
- Rain

Doppler Vertical Velocity

Reflectivity
Proposed Method for Using HMT Freezing Level Data

• Rain versus Snow in the Sierra Nevada, California: Comparing Doppler Profiling Radar and Surface Observations of Melting Level, Lundquist et al., 2008, Journal of Hydrometeorology

• Using Radar Data to Partition Precipitation into Rain and Snow in a Hydrologic Model, Maurer and Mass, 2006, J. Hydrologic Engineering
OHD DMIP 2 Results for the East Fork Carson Basin
## Outlet Hydrograph Statistics from Lumped and Distributed Simulations: Carson Basin

<table>
<thead>
<tr>
<th>Statistics</th>
<th>GRDN2 outlet calibration</th>
<th>CEMC1 outlet calibrated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GRDN2 outlet</td>
<td>CEMC1 outlet</td>
</tr>
<tr>
<td></td>
<td>LMP</td>
<td>OHD</td>
</tr>
<tr>
<td>Overall statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias%</td>
<td>-3.00</td>
<td>-2.40</td>
</tr>
<tr>
<td>RMSE%</td>
<td>51.20</td>
<td>47.60</td>
</tr>
<tr>
<td>R</td>
<td>0.94</td>
<td>0.94</td>
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<tr>
<td>NS</td>
<td>0.87</td>
<td>0.89</td>
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<tr>
<td>Flood event statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias%</td>
<td>19.70</td>
<td>16.70</td>
</tr>
<tr>
<td>RMSE%</td>
<td>23.00</td>
<td>21.40</td>
</tr>
<tr>
<td>R</td>
<td>0.82</td>
<td>0.83</td>
</tr>
<tr>
<td>Rm</td>
<td>0.41</td>
<td>0.54</td>
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<tr>
<td>Peak Error%</td>
<td>22.90</td>
<td>19.30</td>
</tr>
<tr>
<td>Peak Time Error, hr</td>
<td>3.32</td>
<td>3.29</td>
</tr>
</tbody>
</table>
Calibrated and Uncalibrated Dist. Model Simulations of SWE

Ebbets Pass

Blake

Poison Flats

Sprat Creek

Observed  
Calibrated  
Uncalibrated
Overall Results for the Carson Basin

• Distributed model calibration at GRDN2 outlet provides slightly better statistics compared to lumped. However, results for nested outlet CEMC1 lead to considerable runoff bias from both models.

• Calibration of both models at CEMC1 outlet improves simulations significantly.

• Combination of calibrated distributed CEMC1 and GRDN2 local area parameters leads to slightly better results compared to just GRDN2 based calibrated distributed parameters.
Conclusions

- Density of hourly rain gauges near North Fork basin appears sufficient to support distributed modeling.
- Gridded Snow-17 needs areal depletion curve at 4km scale; may need finer scales.
- Calibration starting from lumped parameters seems reasonable.
- HMT radar QPE data needs to be reprocessed.
- In general, may be difficult to identify QPE data impacts given short 3 mo. period.
Recommendations

• Re-process radar QPE in HMT
• Develop correction for gridded hourly gauge-only QPE
• Perform data denial experiments:
  – Remove hourly NCDC gauges from MPE analysis to see where radar QPE begins to add value
• Examine events for rain/snow
Discussion?
Background Slides: Analysis of QPE for North Fork Basin for DMIP 2

Initial DMIP 2 period: 1987 – 2002

Extended DMIP 2 period: 1987 – 2006 (to include HMT QPE)
Deriving Hourly Gridded Basic QPE For Initial DMIP 2 Experiments: 1987-2002

Derive precipitation estimates using three data sources for the period of 1987-2002: 1) NCDC hourly cooperative observer (coop) gauges, 2) NCDC daily total coop gauges, and 3) SNOw pack TELemetry (SNOTEL) daily precipitation gauges. The daily values are disaggregated to hourly using the nearest hourly gauge values. The hourly values, expressed as fraction of normal, are then interpolated to approximately 4km Hydrologic Rainfall Analysis Project (HRAP) (Greene and Hudlow, 1982) grids using an inverse-distance ($1/d^{1/2}$) method. Parameter- elevation Regressions on Independent Slopes Model (PRISM) (http://www.ocs.orst.edu/prism/products/) monthly precipitation climatology grids are used to compute fractions of normal at gage locations prior to the inverse distance interpolation and to convert interpolated fractions of normal to precipitation amounts at each grid point.

Source: Moreda et al., 2006. Gridded Rainfall Estimation for Distributed Modeling in Western Mountainous Areas, Session H23A, AGU 2006 Spring Meeting, May 23 - 27, Baltimore, MD
Checking 1987-2002
OHD Basic QPE

Annual precipitation derived from grids matches annual PRISM for the entire rectangular box

Source: Moreda et al., 2006. Gridded Rainfall Estimation for Distributed Modeling in Western Mountainous Areas, Session H23A, AGU 2006 Spring Meeting, May 23 - 27, Baltimore, MD
Checking 1987-2002
OHD Basic QPE
for DMIP 2

Compare PRISM and OHD QPE
Over Analysis Domain

Monthly OHD QPE time series agree well with PRISM data over the area

High correlation between Monthly OHD QPE and PRISM monthly totals

Source: Moreda et al., 2006. Gridded Rainfall Estimation for Distributed Modeling in Western Mountainous Areas, Session H23A, AGU 2006 Spring Meeting, May 23 - 27, Baltimore, MD
Deriving Six-hourly Mean Areal Precipitation

(1) From the CNRFC, we obtained six-hourly MAP time series for each basin. The two basins are decomposed into subbasins based on elevation differences (Table 1). The CNRFC MAP time series were derived using procedures developed by Anderson (2002) employing pre-determined weights.

(2) To derive an MAPX time series based on the gridded precipitation:
- Clip the subbasin shapefiles of the elevation zones to obtain HRAP points (center) in the subbasins
- Create list of HRAP points within a subbasin.
- For each of hourly gridded field of precipitation, obtain hourly average precipitation for the subbasins by averaging the value of all pixels in the subbasin
- The one hourly time series is then cumulated to obtain six-hourly time series

Source: Moreda et al., 2006. Gridded Rainfall Estimation for Distributed Modeling in Western Mountainous Areas, Session H23A, AGU 2006 Spring Meeting, May 23 - 27, Baltimore, MD
Comparison of OHD 6 hour QPE MAP values and CNRFC 6 hour values from historical MAP time series 1987 to 2002

Source: Moreda et al., 2006. Gridded Rainfall Estimation for Distributed Modeling in Western Mountainous Areas, Session H23A, AGU 2006 Spring Meeting, May 23 - 27, Baltimore, MD
Conclusion

OHD 1987 – 2002 gridded QPE suitable for initial DMIP 2 experiments
Analysis of OHD Basic QPE
1987 - 2006

Accumulated Simulation Error (mm of depth): North Fork American River

Inconsistent Precipitation?
Use HMT data
Possible cause: bad data for the Blue Canyon station: “a lot of rain in Jan 95” was recorded as zeros in the NCDC data. CNRFC set these values to ‘missing’ in their calibration. See email by Pete Fickenscher April 22, 2008.
Analysis of OHD Basic QPE 1987 - 2006

• Problem: time varying bias in precipitation estimates, starting after 2003

• Analyses
  1. Double mass analysis
     • Case 1: OHD QPE values to base of OHD QPE
     • Case 2: OHD QPE values to base of PRISM monthly accumulations
  2. Plot OHD QPE accumulation and PXPP accumulation
  3. Double mass analysis: OHD QPE to Observed North Fork Streamflow
1. Double Mass Analysis of OHD Basic Data

Case 1: Group Base is OHD Basic Gridded QPE

For each set of 4 grids:

- Plot accumulation of grids versus average accumulation of all other OHD grids (group base).
- Use NWS double mass analysis to highlight trends:
  - Compute deviation of grids from group base
  - Plot acc. deviation versus acc. of group base.
Grid Sets Used in Analysis of OHD Gridded QPE
1987 - 2006

Take average of 4 adjoining grids instead of using a single grid
Accumulation of Grid Set 1 versus Average Accumulation of Group Base

DMA Case 1
Accumulation of Deviation of Grid Set 1 from Group Base
Plotted Versus Accumulation of Group Base

DMA Case 1
Accumulation of Grid Set 2 versus Average Accumulation of Group Base

DMA Case 1

1/2002
Accumulation of Deviation of Grid Set 2 from Group Base Plotted Versus Accumulation of Group Base

DMA Case 1

Cumulative Basin MAP, mm vs. Deviation of cum. 4 pixel MAP from cum. basin MAP, mm
Accumulation of Grid Set 3 versus Average Accumulation of Group Base

DMIP2

1/2002

Accumulation of Grid Set 3 versus Average Accumulation of Group Base

DMA Case 1
Accumulation of Deviation of Grid Set 3 from Group Base Plotted Versus Accumulation of Group Base

DMA Case 1
Accumulation of Grid Set 4 versus Average Accumulation of Group Base

DMA Case 1

Accumulation of Grid Set 4 versus Average Accumulation of Group Base

DMA Case 1
Accumulation of Deviation of Grid Set 4 from Group Base Plotted Versus Accumulation of Group Base

DMA Case 1
1. Double Mass Analysis of OHD Basic Data
Case 2: Group Base is PRISM Monthly Gridded QPE

For each set of 4 grids:

- Plot average accumulation of grids versus average accumulation of PRISM grids (group base).
- Use NWS double mass analysis to highlight trends:
  - Compute deviation of grids from group base
  - Plot acc. deviation versus acc. of group base.
Accumulation of Grid Set 1 versus Ave. Accumulation of PRISM Group Base

DMA Case 2
DMA Case 2

Accumulation of Deviation of Grid Set 1 from Group Base Plotted Versus Ave. Accumulation of PRISM Group Base

Cum. Basin MAP, mm

Deviation of cum. 4 pixel MAP from cum. basin MAP, mm

12/96
Accumulation of Grid Set 2 versus Ave. Accumulation of PRISM Group Base

DMA Case 2
Accumulation of Deviation of Grid Set 2 from Group Base Plotted Versus Ave. Accumulation of PRISM Group Base

Cum. Basin MAP, mm

Deviation of cum. 4 pixel MAP from cum. basin MAP, mm

Cum. Basin MAP, mm
DMA Case 2

Accumulation of Grid Set 3 versus Ave. Accumulation of PRISM Group Base
Accumulation of Deviation of Grid Set 3 from Group Base
Plotted Versus Ave. Accumulation of PRISM Group Base

DMA Case 2

10/97
Accumulation of Grid Set 4 versus Ave. Accumulation of PRISM Group Base

DMA Case 2
Accumulation of Deviation of Grid Set 4 from Group Base Plotted Versus Ave. Accumulation of PRISM Group Base

 DMA Case 2

[Graph showing the accumulation of deviation of grid set 4 from group base plotted versus average accumulation of PRISM group base.]
2. Plot OHD QPE accumulation and PXPP accumulation

Method

• Download NCDC hourly/daily and SNOTEL data for 1980-2007 for stations around North Fork basin

• Use PXPP program to generate monthly time series at each station for entire period.

• Plot accumulation of PXPP time series and the accumulation of the ‘co-located’ OHD QPE grid
Period of Record for NCDC Data

Lake Spaulding NCDC daily gauge discontinued
Station accumulation (PXPP)

OHD grid accumulation
Station accumulation (PXPP)

OHD grid accumulation
Station accumulation (PXPP)
OHD grid accumulation
Station accumulation (PXPP)

OHD grid accumulation
Station accumulation (PXPP)  
OHD grid accumulation
Lake Spaulding Station accumulation (PXPP)

Estimated from other gauges

Station discontinued

Co-Located OHD grid accumulation

Cumulative precipitation, mm

Jan89 Jan90 Jan91 Jan92 Jan93 Jan94 Jan95 Jan96 Jan97 Jan98 Jan99 Jan00 Jan01 Jan02 Jan03 Jan04 Jan05 Jan06

date
Station accumulation (PXPP)

OHD grid accumulation
3. Double Mass Analysis: OHD QPE to Observed North Fork Streamflow

- Assumption: real changes in precipitation ‘catch’ should be reflected in the streamflow record
- Convert observed streamflow to mm depth over basin per time
  - 1. Plot accumulated OHD basin-ave QPE versus accumulated observed flow
  - 2. Use NWS approach: plot deviation of OHD basin-ave QPE from obs. flow versus accumulated observed flow to highlight trends
1. Accumulated OHD Basin-ave. QPE versus Accumulated Observed Flow
2. Deviation of OHD QPE from Observed Flow versus Accumulated Observed Flow
Conclusions

• OHD gridded QPE is inconsistent over time after 2003

• Potential causes:
  – Problems interpolating gridded data after Lake Spaulding gage stopped reporting
  – $1/d^{1/2}$ weighting used to interpolate grids