NOAA's Hydrometeorology Testbed (HMT)
American River Basin, NOAA Perspective

8th Annual Climate Prediction Applications Science Workshop
Managing Water Resources and Drought in a Changing Climate

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http://hmt.noaa.gov/
Outline

I. Overview of HMT & Linkages to Climate
   • Physical Processes and Observations

II. Example: Soil Moisture

III. Example: Atmospheric Rivers
Water and a Changing Climate...

“Within the United States, extensive climate-related changes have been documented over the last century. These include increases in continental-average temperatures, rising sea levels in many coastal locations, an increased frequency of extreme heavy rainfall events, lengthening of the growing season, earlier snowmelt, and altered river flow volumes. Water is an issue in every region, but the nature of the potential impact varies. Drought is a serious problem in many regions, especially in the West and Southeast; and floods and water quality problems are likely to be amplified by climate change in most regions.”

– Dr. Jane Lubchenco, NOAA Administrator
Water Extremes in a Changing Climate

Problem

Threat

NIDIS

Challenge

Increase in Heavy Daily Precipitation (Top 5%)

http://hmt.noaa.gov/
Response: HMT’s Major Activity Areas

Verification

DSTs

Obs Network

QPE

Debris Flows

Hydro Apps

Snow Info

March 2-4, 2010

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A National Testbed Strategy

- HMT West (2009+)
- Northwest – Cool Season (2009+)
- Mini-HMTs – AZ (2008+); CO (2009+)
- HMT “Next” (TBD)
- HMT Southeast – All Season (2013+)

http://hmt.noaa.gov/
Projected: based on the President’s Budget Request for FY2011
HMT-West 2010: Regional Scale Domain

March 2-4, 2010

hpt://hmtnoaa.gov/

BLU: Since 2004

BBY, CCO; CCL: Since 1998


Operational & Long-Term Observing Systems
- NWS WSR-88D
- NWS Rawinsonde
- GPS-Met IWV
- WRCC Surface Network
II. Example: Soil Moisture
The monsoon rain event occurring on 00 UTC 22 July finally brought the soil column to saturation. Flooding coincided with a storm that dropped 30 mm of precipitation on top of saturated soil near 00 UTC 23 July.
Snowpack is decreasing at the same time precipitation is being observed suggesting that rain is falling on the snowpack. Rain is quickly moving through the snowpack and saturating the ground under the snowpack. Soil wetness fractions exceeding 0.4 suggest that ponds of water are forming under the snowpack in the saturated soil.
Normal Winter Precipitation  Drought  Wildfires
III. Example: Atmospheric Rivers
SSM/I Display of Integrated Water Vapor from February 16, 2004

http://hmt.noaa.gov/
North Coast: (41.0° - 52.5°N) Oct-Mar

10 contiguous pixels (~5000 km²) of the most moist SSM/I IWV in each AR w/in 1000 km of coast

From the above inventory, the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast
South Coast: (32.5° - 41.0°N) Oct-Mar

10 contiguous pixels (~5000 km²) of the most moist SSM/I IWV in each AR w/in 1000 km of coast

From the above inventory, the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast
CA 20 heaviest 3-day precip. events:

From the above inventory, a histogram of the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast. Dates from the 20 top 3-day precip. events between 1949-2007 (from the CDC 0.25x0.25 deg unified precip. dataset) in the Sierra from Wes Junker are also marked (http://www.hpc.ncep.noaa.gov/research/California_major_rains.htm).

Max. Global Reanalysis IVT in South-Coast Land-Falling ARs WY1998-2008 (Daily occurrences Oct-Mar)
Atmospheric River Observatory (ARO): Russian River Prototype

Objectives: monitor key atmospheric river and precipitation characteristics

Observing systems:
1. Wind profiler/RASS
2. S-band radar
3. GPS-IWV
4. Surface met
5. Rain gauges
6. Disdrometer

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Component of the flow in the orographic controlling layer directed along 230°, i.e., orthogonal to the axis of the coastal mtns
Any rain: $\geq 0 \text{ m/s}; \geq 1 \text{ cm}$

- Blue dots: all
- Orange dots: when raining CZD

Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
Rain > 10 mm/h: 
>12.5 m/s; >2 cm

Atmospheric river quadrant: 
Strongest IWV fluxes yield heaviest rains
Snow levels measured by the S-band radar at CZD during the 4 winters averaged 421 m (1380 ft) higher in AR conditions: Warm conditions & more rain = increased flooding

<table>
<thead>
<tr>
<th>Year</th>
<th>$H_{avg}$</th>
<th>$H_{avgAR}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>(1.341)</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>(0.768)</td>
<td>(1.351)</td>
</tr>
<tr>
<td>2002</td>
<td>(1.675)</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>(1.420)</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>(1.387)</td>
<td>(1.626)</td>
</tr>
<tr>
<td>2005</td>
<td>(1.201)</td>
<td>(1.607)</td>
</tr>
<tr>
<td>2006</td>
<td>(1.361)</td>
<td>(1.801)</td>
</tr>
</tbody>
</table>
Thank You!

http://hmt.noaa.gov/
Coastal Atmospheric River (AR) Monitoring and Early Warning System

Profile and precipitation observations provided by the NOAA/ESRL Physical Sciences Division
GPS observations and model forecast provided by the NOAA/ESRL Global Systems Division

Current model forecast hourly horizontal winds
Current model forecast hourly freezing level
Layer used to derive the up-slope-component wind
Current model forecast integrated water vapor
Current model forecast up-slope water vapor flux
Current model forecast coastal and mountain rainfall
Water vapor flux AR threshold for heavy geographic precipitation
Up-slope-component wind direction
Forecast verification time for model data in the Observations and Prior Forecasts' graphics panel
Forecast rainfall totals and forecast 12-hour rainfall totals in the 'Current Forecast' graphics panel

Observation hourly profiler-derived horizontal winds
Forecast freezing level from prior model runs for a constant verification time
Observed hourly profiler-derived snow level
Observed GPS-derived integrated water vapor
Forecast integrated water vapor from prior model runs for a constant verification time
Integrated water vapor AR threshold for heavy geographic precipitation
Forecast up-slope wind from prior model runs for a constant verification time
Observed profiler-derived up-slope wind
Forecast integrated water vapor flux from prior model runs for a constant verification time
Observed GPS- and profiler-derived integrated water vapor flux
Forecast hourly rainfall from prior model runs for a constant verification time
Observed hourly coastal and mountain rainfall accumulations
Snow Level Varies Significantly in Space & Time
Figure 6. Mean absolute error for 24-h precipitation thresholds (in inches) by forecast lead time (Day-1, Day-2, and Day-3) for the (a) CNRFC and (b) NWRFC.
Partnerships on Research, Demonstration, Evaluation & Impact Assessment

NOAA Research:
• ESRL – PSD
• ESRL – GSD
• NSSL

National Weather Service:
• OHD
• NCEP/HPC
• OCWWS/NOHRSC
• Western Region HQ
• Eastern Region HQ
• Southern Region HQ
• River Forecast Centers: California-Nevada; Colorado Basin; Southeast
• Weather Forecast Offices: Eureka, Monterey, Sacramento, Reno, Seattle, Raleigh-Durham

NESDIS
• STAR

• Federal Agencies
  • NASA; USGS; US-ACE
• State Agencies
  • CA-DWR; NC-RENCI
• Local Agencies
  • SAFCA
• Academic
  • CU; CSU; UW; UCSD/Scripps; NCAR
47 peer reviewed papers since 2000

**Appearing in Journals:**
- Monthly Weather Review
- J. Hydrometeorology
- J. Atmos. & Oceanic Tech.
- Weather & Forecasting
- IEEE Trans. on Geosci. & Rem. Sens.
- J. Appl. Meteor. & Climatology
- J. Climate
- Nonlin. Proc. in Geophys.
- Prog. in Oceanography
- Water Management

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http://hmt.noaa.gov/
HMT Observing Systems

Scanning Radars
- SKYWATER
- HYDRO-X
- SMART-R

Profiling Radars
- 915 MHz
- 449 MHz
- S-band

GPS IWV & Sounding Systems

http://hmt.noaa.gov/
HMT Observing Systems

Precipitation Gauges
- Tipping Bucket
- HotPlate

Precipitation Disdrometers
- Impact
- Optical

Surface Meteorology & Snow Depth

Soil Moisture

Streamlevel

http://hmt.noaa.gov/
Quantitative Precipitation Forecasting Timescales in HMT

Subseasonal Forecasting (Weickman & Berry, 2009):
- global synoptic dynamic model (GSDM)

Reforecasting (Hamill & Whitaker, 2006):
- statistical post-processing
- downscaling
- analogues for various fields

Ensemble Forecasting (Jankov et al., 2009):
- high resolution
- ensembles of deterministic forecasts

QPF: 14 days +
QPF: 5-14 days
QPF: 3-5 days
QPF: 0-3 days

NowCast: QPE->24 hrs.(?)

Downscaling (e.g. PRISM)
Observations: Verification & Assimilation

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HMT-West 2010: WRF Ensemble Modeling Domains (Tentative; Fine Tuning in Progress)

- Single Deterministic Run for the Atmospheric River Monitoring and Early Warning System
  - 12 hour forecast; 1 hour updates
  - 10 km horizontal resolution

- 8-Member Ensemble Run for Probabilistic Forecasts
  - 120 hour forecast; 6 hour updates
  - 9 km horizontal resolution

- 8-Member Super High-Resolution Ensemble Run for Probabilistic Forecasts (nested)
  - 12 hour forecast; 6 hour updates
  - 3 km horizontal resolution

Atmospheric River Observatory (ARO)

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HMT-West EXPERIMENT DESIGN for 2009-2010

WRF Nested domain:
- Outer/inner nest grid spacing 9 and 3 km, respectively,
- 6-h cycles,
- Outer nest: 120 fcst hours,
- Inner nest: 12-h fcst hours.

March 2-4, 2010
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HMT-West ENSEMBLE DESIGN for 2009-2010

- **3 WRF-ARW RUNS AND 1 WRF-NMM RUN**
  - WRF-ARW runs: Ferrier, Schultz, Thompson microphysics
  - WRF-NMM run: Ferrier microphysics
- **8 GFS ensemble members will provide LBCs for the mixed-model, mixed-physics ensemble**
- One additional member will use WRF-ARW with Thompson microphysics and GFS deterministic run will provide LBCs,
- Time lagging optional
- The ensemble mean and probabilistic products will be displayed on ALPS
Calibration of PQPF (statistical post-processing)

An example of probabilistic QPF (PQPF) calibration by using linear regression. The reliability notably improved after the calibration. Several IOPs were used for training purpose.
SEPARATE HIGH-RESOLUTION MODEL RUN FOR PSD’s MOISTURE-FLUX FORECASTING TOOL for 2009-2010

- Domain extended further north and south compared to the ensemble domain
- 10 km horizontal grid spacing
- Hourly update
- 12-hr forecast
- LAPS initial conditions
- NAM LBCs
- HRRR profiles will be extracted

March 2-4, 2010

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The PSD observations made in the Upper Colorado River Basin will support research and operations by providing information about soil moisture, soil temperature, snow depth, latent heat flux, sensible heat flux, net radiative flux, ground heat flux, wind speed, wind direction, surface pressure, temperature and relative humidity.

- Granby and Gunnison, CO selected for instrumentation
- Granby selected for snow sublimation studies
- Granby soil moisture probes along with standard surface meteorological instrumentation were installed and operational on 10/2/09
- Granby eddy flux tower installation planned for May 2010.
- Gunnison soil station installation planned for June 2010
- CBRFC would like to validate NWS hydrological models using observations made in the Gunnison River Basin
Granby operational as of October 2, 2009

- Well defined diurnal heat wave in the soil
- Amplitude of the wave decreases with depth
- Soil moisture increases with depth
First deployment at **Westport, WA** for Winter 2009/2010
- target is for first real-time data available by 1 Nov 2009

- **Satellite communications**
- **10-m met. tower (folds down for storage)**
- **GPS receiver for IWV**
- **Office and storage facility**
- **S-band precipitation profiling radar (S-PROF)**
- **Backup generator**
- **915-MHz wind profiler on swivel to aid deployment and maximize data recovery with respect to beam directions and ground clutter**
## ARO Instrumentation and Measurements

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measure(s)</th>
<th>Vertical Res.</th>
<th>Temporal Res.</th>
<th>Altitude Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>915-MHz Wind Profiler/RASS</td>
<td>Wind and Temperature Profiles, Snow Level, BL Depth</td>
<td>60 m, 100 m</td>
<td>Hourly or Sub-hourly</td>
<td>0.15-2+ km in clear air, 0.15-4+ km in storms (winds); 0.15-1+ km (Tv)</td>
</tr>
<tr>
<td>S-Band Precip. Profiling Radar (S=PROF)</td>
<td>Precipitation Reflectivity and Velocity Profiles, Snow Level</td>
<td>60 m</td>
<td>30-s</td>
<td>0.13-8+ km in storms</td>
</tr>
<tr>
<td>10-m Met Tower</td>
<td>P, T, RH, WS, WD, Solar IR., Net IR, Rainfall</td>
<td>N/A</td>
<td>2-min.</td>
<td>N/A</td>
</tr>
<tr>
<td>GPS Receiver</td>
<td>Integrated water vapor</td>
<td>N/A</td>
<td>Hourly or Sub-hourly</td>
<td>N/A</td>
</tr>
<tr>
<td>Optical Disdrometer</td>
<td>Velocity and Size Distributions of Precipitation</td>
<td>N/A</td>
<td>2-min.</td>
<td>N/A</td>
</tr>
</tbody>
</table>
TRENDS (1950-97) in April 1 snow-water content at snow courses

- Snowmelt supplies about 60-75% of western surface-water supplies, and a roughly equal (or greater) part of western groundwater recharge...
- Recent warming trends appear to have caused significant snowpack declines in much of that area
  - --> Less spring snowpack

Courtesy of Mike Dettinger
Climate change may put some water managers in a real bind!

Storage & transferability of water supplies will thus be at a premium.

The Reservoir Manager's Bind

Maintain empty flood space behind the dams?

- Earlier Runoff
  - Hazard or Resource?
    - Release Water
      - Less Water Later
        - Flood?
          - yes
            - Less Flood Damage
              - Less Water Later
                - smiley
              - sad
          - no
            - No Flood Damage
              - Less Water Later
                - smiley
        - sad
      - no
        - More Water Later
          - Flood?
            - no
              - No Flood Damage
                - More Water Later
                  - smiley
              - sad
            - yes
              - Deaths and Flood Damage
                - xx

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March 2-4, 2010

Courtesy of Mike Dettinger
The Sacramento Flood Risk

- Complex water resource management issues in an urban area with large societal impacts
  - Large demand for water/hydropower
  - Threat of devastating flood

Several feet inundation possible in downtown Sacramento

Photo by Bryan Patrick, Sacramento Bee

Source: Department of Water Resources, Bee research