Methodology of Generating Meteorological Forcing Data In Support of CNRFC Hydrologic Operations

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NWS Mission
- Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy

CNRFC Area of Responsibility
- ~250,000 square miles with extreme variation in hydrologic regimes
- Support large population centers
  - Over 40 million people!
- Highly environmentally sensitive
  - Great pressure on water resources

Hydrologic Operations
- 345 modeled river basins
- Almost 100 flood forecast points
- 70+ reservoir inflows
- 200+ water resources locations
Overview of CNRFC Forecast Operations

- Where Does the Hydrometeorology Fit In?

Hydrologist

Model guidance

Hydrologic expertise & judgment

HAS

Meteorological Forecast Inputs

Precipitation

Freezing Levels

Temperatures

Data

Parameters

CHPS

Community Hydrologic Prediction System

Flood Forecast Guidance

Observation Systems

Model Calibration

Deterministic and Ensemble Graphics

Text Bulletins
Hydrometeorological Function at CNRFC

Dedicated Function at CNRFC *(Unique from Other RFCs)*
- Provide meteorological inputs to hydrologic models
- Team of 4 meteorologists
  - Experience and local knowledge counts toward a more accurate forecast!
  - Over 50 years of combined forecasting with the National Weather Service primarily in California, Nevada, and southwest Oregon
- Extremely diverse meteorological regimes
  - Coastal, mountains, interior valleys, desert, and high desert
  - Results in highly-variable spatial distribution of precipitation over short distances
  - Highest and lowest point in “Lower 48” (~85 miles apart as the crow flies)
    - Mount Whitney at 14,505 feet
    - Death Valley (Badwater Basin) at −282 feet
Hydrometeorological Function at CNRFC

- Provide Meteorological Inputs to Hydrologic Model
  - Precipitation Forecasts (QPF – Quantitative Precipitation Forecast)
    - 6-Hour time steps for 6 Days
    - Gridded forecast is converted to Mean Areal Precipitation for each sub-basin
    - Used to calculate runoff and account for soil moisture
  - Freezing Level Forecasts
    - Instantaneous (12, 18, 00, 06Z) for 6 Days
    - Gridded forecast is converted to Mean Areal Freezing Level for each sub-basin
    - Used to determine rain–snow elevation
    - Each basin has specified offset to determine snow level
  - Temperature Forecasts
    - Instantaneous (12, 18, 00, 06Z) for 10 Days – derived from max/min temps
    - Gridded forecast is converted to Mean Areal Temperatures for each sub-basin
    - Used to balance energy (melting snow)
Hydrometeorological Function at CNRFC

Inputs: What Goes into Making an Accurate Forecast?

- **Weather Models**
- **National Forecasts**
- **Observation Systems**
- **Numerical Models**
- **WPC Weather Prediction Center**
  - “First Cut” QPF
  - Guidance
  - Data

- **Surface Observations**
- **Doppler Radar**
- **Satellite Imagery**
- **Weather Balloons**

**Precipitation Freezing Levels Temperatures Forecasts**

**CHPS**
Community Hydrological Prediction System
Precipitation Forecasts

- Technique: How Is a Precipitation Forecast Created???
  - Points → Grids
    - Uses an annual climatology grid (PRISM) as an underlying dataset to account for impacts of complex terrain on the distribution of precipitation
  - Grids → Basins
    - Simply the sum of the grid boxes within the basin, divided by the number of grid boxes

![Map of the United States showing precipitation zones](image-url)
Precipitation Forecasts

- Technique: How PRISM is Used to Estimate Another Point

\[
\frac{QPF_A}{N_A} = \frac{QPF_B}{N_B}
\]

\[
\frac{0.20''}{8.00''} = \frac{QPF_B}{40.00''}
\]
**Technique: Point QPF Conversion to Gridded QPF**

- Add more QPF points
  - CNRFC → 68 points
  - Can be increased to “dial-in” an area

- Overlay the 4km grid
  - HRAP (Hydrologic Rain Analysis Project) grid

- Weight QPF/PRISM normals to grid points
  - Use inverse-distance squared weighting
  - 5 nearest “neighbors” go into calculation

\[
QPF_x = \frac{\left[ \frac{QPF_1}{N_1} \left( \frac{1}{d_1^2} \right) + \frac{QPF_2}{N_2} \left( \frac{1}{d_2^2} \right) + \frac{QPF_3}{N_3} \left( \frac{1}{d_3^2} \right) + \frac{QPF_4}{N_4} \left( \frac{1}{d_4^2} \right) + \frac{QPF_5}{N_5} \left( \frac{1}{d_5^2} \right) + \ldots \right]}{1/d_1^2 + 1/d_2^2 + 1/d_3^2 + 1/d_4^2 + 1/d_5^2 + \ldots}
\]
Technique: Point QPF Conversion to Gridded QPF

- Move from grid point to grid point
  - The process continues through the grid
Precipitation Forecasts

- Technique: Point QPF Conversion to Gridded QPF
  - Move from grid point to grid point
    - The process continues through the grid
    - And continues . . .

\[
QPF_x = \left[ \frac{QPF_1 \left( \frac{1}{d_1^2} \right) + QPF_2 \left( \frac{1}{d_2^2} \right) + QPF_3 \left( \frac{1}{d_3^2} \right) + QPF_4 \left( \frac{1}{d_4^2} \right) + QPF_5 \left( \frac{1}{d_5^2} \right) + \ldots}{N_1 + N_2 + N_3 + N_4 + N_5 + \ldots} \right] \]

\[
\frac{1}{d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2 + \ldots}
\]
Precipitation Forecasts

- Technique: Point QPF Conversion to Gridded QPF
  - Move from grid point to grid point
    - The process continues through the grid
    - And continues . . .
    - And continues . . .
    - And continues . . .
    - And continues . . .
    - Until finally every point on the grid has a QPF

\[
QPF_x = \frac{QPF_1 \left( \frac{1}{d_1^2} \right) + QPF_2 \left( \frac{1}{d_2^2} \right) + QPF_3 \left( \frac{1}{d_3^2} \right) + QPF_4 \left( \frac{1}{d_4^2} \right) + QPF_5 \left( \frac{1}{d_5^2} \right) + \ldots}{\frac{1}{d_1^2} + \frac{1}{d_2^2} + \frac{1}{d_3^2} + \frac{1}{d_4^2} + \frac{1}{d_5^2} + \ldots}
\]
Freezing Level Forecasts

- Good QPF can be Ruined by a Bad Freezing Level Forecast
  - Freezing level strongly influences runoff in mountains watersheds
    - Study by White et al, *JTech*, 2002
Freezing Level Forecasts

- **Technique: How is a Freezing Level Forecast Created??**
  - Heavily rely on model data
    - Numerous models to choose from, including blending more than one model
      - GFS, ECMWF, GEM, and NAM – just to name a few
    - One technique is to drill down through model data, known as “top down”
    - Other techniques use empirical formulas
      - 700-mb Temperatures
      - 850-mb to 700-mb Thickness
      - 1000-mb to 500-mb Thickness
  - Modifications primarily in areas of concern
  - Basins have offset to determine snow level
    - Offset calculated during basin calibration
Temperature Forecasts

- Technique: How is a Temperature Forecast Created???
  - Heavily rely on 12 NWS Forecast Offices and Model Guidance
    - Starts with maximum and minimum temperatures
    - Converted to instantaneous 6-hour temperatures (12, 18, 00, 06Z)
      - Uses a diurnal curve to derive these temperatures
**The Tool: Graphical Forecast Editor (GFE)**
- Nationally supported software package
- Locally written “Smart Tool” in conjunction with CBRFC
- Used as the primary forecasting tool since 2010 (similar with most RFCs)
  - Much earlier implementation at NWS Forecast Offices (early 2000s)
- Ability to view and utilize a wide spectrum of short- and medium-range weather model precipitation forecasts
- GFE allows collaboration with the 12 NWS Forecast Offices within our area of responsibility by exchanging forecast grids
Network of Vertically-Pointed Snow Level Radars in CA
- Designed, built, & deployed by NOAA / Earth System Research Lab / PSD
- Project in conjunction with CA DWR
- Provides system to address water resource & flood control issues
  - Key locations: Shasta, Oroville, Colfax, New Exchequer, Pine Flat, and Kernville

Photo Credit: Paul Johnston, CRES

Technology Helping to Monitor Moisture Plumes

- Accurately Measuring Moisture in the Atmosphere
  - Twice per day weather balloon soundings (00 and 12 UTC)
  - Satellite derived “total precipitable water” imagery
  - Precipitable water vapor measurements using GPS.
    - Derived by analyzing delays in GPS signal caused by the atmosphere

Imagery courtesy: CIMMS / SSEC / UW–Madison
Improvements to Numerical Weather Models

- Upgraded Version of Global Forecast System (GFS) Model
  - Significant investment ($44.5M) by NOAA to improve forecast accuracy
  - Increased supercomputer capacity (nearly tenfold increase)
  - Date of model implementation: January 14, 2015
  - Greater resolution that extend further out in time
    - Spatial resolution improvements
      - Increase spatial horizontal resolution 27km $\rightarrow$ 13km (Days 0 to 10)
      - Increase spatial horizontal resolution 84km $\rightarrow$ 35km (Days 11 to 16)
    - Temporal resolution improvements
      - 1-hour time steps (First 12 Hours)
      - 3-hour time steps (12 Hours to Day 10)
      - 12-hour time steps (Day 10 to 16)
More Improvements to Numerical Weather Models

- High-Resolution Rapid Refresh (HRRR) Model
  - Implementation of operational version: September 30, 2014
  - 3 kilometer resolution
  - 1-hour time steps (run out to 15 hours)
    - Some fields at 15-minute time steps (reflectivity, 10m wind, 2m temp/dew point)
  - Model is run every hour
  - Resolves clouds, assimilates radar, allows convection
Conveying the Forecast to Our Key Partners

- Just Because the Forecast is Issued, the Job isn’t Done
  - NOAA / NWS initiative known as “Weather–Ready Nation”
    - Strengthen partnerships with external customers
      - Emergency Managers
      - First Responders
      - Government Agencies (ALL levels → federal, state, and local)
      - Businesses
      - Media
      - Public
      - REALLY … ANYONE!
    - Provide information in a way to better support decision making by partners
How the CNRFC Provides Support to Our Partners

- Coordination … Getting Everyone on the Same Page
  - Joint Federal – State Weather and Hydrology Briefing
    - Held at least weekly in winter season (more frequent during high impact events)
    - Provide stakeholders up-to-date weather forecast
    - Discuss resulting hydrology with partners
    - Results in better coordination of overall operations

- Who are Our Key Partners?
  - 12 NWS Forecast Offices
    - Sacramento WFO*
  - CA Dept of Water Resources*
  - US Bureau of Reclamation*
  - US Army Corps of Engineers
  - US Geological Survey
  - Local Water Agencies
  - Local / National Media
  * Co-located offices at Joint Operations Center
Forecast Skill Trends: How Accurate Are Our Forecasts???

- 2010 study conducted by Alan Haynes (CNRFC) / Letitia Soulliard (OCWWS)
  - Attempted to quantify aggregate value added to forecast
  - Relate forecaster improvements made to QPF guidance to the number of years of model development required to reach same level of accuracy. [Reynolds 2003]
  - **Finding 1**: It would take 12.4 years for the GFS accuracy to match the 2000 CNRFC accuracy
  - **Finding 2**: It would take 4.5 years for the WPC forecasts to match the 2000 CNRFC accuracy

- Threat Score = Hits / (Hits + Misses + False Alarms) [0 to 1→ perfect score is 1]
- How well did the forecast “yes” events correspond to observed “yes” events
Viewing Our Forecasts and Other Data

- CNRFC Webpage
  - www.cnrfc.noaa.gov
  - Abundance of meteorological and hydrologic forecasts and data on front map interface
    - Precipitation Data
    - Freezing Level Data
    - Temperature Data
    - River/Reservoir/Ensemble Data
    - Water Resources Data
    - Snow Data
    - Water Temperature Data
    - Climate/Drought Data
    - Flash Flood Guidance
    - QPF Verification
      - Even if the forecast didn’t work out! 😊
    - Ability to download data or images
Newer and Highly Used Pages

- Storm summaries (significant events)
  - February 1986 Floods
  - December 1996 – January 1997 Floods
  - December 2005 – January 2006 Floods

- Water resources (data & forecasts)
  - Ensemble streamflow forecasts
  - Observed streamflow data
  - Reservoir storage
  - Snow data
  - Precipitation data

- Data archive
  - Certain data back to 2001 (or newer)

- Drought information

- Radar and satellite imagery

- Weather observations & forecasts
Let’s Change Gears and Talk El Niño

- 2016 Strong El Niño is in its Dissipating Phase

The Washington Post
Capital Weather Gang

‘Godzilla’ El Niño is dead
By Angela Fritz  April 11

The weekly ENSO 3.4 anomaly is +1.3°C, the first time below the "strong" threshold of +1.5°C since early July 2015
2016 Strong El Niño vs “Typical” Strong El Niño

  - Precipitation
  - Temperature
So What Happened with the 2016 El Niño

- It isn’t that El Niño wasn’t as Strong as Forecast
  - Distribution of precipitation along the west coast is what didn’t pan out
- Slightly Higher Pressure Along the West Coast in 2016
  - Storm track farther north over the Pacific Northwest and Northern CA
Takeaway Messages

- Each and every El Niño is unique (even the strong ones)
- Number of past events is statistically very small for comparison
- There are “no guarantees”, nothing is a “slam dunk” or “too big to fail”

Better consensus on relaying information to the public and media

- A need to correct the misconceptions of El Niño
- Difficult with potential “loud voices”
- However, even valid information can be misinterpreted by the public/media

A few of the misleading headlines

- “Powerful El Niño Storm Hits California”
- “New El Niño Storm Drenches, Disrupts California”
- “El Niño Returns: Big Weekend Storms Coming to Bay Area”

* Credit: Jan Null, CCM and John Monteverdi, CCM (March 2016)
What’s on its Way

- Transition to ENSO–Neutral Likely
  - Late spring or early summer 2016

- Increasing Chance of La Niña During Second Half of 2016
  - La Niña Watch issued by the Climate Prediction Center (April 14, 2016)
  - Official forecast is consistent with model forecasts
  - Supported by historical tendency for La Niña to follow strong El Niños

NCEP CFS.v2 ensemble mean (dashed black line) predicts neutral during the May–June–July (MJJ) period and La Niña after June–July–August (JJA) 2016.
Thank You!

Questions?

Courtesy: Kirkwood Mountain Twitter Feed