HEFS and National Water Model-based inflow prediction

OK/TX FIRO, Sep 2019

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Outline

• HEFS

  Basic Workflow
  Baseline Validation & Implementation Status
  Next steps, Priorities, and Challenges
HEFS basic workflow

- WPC/RFC
- GEFSv10
- CFSv2
- Climatology (any)

Meteorological Ensemble Forecast Processor (MEFP)
- Handle bias/spread
- Merge in time
- Downscale (basin)

Ensemble Post-processor (EnsPost)
- Correct bias
- Quantify uncertainty
- Use recent obs.

Raw ensemble flow forecasts (flow models)

Bias-corrected ensemble flow forecasts

Ensemble Verification System (EVS)

= forcing
= flow
= verification

WPC/RFC
GEFSv10
CFSv2
Climatology (any)
Baseline Validation and Implementation

2017-2019: OWP & River Forecast Centers (RFC) “Baseline Validation”

- **To accelerate implementation**
  - To provide targets for the public distribution of HEFS products on AHPS (i.e. forecast locations)

- **To create a performance benchmark**
  - To provide a benchmark for future HEFS versions
  - To clarify our own requirements (e.g. GEFS (re)forecasts)
  - Provides a 30 year HEFS hindcasts to users

- **To develop best practices for evaluation**
  - First objective, large-sample, evaluation of our hydrologic products and services
Methodology for Baseline Validation

- Streamflow forecast for 1-30 days (GEFS for 1-15, then climatology)
  - Maximizes sample size (allows for daily forecast for 30 years)

- Legacy climatological ensemble (ESP) as a baseline for skill

- Utilize multiple metrics (CRPSS, BSS, correlation coefficient, etc) to capture multi-dimensional character of forecast quality

- Precipitation and temperature, only where necessary to troubleshoot problems identified in streamflow validation
HEFS Implementation Status

- Of the 3560 river forecast locations (in AHPS), HEFS is configured in roughly ¾ of these.
- Baseline Validation completed at 1544 locations.
- HEFS forecast products available at 1246 locations.

HEFS Implementation

- Green: Implemented on AHPS
- Purple: Implemented on RFC Website
- Cyan: Baseline Validation Completed
- Orange: Remaining Locations
- White: River Forecast Centers

Status on 2019-08-01

Sources: ESRI, HERE, DeLorme, TomTom, Intermap, Inc., GeoCorp, GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Anshutzu, MapmyIndia, © OpenStreetMap contributors, © OpenStreetMap contributors
HEFS Baseline Validation Classification

Classified using multiple metrics.
Results

• Failed basins are mainly due to issues with hydrological modeling and/or regulation, & have good MEFP forecasts, especially precipitation

• In some cases, BV has flagged potential optimizations that could be made and/or identified problems with the hydrologic model calibration

• At some locations, especially snow dominated ones, there’s very little or no improvement especially early in the forecast horizon, since it takes longer for the forcings to show up in the streamflow

• Better in big synoptic systems, worse in short-term precip/convection

• Earlier verification results show that the EnsPost can add a further 10-80% skill at the earliest forecast lead times and further increase the "break even" point relative to ESP
Early applications of HEFS

Managing NYC water supply

- Croton; Catskill; and Delaware
- Includes 19 reservoirs, 3 lakes; 2000 square miles
- Serves 9 million people (50% of NY State population)
- Delivers 1.1 billion gallons/day
- Operational Support Tool (OST) to optimize infrastructure, and avoid unnecessary ($10B+) water filtration costs
- HEFS forecasts are central to OST. The OST program has cost NYC under $10M

Slide courtesy of NYCDEP
Early applications of HEFS

Forecast Informed Reservoir Operations (FIRO) in Russian River Watershed

- Multi-Agency study on Lake Mendocino
- Can we enhance reservoir operations and use of available storage by using forecasts to inform decisions about releasing or storing water?
- HEFS forecasts are central to optimized forecast-based reservoir operations
- Supports water control manual change request for Lake Mendocino
- Process can be replicated in other watersheds
1985-2010 Historical Simulation
Lake Mendocino, CA Storage

Simulated Lake Mendocino Storage 1985 - 2010

Date


Storage (ac-ft)

20000 40000 60000 80000 100000 120000

Percent Storage Capacity

17% 34% 52% 69% 86% 103%

Existing Operations  Ensemble Forecast Operations  Perfect Forecast Operations  Spillway

Slide courtesy of Chris Delaney, Sonoma Water
2019 Major Deviation

- Major Deviation to Water Control Manual
  - Approved by USACE in November 2018 for 2018/2019 winter and spring season

Slide courtesy of Chris Delaney, Sonoma Water
HEFS Next Steps and Priorities

- Implement GEFSv12 forcings into operations (WRES)
- Extend and evaluate implementation of hydrologic post-processor (including regulated locations)
- Expand and formalize Validation Testbed for enhancements
  - Facilitates outside development (UTA, ESRL)
- Address performance in extreme events
- Explore update to temp modeling in MEFP to address limitations in steep terrain, etc
- Complete HEFS implementation at ESP locations
National Water Model (NWM)

- Full spectrum hydrologic model, providing complementary hydrologic guidance
- NWM was upgraded to V2.0 in June 2019 by OWP, NCEP and NCAR
- Hydrologic core is WRF-Hydro, a community-based hydrologic modeling framework

River Forecast Centers: Authoritative forecasts at ~3,600 RFC Points
NWM: Guidance at 2.7 million NHDPlus river segments, filling in coverage gaps and enriching existing points
NWM Output: Complementary Guidance for Forecasters

Large River at Traditional RFC Forecast Location

• Leveraging accurate precipitation NWM correctly forecasts minor flooding two days in advance
• Inter-cycle variability/biases highlight need for improved precip forecasts, NWM development

Small Ungauged Stream Away from Traditional Forecast Point

• Successive NWM forecasts indicate correct timing for dangerous flow
• Run-to-run variability indicates need for continued precipitation improvement

NWM Streamflow Forecast, Rappahannock River at Remington, VA

NWM Streamflow Forecasts for Hawlings River, Maryland

Time of swift water rescue at flooded bridge
National Water Model: Development Trajectory

**v1.0**

Foundation: 2016
Water resource model
2.7 million reaches

**v1.1/1.2**

Upgrades: 2017/2018
Increased cycling freq. and fcst length, improved calibration, physics, stream DA

**v2.0**

Domain Expansion: 2019
Hawaii, medium range ens., compound channels, improved modularity, longer Analysis w/MPE

**v2.1**

Future Upgrade: Early 2021
Expansion to PR and Great Lakes, reservoir modules, forcing bias-correction, calibration and improved Hawaii forcing
**National Water Model V2.0: Cycling Overview**

- **Analysis**
  - HRRR/RAP/MRMS/MPE

- **Short-Range**
  - HRRR/RAP

- **Medium-Range Ens**
  - GFS

- **Long-Range Ens**
  - CFS

- **Lookback Range**
  - 3-28 hrs

- **Hawaii**
  - 3 Hour Lookback
  - 60 Hour Forecast
  - NAM-NEST

- **Forecast**
  - 18 Hour Forecast
  - ~10 Day Ensemble Forecast
  - 30 Day Ensemble Forecast
Questions/Discussion