NWS Science and Technology Roadmap

Hydrology

Team Composition

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- Michael Smith, NWS/OHD – Contributor
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Vision/Benefits/Impacts

- **Focus Area Team Vision:**
  - Provide the best hydrologic, water resources and water quality forecasts at inland and coastal watersheds, to meet the needs of decision makers and the public for flood protection, water supply, navigation, recreation, ecosystem management to reduce loss of life and enhance economic prosperity
- **Benefits**
  - Support better management of the nation's water resources from the mountain summits to the open sea
  - Decrease the number of deaths and property losses arising from flooding
- **Impacts[1]:**
  - Average annual economic flood loss reduction from NWS forecasts for reservoir operation of $1B
  - Average annual economic savings of short-term event forecasts of $433M from reduced flood loss damage (e.g. agriculture, power supply, etc.)
  - Average annual economic savings from long-term event forecasts of $163M
  - Additional economic gains from hydrologic forecasts are accrued from optimized use of water resources (e.g. agricultural water supply, hydropower generation, etc.)

[1]http://www.weather.gov/oh/ahps/AHPS%20Benefits.pdf

Goals/Targets:
Emerging Science and Technology and Customer Needs

Goal	Outstanding Issues
Improve model forcings (Observations and forecasts) to provide more accurate hydrologic and water resources forecasts	Capability for short-term (1-3 hr) forecasting is very limited at the spatial and time scales required
Include human intervention effects in the hydrologic cycle	River regulation has a large impact of streamflow forecasting. Current models don't consider the effects of human intervention on river regulation.
Improve data assimilation techniques for hydrology	Data assimilation is currently performed largely manually by the hydrologic forecasters. New techniques are needed to provide objective guidance to the forecasters for both lumped and distributed models. There is a need to implement techniques for large-scale, high-resolution ensemble data assimilation requiring extensive computing power.
Improve Hydrologic Models to provide more accurate hydrologic and water resources forecasts at finer temporal and spatial scales.	Current models need to be improved or new models developed that more accurately simulate a broader range of precipitation/runoff processes, especially at finer time and space scales. Parameterization schemes and model improvements need to be developed that reduce the dependency on parameter calibration

Goals/Targets:
Emerging Science and Technology and Customer Needs

Goal	Outstanding Issues
Link watershed, river, estuary and ocean model	Current models can't capture the combined effect of inland flooding, wind, waves, tides and storm surge. Computational capacity not adequate.
Provide water quality forecasts: water temperature for thermal power plant operation and fisheries management and river navigation, pathogen forecasts for beach closures on the Great Lakes, salinity for river navigation	NWS does not have the capability to provide this service. Research, development and transition to operations will be done in partnership with other federal agencies and the private sector.
Provide dynamic flood forecasts maps to accurately represent the impact of flood in mild slope/backwater areas	There is a need for improved accuracy and resolution of digital elevation channel and flood plain data. Need to improve computational algorithms, including the effect of wind. Computational capacity not adequate.
Estimate and communicate hydrologic forecast uncertainty information for all forecast elements and time scales	NWS is currently issuing probabilistic forecast only in the long-range time horizon. There is a pressing need for short- and medium-range forecasting capability, connected between them and with the long-range forecast in a seamless fashion. Computational capacity not adequate.

Goals/Targets:
Emerging Science and Technology and Customer Needs

Goal	Outstanding Issues
Assess forecast reliability and program effectiveness	Limited verification capability is currently in place. The verification program needs to be expanded to provide a capability to assess the impact of new science on the skill of the forecast
Improve customer centric information and decision support services	There is a need to involve social science in a number of areas: communication of information to the forecasters, stakeholders and the public. Additionally, social science can be used to evaluate of the benefits provided by the Hydrology Program to the nation

Key Science Gaps

Gap	Solution Alternative	Impact
Gap #1. Model forcings (observations and forecasts) need improvement	1.1 Observations: add probabilistic multisensor observation techniques to improve spatial and temporal resolution and representation of uncertainty and quality of probabilistic forecasts at all time scales.	Improved streamflow forecasts, including the associated uncertainty.
Gap #2. Minimum representation of anthropogenic influence on streamflow forecast	2.1 Improve river regulation models (including reservoir operations, water derivations to and return from water supply and irrigation), including uncertainty	Improved streamflow forecasts, including the associated uncertainty.
Gap #3 Lack of automated data assimilation techniques	3.1 Develop new data assimilation techniques both for deterministic and ensemble forecasts, and for lumped and distributed hydrologic models (XEFS)	Improved streamflow forecasts, including the associated uncertainty.

Key Science Gaps

Gap	Solution Alternative	Impact
Gap #4. Lack of hydrologic models that can accurately simulate and predict an ever-growing range of river and water resources variables	4.1 Ignore physically-based models and continue to use conceptual models which are entirely dependent on historical data for parameter calibration.	Although forecasters are more familiar with these models, they won't be able to reflect changes in the watershed, continuing to rely very heavily on model calibration using historical time series; stability of model parameters is dependent on stationary assumptions that do not exist under climate changing conditions.
	4.2 Improve existing models and/or develop new suite of models and parameter estimation techniques from geophysical data sets that solve the existing model deficiencies	Improve river and water resources forecast skill. Allow changes to the watershed to be reflected in the model parameters by the use of GIS. Reduced requirement for watershed calibration and its reliance on historical time series. Reduced exposure to elimination of streamflow gauges at forecast points Reduced exposure to non-stationarity in time series due to climate change No purely physically-based model has demonstrated a consistent capability to provide simulation improvements over existing models.

Key Science Gaps

Gap	Solution Alternative	Impact
Gap #5. Current forecasts do not capture the combined effects of storm surge, winds, waves and tides.	5.1 Operationally link NOS coastal forecasts with NWS hydraulic models as demonstrated on the St. Johns river pilot study NOS needs to provide routine forecasts along the coasts of the United States	Improve river forecast service in coastal communities, including navigation, water supply and emergency management
Gap #6. NWS does not have the capability to provide water quality forecasts	6.1 Develop water temperature forecast in high-priority areas (fisheries management, power generation, Alaska river forecasts). Expand to other water quality concerns (e.g. pathogens on beaches, especially on the Great Lakes)	New water quality forecast information available to decision makers and the public.

Key Science Gaps

Gap	Solution Alternative	Impact
Gap #7. Lack of operational probabilistic dynamic flood mapping capability. Main reason for the gap is the lack of efficient algorithms and computational capability	7.1 Ignore dynamic mapping requirements and keep using static maps.	No improvement over current conditions. Low computational demands
	7.2 Develop efficient dynamic mapping algorithms, including robust and efficient hydraulic models.	Provide users with dynamic mapping reflecting accurate probabilities of inundation, backwater effects. High computational demands.
Gap #8. Lack of seamless short-to-long term probabilistic river forecast capability	8.1 Implement a seamless suite of techniques to accurately quantify river forecasting uncertainty from 1 hr to 2 yr. (HEFS)	Improved streamflow forecasts, including the associated uncertainty.
Gap #9. Lack of a comprehensive river forecast verification system, including deterministic and probabilistic forecast verification	9.1 Develop a comprehensive river forecast verification system, including deterministic and probabilistic forecast verification	Assess the impact of new science on the skill of the forecast, and, as a consequence, improve streamflow forecasts, including the associated uncertainty

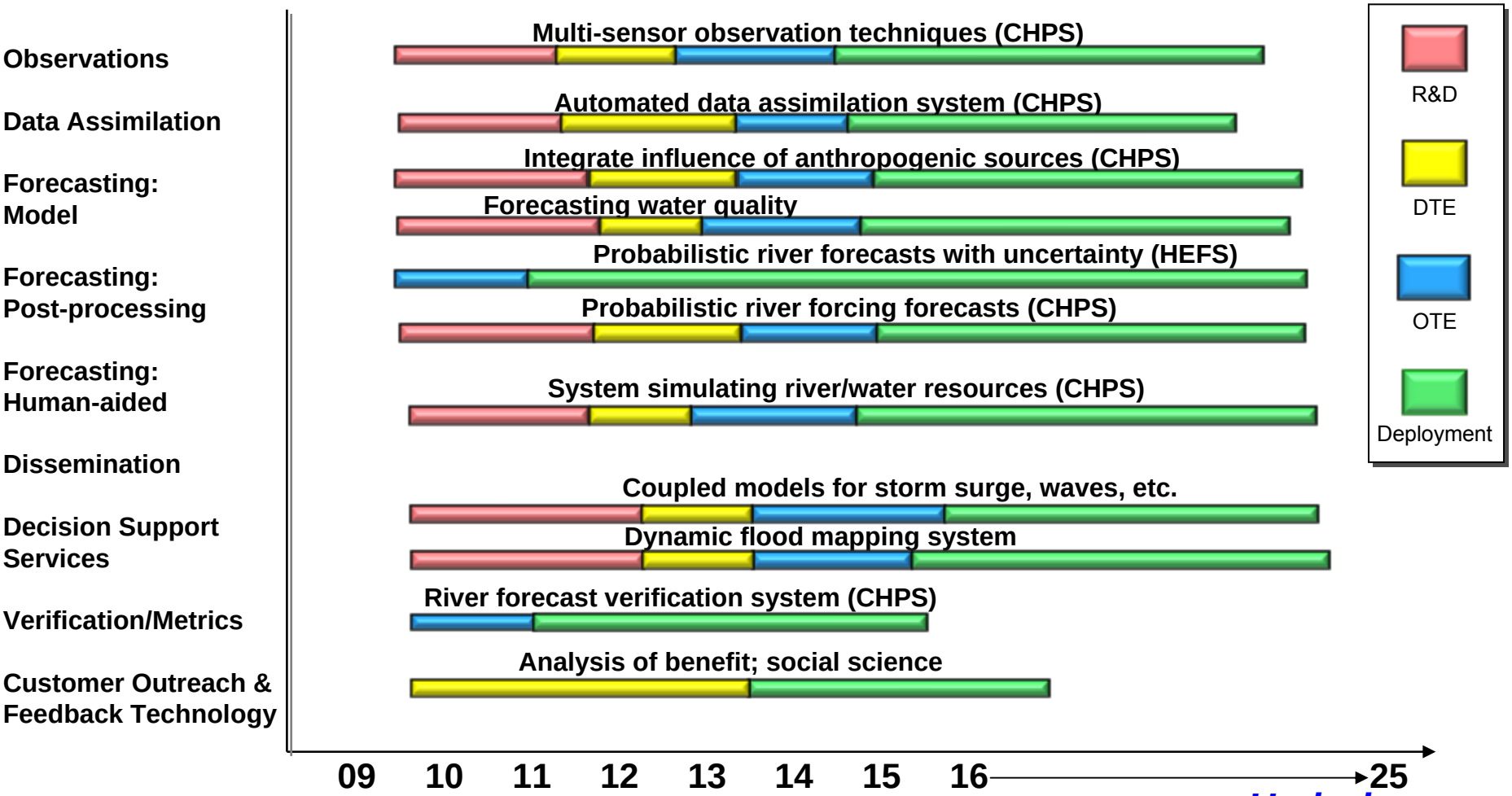
Key Science Gaps

Gap	Solution Alternative	Impact
Gap #10 Social Science issues: Quantification of the Hydrology program benefits to society is incomplete. Communication of information to forecasters, to emergency and water resources managers and to the public is inadequate	10.1 Continue to engage economists to quantify the benefits to society of the hydrology program. Continue to engage cognitive psychologists and human factor engineers in the design of user interfaces for forecasters, and of communication methods to emergency and water resources managers and to the public.	Benefit/cost of the NOAA Hydrology program will be quantified. Forecasters will be able to work more efficiently in a less stressful environment when the proper information is supplied to them in the right format. Emergency and water resources managers and the public at large will be able to understand the information the NWS is conveying

Research Needs and Opportunities

- **Short-term**
  - Improve on physically-based parameter estimation techniques for conceptual models from existing databases
  - Integrate dual polarization algorithms; improve satellite-based precipitation estimates
  - Research coupling of 1-d hydraulic models with 2-d ocean/estuary models
  - Develop pre- and post-processors for hydrologic ensemble forecasting
  - Develop ensemble data assimilation techniques for lumped and distributed models
  - Hydrologic verification and validation techniques
- **Long-term**
  - Develop models with a structure suitable to the use of unmodified physically based parameters
  - Distributed modeling including estimates of uncertainty
  - Implement phased-array, global precipitation mission (GPM) and probabilistic precipitation and temperature observations and forecasts up to 6 hours
  - Develop and implement water quality forecast models
  - Develop probabilistic inundation mapping techniques
  - Seamless hydrologic ensemble forecasting from hourly to seasonal time scales at fine spatial scale
  - Data assimilation of in-situ/remotely sensed observations using emerging techniques
- **Additional outstanding research needed**
  - Accounting for climate change effects in hydrologic modeling and prediction

Hydrology
Alternative Solutions



Focus Area Team Summary: Hydrology

R&D Needs & Opportunities

- Develop hydrologic ensemble-based forecasting
- Coupling of hydrologic and estuary and ocean models
- Integrate dual-pol radars and satellite techniques
- Distributed models with uncertainty analyses

Vision

Production of accurate, relevant, and actionable water information and forecasts that reduces loss of life & property and enhances economic prosperity

Increasing Impact

Current Status:

- Forecasts at 4000+ locations
- Limited probabilistic forecasts
- Coastal points don't have river forecasts
- Short term precip/temp forecasts
- Very limited verification

Near-Term:

- River forecasts with 12 hr lead time at the skill of today's 6 hr lead
- 10% of coastal communities receive hydrologic forecasts
- Distributed modeling at LTE 4km scale
- Ensembles
- Verification info

Long-Term:

- Distributed modeling for river and flash floods at 1km scale; fine-scale products
- Multi-scale, multi-model ensemble data assimilation; prediction of water resources variables
- Comprehensive verification of end-to-end hydrologic forecasting
- Fully coupled hydrologic and ocean/estuary models

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Hydrology Team Additional Information

Target Performance Measures: Hydrology

Proposed	Current (2009)	FY 2016 Target Example	FY 2025 Target Example
Improved, very high resolution flood forecasting with uncertainty estimates	Lumped precipitation/runoff models and hydrologic channel routing in majority of cases; distributed modeling in several headwaters (in parallel with lumped); 4km distributed modeling over entire domain of four RFCs for flash flood guidance; distributed model for flash flood (DHM-TF) being installed for prototype testing	Distributed modeling (in parallel with lumped) used for river and flash flood forecasting at 4k or 1km scale; soil moisture and temperature forecasts generated at 4km scale; models can be parameterized from geophysical data sets and require less calibration	Distributed modeling (with lumped) used for river and flash flood forecasting at 1km scale and include estimates of uncertainty; fine scale products such as soil moisture and soil temperature, surface water forecasts produced at short to long lead times

Target Performance Measures: Hydrology

Proposed	Current (2009)	FY 2016 Target Example	FY 2025 Target Example
Improved ensemble data assimilation and prediction of hydrology and water resource variables	Probabilistic forecasts limited to long-term streamflow ensembles	Hydrologic ensemble forecasting from 1 hr to 2 yrs	Multi-scale multi-model ensemble data assimilation and prediction of hydrology and water resources variables.
Comprehensive verification scheme for hydrologic forecasting	Very limited verification information	Verification information available for most products	Comprehensive verification of end-to-end hydrologic forecasting