GEO In Action:
Revolutionizing Our Understanding of Stream Flow on Every River in the World

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National Oceanic and Atmospheric Administration (NOAA)
On behalf of the GEOGLOWS Partnership

GEOGLOWS

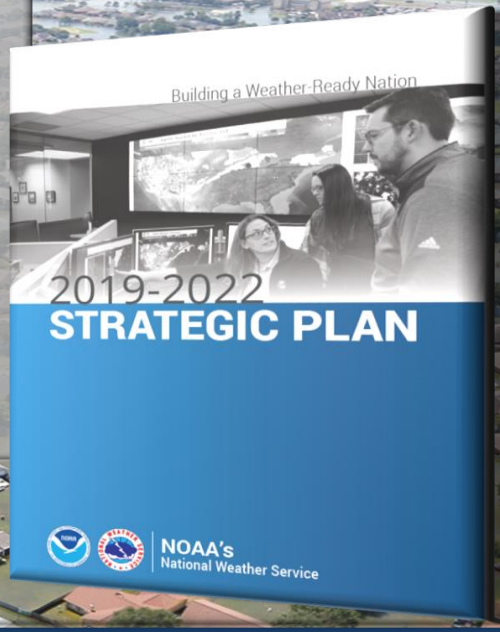
GLOBAL WATER SUSTAINABILITY

GEOGLOWS
GLOBAL WATER SUSTAINABILITY

GEOGloWS **provides vital water-related information in places where little or none exists** and strengthens national, regional, and local water information providers to guide management efforts. Through our partnerships we foster collaborations to provide valuable resources to the broader community in need of water knowledge and services and **to inform and enhance decision making**.

NOAA NWS Strategic Plan 2019-2022:
Water-Specific Goals

- Deliver actionable water resources information from national to street-level and across all time scales;
- Provide minutes-to-months river forecasts that quantify both atmospheric and hydrologic uncertainty;
- Improve forecasts of total water in the coastal zone by linking terrestrial and coastal models in partnership with the National Ocean Service; and
- Deliver forecasts of flood inundation linked with other geospatial information to inform life-saving decisions.



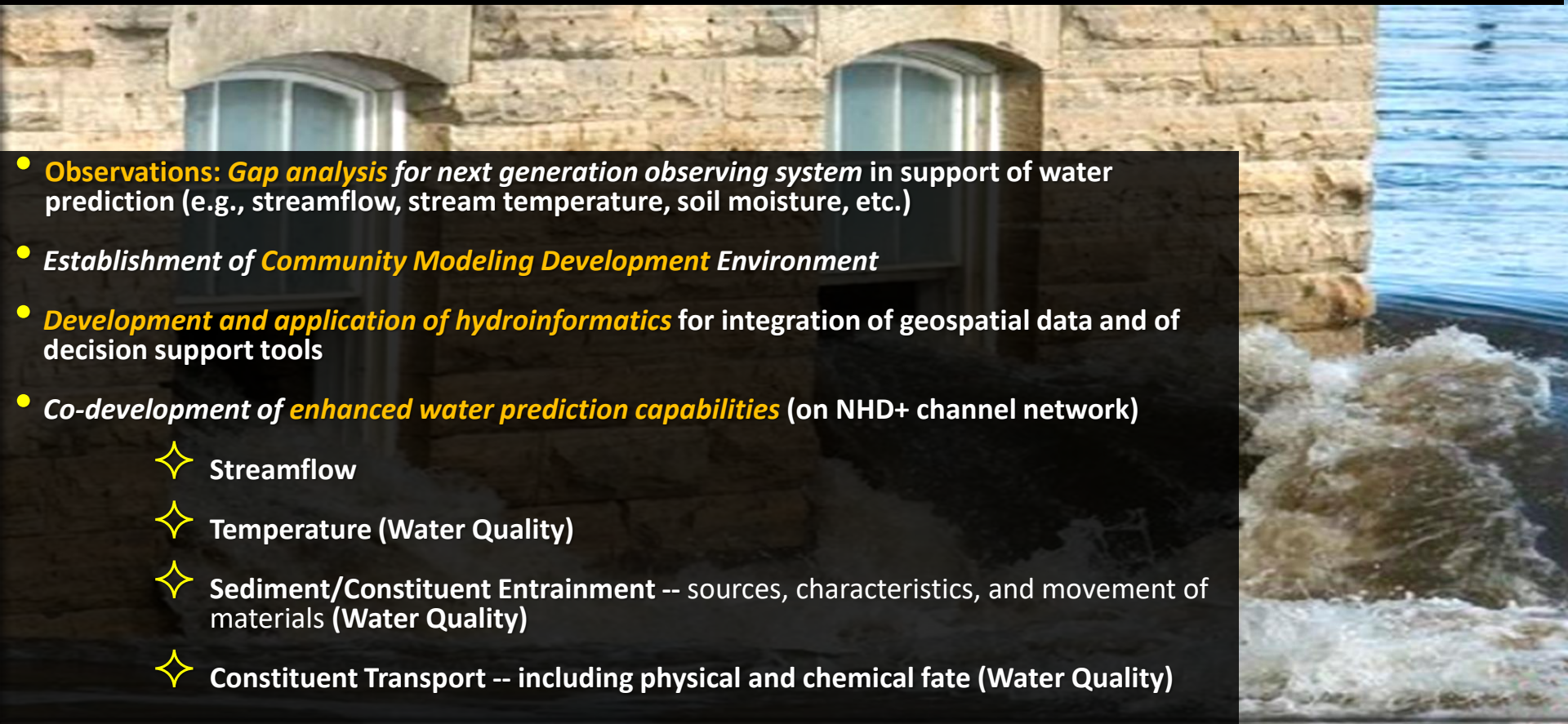
https://www.weather.gov/media/wrn/NWS_Weather-Ready-Nation_Strategic_Plan_2019-2022.pdf

Challenges/Limitations to Improving Water Prediction Capability and Related Services

- Observations, Data, Forcings, Data Assimilation
- Model Enhancement, Integration, and Community Development
- Physical Process Understanding
- Accounting for Anthropogenic Processes
- Application of Hydro-informatics for Integration of Geospatial Data and Development of Decision Support Tools
- Communication, including Uncertainty and Risk
- System Interoperability and Data Synchronization
- High Performance Computing Resources

Enhanced NOAA-USGS Collaboration

Supported by the USGS Water Prediction Work Program



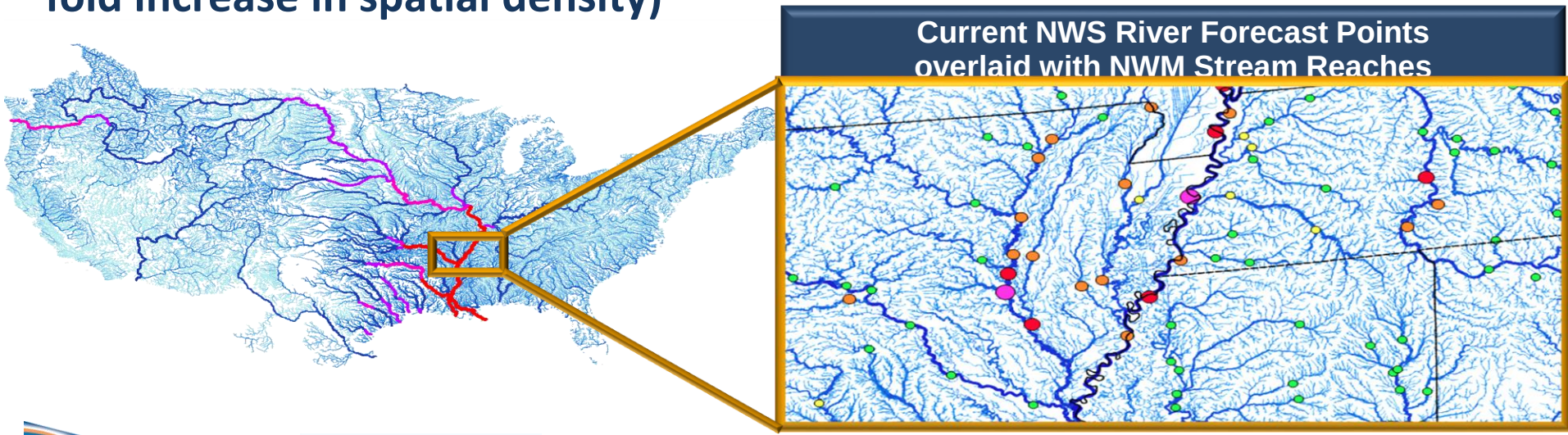
- **Observations:** ***Gap analysis*** ***for next generation observing system*** **in support of water prediction (e.g., streamflow, stream temperature, soil moisture, etc.)**
- ***Establishment of Community Modeling Development Environment***
- ***Development and application of hydroinformatics*** **for integration of geospatial data and of decision support tools**
- ***Co-development of enhanced water prediction capabilities*** **(on NHD+ channel network)**
  - **Streamflow**
  - **Temperature (Water Quality)**
  - **Sediment/Constituent Entrainment --** sources, characteristics, and movement of materials **(Water Quality)**
  - **Constituent Transport -- including physical and chemical fate (Water Quality)**

National Water Model

V1.0 Implemented August 16, 2016

- **Continental-scale water resources model providing high resolution, spatially continuous estimates of major water cycle components**

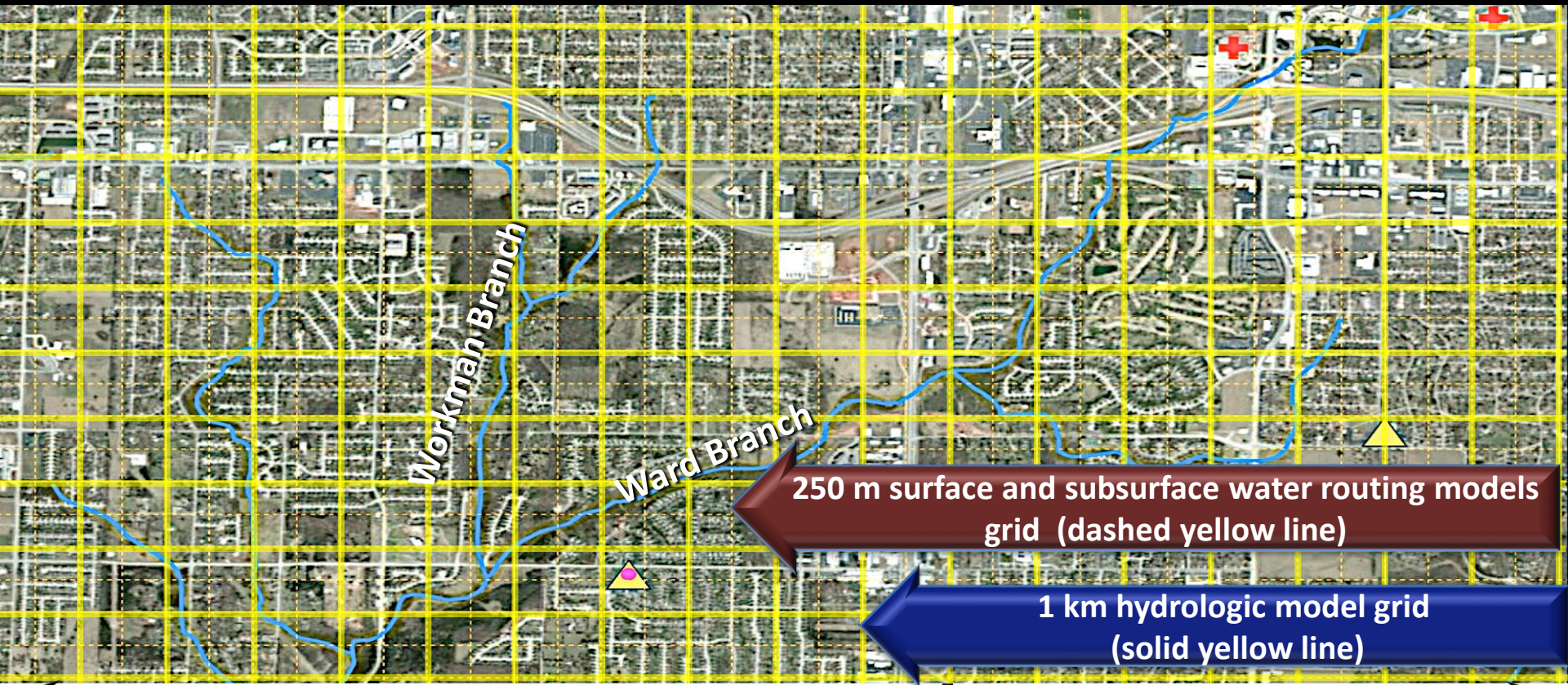
- **Operational forecast streamflow guidance for currently underserved locations: 3,600 forecast points → 2.7 million stream reaches (>700 fold increase in spatial density)**



NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH CUAHSI OWP OFFICE OF WATER PREDICTION

Water Prediction + National Infrastructure

Hospitals, EMS & Fire Stations



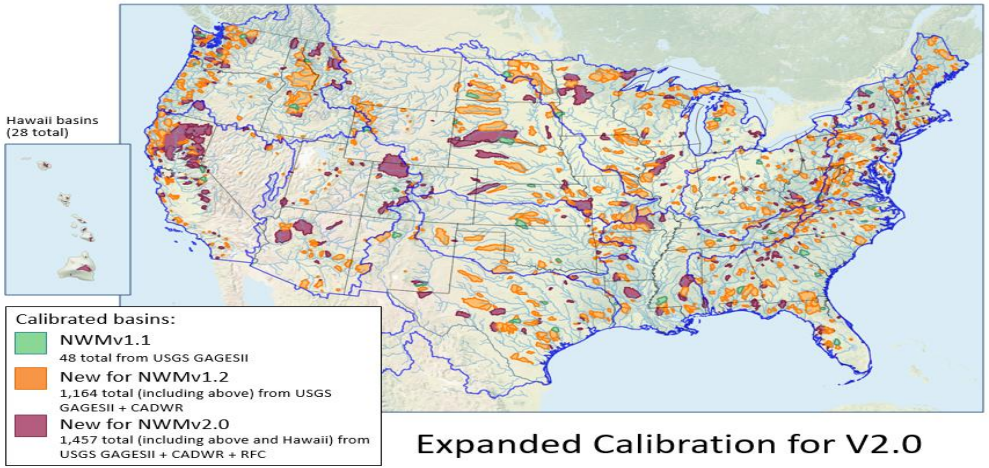
Evolution : Upgrading to NWM V2.0 and Beyond

v1.0 → v1.1/1.2 → v2.0

Foundation Established
August 2016
Water Resource Model for 2.7 Million Stream Reaches

First/Second Upgrade
May 2017/March 2018
Increased cycling freq. and forecast length, improved calibration, soil/snow physics and stream DA

Third Upgrade
May 2019
Expansion to Hawaii, medium range ensembles, compound channel parameterization, increased modularity, improved calibration, longer Analysis w/Multisensor Precipitation Estimates (MPE)



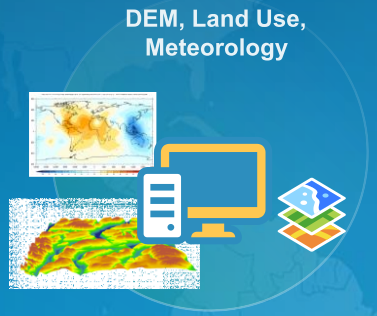
Expanded Calibration for V2.0

v2.1

Fourth Upgrade
Fall 2020
Expansion to Puerto Rico and Great Lakes, increased modularity, enhanced reservoir module, physics improvements, forcing bias-correction, improved calibration, and improved Hawaii QPE

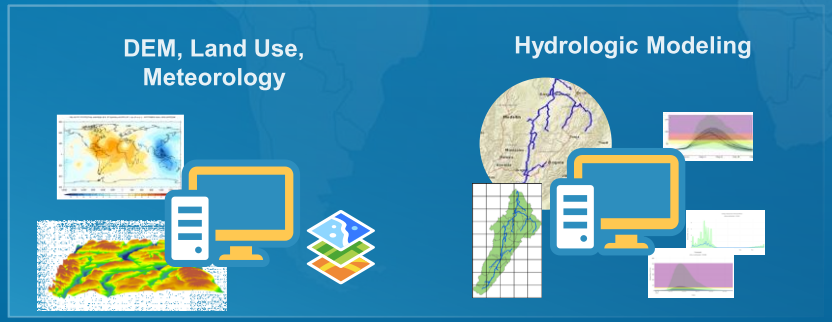
Global Streamflow Services – Is It Possible?

From This

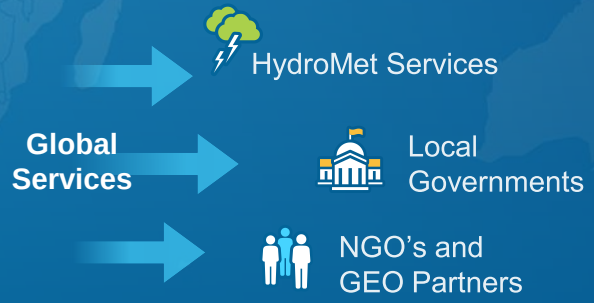


Global Data

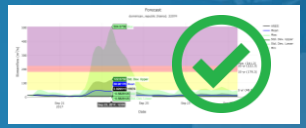
To This

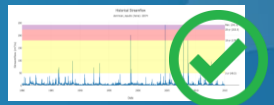


Global Services



Overcoming Global Modeling Barriers





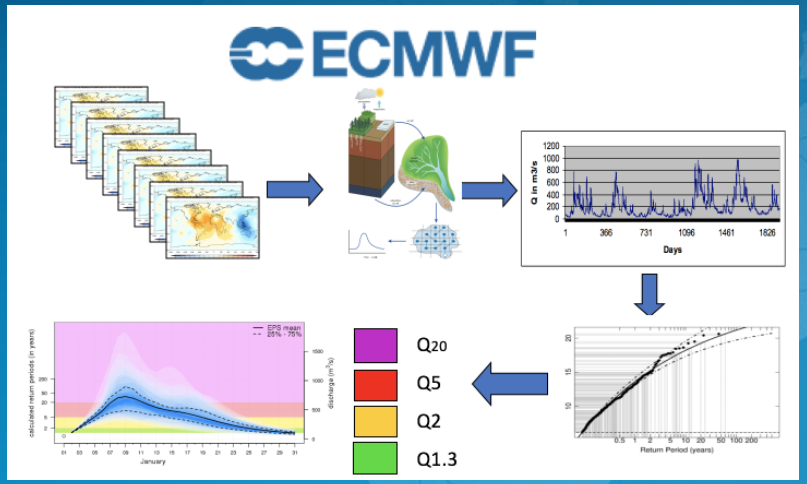
Cyberinfrastructure and Workflows

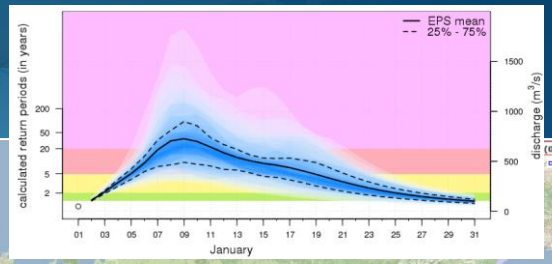
Web apps and web services

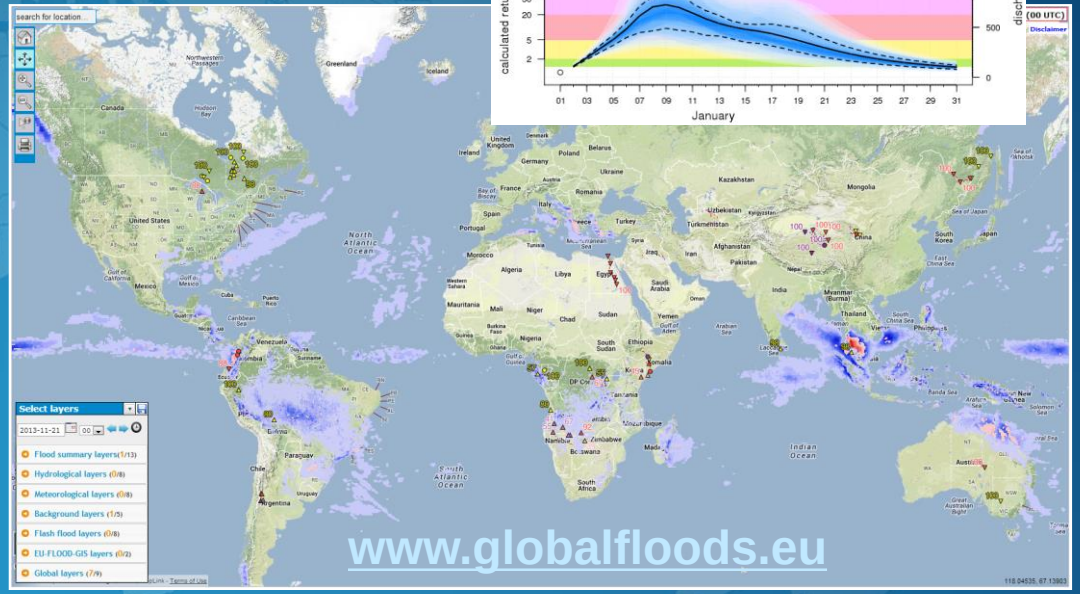
Partnerships, trainings, and collaboration

Accessibility tools and programmatic extraction

Global Flood Awareness System (GloFAS)



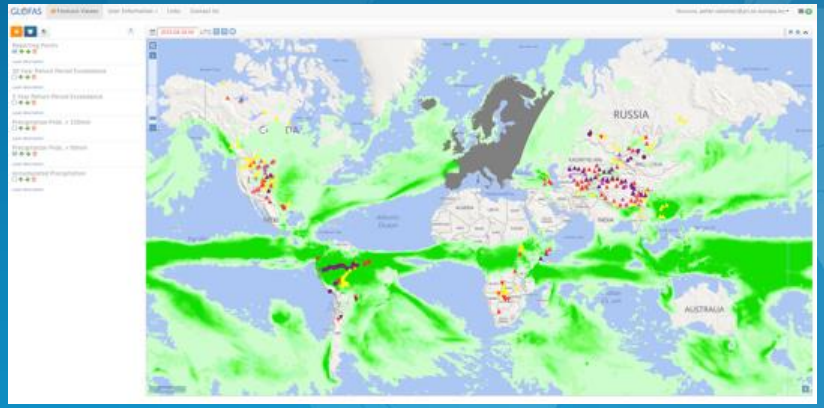


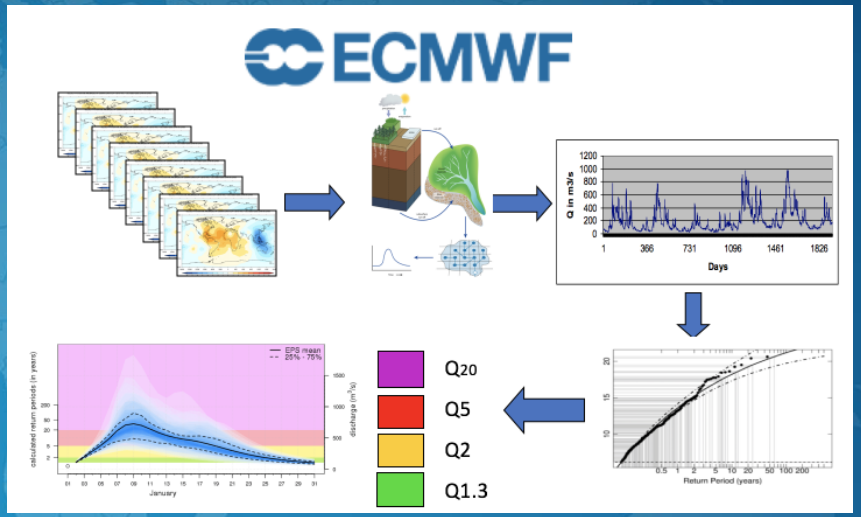


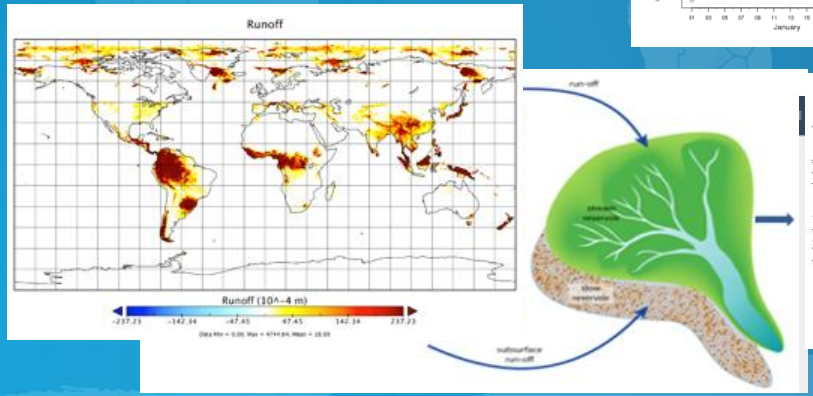
Products:
Frequency: Daily
Lead Time: Up to 30 Days
51-member Ensemble
Resolution: 5,000 – 10, 000 sq. K
Seasonal Outlooks
ERA-5 Retrospective River Flows

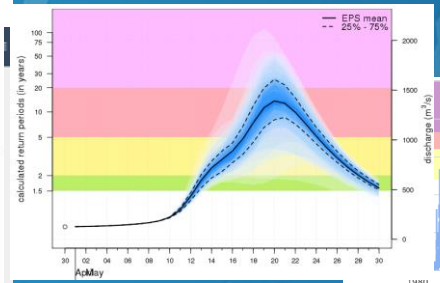
Forecast Day	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
05/08/2017								2	2	4	4	4	6	4	4	4	4	4	4	4				
06/08/2017											2	2	2				4	6	8	12	12			
07/08/2017						2	20	41	65	80	86	88	86	80	69	63	51	49	51	49	41	39		
08/08/2017							100	100	100	100	100	100	100	100	100	100	100	100	100	96	82	73	63	
09/08/2017							100	100	100	100	100	100	100	100	100	100	100	100	100	94	92	86	78	71

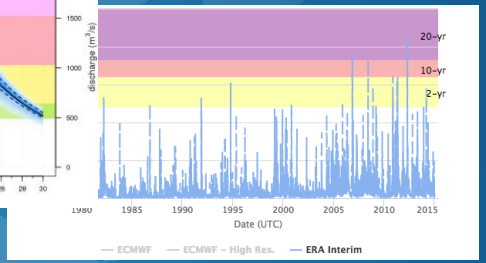
Streamflow Forecasting Conceptual Idea











Different Features between GloFAS and GEOGloWS

GloFAS

LISFLOOD routing model at a 0.1-degree resolution
GloFAS is more suited to watersheds of the order of 5000-10000 sq.
Differences in accounting for lakes and reservoirs, model calibration, and products
GloFAS includes a 30-day forecast and seasonal forecasts, and is planning to release an impact based forecast in the coming months.

GEOGloWS

RAPID routing model at a very high spatial resolution.
GEOGloWS, is more suited to watersheds on the order of 500 sq. Kilometers.
provides web-services/data access, which enables programmatic access and customization of many other derivative applications.
the tailored GEOGloWS web services have been added (in test mode) to the GloFAS web-map -interface.

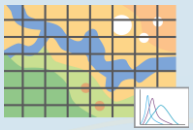
Both GloFAS and GEOGloWS have also been contributing to the Global Flood Partnership

Streamflow Forecasting and Dissemination Framework

- **A modular framework for runoff forecast impact analysis anywhere in the world**
- **Built upon open data, standards, and web services**
- **Configurable applications to understand, plan for, and respond to future hydrologic events**

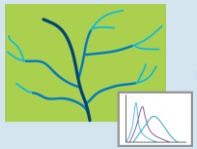
Weather-Hydro Forecast Modeling

- **WRF-Hydro**
- **ECMWF**
- **Any other runoff forecast**



Runoff Downscaling

Python Geoprocessing Workflows



Flow Routing

RAPID
SPRINT
HEC-RAS
MIKE-11

Multi-scale Temporal Map Service

Web services and applications

Global Streamflow Services – What We Accomplished

Global Services

- HydroMet Services
- Local Governments
- NGO's and GEO Partners

GEOGLOWS GLOBAL WATER SUSTAINABILITY

Toolbox

Tethys Apps, Global and Customizable

ESRI Living Atlas Layers, Apps, Widgets

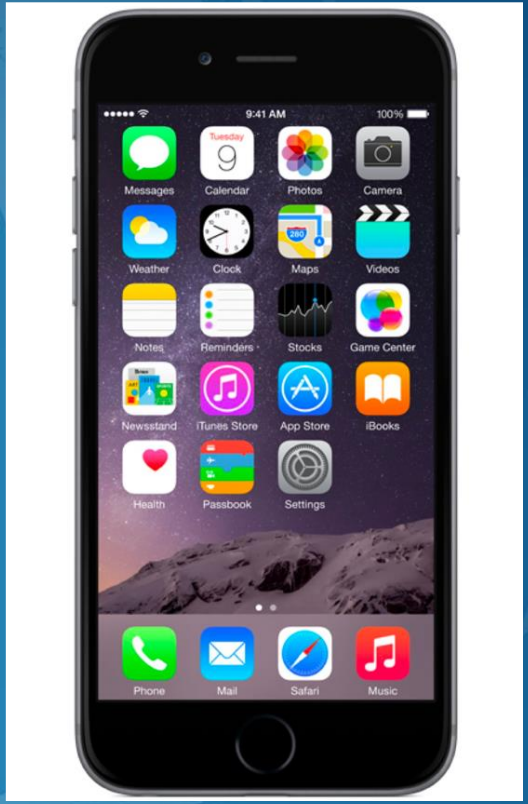
Python Library for Other Uses

NASA GEOGloWS Project – Storehouse

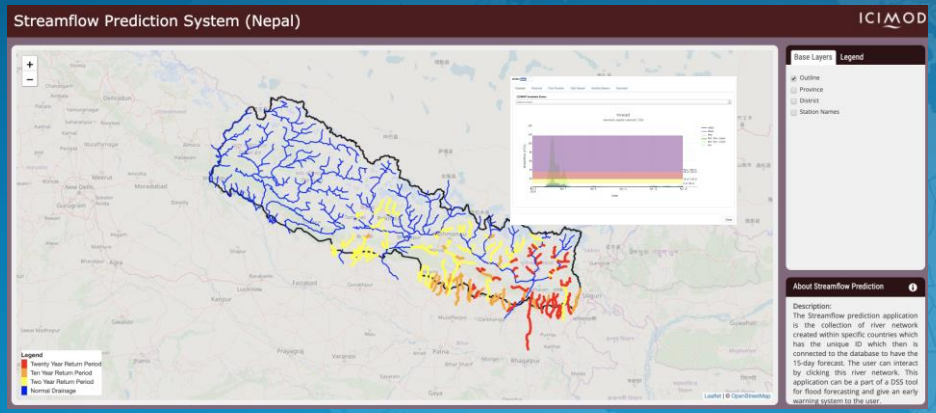
App Store

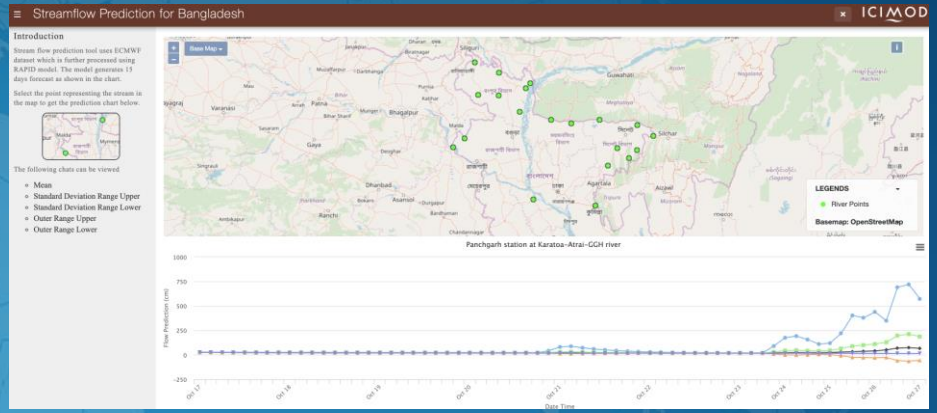
ANDROID APP ON Google play

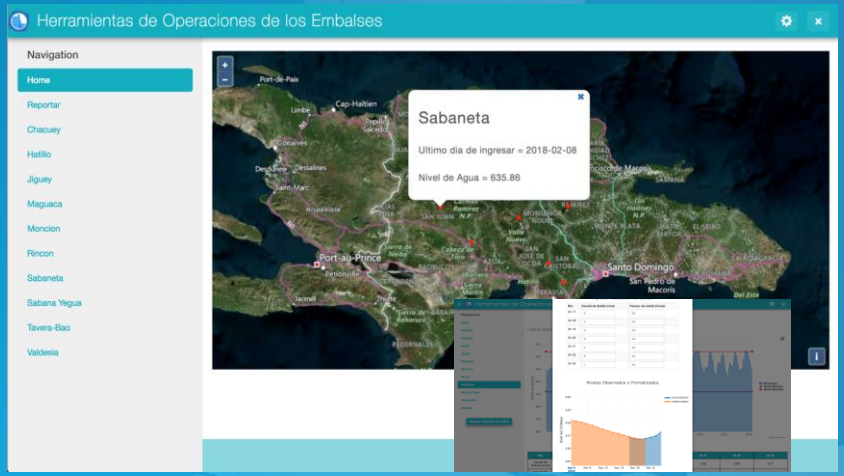
APP WAREHOUSE

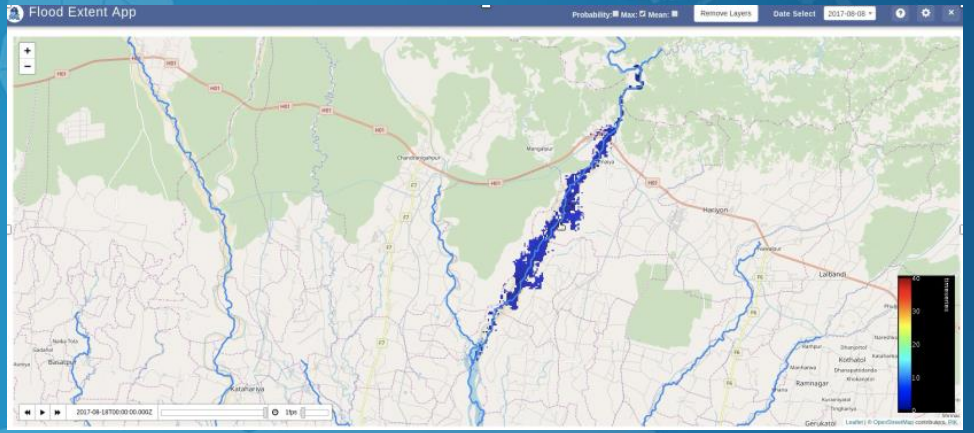


Custom Streamflow and Derivative Applications









Global Streamflow Forecasts

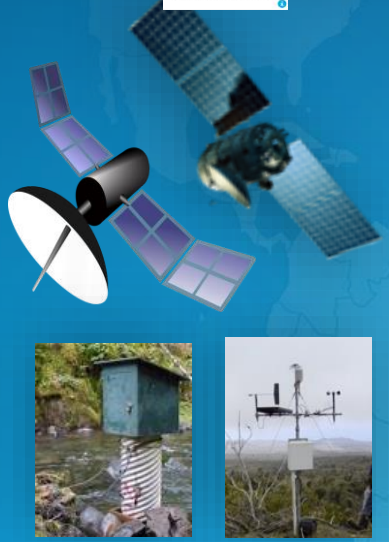
ECMWF 15-Day Forecast
35-Year Historical
Discharge on every river

HydroMet Services

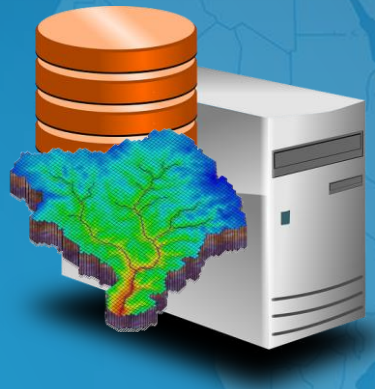
Local Governments

NGO's and GEO Partners

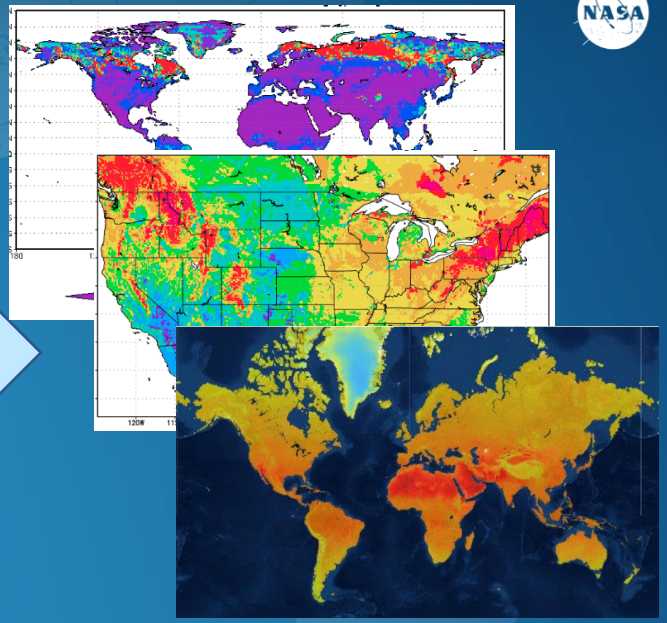
Global Land Data Assimilation System (GLDAS)



Measurements from satellites and in-situ probes



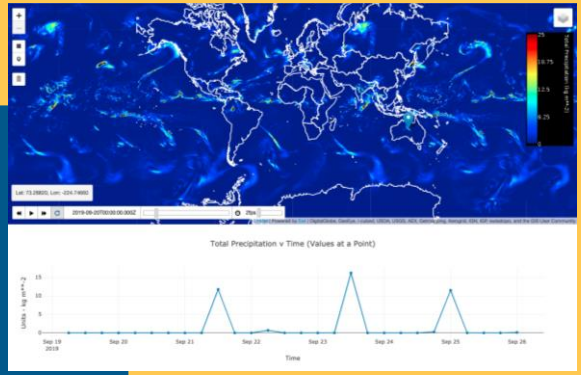
Processed by NASA LIS computer models of the earth



Historical Temperature, Precipitation, many other essential water variables

Global Forecasted Hydrometeorology (GFS)

Temperature
Precipitation
Soil Moisture
Evapotranspiration



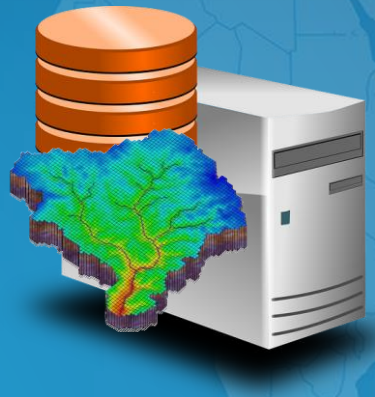
HydroMet Services

Local Governments

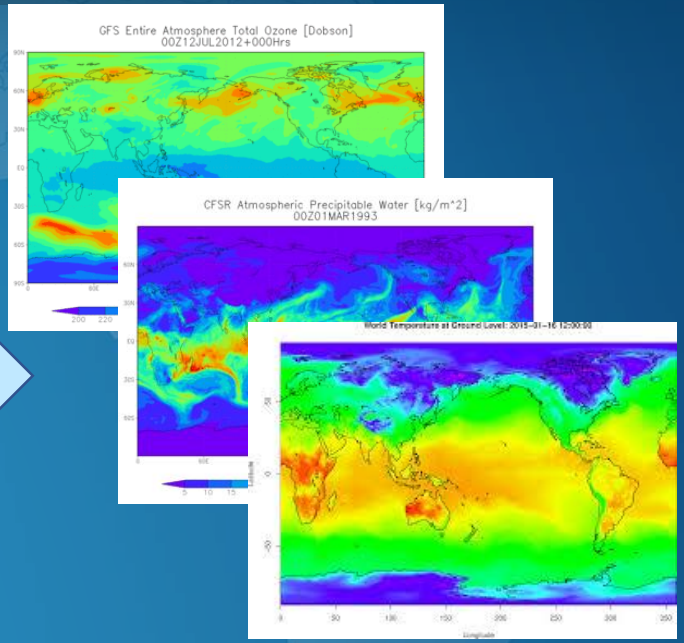
NGO's and GEO Partners

Global Forecasting System (GFS)

Measurements from satellites and in-situ devices



Processed by NOAA computer models (WRF) of the earth



Forecasted Temperature, Precipitation, many other essential water variables

HydroStats Metrics for Validating Hydrologic Time Series

Python Package

- **50 different hydrologic metrics**

Use with Toolbox or other models

Historical Validations

Forecast Skill

Model Comparisons

HydroStats Tools for Model Validation/Comparison

Mean Absolute Error

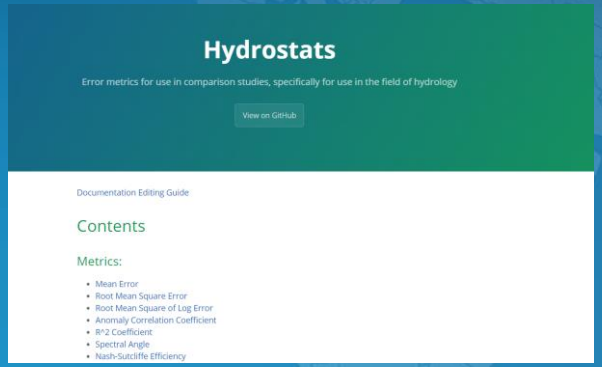
$$MAE = \frac{1}{n}\sum_{t=1}^{n}|y_t - x_t|$$

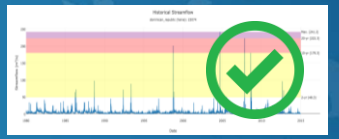
Root Mean Square Error

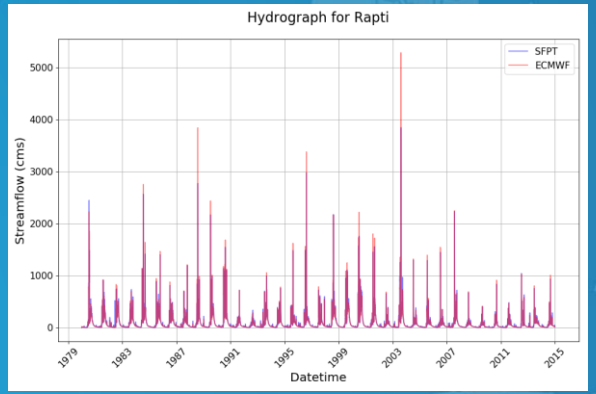
$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t - x_t)^2}$$

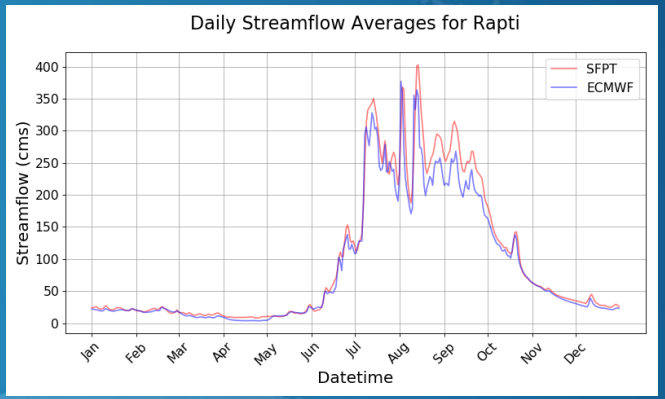
R^2 (Coefficient of Determination)

$$SS_{xx} = \sum_{t=1}^{n}(x_t - \bar{x})^2$$
$$SS_{yy} = \sum_{t=1}^{n}(y_t - \bar{y})^2$$
$$SS_{xy} = \sum_{t=1}^{n}(x_t - \bar{x})(y_t - \bar{y})$$
$$r^2 = \frac{SS_{xy}^2}{SS_{xx}SS_{yy}}$$









Esri Web App Builder

GEOGLOWS Portal

GFS Data Tool

GLDAS Data Tool

Streamflow Prediction Services

Hydrostats App

THANK YOU!

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