

# GEO GLOWS

GLOBAL WATER SUSTAINABILITY

Providing a service to deliver global water information for local decision-making

On behalf of the GEOGloWS Team



AQUAVEO™



THE WORLD BANK



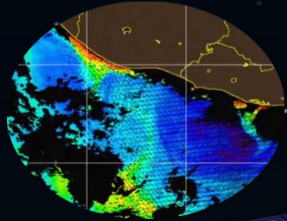
# GEO Global Water Sustainability Initiative



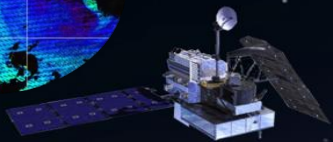
Connect People with Global Water Information

# SERVIR GLOBAL

Weather and Climate



GPM



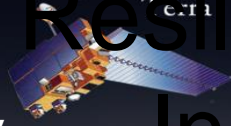
SRTM



Food Security



Resilience  
In...

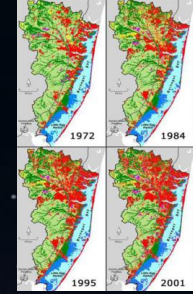


Water and Disasters

SMAP



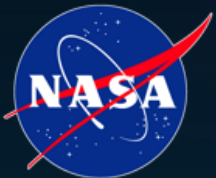
Land Use Change



Landsat 8



ICIMOD



# SERVIR GLOBAL

# Connecting Space To Villages



# In Situ Streamflow Monitoring Systems

Water Quantity  
and Quality



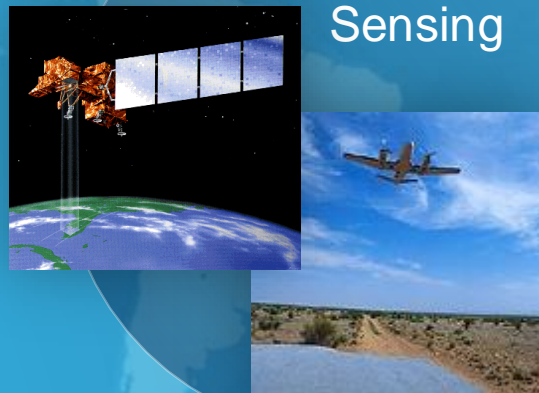
Rainfall & Snow



Meteorology



Remote  
Sensing

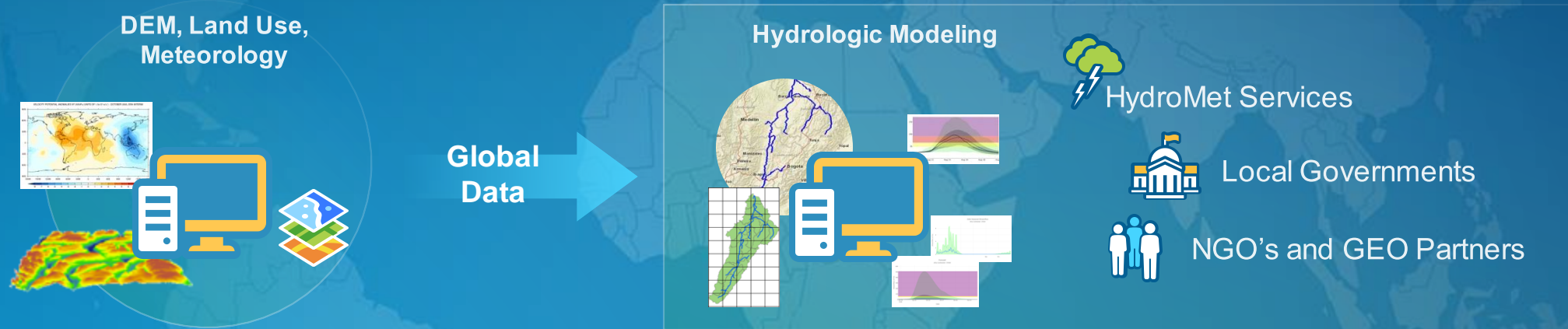


Soil Water

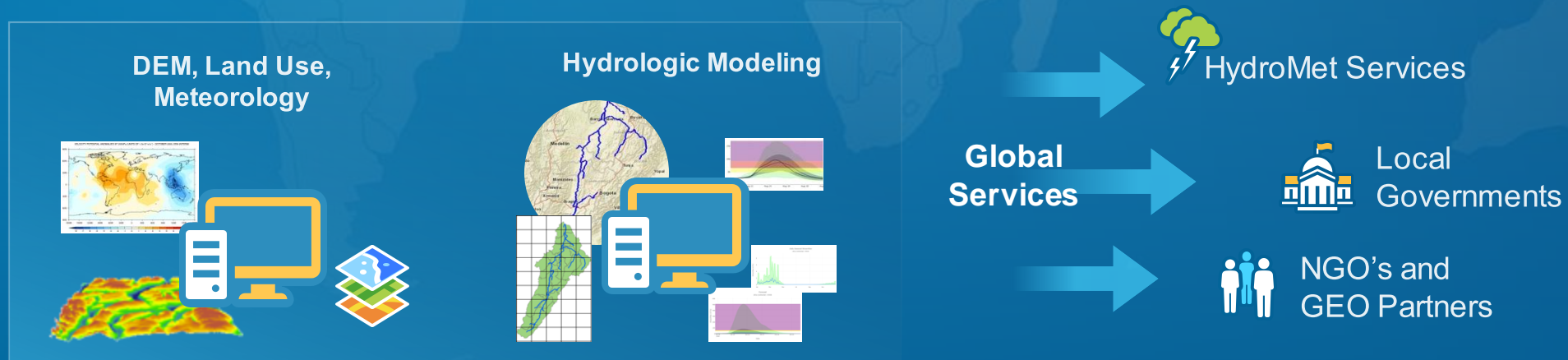


# GEOGIoWS Global Streamflow Services – A Paradigm Shift

## Individual Hydrologic Forecasting

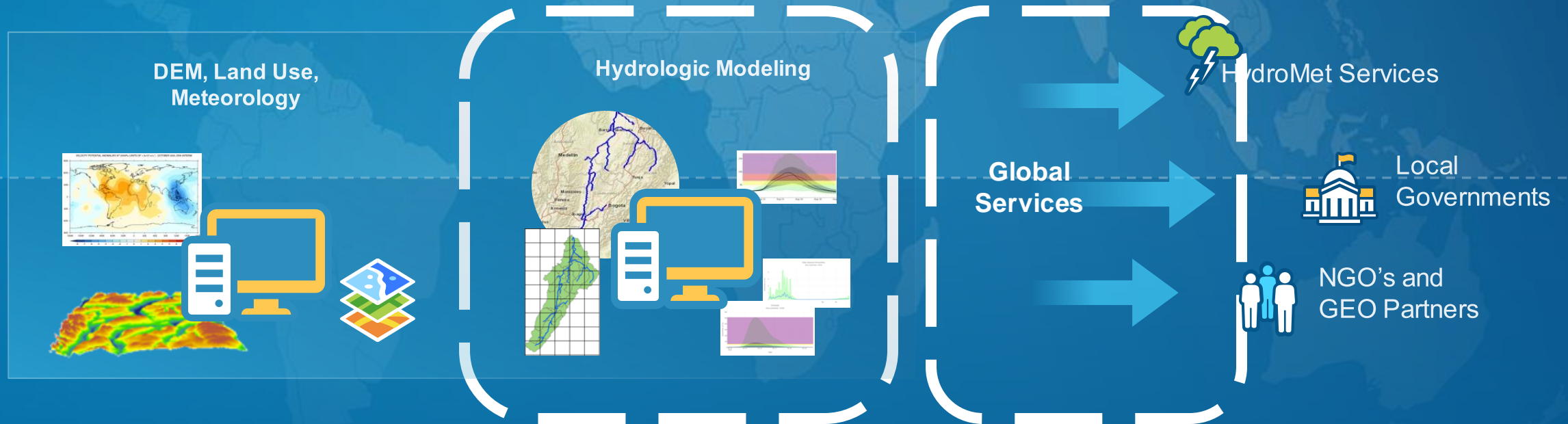


## Global Hydrologic Forecasting

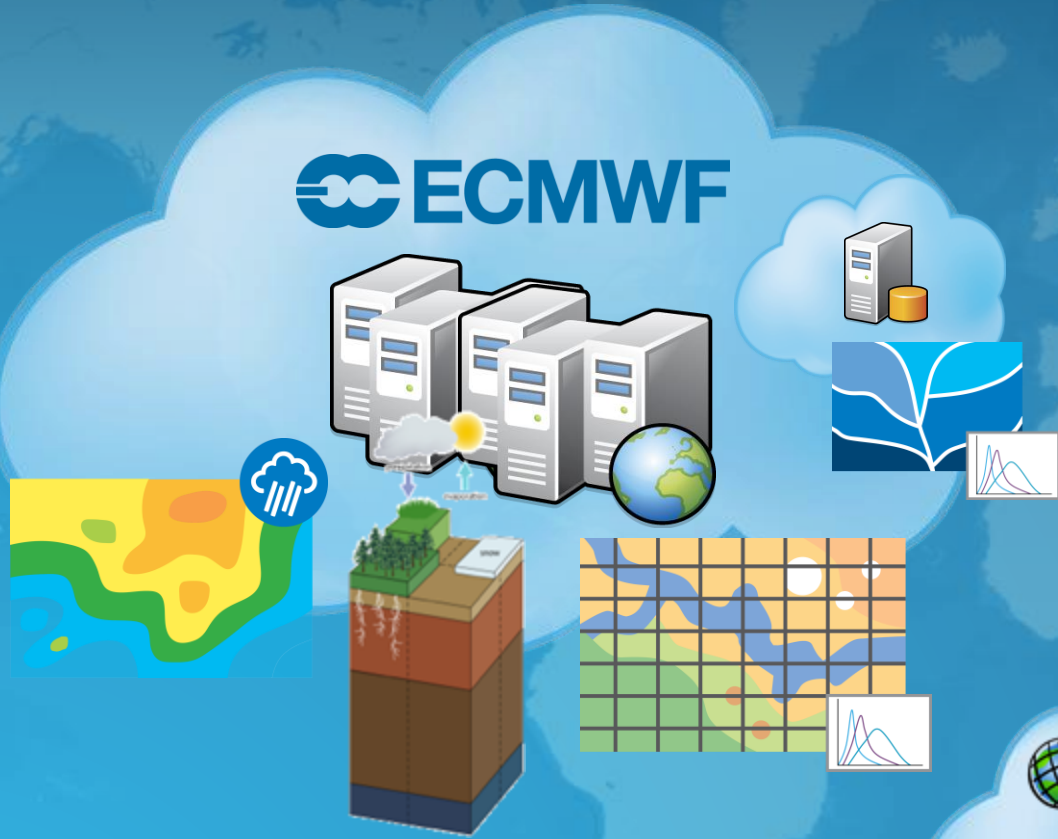


# Primary Challenges of Making a Global Model Useful Locally

Global Hydrologic Forecasting



# GEOGIoWS ECMWF Streamflow Services



## Web Services

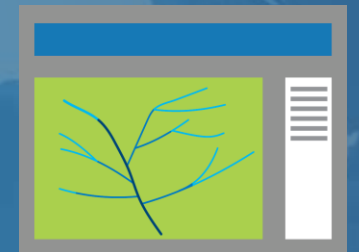
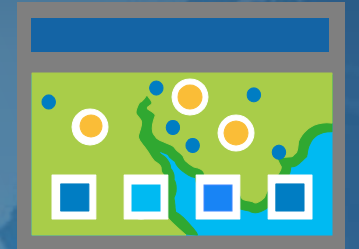


## Streamflow API at ECMWF



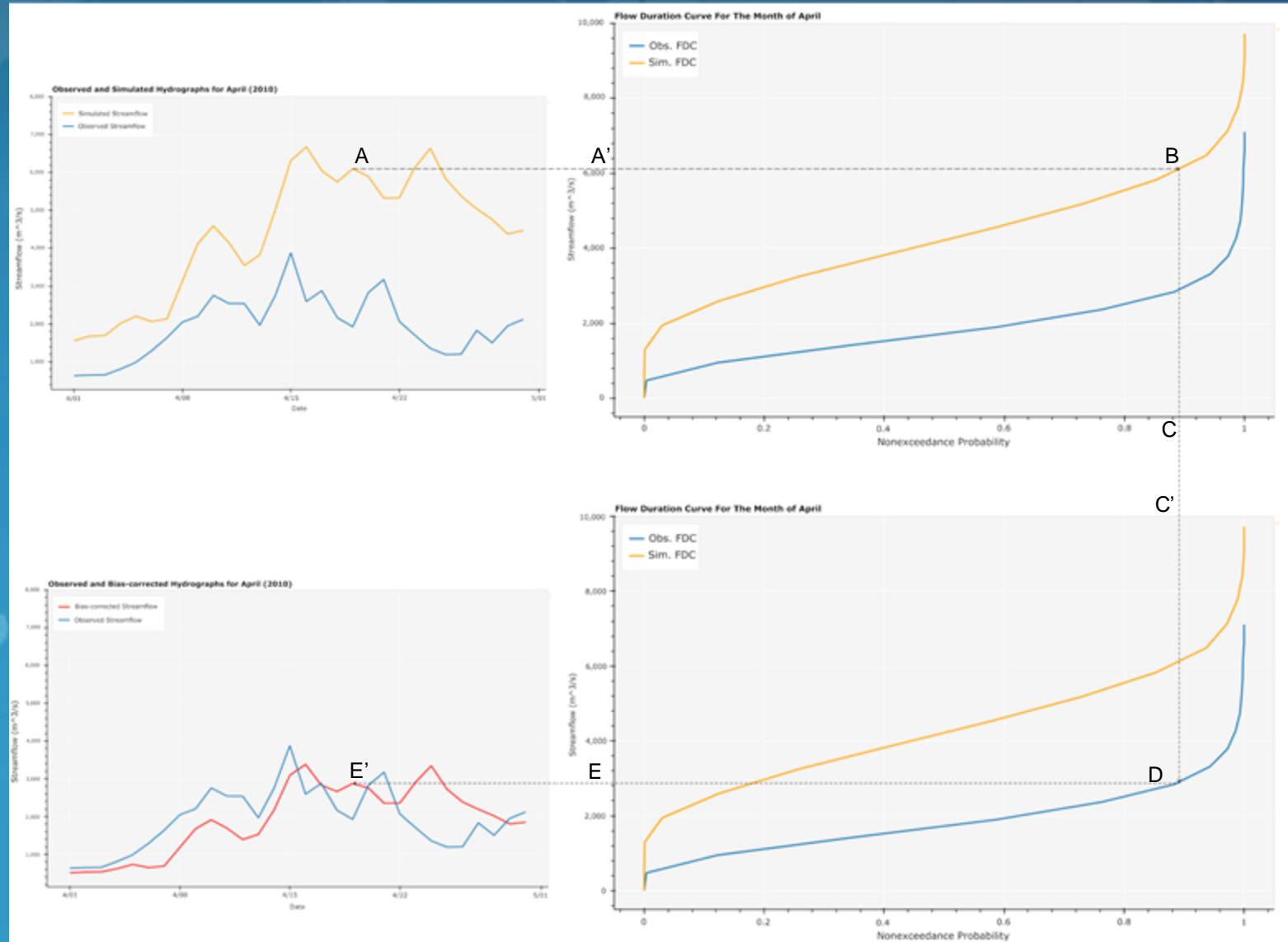
## Global WMS at Living Atlas

## Custom Web Apps



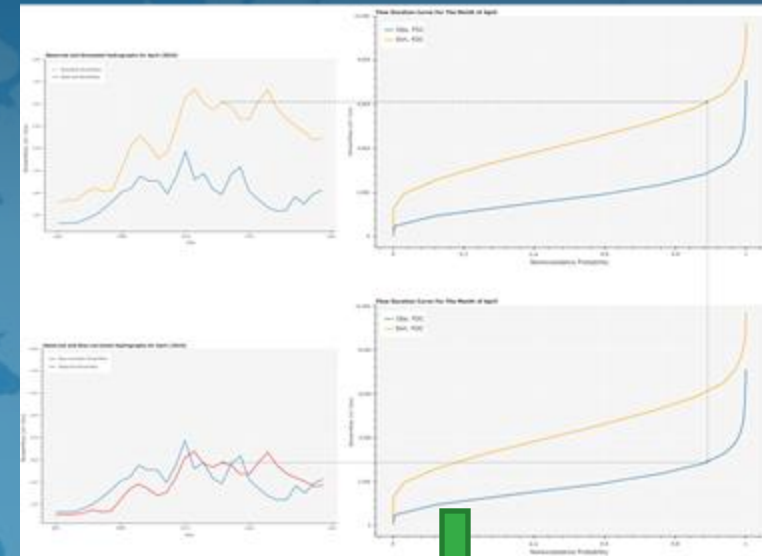
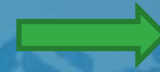
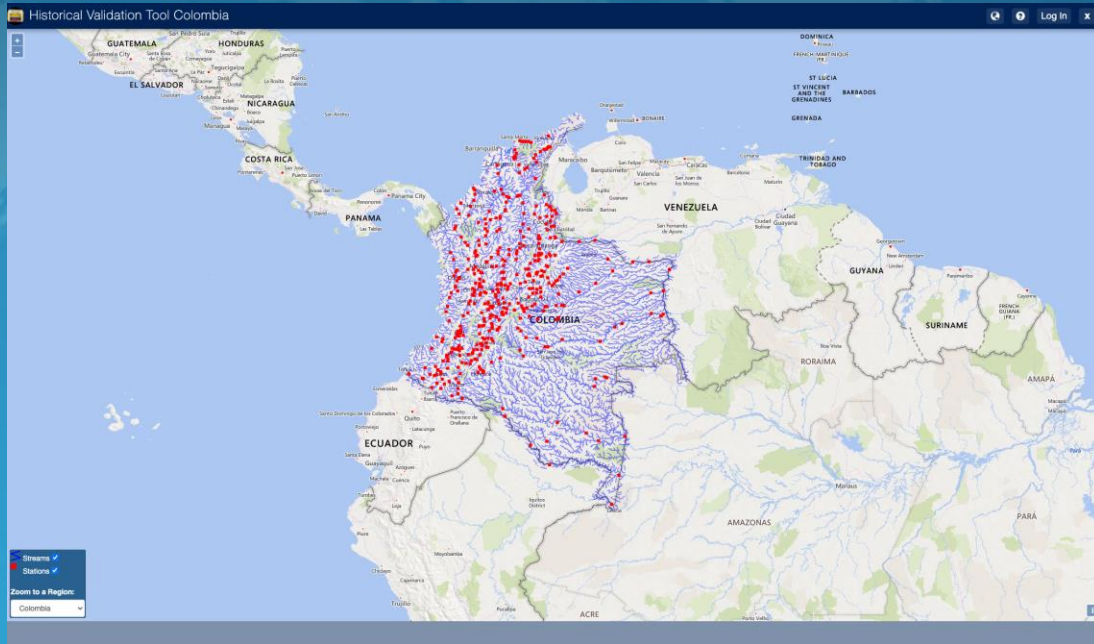
# Farmer's Method of Bias Correction

- Match exceedance probability of simulated to observed
- Remap simulated discharge based on the corresponding discharge from observed





# Bias Correction with Local Data

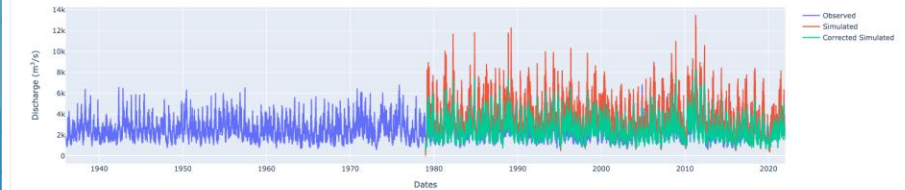


Current Station: PTO BERRIO AUTOMAT  
Station Code: 23097030  
Station COMID: 9006790  
Stream: MAGDALENA



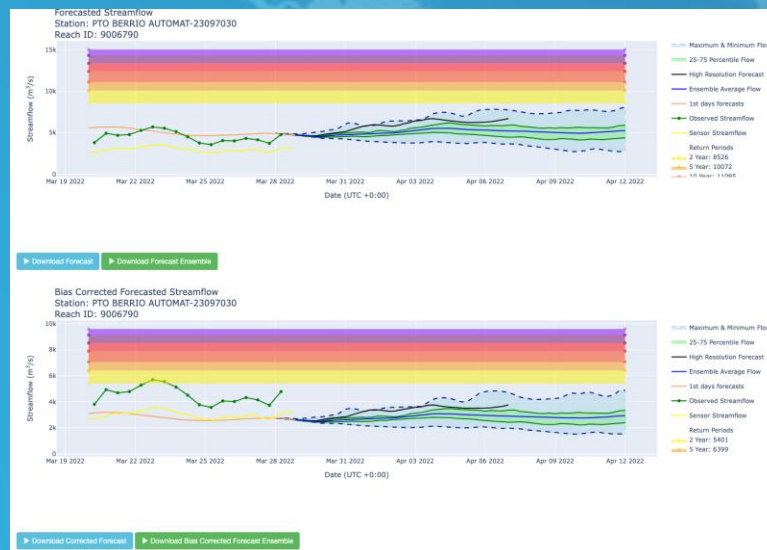
Hydrographs Visual Analysis Metrics Report Forecast

Observed & Simulated Streamflow at 23097030 - PTO BERRIO AUTOMAT

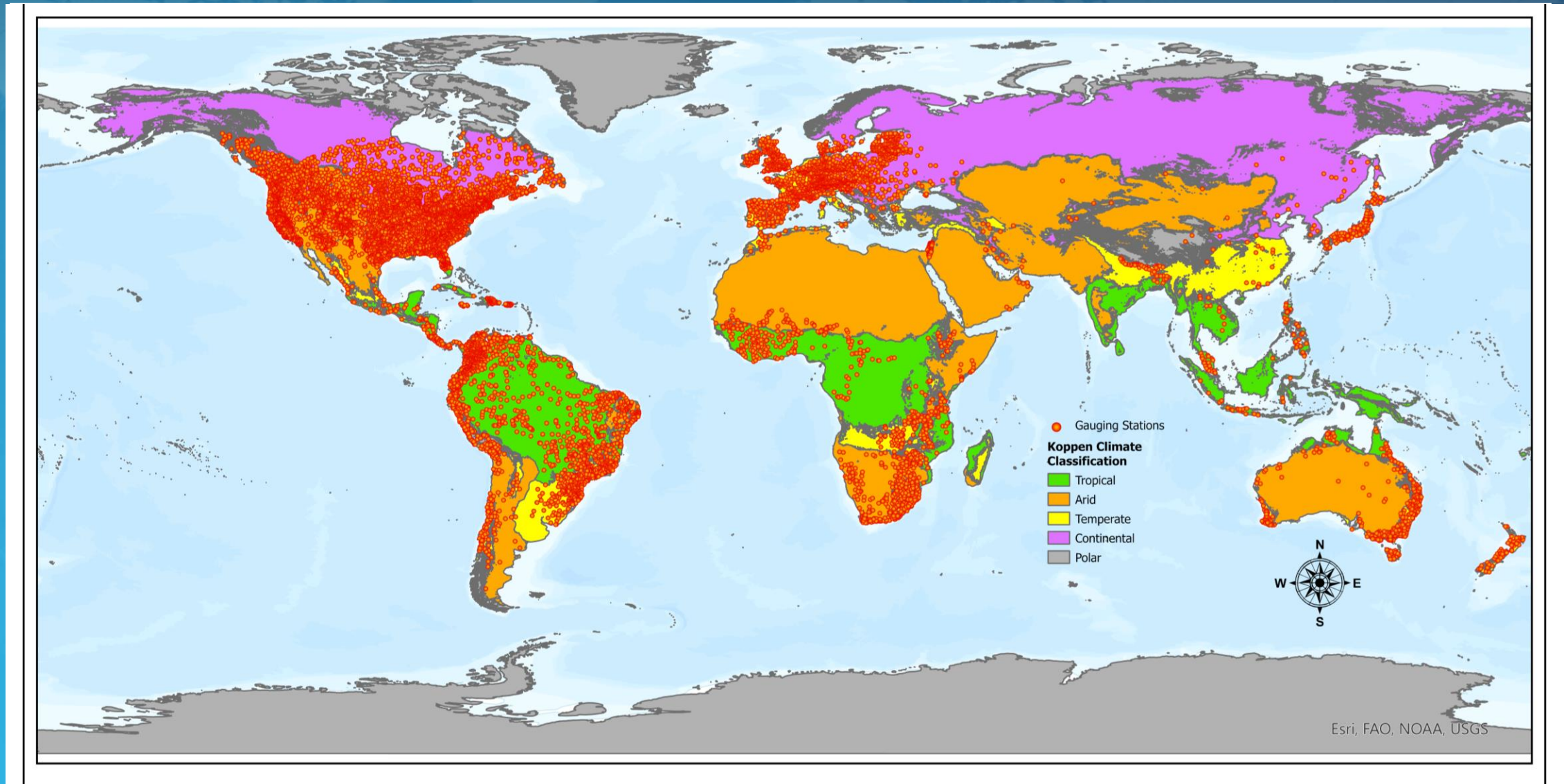


Download Data  
Observed Discharge Simulated Discharge Corrected Simulated Discharge

Close



# Validation and Local Adaptation



# Validation and Local Adaptation

## Observed Data

Gauging Stations per GEOGloWS Region.

Region	Number of Stations
Africa	1198
Australia	486
Central America	1953
Central Asia	2
East Asia	45
Europe	1931
Islands	137
Japan	152
Middle East	80
North America	7336
South America	2155
South Asia	95
West Asia	16

Gauging Stations per Köppen climate classification group.

Köppen climate classification group	Number of Stations
Arid	2471
Continental	5555
Polar	67
Temperate	5487
Tropical	2006

Gauging Stations per Simulated Watershed Area.

Watershed Area	Number of Stations
$\leq 500\text{km}^2$	3802
$500\text{km}^2 - 2500\text{km}^2$	5850
$2500\text{km}^2 - 5000\text{km}^2$	1820
$5000\text{km}^2 - 10000\text{km}^2$	1421
$10000\text{km}^2 - 50000\text{km}^2$	1882
$50000\text{km}^2 - 100000\text{km}^2$	386
$100000\text{km}^2 - 500000\text{km}^2$	321
$> 500000\text{km}^2$	104

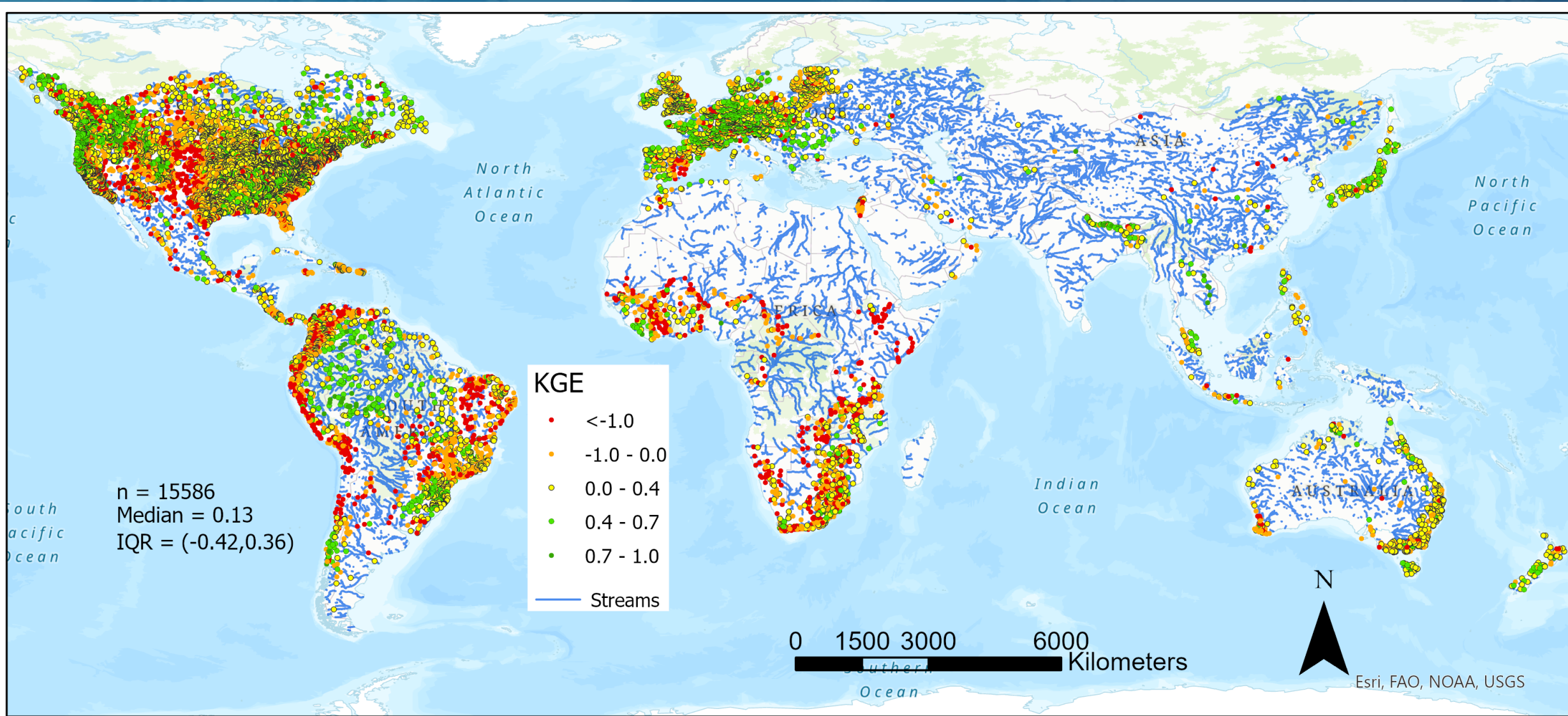
Gauging Stations per Observed Time Series Length.

Watershed Area	Number of Stations
$\leq 5$ years	3802
5 years - 10 years	5850
10 years - 20 years	1820
20 years - 30 years	1421
30 years - 50 years	1882
50 years - 100 years	386
$> 100$ years	104

Gauging Stations per Observed Time Series Length after 1979-01-01.

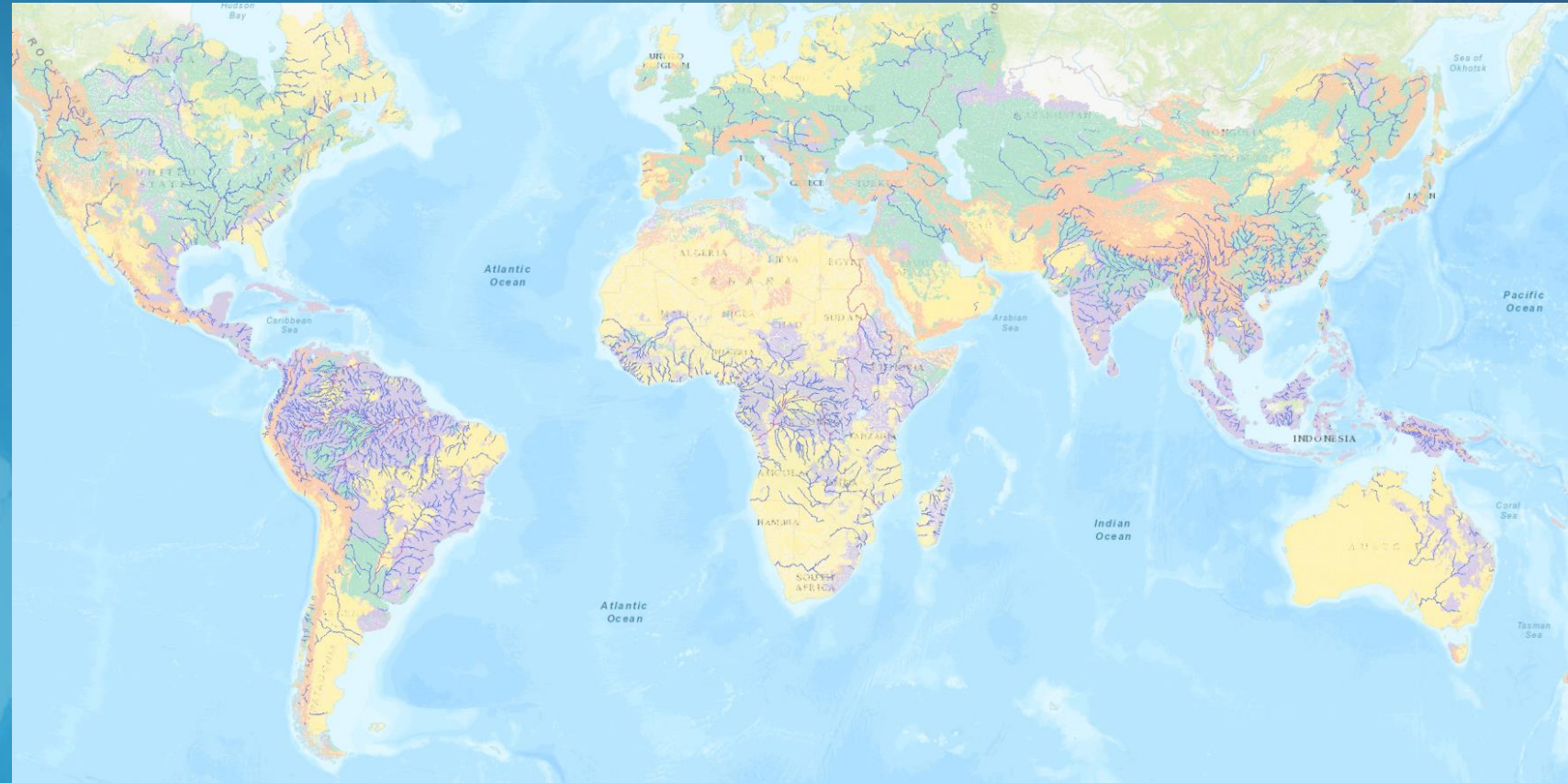
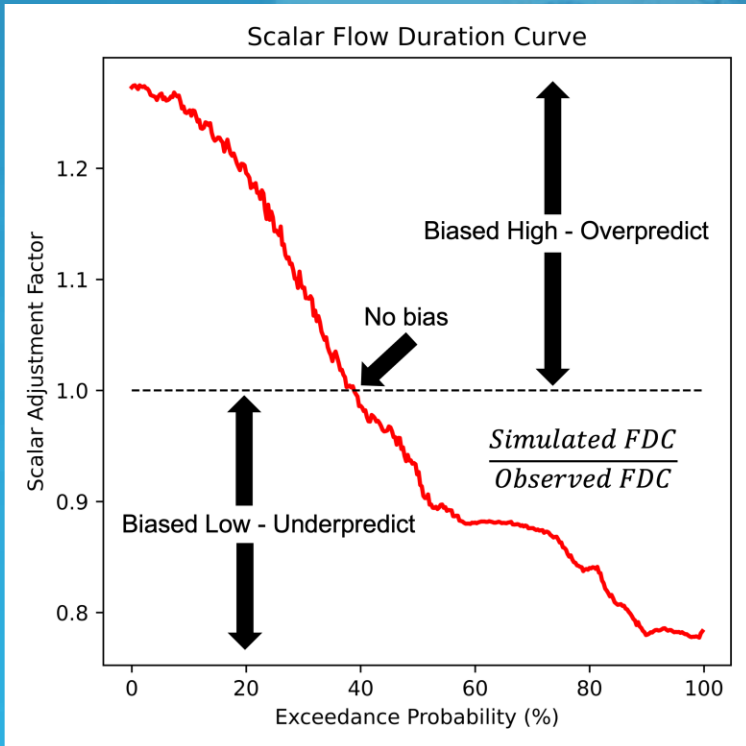
Watershed Area	Number of Stations
$\leq 5$ years	1677
5 years - 10 years	1150
10 years - 20 years	2673
20 years - 30 years	2261
30 years - 40 years	3000
$> 40$ years	4825

# Global Validation

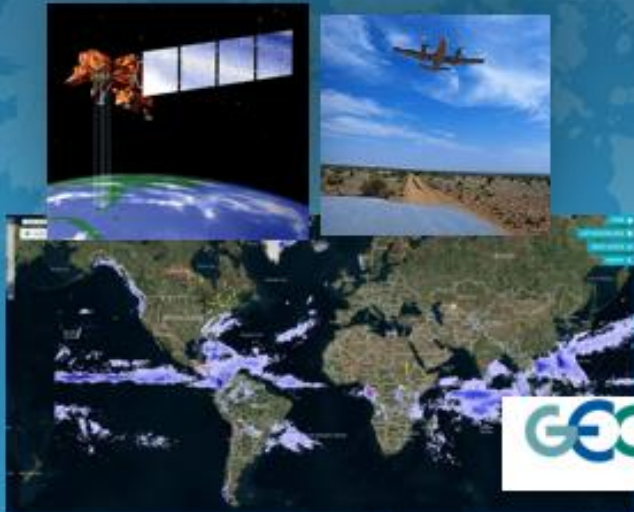


# Validation and Local Adaptation

Extended to ungaged rivers through machine learning

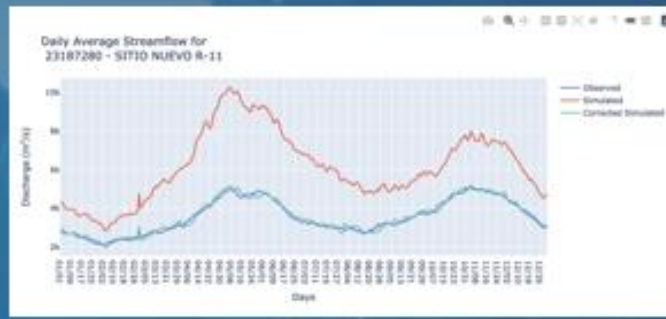
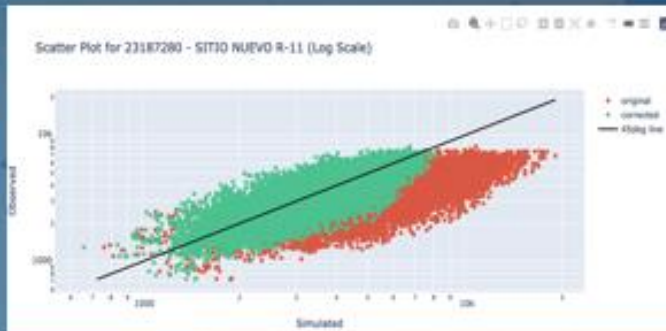
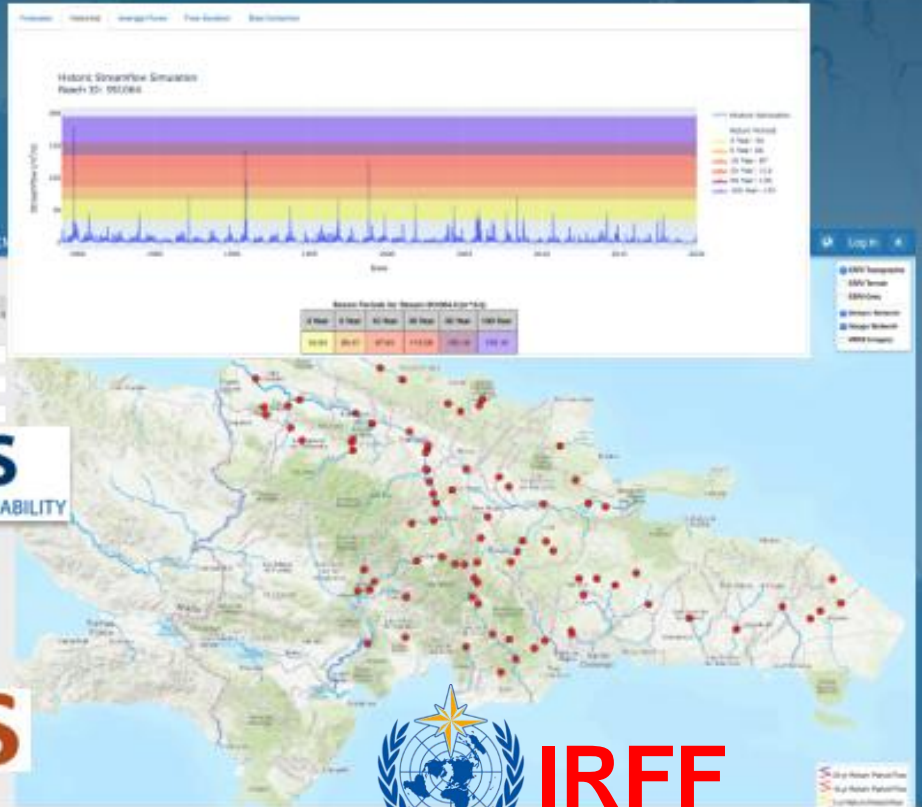


# WHOS and GEOGloWS Global Streamflow Data Services



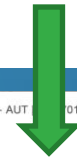
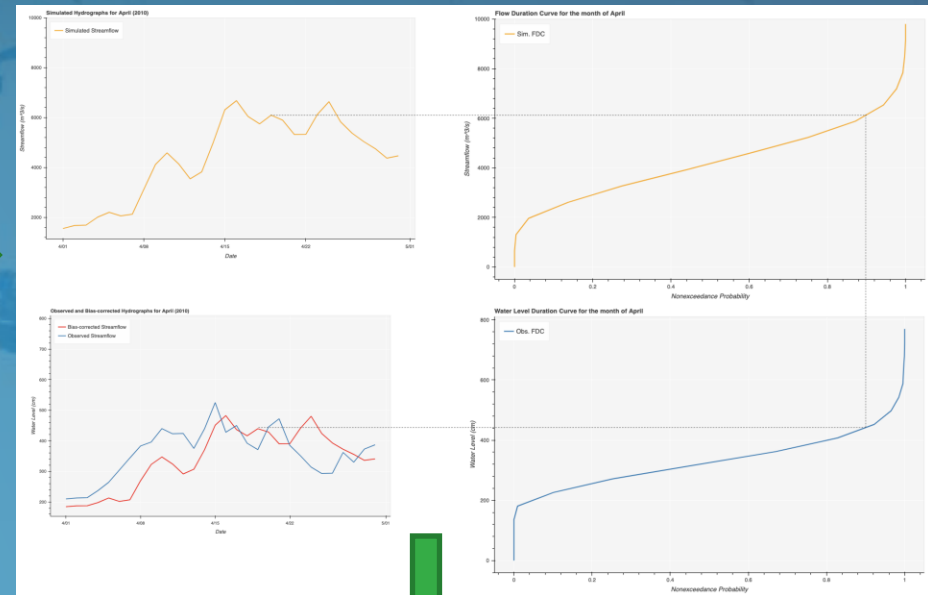
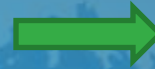
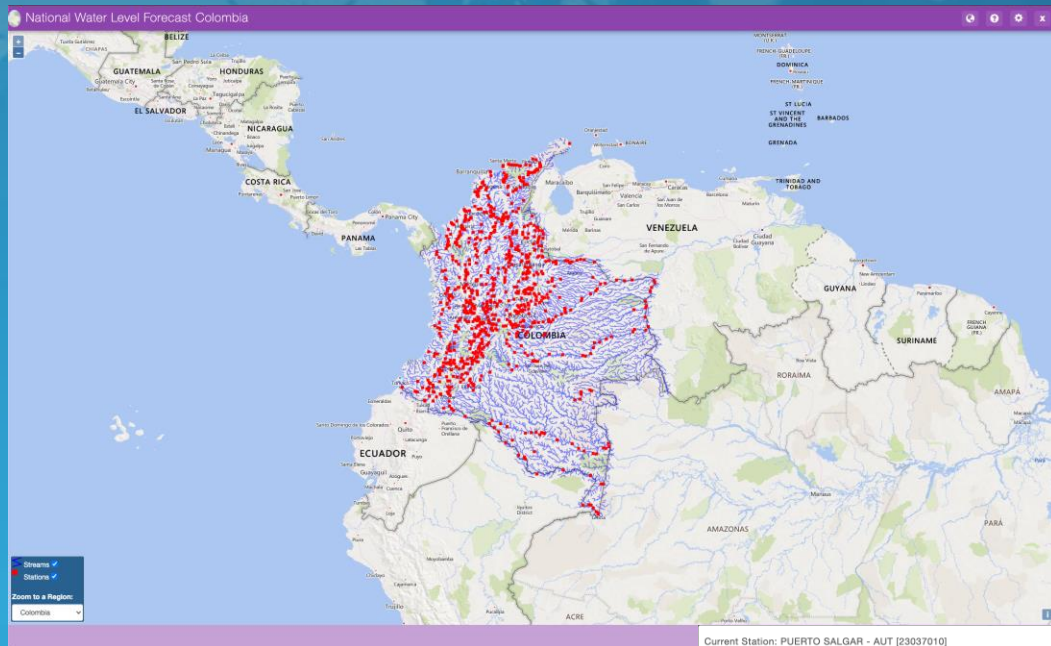
**GEOGLOWS**  
GLOBAL WATER SUSTAINABILITY

**WHOS**





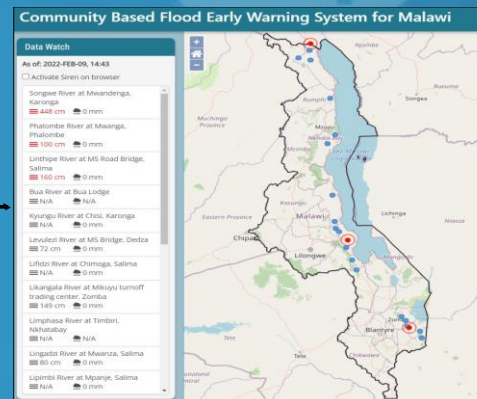
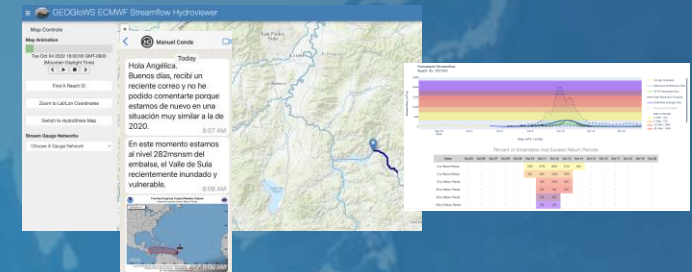
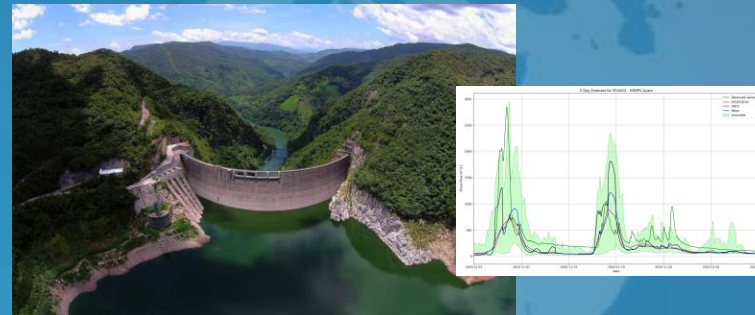
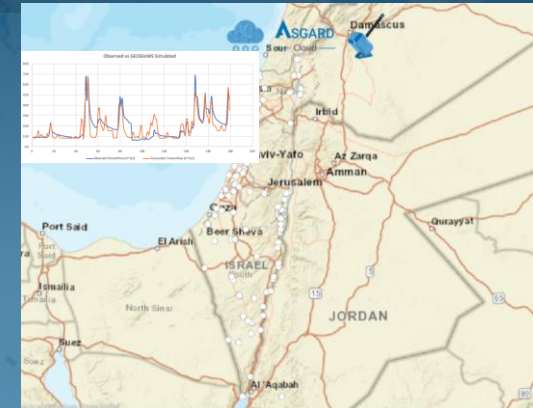
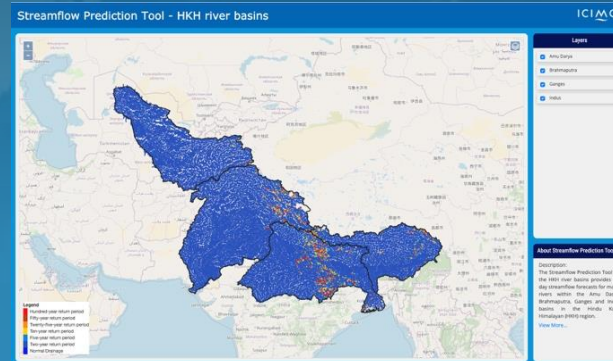
# Using Water Level Information





# Successful Adaptations

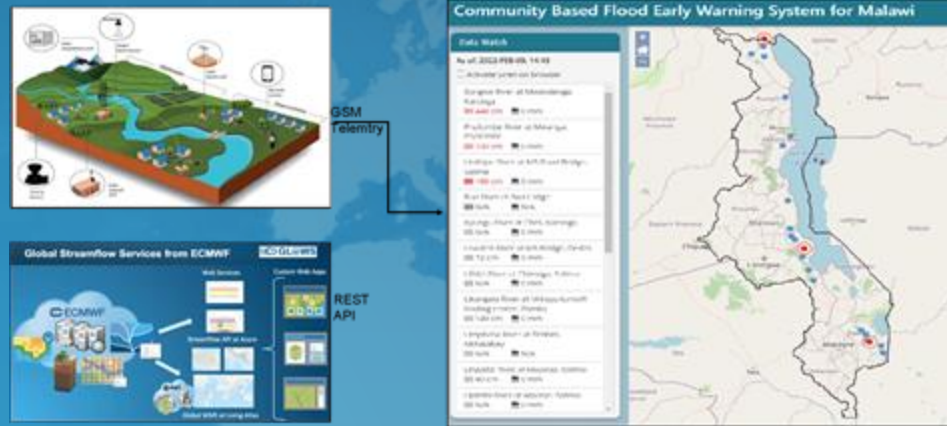
- Nepal
- Bangladesh
- Israel
- Dominican Republic
- Honduras
- Guatemala
- Ecuador
- Peru
- Colombia
- Brazil
- Malawi



<https://stories.geogloss.org/>

# Malawi CBFEWS and GEOGloWS

- Not one life lost compared to 10's of lives lost in a normal flooding season
- Government estimated a \$40,000,000 reduction in damage costs (just one season)
- Scaling and expanding as part of EW4All with support of US Govt through NOAA



*"The system saved their lives and livestock from flood this year. Previous years people were caught unaware by floods thereby losing lives. But this year no single life has been lost as people were able to escape to the uplands on time following alerts from the gadget." Community Chairman – Karongo District*

*Tweet by the Vice President of Malawi, Dr. Saulos Chilima*



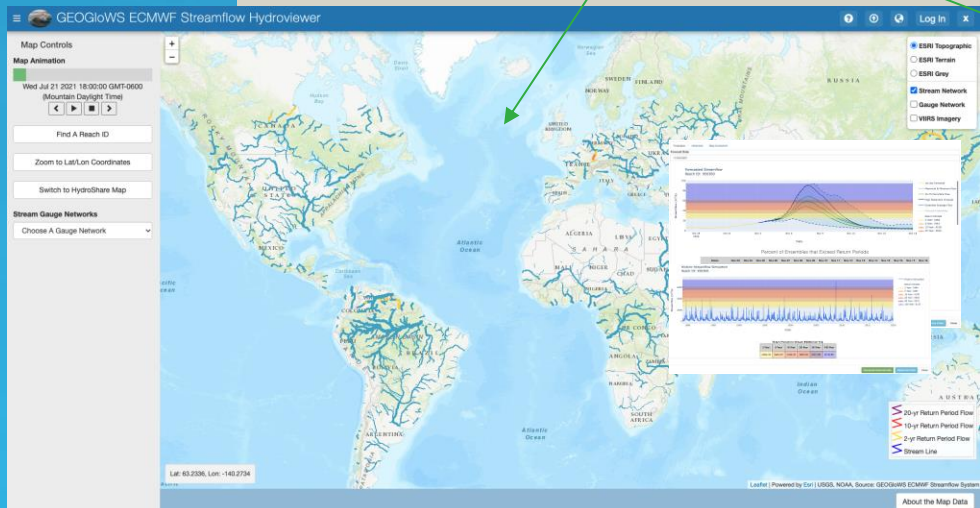
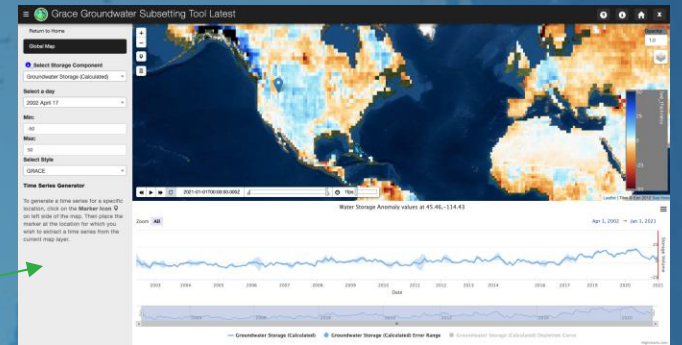
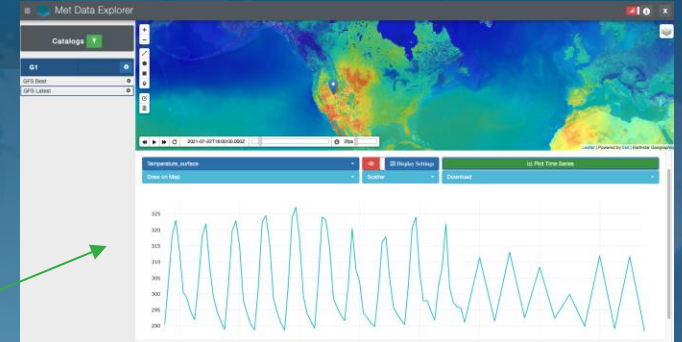
# GEOGloWS Toolbox Customization

**BYU** GEOGloWS Portal Log In

GEOGloWS Toolbox

Filters: All hydrograph geoprocessing WMO Github streamflow Conda BYU Tethys Hydrology timeseries geogloWS esri animations Warehouse

- Water Data Explorer
- GEOGloWS ECMWF Streamflow Hydroviewer
- Groundwater Data Mapper
- Met Data Explorer
- Hydrostats App
- Tethys App Warehouse
- GRACE Groundwater Subsetting Tool



# WMO Hydrologic Observation System (WHOS)

MULTIPLE DATA PROVIDERS

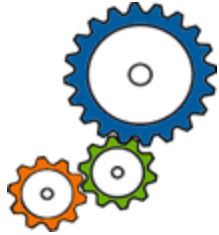
NO DATA STORED

TOOLS

USERS



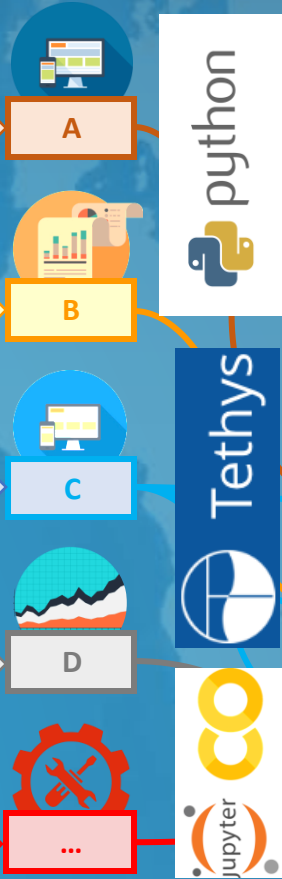
WHOS



- Implement interoperability with exchange protocols
- Metadata mapping
- Data format conversion



WaterML



- SEARCH
- FILE
- AC
- FILE
- DOW
- VISU
- ANA
- MC

Water Data Explorer

Views

WHOS vie...

Met Data Explorer

Catalogs

UCAR Catalog Data

THREDDS Files

GFS Best Data

CHIRPS DAILY

CHIRPS MONTHLY

CHIRTS Tmax

WRF\_DOMINIO\_1

THREDDS Files

Domino\_1

WRF\_DOMINIO\_2

THREDDS Files

Domino\_2

Domino\_2

Clear Graph

Calculator

Whisker and Box

Download Data

precipitation\_shape\_mean

precipitation\_PASTAZA\_mean

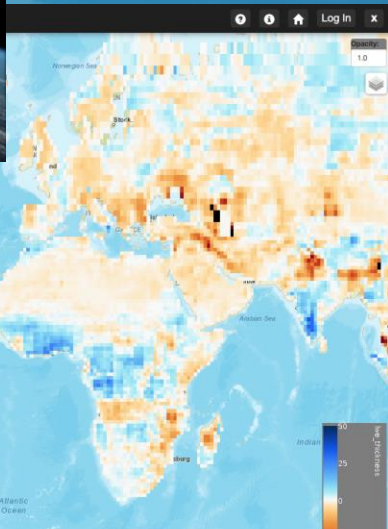
precipitation\_shape\_mean1

# Groundwater Status and Outlook

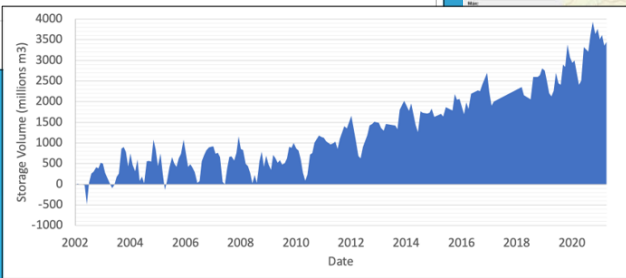
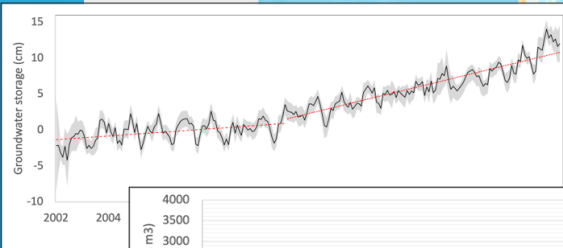
# Groundwater Mapping



## GRACE



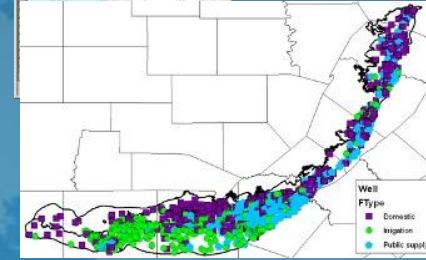
Min: -10  
Max: 10  
Select Style: GRACE  
Time Series Generator  
To generate a time series for a specific location, click on the Marker icon on left side of the map. Then place the marker at the location for which you wish to extract a time series from the current map layer.



A screenshot of the GRACE Groundwater Subsetting Tool interface. It includes a map of West Africa and various configuration options for region, aquifer, and variable selection.

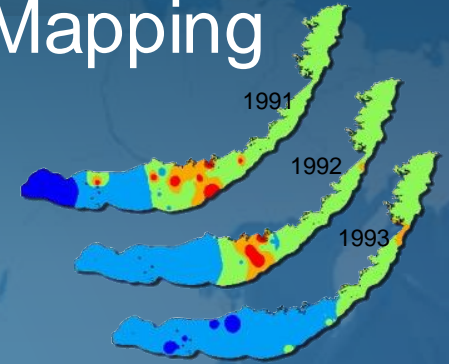
Well ID	Latitude	Longitude	Depth	Category
1	13.5138	9.13239	399.32	Public supply
2	13.5138	9.13239	399.32	Public supply
3	13.5138	9.13239	399.32	Public supply
4	13.5138	9.13239	399.32	Public supply
5	13.5138	9.13239	399.32	Public supply
6	13.5138	9.13239	399.32	Public supply
7	13.5138	9.13239	399.32	Public supply
8	13.5138	9.13239	399.32	Public supply
9	13.5138	9.13239	399.32	Public supply
10	13.5138	9.13239	399.32	Public supply

Water Level Measurements



Well Locations

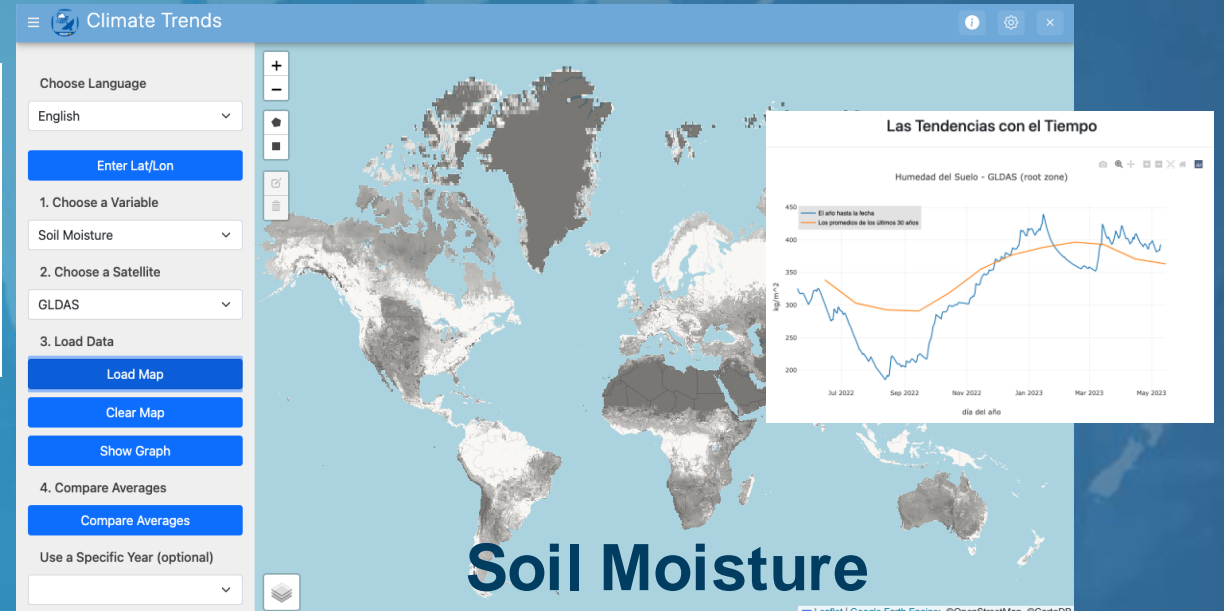
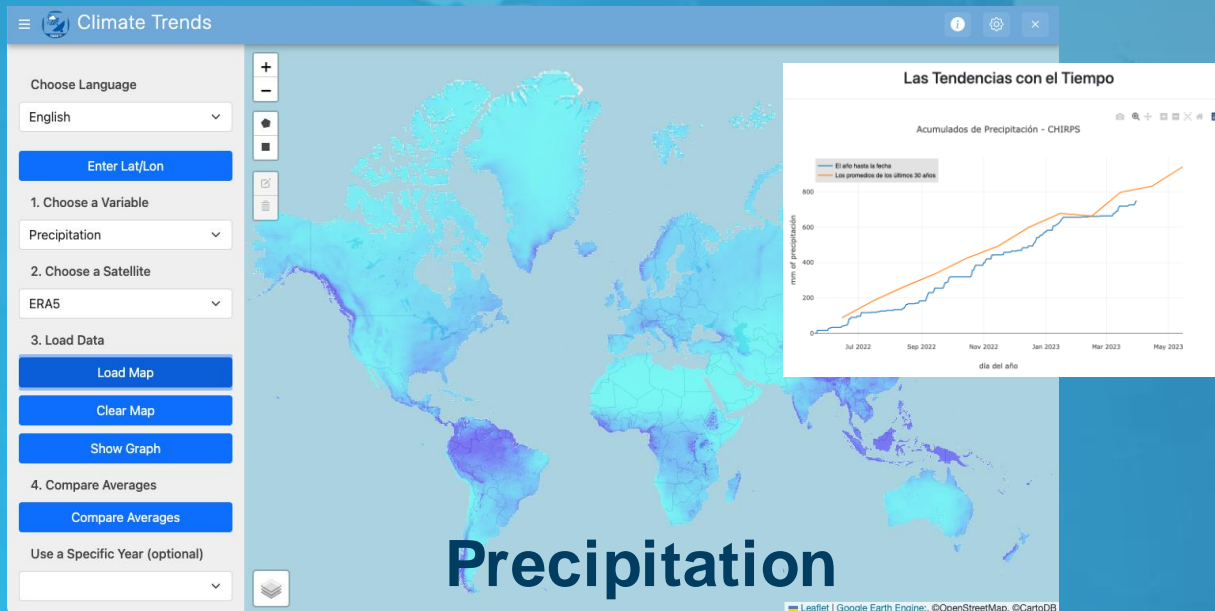
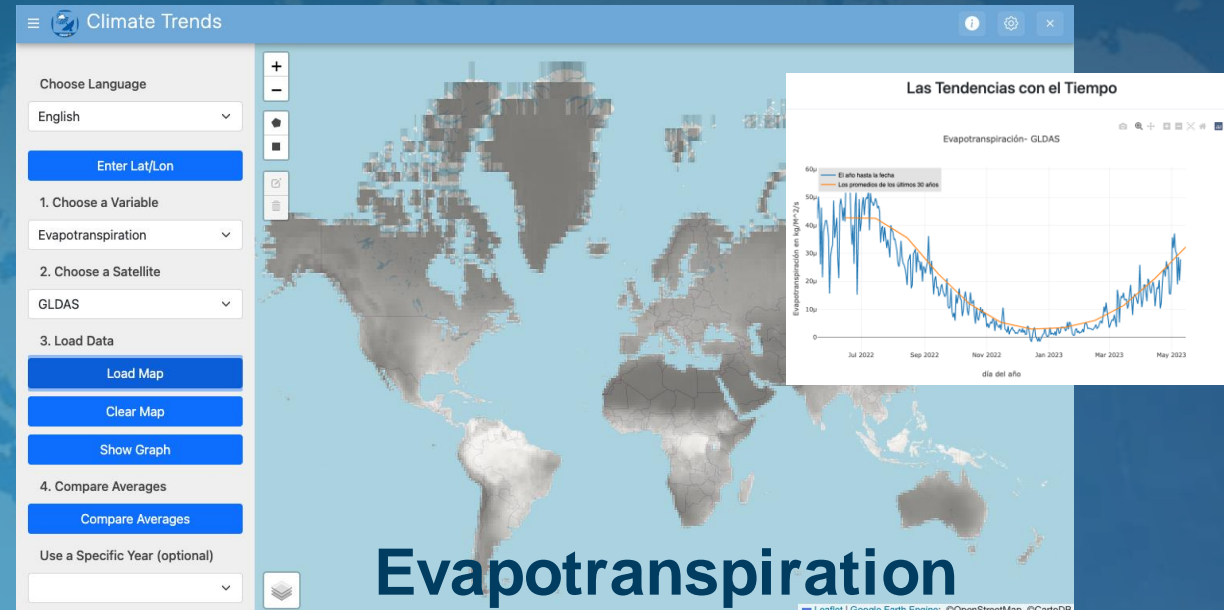
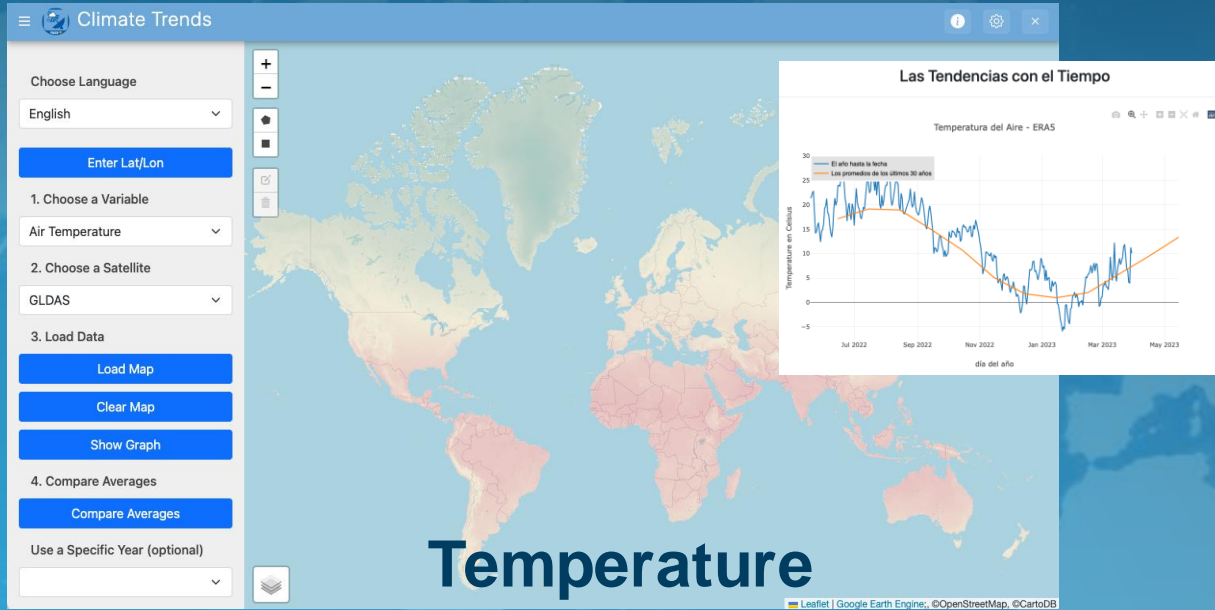
Time and Space Interpolation Algorithms



Earth Observations

A screenshot of the Groundwater Data Mapper interface. It shows a map of the Niger region with a groundwater depth contour plot. The interface includes a sidebar with filters for region, aquifer, and variable, and a legend for well types. A time series graph at the bottom shows groundwater depth from 2010 to 2018.

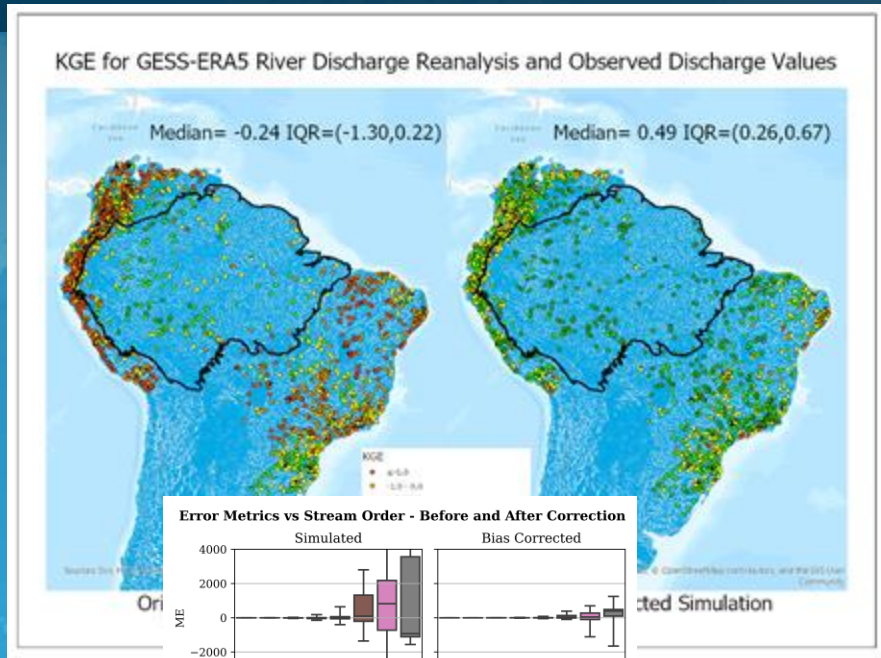
# Global Hydrologic Status and Outlook



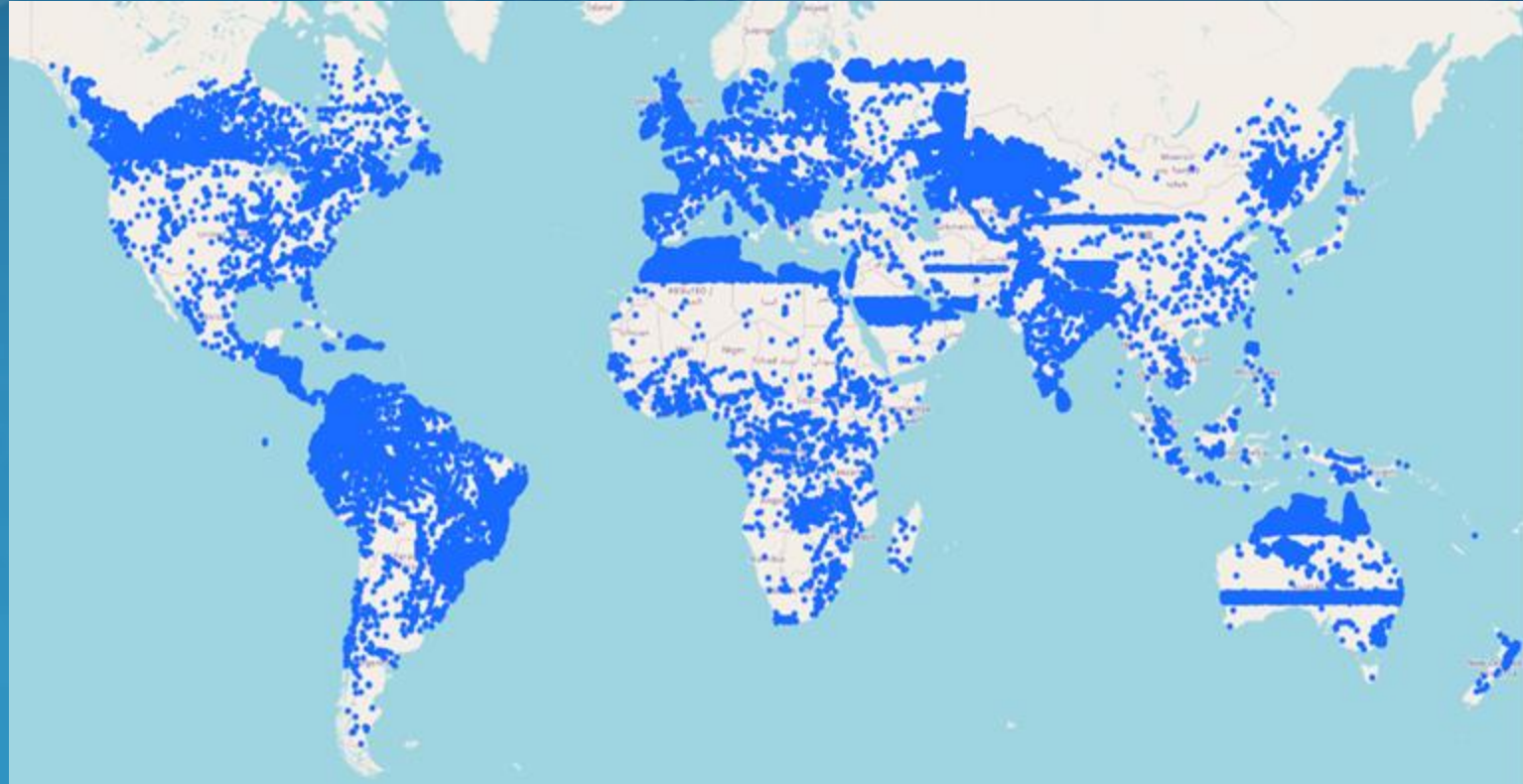
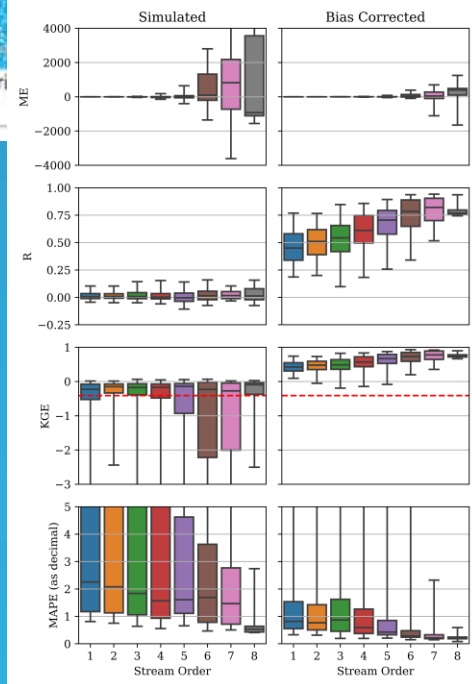
# What's next? Lessons Learned

1. Imperfect models are still useful if their inaccuracies are understood
2. Local “ownership” or “branding” of global data source is essential
3. Need a better stream network
  1. Closer align model reporting points to gauges, POIs
  2. Increase trust if mapping true river locations (e.g. compared to basemap)
  3. Enable flood extent modeling on same network as hydrologic model
4. Better flow magnitude predictions increases application potential
5. Flow status and outlook products are useful for monitoring

# 1 – Imperfect Models are Still Useful Locally



Error Metrics vs Stream Order - Before and After Correction

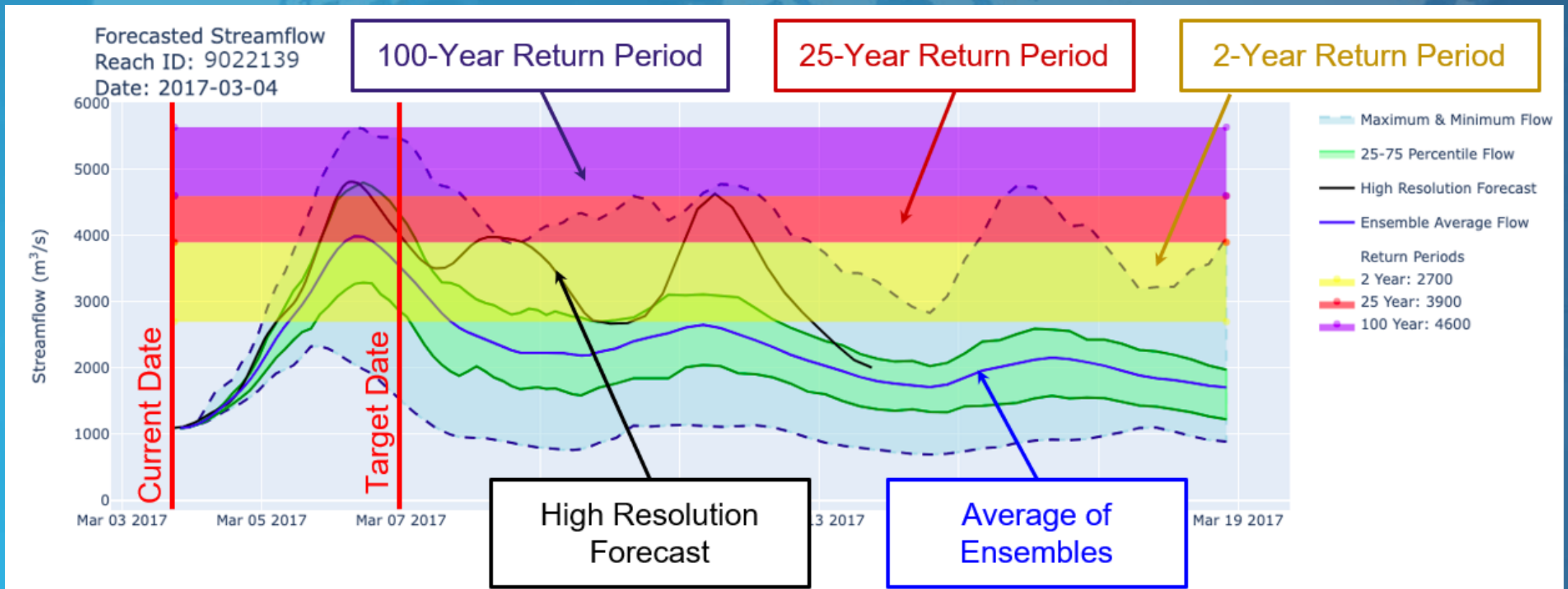


- 6,000,000 requests annually
- or ~16,500 requests daily



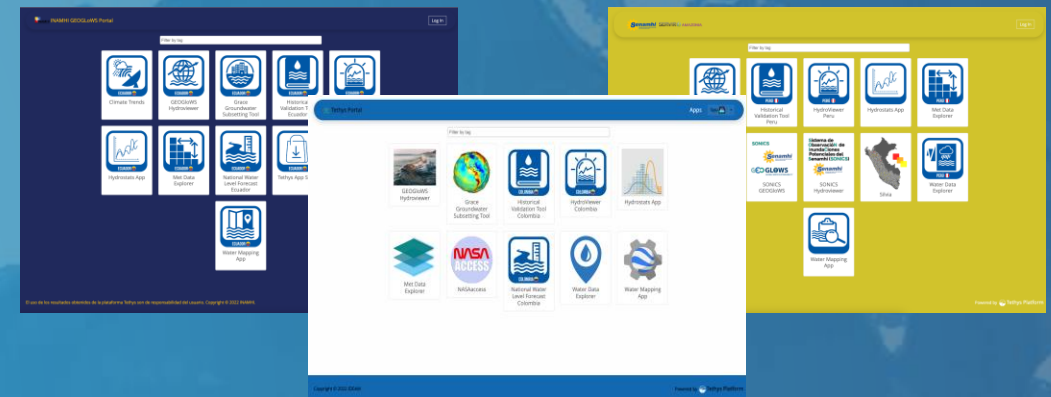
## 2 – Serious Game Training is Important

- Handle uncertainty in magnitudes
- Risk of false positive/negative
- Simulate Financial Costs of Disaster
- Decide to wait or take actions



# 3 – Local “Ownership” is Critical

- Redistribute global data through branded web pages, domain names
- Customize interface and include data for local needs, legal requirements
- Amazon Web Services & GEO/GEOGloWS Collaboration
- 2 years credit and IT support to build, run, cloud optimize GEOGloWS tools
- ~20 countries enrolled in program



# The App Store – Sharing Resources



## BYU GEOGloWS Portal

[Log In](#)

### GEOGloWS Toolbox

All
hydrograph
geoprocessing
WMO
Github
streamflow
Conda
BYU
Tethys
Hydrology
timeseries


geogloWS
esri
animations
Warehouse


Available Tethys Applications

Tethys App Name	Latest Version	Developer	Actions
+ data_rods_explorer	0.0.4	Gonzalo E. Espinoza	<a href="#">Install</a> <a href="#">Github</a>
+ embates	1.0.0	Riley Hales	<a href="#">Install</a> <a href="#">Github</a>
+ epanet_model_repository	0.0.2	-	<a href="#">Install</a> <a href="#">Github</a>
+ epanet_model_viewer	0.0.2	-	<a href="#">Install</a> <a href="#">Github</a>
+ gfs	4	Riley Hales	<a href="#">Install</a> <a href="#">Github</a>
+ ggot	0.0.1	Sarva Pulla	<a href="#">Install</a> <a href="#">Github</a>
+ gidas	4	Riley Hales	<a href="#">Install</a> <a href="#">Github</a>
+ gwdm	0.0.1	Sarva Pulla	<a href="#">Install</a> <a href="#">Github</a>
+ gwim	0.0.1	Sarva Pulla	<a href="#">Install</a> <a href="#">Github</a>
+ historical_validation_tool_australia	1.0	Jorge Luis Sanchez-Lozano	<a href="#">Install</a> <a href="#">Github</a>


Showing 1 to 10 of 39 rows | 10 rows per page




Groundwater Data Mapper



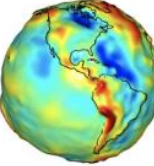
Met Data Explorer



Hydrostats App



Tethys App Warehouse



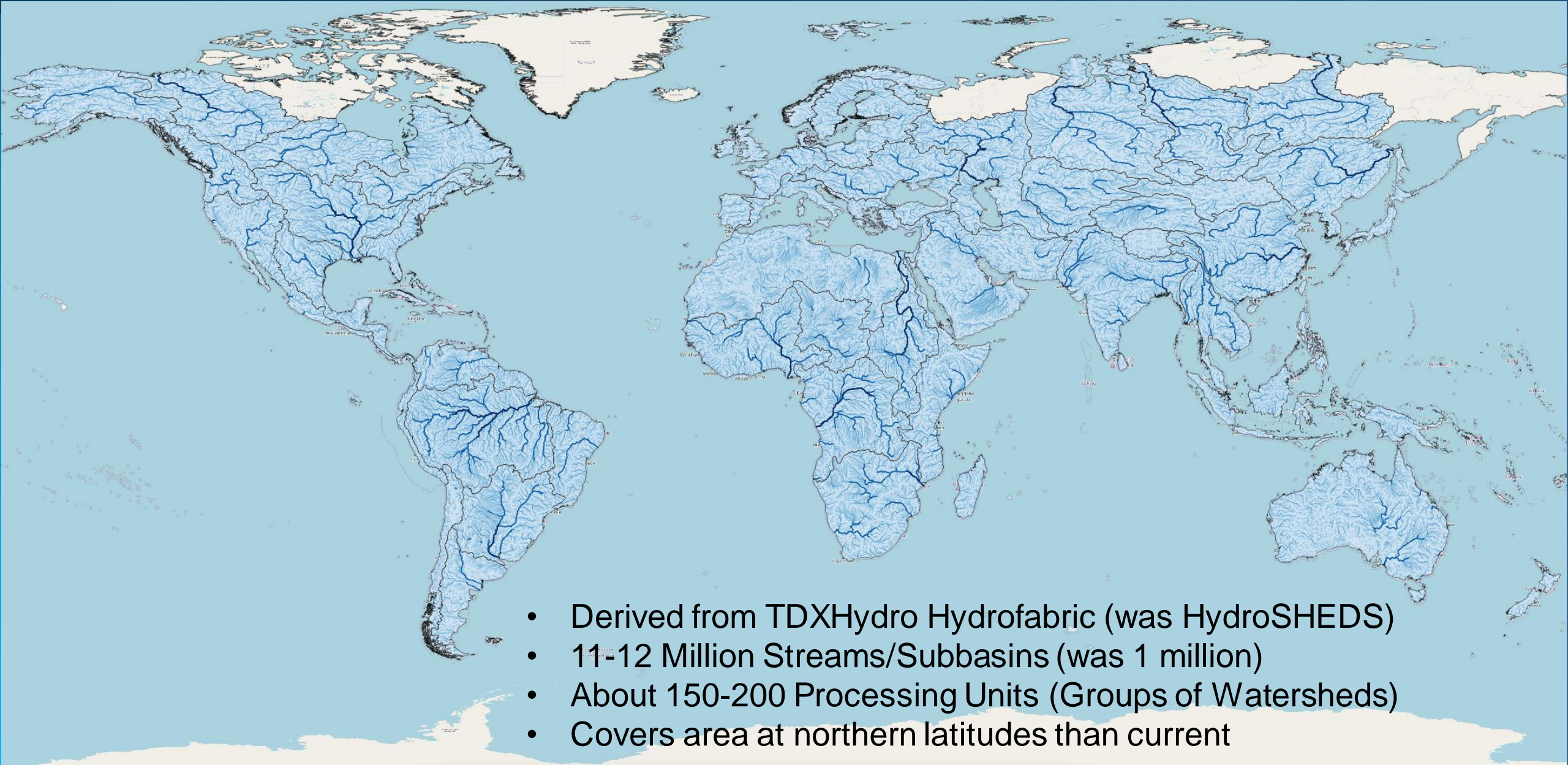
GRACE Groundwater Subsetting Tool

Installed Tethys Applications

Tethys App Name	Installed Version	Latest Version	Actions
+ app_store	1.0.9	1.0.9	<a href="#">Uninstall</a> <a href="#">Update</a>
+ earth_engine	1.1.1	1.1.1	<a href="#">Uninstall</a> <a href="#">Update</a>
+ flood_impact_viewer	1.0.0	1.0.0	<a href="#">Uninstall</a> <a href="#">Update</a>
+ geogloWS_hydroviewer	1.7	1.7	<a href="#">Uninstall</a> <a href="#">Update</a>
+ historical_validation_tool_ecuador	1.1	1.1	<a href="#">Uninstall</a> <a href="#">Update</a>
+ hydroviewer_ecuador	1.2	1.2	<a href="#">Uninstall</a> <a href="#">Update</a>
+ metdataexplorer2	1.3.11	1.3.11	<a href="#">Uninstall</a> <a href="#">Update</a>
+ national_water_level_forecast_ecuador	1.0	1.0	<a href="#">Uninstall</a> <a href="#">Update</a>
+ statistics_calc	1.0.1	1.0.1	<a href="#">Uninstall</a> <a href="#">Update</a>
+ water_data_explorer	1.1.17	1.1.17	<a href="#">Uninstall</a> <a href="#">Update</a>

Showing 1 to 10 of 10 rows

# 4 – Better Stream Network Needed



- Derived from TDXHydro Hydrofabric (was HydroSHEDS)
- 11-12 Million Streams/Subbasins (was 1 million)
- About 150-200 Processing Units (Groups of Watersheds)
- Covers area at northern latitudes than current

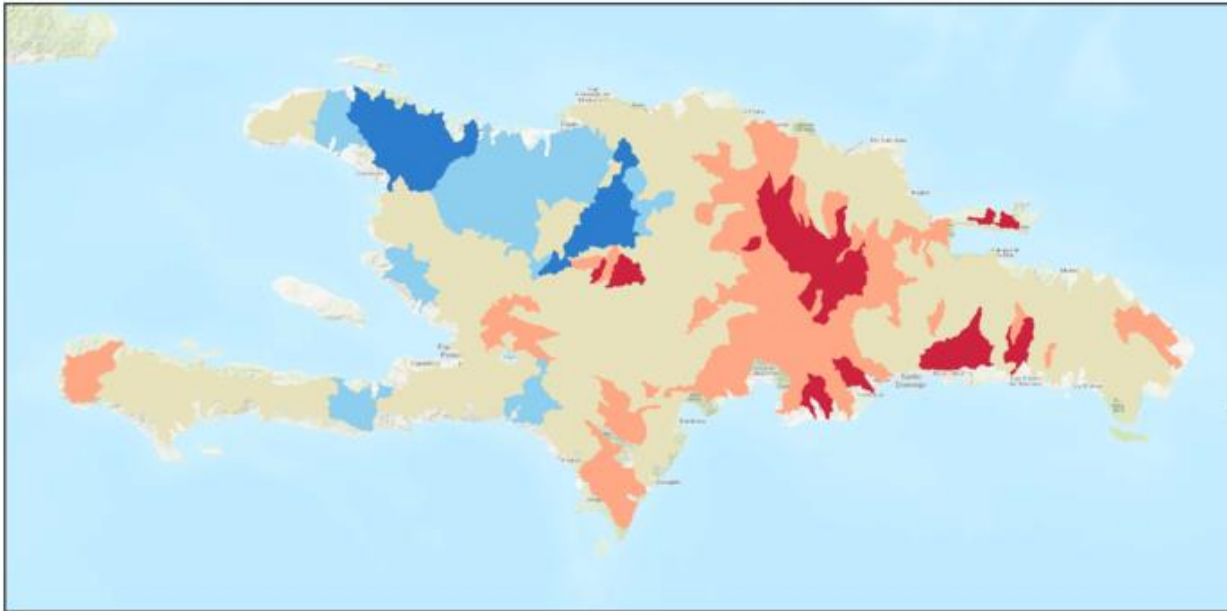
# TDXHydro Derived from same Underlying DEM as FABDEM



## 5 – WMO Status and Outlook (HydroSOS)

Monthly Mean Basin Flow - 1984-03

Low Flow Below Normal Normal Above Normal High Flow



- Summary products of current and recent past add context
- Collaboration with WMO's HydroSOS for calculating status
- Collaborate with WMO's call for Early Warnings for All challenge
- Each basin classified as normal or above/below average using monthly flow and historical simulation.

# GEOGIoWS 2.0 Summary

Model Parameter	Hindcast	Forecast
Temporal Coverage	<del>1980</del> → <del>2 Months Lag</del> <b>1940 → &lt;1 Week Lag</b>	15 days
Temporal Resolution	Daily average flow	3 hours
Simulation Type	Deterministic	Ensemble (52)
Update Frequency	<del>Monthly</del> <b>Weekly</b>	Daily
Reporting Points	<del>1 Million Basins</del> <b>11.5 Million Basins</b>	<del>1 Million Basins</del> <b>11.5 Million Basins</b>

# Conclusions

- GEOGloWS has significant impact despite shortcomings and challenges common to all large/global models.
- Lasting impact is more likely achieved when the model developers intentionally address specific needs of local implementers.
- Next generation model is driven by lessons learned in case studies of early implementers of GEOGloWS streamflow products.
- Document attempts to implement your model, tools, etc whether they succeed or not so you can find patterns and good strategies.



# Thank You!

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