“Application of Machine Learning in Global Precipitation Estimation”: The PERSIANN System

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• How will Climate change affect precipitation variability and water Availability?

• Can we predict the future changes which are responsive to “user” needs?
Information Relevant to Water Resources Planning

- Models Projections
- Observations
Required Hydrometeorologic Predictions

- **Short Range**
  - hours
  - days
  - weeks
  - months
  - seasons
  - years
  - decades

- **Long Range**
  - Forecast Requirements

- **Flash Flood Warning**
- **Flash Flood Guidance**
- **Headwater Guidance**
- **Flood Forecast Guidance**
- **Reservoir Inflow Forecasts**
- **Spring Snow Melt Forecasts**
- **Water Supply Volume**
Seasonal-Scale Predictions

Short Range → Long Range

- hours
- days
- weeks
- months
- seasons
- years
- decades

Flash Flood Warning
Flash Flood Guidance
Headwater Guidance
Flood Forecast Guidance

Reservoir Inflow Forecasts
Spring Snow Melt Forecasts
Water Supply Volume

Mid-range
Forecast Requirements
IRI 3-Month Multi-Model Probability Precipitation Forecast

IRI Multi-Model Probability Forecast for Precipitation for August–September–October 2019, Issued July 2019
IRI 3-Month Multi-Model Probability Precipitation Forecast

IRI Multi-Model Probability Forecast for Precipitation for January–February–March 2019, Issued December 2018

Probability (%) of Most Likely Category

- Below Normal: 40, 45, 50, 60, 70+
- Normal: 40+
- Above Normal: 40, 45, 50, 60, 70+

White indicates Climatological odds
Red indicates dry season (no forecast)
Climate-Scale approaches to addressing hydrologic extremes

Forecast Requirements

- Flash Flood Warning
- Flash Flood Guidance
- Headwater Guidance
- Flood Forecast Guidance
- Reservoir Inflow Forecasts
- Spring Snow Melt Forecasts
- Water Supply Volume

Short Range → Long Range

hours → days → weeks → months → seasons → years → decades
Western U.S. future model projections
Representative Concentration Pathways (RCP) Scenarios:

**RCP2.6:** represent ‘low’ scenarios featured by the radiative forcing of 2.6 W/m² by 2100, the resulting CO₂-equivalent concentrations is 421 ppm in the year 2100.

**RCP4.5:** represent ‘medium’ scenarios featured by the radiative forcing of 4.5 W/m² by 2100, the resulting CO₂-equivalent concentrations is 538 ppm in the year 2100.

**RCP8.5:** represent ‘high’ scenarios featured by the radiative forcing of 8.5 W/m² by 2100, the resulting CO₂-equivalent concentrations is 936 ppm in the year 2100.
RCP2.6

Time period: 2006-2099

CNRM-CM5 (France GCM)
CSIRO-MK3.6.0 (Australian GCM)
GISS-E2-R (U.S. GCM)
HadGEM2-ES (U.K. GCM)

Precipitation change (mm per day per decade)
RCP8.5

Time period: 2006-2099

CNRM-CM5 (France GCM)
CSIRO-MK-3.6.0 (Australian GCM)
GISS-E2-R (U.S. GCM)
HadGEM2-ES (U.K. GCM)
Models indicate different signs and magnitudes of changes in the mean precipitation over the Western U.S. under the SRES A2 emissions scenario.
For users of model information the question is:

Which model (or groups of models) should be “trusted” for their “Accuracy”
To what degree should we trust observations used as both input and reference to test the models
A Key Requirement!

Precipitation Measurement is one of the KEY hydrometeorologic Challenges

Having adequate high resolution (time and Space) observations for model Input, Calibration, Testing, and to capture extremes is crucial
Space-Based Observations

Satellite Observations: Rainfall Estimation
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)
Satellite Data for Precipitation estimation

- **Geostationary IR**
  - Cloud top data
  - 15-30 minute temporal resolution

- **Passive Microwave (SSM/I)**
  - Some characterisation of rainfall
  - ~2 overpasses per day per spacecraft, moving to 3-hour return time (GPM)

- **TRMM precipitation RADAR**
  - 3D imaging of rainfall
  - 1-2 days between overpasses
  - S-35° N-35°
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)

PERSIANN System “Estimation”

Satellite Data
- Global IR (CPC, NOAA)
- High Temporal-Spatial Res. Cloud Infrared Images
- MW-RR (TRMM, NOAA, DMSP Satellites)
- MW-PR Hourly Rain Rates (GSFC, NASA; NESDIS, NOAA)

Ground Observations
- GPCC & CPC
- Gauge Analysis
- Gauges Coverage

Products
- Hourly Global Precipitation Estimates
- Merged Products
  - Hourly rainfall
  - 6 hourly rainfall
  - Daily rainfall
  - Monthly rainfall

Error Detection

Feedback

Quality Control

Merging

Sampling

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PERSIANN Websites and Apps

- CHRS iRain
- CHRS RainSphere
- CHRS Data Portal
PERSIANN Extensions: Weather-Related

CHRS iRain
An Integrated System for Global Real-time Precipitation Observation

http://irain.eng.uci.edu
CHRS iRain capturing Tropical Storm Harvey - August 2017
irain.eng.uci.edu
Tracking Hurricane Florence (CONNECT Algorithm)

Storm Statistics

- Storm ID: 10
- Max Rain Intensity: 94 mm/3hrs
- Avg Rain Intensity: 15 mm/3hrs
- Max Point Accum: 262 mm
- Storm Coverage Area: 7.97e+5 km²
- Total Rain Volume: 47.41 km³
- Storm Duration: 72 hrs
- From: 2018 Sep 11 22:00
- To: 2018 Sep 14 22:00
- Storm Status: Active

Center for Hydrometeorology and Remote Sensing, University of California, Irvine
Extreme rainfall event in Alabama (09-07-2018)

Location query
PERSIANN-CDR

- Daily Precipitation Data
- Data Period: 1983~2019
- Coverage: 60°S ~ 60°N
- Spatial Resolution: 0.25°x0.25°

http://www.ncdc.noaa.gov/cdr/operationalcdrs.html

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Ashouri, Hsu et al., BAMS, 2015.
Sierra-Nevada Mountain Region

Area: 63,100 square kilometers (24,370 sq mi)
Length: 400 mile, Width: 64 mile.

Map Source: Google Earth
Sierra-Nevada Mountain (California and Nevada)
CHRS RainSphere
Rainfall Trend Analysis: Countries and Political Divisions

Precipitation trends from 1983 to 2015 over 201 countries (60°N - 60°S) and state/province political divisions of US, Saudi Arabia and China

Nguyen et al. BAMS (2018)
Rainfall Trend Analysis: Continents and Oceans

Nguyen et al. BAMS (2018)

Changes in precipitation over oceans and land (60°S-60°N):
PERSIANN-CDR dataset 1983 to 2015.

Precipitation trends over oceans and land (No detectable trend)

Precipitation changes over continents (No detectable trend)
Many Regional Evaluation of PERSIANN-CDR Have Already Been Reported:
What is the value of this data set to application and Modeling communities?
Model historical simulation - China (1983-2005)

- bcc_csm1_1_m (Chinese GCM)
- CCSM4 (NCAR, USA GCM)
- HadGEM2-ES (U.K GCM)
- MIROC5 (Japan GCM)
- MPI-ESM-MR (Germany GCM)

Observation
- (CRU Dataset)
- (PERSIANN-CDR)

Mean Annual Precipitation (1983-2005) (mm per year)
Model historical simulation (1983-2005)

- **bcc_csm1_1_m (Chinese GCM)**
- **CCSM4 (NCAR, USA GCM)**
- **HadGEM2-ES (U.K GCM)**
- **MIROC5 (Japan GCM)**
- **MPI-ESM-MR (Germany GCM)**

**Observation (CRU Dataset)**

**Remotely Sensed Estimates (PERSIANN-CDR)**

Mean Annual Precipitation (1983-2005) (mm per year)

0 200 400 600
News & Recent Events

Houston Flooding Rainfall

The second most severe rainfall in Houston since 1888

Houston flooding rainfall in April 2016 was the second wettest calendar day on record for official reporting stations in Houston, since 1888, with 9.92 inches of rain measured at Bush Intercontinental Airport. The storm hit the area in two major waves: the first wave covered the area by the high pressure system late on 17 April. Fed by the moisture originating from the Gulf of Mexico and moving north, the second and more intense wave was triggered early on 18 April.
What is Next?

• High-Resolution PERSIANN-CDR

• Next Version of PERSIANN-CCS
High Resolution Precipitation Climate Data Record (PERSIANN CCS-CDR)

- PERSIANN-CCS estimation at 0.04° x 0.04° lat-lon scale
- Bias adjustment of PERSIANN-CCS estimation using passive microwave rainfall estimation
- Bias adjustment using GPCP estimation at 2.5 degree monthly

Louisiana flood, August 12, 2016
Average annual rainfall in mm/year (2008-2013)

The Dynamic Infrared – Rain rate model
Average annual rainfall in mm/year for the validation period (2008-2013) for the baseline product Stage IV (ST4), the near real-time Stage II (ST2), the three satellite-based precipitation products (CMORPH (CMO), TRMM, and PERSIANN-CCS (CCS)) and the new product, PDIR.
PERSIANN Dynamic Infrared - Rain rate model (PDIR)

Rainfall during the period November 28th, 2012 to December 7th, 2012 associated with an extreme AR event over California
Usage of CHRS’s products

CHRS User Statistics

Total Visits: 885,619 since 01-Jan-2010
Countries: 205 countries registered

Data Download

User Visit
Despite advances to date, predicting the future Hydro-Climate variables will remain a major challenge:

- Nature is complex and observing and modeling its nonlinear behavior is very challenging. So, “have a will to doubt” the credibility of information generated by models.

- Long-term and sustained observation programs are critical, especially for model verification. Without some degree of verifiability, hard to expect their use.

Take Home Message
Factoring in Resiliency in water resources system’s design and planning is still the safest approach!
Thank You for the
Invitation and Listening

Somewhere in New Mexico, USA - Photo: J. Sorooshian