Global Flood Modeling: 7 Challenges

Huan Wu（吴　欢）

Hydrometeorological Extremes simulatioN Group (HENG),
School of Atmospheric Sciences, Sun Yat-sen University (SYSU)

Rapid-response flood mapping during *Hurricane Harvey* by the *Global Flood Partnership (GFP)*

GFP
global flood partnership

Sagy Cohen*, *University of Alabama (sagy.cohen@ua.edu)*; Robert Adler, *University of Maryland*; Lorenzo Alfieri, *EU Joint Research Centre*; G Robert Brakenridge, *University of Colorado*; Erin Coughlan, *VU University Amsterdam;* Zac Flamig, *University of Chicago*; John Galantowicz, *Atmospheric and Environmental Research;* Yang Hong, *University of Oklahoma;* Albert Kettner, *University of Colorado;* Patrick Matgen, *Luxembourg Institute of Science and Technology (LIST);* Son V Nghiem, *Jet Propulsion Laboratory, California Institute of Technolog;* Ana Prados, *University of Maryland;* Roberto Rudari, *CIMA Foundation;* Peter Salamon, *EU Joint Research Centre;* Mark Trigg, *University of Leeds;* Albrecht Weerts, *Deltares; Huan Wu, Sun Yat-sen University*

Hurricane Harvey made landfall as a Category 4 storm at the Texas Gulf Coast (near Rockport) on August 25, 2017, causing wind damage and storm surge-induced coastal flooding. The storm slowly moved east along the coast (meandering in and out of Gulf waters), in effect, stalling over southeast Texas and southwest Louisiana until September 1st. The slow-moving storm produced historically high amounts of rain over the region, with maximum accumulated rainfall of over 1,500 mm in southeast Texas. This led to catastrophic riverine and flash flooding in the region. Houston Metropolitan area (Texas) received over 750 mm of rainfall between August 24 and September 1, leading to widespread urban flooding, displacing scores of people and damaging properties and infrastructure. It was estimated that the Hurricane Harvey was the costliest natural disasters in US history, with a total estimated damage of over $180 billion.

GFP is not regularly activated for flooding events in first-world countries, as these typically have established flood prediction and observation capabilities. GFP activation for this event evolved as its magnitude became apparent.
Below we provide a chronology of GFP activities during Hurricane Harvey:

Aug 25

Landfall

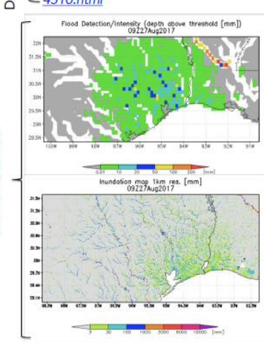
Source: National Weather Service; NASA Geostationary Operational Environmental Satellite; International Best Track Archive for Climate Stewardship (via nytimes.com)

Aug 27

GFP Partial Activation:
Dartmouth Flood Observatory (DFO) sent a limited-distribution email (not via GFP mailing list) informing about the activation of the 'International Charter', setting up of a DFO event webpage, and outlining available satellite imagery resources from before the flooding. The email led to inclusion of the recipients in the FEMA daily Remote Sensing Coordination and Geospatial Coordination calls which was later proved instrumental in connecting GFP products to the hurricane response community (including for the following flood events in Florida and Puerto Rico). The email was shared with NOAA National Water Center. A few hours following the initial email, precipitation and inundation predictions from GFMS were shared.

DFO Event webpage

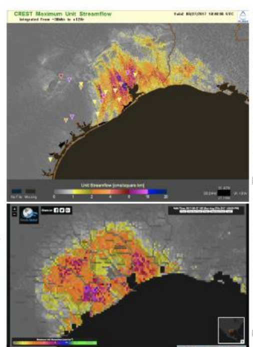
GFMS Predictions



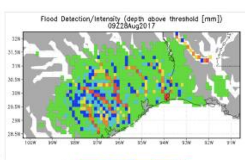
Acknowledgments for Son V Nghiem : "The research carried out at the Jet Propulsion Laboratory (JPL), California Institute of Technology, was supported by the NASA Land-Cover and Land-Use Change Program and by the NASA Terrestrial Hydrology Program. These results contained modified Copernicus Sentinel data (2017). Thanks to D. T. Nguyen of JPL for SAR data processing to produce flood maps

Aug 28

Flooding in Houston
GFP Full Activation:
The first email was sent to the GFP mailing list, proposing using this event as a case study to study GFP-members flood prediction systems. The same email also included streamflow predictions from the Flooded Locations And Simulated Hydrographs Project (FLASH). These predictions were re-distributed to a range of stakeholders (e.g. FEMA, NASA), an action which thereafter became standard operating procedure, with growing list of recipients.



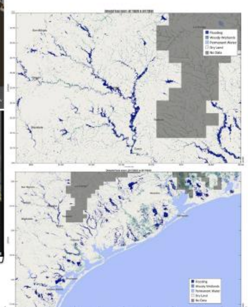
FLASH Products



GFMS Predictions

Aug 29

Initial Remote Sensing Mapping:
DFO shared (via FEMA Geospatial Coordination email distribution) an update on flood mapping and modeling efforts, including using Radarsat images (from Aug 28) to map flooding, and sharing JPL-produced flood maps from the ALOS-2 satellite. The confidence in these products were relatively low. Atmospheric and Environmental Research (AER) shared (via GFP mailing list) a large-scale 90-m resolution flood map of the impacted area, analyzed from the AMSR2 (passive microwave) sensor using an experimental configuration of the FloodScan system. Link between DFO/GFP to the State Operations Center of the Texas Division of Emergency Management (TDEM) was established which initiated data sharing via the TDEM data server (restricted access).

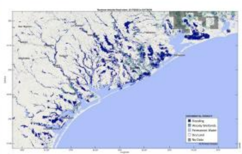


AER FloodScan

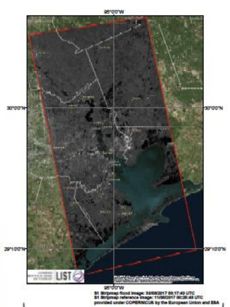
DFO Flood map

Aug 30

SAR-based Mapping:
Following a pass by Sentinel-1 satellite, SAR-based flood maps were shared by Luxembourg Institute of Science and Technology (LIST), JPL and DFO. DFO ftp server was used to store and distribute the GIS files of these, and future, products relating to this event. AER produced an updated maximum flood map for the region using new AMSR2 imagery, which was shared via the GFP mailing list. It was then distributed to the FEMA Geospatial Coordination mailing list (now over 300 recipients) and was uploaded to the TDEM data server.



AER FloodScan

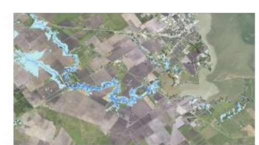


LIST

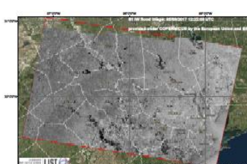
Aug 31

Additional Sentinel-1 imagery was shared by LIST via the GFP mailing list. DFO provided an updated inventory of GFP-produced flood maps and links to its event-dedicated web-portal and ftp server. The Surface Dynamics Modeling Lab (SDML) shared a floodwater depth map based on the AER maximum flood extent map and a DEM. AER shared updated large-scale maximum flood extent maps incorporating AMSR2 data from August 30 and set up a FloodScan web interface with daily Hurricane Harvey maps. LIST shared SAR-based flood map covering the Houston area from a 30 August Sentinel-1 pass. Aerial photography was becoming available via NOAA but with limited coverage outside the coast.

AER FloodScan



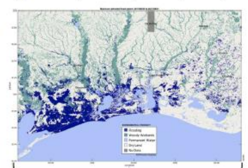
SDML Floodwater Depth



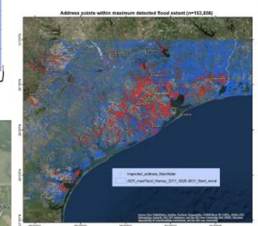
LIST

Sep 1

AER shared updates from AMSR2 passes on 31 August, revealing the extent of flooding in east Texas (Beaumont area). SDML shared a building impact map based on AER maximum flood extent map and address points layer from the TDEM server (uploaded by University of Texas, Austin).



AER FloodScan

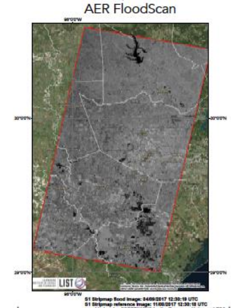


SDML Floodwater Depth and building impact

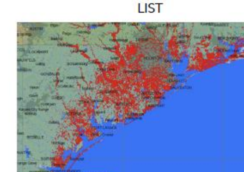
Sep 2 onward

AER shared final maximum flood extent estimates incorporating all AMSR2 data 26 August - 2 September with expanded coverage into Louisiana. LIST shared flood maps from two Sentinel-1 passes on 4 September. DFO shared a maximum extent map based on Sentinel-1 imagery. DFO website was updated to include these and other final products:
http://floodobservatory.colorado.edu/Events/2017USA4510/2017USA4510.html

AER FloodScan



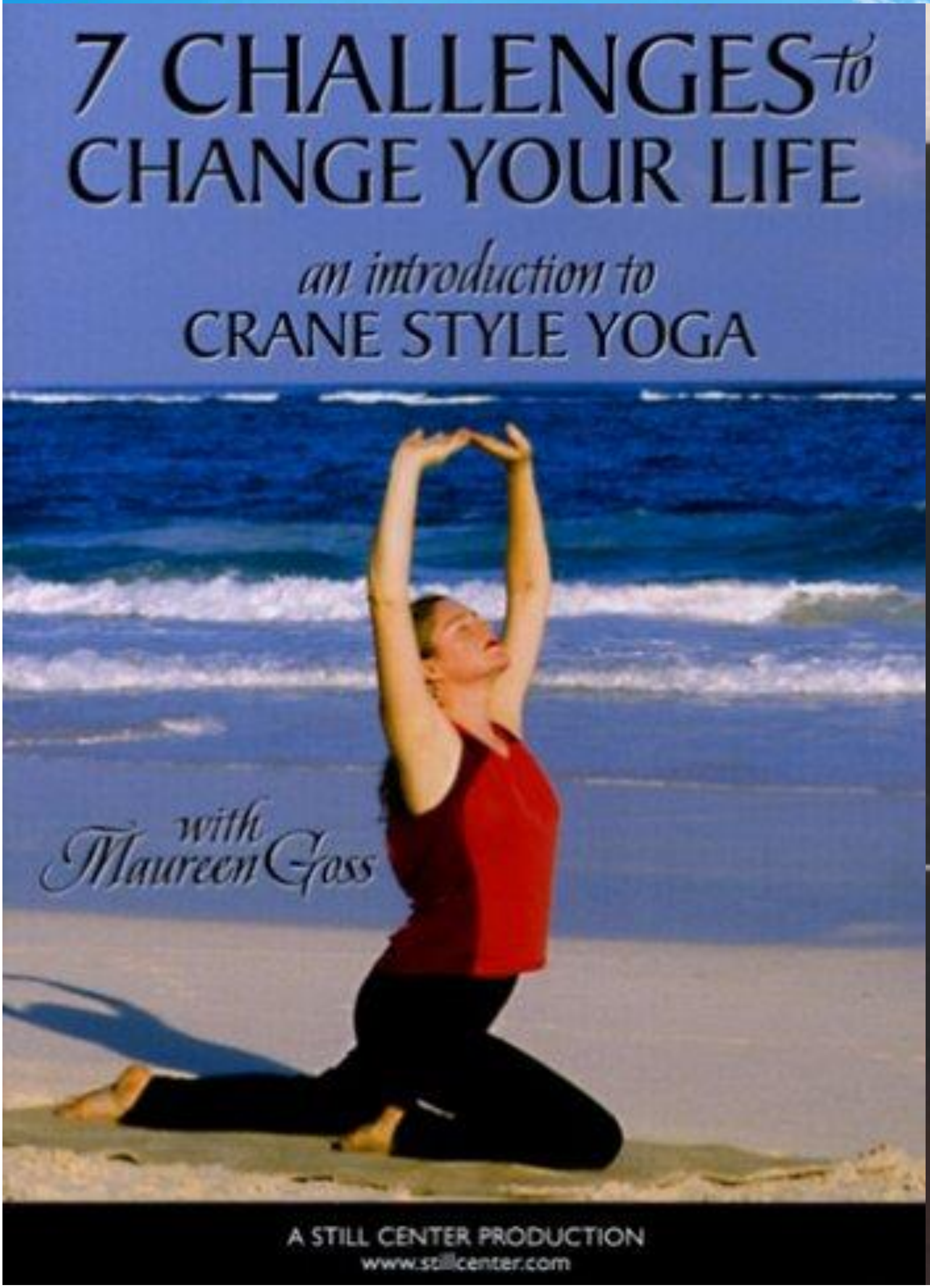
LIST

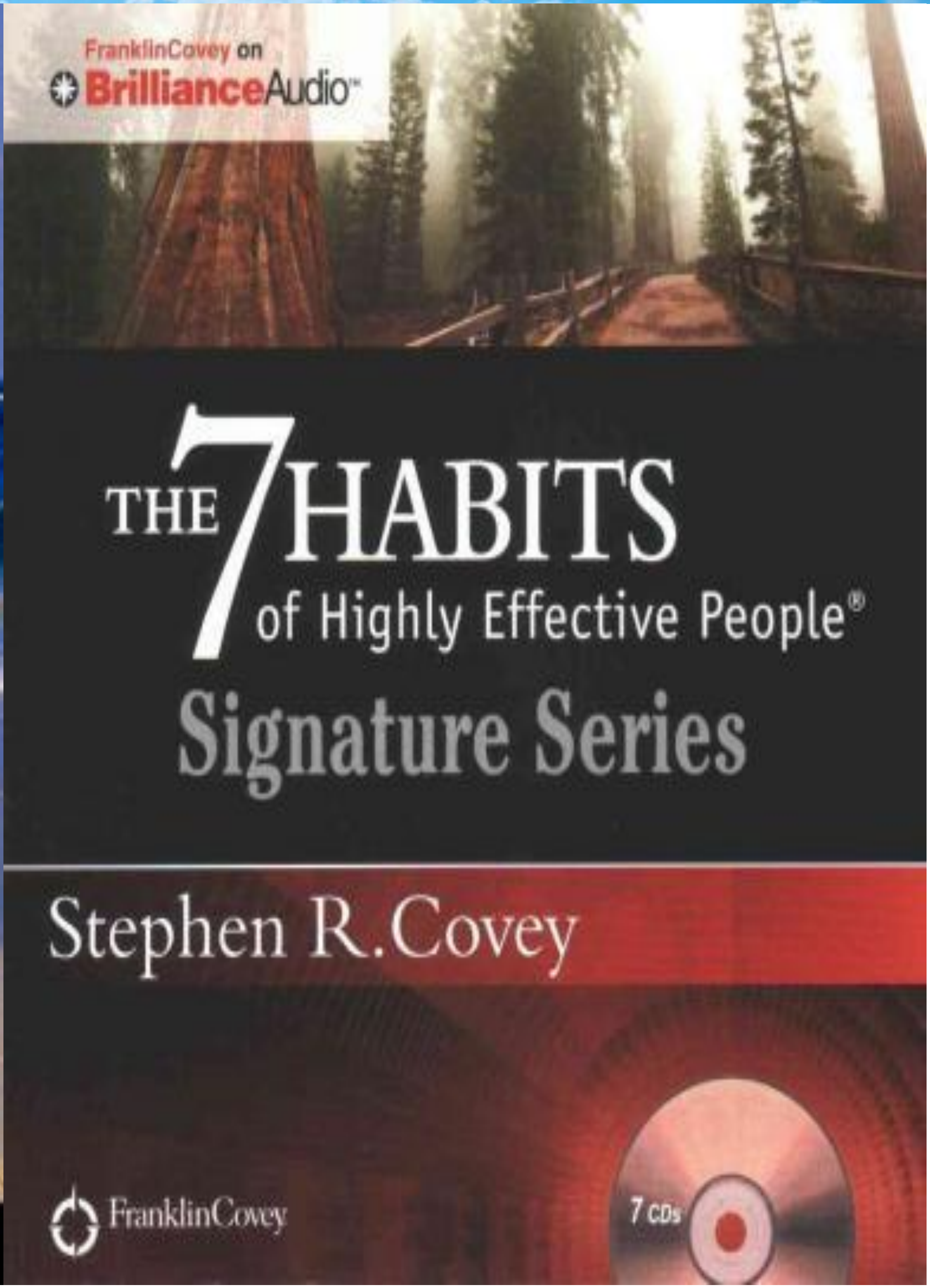


DFO Flood map

GFP
global flood partnership
https://gfp.jrc.ec.europa.eu

Flood: history, now, tomorrow, next week, next month, next year and future

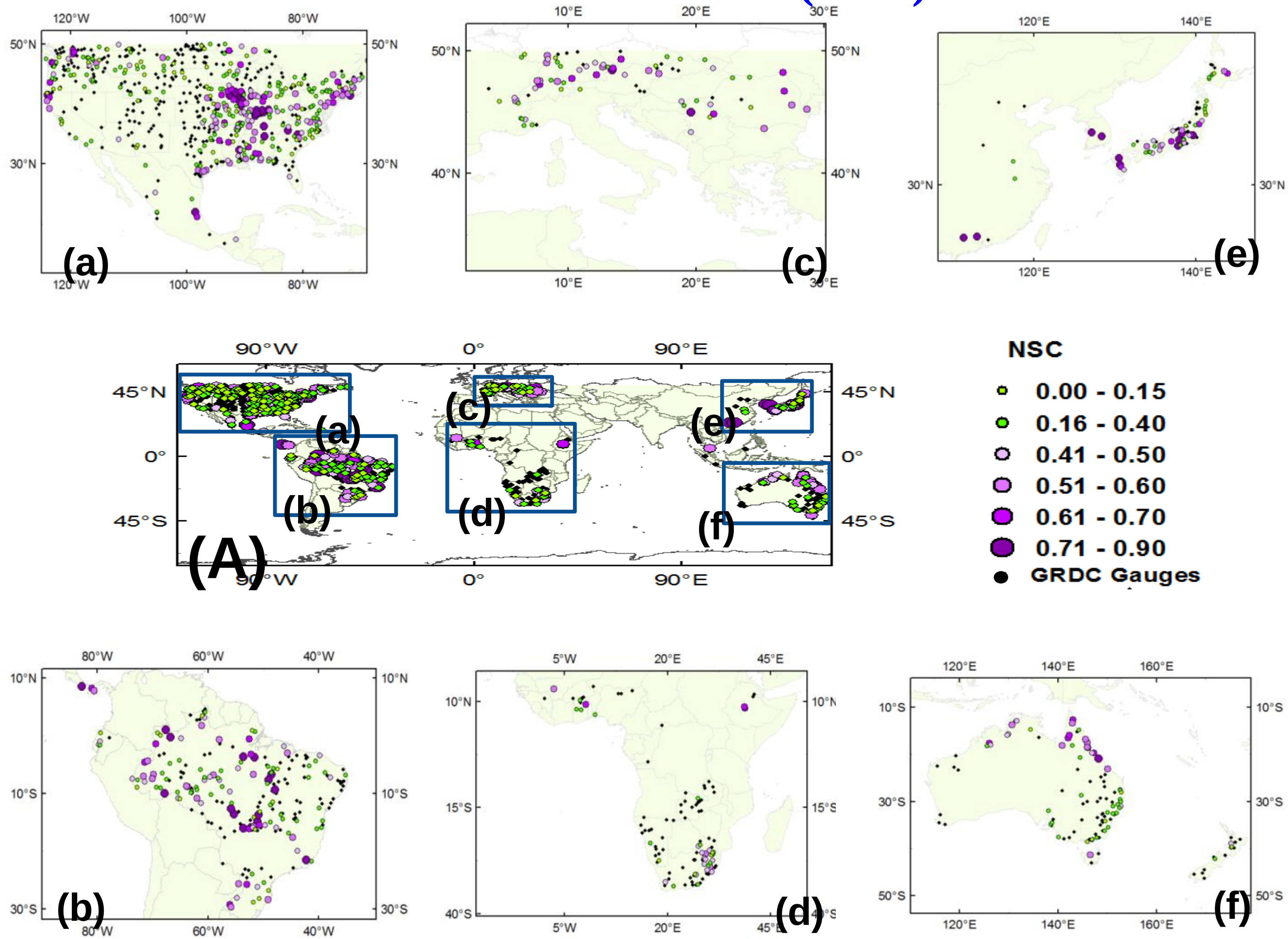




Challenge one: Global Validation

Comparison with 1,121 GRDC Streamflow Gauges

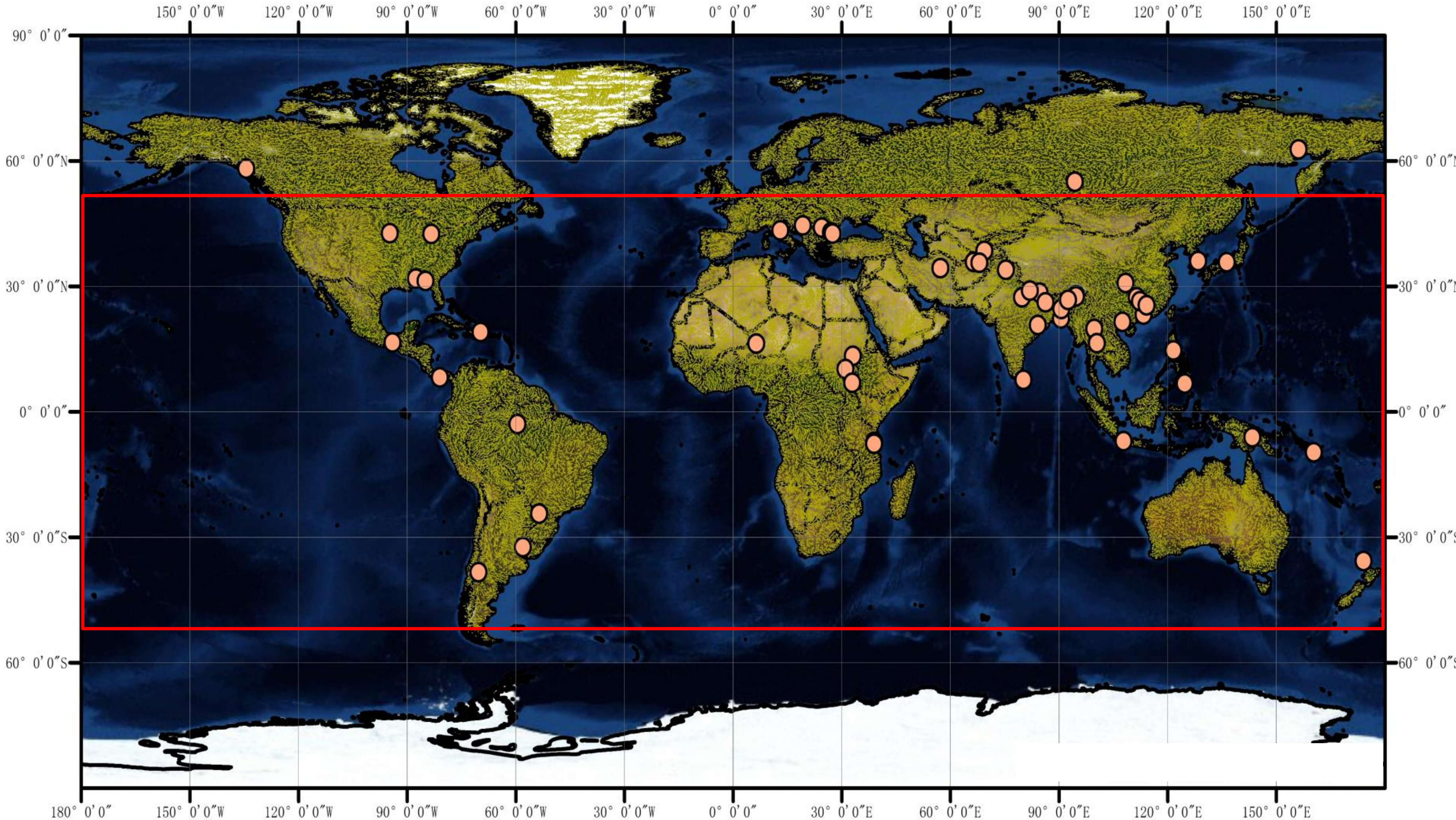
Nash-Sutcliffe (NSC)



Wu et al., 2014, WRR

Dartmouth Flood Observatory

All models detected 100 percent of the 54 large flood from April 1 to Sep.30, 2014 archived by DFO based on MODIS and news.

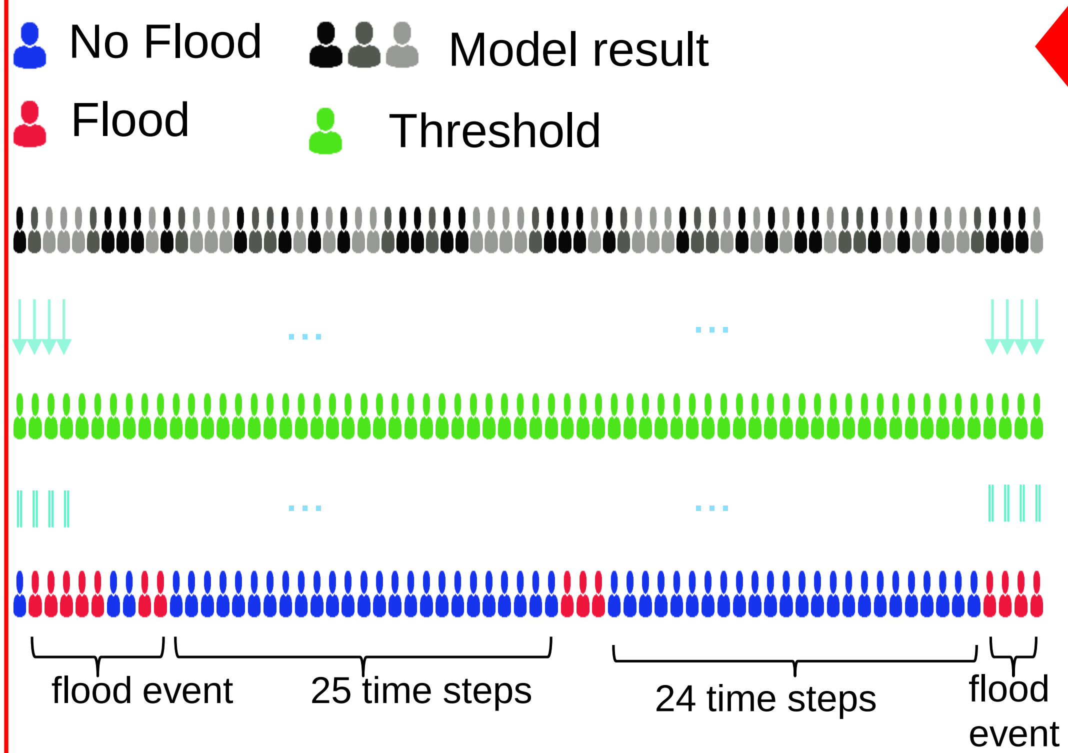


Evaluation of Global Flood Detection Using Satellite-Based Rainfall and a Hydrologic Model

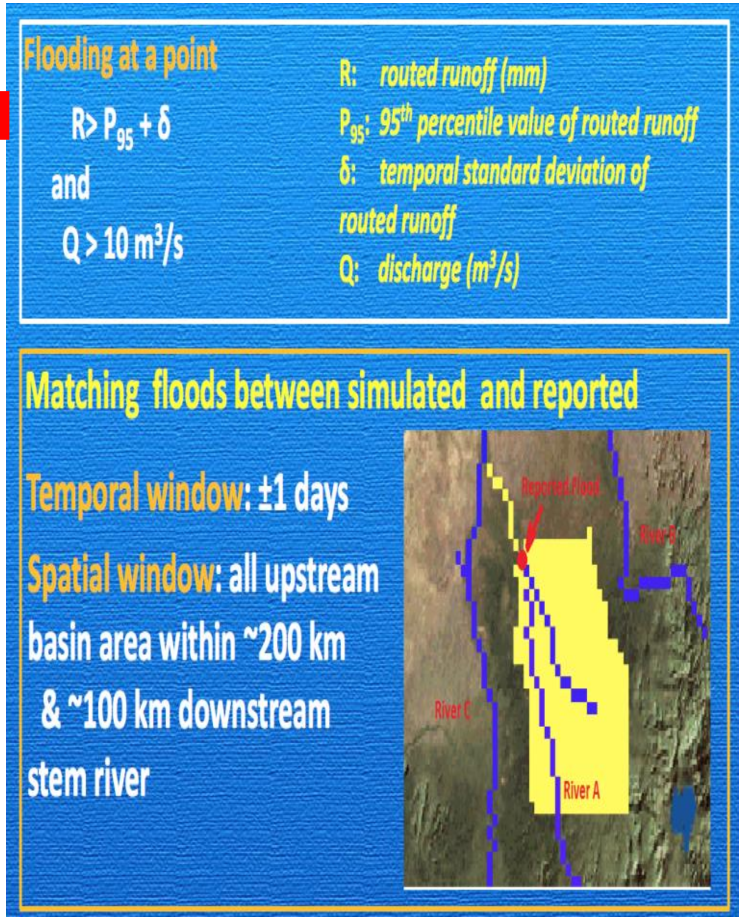
JOURNAL OF HYDROMETEOROLOGY

AMS American Meteorological Society

Huan Wu *and* Robert F. Adler
Earth System Science Interdisciplinary Center, University of Maryland, College Park, College Park, and NASA Goddard Space Flight Center, Greenbelt, Maryland

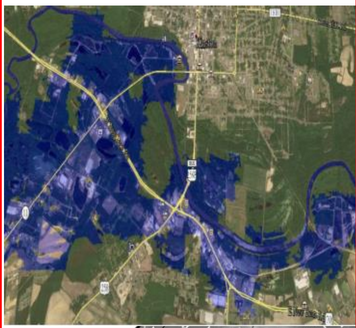


Wu et al., 2012 JHM, 2014 WRR

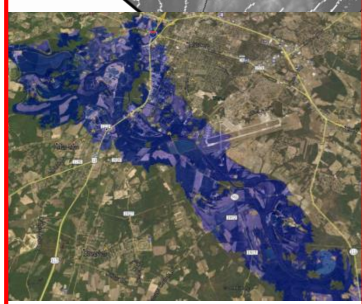


Hurricane Matthew (Oct. 13, 2016

Princeville, NC

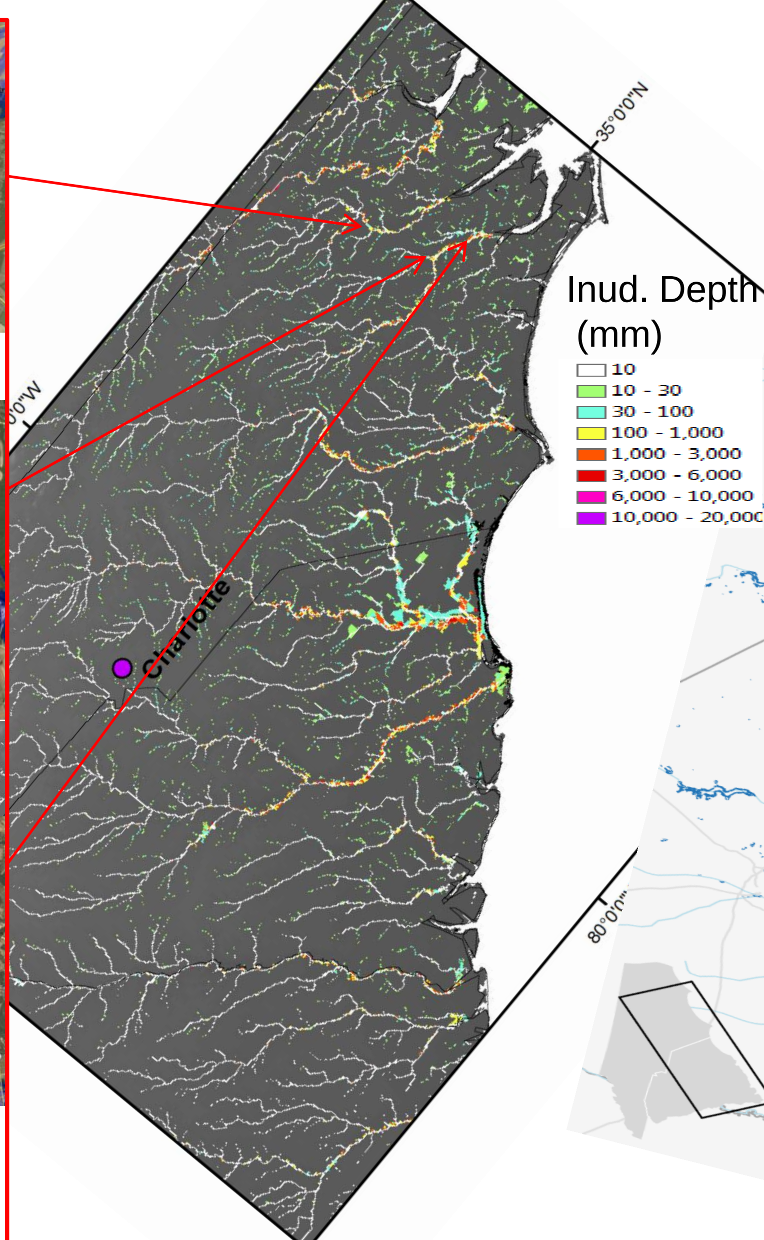


Kinston, NC

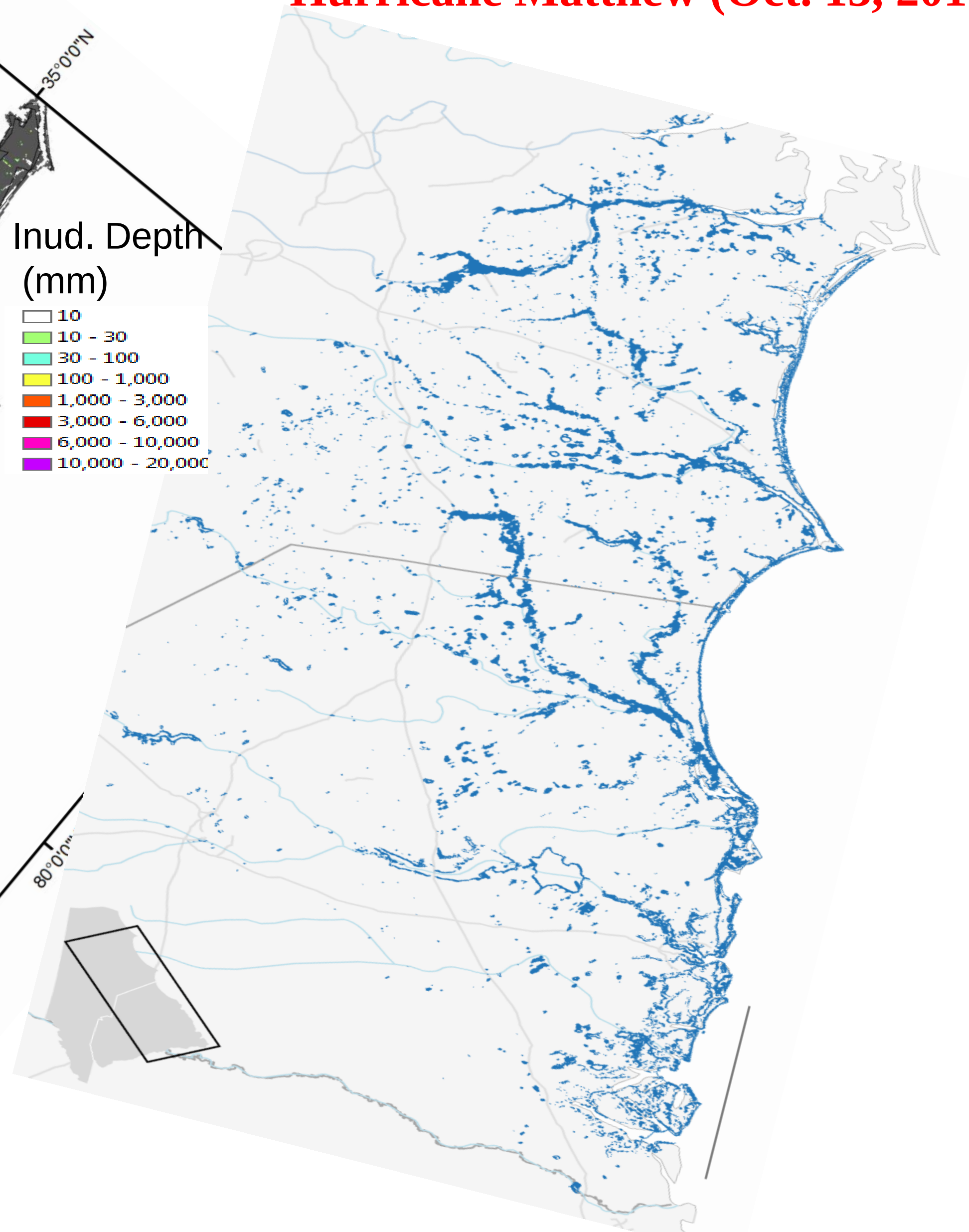


Goldsboro, NC

VIIRS downscaled 9-m flood map on Oct. 13 (GMU)



GFMS maximum flood depth during period of Oct 11-13.



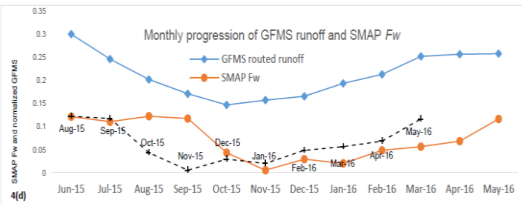
Flood Observatory U. Of Colorado From MODIS, In NYTimes

Evaluation of Real-time Global Flood Modeling with Satellite Surface Inundation Observations from SMAP

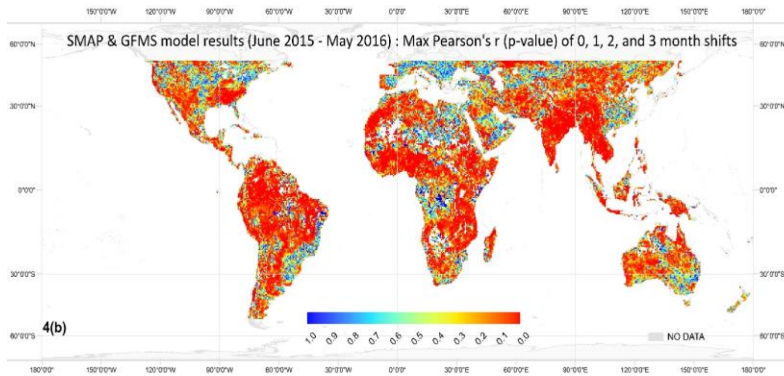
Huan Wu[1,2], John S. Kimball[3], Naijun Zhou[4], Lorenzo Alfieri[5], Lifeng Luo[6], Jinyang Du[3], Zhijun Huang[1,2]

[1] Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, and School of Atmospheric Sciences, Sun Yat-Sen University, China
[2] Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, USA
[3] Numerical Terradynamic Simulation Group, W.A. Franke College of Forestry & Conservation, The University of Montana, Missoula, USA
[4] Department of Geographical Sciences, University of Maryland, College Park, Maryland, USA
[5] European Commission Joint Research Centre, Disaster Risk Management Unit, Ispra, Italy
[6] Department of Geography, Environment, and Spatial Sciences, Michigan State University, East Lansing, Michigan, USA
wuhuan3@mail.sysu.edu.cn, njzhou@umd.edu

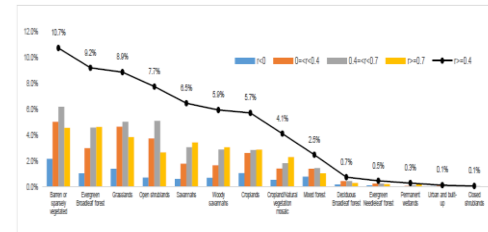
Poster 1:



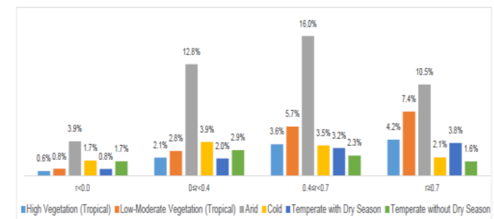
Temporal Correlation



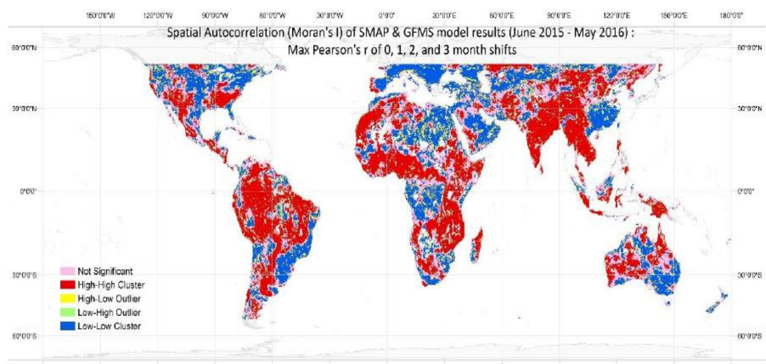
Spatial correlation

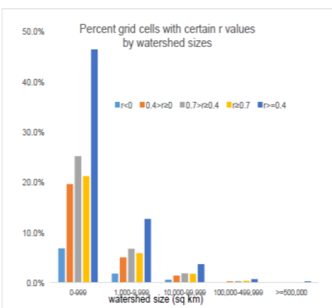


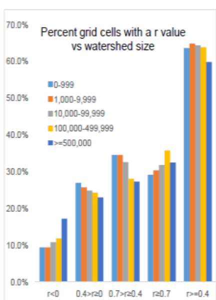
LULC



Climate



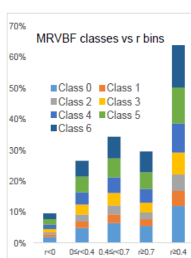


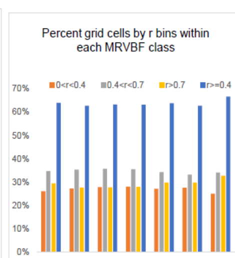


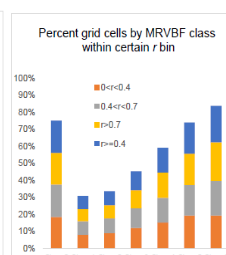
Catchments

Clustered spatial correlation

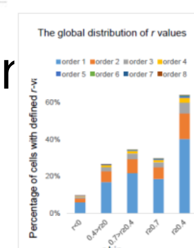
Wu et al., Remote Sensing of Environment, in review

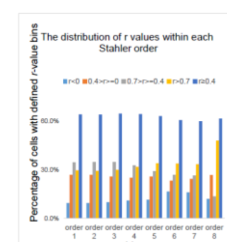






Topography





River Order
(Strahler order)

Challenge Two: Precipitation Uncertainty

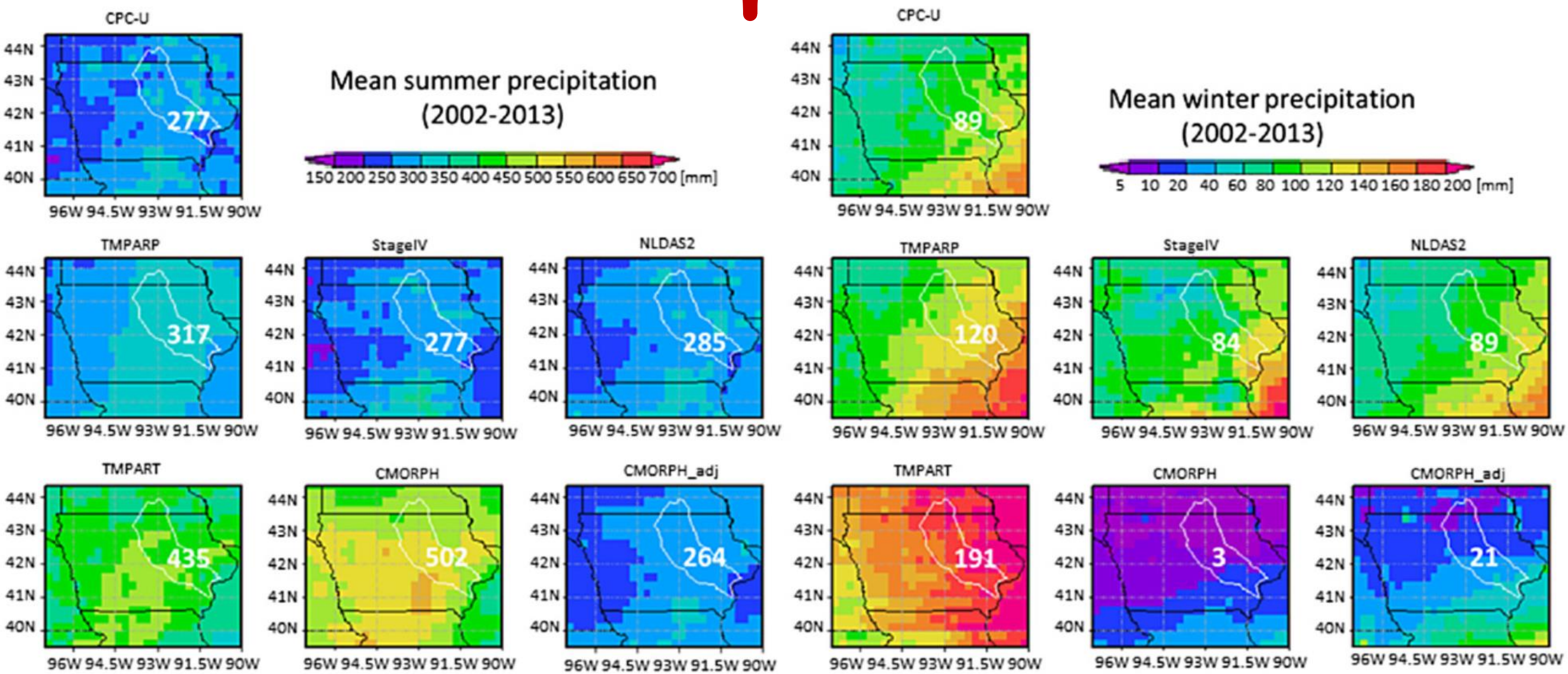
Tipping Bucket Raingauge

Weather Radar

Satellite

NASA Iowa Flood Center
IFloodS Iowa Flood Studies

Wu et al., JHM, 2017

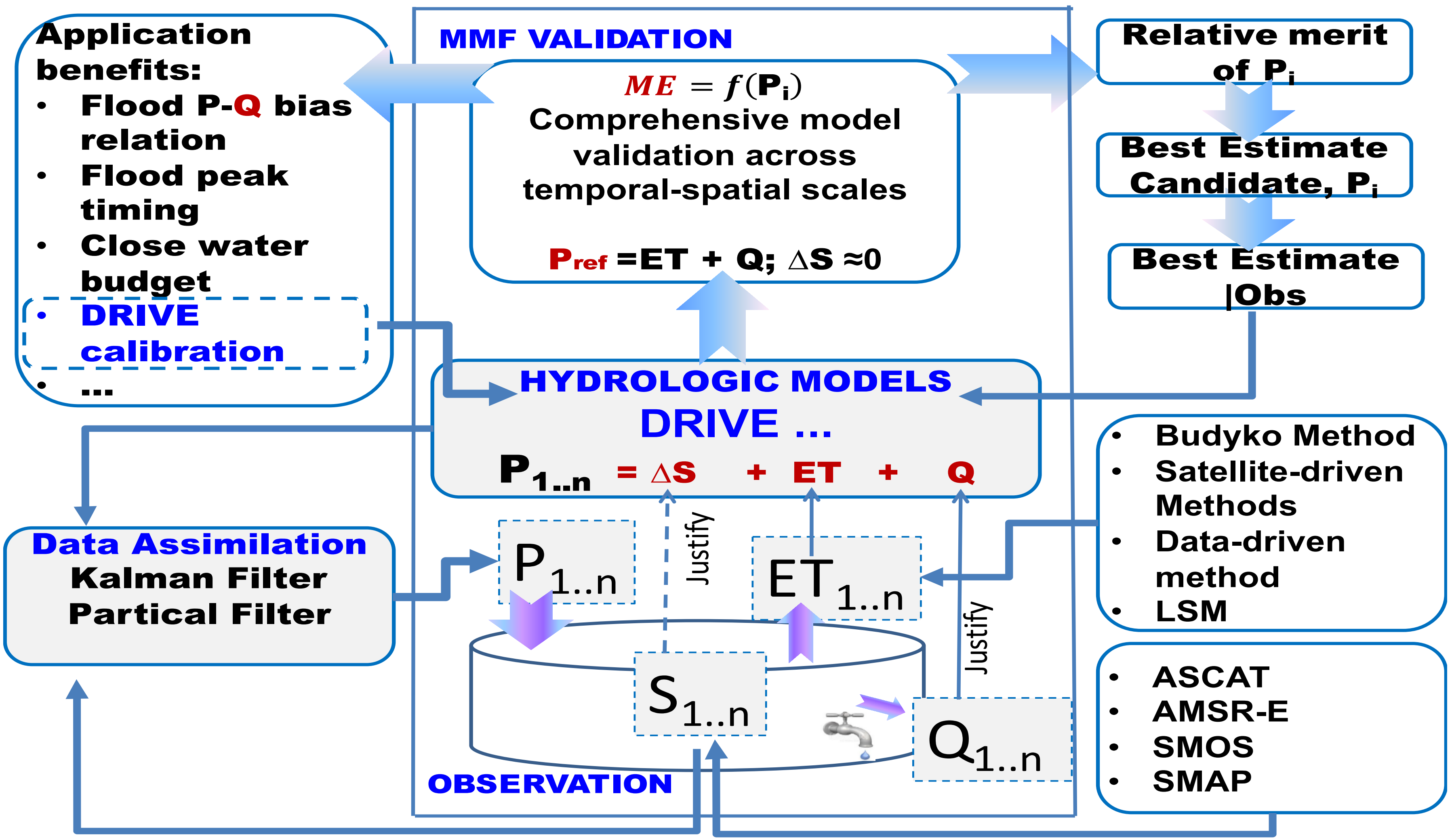


Talk By Nanding on Day 3

基于水文学方法的流域QPE及其水文模拟不确定性影响评估

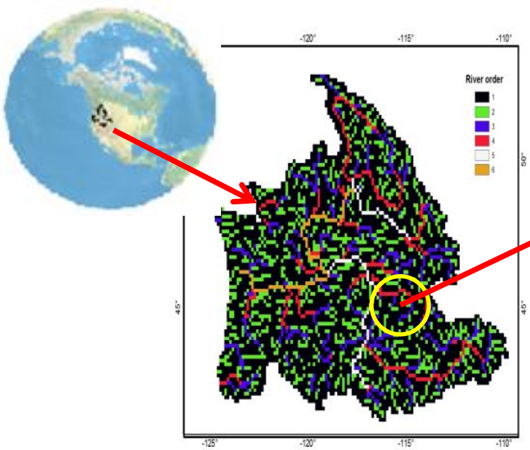
Wu et al., 2017, Journal of Hydrometeorlogy

Multiple-product-driven hydrologic Modeling Framework (MMF)

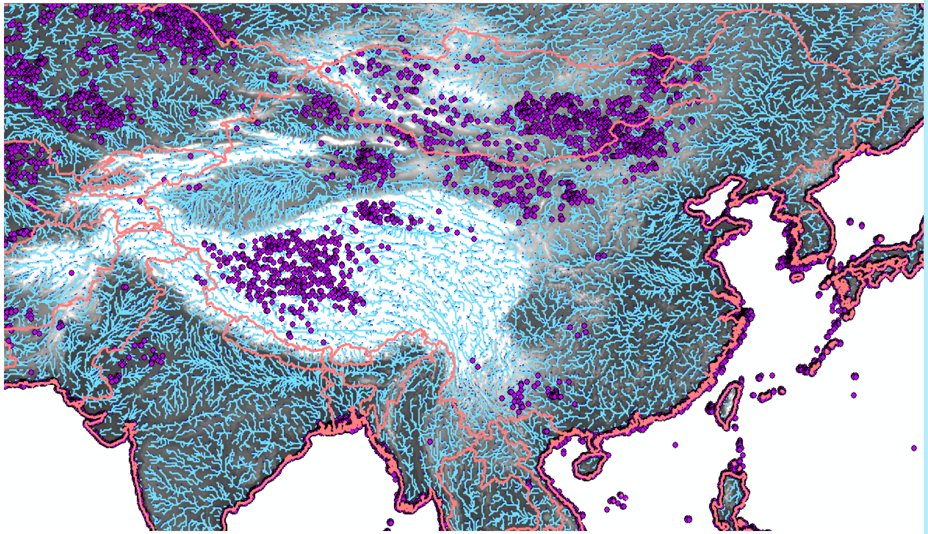


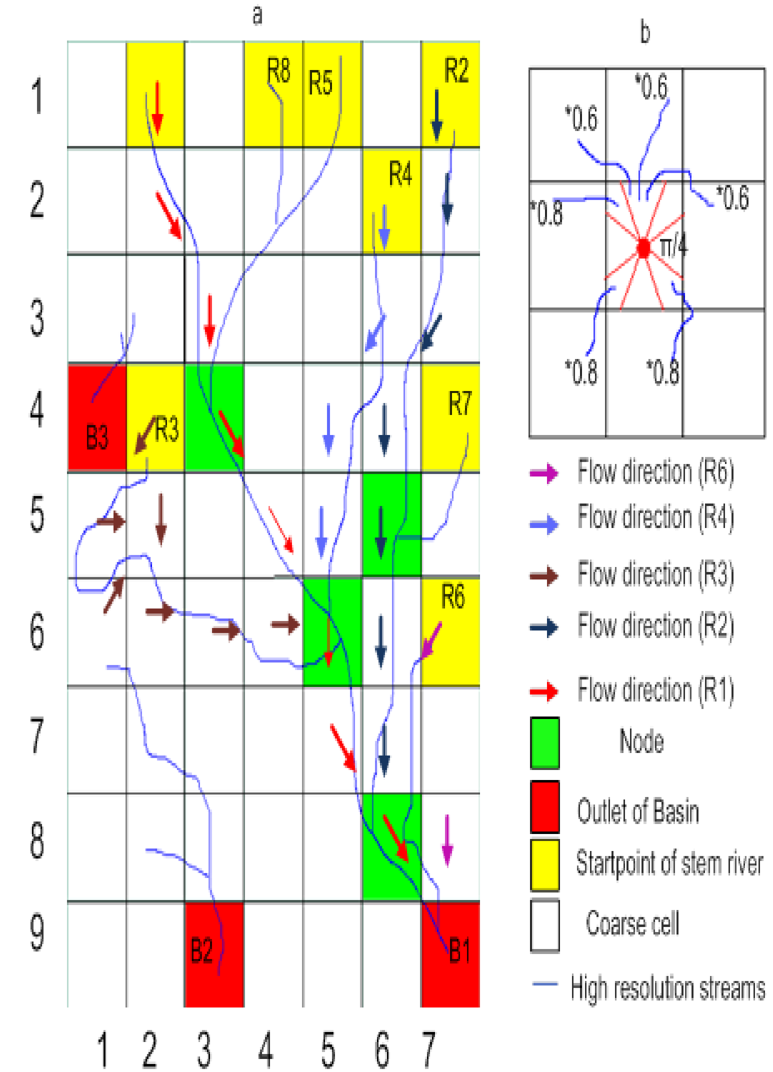
Challenge Three: Global Drainage Networks

1/20, 1/16, 1/12, 1/10, 1/8, 1/4, 1/2, 1, 2 degrees



河网分级拓扑关系





(**<u>Wu</u>** et al., *Water Resources Research, 2011,2012*)

A New Global Hydrography Database at Multiple Spatial Resolutions Based on MERIT DEM and DRT Algorithm

Zequn Huang[1,2], Huan Wu[1,2*], Chaoqun Li[1,2], Dai Yamazaki[3,4], Jing Tao[5]

1) School of Atmospheric Sciences, Sun Yat-sen University, Guangzhou, China

2) Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, Sun Yat-sen University, Guangzhou, China

3) Department of Integrated Climate Change Projection Research, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

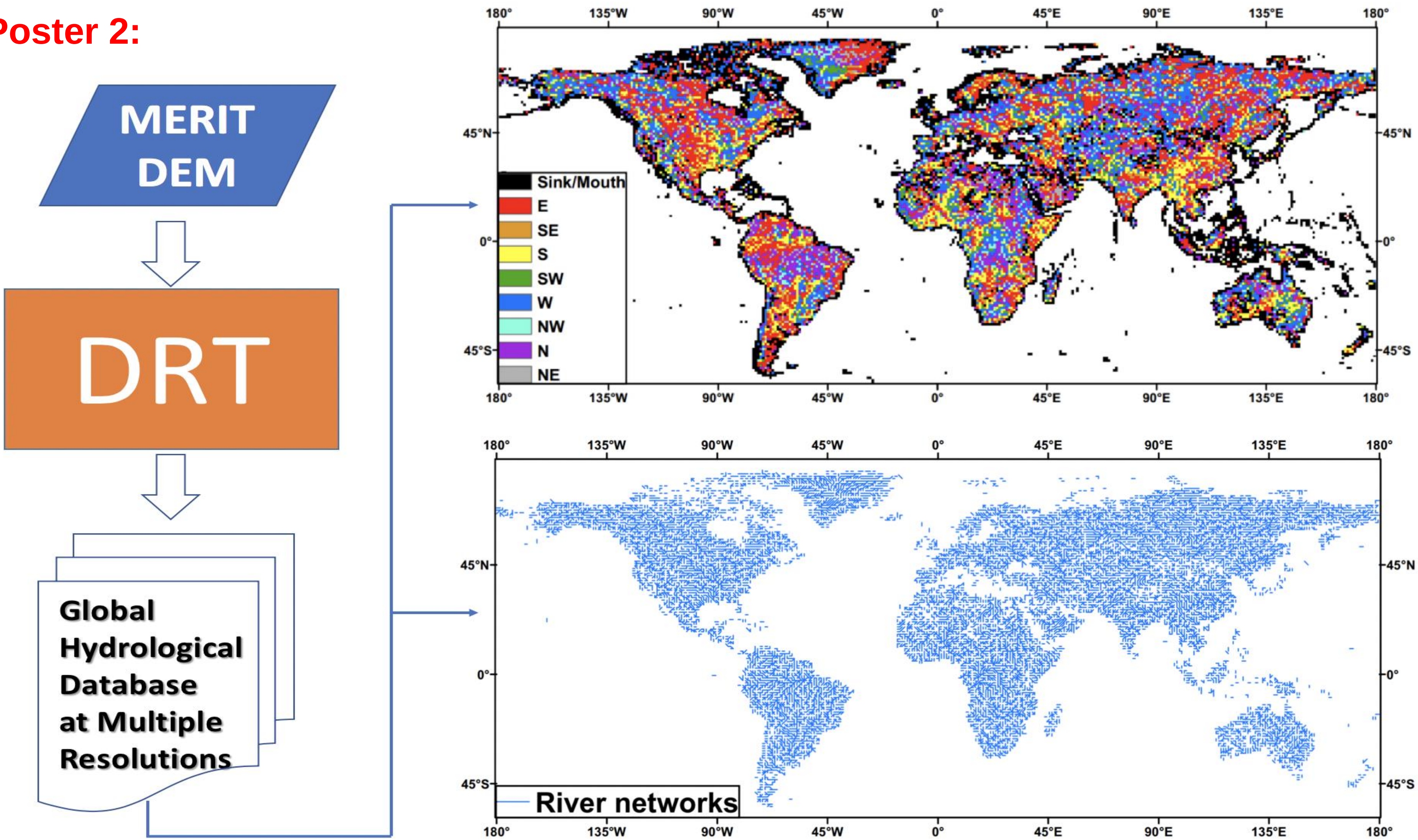
4) Institute of Industrial Sciences, University of Tokyo, Tokyo, Japan

5) Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, USA

huangzq9@mail2.sysu.edu.cn
wuhuan3@mail.sysu.edu.cn

HENG
Hydrometeorological Extremes simulatioN Group

Poster 2:



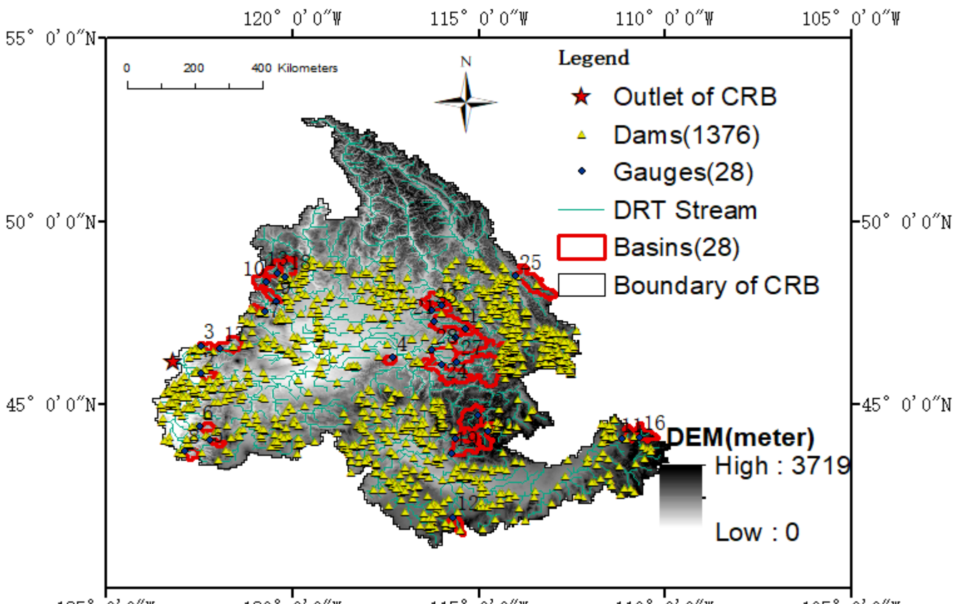
Challenge Four: Global Calibration

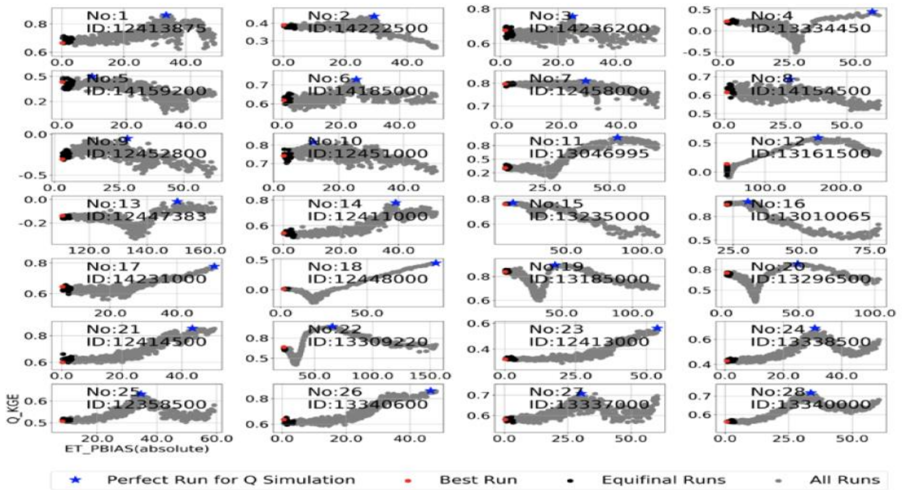
Poster 3:

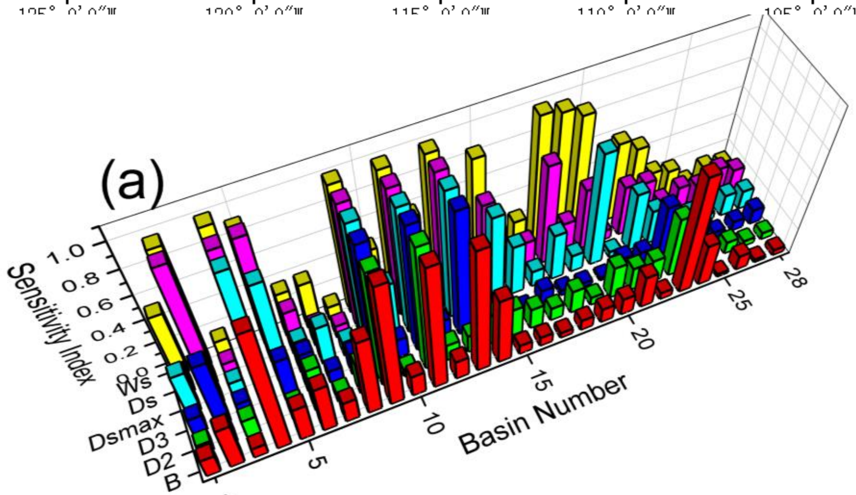
Effective Calibration for Hydrological Models in Ungauged Basins: Utility of Satellite-based Evapotranspiration Product

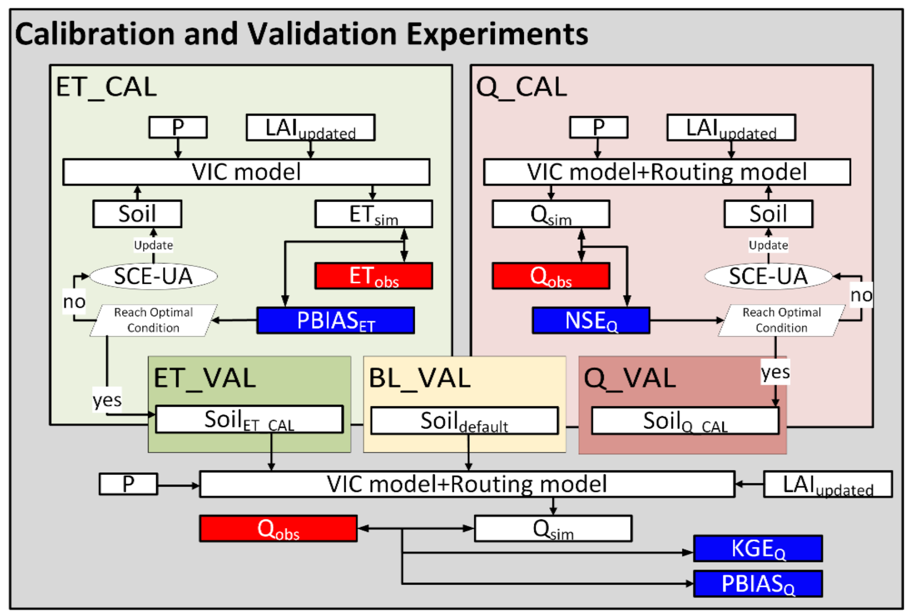
Lulu Jiang[1,2], Huan Wu[2,5*], Jing Tao[3,4]

[1]School of Earth and Space Sciences, Peking University, China
[2]Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, and School of Atmospheric Sciences, Sun Yat-sen University, China
[3]Climate and Ecosystem Sciences Division, Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA
[4]Department of Civil and Environmental Engineering, University of Washington, Seattle, WA
[5]Earth System Science Interdisciplinary Center, University of Maryland, USA









Challenge Five: global flood database

A Multi-Sourced Flood Inventory in Contiguous United States During TRMM Era

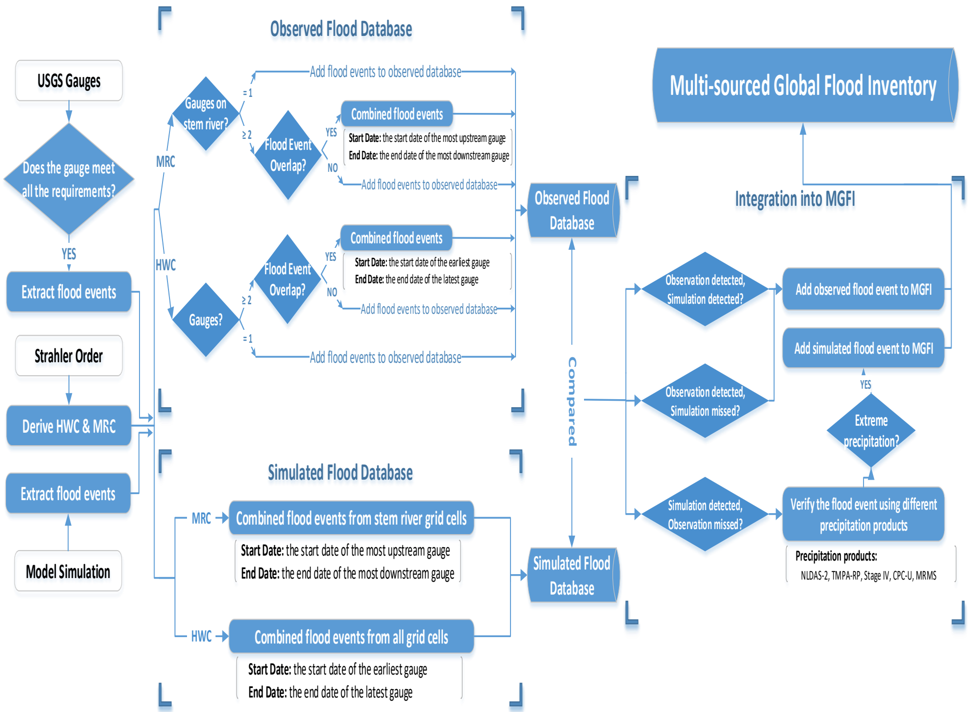
Zhijun Huang[1], Huan Wu[1,2,*]

[1] Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, and School of Atmospheric Sciences, Sun Yat-Sen University, China
[2] Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, USA

GFP global flood partnership

HENG Hydrometeorological Extremes simulatioN Group

Poster 4:



HWC: Head water catchment
MRC: Major river catchment

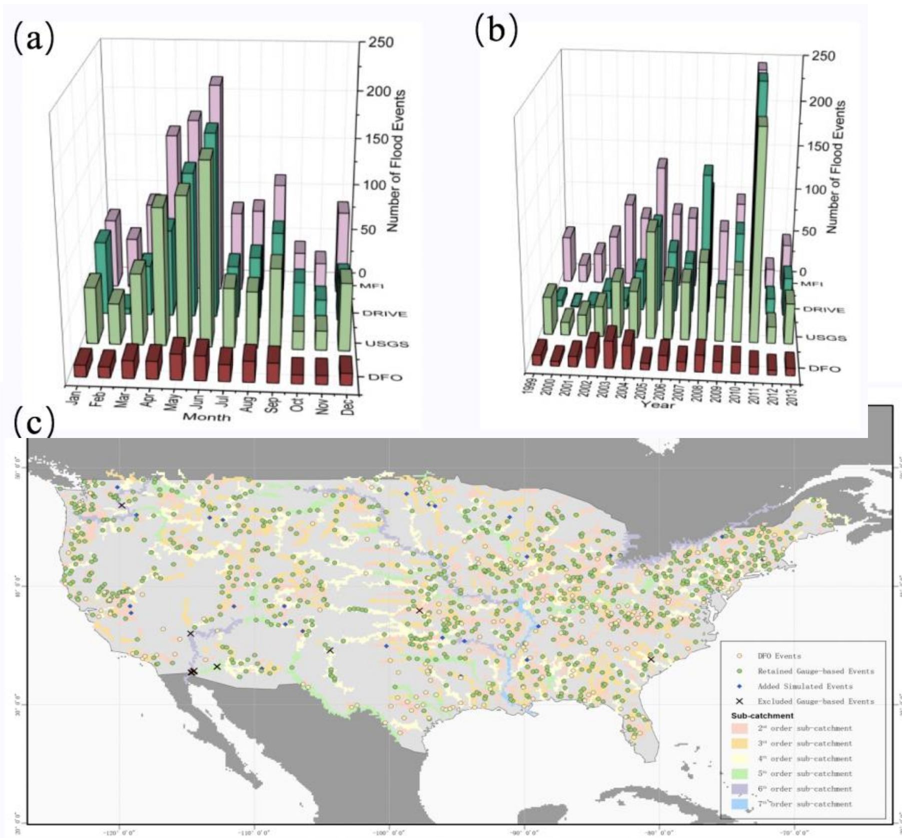


Fig 4. The distribution of preserved events, discarded events and recovered events

Multi-source Global Flood Inventory (MGFI)

Challenge Six: urbanization, dam/reservoir

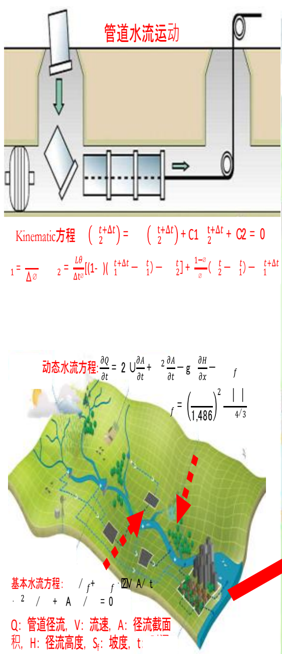
Urban Flood Monitoring Using an Integrated River Basin-Urban Flood Modeling Approach: A Case Study in Haikou City, Hainan, China

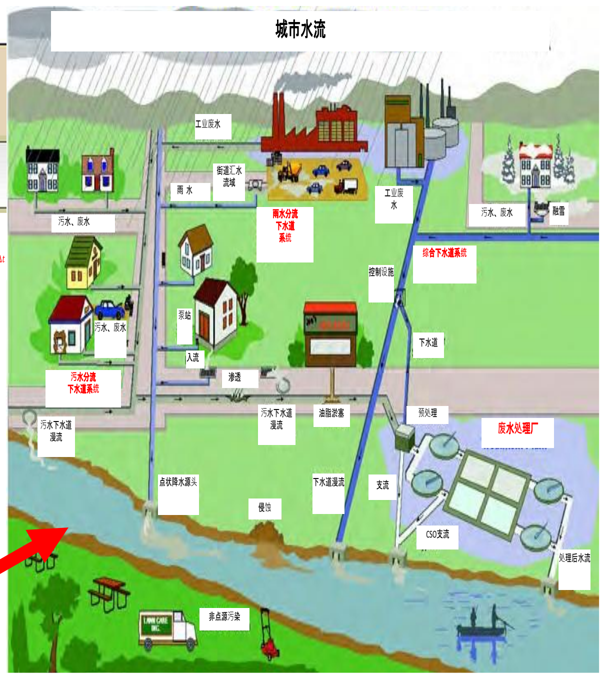
Weitian Chen[1,2], Huan Wu[1,2*], Naijun Zhou[3], Si Shi[4], Qinbo Cai[4], Yingchun Tao[5], Shihu Zhao[6]

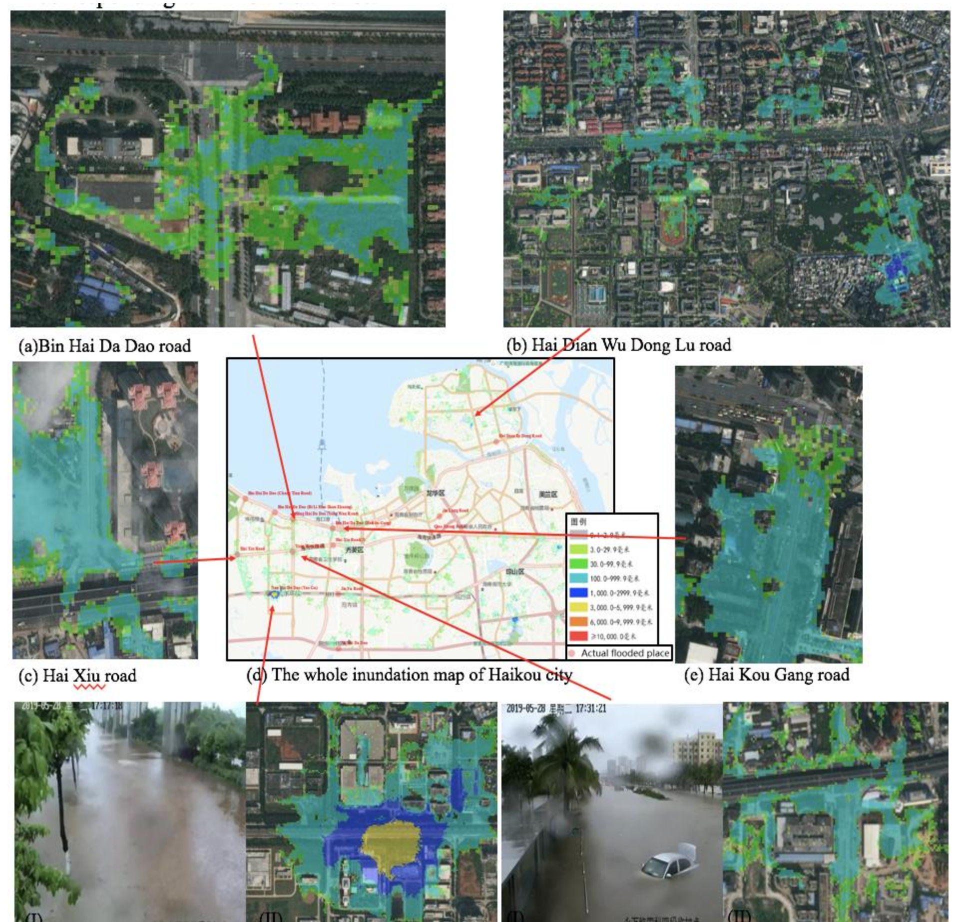
1) School of Atmospheric Sciences, Sun Yat-sen University, Guangdong, China
2) Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, Sun Yat-sen University, Guangzhou, China
3) Department of Geographical Sciences, University of Maryland, College Park, MD, USA
4) Meteorological Observatory of Hainan Province, Haikou, China
5) Beijing Institute of Surveying and Mapping, Beijing, China
6) Satellite Surveying and Mapping Application Center, NASG, Beijing, China

Poster 5:

城市水流要素与概念模型

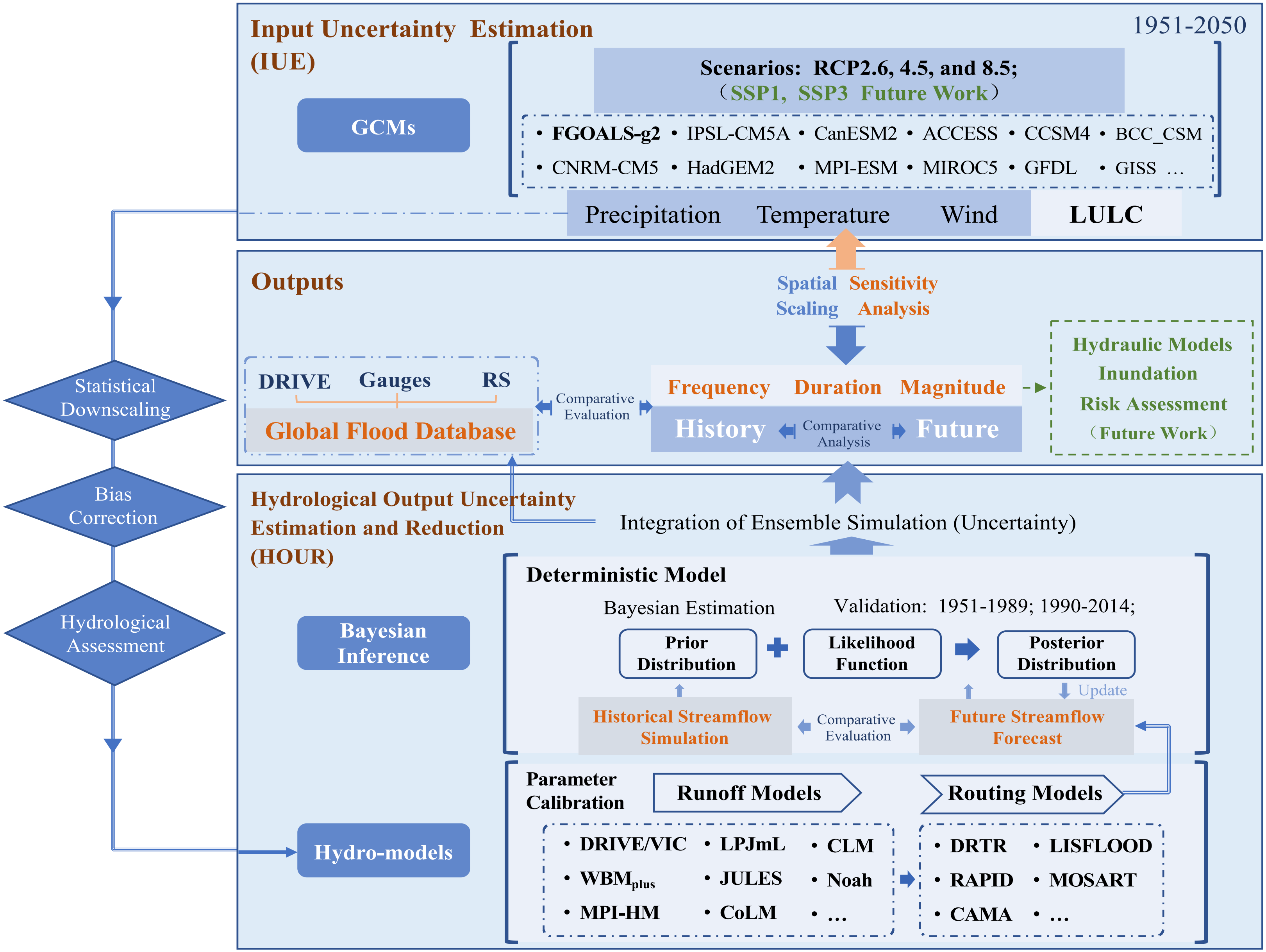






(a)Bin Hai Da Dao road
(b) Hai Dian Wu Dong Lu road
(c) Hai Xiu road
(d) The whole inundation map of Haikou city
(e) Hai Kou Gang road
(f) Nan Hai Da Dao road (I) Video photo (II) The

Challenge Seven: Climate change and LUCC impacts on flood and the uncertainty in the assessment



Global Floods/Precipitation and Their Connections with the El Niño-Southern Oscillation During the TRMM Era

yany53@mail2.sysu.edu.cn
wuhuan3@mail.sysu.edu.cn

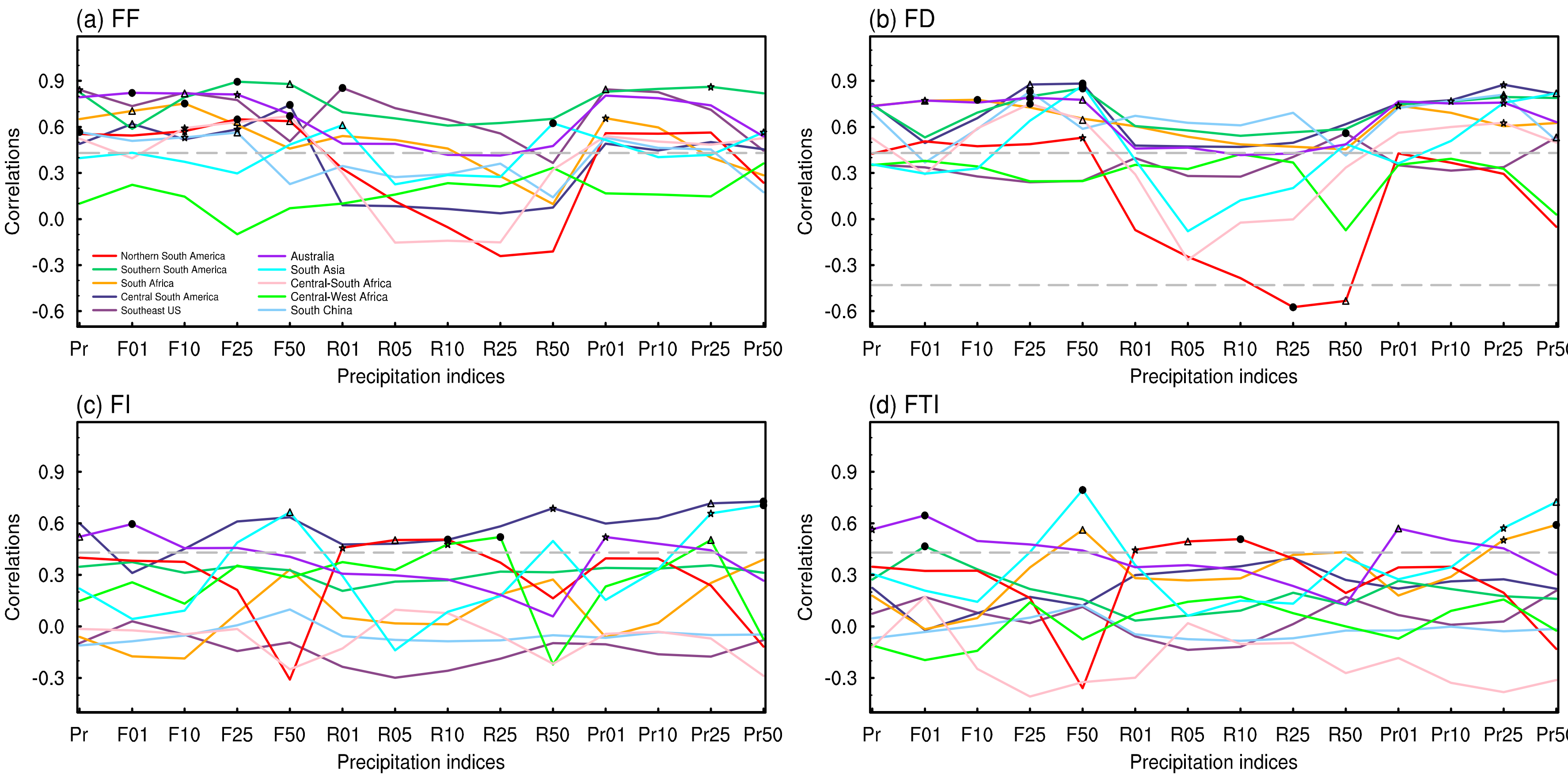
Yan Yan[1,2], Huan Wu[1,2]*, and Guojun Gu[3]

1)School of Atmospheric Sciences, Sun Yat-sen University, Guangzhou, China

2) Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, Sun Yat-sen University ,Guangzhou, China

3) Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740

Poster 6: Yan, et al, Submitted to Journal of Climate



Correlations between FF/FD/FI/FTI and various precipitation indices in ten regions during DJF

Summary

HENG's Mission & Keywords

wuhuan3@mail.sysu.edu.cn

- **Challenge one:** Global Validation of flood models
- **Challenge Two:** Precipitation Uncertainty and its impacts on flood prediction
- **Challenge Three:** Global drainage network derivation and parameterization
- **Challenge Four:** Global optimization (calibration) of flood models
- **Challenge Five:** Baseline global flood event database
- **Challenge Six:** Human activity impacts on floods: urbanization, dam/reservoir
- **Challenge Seven:** Climate change and LUCC impacts on flood prediction and the uncertainty in the assessment