Precipitation Estimation from Multi-Satellite Measurements Using Machine Learning Methods

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New Orleans, Louisiana, November 18, 2017

- ***CHRS Multi-Satellite Precipitation Analysis***
- ***Reconstruction of Historical Precipitation Estimation for Hydro-climate Applications***

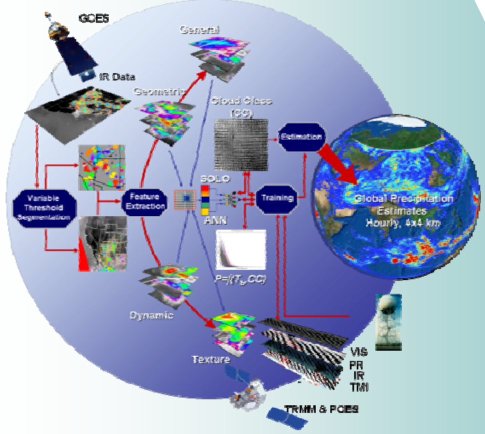
Climate Variability and Change & Extreme Hydrologic Events

Floods & droughts are more frequent due to climate variability and change

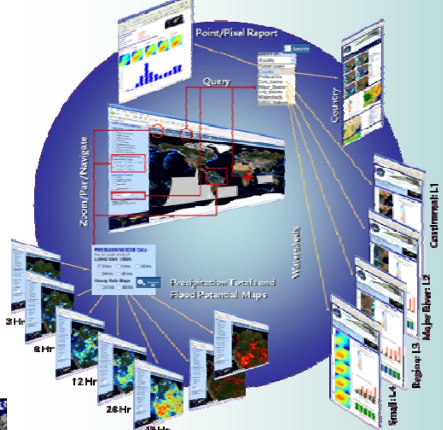
Long term high resolution precipitation data are needed for hydroclimate studies

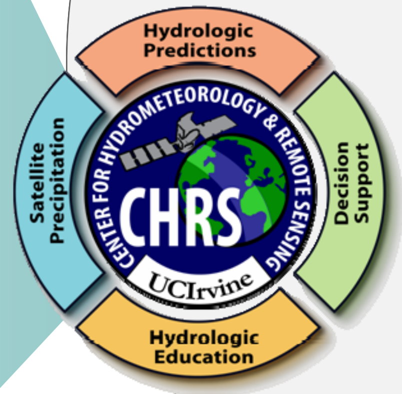
CHRS Remote Sensing Precipitation

Develop state-of-the-art systems to estimate rainfall from satellite observations at global scale and high spatial and temporal resolutions



Information Technology to provide world-wide access to global precipitation products:



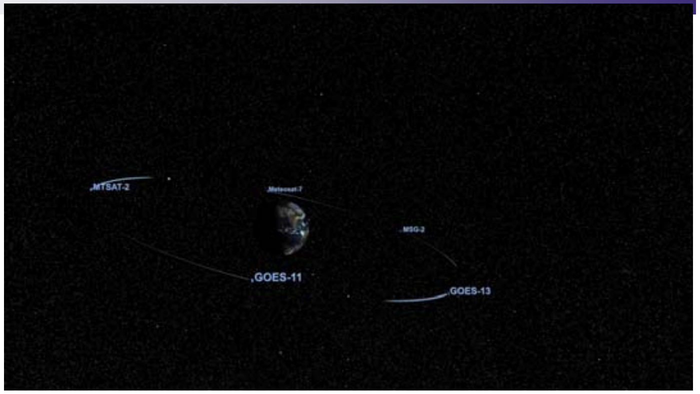


Goal:

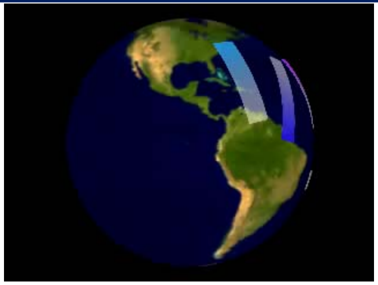
High spatial and temporal resolution of precipitation measurements at global scale for hydrological applications:

- ***Short-term operational applications***
  - ***Flood forecasting***
  - ***Data assimilation in numerical weather models***
- ***Long-term climate extreme event analysis***
- ***Hydro-climate studies***
- ***Validation GCM models***

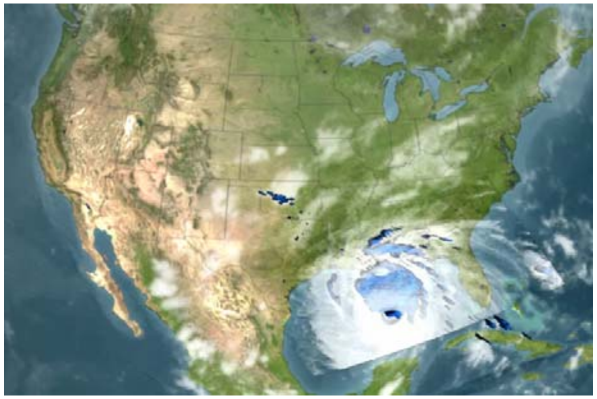
Satellite Data for Precipitation estimation



Geostationary IR
Cloud top data
15-30 minute temporal resolution

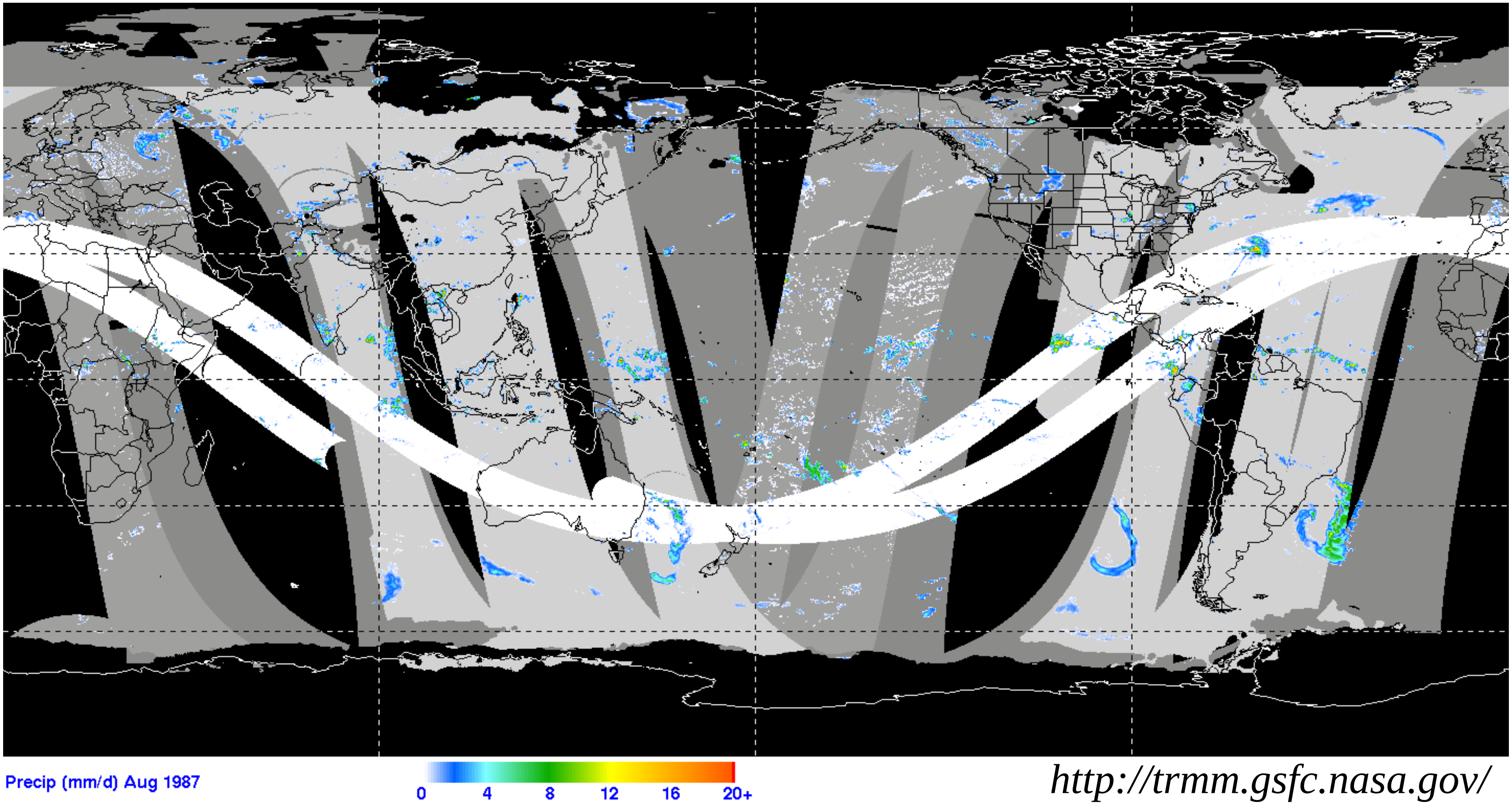


Passive Microwave (SSM/I)
Some characterisation of rainfall
~2 overpasses per day per spacecraft, moving to 3-hour return time (GPM)



TRMM precipitation RADAR
3D imaging of rainfall
1-2 days between overpasses
(S-35° N-35 °)

Typical Microwave Coverage in 3 Hr



http://trmm.gsfc.nasa.gov/

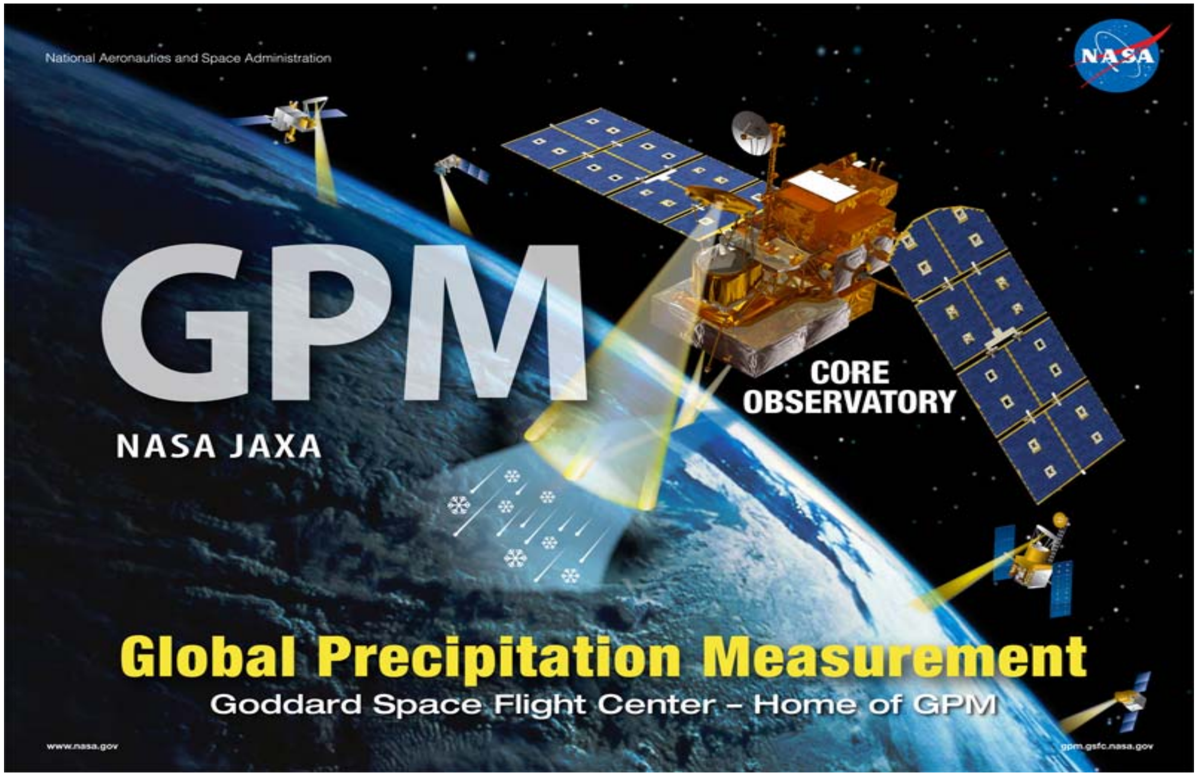
TMI – white

SSM/I – light grey

AMSR-E – medium grey

AMSU-B – dark grey

Global Precipitation Measurement (GPM)



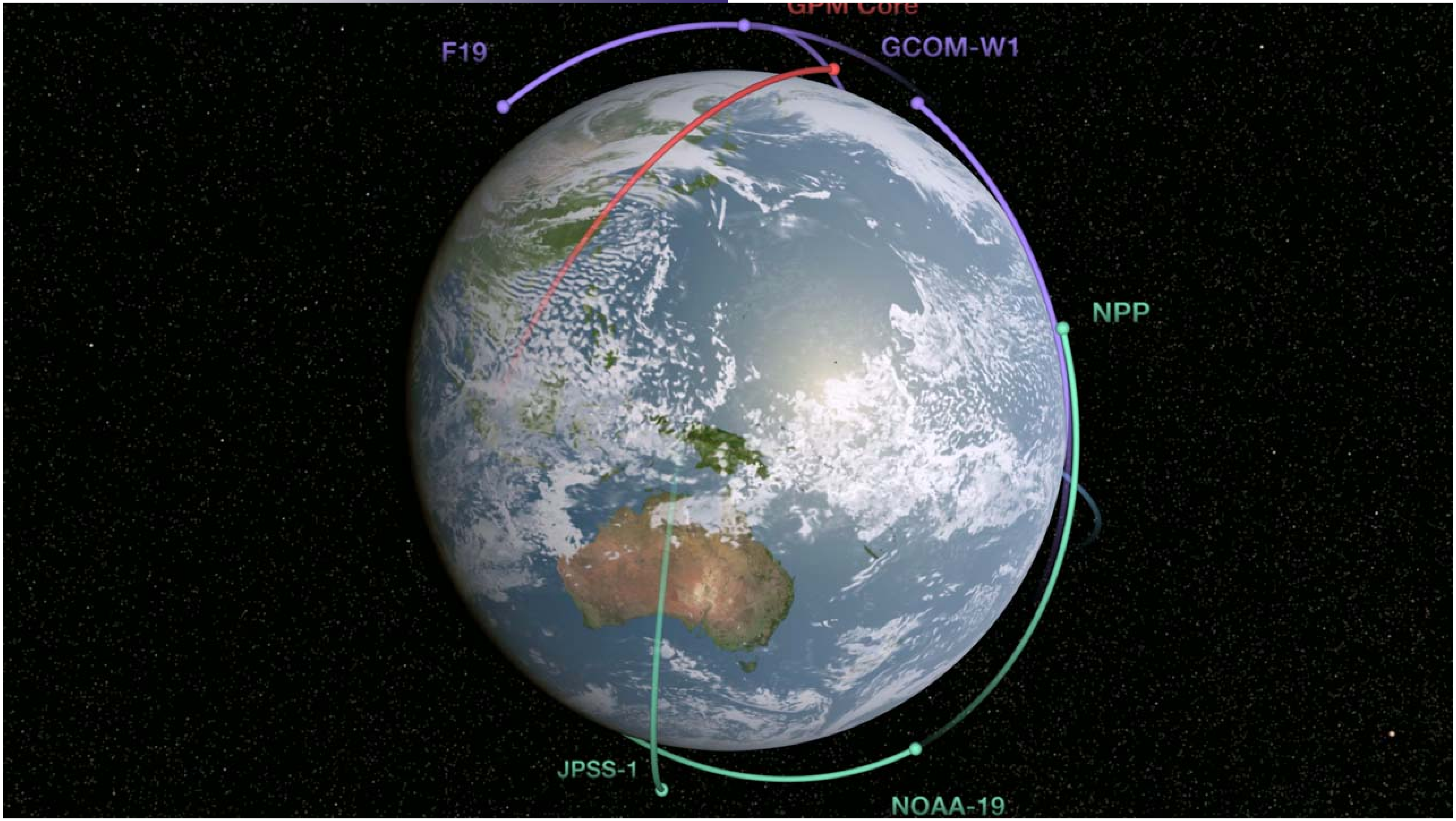
The GPM spacecraft will collect information that unifies data from an international network of existing and future satellites to map global rainfall and snowfall every three hours.

Tanegashima Space Center, Japan

Friday, Feb. 28, 2014

GPM Animation

Courtesy: NASA's ESE



Integrated Multi-satellitE Retrievals for GPM (IMERG)

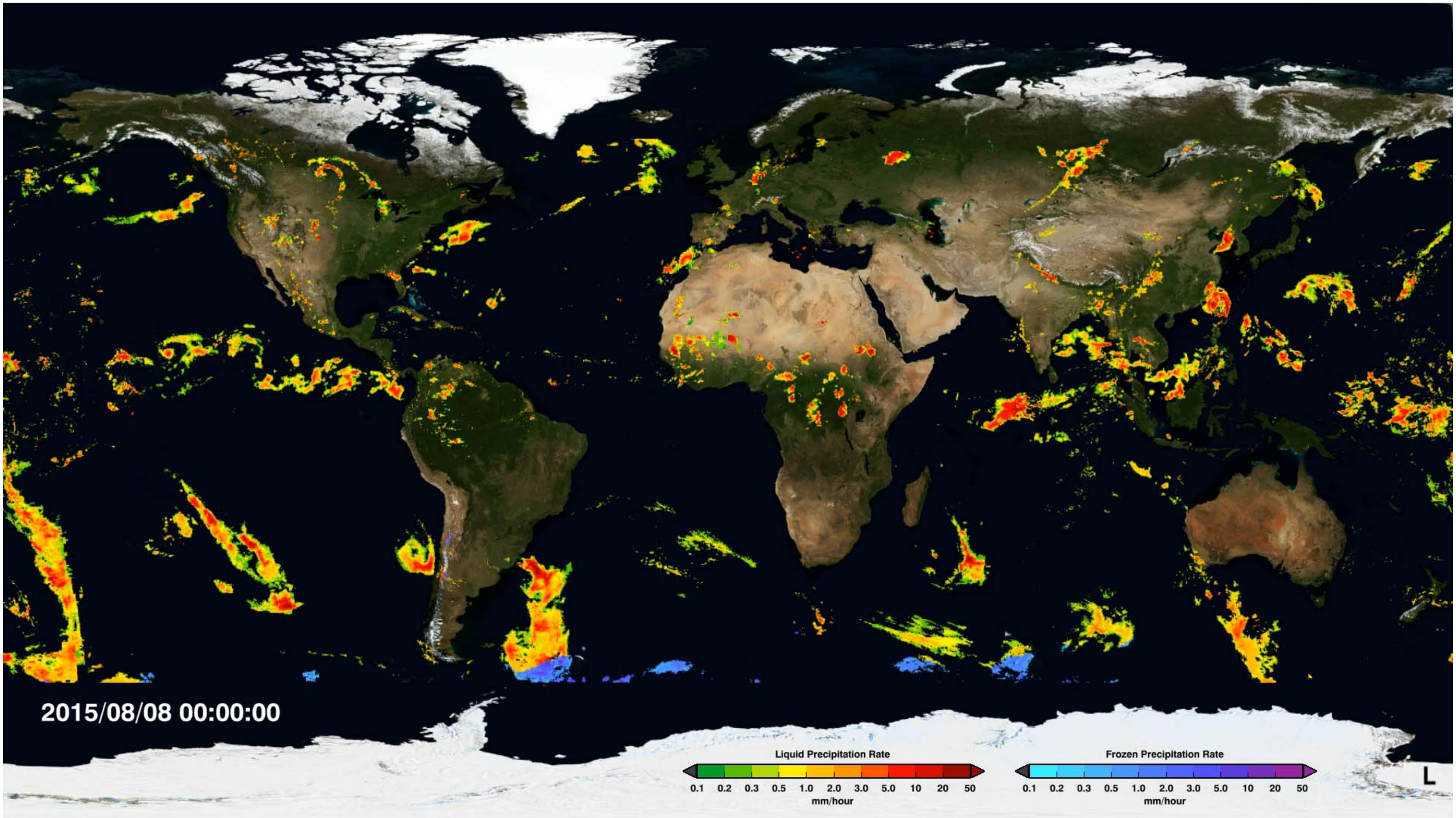
Integrated Multi-satellitE Retrievals for GPM – IMERG

- NASA TMPA: intersatellite calibration, gauge adjustment
- NOAA CMORPH: Lagrangian time interpolation
- U.C. Irvine: PERSIANN-CCS: neural-net microwave calibrated GEO-IR

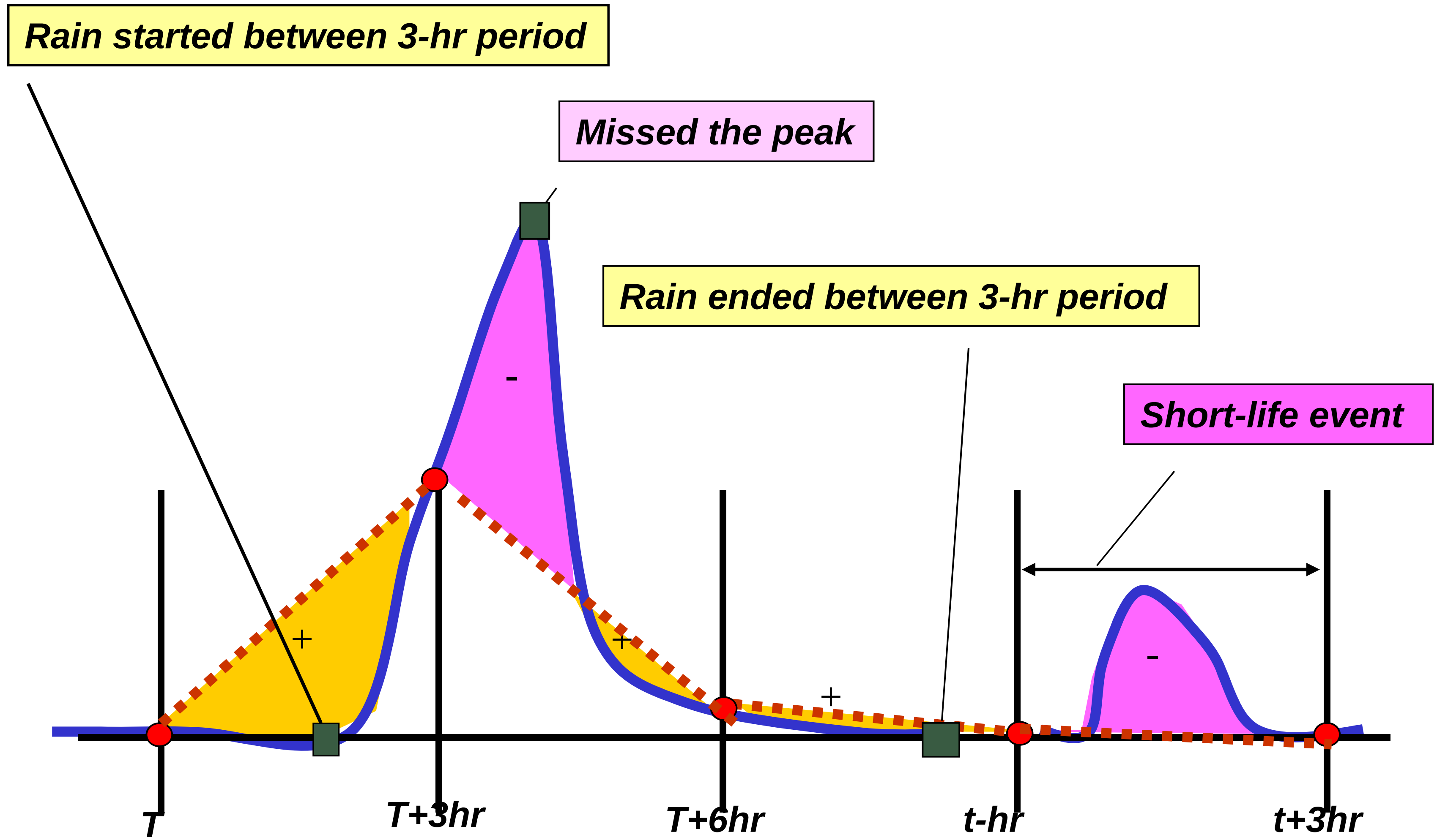
Address different user needs in 3 “runs”

- “early” (~4 hr after observation)
- “late” (~12 hr after observation)
- “final” (with gauge, ~2 months after observation)

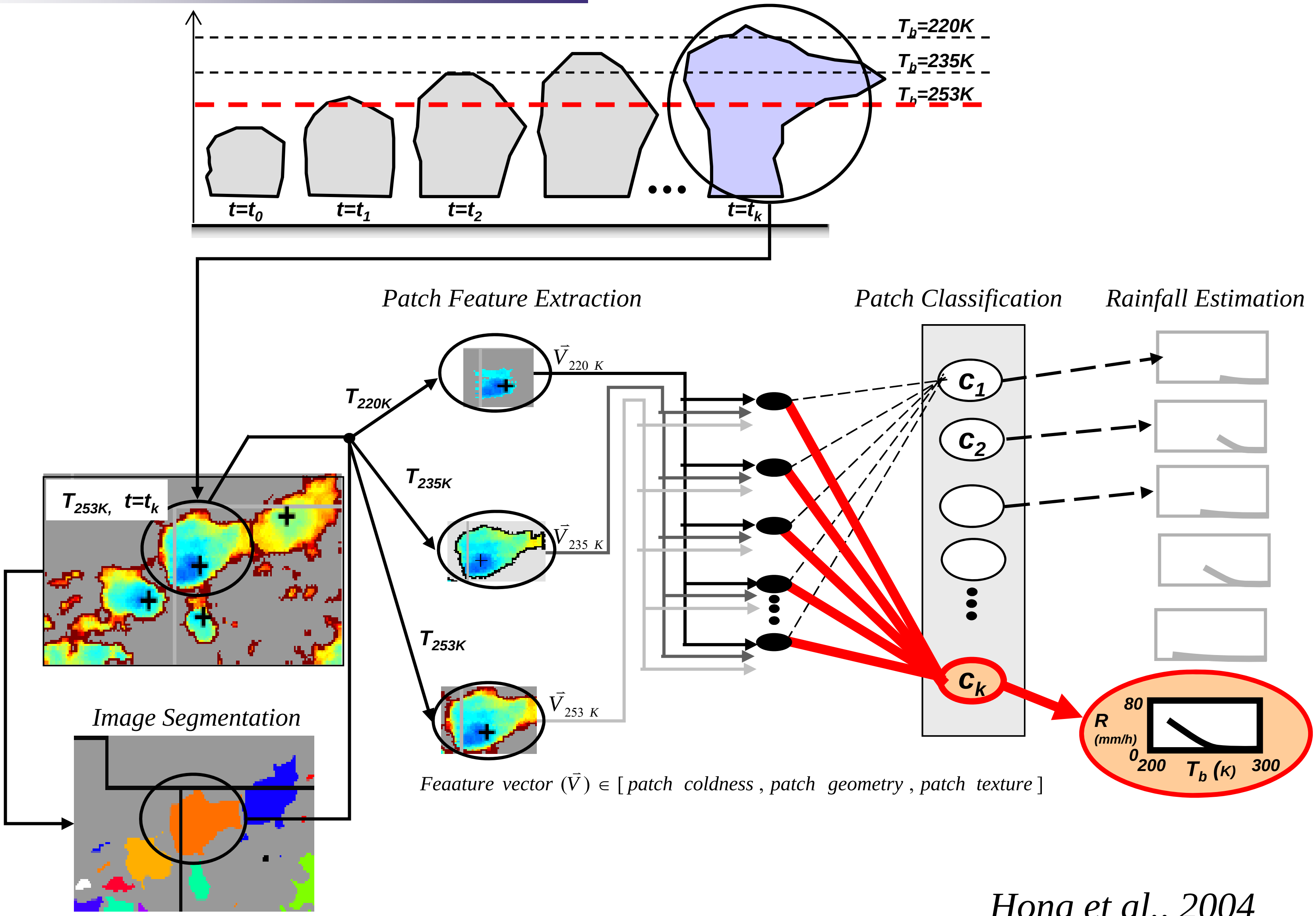
Integrated Multi-satellitE Retrievals for GPM (IMERG)



Interpolation of 3-hour Precipitation



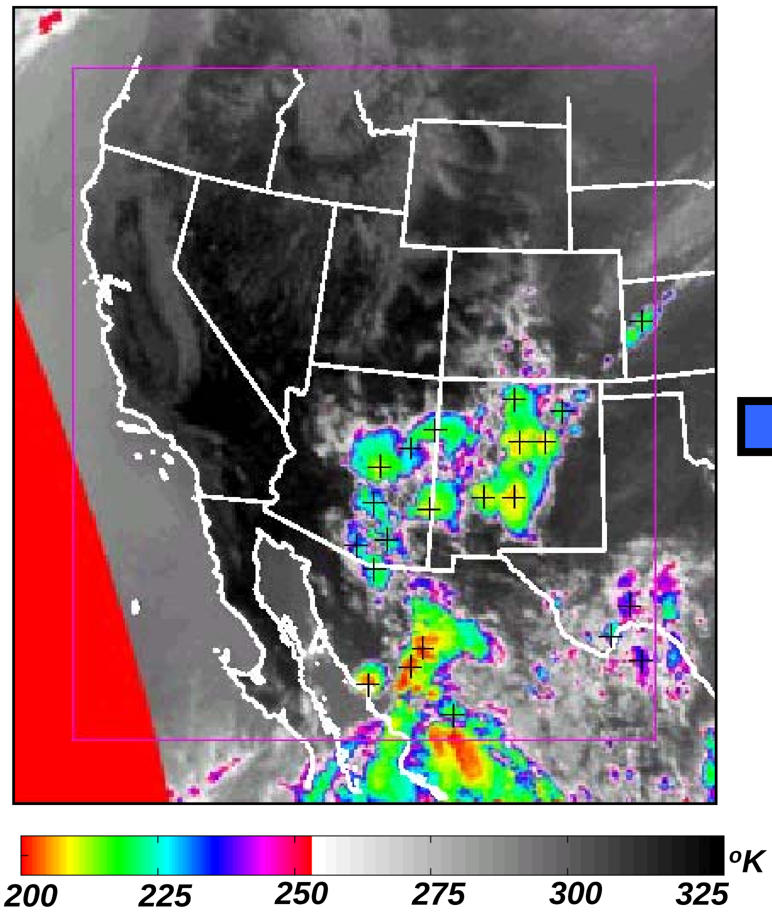
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Cloud Classification System (PERSIANN-CCS)



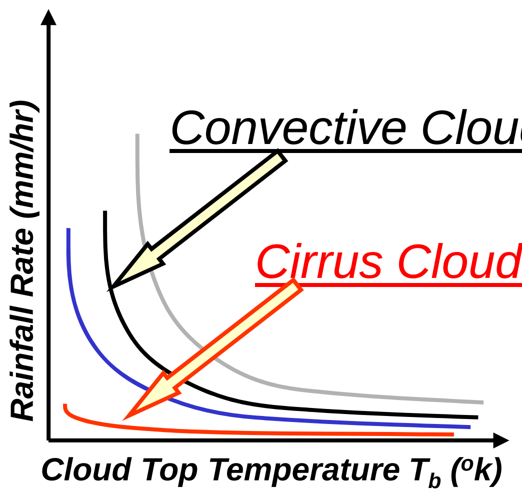
Hong et al., 2004

Cloud Types and Rainfall Distribution

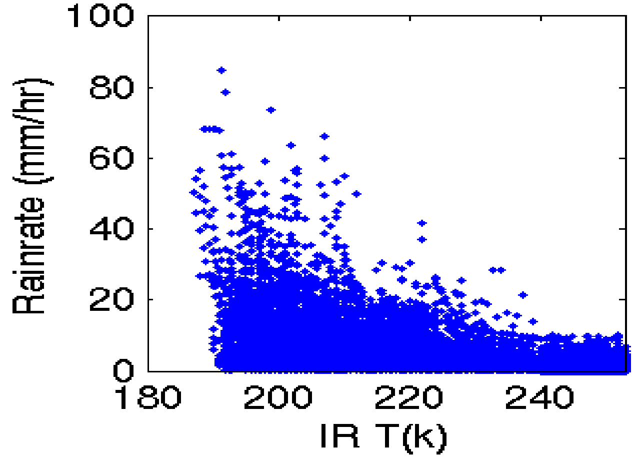
Cloud Type Classification

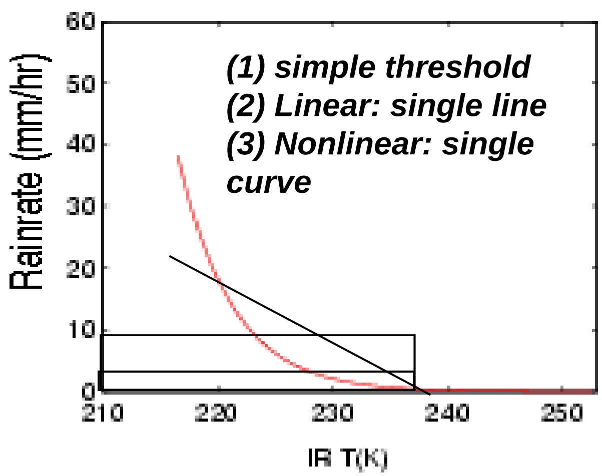


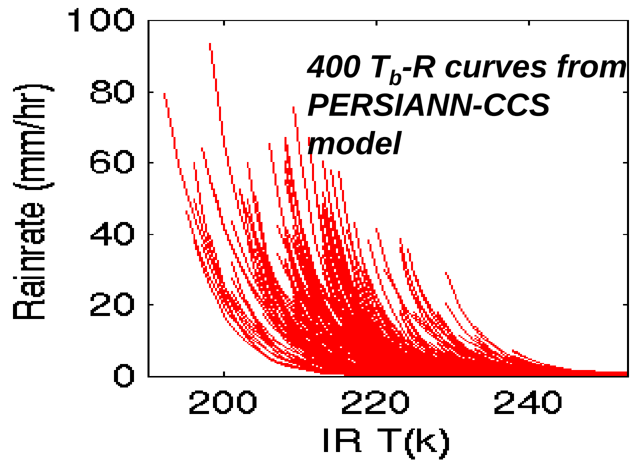
T_b–R relationship



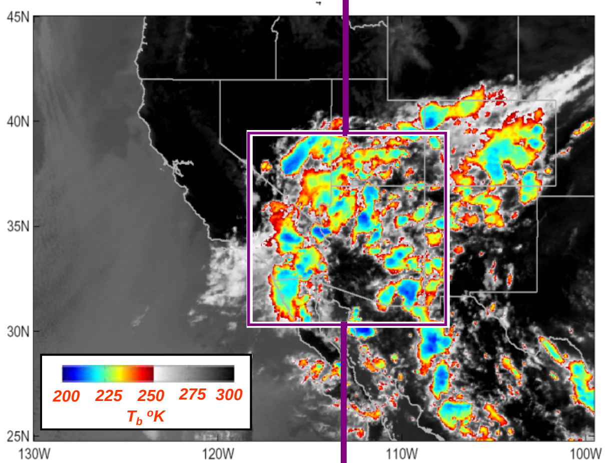
Multiple vs. Single Curve Fitting Models



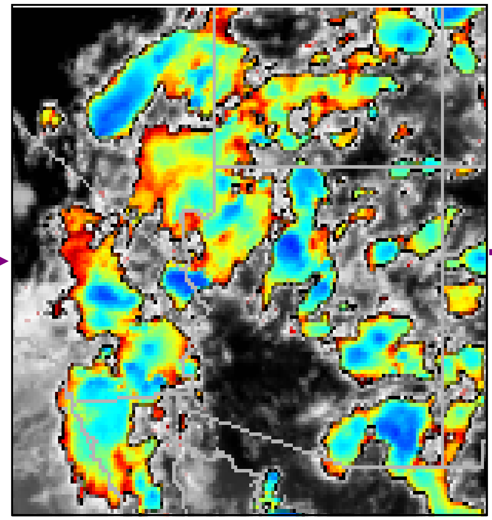


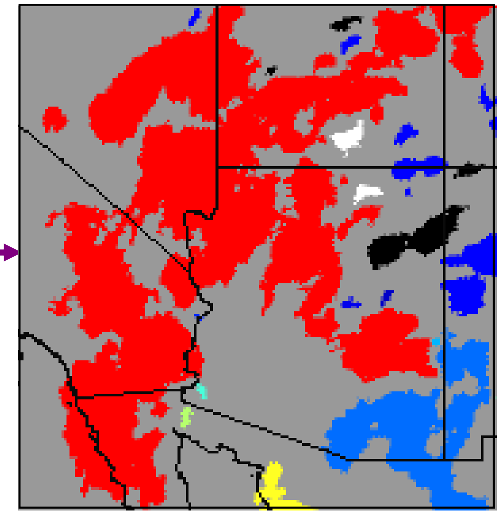


Cloud Image Segmentation

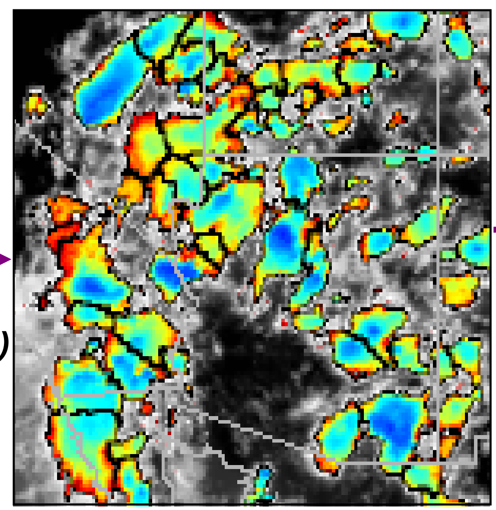


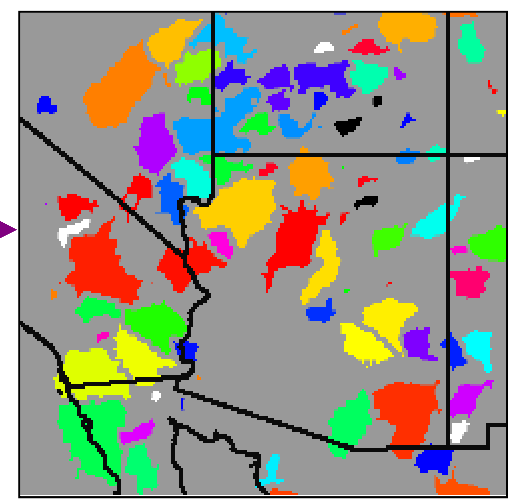
Constant Threshold (253 °K)



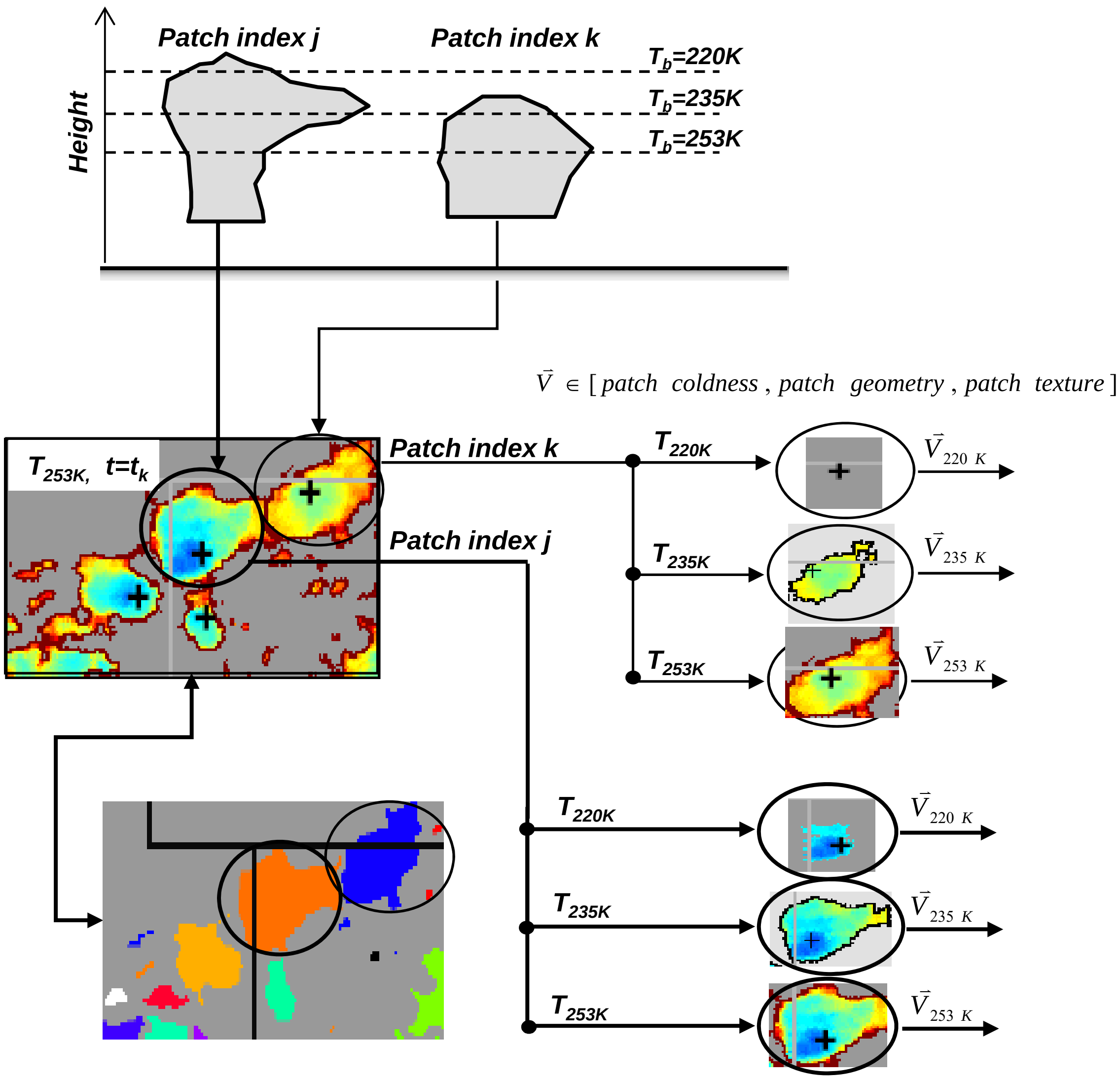


Variable Threshold (Watershed Segmentation) (210°K - 253 °K)

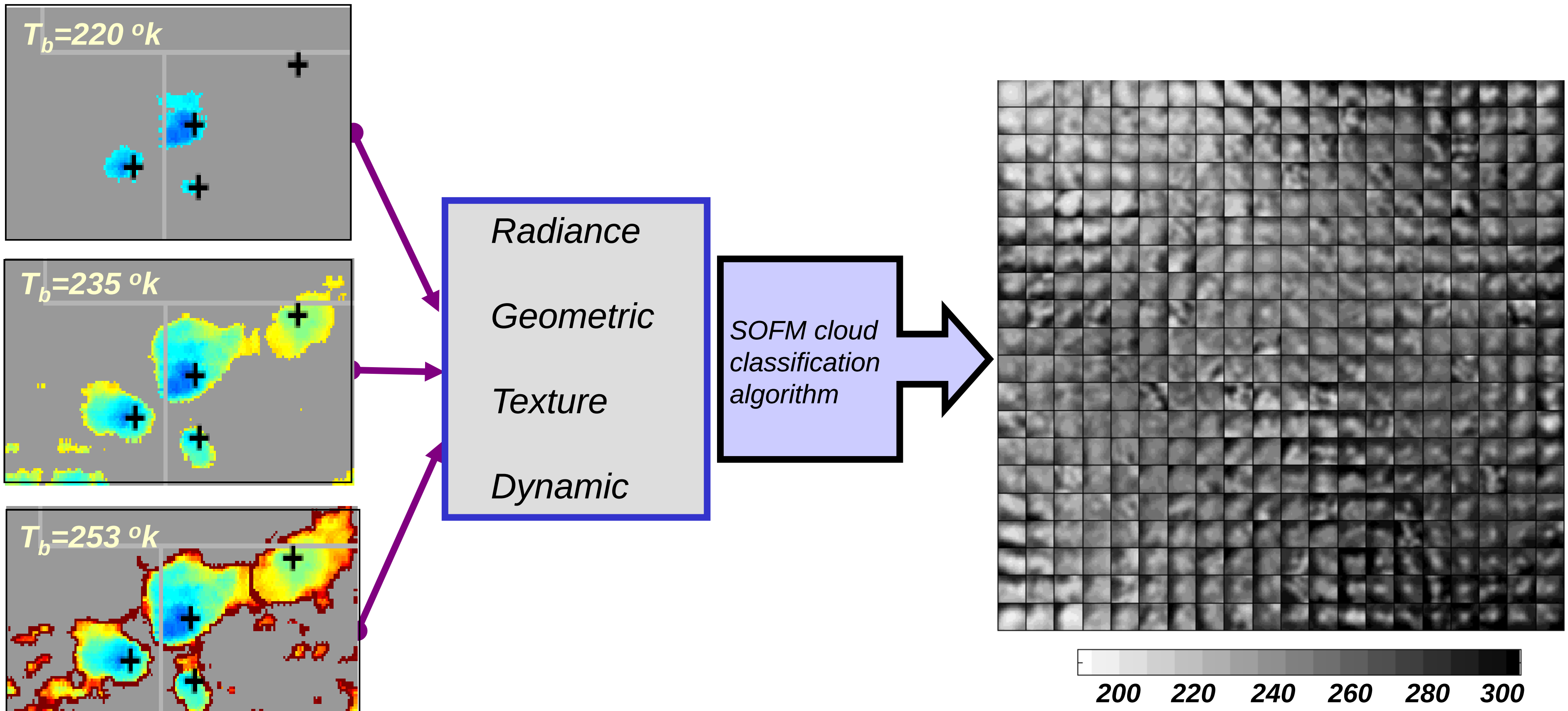




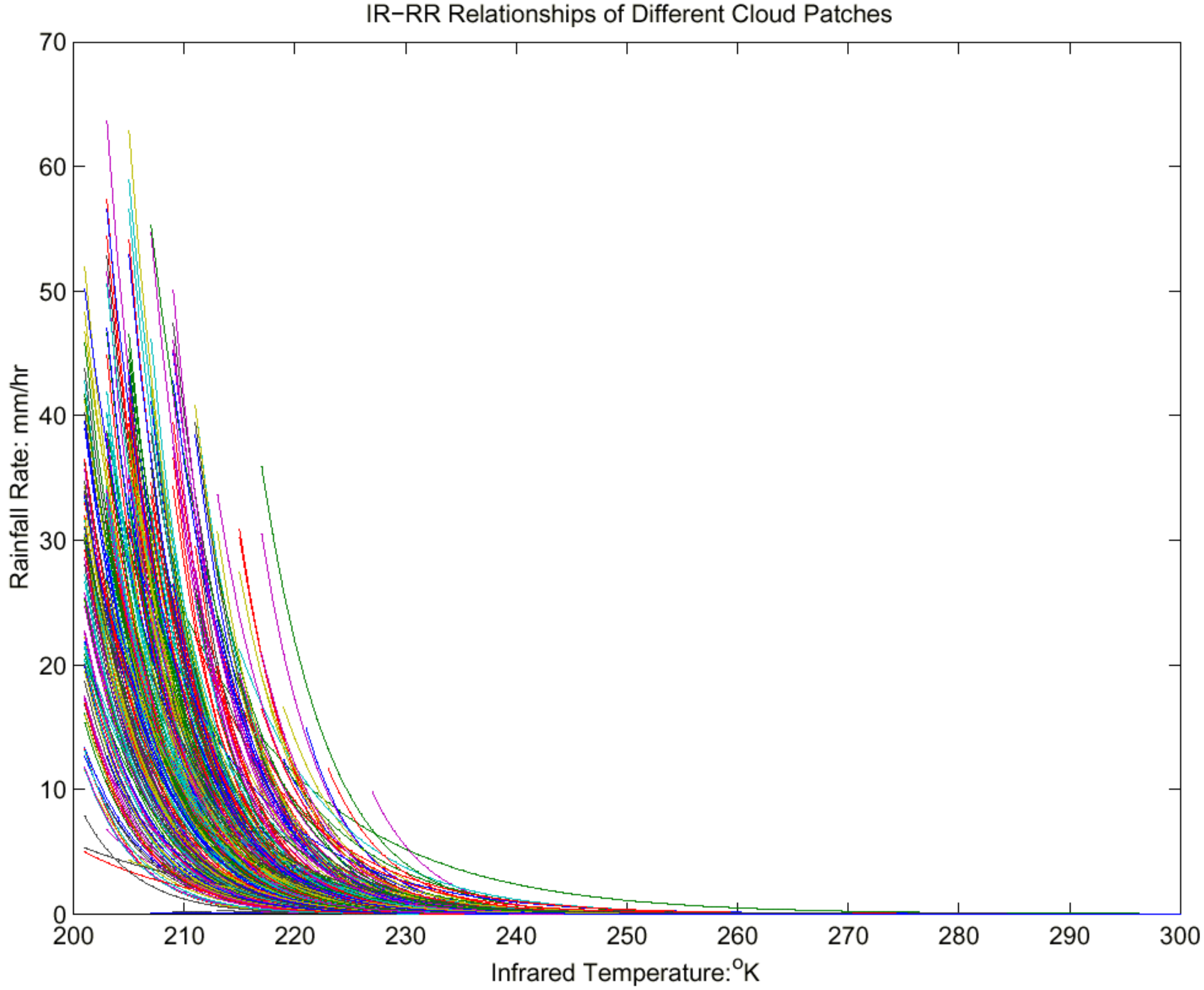
Features Extraction



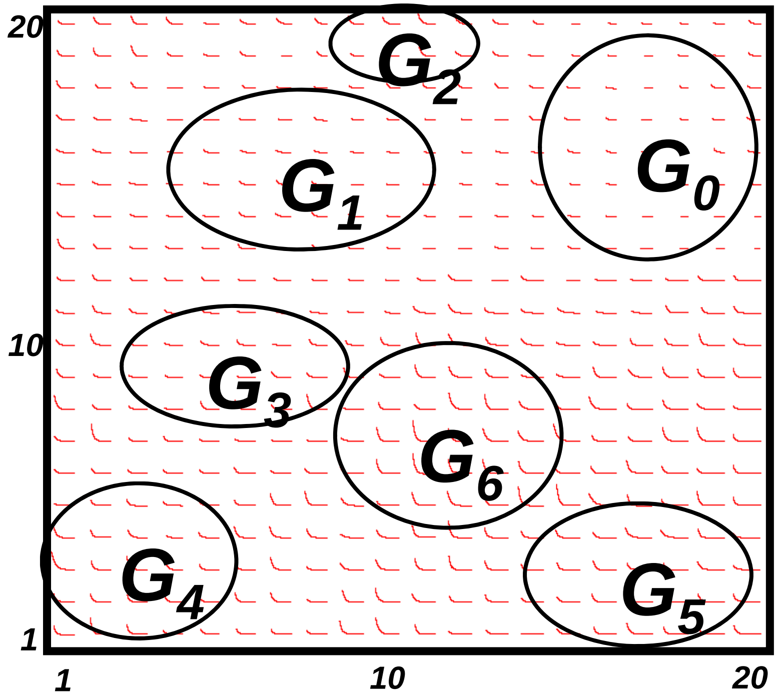
Self-Organizing Feature Map Image Classification

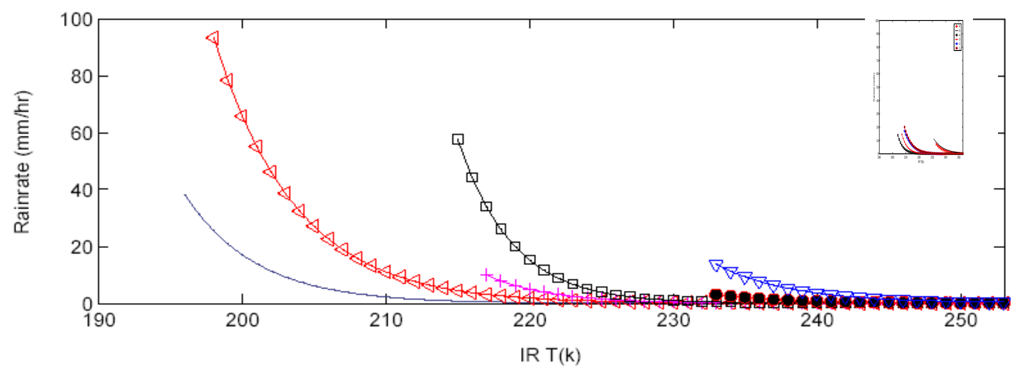


Infrared Cloud Image & Rainfall Mapping



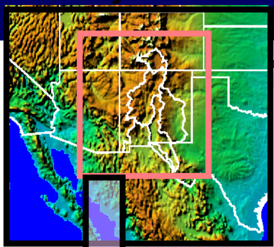
SOFM Classification of Tb(IR)-RR Mapping



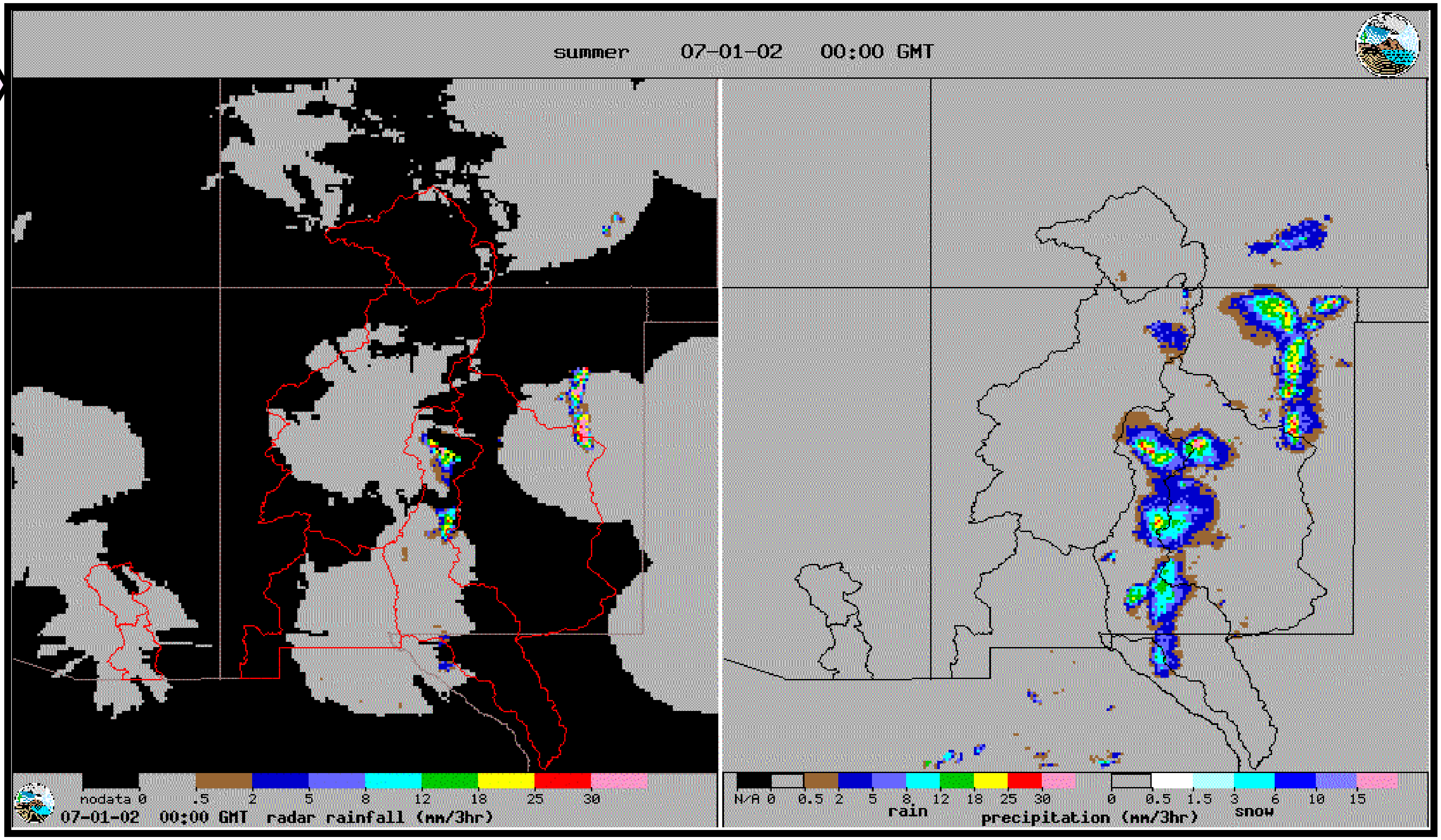


PERSIANN-CCS Precipitation Estimates

Study Area

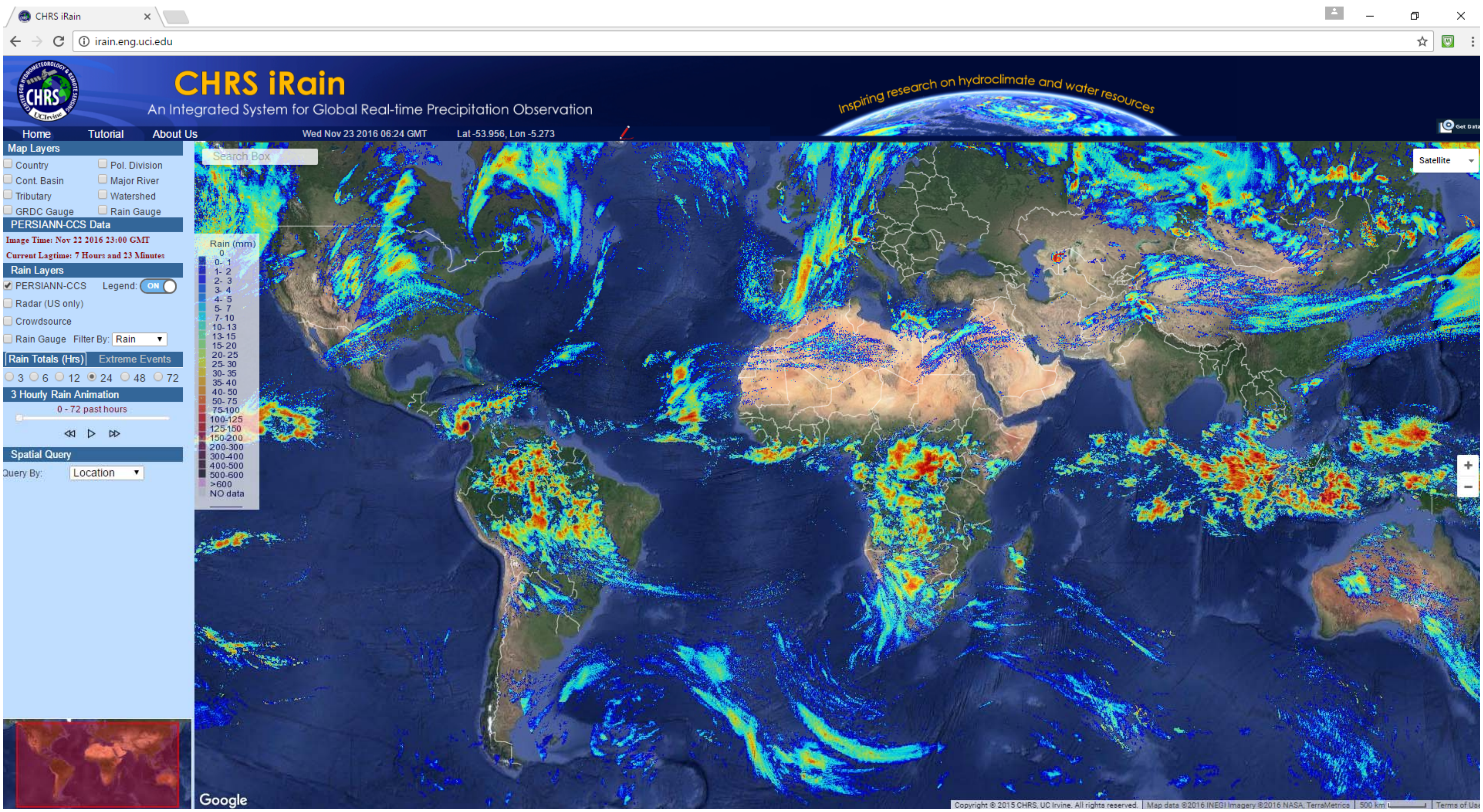


Radar Observation (2 km AGL) **PERSIANN-CCS Estimates**



4km x 4km, 3-hour accumulated precipitation

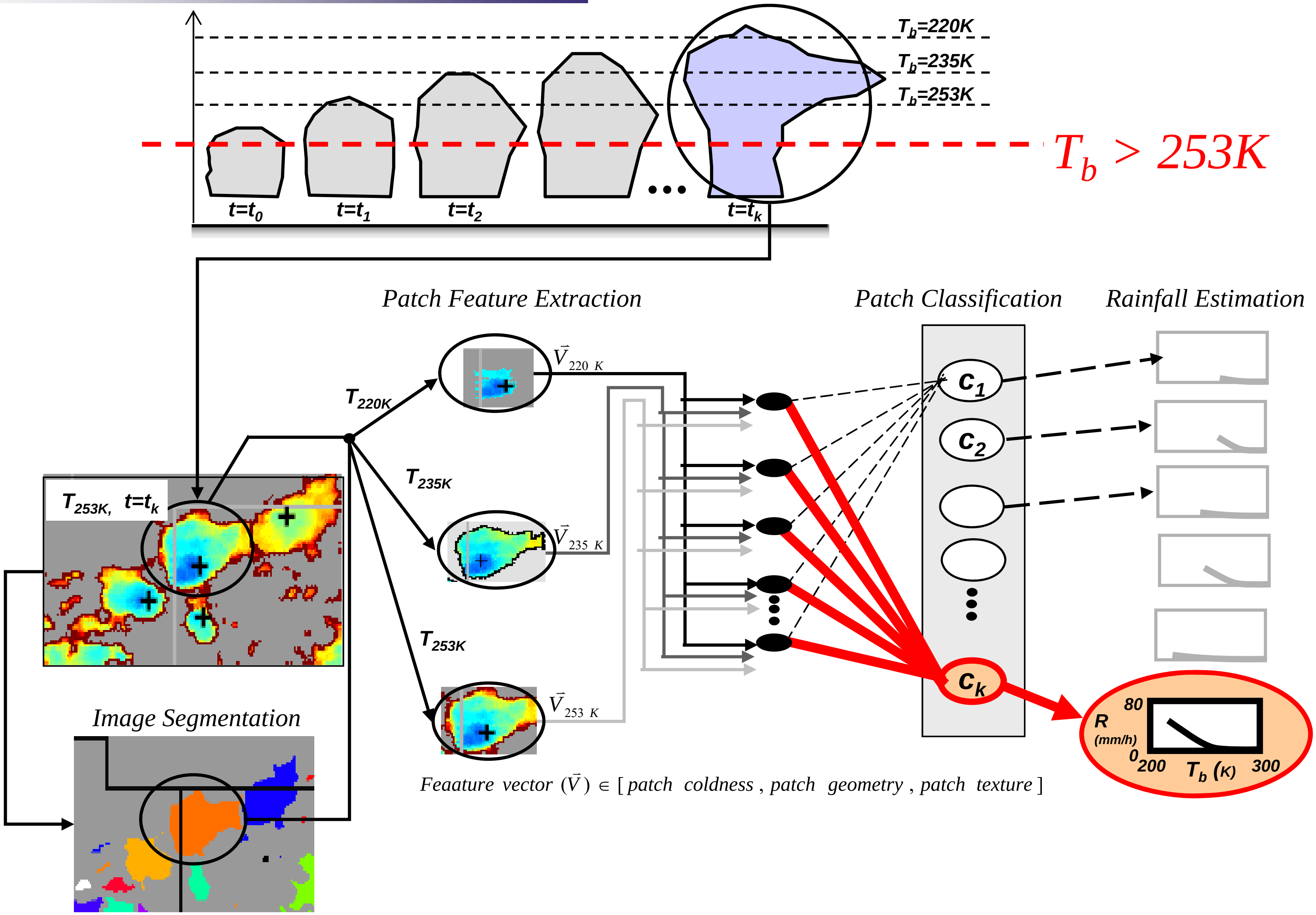
iRain: http://irain.eng.uci.edu/



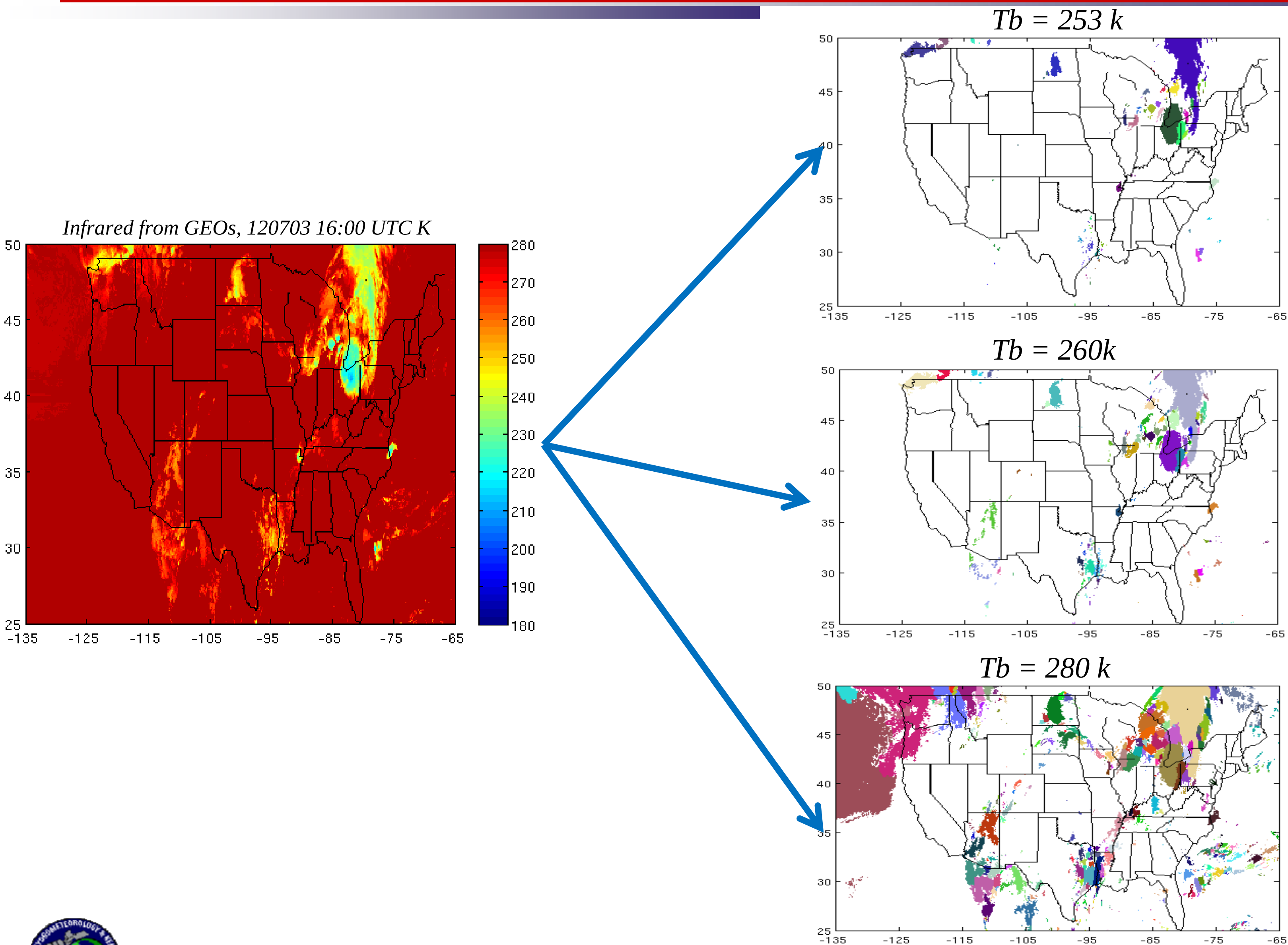
Continue Development

- *Precipitation Estimation from Warm Cloud*
- *Multi-Spectral Information*
- *Two-stage DNN Model*
- *Dynamic Cloud Model and Data Assimilation*

Cover Warm Clouds

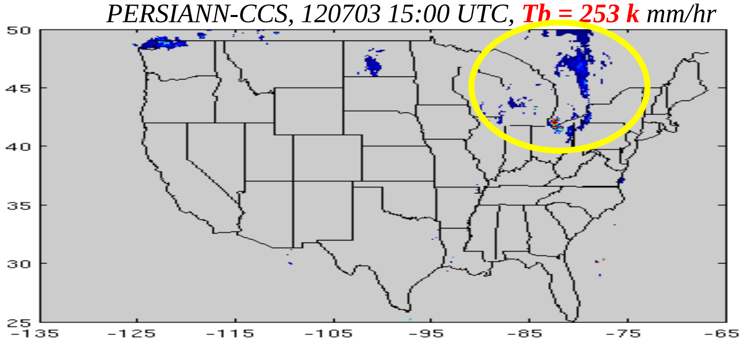


Cloud segmentation

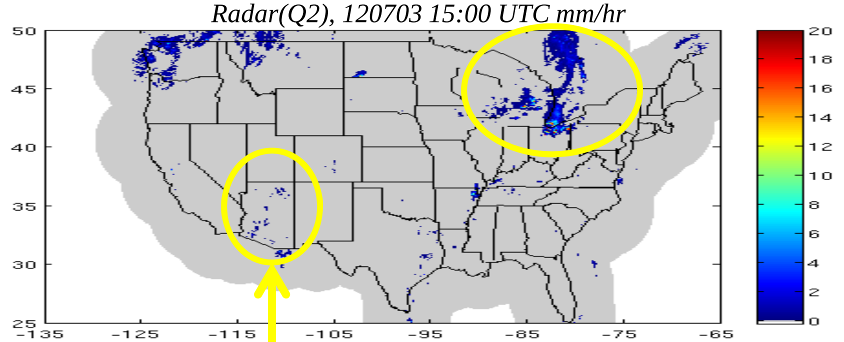


Estimation Improvement(PERSIANN-CCS)

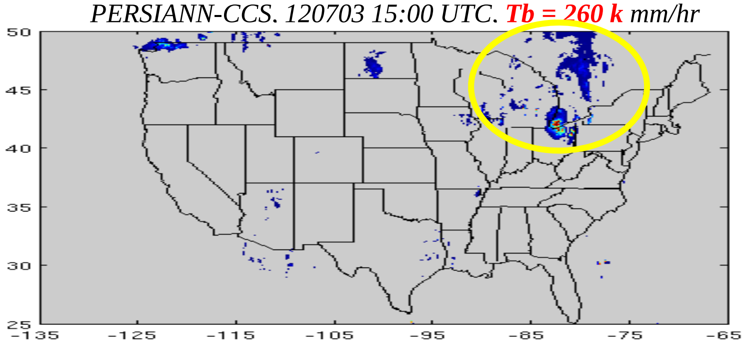
*PERSIANN-CCS, 120703 15:00 UTC, **Tb = 253 k** mm/hr*



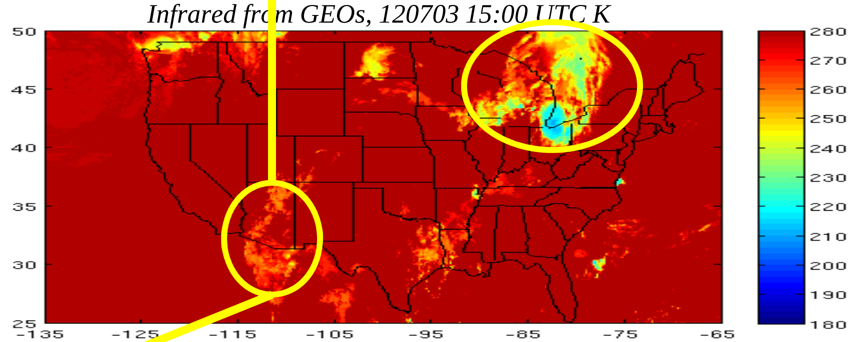
Radar(Q2), 120703 15:00 UTC mm/hr



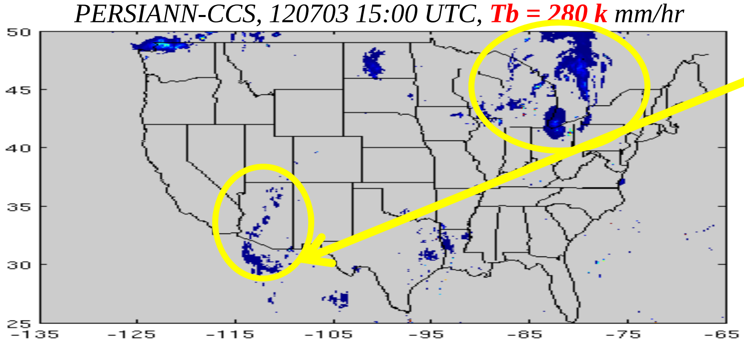
*PERSIANN-CCS. 120703 15:00 UTC. **Tb = 260 k** mm/hr*



Infrared from GEOs, 120703 15:00 UTC K

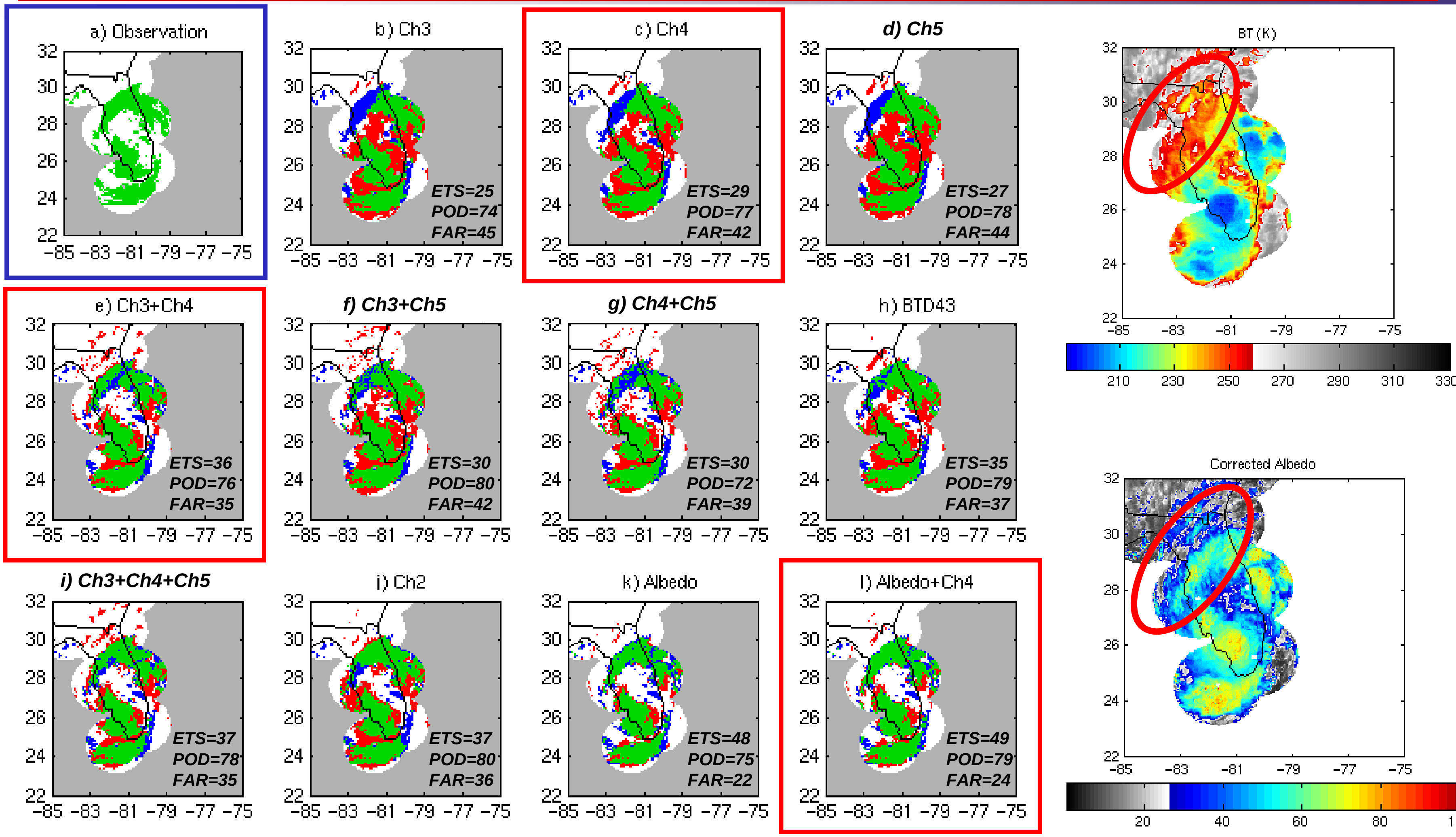


*PERSIANN-CCS, 120703 15:00 UTC, **Tb = 280 k** mm/hr*



# of rainfall captured : TP(t = 253 K) = 7922 pixels
# of rainfall captured : TP(t = 280 K) = 12405 pixels
# of rainfall captured specifically from warm clouds: TP(t > 253 K) = 1084 pixels

Include Other Channels



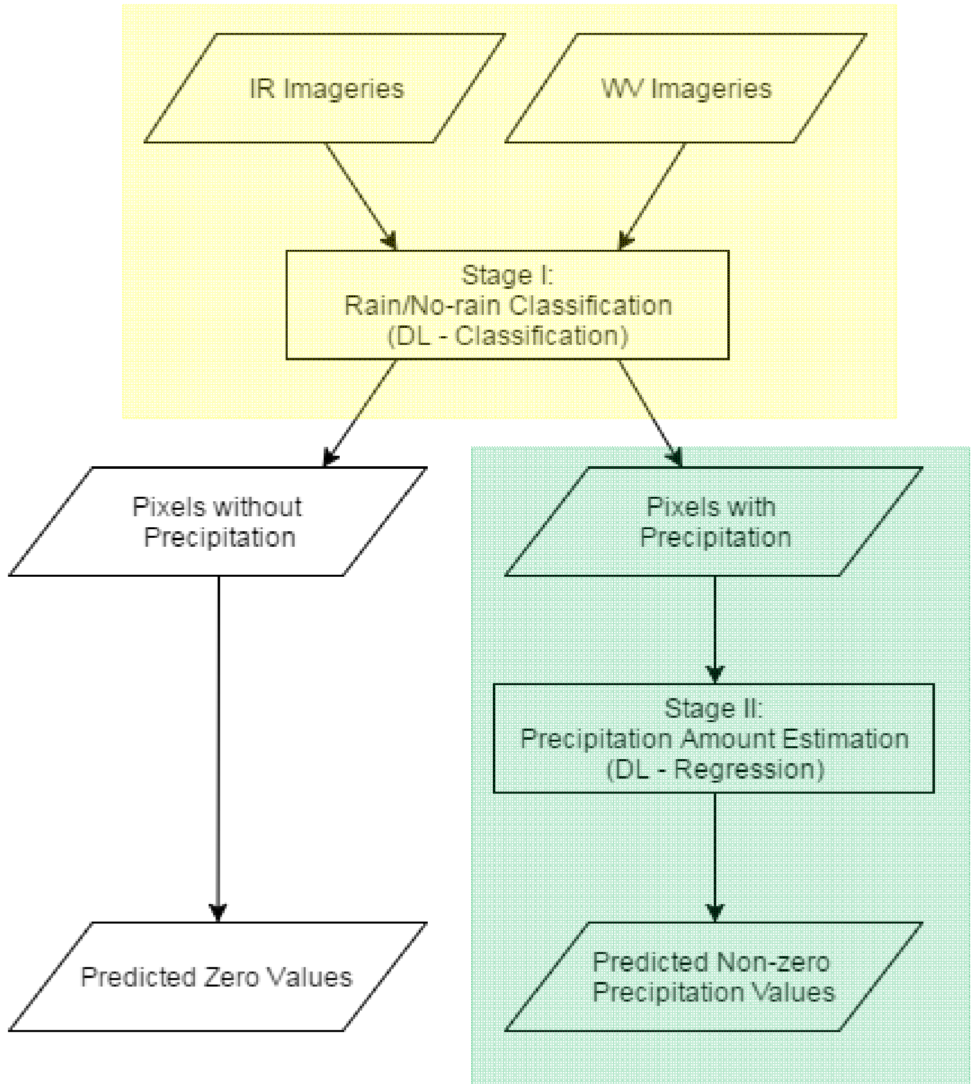
Hit **Under Estimation** **Over Estimation**

Ch 1 : 0.6 µm Ch2 : 3.9 µm Ch3 : 6.5 µm Ch4:10.7µm Ch5 : 13.3µm

Behrangi et. al. JHM, 2017

Two-Stage DNN for Rainfall Estimation

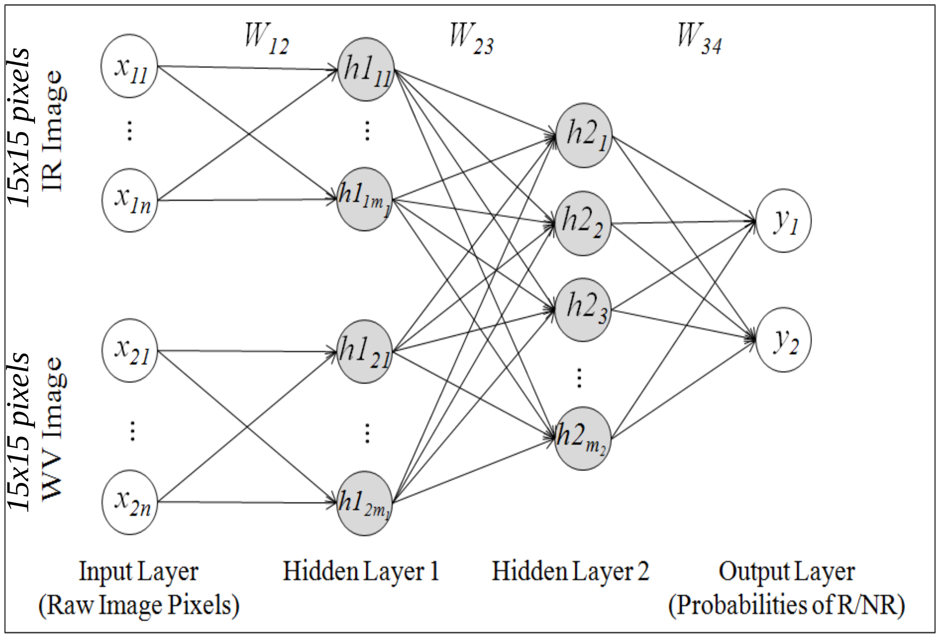
- Two stage process:
  - Rain detection
  - Rainfall estimation
- Inputs:
  - IR & WV channels
- Outputs:
  - Rain/No-Rain
  - Rainfall Rate



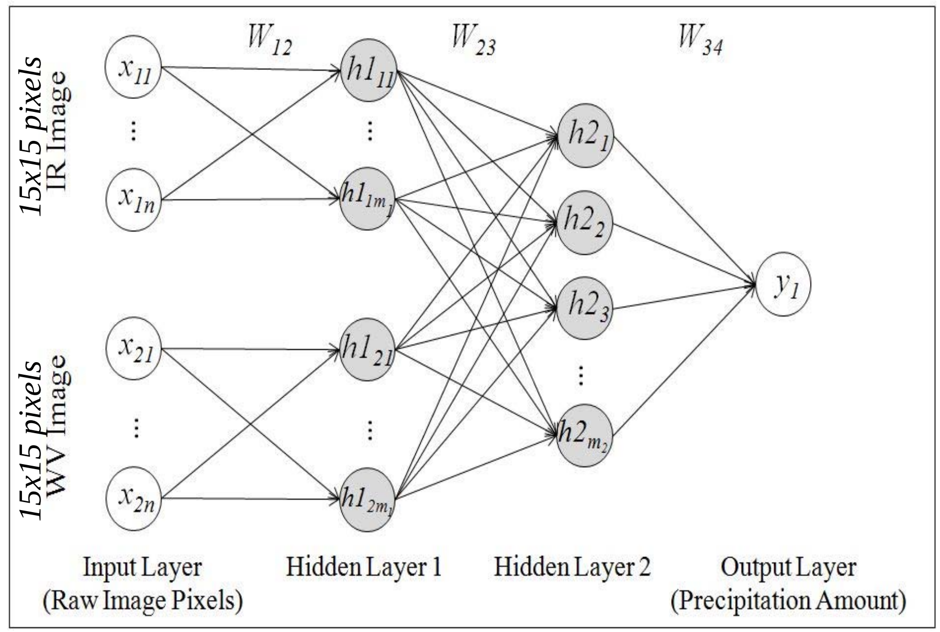
Tao et. al. JHM, 2017

Two-Stage DNN for Rainfall Estimation

Rain Detection

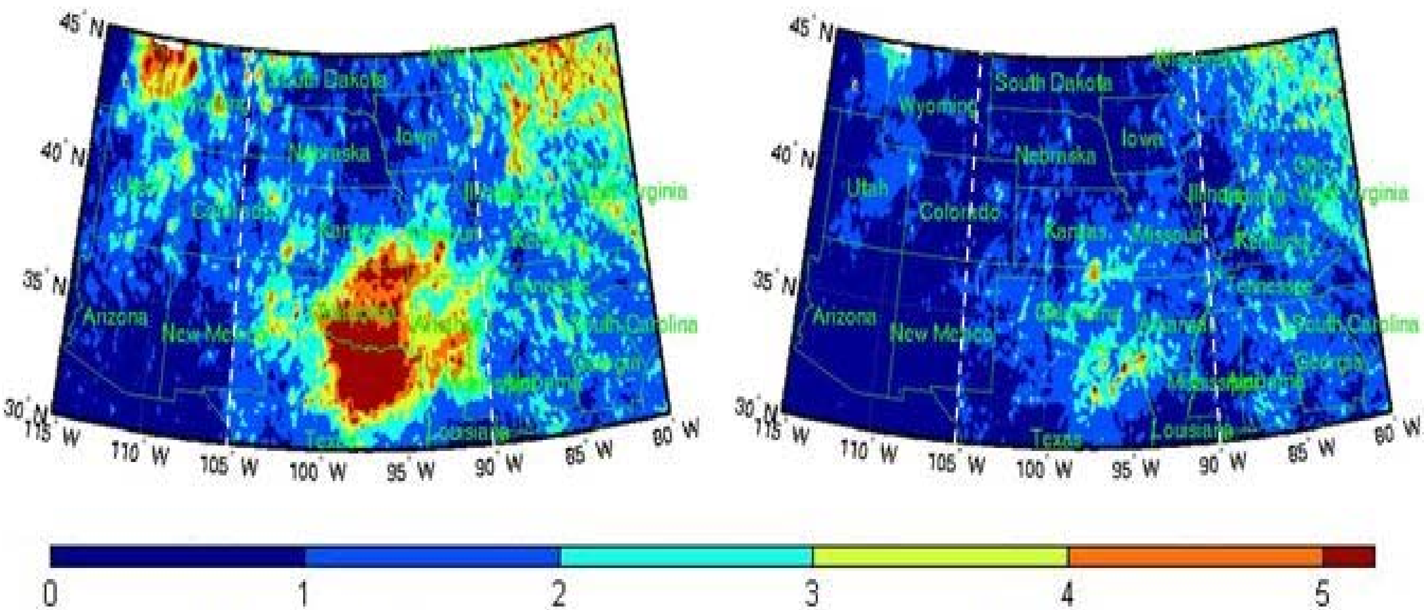


Rain Estimation



Evaluation of PERSIANN-CCS & Two-Stage Model

- *Evaluation of PERSIANN-CCS & Two Stage Model*
- *Reference: Hourly & 0.08º Stage IV Radar Estimation*
- *Spatial Coverage: 30-45ºN, 85-115ºW*
- *Time Period: June—August 2013*



(a) PERSIANN-CCS - Summer

(b) Two-Stage - Summer

Mean Square Error (MSE): (mm/hr)²

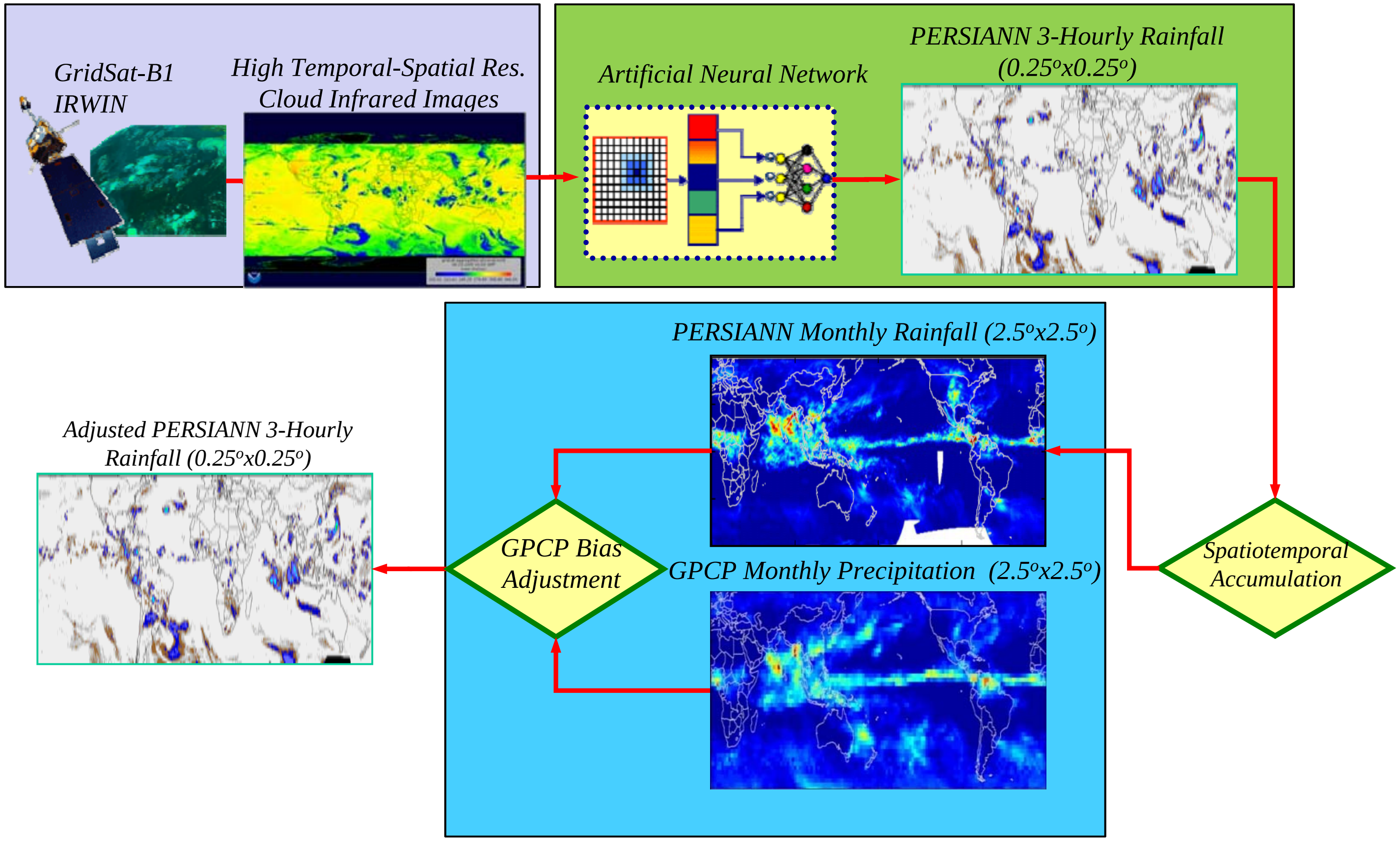
PERSIANN-CDR

Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks -Climate Data Record

Reconstruction of more than 30 years of daily precipitation data (1983 ~2017)

PERSIANN-CDR

- *PERSIANN estimation at 0.25^o every 3-hr from GridSat B1 IRWIN*
- *Monthly accumulation and bias adjusted using GPCP monthly estimation at 2.5^o*
- *Bias adjustment of short-term 3-hr estimation*

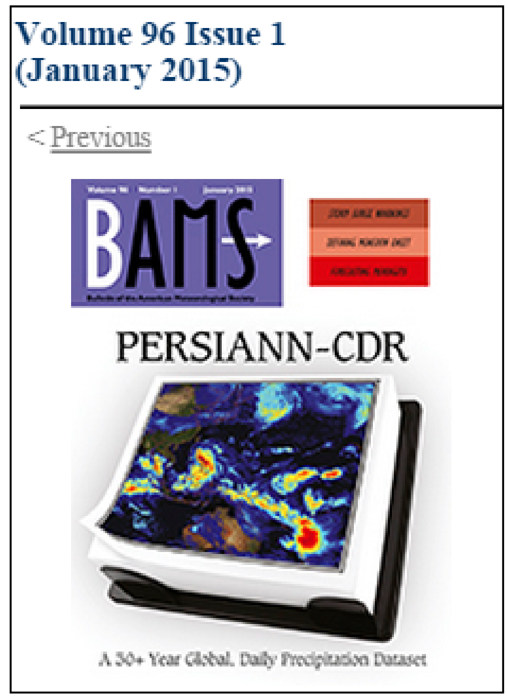


Ashouri et al, BAMS, 2015

PERSIANN -CDR

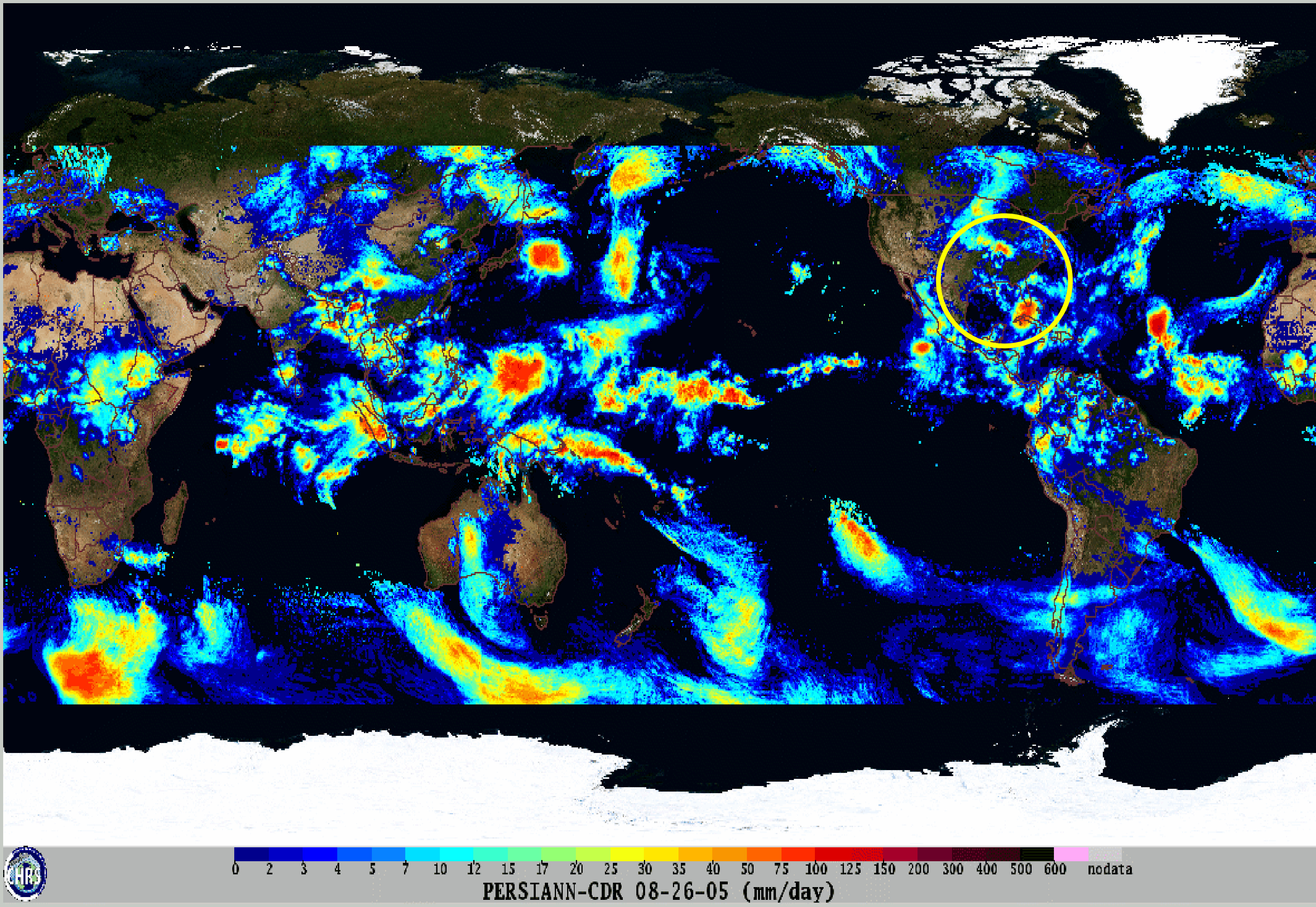
http://www.ncdc.noaa.gov/cdr/operationalcdrs.html

- *Daily Precipitation Data*
- ***Data Period: 1983~2016***
- ***Coverage: 60^{o}S ~ 60^{o}N***
- ***Spatial Resolution: 0.25^{o}x0.25^o***

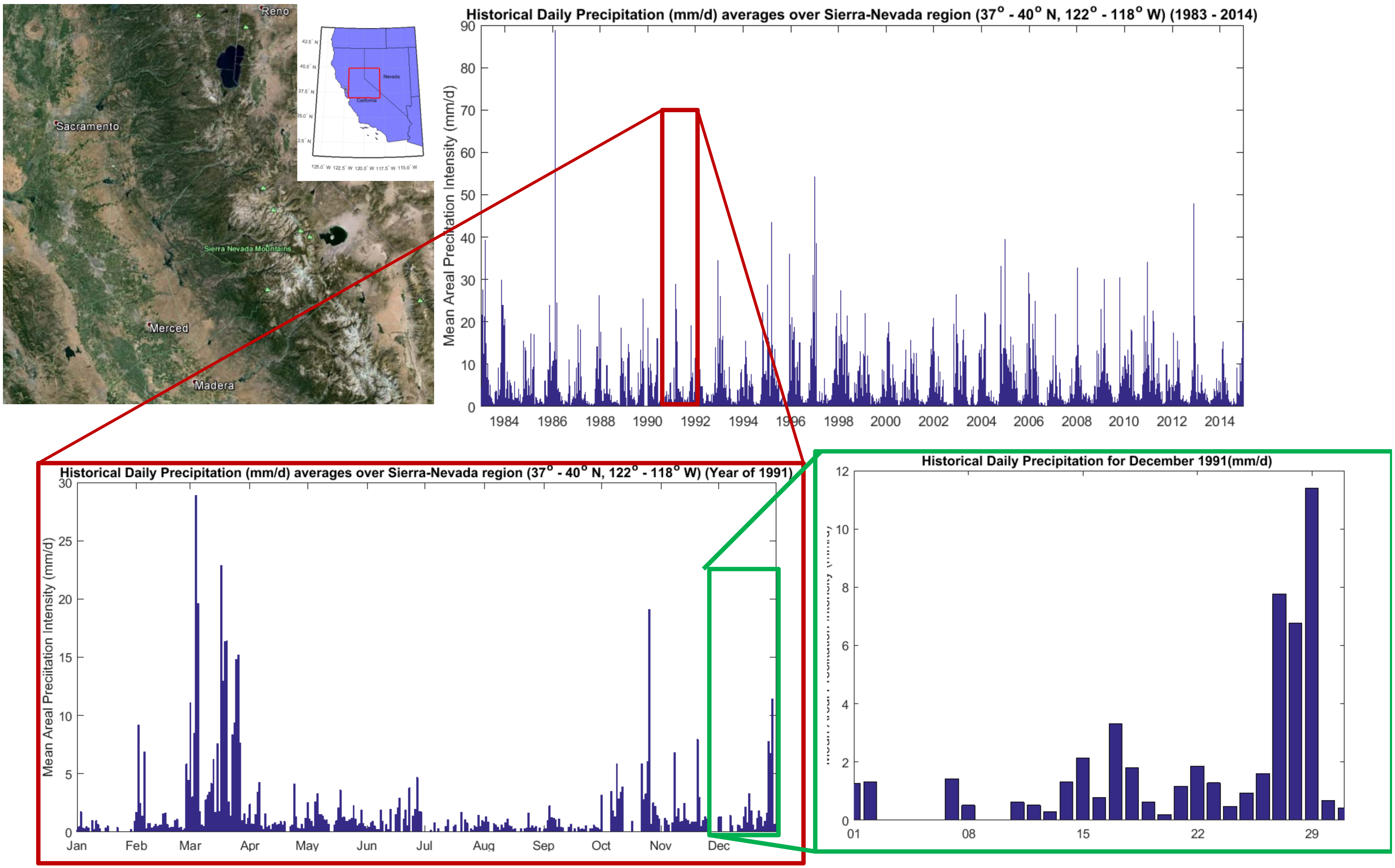


Ashouri, Hsu et al., BAMS, 2015.

PERSIANN-CDR daily rainfall During Katrina 2005

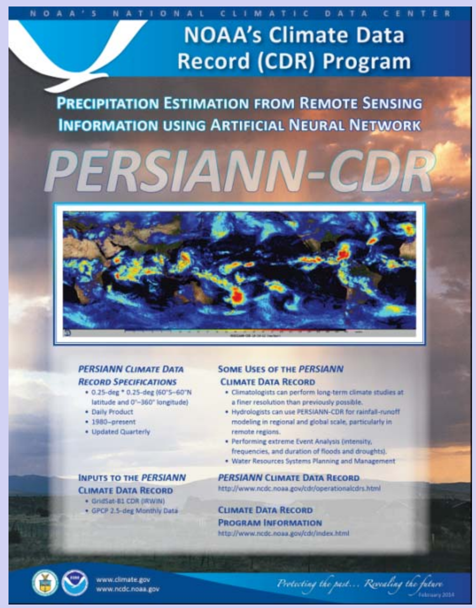


Sierra-Nevada Mountain (California and Nevada)



PERSIANN-CDR:

Potential Usefulness for Model testing

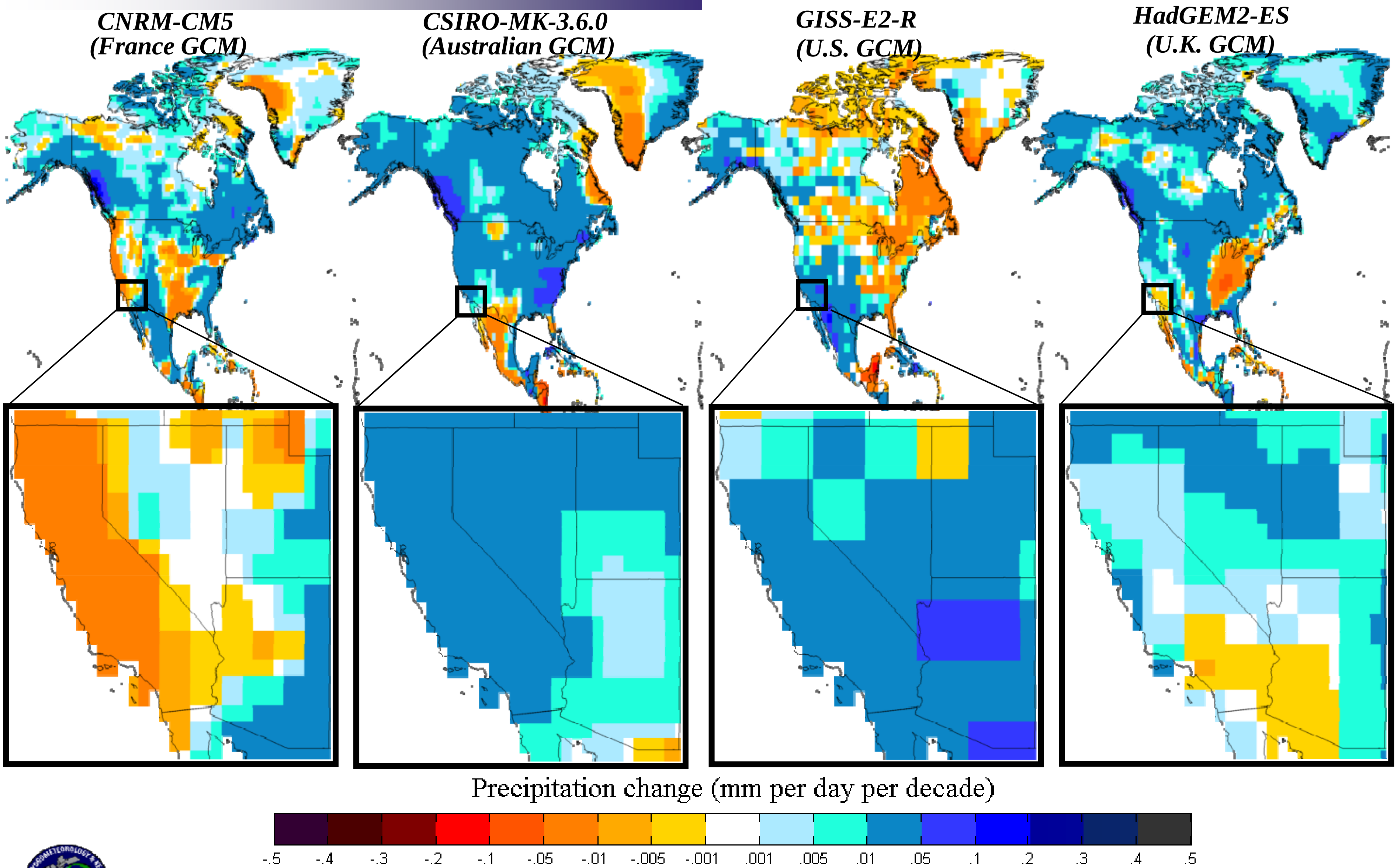


Ashouri et al., BAMS 2015

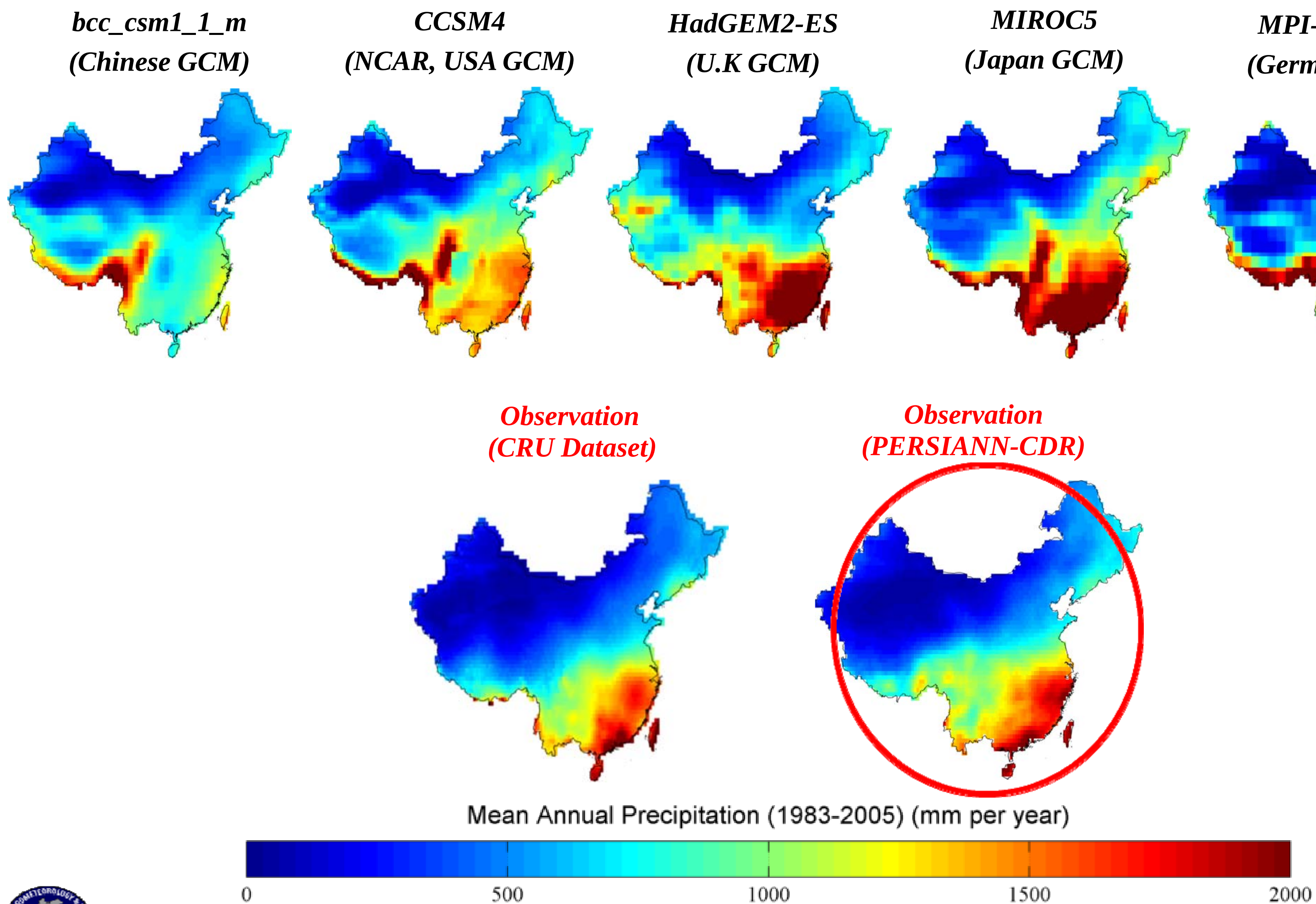
Future Modeling Scenarios – IPCC AR5

RCP2.6

Time period: 2006-2099

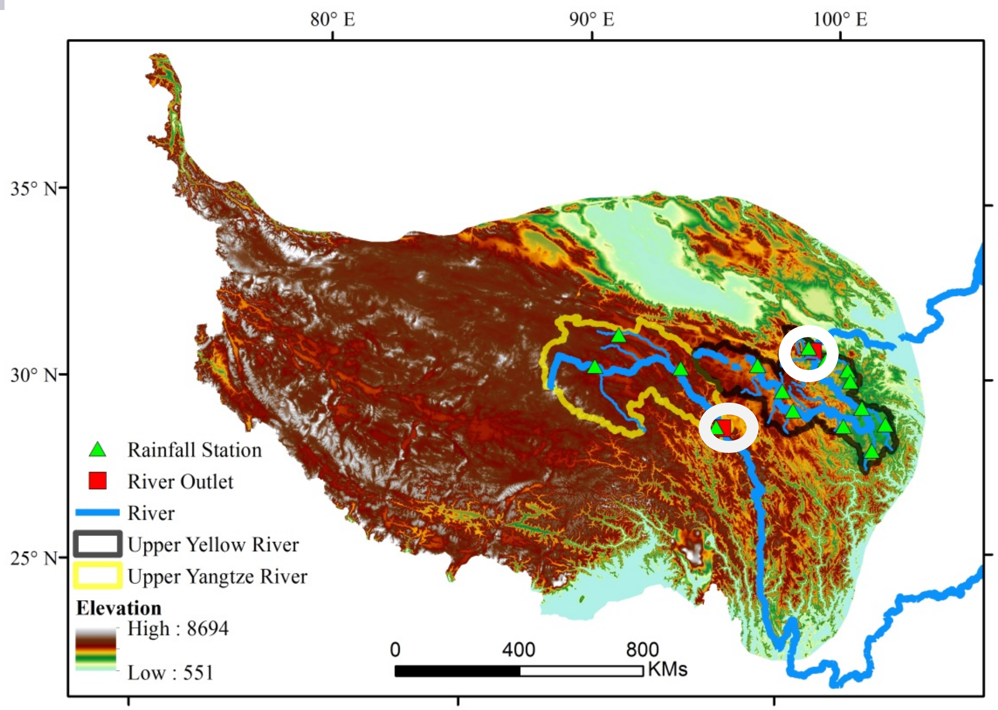


CMIP5 Models' historical simulation (1983-2005): CHINA



Center for Hydrometeorology & Remote Sensing, University of California, Irvine

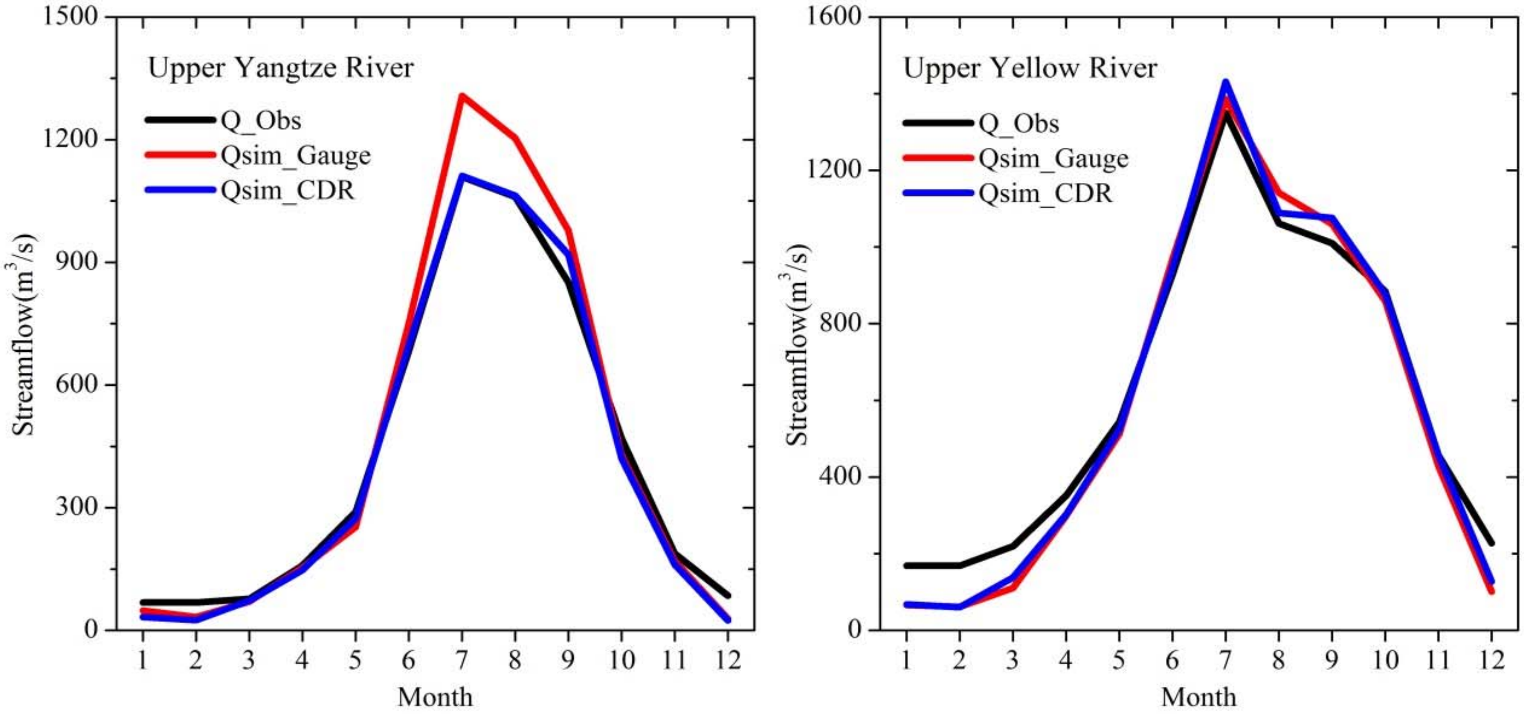
PERSIANN-CDR Evaluation in Tibetan Plateau



The selected river basins (the upper Yellow River and upper Yangtze River Basin) on the Tibetan Plateau and location of rainfall stations and river outlets.

Xiaomang Liu & Tiantian Yang, 2015

PERSIANN-CDR Evaluation in Tibetan Plateau



Comparisons of the simulated and observed average monthly streamflow driven by the gauge-based precipitation and PERSIANN-CDR precipitation for the two basins from 1983 to 2012.

Conclusions

- ***Remote sensing precipitation is a way to extend rainfall estimation to regions where ground observations are limited.***
- ***Operation requirement of precipitation data:***
  - *High quality near real-time estimation is needed for hydrologic applications*
- ***Precipitation Climate Data: PERSIANN-CDR:***
  - *A more than 30 year daily precipitation data is introduced.*
  - *PERSIANN-CDR is a very useful source for hydro-climate studies.*

Who Uses CHRS Products

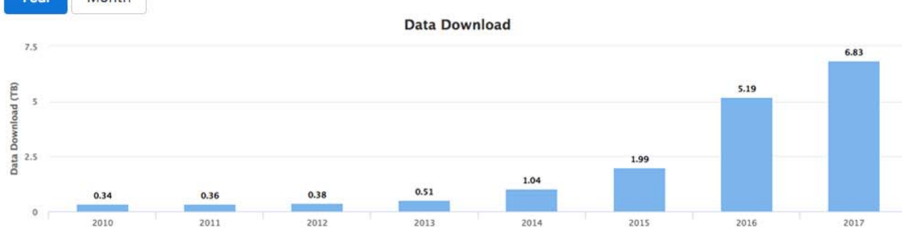
CHRS User Statistics

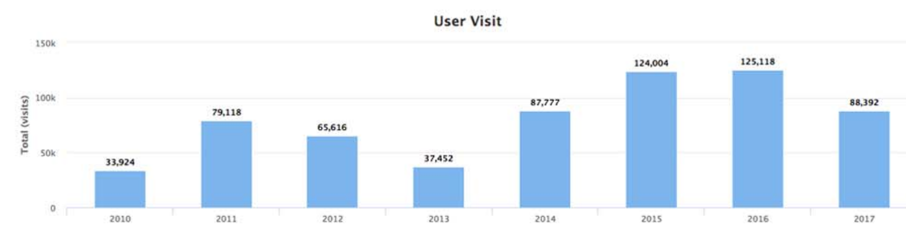
Overall | CHRS Homepage | G-WADI | iRain | RainSphere | Data Portal

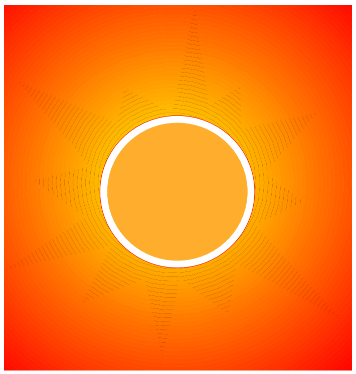
Total Visits: 641,401 since 01-Jan-2010
Countries: 198 countries registered

#	Country	Total Visits
1	United States	403,254
2	China	41,383
3	Thailand	25,161
4	France	21,056
5	Japan	16,079
6	Germany	13,280
7	Iran, Islamic Republic Of	11,801
8	Israel	9,915
9	Ukraine	7,753
10	Peru	7,440
11	Canada	6,123
12	Viet Nam	5,754
13	Poland	5,648
14	Romania	4,539
15	Netherlands	4,334

Year | Month







Thank you for your attention!