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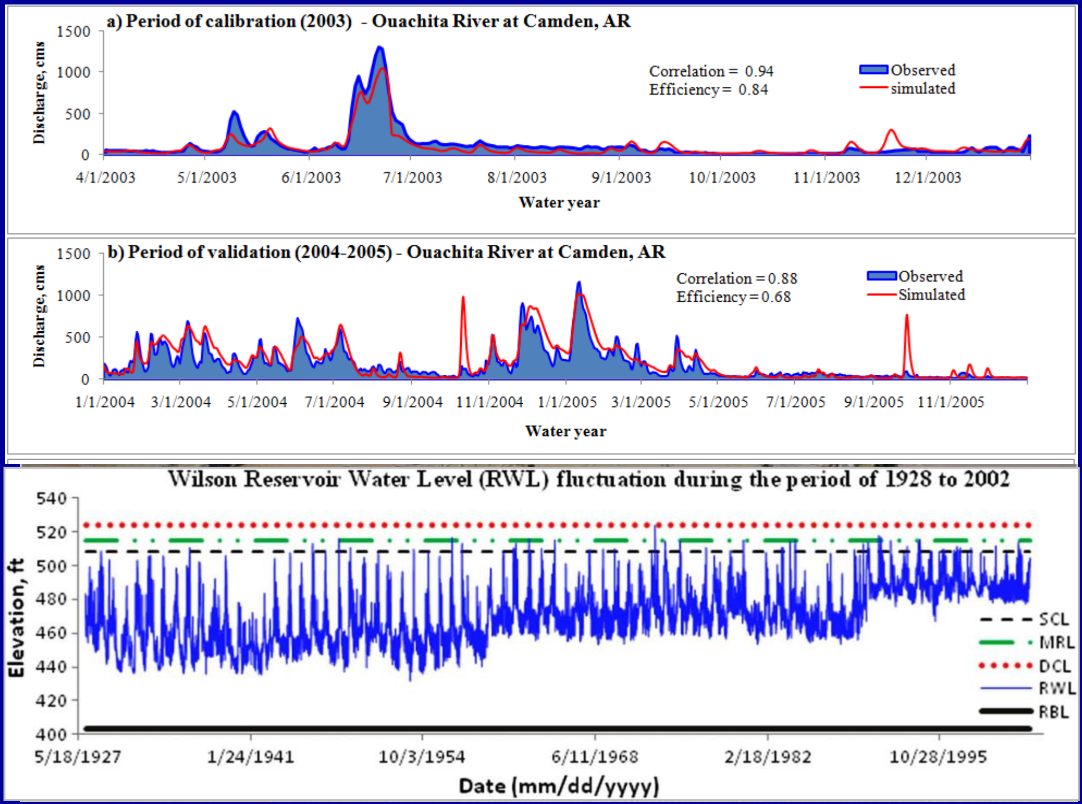
MAKING SATELLITE PRECIPITATION PRODUCTS WORK FOR HYDROLOGIC APPLICATION

Part of my PhD work at Tennessee Technological University (TTU)
2008 - 2013

1. Introduction

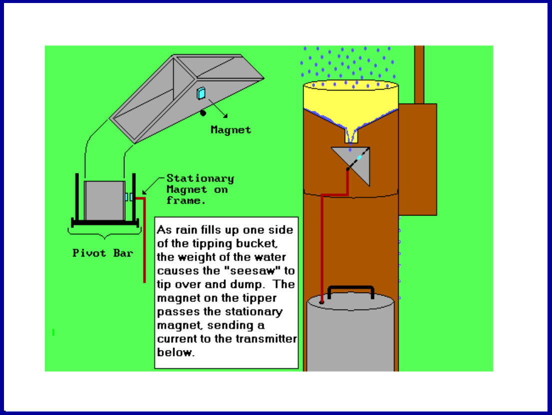
- Accurate rainfall estimation is critical for many applications
  - Climate forecasts and studies
  - Agricultural forecasts
  - Natural hazards
  - **Hydrologic application**



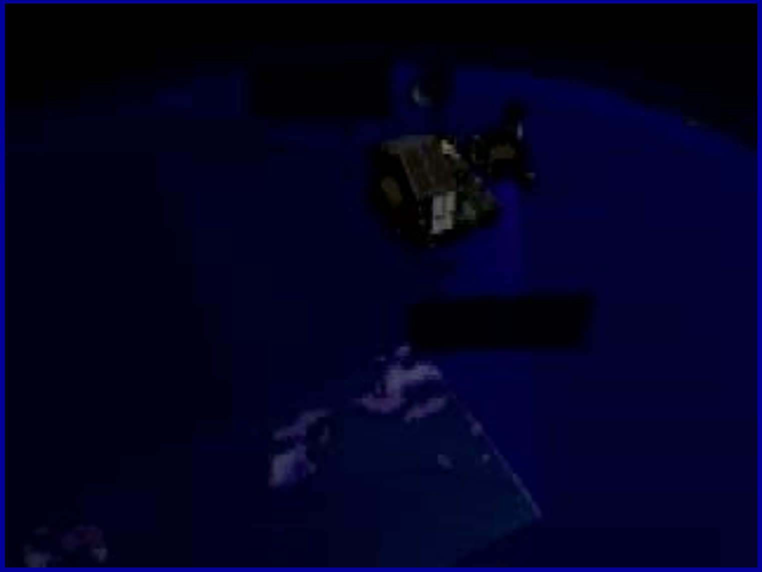
Source: Gebregiorgis and Hossain, 2010 (JHE, 17(1); 2011 (JHM, 12)

Rainfall measurement systems

– Rain gauges/radar – on the ground



– Remote sensing – from space



Source: http://earthobservatory.nasa.gov/Features/TRMM/

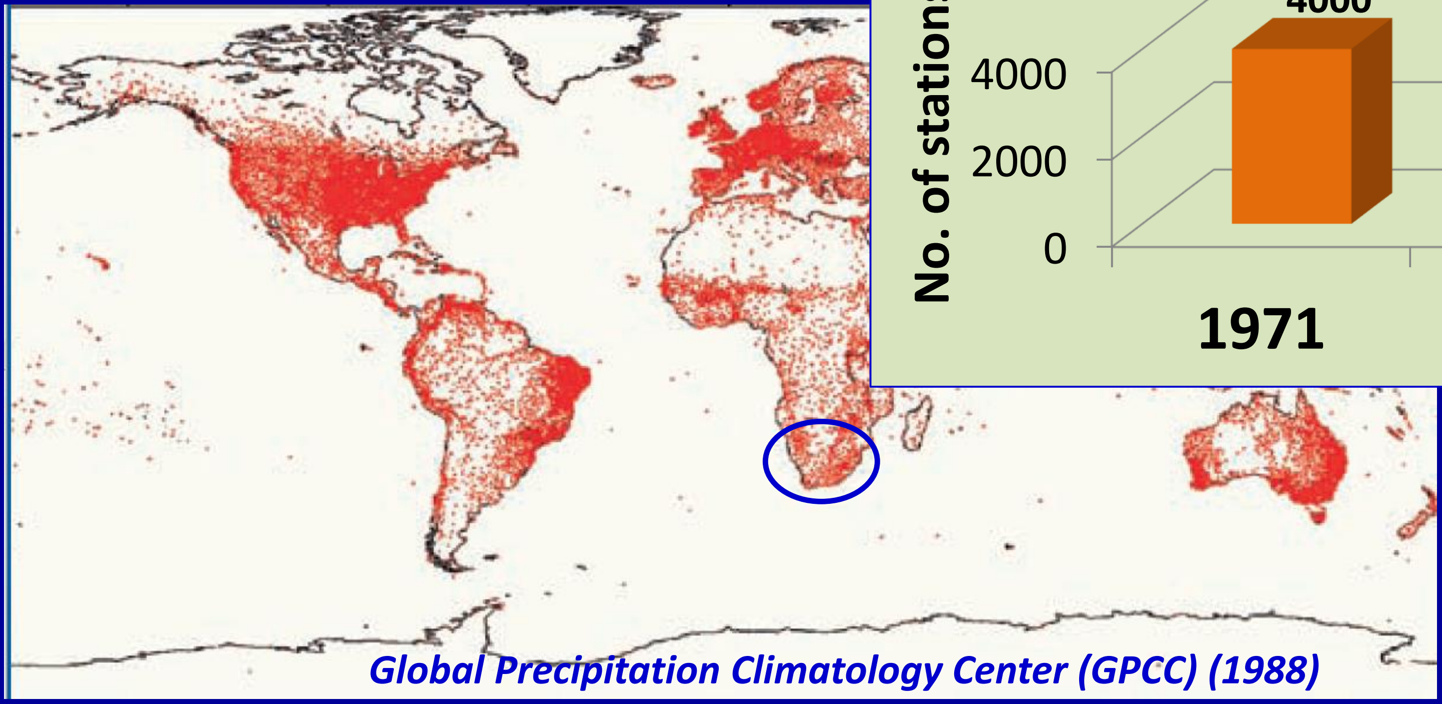
Satellite rainfall estimate

- Remote sensing based rainfall estimate has experienced tremendous progress
- Satellite rainfall estimate:
  - addresses spatial and temporal variability issue
  - covers both the terrestrial and water bodies of the earth
  - provides a continuous & consistent measurements
  - evades high operational cost of in situ networks
  - delivers information on near real-time bases
  - avoids the hurdle of geo-political boundaries issues

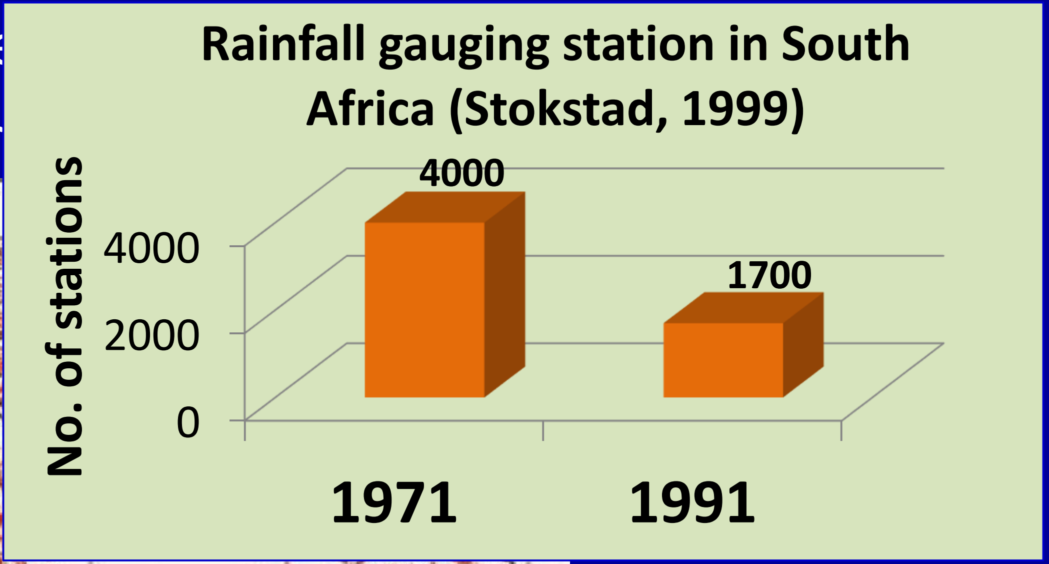
2. Problem Statement

Challenges in hydrologic modeling – related to ground based measurement

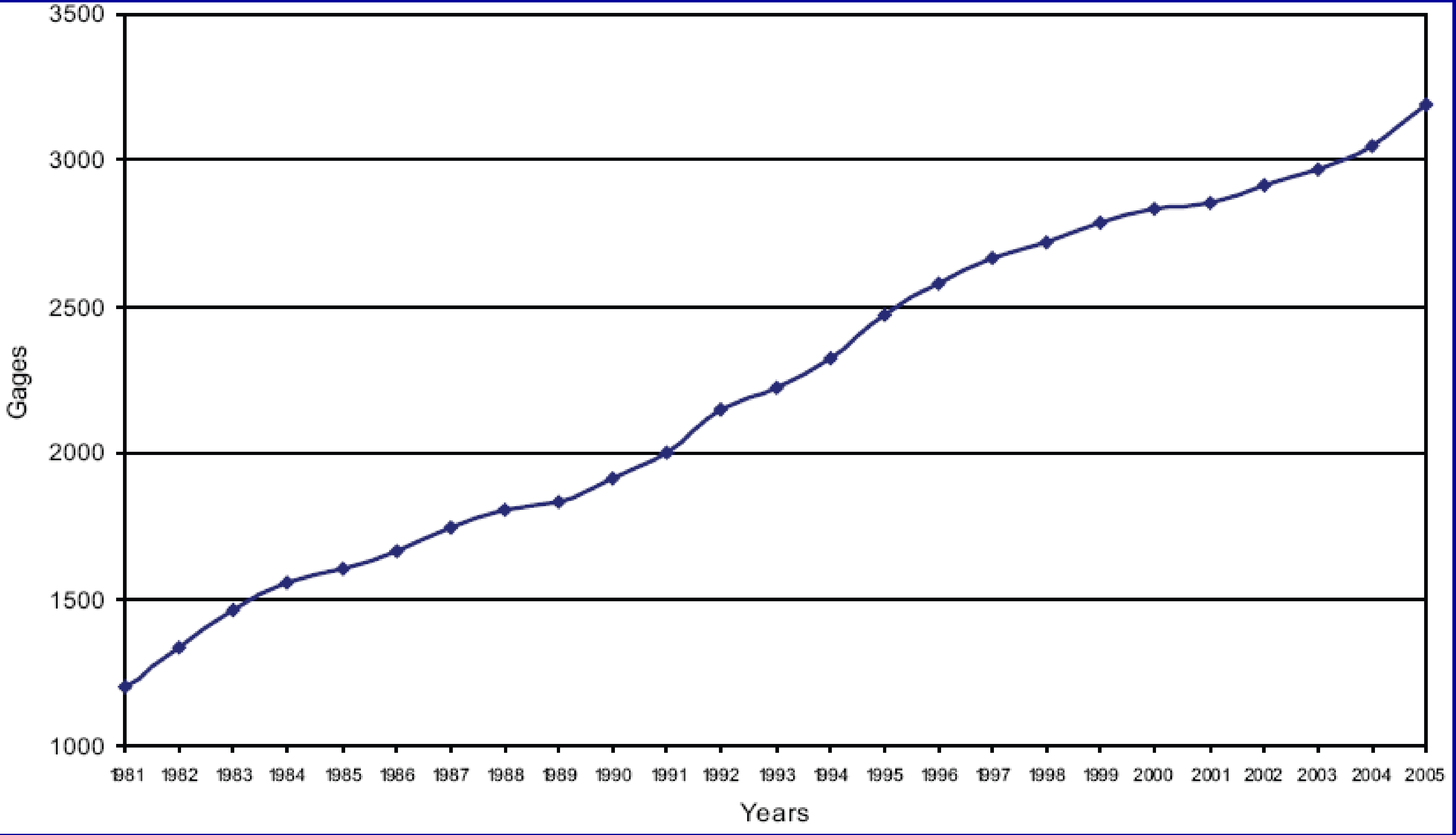
- surface observation networks are sparse, & declining (both rain gauge and streamgauge)
- lack of information on wate
- Point measurement – not r



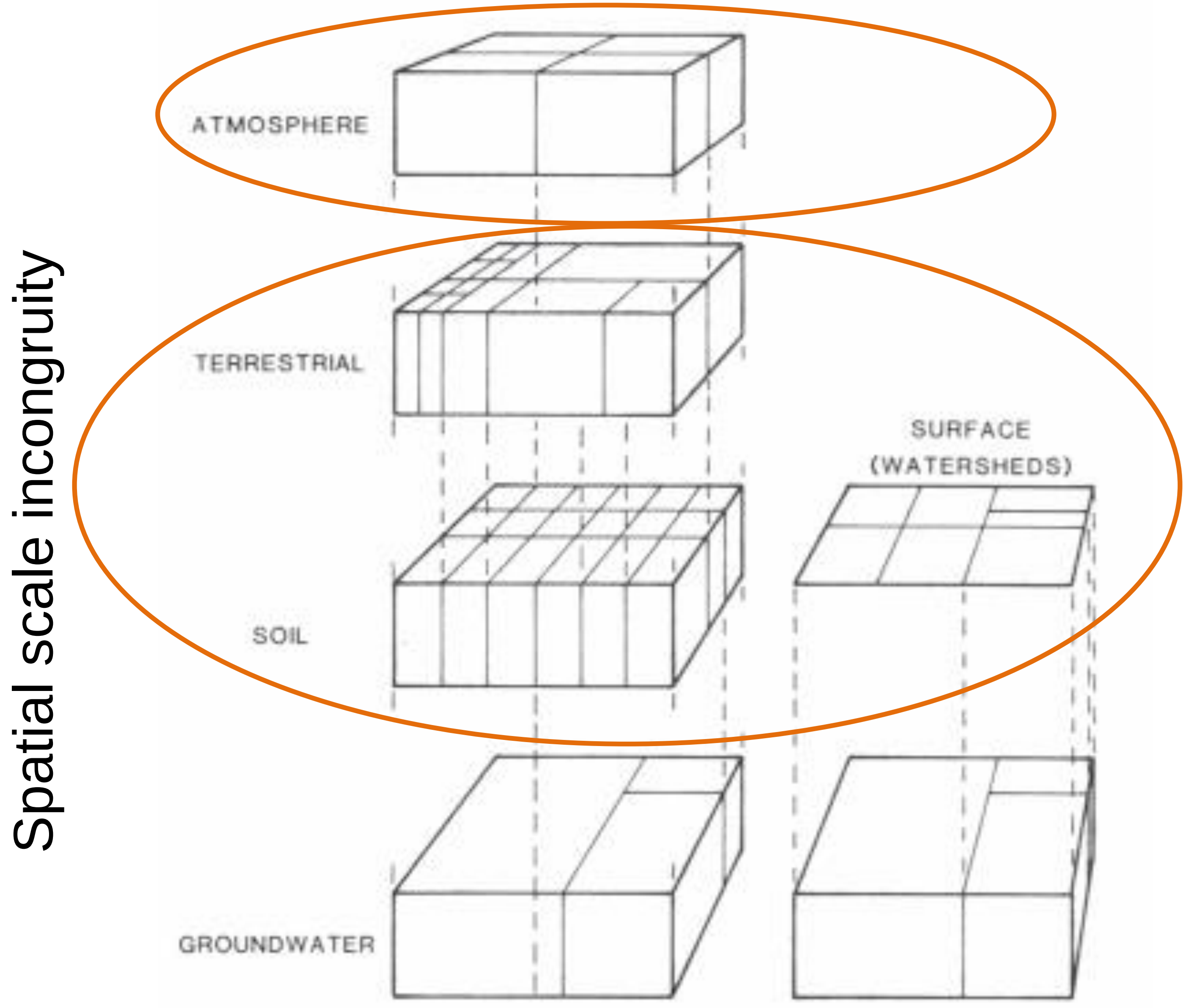
Global Precipitation Climatology Center (GPCC) (1988)



Cumulative loss of USGS stream gauges with 30 or more years of data: 1980-2005 (USGS, 2006)



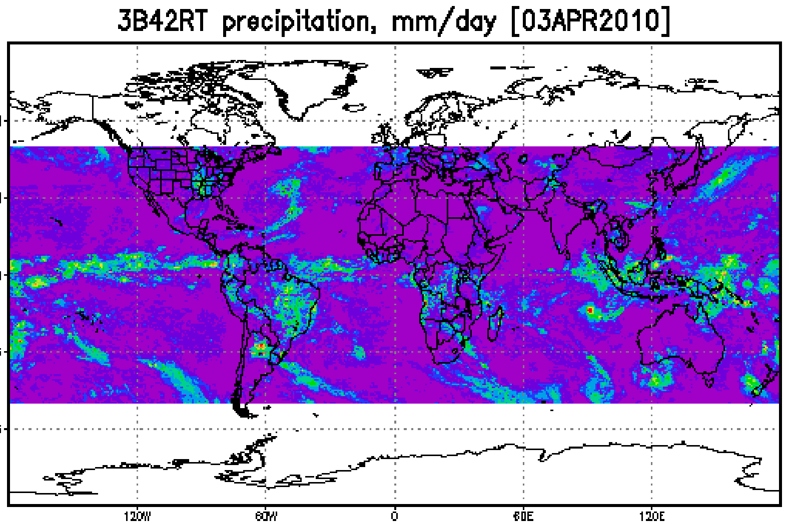
Difficulty of getting information at appropriate spatial and temporal scale

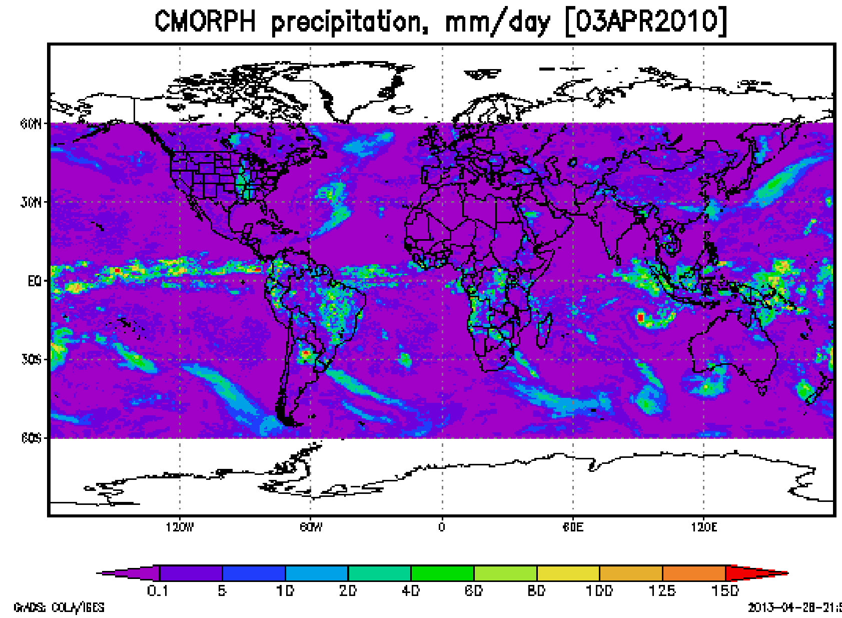


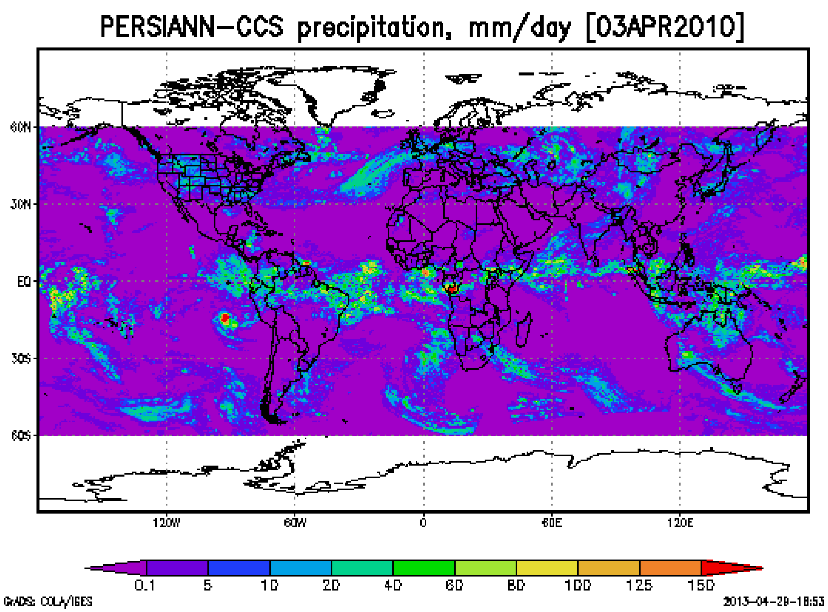
Challenges in satellite rainfall estimation

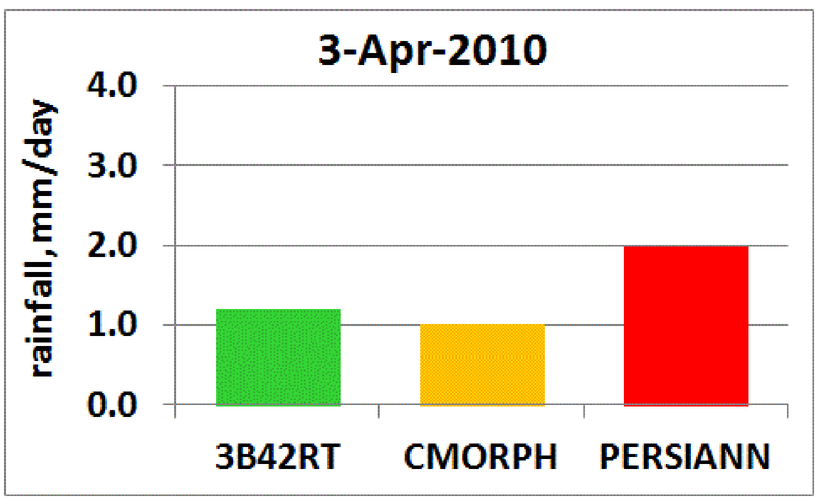
- Satellite rainfall estimate involves indirect way of measurement
  - measures cloud-top properties or emitted/reflected radiation instead of rain
  - difficulty in interpreting the information
- Several studies proved that satellite based rainfall estimations have large uncertainties
  - from sampling to retrieval/estimation errors

Global rainfall estimates from three satellite rainfall products



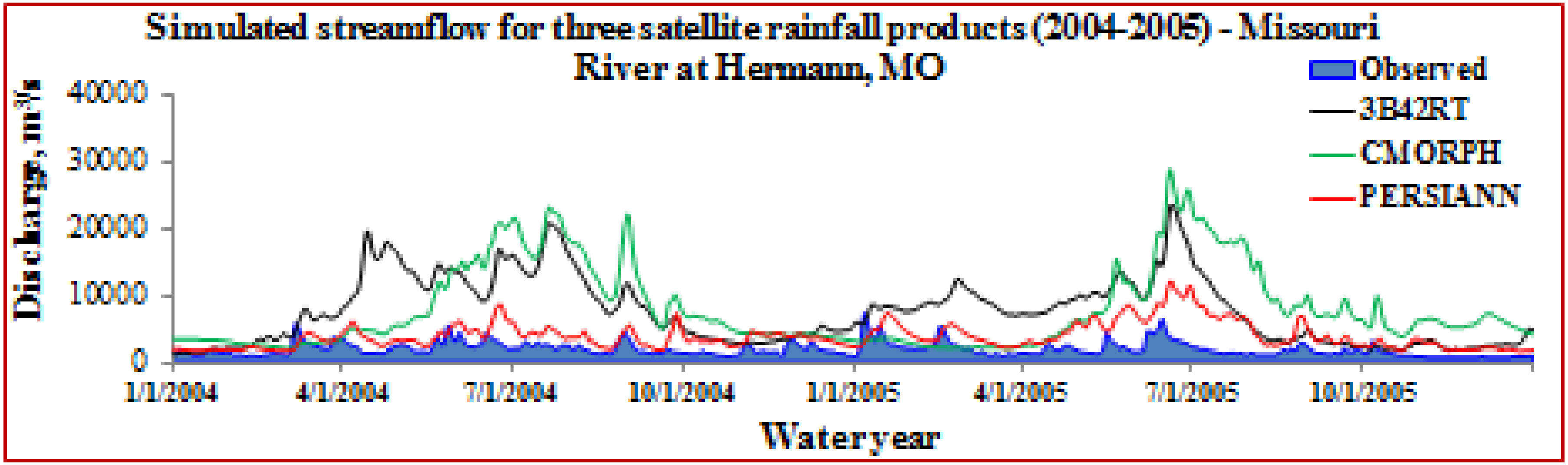


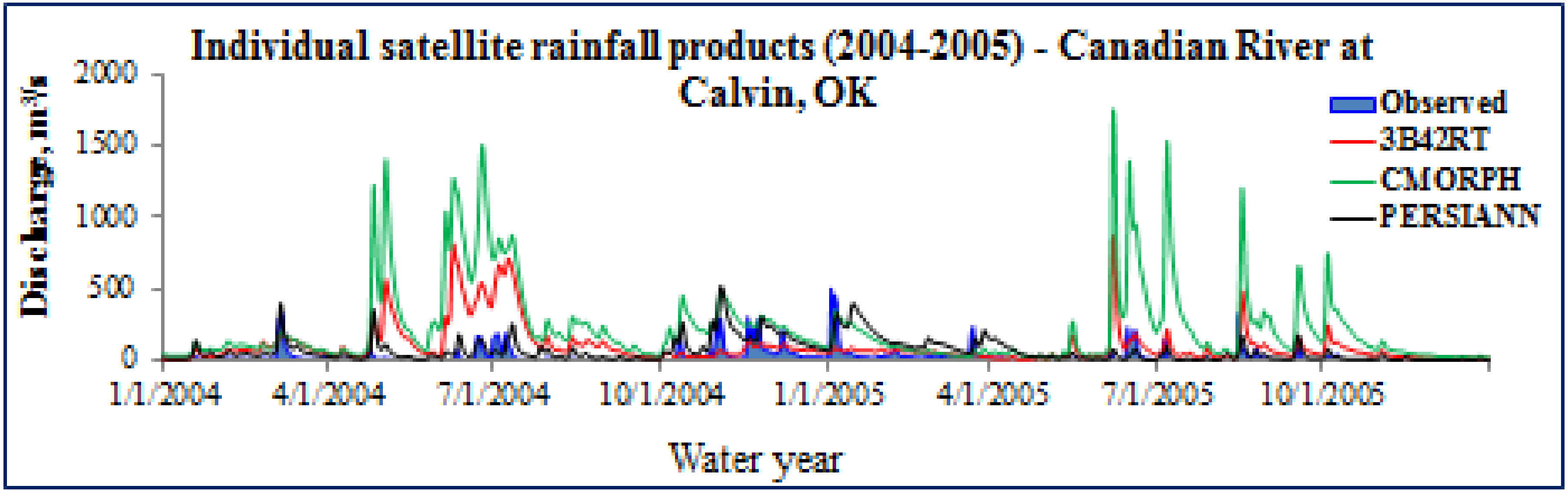




Spatial average rainfall over USA

Impact of satellite rainfall uncertainty in stream flow simulation





Science Questions

- How can the accuracy of various satellite rainfall products be enhanced to advance hydrologic applications?

- To what extent does merging of satellite rainfall products based on hydrologic predictability improve the streamflow simulation?

- How can satellite rainfall error be estimated without having ground reference data?

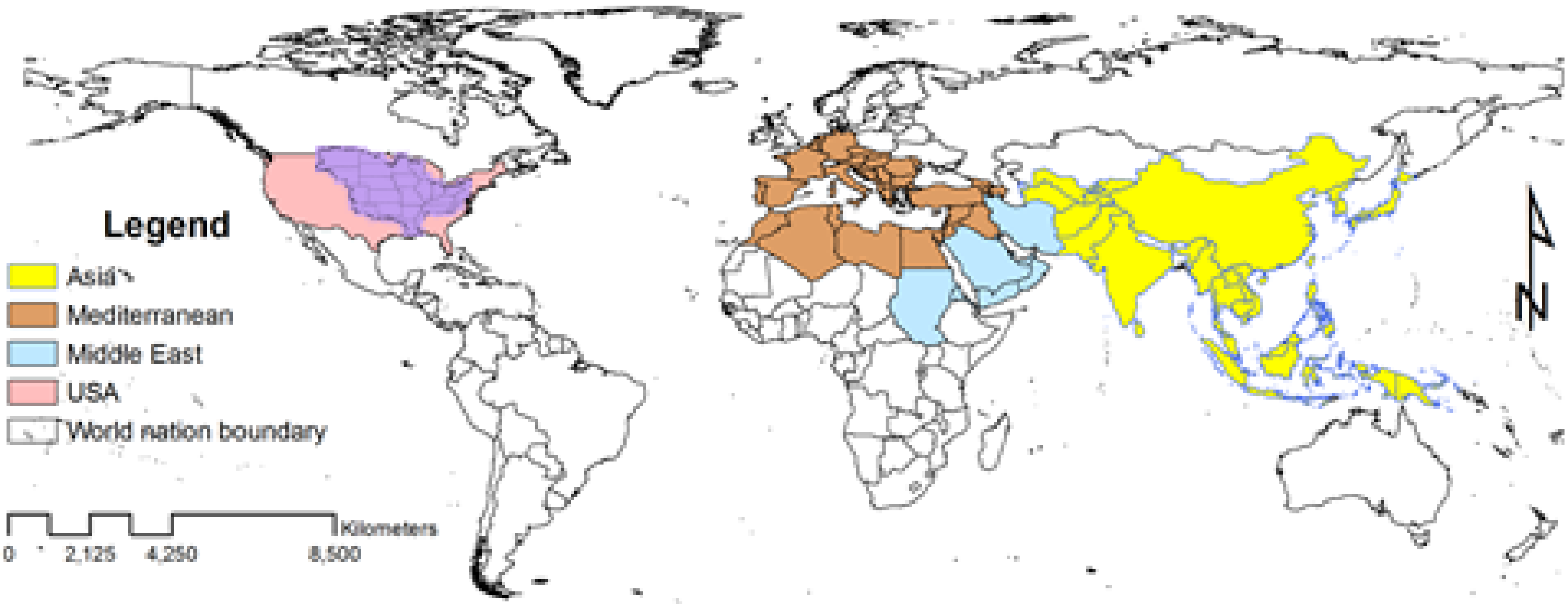
3. Objectives of the Research

- To develop methodologies for merging various satellite products for optimal application of hydrologic modeling based on their individual predictive ability.

- To characterize the performance of various satellite products with respect to seasons, climate and landform features and ultimately develop generalizable rules of thumb for merging of precipitation products that applicable to un-gauged basins

4. Study Regions, Tools and Methods

Study Regions



Validation datasets

- USA – NEXRAD IV/ground gridded data
- Mediterranean region – ECAD
- Middle East – APHRODITE
- Asia - APHRODITE

Satellite rainfall data

3B42RT
CMOPRH
PERSIANN-CCS

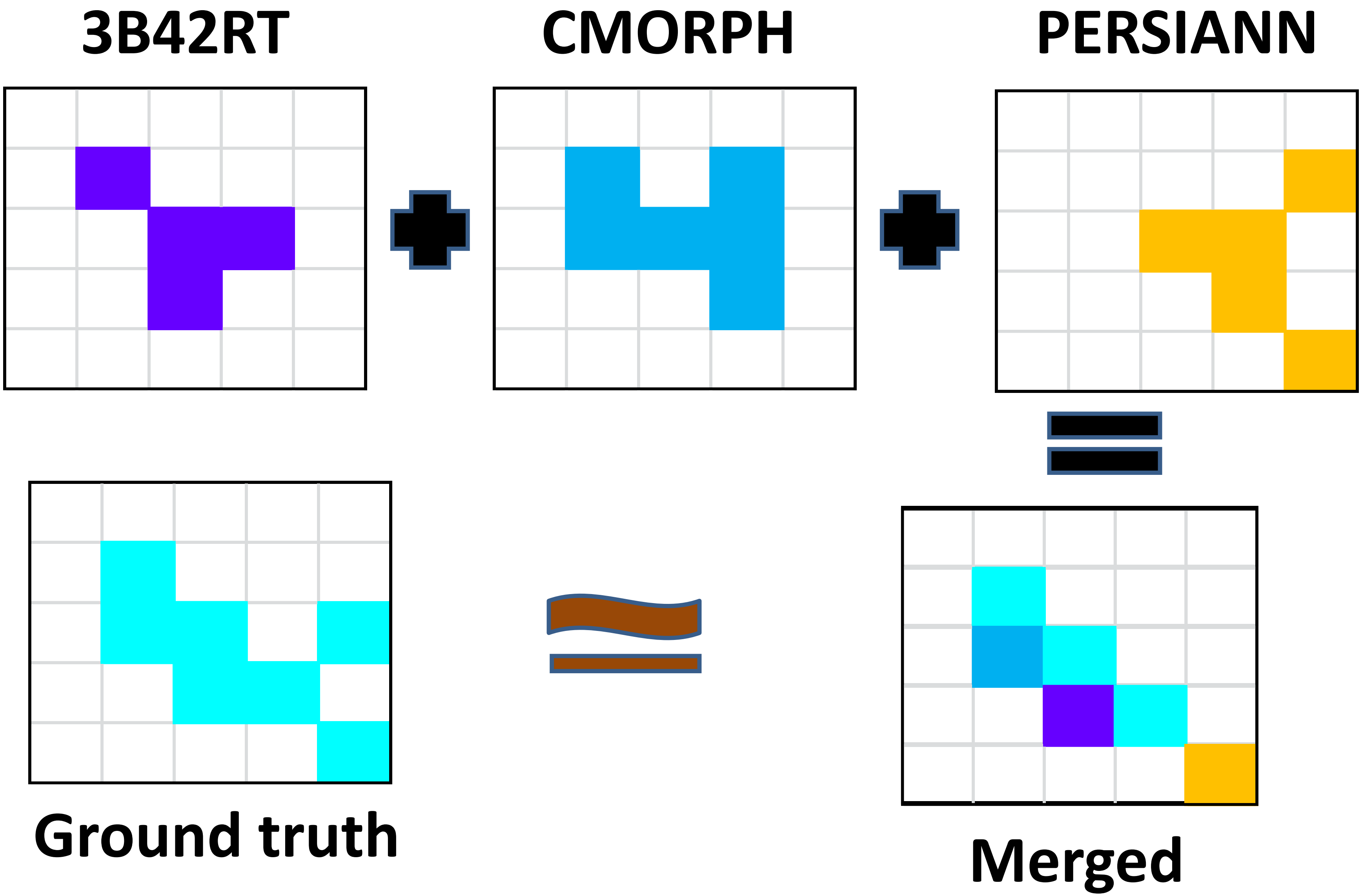
Study period

2003 - 2010

Tools

- Variable Infiltration Capacity model (VIC)
- Horizontal Routing Model (ROUTE)
- Error Variance Regression Model (EVR)

Methodology – Concept of merging



Methodology

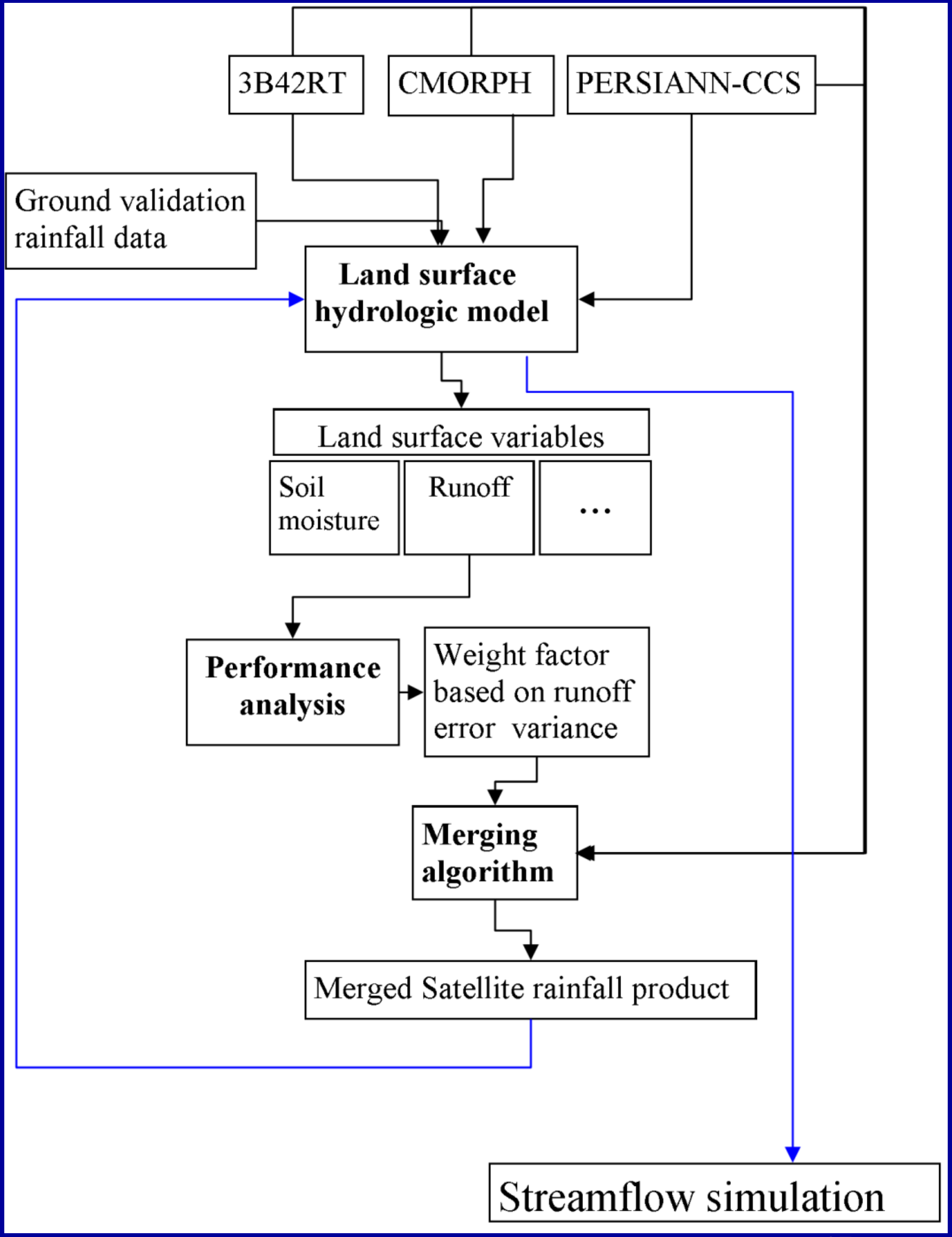
Merging three satellite rainfall products based on hydrologic predictability

- Runoff predictability
- Soil moisture predictability

- The merging weights are the inverse of error variance

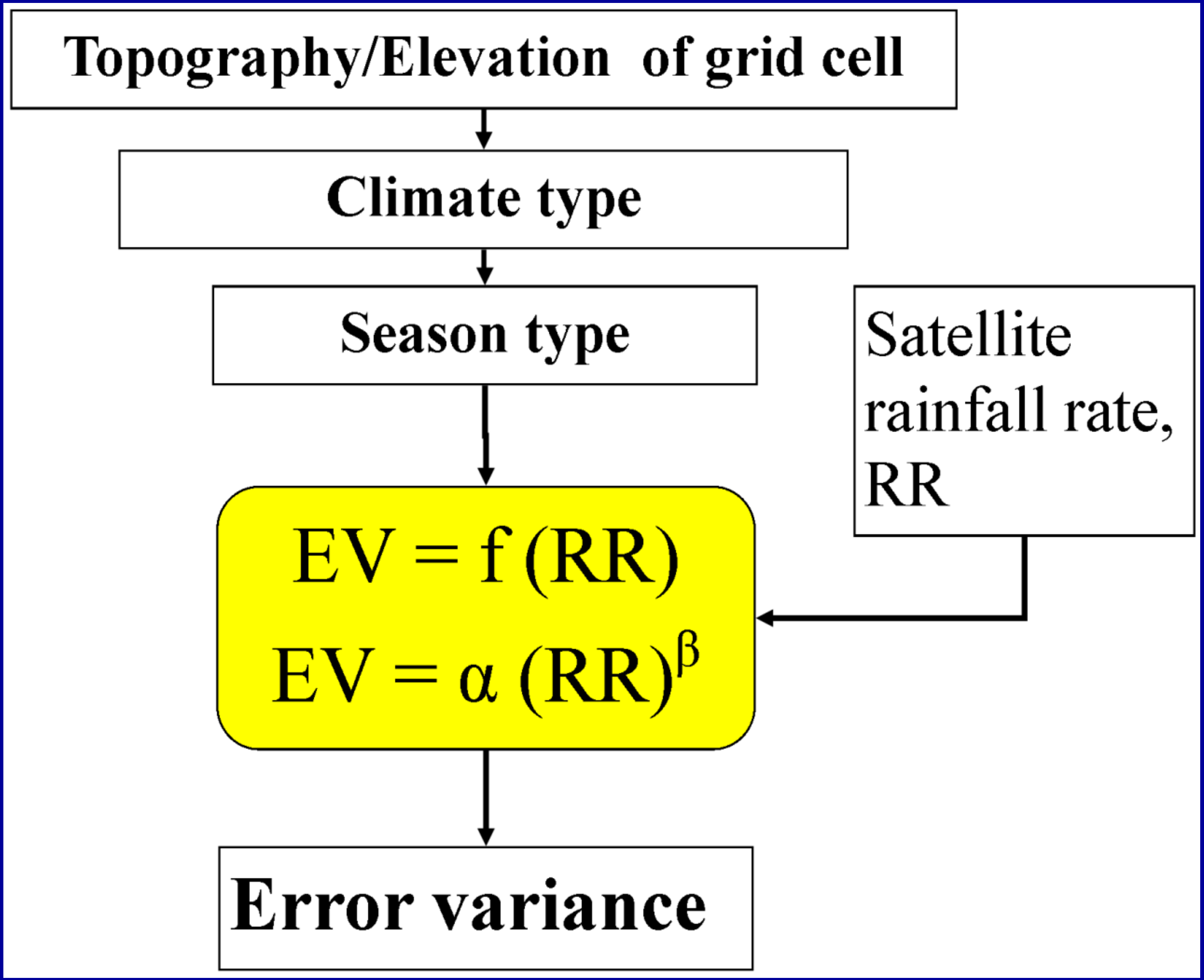
Experimental scenarios

- Spatially & seasonally varying (non-stationary)
- Spatially varying
- Constant merging factor (stationary)
- Simple average



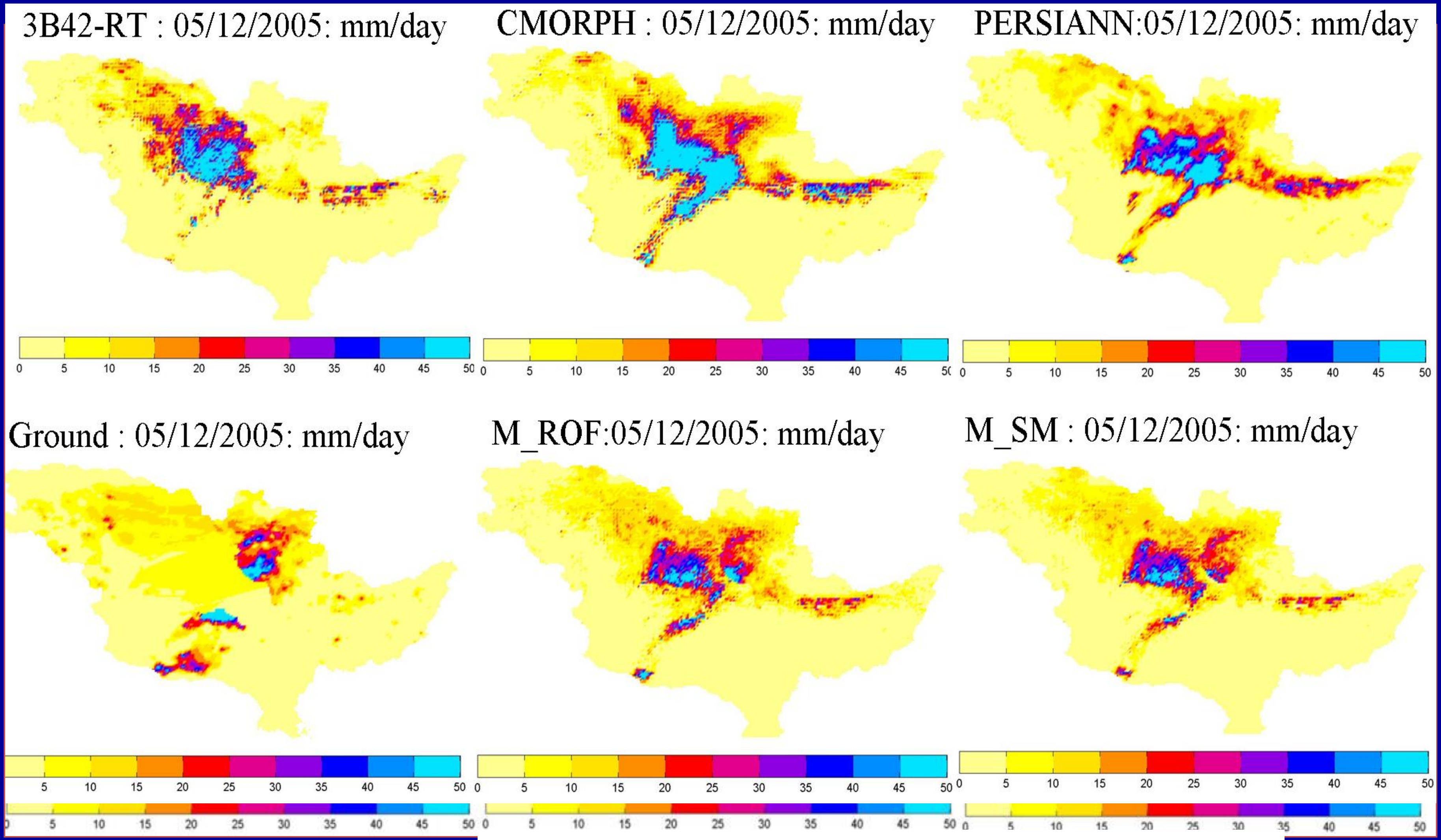
Methodology…

Regression scheme for error variance estimation



5. Findings

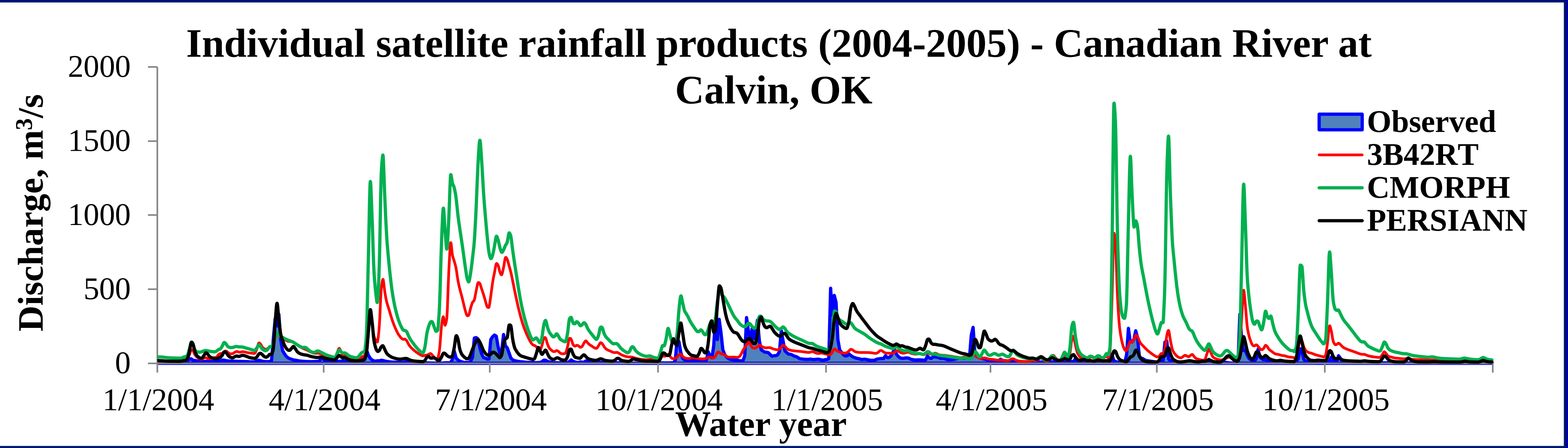
Comparison of spatial rainfall distribution over Mississippi basin

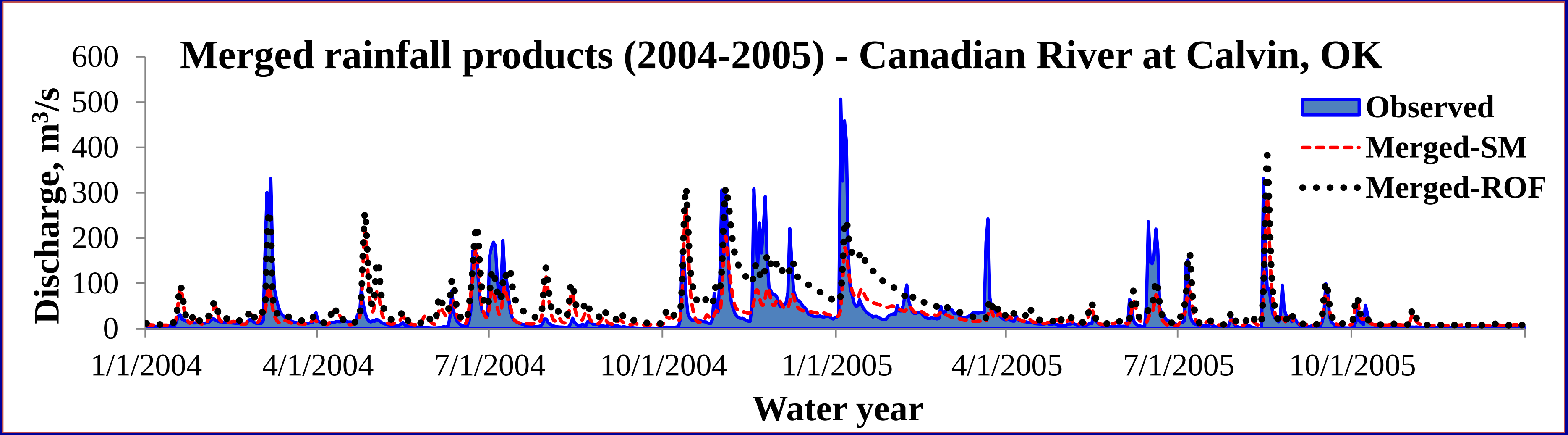


M-SM: soil moisture error based merged product
M-ROF: runoff error based merged product

Findings on merging …

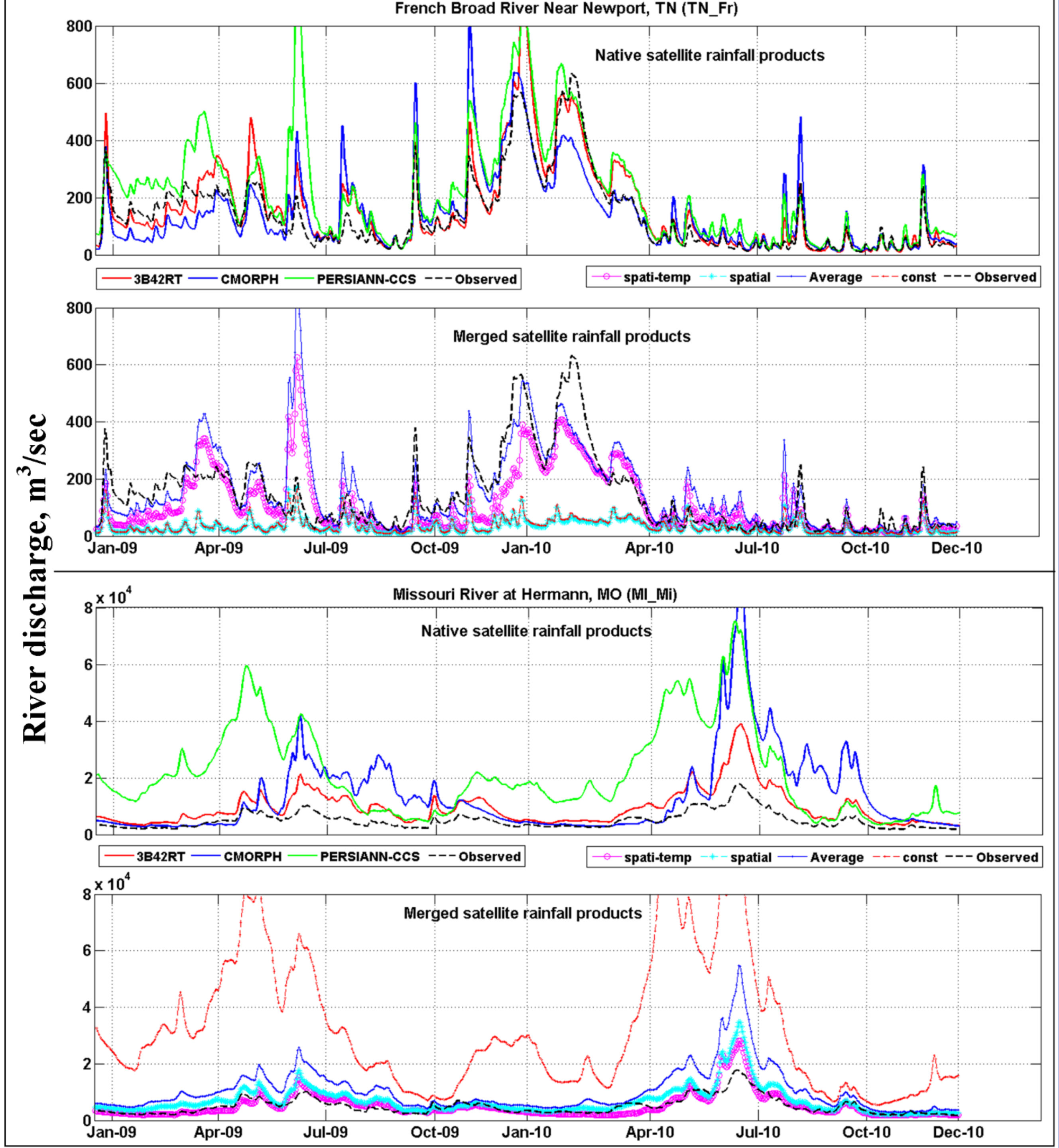
Streamflow simulation for satellite & merged rainfall products





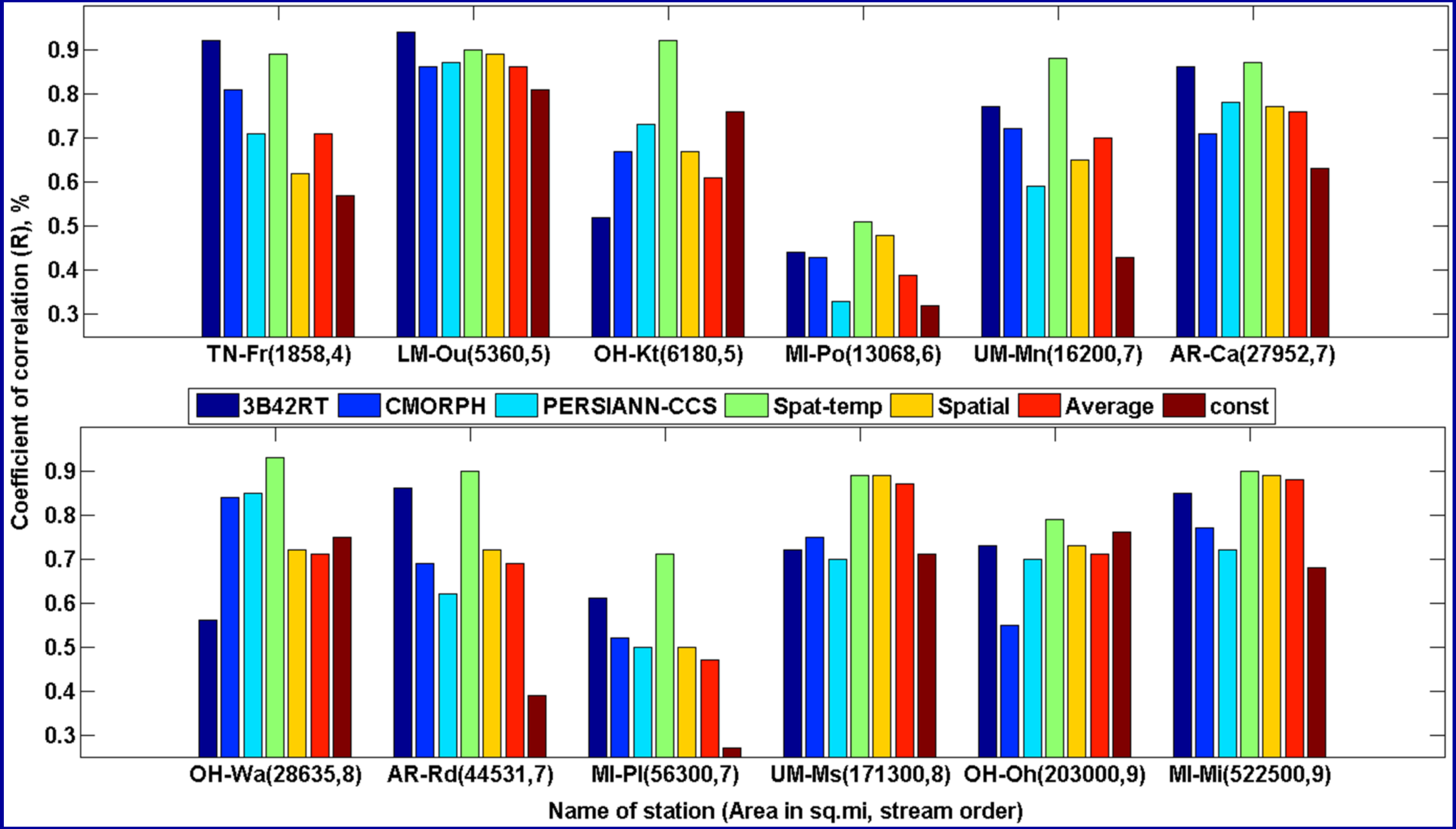
Findings on merging …

Which is more important? Spatial or temporal signatures?



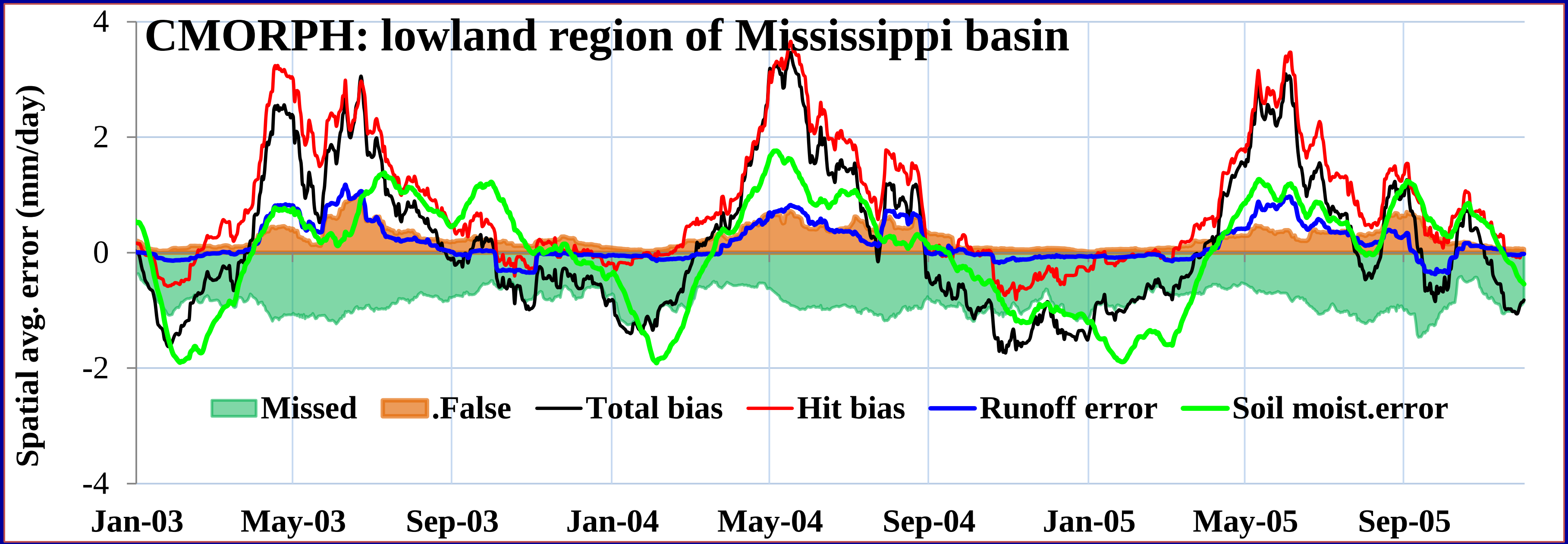
Findings on merging…

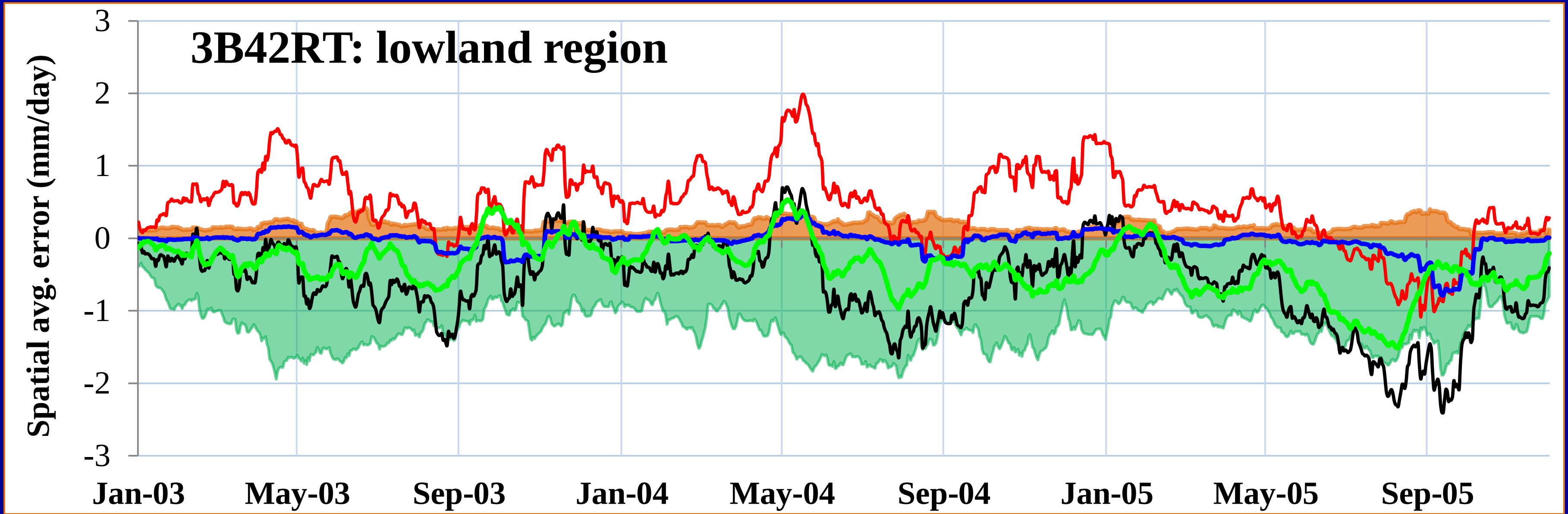
Correlation coefficient for simulated & observed streamflow at 12 gauging stations



Findings error variance estimation

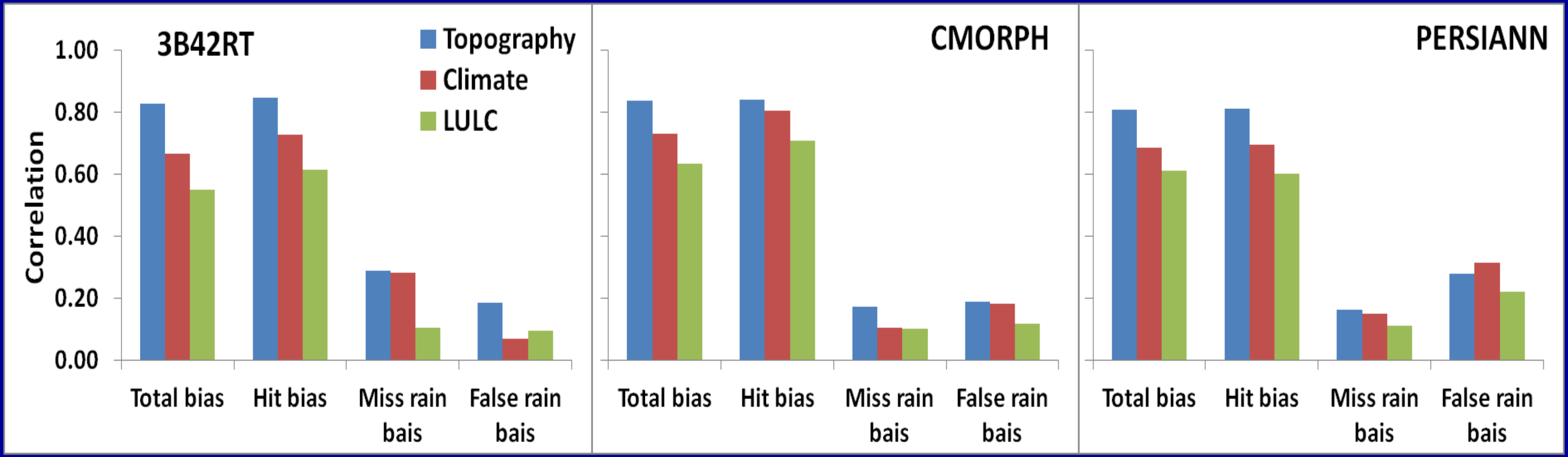
Characterizing error as function of geophysical features





Findings error variance estimation…

Which geophysical feature is more important to characterize the impact of satellite rainfall error on hydrologic simulation?



Average correlation coefficient between satellite rainfall error components and runoff error based on three geophysical features

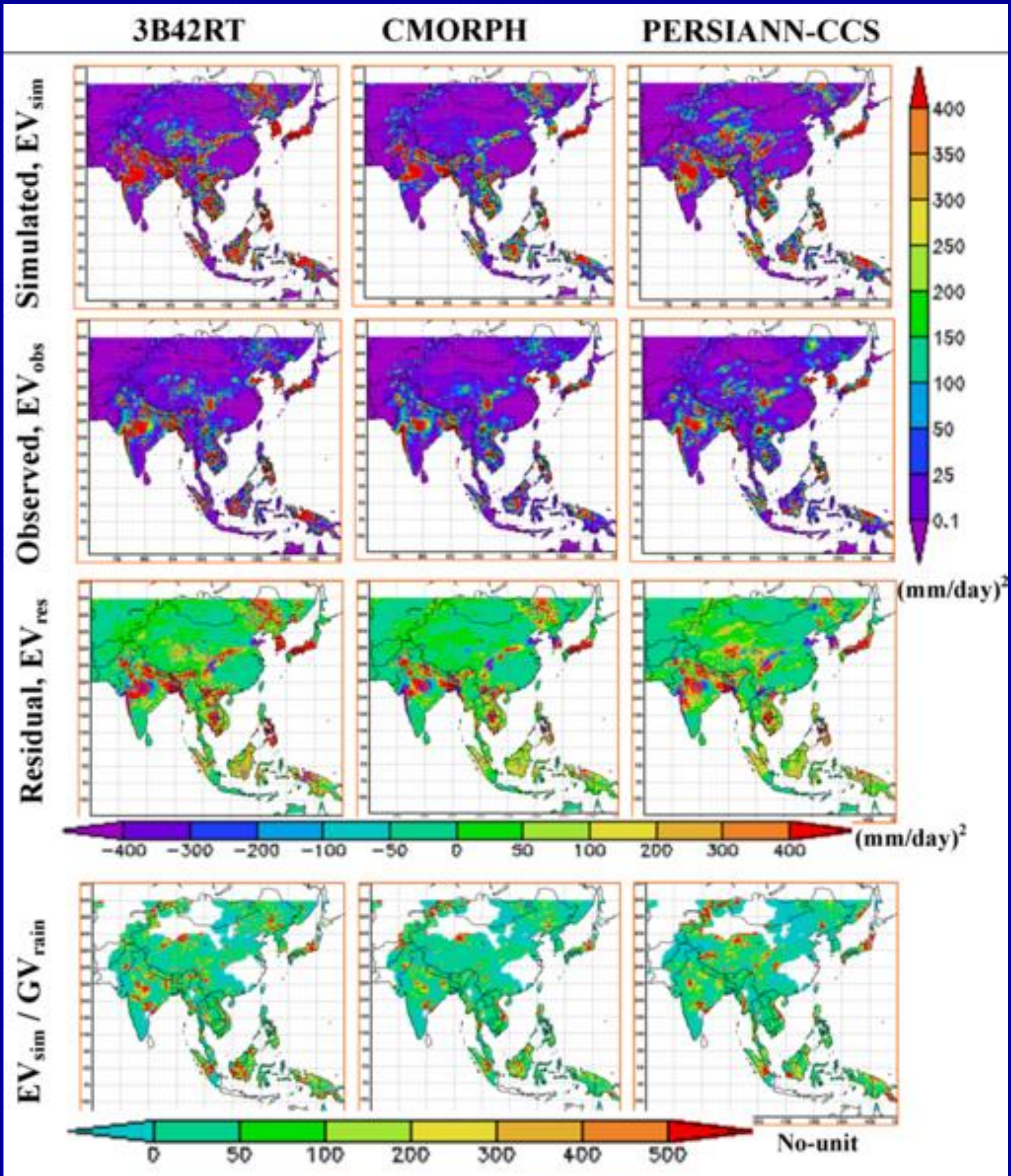
Error variance model

$$EV = \propto (RR)^{\beta}$$

- $\propto$ - scaling factor, moving the values of '$(RR)^{\beta}$' up or down
- β – exponent, determines the shape and behavior of the function

- In the regression model, the error variance is expressed explicitly as function of rainfall rate and implicitly as function of:
  - Topography
  - Climate and
  - Season

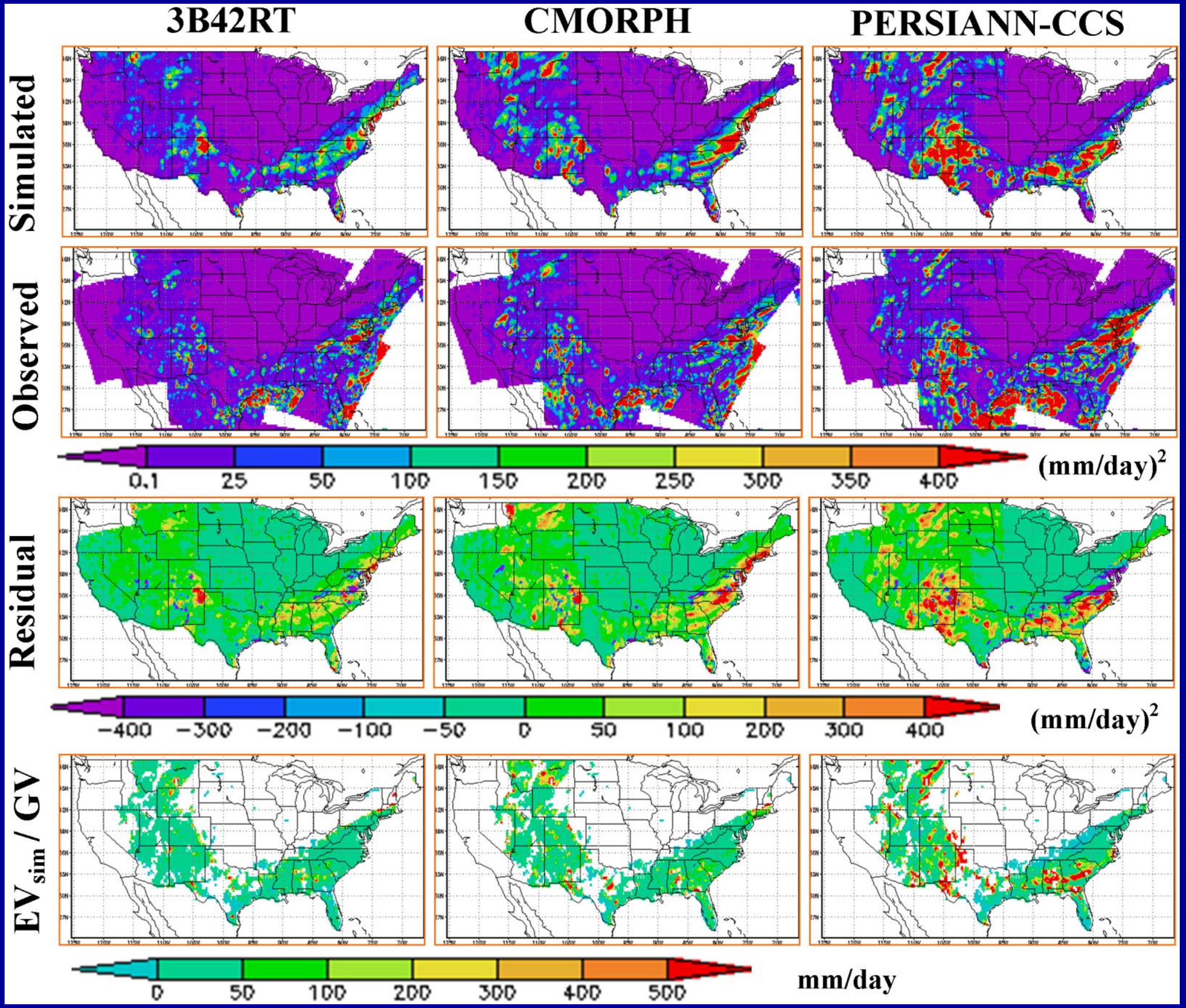
Satellite rainfall error variance estimation



Asia
07/03/2007

Satellite rainfall error variance estimation

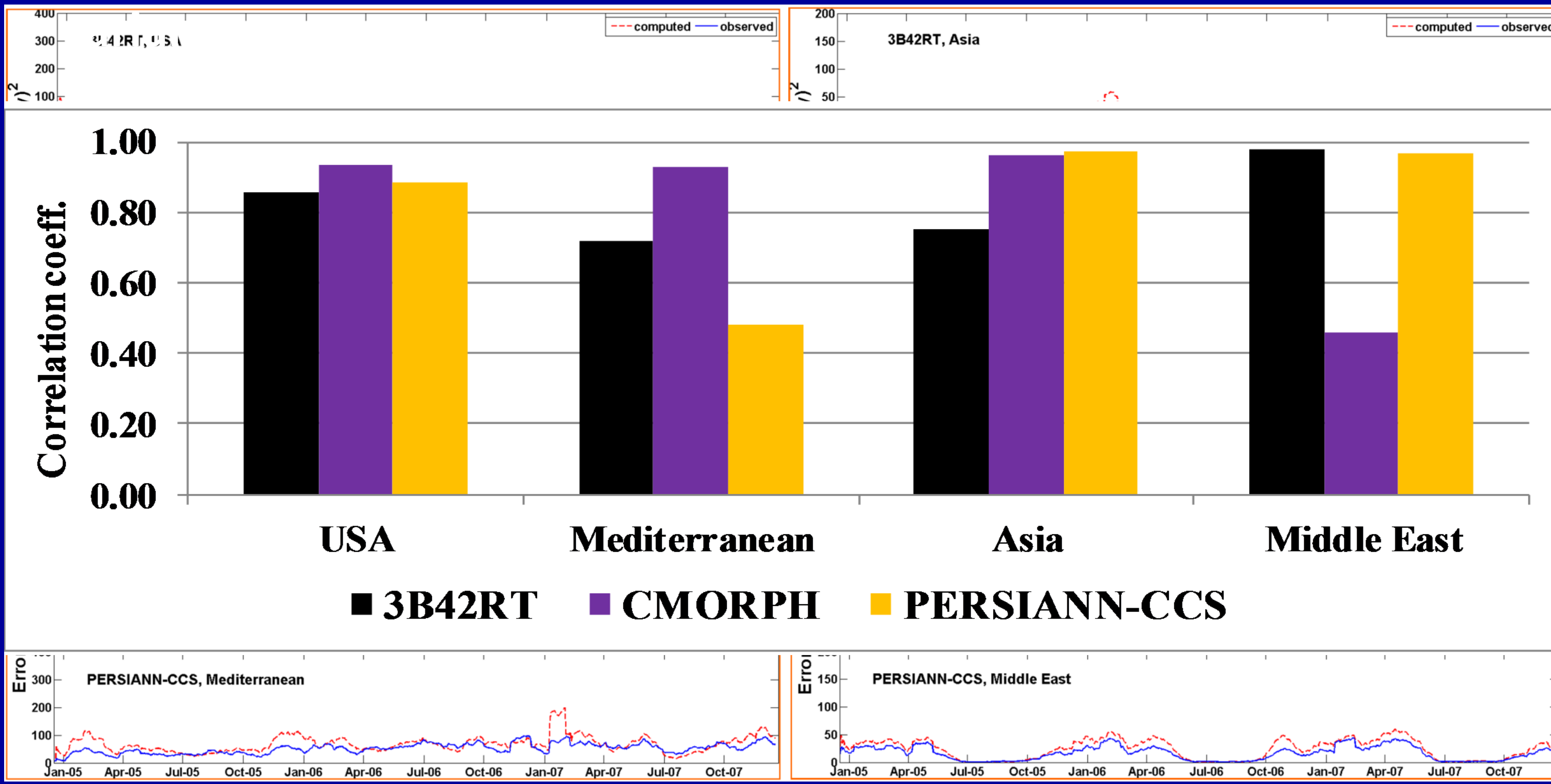
USA
07/06/2006



Findings on error variance estimation…

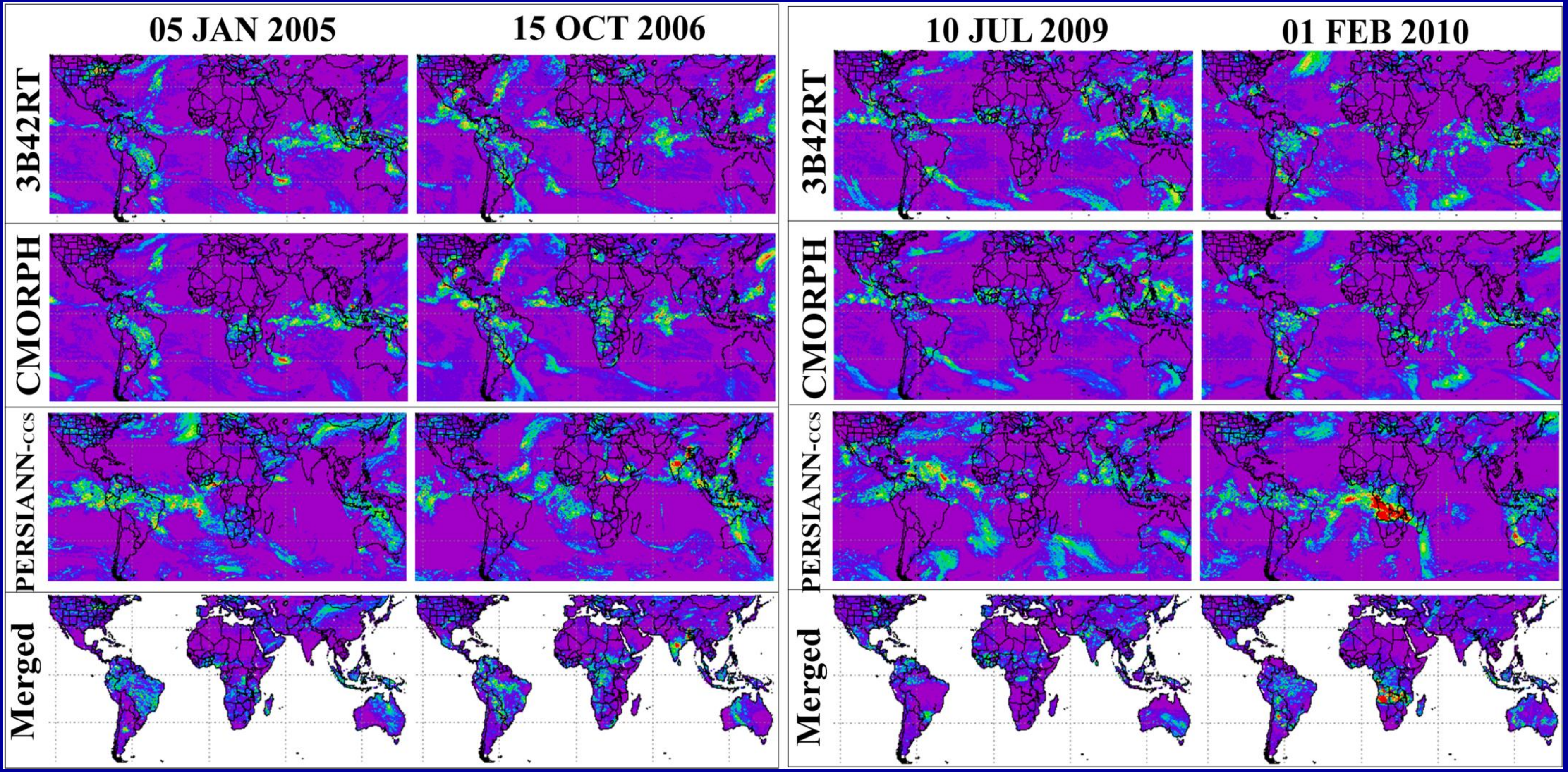
Time series of simulated and observed error variance

Correlation coefficient between simulated and observed error



Merging and error variance estimation

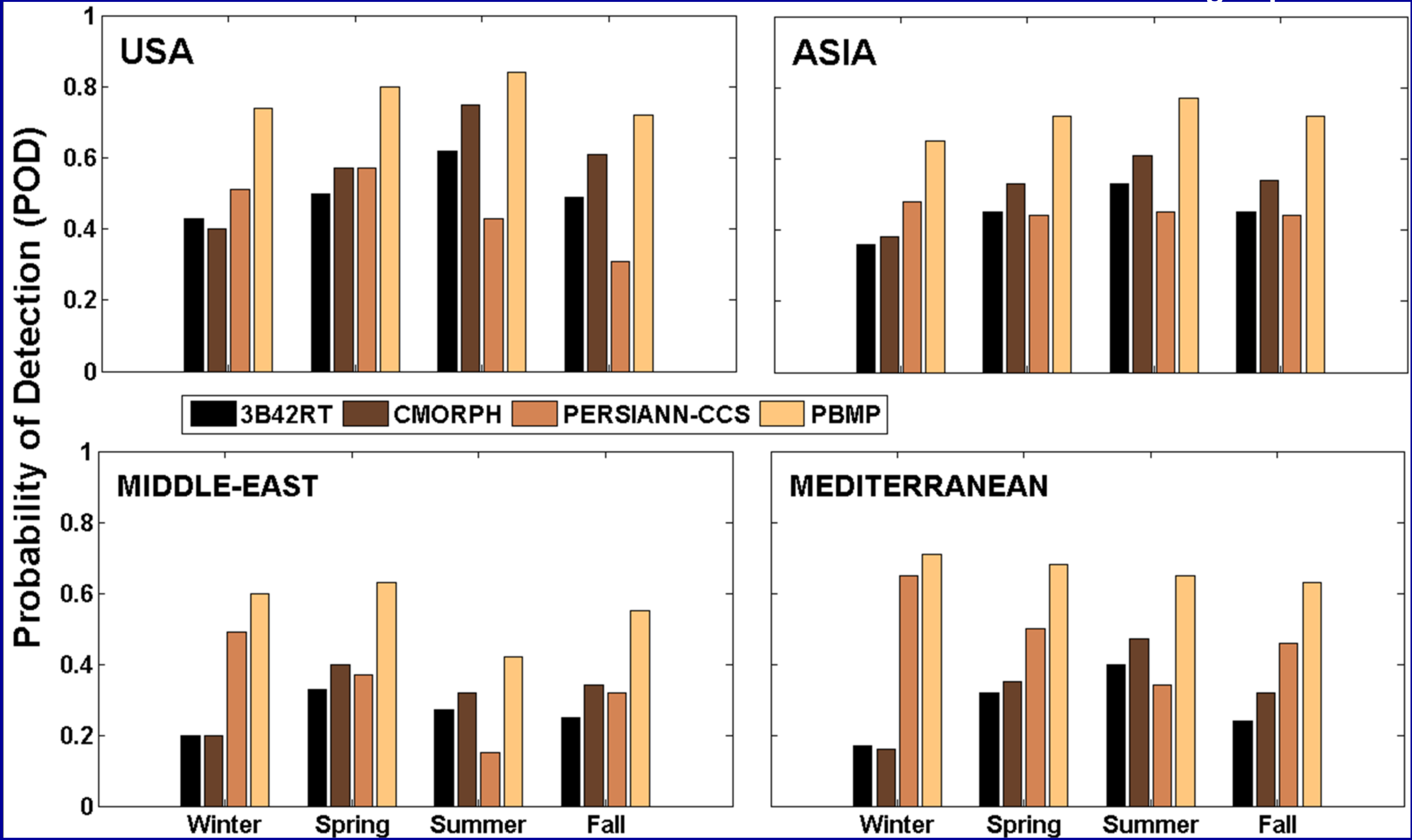
Spatial distribution of satellite rainfall and merged products at Global scale



Merging and error variance estimation…

Error metrics analysis – POD

PBMP: Performance based merged product



6. Conclusions and Recommendations

Conclusions

- Merging based on **spatial and seasonal signature** of **runoff predictability** yields a more superior merged product
- The improvement is originated from the **complementary strengths** of the three algorithms and it is tailored toward the hydrologic performance of individual products
- Topography plays a direct role on the pattern of climate, hydrology and land-use and land-cover of the region due to its forcing on the formation of clouds, temperature, albedo, wind movement, etc…
- Therefore, ***topography*** is found to be the most important governing factor to identify and quantify the uncertainty type associated with satellite rainfall estimates

Conclusions…

- Indirect way of error estimation method is an alternate and pragmatic solution to perform meaningful prediction using satellite rainfall data for many applications particularly over un-gauged basins

Recommendations

- The current merging scheme works most effectively when each product has complementary signal-to-noise ratios. Therefore, further explorations into the concept of non-static (dynamic) weighting factor are required
- The proposed error variance model includes only one independent variable and it underestimates the error budget accumulated over specific period in location where missed precipitation is dominant. Further studies on probabilistic approach by including other variables are recommended.

Acknowledgment

- NASA – funding for 3 years
- TTU Center for the Management, Utilization and Protection of Water Resources Center

Thank you