CARFFGS SCM4 Astana Kazakhstan, 31 October- 2 November 2017

Precipitation Estimate and Bias Adjustment

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Established in 1993 as a nonprofit research, technology transfer, and training organization.
HRC's objectives are to help bridge gaps between scientific research in hydrology and applications for the solution of important societal problems that involve water.

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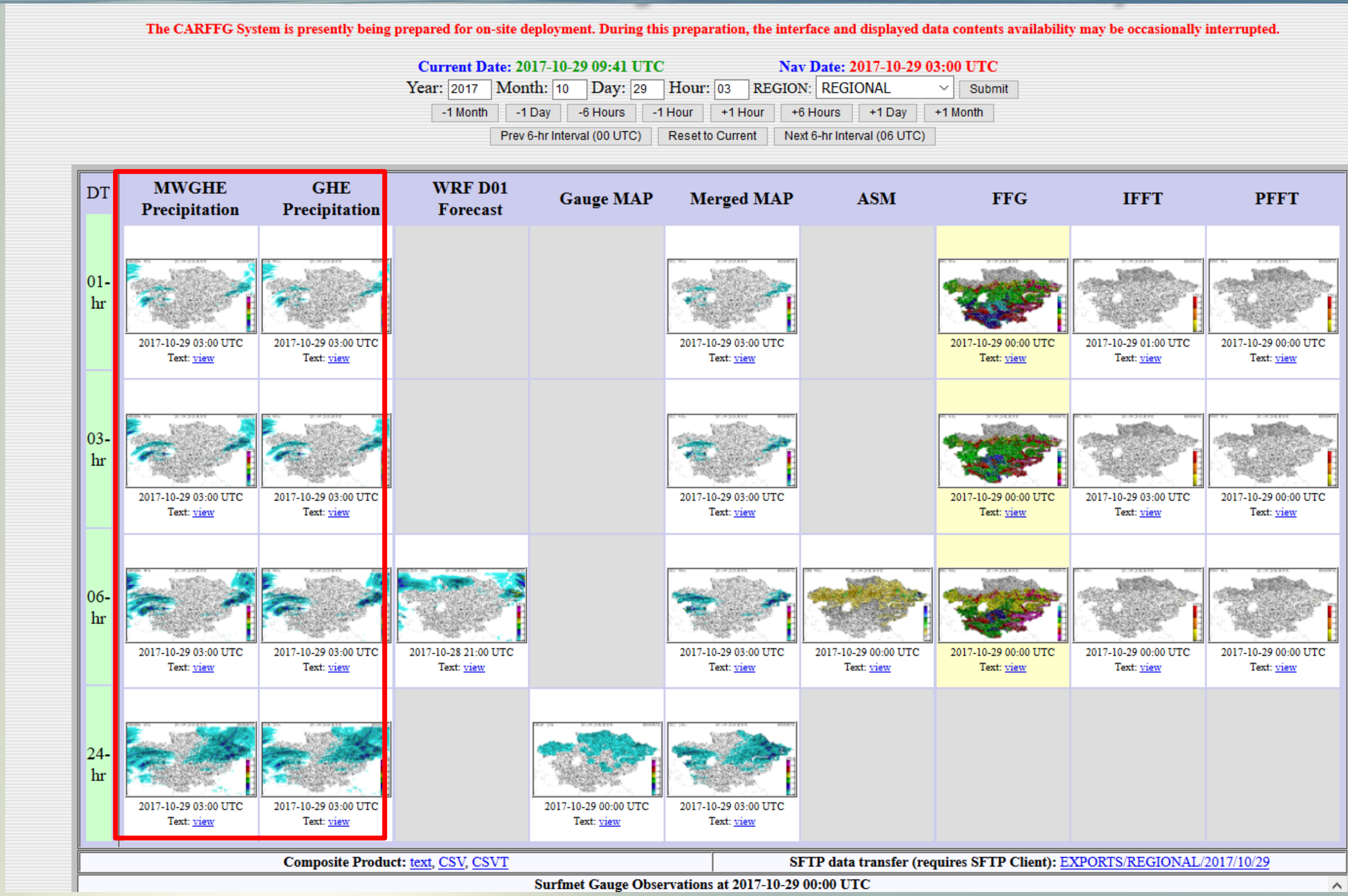
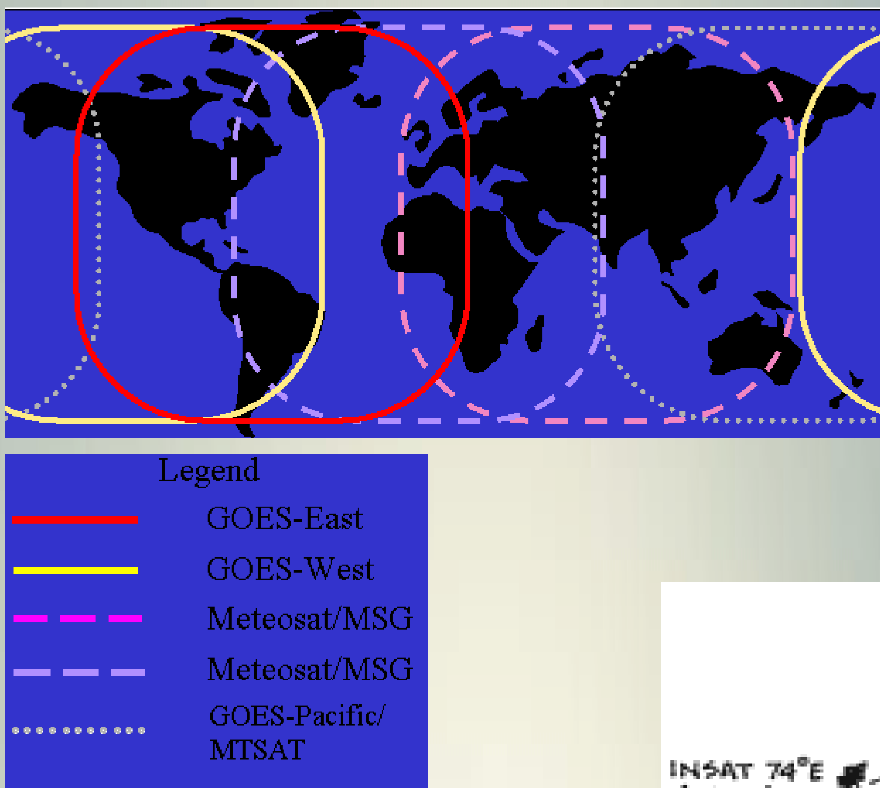
Satellite Precipitation in FFG Systems



Hydro- Estimator National Environmental Satellite, Data, and Information Service (NESDIS) (NOAA)



- **Real-time operational since August 2002**
- **Available globally (60N-60S)**
- **Hourly values for about 4 km.**
- **geo-stationary GOES satellites IR 10.7 micron.**
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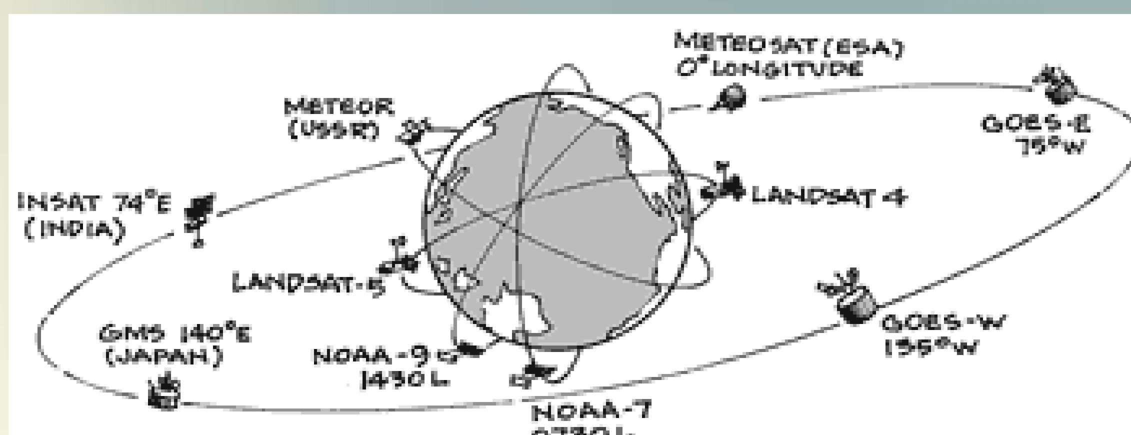
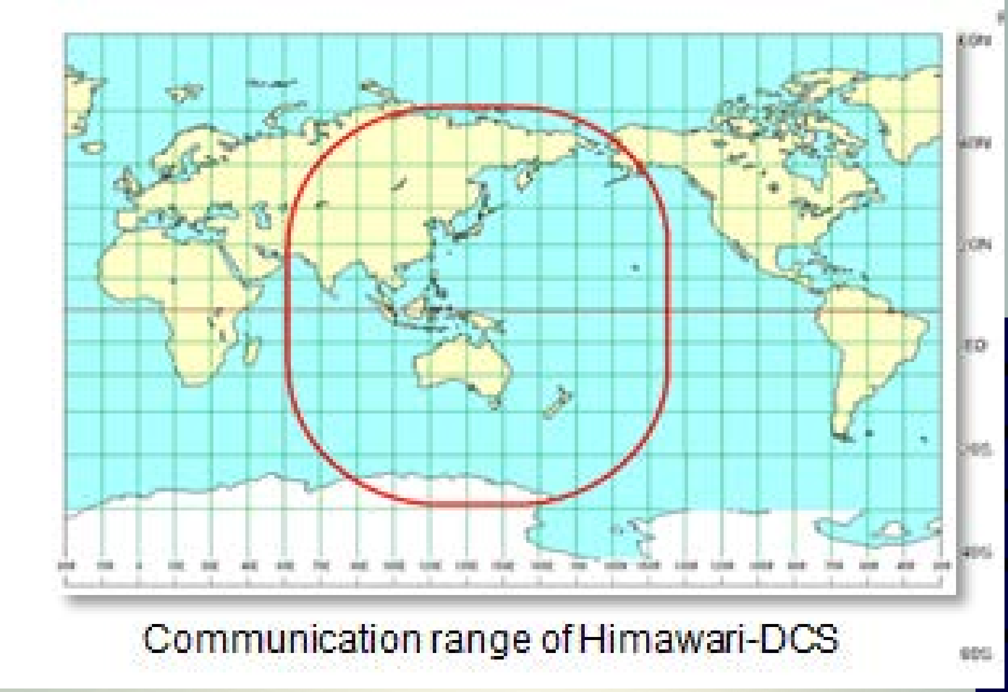
- **Data are produced at the full instrument resolution and are updated whenever new imagery becomes available, with a latency of less than 15 minutes.**

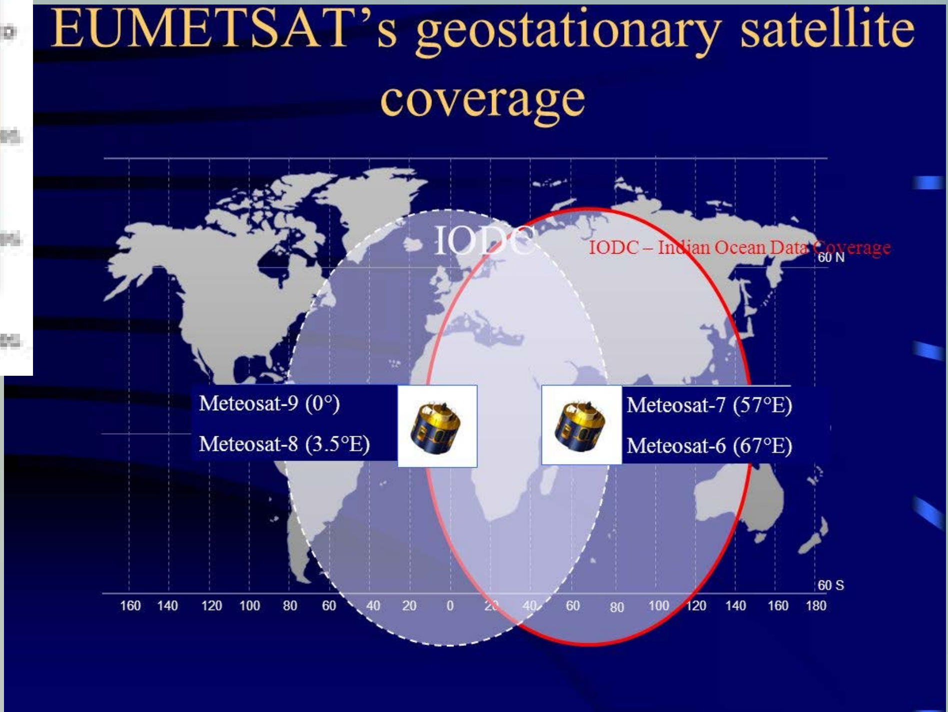


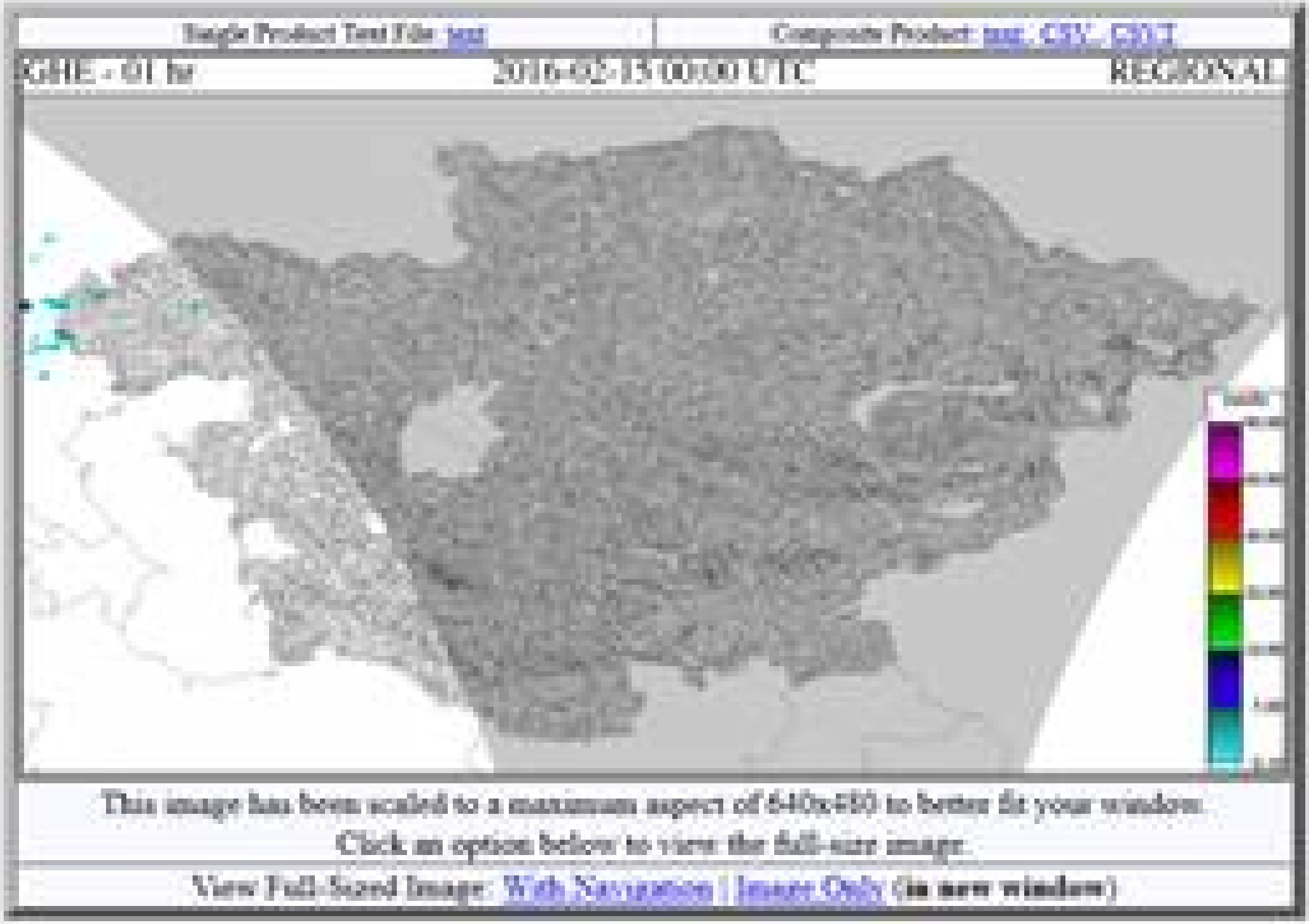
Geo Stationary Satellite that cover Central Asia

HIMAWARI



METEOSAT




Single Product Text File:
Composite Product:
GHE - 01 hr
2016-02-15 00:00 UTC
REGIONAL
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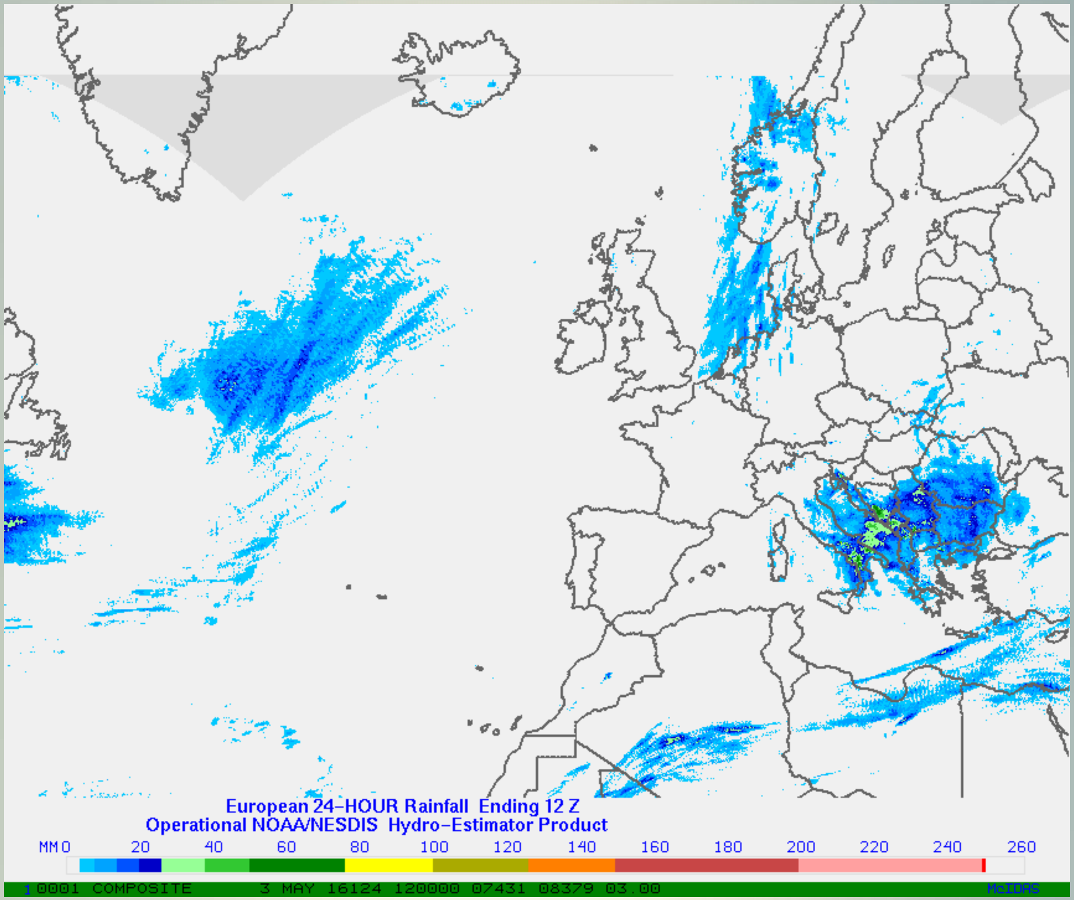
Click an option below to view the full-size image.
View Full-Sized Image: With Navigation | Image Only (in new window)

Global Hydro-Estimator

GHE: Rainfall rate based on Cloud Top Brightness Temperature (*indirect measurement*)



- ❖ Produced by NOAA/NESDIS
- ❖ Research on satellite precipitation
  - since late 1970s;
  - Hydro-Estimator since 2002;
  - GHE Operational in 2012.
- ❖ Infrared (IR)-based, 10.7 mm
- ❖ ** Short latency **(< ½ hour)
- ❖ ~4km resolution

Enhanced for:

1. Atmospheric moisture effects
2. Orography (upslope/downslope)
3. Convective Eqlb. Level (warm-top convection)
4. Local pixel temperature differences
5. Convective core / no-core region

Geostationary Operational Environmental Satellite - R Series (GOES-16 temporarily named GOES-R)
Launched in Nov 19, 2016
GHE (as of Nov 2017):
GOES-16 not incorporated
Meteosat-8 incorporated
Himawary-8 incorporated

QPE:

- 2km
- 4- time per hour
- Latency ~5min
- Using 5 IR bands
- Calibrated with MW

FFGS short term plan to incorporate all new satellites in 4km^2 GHE

In future FFGS the 2km^2 GHE will be used

Channel Number	*Wavelength (μm)*	*Resolution (km)*	*Used in Rain Rate*
1	0.47	1.0	
2	0.64	0.5	
3	0.865	1.0	
4	1.378	2.0	
5	1.61	1.0	
6	2.25	2.0	
7	3.9	2.0	
8	6.19	2.0	✓
9	6.95	2.0	
10	7.34	2.0	✓
11	8.5	2.0	✓
12	9.61	2.0	
13	10.35	2.0	
14	11.2	2.0	✓
15	12.3	2.0	✓
16	13.3	2.0	

Table 2. Channel numbers, wavelengths, and footprint sizes of the ABI bands.

http://www.goes-r.gov/products/ATBDs/baseline/Hydro_RRQPE_v2.0_no_color.pdf

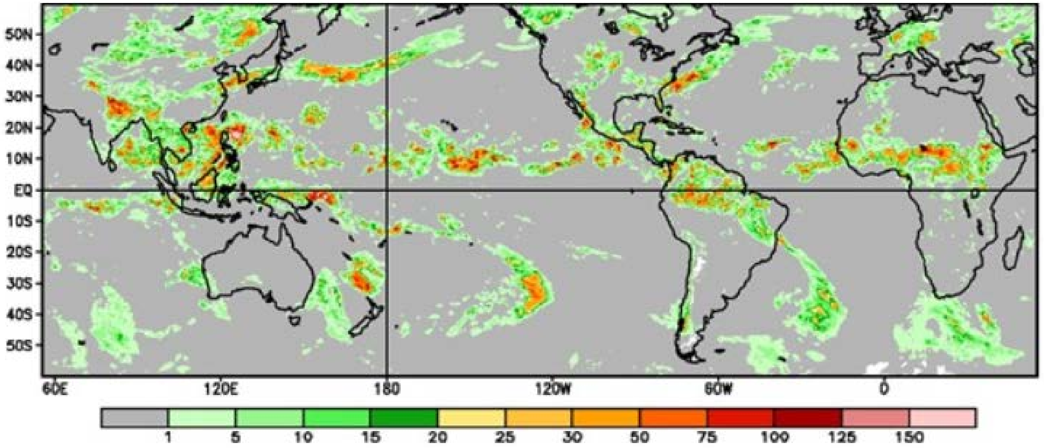
Multi-Spectral Satellite Rainfall for FFG Systems

HRC effort to combine IR-based GHE rainfall with MW-based CMORPH rainfall

CMORPH is based on measurements of microwave scattering from raindrops.
- measure of the hydrometeors in clouds
- still not observation of rainfall at surface

High-Resolution Satellite Estimates

- CMORPH : CPC Morphing technique (Joyce et al. 2004
  - Combined use of satellite PMW and IR data
  - 8kmx8km / 60°S-60°N;
  - 30-min interval / from September 2000 / Real-time
  - Project on the way to back-extend the CMORPH to 1998
  - Sample for August 18, 2003



Multi-Spectral Satellite Rainfall for FFG Systems

GHE

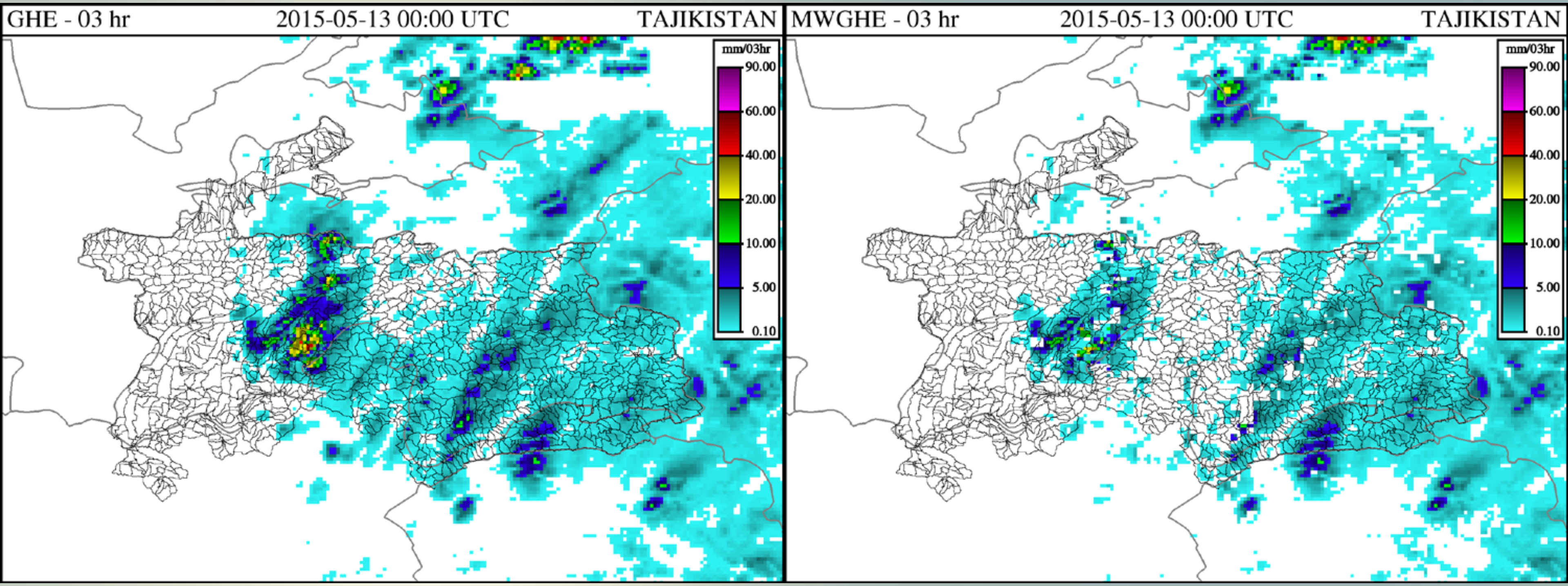
- Infrared – based
- Measurements of brightness temperature at the top of the cloud
- 30-min latency in operations
- ~4km resolution

CMORPH

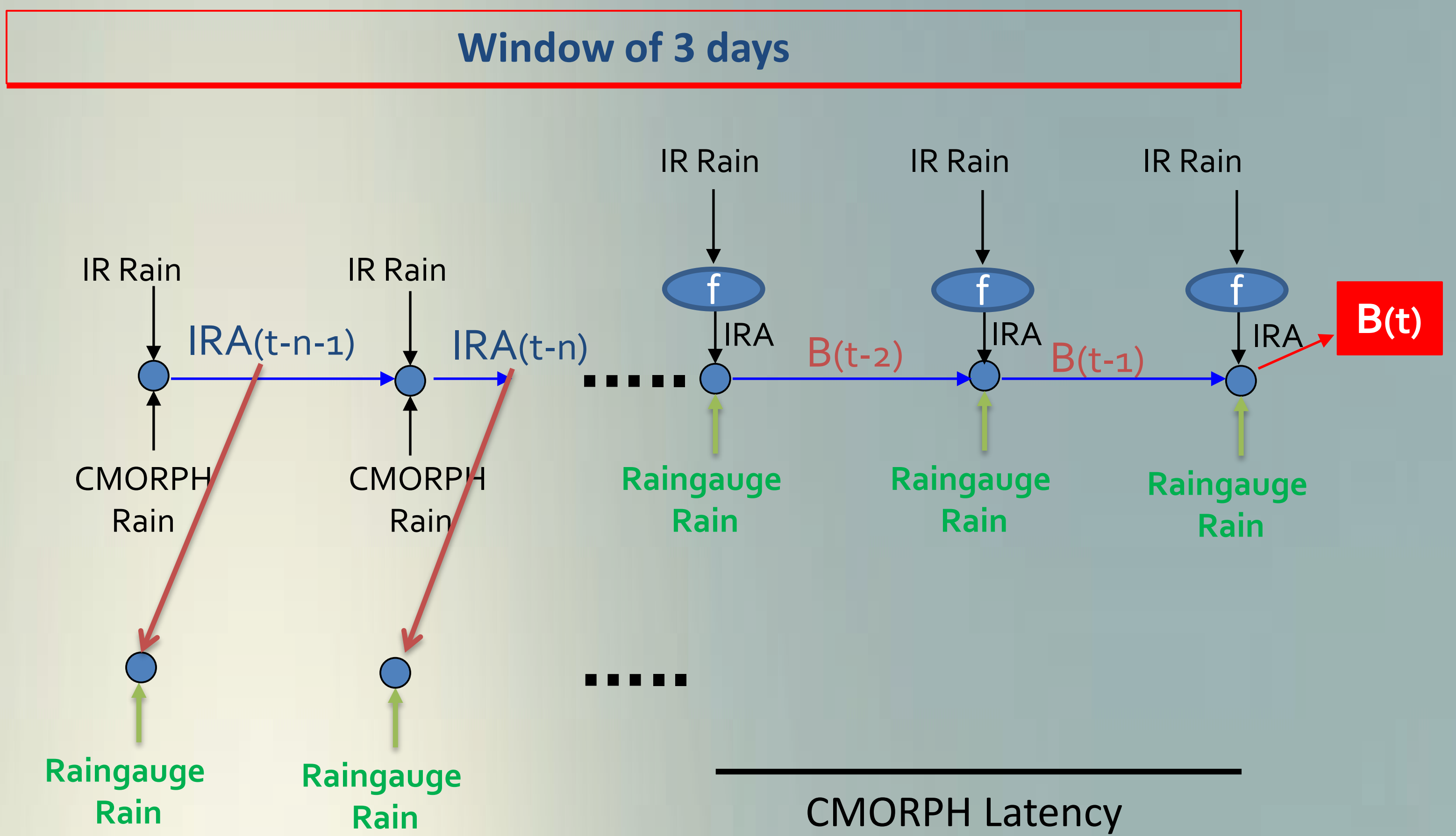
- Microwave – based
- Measurements of microwave scattering from raindrops
- 18-26 hour latency in operations
- ~ 8km resolution
- **No estimation over snow**

FFGS Product combines IR-based GHE with MW-based CMORPH: MWGHE

EXAMPLE FROM CARFFG



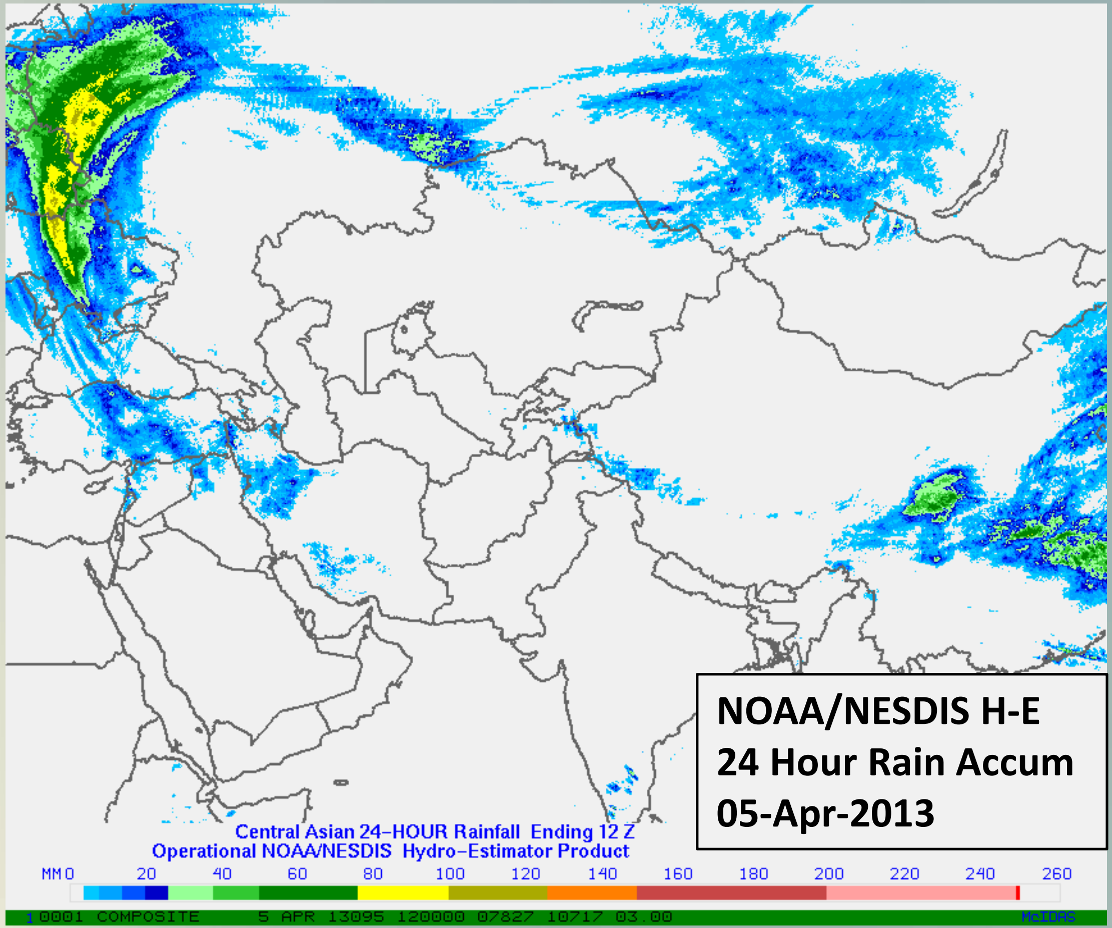
Multi-Spectral Satellite Rainfall for FFG Systems



Motivation for Bias Adjustment

Remotely-sensed precipitation estimates provide good spatial coverage and detail.
In situ observations (gauges) provide "ground truth".

- Satellite estimates do not measure precipitation!
- Bias may exist in remotely sensed precipitation.
- Bias should be removed for "best estimate" to provide input to hydrologic models.

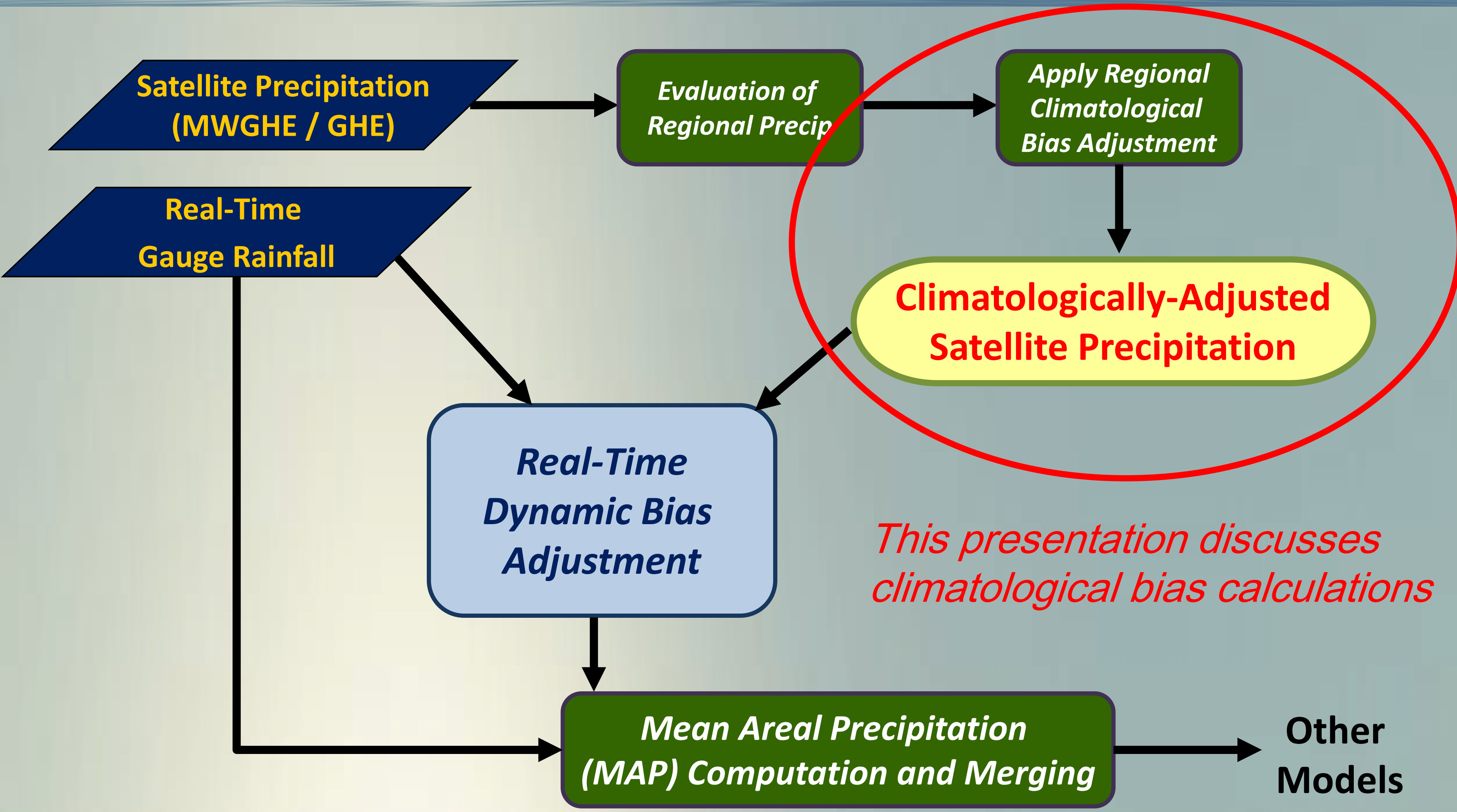


Precipitation Adjustments Using Real-Time Rain Gauges

<u>2 Steps:</u>

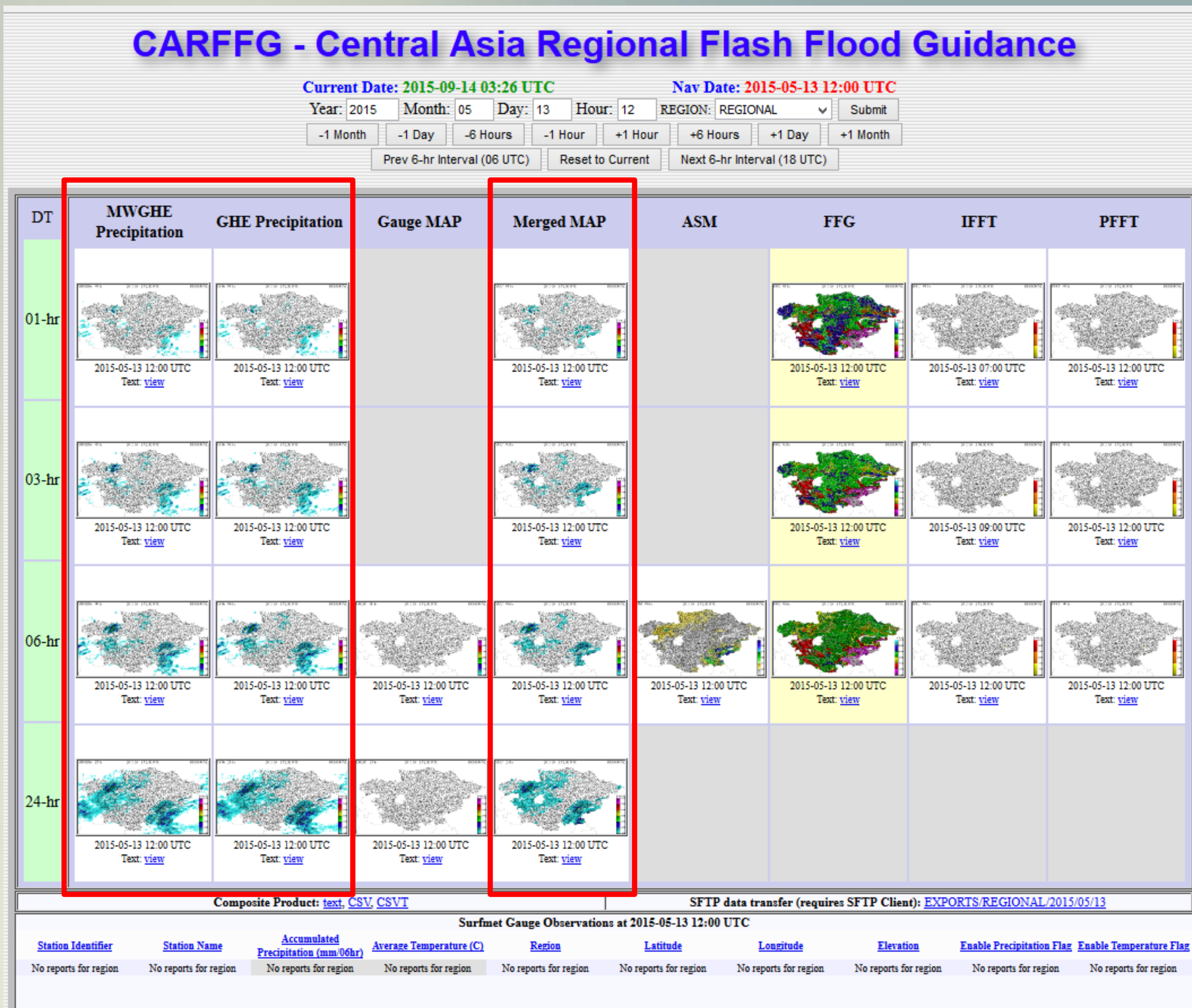
- a climatological bias adjustment Technique
  - quantile-quantile mapping between the log transformed areal-average gauge precipitation radar
- a dynamic bias adjustment technique.
  - adaptive Kalman filtering for the logarithmic ratio of the gauge to the radar precipitation averages over the same Pre-specified area

Real-time Implementation of Bias Adjustment



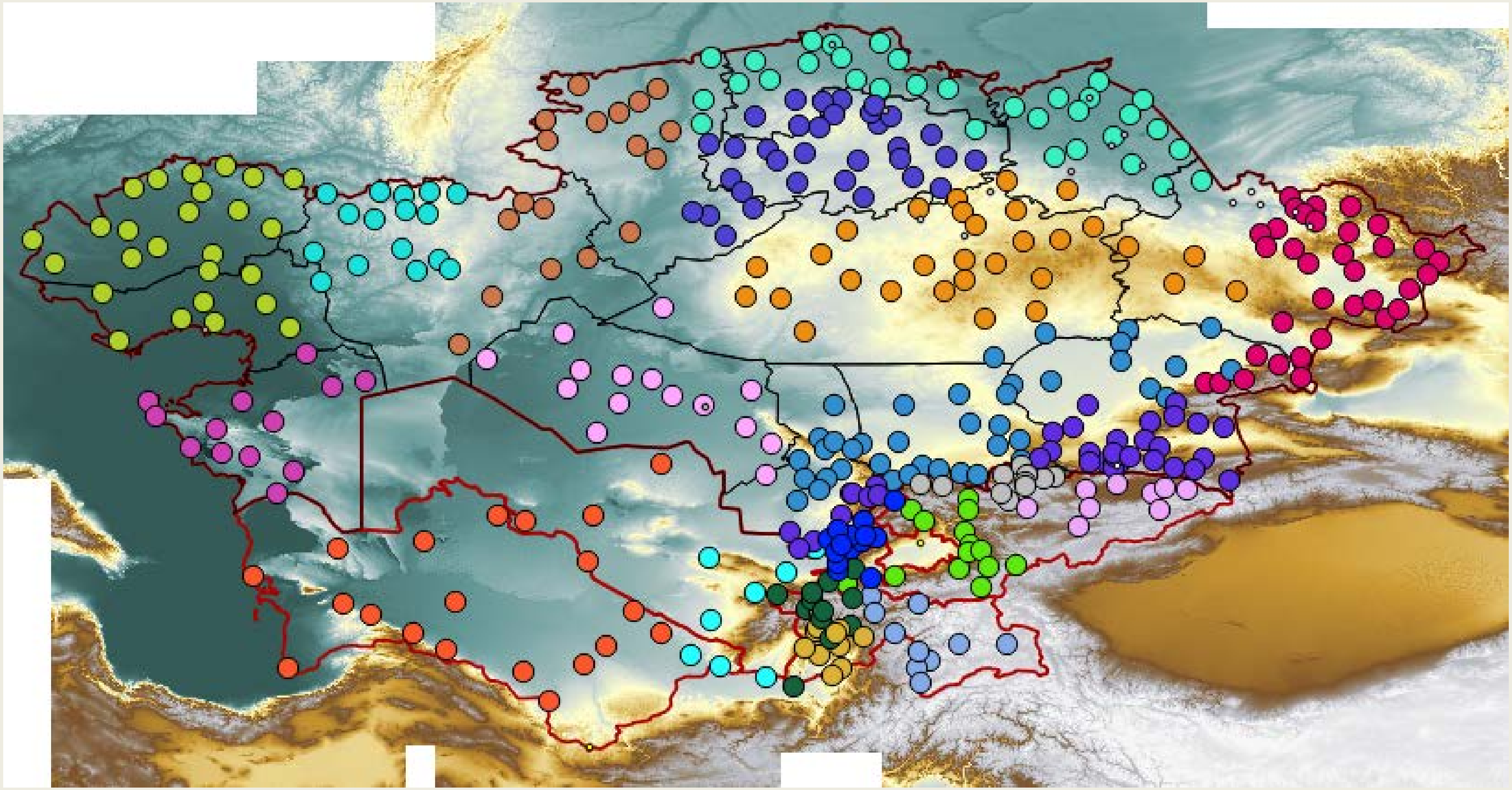
This presentation discusses climatological bias calculations

Merged Mean Areal Precipitation (MAP) Product

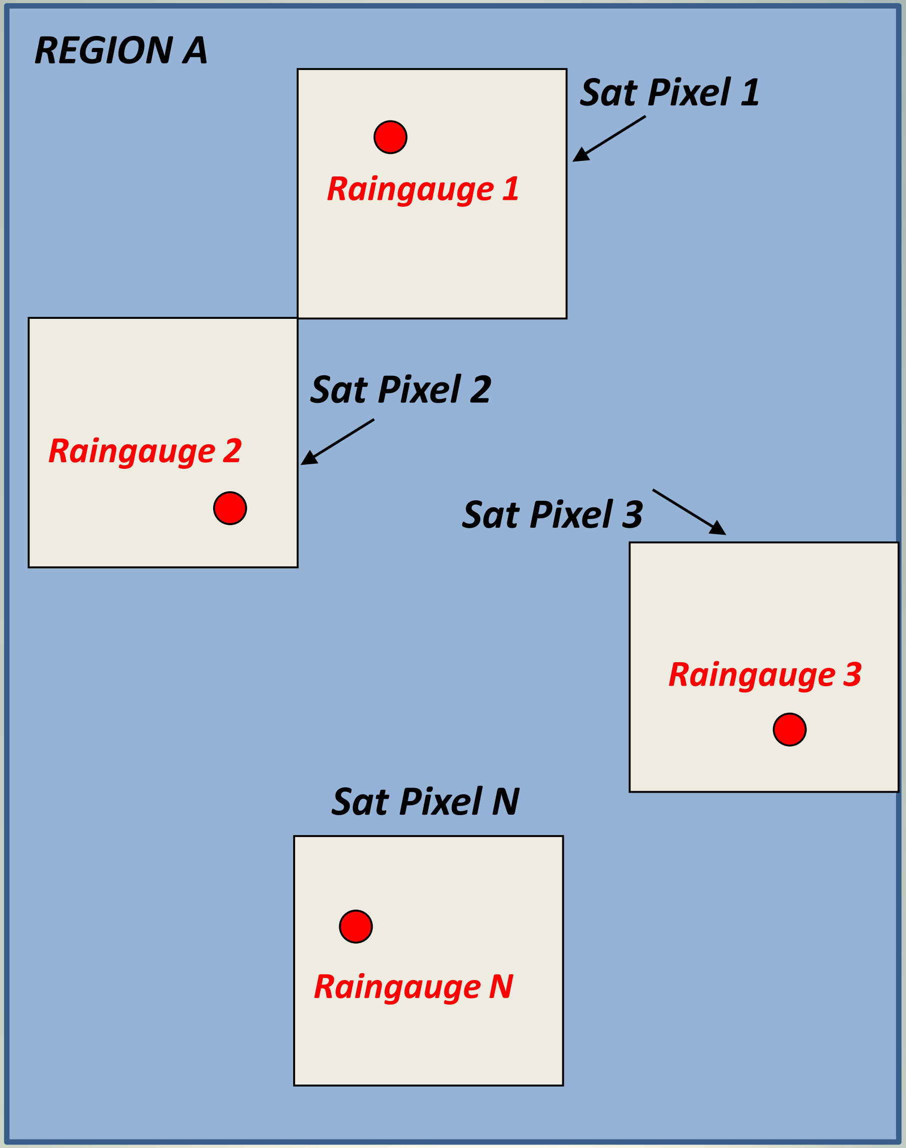


Climatological Bias Regions

- STEP 1: Identify locations
- STEP 2: Define sub-regions
- STEP 3: Extract time series of satellite pixel (both GHE and MWGHE) gauge data pairs



Satellite Precipitation Bias Adjustment



Log Bias:

$$\beta_t = \ln\left\{\frac{\sum_{j=1}^{N_G} R_G\,(j,t)\,/NG}{\sum_{j=1}^{N_G} R_{SAT}(j,t)/NG}\right\}$$

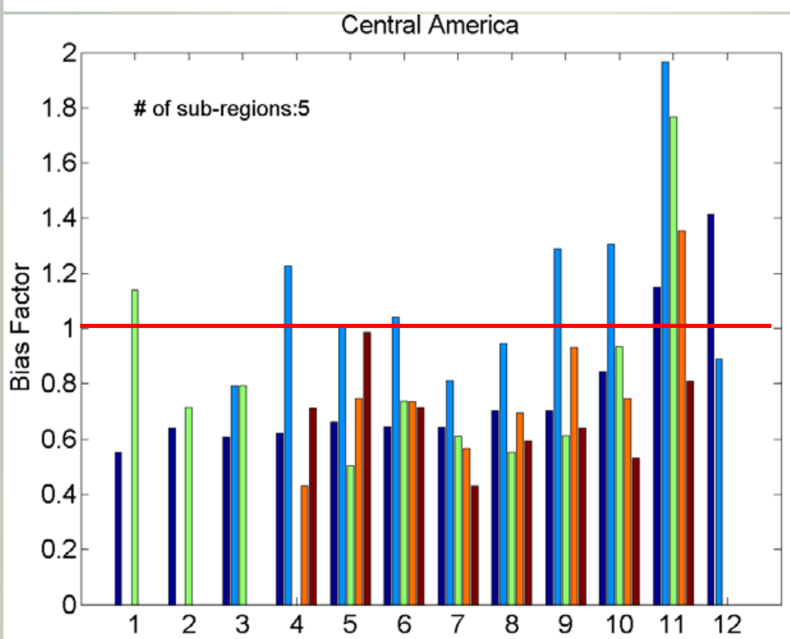
This is foundation of both the real-time and climatological bias adjustment.

Climatological Bias Adjustment

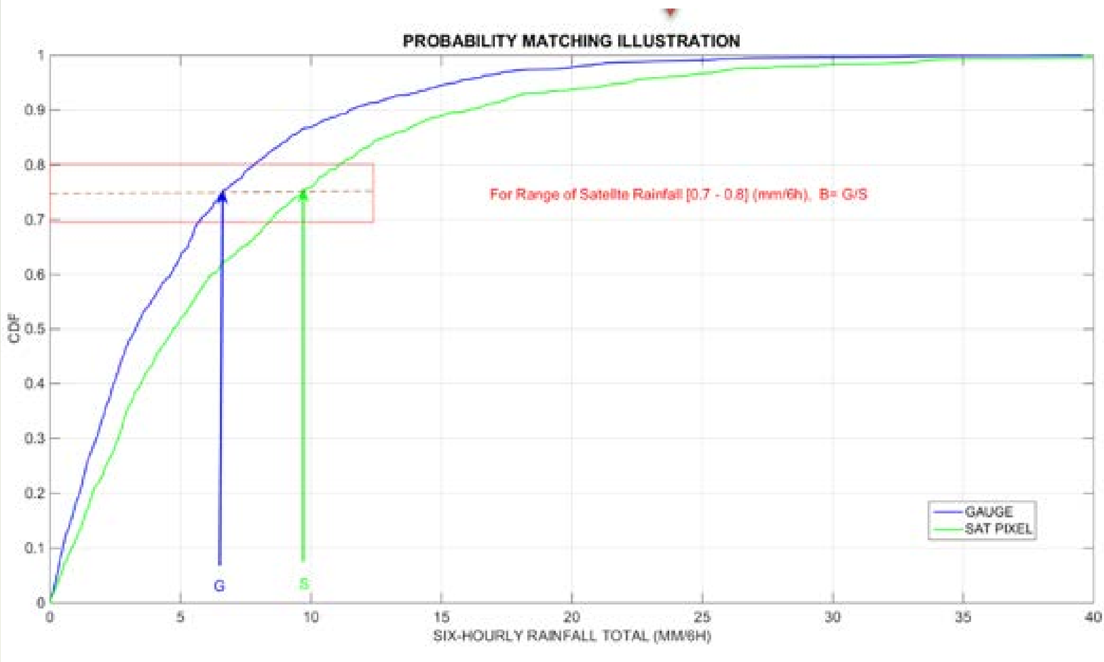
Goal is to determine long-term bias in satellite precipitation within a given region using historical records

- ❖ Hydro-climatic sub-regions
- ❖ Monthly or Seasonal basis
- ❖ Approach can involve mean values or probability matching

a. Mean Values



b. Probability Matching



Dynamic Bias Adjustment

$$\beta_t = \ell n \left[\frac{\sum_{j=1}^{N_g} R_g(t,j)}{\sum_{j=1}^{N_g} R_s(t,j)} \right]$$

$$\beta_{t+1} = \beta_t + w_{t+1}$$

$$z_{t+1} = \beta_{t+1} + v_{t+1}$$

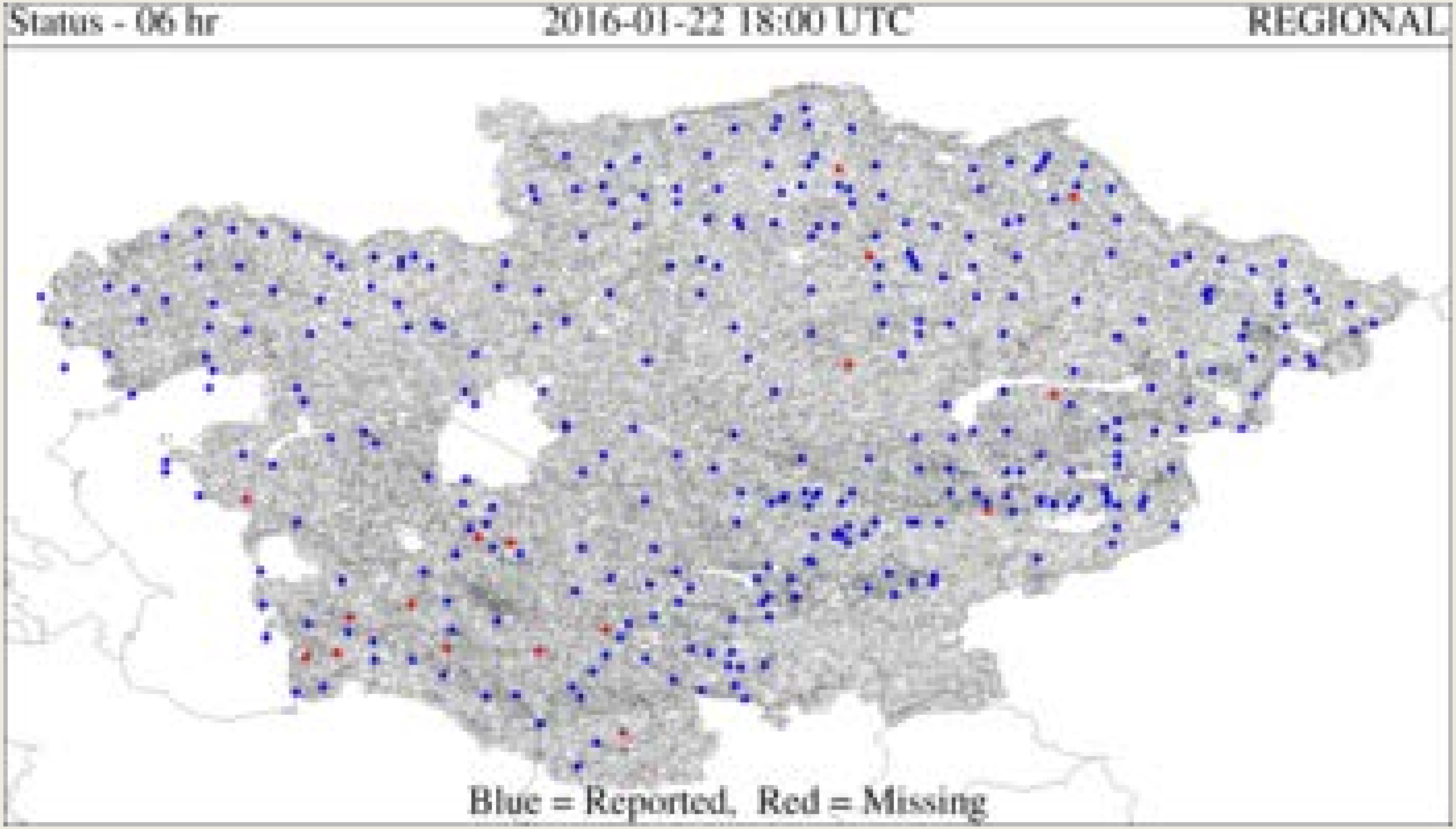
Kalman Filter
Stochastic Approximations

- N pairs of consecutive values > Nthr
- At least Xthr% raingauges with rain
- Conditional Mean > Threshold (mm/h) (satellite/radar and gauge)

Bias (B)

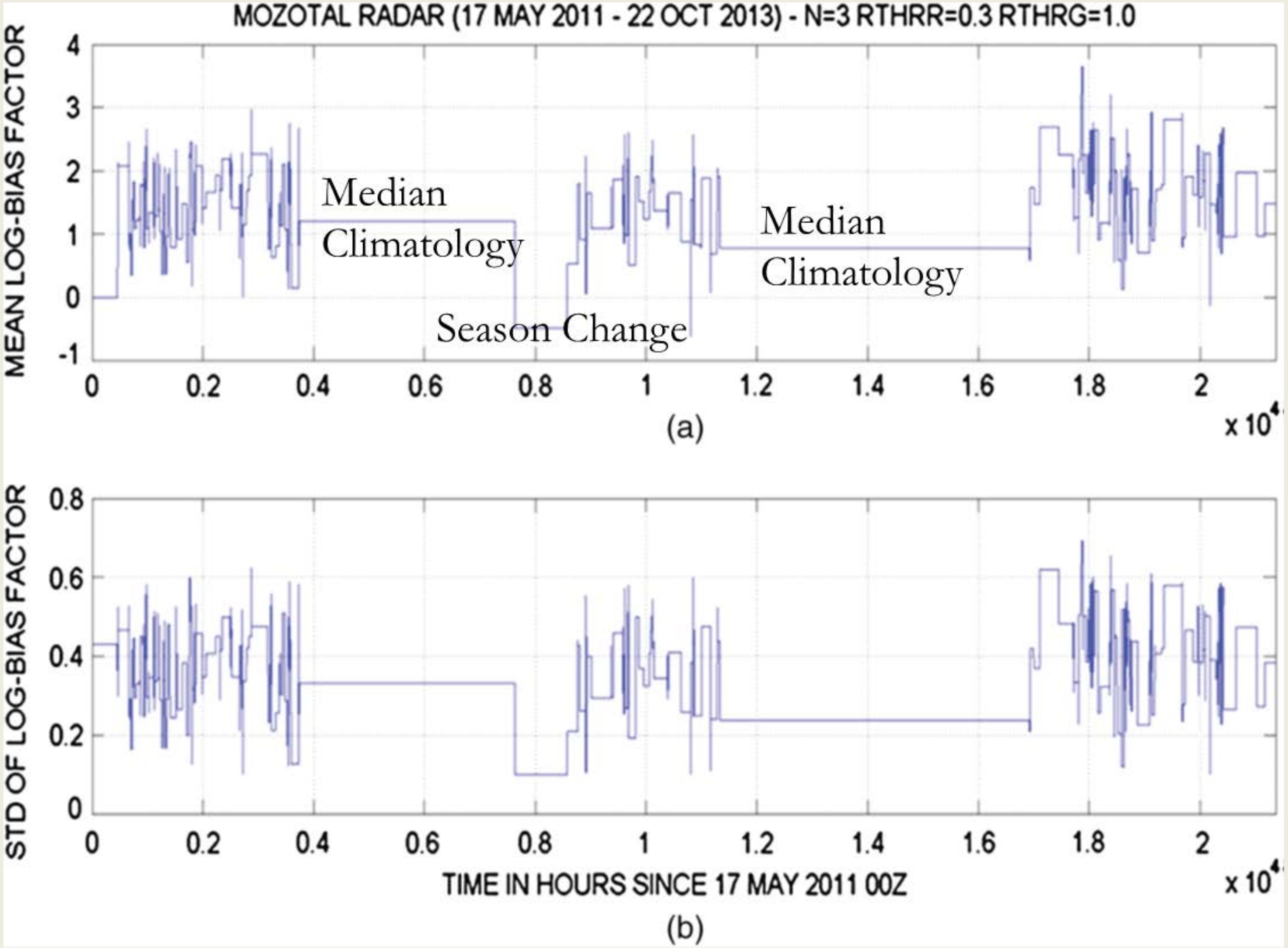
Georgakakos 1984

Available Stations for CARFFGS



Dynamic Bias Adjustment

Kalman Filter Prediction of the hourly bias adjustment



Modrick et al., 2016 & Georgakakos 1984

General Methodology for Climatological Bias Analysis

- Gather available historical gauge data *with* gauge coordinates
  (often use data records due to greater number of stations,
  number of historical gauges often > real time locations)

- Define sub-regions based on topography, climate, number of gauges, and spatial distribution of stations.

- Extract time series of precipitation for selected gauges and corresponding satellite pixel.

- Compute time series of log bias within each region subject to constraints:
  - Minimum # pairs with precipitation within region
  - Conditional average at given timestep > precipitation threshold

- Compute an average log bias on monthly or seasonal basis OR probability deciles for each region and determine climatological bias factor.

Final Comments on Bias Adjustment

- *Climatological precipitation bias adjustment should be reviewed and updated on regular basis (every 2-3 years) with operational personnel. Updates could include additional stations (i.e., not in real-time archive) with consistent resolution using utilities that we will provide during training.*
- *Note: No precipitation bias adjustment is performed for FORECAST precipitation product.*