WMO Space-based Weather and Climate Extremes Monitoring (SWCEM) for East Asia and Western Pacific (SWCEM-EAWP)

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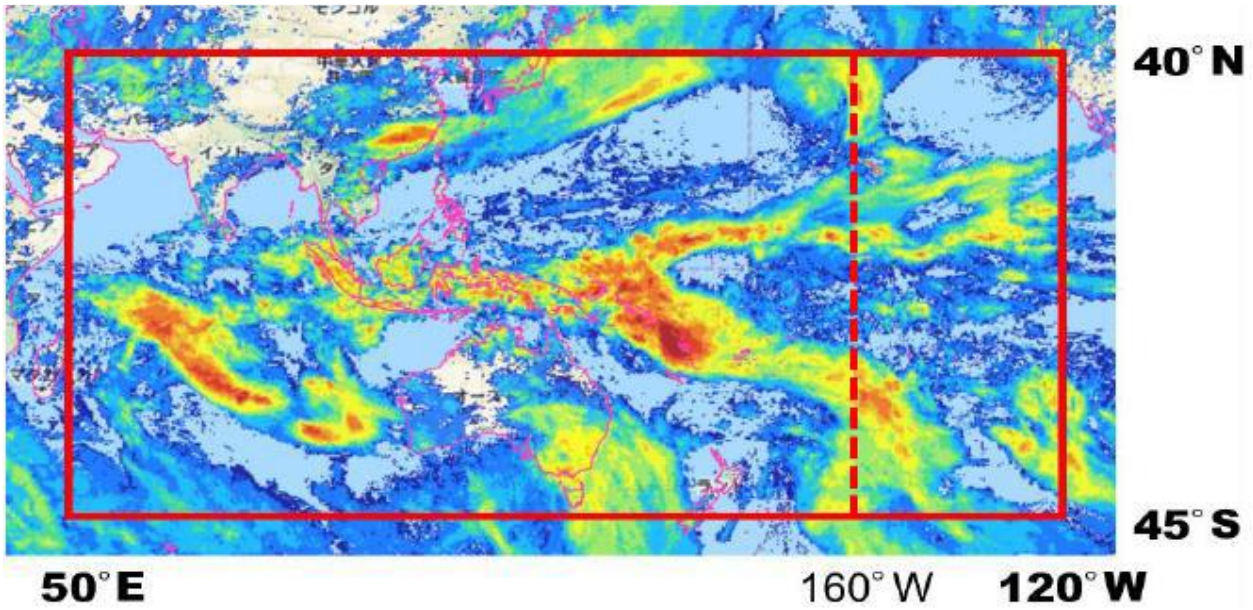
History of SWCEM

The Workshop on Operational Space-based Weather and Climate Extremes Monitoring (SWCEM) was held in Geneva, Switzerland on 15-17 February, 2017

- Recognizing high impact of weather and climate extremes on society, the WMO established the Space-based Weather and Climate Extremes Monitoring (SWCEM) International Initiative.

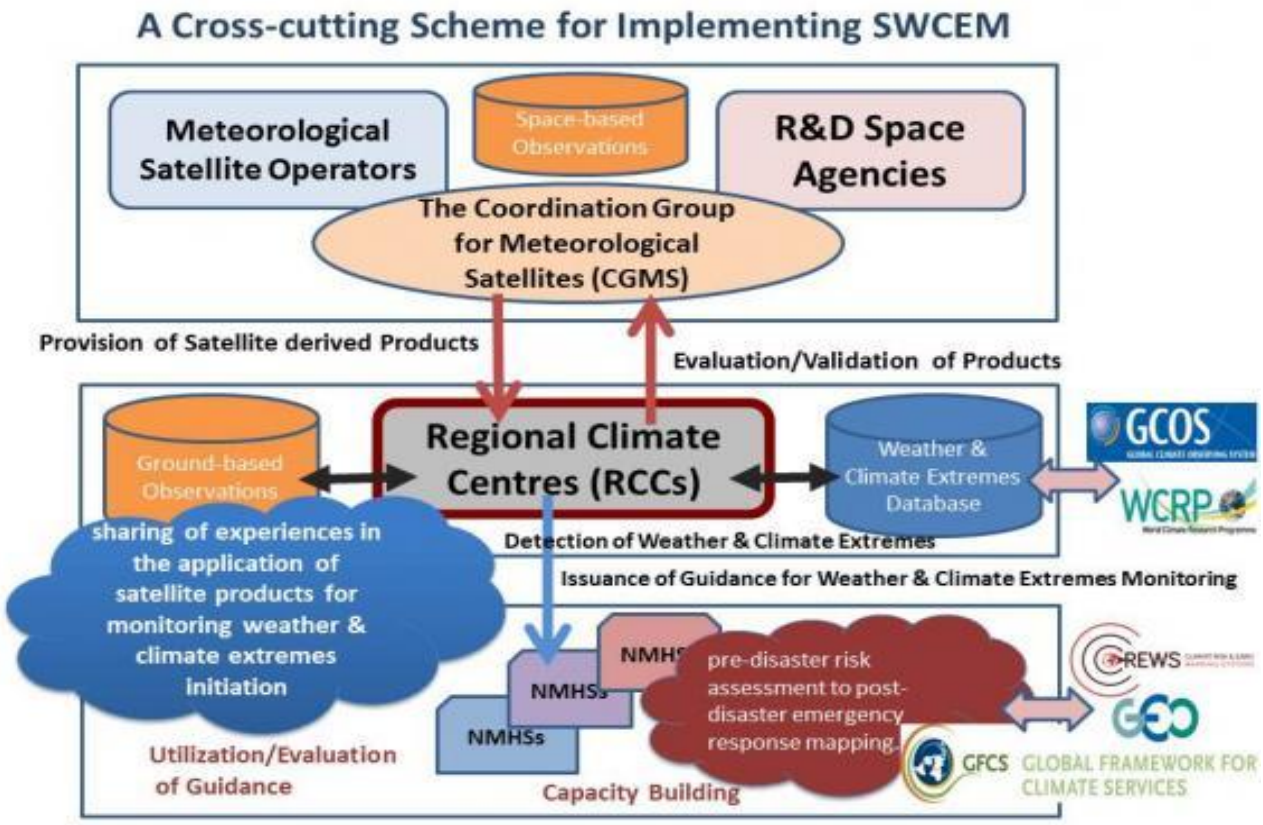
- Provision of timely and accurate information on monitoring extreme events helps to build greater resilience of society against drought, floods, storms and other hydro-meteorological hazards.

SWCEM Demonstration Project in WMO RA-II and V



- The first SWCEM demonstration project was successfully implemented in WMO Region II (Asia) and Region V (the South-West Pacific) in 2018-2019.
- The project was focused on monitoring **drought** and **heavy precipitation**
- Implemented in geographical domain which covers the **South-EastAsia** region and the **Western Pacific Ocean** area from 40°N to 45°S; 50°E to120°W.

Structure of SWCEM-EAWP



Global Satellite-derived Products Providers (GP-SAT)

- Japan Aerospace Exploration Agency (JAXA)
- National Oceanic and Atmospheric Administration (NOAA)

WMO RCCs in RA-II

- RCC Beijing (BCC)

WMO RCCs in RA-V: SEARCC-Network

- Indonesia (BMKG)
- Philippines (PAGASA)
- Singapore (Meteorological Service Singapore)

WMO RCCs in RA-V: Pacific RCC-Network

- Australia (RMIT & BoM)

WMO NMHSs in RA-II

WMO NMHSs in RA-V

- Malaysia (MetMalaysia)

Associated Members

- WCRP (Grand Challenge on Weather and Climate Extremes)

WMO Secretariat

Global Satellite-derived Product Providers (JAXA)

- JAXA provides the Global Satellite Mapping of Precipitation (GSMaP; Kubota et al. 2007*) data for detecting extreme precipitation

- GSMaP data are available from January 1998; thresholds for detecting the extreme events are calculated using the GSMaP data during 24 years(1998 - 2022)

- GSMaP data can be viewed graphically on Web Site;

"JAXA Climate Rainfall Watch" (https://sharaku.eorc.jaxa.jp/GSMaP_CLM/)

"JAXA Realtime Rainfall Watch" (https://sharaku.eorc.jaxa.jp/GSMaP_NOW/index.htm)

*Kubota T, Shige S, Hashizume H, Aonashi K, Takahashi N, Seto S, Hirose M, Takayabu YN, Ushio T, Nakagawa K, Iwanami K, Kachi M &Okamoto K. Global Precipitation Map Using Satellite-borne Microwave Radiometers by the GSMaP Project: Production and Validation. IEEE Transactions on Geoscience and Remote Sensing. 2007: 45(7, part2): 2259-2275. DOI: 10.1109/TGRS.2007.895337

Global Satellite-derived Product Providers (NOAA)

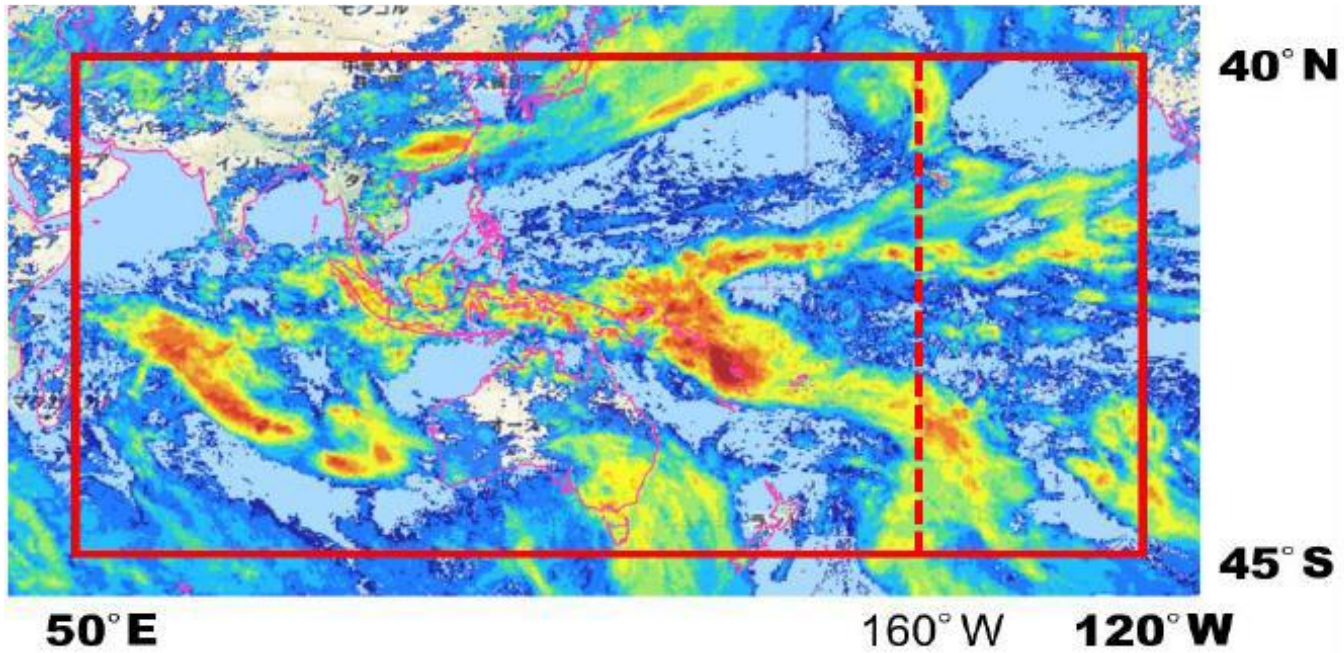
- NOAA/CPC provides products using the Climate Prediction Center morphing technique (CMORPH; Xie et al. 2017*); satellite precipitation estimates are available from 1998.

- In addition to precipitation estimates, NOAA provides vegetation indices; the NDVI and the VHI for the SWCEM region.

NOAA / NESDIS / STAR Web Site
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_blended_cmorph.php
NOAA / CPC ftp site
https://ftp.cpc.ncep.noaa.gov/precip/CMORPH2/CMORPH2NRT/

*Xie P, Joyce R, Wu S, Yoo S-H, Yarosh Y, Sun F & Lin R. Reprocessed, Bias-Corrected CMORPH Global High-Resolution Precipitation Estimates from 1998. Journal of Hydrometeorology. 2017: 18(6): 1617-1641. DOI: 10.1175/JHM-D-16-0168.1.

SWCEM-EAWP Operational Products



Mean precipitation estimates
- hourly
- daily (00-23UTC)
- pentad (5-day)
- weekly (Monday–Sunday)
- 10-days
- monthly

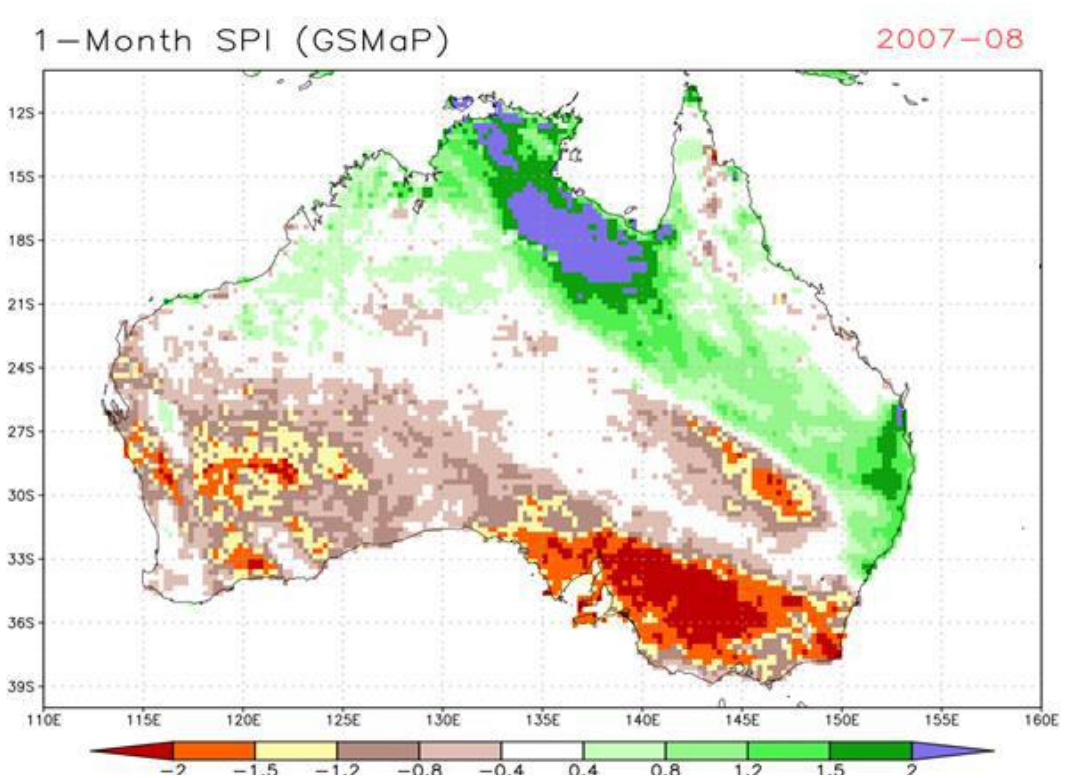
Statistics:
- Climate normal
- 90th～99th Percentiles
- Percentage of rainy days (>=1mm/day) in a month

Indices: SPI, NDVI, VHI

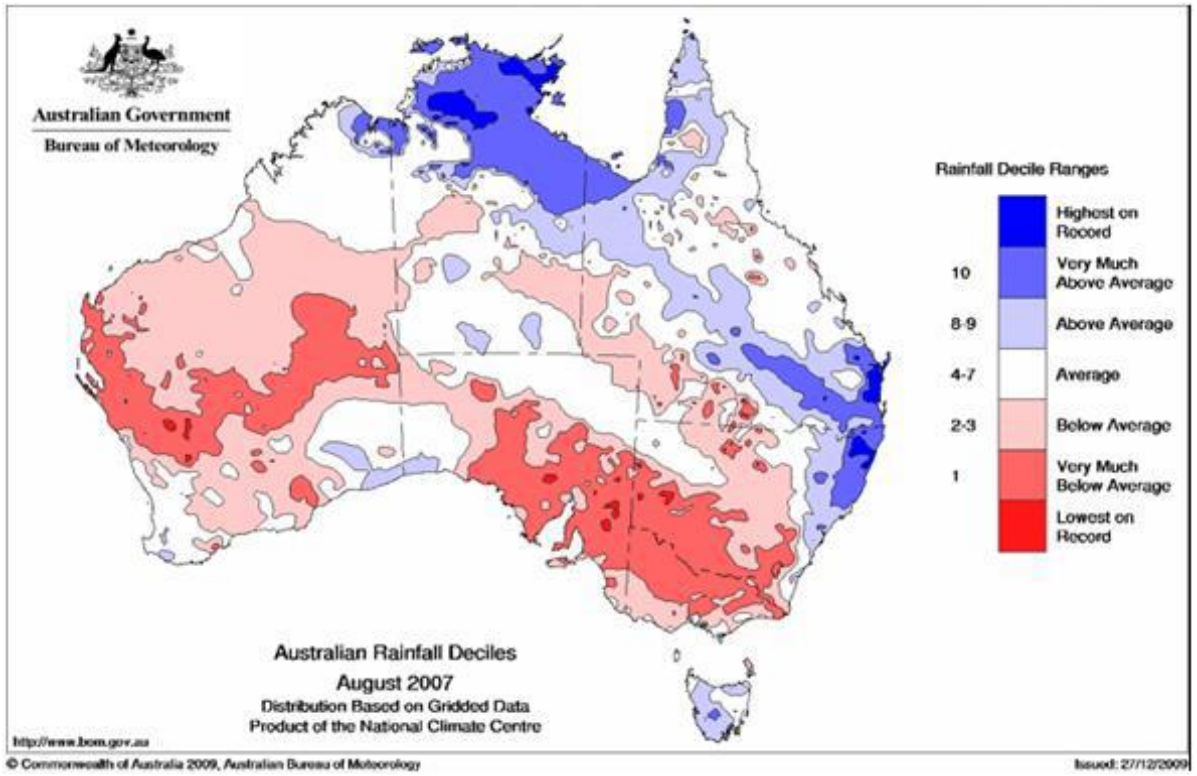
Spatial Resolution: 0.1 X 0.1 degrees
Coverage: from 40°N to 45°S; 50°E to120°W

SWCEM precipitation products include mean precipitation estimates for hourly, daily, pentad, weekly, 10days and monthly precipitation. In addition, statistics for daily, pentad and weekly extreme precipitation and percentage of rainy days in a month is provided.

Drought Monitoring Using SWCEM Product (SPI*)



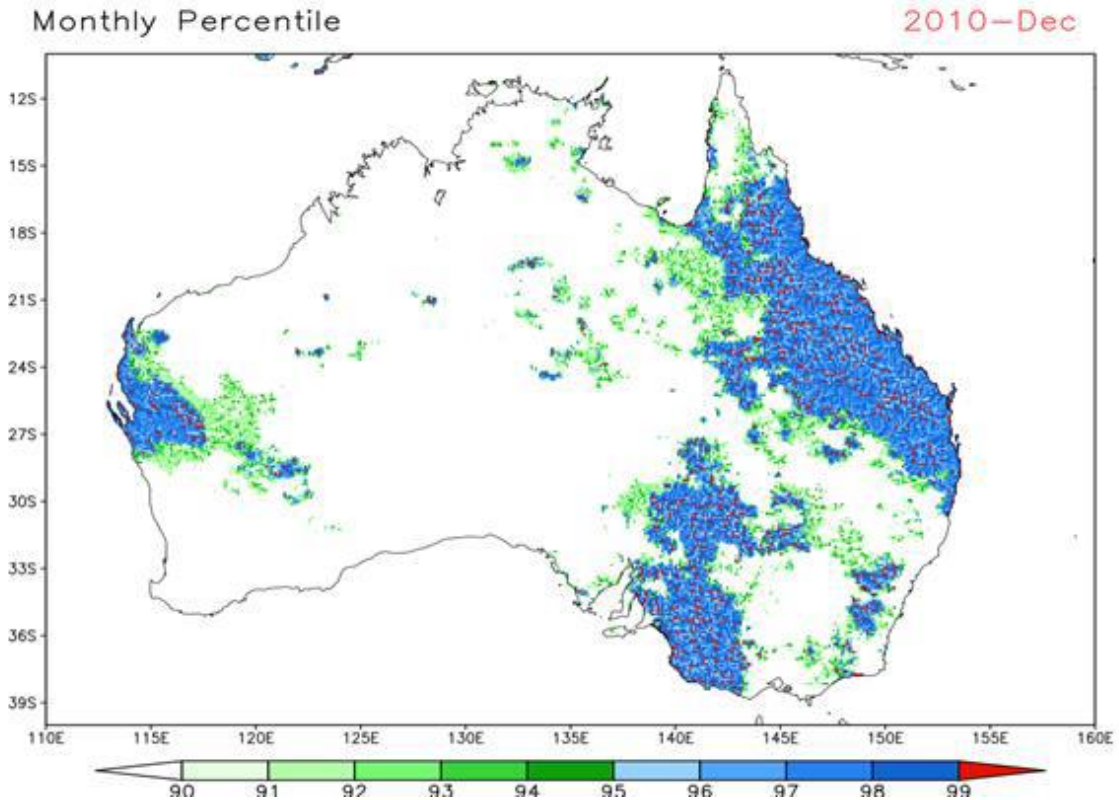
SPI for Australia in August 2007
derived from JAXA GSMaP data



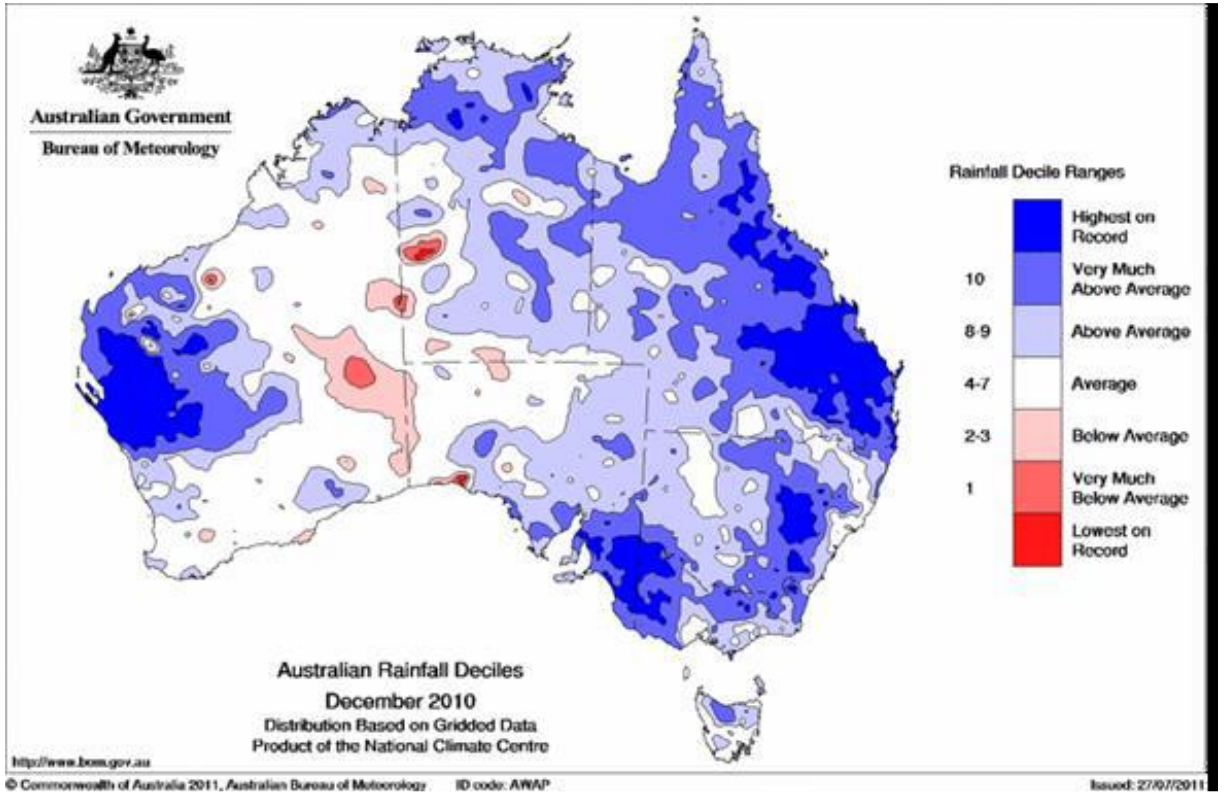
Rainfall Deciles for Australia in August 2007
BoM rain gauge observations.

*** Standardized Precipitation Index (SPI)** is a widely used index to characterize meteorological drought on a range of timescales. On short timescales, the SPI is closely related to soil moisture, while at longer timescales, the SPI can be related to groundwater and reservoir storage. (https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi)

Heavy Precipitation Monitoring Using SWCEM Product (Monthly Rainfall Percentile)



JAXA GSMaP **Rainfall Percentile** over Australia for December 2010



Australian **Rainfall Deciles** for December 2010 BoM rain gauge observations

SWCEM-EAWP in Operations

- The Eighteenth World Meteorological Congress (Cg-18) in 2019 - recognizing significant achievements of SWCEM in Asia -Pacific, adopted project implementation plan for 2020 - 2021

- Cg-18 - to progress with the implementation of the SWCEM regional **operational** subproject in East Asia and Western Pacific

- Cg-18 - to consider the possibility of implementing similar projects in Africa (RA I) and South America (RA III)

Steering Group for SWCEM-EAWP (SG-SWCEM-EAWP)

The Terms of Reference for the SWCEM-EAWP Steering Group (SG-SWCEM-EAWP) are defined as follows:

(i) Guide the implementation of the project;
(ii) Monitor the progress and, if needed recommend adjustments as needed;
(iii) Recommend the integration of new tools, techniques and data into the SWCEM;
(iv) Promote synergies and collaboration with other programmes and initiatives;
(v) Encourage the participation and/or contribution of other Regional Climate Centres (RCCs) and NMHSs not directly involved in the implementation of SWCEM activities;
(vi) Review and make recommendations on the scope of the cascading weather and climate extreme event monitoring process.

SG	Date & Location
1st Session	31 October - 1 November 2018, Kuala Lumpur, Malaysia
2nd Session	21 - 23 August 2019, Tokyo Japan
3rd Session	8 October 2020 (online)
4th Session	23-24 March 2022 (online)
5th Session	27-28 July 2023 (online)

Achievements presented in SG-SWCEM-EAWP-5 (27-28 July 2023)

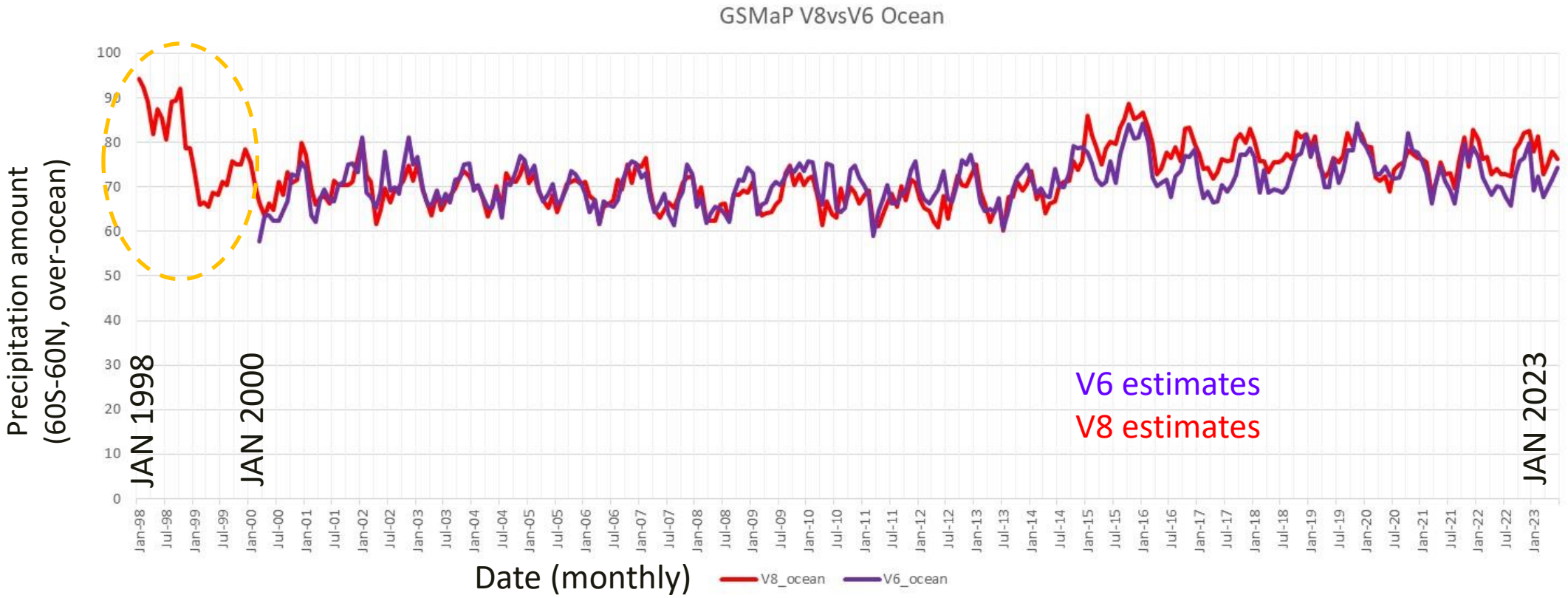
JAXA: Reprocessing for the GSMaP new version (V8)

- GSMaP had a major update in Dec. 2021 (Algorithm V8), and re-processing of the GSMaP products was completed in July 2023.
- Past GSMaP products did not cover the first 2 years of TRMM era (1998 - Mar. 2000) due to lack of CPC-4km Global IR dataset (Janowiak et al. 2001).
- In the new version of the GSMaP, GridSat-B1 data (Knapp et al. 2011) were used to fill the lack of period as follows (Kubota et al. 2023).
  - GridSat-B1 during a period from Jan. 1998 to Jan. 2000
  - GridSat-B1 & CPC-4km during Feb. 2000
  - CPC-4km after Mar. 2000
- The new version of the GSMaP is available during a period of the last 25 years since Jan. 1998.

- Janowiak J. E., R. J. Joyce, and Y. Yarosh, 2001: A Real-Time Global Half-hourly Pixel-Resolution Infrared Dataset and Its Applications. (Bull. Amer. Meteor. Soc., vol. 82, No.3., 205-217.)
- Knapp, K. R., S. Ansari, C. L. Bain, M. A. Bourassa, M. J. Dickinson, C. Funk, C. N. Helms, C. C. Hennon, C. D. Holmes, G. J. Huffman, J. P. Kossin, H.-T. Lee, A. Loew, and G. Magnusdottir, 2011: Globally gridded satellite (GridSat) observations for climate studies. *Bulletin of the American Meteorological Society*, 92, 893-907. doi:10.1175/2011BAMS3039.1
- Kubota, T., M. K. Yamamoto, and M. Yamaji, 2023: Reprocessing of Global Satellite Mapping of Precipitation (GSMaP) Product, AOGS2023, AS02-A019, Singapore.

JAXA: Monthly time series of GSMaP: V6 vs V8

- Precipitation estimates for the period during 1998-2000 are available only in the V8 (Red line).
- We're now processing calculation of statistics (climatology, percentile values and so on) and the drought index using 25 yr-GSMaP data for the SWCEM users.

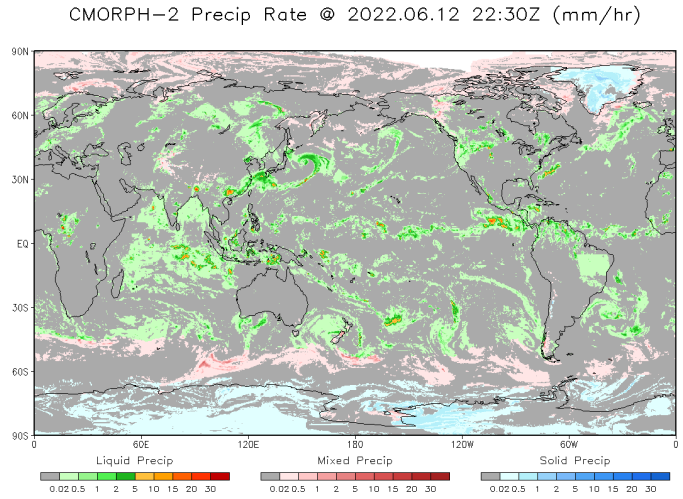


NOAA/CPC: 2nd Generation CMORPH Overview

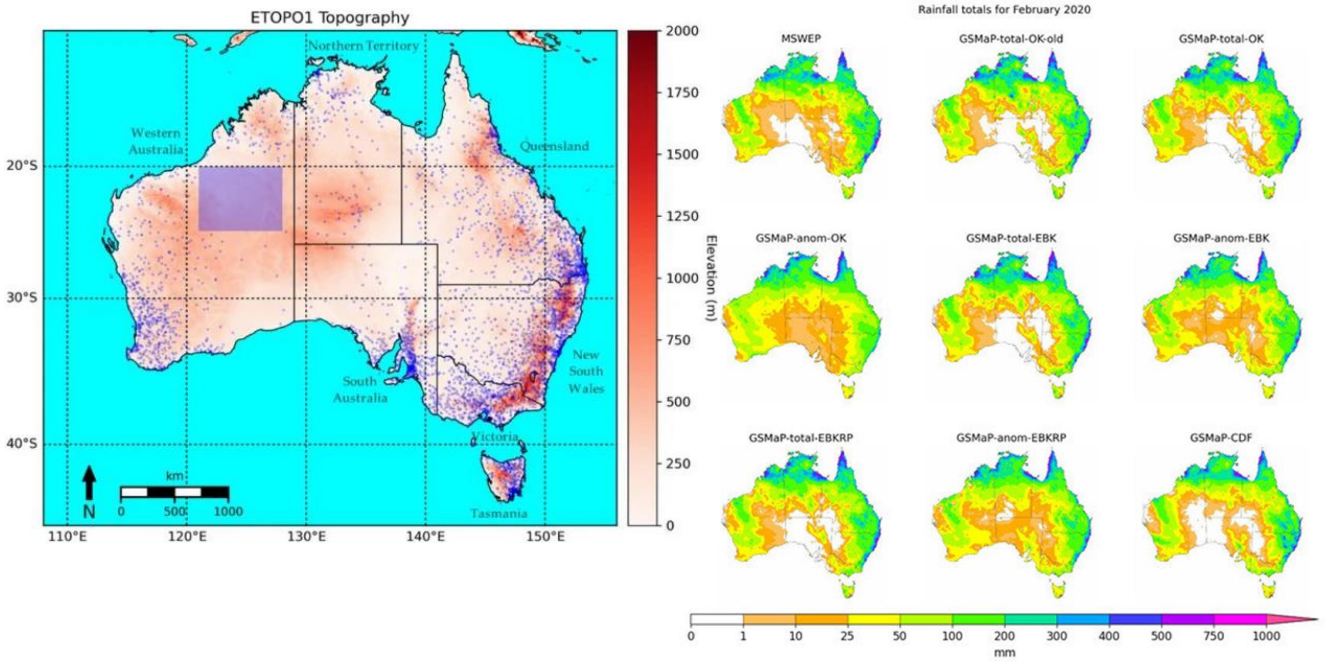
- The NOAA/Climate Prediction Center (CPC) has initiated operational real-time routine production of CMORPH-2 products since Jan 2023;
- Real-time CMORPH2 is now constructed on an NWS 7/24 operational environment
- Real-time CMORPH2 shows good skills in estimating cold season precipitation as well as in capturing severe rainfall storms;
- Bias correction further improves the performance of CMORPH2, especially in accurately quantifying the magnitude of precipitation;
- Real-time data are accessible thru NESDIS/STAR webpage or CPC ftp site;
- NOAA/CPC are in process of:
  - Implementing the bias correction procedures to the operational production;
  - Improving the representation of orographic rainfall;
  - Constructing retrospective analysis of CMORPH2 for a 30+ year period

Main Features of CMORPH-2

- High spatial / temporal resolution (0.05°lat/lon/30-min) infused with PMW retrievals from LEO satellites and IR observations from LEO & GEO platforms
- Complete global coverage (90°S-90°N)
- Low production latency (One hour, updated once every 30-min until 12-hour latency)
- Greatly improved representation of cold season precipitation (snowfall) thanks to the SFR retrievals from NESDIS/STAR;
- In addition to the total precipitation, fraction of solid precipitation also estimated (quantitative estimation of snowfall)



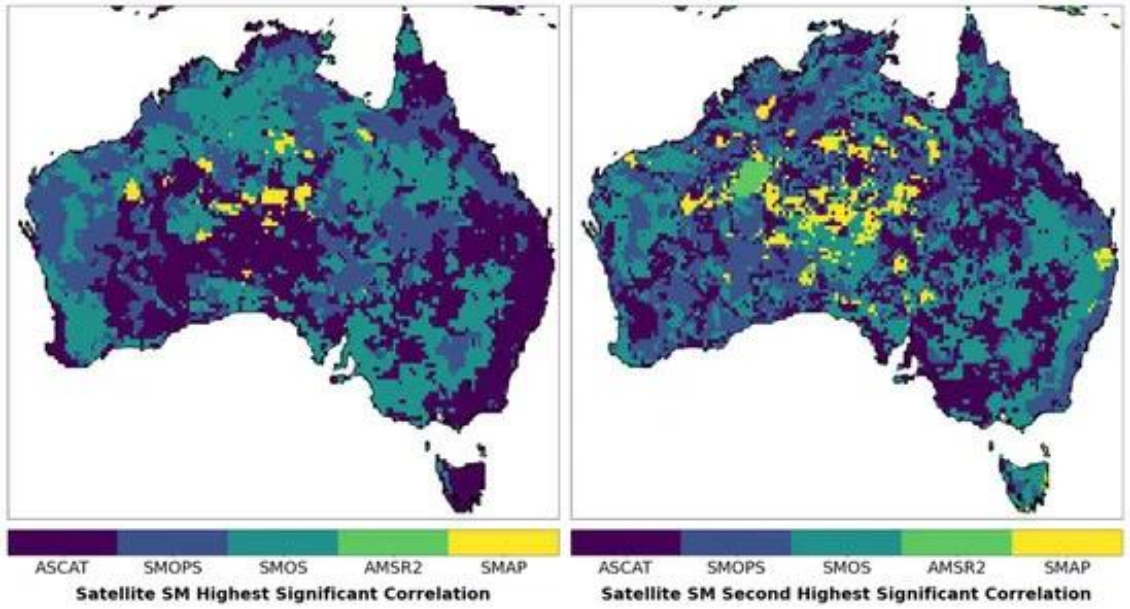
Operational Data Services: Australia BoM Rainfall Monitoring



- The performance of these monthly datasets was evaluated over the Australian domain from 2001 to 2020.
- Evaluated over the entire national domain, the satellite-based SI datasets had similar to slightly better performance than the station climatology-based SI datasets with some individual months being more realistically represented by the satellite-SI datasets.
- However, over gauge-sparse regions, there was a clear increase in performance.

- Rain gauge network of over 6,000 stations
- Spatial distribution of the station is not uniform
- Performance of a gauge-based analysis for rainfall estimation can be severely limited over regions with low gauge density.
- Australian station data along with the JAXA GSMaP and the BOM Australian Gridded Climate Dataset (AGCD) rainfall analysis are combined to develop an improved satellite-gauge rainfall analysis.
- Satellite observations of rainfall were used as the background field instead of station climatology to produce improved monthly rainfall analyses.

Operational Data Services: Australia BoM Soil Moisture (SM) Monitoring



BoM investigated the performance of

- Soil Moisture Active Passive (**SMAP**),
- Soil Moisture and Ocean Salinity (**SMOS**),
- Soil Moisture Operational Products System (**SMOPS**),
- SM from the Advanced Microwave Scanning Radiometer 2 (**AMSR-2**)
- SM from the Advanced Scatterometer (**ASCAT**).

- Soil moisture (SM) is critical in monitoring the time-lagged impacts of agrometeorological drought.
- In Australia and several south-west Pacific Small Island Developing States (SIDS), there are a limited number of in situ SM stations that can adequately assess soil-water availability in a near-real-time context.
- Satellite SM datasets provide a viable alternative for SM monitoring and agrometeorological drought provision in these regions.
- ASCAT and SMOS were consistently superior in their performance.
- The case study of the 2015 El Niño and Positive Indian Ocean Dipole-induced drought in Papua New Guinea shown that ASCAT is a valuable dataset indicative of agrometeorological drought for the nation as an early warning of drought in data-sparse regions.

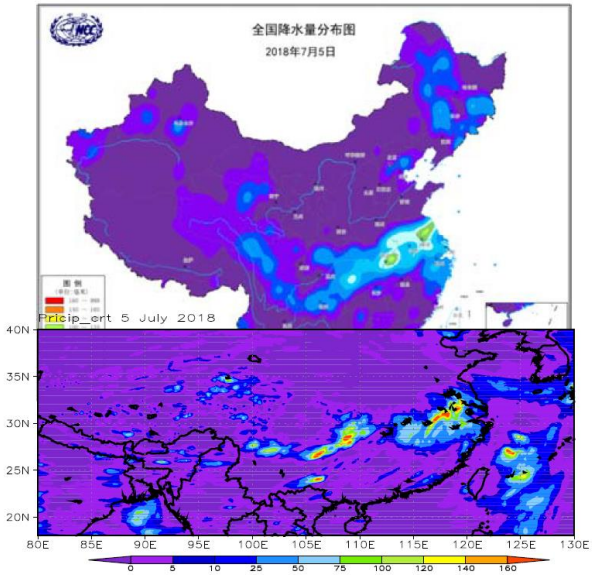
CMA/NCC as WMO RCCs in RA-II: Basin Climate Center (BCC)

The Meteorological Disaster Management Operational System in BCC

- The operational system in BCC for meteorological disaster monitoring and assessment
- A real-time and interactive system

- CMORPH and GsMaP data are updated everyday.
- Spatial and temporal analysis tools based on the satellite-derived data have been developed.

The Meteorological Disaster Management Operational System of BCC

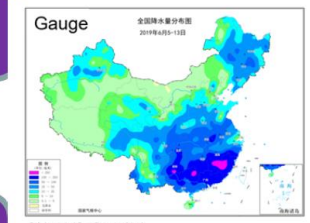


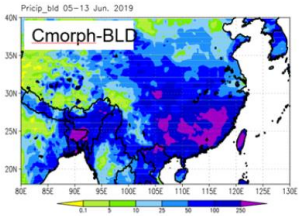
Case study 1: Comparison between CMORPH and gauge data

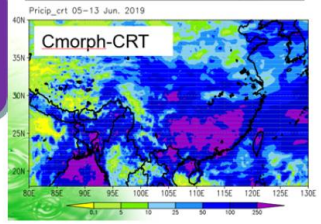
Case study 2: Comparison between CMORPH, GsMAP and gauge data

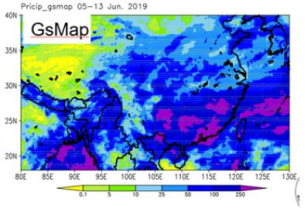
Developing the operational monitoring system

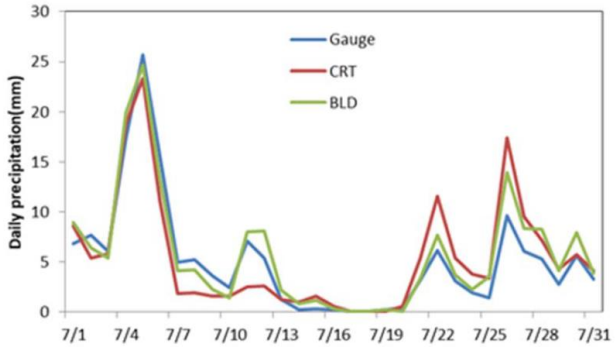
Operational monitoring











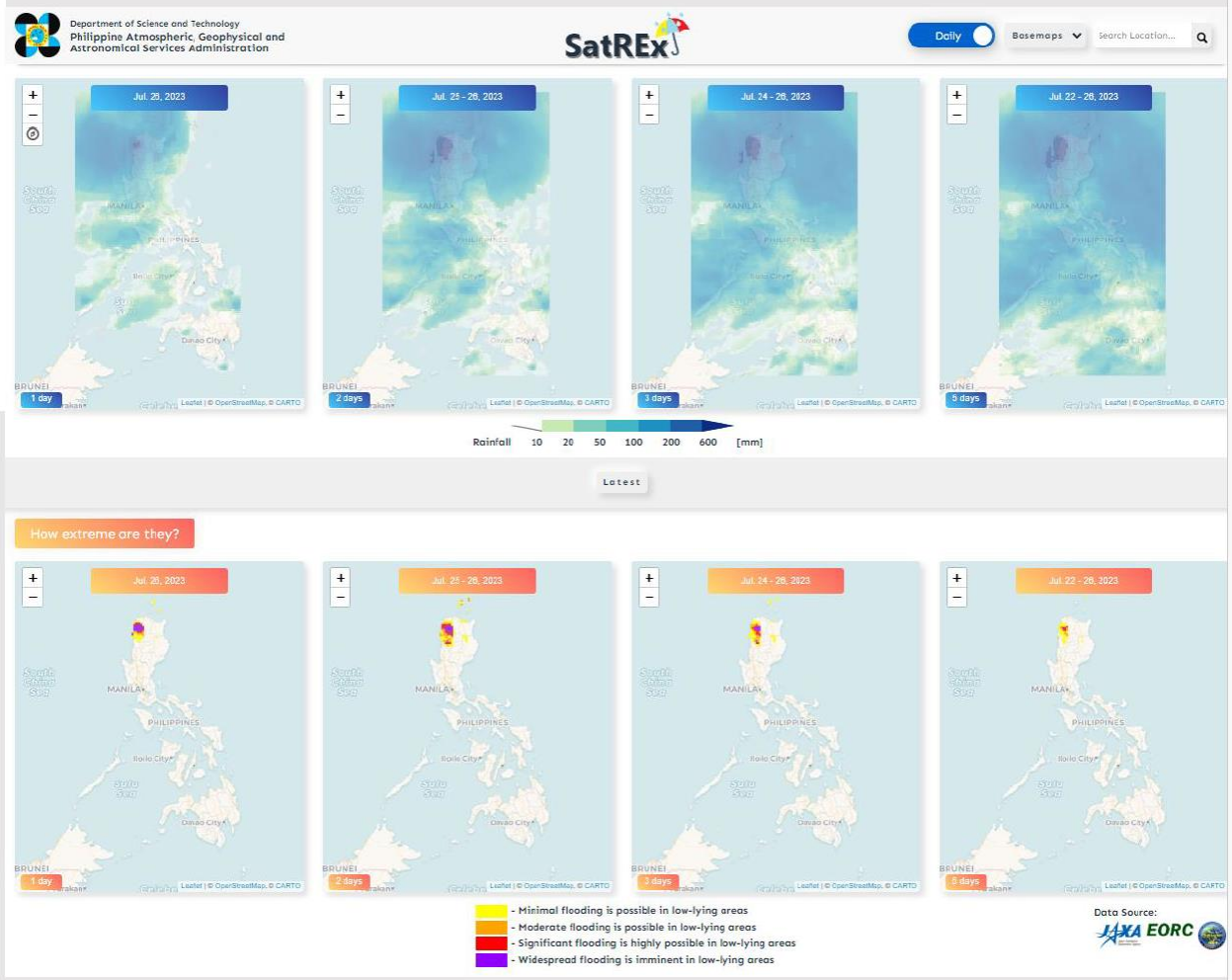
Philippine PAGASA as WMO RCCs in RA-V: SEARCC-Network for Climate Monitoring Development of Extremes Monitoring System (SatREx) derived from GSMaP

SatREx: Near-Real-Time Satellite Rainfall Extremes Monitoring System of the Philippines

Marcelino Q. Villafuerte II*, Mike A. Petaca, Wilmer Agustin, Charlie Ray Pascua, and Joanne Mae Adelino

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)

**Email: mvillafuerte@pagasa.dost.gov.ph*



- Provides near-real-time satellite rainfall estimates observed in the previous 1-, 2-, 3-, and 6-hour, as well as the previous 1-, 2-, 3-, and 5-day rainfall accumulations
- Translates observed rainfall relative to historical data
- Indicates areas possible to experience flooding

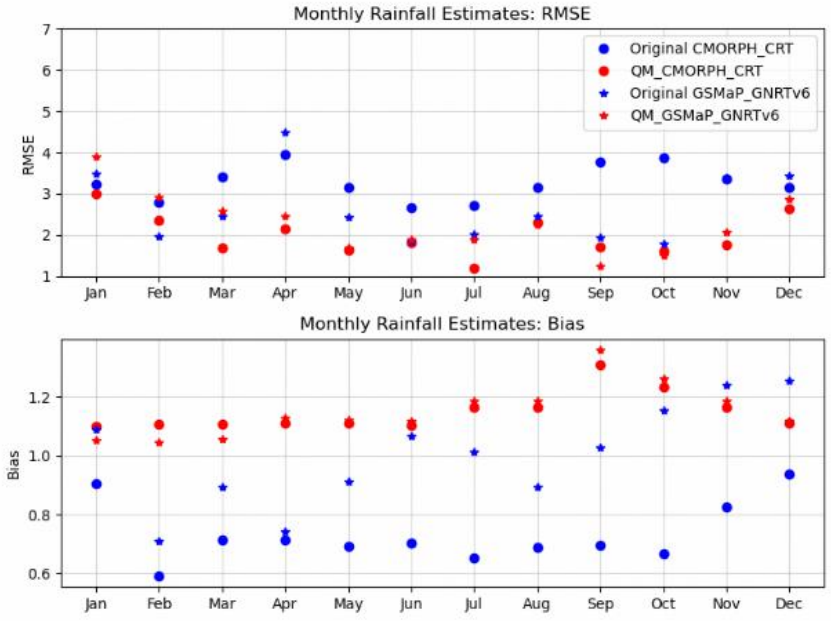
https://rainx.pagasa.dost.gov.ph/daily

METEOROLOGICAL SERVICE SINGAPORE
Centre for Climate Research Singapore

MSS Satellite Rainfall Estimate Calibration

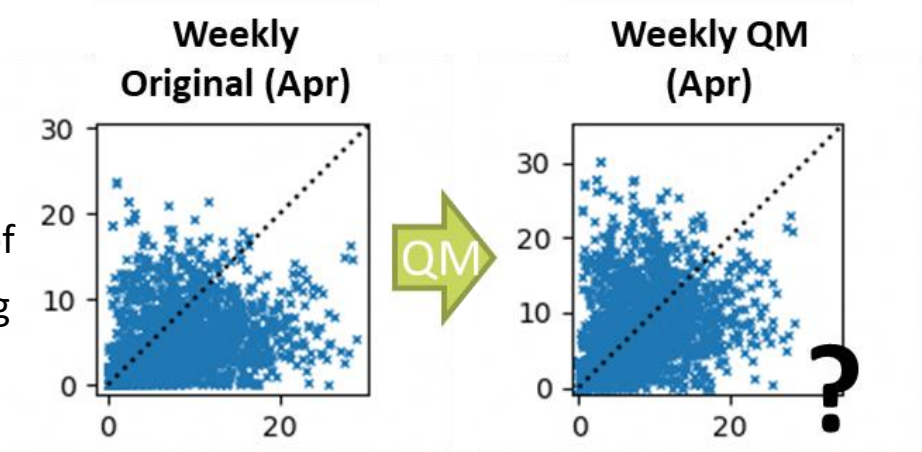
Quantile Mapping Technique with Machine Learning Aided Categorization

Previous Evaluation with QM: Gauge vs Satellite Estimates (CMORPH CRT, GSMaP_GNRTv6):

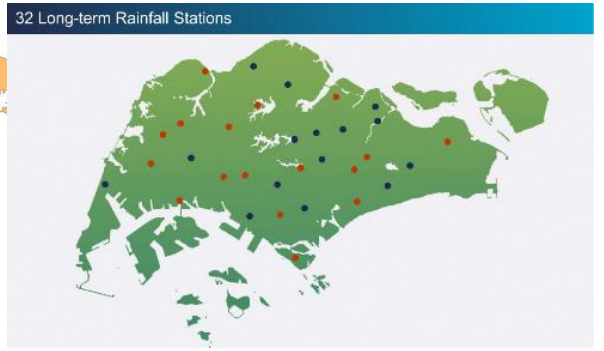


- Tested against rain gauge measurements over Singapore Quantile Mapping (QM) calibration of SWCEM-EAWP rainfall products using rain gauges achieved fairly good results for longer time period (e.g. monthly rainfall total)

- While bias improved considerably for shorter time scale (e.g. weekly rainfall total), but less so for RMSE and MAE



Two regions of study:
Singapore and Johor, Malaysia

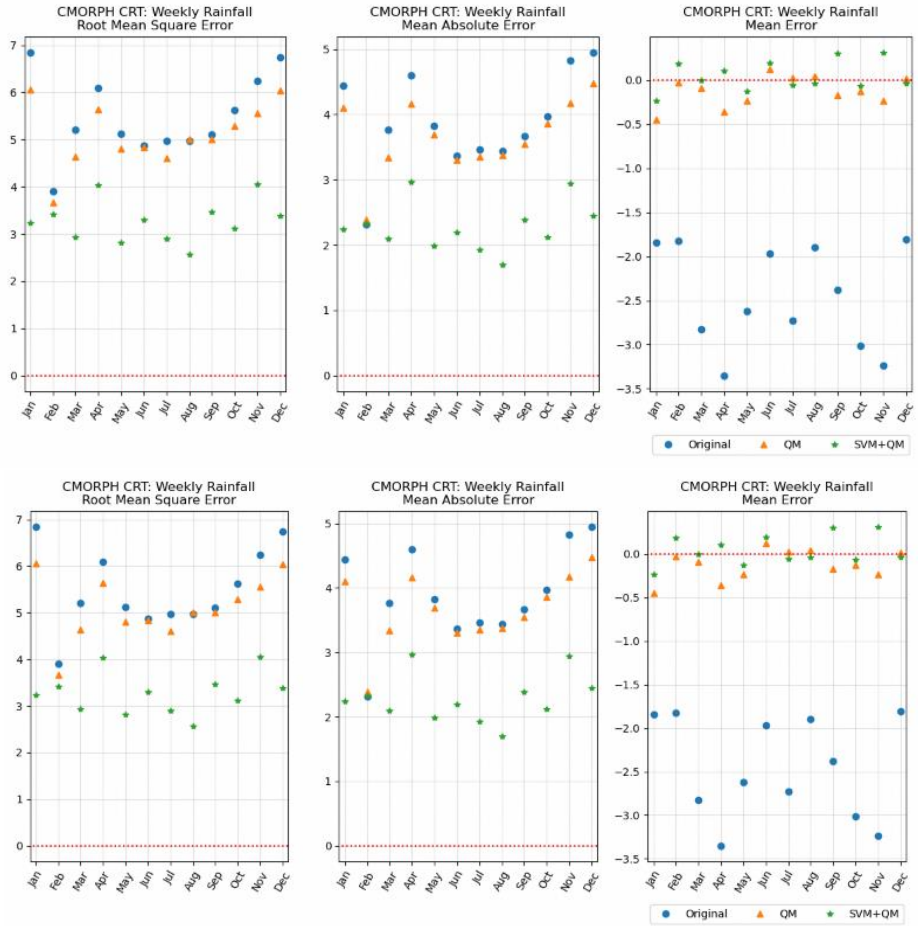


METEOROLOGICAL SERVICE SINGAPORE
Centre for Climate Research Singapore

MSS Satellite Rainfall Estimate Calibration

Quantile Mapping Technique with Machine Learning Aided Categorization

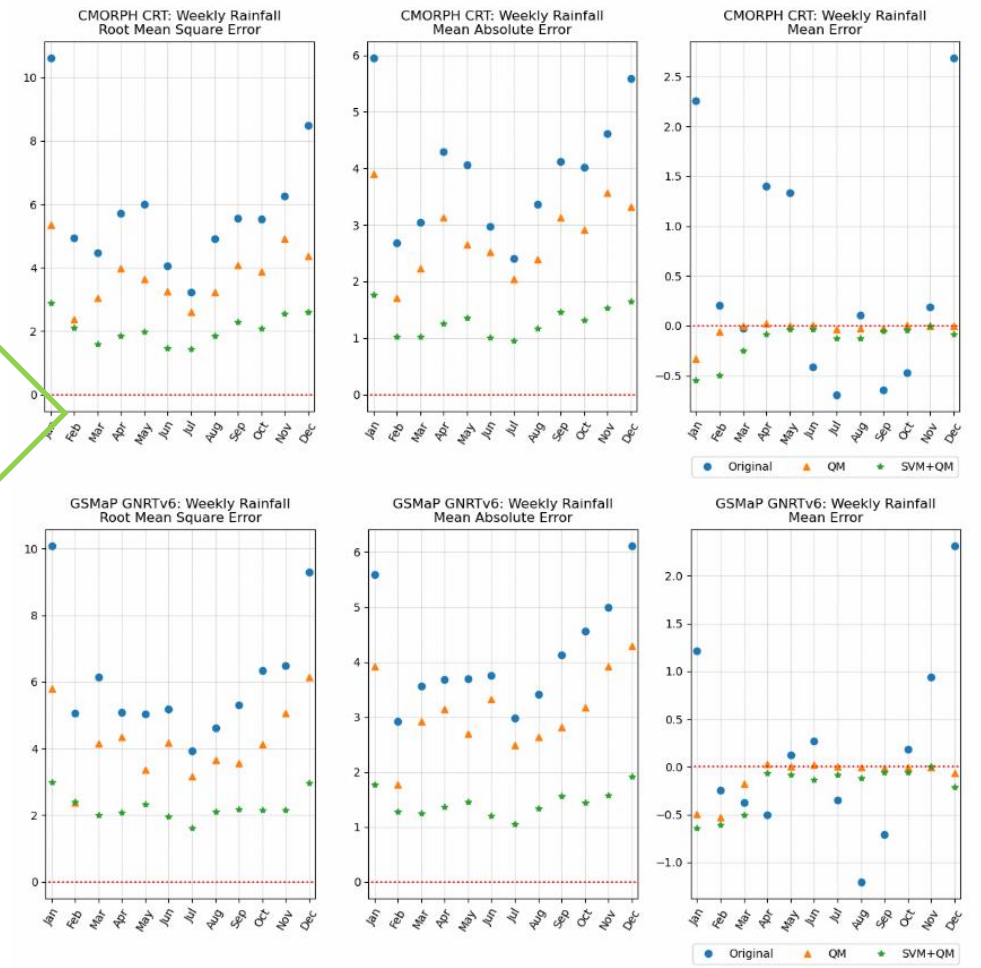
QM without ML



Concepts and Methodology

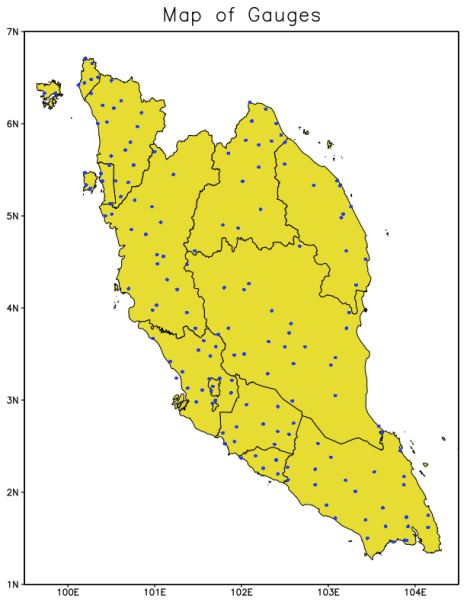
- Bias differences could be due to the rainfall type:
  - for shorter timescale (weekly), the scatter plot appears noisier with larger spread
- Through Machine-Learning (ML) (Support Vector Machine; SVM), achieve categorization of the rainfall estimate bias before applying Quantile Mapping (catQM)
  - self-driven categorization without the need for other inputs
  - gauge measurements for model learning and calibration

ML-aided catQM

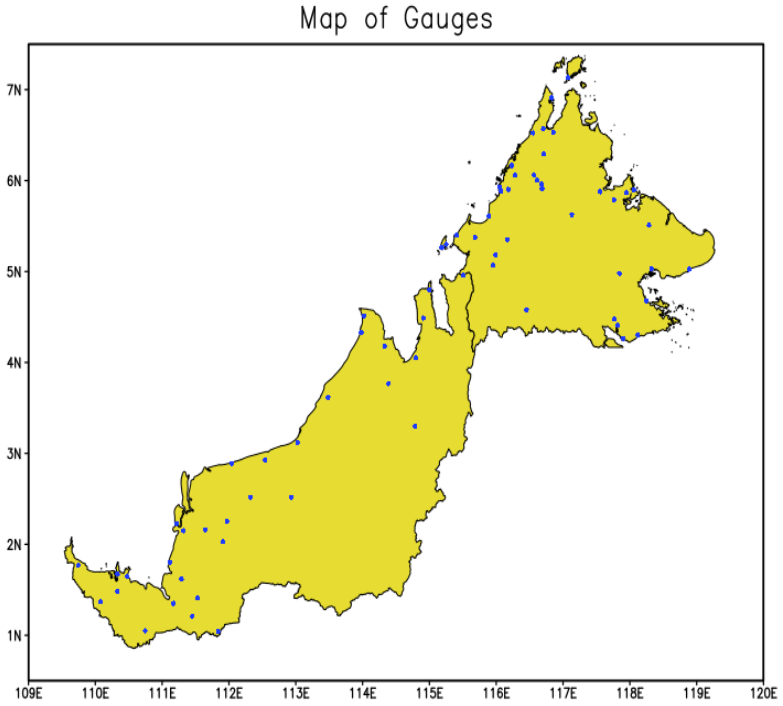


Satellite Rainfall Datasets Evaluation: Malaysia

Two satellite rainfall datasets (GSMaP_Now & PDIR-Now) were evaluated using three hundred and four (304) gauges from 01 November 2022 – 01 March 2023 corresponding to the Northeast Monsoon (NEM)



Peninsular Malaysia

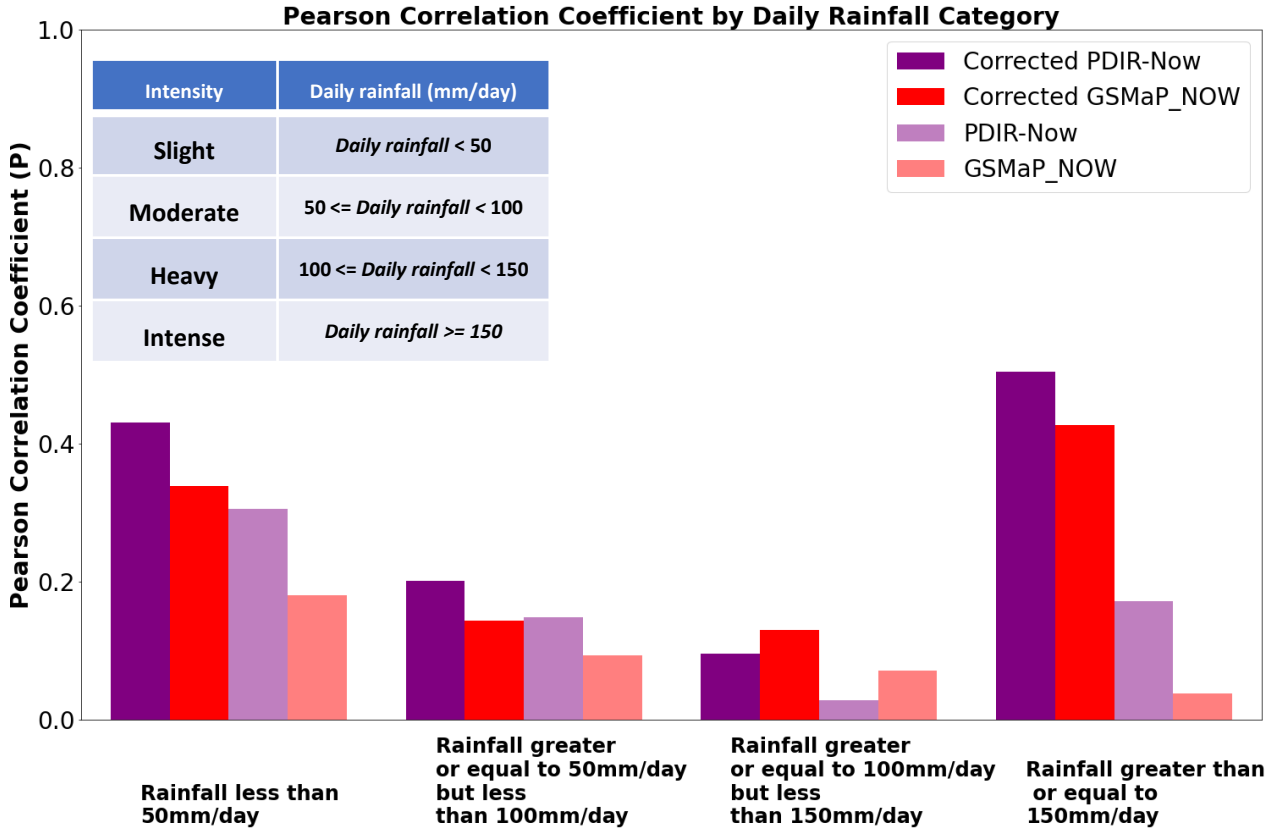


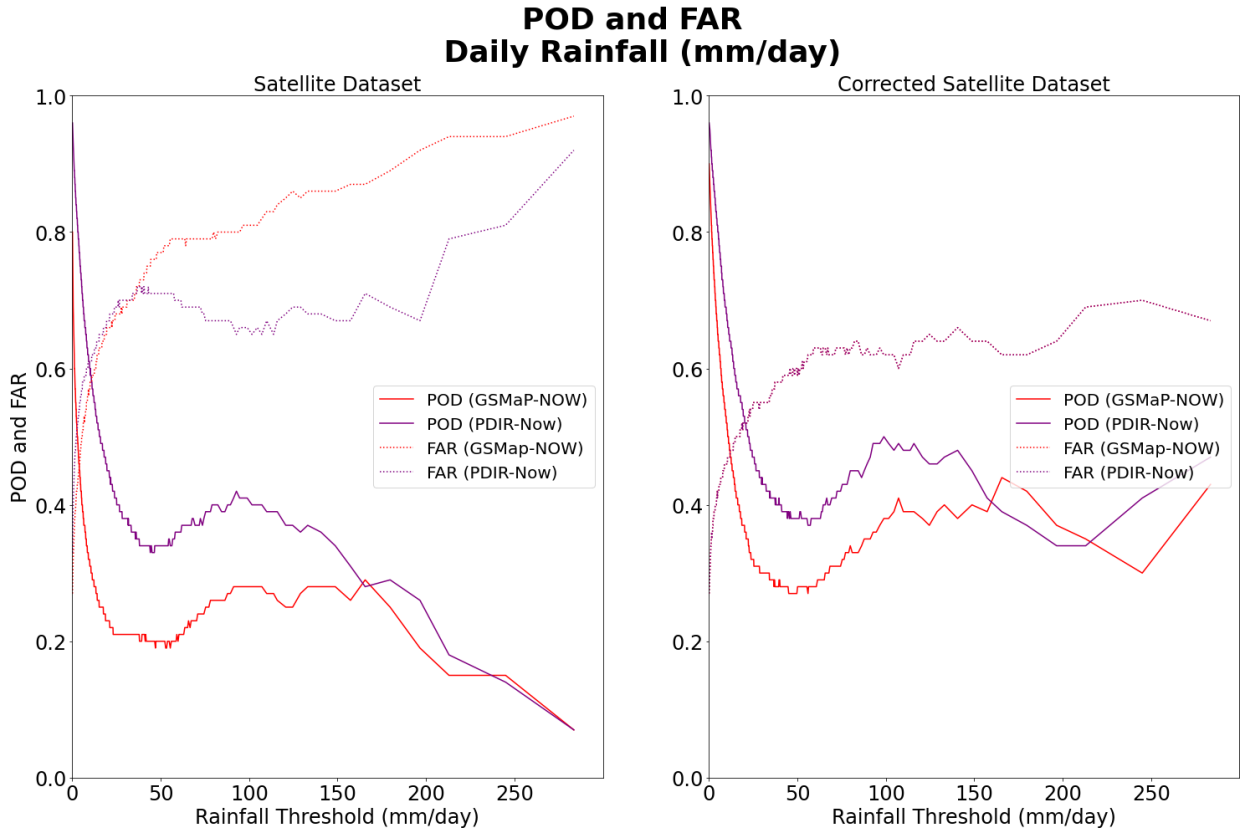
Borneo

1. PDIR-Now is based on infra-red (IR) measurements from geostationary satellites.
2. Rainfall rates are estimated from cloud types that are identified using self-organizing feature maps (SOFMs) trained using PMW dataset.
3. Cloud top precipitation rate (T_b – IR) calibrated using monthly rainfall climatology data.
4. PDIR-Now has latency 15-60 minutes, spatial resolution of 0.04° (4km x 4km), one (1) hour rainfall (mm/hr).
5. Provided by the University of California, Irvine (UCI).
6. Refer to Nguyen et al., 2020*.

*Nguyen, P. et al. (2020). Persiann dynamic infrared-rain rate (PDIR-Now): A near-real-time, quasi-global satellite precipitation dataset. *Journal of Hydrometeorology*, 21(12). *pp. 2893 – 2906.* DOI: 10.1175/JHM-D-20-0177.1

Evaluation Results: Daily Rainfall





- Rainfall estimation by PDIR-Now is more consistent with gauges than GSMaP_NOW
- Corrected PDIR-Now (GSMaP_NOW) can detect significant rainfall events at threshold 20.1 mm/day (11.9 mm/day) ; POD>0.5 & POD>FAR

SWCEM Contribution to CREWS

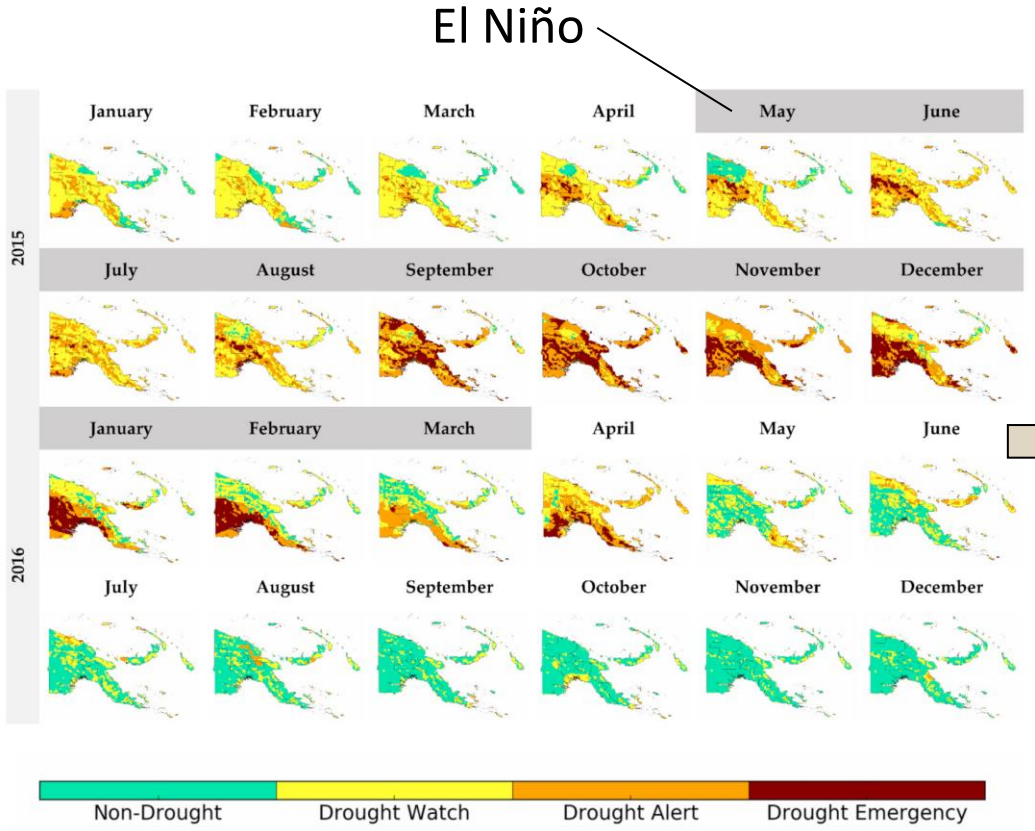
Australia Finland France Germany Luxembourg (Chair) Netherlands

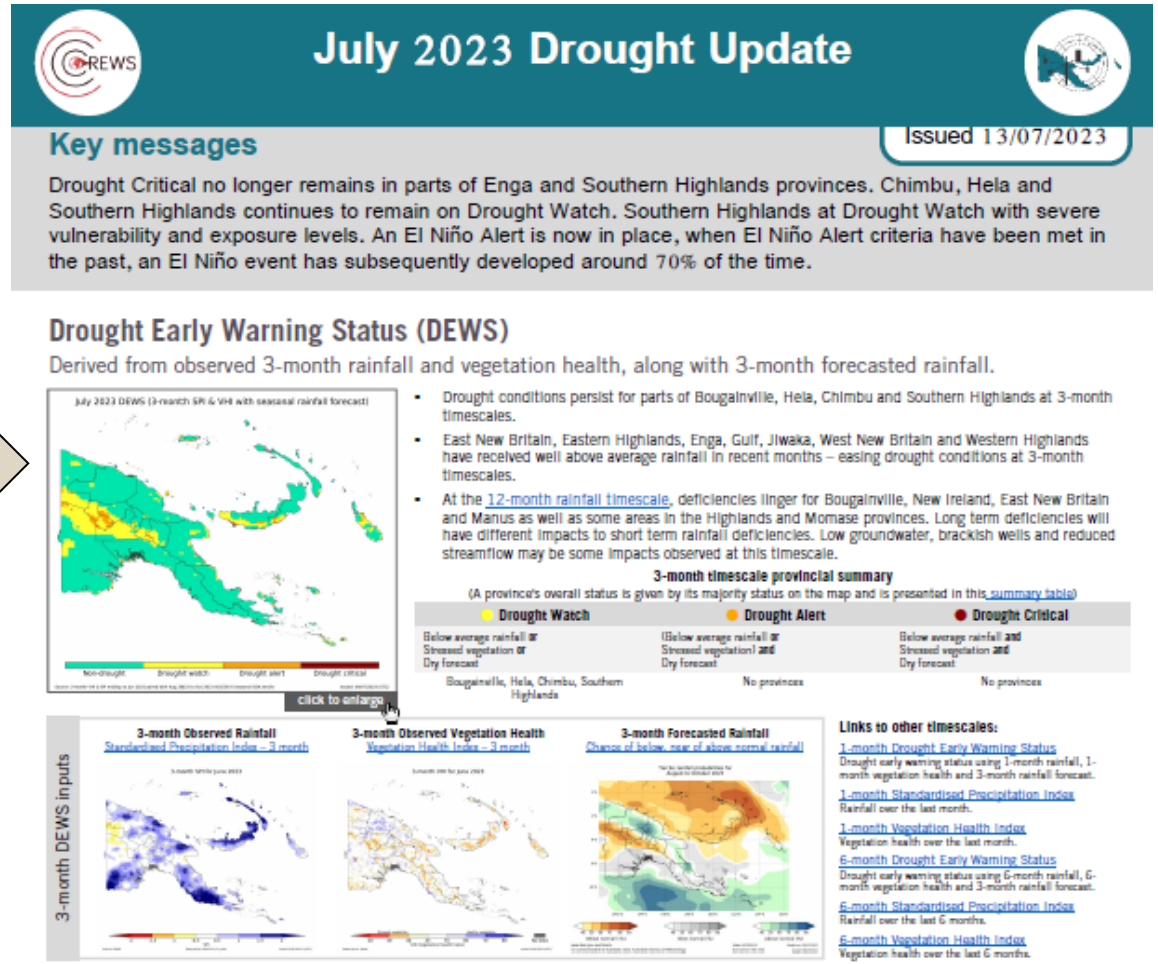
Switzerland United Kingdom

WORLD METEOROLOGICAL ORGANIZATION · WORLD BANK GROUP · GFDRR · UNDRR UN Office for Disaster Risk Reduction

- Recognizing the urgency of enhancing early warning systems to assist vulnerable countries with climate change adaptation, the Climate Risk and Early Warning Systems (CREWS) international initiative has been established at COP-21 in Paris in 2015.
- Over 60 countries assisted through CREWS - 15 CREWS projects in operation - 9 country, 5 regional and 1 global.
- CREWS International Initiative helps SIDS (Small Island Developing States) and LDCs (Least Developed Countries) with climate change adaptation.
- Supporting CREWS with reliable observations of climate extremes is vital.
- Space-based observations provide valuable information on a global scale and complement surface-based observations - this is particularly important for SIDS and LDCs.
- Incorporate SWCEM satellite precipitation estimates and derived products to enhance drought monitoring and EWS.

CREWS: Drought Monitoring Using SWCEM Products
Drought EWS for PNG





Drought EWS: drought status for 22 PNG provinces in June 2023 – four categories: “critical”, “alert”, “watch” and “non-drought”. (derived from 3-month SPI & VHI with seasonal rainfall forecast)

A Possible Contribution of SWCEM to “Early Warnings for All” Initiative

At the 19th World Meteorological Congress (Cg-19) in 2023 the “Early Warnings for All” was recognised as the top priority for the WMO, and the SWCEM community is determined to assist the WMO with the task to enhance space-based observations for developing Early Warning Systems.

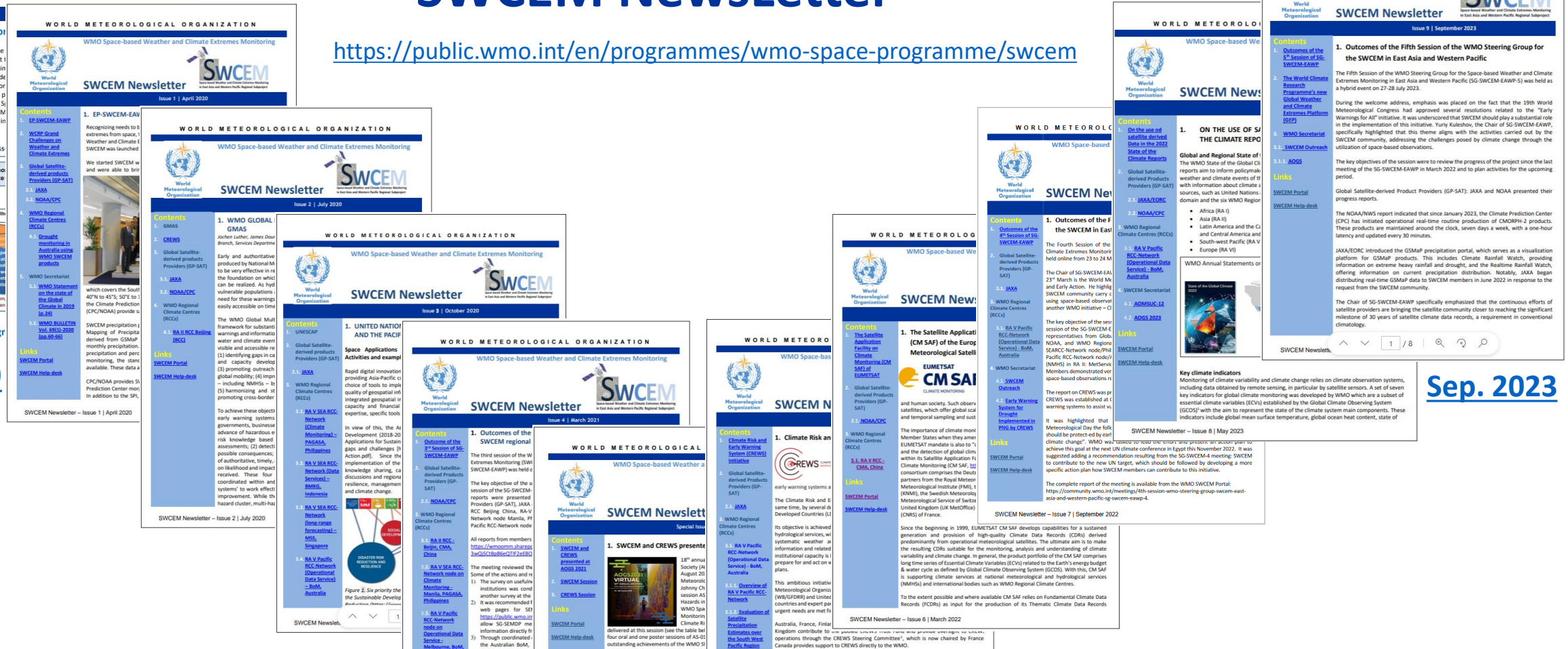
Considering priorities for the SWCEM for 2024 - 2027, SG-SWCEM recommended the following activities:

(1) SWCEM satellite precipitation estimates as input into the “Early Warning for All” initiative, especially for the regions with limited rain gauge observations, capitalizing on the experience gained from PNG;
(2) Strengthening collaboration with CREWS, tailoring SWCEM rainfall products from JAXA and NOAA to CREWS user needs and producing an extended set of products if needed;
(3) Expanding the set of SWCEM products, including not only satellite precipitation estimates, SPI, and VHI, but also soil moisture (from SMOS/ASCAT);
(4) Demonstrating the importance of SWCEM products not only for WMO Regional Climate Centres, but also for nowcasting applications;
(5) Providing GSMaP satellite data for the CREWS project focused on the Southwest Indian Ocean region (CREWS-SWIO);
(6) Providing CMORPH-2 products (at a latency of one hour) which show substantially improved quality compared to CMORPH-1;
(7) Establishing SWCEM for Africa (WMO RA I);
(8) Drafting the SWCEM Implementation Plan for 2024 – 2027.

SWCEM NewsLetter

https://public.wmo.int/en/programmes/wmo-space-programme/swcem

Sep. 2019



Sep. 2023

SWCEM Help-desk

For user feedback, contact:

sat-help-desk@wmo.int

Early Warning for All

UN unveils ambitious target to adapt to climate change and more extreme weather