Satellite Based Climate Monitoring at NOAA Climate Prediction Center

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NOAA Climate Prediction Center
We deliver climate prediction, monitoring, and diagnostic products for timescales from weeks to years to the Nation and the global community for the protection of life and property and the enhancement of the economy.

Operational Requirements:

- Deliver national outlook products: temperature, precipitation, drought, hurricanes,..
- Span weeks, months, seasons, years
- Embrace collaborative forecasting with other NCEP Service Centers, NOAA line offices, other agencies and labs
- Ensure real-time, on-time, all the time (since ’79)
Monitoring and Diagnosing Short-Term Climate Variability

- **Short-Term Climate Variability**
  - **Weeks (MJO) to years (ENSO)**
  - Accumulated effects of individual weather events and affected / modulated by long-term climate changes
  - Measured as departure from normal long-term (often 30-years) climatology
    - Anomaly from long-term mean (for mean situation)
    - Ranking (percentiles) in a long-term data set (for extreme events)

- **Common Basic Requirements for Data Sets to be Used for the Monitoring and Documenting of Short-Term Climate Variability**
  - A gridded data set of reasonable spatial resolution (or station data at unchanging locations)
  - Covering a time period of sufficient length (ideally >=30 yr)
  - With appropriate temporal homogeneity
  - Updated on a quasi real-time basis
CPC is a Pioneer in Climate Applications of Satellite Data

- **Applications of Satellite Data at NOAA/CPC**
  - Monitoring and documenting climate variability
  - Verifying climate forecasts and climate model simulations
  - *In situ observation networks are often inappropriate for such applications (sparse networks, spatial representativeness et al)*.

- **CPC Started Satellite-based Climate Monitoring 30 years ago**
  - SST (Reynolds); OLR (Janowiak); Convection and Precipitation (Arkin)
  - The Global Precipitation Climatology Project (GPCP) was initiated by CPC (then CAC) sponsored by WMO aiming to creating satellite based global precipitation estimates (GPI) using IR data from GEO satellites from member countries.
Unique Approach of CPC to Utilize Satellite Data

- Satellite Data Generated by Satellite Centers Are Often Not Readily / Easily Usable by Climate Centers
  - Level 2 retrievals from individual satellites instead of gridded data sets combining information from all available sensors / platforms
  - Contains bias and random error of various magnitude
  - Frequently changes of processing retrieving algorithms without reprocessing throughout the data periods
  - Varying real-time availability (improving)

- Two Basic Types of Satellite Data Applications at CPC
  - Direct use of satellite data from NESDIS and other satellite agencies when they are ready for climate applications
  - Integrating individual satellite data into climate analyses

- Over the past three decades, CPC developed several satellite-based global analyses for climate applications, including its widely used SST, OLR, and precipitation analyses
• Satellite measured OLR is important
  • An index of the intensity of tropical convection and thereby global climate variations
  • Relationship to precipitation (may be used to derive quantitative precipitation estimates)

• CPC integrates OLR retrievals from NOAA/NESDIS into gridded analysis
  • 2.5° lat/lon; monthly / pentad; updated real-time
  • A new version is underdevelopment taking advantage of newly available broadband and hyperspectral measurements

• CPC utilizes OLR data for
  • Monitoring of ENSO, MJO / sub-seasonal variability
  • Global Tropics Hazards Outlook
  • Deriving precipitation estimates
Precipitation information is critical to:
- Climate Monitoring, climate diagnostics
- Validations of climate prediction, climate model performance
- Forcing climate models (land-surface)

Sources of Precipitation Information:
- In situ measurements (gauge, buoys)
- Remote sensing (Radar / satellite estimates)
- Numerical model simulations (forecasts, reanalyses)

Each individual source has strengths and shortcomings:
- In situ (gauge):
  - Long-term record; point accuracy / sparse network
- Remote sensing:
  - Broad spatial coverage / compromised accuracy; saturation
- Model data:
  - Reasonable for cold season / poor for convective rain

Blending (fusion) is an effective mean to improve precipitation analyses.
• CPC Heritage Precipitation Products

  ▪ CPC Merged Analysis of Precipitation (CMAP)
    ▪ Blending IR / PMW satellite estimates with gauge reports
    ▪ Monthly / pentad from 1979; 2.5°lat/lon over the entire globe

  ▪ CAMS-OPI
    ▪ Combining OLR-based precipitation estimates with CAMS gauge data
    ▪ Same time / space resolution as CMAP, updated real-time
CPC Precipitation Products [3]

- CPC Heritage Precipitation Products
  - RFE2
    - RainFall Estimation Version 2
    - Operated by CPC International Desk (Dr. Wassila)
    - Combining IR / satellite estimates with GTS daily gauge reports with a modified CMAP algorithm
    - 0.1° lat/lon grid over several regions (Africa, C. Asia and S. Asia);
    - Daily time resolution
    - Supporting USAID/FEWS-NET
CMORPH: CPC Morphing Technique [1]

- Creating high-quality, high-resolution global precipitation estimates through integrating information from multi-channel measurements from multiple platforms (GEO/LEO)
- Bias corrected against gauge observations over land
- 8kmx8km / 60°S-60°N;
- 30-min interval / from Jan. 1998 / Real-time (2 / 12 hours)
The CMORPH Flow Chart

Raw CMORPH
- L2 PMW Orbit Data
- GEO-IR Data
- Snow Cover Data

Generate Raw CMORPH

CMORPH_RAW

Bias Correction
- CPC_GAUGE Data
- GPCP Data

Remove Bias

CMORPH_ADJ
• The Raw (purely satellite based)
  - Cloud motion vectors derived from consecutive GEO IR images
  - Level 2 precipitation retrievals from all available PMW sensors propagated along the cloud motion vectors from their respective observation times to target analysis time
CPC Precipitation Products [7]

- Sample

2014-Aug-01 00:00Z

a) MWCOMB

b) Motion Vector

c) Raw CMORPH

d) Bias-Corrected CMORPH
• Purely Satellite Based CMORPH Presents Bias

(a) Seasonal Cycle

(b) Year-to-Year Changes

(c) Sub-Monthly Variations

(d) Nonlinearity of CMORPH Bias
• **CMORPH Bias Correction**
  - PDF calibration against CPC daily gauge analysis
  - Calibration performed twice using PDF tables established with historical and real-time data, respectively
  - Created for 1998 to present as a CDR

**CMORPH**  **TMPAV7**

![CMORPH Bias Correction Diagram](image-url)
• CMORPH Captures Snowstorm

2016–Jan–21 (Thu) 19:00 EST

- Bias-Corrected CMORPH Further Combined with Gauge

- OI-based algorithm
  - Bias-corrected CMORPH as the first guess
  - Gauge data as observations

- Daily / 0.25°lat/lon

- 1979 to the present
CPC Precipitation Products [12]

- Second Generation CMORPH

  - 0.05° lat/lon grid over the entire globe pole to pole
  - Rainfall and snowfall
  - Kalman Filter (KF) based CMORPH (Joyce and Xie 2011)
  - under internal tests
Summary

• NOAA CPC is not only a user of satellite-based climate products but also develops such products to meet its requirements for climate monitoring, climate analysis, and climate verifications.

• NOAA CPC produces a suite of satellite-based precipitation analyses:
  – CMAP
  – CAMS-OPI
  – RFE2
  – CMORPH

• Our experience in developing satellite precipitation analyses:
  – Long-term record (ideally >=30 years) with reasonable temporal homogeneity
  – Capable of capturing precipitation of various intensity (fidelity of PDF)
  – Infusion of information from multi-sensor / multi-satellites and with ground-based observations
Data Base of Daily Gauge Reports

- Sources of Gauge Reports
  - GTS, NCDC archives (GHCN/GDCN..), COOP, RFC, Mexico, Brazil, Australia, China, India…;
- Number of daily station reports
  - Historical records: > 32,000 stations
  - Real-time daily reports: ~16,000 stations
- QC performed for station data
Interpolation of gauge reports from ~30K stations

Optimal Interpolation (OI) with orographic correction (Xie et al. 2007)

Interpolated on 0.125°lat/lon, then averaged on 0.5°lat/lon grid over global land for release

Global fields from 1979 to present updated daily on a real-time basis

CONUS analysis
from 1948 on
0.25°lat/lon

Example
for July 1, 2003
Combining information from daily/monthly gauge analyses, OLR and CMORPH to achieve a global daily precipitation analysis with an optimal balance among:

- Extended data period (30+years),
- quasi-global coverage
- temporal homogeneity
- time/space resolution
- quantitative accuracy
- real-time availability

Daily gauge analysis adjusted against monthly gauge analysis to remove bias.

OLR calibrated against CMORPH for late years to secure reasonable performance.

Adjusted daily gauge and OLR-based precip estimates combined to achieve best possible accuracy.