Feasibility of Global Weather Datasets for Index Insurance

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CHAPTER

ONE

FEASIBILITY OF GLOBAL WEATHER DATASETS FOR INDEX INSURANCE

The aim of this report is to explore the feasibility of freely available satellite-derived climate products to be used in index insurance projects globally. This report also describes the suitability and applicability of these products, with describing specific characteristics that affect how these products can be used in an insurance context.

1.1 Overview

In order to design index insurance, current continuous precipitation measurements as well as an extensive historical precipitation data record are needed. A limited number of rain gauge networks means that index insurance is not scalable if it only works in areas covered by existing rain gauges with long histories. To overcome this limitation, many index insurance projects around the world rely on satellite-based datasets, which have long historical records and global spatial coverage.

There are many types of satellite-derived products available, each with their own strengths and weaknesses. Here we have focused on three categories: satellite rainfall estimates, merged satellite and rain gauges estimates, estimates of vegetative abundance, and soil moisture estimates.

Although success with satellites has allowed index insurance programs to expand around the globe, remotely sensed data can conflict with on-the-ground observations and the products certainly cannot be applied blindly over all landscapes, thus this report aims to assess the feasibility of datasets for climate insurance products. Each of the products can provide a new piece of information about conditions on the ground. For example, a vegetation index might be able to indicate locations where a satellite rainfall estimate is (or is not) adequately capturing drought years.

This document also provides direct links to resources openly available through the IRI Data Library.

1.2 Global Satellite Products

All of the datasets described are gridded at a range of pixel sizes, lengths of historical record, and spatial coverage. The gridded data can further be categorized into three groups: satellite estimates, merged station and satellite estimates, and interpolated data from meterological stations.

A key factor of climate products for use in index insurance is temporal frequency of observations. Because frequently collected, continuous rainfall information is needed to calculate payouts and a historical record is necessary to design and calculate the price of the insurance, it is important that the climate products are aboard sensors that are operational (will continue to take measurements into the future) and have a significant historical record (we generally recommend a minimum of 15 years). Although non-operational climate products are not useful to calculate insurance payouts, they are valuable for comparison with active climate products, thus a list of inactive climate product is included in this report. Other significant factors of climate products in insurance projects are spatial resolution and measurement accuracy.

Historically, rain gauge networks formed the basis of most pilot index insurance programs because of the direct relationship with ground phenomena. Rain gauges are a good source of information when their location coincides with the insured location. However, in developing countries rain gauge networks tend to be sparse and unevenly distributed, with most gauges located in towns and cities, not agricultural areas which render them ineffective for larger scale index insurance projects. Also, rain gauge data relies on manual maintenance, which can lead to errors in the recording such as missing or tampered data, disrupting the time series.

As rainfall can vary significantly at a fine scale, especially in regions with complex geographic and climate characteristics, it is important to have information that reflects the reality on the ground as close as possible to the insured location to decrease the likelihood of basis risk [1] . Weather information at too coarse a spatial resolution presents difficulties for designing an accurate index, because local variability is lost in the aggregation of information. However, if the spatial resolution is too fine, the impact of a regional event may not be recognized. It is crucial to find a balance between these characteristics in order to have a reliable and accurate index.

1.2.1 Gridded Climate Products

There are three types of gridded climate products presented: (1) satellite estimates, (2) merged station and satellite estimates and (3) interpolated data from stations.

Table 2.1 shows operational gridded climate products that were considered for this report as useful for index insurance schemes. A detailed analysis of each one is presented in Sections 2.4 - 2.8.

Table 2.2 depicts a list of historical climate products that could be useful to validate indexes developed with operational products. Again, it is critical to be able to compare environmental variables across different sensors in order to get the most accurate depiction of ground-based phenomena. Although these historical projects are no longer operational, they can be extremely useful in understanding and confirming significant weather events.

[1] Basis risk occurs in index insurance when either payments are issued when the weather event did not occur, or when a weather event occurs and a payout is not issued. Both types of basis risk are significant and can affect the insurance product.

Table 1.1: Operational Gridded Climate Products

Short Name	Producer	Description	Start Year	Temporal Resolution	Reporting Lag Time	Spatial Coverage	Spatial Resolution
NOAA NCEP CPC PRECL	NOAA-CPC	Gridded rainfall interpolated data based on stations	1948	Monthly	1 month	Global	0.5 degrees (~50 km)
NOAA NCEP CPC UNIFIED_PRCP	NOAA-CPC	Gridded rainfall interpolated data based on stations	1979	Daily	1 day	Global	0.5 degrees (~50 km)
CAMS-OPI	NOAA-CPC	Merge Gauge observations and Satellite rainfall estimates	1979	Monthly	1 month	Global	2.5 degrees (~250 km)
CHIRPS v2p0	UCSB	Merge Gauge observations and Satellite rainfall estimates	1981	Daily	3 weeks	50S-50N / all longitudes	0.05 degrees (~5 km)
GPM	NASA	Satellite rainfall estimates	2014	30 minutes, Daily	6 hours	90S-90N / all longitudes	0.1 degree (~10 km)
CMORPH	NOAA-CPC	Satellite rainfall estimates	2002	30 minutes, 3-hourly, Daily	24 hours	60N-60S / all longtitudes	0.25 degrees (~25 km)
CMAP - Monthly	NOAA-CPC	Merge Gauge observations and Satellite rainfall estimates	1979	Monthly	2 months	Global	2.5 degrees (~250 km)
GPCP V2p2	NASA	Merge Gauge observations and Satellite rainfall estimates	1979	Monthly	5 months	World	2.5 degrees (~250 km)
CHIRP v1p0	UCSB	Satellite rainfall estimates	1981	Dekadal	2 days	50S-50N / all longitudes	0.05 degrees (~5 km)
GPCP V1DD V1p2	NASA	Satellite rainfall estimates	1996	Daily	2 months	Global	1 degree (~100 km)
EVI MODIS	NASA	Satellite estimates of vegetation abundance	2000	16 days	15 days	Global	250 m
NDVI MODIS	NASA	Satellite estimates of vegetative health	2000	16 days	15 days	Global	250 m
ESA CCI SM	ESA	Soil moisture satellite estimations	2014	Daily	Not online yet	Global	0.25 degrees (~25 km)
GMSM	NOAA-CPC	Soil moisture is estimated by a one-layer hydrological model	1948	Monthly	1 month	Global	0.5 degrees (~50 km)

Table 1.2: Historical Gridded Climate Products

Short Name	Producer	Description	Length of Record	Temporal Resolution	Spatial Coverage	Spatial Resolution
NOAA NCEP CPC REGIONAL SA daily gridded prcp	NOAA-CPC	Gridded interpolated data based on stations	2 Jan 2000 - 15 Jan 2012	Daily	North America: 10N-60N / 140W-60W	0.25 degree (~25 km)
TRMM	NASA	Satellite estimates of rainfall	1998 - 2013	Daily	50N - 50S / all longitudes	0.25 degree (~25 km)
VASClimO	German Weather Service	Gridded interpolated data based on stations	Jan 1951 - Dec 2000	Monthly	Global	0.5 degrees (~50 km)
CRU TS3p21	University of East Anglia	Gridded interpolated data based on stations	Jan 1901 - Dec 2012	Monthly	Global	0.5 degrees (~50 km)
UNAM gridded	UNAM	Gridded interpolated data based on stations	1901 - 2002	Monthly	USA / Mexico / Central America:	0.5 degrees (~50 km)
WCRP GCOS GPCC FDP	WCRP	Gridded interpolated data based on stations	Jan 1901 - Dec 2012	Monthly	Global	0.5 degrees (~50 km)
NOAA NCEP CPC REGIONAL SA daily gridded prcp	NOAA-CPC	Gridded interpolated data based on stations	1 Jan 2000 - 15 Jan 2012	Daily	South America: 60S-15N / 90W-30W	1 degree (~100 km)
PSD	NOAA-ESRL	Gridded interpolated data based on stations	Jan 1940 - Jan 2011	Daily	South America: 60S-15N / 85W-30W	1 degree (~100 km)
CAMS	NOAA-CPC	Gridded interpolated data based on stations	Jan 1950 - Mar 2001	Monthly	Global	2 degrees (~200 km)
CMAP - Pentad	NOAA-CPC	Merge Gauge observations and Satellite rainfall estimations	Jan 1979 - May 2013	Pentad	Global	2.5 degrees (~250 km)
ESA CCI SM (previous version)	ESA	Satellite surface soil moisture estimations	1 Jan 1978 - 31 Dec 2013	Daily	Global	0.25 degrees (~25 km)
GIMMS NDVI AVHRR	UMD	Satellite estimates of vegetative health	Jul 1981 - Dec 2006	16 days	Global	0.07 degrees (~7 km)

1.3 Use of Operational Climate Products around the Globe

Climate index insurance products need reliable climate products: historical climate data is necessary to build the index and develop comparisons, and near real time data is necessary for the calculation of payouts. Therefore an operational climate product with historic data is needed for an insurable area. It is fundamental that the "bad" years, or the years in which significant weather events occurred, recognized by a climate product are similar to the "bad" years that affect the livelihood of farmers on the ground.

Climate products have strengths and weaknesses for use in index insurance, thus an analysis of a product's utility is shown in this section, focusing on the following questions:

- Is the spatial resolution at an appropriate scale for use in index insurance?
- Does the product have spatial coverage of the region of interest?
- Is the temporal resolution practical for index insurance?
- Is the historical data record long enough to use the climate product for index insurance products?
- How accurate are the measurements?
- What kind of biases affect the product?

1.4 Gridded rainfall interpolated data based on gauge observations

1.4.1 Precipitation Reconstruction over Land (PRECL)

The Precipitation Reconstruction over Land (PRECL) is a monthly global dataset with a resolution of 0.5 degrees (~50 km), derived from gauge observations from over 17,000 stations collected in the Global Historical Climatology Network (GHCN), version 2, and the Climate Anomaly Monitoring System (CAMS) datasets. Its record starts in January 1948.

To determine the most suitable objective analysis procedure for gridding, the analyses generated by four published objective analysis techniques [those of Cressman, Barnes, and Shepard, and the optimal interpolation (OI) method of Gandin] were compared. The evaluation demonstrated that better results are obtained when interpolating anomalies rather than the precipitation totals, and that the OI analysis procedure provided the most accurate and stable analyses among the four algorithms that were tested. Therefore the OI technique was use to create monthly gridded analyses of precipitation over the global land areas for the 53-yr period from 1948 to 2000.

1.4.2 CPC Unified Gauge-Based Analysis of Global Daily Precipitation

CPC Unified Gauge-Based Analysis of Global Daily Precipitation is a gridded rainfall dataset (0.5 degrees resolution) available from 1979. It uses the optimal interpolation (OI) technique as the method to obtain gridded data from station observations.

The OI technique defines the analyzed value at a grid point by modifying a first-guess field with the weighted mean of the differences between the observed and the first-guess values at station locations within a search distance. The weighting coefficient is determined from the variance and co-variance structure of the target precipitation fields.

The creation of the daily precipitation analysis is conducted in three steps. First, analyzed fields of daily precipitation climatology are defined from historical gauge observations collected at CPC. Gridded fields of the ratio between the daily precipitation and daily climatology are then computed by interpolating the corresponding values at the gauge locations through the OI technique. Daily precipitation analysis is finally defined by multiplying the fields of the daily climatology and the daily ratio. By interpolating the ratio of total rainfall to the climatology, instead of the total rainfall itself, the OI is capable of better representing the spatial distribution of precipitation, especially over regions with substantial orographic effects.

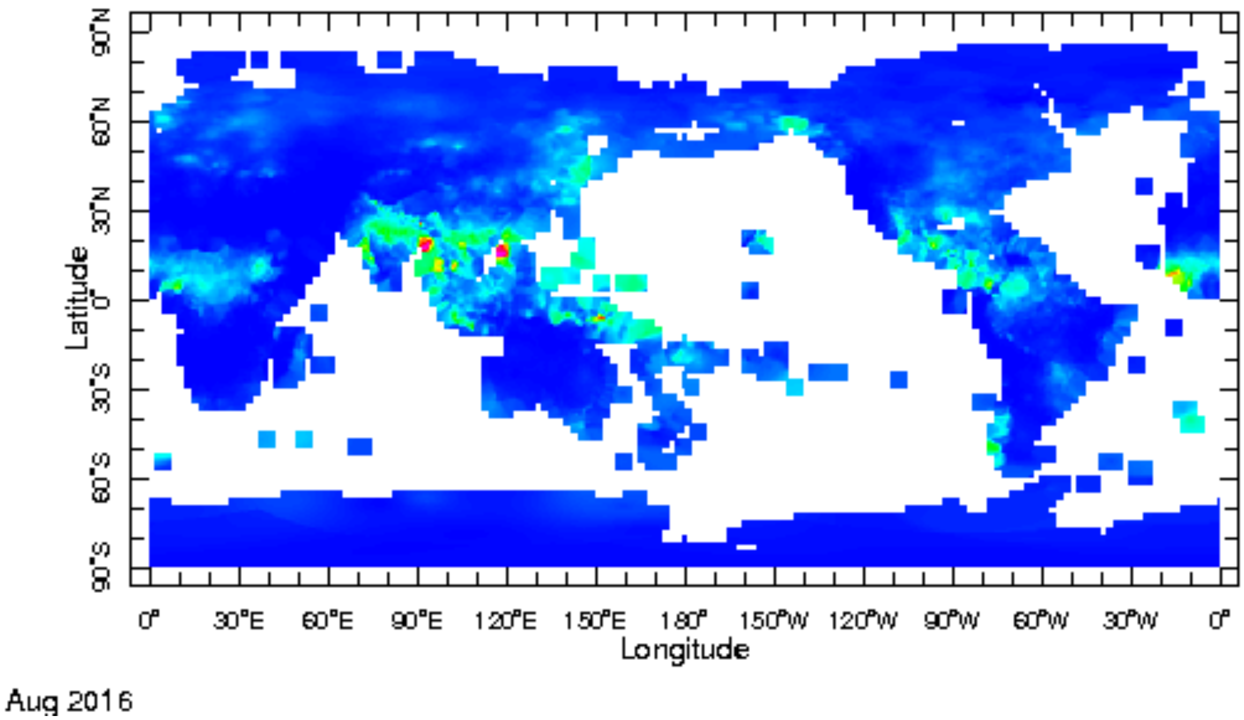

Figure 1.1: *Precipitation Reconstruction over Land (PRECL)*
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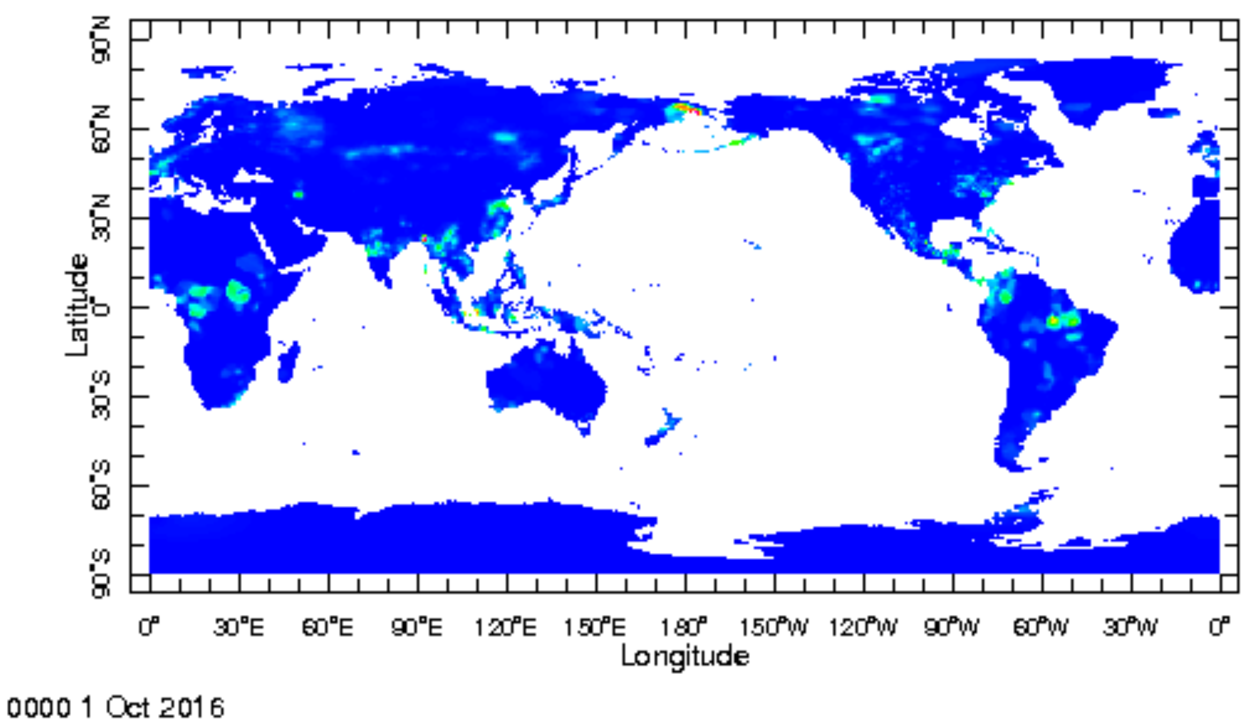

Figure 1.2: *CPC Unified Gauge-Based Analysis of Global Daily Precipitation*
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.UNIFIED_PRCP/.GAUGE_BASED/.GLOBAL

1.5 Merged gauge observations and satellite rainfall estimations

1.5.1 Climate Anomaly Monitoring System-Outgoing longwave radiation Precipitation Index (CAMS_OPI)

The CAMS_OPI (Climate Anomaly Monitoring System (CAMS) and OLR Precipitation Index (OPI)) is a precipitation estimation technique, which produces real-time monthly analyses of global precipitation on a 2.5 degrees resolution since 1979. To do this, observations from rain gauges (CAMS data) are merged with precipitation estimates from a satellite algorithm (OPI).

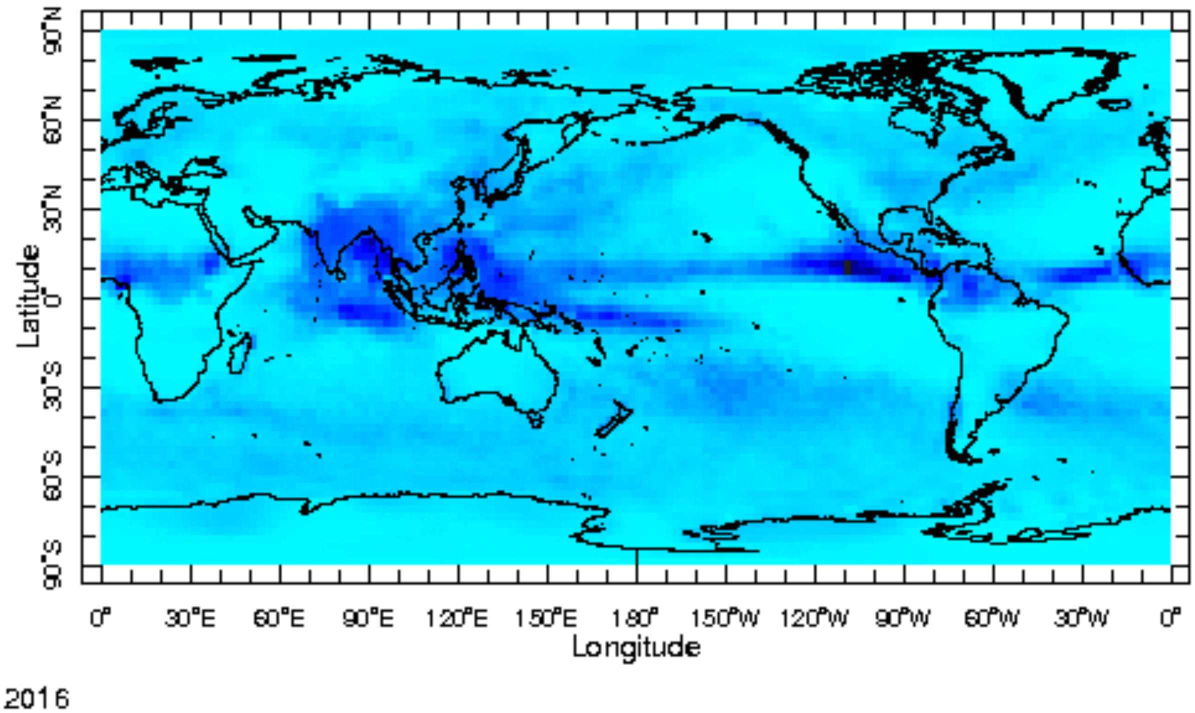

Figure 1.3: *Climate Anomaly Monitoring System-Outgoing longwave radiation Precipitation Index (CAMS_OPI)* http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CAMS_OPI/.v0208/.satellite/.prcp/

The merging methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the rain gauge analysis over the surrounding area. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988). Here the data output from the first step is used to define the "shape" of the precipitation field and the rain gauge data are used to constrain the amplitude.

1.5.2 Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS V2.0)

Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a 30+ year quasi-global rainfall dataset. Spanning 50°S–50°N (and all longitudes), starting in 1981 to near-present, CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

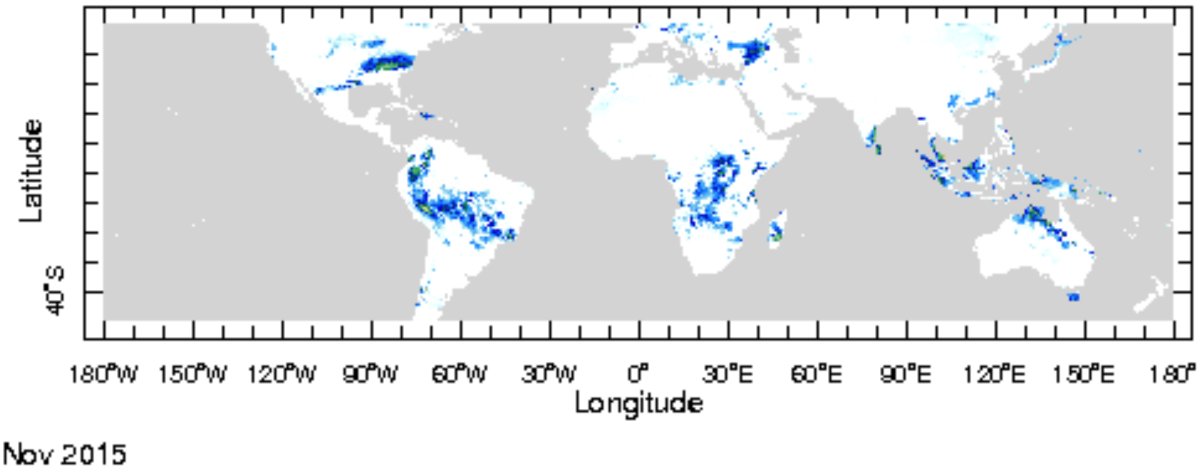

Figure 1.4: *Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)*
http://iridl.ldeo.columbia.edu/SOURCES/.UCSB/.CHIRPS/.v2p0/.daily/.global/

CHIRPS is calculated in a two parts process, first InfraRed Precipitations (IRP) are estimated from satellite data by calculating the percentage of time that IR observations shows cold cloud tops (<235ºK) and converting that percentage into millimeters of precipitation by means of previously determined local regression with TRMM 3B42 precipitation. Then these values are divided by their long term IRP mean (1981-2012). The percent of normal IRP daily is then multiplied by the corresponding Climate Hazards Group's Precipitation Climatology (CHPClim) to produce an unbiased gridded estimate, with units of millimeters per day, called the Climate Hazards Group IR Precipitation (CHIRP). The second part of the process is to add the station observations information to get the final CHIRPS product. To blend CHIRP with the station information, for each grid location of CHIRP, the five nearest stations are used to calculate and adjustment ratio for CHIRP. Each of the five stations is assigned with a weight proportional to square of their expected correlation; afterwards the five weights are scaled to sum 1 and used to blend the station data into a single modifier (ratio) that can be used to adjust the CHIRP estimates.

CHIRPS is best used to identify trends in precipitation over longer periods, for providing spatial context of drought events, or for quantitative assessment over collections of points. **The use of individual pixels to identify a precise rainfall amount is not recommended.**

CHIRPS performs at its best over areas that have a network of contributing stations in a region. Performance in areas without station data will have mixed results. CHIRPS is generally designed to assess agroclimatic drought; the product's use for quantifying flood events, especially at short time intervals, will have mixed results. In some cases where there are missing values due to incomplete satellite coverage, CHIRPS uses a climate model reanalysis to fill in missing data gaps.

1.5.3 CPC Merged Analysis of Precipitation (CMAP)

The CPC Merged Analysis of Precipitation (CMAP) is a technique which produces pentad and monthly analyses of global precipitation in which observations from rain gauges are merged with precipitation estimates from several satellite-based algorithms (infrared and microwave). The analyses are on a 2.5 x 2.5 degree grid and extend back to 1979.

It is important to note that the data inputs used in this product are not uniform throughout the period of record.

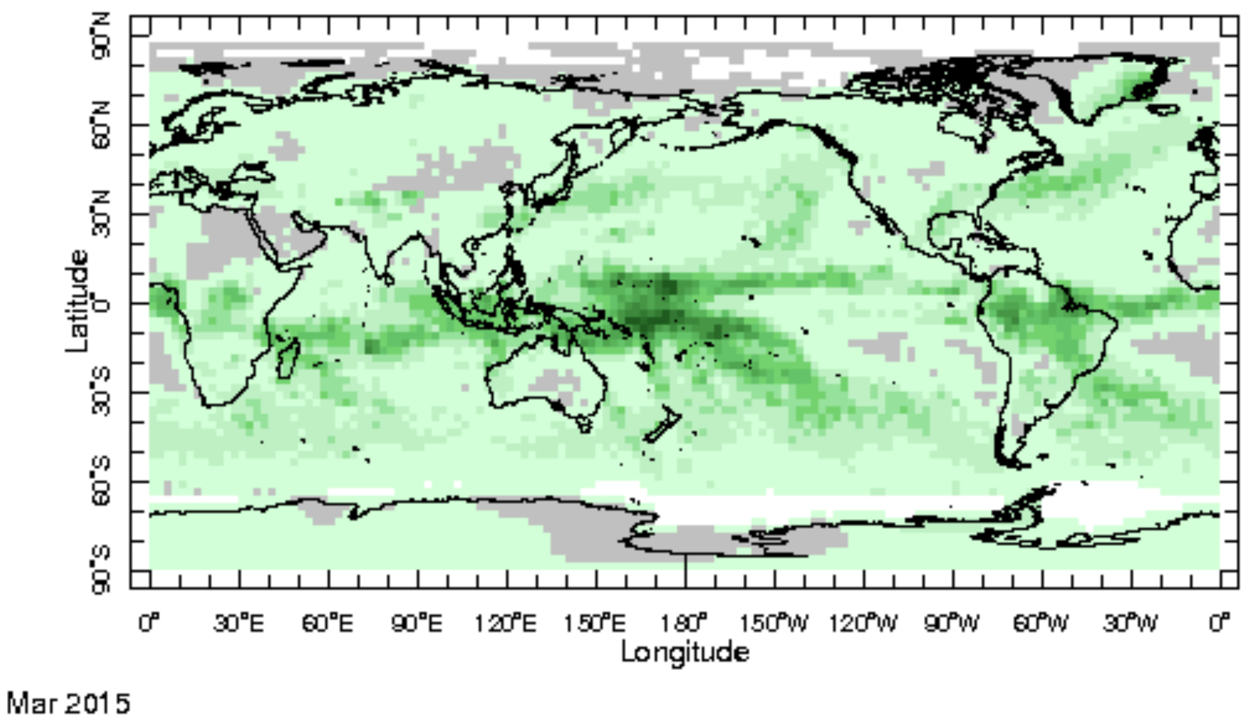

Figure 1.5: *CPC Merged Analysis of Precipitation (CMAP)*
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.Merged_Analysis/.monthly/.v1504/.ver2/.prcp_est/

The merging technique is thoroughly described in Xie and Arkin (1997). Briefly, the methodology is a two-step process. First, the random error is reduced by linearly combining the satellite estimates using the maximum likelihood method, in which case the linear combination coefficients are inversely proportional to the square of the local random error of the individual data sources. Over global land areas the random error is defined for each time period and grid location by comparing the data source with the raingauge analysis over the surrounding area. Over oceans, the random error is defined by comparing the data sources with the raingauge observations over the Pacific atolls. Bias is reduced when the data sources are blended in the second step using the blending technique of Reynolds (1988). Here the data output from the first step is used to define the "shape" of the precipitation field and the rain gauge data are used to constrain the amplitude.

1.5.4 Global Precipitation Climatology Project (GPCP V2.2)

The GPCP satellite-gauge precipitation product is a monthly global gridded dataset produced by merging multi-satellite (MS) rain estimations and rain gauges. It is produced in two steps. The analyses are based on a 2.5 x 2.5 degree latitude/longitude grid and extend back to 1979.

First, for each grid box that is less than 65% water, average gauge data and MS estimates are calculated centered in the grid box of interest with weighting by numbers of gauges. Then the ratio of weighted-average gauge to weighted-average is computed, controlling the maximum ratio to be 2 for the weighted-average MS in the range [0,7]mm/d, 1.25 above 17 mm/d, and linearly tapered in between to suppress artifacts. When the ratio exceeds the limit, compute an additive adjustment that is capped at 1.7mm/d at zero weighted-average MS and linearly tapers to zero at 7 mm/d. This is intended to account for the MS badly missing light precipitation.

In each grid box, whether or not there was any adjustment, the gauge-adjusted MS is the product of the MS and the ratio, added to the additive adjustment. The estimated random errors for both gauge and gauge-adjusted MS are recomputed, using the straight average of the two as the estimated precipitation value for both calculations. This step

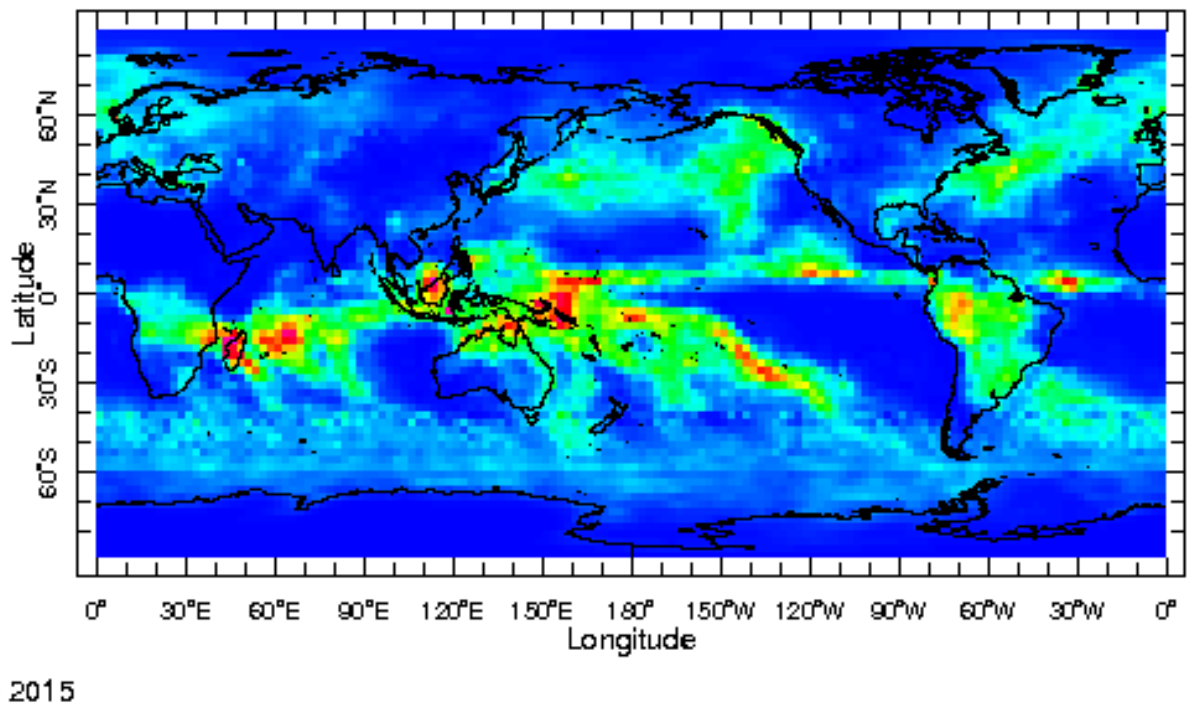

Figure 1.6: *Global Precipitation Climatology Project (GPCP)*
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V2p2/.satellite-gauge/.prcp/

prevents inconsistent results that arise when the random errors are computed with individual precipitation values that are not close to each other.

In the second step the gauge-adjusted MS and gauge values are combined in a weighted average, where the weights are the recomputed inverse (estimated) error variances, to form the satellite-gauge combination product.

1.6 Satellite Rainfall Estimate Products

1.6.1 Climate Hazards Group InfraRed Precipitation (CHIRP)

Climate Hazards Group InfraRed Precipitation (CHIRP) is a 30+ year quasi-global rainfall decadal dataset. Spanning 50°S–50°N (and all longitudes), starting in 1981 to near-present, CHIRP uses 0.05° resolution satellite imagery to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

To calculate CHIRP, first InfraRed Precipitations (IRP) are estimated from satellite data by calculating the percentage of time that IR observations shows cold cloud tops (<235ºK) and converting that percentage into millimeters of precipitation by means of previously determined local regression with TRMM 3B42 precipitation. Then these values are divided by their long term IRP mean (1981-2012). The percent of normal IRP dekadal is then multiplied by the corresponding CHPClim to produce an unbiased gridded estimate, with units of millimeters per day.

1.6.2 CPC Morphing Technique (CMORPH)

CMORPH is a global gridded precipitation dataset at a very high temporal and spatial resolution, 8 Km and 30 minutes respectively. The start date of the dataset is December 2002.

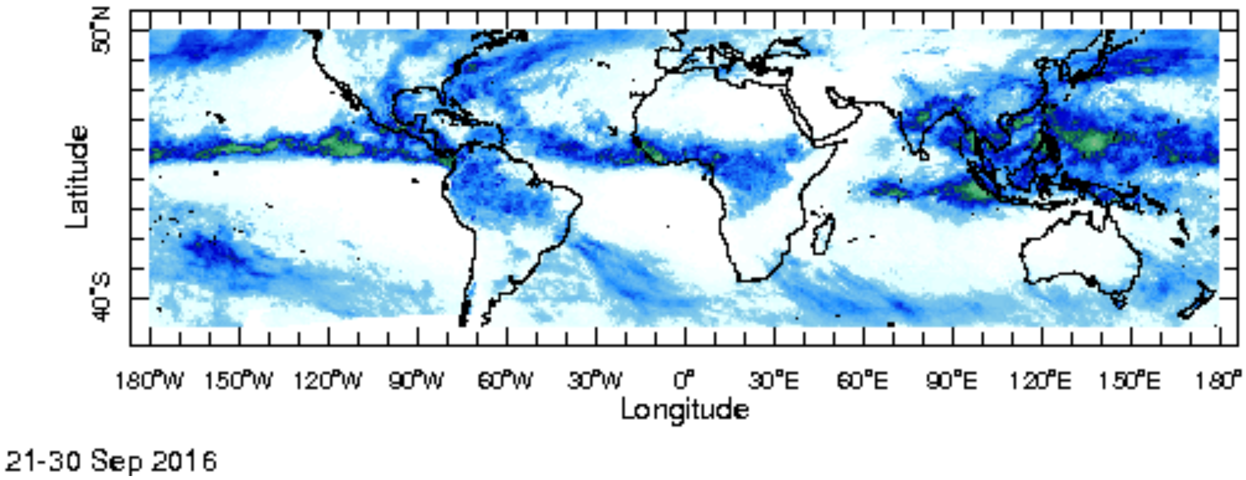

Figure 1.7: *Climate Hazards Group InfraRed Precipitation (CHIRP)*
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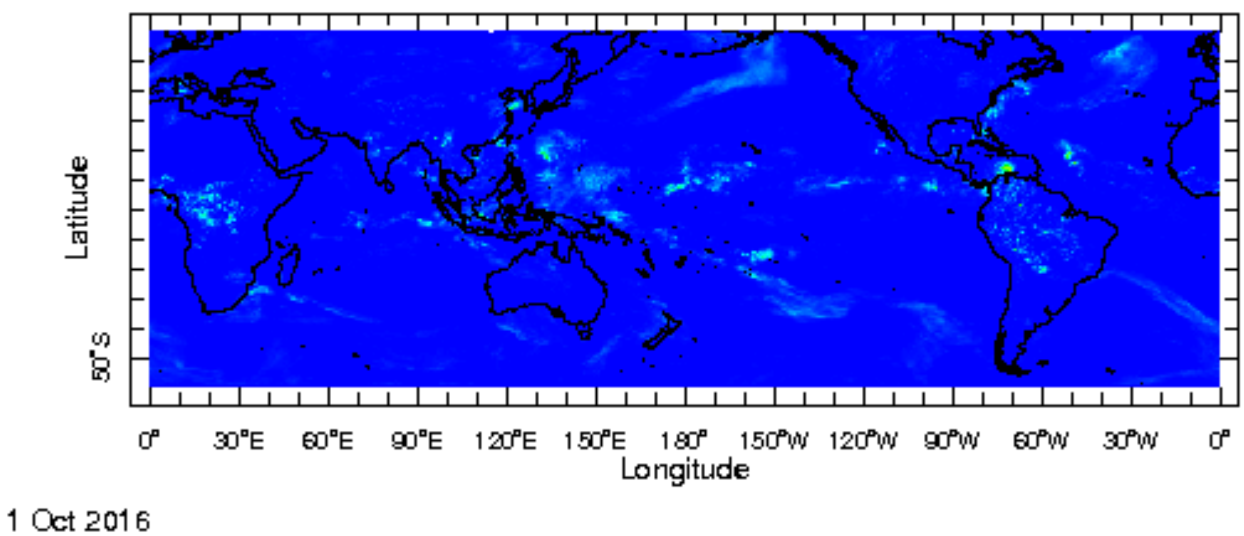

Figure 1.8: *CPC Morphing Technique (CMORPH)*
https://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CMORPH/

The morphing technique uses precipitation estimates that have been derived from low orbiter satellite microwave observations exclusively, and whose features are transported via spatial propagation information that is obtained entirely from geostationary satellite IR data.

At present it incorporates precipitation estimates derived from the passive microwaves aboard the DMSP 13, 14 & 15 (SSM/I), the NOAA-15, 16, 17 & 18 (AMSU-B), and AMSR-E and TMI aboard NASA's Aqua and TRMM spacecraft, respectively. These estimates are generated by algorithms of Ferraro (1997) for SSM/I, Ferraro et al. (2000) for AMSU-B and Kummerow et al. (2001) for TMI. Note that this technique is not a precipitation estimation algorithm but a means by which estimates from existing microwave rainfall algorithms can be combined.

IR data are used as a means to transport the microwave-derived precipitation features during periods when microwave data are not available at a location. Propagation vector matrices are produced by computing spatial lag correlations on successive images of geostationary satellite IR that are then used to propagate the microwave derived precipitation estimates. This process governs the movement of the precipitation features only. At a given location, the shape and intensity of the precipitation features in the intervening half hour periods between microwave scans are determined by performing a time-weighting interpolation between microwave-derived features that have been propagated forward in time from the previous microwave observation and those that have been propagated backward in time from the following microwave scan, this latter step is referred as "morphing" of the features.

1.6.3 Global Precipitation Climatology Project 1-Degree Daily Combination (GPCP 1DD)

The One-Degree Daily (1DD) precipitation data set is a first approach to estimating global daily precipitation since October 1996, at the 1ºx1º scale strictly from observational data. It is composed of Threshold Matched Precipitation Index (TMPI) where available (40ºN-S) and Adjusted Sounding-based precipitation estimates (AdSND) elsewhere. The data boundaries at 40ºN and 40ºS do not exhibit serious problems, probably because both the TMPI and AdSND are responding to cloud features. Nevertheless, smoothing was performed at the data boundaries.

The TMPI technique is based on the use of geostationary satellite IR observations. Colder IR brightness temperatures are directly related to higher cloud tops, which are loosely related to increased precipitation rates. From data collected during the Global Atmospheric Research Programme (GARP) Atlantic Tropical Experiment (GATE), an empirical relationship between brightness temperature and precipitation rate was developed. For a brightness temperature less than or equal to 235K, a rain rate of 3 mm/hour is assigned. For a brightness temperature greater than 235K, a rain rate of 0 mm/hour is assigned. The available geo-IR histograms in each 3-hrly global image are processed into precipitation estimates, and the adjusted leo-GPI data are used to fill holes in the individual 3-hrly geo-IR images. Then all the available images in a day are averaged to produce the daily estimate (on a 1ºx1º grid).

The AdSND is computed with both TOVS and AIRS estimates, and are produced outside 40ºN-S to make the 1DD globally complete. The Susskind et al. (1997) precipitation estimates from TOVS (AIRS) were considered to have too large a number of rain days, therefore estimates were revised by first computing the ratio of TMPI rain days to TOVS (AIRS) rain days separately for 39-40ºN and 39-40ºS, then using the corresponding ratio in each grid box over the entire hemisphere to reduce the occurrence of TOVS (AIRS) precipitation by zeroing the (1-ratio) smallest daily TOVS (AIRS) rain accumulations and finally rescaling the remaining (non-zero) TOVS (AIRS) rain days to sum to the monthly the GPCP satellite-gauge precipitation product.

Note: The AIRS and TOVS precipitation estimates infer precipitation from deep, extensive clouds. The technique uses a multiple regression relationship between collocated rain gauge measurements and several satellite-based parameters (AIRS and TOVS respectively) that relate to cloud volume: cloud-top pressure, fractional cloud cover, and relative humidity profile. This relationship is allowed to vary seasonally and latitudinally. Furthermore, separate relationships are developed for ocean and land.

1.6.4 Tropical Rainfall Measurement Mission (TRMM)

Tropical Rainfall Measuring Mission (TRMM) consists of an algorithm, called 3B42, that produces merged high quality (HQ)/infrared (IR) precipitation estimates. These gridded estimates are on a 3-hour temporal resolution and

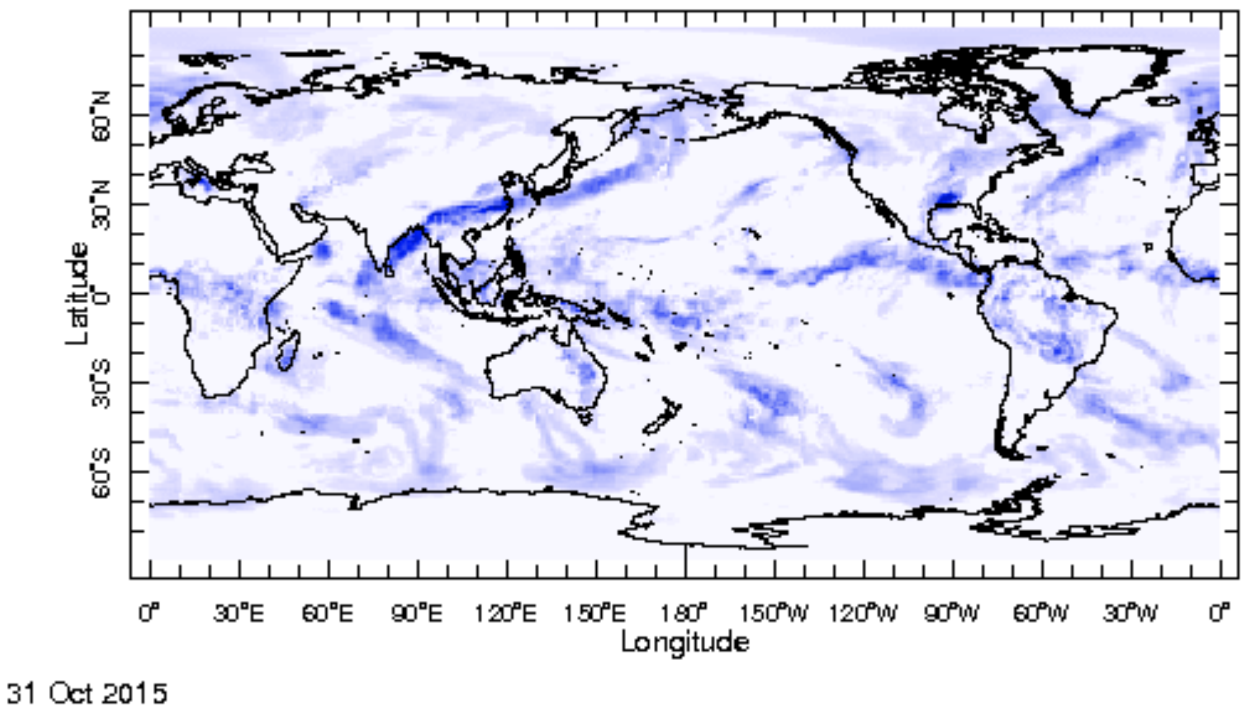

Figure 1.9: *Global Precipitation Climatology Project 1-Degree Daily Combination (GPCP 1DD)* http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V1DD/.V1p2/.prcp/#info

a 0.25-degree by 0.25-degree spatial resolution in a global belt extending from 50 degrees South to 50 degrees North latitude available from March 2000.

The 3B42 estimates are produced in four stages; (1) the microwave precipitation estimates are calibrated and combined, (2) infrared precipitation estimates are created using the calibrated microwave precipitation, (3) the microwave and IR estimates are combined, and (4) rescaling to monthly data is applied.

Note: The Global Precipitation Mission (GPM) is a new satellite precipitation product from NASA; it is a global (65N-65S) gridded rainfall dataset with 0.1 degrees resolution with information every 30 minutes March 2014.

The GPM constellation of satellites can observe precipitation over the entire globe every 2-3 hours. The core satellite measures rain and snow using two science instruments: the GPM Microwave Imager (GMI) and the Dual-frequency Precipitation Radar (DPR). The GMI captures precipitation intensities and horizontal patterns, while the DPR provides insights into the three dimensional structure of precipitating particles. Together these two instruments provide a database of measurements against which other partner satellites' microwave observations can be meaningfully compared and combined to make a global precipitation dataset.

The GMI uses 13 different microwave channels to observe energy from the different types of precipitation through clouds for estimating everything from heavy to light rain and for detecting falling snow. The DPR provides three-dimensional information about precipitation particles derived from reflected energy by these particles at different heights within the cloud system. The two frequencies of the DPR also allow the radar to infer the sizes of precipitation particles and offer insights into a storm's physical characteristics. The GPM mission aims to build on the legacy of TRMM by providing a research standard for precipitation measurements (rain and snow), carrying both radar and radiometer sensors as well as combining measurements from multiple operational satellites. Launched in February 2014, the GPM Core Observatory system improves from TRMM's successful rain measurement system by increasing the ability to measure light rain and falling snow, which relates to the design of both the active and passive sensors.

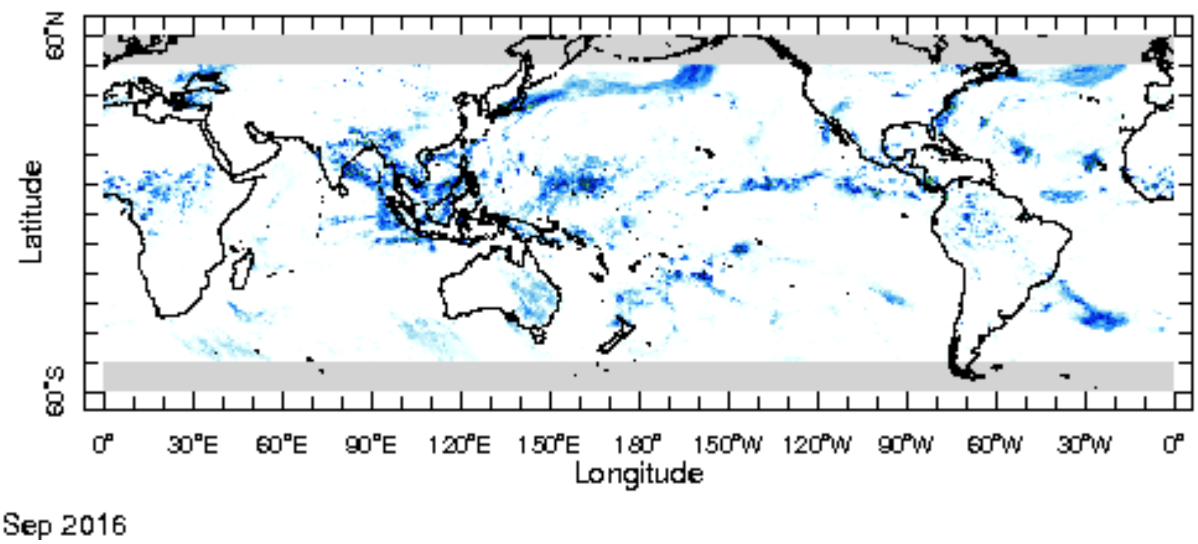

Figure 1.10: *Tropical Rainfall Measurement Mission (TRMM)*
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GES-DAAC/.TRMM_L3/.TRMM_3B42RT/.v7/

1.6.5 Africa-Only Rainfall Estimates

It is important to note two widely used satellite rainfall products: TAMSAT and ARC2. They only have coverage of the African continent, not global or semi-global coverage.

TAMSAT, University of Reading

TAMSAT is a satellite rainfall estimate which uses 10.8 micrometer infra-red channel from the METEOSAT geostationary satellite, which is then locally calibrated against historical gauge data to produce rainfall estimates using a simple linear relationship. The final product is not merged with gauge data. The main TAMSAT output is a 10-daily rainfall sum, which is also disaggregated to a daily product going back 30 years. TAMSAT is one of the simplest methods employed for remotely sensed rainfall, but nevertheless generally performs as well as more complicated methods.

As there is often cirrus associated with thunderstorms, TAMSAT is not accurate if you wish to have instantaneous rainfall estimates, but more accurate over daily and dekadal (10-daily) time-scales. TAMSAT is also less accurate in places without convective rainfall i.e. coastal regions or places that receive frontal rainfall.

Currently, region boundaries are chosen manually, where there is evidence that a different rainfall regime may dominate. Therefore more detailed regions are found in climatologically complex areas or areas with detailed or varied topography.

The spatial scale of the TAMSAT product is nominally at the current METEOSAT satellite resolution (< 5km). However, there is a lot of uncertainty in the product at these scales. It is recommended to use the main TAMSAT product averaged either over several pixels, or over several dekads.

ARC2, NOAA

The Africa Rainfall Climatology Version 2 (ARC2) product issued by the Climate Prediction Center at NOAA combines gauge data, geostationary IR data, and poloar-orbiting microwave SSM/I and AMSU-B satellite data. These are daily precipitation estimates with a 30-year record.

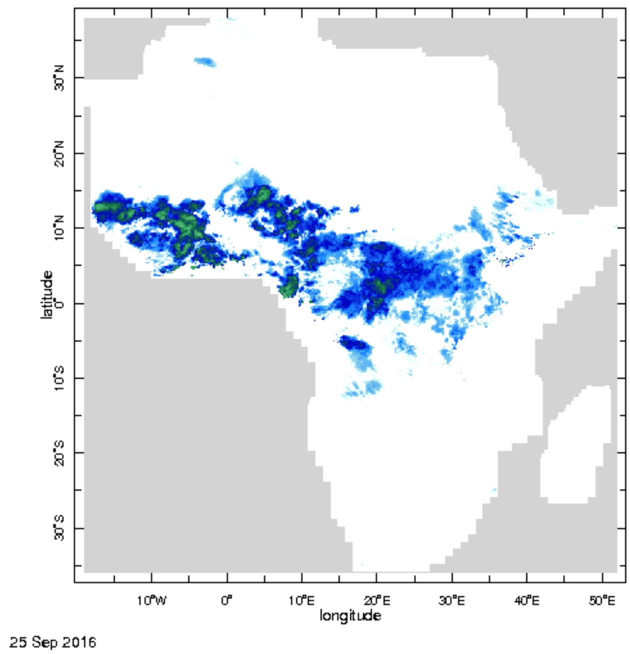

Figure 1.11: *TAMSAT Daily Estimate*
Available at the IRI DL here

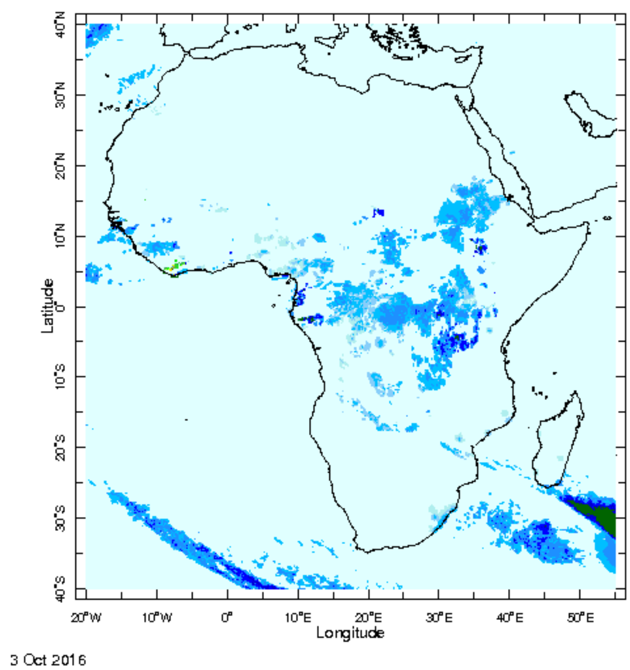

Figure 1.12: *ARC2 Daily Estimate*
Available at the IRI DL here

1.7 Satellite-derived Vegetation Indices

1.7.1 MODIS NDVI and EVI

The Enhanced Vegetation Index (EVI) and Normalized Difference Vegetation Index (NDVI) are a vegetation indices that provide a quantitative measure of the amount of photosynthetically active plants on the ground at a particular place and time. Both products have a global coverage with a spatial resolution as fine as 250 m from February 2000 - present, with measurements provided twice a month (16-day temporal resolution).

NDVI is calculated as a ratio of the difference of the Near Infrared (NIR) and the Red bands on a sensor:

NDVI=(NIR-Red)/(NIR+Red)

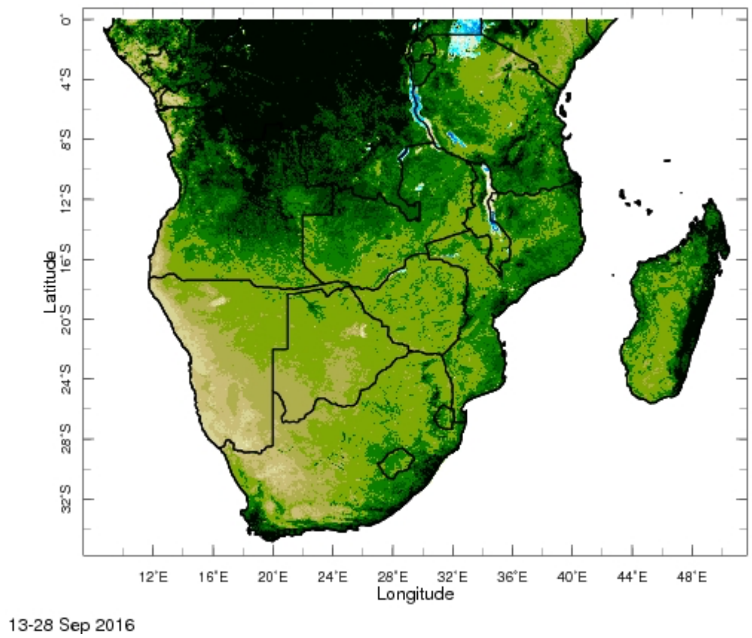

Figure 1.13: *MODIS NDVI Southern Africa*
http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.250m/.16day/.NDVI/

EVI uses a similar algorithm but incorporates other terms to be less influence by soil color and shadows, as well as to stabilize the index value against variations in aerosol concentration levels. The following formula is used to calculate EVI:

EVI=G*(NIR-Red)/(NIR+C_1*Red-C_2*Blue+L)

Where L is the canopy background adjustment for correcting nonlinear, differential NIR and red radiant transfer through a canopy; C1 and C2 are the coefficients of the aerosol resistance term (which uses the blue band to correct for aerosol influences in the red band); and G is a gain or scaling factor. The coefficients adopted in the EVI algorithm are, L=1, C1=6, C2=7.5, and G=2.5.

Because vegetation has high NIR reflectance but low red reflectance, vegetated areas will have higher NDVI and EVI values compared to non-vegetated areas.

The difference between NDVI and EVI is that NDVI can be directly compared to observations from other sensors such as AVHRR and SPOT Vegetation. EVI is designed to be less sensitive to soil color and shadows, and thus is more useful in some regions than NDVI.

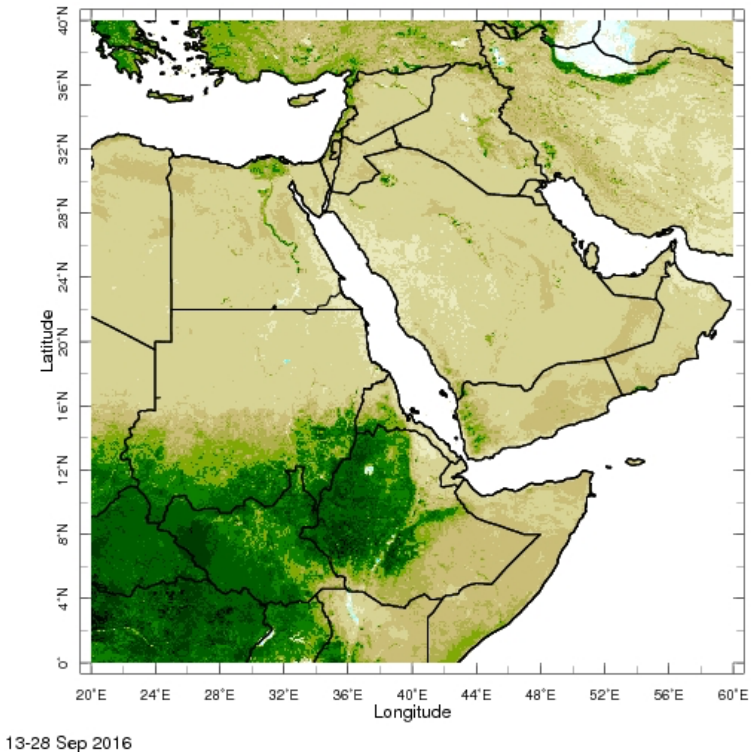

Figure 1.14: *MODIS EVI East Africa*
http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.250m/.16day/.EVI/

The power of the vegetation index is in comparing across time. NDVI and EVI are excellent measures of changes in overall productivity in a region due to changes in rainfall or temperature. It is very comparable over space and time when there have not been large-scale changes in land cover.

Vegetation indices do not perform well in tropical ecosystems with large amounts of rainfall and clouds, as the instrument cannot see through clouds. When there is vegetation all the time with little variation through the seasons or from one year to the next, vegetation indices do not provide much information.

1.8 Soil Moisture Estimate products

1.8.1 European Space Agency (ESA) Climate Change Initiative (CCI) Soil Moisture Product

The surface soil moisture dataset, created within the Climate Change Initiative of the European Space Agency is derived using a series of satellite-based passive and active microwave instruments providing soil moisture retrievals covering a period of more than three decades (from 1978) at a spatial resolution of 0.25 degrees with global coverage. This offers the opportunity to generate a combined product that incorporates the advantages of both microwave techniques (different wavelengths, geometries, footprints, etc.). Passive sensors (radiometers) tend to perform better over regions with very sparse vegetation, active sensors (radars) over moderate vegetation. Due to the use of microwave technology the retrieval of surface soil moisture in the first few centimeters of the soil layer can be carried out independently from weather conditions (e.g. cloud cover).

Within the CCI, several soil moisture products were merged by rescaling them to a global reference dataset, which is provided by a land surface model (GLDAS-1-NOAH). All products were then blended into a single active/passive dataset, which is available at daily time steps and at a spatial resolution of 0.25 degrees. If the correlation between the

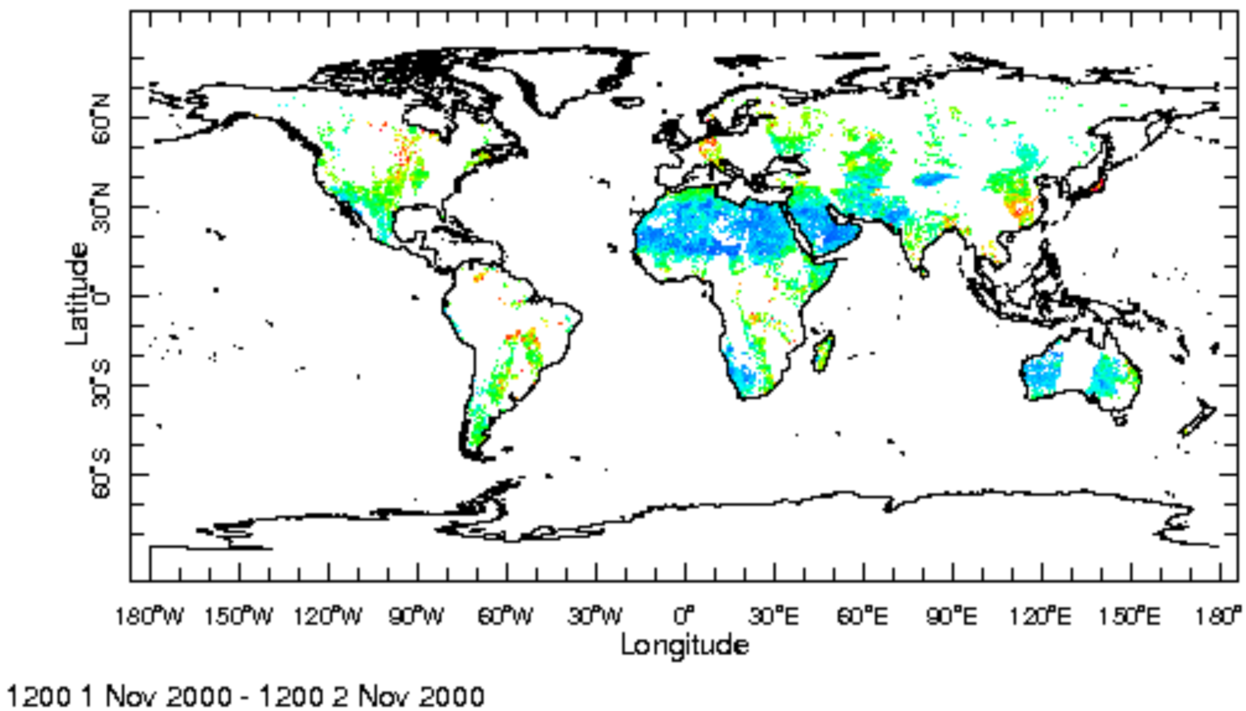

Figure 1.15: *European Space Agency (ESA) Climate Change Initiative (CCI) Soil Moisture Product*

active and the passive product exceeds 0.65 the measurements are averaged. The multi-decadal dataset is expected to enhance our basic understanding of soil moisture in the water, energy and carbon cycles.

Please note: we cannot provide the IRI Data Library access to this dataset at this time, because this product is an "in-house" and therefore, restricted access product. If this status changes, this entry will be updated.

1.8.2 Global Monthly High Resolution Soil Moisture (GMSM)

The GMSM is a global monthly data set starting in 1948 with a spatial resolution of 0.5 degrees. Soil moisture is estimated by a one-layer hydrological model (Huang et al., 1996; van den Dool et al, 2003). The model takes observed precipitation (NOAA NCEP CPC PRECL) and temperature (CPC Global Land Surface Air Temperature Analysis) and calculates soil moisture, evaporation and runoff. The potential evaporation is estimated from observed temperature. Model parameters are constant spatially (tuned based on Oklahoma observed runoff data).

1.9 Conclusion

To create robust index insurance contracts, near real time climate information as well as historical datasets are essential in order to form a strong, reliable index. It is also important to use products with a spatial and temporal resolution that represents the areas to be insured. In our experience, the most appropriate satellite-derived product for index design has an extensive 15+ year historical record, with frequent temporal measurements (Daily, Dekadal) at a moderate spatial resolution (less than 10 km). Datasets that do not share all of these characteristics may not be suitable for index design, but can be used in validation comparisons which strengthen the understanding of seasons with extreme weather events.

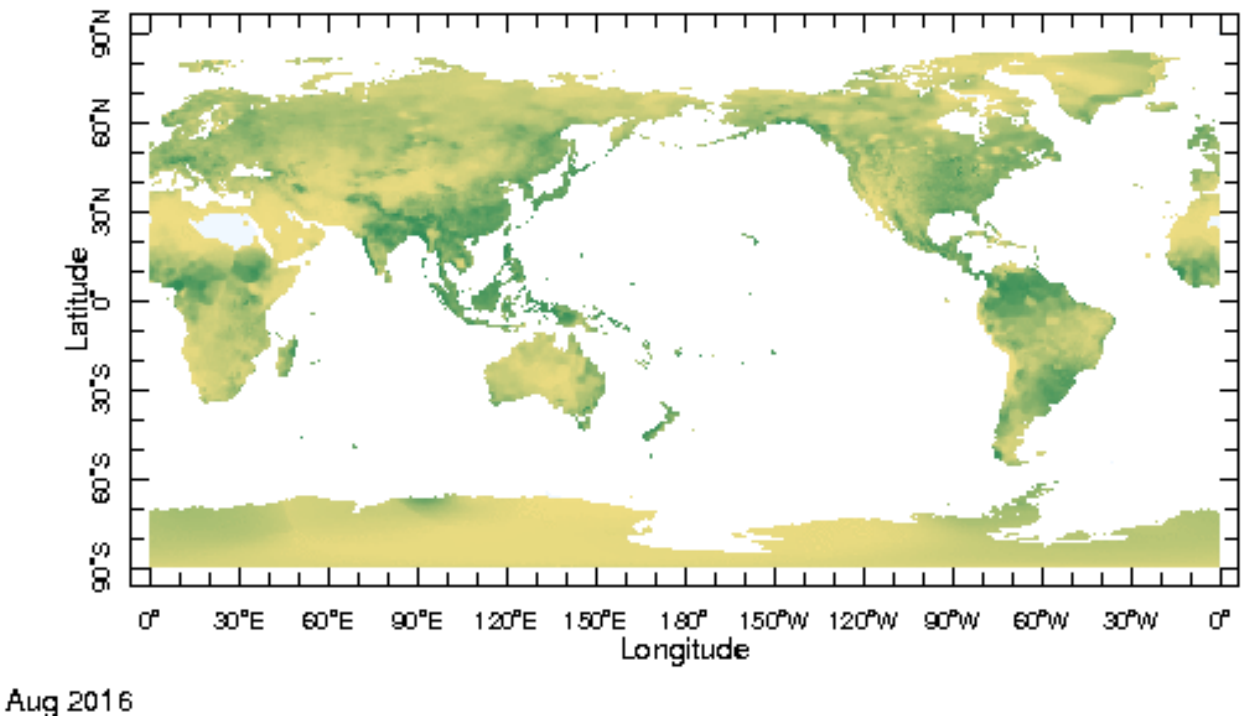

Figure 1.16: *Global Monthly High Resolution Soil Moisture (GMSM)*
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.GMSM/.w/

CHAPTER

TWO

ADDITIONAL RESOURCES

This table provides links to the weather datasets described in this report. If available at the IRI Data Library, the IRI Data Library link is provided.

Table 2.1: Climate Data Product Sources

CAMS
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CAMS/.mean/.prcp/
CAMS-OPI
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CAMS_OPI/.v0208/.satellite/.prcp/
CHIRP v1p0
http://iridl.ldeo.columbia.edu/SOURCES/.UCSB/.CHIRP/.v1p0/.dekad/.prcp/
CHIRPS v2p0
http://iridl.ldeo.columbia.edu/SOURCES/.UCSB/.CHIRPS/.v2p0/.daily/.global/
CMAP - Monthly
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.Merged_Analysis/.monthly/.v1504/.ver2/.prcp_est/
CMAP - Pentad
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.Merged_Analysis/.pentad/.v1306/.ver2/.prcp_est/#info
CMORPH
http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html
CRU TS3p21
http://iridl.ldeo.columbia.edu/SOURCES/.UEA/.CRU/.TS3p21/.monthly/.pre/
ESA CCI SM
Not online yet
ESA CCI SM (previous version)
http://www.esa-soilmoisture-cci.org/
EVI MODIS
http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.250m/.16day/.EVI/
GIMMS NDVI AVHRR
http://iridl.ldeo.columbia.edu/SOURCES/.UMD/.GLCF/.GIMMS/.NDVIg/.global/.ndvi/#info
GMSM
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.GMSM/.w/
GPCP V1DD V1p2
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V1DD/.V1p2/.prcp/#info
GPCP V2p2
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GPCP/.V2p2/.satellite-gauge/.prcp/
GPM
http://pmm.nasa.gov/data-access/downloads/gpm/
NDVI MODIS
http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.250m/.16day/.NDVI/
Continued on next page

Table 2.1 – continued from previous page

CAMS
NOAA NCEP CPC PRECL
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.PRECL/.v1p0/.deg0p5/.rain/
NOAA NCEP CPC REGIONAL daily gridded prcp
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.REGIONAL/.US_Mexico/.daily/.gridded/.realtime/.prcp/
NOAA NCEP CPC UNIFIED_PRCP
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.UNIFIED_PRCP/.GAUGE_BASED/.GLOBAL/.v1p0/
PSD
http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.ESRL/.PSD/.SA23/.1p0/.precip/#info
TRMM
http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GES-DAAC/.TRMM_L3/.TRMM_3B42RT/.v7/
UNAM gridded
http://iridl.ldeo.columbia.edu/SOURCES/.UNAM/.gridded/.monthly/.v0705/.prcp/
VASClimO
http://iridl.ldeo.columbia.edu/SOURCES/.DEKLIM/.VASClimO/.PrcpClim/.Resolution-0p5x0p5/.prcp/#info
WCRP GCOS GPCC FDP
http://iridl.ldeo.columbia.edu/SOURCES/.WCRP/.GCOS/.GPCC/.FDP/.version6/.0p5/.prcp/#info

CHAPTER

THREE

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