Precipitation Climatology

Cloud and Precipitation Systems

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1. Introduction

Knowing the global precipitation climatology is extremely useful in a variety of applications such as modeling the climate, forecasting flash floods and droughts, and managing watersheds. However, accurately measuring instantaneous rainrates with surface rain gages is not an exact science. Further, rainrates measured through remote sensing techniques are inherently complex due to the interactions between electromagnetic radiation with atmospheric constituents. These difficulties have led to many clever techniques to model global precipitation rates. These precipitation rates, when integrated over time, provide global daily, monthly, yearly, etc… precipitation estimates.

2. Surface Measurements of Precipitation Rate

Measuring surface precipitation rates accurately is challenging due to a number of reasons. Foremost, the spatial and temporal variability of precipitation is difficult to resolve without extensive precipitation gage networks, and even with extensive networks each gage is prone to error. These errors can arise from gage malfunctions and design as well as environmental disturbances.

To elaborate on gage design, there are numerous designs that have been implemented in the field. The tipping bucket is a device that has a collector chute which funnels any precipitation by means of gravity into an oscillatory device that registers an electric signal every time a mass threshold is reached. For light precipitation events, this device may be in error due to precipitation sticking to the side of the funnel and evaporating before it can reach the bottom. Further, this device is sometimes equipped with heated sides which also may evaporate a light precipitation event like snowfall causing error. On the other hand, for moderate to heavy precipitation splashing on the sides of these gages may alter precipitation rates again causing error.
The hotplate precipitation sensor is a different type of precipitation rate measuring device which is heated and calculates precipitation rate by measuring the difference in the amount of electricity supplied to a top plate which is exposed to precipitation from any angle and a reference plate which is insulated from the top plate and used as a reference. This plate infers wind speed and temperature contributions via a few proprietary algorithms. The hotplate has numerous advantages over conventional gages including a high temporal resolution providing precipitation rates at 1 Hz; however, it is not yet applicable to higher precipitation rates associated with thunderstorms and tropical climates.

The snow pillow is another device used often in the West at SNOWfall TELemetry stations (SNOTEL) among other sites. This device is strictly applicable to winter precipitation events and is useful in remote locations. Its design incorporates an inflated “balloon” which measures the pressure created by a mass of snowfall on top of the pillow (the snowfall mass water equivalent) and infers a snow depth. The disadvantages are the slow time response, differing densities of snowfall (for snow depth), drifting of snow, and only winter applicability.

All of the gages mentioned are prone to wind effects and turbulence. Blowing precipitation, especially snow, is probably the leading cause of error in most gages. Some designs have attempted to counter this error source by installing wind shields, but it is nearly impossible to overcome all of the errors associated with precipitation gages. The overall performance of precipitation gage measurements is quite good and the results they give are very accurate [Huffman et al., 1997].

The final limitations of automated precipitation gages to measure global precipitation are at least two fold: most of the world is water and most of the world is poor. Thus methods to parameterize precipitation rates via remote sensing techniques coupled with known precipitation rates are required.

3. Measuring Precipitation Rates Via Remote Sensing

An accurate radar and rain/snow rate parameterization can overcome the spatial and temporal resolution faults associated with surface precipitation rate sensors. By using radar, a local relatively large spatial domain can be observed on a relatively short time
domain (5-10 minutes, less if only looking at one elevation angle). Reflectivity measurements are usually correlated to rainfall rate through an empirical power law relationship through a parameterization of precipitation rates with radar reflectivities. However, this relationship is typically case sensitive, meaning, when it is calibrated correctly and used for a commonly occurring event it does a good job at estimating the precipitation rate. Radar’s are very useful on a local scale and provide reliable estimates of precipitation over a 100 x 100 km domain (approximate number for ground based Weather Surveillance Radar’s, as many variables influence this domain), but to measure precipitation on a global scale requires a different approach especially since the array of radar’s needed to monitor the entire earth is monetarily demanding. Again, most of the world consists of water and the population as a whole is poor.

The inherent downfall of remote sensing using satellites is rain cannot be seen. A technique developed in the 1970’s called Geostationary Operational Environmental Satellites (GOES) Precipitation Index (GPI) uses a threshold brightness temperature of 235 K measured by GOES to correspond to a precipitation rate of 3 mm/hr. This clever idea allowed estimations of rainrates from the IR imagery available at the time. With the advances of remote sensing, this archaic method (GPI) still proves to work rather well. Kebe et al. [2005], among others, implemented an analog to the GPI method known as the area-time integral (ATI) which uses a similar approach as the GPI method but uses a rainfall rate inferred by radar to determine an integrated precipitation rate over a particular area. Remarkably, they found that this value shows good correlation with the GPI method 30 years after the GPI’s introduction.

The Tropical Rainfall Measuring Mission (TRMM) satellite is a low earth orbiter (or more precisely, tropical region orbiter between 40°N and 40°S) and is the first and only microwave spaceborne radar (scanning at a frequency of 13.8 GHz), until the upcoming launch of CloudSat, a 95 GHz space radar to be launched in late October. TRMM’s radar is a pioneer when it comes to monitoring global precipitation rates over the vast expanses of ocean that cover much of the equatorial belt. In addition to the active radar, the satellite is also equipped with passive sensors with a lower resolution to better monitor the global tropical region precipitation over a larger domain as opposed to the high sensitivity of the active radar.
Another remote sensing satellite that incorporates microwaves into its analysis of
global atmospheric water constituents is the advanced microwave sounding unit
(AMSU). This instrument is a multi-channel radiometer (some included channels are 89,
150, and 183 GHz) that allows it to penetrate through certain windows of the atmosphere
enabling it to detect various forms of water vapor and from these create humidity profiles
throughout the depth of the atmosphere. All of the benefits of remote sensing
precipitation are apparent when incorporated into unique datasets such as that found in
the Global Precipitation Climatology Project (GPCP).

4. Global Precipitation Climatology Project

Similar to cloud climatology’s ISSCP, the precipitation climatology’s GPCP aims to
provide a thorough dataset that incorporates GOES’s GPI, low-earth orbiter microwave
data, and precipitation gage data to provide global monthly mean precipitation datasets.
The blending of these interrelated fields attempts to minimize the downfalls of each
method used individually and thrive off the advantages of each. Some difficulties in
melding these datasets are the variability within them particularly in the precipitation
gage set as most gages are land based. With an averaging and interpolation technique
described by Rudolf [1993] a grid can be created with gage data. The microwave sensors
have to deal with differing land and ocean cover emissivities which can be accounted for
through different scattering and emission techniques such as the scattering of ice at 150
GHz over the ocean and the scattering at 85 GHz over land. Differences in the scattering
can provide information about particular rainrates. The scattering of these wavelengths
implies ice in the cloud which is a fundamental precipitation characteristic; these clouds
generally would have more precipitation than a typical warm cloud, i.e. no ice. Despite
the relatively low resolution 2.5º x 2.5º lat-lon, it represented the annual global
precipitation well [Huffman et al., 1997]. This data is used throughout the atmospheric
sciences including drought analysts and modelers.

One of the most useful applications of global precipitation climatology is as a
parameter in a model. The accuracy of this value will determine how well the model
performs due to the role that precipitation plays in the climate and inaccuracies will
undulate throughout the model causing error. Thus, the fervor to keep improving
precipitation climatology techniques as every improvement benefits our understanding of the global climate.

5. Global Precipitation Characteristics

Focusing on the United States for the local precipitation characteristics, the general precipitation climatology is influenced primarily by topography as can be seen in Fig 6.1 of the Wyoming Climate Atlas. Definite features are distinguishable, the western sides of most, if not all, mountain ranges have a predominant precipitation abundance where the eastern slopes typically have a rain shadow, i.e. lower precipitation rates. The other noticeable feature is the land/sea boundary influencing much of the south as precipitation amounts increase towards the ocean. In opposition, the local variability is not seen on the global scale and tends to average out over the global zonal averaging domain mainly due to the broad global resolution.

6. Summary

To refrain from a completely negative connotation within this entirety, there is much within global precipitation climatologies that is superb. The ideas, inventions, and theories that have propelled this field into the day and age of computer technology are phenomenal. Focusing on the negative aspect of techniques and methods only increases the desire to fix and mend the faults to further the science. The techniques mentioned herein are not unrepresentative of the actual precipitation rate/climatologies by any means. There will always be error associated with any methodology; however, reducing that error to a reasonable level attains a high level of confidence into further pursuing endeavors and provides insight into future research. In the future, better quantifications of precipitation rate, accumulation, and climatology should be invaluable to many natural resource and global climate entities.

7. References

Some references are found within the following:
Huffman, George J., Robert F. Adler, Philip Arkin, Alfred Chang, Ralph Ferraro,