A Simple, Analytic Precipitation Model

The City College of New York

The Pinkerton Foundation

HIRES- *High School Initiative in the Remote Sensing of Earth Systems Science*

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1. Introduction

Precipitation remains one of the most difficult weather conditions to forecast. This analysis uses a model to: (a) explain the multiple processes involved in precipitation and, (b) explore how well the model matches observed precipitation for a set of cloud parameters.

Precipitation is the product of two main factors:

- **Lifting-** i.e., air rising. Usually occurs through either convection or convergence-forced ascent. Lifting is linked to a number of meteorological events, such as wintertime storms, hurricanes, and thunderstorms on hot summer days.
- **Moisture-** the amount of water vapor that the air can contain is directly related to temperature.

The model here assumes lifting is constant and focuses on moisture.

2. Methods

The Precipitation Model

density (ρ: kg/m^3) and pressure (p: hPa) at Zb (cloud base height, km):

$$\rho = \rho_0 * e^{(-Zb/7.5)}$$

And similarly for p. The 7.5 (km) is based on current climate conditions.

temperature at height Zb:

$$T_{Zb} = T_s - \Gamma_m * Zb$$

(T_s = surface temp.; Γ_m = moist adiabatic lapse rate:K/km)

saturation vapor pressure (pressure of a saturated air parcel, hPa):

$$e_{SAT} = 6.112 * e^{[(17.67*T/)\,(T + 243.5)]}$$

specific humidity (mass of water per mass of air:kg/kg):

$$q = .62 * e_{SAT}/p$$

estimated precipitation (mm):

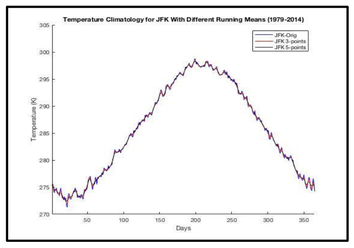
rainfall $= q * \rho * Zt * dt$

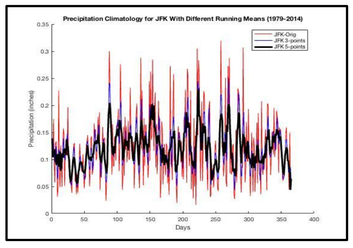
(dt is rain interval; Zt is cloud depth)

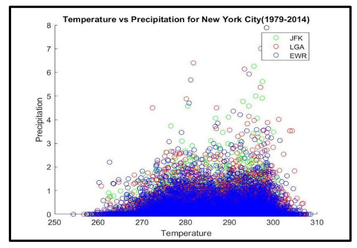
- An annual model of precipitation was created using a climatological average of temperature and by varying the cloud parameters.
  - This was then compared to the observed precipitation climatology at JFK airport.
- Then, the top 20 seasonal precipitation events from 1979 to 2014 were chosen for analysis.
  - An atmospheric profile on the day of each event determined each of the various parameters.
  - This was then incorporated into the model and the modeled and observed precipitation were compared for each event.
- This climatological data is from the Daily Summary Data, a subset of the Integrated Surface Dataset maintained by NOAA (Smith et al, 2011).

Smith, A., N. Lott, and R. Vose, 2011: The Integrated Surface Database: Recent Developments and Partnerships. Bull. Amer. Meteor. Soc., 92, 704-708.

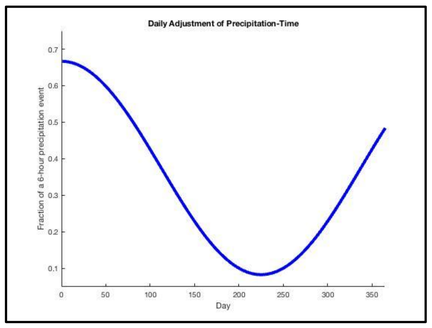
3. Temperature and Precipitation Climatologies





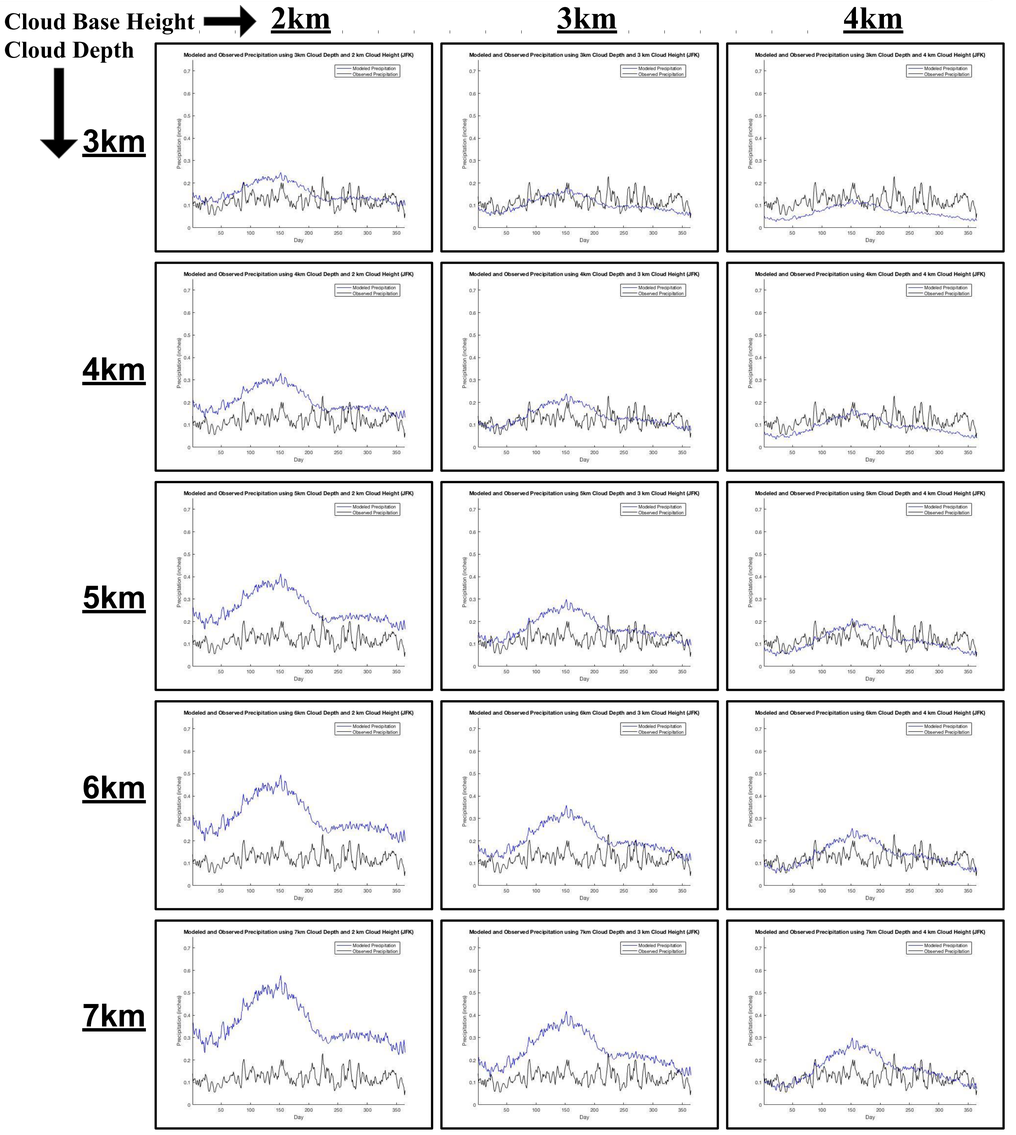


4. Sensitivity of Modeled Precipitation to Cloud Depth & Cloud Base Height



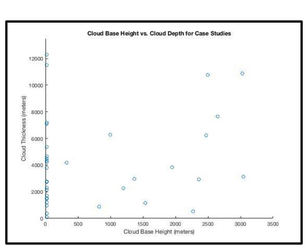
To the right is the annual model of precipitation, created by varying the cloud depth and cloud base height. Modeled and observed precipitation (a 7-point running average) are shown in blue and black, respectively.

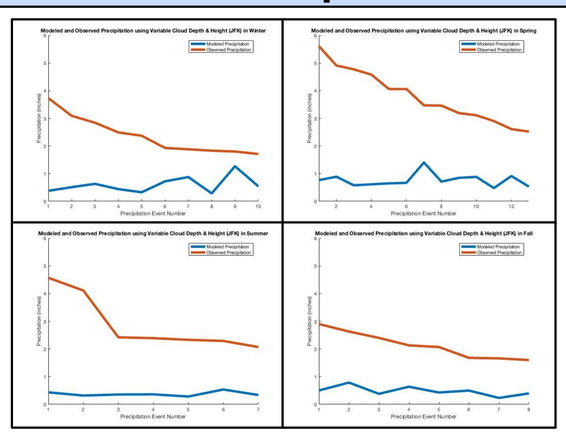
Shown above is the daily precipitation-time adjustment. Its purpose is to correct for the fact that in general, precipitation events in winter last longer than those in summer (i.e. snow showers vs. afternoon thunderstorms). The values are fractions of a 6-hour precipitation event.



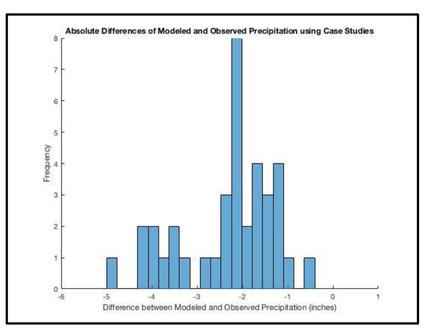
5. Estimated vs. Observed Precipitation using Case Studies from the Top 20 Seasonal Precipitation Events (1979-2014)

Below is a plot of cloud base height vs. cloud depth. To the right are the modeled (blue) vs. observed (red) plots of precipitation by season.





The modeled was less than the actual precip. in every season.



6. Discussion

- In the sensitivity of modeled precipitation, modeled precipitation was usually greater than the observed historical average of precipitation.
- Also observed was that a 1 km change in cloud base height produced a greater change in precipitation than did a 1 km change in cloud depth.
- In the case studies, the modeled was less than the observed precipitation.
- One possible explanation for this is that the atmospheric profile data did not represent the precipitation conditions, as the precipitation data at JFK were obtained 50 miles from the creation of the atmospheric profiles. Further, the duration of rainfall on any day was estimated, not known.
- These results indicate that the processes associated with precipitation events are much more complicated than previously thought.

THIS RESEARCH PROJECT AND MY HIRES SUMMER RESEARCH INTERNSHIP ARE FUNDED BY THE PINKERTON FOUNDATION UNDER THE CUNY CREST INSTITUTE

The NOAA-CREST program is funded by NOAA/EPP Grant # NA11SEC4810004