Model Estimates of Lightning in Convective Systems in Southern Mexico and the Gulf of Tehuantepec

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Abstract

Convection in southern Mexico during the rainy season can lead to extreme precipitation and flooding. Often, such precipitation events lead to landslides, loss of properties, and lives in the mountainous regions. Convective systems can be the result of synoptic scale forcing in the tropics (e.g. easterly waves) and can be either precursors of tropical systems or remnants of landfalling tropical depressions / storms. Three case studies of extreme precipitation observed in 2008 were selected to evaluate their lightning potential. The systems were simulated with the Weather Research and Forecasting (WRF) model, at high resolution (3 and 1 km horizontal spacing). Lightning flash rates were determined for a variety of proxies, calculated from the modelled values and compared against observations made with the Worldwide Lightning Location Network (WWLLN). Six model parameters were calculated: precipitation ice mass, ice water path, updraft volume, cloud top height, maximum vertical velocity (Barthe et al. 2010), and lightning potential index (LPI, Yair et al. 2010). Note that the cited studies pertain to mid-latitude convective storms and this study attempts to assess if the parameters selected in those studies are relevant for tropical regions in Mexico. Correlation coefficients showed good agreement between four model parameters (precipitation ice mass, updraft volume, maximum vertical velocity, and LPI) and the observations. It is worth noting that neither cloud top height nor ice water path were useful as proxies for lightning, since the threshold for reflectivity was never reached in the simulations of these tropical systems.

Introduction

Over the regions with a sparse radar coverage, both prediction and detection of lightning could contribute to the determination of precipitation events.

The migration of the Inter-Tropical convergence Zone, easterly and Rossby waves, the Madden-Julian Oscillation, and the intensification of the jet of Tehuantepec are among the most important atmospheric phenomena over the Gulf of Tehuantepec, located at approximately 16°N 97°W (Figure 1).

During the rainy season over the Gulf of Tehuantepec and adjacent land areas, from May to October, the precipitation distribution shows two maxima. The first maximum is observed in June while the second is in September-October. Between them, there is a decrease in precipitation of up to 40% (this period is known as the Mid Summer Drought). It is worth mentioning that precipitation over this region comes from tropical convective systems.

Spatial distributions of lightning and precipitation are similar. Nevertheless, the monthly evolution of lightning differs from that of precipitation. It decreases from May to June, increases from June to July, and again decreases from August to September, (Kucienska et al. 2012a).

Figure 1. Map of Southern Mexico.

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ACKNOWLEDGEMENTS: This work was carried out with the aid of:
Project: *"Observaciones de radar y descargas eléctricas"* funded by Mexican National Weather Service (SMN).
Master´s scholarship from the National Council on Science and Technology (CONACyT), grant 419170.
Financial support for three months from funds of the Centro de Ciencias de la Atmósfera, UNAM.

Research Questions

What is the relationship between a lightning potential index estimated from numerical simulations, using the Weather Research and Forecasting (WRF), and lightning detected by the World Wide Lightning Location Network (WWLLN)?

Which are the relationships between cloud parameters simulated with the aid of the WRF model that best represent lightning observed in the study region?

Data and Methodology

Lightning data collected in 2008 by the World Wide Lightning Location Network (WWLLN) was used (figure 2) in the study.

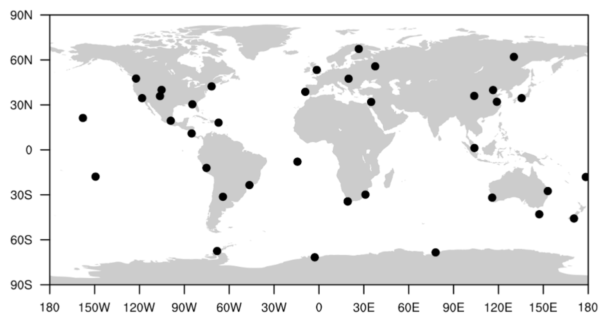

Figure 2. WWLLN sensor locations.

Three case studies of extreme precipitation in 2008 were simulated with the Weather Research (WRF) model model version 3.4.1 (Skamarock et al. 2008), at high resolution, 3 and 1 km horizontal spacing (figure 3): first case study, from June 3rd to June 6th 2008; second case study, from July 6th to July 7th 2008; and third case study, September 24th 2008. Several microphysical schemes were tested to determine which one reproduced better the systems.

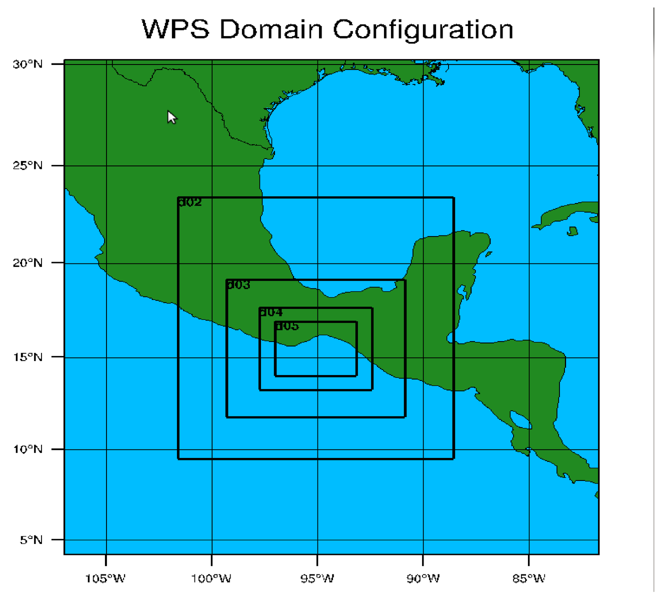

Figure 3. WRF domains.

Six lightning estimates were calculated: precipitation ice mass, ice water path, updraft volume, cloud top height, maximum vertical velocity (Barthe et al. 2010), and Lightning Potential Index (LPI, Yair et al. 2010).

Results: modelling with WRF

Only the first case study with a horizontal resolution of 3 km is presented in this poster.

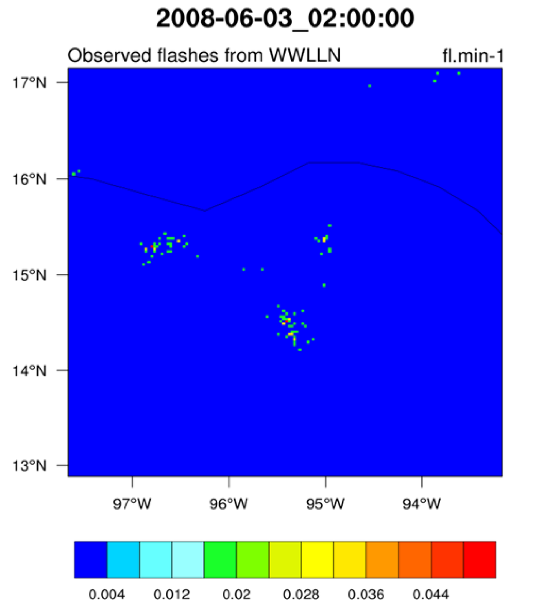

Figure 4. Observed flashes from WWLLN.

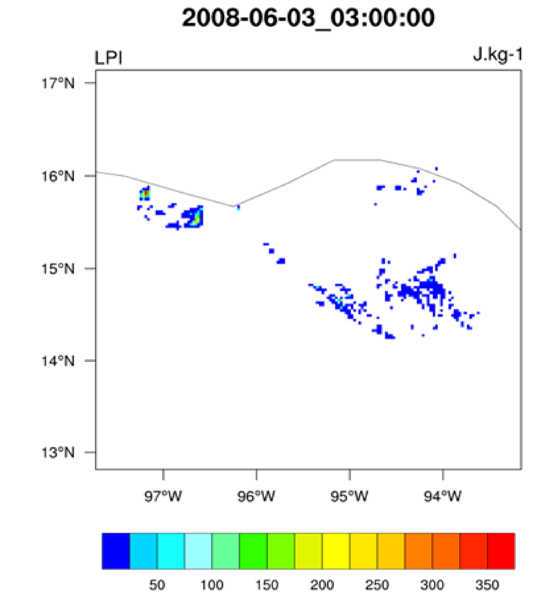

Figure 5. LPI calculated with the Lin et al. 1983 microphysical parameterization.

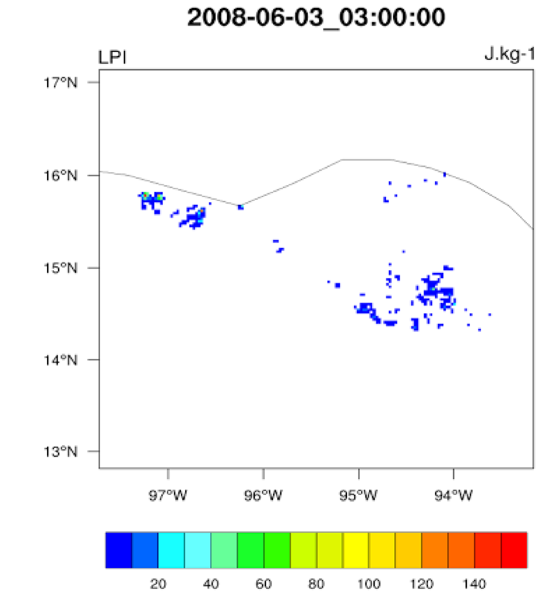

Figure 6. LPI calculated with the Thompson et al. 2004 microphysical parameterization.

Parameterization / correlation	Lin et al. 1983	Thompson et al. 2004	WSM5
LPI	0.705	0.827	0.765
Precipitation Ice Mass	0.781	0.593	0.551
Updraft Volume	0.756	0.846	0.738
Maximum Vertical Velocity	0.756	0.720	0.526

Table 1. Correlation coefficients obtained from each of the lightning estimates.

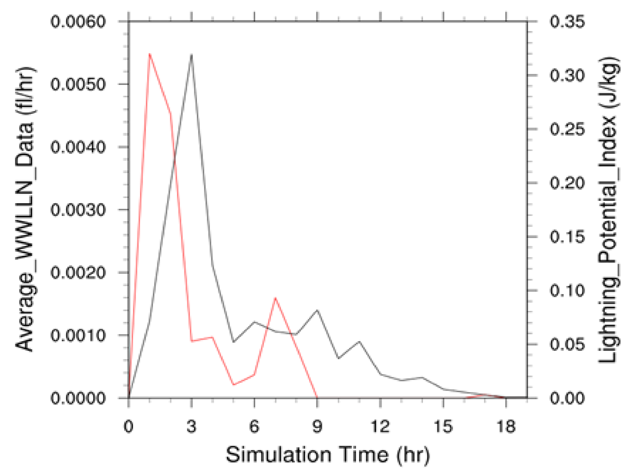

Figure 7. WWLLN (red) and LPI (black) calculated with the Lin et al. 1983 microphysical parameterization .

Conclusions

- Neither cloud top height nor ice water path were useful as proxy for lightning.
- The best correlation between LPI and observations was calculated from results with the Thompson et al. 2004 microphysical parameterization. Similar results were obtained for the updraft volume.
- The best correlations for precipitation ice mass and maximum vertical velocity were calculated from results with the Lin et al. 1983 microphysical parameterization.
- A one hour lag was observed between observations and simulations, probably related to the time of spin-up from WRF.

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