Examining the Effect of Tropical Cyclones on Atmospheric Chemistry Using a High Resolution WRF-Chem Model

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INTRODUCTION

The transport of gases and aerosols to the upper troposphere/lower stratosphere (UTLS) impacts the Earth’s climate. This study aims to improve our understanding of the vertical transport of surface-based species by examining the widespread convection associated with tropical cyclones (TCs). We focus on TCs in the western North Pacific (WNP) because it is the world’s most active basin. It produces larger and stronger storms than any other basin, and TCs in the WNP often make landfall in East Asia, one of the world’s most polluted regions.

OBJECTIVES

• Re-examine Typhoon Mireille using the high-resolution WRF model with chemistry (WRF-Chem; Grell et al. 2005).
• Determine how well in situ chemical data agree with WRF-Chem simulations.
• Compute vertical chemical fluxes.

MODEL CONFIGURATION

WRF-Chem v3.7
• 27-9-3 km grid spacing
• The innermost domain (9 km) will be used in future WRF-Chem simulations
• Two-way nesting
• 48 h nudging period
• 60 vertical levels
• WSM6 microphysics
• RRTM longwave
• Dudhia shortwave
• YSU PBL scheme
• Kain-Fritsch CPS

IC and BC
• ERA-Interim, 0.7° global grid at 38 pressure levels
• Chemistry: MOZART-4, 1.9° x 2.5° with 56 vertical levels
• BCS updated every 6 h

SST
• OISST dataset on a 0.25° global grid
• SST valid for 18 Sep 1991 and held constant during simulation

WRF-Chem settings
• 48 h nudging
• Two-way nesting
• 60 vertical levels
• WSM6 microphysics
• RRTM longwave
• Dudhia shortwave
• YSU PBL scheme
• Kain-Fritsch CPS

Chemical Emissions
• RETRO anthropogenic
• MEGAN biogenic

CASE STUDY: MIREILLE (1991)

Typhoon Mireille is the most chemically sampled TC (Newell et al. 1996), making it an excellent case for evaluating the WRF-Chem model. Chemical measurements were obtained from the NASA DC-8 from an altitude of 300 m (PBL region) to ~12 km (UTLS region) just before Mireille made landfall (black circle; Fig. 4).

MODEL SENSITIVITY TESTS

DETERMINING THE BEST TC SIMULATION

SEA LEVEL PRESSURE

1200 UTC 25 SEP

1200 UTC 27 SEP

Figure 6. Two-domain WRF-Chem simulation showing different physics combinations. Plot shows Typhoon Mireille (a) chemistry (MSLP) and (b) track (location of 4 km on track every 6 h).

REFLECTIVITY AND SATELLITE IMAGERY

1200 UTC 27 SEP

Figure 7. Two-domain WRF-Chem simulation showing different physics combinations. Plot shows typhoon Mireille (a) intensity (MSLP) and (b) reflectivity with corresponding images.

CHEMICAL EMISSIONS (d01 only)

ANTHROPOGENIC EMISSIONS

1200 UTC 25 SEP

1200 UTC 27 SEP

Figure 8. As in Fig. 7, for different combinations of (a) anthropogenic (b) biogenic.

Figure 9. As in Fig. 7, for different combinations of (a) CO (ppbv), (b) NOX (ppbv), and (c) SO2 (ppbv) at 1800 UTC 16 September for d01.

INITIAL CHEMICAL OUTPUT (d01 only)

SURFACE CHEMICAL CONCENTRATIONS

1800 UTC 16 SEP

Figure 10. Surface anthropogenic emissions of (a) CO concentration (ppbv), (b) NOX concentration (ppbv), and (c) SO2 concentration (ppbv) at 1800 UTC 16 September for d01.

FUTURE RESEARCH

• Add innermost nest of 3 km grid spacing to explicitly resolve convection (Fig. 3).
• Compare WRF-Chem simulated output to DC-8 chemical measurements.
• Analyze forward-backward trajectories using HYSLIP to increase understanding of the role TCs play in driving chemical species.
• Compute vertical chemical fluxes at various levels to quantify a TC’s impact on the upper atmosphere energy (chemistry) budget.
• A more recent WNP TC (2004-present) also will be studied.

REFERENCES


Summary: WRF meteorology output (i.e., MSLP, reflectivity, etc.) from the two-domain simulation agrees closely with available observations.