Orographic Impacts on Liquid and Ice-Phase Precipitation Processes during OLYMPEX

Walter A. Petersen  
Earth Science Branch  
NASA MSFC, Huntsville, AL

Alexis Hunzinger  
Dept. of Atmospheric Science  
University of Alabama in Huntsville, Huntsville, AL

Patrick N. Gatlin  
Earth Science Branch  
NASA MSFC, Huntsville, AL

Introduction

• NASA Global Precipitation Measurement (GPM) mission Olympic Mountain Experiment (OLYMPEX) during winter of 2015-16  
• Ground and airborne in situ and remote sensing measurements  
• NASA S-band dual-pol (radar) (NPOL) used to analyze evolution of hydrometeor profiles as precipitation moved from the ocean and over mountainous terrain

Motivation

• Analysis suggests satellite-based precipitation products such as GPM IMERG underestimate by 57% over orography in the OLYMPEX domain (e.g., Cao et al., 2018)  
• IMERG relies on combined passive microwave (PMW) and IR sensors to make a precipitation estimate.  
• PMW sensors rely on ice scattering over land for precipitation estimation. Often underperform in warm-rain conditions.  
• IR sensors see cloud top, often underperform in stratiform (shallow) clouds.  
• Orographic enhancement of precipitation is observed ahead of and on windward slopes  
• Resultant enhancement of both warm and cold rain processes

(1) What changes are occurring in the low levels due to orography?  
(2) Are these changes systematic?  
(3) Is IMERG capturing these changes?

Methodology

Radar-based approach with NPOL

• GPM satellite retrievals are limited by assumptions made about content and behavior of clouds and precipitation  
• Use NPOL’s ground-based perspective to estimate relative ice and liquid contributions within a cloud column  
• Compare near-surface rain rate estimates from Integrated Multi-Satellite Retrievals for GPM (IMERG) with NPOL

Systematic Partitioning

-Extra tropical cyclones (frontal systems) are the primary source of precipitation and provide rapidly changing dynamic and thermodynamic conditions  
- Times of precipitation during OLYMPEX are categorized using four primary cyclone sectors with distinct characteristics: prefrontal, warm sector, frontal, and post-frontal. (cf., Houze et al., 2017)

Calculating water paths from an RHI

1. Use hydrometeor ID to discriminate ice and liquid hydrometeors  
2. Calculate ice and liquid mass content (LWC, UWLC) of hydrometeors by relating reflectivity (Z) and differential reflectivity (ZDR) to water mass content  
3. Grid IWC and LWC, 1000 m x 500 m (x,y)  
4. Integrate IWC and LWC to obtain ice and liquid water path (IWP, LWIP)

Conclusions

• Warm sector and post-frontal regimes indicate different processes controlling ice and liquid enhancement  
• Warm-sector lifting of low-level flow is observed ~40 km upstream of barrier, enhancing warm rain process, while mountain-induced uplift and turbulence enhances ice processes  
• Coupling of warm and cold process yields heavy rainfall via the feeder-feeder mechanism  
• Post-frontal exhibits cellular behavior and very limited signatures of a dendritic/branching crystal growth layer.  
• When raining, IMERG IR tends to underestimate, PMW may, at times, overestimate due to ice contribution  
• IMERG captures the approximate range, but not always the magnitude of near-surface rain rate

Future Work

• Comprehensive analysis of all collected RHI azimuths with stricter categorization of regimes and more detailed analysis of processes using combinations of all available column-profiling data.  
• Multivariable correlation index to evaluate the most meaningful combination of environment parameters for precipitation enhancement.

Acknowledgments

The NASA GPM and PMM Programs are acknowledged for supporting this research. Fruitful discussions with Dr. Lynn McMurdie, and J. Zagrodnick, U. Washington, are also acknowledged.

References:

House et al. (2017): The Olympic Mountains Experiment (OLYMPEX), Bull. Amer. Meteorol. Soc., doi:10.1175/BAMS-D-16-0181.2  