High resolution modeling to understand the physical processes relating to rainfall in the Mantaro basin (central Peruvian Andes) using WRF

Yamina Silva Vidal¹,

Alan García Rosales¹,² and Clementine Junquas³

¹-Instituto Geofísico del Perú; ²- Universidad Nacional Agraria La Molina;
³- Laboratoire d'Etude des Transferts en Hydrologie et Environnement (LTHE), France

yamina.silva@igp.gob.pe
Fig. 3. Schematics of the low-level atmospheric flow (roughly from surface to about 1.5 km a.s.l.) around the Andes cordillera. Also shown major climate features of South America.

Garreaud et al., 2009
Climate of the central Peruvian Andes

**Monthly precipitation in the Mantaro valley**

- **Rainy season 86%**
- Minimum air temperature in the Mantaro valley

**Annual precipitation**

<table>
<thead>
<tr>
<th>Region</th>
<th>mm/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coast</td>
<td>1-5</td>
</tr>
<tr>
<td>Andes</td>
<td>400-800</td>
</tr>
<tr>
<td>Amazon</td>
<td>3000-7000</td>
</tr>
</tbody>
</table>
The hydropower energy from the basin supplies the 34% of the National demand.

Population of over 700,000 inhabitants.

Area approx. 34,000 km²: Altitude: 1000-4900 masl

The valley has great agricultural production that provides food to Lima (8.5 millions inhabitants).

Over then 80% of agriculture depends directly of rainfall (no irrigation)

IGP (2005)
Domains and model configuration

- Microphysics: Thompson (Rasmussen and Hall, 2008)
- Cumulus: Grell-Devenyi (Grell et al., 2002)
- Surface: Unified NOAA LSM (Chen & Dudhia, 2001)
- PBL: Yonsei University (Hong et al., 2006)

- Initial & boundary condition: NCEP FNL 1°x1° resolution
- Precipitation: TRMM product 2A25 & station data
- Topography was changed from USGS to Shuttle Radar Topography Mission (90m)
- Land use: MODIS IGBP, 21 categories

- Period of simulation: February 2000 - 2012

<table>
<thead>
<tr>
<th>Setting parameterizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microphysics</td>
</tr>
<tr>
<td>Thompson (Rasmussen and Hall, 2008)</td>
</tr>
<tr>
<td>Cumulus</td>
</tr>
<tr>
<td>Grell-Devenyi (Grell et al., 2002)</td>
</tr>
<tr>
<td>Surface</td>
</tr>
<tr>
<td>Unified NOAA LSM (Chen &amp; Dudhia, 2001)</td>
</tr>
<tr>
<td>PBL</td>
</tr>
<tr>
<td>Yonsei University (Hong et al., 2006)</td>
</tr>
</tbody>
</table>
Observed vs TRMM precipitation

The TRMM tends to underestimate the precipitation over high altitudes.

Topographical profile (gray) and total annual rainfall from meteorological stations. The x axis represents the horizontal distance and the y axis the altitude (masl) and the mean total rainfall (mm/yr) from observations (blue bars) and TRMM PR-2A25 (blue line).

Espinoza, et al, 2015
Observed vs TRMM and modeled precipitation for February (mm/month)

- TRMM underestimate precipitation compared with station data.
- WRF precipitation overestimate.
Diurnal cycle of precipitation in the Andes

Percentage of the total precipitates rains interval during the day (TRMM)

01-06 Hrs (Local time)

13-18 Hrs (Local time)

TRMM:
The major precipitation occurs in the eastern slope of the Andes during 13-18 Hr (LT)

Chávez, 2013

Precipitation in the valley:
• observed peak is at 18-19 Hr (LT)
Diurnal cycle of TRMM 2A25 precipitation (mm/day) for the Mantaro basin (2000-2012)

TRMM shows the precipitation peak at 16 Hr, two hours earlier than observed.
Diurnal cycle of 9km WRF precipitation (mm/day/4) (2002-2012)

WRF shows the peak of precipitation also at 16 LT but its distributed in the eastern side of the basin
Diurnal cycle of the local humidity transport over the central Andes of Peru

High humidity convergence is observed at 16 hrs in the central parts of the basin.
Interannual precipitation variability in the Mantaro basin

- The model does not reproduce adequate the dry and wet years.
- There is only 3 from 13 years that they coincide, mostly for dry years.
- The region C, seems to be a bit better for the model
To understand the physical, microphysics, and dynamics of clouds and precipitation in the Andean region and its effect on the radiation and water balance and extreme weather and climate events (frost, heavy rainfall, droughts).
Cloud precipitation radar vs disdrometer

Thesis: Elver Villalobos (UNMSM) in progress
Cloud-precipitation radar & wind profiler (BLTR)

BLTR

MIRA 35C

UTC Time (hours) - 19-Jan-2016

Vertical Wind (m s$^{-1}$)

Equivalent Reflectivity Factor (dBZ)

Range (m)

Range (km)

High clouds

Precipitation

UTC Time (hours) - 19-Jan-2016

Universal Time (hours) - 19-Jan-2016

Courtesies: Danny Scipion (ROJ/IGP)

WCRP

CORDEX

ICRC-CORDEX 2016
Summary

• The WRF tends to overestimate precipitation by a factor of four with respect to TRMM and by a factor of two as compared to ground measurements.

• The diurnal cycle of simulated precipitation is reasonably well reproduced, however the maximum of diurnal cycle occurs somewhat earlier as compared to observations.

• The model reveals poor skill in reproducing interannual variability of precipitation across the basin.

• Satellites tend to underestimate the precipitation over the Andes in comparison to observational data.

• Very high resolution models (300m) are required to study the physics of storms and cloud and precipitation over Andes.
Acknowledgments

- Impact of transboundary biomass burning pollution transport over the Central Andes of Peru.
- Study the physical processes that control the surface energy and water fluxes to improve models of frost, intense rainfall and evapotranspiration in the central Andes of Peru.