Regional climate modeling of the diurnal cycle of precipitation and associated atmospheric circulation patterns over an Andean glacier region (Antisana, Ecuador)

Junquas et al. (2022)
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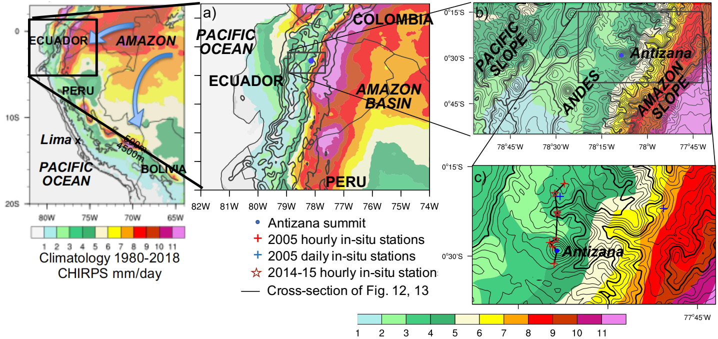
Summary

Introduction

The Antizana region (Ecuadorian Andes)

- 3 main climate zones :
  - The humid Pacific slope,
  - The dry Andes mountains,
  - The very humid Amazon slope
- The Antizana glacier (5700m) is situated in the eastern side of the Ecuadorian Andes (South East of Quito city), close to the Amazon region.

2005 precipitation mean (mm/day) from CHIRPS



Objectives

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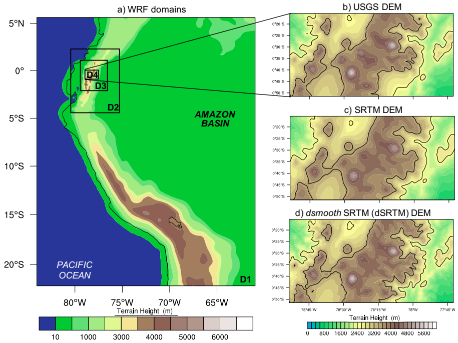
- Simulate the precipitation at high spatio-temporal resolution (1km; 1h) in the Antizana region with the WRF model.
- Identify how different orographic forcing data and model parameterizations (including convection-permitting configurations) can influence the diurnal cycle of precipitation at local scale.
- Understand the atmospheric processes associated with the different model configurations, including the local valley wind circulations.

Dynamical downscaling in the Antizana region

WRF regional climate model

- WRF 3.7.1 = Weather Research and Forecasting (NCAR)
- 4 Nesting domains (D1-D4), one simulated year 2005 (available in-situ data)
- 3 DEM (Digital elevation domain) : **USGS** (United States Geological Survey ; default data in WRF3.7.1; original resolution of 1km, and **SRTM** (Shuttle Radar Topography Mission; Farr et al., 2007; original resolution : 90m (3 arc-seconds), with a possibility of *dsmooth* option; hereafter called **dSRTM**



Experiments of the dynamical downscaling

Characteristics and parametrizations of the WRF modelisation (1/2)

Table 1: Characteristics of the WRF simulations at the four different spatial scales.

	WRF-27km	WRF-9km	WRF-3km	WRF-1km
Horizontal resolution (km)	27	9	3	1
Domain	Tropical Andes	Ecuador	Northern Ecuador	Antizana region
Domain center coordinates	8°30'S, 72°W	15°32'24''S, 70°33'34''W	13°25'37''S, 72°34'3''W	0°33'26''S, 78°18'3''W
Configuration	Regional simulation	One-way nesting	One-way nesting	One-way nesting
Forcing	NCEP_FNL	WRF-27km	WRF-9km	WRF-3km
Vertical resolution	30 sigma levels	30 sigma levels	30 sigma levels	30 sigma levels
Run time-step (s)	150	50	16.667	5.556
Outputs time resolution (h)	6	3	3	1

Table 2: List of the WRF physical parameterizations tested in the simulations.

	Parameterizations	References
Clouds microphysics	New Thompson Scheme **(NT)** Purdue Lin scheme **(L)**	Thompson et al. (2008) Chen and Sun (2002)
Radiation	Longwave: Rapid Radiative Transfer Model (RRTM)	Mlawer et al. (1997)
	Shortwave : Dudhia Scheme	Dudhia (1989)
Cumulus parametrization	Grell-Devenyi ensemble scheme **(GD)** Grell-Freitas scheme **(GF)**	Grell and Devenyi (2002) Grell and freitas (2014)
Planetary boundary layer	Yonsei University Scheme Wind topographic correction (option 1)	Hong et al. (2006) Jimenez and Dudhia (2012)
Land surface	Noah-MP (Multi-Physics) with partitioning precipitation option 2	Niu et al. (2011); Yang et al. (2011)
Surface layer	MM5 similarity	Paulson (1970)

Experiments of the dynamical downscaling

Characteristics and parametrizations of the WRF modelisation (2/2)
–> 10 experiments of the year 2005, groups of analysis for different purposes

Experiment name	USGS DEM	SRTM DEM	dsmth	Cu (D1,D2)	Cu (D3,D4)	MI	Analysis Group(s)
USGS_NT	X			GD	GD	NT	1
USGS_L	X			GD	GD	Lin	1
USGS_GF	X			GF	GF	NT	2
USGS_GFNoCu	X			GF	0	NT	2
dSRTM_NT		X	X	GD	GD	NT	1
SRTM_L		*X*		*GD*	*GD*	*Lin*	*1, 3*
SRTM_LRad		X		GD	GD	Lin	3
dSRTM_L		*X*	*X*	*GD*	*GD*	*Lin*	*2, 3*
dSRTM_LNoCu		X	X	GD	0	Lin	2
dSRTM_LRad		X	X	GD	GD	Lin	3

Table 3 : List of the experiments and their characteristics.

Group ('NoCu' =CP exp.)

Cumulus scheme activated or not at 3km and 1km

Experiments of the dynamical downscaling

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–> 10 experiments of the year 2005, 3 groups of analysis for different purposes

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USGS_GFNoCu	X			GF	0	NT	2
dSRTM_NT		X	X	GD	GD	NT	1
SRTM_L		*X*		*GD*	*GD*	*Lin*	*1, 3*
SRTM_LRad		X		GD	GD	Lin	3
dSRTM_L		*X*	*X*	*GD*	*GD*	*Lin*	*2, 3*
dSRTM_LNoCu		X	X	GD	0	Lin	2
dSRTM_LRad		X	X	GD	GD	Lin	3

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USGS_GF and USGS_GFNoCu

- Grell and Freitas (2014)
- New Thompson Microphysics
- DEM USGS

Experiments of the dynamical downscaling

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- New Thompson Microphysics
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dSRTM_L and dSRTM_LNoCu

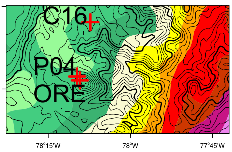
- Grell and Devenyi (2002)
- Lin Purdue Microphysics
- DEM SRTM without smooth

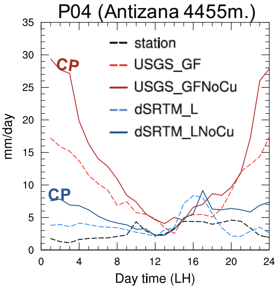
Statistical precipitation analysis

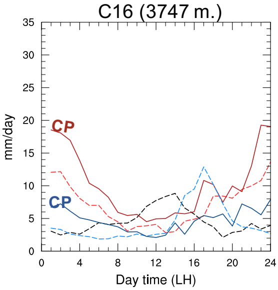
Results of experiments (WRF-1km) when compared with in-situ stations

Influence of convection-permitting with 2 Cu schemes

- **Annual mean of diurnal cycle precipitation at two elevated stations**
  - Every expriments overestimates observed precipitation, particularly **during the night**
  - The activation of Cu scheme reduces strongly the overestimation. –> need to better understand the nighttime processes in order to understand how this bias is reduced.



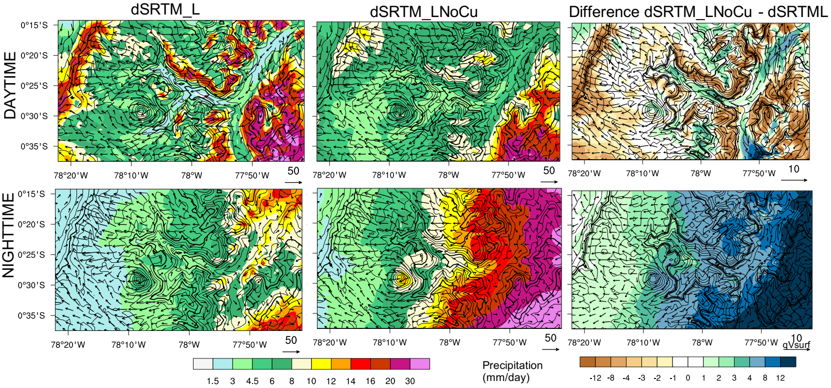




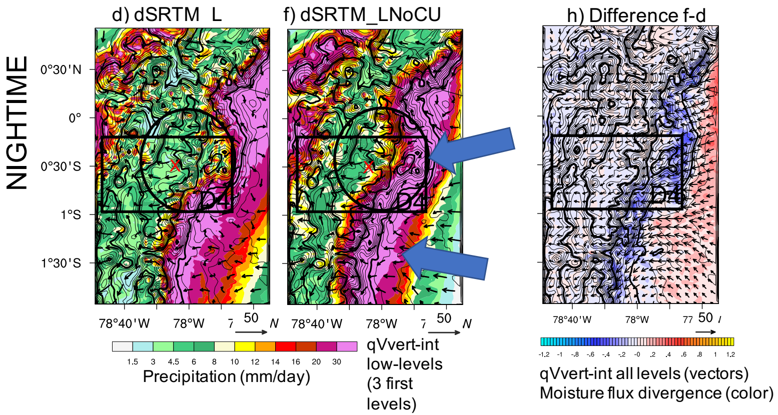
Analysis of precip spatial variability
and associated physical processes (WRF-1km)

Influence of convection-permitting : **local scale**

- **Daytime** : Channelization of the surface moisture transport, upward valley wind along the slopes, localized maximum of precip in slopes. Weakened when Cu not activated.
- **Nighttime** : Regional pattern of precip reaches highest elevation when Cu not activated, including an increase precip in Antizana summit.



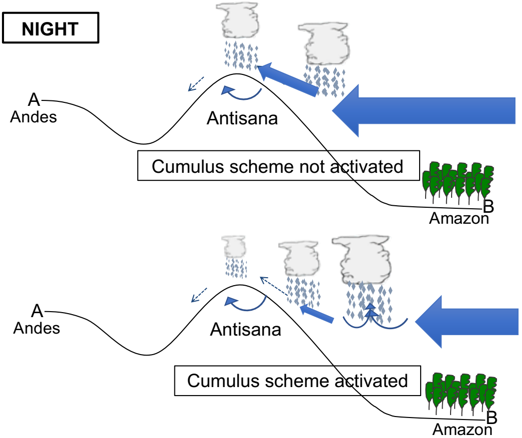
Analysis of precip spatial variability
and associated physical processes (WRF-3km; D3)



Regionale scale

Nighttime when Cumulus is not activated (NoCu) :
- Hotspot of precipitation found at higher elevation
- Intensified easterly moisture flux

Conclusion (1/2)



When activating Cu schemes at high spatial resolutions (3km, 1km)
–> it increases/triggers the convection upstream of the flow in the lower part of the Andes-Amazon slope
–> reducing the easterlies moisture fluxes reaching the higher Andes
–> it indirectly reduces the nighttime precipitation bias.

Conclusion 2/2

- Lucas-Picher et al. (2021) –> some studies underlined that kilometer-scale resolutions only allows to partially resolve convective clouds (Chow et al., 2019) and convective updrafts (Kendon et al., 2021)
- 1-3km seems to be still a “grey zone” for convection in this region. Parameterization should be still needed to better resolve the Ecuadorian hotspot (Andes-Amazon transition zone).
- While Cu schemes are not physically implemented for such high resolutions, it appears that locally and indirectly they can reduce precipitation biases in the Andes of Ecuador. This configuration should be used with caution, but could be considered for ex. to simulate atmospheric forcings for further be used in hydrological/glaciological models.
- However during daytime, the Cu activation increases upward valley wind circulation and precipitation increases strongly locally in slopes and in some localized relative orographic peaks. We don’t know if it improves or not the model performance during the day because we would need more in-situ stations particularly located on the slopes and summits where they are mainly missing today.

Thank you !