

Department of Water Resources Engineering  
Lund University

## Hydrological modelling in mountainous basins

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*Claudia Canedo*  
*Ronny Berndtsson*



# Bolivian mountainous basins



- The Altiplano highland is located along the middle part of the Andes, with a mean elevation of 4000 m.
- The Titicaca-Desaguadero-Poopo System (TDPS) area is 145 000 km<sup>2</sup> with 65% in Bolivia and 35% in Peru.
- Total population is about 3 million (62% Bolivia and 38% Peru).
- The rural inhabitants represent more than 50% of the population.

# Extreme events

Drought

Frost

Hailstorm

Flooding





# Extreme event: flooding



Newspaper pictures: a) La Patria (22/01/2015), b) Correo del Sur (26/01/2015), c) Pagina Siete (27/01/2015)

DECEMBER 2014



JANUARY 2015



# Research questions

- How to estimate peak flow in ungauged mountainous basins?
- Best techniques to understand the hydrological response in mountainous basins of flash floods?



# Objective

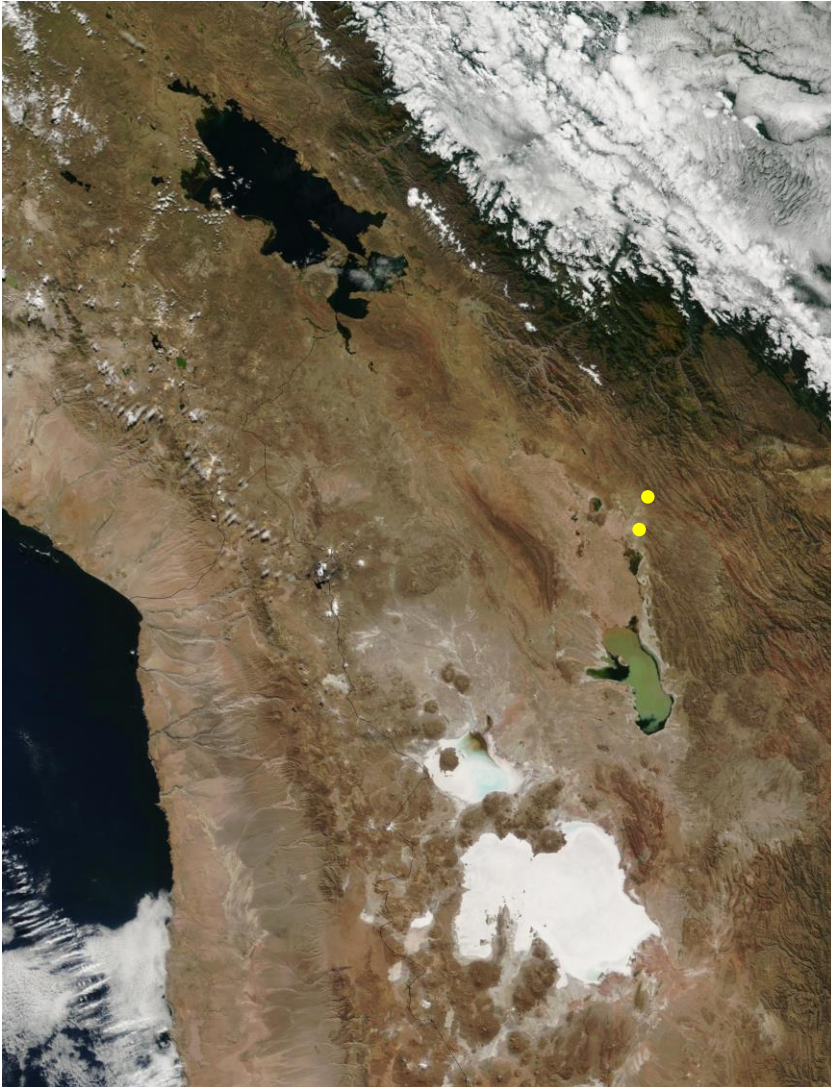
The current research is aiming at broadening the applicability of hydrological modeling for flash flood events in an arid mountainous watershed.

- 1) To improve predictive ability when flood characteristics are significantly influenced by antecedent hydrologic conditions and allow for prediction of flood events that involve rain storms in ungauged basins.

and

- 2) improve physical understanding of flood inducing storms in mountainous arid basins.

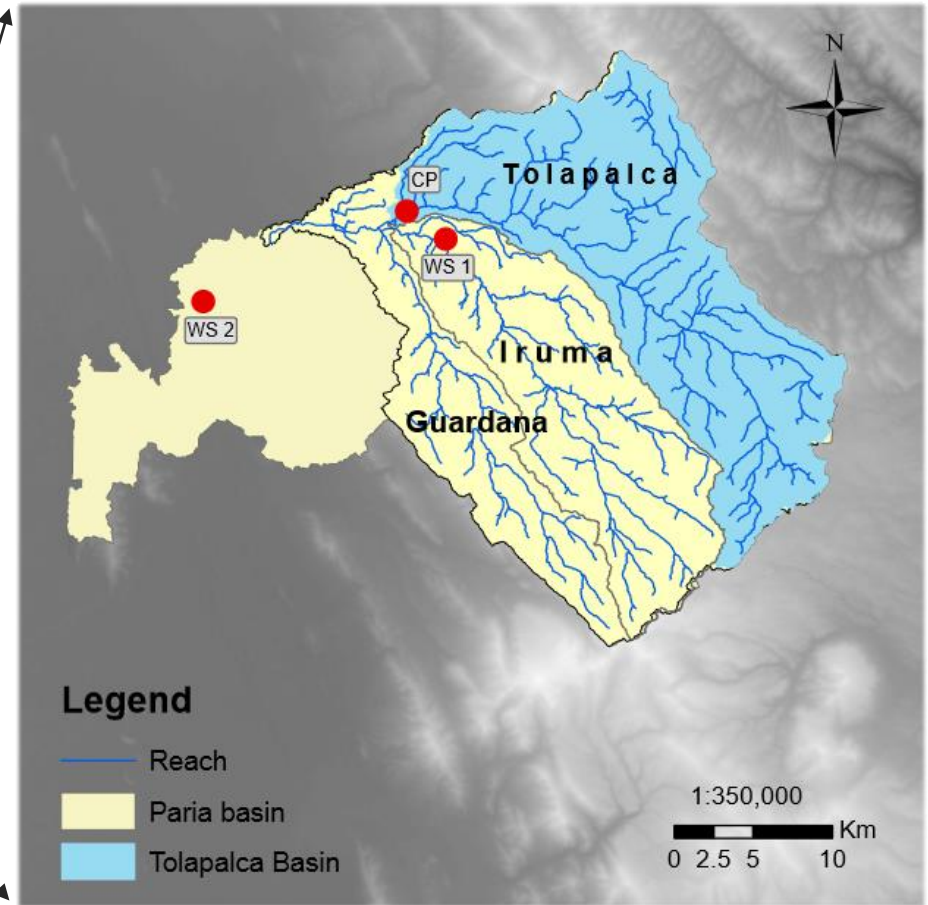
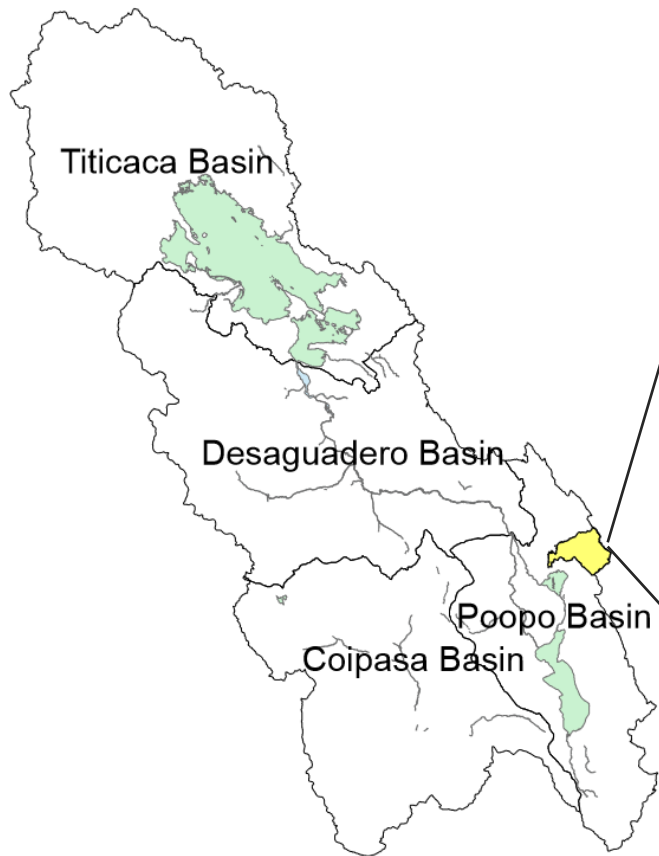
# Bolivian mountainous basins



- TDPS system area 145,000 km<sup>2</sup>
- Lake Poopó basin area is 24,000 km<sup>2</sup> including Oruro City and Paria sub-basin (925 km<sup>2</sup>)
- **Paria subbasin's** main river was flooded in January, 2015.
- The flooding affected 4000 families



# Paria basin



WS: Weather station  
CP: Discharge station

Figure: TDPS and Paria basin map

Paria river basin area is 925 km<sup>2</sup>  
Tolapalca (blue) is 336 km<sup>2</sup>

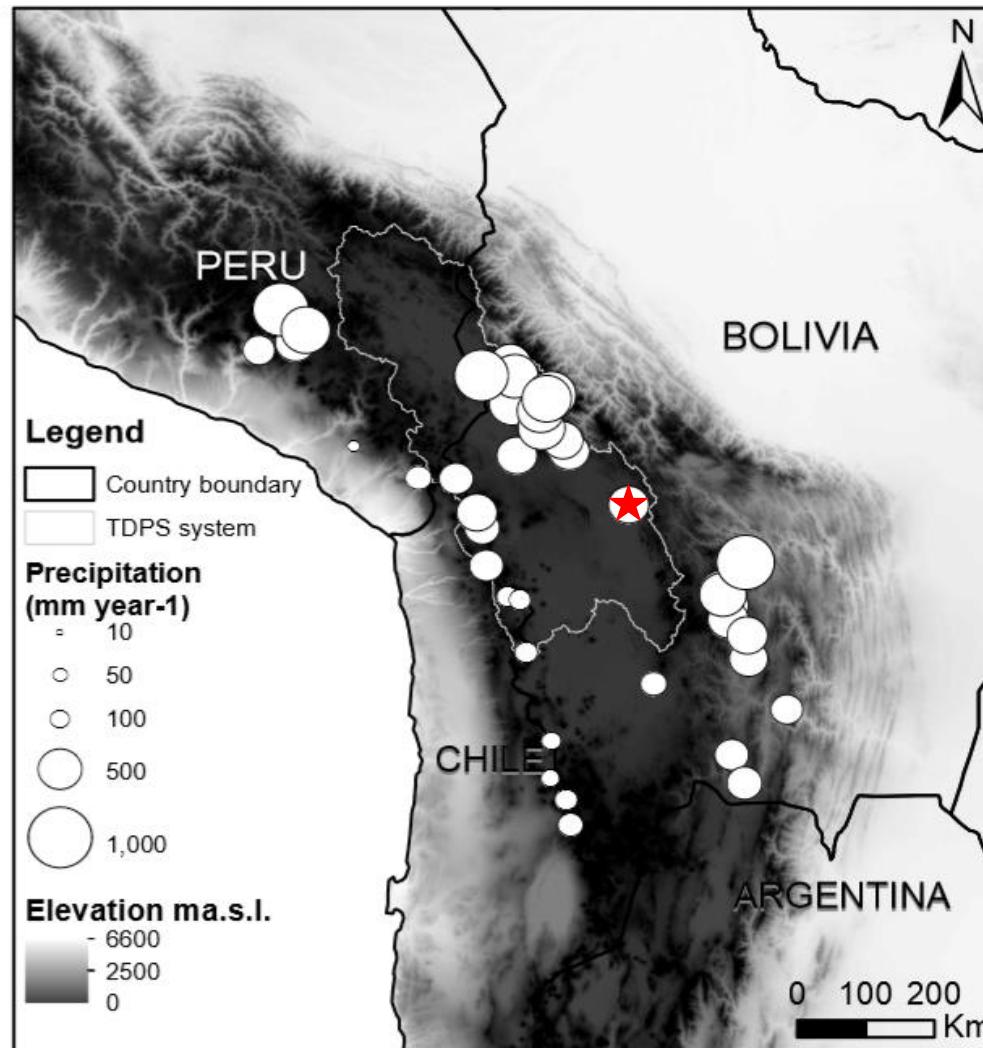
# Climate

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The TDPS system shows a pronounced north–south gradient (200-900 mm year<sup>-1</sup>) in annual precipitation with the wet season from November to March and the dry season from mid-April to October.

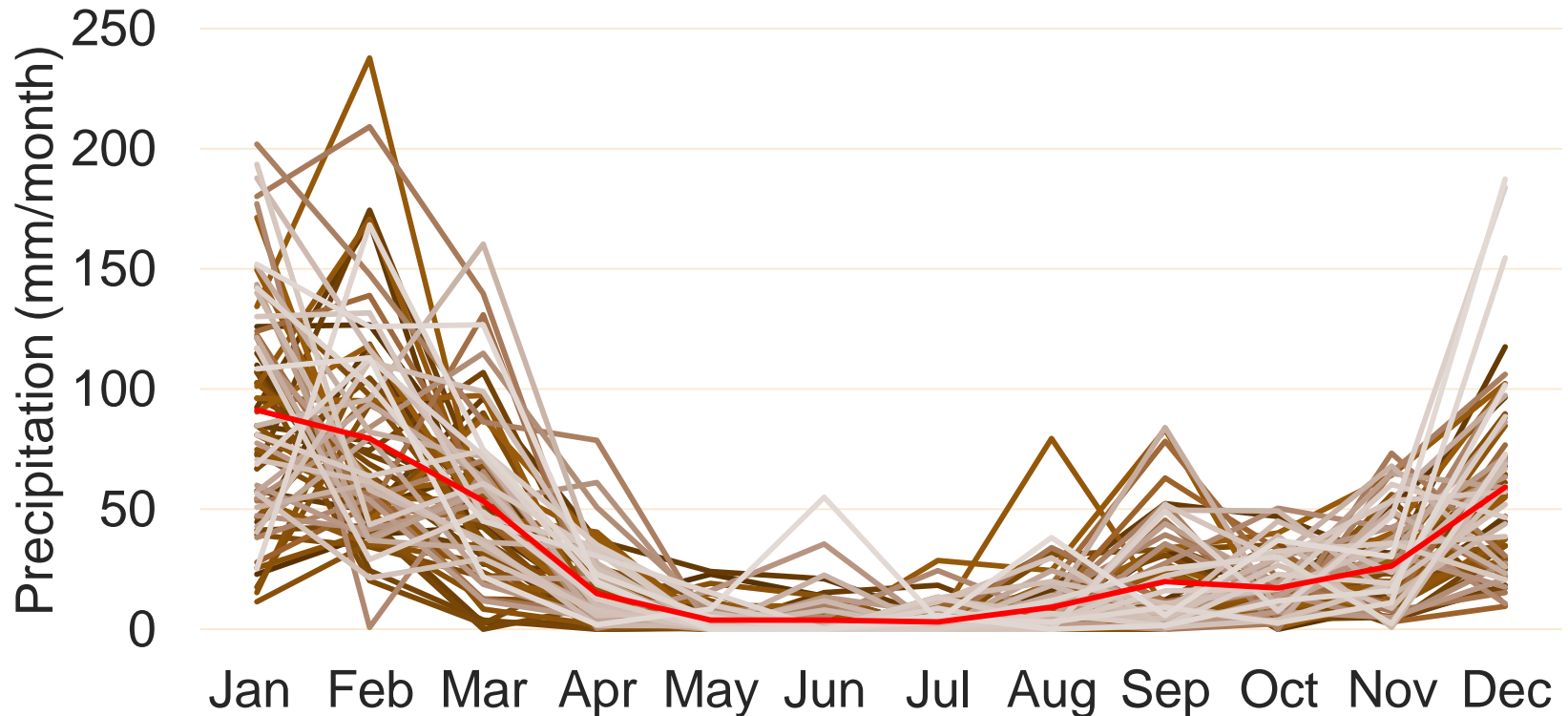


# Altiplano precipitation gradient





# Monthly precipitation (1943-2013)



Precipitation in central Altiplano, rainy season from December and March (January and February)



# Hydrological and climatological data

Water level: December 2014 - January 2015

Precipitation (mm/10min), Temperature ( $^{\circ}$  C) and other climatological variables.

Concentration time: 410 min (6.8 h)

Lag time: 246 min (4.1 h)

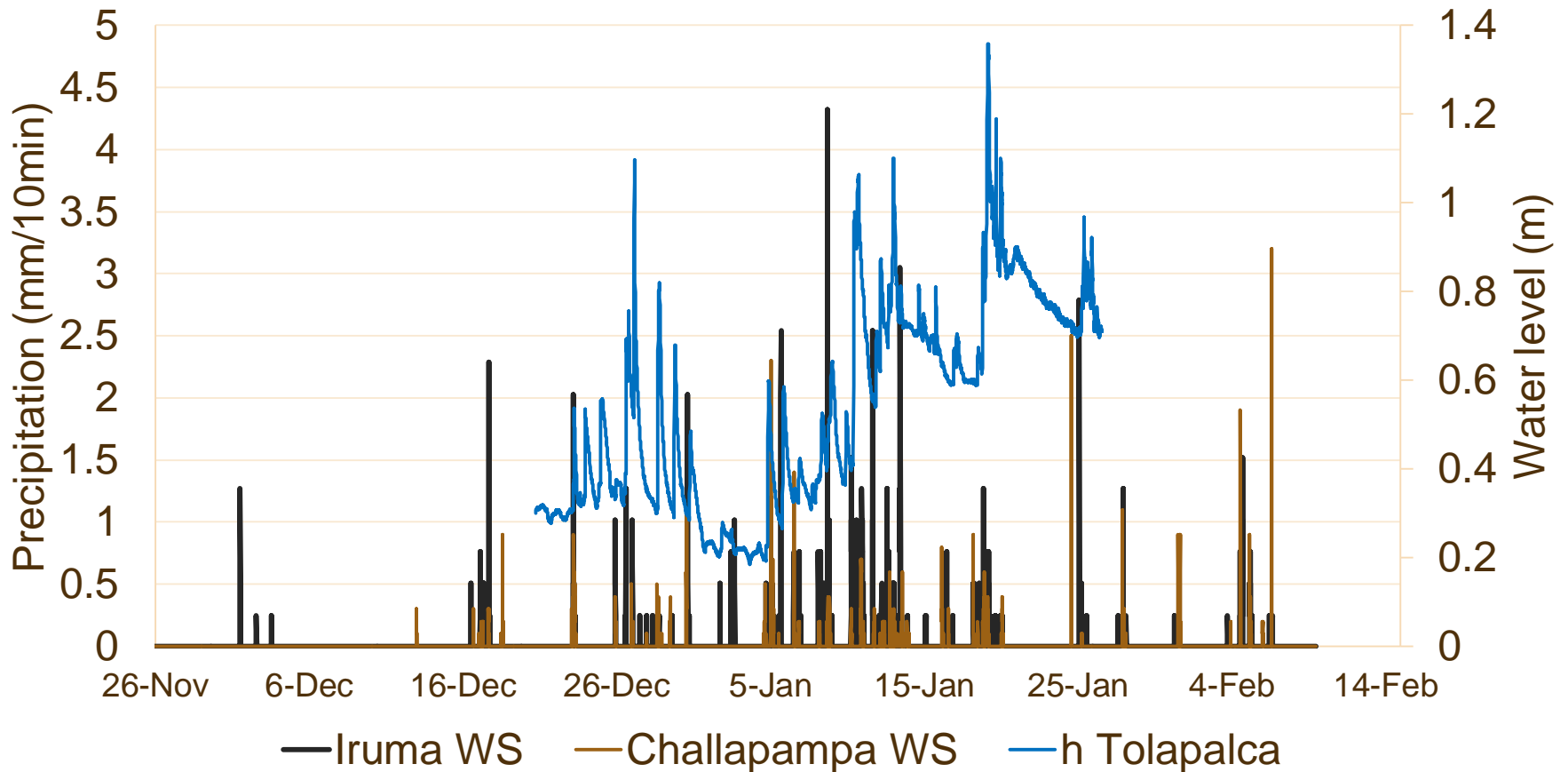
Curve number: 68-72 (infiltration test)

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Paria river basin area is 925 km<sup>2</sup>

Tolapalca (blue) is 336 km<sup>2</sup>

# Paria Basin rainfall vs. water level 2014-2015





# Antecedent hydrological conditions

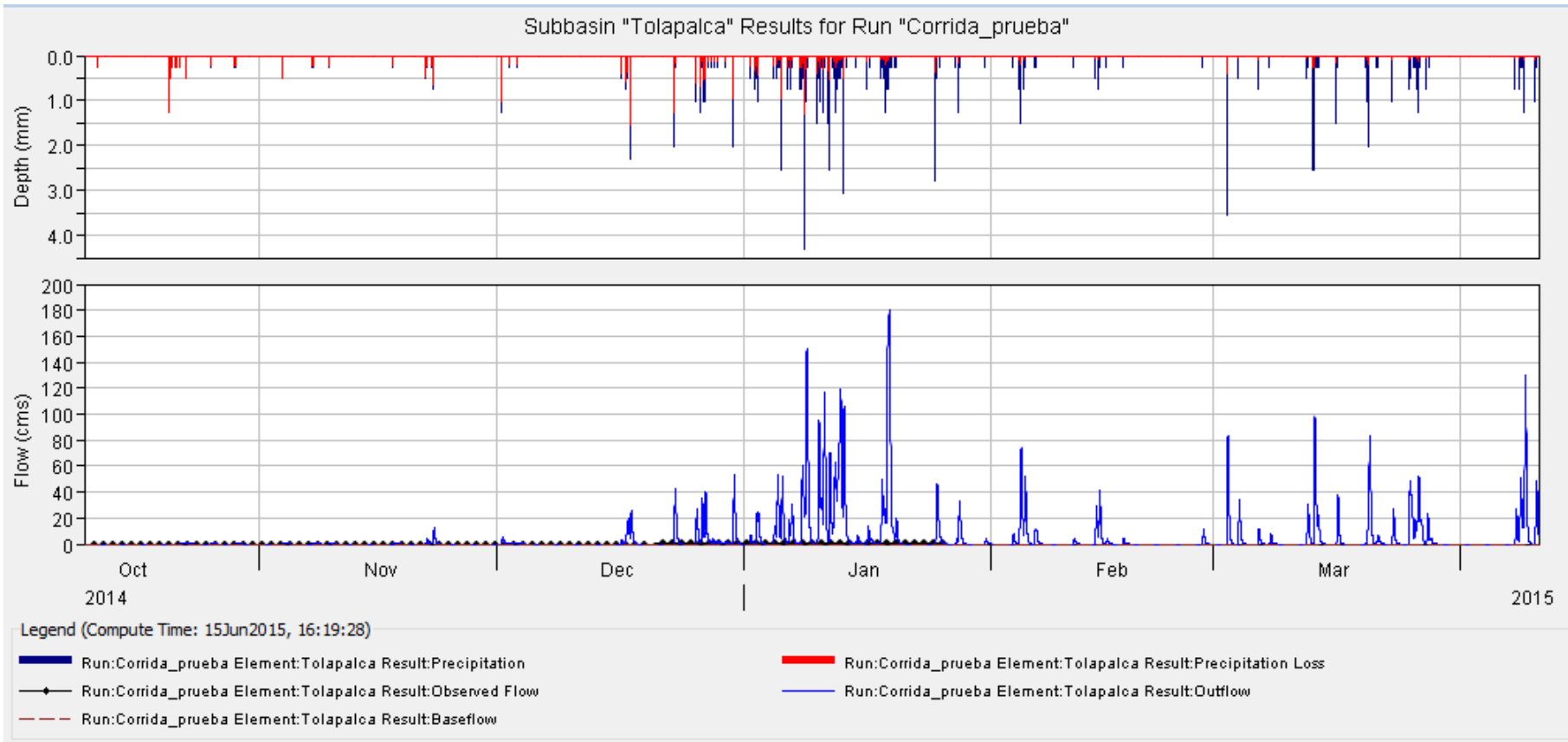
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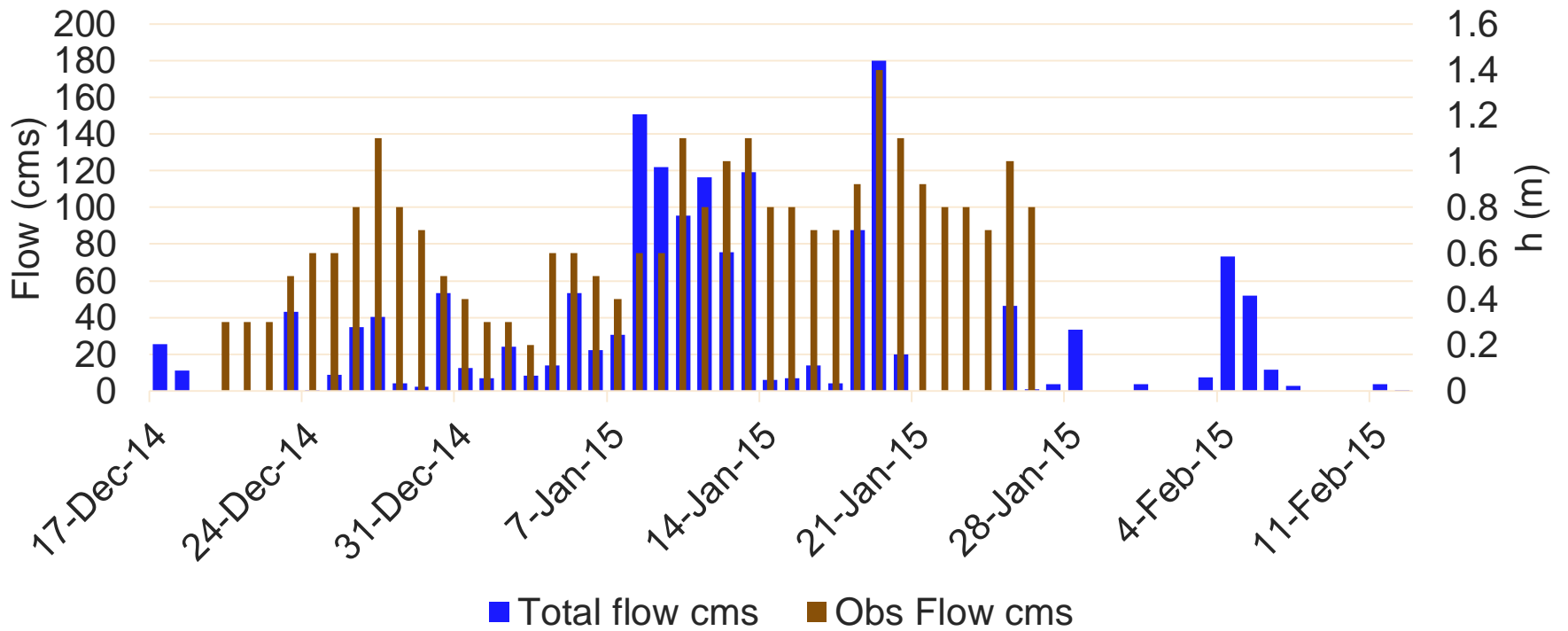
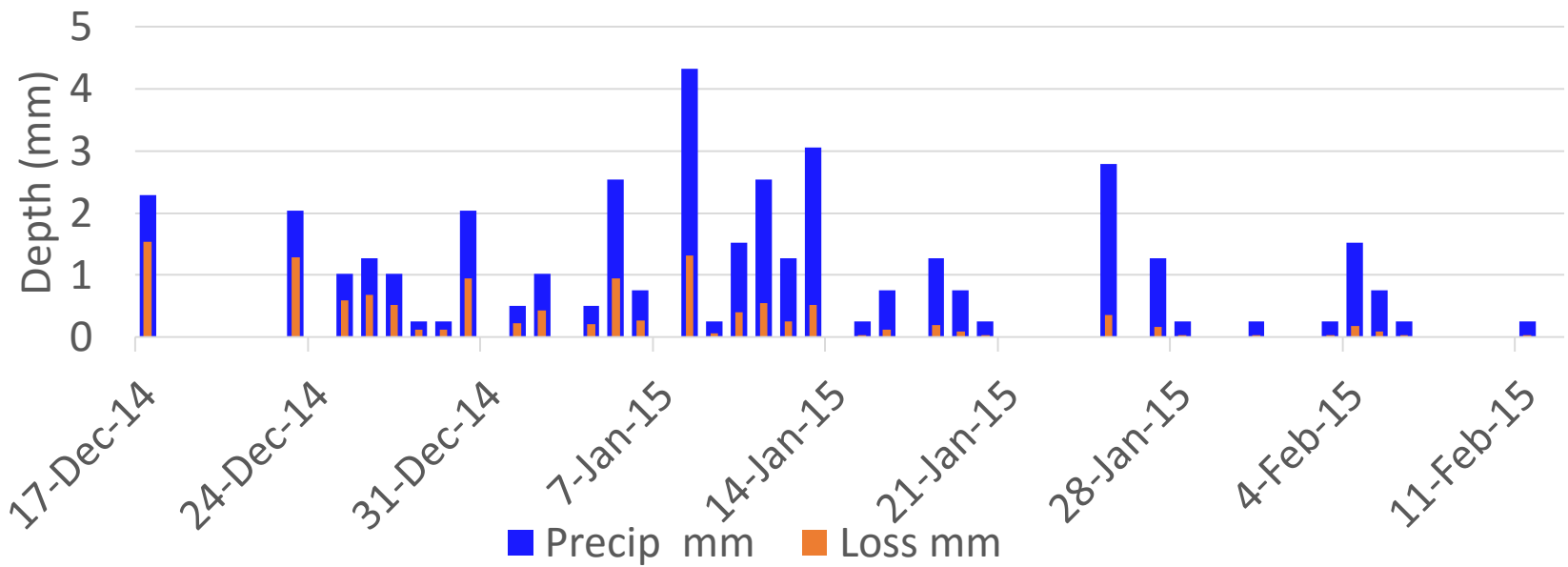
The latest event of continued precipitation before the maximum water levels has had a duration of 8 hours, at that time the accumulated precipitation was 19.5 mm in the mountainous region and 8.8 mm in the flat lands.

The soil shows saturated conditions due to earlier precipitations.



# HEC HMS model results







# Antecedent hydrological conditions

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- Explain and compare field work data with the hydrological model results, compering the peaks and the precipitation
- Explain about the highest peak
- The model fits to the highest peak, but it is note correlated very well with the fieldwork data collected



# Conclusion

1. Characterization of small basins in the central Altiplano has to be based on fieldwork in key representative basins. By use of prediction in ungauged basins (PUB) methods predictive areas can be extended.
2. The climate and topography of the Andes highlands create a particular environment, where the basin response of flash floods shows an abrupt increase of runoff that affects population and agriculture.
3. A hydrological model was used to characterize the flash floods over a small mountain basin, based on climatological and hydrological information from a small Altiplano river basin.

# Methodological steps

1. Elaborate runoff curve numbers of the river basin to compare with runoff based water level measurements.
2. Calibrate the model to simulate the basin response of flash floods.
3. Improve the ability to predict of flood events at times when flood characteristics are significantly influenced by antecedent hydrologic conditions.



Thank you very much

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Uyuni Salt Flat, Bolivia





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# Peak flow methodology

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- Water level to Q with Manning eq. (n obtained with streamflow measurements)
- Lag time = Time of concentration \* 0.6 ( $L=0.6 * t_c$ ) (Mockus 1957; Simas 1996)

- Kirpich eq. 
$$t_c = 0.0078 \left( \frac{L^{0.77}}{S^{0.385}} \right)$$

L = Length of overland flow (ft, m), S = Average catchment slope (ft/ft, m/m)

- CN Curve Number, with Martin fieldwork data.

