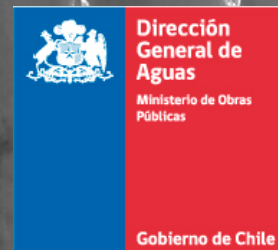
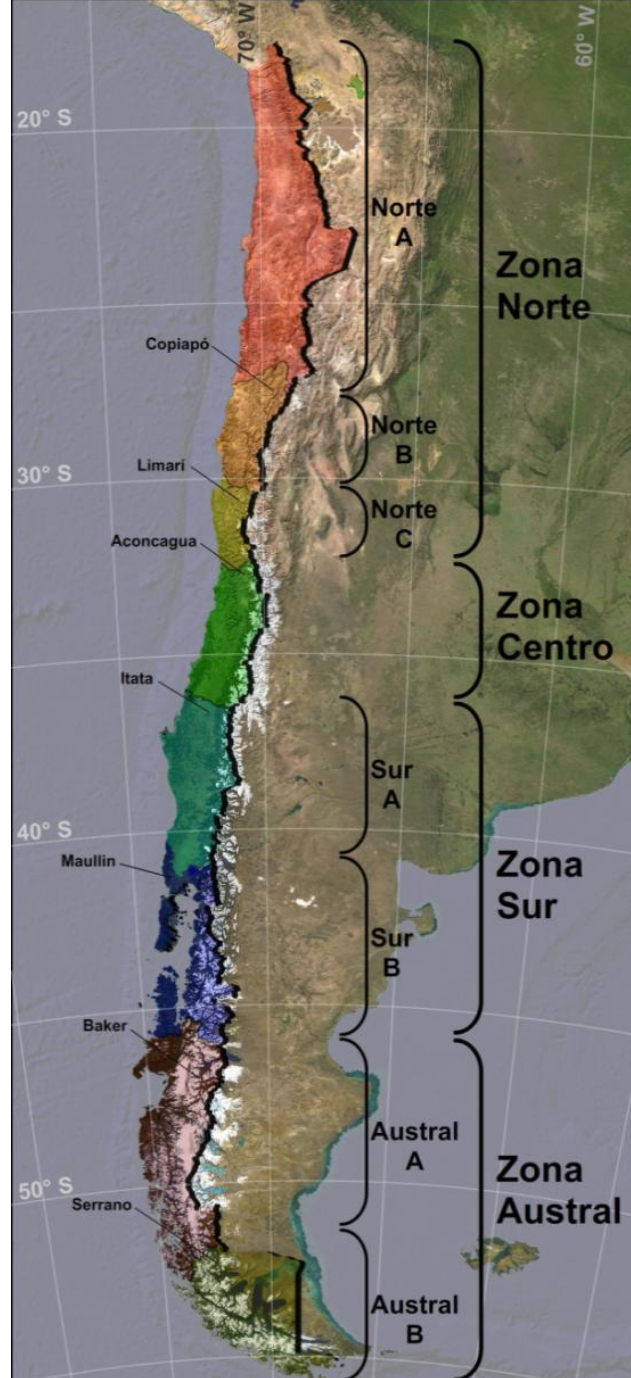


Glaciers (and snow) in the Atacama Desert

Shelley MacDonell





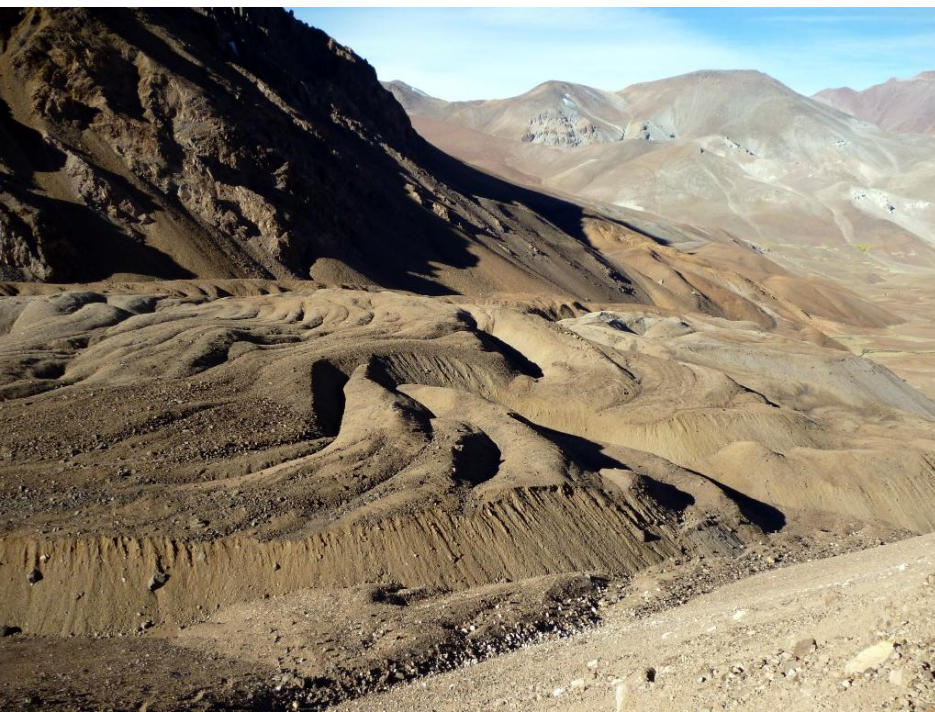
CECS-DGA: National Glacier Strategy



Driving research questions:

What is the contribution of the cryosphere to the catchment?

How might this change in future?



- Dry: ~ 200 mm/y



- Dry: ~200 mm/y
- Episodic precipitation events
- 90 % of precipitation: May - August



- Dry: ~ 200 mm/y
- Episodic precipitation events
- 90 % of precipitation: May - August
- The snow cover disappears during the spring - summer period



August 10

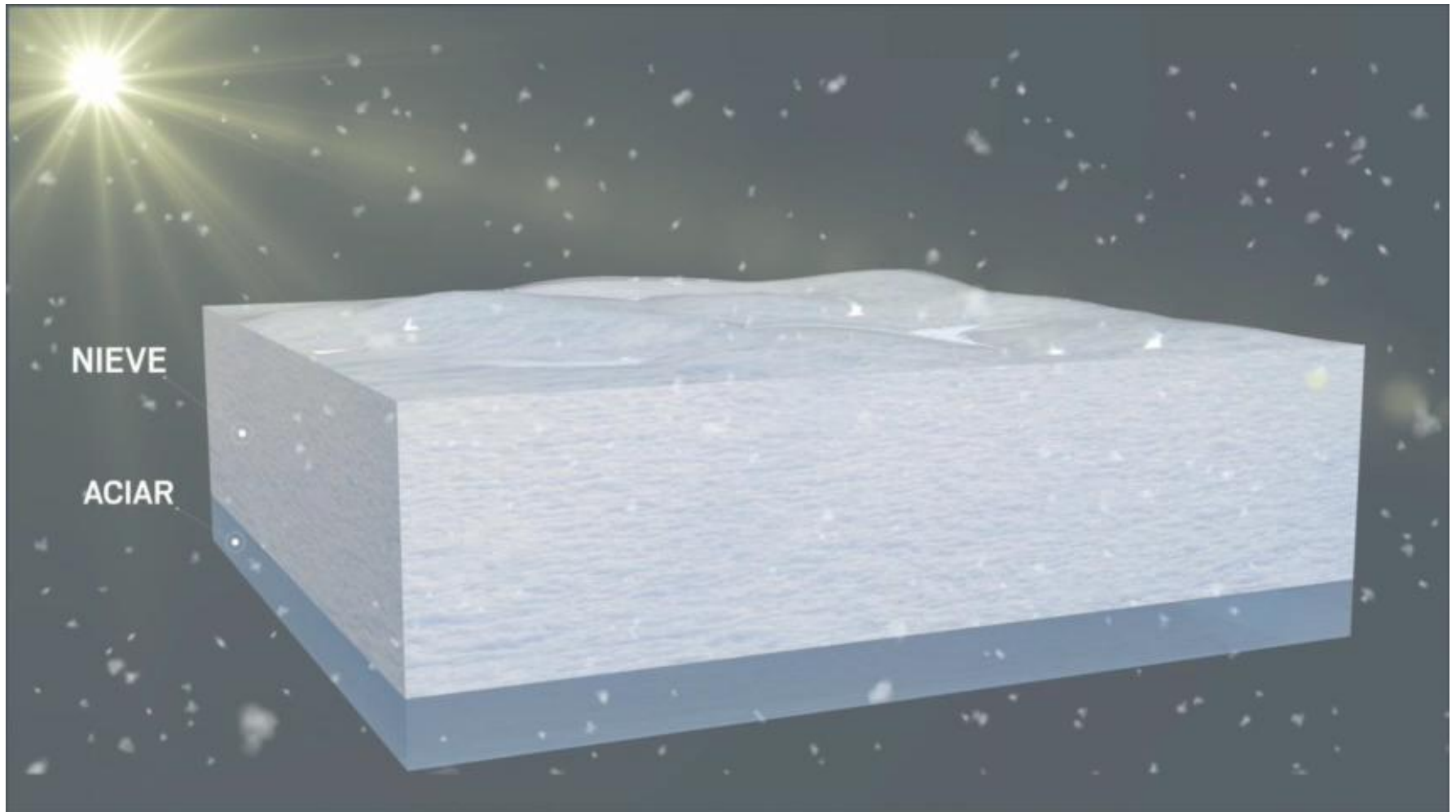


October 13



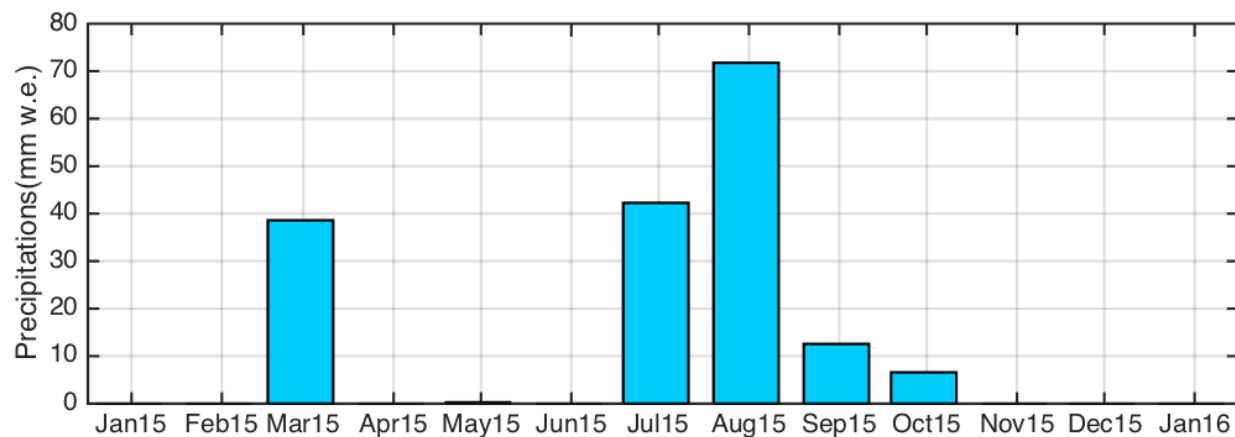
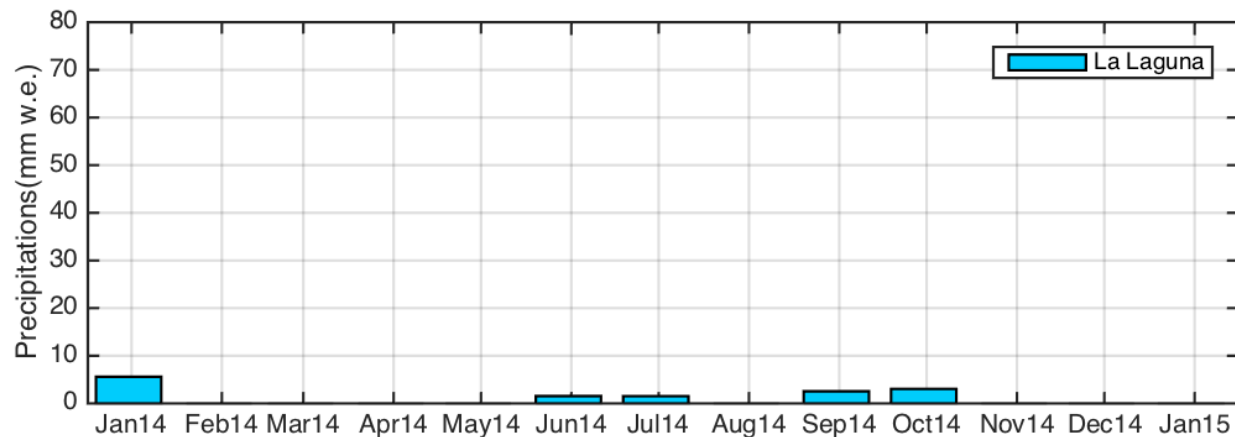
December 16

- Sublimation is the dominant ablation process on glaciers
- Snow depth can disappear during winter only due to sublimation.



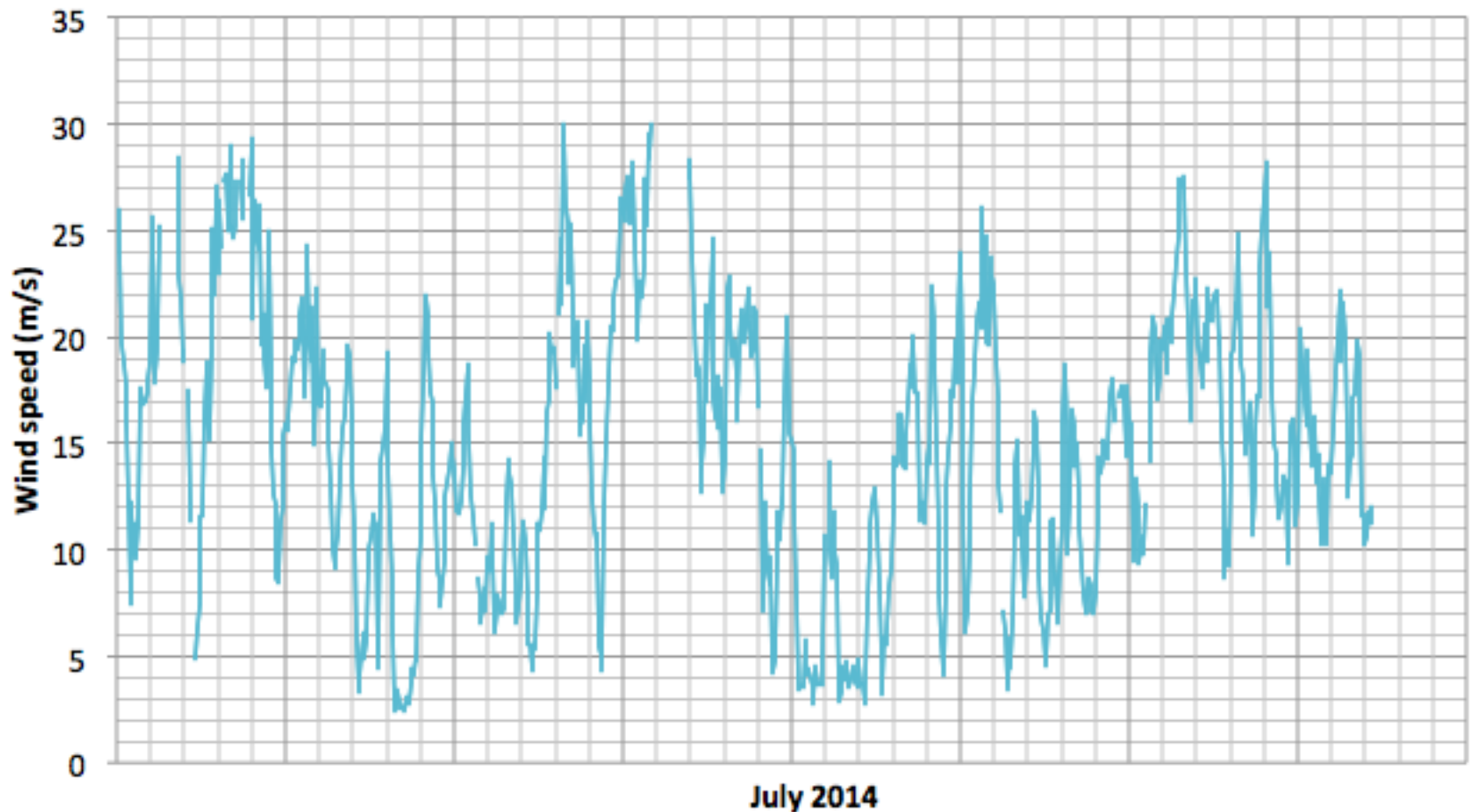


- Precipitation:
 - Temporal variability: dry and wet years (ENSO events)



- Wind:
 - Strong wind speed
 - Importance of sublimation of blowing snow

Paso Agua Negra - 4774m





Snow processes

How is precipitation distributed across the catchment?

What is the sublimation to melt ratio?

What is the hydrological contribution?

Can we reduce the sublimation rate?

Marion Réveillet, Simon Gascoin, Christophe Kinnard, Stef Lhermitte,
Nicole Schaffer, Annelies Voordendag, Álvaro Ayala

Puclaro Dam



La Laguna Dam



Tapado Glacier



ARID ANDES

La Serena

SANTIAGO

PATAGONIAN ANDES



La Laguna
3100 - 5800 m

Paso Agua Negra

SnowModel (Liston and Elder 2006)



marion.reveillet@ceaza.cl

Met.
Forcing

AWS network

MicroMet

Creates distributed
atmospheric fields based on
spatial interpolations

SnowTran-3D

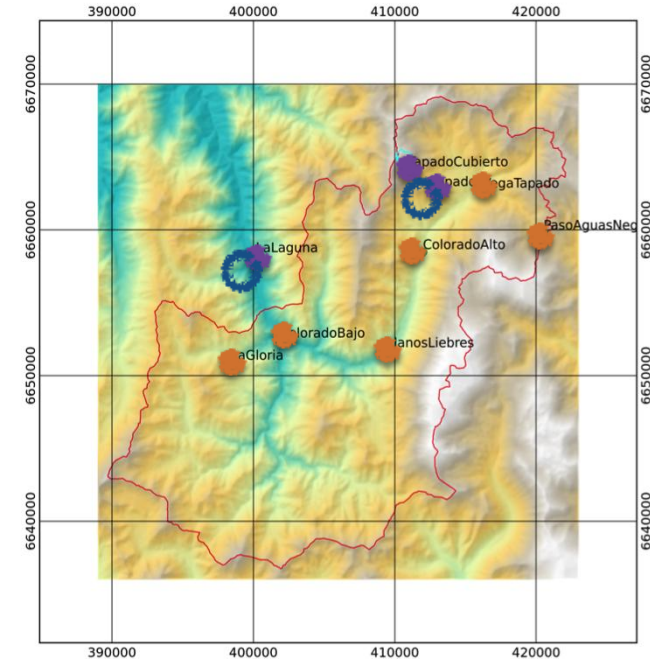
3D model that simulates
snow depth evolution
(deposition and erosion)

EnBal

Performs standard surface
energy balance calculations

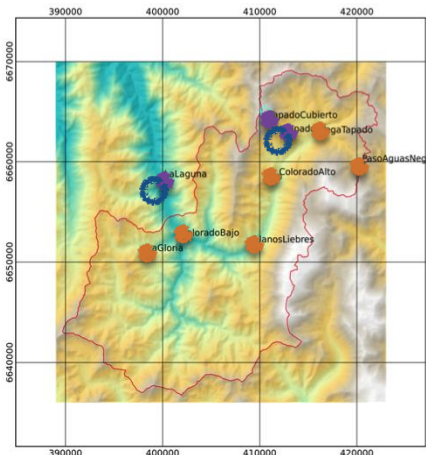
SnowPack

Describes snowpack
changes in response to
precipitation and melt fluxes
defined by MicroMet and
EnBal

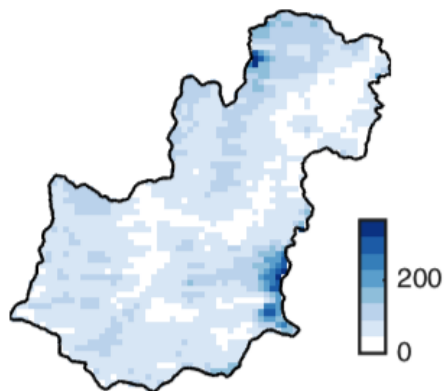


WRF output (3 km)

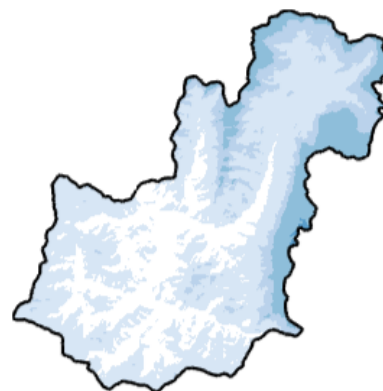
Snow depth
evolution



a - MODIS obs. 2014



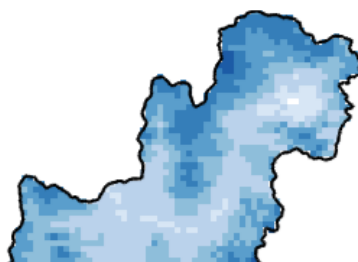
b - AWS sim. 2014



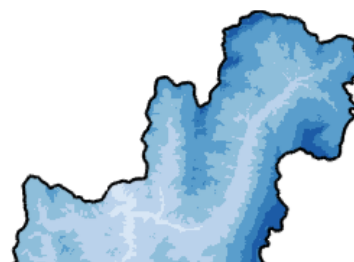
c - WRF sim. 2014



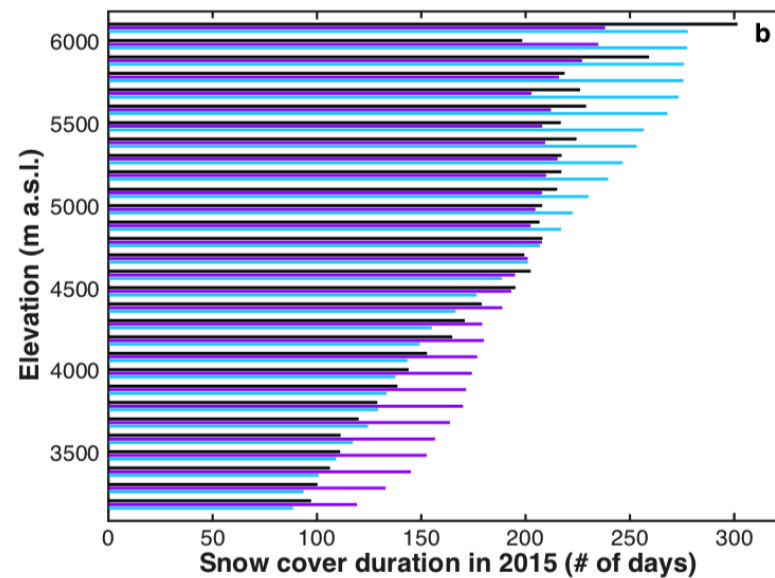
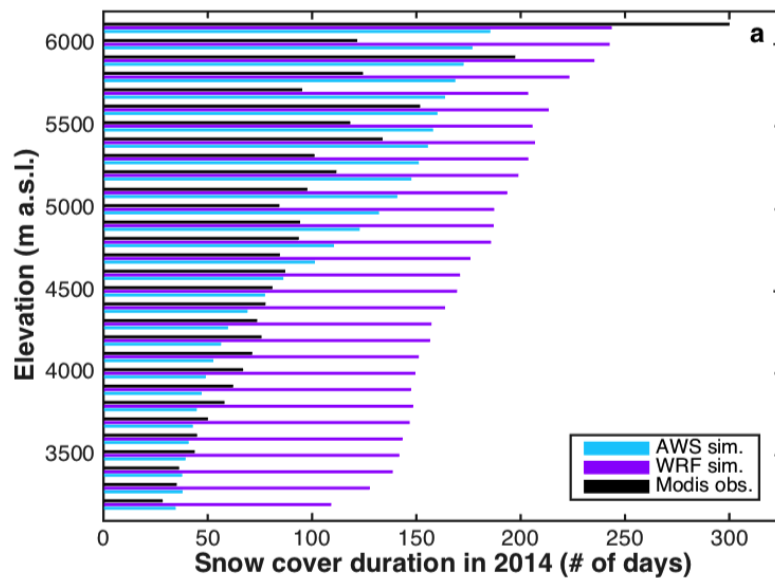
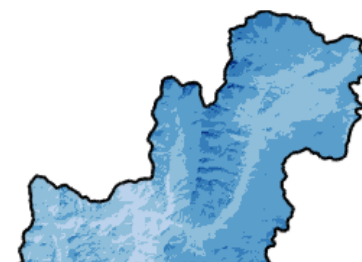
d - MODIS obs. 2015



e - AWS sim. 2015



f - WRF sim. 2015

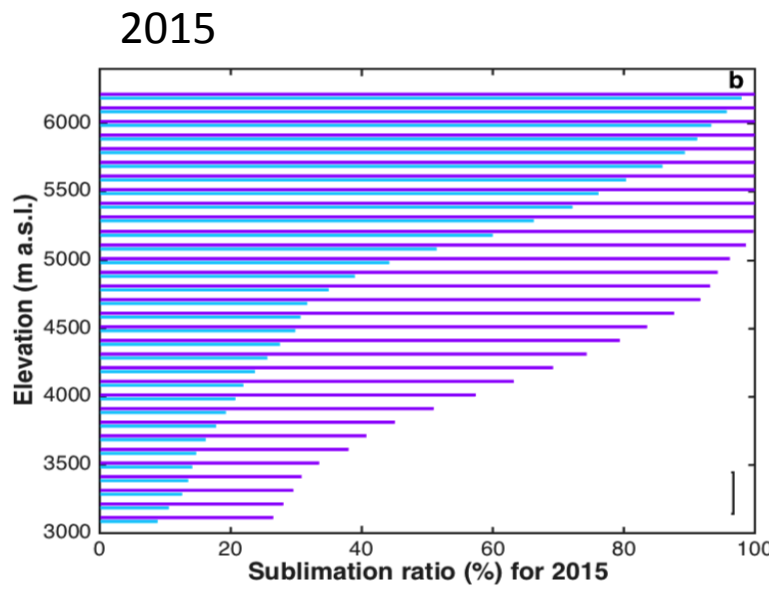
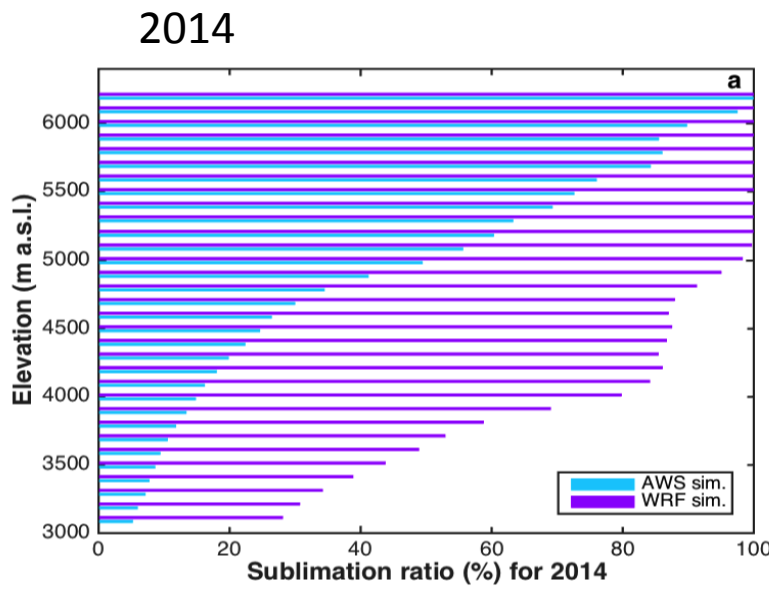


Rates per elevation band:

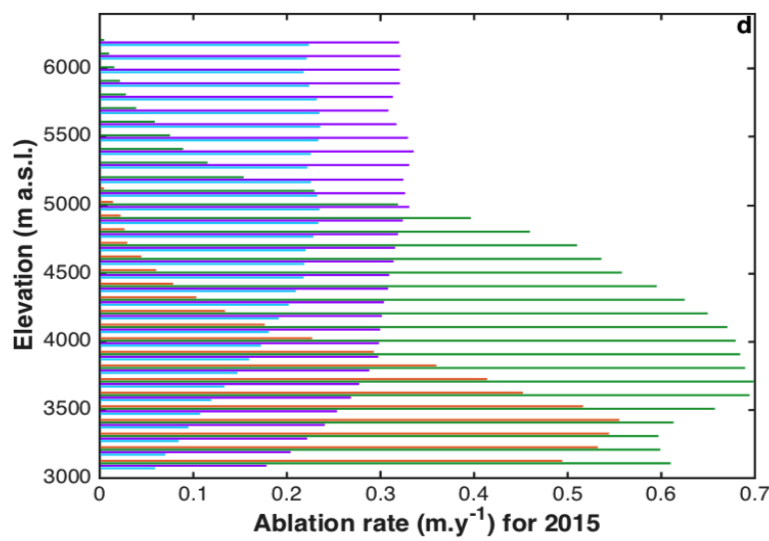
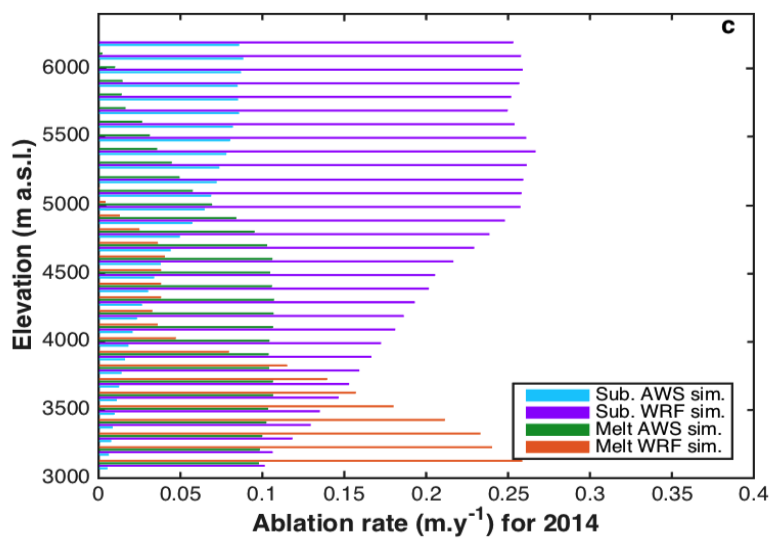
Overall sublimation %:

	AWS	WRF
2014:	39	81
2015:	31	86

Sublimation
(%)



Ablation
rate



Next steps:

- Improve WRF quality (help welcome)
- Extend timespan
- Hydrological importance and connection to glaciers



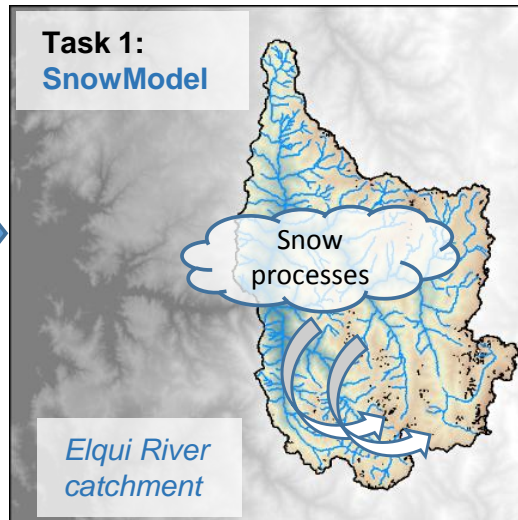
SWE maps (Cortés and Margulis, 2017; Cornwell et al., 2016; Marti et al., 2017)

Geodetic mass balances



Input data:
Meteo data
WRF outputs

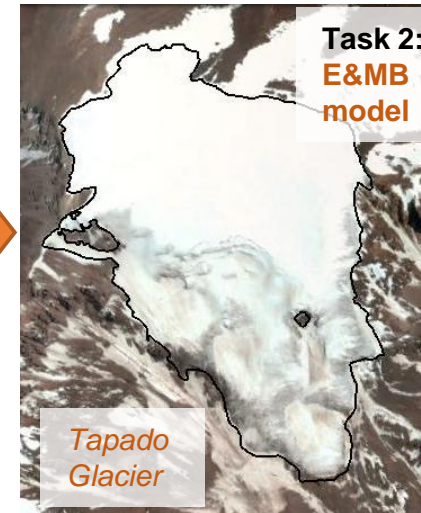
Forcing
inputs
Snow
Model



Input data:
Snow accumulation over
glacierized areas (from
SnowModel)

Forcing
inputs
E&MB
model

Additional input data:
Lidar DEMs
Manual mass balances



G1: Identify the controls on the formation, evolution and runoff contribution of the snowpack at key sites in the Elqui River catchment

G2: Identify the controls on the glacier mass balance and runoff generation of Tapado Glacier

Comparison



Glacier processes

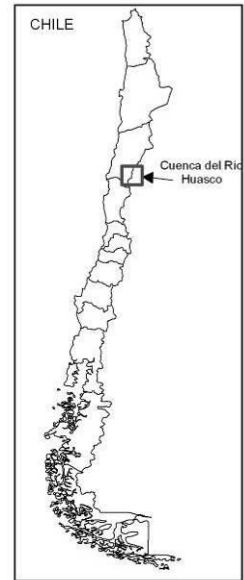
What is the sublimation to melt ratio?

What is the role of penitentes in the energy and mass balance?

What is the hydrological contribution?

Álvaro Ayala, James McPhee, Francesca Pellicciotti, Marion Réveillet,
Christophe Kinnard

Glacier mass and energy balance modelling

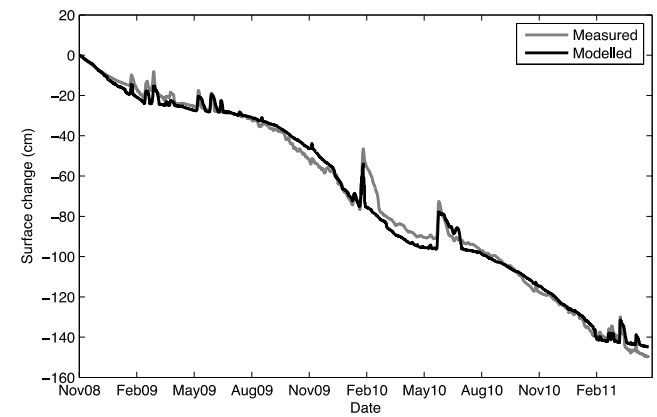
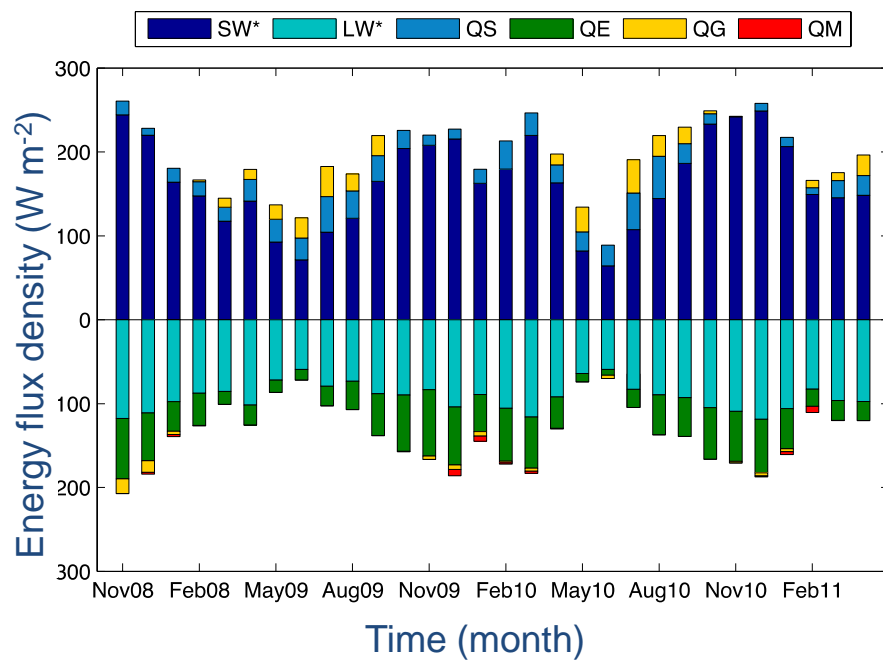


What is the effect of penitentes on the turbulent heat fluxes?

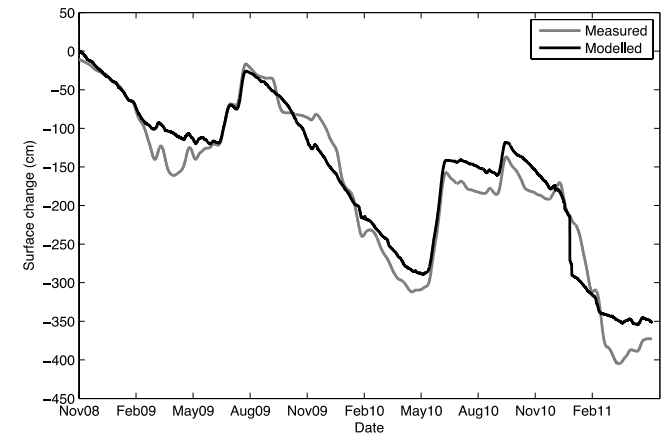
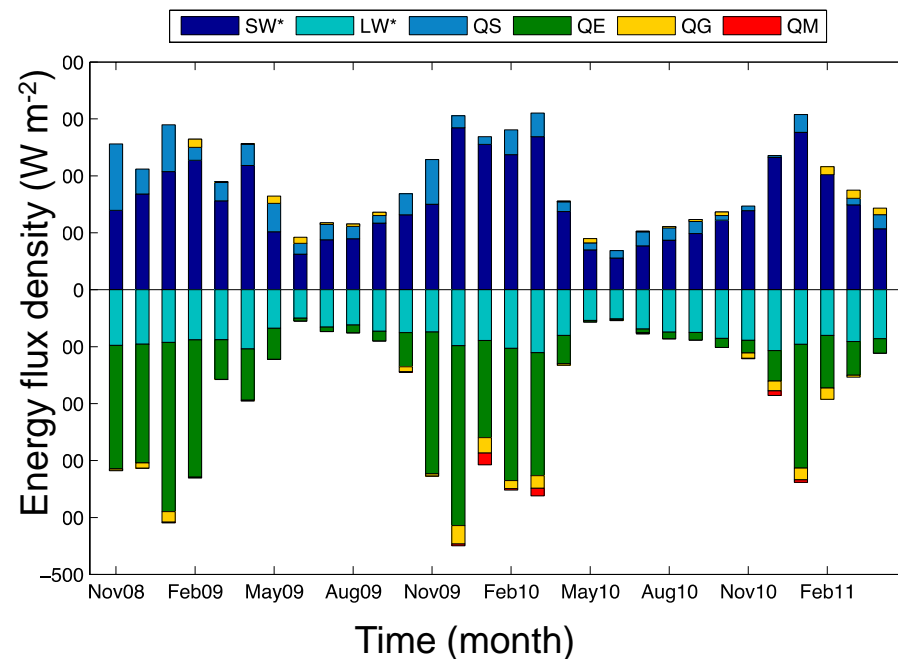
Eddy covariance measurements

What is the difference in ablation rate and fraction between sites?

Energy/mass balance modelling



Surface change (mea) = -1500 mm
 (mod) = -1450 mm
 RMSE = 4.1 mm
 MacDonell et al. (2013)



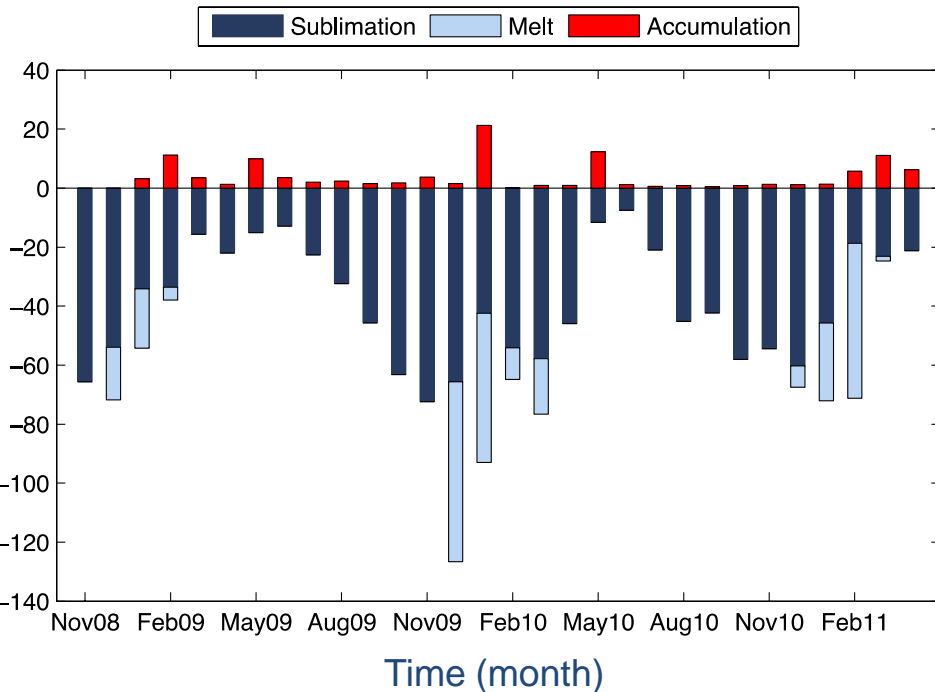
Surface change (mea) = - 3728 mm
 (mod) = - 3511 mm
 RMSE = 25.9 mm

Guanaco

Toro 1

Mass balance results

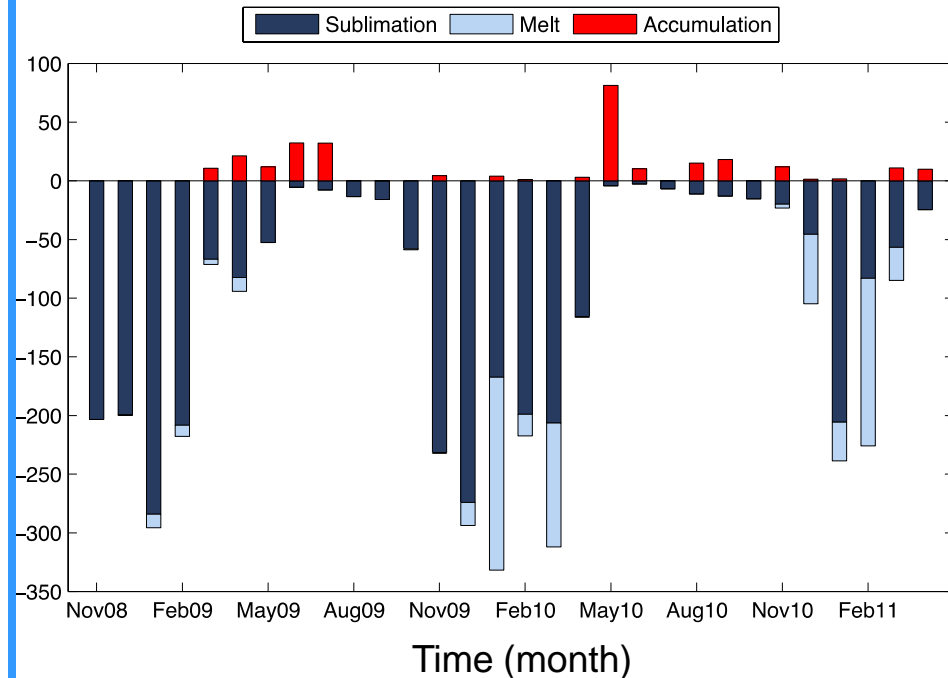
Guanaco



Total melt = 271 mm w.e.
Total sublimation = 1164 mm w.e.
Melt % of total ablation = 19%

MacDonell et al. (2013)

Toro 1



Total melt = 613 mm w.e.
Total sublimation = 2882 mm w.e.
Melt % of total ablation = 18%

In subsequent studies:

- Chemistry to analyse whether permanent features + sublimation rate
- Kinect to analyse ablation spatially (and validate ablation frames)

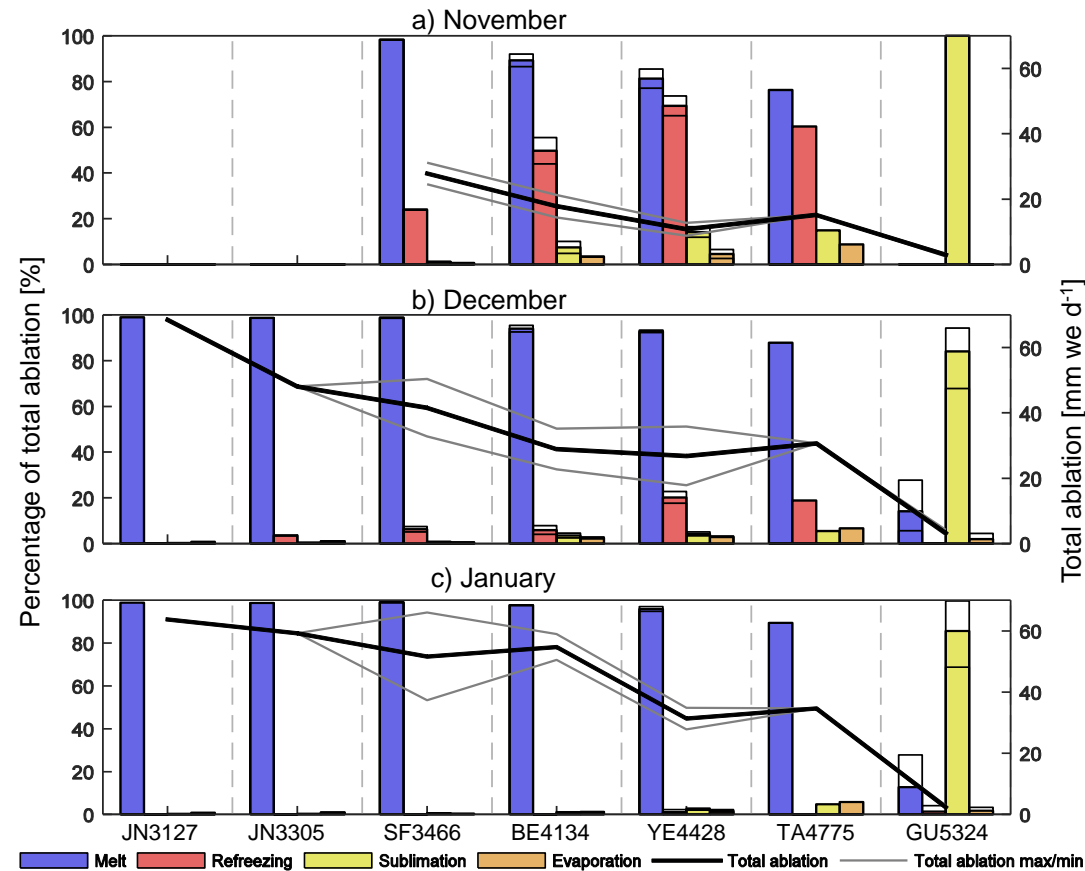
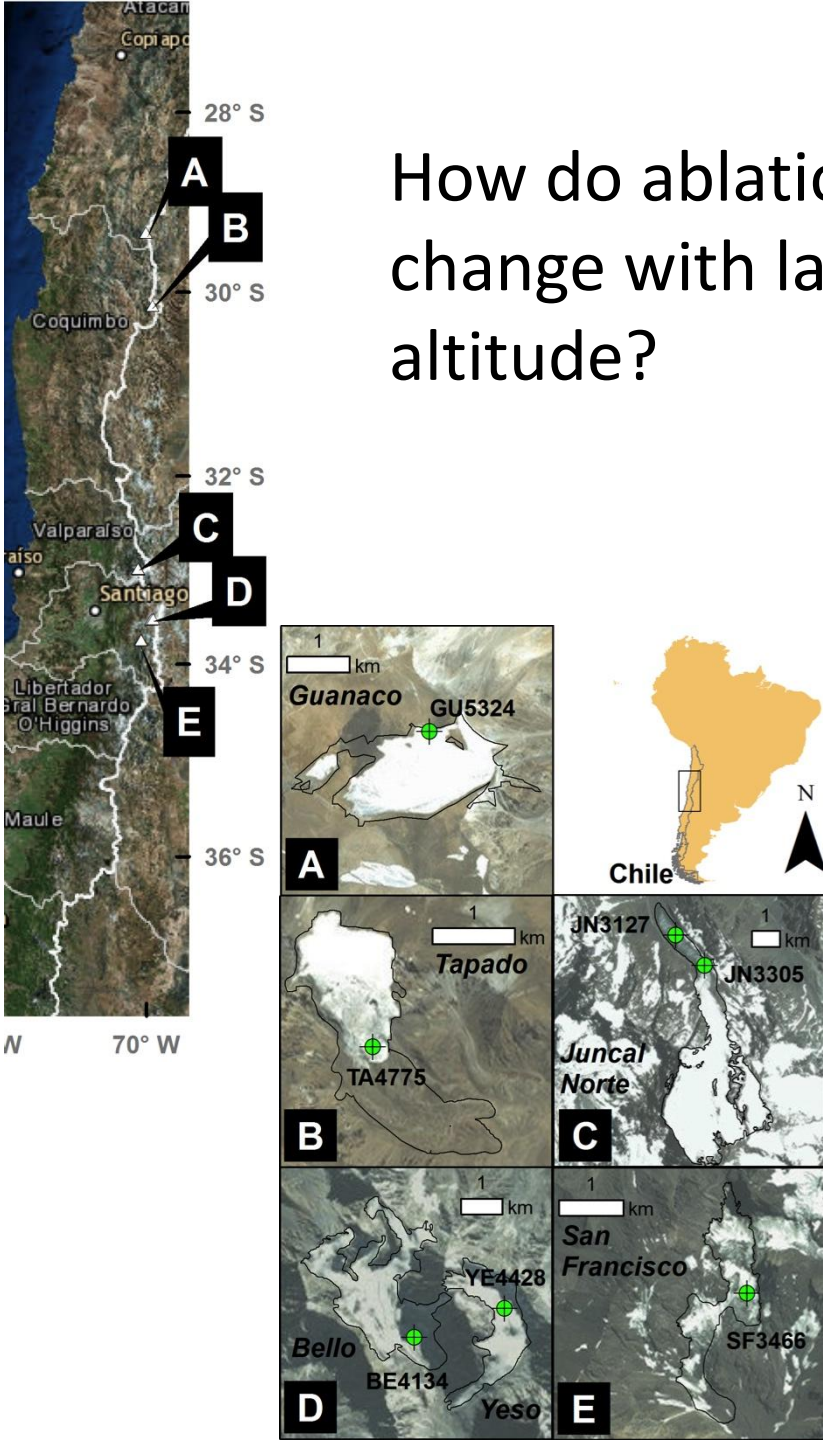
And now:

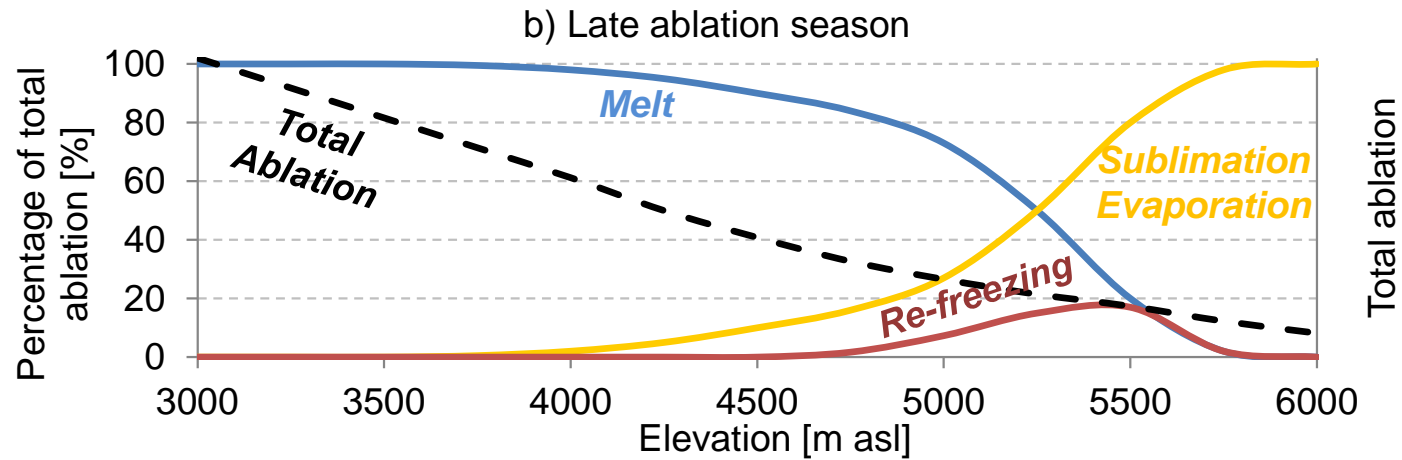
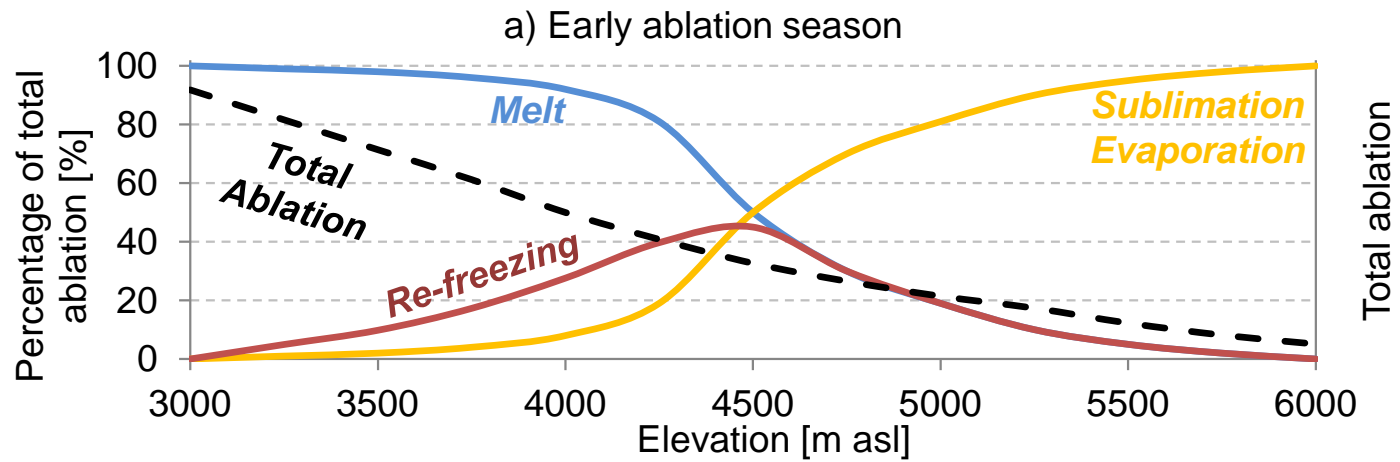
What is the accumulation
in a penitente field?





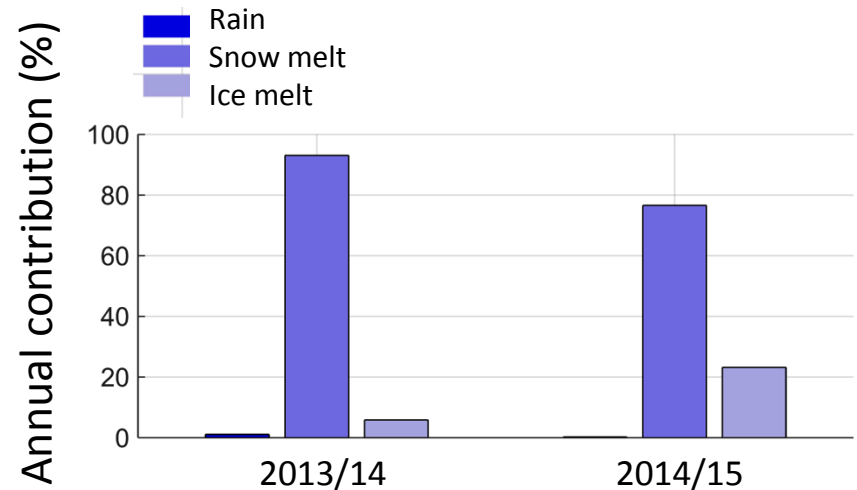
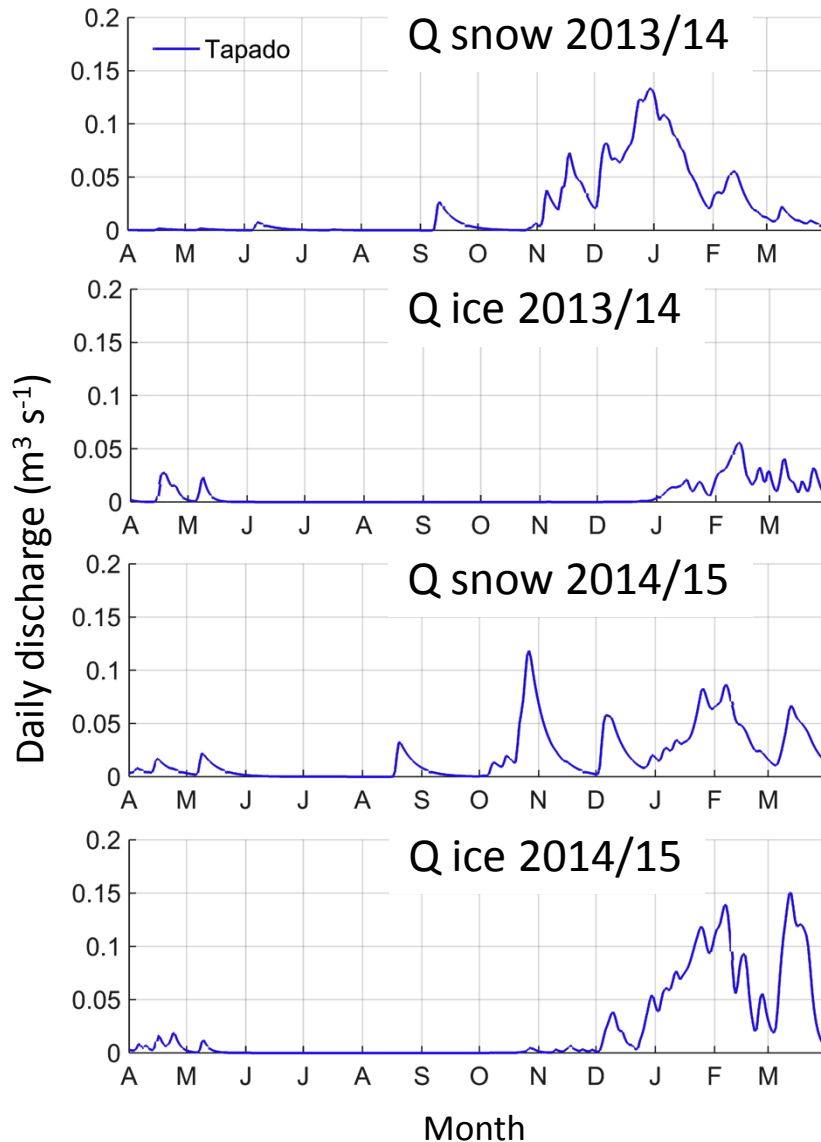
How do ablation processes change with latitude and altitude?





Tapado catchment – Hydrological Implications

Daily discharge totals





Rock glacier processes

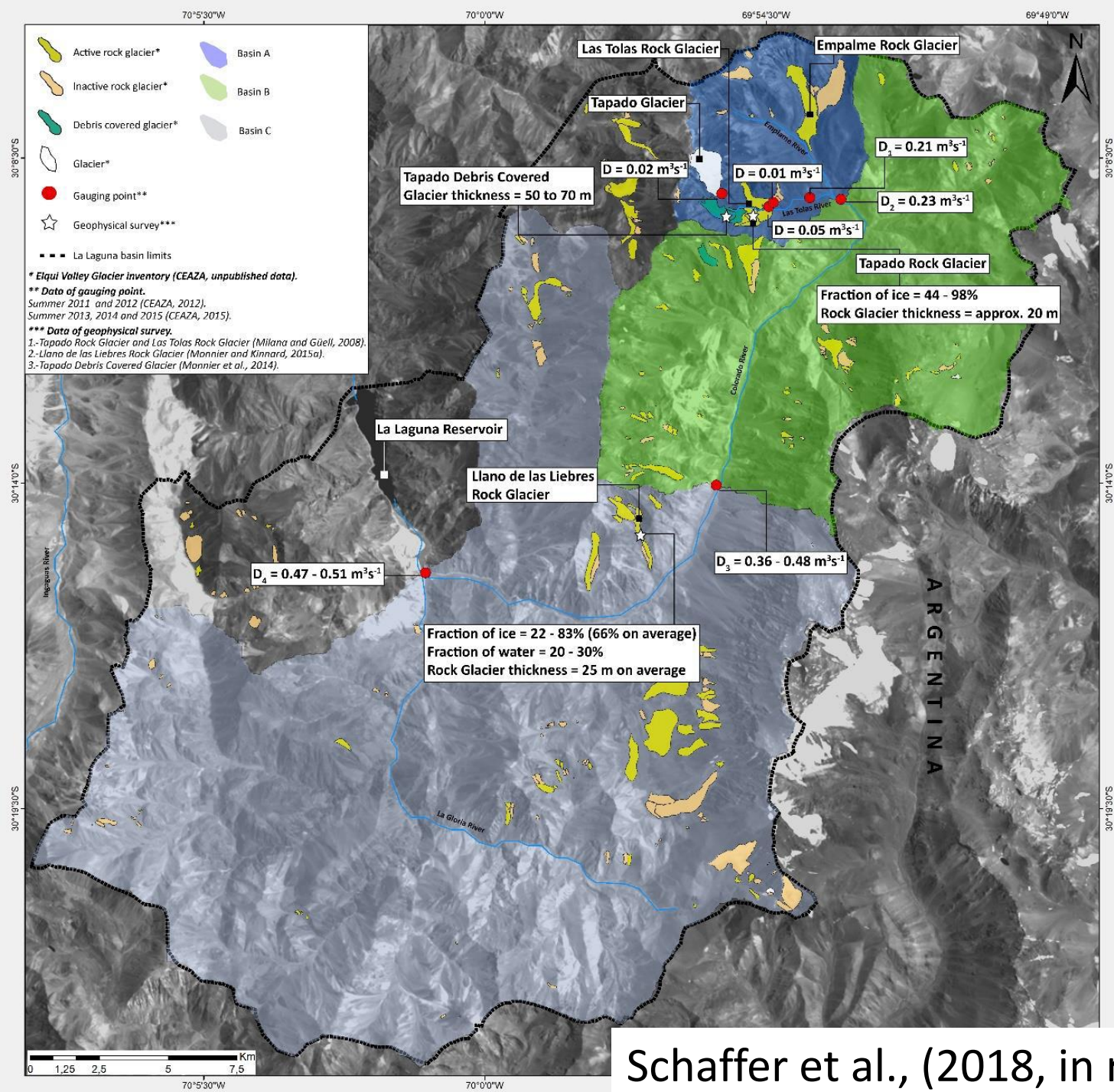
What is the distribution of active and inactive rock glaciers?

How have they changed through time?

What is the amount of ice stored?

What is their hydrological role?

Nicole Schaffer, Francesca Pellicciotti, James McPhee, Ben Robson, Camilo Guzmán, Eduardo Yáñez, Iván Fuentes, Benjamín Castro



Schaffer et al., (2018, in review)

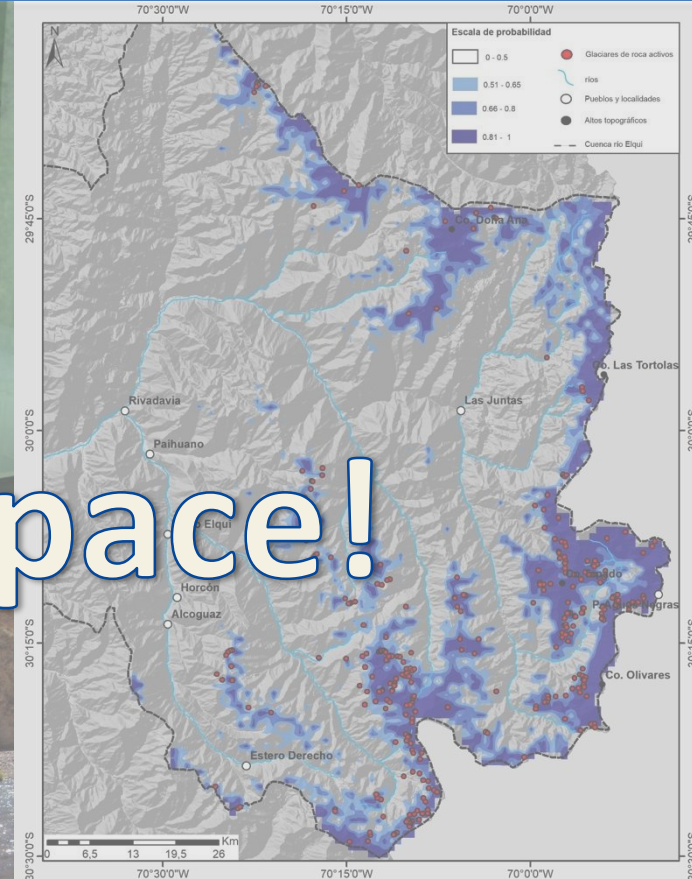


Rock glacier field programme re-started 2018:

- How much ice?
 - Is there a difference between different rock glacier types (or expressions)?
- Where is it?
 - Has it been changing? And in response to what?



Watch this space!



- + Geophysics
- + Geodetic mass balance
- + Hydro-glacio modelling

Points for discussion

- Should we explicitly include rock glaciers in catchment models? How?
- Do we need to treat active and inactive rock glaciers differently?
- Does a rock glacier lose mass, or just channel water generated at the surface?
- How should we consider contributions to / interactions with groundwater?
- What's happening on the other side of the border?