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FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS
UNIVERSIDAD DE CHILE

# Relative influence of wind and avalanche redistribution at the mountain range scale in the South American Andes

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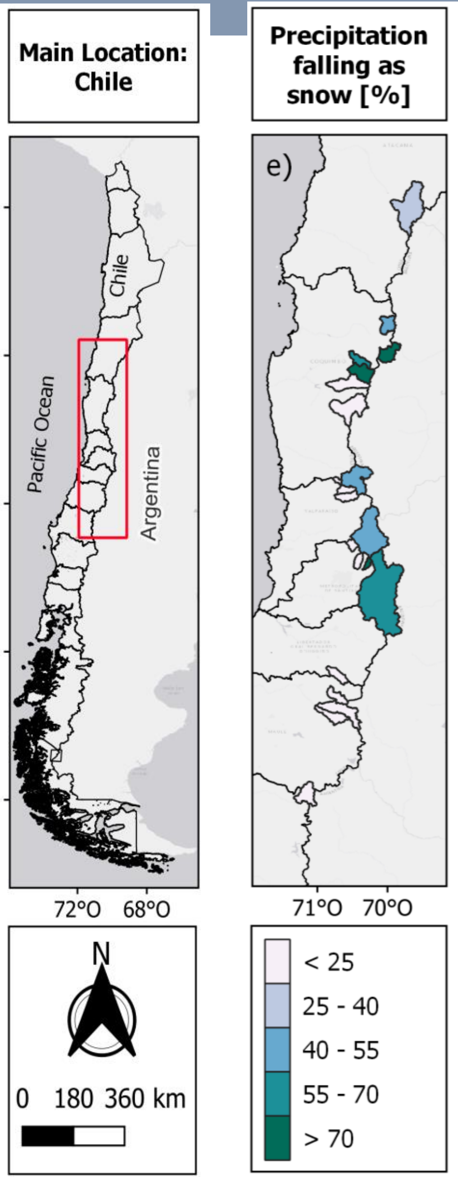
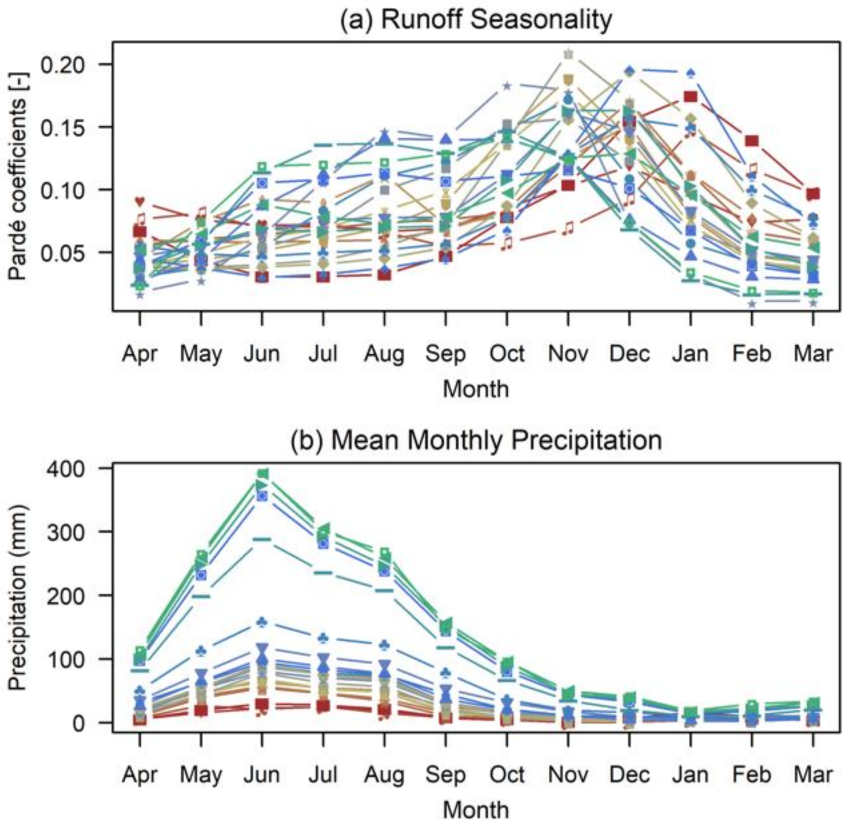
James McPhee

# Chile is a mountain country where snow accumulation plays a critical hydrological role.

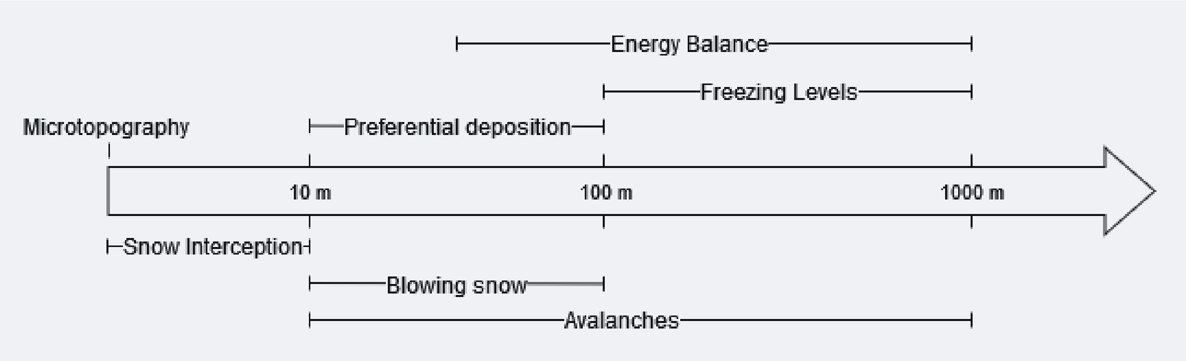
**Recent efforts at retrospective modeling and reanalysis provide many insights, but no operational SWE estimates exist for the region.**

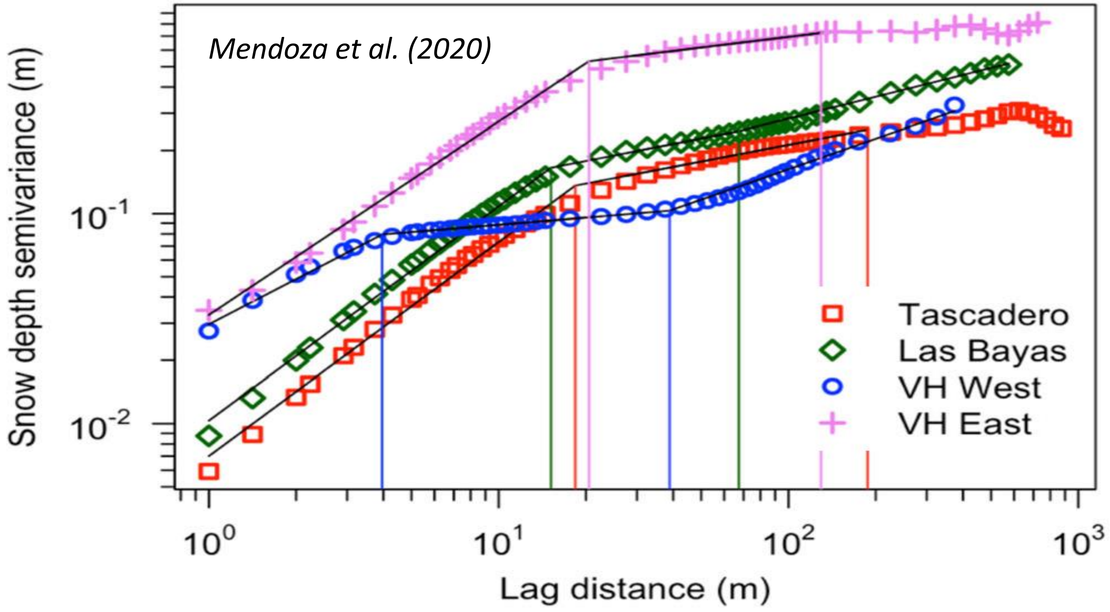


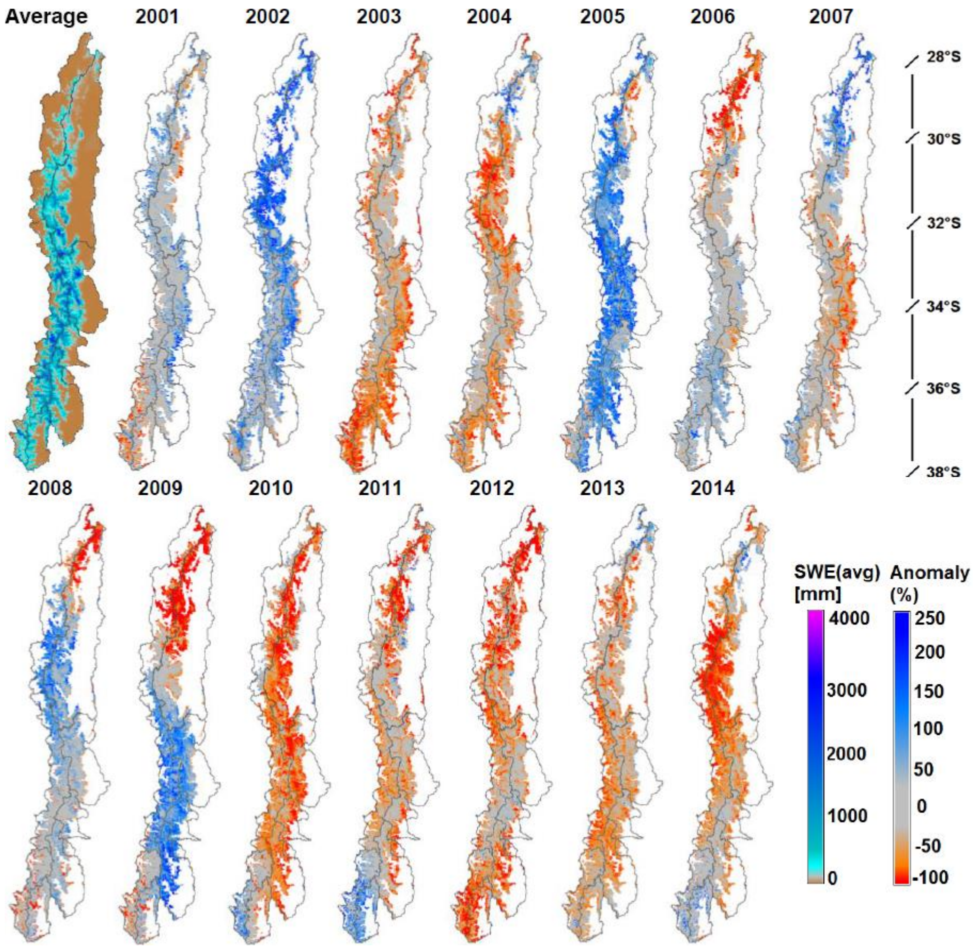




Araya et al. (2024)

# We aim to characterize and represent snow spatial variability relevant for hydrological applications



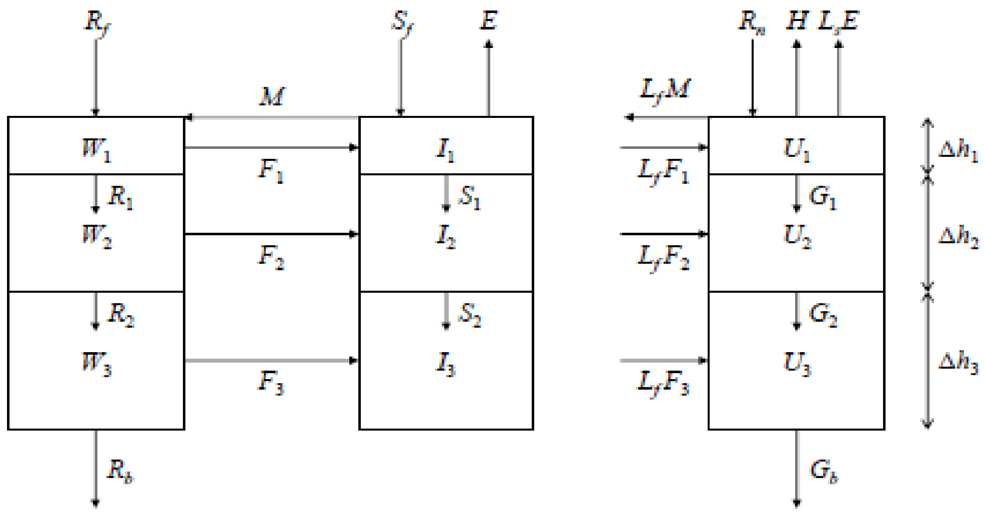




*Cornwell et al. (2016)*

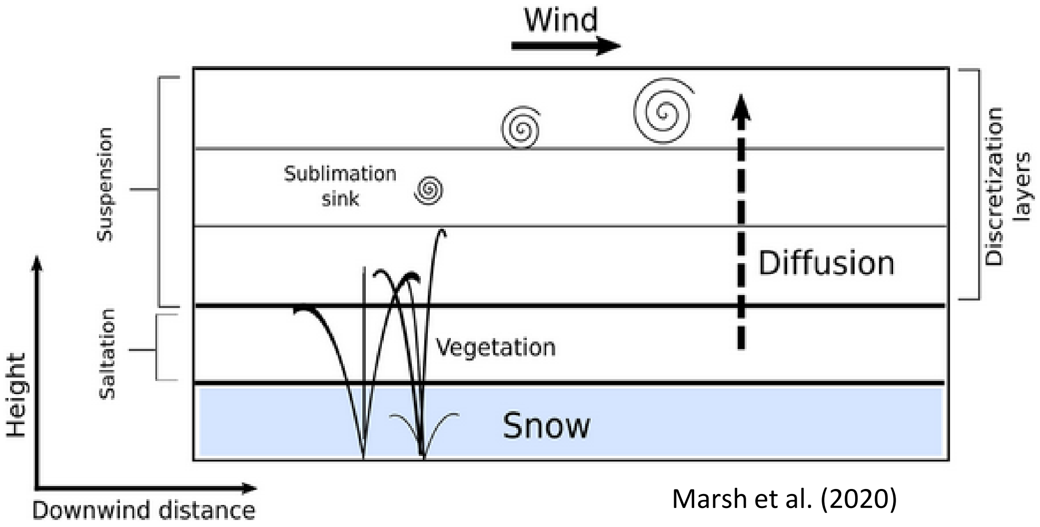
# Snowpack modelling with CHM

**Canadian Hydrological Model (CHM; Marsh et al., 2020):**

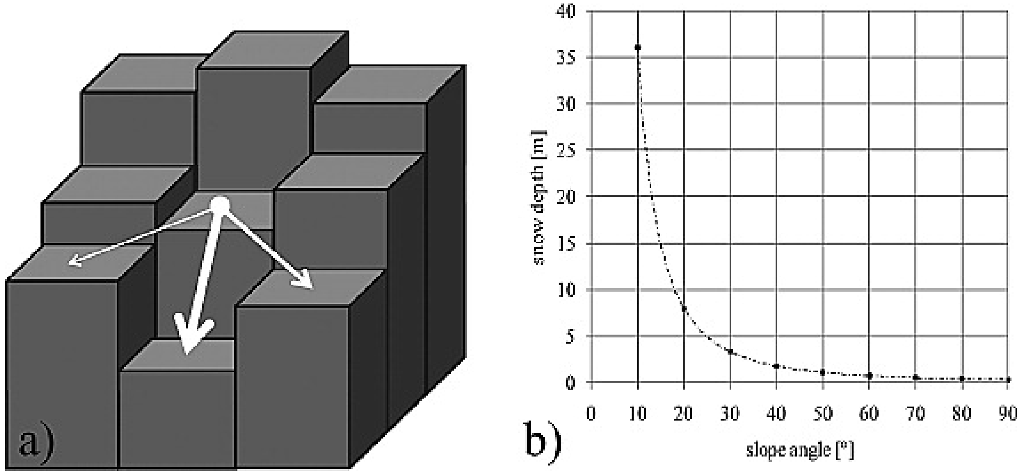
- <u>Cold regions</u>: snow processes
- <u>Modular</u>: activate/deactivate processes
- <u>Spatially distributed</u>: unstructured triangular meshes
- Designed for high-performance computing




Essery (2015)

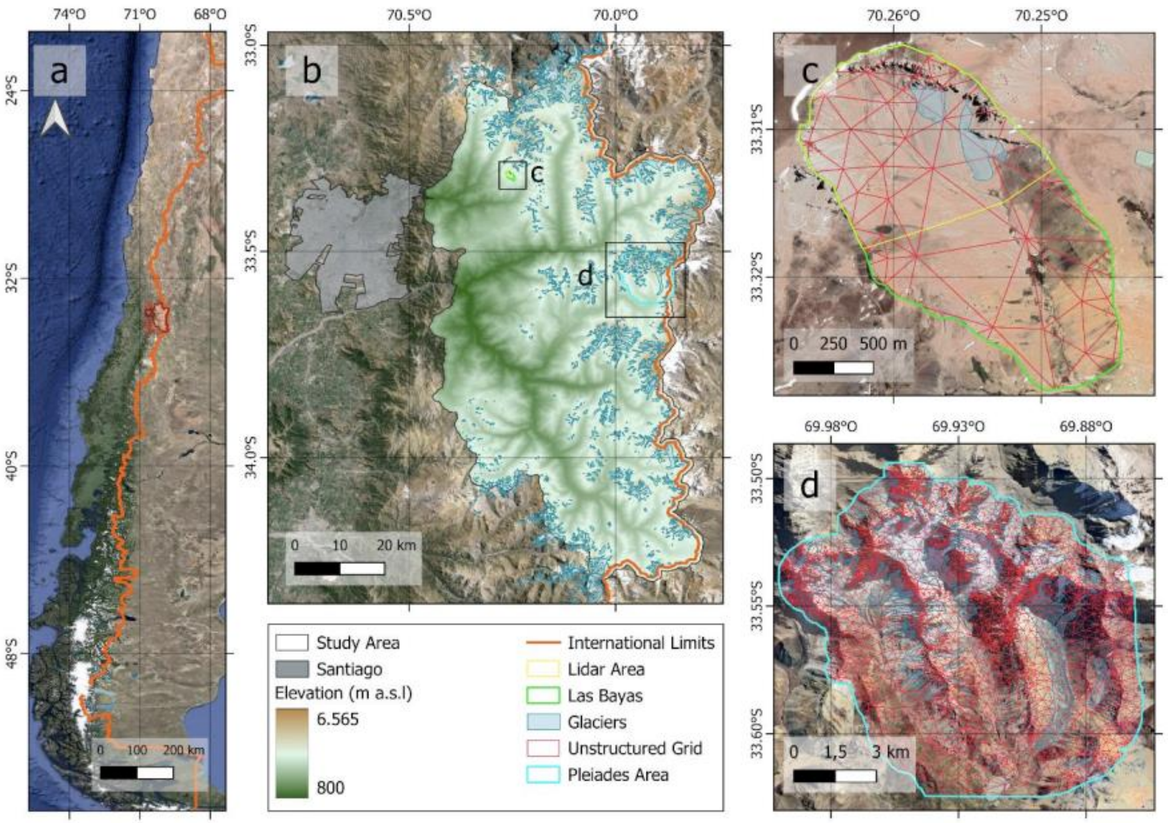


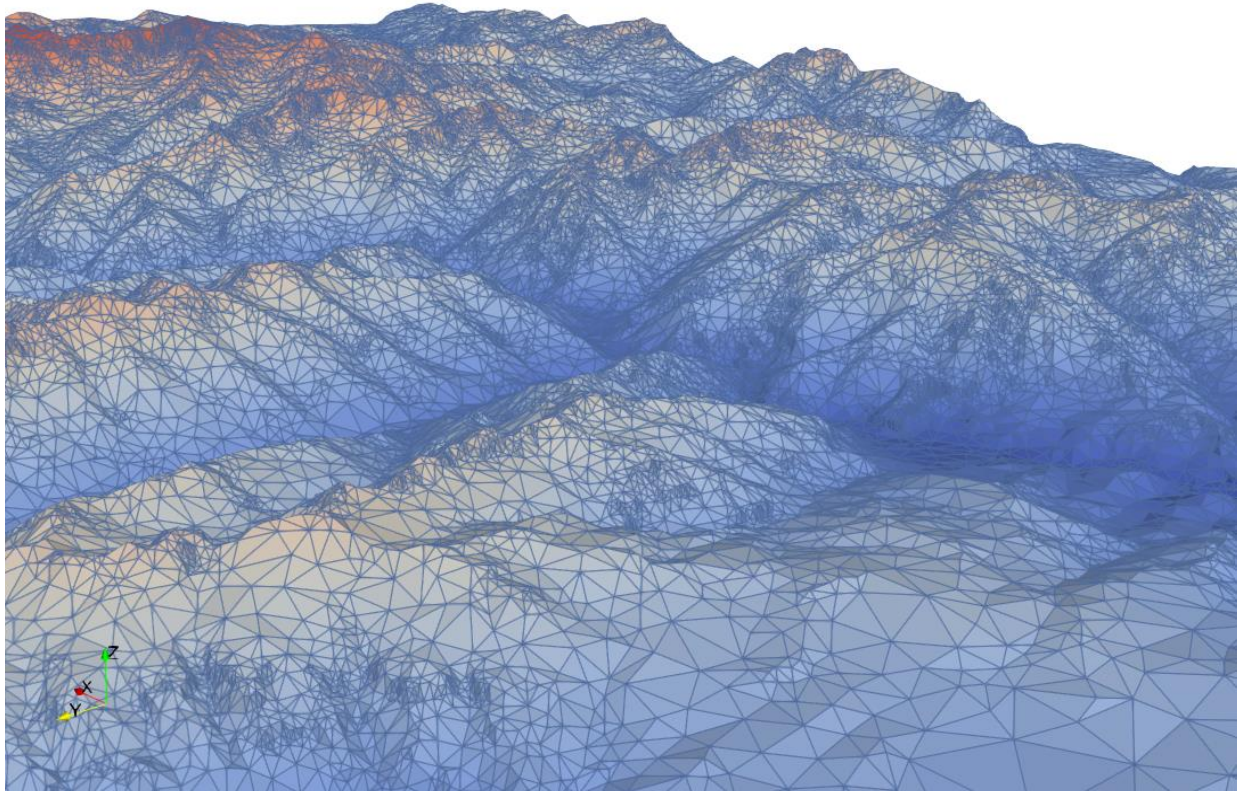

Marsh et al. (2020)




Bernhardt and Schultz (2010)

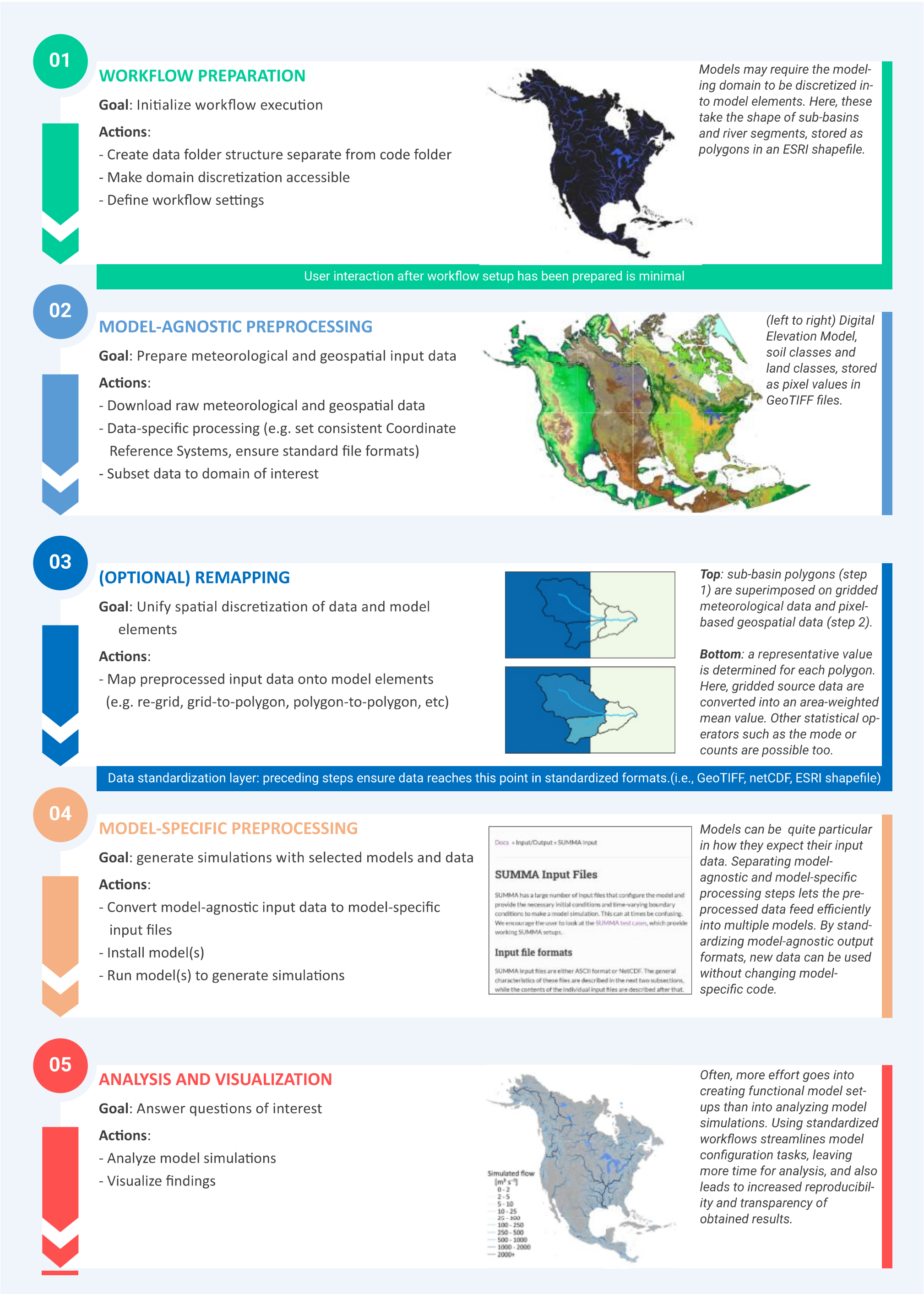
# Initial model deployment in the Santiago area



| Min theoretical area (m²) | Max RMSE (m) | Number of triangles | Area range (m²) | Median area (m²) | Mean area (m²) | Mean resolution (m) |
|---|---|---|---|---|---|---|
| 2 500 | 15 | 215 000 | 400 – 1 780 000 | 18 000 | 27 600 | 166 |

# The model domain contains two experimental catchments plus operational snow and met stations

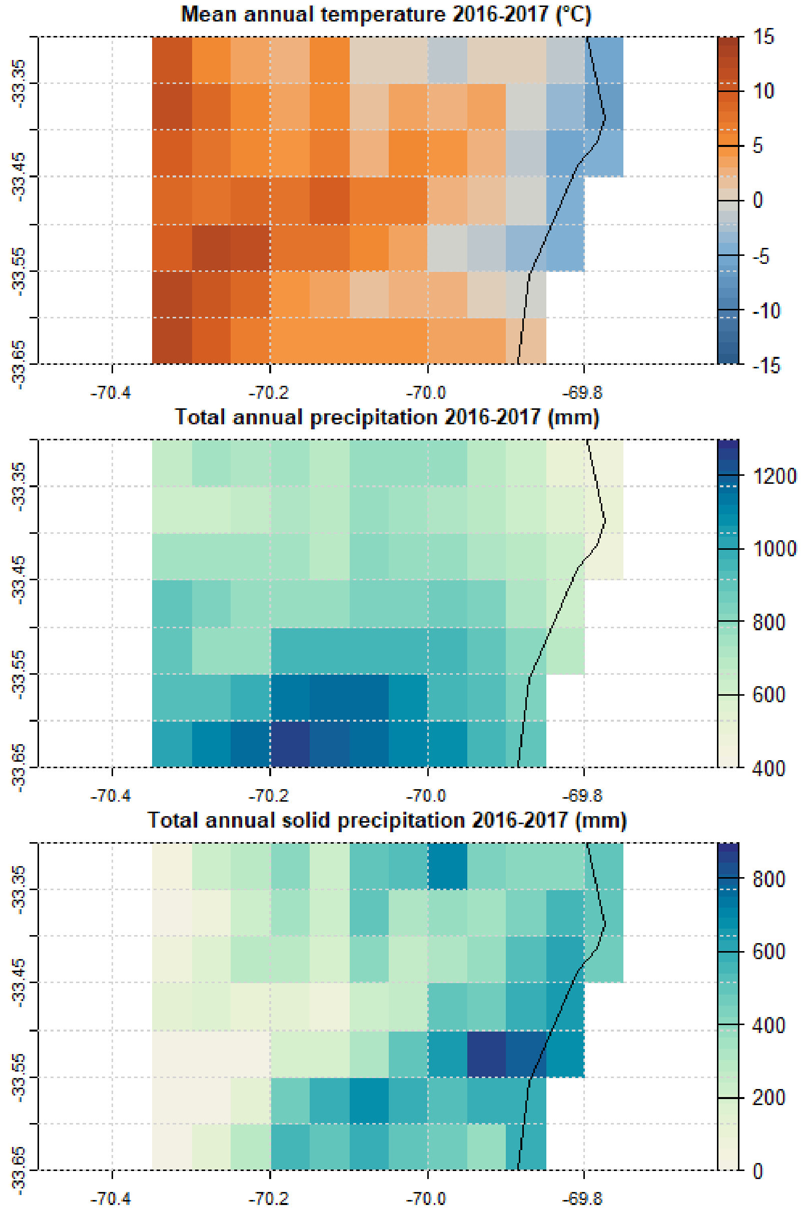



# Model-agnostic and model-specific preprocessing steps kept separate.

1. Workflow preparation: domain discretization in TIN
2. Model-agnostic preprocessing
   a) NWP met forcings:ECMWF, ERA5-Land)
   b) Scaled station-based local gridded met. reference product (Álvarez-Garretón et al., 2018; Boisier, 2023) -> daily precipitation, max/min air temperature
   c) Downscaling of a. based on b.
3. Remapping of preprocessed forcings to model elements
   a) Elevation gradients
   b) Wind mapping
4. Model-specific preprocessing

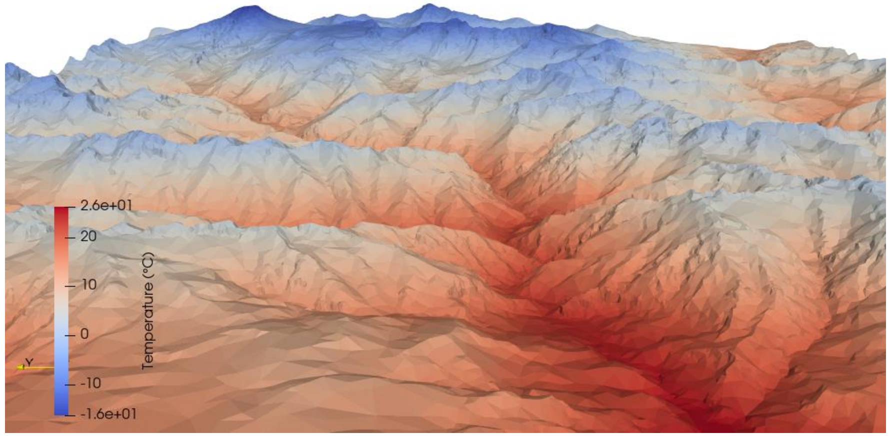
Knoben et al. (2022)

# We force the model with ECMWF-HRES downscaled to station-based local products -> development stage aimed at real-time forecasts

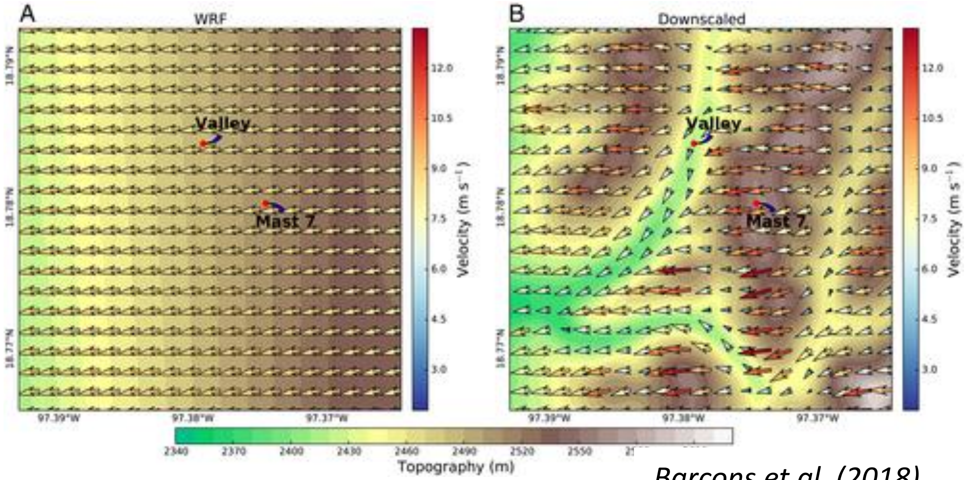



DOWNSCALING

## Precipitation and air temperature: monthly lapse rates

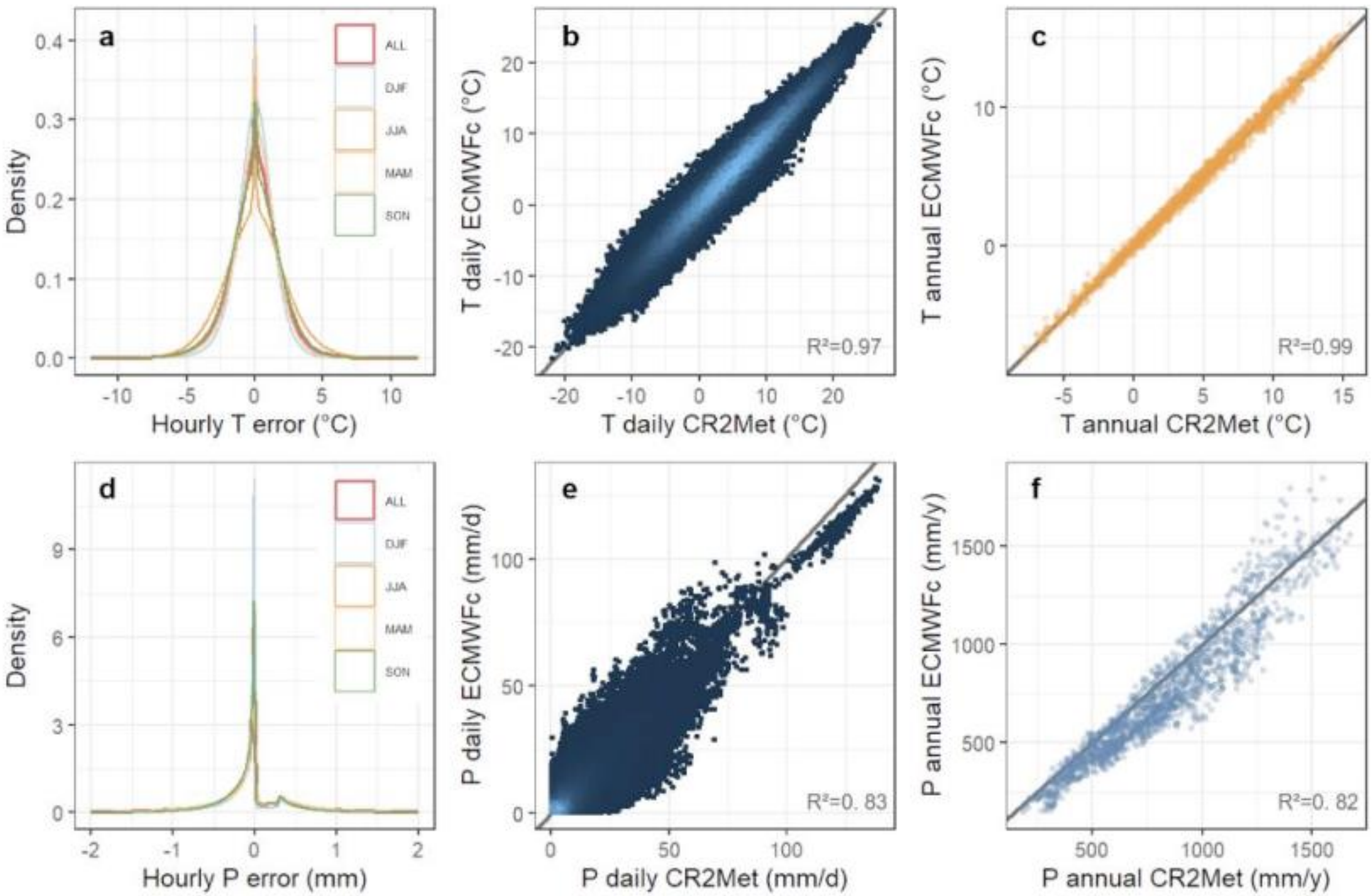



## Wind: WindNinja




*Barcons et al. (2018)*

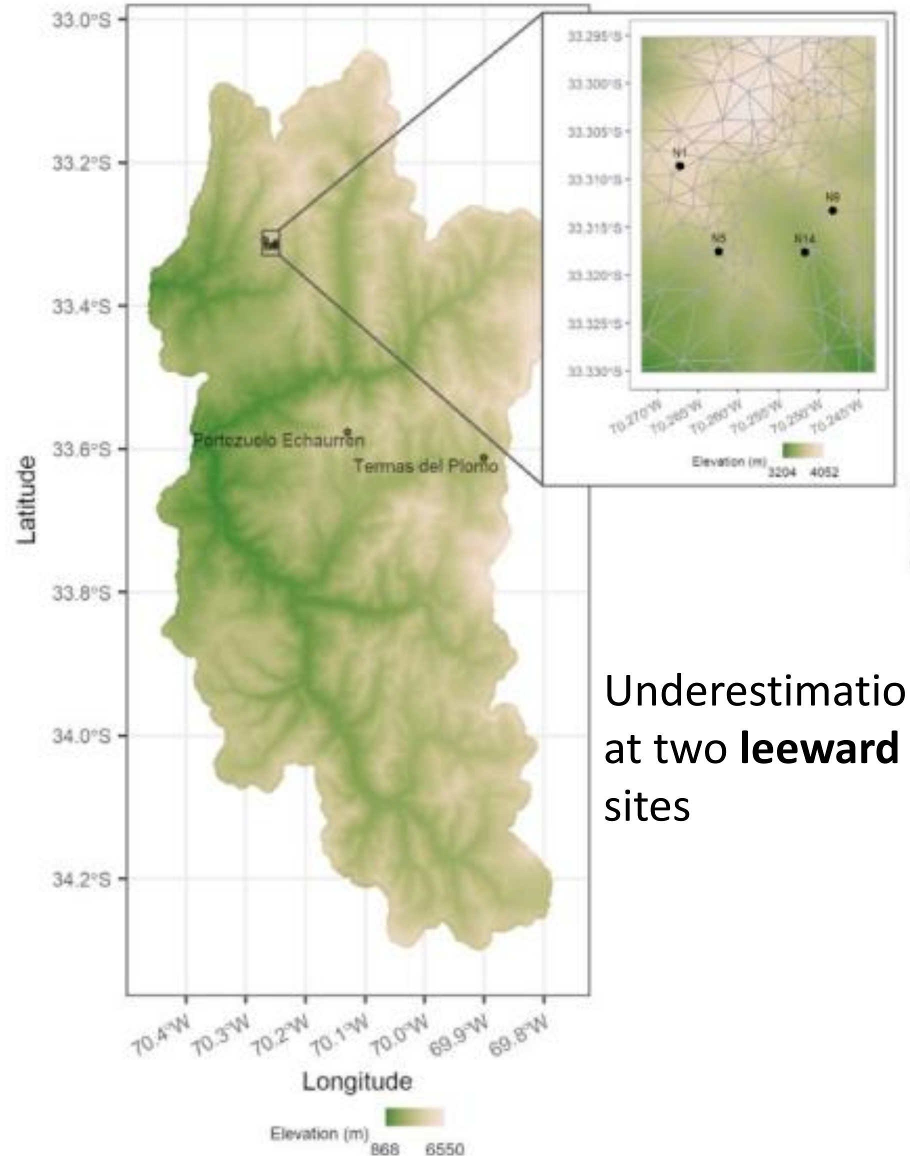
# Assessing the skill and downscaling of NWP data through experimental catchment observations and gridded product



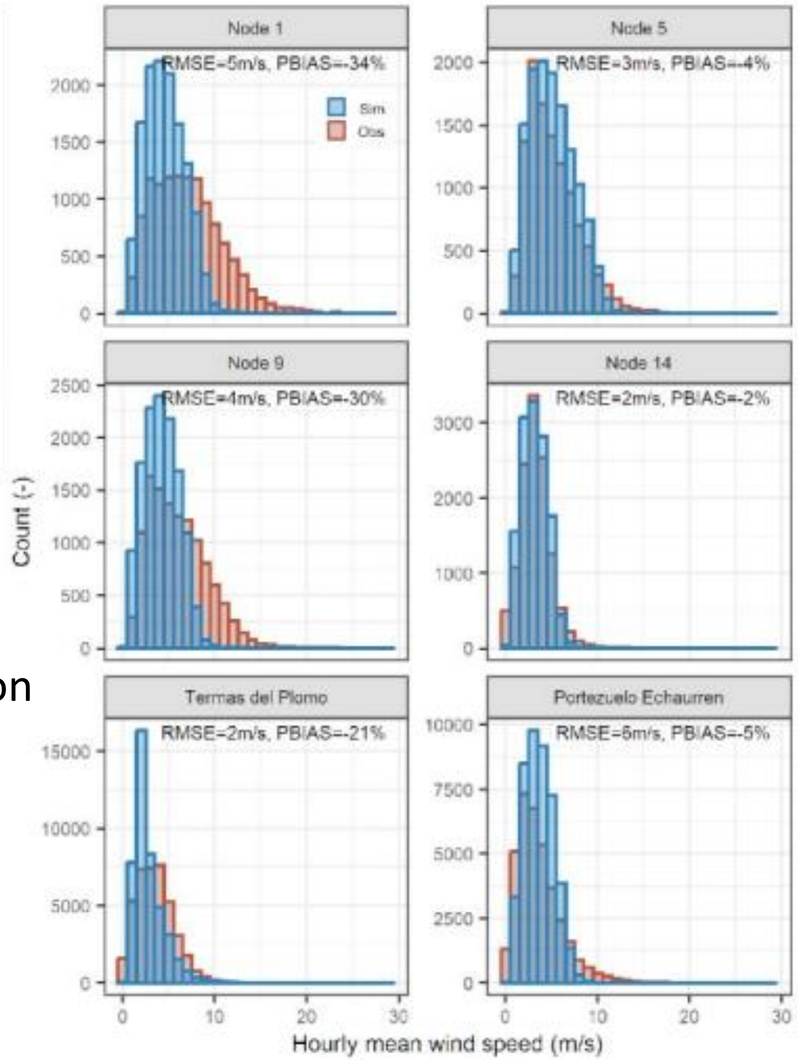

± 5°C uncertainty in daily air temperature

± 50% uncertainty in annual precipitation

# Assessing the skill and downscaling of NWP data through experimental catchment observations and gridded product

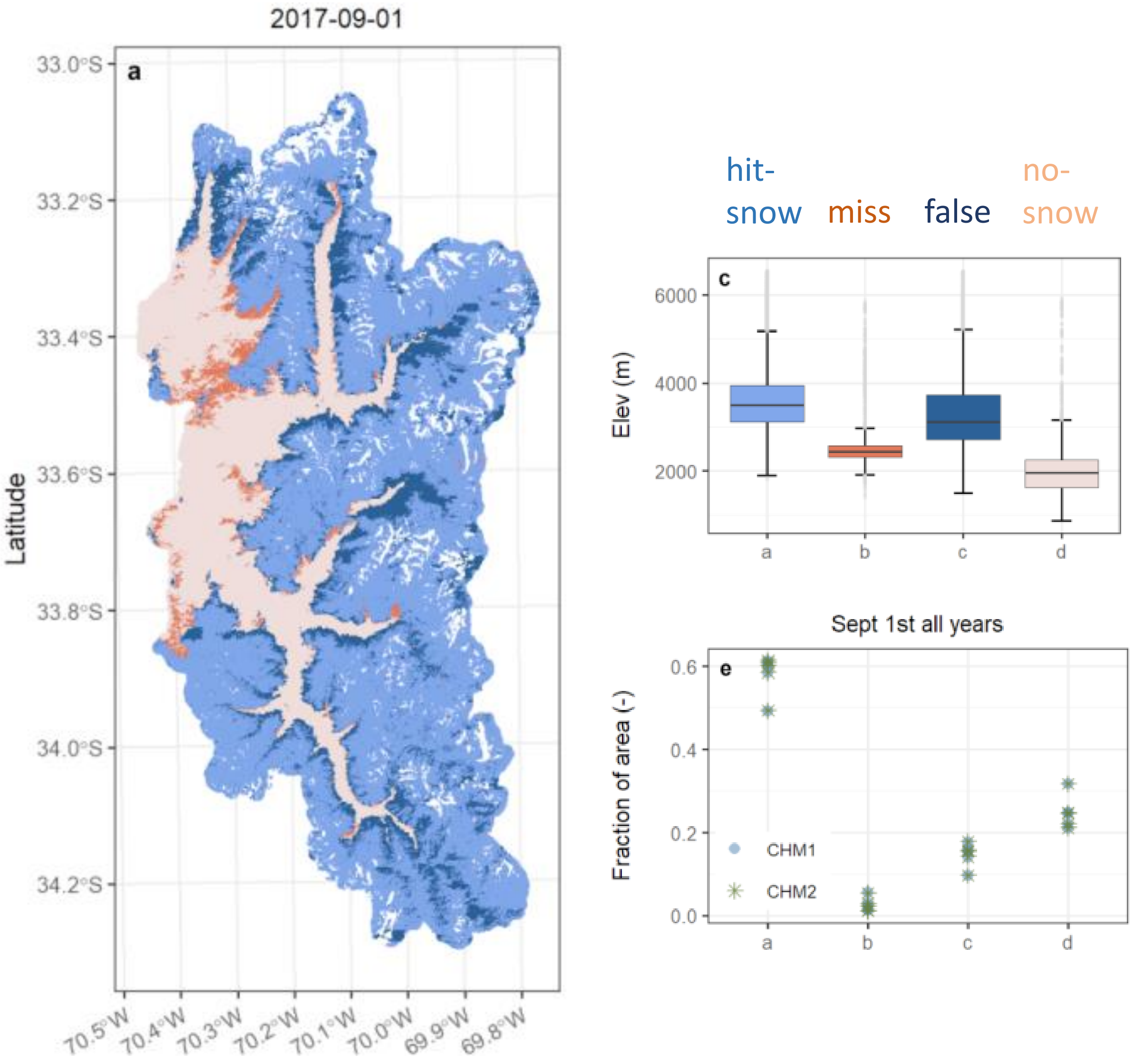



Underestimation at two **leeward** sites




Wind properties reasonably represented at existing stations.

# Model evaluation – SCA distribution



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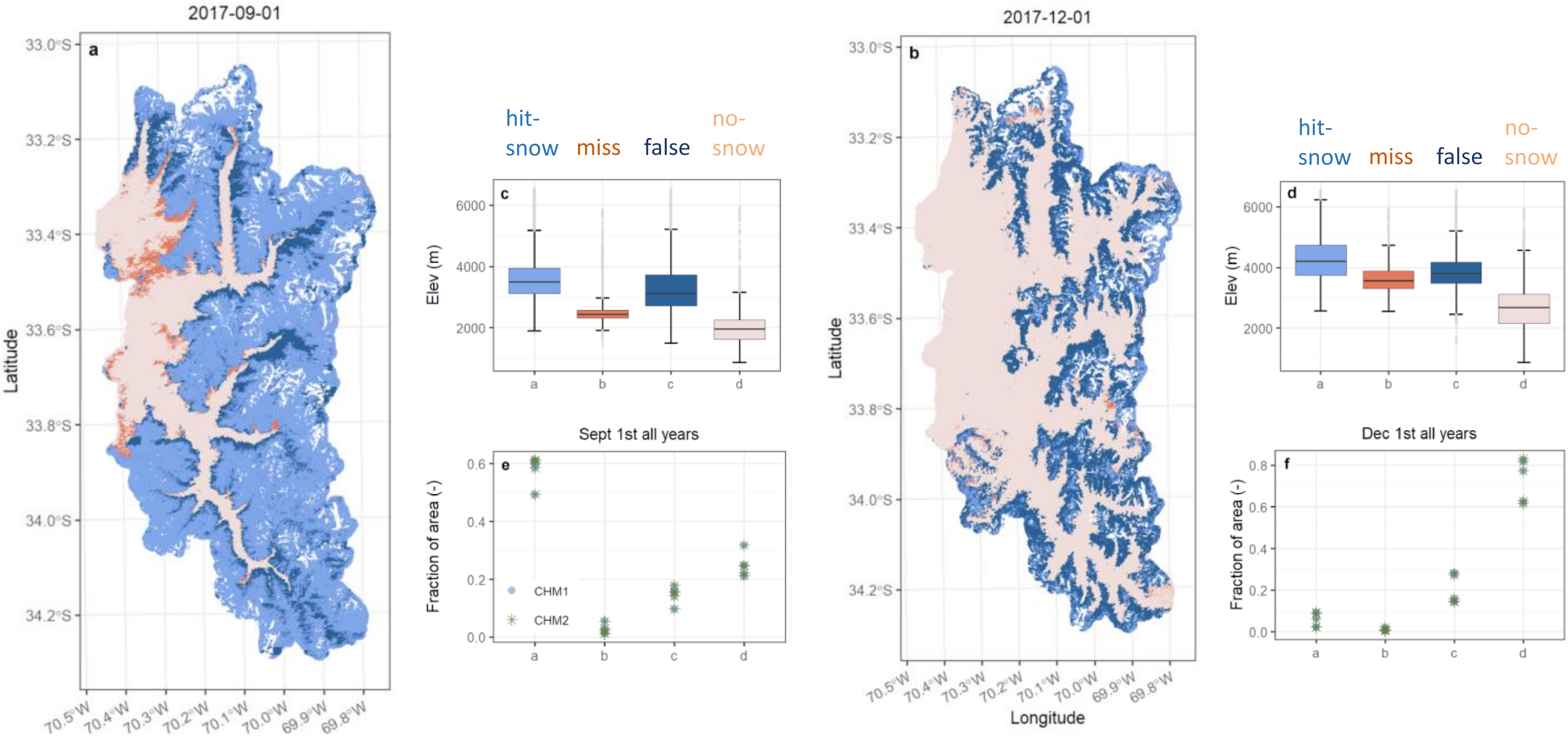
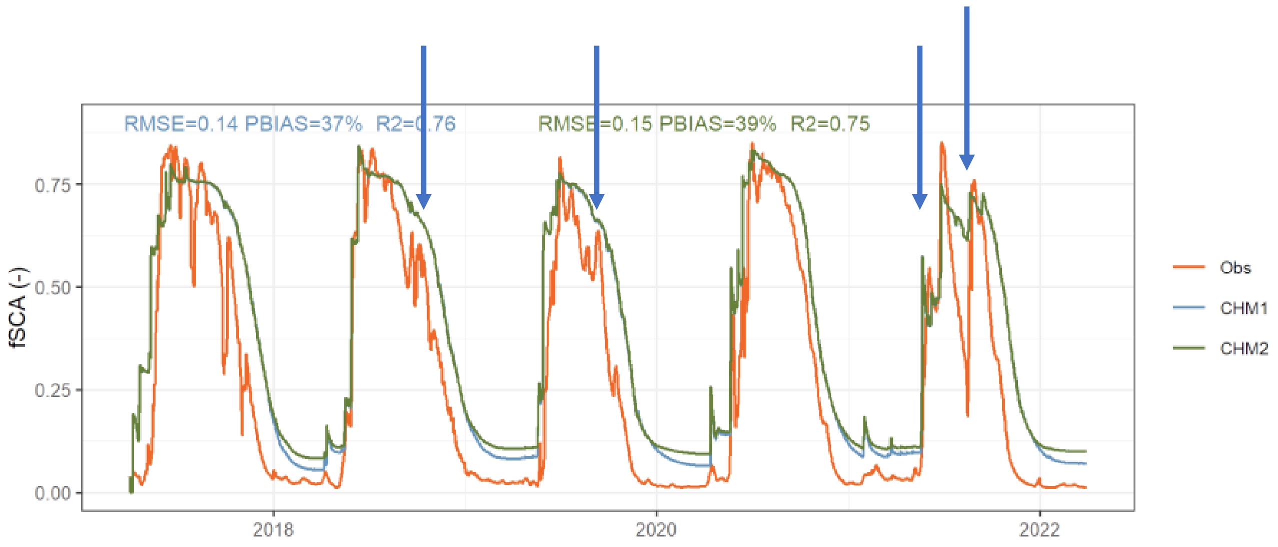


# Model evaluation – SCA time series




+ Good correlation
+ Events well represented

- Systematic bias in spring (but maybe in the reference product, too)

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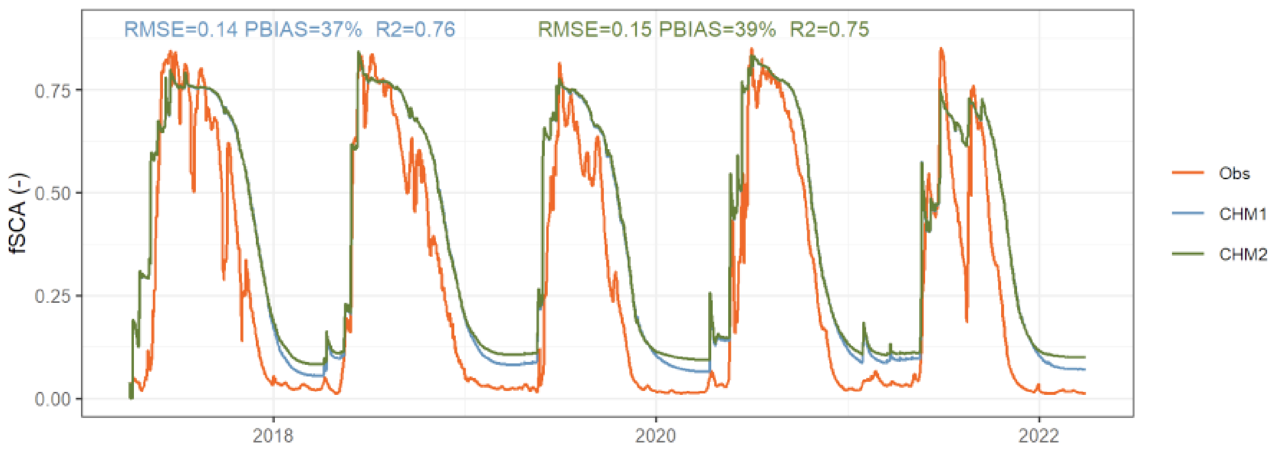


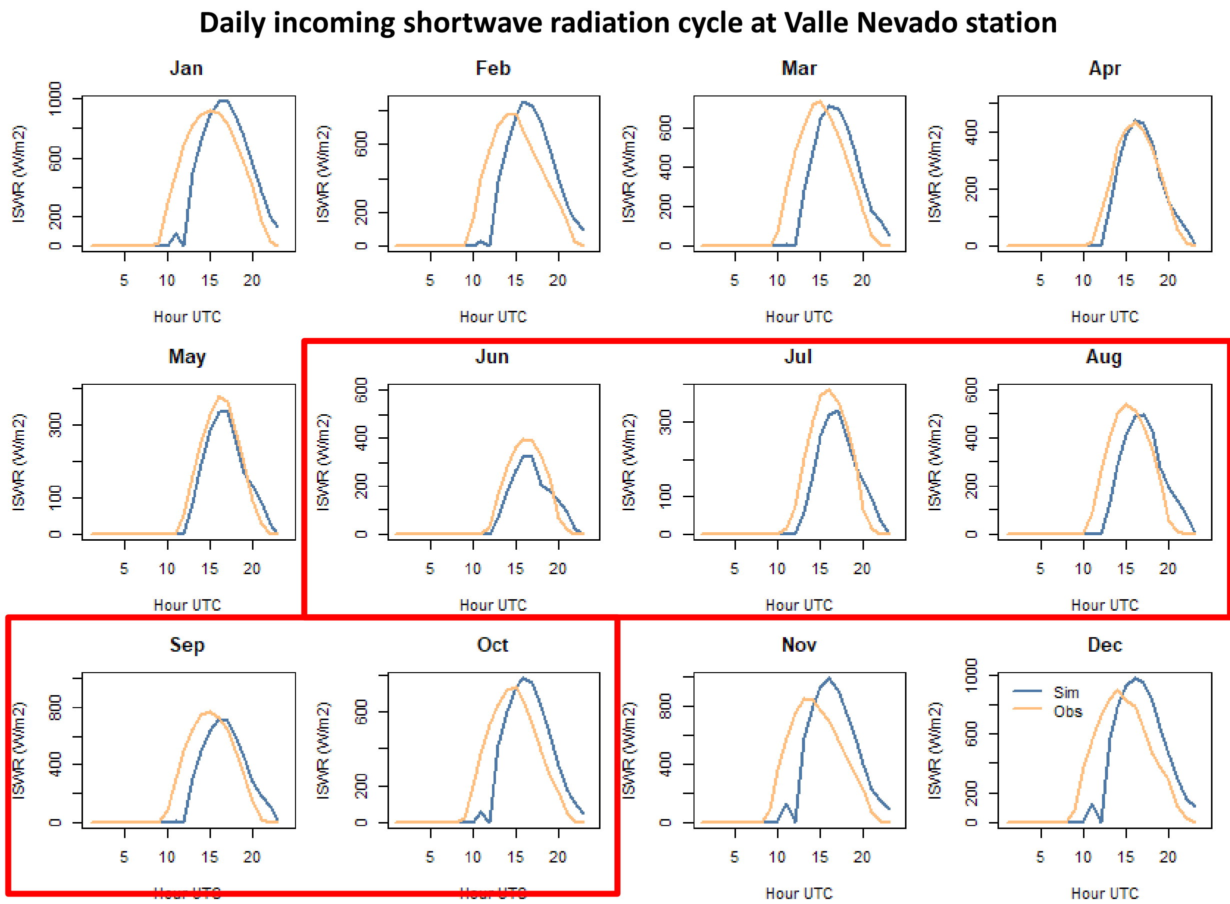


+ Good correlation
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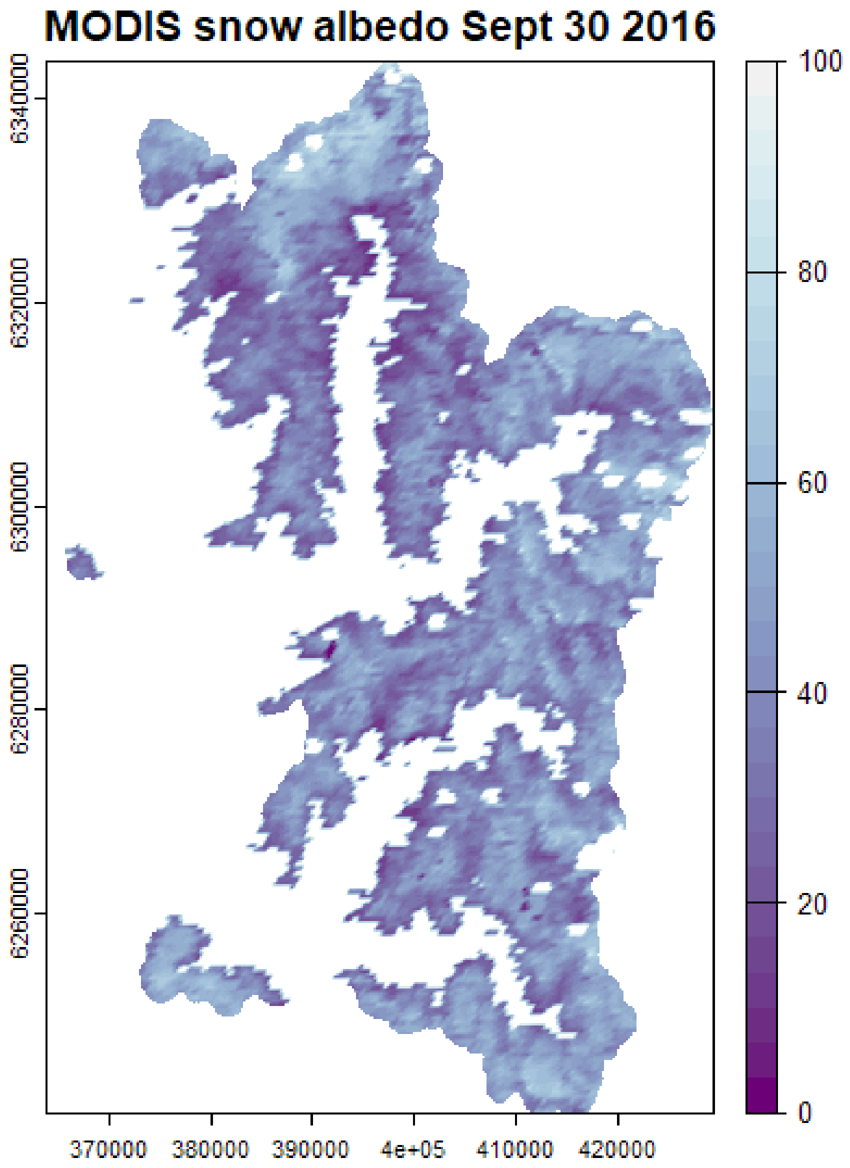
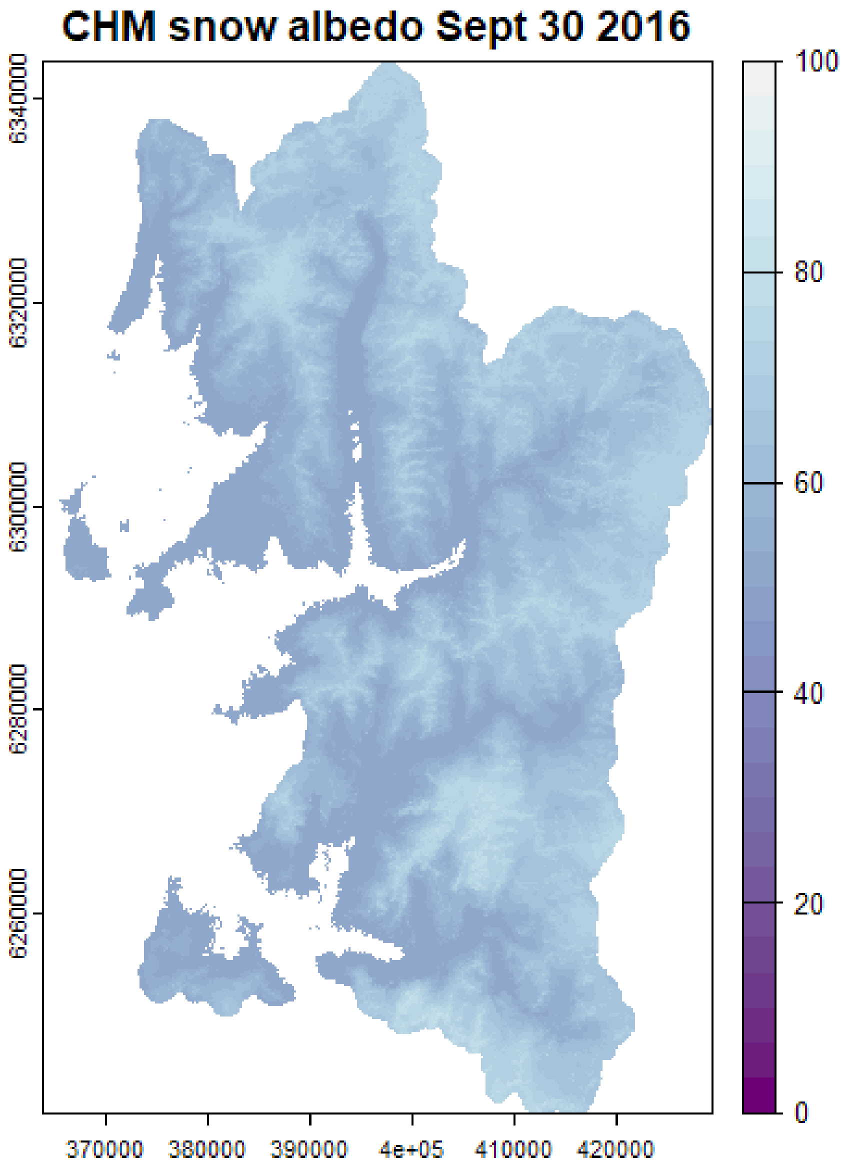
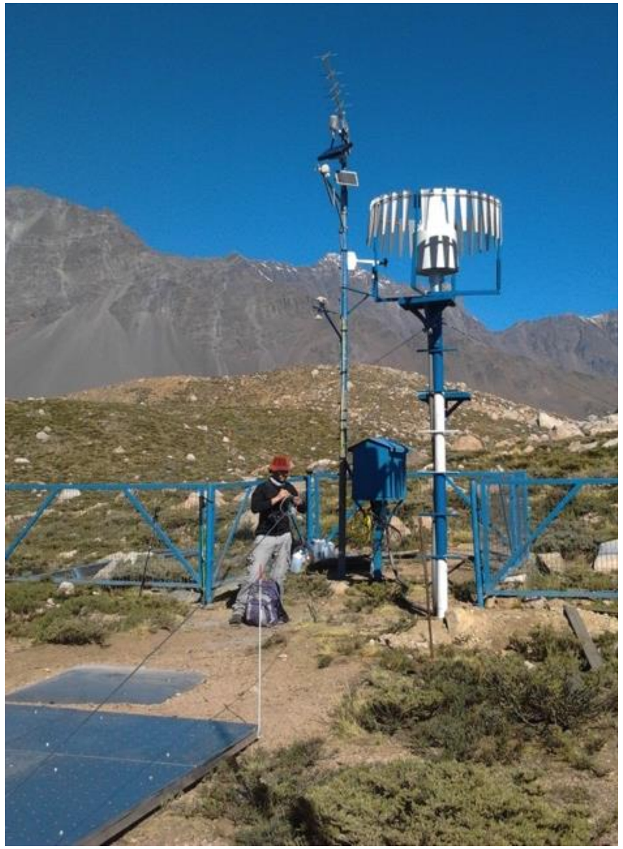
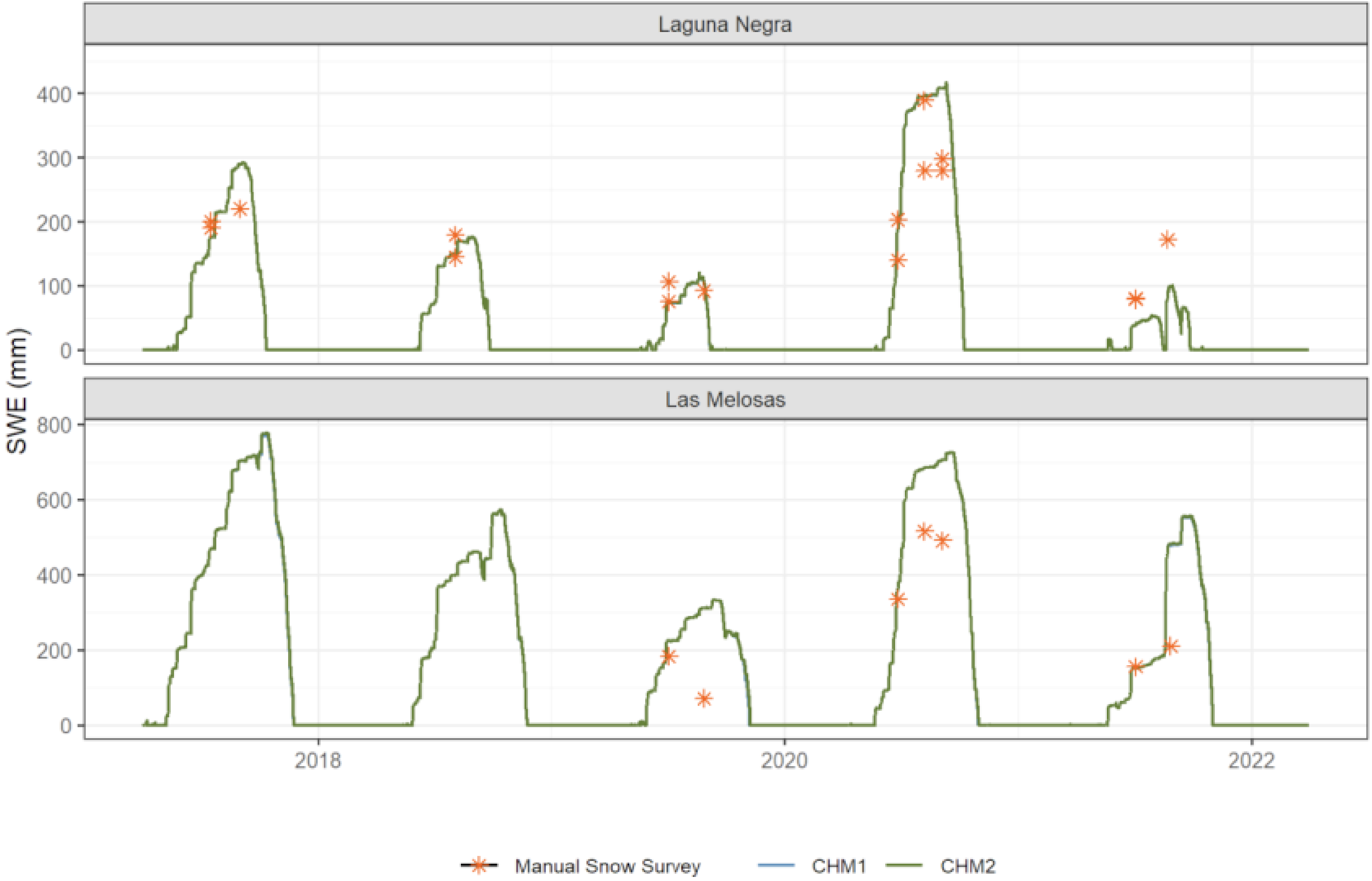
# Simulated albedo seems high compared with R.S. retrievals



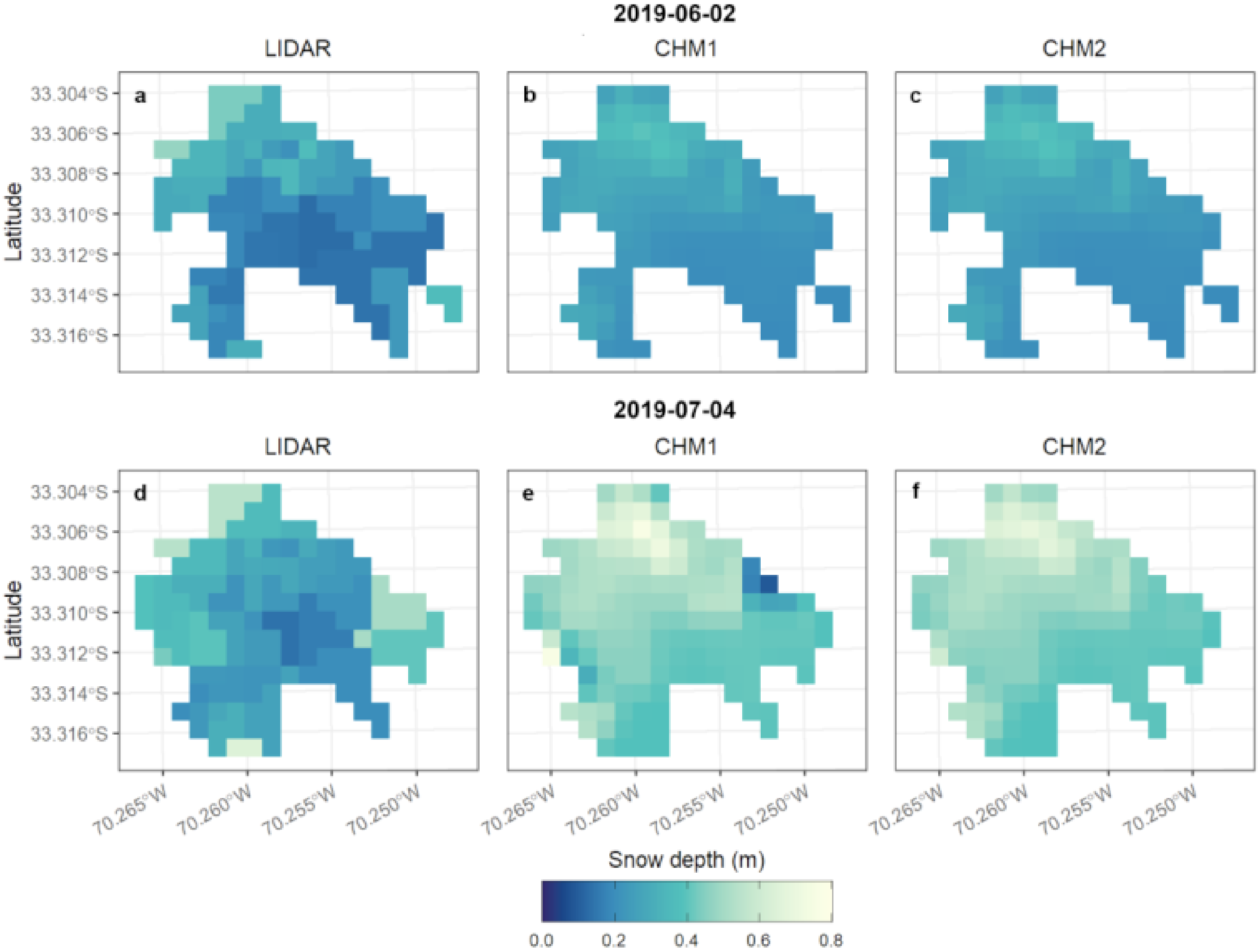
# Against the few point-scale SWE observations in the area, adequate timing and magnitude.



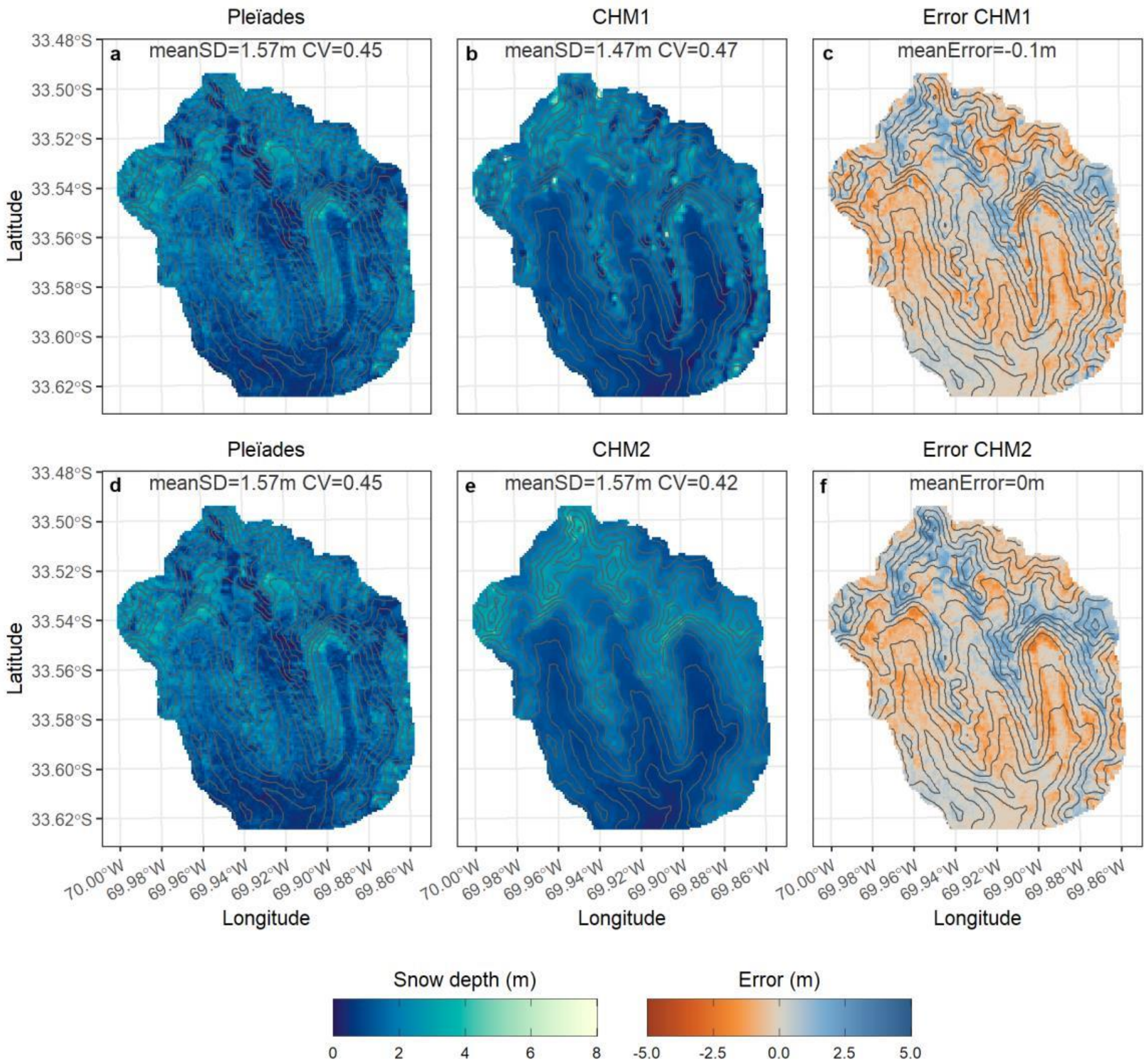


# Snow Depth evaluation: 1 km2-scale

| | Depth | | | CV | | |
|---|---|---|---|---|---|---|
| | Lidar | CHMr | CHMn | Lidar | CHMr | CHMn |
| Avg 7 scans | 0,75 | 0,61 | 0,62 | 0,52 | 0,26 | 0,19 |



# Snow depth evaluation: 100 km2 -scale

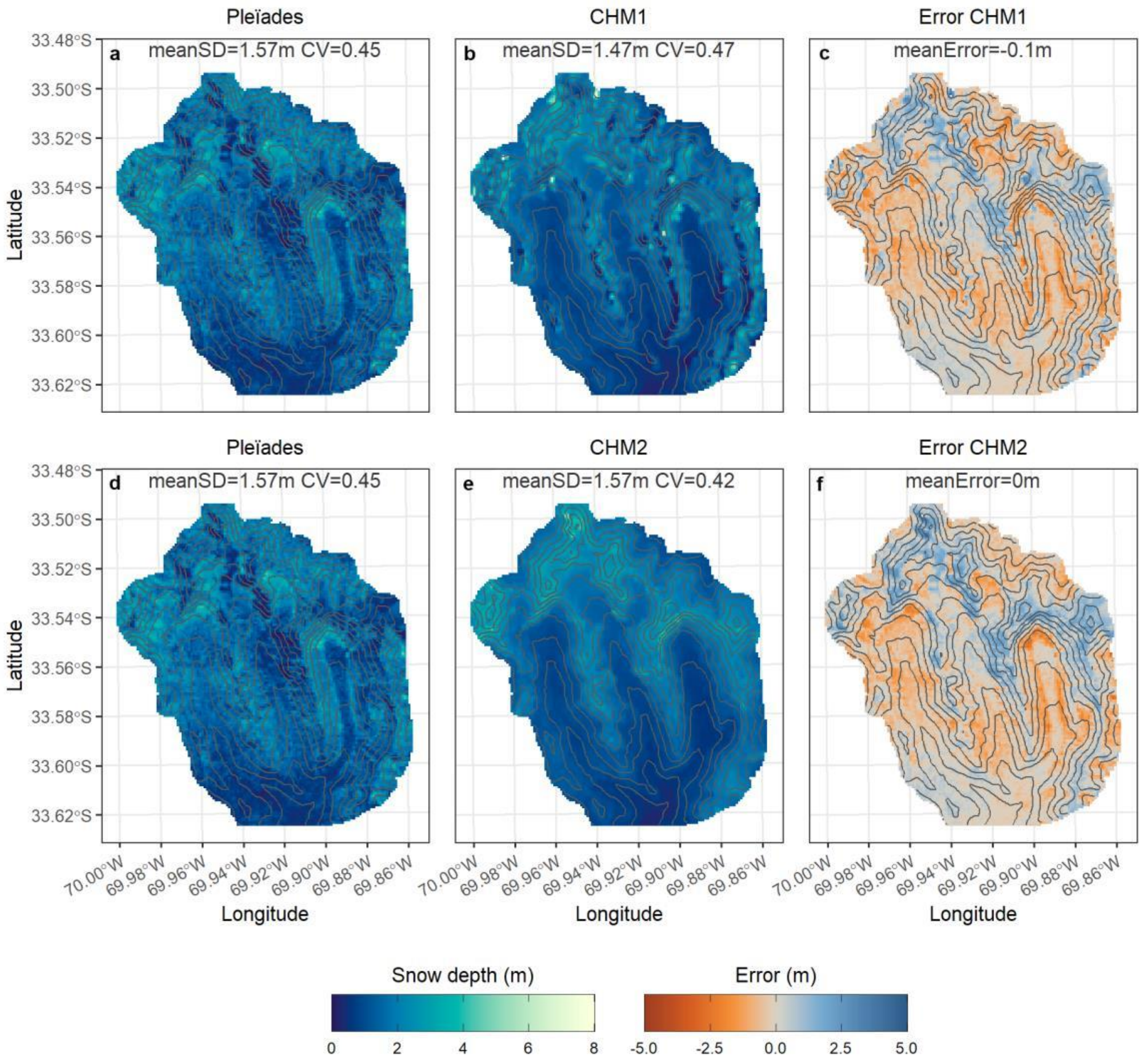


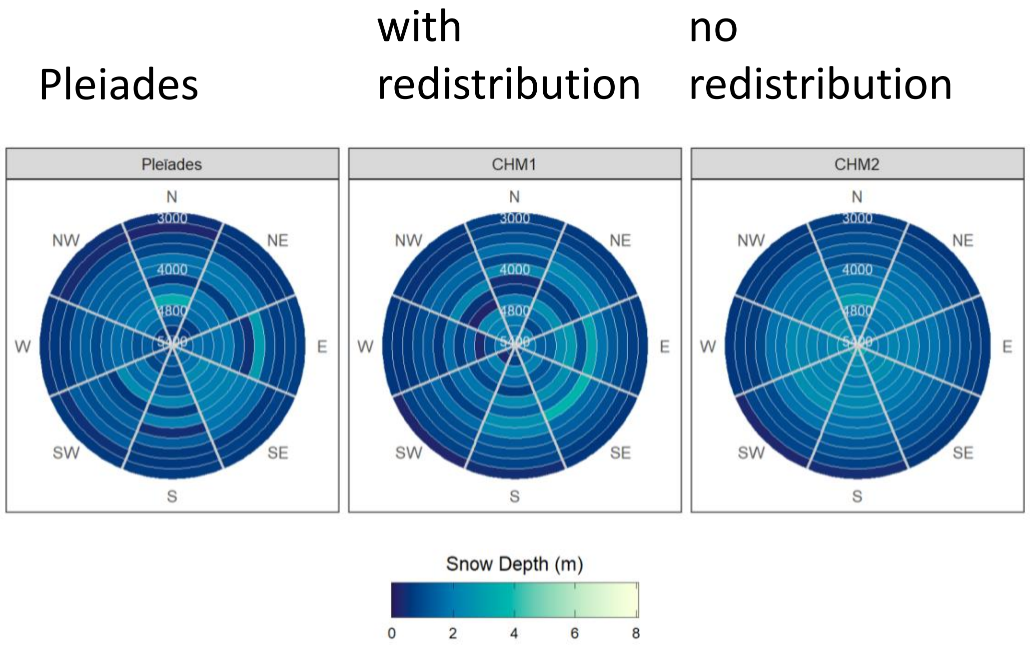

with redistribution

no redistribution

Pleïades data from Shaw et al. (2019)

# Snow depth evaluation: 100 km2 -scale

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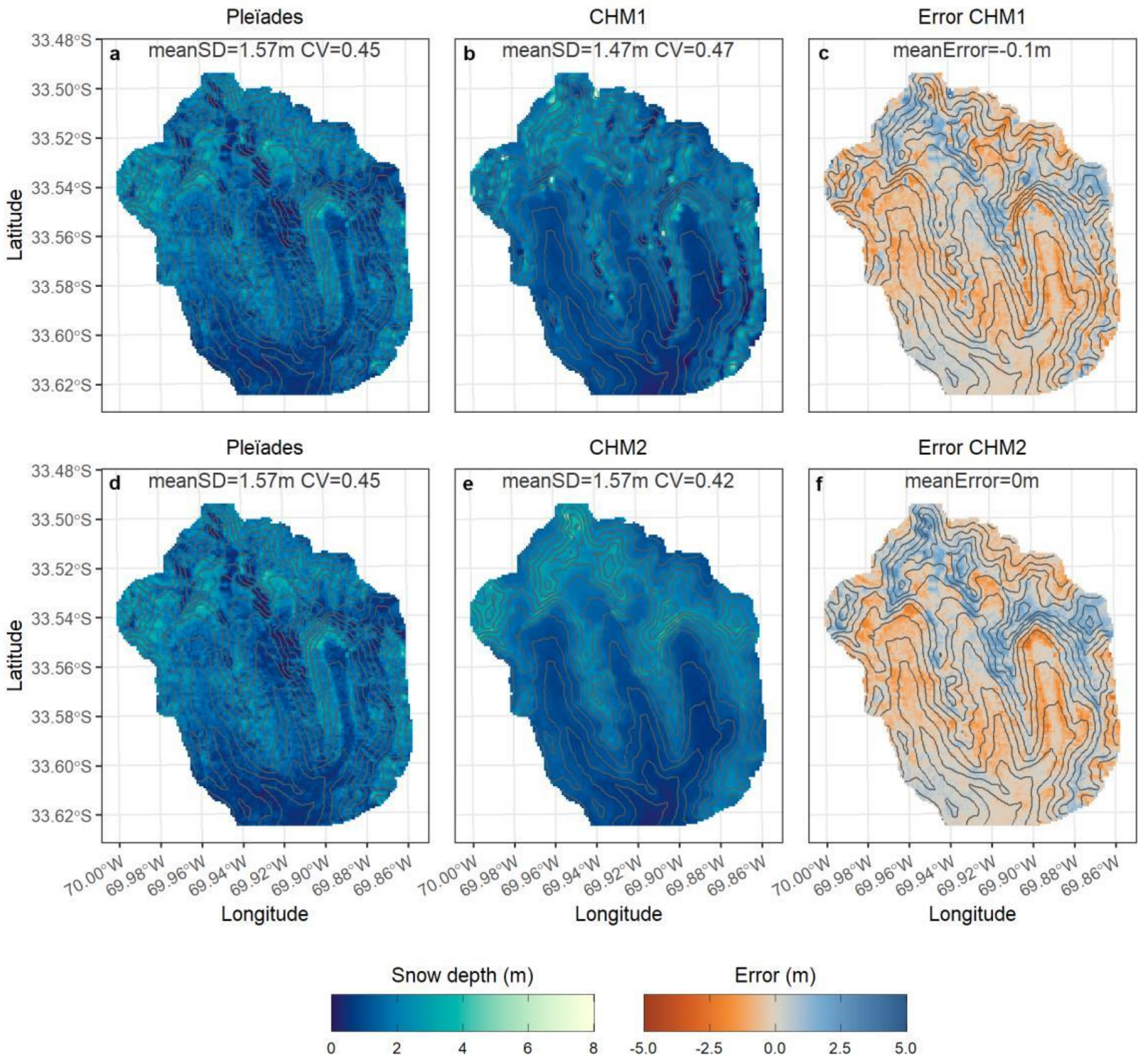
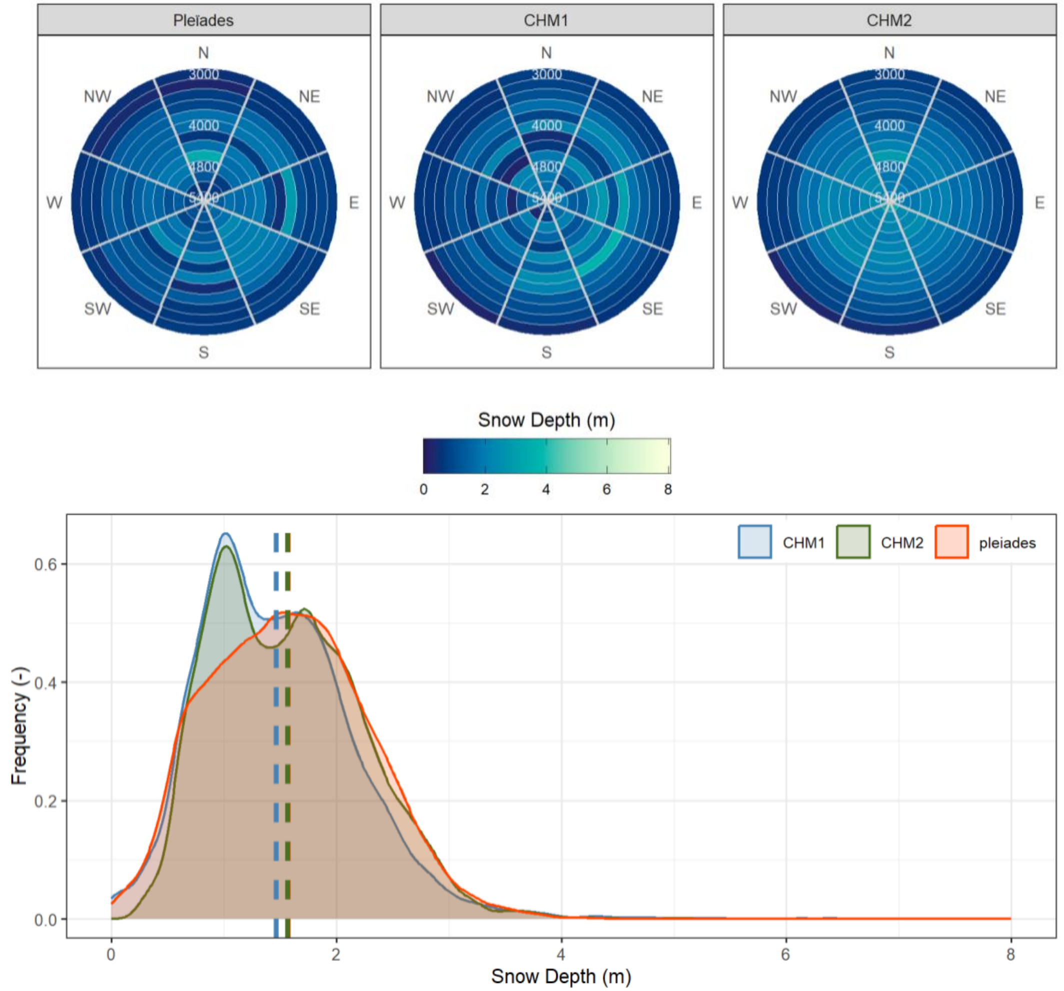
# Snow depth evaluation: 100 km2 -scale




Pleiades

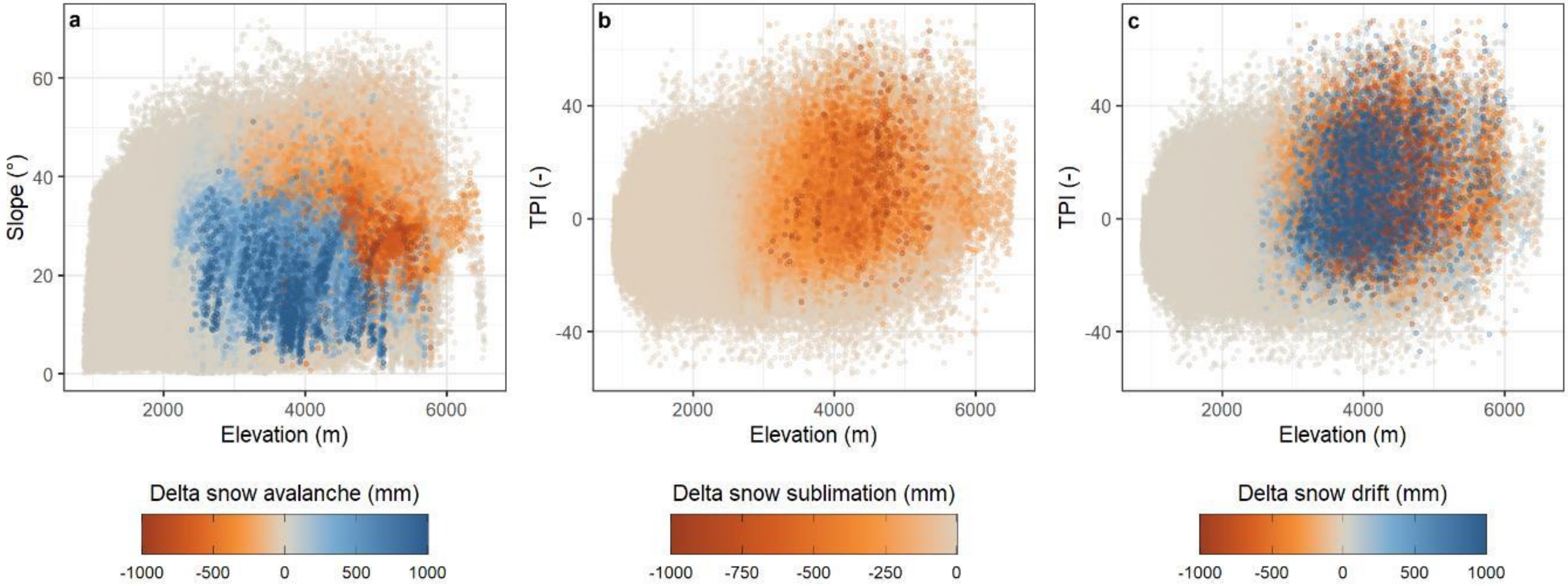
with redistribution

no redistribution




. (2019)

# Contribution of simulated redistribution processes



# Summary

- Efficient implementation of high-resolution snow model with redistribution by wind and avalanching
- Bias corrected NWP forcings reproduce:
  - Timing of SWE accumulation
  - Large-scale precipitation patterns
- Ongoing work:
  - Better assessment of density vs. depth estimation
  - Melt dynamics -> albedo, Sw input
  - Structural uncertainty **Yerel Morales**
  - Parameter estimation **Elizabeth Ramirez**
  - Data assimilation **Cristobal Sardá**

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