Assimilation of multiscale terrestrial photography data into a physical model of snow processes

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SECTIONS

1. INTRODUCTION
2. OBJETIVES
3. STUDY SITES
4. METHODOLOGY
   - Georreferencing terrestrial photography
   - Automatic detection of snow
5. RESULTS
   - Hillslope scale
   - Detail scale
6. CONCLUSIONS

- **MEDITERRANEAN REGION CLIMATE**
  - High level of solar energy income througthout the year
  - Extremely variable character with lower precipitation
- **SIERRA NEVADA (SPAIN)**

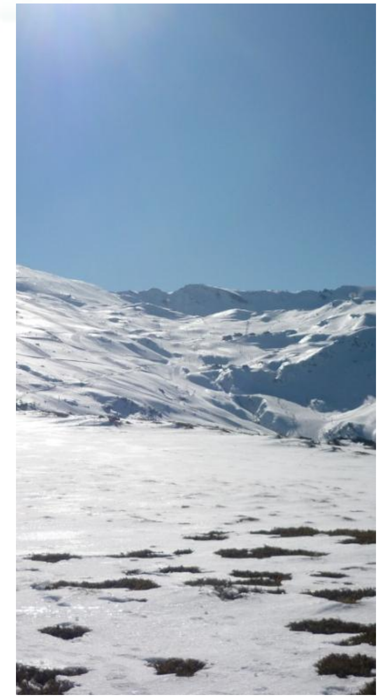
- **SNOW**
  - Strong spatiotemporal variability
  - High evaporation rates
  - Several snowmelt cycles
- **SNOWMELT- ACCUMULATION MODEL**

POINT MODEL (Water and Energy Balance) → DEPLETION CURVES → DISTRIBUTED MODEL (30 x 30m)

Point Measurements

Landsat images

IMAGES TO STUDY THE SNOW EVOLUTION



IMAGES	SATELLITE	AERIAL	TERRESTRIAL
Spatial Resolution	Fixed	Variable	Variable
Temporal Resolution	Fixed	Variable	Variable
Cost	High	High	Low

EVALUATE THE USE OF TERRESTRIAL PHOTOGRAPHY AT DIFFERENT SCALE, TO CHARACTERICE THE SPATIAL EVOLUTION OF THE SNOW COVER

- **Validate the calibration of distributed values (Landsat, 30x 30 m) at hillslope scale (10 x 10 m)**
- **Add the microscale effects analyzing the spatial variability on the model cell (0.1 x 0.1 m)**

STUDY SITES

- Different study sites
- Different scale resolution

VALIDATE DISTRIBUTED MODEL

RECALIBRATE POINT MODEL

METEOROLOGICAL DATA

- Anual Precipitation (400-1500mm)
- Percent of snow (40-70%)
- Average Temperature in snow season (-5,+5 ºC)
- Sunny days dominant even during winter

SCALE	HILLSLOPE O (~100m)	DETAIL O (~m)
STUDY PERIOD	May- Jun 2009	Sep 2009-Jun 2011
TEMPORAL RESOLUTION	1 to 4 days	2 hours
PHOTO RESOLUTION	6 Mpix	3.6 Mpix
COVERED AREA	~ 2.7 km2	~ 0.09 km2

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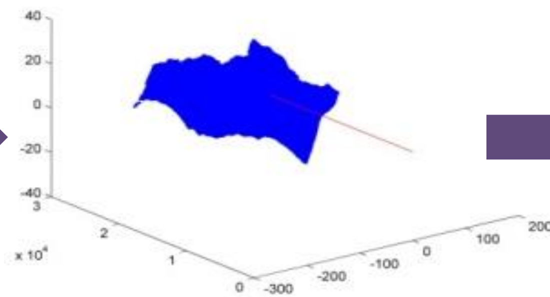
GEOREFERENCING TERRESTRIAL PHOTOGRAPHY

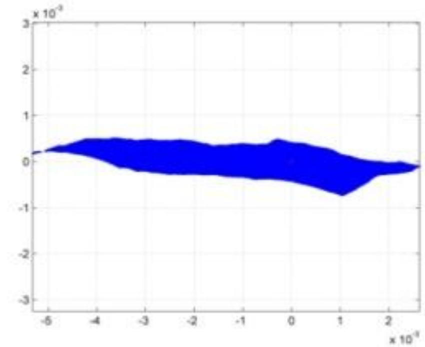
- Based on graphics desing principles
- AIM: To find a function to relate 2D pixel to 3D point DEM

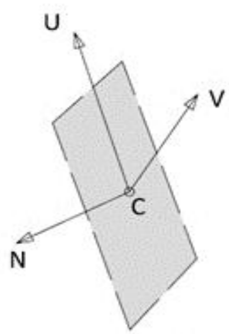
DEM

Transformation to camera coordinate system

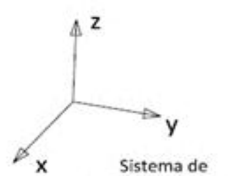


Perspective Projection



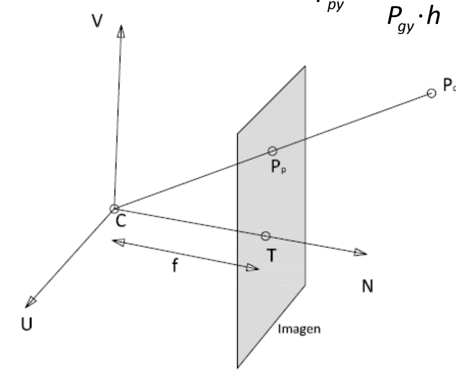


$$\begin{pmatrix} P_{cx} \\ P_{cy} \\ P_{cz} \\ w \end{pmatrix} = \begin{pmatrix} U_x & U_y & U_z & -C_x \\ N_x & N_y & N_z & -C_y \\ V_x & V_y & V_z & -C_z \\ 0 & h/2\cdot f & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} P_{gx} \\ P_{gy} \\ P_{gz} \\ 1 \end{pmatrix}$$



$$P_{px} = \frac{P_{cx}\cdot 2\cdot f}{P_{gy}\cdot h} = \frac{P_{cx}}{w}$$

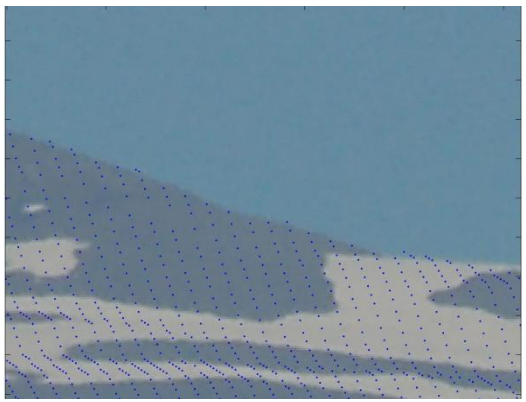
$$P_{py} = \frac{P_{cz}\cdot 2\cdot f}{P_{gy}\cdot h} = \frac{P_{cz}}{w}$$



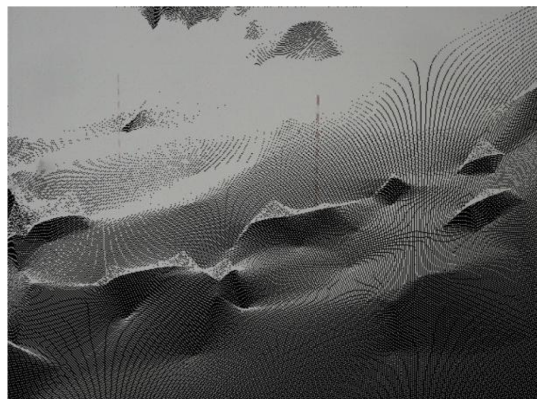
GEOREFERENCING TERRESTRIAL PHOTOGRAPHY

- 2D projection of the DEM scaled according the image resolution
- Stablish the correspondence between pixel and projected coordinates

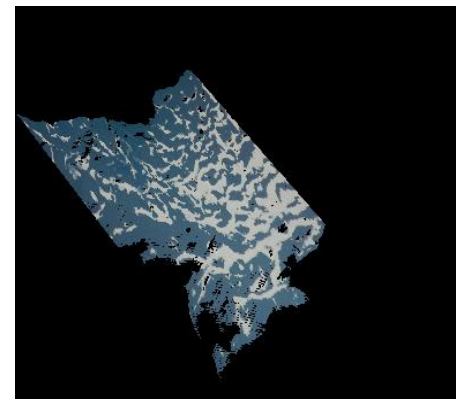
Scaling and Overlay



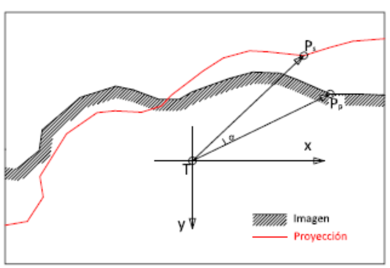
Assignment

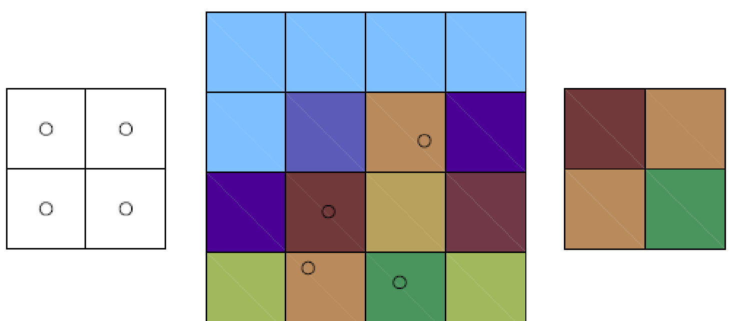


Georeferenced image



Ground Control Points



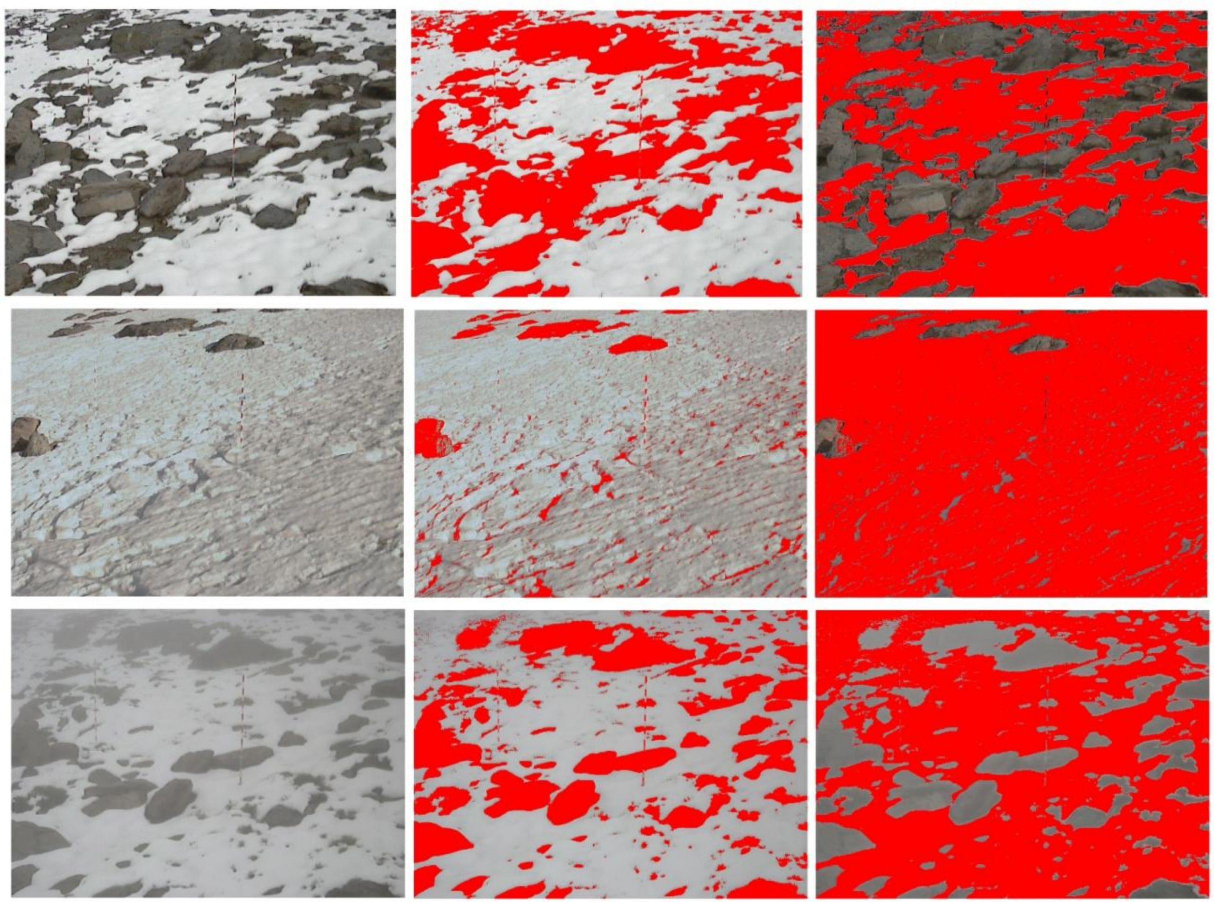


AUTOMATIC DETECTION

CLOUDS

SHADOWS

FOG

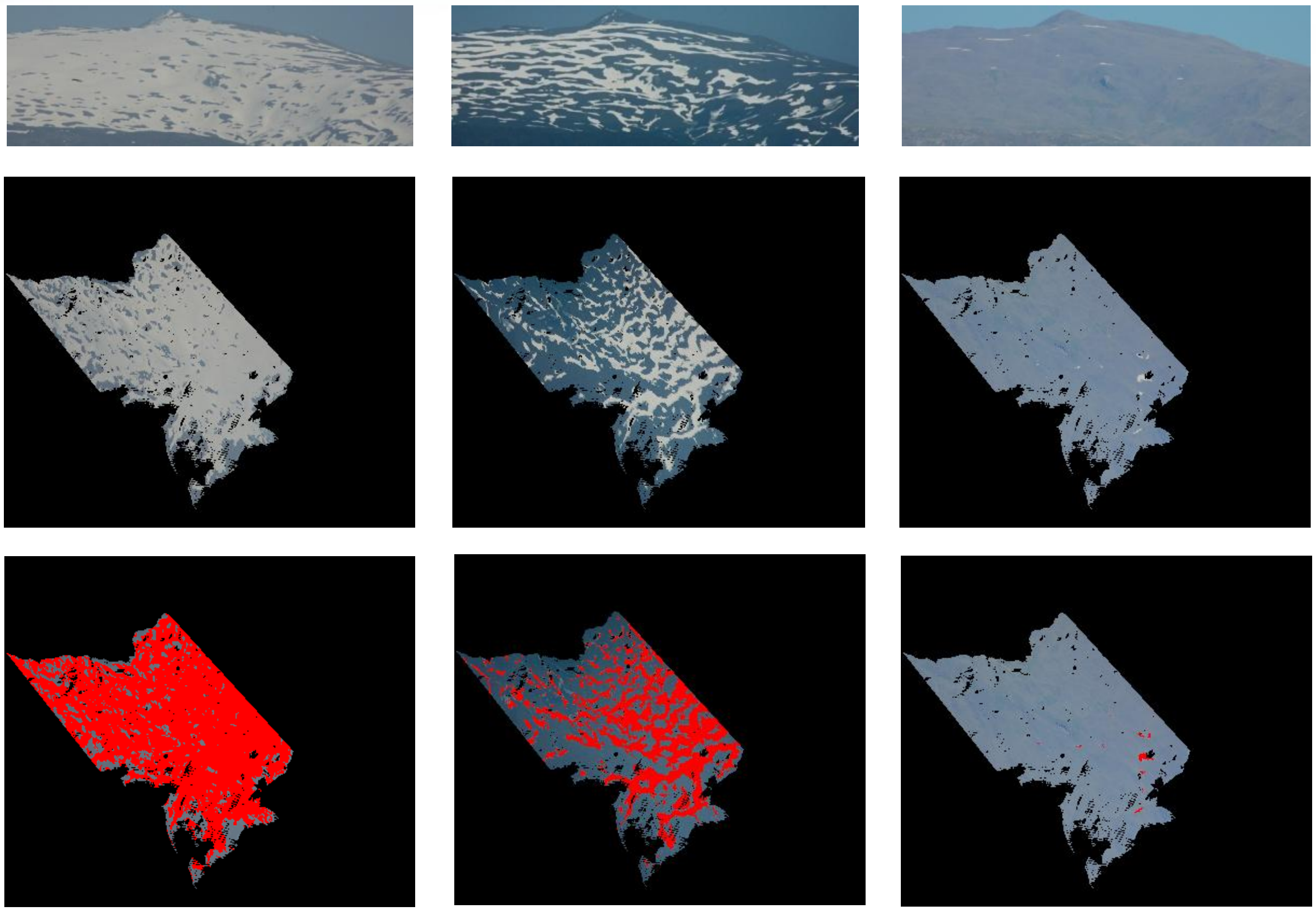


- Based on machine learning techniques
- K-mean algorithm
- No fixed thresholds
- Small misclassifications related to hard shadows

SECTIONS

HILLSLOPE SCALE MEASSURES

06/05/2009 | 23/05/2009 | 29/06/2009

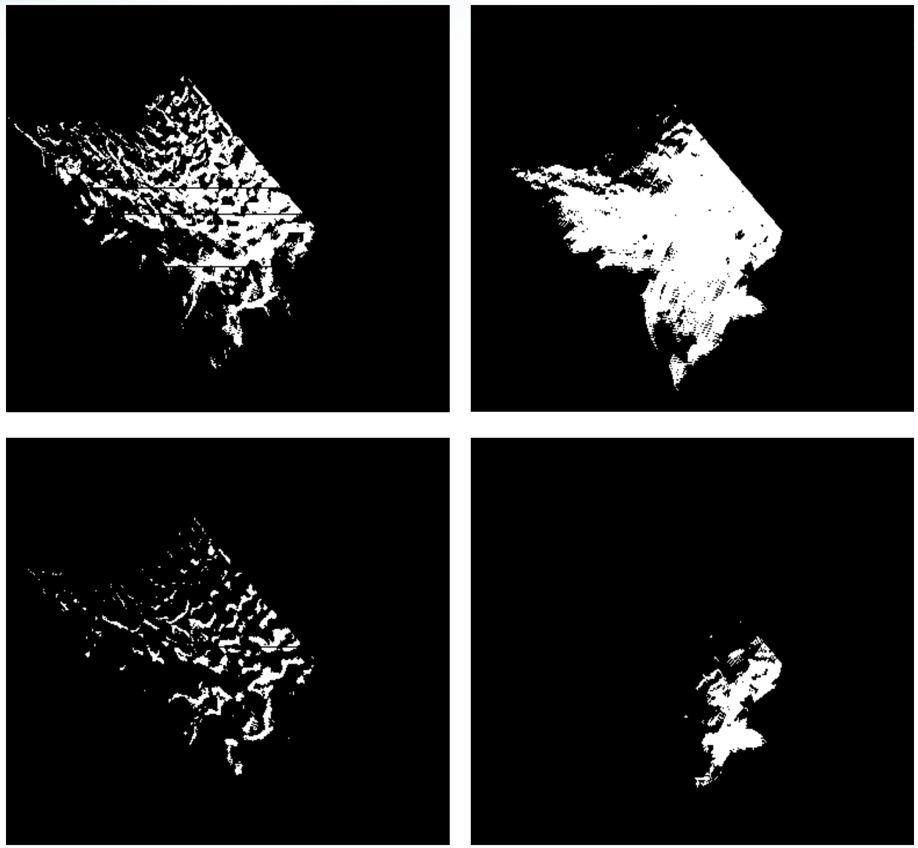


HILLSLOPE SCALE

- Snow masks

06/05/2009

23/05/2009



Measured
(Terrestrial photography)

Simulated
(Model)

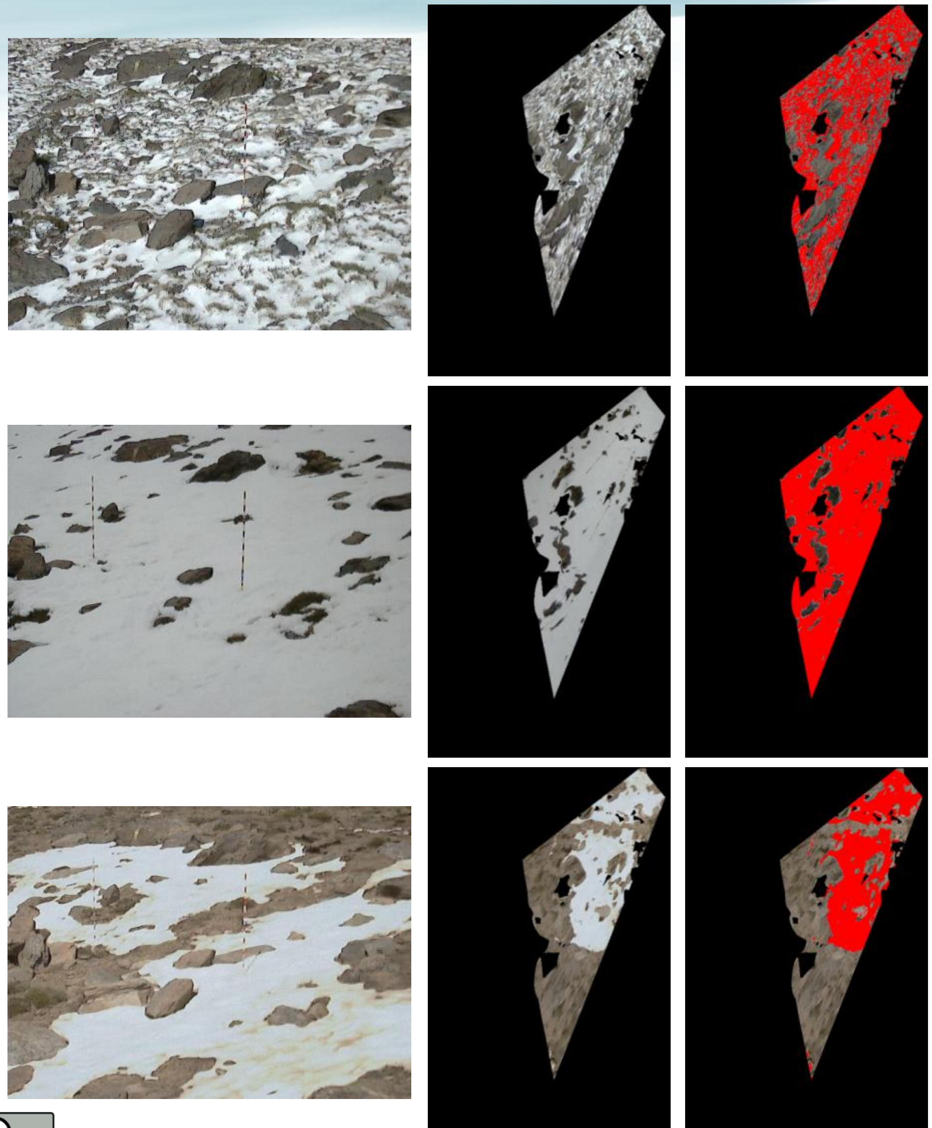
DETAIL SCALE MEASSURES

ORIGINAL GEOREFERENCED MASK

06/12/2009

20/02/2010

01/04/2011



PHOTOGRAPHED AREA ≈ CELL MODEL AREA

RECALIBRATE MORE EFFECTIVE THE MODEL AT CELL SCAIL (30 x 30 m)

Windless transfer coefficient for the turbulence sensible heat flux (kE_{H0})

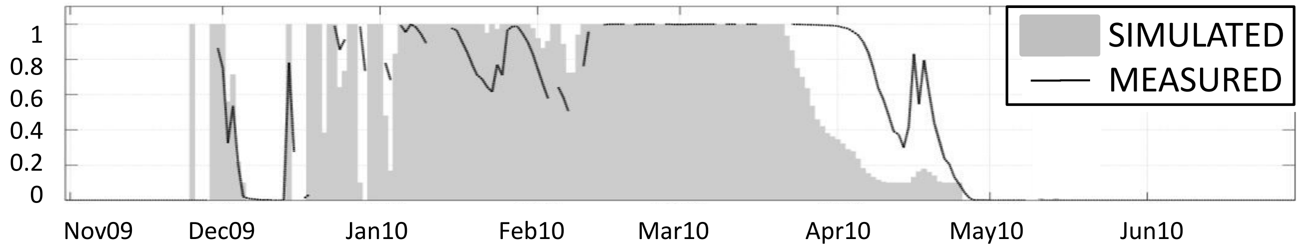
- $kE_{H0} = 5\ Wm^{-2}K^{-1}$ (Herrero, 2009)
- $kE_{H0} = 3\ Wm^{-2}K^{-1}$ (Pimentel, 2011)

DETAIL SCALE (Snow Cover Area)

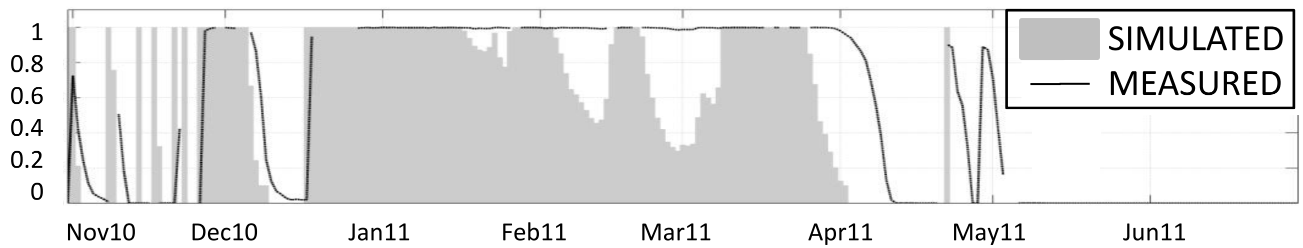
- New values for calibration parameter

Simulation 1 [kE_{H0}=5 $Wm^{-2}K^{-1}$] RMSE=0.2570

SNOW COVER AREA MODEL CELL (30 x 30)

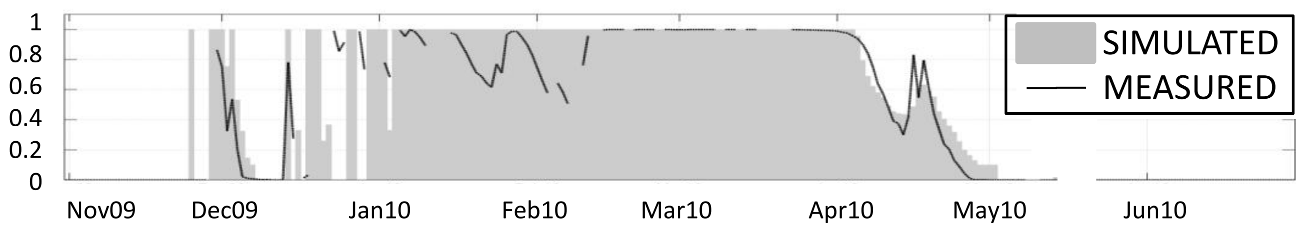


SNOW COVER AREA MODEL CELL (30 x 30)

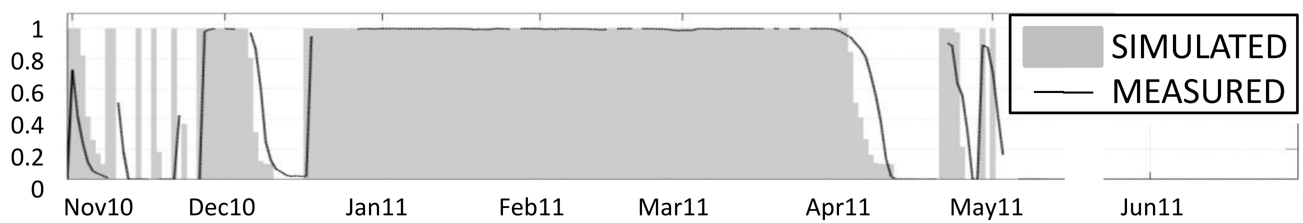


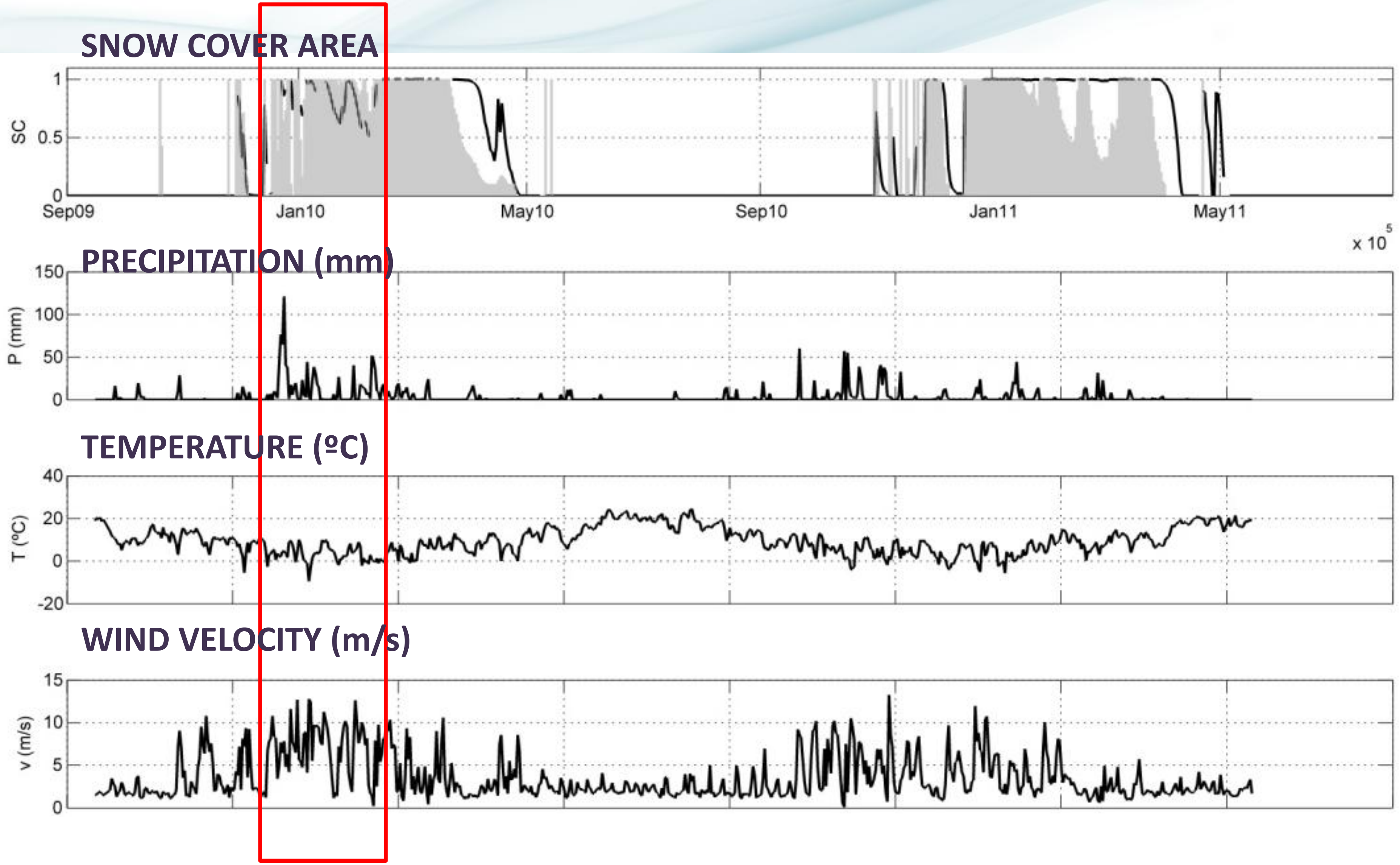
Simulation 2 [kE_{H0}=3 $Wm^{-2}K^{-1}$] RMSE=0.1908

SNOW COVER AREA MODEL CELL (30 x 30)



SNOW COVER AREA MODEL CELL (30 x 30)




SNOW COVER AREA
SC
1
0.5
0
Sep09
Jan10
May10
Sep10
Jan11
May11
x 10^5
PRECIPITATION (mm)
P (mm)
150
100
50
0
TEMPERATURE (ºC)
T (ºC)
40
20
0
-20
WIND VELOCITY (m/s)
v (m/s)
15
10
5
0

CONCLUSIONS

- **Terrestrial photography allow to characterize the variability of the snow cover in the study scales**

▪ **<u>Hillslope scale</u>**

- **The snow patches are not corectly represented with the current model.**

▪ **<u>Detail scale</u>**

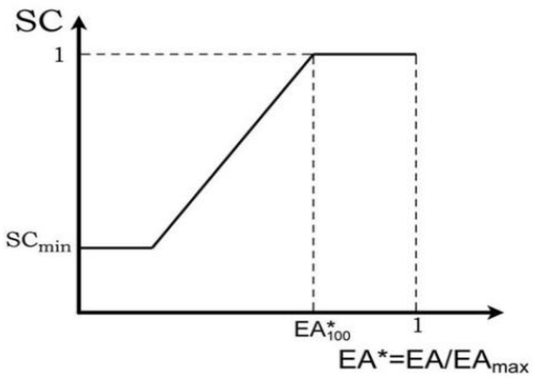
- **The snow masks indetify the period where the initial calibration model has no success in representing the spatiotemporal variation and improve the calibration of the model representing more satisfactorily the final snowmelt spring season.**

- **Wind interpolation is needed to capture the join influence of high precipitation rate and wind speed specially with these conditions are maintained on several days**

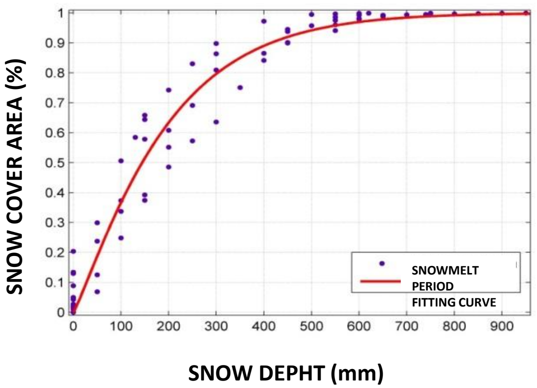
ONGOING WORK

- New parametrization Depletion Curves

Current parameterization



New parameterizarion



Snow depth detection

- **Improvement of wind interpolation in a very complex terrain - ARPS model in Sierra Nevada**

ACKNOWLEDGEMENT

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THANKS FOR YOUR ATENTION

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