Climate Change

Service development and prototyping : Mountain tourism

Samuel Morin[1], Hugues François[2], Jean-Michel Soubeyroux[3], Bruno Abegg[4], Pierre Spandre[1,2], Matthieu Lafaysse[1], Deborah Verfaillie[1], Emmanuelle George[2], Cenk Demiroglu[5], **Marc Pons**[6], Fabian Weber[7], Adeline Cauchy[8]

[1]Météo-France – CNRS, CNRM, Centre d'Etudes de la Neige, Grenoble
[2]Irstea, LESSEM, Grenoble
[3]Météo-France, Direction de la Climatologie et des Services Climatiques
[4]University of Innsbruck
[5]UMU
[6]UPC and Snow and Mountain Research Center of Andorra
[7]ITL
[8]TEC Conseil

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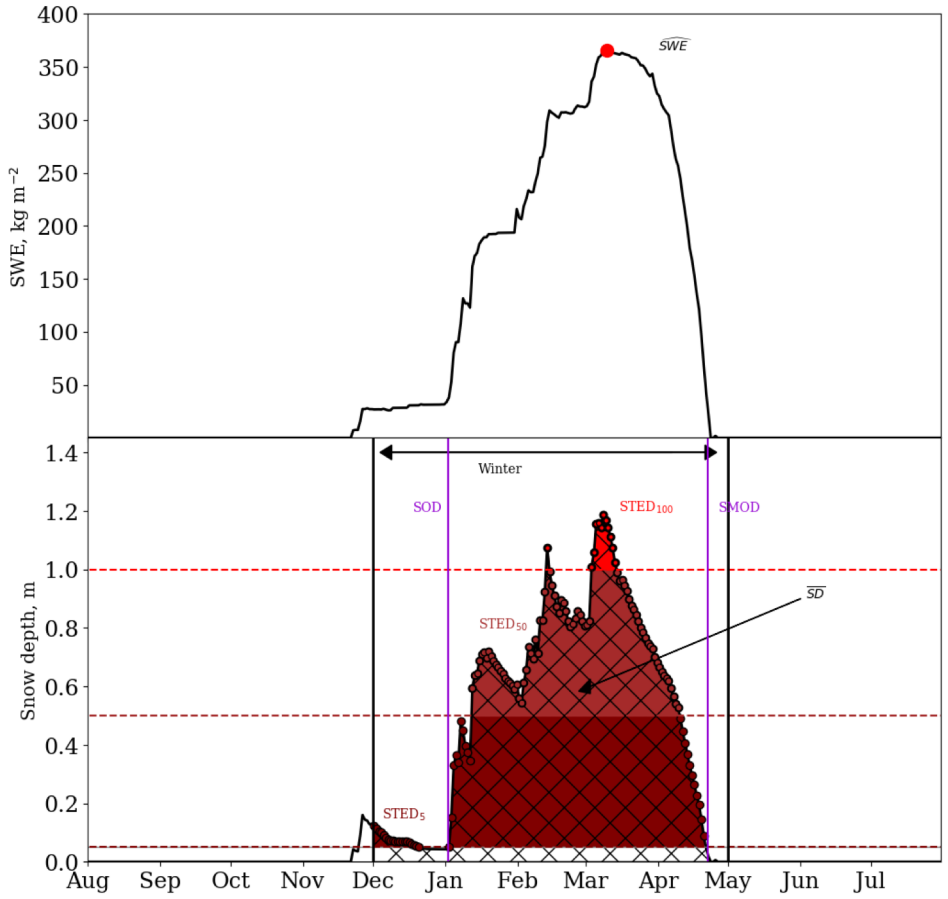
Ski tourism indicators (point scale)

Uses daily or subdaily meteorological conditions and daily snow conditions (depth, SWE)

Annual indicators based on various time periods, threshold exceedance counts, or min/max value, or average over given period



Verfaillie et al., 2018

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Climate Change

Ski tourism indicators (point scale)

Example (countless):

Variables	Time period	Reference to threshold	Threshold	Purpose
Wet bulb temperature	November-December	Lower than	-2°C, -4°C	Snowmaking conditions
Snow depth (natural, flat terrain)	November to April	Larger than	5 cm	"Wintery conditions"
Snow depth (natural, flat terrain)	November to April	Larger than	30 cm	Match with "100-days rule" (ski resorts operating conditions)
SWE of managed snow (managed: groomed+snowmaking)	Dec 22-Jan 4 and February 1-28 (holiday period)	Larger than	100 kg m^{-2}	Combined holidays snow reliability indicator
…	…	…	…	…

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Geographical scale : NUTS-3 regions

Advantages:

-Defined throughout all countries of the European Union (EU-28), with corresponding statistical regions in EFTA countries, candidate countries and potential candidates

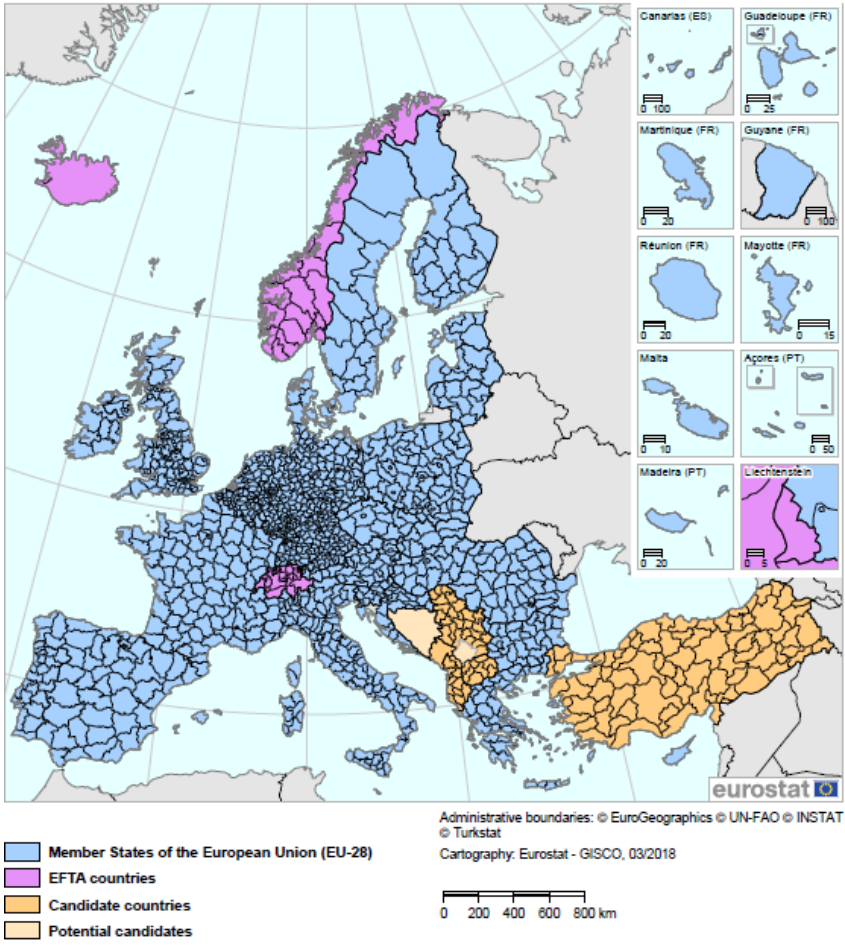
- Allows for homogenous treatment for all relevant coutries

- Potential for direct coupling with other socio-economic statistical indicators

- « Reasonable » spatial scale for a European-wide service (ca. 1300 NUTS-3 in total)

Disadvantages:

- Administrative boundaries not always relevant for climate information (there could be better national/local products)



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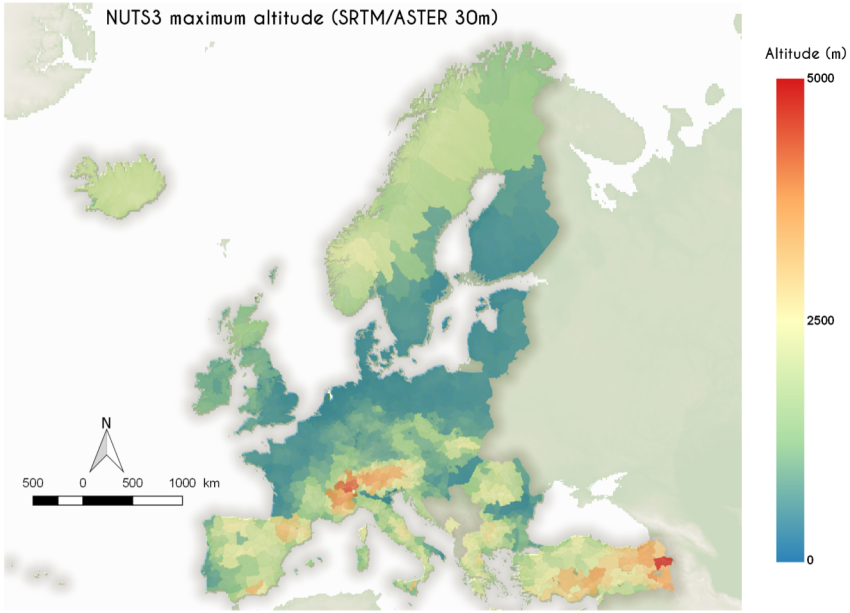
Geographical scale : NUTS-3 regions

Altitude ranges:

Based on interviews with stakeholders (and consistent with literature), the altitude range attracting most attention and critical challenges lies between **1000 and 2000 m altitude, within which indicators should be computed every 100 m altitude**. It is further suggested to add altitude levels **of 2500 m, 3000 m and 3500 m altitude, relevant for some alpine locations, and add altitude levels between 300 m and 1000 m (every 200 or 300 m altitude) for lower-lying mountain areas (e.g., Scandinavia)**.

Flat terrain and also representative slopes can be processed (typically, 20° slope, N-E-S-W aspect).



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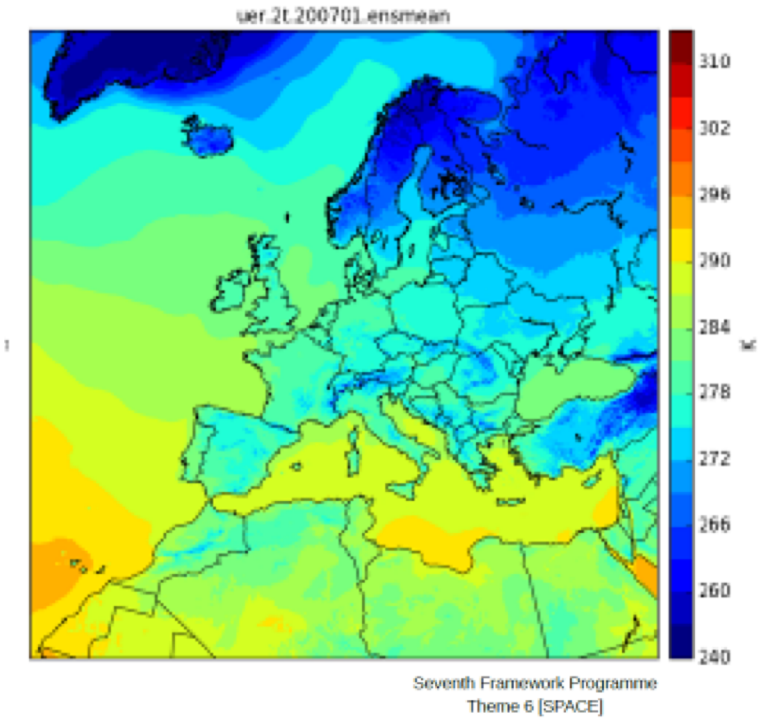
Climate information at NUTS-3 scale

Best available RCM runs = EUROCORDEX 12 km resolution, needs dowscaling and bias correction (adjustment)

Use of UERRA 5.5 km reanalysis 1950-2006, covers all relevant meteorological information for running detailed snowpack models



MESCAN-SURFEX, Bazile et al., 2017

Seventh Framework Programme
Theme 6 [SPACE]

UERRA
Uncertainties in Ensembles of Regional ReAnalyses

Project: 607193 UERRA

Full project title:
Uncertainties in Ensembles of Regional Re-Analyses

Deliverable D2.9

Ensemble surface reanalysis report

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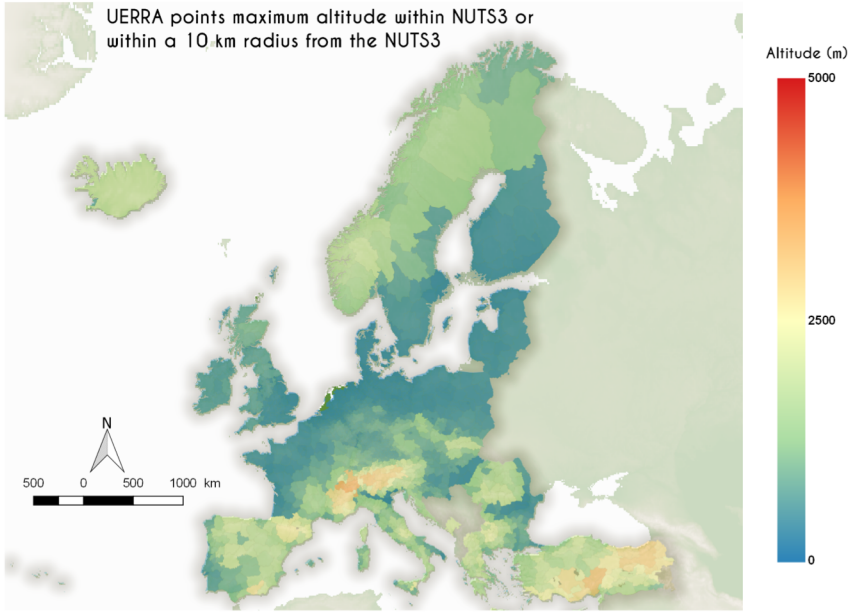
Climate information at NUTS-3 scale

Best available RCM runs = EUROCORDEX 12 km resolution, needs dowscaling and bias correction (adjustment)

Use of UERRA 5.5 km reanalysis 1950-2006, covers all relevant meteorological information for running detailed snowpack models

Preliminary investigations indicate that the 5.5 km grid of UERRA reanalysis features reasonable coverage of altitude ranges in each NUTS-3



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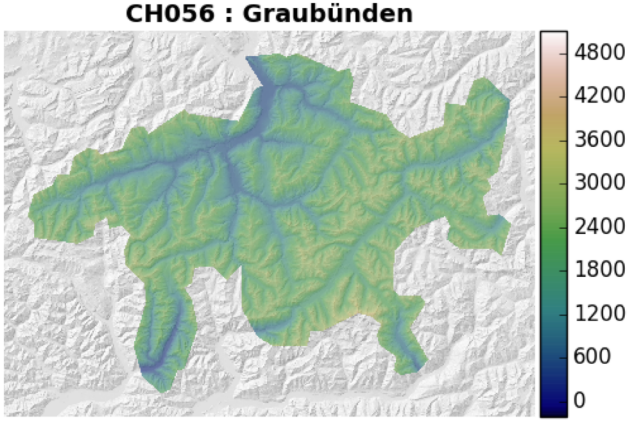

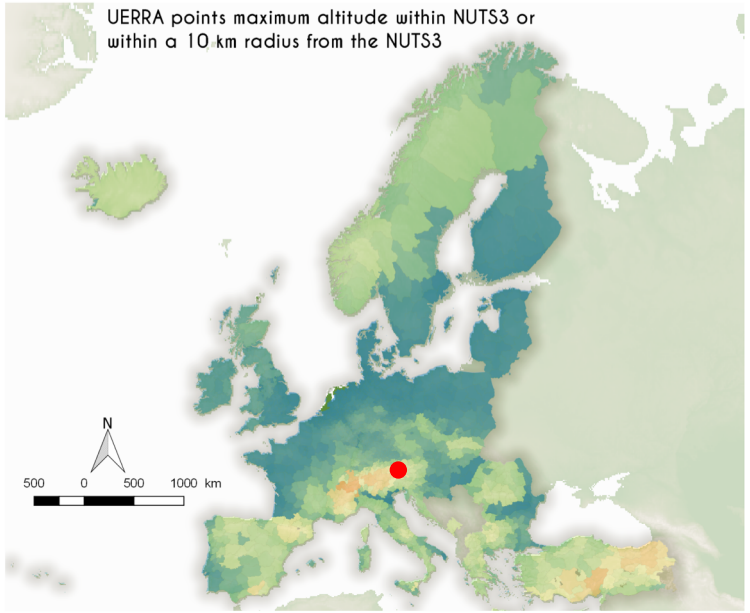

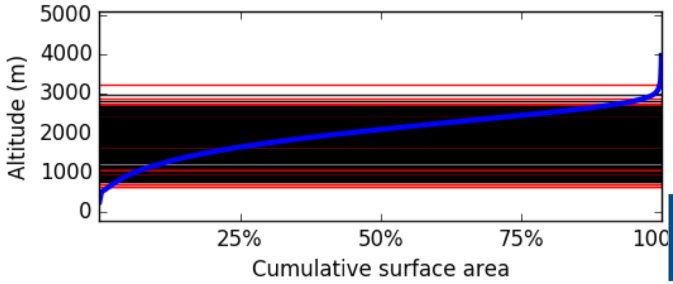

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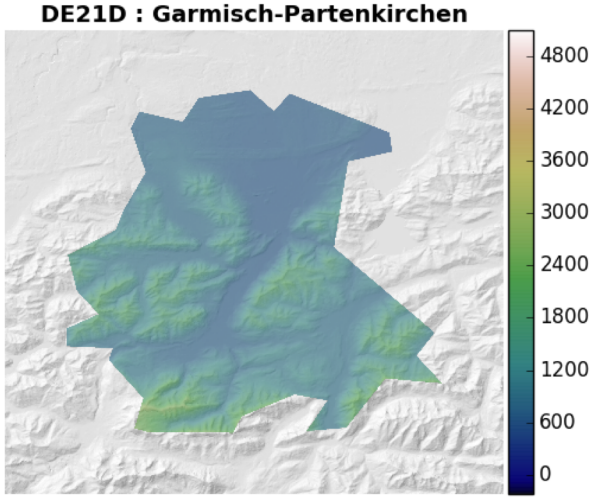

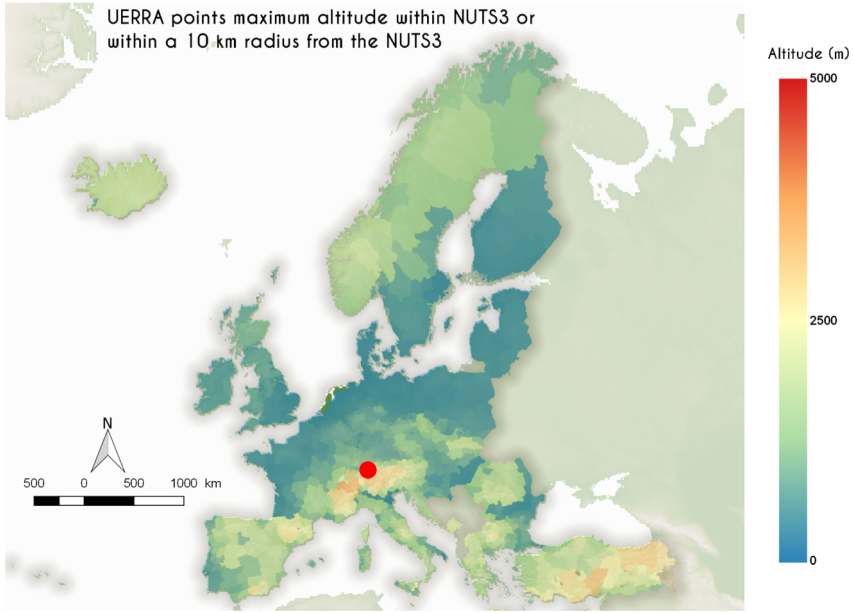

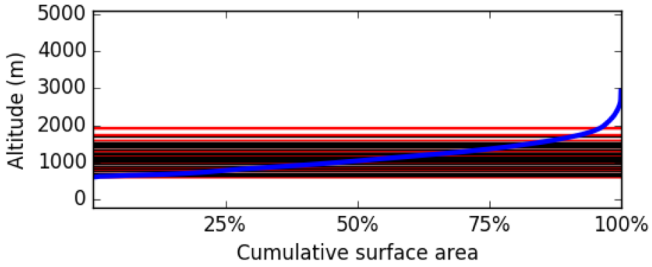

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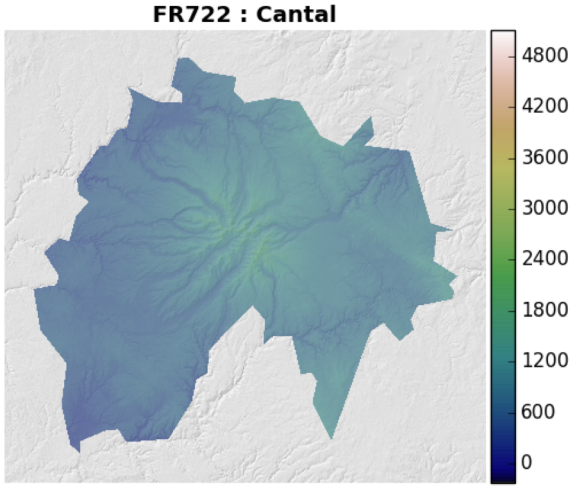

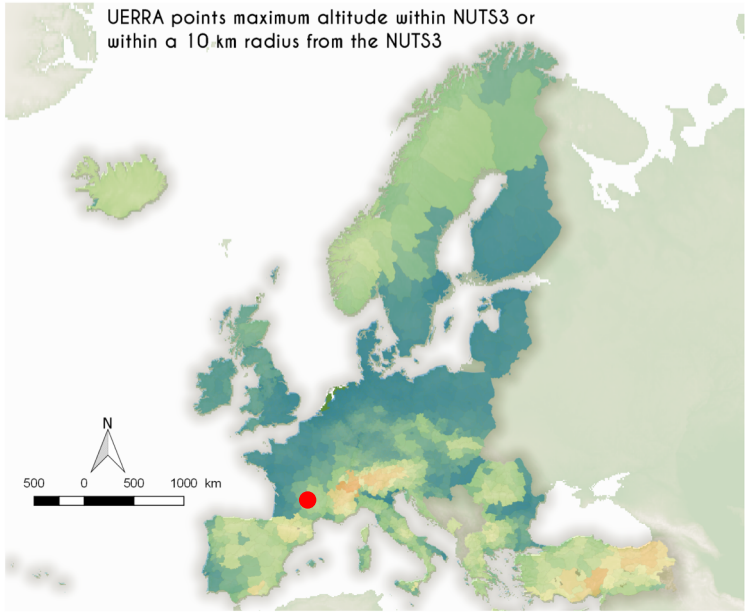

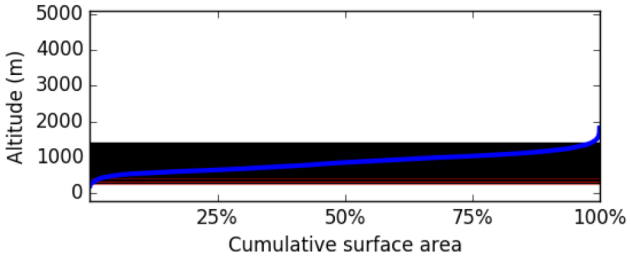

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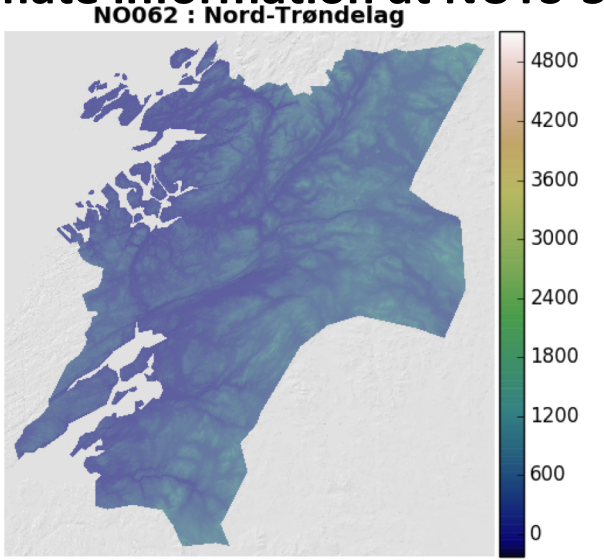

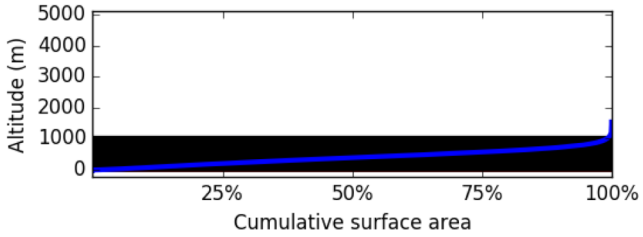

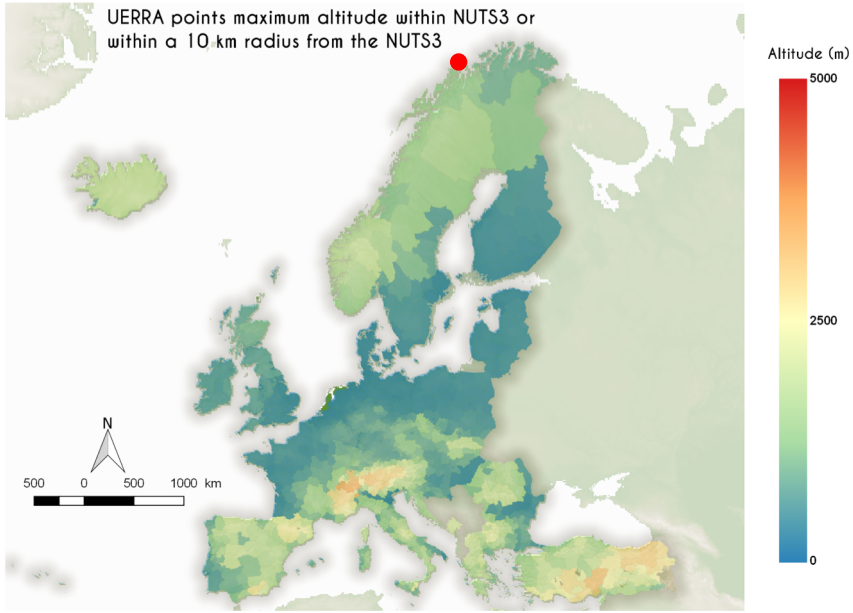

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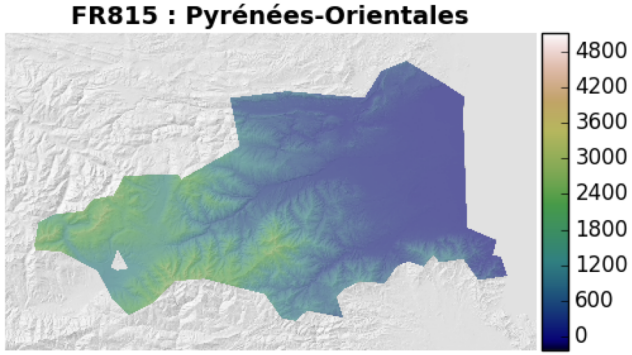

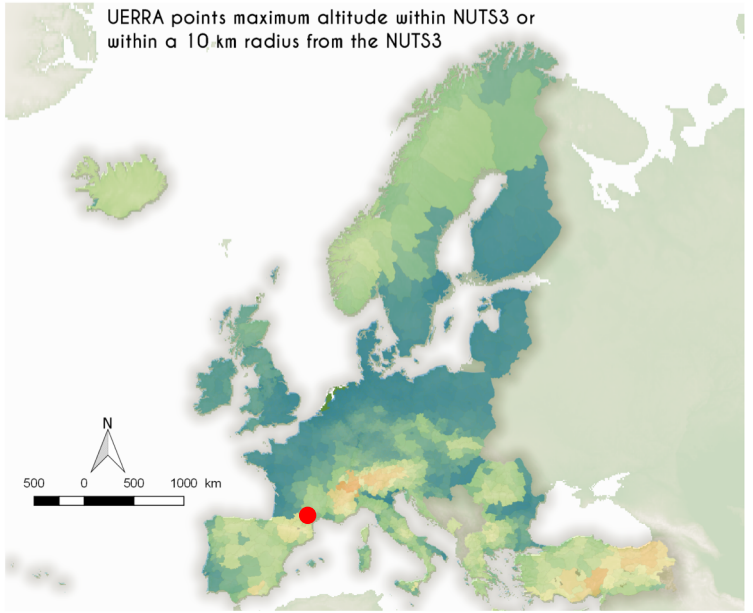

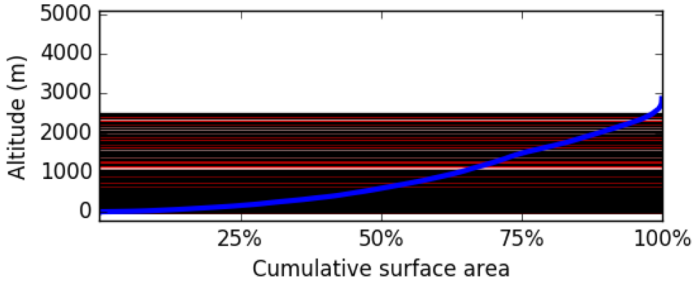

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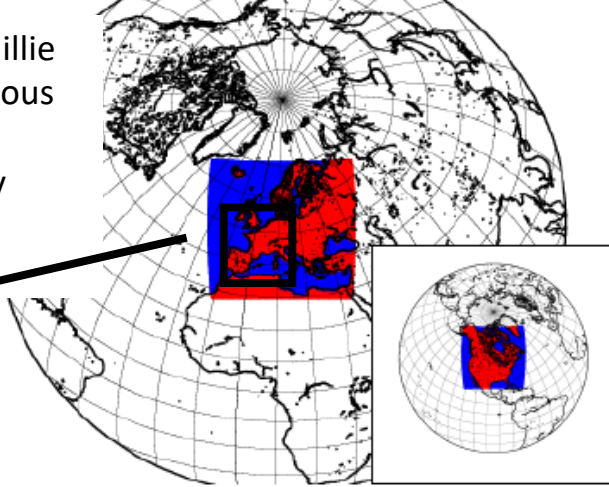
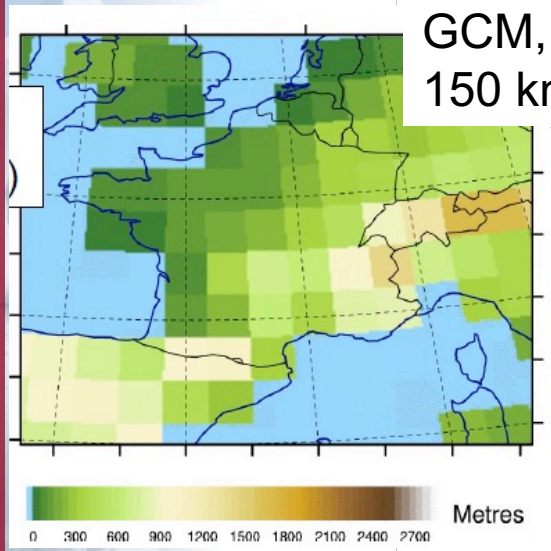
Climate Change

Dowscaling/ bias correction

Planned use of the **ADAMONT** method (Verfaillie et al., 2017 GMD), proved in French mountainous areas and providing sub-daily & adjusted meteorological files capable for driving energy balance land surface models.

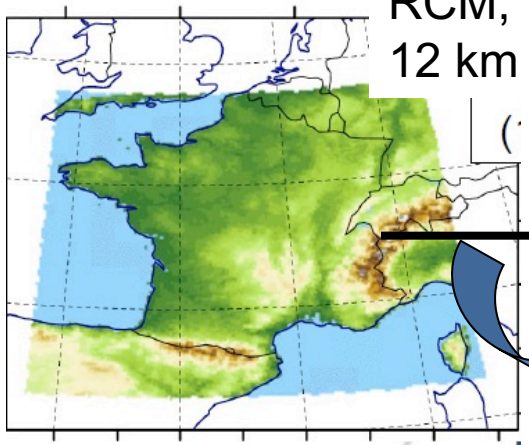


GCM, 150 km



EUROCORDEX

RCM, 12 km



Statistical adjustment ADAMONT at NUTS-3 altitude level

Regional climate model (RCM)

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Dowscaling/ bias correction

Planned use of the ADAMONT method (Verfaillie et al., 2017 GMD), proved in French mountainous areas and providing sub-daily & adjusted meteorological files capable for driving energy balance land surface models.

GCM/RCM pairs : planned use of the subset of 7 EUROCORDEX GCM/RCM pairs selected for C3S SIS (TBD)

Time range : 1950 – 2100.

Data will be generated for all seasons, including summer (possible to compute mountain holiday comfort indices etc.)

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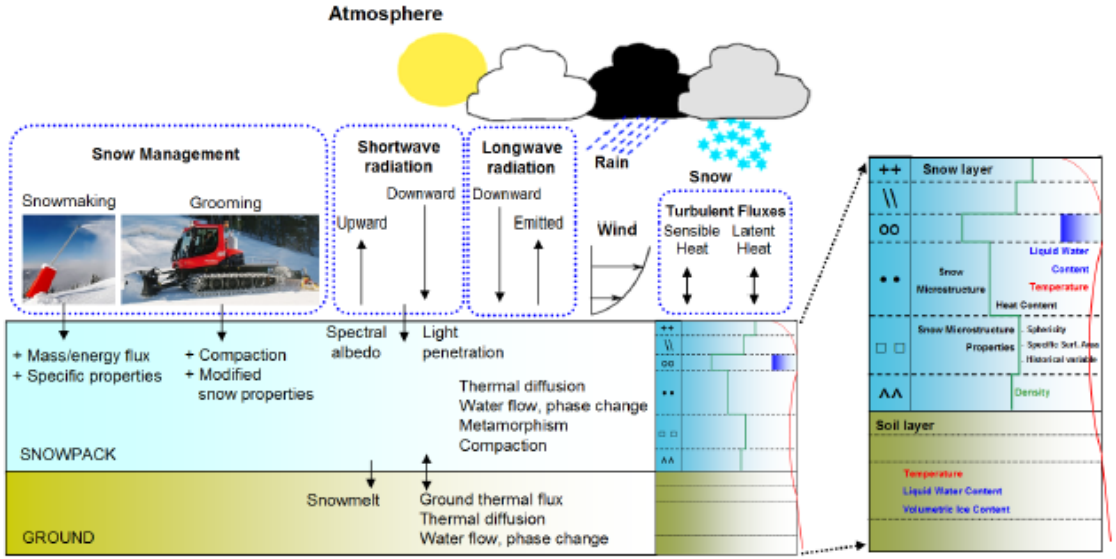
Snow modeling

Crocus-Resort snowpack model (Spandre et al., 2016)

Feature realistic options for snow management (grooming, snowmaking), details of the implementation to the discussed in the group prior to the implementation (thresholds, periods of time, water consumption targets etc.)

Model will be driven by UERRA 5.5 km reanalysis and adjusted climate projections (in NUTS-3 points)



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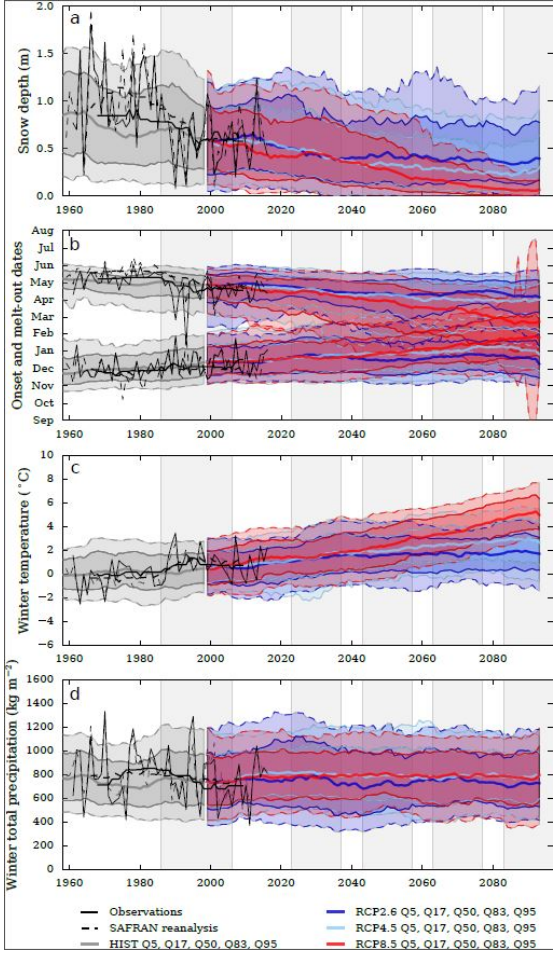
Processing and visualization of annual indicators ?

Examples :

- Time series ? (with quantile of annual values and/or multi-model averages over variable integration windows, or frequency of occurrence of « worst-case » quantile values ?)

- Relationships to global warming levels ?

(this should all be parameterized on the CDS toolbox)



Example 1500 m altitude, Chartreuse range

Verfaillie et al., 2018

Time slot		$\overline{SD}$ (m)		
		Q17	Q50	Q83
Ref	OBS		0.66	
	S-C		0.69	
	HIST*	0.30	0.63	1.02
	HIST**	0.27	0.65	1.04
2030	2.6	0.19	0.43	0.82
	4.5	0.20	0.46	0.86
	8.5	0.18	0.45	0.82
2050	2.6	0.16	0.46	0.83
	4.5	0.12	0.33	0.64
	8.5	0.08	0.28	0.59
2070	2.6	0.17	0.41	0.79
	4.5	0.06	0.28	0.61
	8.5	0.03	0.13	0.33
2090	2.6	0.12	0.36	0.77
	4.5	0.05	0.24	0.55
	8.5	0.00	0.06	0.16

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EUROCORDEX Regional projections (daily, surface fields + synoptic geopotential) - UERRA 5.5 km Reanalysis (subdiurnal) for selected mountain points

Adjustment ADAMONT

5.5 km Projections of subdiurnal **meteorological** conditions (several GCM/RCM pairs, several RCPs)

Crocus

Daily **meteorological** conditions

Daily natural and managed **snow** conditions (depth, SWE, water used for snowmaking)

Yearly seasonal indicators of **meteorological** conditions

Yearly seasonal indicators of natural and managed **snow** condtions

Multi-annual/ multi-scenarios aggregated indicators of **meteorological** conditions

Multi-annual/ multi-scenarios aggregated indicators of **snow** conditions

User

Increasing level of Interactivity (**user experience**)

Increasing level of CDS post-processing capabilities

Increasing level of CDS integration of models

Increased **development** cost (no benefit for users)

Downscaling /adjustment	Snow modeling	Computation of individual annual indicators	Post-processing of annual indicators	User access
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Downscaling /adjustment	Snow modeling	Computation of individual annual indicators	Post-processing of annual indicators	User access

Download/visualize predfined added-value indicators only

User selects method for time/space/ scenarios/pairs aggregation of pre-defined annual indicators

User defines own annual indicators based on available daily data

Snow simulations performed online at ECMWF (requires that subdiurnal data are available and Crocus installed at ECMWF)

Climate projections adjusted online (requires that PRECISE and PRINCIPLES are implemented and data available) and ADAMONT method installed at ECMWF.

CDS online tools

Offline (MF)

Recommandation for C3S SIS European Tourism SC2

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EUROCORDEX
Regional projections
(daily, surface fields
+ synoptic geopotential)
-
UERRA 5.5 km
Reanalysis (subdiurnal)
for selected
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Adjustment
ADAMONT

5.5 km
Projections of
subdiurnal
meteorological
conditions
(several
GCM/RCM
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several RCPs)

Crocus

Daily
meteorological
conditions

Daily natural
and managed
snow conditions
(depth, SWE,
water used
for snowmaking)

Yearly seasonal
indicators of
meteorological
conditions

Yearly seasonal
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Multi-annual/
multi-scenarios
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Downscaling
/adjustment

Snow
modeling

Computation of
individual
annual
indicators

Post-processing
of annual
indicators

User access

User defines own annual indicators based on available daily data

CDS online tools

Offline (MF)

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Requirements of CDS/Toolbox for proposed scenario

• Capability to handle and process (data generation and plotting) multi-annual / multi-GCM/RCM pair annual indicator data) using state-of-the-art methods (quantiles or averages over various integration windows, thresholding above/below value, relationship to global warming levels), at the scale of each NUTS-3 region but also displayed on maps for a given altitude level (e.g., 1200 m altitude for all of European mountain regions featuring this altitude level)

• Capability to compute annual indicators from series of daily or subdaily meteorological or snow values, univariate or multivariate indicators, averages/sums/averages/threshold exceedance over given (variable) time period(s) (e.g., combined Christmas / February snow reliability indicator)

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Requirements of CDS/Tooblox for full scenario

- Implementation of Crocus-Resort snowpack model on the CDS
- Implementation of the ADAMONT adjustment/downscaling/disaggregation method on the CDS

Probably impractical to do within time constraints of SC2, to be planned for future developments.

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Users Case Studies

- ATC Mountain Consultats
- Association of Swiss Cable cars
- Andorra Climate Change Office
  Andorra Ski Resorts

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Summary

-Copernicus C3S SIS European Tourism / Mountain embarks us on an ambitious plan of generating European-wide mountain tourism indicators (in particular for snow-related indicators).

-A pragmatic plan building on existing state-of-the-art tools is proposed, reaching beyond their current implementations and filling a gap in scientific knowledge and climate services

- The spatial resolution chosen is a compromise between mountain topography, operational constraints of tourism stakeholders, and the representation of mountains in regional reanalysis (UERRA-5.5 km -> Copernicus European Reanalysis) and regional climate projections (EUROCORDEX -> Copernicus Regional Climate Projections)

- Attention will ne needed to ascertain the quality of the obtained product (one of the advantages of the case studies for target areas where higher resolution, better “known” products are available – e.g. SAFRAN in Andorra) ; neithet the UERRA 5.5 km reanalysis nor EUROCORDEX are designed for moutains.

- Tools for generating and processing annual-scale indicators is the minimum we should thrive to achieve on the CDS / toolbox

Thanks for your attention. Questions ?

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