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A 18-yr long (1993–2011) snow and meteorological dataset from a mid-altitude mountain site (Col de Porte, France, 1325 m alt.) for driving and evaluating snowpack models

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Abstract

A quality-controlled snow and meteorological dataset spanning the period 1 August 1993–31 July 2011 is presented, originating from the experimental station Col de Porte (1325 m altitude, Chartreuse range, France). Emphasis is placed on meteorological data relevant to the observation and modelling of the seasonal snowpack. In-situ driving data, at the hourly resolution, consist in measurements of air temperature, relative humidity, wind speed, incoming short-wave and long-wave radiation, precipitation rate partitioned between snow- and rainfall, with a focus on the snow-dominated season. Meteorological data for the three summer months (generally from 10 June to 20 September), when the continuity of the field record is not warranted, are taken from a local meteorological reanalysis (SAFRAN), in order to provide a continuous and consistent gap-free record. Evaluation data are provided at the daily (snow depth, snow water equivalent, runoff and albedo) and hourly (snow depth, albedo, runoff, surface temperature, soil temperature) time resolution. Internal snowpack information are provided from weekly manual snowpit observations (mostly consisting in penetration resistance, snow type, snow temperature and density profiles) and from a hourly record of temperature and height of vertically free "settling" disks. This dataset has been partially used in the past to assist in developing snowpack model and is presented here comprehensively for the purpose of multi-year model performance assessment. The data is placed on the PANGAEA repository (http://doi.pangaea.de/10.1594/PANGAEA.774249) as well as on the public ftp server ftp://ftp-cnrm.meteo.fr/pub-cencdp/.

1 Introduction

The development of complex geophysical models requires adequate driving and evaluation data. In the case of hydrological models able to handle the inception, build-up and melt of a seasonal snowpack, the driving data consist in meteorological data and the evaluation data consist in detailed information pertaining to the soil and the

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overlying snowpack. Such data-sets are relatively scarce when meteorological data are required to include all the needed components, including both solar and thermal incoming fluxes and a precise estimate of snow and rain precipitation at a time step on the order of one hour. However, such data-sets are absolutely necessary to develop and evaluate snowpack and hydrological models, which are then used for hydrological forecasting, avalanche risk prediction, or within land surface models of numerical weather prediction of climate models.

The Col de Porte (CDP) site, located at 1325 m altitude (45.30° N, 5.77° E) in the Chartreuse mountain range, France, has been operated by Météo-France, in collaboration with several academic and non-academic partners, since 1959. Hourly driving data and the corresponding evaluation data were collected during the snow season 1987–1988 during the early stages of the developments of the Crocus snowpack model (Brun et al., 1989). Since the snow season 1993–1994, the full range of required meteorological driving data and the adequate evaluation data have been collected. The data have been instrumental in developing and evaluating snowpack models, including the initial SnowMIP effort (Etchevers et al., 2004). Here we provide background and up-to-date information on the data that has been collected between 1993 and 2011, resulting in an uninterrupted 18-yr long dataset freely available.

2 Data description

2.1 Site description

The CDP experimental site is located in a grassy meadow surrounded by a coniferous forest; all the measurements are located within an area of 50 × 50 m at most. A building (ca. 50 m^2) hosts the data acquisition system, laboratory space and a cold-room used for experimental work on snow. Figure 1 provides an overview of the site environmental setting and the relative location of the instruments used. The height of the coniferous trees on the eastern side of the meadow lies between 10 and 20 m. Direct solar radiation can be blocked by surrounding mountains, trees or other obstacles. Solar masks were obtained in the middle of the plot (specifically, at the location of the radiation sensors) and are provided along with the current dataset.

Besides natural growth of the trees and occasional cutting of some in the forest nearby on the eastern side of the meadow, the only significant change in the site characteristics occurred in the summer 1999, when all the trees forming a natural ridge on the northern side of the experimental plot were cut, resulting in a slight change in wind patterns at the site.

Snow is present on the ground several months per year, but owing to the relatively low altitude of the site, surface melt or rain events can occur anytime in the season. In the absence of snow, the soil can undergo subsurface freezing; however, sustained soil freezing has only seldom been observed at −10 cm (one significant occurrence within the last 18 seasons, during the season 2001–2002).

The soil texture can be reasonably characterized by the following proportions: 30 % clay, 60 % sand, 10 % silt.

2.2 Meteorological driving data

All the data presented here have undergone careful (manual) quality insurance during the period of the year concerned with snow on the ground. This time period has stabilized over the years to the period between 20 September and 10 June. Outside this time interval, atmospheric data are replaced by the output of the SAFRAN meteorological analysis and downscaling model using ARPEGE meteorological fields and neighbouring observations (Durand et al., 1993). This discontinuity of the dataset is insignificant provided that the data is used with a focus on the winter (snow) season. However, such a gap-filling is needed to run a land surface model over several years continuously with a consistent physical state of the soil vertical column in summer. Figure 2 shows a summary of the partitioning between in-situ and SAFRAN data for the years used in the present dataset. Within the snow season, data gaps were filled using duplicate sensors from the research plot or, alternatively, using data from neighbouring days consistent with the weather conditions. Depending on the years and on the sensors, missing data represent at most a few % (less than 5 %) of the in-situ winter record. The last step of the quality-control procedure consists in using them to run the snowpack model Crocus (Brun et al., 1992; Vionnet et al., 2011), which allows to identify potential inconsistencies in the driving data, such as missing precipitation events.

Table 1 provides an overview of the hourly meteorological driving data, with the corresponding instrument type and height.

2.2.1 Air temperature and relative humidity

Air temperature (Pt100) and relative humidity (capacitive) sensors are placed in a WMO-standard meteorological shelter, which can be moved vertically to keep a relative constant height over snow. This adjustment is generally carried out on a weekly to semi-weekly basis, consistent with the frequency of visits to the site during the snow season. The uncertainty on temperature and relative humidity lies within 0.1 K and 5 %, respectively, consistent with common uncertainties on meteorological data.

2.2.2 Wind speed

Wind speed is measured using both heated and non-heated cup anemometers. They differ in terms of starting threshold, so that a combination of the two needs to be performed to provide a reliable assessment of wind-speed. This and the hourly averaging procedure hampers a precise quantification of the associated uncertainty.

2.2.3 Incoming shortwave and longwave radiation

The shortwave and longwave radiation sensors are mounted on a rotating arm, which allows to automatically clean them every hour provided that the air temperature is below 5 °C. The procedure consists in brushing the surface of the sensors, warming them up using an heated-air blower, followed by returning them to ambient temperature conditions using blowing air at ambient temperature. Countless experiments and adjustments have resulted in the establishment of this procedure, which was found to prevent significant frost build-up and the accumulation of snow on the sensors. In addition, the sensors holder can be moved vertically to manually adjust to the snow depth and keeping an approximately constant distance between the sensors and the snow surface. For both shortwave and longwave radiation, identical sensors are used for upwards and downwards flux measurements. During snowfall, the shortwave incoming radiation measurements are not reliable due to snow build-up on the sensor during the measurement period. To circumvent this problem and provide gap-free records, the incoming radiation is computed from the reflected radiation measurement (not affected by snow deposition on the sensor) using albedo data from subsequent hours as soon as the snowfall has ceased. The total uncertainty affecting the radiation measurements is estimated to be on the order of 5 %.

2.2.4 Precipitation

Precipitation is measured using three gauges: one GEONOR gauge and two PG2000, only one of both is heated as soon as the air temperature drops below 5 °C. Note that the heat rate is adjusted so that the temperature of the precipitation collector remains lower than 5 °C to avoid evaporation as much as possible. The GEONOR gauge is corrected for wind-speed following Forland et al. (1996), using a heated cup anemometer placed a short distance from the gauge (1 m horizontally, same height above ground), since the snow season 1999–2000. Before then, a constant correction factor was applied on a yearly basis, which was adjusted for a given year from the comparison between precipitation and SWE measurements; this factor remained on the order of 10 % maximum.

The three instruments provide hourly increments in precipitation, which must be partitioned between rain and snow. The latter partitioning is carried out manually using all possible ancillary information, primarily air temperature but also dual information from the heated/non-heated instruments, snow depth and albedo measurements.

2.2.5 Atmospheric pressure

Atmospheric pressure is measured inside the laboratory and its average value of 780 hPa is often used instead of its real variations due to the generally negligible impact of this variable on snow-related processes.

2.3 Evaluation data

Table 2 gives an overview of the hourly and daily evaluation data, along with the corresponding sensor and the time period covered in the dataset.

2.3.1 Snow depth

Snow depth is measured using ultra-sound depth rangers. The correction of the impact of air temperature on the velocity of sound in the atmosphere is carried out using air temperature measured at ca. half distance between the sensors and the ground surface. The data are further manually corrected to remove outliers in the dataset, mostly occurring during snowfall. Since the year 2010–2011, a laser ranger was installed, which has proven less disturbed by ongoing snowfall. Data from the two instruments are now used together to provide the best possible continuous snow depth record. Ultra-sound depth rangers provide measurements accurate within 1 cm for a surface area of a few cm^2 on the ground. In contrast, laser ranger tend to provide more accurate results, but the footprint of the instrument is much smaller (ca. 1 cm^2). The overall accuracy of the automated snowdepth record is on thus the order of 1 cm.

In addition to these automated measurements, manual snow depth measurements are available at a weekly time resolution from the snowpit observations, complemented by two additional manual snow depth measurements.

2.3.2 Snow water equivalent

Snow water equivalent (SWE) monitoring is challenging although it is key to evaluate snowpack models. Several methods exist to attempt to monitor it automatically (snow pillow (e.g. Reba et al., 2011), sensors based on ground-emitted particles, etc.). At CDP, SWE is measured since the season 2001–2002 using a ground-based cosmic rays counter operated by EDF-DTG (termed NRC; Kodama et al., 1979; Paquet and Laval, 2006). This instrument requires a site-specific calibration, which is performed using manual measurements of SWE and shows little variation from year to year. The resulting uncertainty is on the order of 10 %. The key advantage of using this method is that the interface between the snowpack and the underlying ground is not disturbed; indeed, the instrument consists in a small box (horizontal footprint 1 × 0.2 m) whose top is at ground level, thereby minimizing the disturbance induced by the sensor. The manual SWE measurements are carried out on a weekly basis. Up to three measurements are taken (one at the snowpit sampling site, terme "Snowpit", and two others besides the NRC instrument, termed "Snowpit South" and "Snowpit North").

2.3.3 Snow albedo

Snow albedo is measured using the radiation sensors described in Sect. 2.2.3. Hourly albedo data are computed from the ratio between incoming and reflected shortwave radiation. However, data are discarded when the incoming radiation level is below 20 $\mathrm{W\,m^{-1}}$ and the reflected radiation is below 2 $\mathrm{W\,m^{-1}}$. In addition, data from simultaneous snowfall are also discarded from the hourly record.

Daily integrated albedo data are computed from the daily summation of all incoming fluxes divided by the summation of all reflected fluxes, using the thresholds described above. This provides a useful measure of the effective albedo of the snowpack, and removes effects from varying solar zenith angle and shades due to the surrounding forest. Data are reported if more than 5 h can be used to compute the albedo.

2.3.4 Surface snow temperature

Snow surface temperature (SST) can be computed from the outgoing longwave flux measured using the sensors described in Sect. 2.2.3. Alternatively, a narrow field of view infra-red sensor is also used. The latter is placed on the same structure as the radiation sensors, but it does not undergo any particular cleansing or defrosting. The other difference is that this sensor records punctual measurements every hour, rather than hourly-integrated measurements. For both sensors, the snow emissivity is set to 1. when computing the SST from the outgoing longwave radiation. The lower of the two measurements is provided in the dataset; spurious exceedance of the melt point can be observed, in such case the record has to be interpreted in a more qualitative manner.

2.3.5 Internal snow temperature (“settling disks”)

Internal snow temperature is measured continuously from several plates, allowed to slide freely on a vertical wire, and placed at the top of the snowpack following each significant snowfall (i.e. the SWE of the snowfall is larger than approximately 40 $\mathrm{kg\,m^{-2}}$). In addition to the snow temperature measurements, the vertical position of the plates is recorded through a resistance measurement through the wire holding the plates. The electrical contact between the plates and the wire is secured using a metal spring; previous versions of this device were carried out using liquid mercury, and was replaced for obvious environmental reasons. The uncertainty on the temperature and height of the disks is within 0.1 K and 1 cm, respectively.

2.3.6 Runoff

Runoff is measured in the basement of the laboratory, by weighting the water flowing through two pipes connected to each lysimeters (1 and 5 $\mathrm{m^2}$). Note that inconsistencies between total precipitation and runoff at the scale of the season is possible owing to lateral transport in the snowpack, which depends on the snowpack type, e.g. the occurrence of melt-freeze crusts and the location of percolation channels. Several approaches have been employed over the years to try to avoid such issues, relying in particular on the use of vertical walls around the lysimeter collector space, with unconclusive results. Nevertheless, such data provide useful indications on the timing and magnitude of basal runoff. It is virtually impossible to provide an uncertainty assessment for runoff data; a good indication of the variance can be found by looking at the two records from the two instruments.

2.3.7 Soil temperature

Soil temperature is measured at 10, 20 and 50 cm below ground. The probes are placed in the ground a few meters from the automated snow depth measurements. The uncertainty lies within 0.1 K for such measurements.

2.3.8 Basal heat flux

Basal heat flux is measured since the season 2010–2011 using three heat flux plates located in the immediate vicinity of the automated snow depth measurements, 1 cm below ground and at ca. 1 m distance to each other. The three resulting values are provided, which is useful to estimate the short-scale variability of this variable, hence an assessment of the degree of confidence which can be placed in such data.

2.3.9 Vertical profiles of the physical properties of snow

Snow stratigraphy observations have been carried out at approximately weekly time resolution throughout the period considered. They consist of manual measurements of the vertical profile of penetration resistance (standard Ramm sonde), snow temperature, density, type, liquid water content, and grain size as determined by visual inspection of grains following Fierz et al. (2009). The 303 profiles are provided as separate files using the international CAAML format (http://www.caaml.org).

3 Data availability

The data from CDP have been widely used for snowpack development and evaluation, thereby meeting the needs of Météo-France and external users nationally and internationally. However, until now, all known uses of the data have consisted in year-by-year model runs and evaluation. The new collated data set allows multi-year model runs. The driving and evaluation data are provided as ascii and netCDF files; the latter are formatted to be used as is in the land surface model ISBA within SURFEX, which allows coupling to several snowpack schemes (ES, Crocus; Vionnet et al., 2011). Summary plots of the present data-set are provided as Supplement to this article.

The dataset presented here is available freely, either from PANGAEA (http://doi.pangaea.de/10.1594/PANGAEA.774249 or on the anonymous ftp server ftp://ftp-cnrm.meteo.fr/pub-cencdp/.

All inquiries regarding the dataset should be addressed at col_de_porte@meteo.fr.

4 Conclusions

18 yr of quality-controlled data driving and evaluation data from the meteorological research station Col de Porte, Chartreuse mountain, France, have been collated and consolidated, are presented comprehensively and made freely available and accessible to the scientific community. It is anticipated that such a dataset will continue to prove useful for snow and hydrological model development and evaluation. Data for upcoming years will be added to the data set on a yearly basis, following the strict quality-control procedure described above. CDP also hosts short-term experimental campaigns, some of which end up providing long-term records of previously unmeasured data; we hope that further instrumental developments will allow to improve the monitoring of the atmospheric, snow and soil column in the future, leading to further extension of the CDP snow and meteorological data base.

Supplementary material related to this article is available online at: http://www.earth-syst-sci-data-discuss.net/5/29/2012/ essdd-5-29-2012-supplement.zip.

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References

Brun, E., Martin, E., Simon, V., Gendre, C., and Coléou, C.: An energy and mass model of snow cover suitable for operational avalanche forecasting, J. Glaciol., 35, 333–342, 1989. 31

Brun, E., David, P., Sudul, M., and Brunot, G.: A numerical model to simulate snow-cover stratigraphy for operational avalanche forecasting, J. Glaciol., 38, 13–22, 1992. 33

Durand, Y., Brun, E., Mérindol, L., Guyomarc'h, G., Lesaffre, B., and Martin, E.: A meteorological estimation of relevant parameters for snow models, Ann. Glaciol., 18, 65–71, 1993. 32

Etchevers, P., Martin, E., Brown, R., Fierz, C., Lejeune, Y., Bazile, E., Boone, A., Dai, Y.-J., Essery, R., Fernandez, A., Gusev, Y., Jordan, R., Koren, V., Kowalczyk, E., Nasonova, N. O., Pyles, R. D., Schlosser, A., Shmakin, A. B., Smirnova, T. G., Strasser, U., Verseghy, D., Yamazaki, T., and Yang, Z.-L.: Intercomparison of the surface energy budget simulated by several snow models (SNOWMIP project), Ann. Glaciol., 38, 150–158, doi:10.3189/172756404781814825, 2004. 31

Fierz, C., Armstrong, R. L., Durand, Y., Etchevers, P., Greene, E., McClung, D. M., Nishimura, K., Satyawali, P. K., and Sokratov, S. A.: The international classification for seasonal snow on the ground, IHP-VII Technical Documents in Hydrology no 83, IACS Contribution no 1, 2009. 38

Forland, E., Allerup, P., Dahlström, B., Elomaa, E. T., Perälä, J., Rissanen, P., Vedin, H., and Vejen, F.: Manual for operational correction of Nordic precipitation data, Tech. rep., Det Norske Meteorologiske Institutt., 1996. 34

Kodama, M., Nakai, K., Kawasaki, S., and Wada, M.: An application of cosmic-ray neutron measurements to the determination of the snow-water equivalent, J. Hydrol., 41, 85–92, doi:10.1016/0022-1694(79)90107-0, 1979. 36

Paquet, E. and Laval, M.-T.: Operation feedback and prospects of EDF Cosmic-Ray Snow Sensors, La Houille Blanche, 2, 113–119, doi:10.1051/lhb:200602015, 2006. 36

Reba, M. L., Marks, D., Seyfried, M., Winstral, A., Kumar, M., and Flerchinger, G.: A long-term data set for hydrologic modeling in a snow-dominated mountain catchment, Water Resour. Res., 47, W07702, doi:10.1029/2010WR010030, 2011. 36

Vionnet, V., Brun, E., Morin, S., Boone, A., Faroux, S., Le Moigne, P., Martin, E., and Willemet, J.-M.: The detailed snowpack scheme Crocus and its implementation in SURFEX v7, Geosci. Model Dev. Discuss., 4, 2365–2415, doi:10.5194/gmdd-4-2365-2011, 2011. 33, 39

Table 1. Overview of the sensors used to gather the hourly meteorological data used to drive snowpack models, between 1993 and 2011 at Col de Porte, France.

Variable	Sensor	Period of operation	Height	Unit	Integration method
Air temperature	PT 100/ 3 wires PT 100/ 4 wires	... → 1996/1997 1997/1998 → ...	1.5 m*	K	Instantaneous
Relative humidity	SPSI MU-C.1/MUTA.2 Vaisala HMP 35DE Vaisala HMP 45D	... → 1994/1995 1995/1996 → 2005/2006 2006/2007 → ...	1.5 m*	%RH	Instantaneous
Wind speed	Laumonier – heated	1997/1998 → ...	10 m	$\mathrm{m\,s^{-1}}$	Integrated (60 min)
	Chauvin Arnoux Tavid 87 – non-heated	whole record	10 m	$\mathrm{m\,s^{-1}}$	Integrated (60 min)
	Laumonier – heated	2000/2001 → ...	3,3 m	$\mathrm{m\,s^{-1}}$	Integrated (60 min)
Inc. shortwave radiation	Kipp & Zonen CM7 Kipp & Zonen CM14	... → 15/03/1996 15/03/1996 → ...	1.2 m*	$\mathrm{W\,m^{-2}}$	Integrated (55 min)
Inc. longwave radiation	Eppley PIR Kipp & Zonen CG4	... → 2010/2011 2010/2011 → ...	1.2 m*	$\mathrm{W\,m^{-2}}$	Integrated (55 min)
Precipitation	PG2000 heated (2000 $\mathrm{cm^2}$)	whole record	2.75 m	$\mathrm{kg\,m^{-2}\,s^{-1}}$	Difference
	PG2000 non-heated (2000 $\mathrm{cm^2}$)	whole record	2.75 m	$\mathrm{kg\,m^{-2}\,s^{-1}}$	Difference
	GEONOR (200 $\mathrm{cm^2}$)	whole record	3 m	$\mathrm{kg\,m^{-2}\,s^{-1}}$	Difference
Atmospheric pressure	Standard Météo-France sensor	whole record	surface	Pa	Instantaneous

* Height adjusted manually above snow surface (≈ weekly).

Table 2. Overview of the sensors used to gather the hourly and daily snow data used to evaluate snowpack models, between 1993 and 2011 at Col de Porte, France. Note that outgoing shortwave and longwave radiation is measured using instruments similar to the corresponding incoming radiation, described in Table 1. Note also that snow surface temperature can be derived from the outgoing longwave radiation sensor, in addition to the sensors presented here.

Variable	Sensor	Period of operation	Height	Unit	Time resolution	Integration method
Snow depth	Ultra-sound depth gauge BEN	... → 1999/2000	3 m	m	hourly	Instantaneous
	Ultra-sound depth gauge FNX	2000/2001 → 2008/2009				
	Ultra-sound depth gauge SR50A	2009/2010 → ...				
	Laser ranger	2010/2011 → ...	3 m	m	hourly	Instantaneous
	Snowpit (up to three values)	whole record	N.A.	m	≈ weekly	N.A.
Snow water equivalent	Cosmic-Ray Neutron sensor	2001/2002 → ...	0 m	$\mathrm{kg\,m^{-2}}$	daily	24h integration
	Cosmic-Ray Neutron sensor[a]	2008/2009 → ...				
	Snowpit (up to three values)	whole record	N.A.	$\mathrm{kg\,m^{-2}}$	≈ weekly	N.A.
Runoff	$5\,\mathrm{m^2}$ lysimeter – scale	1994/1995 → ...	0 m	$\mathrm{kg\,m^{-2}\,s^{-1}}$	hourly	Difference
	$1\,\mathrm{m^2}$ lysimeter – tipping gauge	... → 1995/1996	0 m	$\mathrm{kg\,m^{-2}\,s^{-1}}$	hourly	Difference
	$1\,\mathrm{m^2}$ lysimeter – scale	1997–1998 → ...				
Surface temperature	Testo term Pyroterm	whole record	1.2 m[b]	K	hourly	Instantaneous
	Heitronics KT15	2010/2011 → ...	2.5 m	K	hourly	Instantaneous
Soil temperature	PT 100/3 wires	... → 1996/1997	−0.1 m	K	hourly	Instantaneous
	PT 100/ 4 wires	1997/1998 → ...				
	PT 100/ 3 wires	... → 1996/1997	−0.2 m	K	hourly	Instantaneous
	PT 100/ 4 wires	1997/1998 → ...				
	PT 100/ 3 wires	... → 1996/1997	−0.5 m	K	hourly	Instantaneous
	PT 100/ 4 wires	1997/1998 → ...				
Settling disks temp.	PT 100/3 wires	... → 1996/1997	variable	K	hourly	Instantaneous
	PT 100/ 4 wires	1997/1998 → ...				
Settling disks height	In-house positioning system	whole record[c]	variable	m	hourly	Instantaneous
Ground flux	Hukseflux HFP01	since 2010/2011	0	$\mathrm{W\,m^{-2}}$	hourly	Instantaneous

[a] Sensor including a shielding for ground-originating neutrons (reduced data scatter).

[b] Height adjusted manually above snow surface (≈ weekly).

[c] Progressive migration from mercury to solid state electric contact.

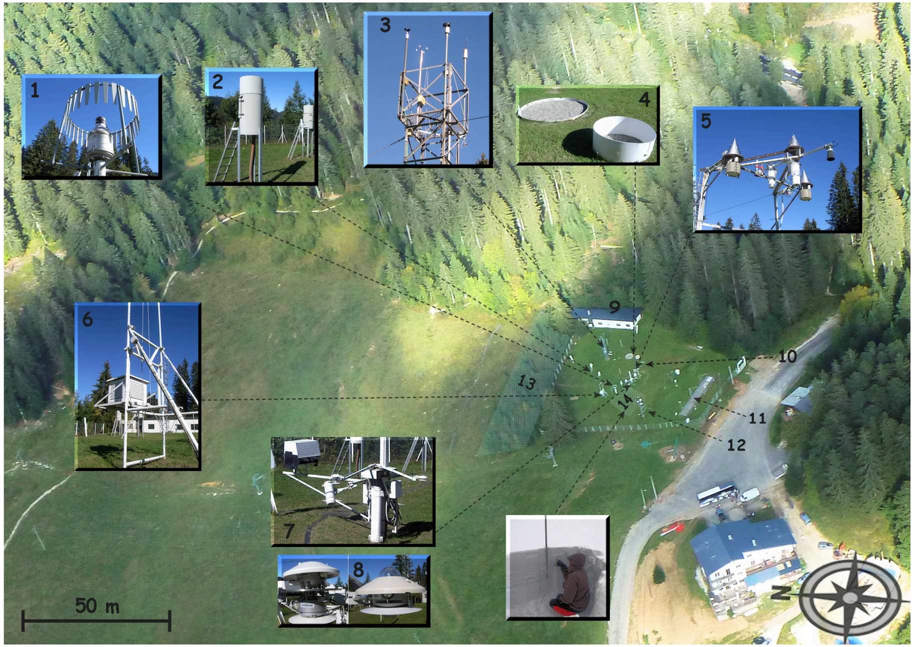

Fig. 1. Overview of the experimental site at Col de Porte (1325 m altitude, Chartreuse mountain range, France). All sensors are located within a radius of a few tens of meters. (1) Geonor precipitation gauge, (2) PG2000 heated and non-heated precipitation gauges, (3) wind-speed measurements at the top of the 10 m meteorological mast, (4) lysimeters, (5) snow depth sensors and settling disks, (6) temperature and relative humidity sensors placed in the shelter, (7) radiation sensors placed on the rotating arm, (8) close-up on the 4 components radiation sensors, (9) building (cold room, data acquisition, lab space), (10) neutron ray counter for SWE measurements, (11) former experimental area for the study of road/snow interactions, (12) automatic snow and weather station Nivose for testing purposes (generally used in remote mountain areas), (13) forest area impacted by the cut in 1999, (14) snow pit area. See text for further details on instruments.

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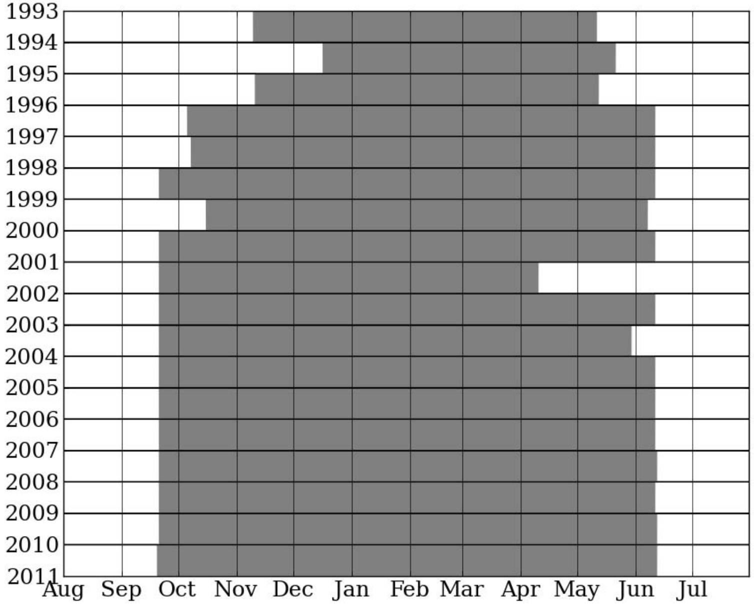

Fig. 2. Summary of the partitioning between in-situ data (grey) and the output of the meteorological downscaling tool SAFRAN (white) used to build the gap-free driving dataset.