

# Meteorological Nowcasting for an Environmental Emergency Decision Support System

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**Keywords:** complex terrain, diagnostic model, automatic process, now casting, decisions support system.

## 1 Introduction

The Regional Civil Protection Department in Lombardy has started a project where a user-friendly decision support system for environmental emergency management has been produced. One of the applications regards meteorology. It supplies, in real time, weather information (historic, actual and forecasted), spatial distribution of different meteorological variables both measured and modelled with point, grid, or isoline, where the spatial resolution depends on the area selected by the user. The D.S.S. (decisions support system) – called LTK3 – is a modular environment, provided with several different applications and services; its graphical user interface, with GIS functionality, allows to display environmental data and model outputs over raster or vector maps and to save results in a geographic catalogue.

This work describes the implementation of the CALMET meteorological model (*Scire et al., 1999*) in this decision support system. The system automatically produces the inputs necessary for CALMET to run every hour, using the meteorological data from various network stored and updated in real time on the Civil Protection database. Some filters have been included in the system to realise a real time quality assurance of the measured data: temporal persistence, range and spatial consistency have been considered. A sensitivity analysis has been performed in order to determine the best and the minimal conditions to run the model; the system wait for these decision rules to be respected to execute the model.

In conclusion, every hour the user, local or remote, has the possibility to connect to the system and visualise the real time maps of the various meteorological (temperature, wind, ...) and turbulence (mixing height, stability class ...) parameters produced by CALMET or to use them to drive other modelling system (i.e. for accidental release, for explosion and fire). The standard domain (about 240x230 Km<sup>2</sup>) covers the entire Lombardy with an horizontal resolution of 4 km. In case of a specific interest, the user can zoom on a particular area. Then the system produces the inputs and automatically re-runs the model hourly on the new domain.

The choice of CALMET has been driven by the need to have high-resolution meteorological information (up to a 500 m resolution) in a complex terrain, such as the Lombardy one, and to have detailed information on PBL turbulence, with low computational costs. New algorithms for temperature and energy balance calculation in complex terrain are right now in phase of test.

## 2 CALMET domain and input

CALMET domain consists of 59 x 57 grid points with a resolution of 4 x 4 km<sup>2</sup>, covering the whole Lombardy region and part of the neighbouring regions: Emilia Romagna, Veneto, Trentino-Alto Adige, Piemonte and Canton Ticino (Switzerland). The morphology of the territory is very different through out the region, passing from the Alps (about 4000 m asl) to the flat Pianura Padana, through the Prealps and hills. *Figure 1* represents CALMET chosen surface stations over a satellite image. The landuse is the gridded Corine Landcover with a resolution of 500x500 m. Orography is gridded with a resolution of 250x250 m. Nine vertical layers from the lowest layer at 20 m above the ground until 3000 m have been defined applying an exponential increment of the vertical spacing.

The main focus of this work is to produce, every hour, the CALMET wind field by an objective analysis of a set of about 30 meteorological surface stations (see *figure 1*), of the vertical sounding of Milan Linate airport and of the forecasted vertical profiles on Milan, computed by the prognostic model Mephysto (*Bonelli et al., 1998*). About 20 surface stations have been chosen among the ones of the Air Quality and the Hydro-pluviometric regional networks to complete, in space and time, the Aeronautica Militare synoptic stations present in the domain and in surroundings. The criteria used to choose this set of stations are based on the analysis of the following elaboration during the biennium 1999-2000:

- seasonal wind-roses;
- wind direction seasonal typical day;
- daily minima and maxima and typical day and year for wind speed, temperature, pressure and relative humidity;

and taking into account the following considerations:

- presence of persistence,
- lack of daily and seasonal cyclic trend;
- presence of discontinuities;
- overcoming of "reasonable" seasonal limits for all variables.

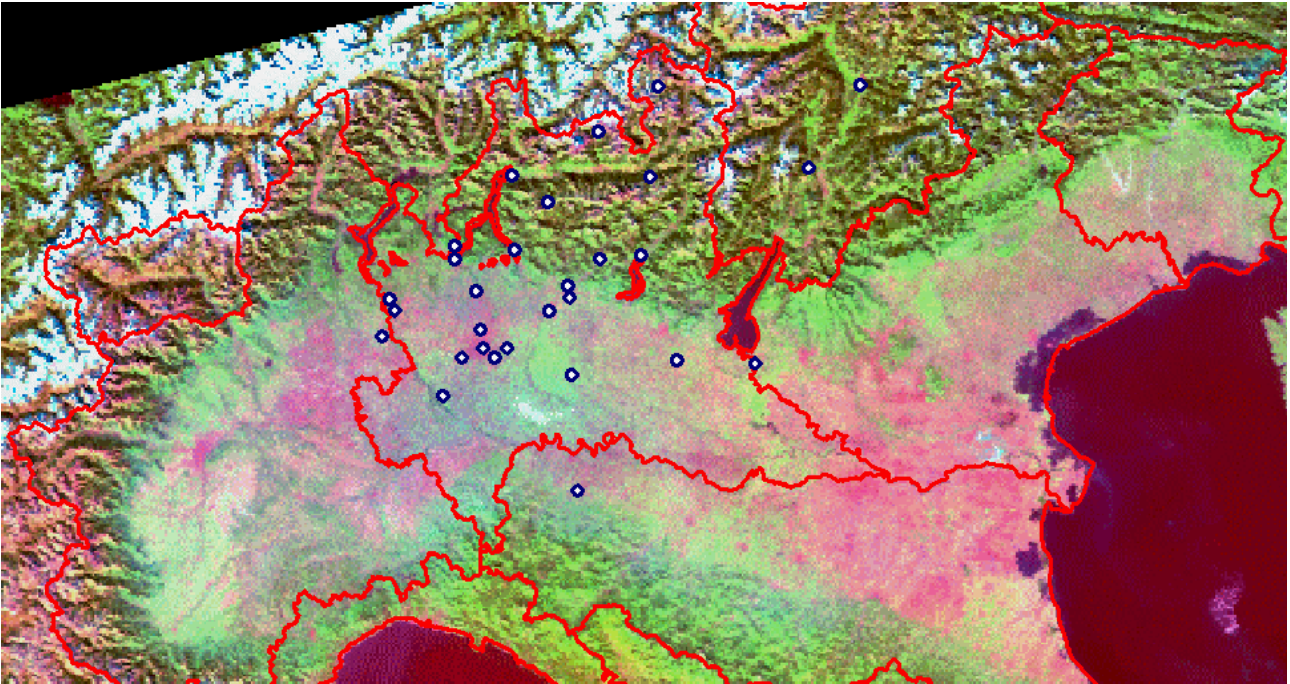
### 3 CALMET operational conditions

The system checks constantly the conditions for the hourly run, so that the user could see the more updated CALMET output. Model outputs have to pass through two steps: a physical test and a model one. The physical test controls if a measure is acceptable or not. On the surface data there are the following checks: (1) reasonable range of measured values, (2) temporal persistence for wind speed and direction and for temperature, (3) spatial continuity control. On the sounding data the checks are: (1) pressure should be always positive and decreasing with height, (2) temperature should belong to a certain range depending on the level, (3) each level should not overcome a maximum wind speed, (4) reasonable range of the values on the first level (as before), (5) control of the wind speed shifting and on the combined shifting of wind speed and wind direction.

With respect to model check, CALMET is executable if, for each hour of run, at least one station in flat terrain and one station in mountain has a valid measure of wind speed, wind direction and temperature (a more restricted tie respect to the one asked by CALMET itself). Moreover for each of relative humidity, pressure, cover of sky, ceiling height, at least one station should have a valid value, for each hour of run. CALMET run is inhibited if the vertical sounding hasn't valid measurements at ground level and over CALMET vertical top. Last, to run CALMET, 0 a.m. sounding and a valid vertical profile every 12 hours should both exist. To guarantee this, CALMET needs to include a forecasted vertical profile of temperature, wind and pressure, since experimental soundings are only every 6 hours. This information is provided by the model Mephysto, which produces the forecasting profile for the next two days, with a temporal resolution of three hours.

### 4 Test

Two typical situations of the year 2000 have been chosen for the model test: 4 August and 20 September. The first day was characterised by an intense rain (alert situation for the Civil Protection Department). The 20 September was chosen as a very windy day (another situation of alert for fire). For both days, data relative to 26 stations were available. In order to test the model performances, these stations have been group in three subsets respectively of 9, 9 and 8 stations. These three groups maximise the distance among the stations belonging to the group itself. By not considering one at time, each of these three groups, the stations belonging to it could be used as an independent test set against which CALMET results could be tested.



**Figure 1** CALMET domain and orography.

In order to choose the best model parameter configuration to start with the sensitivity analysis, three different CALMET inputs, coming from three different works on Lombardy region, have been considered: (a) *De Martini et al., 1998*; (b) *Ghezzi et al., 2000*; (c) *Deserti et al., 1999*. After a qualitative observation of the wind field produced by the three different configurations on each of the two test days, some statistical indexes for the wind speed have been evaluated to compare the model results. As done by EPA (1990) and Steyn and McKendry (1988), the following indexes have been computed: *mean and standard deviation of estimations and of observations, bias, root mean square error, skill-var, Pearson coefficient, index of agreement, ratio between root mean square error and standard deviation of observations, ratio between mean error and standard deviation of observations*.

As example, see the following formulation:

*mean error or bias*

$$B = \frac{1}{N} \sum_i (C_i - O_i) \quad (1)$$

where  $N$  is the number of data (calculated by the model  $C_i$  and observed  $O_i$ );

*index of agreement between the estimated and observed data*

$$I = 1 - \frac{\sum_i (C_i - O_i)^2}{\sum_i (|C_i - \bar{O}| + |O_i - \bar{O}|)^2} \quad (2)$$

which varies between 0 and 1 (perfect agreement);

*Pearson coefficient* that defines the correlation degree between two data sets

$$R = \frac{\sum_i (O_i - \bar{O})(C_i - \bar{C})}{\sqrt{\sum_i (O_i - \bar{O})^2 \sum_i (C_i - \bar{C})^2}} \quad (3)$$

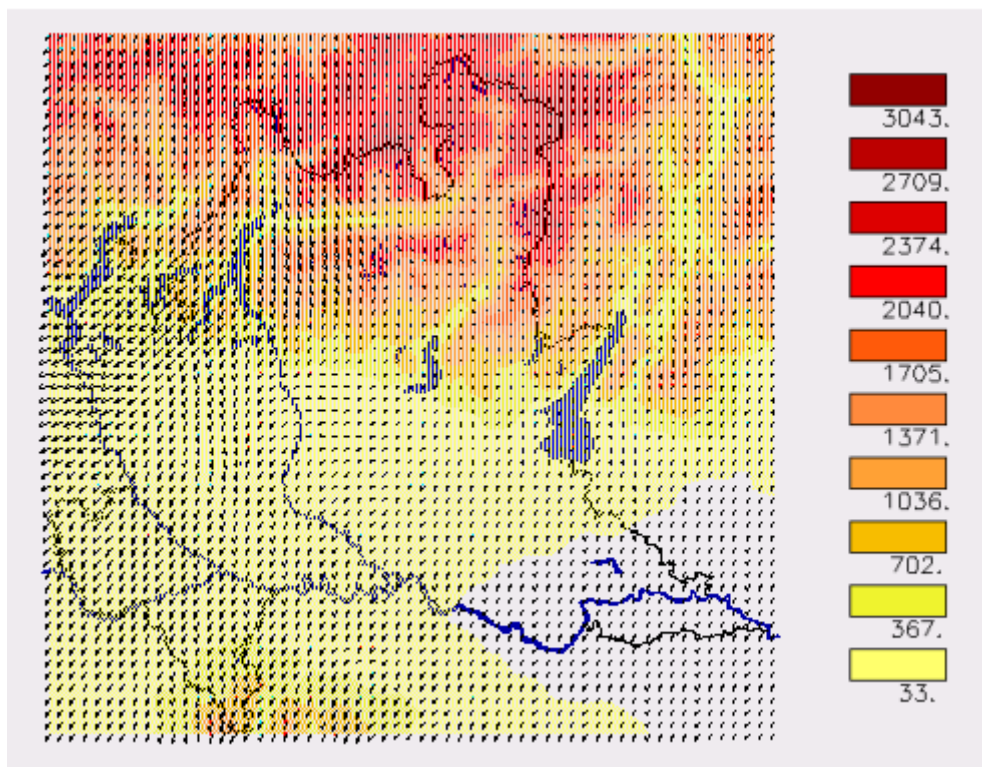
For the wind direction the index of success has been used. It is calculated as the number of hours where the difference between the calculated direction and the observed one is less than a fixed value ( $45^\circ$ ,  $60^\circ$  and  $90^\circ$  are the thresholds used) divided per the number of valid hours:

$$S = \frac{\sum_i h_i \text{ where } |O_i - C_i| \leq \text{threshold}}{\sum_i h_i} \quad (4)$$

Table 1 shows a first example of these statistical indexes for configuration (c) on the 4<sup>th</sup> of August. Each column represents one of the 26 stations (as explained before not used in the test run); the last column summarises the test results with an average value. Figure 2 shows the wind field at 15:00 on 4 August 2000, computed using configuration (c). An unusual situation for the afternoon is present: in accordance with the observed wind directions, the wind is blowing from the Alps to Pianura Padana.

Starting from these already discrete results, a base configuration has been "distilled" from of the three original ones. Then a sensitivity analysis of the following key parameters of CALMET (around base values), has been carried on:

- RMAX1 the maximum radius of influence of a station over land in the surface layer;
- TERRAD, the radius to search the maximum terrain height in the computation of orographic effects;
- R1, the weight given at the initial wind field with respect to the observations of a station in the interpolation in the surface layer;
- NINTR, the maximum number of stations used in each layer for the data interpolation in each grid point;
- IKINE, the control variable for computing kinematic effects;
- NSMTH, the number of smoothing passes in each layer.



**Figure 2** Wind field at 15:00 on 4 August 2000, estimated using one of the three different inputs and orography.

**Table 1** Statistical results for the stations of test1 for one of the three inputs.

	APRICA	LA VALLACC.	VALGER.	CORSICO	COSTA VOLP.	JUVARA	OSIO	MALP.	CASNIGO	MARIANO	MOTTA V.	RODANO	SOMMA L.	PAGAN.	ORIO	PALU'	GOISIS V.	GALLIA	CAMERI	LINATE	GHEDI	VERONA	AVERAGE
Mean estimation	1.08	1.42	1.24	1.83	1.06	1.82	1.69	1.92	1.25	1.98	1.59	1.87	1.62	1	1.9	0.84	2.82	1.87	1.65	1.88	0.77	0.89	1.55
Mean observation	0.92	0.95	2.17	1.54	0.97	2.01	2.5	1	1.05	2.56	1.95	2.16	1.91	3.5	1.8	1.45	2.09	3.64	2	2	2.62	1.67	1.93
Stand. dev. of estim.	0.74	0.89	0.66	1.03	0.35	0.99	0.81	1.57	0.62	1.45	0.84	0.82	1.28	0.63	0.8	0.36	1.08	1.01	0.59	1.21	0.67	0.62	0.86
Stand. dev. of obs.	0.37	0.42	1.34	0.83	0.23	1.11	1.29	0.61	0.3	1.28	1.11	1.17	1.31	1.82	1.1	0.53	0.82	2.46	2.03	1.14	1.88	0.9	1.09
Skill-Var	2.01	2.11	0.5	1.25	1.52	0.89	0.62	2.56	2.09	1.13	0.76	0.7	0.98	0.35	0.7	0.69	1.33	0.41	0.29	1.06	0.35	0.69	1.05
Bias	0.16	0.47	-0.92	0.29	0.08	-0.19	-0.8	0.92	0.2	-0.58	-0.35	-0.29	-0.29	-2.5	0.1	-0.6	0.73	-1.77	-0.35	-0.12	-1.9	-0.78	-0.38
RMSE	0.96	1.26	1.75	0.49	0.38	0.73	1.17	1.38	0.59	0.74	0.62	0.68	0.89	3.44	0.4	0.94	1.39	2.34	1.63	0.68	2.22	1.06	1.17
Revised Skill-E	2.6	2.97	1.31	0.59	1.65	0.66	0.9	2.26	2	0.58	0.56	0.58	0.68	1.9	0.4	1.78	1.71	0.95	0.8	0.59	1.18	1.18	1.26
Normalized RMSE	0.93	1.19	1.14	0.09	0.14	0.15	0.32	1	0.27	0.11	0.12	0.11	0.25	3.4	0.1	0.73	0.33	0.8	0.81	0.12	2.42	0.76	0.69
Pearson coefficient	-0.38	-0.51	0	0.93	0.24	0.78	0.77	0.92	0.44	0.95	0.9	0.87	0.79	-0.82	1	-0.3	0.24	0.95	0.81	0.84	1	0.6	0.50
Index of Agreement	0.17	0.08	0.44	0.93	0.46	0.86	0.72	0.66	0.58	0.93	0.9	0.88	0.88	0.33	1	0.31	0.53	0.68	0.59	0.91	0.62	0.57	0.64
Bias/Stand. dev. of est.	0.44	1.11	-0.69	0.35	0.37	-0.17	-0.6	1.5	0.69	-0.45	-0.32	-0.25	-0.22	-1.38	0.1	-1.2	0.9	-0.72	-0.17	-0.11	-1	-0.86	-0.12
Success index (<45)	0.5	0.2	0.12	0.89	0.93	0.78	0.67	1	0.38	0.72	0.89	0.71	0.72	0.2	1	0.23	0.75	0.61	1	0.8	0.25	0.17	0.61
Hours (<45)	9	3	2	16	14	14	12	4	5	13	16	12	13	1	5	3	6	11	4	4	1	1	7.68
Success index (<60)	0.67	0.27	0.29	0.94	0.93	0.83	0.83	1	0.62	0.78	1	0.82	0.94	0.2	1	0.23	0.88	0.72	1	1	0.5	0.33	0.72
Hours (<60)	12	4	5	17	14	15	15	4	8	14	18	14	17	1	5	3	7	13	4	5	2	2	9.05
Success index (<90)	0.78	0.47	0.59	1	1	0.94	0.94	1	0.85	0.83	1	0.88	0.94	0.4	1	0.54	0.88	0.89	1	1	0.75	0.67	0.83
Hours (<90)	14	7	10	18	15	17	17	4	11	15	18	15	17	2	5	7	7	16	4	5	3	4	10.50

## 5 Acknowledgements

A special thanks to Maurizio Casati and to Maurizio Molari (Regione Lombardia) for the help provided; to Paolo Patrino (ARPA-Meteorological Service of Emilia Romagna) for his useful advices.

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