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Operational setup of a diagnostic chain, implemented within the Proterina-C project, to include weather measures in the RISICO system for dynamic wildfire risk evaluation in Sardinia (Italy)

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Abstract

Within the Operational Project "PROTERINA-C" (a forecast and prevention system for climate change impacts on risk variability for wildlands and urban areas), co-funded by the European Regional Development Fund (ERDF) under the Italy-France Maritime Program, methods and strategies, already in use in the regions of Sardinia, Liguria and Corsica, for the predictions of wildlands fires have been developed and adapted; RISICO System, by CIMA Foundation which plays the role of technical and scientific support for the region of Liguria, used by the Italian National Civil Protection Department, is one of them. In such a prediction model of risk of wildlands fires, it is arranged the integration, on a regional scale, of products related to the main meteorological, diagnostics and prognostics forcing, measured by ground stations, weather radar and advanced limited area weather prediction models. With the aim to improve prediction of wildlands fires in Sardinia, an operational chain to insert in RISICO weather data provided in near-real time by the meteorological monitoring network has been designed and developed. In fact, the forecast errors can be reduced by conditioning the initial state of dynamic models of fuel moisture on the information obtained from sensors on land, at every time interval at which the fields of meteorological variables of interest are available. A dataset of wildland fires occurred in Sardinia has been considered in order to valuate the system effectiveness; for these cases the developed setup has improved the fires risk assessment to respect a version of RISICO initialised only by a mesoscale numerical weather prediction model. In the present work the system setup, the configuration of the network of meteorological stations and some preliminary analysis results are argued.

RISICO System (**RIS**chio **I**ncendi e **CO**ordinamento, *Fiorucci et al., 2008*)

RISICO has been providing Italian Civil Protection Department (DPC) with daily wildlands fire risk forecast maps relevant to the whole national territory since 2003. The main objective of the dynamic Risk Assessment System is to identify, within the considered territory, a finite number of areas affected by the highest risk values. The implemented semi-physical models are able to simulate in space and time the variability of the fuel moisture content, i.e. the main variable related with the ignition of a fire.

The design of the module followed reasoning lines similar to those of the Fire Weather Index (Van Wagner and Pickett, 1985; Van Wagner, 1987) of the Canadian Forest Fire danger Rating System (CFFDRS). In fact, the risk assessment system module is made by two separate models: the first is a model that provides the dynamics relevant to the fine fuel moisture content, and the second is a potential fire spread model able to evaluate the potential behaviour of the wildfire front in terms of rate of spread ($m \cdot s^{-1}$) and linear intensity ($kW \cdot m^{-1}$).

In RISICO it is assumed that the moisture contents of a unit of fuel should be modelled through a functional relationship between the main meteorological variables. The model stems on the assumption that the moisture content $u(t)$ of a particle of dead fuel, within a system with constant temperature and humidity, depends on time t so that it increases or decreases until, eventually, a value denoted as Equilibrium Moisture Contents (*EMC*) is reached; the model is expressed by the differential equation:

$$\frac{du}{dt} = -\frac{u - EMC}{\tau} \qquad (1)$$

where *EMC* is a function of the temperature and relative humidity nearby the fuel (Catchpole et al., 2001) and τ is a time constant which represents the fuel response time, i.e. the time used by fuel to absorb or release about 63% of the variation between the initial moisture and his asymptotic value.

The solution on discrete time can be expressed as function of meteorological variables and of various parameters suitably calibrated to the regional environment conditions. Meteorological data are the main dynamic information used by the system; the considered fields are the 3-hour cumulated rainfall, the air temperature, the relative humidity and the wind speed and direction.

The system simulates (Figure 1) the dynamics of (fine) dead and live moisture contents with a resolution of 3-hour time step and 100 metres grid cell.

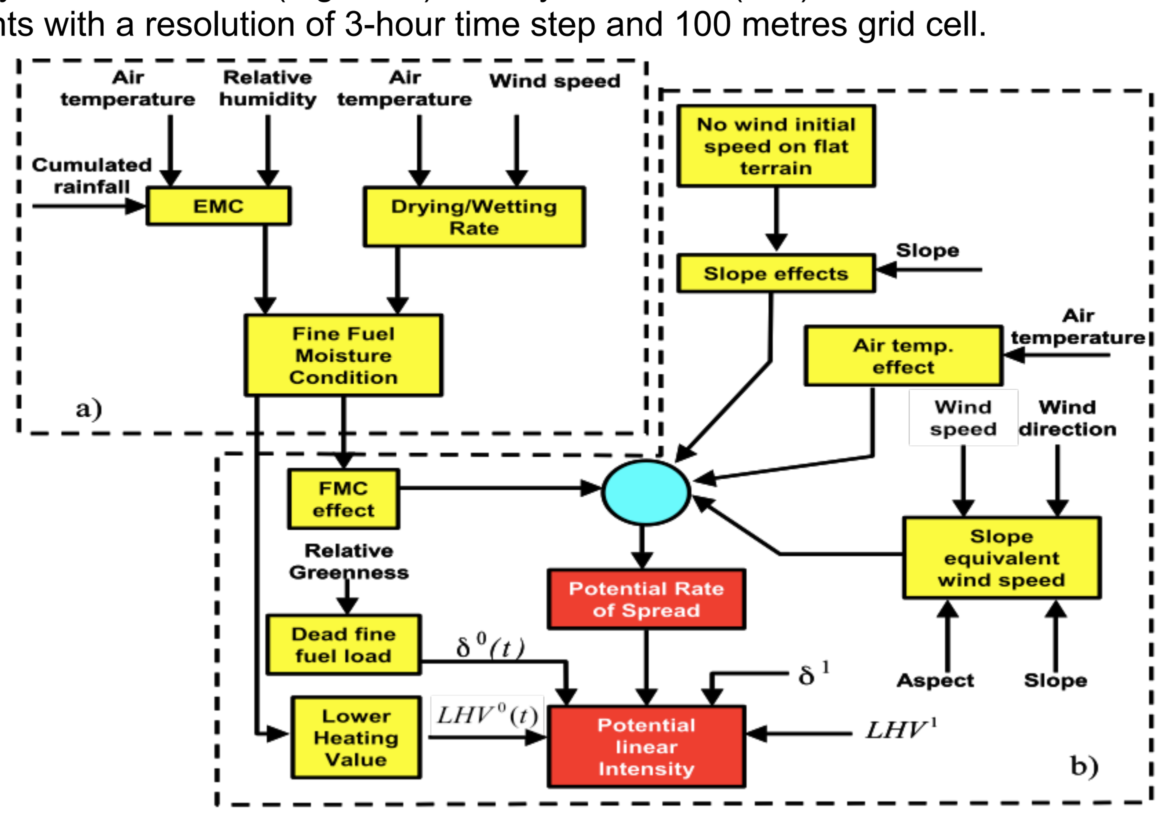

Figure 1 – Logical architecture of RISICO system.

Basing on these values and on other parameters (topography and fuel load) the system calculates the potential rate of spread and the linear intensity of the cells, whose aggregation in time and space represents the expected risk.

All obtained information are intrinsically conditioned by the uncertainty of weather forecasts that can propagate to each run of the daily pattern, thus generating errors in the state of humidity of the fuel that gradually propagate for different time intervals, up to alter the estimate of the areas subject to fire risk.

Prediction errors can however be reduced by conditioning the initial state of the dynamic models of humidity of the fuel to information obtained from sensors on the ground, at each time interval at which they become available fields of the meteorological variables of interest obtained from a process of interpolation of ground measurements. Whenever the operational chain has these fields, the RISICO system performs a new run at the time instants in which fields are available, continuously updating the information estimate, and thus making it more reliable.

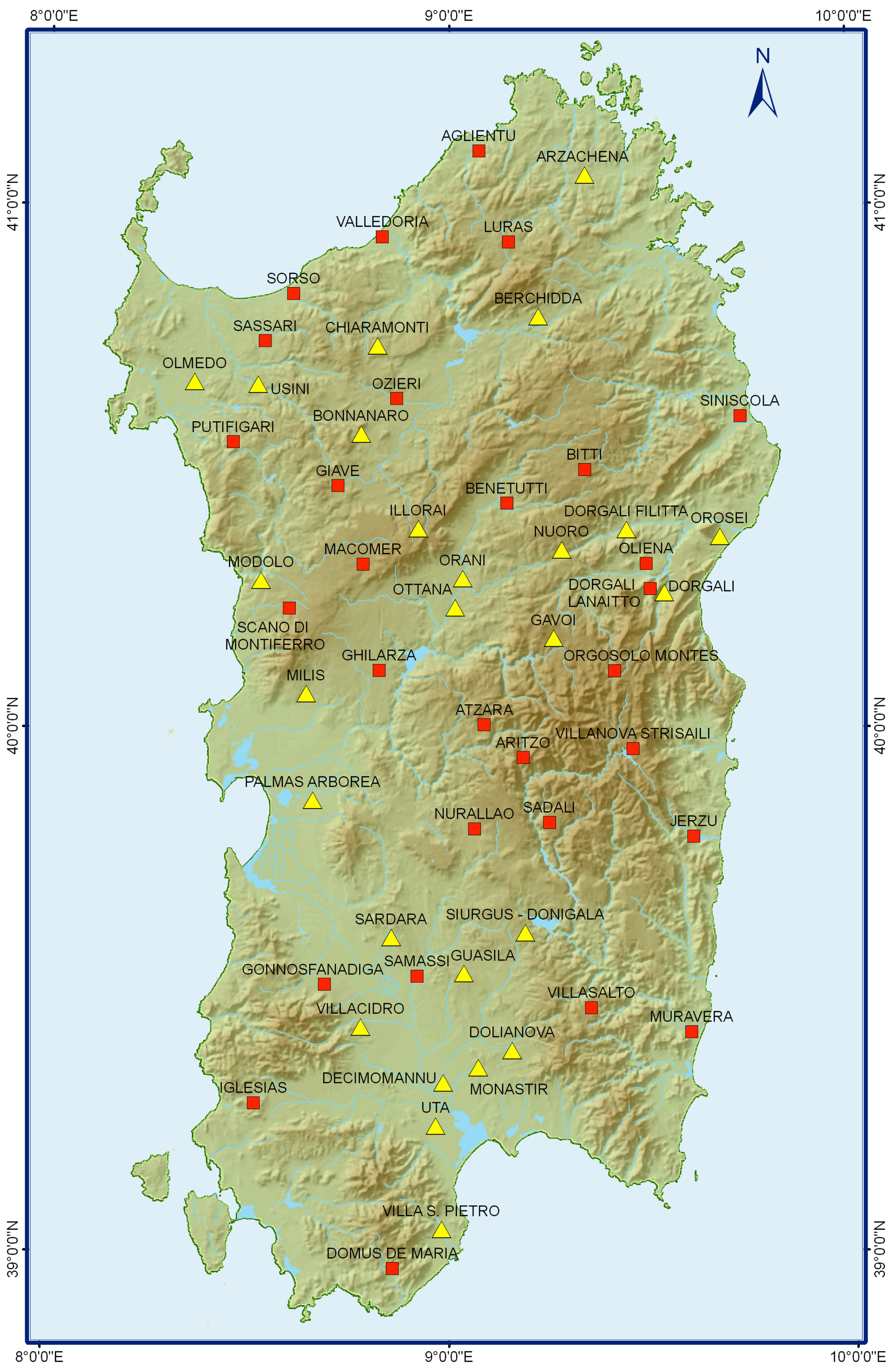

Figure 2 – ARPAS weather ground stations; squares and triangles denote, respectively, stations with and without anemometer.

METEOROLOGICAL NETWORK

The stations usable for the purpose of the project belong to the network managed by ARPAS, are located throughout the region (Figure 2), homogeneous by devices and sensors, follow the directions of WMO and are capable of automatic remote transmission.

The individual stations, designed as a data logger (SIAP SM3830) that acquires measures from sensors wired directly to it, are connected by GSM mobile telephone network to front-end at the HydroMeteoClimatic Department, and from this to the back-end for insertion into a client-server database defined in ORACLE. The call of the weather stations is automatic and sequential on time, twice a day, but the interrogation may be carried out in manual mode at any time. The sensors used are of the "intelligent" kind as they have a microcontroller that oversees the acquisition and pre-processing of measured data; each sensor communicates with the data logger via an asynchronous serial line using ASCII messages. The acquired data are stored locally in a circular RAM buffer waiting for the call on the GSM network from the front-end, and stored on removable EPROM memory modules (FMM), which are periodically collected to verify the measures already put in the database and the *"coverage"* of any missing data.

Through the management console, the ARPAS operator is able to program the automatic acquisition of data from the stations, eventually to perform any calls extemporaneous and also send a new remote configuration of operation to the data logger of the stations. The validated information, measured in the set of available stations, are collected at regular intervals from the ARPAS database through automatic procedures, implemented on both SUN and Linux Server, and then typed in files in ASCII format; all procedures were developed and implemented in a Unix environment and mainly in open-source GNU-Linux in order to facilitate the dissemination and reuse.

Data on different variables of interest are taken from the online database through some SQL procedures so that new lists containing the measures of physical quantities for all stations are built in matrix format: the temperature at two meters and the relative humidity at two meters are sampled by instruments every ten minutes and it is determined the hourly median, the wind direction at ten meters and the wind speed at ten meters are sampled and acquired at intervals of ten minutes, the rainfall is measured as accumulated every ten minutes. The data are automatically provided to CIMA to be available for RISICO.

PRELIMINARY RESULTS

To the end of evaluating the performances of the regional implementation of RISICO, i.e. his predictive capacity in terms of rate of spread and linear intensity of the wildfire front, and particularly the impact resulting from the integration of the ground measured weather data, we considered the events occurred in the municipalities of Arbus, Bonorva and Nuoro respectively on the 26th August 2011, 23rd July 2009 and 23rd July 2007. The three considered cases, spanning from one of the largest fire occurred during summer 2011 and the highest fire risk scenarios in the last years. Although they are few to have statistical significance, are anyway particularly relevant because of the involved forest areas and the total burned area.

As can be seen from the graphs (Figure 3) the system shows encouraging results with noticeable improvement resulting from the integration of the weather observations than the exclusive introduction of forecasts provided by NWP model. In all the considered case studies, using observation allow to better identify the extreme danger conditions close to the time of ignition. Certainly the results suggest the usefulness of carrying out a broader analysis by considering more cases and a longer period.

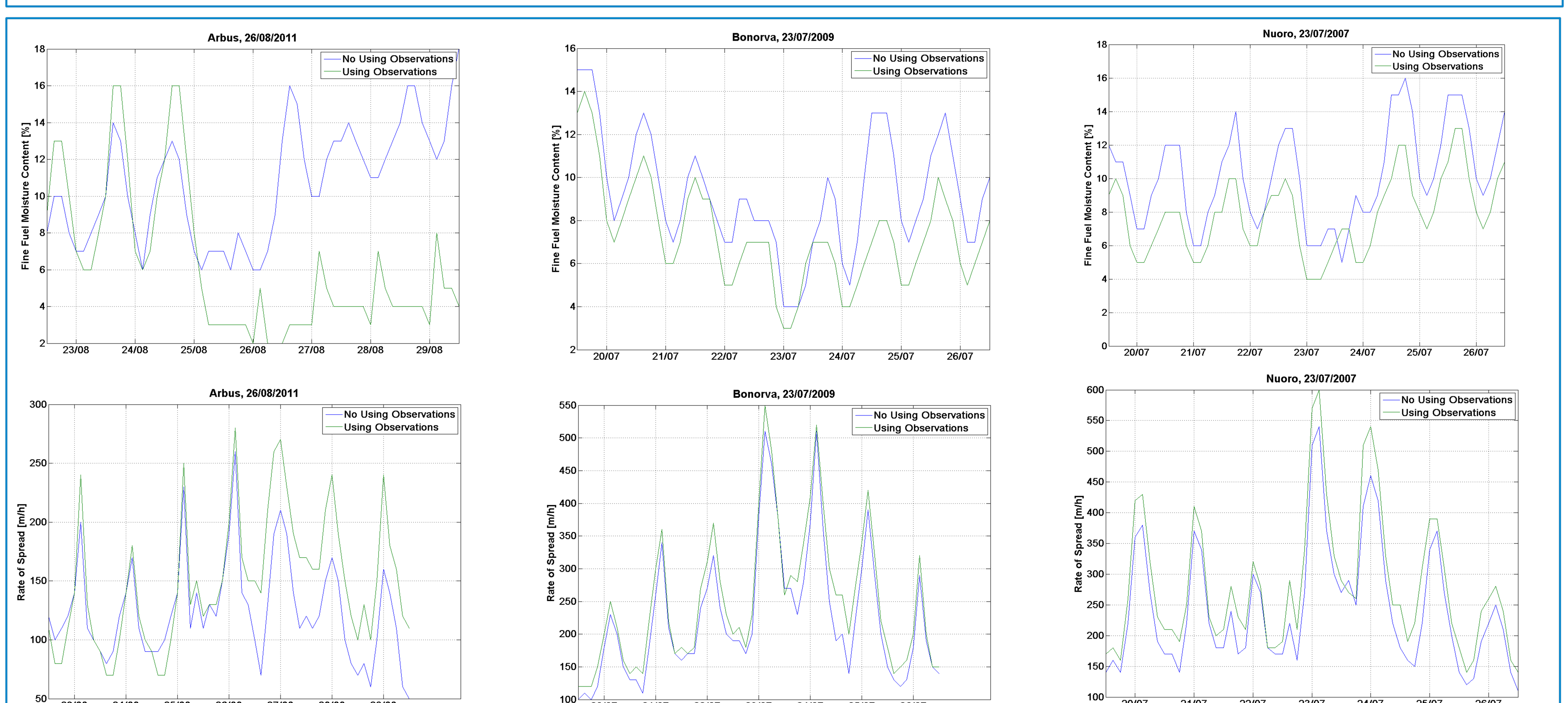

Figure 3 – Trend of fine fuel moisture content and rate of spread in the three considered case studies: Arbus (26 August 2011), Bonorva (23 July 2009) and Nuoro (23 July 2007).

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