LATE REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: Italy

Principal Investigator[1]: Simone Sperati

Affiliation: Ricerca sul Sistema Energetico (RSE) SpA

Address: Via Rubattino 54, 20134 Milano, IT

Other researchers: Davide Airoldi (RSE SpA)

Project Title: WRF-based high resolution numerical weather simulations to update the new Italian Wind Atlas

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for project year:		**2024**	**2025**	**2026**
High Performance Computing Facility	[SBU]	45,000,000		
Accumulated data storage (total archive volume)[2]	[GB]	37,800		

EWC resources required for project year:		**2024**	**2025**	**2026**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Continue overleaf.

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Principal Investigator: Simone Sperati

Project Title: WRF-based high resolution numerical weather simulations to update the new Italian Wind Atlas

Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 10,000,000 SBU should be more detailed (3-5 pages).

Introduction

Wind atlases are essential for determining the best locations for wind energy turbines. They are commonly used to support institutional authorities in planning the use of local resources, to assist regulatory authorities in the proper development of the electricity grid, to support producers in wind energy turbine siting and to evaluate cases of lost wind power production due to curtailments.

The European Union (EU) Green Deal has set ambitious goals for renewable energy installations by 2030. These goals were solidified in the "Fit for 55" package [1], which includes the aim of reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. For Italy's wind power sector, this means increasing from 11 GW of installed capacity in 2022 to 25 GW by 2030, with 3.6 GW of that target coming from offshore installations [2]. To meet these objectives and effectively support stakeholders in planning future wind energy projects, it is crucial to analyze the spatial distribution of wind potential and identify prime locations for wind energy development.

In response to these needs, we developed the new Italian Wind Atlas - Atlante EOLico ItaliANo (AEOLIAN) [3], which follows the first Wind Atlas released back in the early 2000s [4]. In fact, after two decades, it became clear that the Wind Atlas required updates to incorporate new data, more accurate meteorological models, advancements in wind turbine technology, and the evolving needs of stakeholders. A specific survey of stakeholders highlighted the need for longer data time series and higher horizontal resolution as top priorities [5]. In this sense, utilizing a meteorological model allows for a three-dimensional reconstruction of meteorological variables with high spatial and temporal resolution over any area of interest, enhancing wind resource estimates. The project has been carried out as a collaboration effort between RSE and the National Center of Atmospheric Research (NCAR), which provided additional scientific support and computational resources.

AEOLIAN provides 30 years (1990-2019) of wind speed data across Italy, including marine areas. It features a horizontal grid spacing of 1.33 km and provides hourly data outputs. The Atlas integrates a 2-grid dynamical downscaling of the ERA5 global reanalysis fields using the WRF model [6] with a statistical approach based on the Analog Ensemble (AnEn) [7] technique. These two methods have been used together to temporally extend high-resolution weather model data only available for a limited time. The motivation for this work is due to the fact that reconstructing 30 years of data at a horizontal grid spacing of around 1 km requires a costly computational effort. Thus, the AnEn has been applied to extend 5 recent years (2015-2019) of high-resolution model data to an additional 25 years further in the past (1990-2014) using coarser mesoscale model runs [3].

Observational nudging on both domains has been activated using surface synoptic observations (SYNOP) of 2-m temperature, which are available for the entire 30-year period of this study. Also, observations of 10-m wind collected by the Regional environmental agencies (ARPAs) that include about 300 stations across Italy and a set of selected surrounding marine locations have been used for observational nudging on the fine-resolution grid because of their limited availability with time, becoming more abundantly available only after 2010.

A comprehensive evaluation [3] using 104 evenly distributed measurement stations across the region, enabled an assessment of the performance of AEOLIAN, which generally exhibits slightly superior performance compared to the New European Wind Atlas (NEWA) [5], which is currently considered the pinnacle of wind atlases in Europe. Notably, AEOLIAN demonstrates a lower bias than NEWA, particularly in regions with complex topography, both at 10-meter and upper-height stations, owing to its enhanced horizontal resolution.

Future enhancements for AEOLIAN include extending the AnEn technique to generate past wind direction data for all available vertical levels of wind speed, as well as updating the dataset to include more recent years. Regarding the latter, we decided to propose this project in order to extend the dynamically downscaled 5-year period beyond 2019 using WRF. In fact, while the AnEn approach demonstrated to be suitable to reconstruct the previous 25 years with an adequate level of reliability, the increasing availability of stations with wind measurements makes it preferrable to dynamically downscale the global fields to better capture the atmospheric dynamics, also in light of the increasing frequency of weather extremes of recent years which would be difficult to capture with a statistical approach.

Scientific plan

The work will be carried out setting up the WRF model V3.9, in order to remain consistent with the meteorological fields already generated for the period 2015-2019, aiming to reconstruct the years 2020 and 2021. WRF is nested on the ERA5 global reanalysis fields using two grids, as shown in Figure 1.

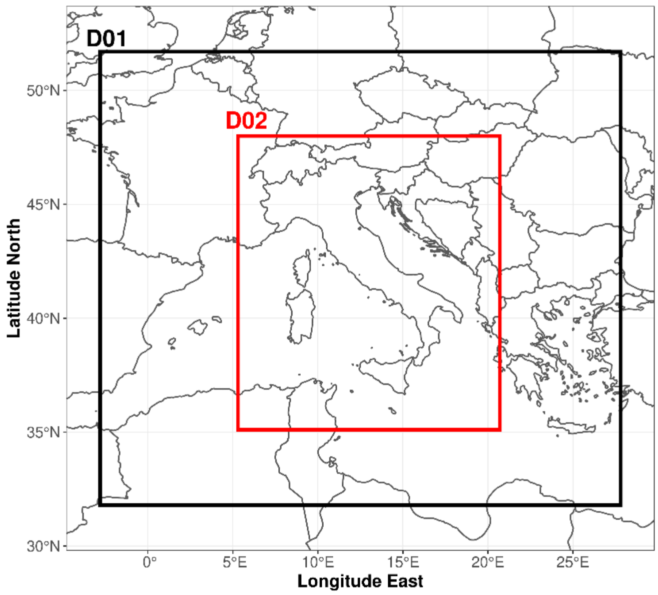

Figure 1 WRF computational domains. D02 is the finer, 1.33 km grid nested on the coarser, 4 km grid (D01).

The inner domain, identified as D02, constitutes the high-resolution meteorological fields of AEOLIAN. The setup of WRF follows the description reported in [3], using a configuration based on different case studies aimed at reliably reconstructing the wind fields [8]. In particular, a surface drag parameterization option has been activated to enhance the reconstruction of WRF's 10-m wind, which generally shows positive bias in the literature [9] which could also affect the wind reconstruction at higher levels. Also, vertical resolution in the Planetary Boundary Layer (PBL) has been increased defining more levels up to 500 m asl/agl.

An important feature of AEOLIAN is the observational nudging, which relies on 10-m wind data coming from measuring stations available from the Italian regional services. The weather network consists of about 300 stations homogeneously distributed across the Italian territory, as shown in Figure 2.

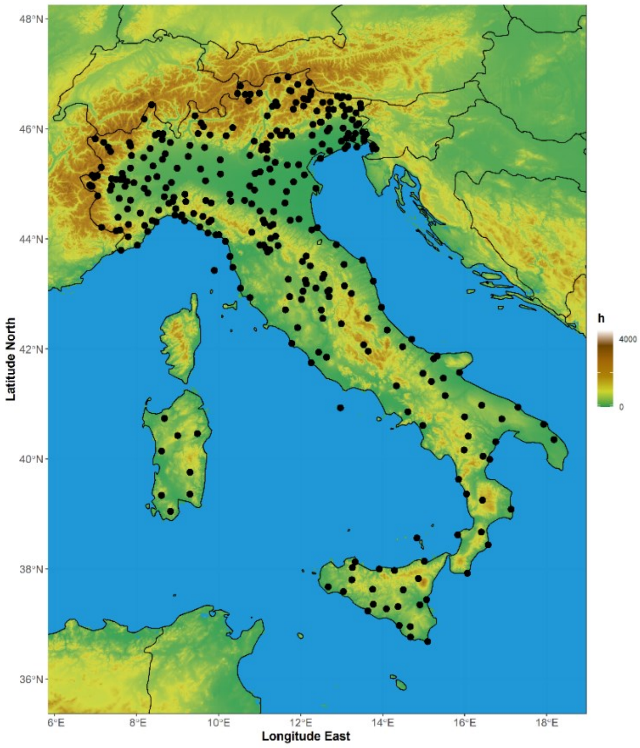

Figure 2 ARPA 10-m wind stations available for observational nudging in the WRF simulations.

The model runs are all initialized at 12 UTC every two days for the entire period to reconstruct with a temporal horizon of 60 hours, discarding the first 12 hours as a spin-up time. Each run is then concatenated with the next one at 00 UTC.

Justification of the computer resources requested

Tests carried out at the ECMWF's AC server allowed estimating the required resources for this project as follows:

- A single, 2-day WRF run submitted as a parallel job requires about 125,000 SBU
- 360 runs are required to reconstruct years 2020 and 2021
- Each run requires a disk storage of about 105 GB after cleaning of unnecessary files.

Technical characteristics of the code to be used

The required code for this project is the WRF model V3.9, which has been already installed on the ECMWF's AC server. The scripts to prepare the input files and launch the simulations are developed in R language.

References

1. European Commission. COM/2021/550 final - 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality; 2021.
2. Gaeta, M.; Lanati, F.; Odifreddi, F.; Tagliabue, L.; Nsangwe Businge, C.; Gelmini, A. Studi a supporto della Governance del sistema energetico nazionale. Ricerca di Sistema (RdS); Milano; 2021.
3. Sperati S, Alessandrini S, D'Amico F, et al. A new Wind Atlas to support the expansion of the Italian wind power fleet. Wind Energy. 2024; 27(3): 298-316. doi:10.1002/we.2890.

4. Ratto, C., Festa, R., Nicora, O., et al. Wind field numerical simulations: a new user friendly code. In European Community Wind Energy Conference; Madrid; 1990.
5. Badger, J., Bauwens, I., Gottschall, J., et al. The New European Wind Atlas (NEWA) and web platform. In 6th International Conference Energy & Meteorology; Copenhagen; 2019.
6. Skamarock, W., Klemp, J., Dudhia, J. A description of the Advanced Research WRF Version 3. Tech. Note NCAR/;475;2008.
7. Delle Monache, L., Eckel, F.A., Rife, D.L., Nagarajan, B., Searight, K. Probabilistic weather prediction with an analog ensemble. Mon Weather Rev. 2013;141(10):3498-3516. doi:10.1175/mwr-d-12-00281.1
8. Lacavalla, M., Bonanno, R., Sperati, S. Dataset MERIDA per il calcolo dei tempi di ritorno delle principali minacce meteorologiche per l'alimentazione dei modelli di vulnerabilità della rete. Ricerca di Sistema (RdS); Milano; 2020.
9. Jimenez, P.A., Dudhia, J. Improving the representation of resolved and unresolved topographic effects on surface wind in the WRF model. Journal of Applied Meteorology and Climatology, vol. 51, n. 2, pp. 300-316, 2012.