DAM DAY 2024

L'IMPORTANZA DELLA RISORSA IDRICA INVASATA NEL QUADRO DEI CAMBIAMENTI CLIMATICI

UNA NUOVA ARCHITETTURA MULTI-SPEED CONVOLUTIONAL TRANSFORMER PER LE PREVISIONI METEOROLOGICHE

PROGETTO TETI - ASI (Agenzia Spaziale Italiana)

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30 maggio 2024

Introduction

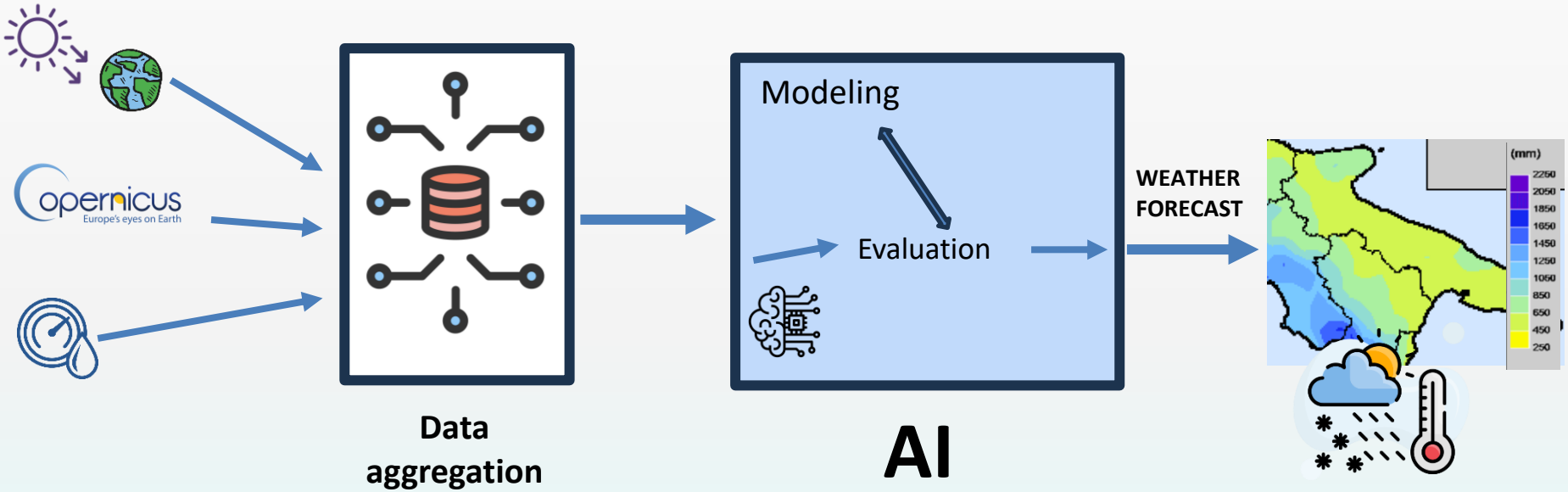
This WP aims to study and develop advanced **Machine Learning** and, more generally, **Artificial Intelligence systems** for forecasting meteo-climatic parameters of specific interest and decision support modeling.

Among these parameters, examples include solar radiation index and the amount of precipitation.

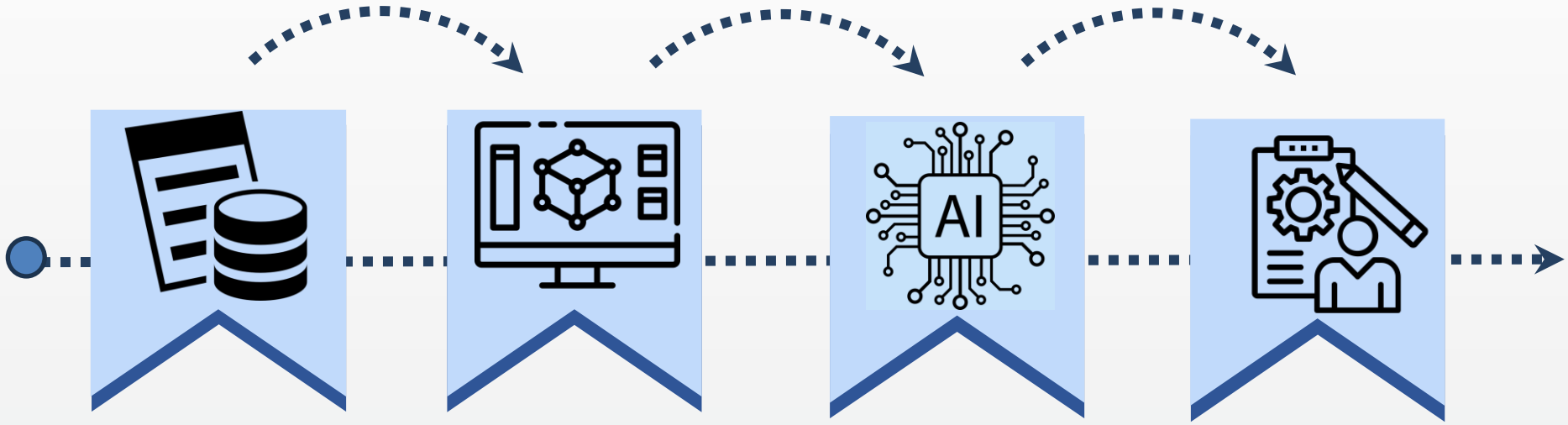
Another activity involves spatializing this data (both current and forecasted).

In fact, if the observations are linked to a specific meteorological station located on the territory, it is possible that the final irrigation advice from the SDSS is related to an area not in the immediate vicinity of the weather station.

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Att. 1 - Identification of Specific Meteo-climatic Parameters of Interest

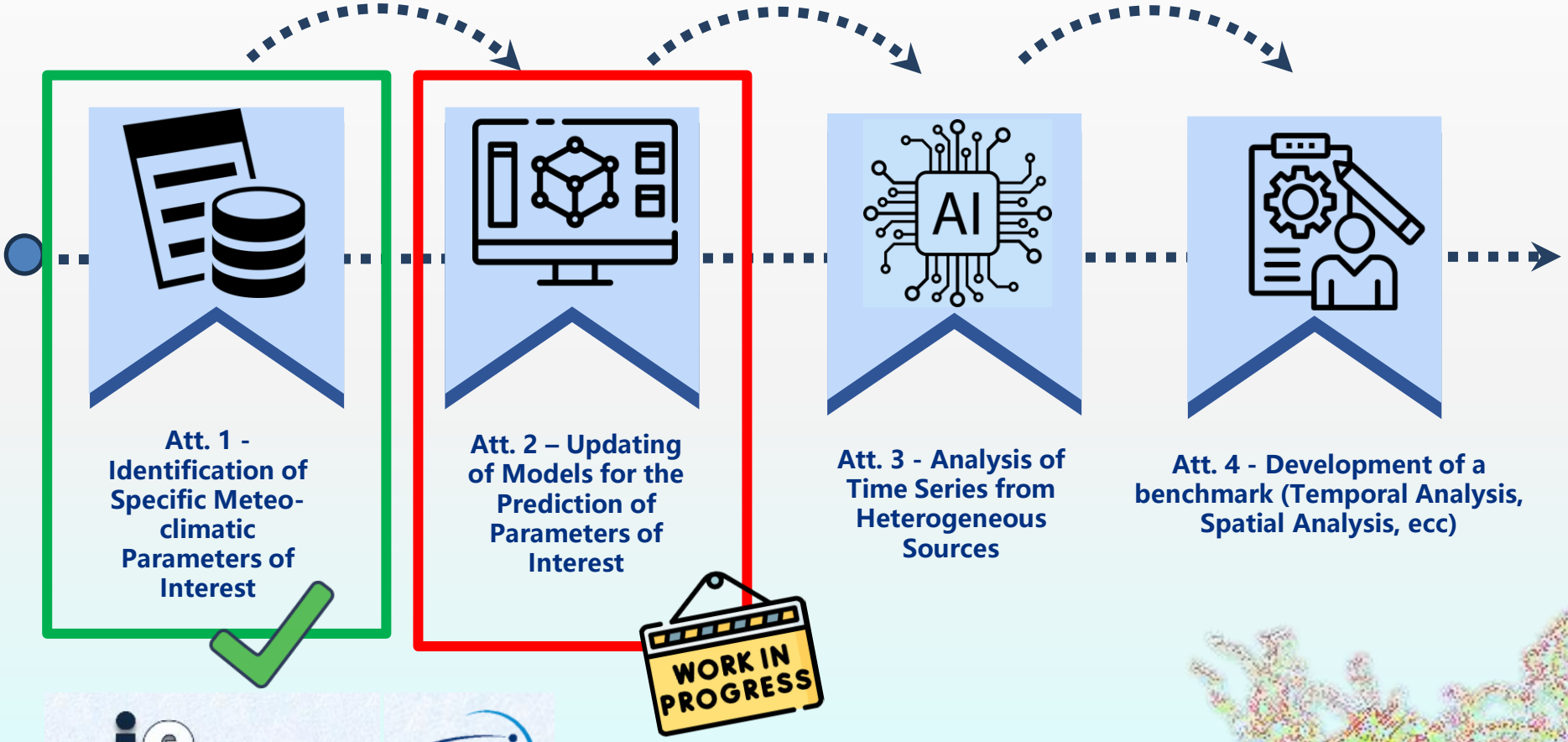
Att. 2 – Updating of Models for the Prediction of Parameters of Interest

Att. 3 - Analysis of Time Series from Heterogeneous Sources

Att. 4 - Development of a benchmark (Temporal Analysis, Spatial Analysis, ecc)

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Analysis of Specific Meteo-climatic Parameters of Interest



Uniba made a follow-up meeting with project partners where the following points were discussed:

- *Spatialization/downscaling of observed weather-climate data and Copernicus forecasts;*
- *Observed meteo-climatic data from stations;*
- *Copernicus forecast meteo-climatic data;*
- *Description of ongoing preliminary activities on Copernicus forecast data;*
- *Discussion on downscaling of Copernicus forecast data (subsequent to MADIA dataset presentation by CREA).*



Uniba Work Conducted

Based on the points discussed Uniba conducted:

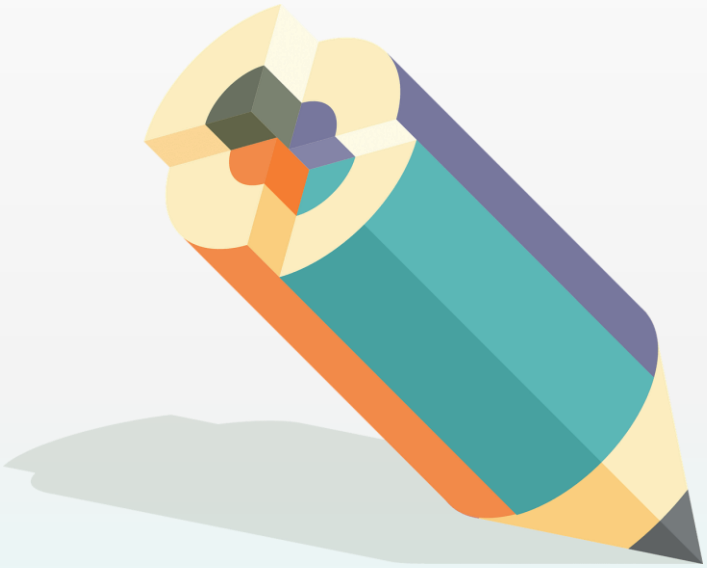


- ***State-of-the-art study*** *related to the meteo-climatic parameters to be predicted and Artificial Intelligence algorithms,*

- ***Benchmark between Shallow Learning and Deep learning algorithms on the historical dataset of the consortium stations (CBC)****, to validate the selected models (Support Vector Regression (SVR); Random Forest; Multi-Speed Dilated Convolutional Deep Neural Network (MSDC); Time Convolutional Network (TCN); Standard Transformer;) for the prediction task of the following features: Rain (mm), Air Temperature (°C) - Maximum, Air Temperature (°C) - Minimum, Air Temperature (°C) - Mean, Wind (m/sec) - Maximum, Wind (m/sec) - Mean, Wind (m/sec) - Direction.*



- *State of the art*
- *Dataset*
- *AI models*
- *Experimental phase*



State of the art

Two-Way Transformer Model for Temperature :
Kim et al. : Uses independent spatial and temporal encoders to improve forecast accuracy of extremely high coastal temperatures.

Electricity Demand Forecasting with TNET:
Ghimire et al: TNET model for accurate energy demand forecasting based on regional climate factors, demonstrating high performance compared to other deep learning models.

Informer Model for Temperature Forecasting:
Jun et al: Replaces LSTM with Informer to better handle long-term dependencies, improving accuracy of temperature forecasts.

GNN for Temperature-Dependent Activity Coefficients:
Rittig et al: Uses graphical neural networks to predict activity coefficients in ionic liquids, showing excellent performance

Multimodal Transformer Model:
Cao et al: Combines observational and reanalysis data with cross-modal attention mechanisms to increase the accuracy of temperature forecasts.

ALTF Net for Long-Term Forecasts:
Nandi et al: Attention-based model for long-term forecasts, surpassing traditional RNN approaches.

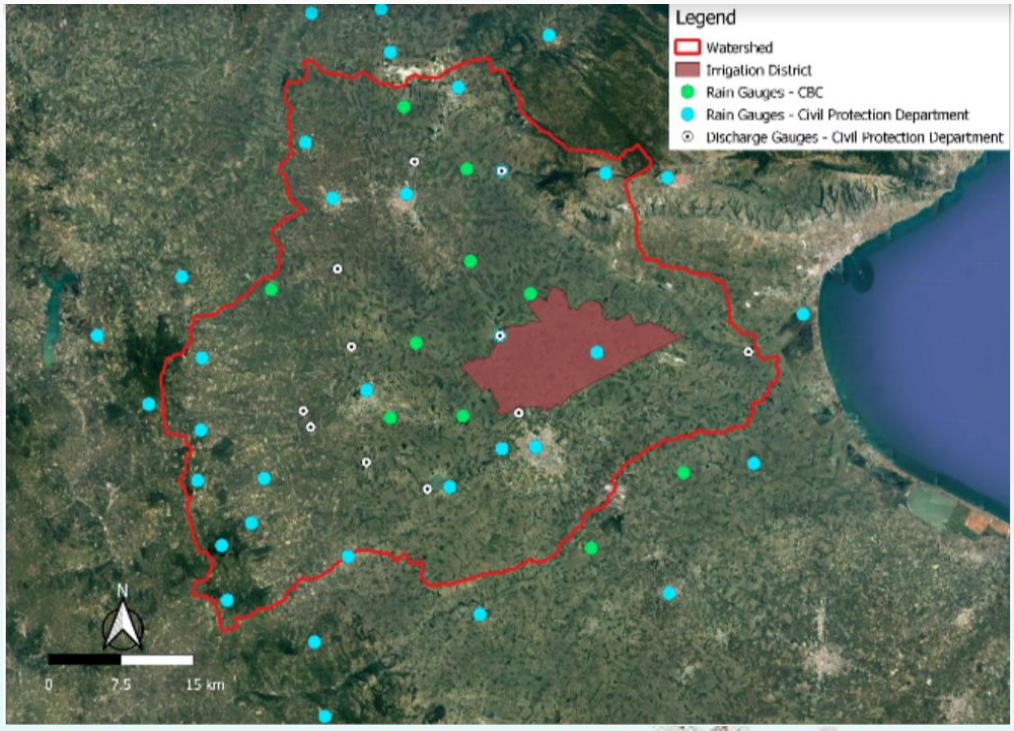
Forecasting Temperatures in Transformers:
Juarez-Balderas et al: ANN model for predicting hotspot temperatures in transformers, improving instrument design and optimization.

Multi-Speed Transformer for Neurodegenerative Diseases:
Model for early diagnosis of neurodegenerative diseases based on pitch analysis, showing superiority in performance over existing methods.

Dataset

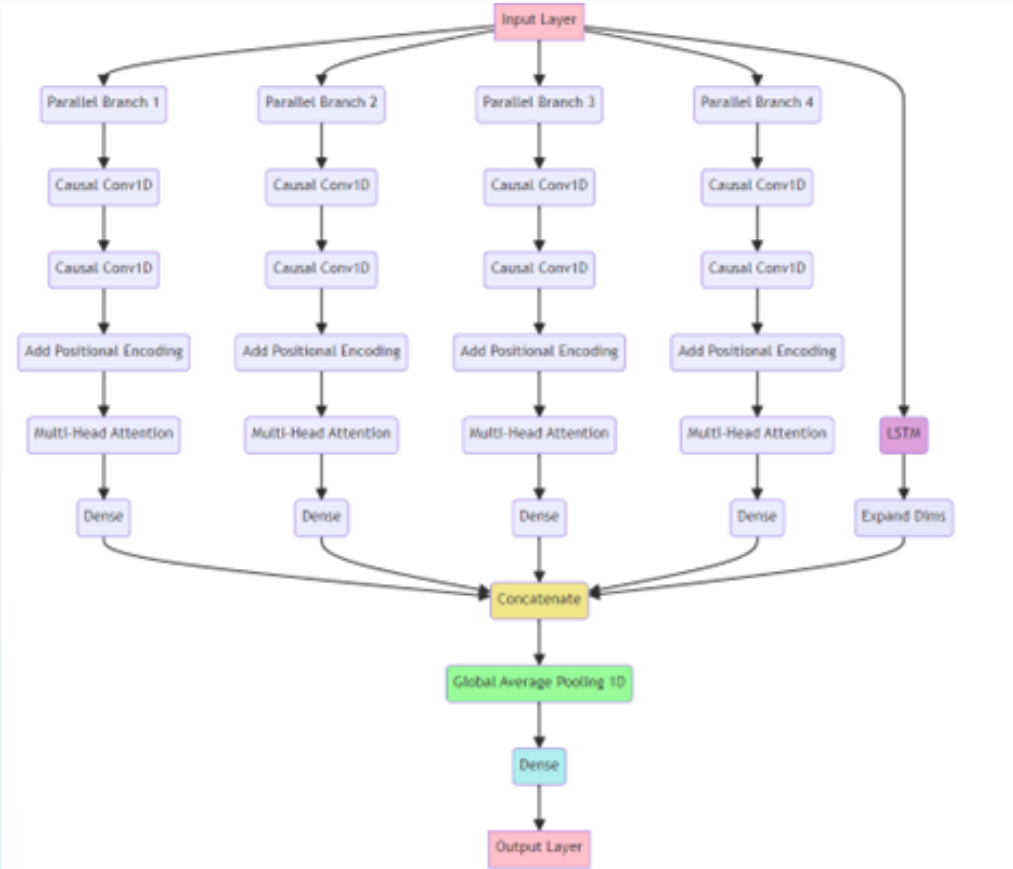
Meteo Station:

- *st.1 - Trinitapoli*
- *st.2 - Stornara*
- *st.4 - Candela*
- *st.5 - San Severo-Torre P1*
- *st.6 - Apricena*
- *st.7 - Serracapriola*
- *st.8 - San Severo-Mass.Sborro*
- *st.9 - Lucera Loc Nocelli*
- *st.10 - Cerignola*
- *st.11 - Torremaggiore*
- *st.12 - Foggia*
- *st.13 - Lucera Mass. Chiarella*
- *st.14 - Ascoli Satriano*
- *st.15 - San Severo-Radicosa*
- *st.16 - Manfredonia*



AI models

MSDC model



Experimental phase

Artificial Intelligence Models:

- Deep learning models include the MSDC, TCN (Time Convolutional Network), and Standard Transformers.
- Shallow learning models include SVR (Support Vector Regression) and Random Forest.

Metrics:

- Model performance is evaluated through several metrics: MAE (Mean Absolute Error), RMSE (Root Mean Squared Error), and R^2 (R-squared).

Evaluation method:

- 50% Train and 50% Test for each Weather Station



AI Model	Metric	Averages	Standard Deviation
SVR	MAE	0.0861	0
	RMSE	0.1111	0
	R^2	0.4251	0
Random Forest Regressor	MAE	0.0727	0
	RMSE	0.1054	0
	R^2	0.4598	0
TCN model	MAE	0.0793	0.0023
	RMSE	0.1144	0.0037
	R^2	0.3423	0.0551
Transformer Model	MAE	0.0796	0.0032
	RMSE	0.1128	0.0029
	R^2	0.3377	0.0359
Our Model: MSDC	**MAE**	**0.0595**	**0**
	RMSE	**0.0957**	**0.0008**
	R^2	**0.5336**	**0.0116**

Upcoming activities

The **Uniba team plans to train AI algorithms for spatialization and test them in Cross-Dataset mode**, on seasonal forecast data for meteo-climatic variables of interest for CM and SWB (Copernicus). These data were downloaded and pre-processed by CNR-IREA. Additional datasets that will be used in this activity will be the MADIA dataset provided by CREA and the CBC consortium station dataset.

Three tests will be conducted:

1. *Train algorithms for spatialization on Copernicus dataset and to test on MADIA dataset;*
2. *Train algorithms for spatialization on MADIA dataset and to test on historical dataset of CBC consortium stations;*
3. *Train algorithms for spatialization on MADIA and Copernicus datasets and to test on historical dataset of consortium stations.*

STATUS OF TECHNICAL AND SCIENTIFIC ACTIVITIES:

- During the T0+6M activity period, **staff in KIND and Dr. Vincenzo Gattulli**, who signed an occasional contract (All. Contratto_Gattulli), **performed** a state-of-the-art analysis on specific weather-climate parameters and identified AI algorithms for prediction and spatializing weather-climate parameters.

- **Submission to** - 27th International Conference on Pattern Recognition (ICPR 2024) - 01-05 December 2024, Kolkata, India. Title: "*A Novel Multi-Speed Convolutional Transformer Architecture for Meteorological Forecasting*". Authors: D. Impedovo, V. Gattulli, L. Sarcinella, D. Veneto, G. Satalino, A. Balenzano, F. Lovergine, C. Albertini, D. Palmisano, F. Mattia, S. Ruggieri, P. Garofalo, M. Rinaldi, V. Iacobellis, A. Gioia, L. Nardella, M. Di Cataldo, N. Noviello, R. Guarini, P. Sacco, M. Virelli, D. Tapete.

Thank you for your Attention

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