Highlights of verification activities in COSMO consortium

Flora Gofa, HNMS

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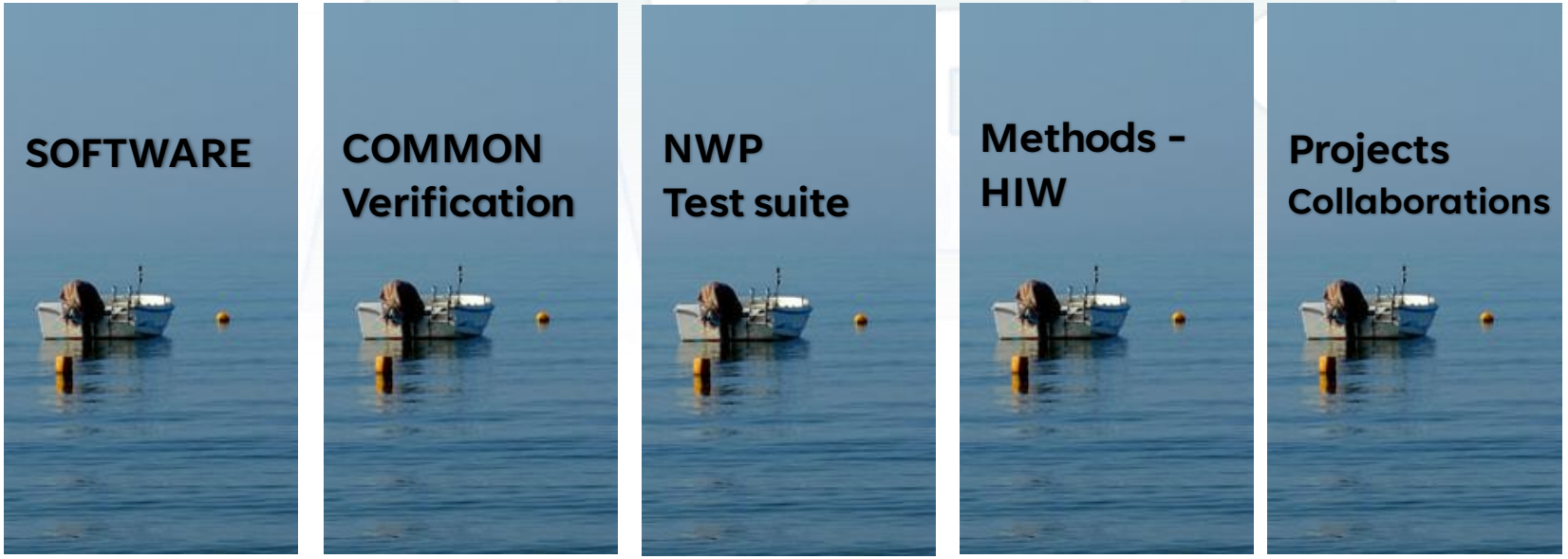
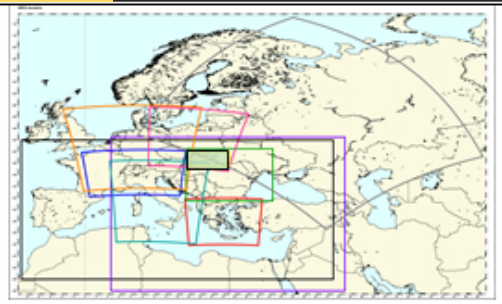
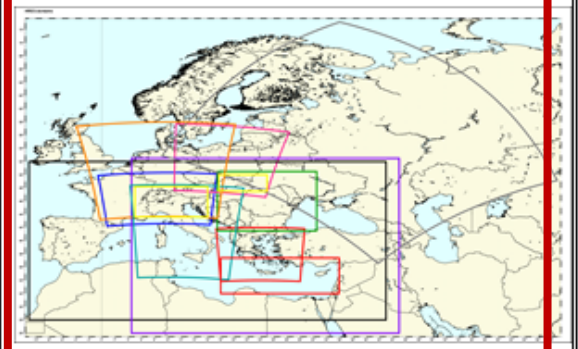
WG on Verification and Case Studies ScPI derived Guidelines

http://www.cosmo-model.org/content/consortium/reports/default.htm

- Common Verification framework: *MEC/FFV2 platform* for standardized verification, developments concerning EPS and conditional verification capabilities (*PP-CARMENs)*
- Spatial verification techniques: Analyse how methods relate to one another, how each method works, what information could be gleaned from each method, and whether a given method actually conveys any useful information *PP-INSPECT, PP-AWARE, SINFONY (DWD)*
- Severe and High Impact Weather. Forecast methods and verification are important aspects of any HIW consideration. *PP-AWARE* addressed issues such the representation in the observations of HIW, importance of observation uncertainty, systematic and stochastic errors of HIW forecasts and their sensitivity to model resolution.
- Utilization of non-conventional observational datasets: *PT-EPOCS* on assessing the use of weather data from Personal Weather Stations (PWS) and other Opportunistic Sensors (OS).



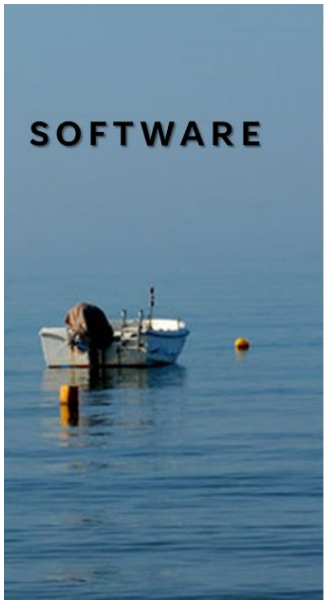
Common Plots: redefined areas

	COARSE ComA-1	FINE ComA-2	MIX NoComA (National Domains)
Specs	 **Forecast run:** 00UTC **Forecast Horizon:** 48h **Seasons:** JJA22, SON22, DJF23, MAM23	 **Forecast run:** 00UTC **Forecast Horizon:** 48h **Seasons:** JJA22, SON22, DJF23, MAM23 **Area: 43.5/5.0/48.2/16.0**	 **Area:** national domains **Forecast Horizon:** variable **Seasons:** JJA22, SON22, DJF23, MAM23
Models	**Global**: ICON, IFS **LAMS**: DWD: ICON-EU, COMET: COSMO-ME IMGW-PIB: COSMO-PL7	**Driving models**: ICON-EU, IFS, ICON **LAMs:** DWD: ICON-D2, MCH: COSMO-1E (control), COSMO-2E, HNMS: ICON-GR COMET: COSMO-I2, ICON-I2, ARPA-E: COSMO-2I IMS: ICON_IL2p5	**COSMO and ICON-LAM** DWD, MCH, COMET, HNMS, IMGW-PIB, NMA, RHM, IMS, ARPA-E
	FINE ComA-3	**MIX** ComA-TCC	**Optional** ComA-OnDemand
Specs	 **Forecast run:** 00UTC **Forecast Horizon:** 48h **Seasons:** JJA22, SON22, DJF23, MAM23 **Area: 47.5/17.7/50.0/25.0**	 **Forecast run:** 00UTC **Forecast Horizon:** 48h **Period:** June2022, Dec2022, Apr2023 **Area: 31.0/18.0/37.4/32.0**	
Models	**Driving models**: ICON-EU, IFS, ICON **LAMs:** HNMS: ICONGR2.5, NMA: COSMO-NMA/ICON NMA. IMGW-PIB: ICON-PL, IMS: ICON–IL2.5	**Driving models**: IFS, ICON **LAMs:** HNMS: ICONGR2.5, IMS: ICON_IL2p5, ICON-EU	**Area and LAMs, Specs based on specific experiment**

Advances in Feedback File based Verification

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
Felix Fundel

User defined subdomains



- Verification can be performed on user defined model sub-domains
- Subdomains can be defined by polygons or station lists
- Old: overlapping sub-domains were not allowed due to unclear observation handling
- New: overlap is allowed

Application example:

- Calculate and show scores for common area 1 and 2 in one run

Advances in Feedback File based Verification

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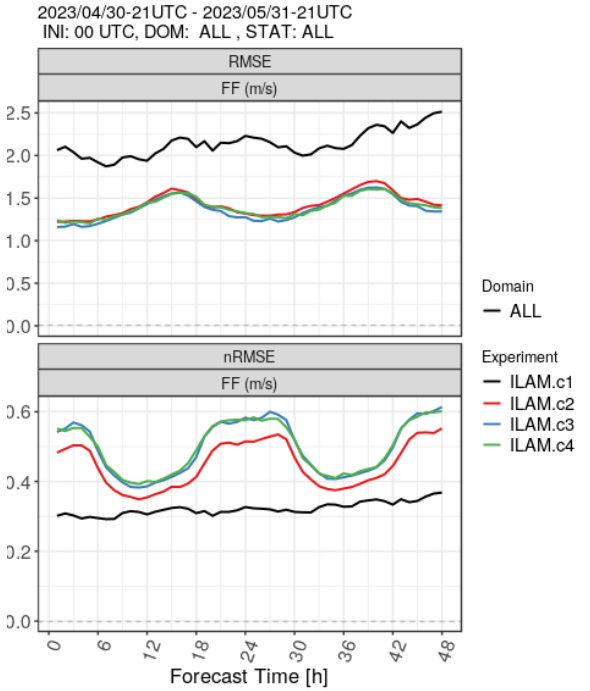
Conditional verification

- Conditional verification capabilities of FFV2 were restricted to data contained in feedback files (e.g. verifying T2M as function of TCC)
- Sometimes additional external input is needed for a conditional verification
- Single external field (e.g. extpar data) can be used to define conditions (e.g. scores for classes of roughness length)
- External data and category thresholds must be specified by namelist
- Grid structure of model and external data must be the same!
- Comparison of models on different grids is not advisable.
- Supporting only icosahedral grids, lat/lon support could be implemented on request.
- For better comparison between conditions a RMSE normalized by observation mean (nRMSE) was introduced.



C1 Z0<1.1e-6
C2 1.1e-6<Z0<0.154
C3 0.154<Z0<0.47
C4 0.47<Z0

Advances in Feedback File based Verification

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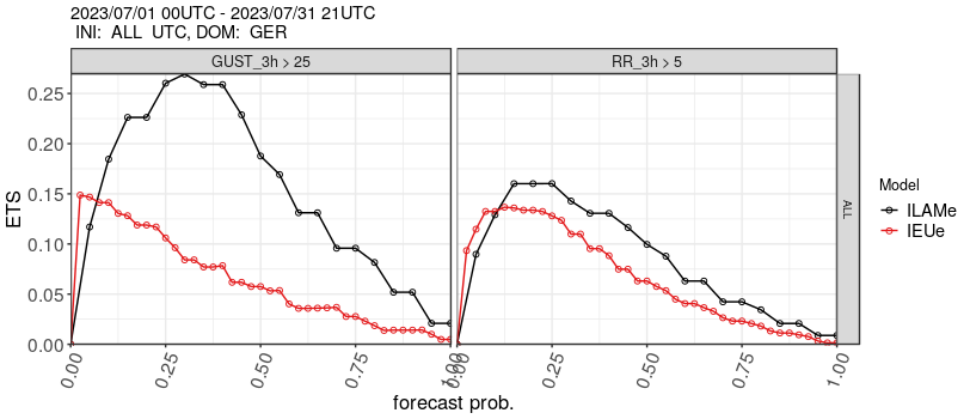
Categorical Scores in Ensemble Verification

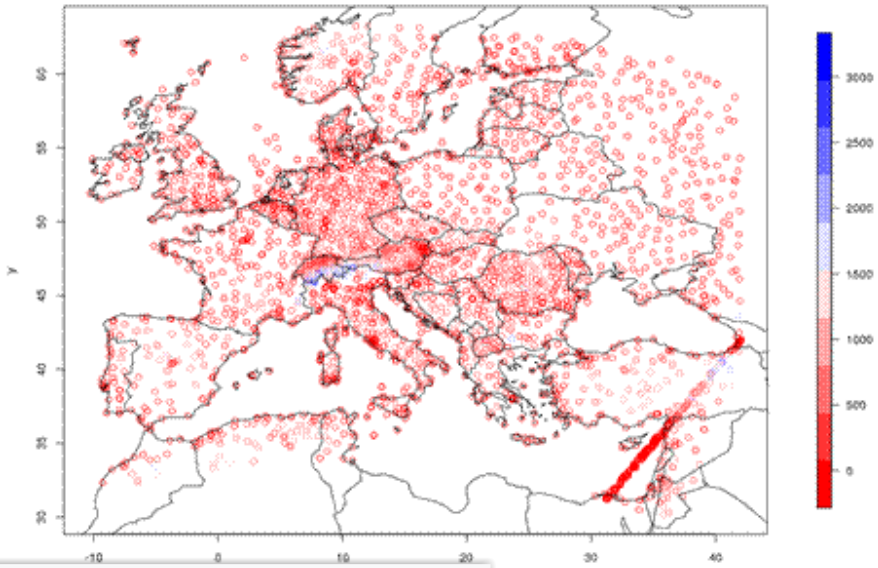
- Motivation: finding the best probability threshold for decision making based on ensemble forecasts
- Simple but effective verification solution is to give a categorical score for all possible probabilities
- I.e. the ensemble forecast for an event is treated as hit if the probability to exceed the event reaches a certain threshold of a score
- For more extreme events scores like the SEDI are included

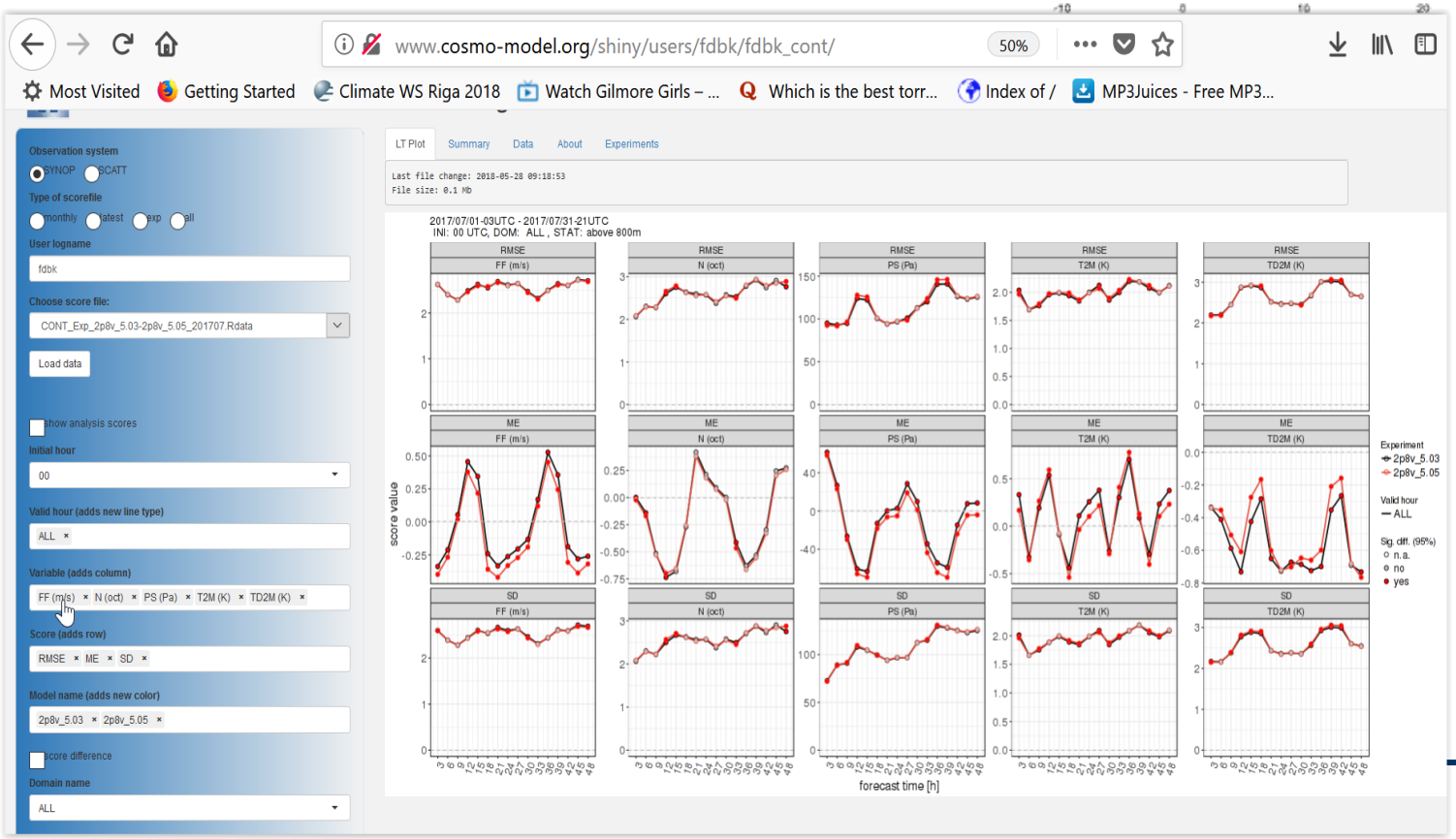


NWP Meteorological Test Suite @ ECMWF

Coarse and high resolution experiments based on NEW ICON model versions
Hindcast mode experiments
Winter and summer period

http://www.cosmo-model.org/shiny/users/fdbk/





FFV2 Verification Software

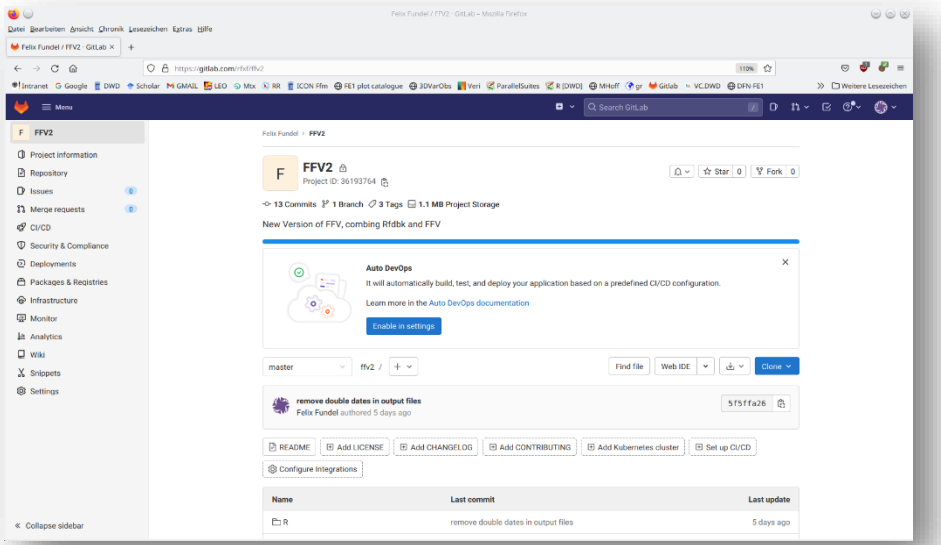
Felix Fundel, DWD

Package

https://gitlab.com/rfxf/ffv2

Install

git clone git@gitlab.com:rfxf/FFV2.git
R CMD INSTALL FFV2



Run (example)

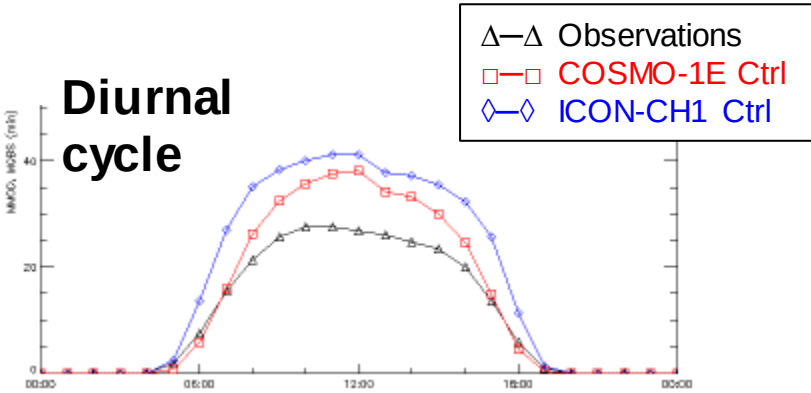
Rscript ../Rlib/FFV2/demo/starter_scores_by_date.R namelist.nl SYNOP DET 6
Rscript ../Rlib/FFV2/demo/starter_aggregate.R namelist.nl SYNOP DET 6

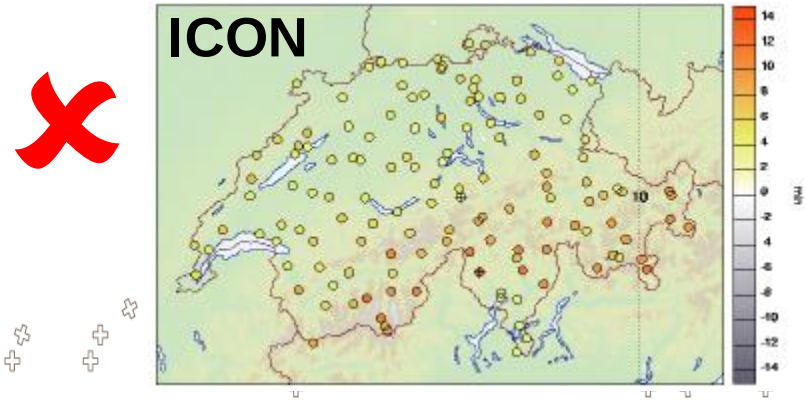
Performance differences between COSMO and ICON

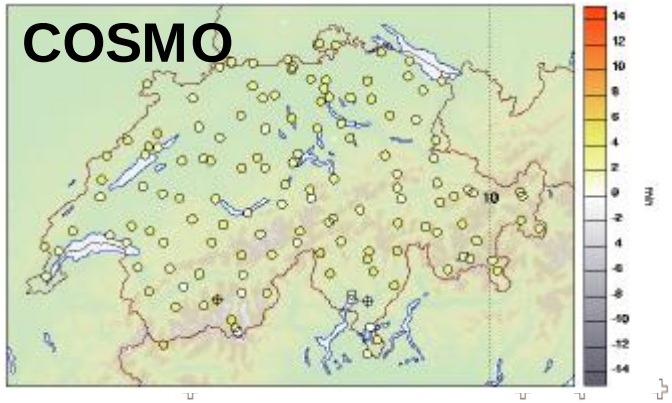
Sunshine Duration

Sunshine = direct shortwave radiation > 200 W m^{-2}

- ICON stronger overestimation
- Mostly south side of Alps



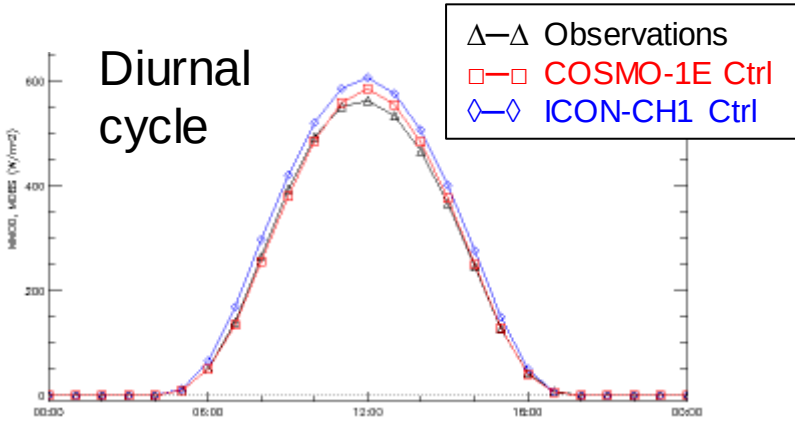


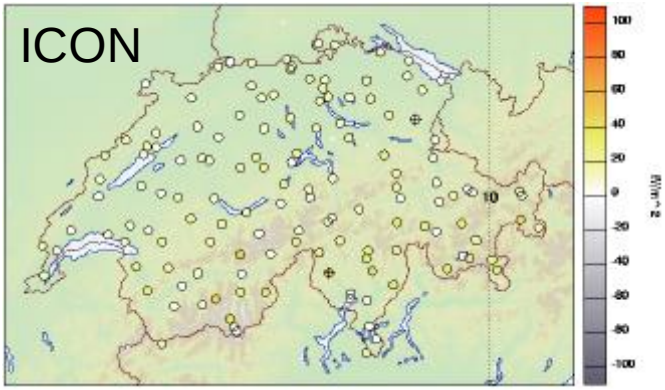


Performance differences between COSMO and ICON

Shortwave (Global) Radiation

- ICON only slightly stronger overestimation
- → Problem due to partitioning between direct and diffuse





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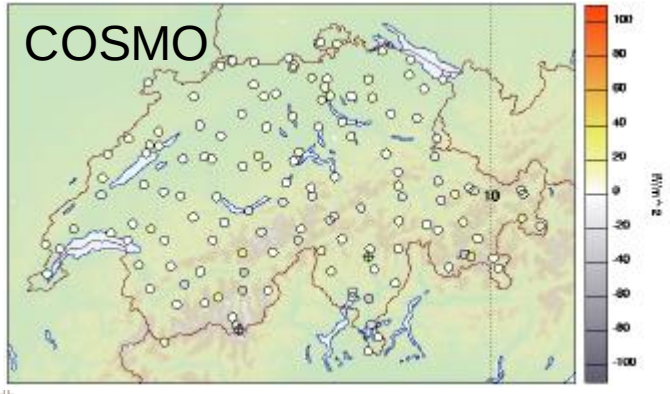
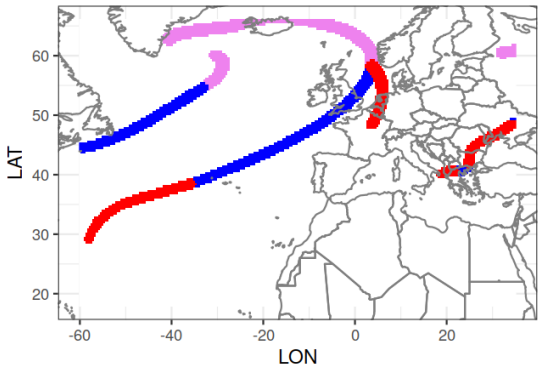


ML Weather Fronts Prediction and Application in Verification

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
Felix Fundel

Motivation

- Making use of ML in verification
- Making use of weather front analysis from DWD forecasters (human)
- Train ML model to identify fronts in forecasts
- Verify in the vicinity of fronts
- Verify properties of front predictions as objects



Literature:

- ML superior to classical methods (Niebler et al., WCD, 2021)
- Methodology inspired by Biard and Kunkel, ASCMO, 2019

Advantages:

- Front analysis and prediction based on (ICON) model only (consistent in time)
- AI should learn robust front properties and (hopefully) discard personal forecaster preferences
- AI can predict fronts for every model date, not just 00 & 12 UTC and some selected forecast times
- AI might help quantify and understand model errors
- AI might support forecasters for drawing fronts or fast identification of areas of relevant weather

Data

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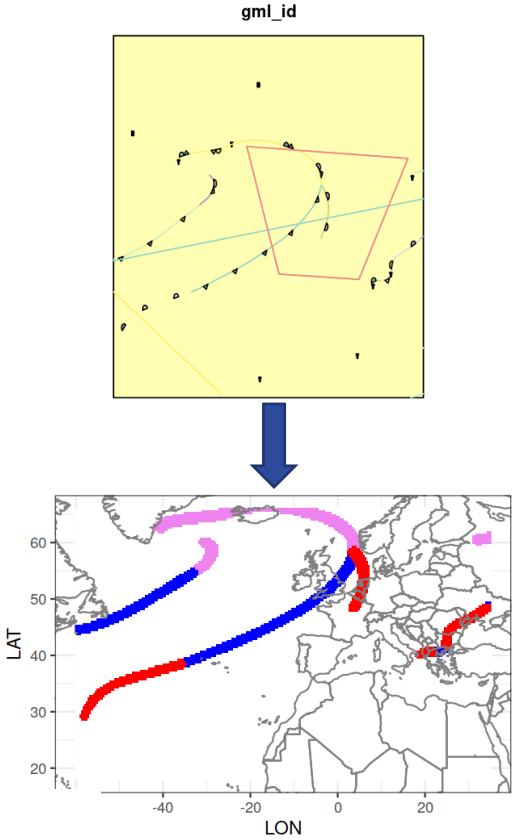
Front Analysis (human)

- Drawn by DWD forecasters
- Export of Ninjo meteobjects in gml (xml) format (lines)
- Provided 00 & 12UTC
- North-Atlantic Europe
- Started March 2021, total of >1800 cases and growing
- Recently also forecasts are provided (+36,48,60,94,108h)

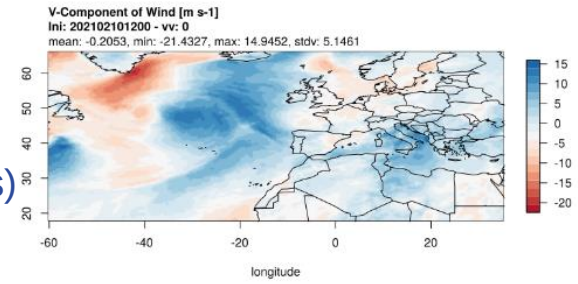


Postprocessing

- Extracting front lines from gml file
- Define a buffer zone of 100 km around the front line (analysis uncertainty)
- Convert polygon to pixel map on model grid (256x128, 0.4°x0.4°)
- Resulting pixel map of 4 categories (warm-front, cold-front, occlusion and no front)

Model Input (Predictors)

- ICON global deterministic (~0.12°), vv=0
- PMSL, RH2M, T2M, U10M, V10M
- Regridded with CDO
- Horizontal res. ~0.4° (256x128 grid points)
- Each variable normalized



ML Weather Fronts Prediction and Application in Verification

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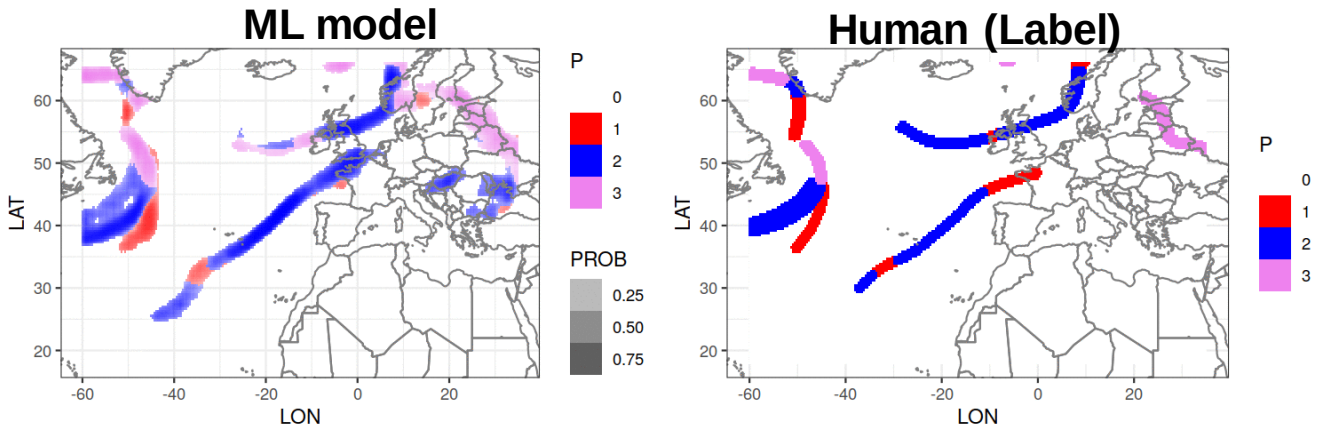
ML Model

- Written with the Tensorflow library with Keras functionality
- 2d convolutional Encoder-Decoder NN with concatenation of features from the encoder path (Unet)

Prediction

- Some examples from the validation data set (unseen during training)
- red: warm front, blue: cold front, violet: occlusion
- Transparency ~ class probability
- No front is drawn if “no-front” probability is >60%



- Realistic front prediction.
- Discarding lower probabilities will lead to sharper fronts and less artefacts but some true features might be lost.

ML Weather Fronts Prediction and Application in Verification

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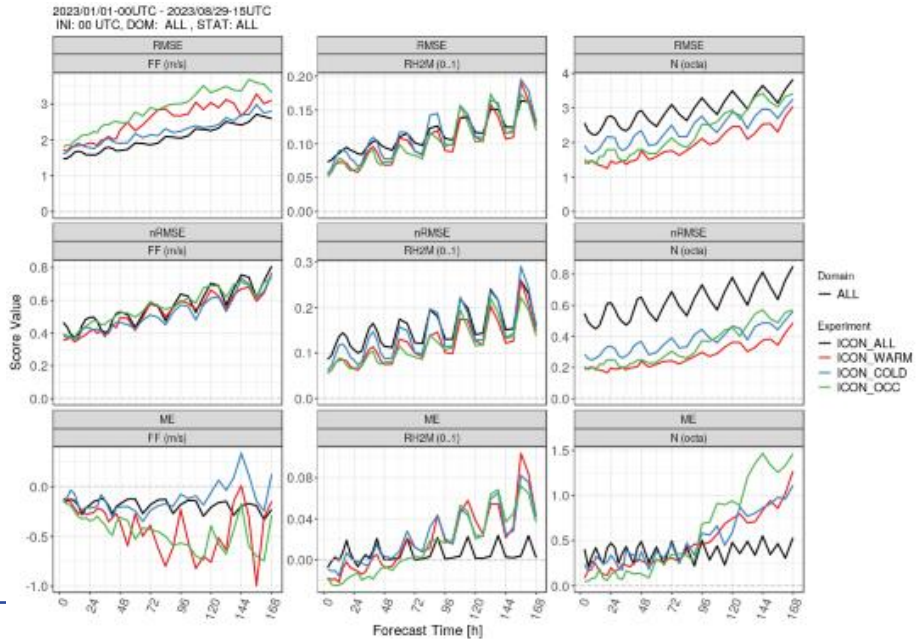
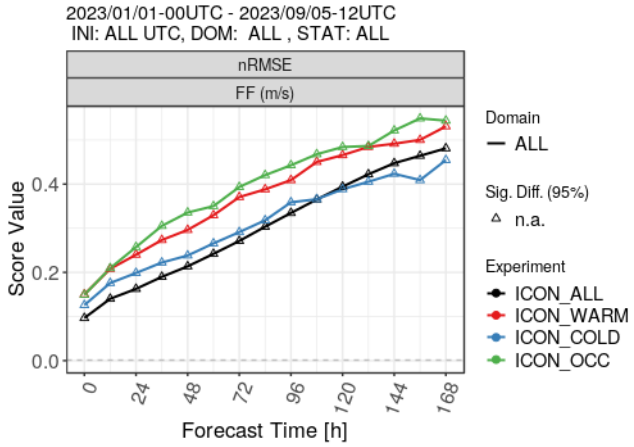
Station Based Verification

- Observation based verification has been upgraded to ingest varying polygons as mask for a conditional verification
- Forecast errors are calculated for observations in the vicinity of cold- and warm fronts and occlusions
- RMSE can be misleading, normalized RMSE is more appropriate
- SYNOP: Wind forecasts equally good in all classes, humidity and cloud cover probably influenced by range of data.
- SCATT: Higher forecast errors in front classes, especially warm fronts and occlusions.

SYNOP



SCATT



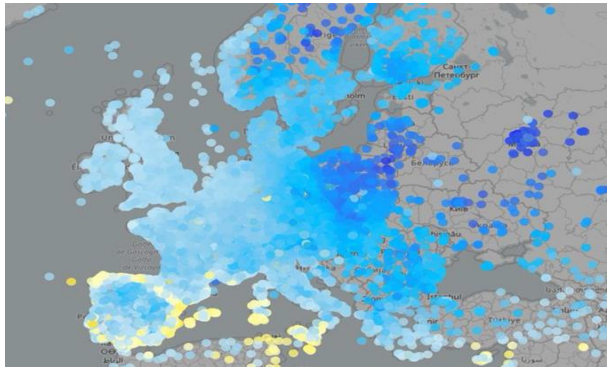
EPOCS (Evaluate Personal Weather Station and Opportunistic Sensor Data CrowdSourcing)

PL: Joanna Linkowska, IMGW-IB

The aim of PT EPOCS is to assess the use of weather data from Personal Weather Stations (PWS) and other Opportunistic Sensors (OS).

The main scientific aims of this PP are:

- The development and testing of data Quality Control (QC) algorithms.
- The evaluation of quality and usefulness of this data for potential applications (nowcasting, NWP and model forecast verification)



IMGW-PIB: Joanna Linkowska, Jan Szturc, Anna Jurczyk, Katarzyna Ośródka, Marcin Grzelczyk, +Radosław Droździoł
CIMA: Massimo Milelli, Elena Obert, Umberto Pellegrini
CNMCA: Francesco Sudati

COSMO GENERAL MEETING, Gdańsk, 11-14.09.2023

PWS databases survey and exploitation

The applicability of PWS data generated by the distributed network of private owners depends highly on centralized API based storage system allowing for a near–real time access to obs. Survey was made of available data platforms at the European and Global level with the analysis of the API data access. Legal limitations for data usage is a key issue in data application for the research and operational use.

No	Web service	Stations in EU	API	Privacy Policy (Terms of service)	API Data
1	Wunderground (www.wunderground.com)	EU >1000	Yes, professional	Not commercial or science usage; only personal use; commercial need to pay	All data (observation, historical above 5min steps)
2	Aeris weather (www.pwsweather.com/)	EU >1000 (DE, GE, IT, PL ~60, RO, CH)	Yes, professional	Attribution required for public usage,	1,000 accesses/day (rate limit: 100 accesses/minute), Observations, Daily Forecasts (7 days), Hourly Forecast (24 Hours), Sun & Moon, Places, Alerts, Observations/Summary, Observations/Archive , Air Quality
3	Awekas (www.awekas.at)	EU >1000 (DE, GE, IT, PL ~90, RO, CH)	No, only text information without download	Not commercial or science usage; only personal use after pay annual fee (https://www.awekas.at/wp/shop/licenses/awekas-stationsweb-annual-fee/?lang=en)	No API, but have primitive export option
4	Meteomatics (https://www.meteomatics.com/), WMO (https://public.wmo.int/en/programmes/public-weather-services-programme)	EU = 13154 station of WMO	Yes, professional	free basic package for non-commercial use, but this has only forecast data and 24 hours of historical data (no observations).	Wind speed, Maximum temperature, Minimum temperature, Precipitation amount, Sunrise, Sunset
5	Weathercloud (weathercloud.net)	EU >30.000 (**Germany**: 20,000, **Greece**: 600, **Italy**: 5,000, **Poland**: 2,000, **Romania**: 300, **Switzerland**: 1,200)	Yes, basic	Personal, worldwide, non-assignable and non-exclusive license to use Weathercloud. This license is for the sole purpose of enabling you to use and enjoy Weathercloud in the manner permitted by these terms. This license is revocable at any time. This license does not include: The distribution of Weathercloud's content., Modifying or otherwise making any derivative uses of Weathercloud or any portion thereof., Use of any scraping, data mining, robots or similar data gathering or extraction methods., Downloading, other than page caching, any portion of Weathercloud, except as expressly permitted., Accessing Weathercloud's API with an unauthorized client., Any use of Weathercloud other than for their intended purposes.	3 Devices (basic plan), **10 Minute** update interval, **12 Month** cloud database, Current weather & evolution graphs, Data export to CSV, Custom plots, Daily & monthly reports

QC algorithms for precipitation: development and testing automatic QC methods based on the RainGaugeQC algorithms

METEO IMGW-PIB meteo.imgw.pl

PWS do not follow WMO measurement standards are rarely regularly maintained, and calibrated. Applying appropriate QC methods is essential to increase data reliability and to enhance user confidence in good quality forecast.

Design and implementation of version of the RainGaugeQC software for QC of unprofessional gauges (standard RainGaugeQC: Ośródka et al., AMT 2022)

Abbr.	Algorithm	Sub-algorithms	Standard RainGaugeQC	Version for unprofess. gauges
GEC	Gross Error Check		x	x
RC	Range Check		x	x
RCC	Radar Conformity Check	1) Detection of incorrect „no precipitation" data	x	x
		2) Detection of false precipitation reports	x	x
TCC	Temporal Consistency Check	1) Detection of blocked sensors	x	x
		2) Comparison of two sensors	x	
		3) Time series comparison with weather radar		x
		4) Bias correction with adjusted radar data		x
SCC	Spatial Consistency Check	1) Detection of outliers from the local vicinity	x	x
		2) Advanced detection of outliers taking into account additional percentiles	x	x

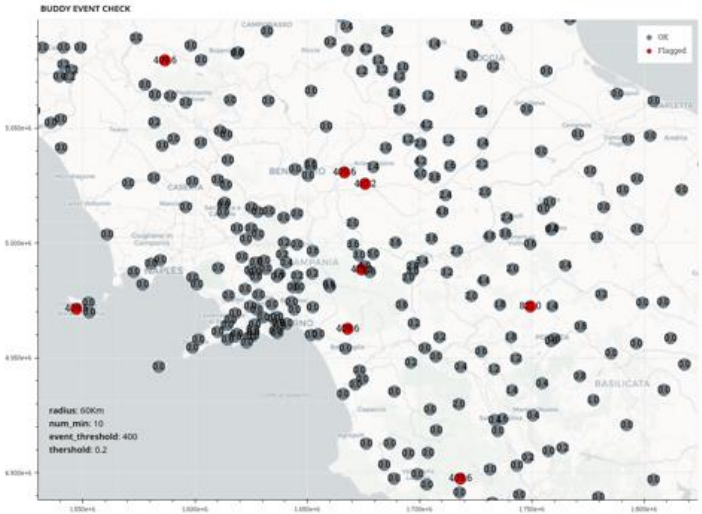
Testing and application of the open-source software packaITAN for a quality control of ground data

TITANLIB is an open source software developed at the Norwegian meteorological institute. It is a library of automatic quality control routines for weather observations. The main goal of the task is to prepare a “clean” precipitation field for model verification, for instance. Starting point – test on the official Italian network, not on personal weather stations (PWS).

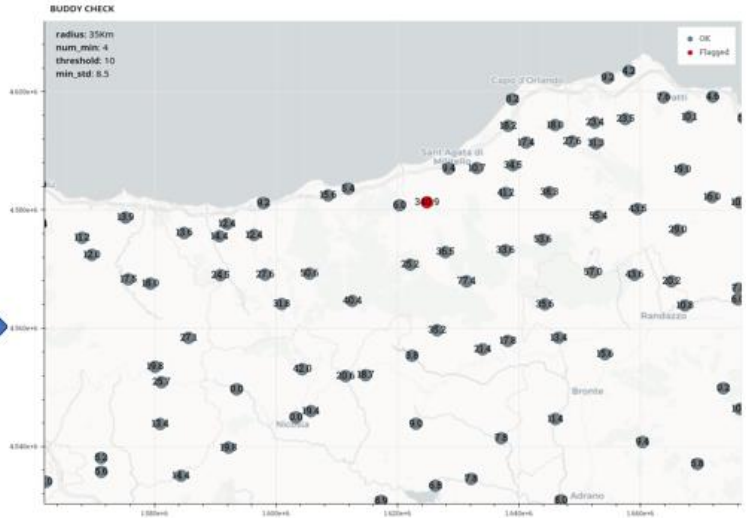
TITANLIB main tests

Buddy event check →

The observations are converted into yes/no values of exceeding a specified threshold (**event_threshold**).
The **threshold** argument in this test is minimum fraction of other observations in the neighbourhood that must agree with the observation being inspected.



Buddy check →



The buddy check compares an observation against its neighbours (i.e. buddies) and flags outliers in a radius specified by the user.
The buddy check flags observations if the (absolute value of the) difference between the observations and the average of the neighbours normalized by the standard deviation in the circle is greater than a predefined **threshold**.

Slide courtesy of Elena Oberto

Multi-source precipitation (RainGRS+)

METEO IMGW-PIB meteo.imgw.pl

RainGRS+ model:

Quality-based combination of rain gauge, radar and satellite data (QPE)

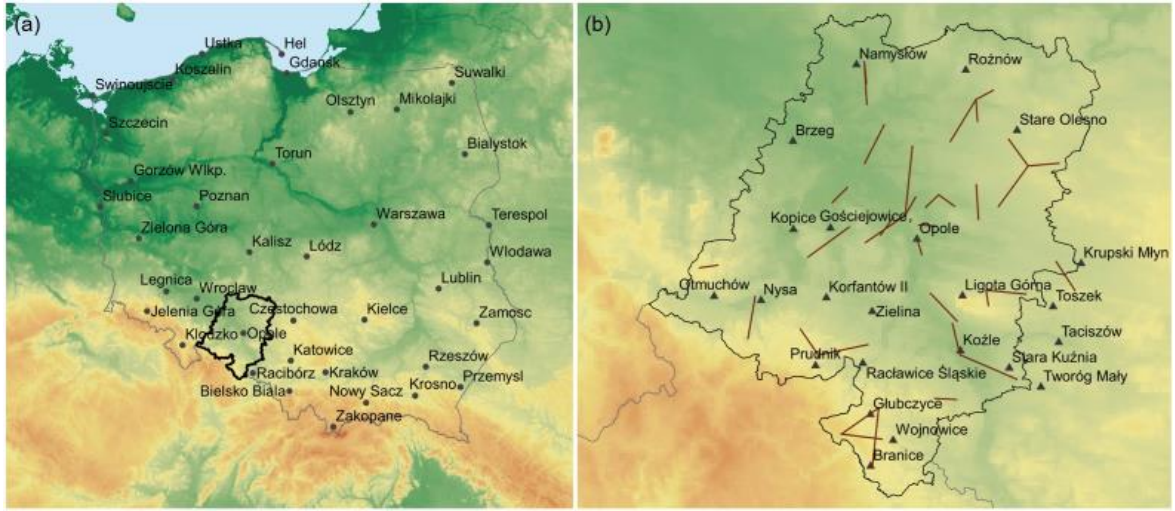
Input data:

Data	Spatial resolution	Temporal resolution	Delay	From the software
IMGW rain gauge network	point	10 min	6 min	RainGaugeQC
Unprofessional networks (PWS)	point	10 min	12 min	RainGaugeQC
IMGW POLRAD radar network + neighbouring countries radars	1 km	10 min	7 min	RadComposite
EUMETNET OPERA radar precipitation	1.9 km x 2.2 km	15 min	13-23 min	EUMETNET OPERA
Meteosat (NWC-SAF) based precipitation estimates (algorithm, see: Jurczyk et al., 2020, Remote Sensing)	1 km	10 min	3 min	sat_qc_int
CML (microwave commercial links)	point	15 min	?	COST OPENSENSE

Multi-source precipitation (RainGRS+)
CML-based data

METEO IMGW-PIB
meteo.imgw.pl

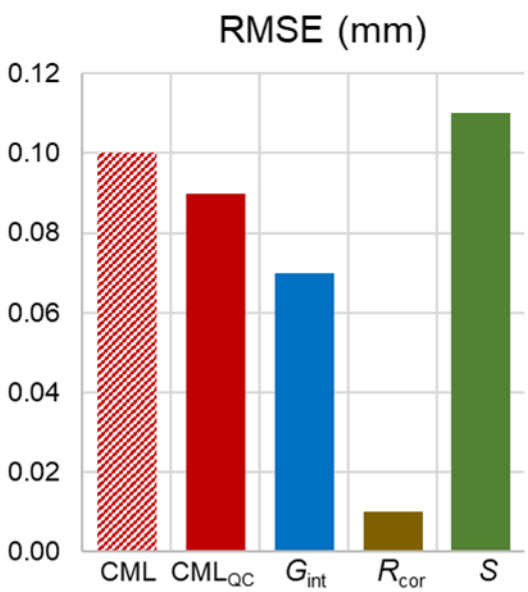
Commercial microwave links (CMLs) are used to transmit information between towers of cellphone networks. **If there is rainfall along the transmission path, the signal level is attenuated**. By comparing the transmitted and received signal levels, the average rainfall intensity along the path can be estimated.

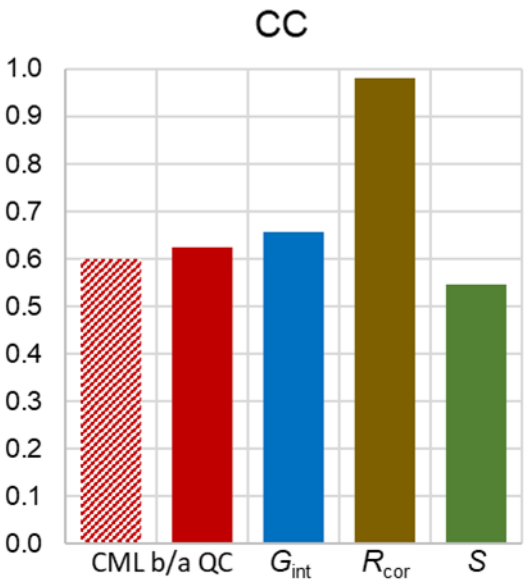


RMSE and correlation coefficient (CC) of CML-based precipitation determined before and after quality control, telemetric rain gauges (G_{int}), corrected radar (R_{cor}), and satellite (S) data.

RainGRS as a reference.

Half-hourly accumulations (July 19 – August 18, 2022)





Slide courtesy of Jan Szturc

Development and testing automatic QC methods based on the RainGaugeQC algorithms

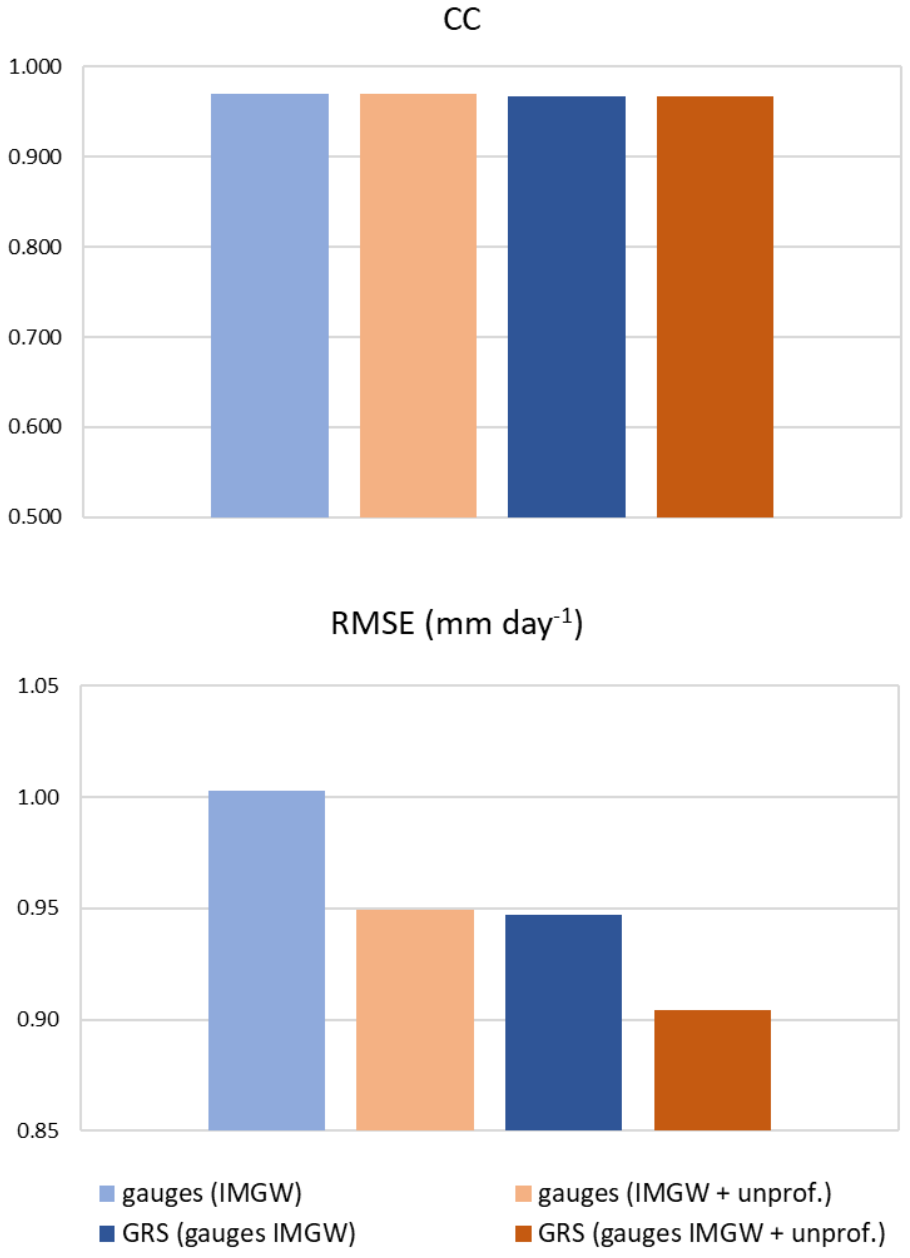
METEO IMGW-PIB meteo.imgw.pl

Reliability statistics of rainfall fields:

- spatially interpolated from rain gauges from IMGW,
- spatially interpolated from IMGW + unprof.,
- RainGRS fields based on data from IMGW,
- RainGRS fields based on data from IMGW + unprof.

Reference: data from manual rain gauges.

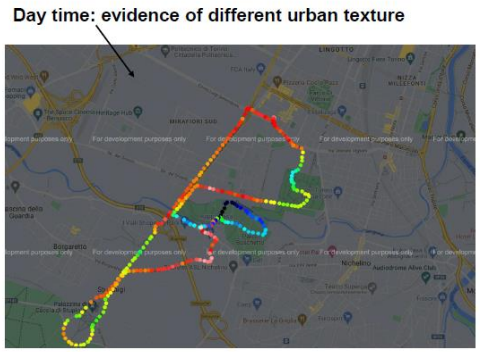
May 2023.

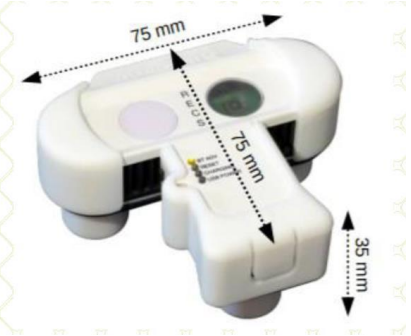


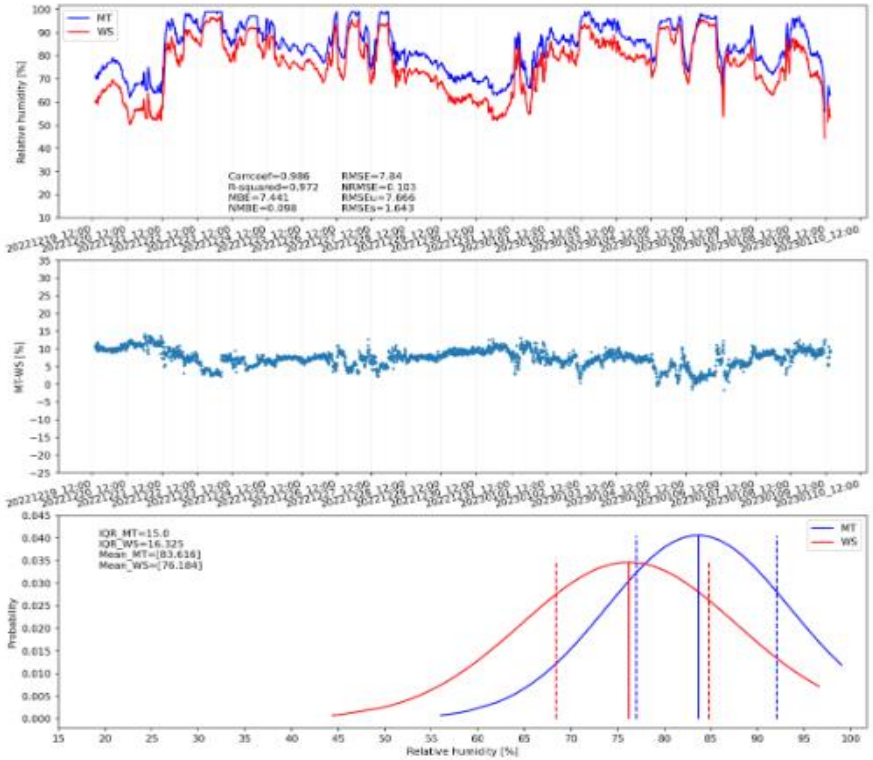
Massimo Milelli, CIMA

Analysis of the mobile PWS sensors: testing QC proprieties of a new mobile weather sensors from Meteotracker

MeteoTracker is a mini weather station specifically designed and patented for measurements taken on the move: ✓ Air temperature, ✓ Relative Humidity, ✓ Pressure.
Derived parameters: Dew Point, Altitude, Vertical Temperature Gradient, Solar Radiation Intensity, Humidex Index (thermal comfort), Vehicle Velocity.



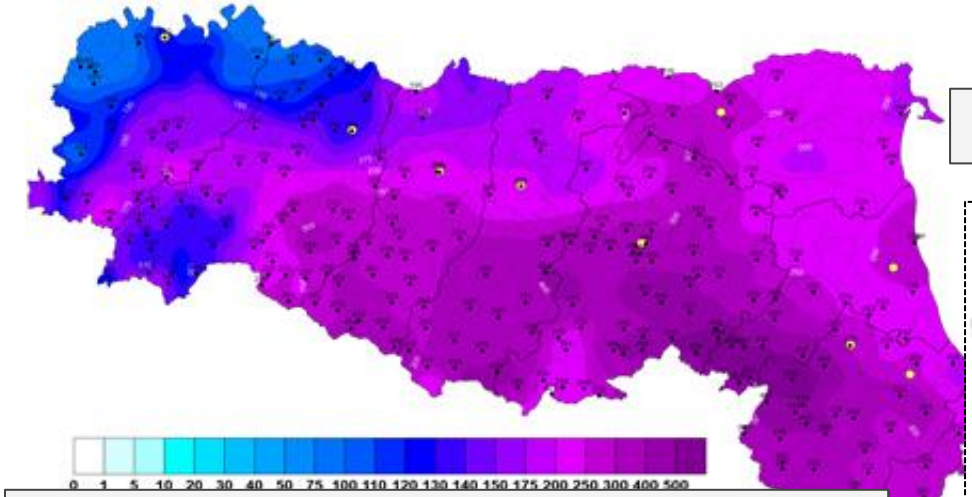




Comparison between a MT in a Stevenson box and a WMO sensor (WS) on the roof of CIMA. Relative Humidity, Winter period (19/12/2022 - 10/01/2023)

Models perfomance during the flood events of May 2023 in Emilia-Romagna region

Maria Stefania Tesini, ARPA-E

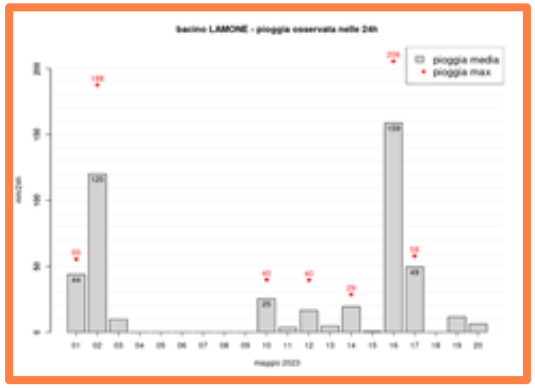


Cumulative precipitation observed from 1 to 31 May 2023 (validated ERG5 dataset)

Hydrological basins (400-500 Km^2)

Maximum amounts in the period 1-17 May:

- Trebbio (Lamone basin) 609 mm
- Le Taverne (Santerno basin) 563 mm
- Historical records for most rain gauges in the central-eastern sector with values over 300-400 mm (some with 100 or more years of data)
- The rain that has fallen in these areas over the entire period represents about a quarter of the annual cumulative climate value, while in each of the two main events (1-3 May and 16-17 May) it clearly exceeded the monthly cumulative climate value.

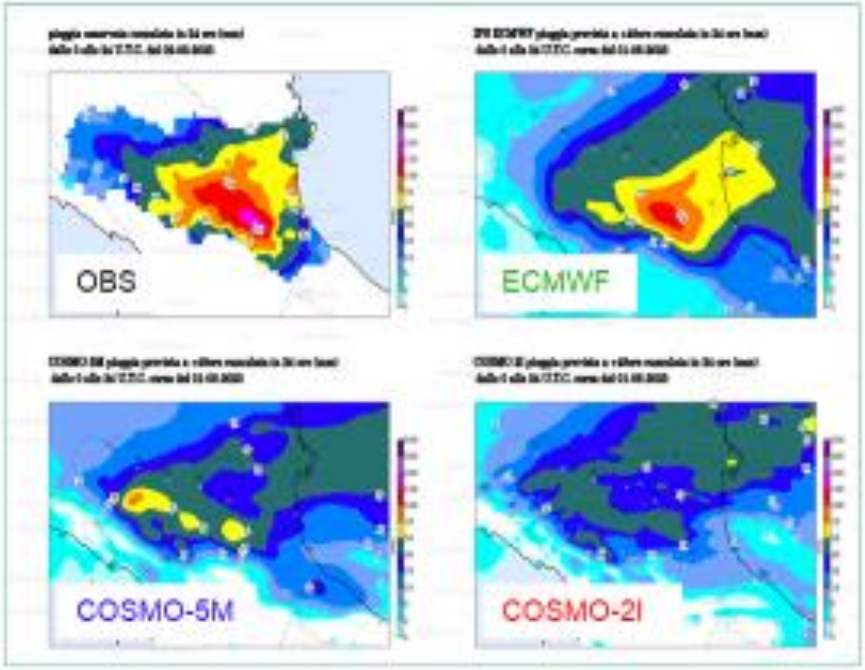


Models perfomance during the flood events of May 2023 in Emilia-Romagna region

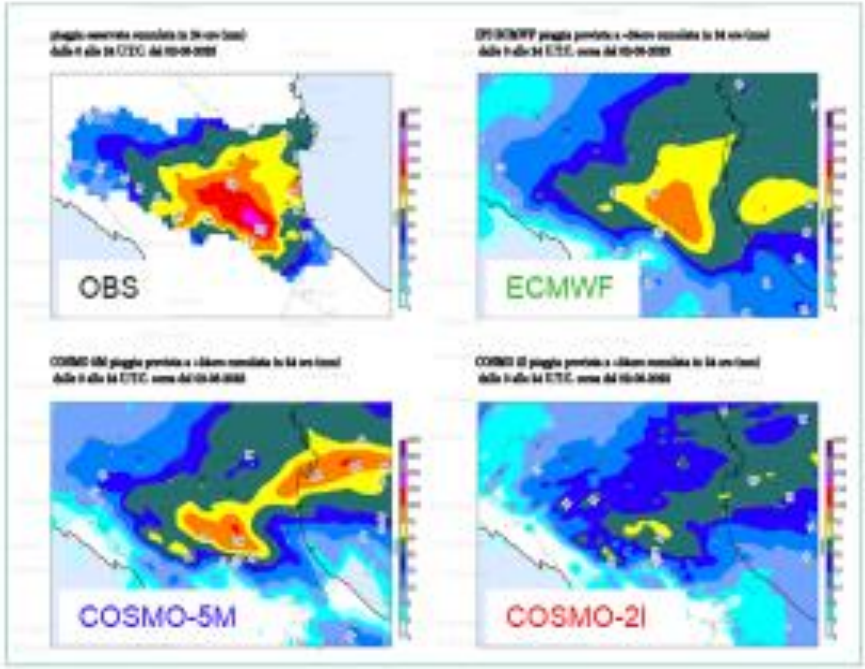
Maria Stefania Tesini, ARPA-E

How was the forecast for May 2?

FORECAST ISSUED 01-05-2023 00 UTC
VALID FOR MAY 2 (accumulated in 24 hours at +48h)



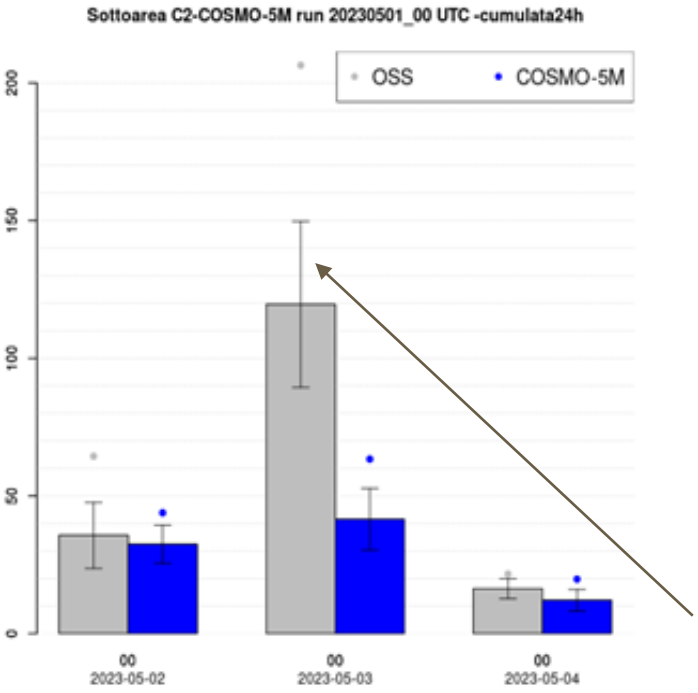
FORECAST ISSUED 02-05-2023 00 UTC
VALID FOR MAY 2 (accumulated in 24 hours at +24h)



Models avaliable for operative use at Arpae

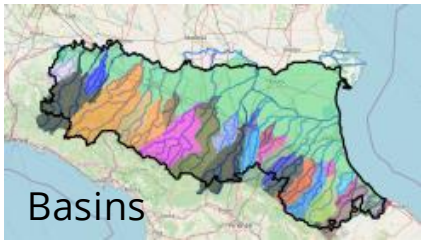
Maria Stefania Tesini, ARPA-E

Forecast/observed rain comparison



The gray (obs) and colored (fcst) bars represent the average precipitation evaluated using all the points that fall in the basin or alert zone

Dots represent the maximum precipitation observed (gray) or predicted (colored) within the basin or alert zone

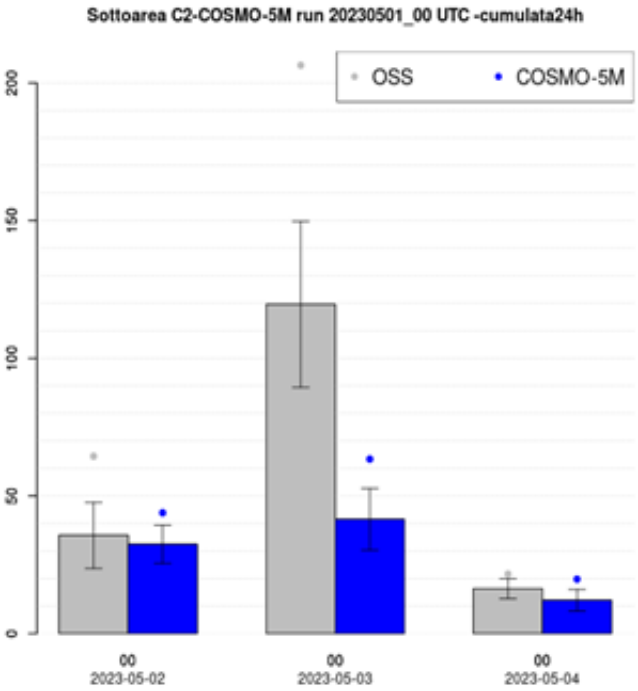


OBS	ECMWF	COSMO-5M	COSMO-2I	ICON-2I

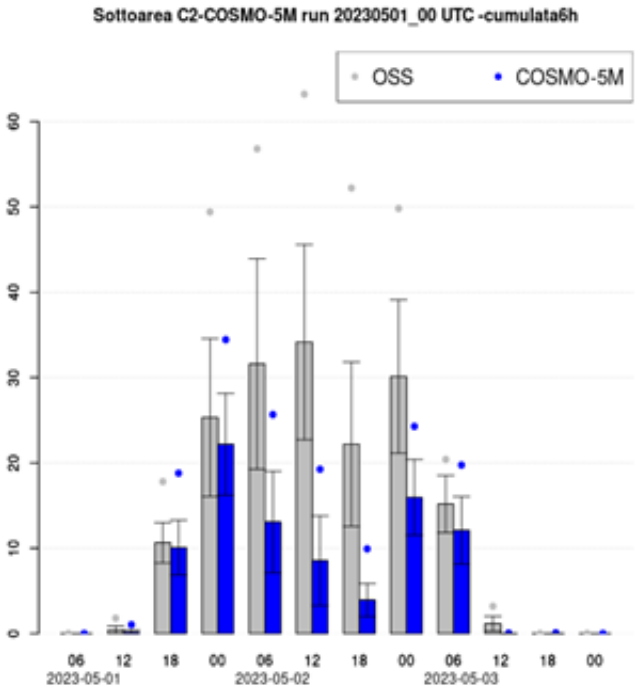
Error bars represent the standard deviation of precipitation of the points that fall in the basin or zone.
It is used as an indicator of data dispersion around the average.

Maria Stefania Tesini, ARPA-E

Rain forecast/observed 1-2-3 May



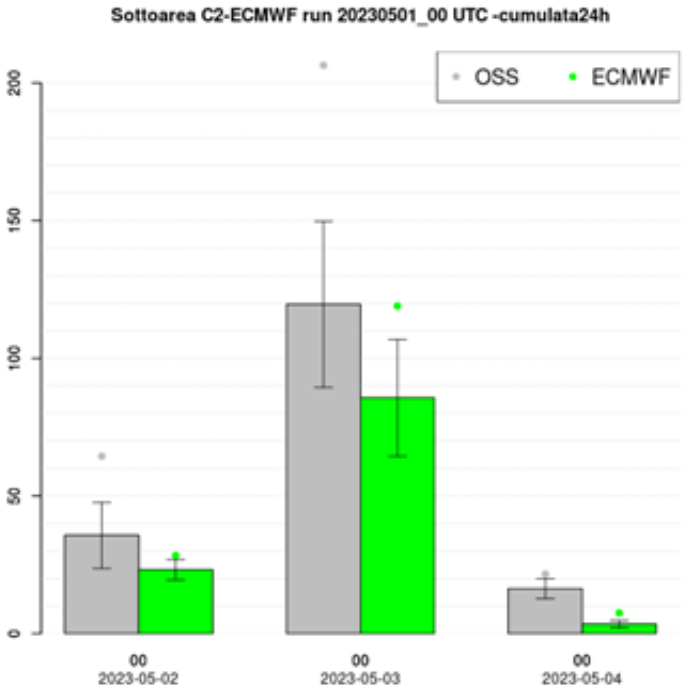
Accumulated in 24 hours
run 01-05-2023 00 UTC



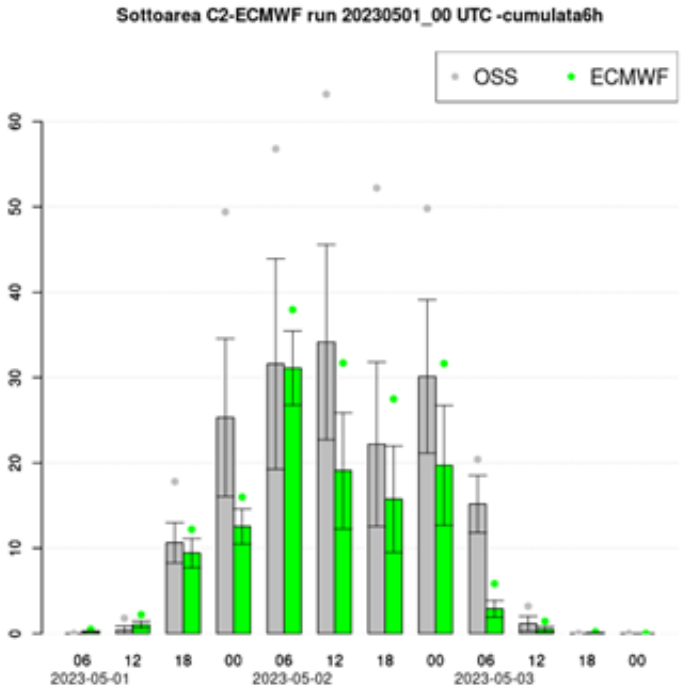
Accumulated in 6 hours
run 01-05-2023 00 UTC

Maria Stefania Tesini, ARPA-E

Rain forecast/observed 1-2-3 May



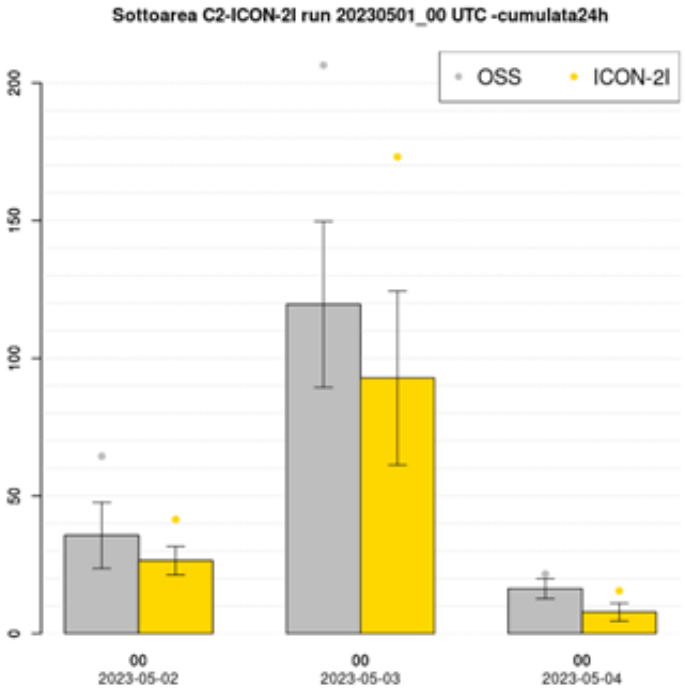
Accumulated in 24 hours
run 01-05-2023 00 UTC



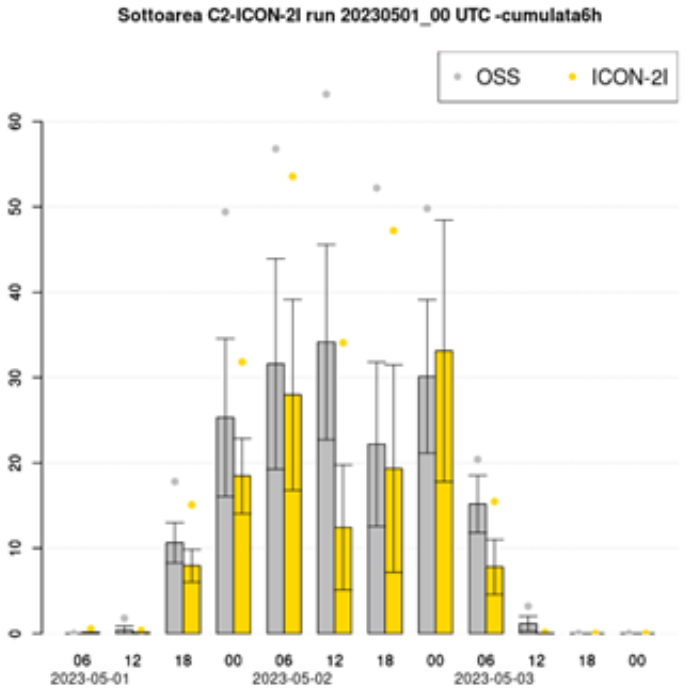
Accumulated in 6 hours
run 01-05-2023 00 UTC

Maria Stefania Tesini, ARPA-E

Rain forecast/observed 1-2-3 May



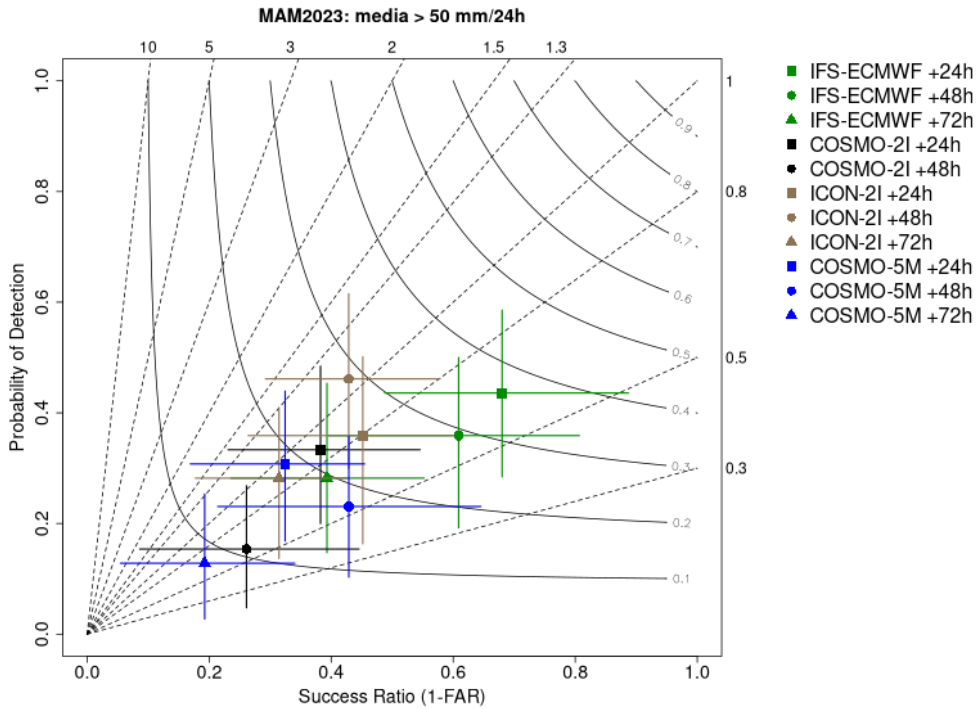
Accumulated in 24 hours
run 01-05-2023 00 UTC



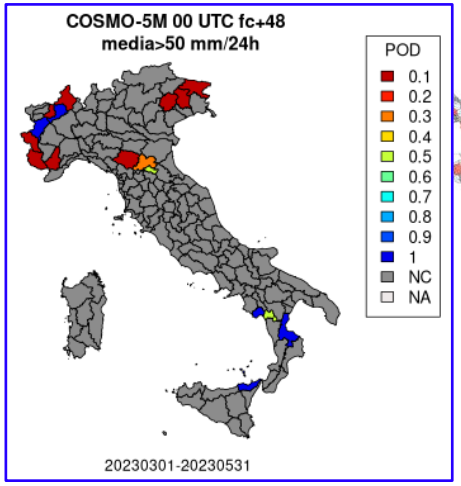
Accumulated in 6 hours
run 01-05-2023 00 UTC

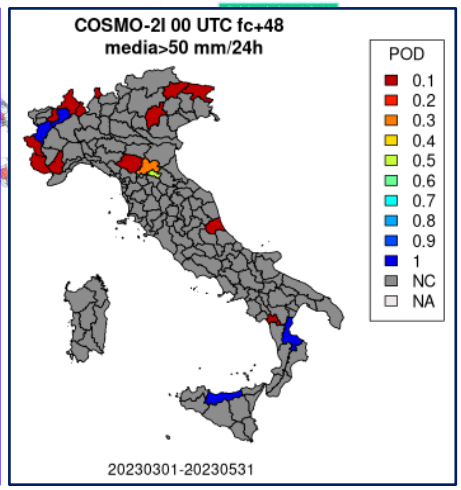
Maria Stefania Tesini, ARPA-E

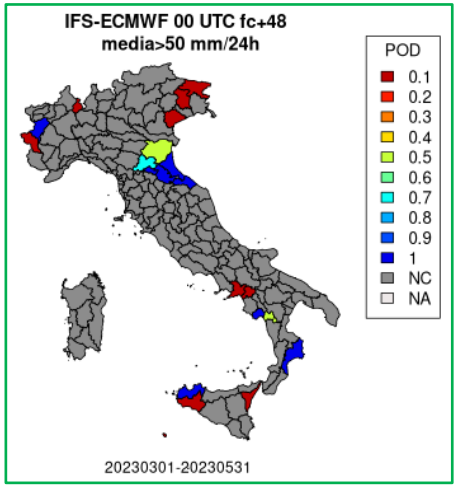
MAM 2023
operational verification

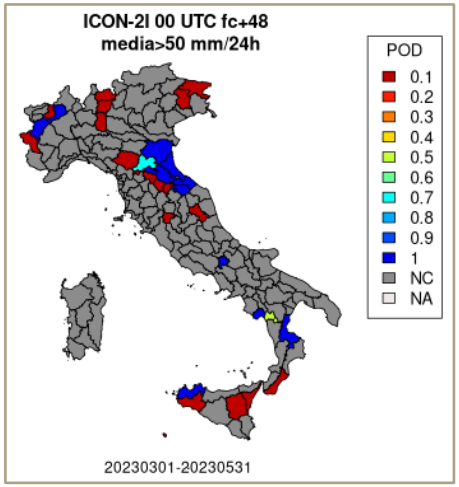


AVERAGE IN THE AREA > 50 mm/24

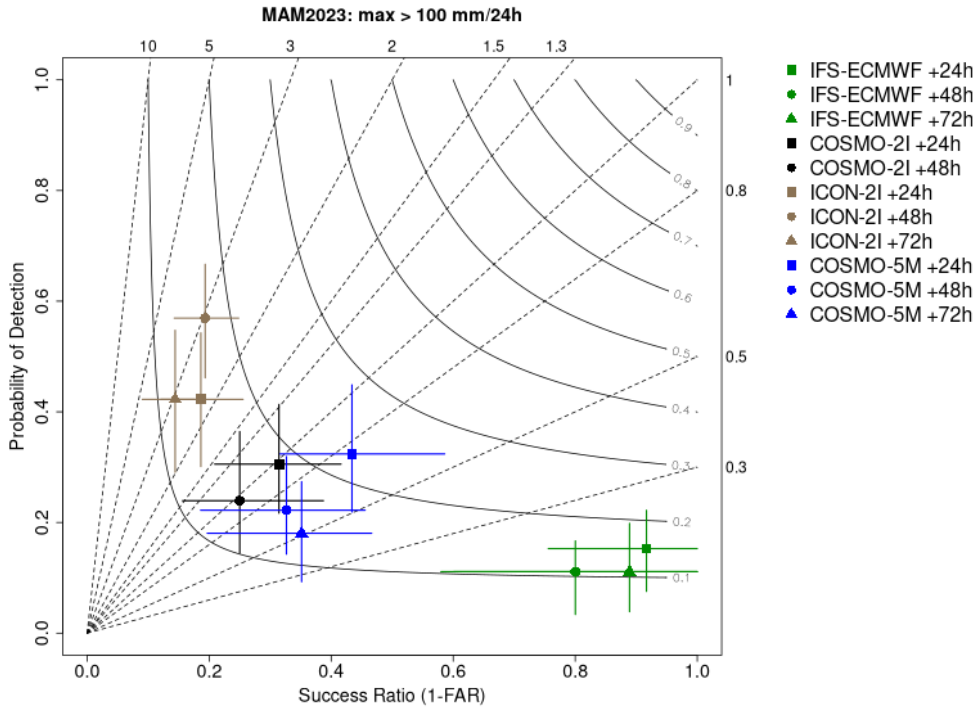




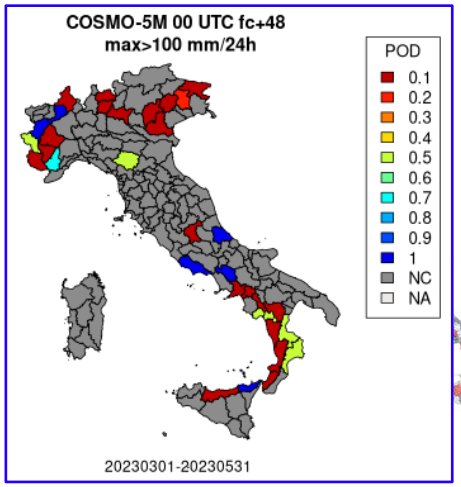


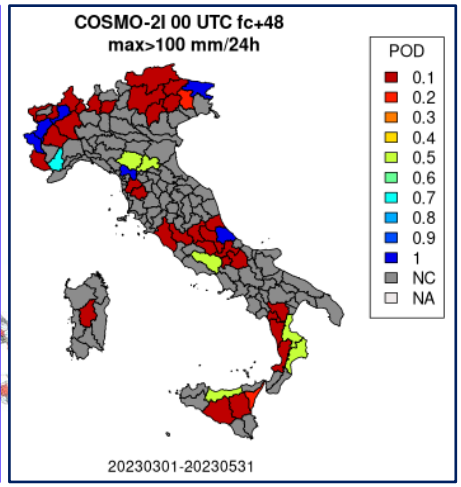


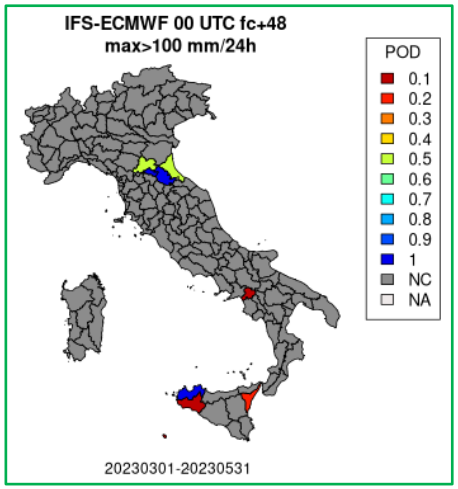
MAM 2023
operational verification

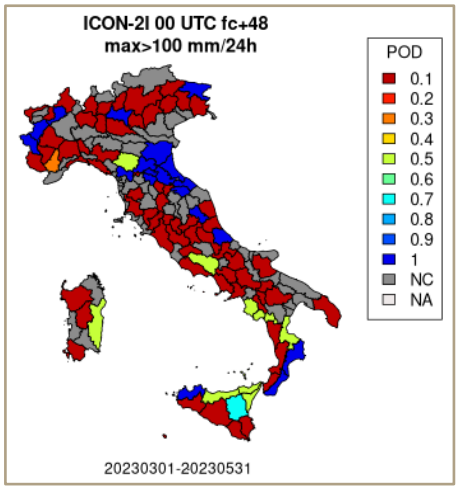


MAX IN THE AREA > 100 mm/24









The location of precipitation maximums remains a problem to be managed especially when the QPF is an input for hydraulic / hydrogeological models (due to significant differences between neighboring basins)

Highlights of verification activities in COSMO consortium

Flora Gofa