Post-processing in COSMO (activities in COSMO Working Group 4 on Application and Interpretation)

Anastasia Bundel
and the COSMO colleagues

40th EWGLAM - 25th SRNWP Workshop

WG4

Outlook

- COSMO users survey overview
- Activity in COSMO institutions
- New projects

CONSORTIUM FOR SMALL SCALE MODELING
COSMO

USERS

MODELERS ⟷ VERIFICATORS

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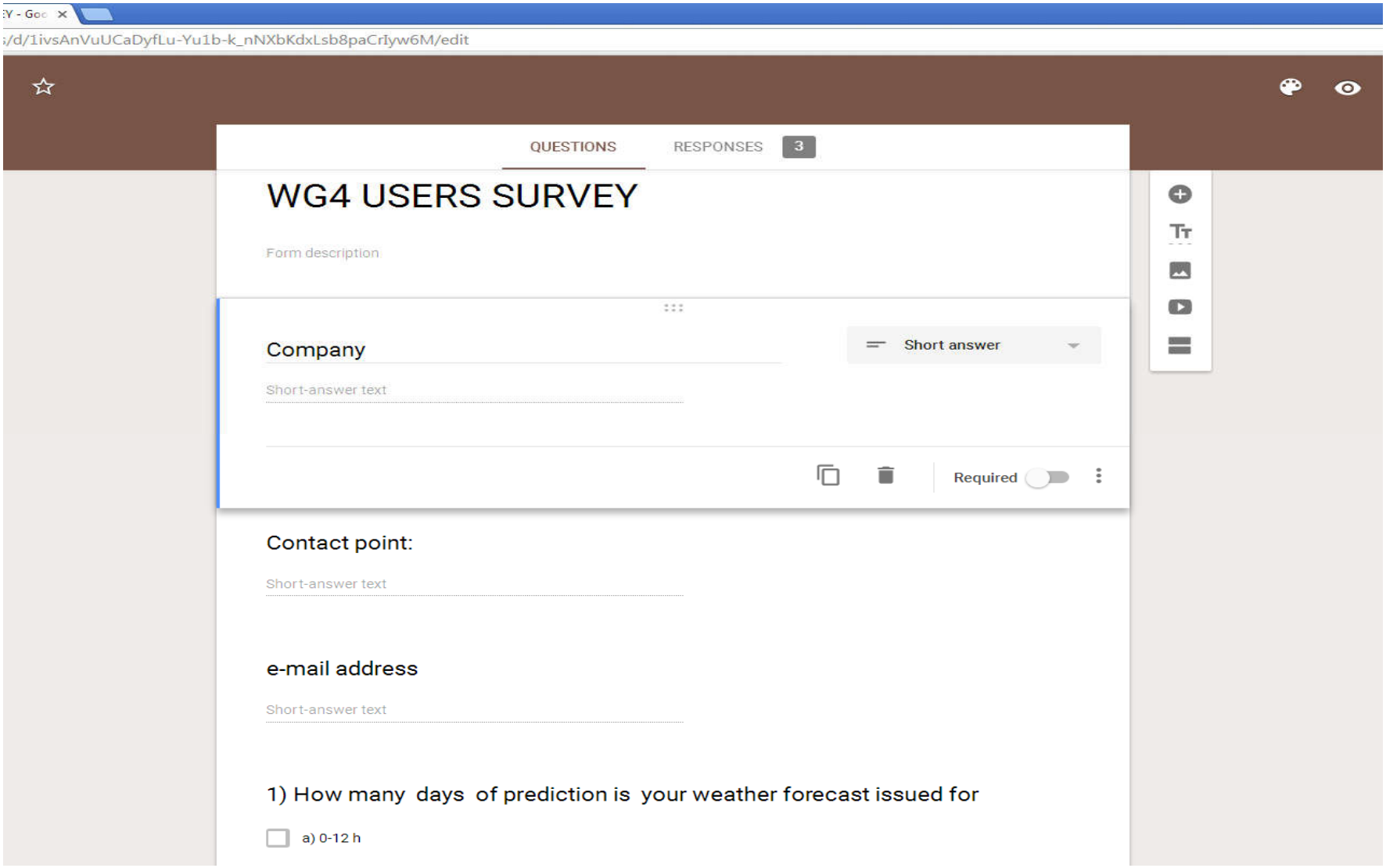
Overview of COSMO users survey



*It was decided to carry out the **a Working group 4 users survey** to better understand perspectives as a group and the user needs*

Contributing persons

- ***Pierre Eckert*** (MeteoSwiss)
- ***Daniel Cattani*** (MeteoSwiss)
- ***Andrzej Mazur*** (IMGW-PIB, Poland)
- ***Dimitra Boucouvala*** (Hellenic National MeteoService)
- ***Anastasia Bundel*** (Roshydromet)

  Comments to the questions from Daniel Rieger (DWD) and Roshydromet colleagues

Survey blocks

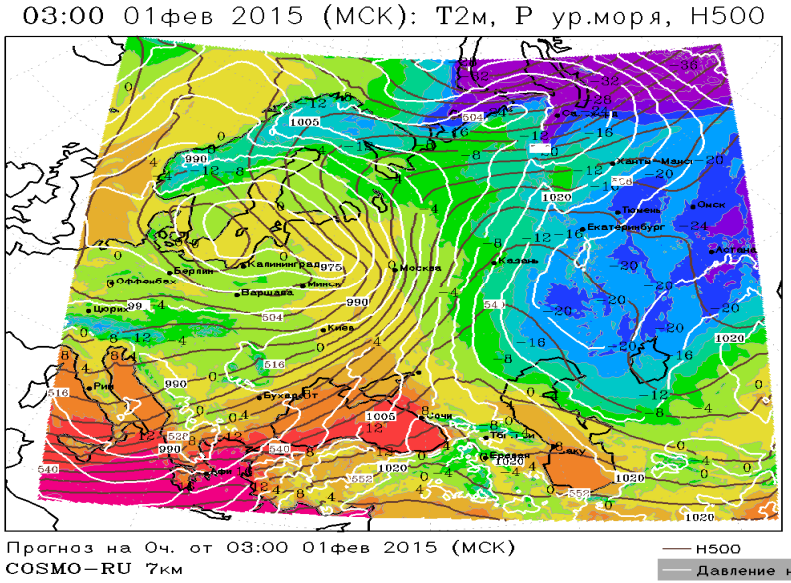
- General questions (NWP used, critical lead times, most important variables and phenomena, …)
- Verification questions
- NWP correction
- Probabilistic forecasts, EPS
- Nowcasting questions
- COSMO/ICON ART (aerosols and trace gases)
- Willingness to share postprocessing methods

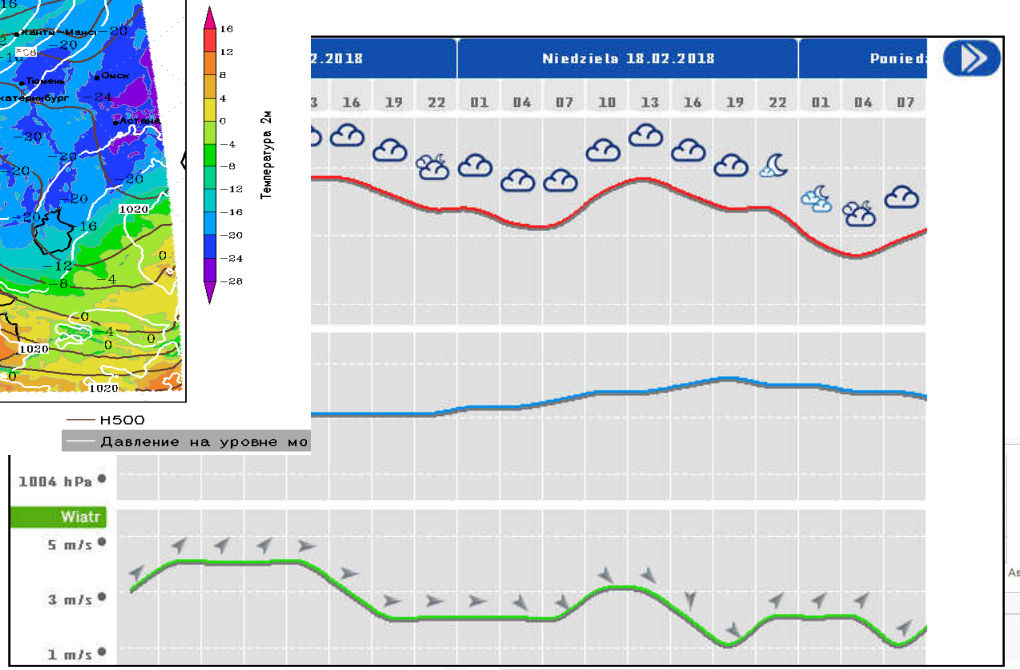
NWP used

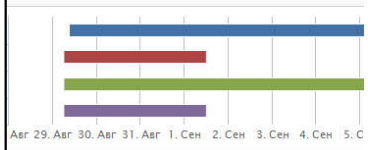
- **COSMO (1, 2, 4, 7 km) and ECMWF-hres and ENS**.
- The **COSMO guidance** is estimated as **good** by majority of answers!
- ICON-LAM is not used operationally in any of our services as yet, but transition to ICON is taken into account.

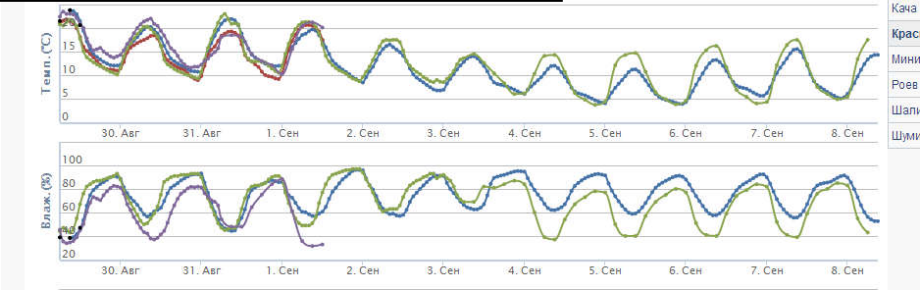
NWP representation from

- Mostly traditional forms: maps -> meteograms -> other plots









Warnings for the population are most important!

Special products (aeronautical, sea-route, other…)

- Big diversity, but the main sectors are:

➢ ***Transport (mainly aviation and road services)***

➢ ***Energy production and supply***

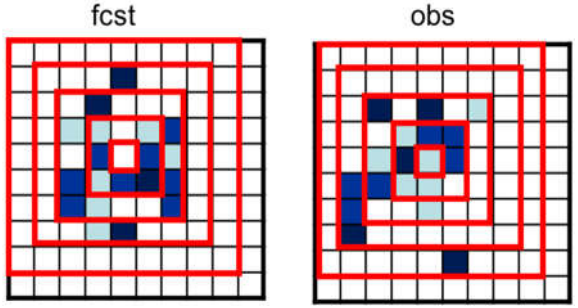
thunderstorms, frost, wind gusts, strong winter storms, fog, wind shear, power lines- and road icing, insolation, precipitation for hydroelectric power plants, squall lines, road/constructions temperatures

Verification

- Historical verification is taken into account, but could be used wider.
- Forecaster experience is essential!
- Some forecasters underlined the importance of real-time forecast quality monitoring, that is, taking into account the errors of the last forecasts.
- Mostly traditional observations are used

Could be useful

- More interactive and real-time verification products
- Stratified verification (weather types, …)
- Spatial verification using gridded data



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Probabilistic forecasts, EPSs

- **EPSs are used, but moderately** (COSMO-EPS, ICON-EU, ECMWF ENS)
- **Added value** of EPSs by majority of answers. E.g., good experience combining EPS and COSMO-1 in case of convective situations (MeteoSwiss), good guidance for days 2-7 (Hellenic NWS, Roshydromet)
- Most useful EPS products: Ensemble median and spread, uncertainty, spaghetti plots, probability maps for precipitation, extreme temperatures, precipitation, wind

Further expectations from EPSs:

- More friendly to non-experienced forecasters, easier to interpret
- Statistical adaptation of EPS output

Forecast correction

- **is necessary**. Automatic (e.g., Kalman filter) or based on forecaster experience

Nowcasting

- “Seamless forecast from actual measurements to model forecast”
- “Nowcasting product should be available in almost real time to the forecaster, and provide information for decision making in the case of the evolution of a phenomenon, so mainly important in severe weather”

Common wish to have nowcasting blended with model output for extended range of ca. 9 hours

What type of postprocessing method are you ready to share with other COSMO members?

- **All respondents noted their willingness to share all available methods, possibly, after official approval of their administration**

The Users survey helped a lot in preparing the project plans. It can be modified according to the applications

It was decided to perform a collection of cases of model failures for the COSMO countries according to the forecasters, in particular, for high-resolution model versions.

Institute of Meteorology and Water Management
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Flashrate – definition

Assumption – relationship between CAPE (→ updraft velocity *W*), cloud-top/cloud-base temperatures (*CTT/CBT*, respectively) and frequency of lightnings *(FR, #/minutes)*. Additional filters can be applied.

$$W = 0.3 \cdot \sqrt{2 \cdot CAPE}$$

$$FR = \left(\frac{W}{14.66} \right)^{4.54}$$

$$if \quad CTT > -15°C \quad FR = FR \cdot \left[\max\left(\frac{-CTT}{15}, 0.01 \right) \right]$$

$$if \quad CBT < -5°C \quad FR = FR \cdot \left[\max\left(\frac{CBT + 15}{10}, 0.01 \right) \right]$$

Wong *et al.*, 2013: Evaluating a lightning parameterization based on cloud-top height for mesoscale numerical model simulations. Geosci. Model Dev., 6.
Lopez, 2016: A Lightning Parameterization for the ECMWF Integrated Forecasting System. Mon.Wea. Rev. 144
Forecasts verified against measurements at Polish lightning detection network

IMGW-PIB: Flashrate forecast users

- Three main groups of customers: aviation services, energy production sector, crisis management centers
- The most obvious impact of severe weather on electric utility operations – power outrages. Improvements in forecasts of thunderstorms – an aid for managers in resource scheduling and management.

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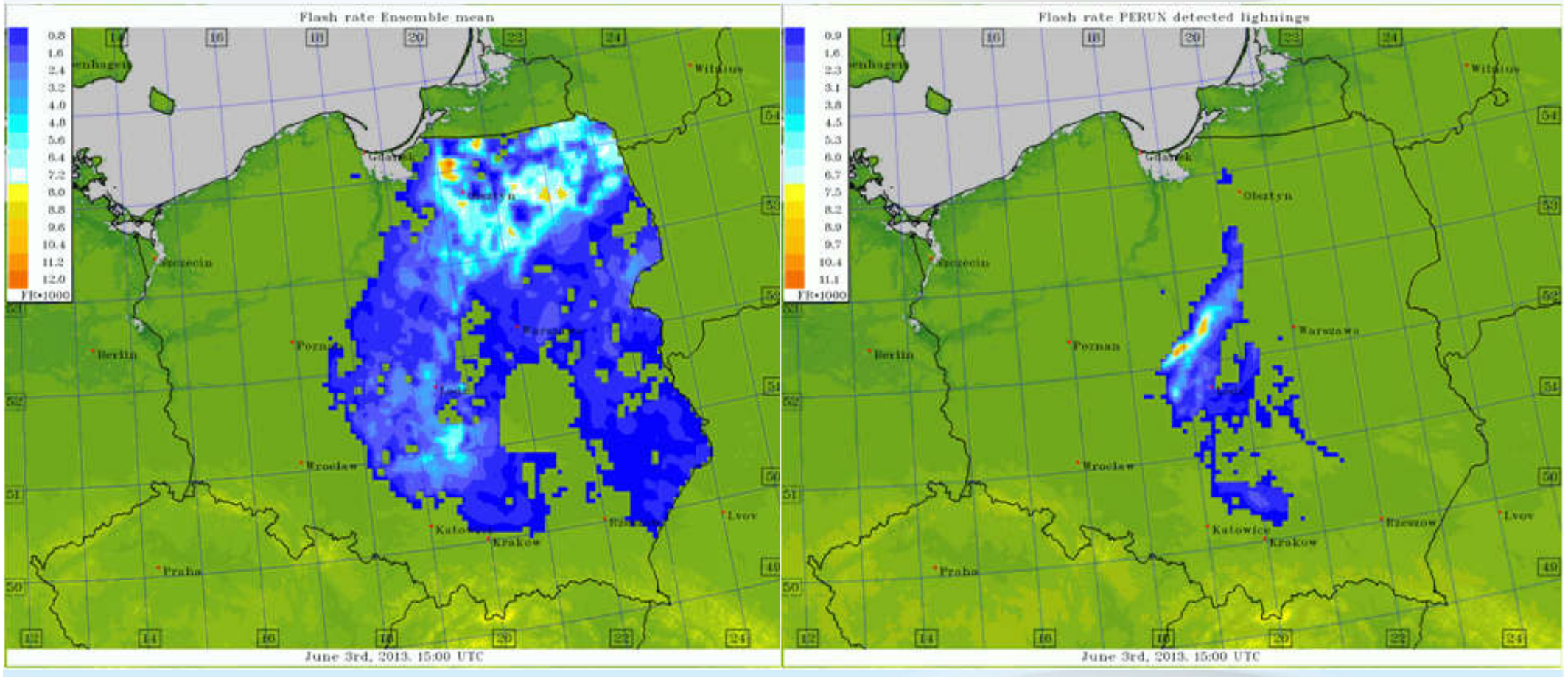
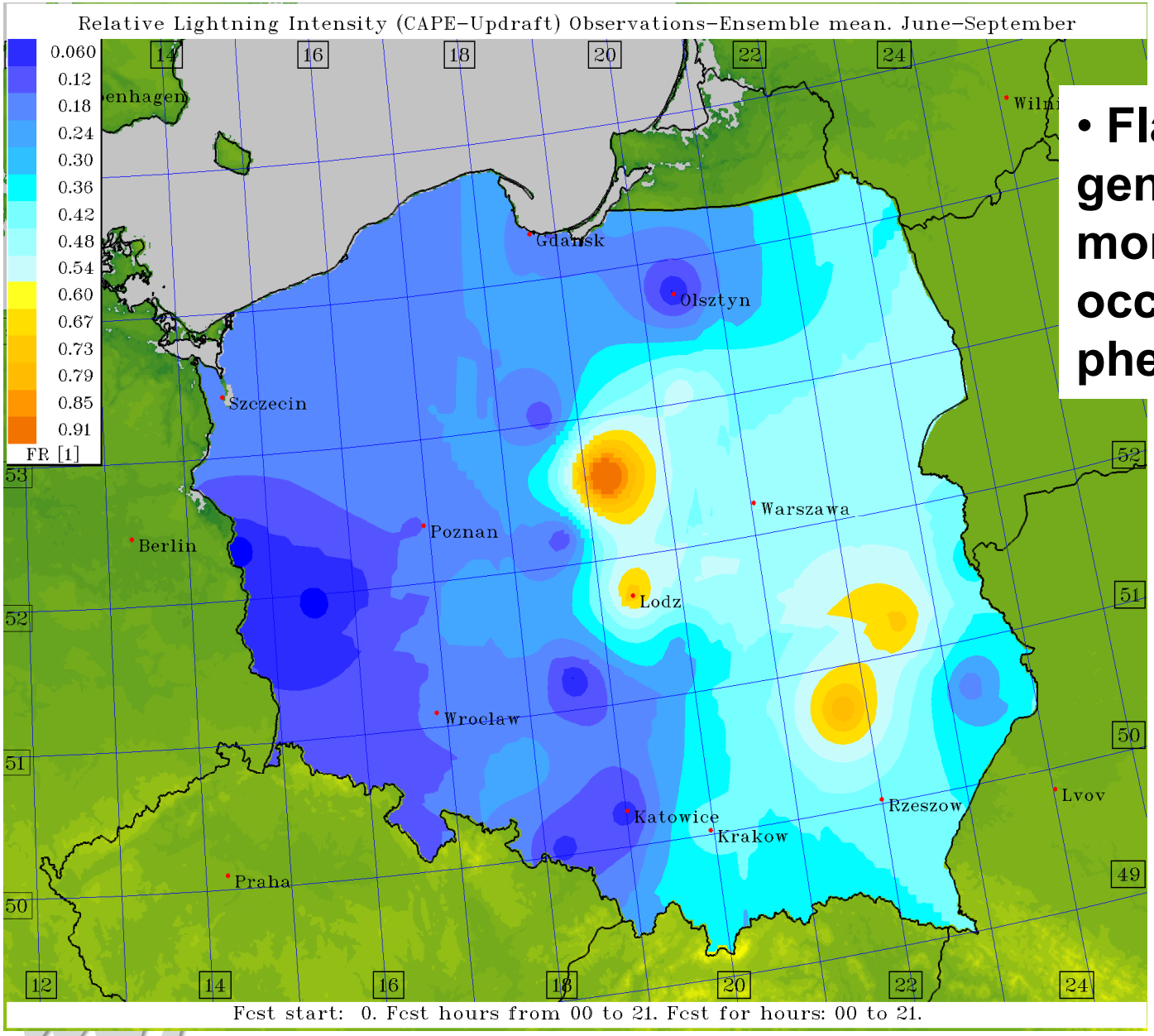
An example – Flashrate



”Raw” CAPE/updraft algorithm overestimates lightning rates…

IMGW-PIB: Flashrate verification against Polish lightning network measurements, MAE, June-Sept 2013



- **Flashrate forecasts were generally better in dry months with high occurrence of convective phenomena.**

Visibility Range – definition

Forecasts of visibility range – from DMO; algorithm based on forecast of extinction coefficient $ß_{ext}$ (a function of water/ice amount in the air):

$$VIS = -\frac{\ln(0.02)}{\beta_{ext}}$$

(Boudala *et al.*, 2012: Parameterization of Runway Visual Range as a Function of Visibility Implications for Numerical Weather Prediction Models. Journal of Atmospheric and Oceanic Technology, (**2**) vol. 29.

See also Kunkel, 1984: Parametrization of Droplet Terminal Velocity and Extinction Coefficient ir Fog Models. Journal of Climate and Applied Meteorology, vol. 23)

Forecasts verified against observations at Polish SYNOP stations

VR – usages, applications, customers

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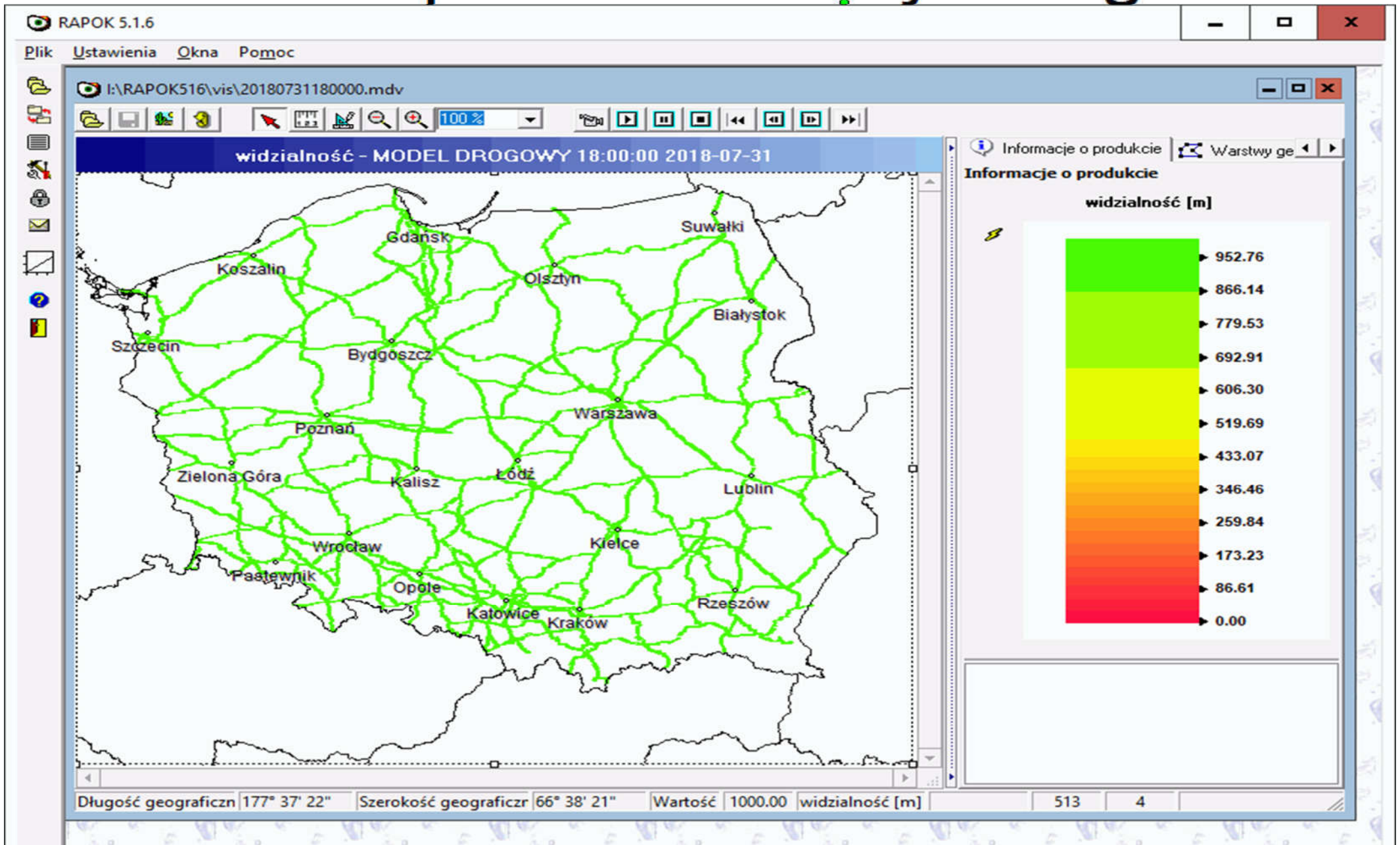
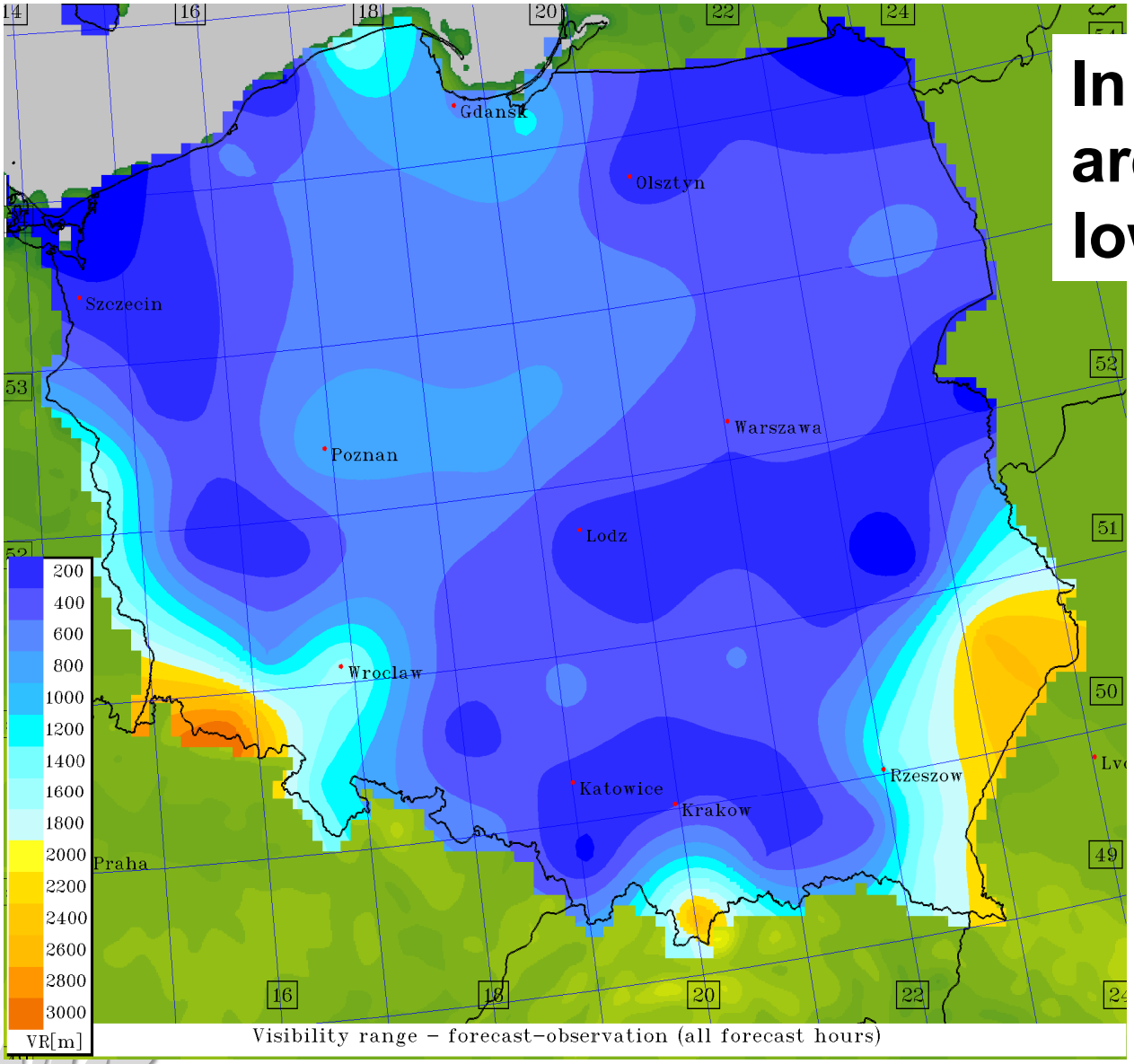
Examples – Visibility Range



IMGW-PIB: Visibility range verification against observations at Polish SYNOP stations, MAE, June-Sept 2013



In general, forecasts are better for lowlands.

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Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

PostprocVeri: New postprocessing project in MeteoSwiss

Christoph Spirig, D. Cattani, J. Bhend, M. Liniger

© S Petersburg – GM COSMO, sept 2018

Daniel.Cattani@meteoswiss.ch

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Main elements

- **Probabilistic postprocessing** - well in line with NWP developments @ MeteoSwiss and international developments in the field of postprocessing → Ensemble postprocessing routines, aiming at delivering calibrated ensemble predictions
- **Spatial output** given the increasing importance of local forecast information, the postprocessing approaches aim at delivering output for any surface location of interest in Switzerland.
- **Start with basic meteorological variables** introduce postprocessing for four basic meteorological variables (temperature, precipitation, wind, and cloud cover), build up knowhow to apply to derived variables later on
- **COSMO and IFS ensembles** limit NWP data sources to COSMO and IFS ensembles (models operationally used in today's forecast production), but ensure applicability to other NWP models

Collaborations

The Project team of MeteoSwiss do not wish not develop new methods from scratch, but aims to collaborate, use know-how and experiences in PP domain.

- EUMETNET program
- University ETHZ
- COSMO WG4

Daniel.Cattani@meteoswiss.ch

ETHZ collaborations

- Sebastian Schemm : analysis of error stratified by weather type
- ETHZ master thesis
  - Nino Weingart : deep learning based error correction of Numerical Weather Prediction for Switzerland,
    - **Automatic post-processing** of COSMO-1 output to predict temperature
      - At arbitrary point in Switzerland
      - Considering spatial-temporal dependencies
      - Including uncertainty estimation of model
    - Using **neural network architecture**

Daniel.Cattani@meteoswiss.ch

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Recent analysis on the 10-wind forecast in Switzerland, comparing direct model output, forecasters and MOS

J. Bhend, D. Cattani, Ch. Spirig, M. Liniger

Analysis of
Burglind/Eleanor storm
on Zugersee,
3rd January 2018

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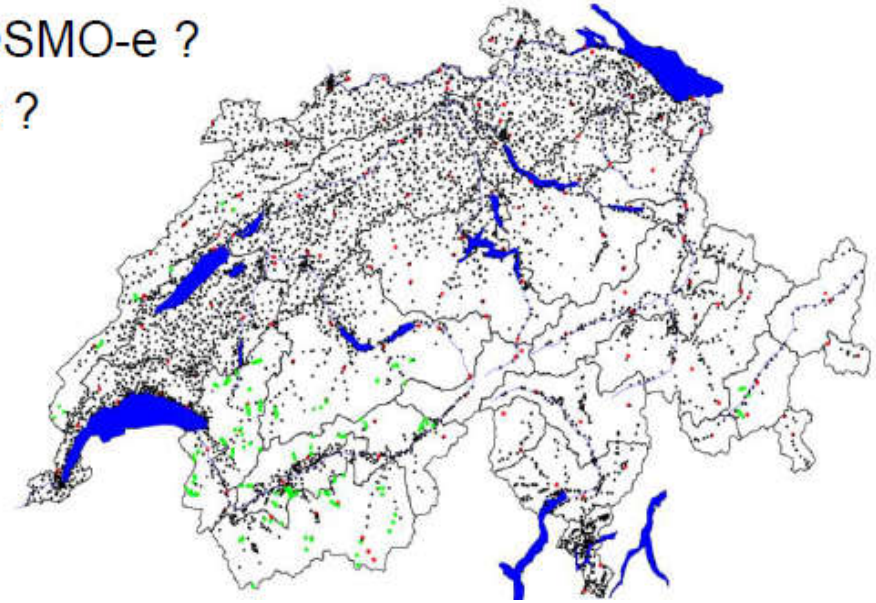
Questions

MeteoSwiss goal is to provide high quality hourly winds and gusts at ~5000 sites

- Is there a potential to postprocessing ?
- Is there an added-value form the forecasters ? How can we benefit of it ?
- Which model is better ? COSMO-1, COSMO-e ?
- How can we improve warning forecasts ?



MeteoSwiss

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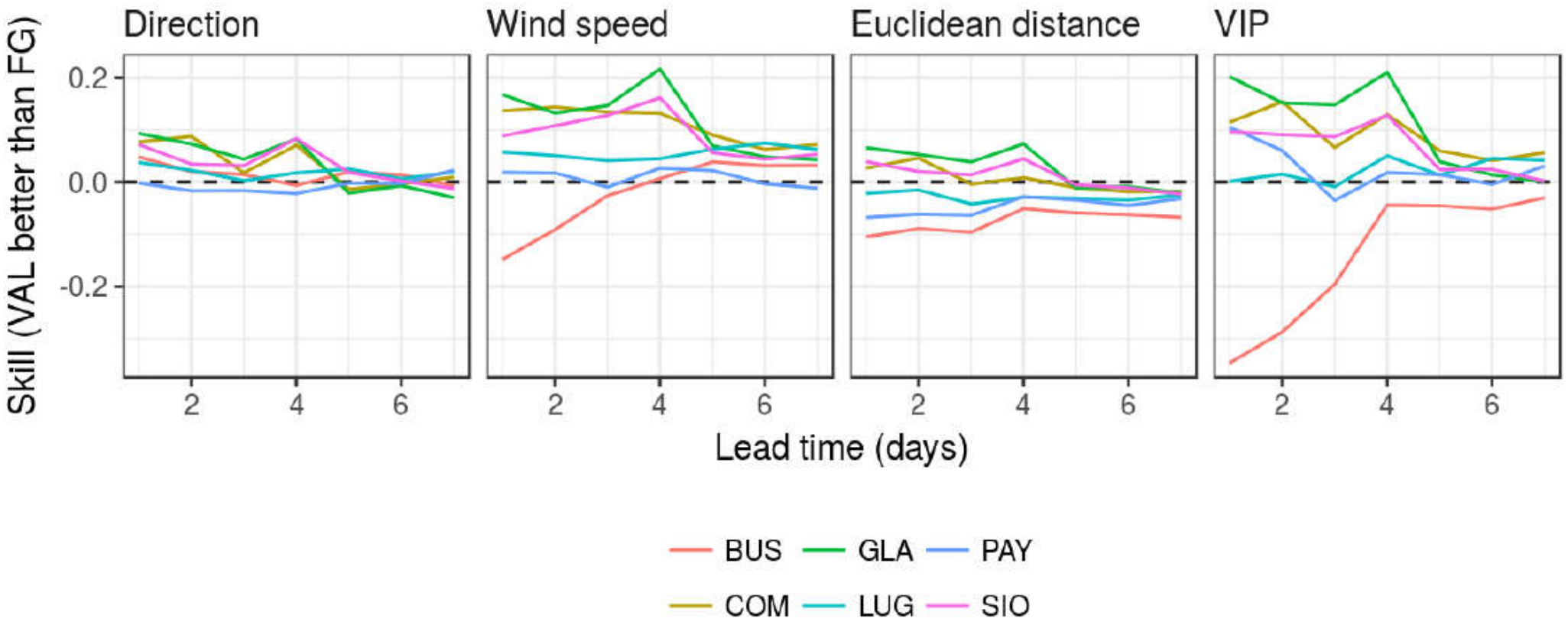
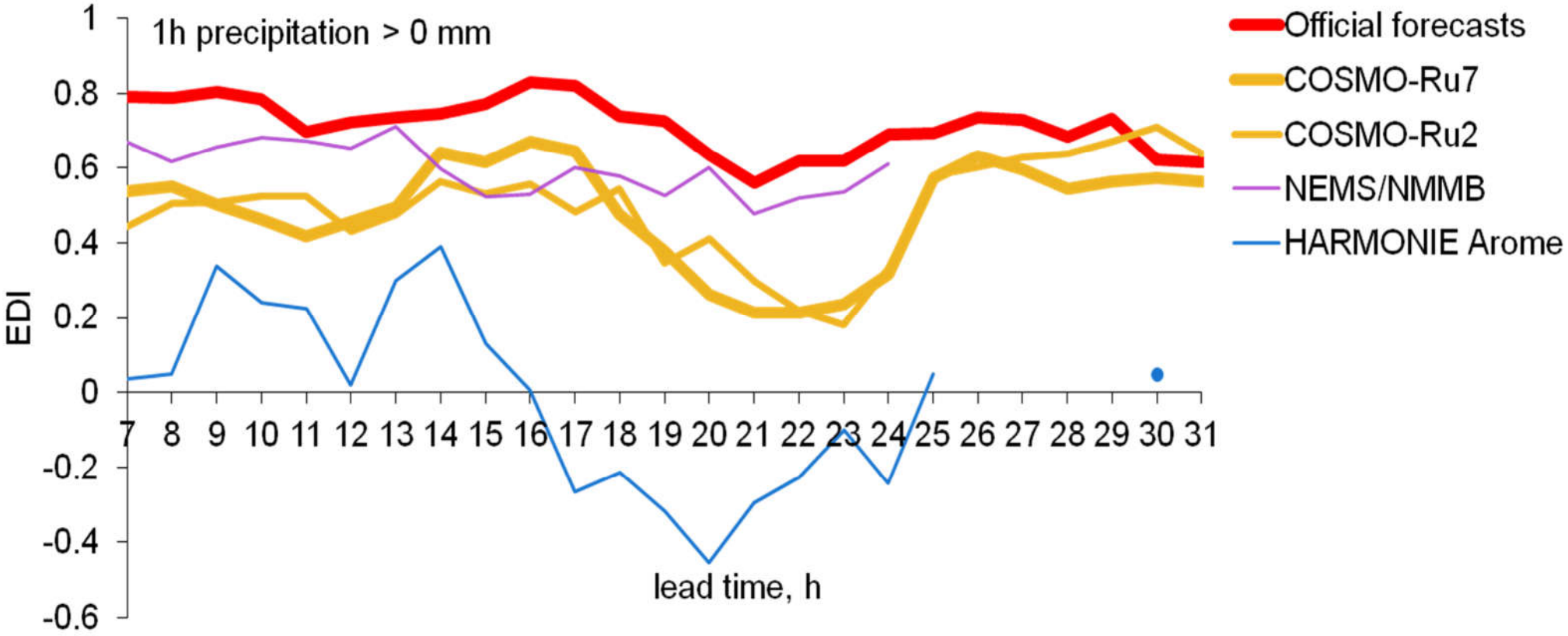
Understanding forecaster's modification



DMO vs. Official human forecasts (Sochi-2014 experience)



Extremal Dependence Index (the higher the better) of precipitation occurence aggregated over the Sochi mountain cluster,
1 November 2013 - 23 February 2014

From Kiktev, D., P. Joe, G. Isaac, A. Montani, I. Frogner, P. Nurmi, B. Bica, J. Milbrandt, M. Tsyrulnikov, E. Astakhova, A. Bundel, S. Belair, M. Pyle, A. Muravyev, G. Rivin, I. Rozinkina, T. Paccagnella, Y. Wang, J. Reid, T. Nipen, and K. Ahn, 2017: AMERICAN METEOROLOGICAL SOCIETY FROST-2014: The Sochi Winter Olympics International Project. Bull. Amer. Meteor. Soc. doi:10.1175/BAMS-D-15-00307.1

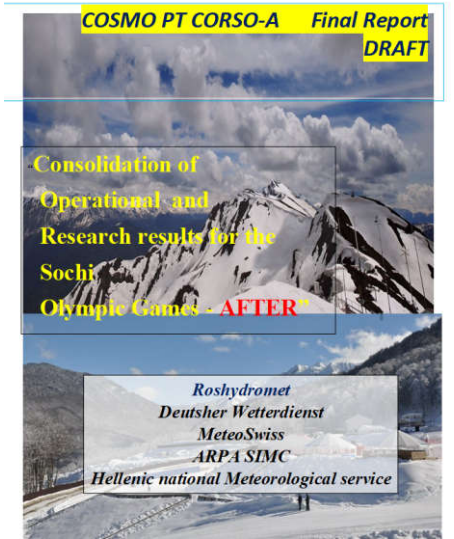
DMO vs. Official human forecasts (Sochi-2014 experience), conclusions

- **For precipitation, the manual forecasts did add value to model forecasts**
- Automated temperature forecasts, especially blended multi-model forecasts, were competitive to manual forecasts
- for wind speed and visibility, the human forecasts demonstrated the psychological biases towards higher speed and lower visibility (the phenomenon of overforecasting hazardous events by human forecasters discussed, e.g., by Doswell (2004)

From Kiktev, D., P. Joe, G. Isaac, A. Montani, I. Frogner, P. Nurmi, B. Bica, J. Milbrandt, M. Tsyrulnikov, E. Astakhova, A. Bundel, S. Belair, M. Pyle, A. Muravyev, G. Rivin, I. Rozinkina, T. Paccagnella, Y. Wang, J. Reid, T. Nipen, and K. Ahn, 2017: AMERICAN METEOROLOGICAL SOCIETY FROST-2014: The Sochi Winter Olympics International Project. Bull. Amer. Meteor. Soc. doi:10.1175/BAMS-D-15-00307.1

Priority task plan:
Guidelines for users of LAM (limited area model) forecasts

- **Forecast production chain: Sequences of maps, meteograms, …**
- **Improving the link between verificators and forecast users, explaining state-of-the-art verification techniques (e.g., how to read spatial verification results?)**
- **EPS applications. How to use EPS products?**



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Collaboration Terrain: New project on High Impact Weather applications, joint between COSMO verification, ensemble, and applications groups

Most important are severe, and more generally, high impact weather (HIW) forecasts, which are often a result of postprocessing

In line with WMO focus of research through WMO JWGFVR HIWeather project led by Beth Ebert

Goal: To provide COSMO Community with an overview of forecast methods and forecast evaluation approaches related to high impact weather (not necessarily considered extreme to all users).

Main weather parameters of interest: thunderstorms, wind (+gusts), min-max temperature (persistence), visibility (fog)

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A WG4 task about postprocessing techniques for HIW forecasts could include:

- **Overview of forecast methods for HIW events: postprocessing techniques vs. direct model output (including results of parameterizations)**
- **Verification of postprocessing results and comparison with DMO, where possible**
- **Improving existing methods**
- **Exploring new approaches. Machine learning? Neural networks?**
- **Link to COSMO/ICON-ART for fog forecasts**
- **<u>Restrictions:</u>** Small number of observed extreme events. Dataset with observations and model outputs need to include rare events (various single test cases or long time series).

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THANK YOU FOR YOUR ATTENTION!

Chemical transport model COSMO/ICON-ART

At present:

- Pollen in MCH
- In RHM, concentrations of pollutants: CO, NO, NO2, O3, etc. in Moscow are sent to Mosecomonitoring (an organization controlling the air quality)

In future:

- «Processes like fog formation could benefit from a prognostic (hygroscopic) aerosol forecast. Radiation as well» (Pierre Eckert)
- «We are interested in COSMO/ICON-ART in the near future. The most important species are O3, SO2, NOx, aerosols" (Greek National Weather Service)

Conclusions

- Forecaster's modification is positive, but difficult to to specify
- COSMO-1,COSMO-e better than MOSMIX ?
  - In strong events, potential of COSMO-1, and –e is real
  - On large period, more stations, MOSMIX shows better scores
  - → Potential for postprocessing on winds is important
- Postprocessing should focus on the type of errors

….. postprocessing wind forecast in complex terrain is a challenge

Daniel.Cattani@meteoswiss.ch