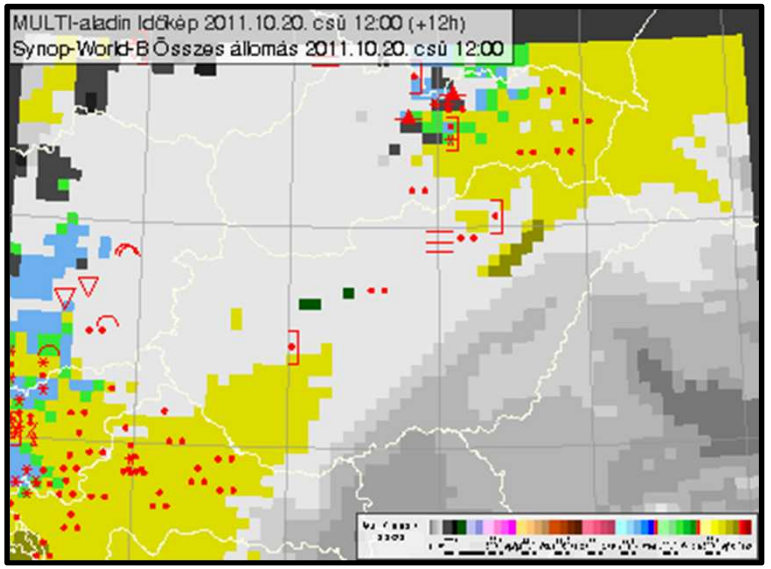
Developments towards multi-model based forecast product generation



Ervin Zsótér

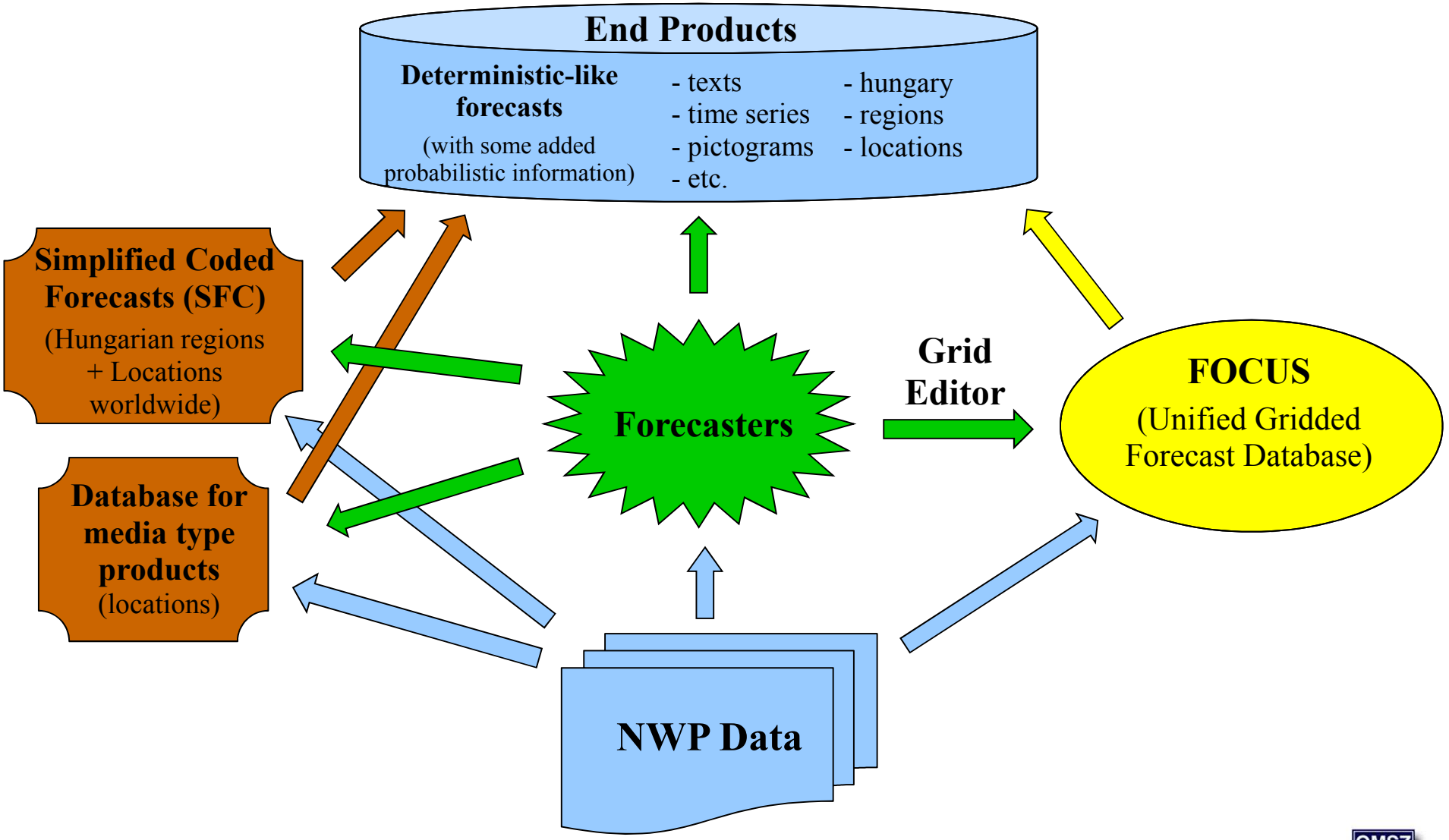
Methodology and Forecasting Section

Hungarian Meteorological Service

Outline

- Introduction to the currently operational forecast production at short and medium range
- The system we are developing
- Comparison of numerical models and their multi-model version in the new system
- Summary and plans

Schematic of the short and medium range forecast production



Simplified Coded Forecasts

OOSSSSII HHNN BBJJ CCVW SSSS AALL YYXX

1284300	1111	8///	6/3/	32//	0614	04//
1277200	1111	9/11	6/3/	32//	0307	04//
1288200	1111	9/11	6/3/	32//	0308	05//
1298200	1111	9//1	6/3/	32//	0511	05//
1293200	1111	97/1	6/3/	32//	0513	03//
1282500	1111	94//	6/3/	32//	0514	02//

Day1

1284301	1112	30/2	8/2/	32//	0413	//09
1277201	1112	82/1	682/	27//	0308	//08
1288201	1112	86/1	682/	27//	0308	//09
1298201	1112	72/1	681/	32//	0412	//10
1293201	1112	2//1	8/1/	3223	0308	//11
1282501	1112	2//1	861/	3223	0308	//10

Day2

1284302	1113	17/1	////	23//	0206	0012
1277202	1113	28/1	////	23//	0207	0010
1288202	1113	28/1	////	23//	0307	0211
1298202	1113	14/1	8/1/	23//	0307	0113
1293202	1113	2//2	////	23//	0307	0113
1282502	1113	3//2	////	23//	0205	0012

Day3

Forecast for Budapest

Mostly cloudy first then sunny

Patches of fog in the morning

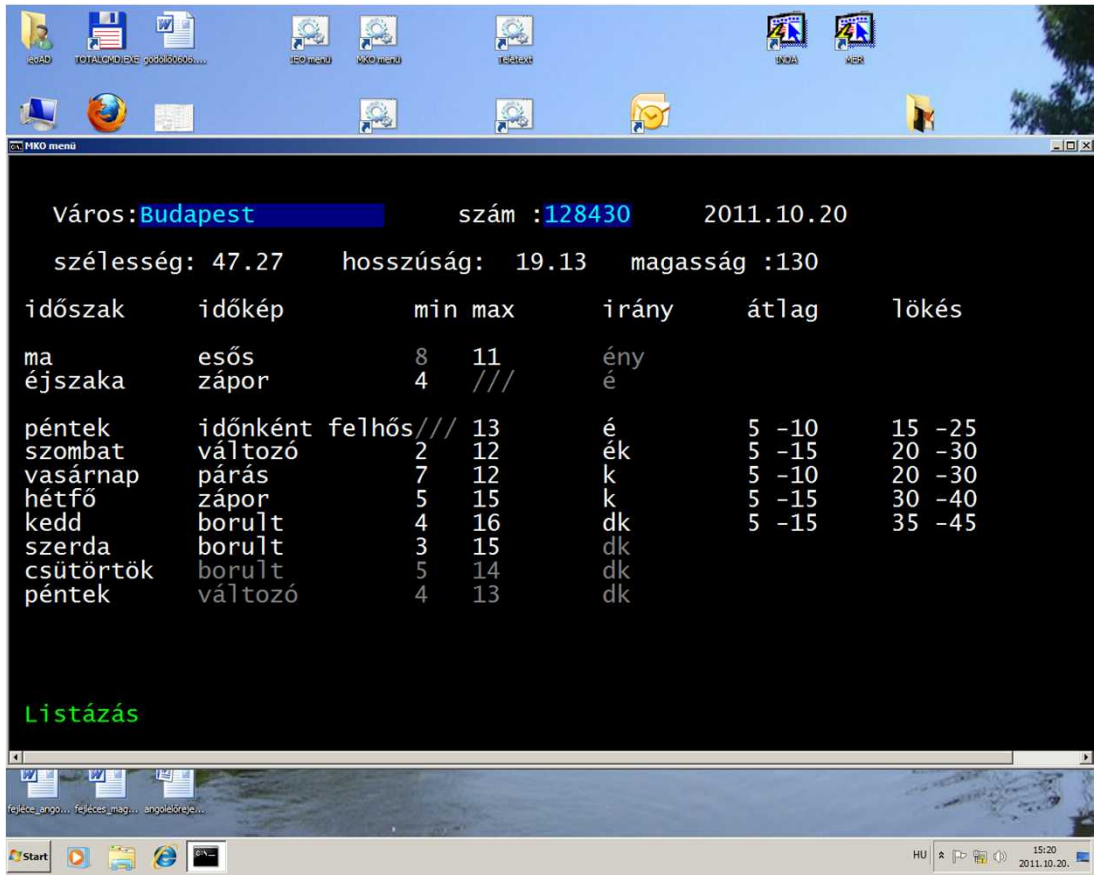
Showers possible

NW-erly wind with gusts up to 40-55 km/h

Tmax: 9 degrees

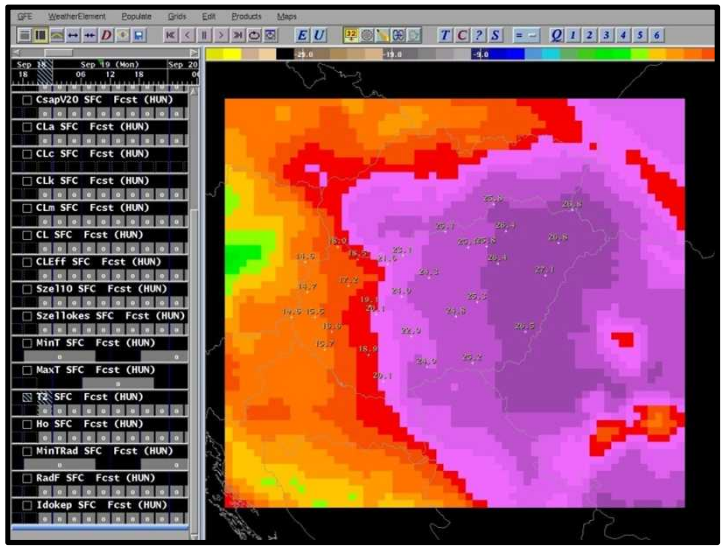
- Forecast summaries for 12- or 24-hour periods
- Forecast values/codes for the main weather parameters
  - Cloud cover
  - Mist / Fog / Thunderstorm
  - Precipitation (type / amount / probability)
  - Wind (direction / mean speed / gust)
  - Temperature (minimum / maximum)
- For different regions in Hungary and locations worldwide
- Produced operationally from different sources
  - Forecasters
  - NWP models
- Used in various applications:
  - Forecast text generation
  - Commercial products
  - Verification

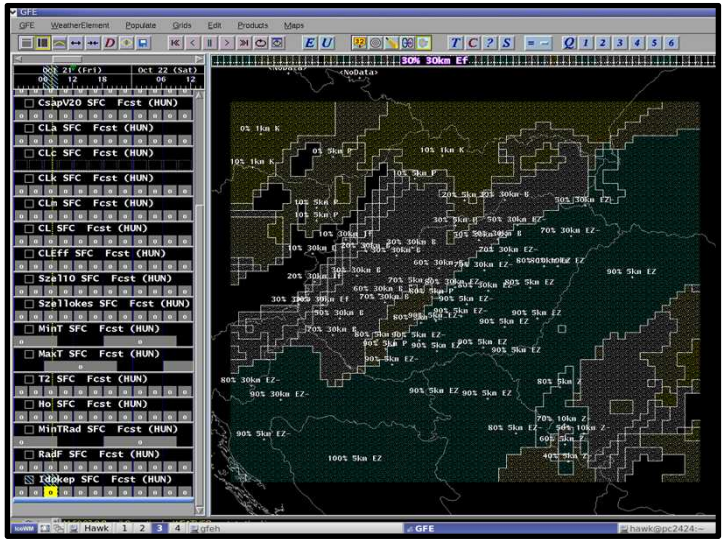
Media forecast database with locations



- Forecast summary for locations in Hungary and worldwide for the following days
  - Weather type
  - Min+Max temperature
  - Wind direction, average speed and gust
- It is initialised with combination of the deterministic ECMWF model and the SCF prepared by the forecasters for some Hungarian regions
- Used mainly in products for media
  - Television
  - Newspapers
  - Web

FOCUS + Grid Editor



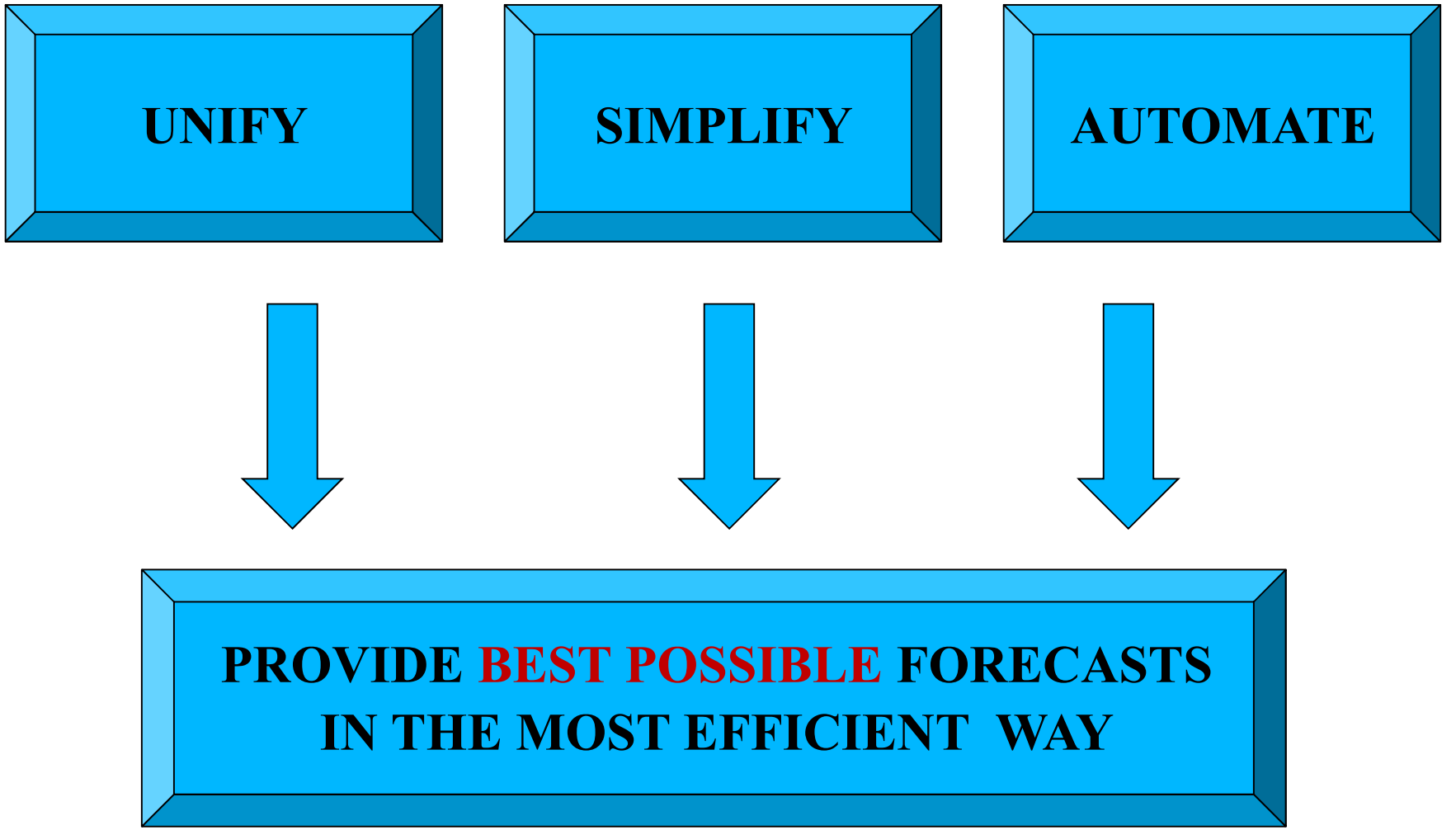


- FOCUS (Unified Gridded Forecast Database)
  - Gridded NetCDF database
  - 10 km horizontal resolution over a large Hungarian region with1-hour temporal resolution up to D+15
  - Initialisation is done with deterministic ECMWF with an option to use ALADIN for short range
  - Includes all main categorical weather parameters with some probabilities
  - Data is extracted directly from the grid without further corrections for hundreds of products
- Grid Editor (Graphical Forecast Editor - US National Weather Service)
  - Used by the forecasters to modify FOCUS fields
  - Only temperature parameters are modified (min, max, time steps)

Problems in the existing system

- Three different databases with various formats
  - Different sources of potentially inconsistent forecast information for the end products
  - Consistency checks by the forecasters at different places (duplicated manual work)
  - The gridded database (FOCUS) is only partially modified/checked by the forecasters, therefore all other parameters can be totally inconsistent at times with the other databases
- In its existing state FOCUS is only meant to be the a unified, consistent source of forecast information controlled by the forecasters (at one place only)
  - The weather type (mist/fog, precip/no precip, rain/snow/sleet, etc.) related variables in FOCUS are designed with too much complexity and therefore hard to modify consistently (operational time constraint)
  - Locations' forecast data is directly taken from the FOCUS grid, no station height / land-sea related corrections applied

Requirements from the new forecast system



Main characteristics of the new forecast system

- It replaces the existing databases with a truly unified system
- It provides all necessary categorical forecast data for end products including also probabilities
- The core of the system is the FOCUS netCDF database with 10 km horizontal resolution and hourly frequency to D+15
- FOCUS can be initialised by the available deterministic models, ensemble models (including e.g. EPS clusters), lagged version of the models or any of the weighted multi-model combination of these
- The forecasters can decide on the “Best Guess”, i.e. how to blend the available models, multi-model combinations into a consensus for grid editing (harmonised FOCUS)
- Default multi-model combinations are prepared to help the forecasters in making their decision
- Some weather parameters are redefined in the new FOCUS, especially the ones related to weather types

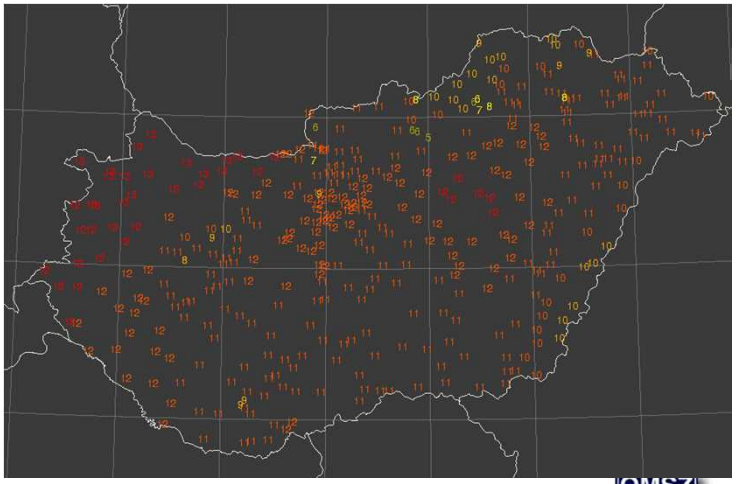
Grid editing in the new forecast system

- The parameter fields are edited in the harmonised FOCUS
- We follow a simplified strategy for grid editing
- The core parameter is the “significant weather type”
  - It summarises the main weather features (includes all precipitation types, and only main visibility, cloud cover and wind categories)
  - It is used only in relation to the grid editing
  - It is the first parameter to be edited
  - By setting the significant weather type, the forecasters can guarantee that the synthesis of the weather surely agrees with their own conception (on the hourly basis)
  - Modification of other parameters is done with consistency checks to the significant weather type
- Forecast data is controlled by the forecasters only by the grid editing (no duplicated work)

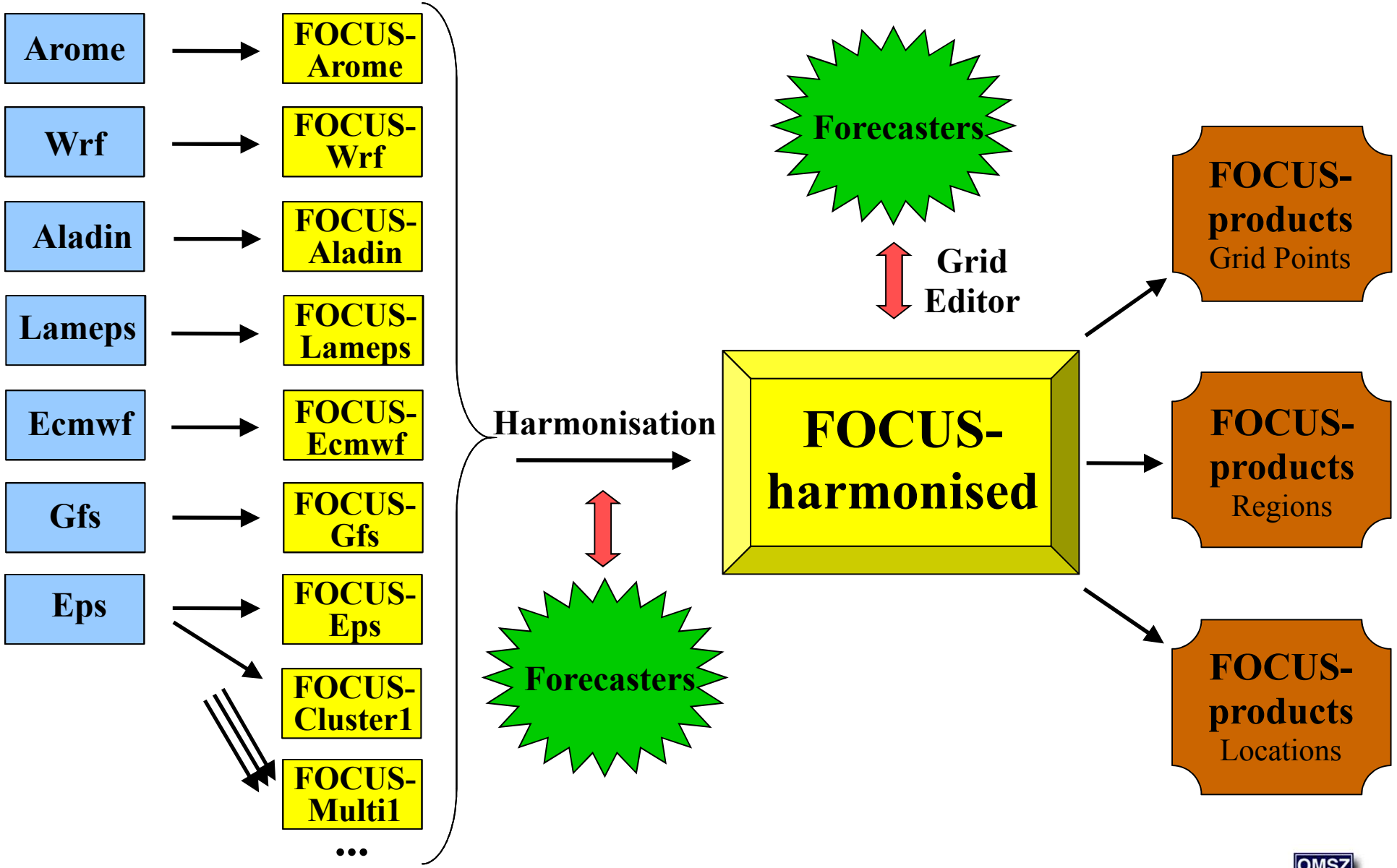
Product generation in the new forecast system

- Forecast data for end products is derived from the FOCUS (one source)
  - Besides the hourly forecast data, forecasts for periods with 6-, 12-, 18- and 24-hour length are prepared
  - The weather parameters for periods are determined from the hourly values in the period (no human intervention)
  - Forecasts are derived for grid points, locations and also regions
  - Unified algorithms are used to process all data from FOCUS
  - Temperature forecasts for locations are determine from best grid point with station height / land-sea correction, and in parallel precipitation type parameters are adapted to the modified temperature if necessary

- Unified data structure
  - The FOCUS files are also useful operational forecast tools by providing standardised platform for comparing numerical model data
    - ✓ Same parameters determined by the same algorithms from every model
    - ✓ Same spatial and temporal resolution



Schematic of the new FOCUS based forecast production



Data processing

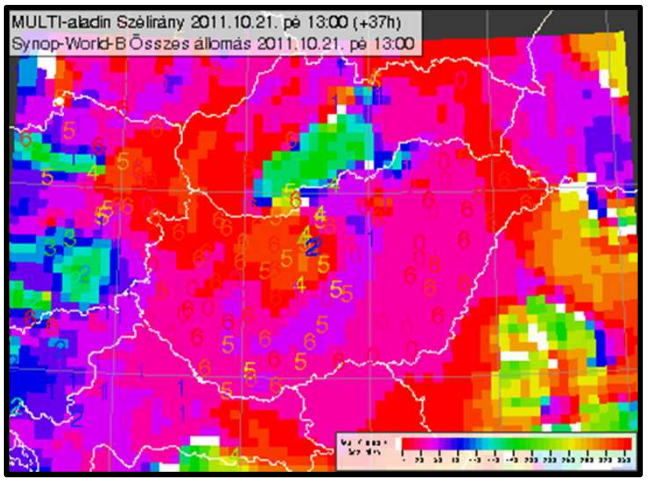
- Interpolation / upscaling at FOCUS initialisation
  - All models are converted to the unified horizontal resolution (10 km)
    - ✓ At upscaling the areal average is computed by using each grid point's value once
  - All models are converted to the unified 1-hour temporal resolution
    - ✓ The original interval extreme/accumulation values are preserved
    - ✓ Tmin / T2 / Tmax relation at each hourly time step is guaranteed
    - ✓ The interval maximum/minimum is placed at a season related hour (e.g. minimum temperature is reached at an earlier hour at summertime than at wintertime)
- Relaxation in time at FOCUS harmonisation
  - FOCUS parameters are relaxed between two different sources in a +- 6hours interval around the merging time
  - It needs to be done when FOCUS data from different models are combined, or when FOCUS data from differently blended multi-models are combined
  - Consistency is checked between temperature and precipitation phase and corrections are made in the precipitation phase if necessary

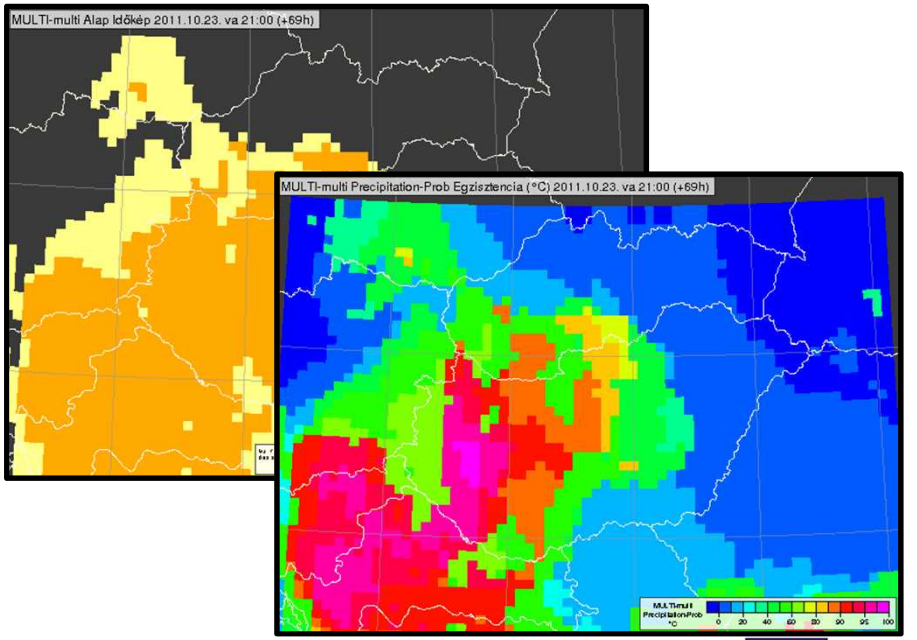
How do we determine the parameters

- With ensemble mean (deterministic way)
  - For parameters where it is meaningful we define parameter values in FOCUS with the mean
  - For cloudiness, wind speed and gust, temperature and precipitation amount
  - At initialisation of the FOCUS when grid point values are defined (weighted mean)
  - At derivation of the FOCUS-product files
    - ✓ Computing the period value as a mean over the period
    - ✓ Computing the areal mean of grid points for regions and locations (a small circular area represents a location if no station height temperature corrections needs to be done)
- From the value distribution
  - For weather events (precipitation, thunderstorm, etc.) and wind direction the mean value should not be used, instead we use the most frequent value range/bin/type, etc.
    - ✓ At initialisation of the FOCUS the hourly grid point values are defined by counting each forecast member (with a weight) in the distribution
    - ✓ At derivation of the FOCUS-product files the period forecast values are determined by counting each hourly step in the period and the region values by counting each grid point in the area

How do we determine the parameters

- Wind direction
  - It is determined as one of the 16 main wind directions or “variable wind”
  - The most frequent bin is chosen, where each bin is weighted by the average speed in that bin
  - When bins are very evenly distributed and the wind speed is low then variable wind is coded
  - When a 2-3 bins are evenly distributed we simplify to 8 directions and take the most frequent weighted bin



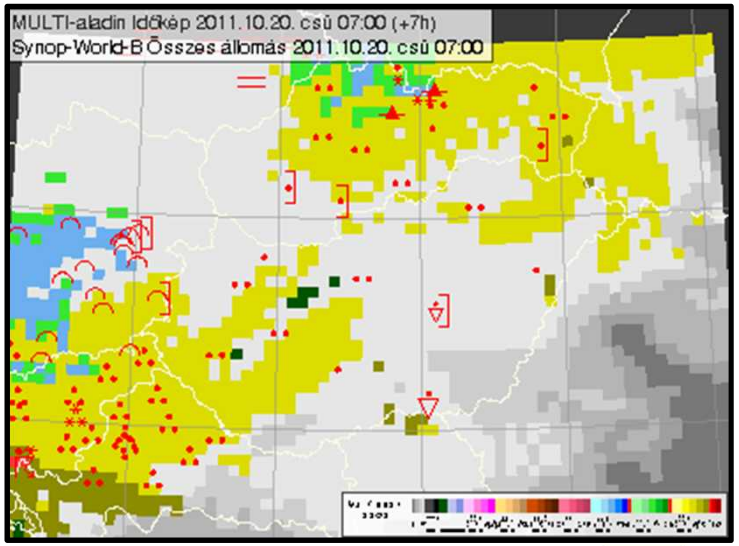


- Precipitation occurrence
  - Three general precipitation occurrence types are distinguished based on the precipitation probabilities
    - ✓ No precipitation
    - ✓ Less likely precipitation
    - ✓ Precipitation

How do we determine the parameters

- Precipitation types
  - In FOCUS we use in total about 40 precipitation types, distinguishing
    - ✓ 7 phases - snow, freesing rain, rain, ice pellets and mixtures
    - ✓ Intensities as drizzle / normal / shower with mixtures
    - ✓ 3 thunderstorm intensities
  - They are determined based on the model's snow fraction of total precip, an in-house snow probability index, the convective/lscale precip rate, the thunderstorm probability, and the lower tropospheric temperatures of the model (for freesing rain)

- Weather types
  - Significant weather type designed specifically for helping the consistent grid editing
  - Extended weather types for using in the end products
    - ✓ All necessary combination of cloud cover, precipitation types, and amount, visibility, wind speed, etc.



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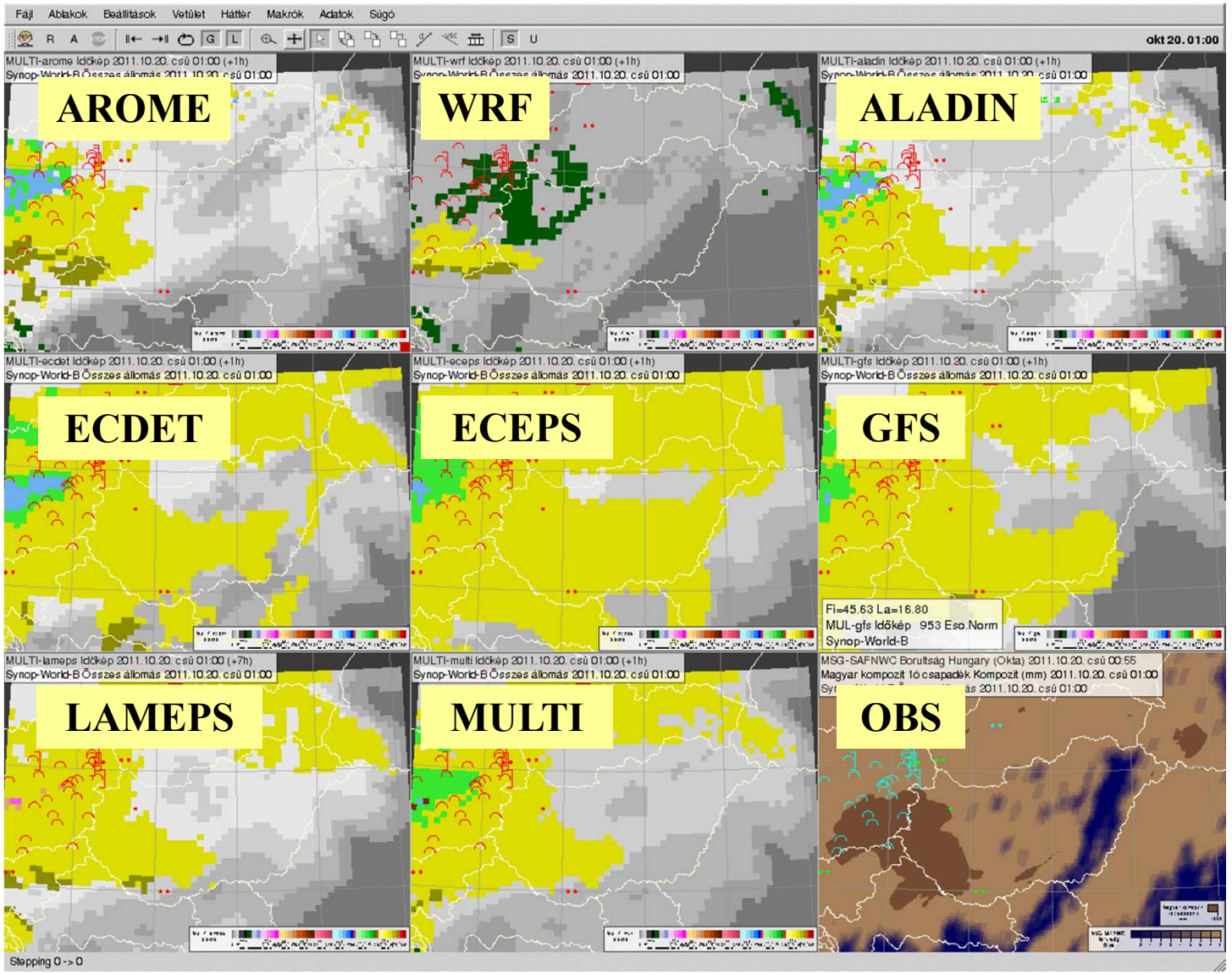
Example with significant weather types



Shades of grey/white
Cloud cover

Shades of dark grey/black
Visibility

Dark Green
Strong wind

Shades of Yellow
Rain

Shades of light green
Sleet

Shades of blue
Snow

Shades of pink
Freesing rain

Shades of light brown
SAT-based cloud cover

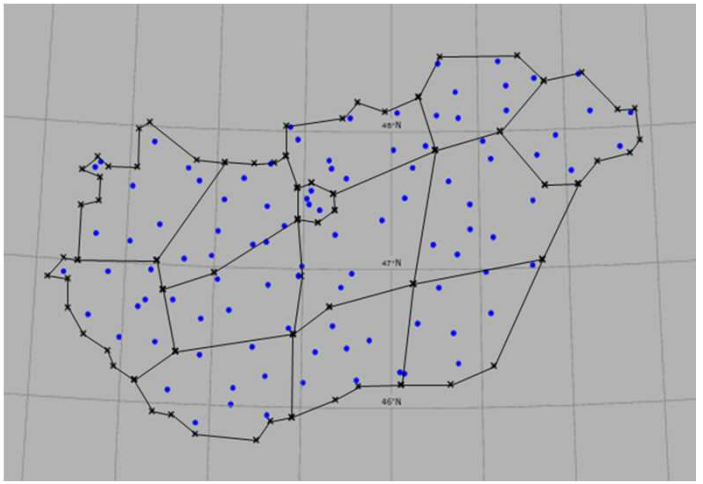
Dark brown
Radar-based precip mask

Coloured symbols
SYNOP weather obs

Model performance in the new FOCUS system

- We performed a model comparison of the models we process in the new FOCUS
  - Using a default multi-model combination
    - ✓ Equal weights at short range
    - ✓ Variable weights beyond T+54 for the 3 available models (ECMWF models & GFS) with gradually increasing weights for the EPS up to D+10
  - For the recent ~3 months, for the 00 UTC models

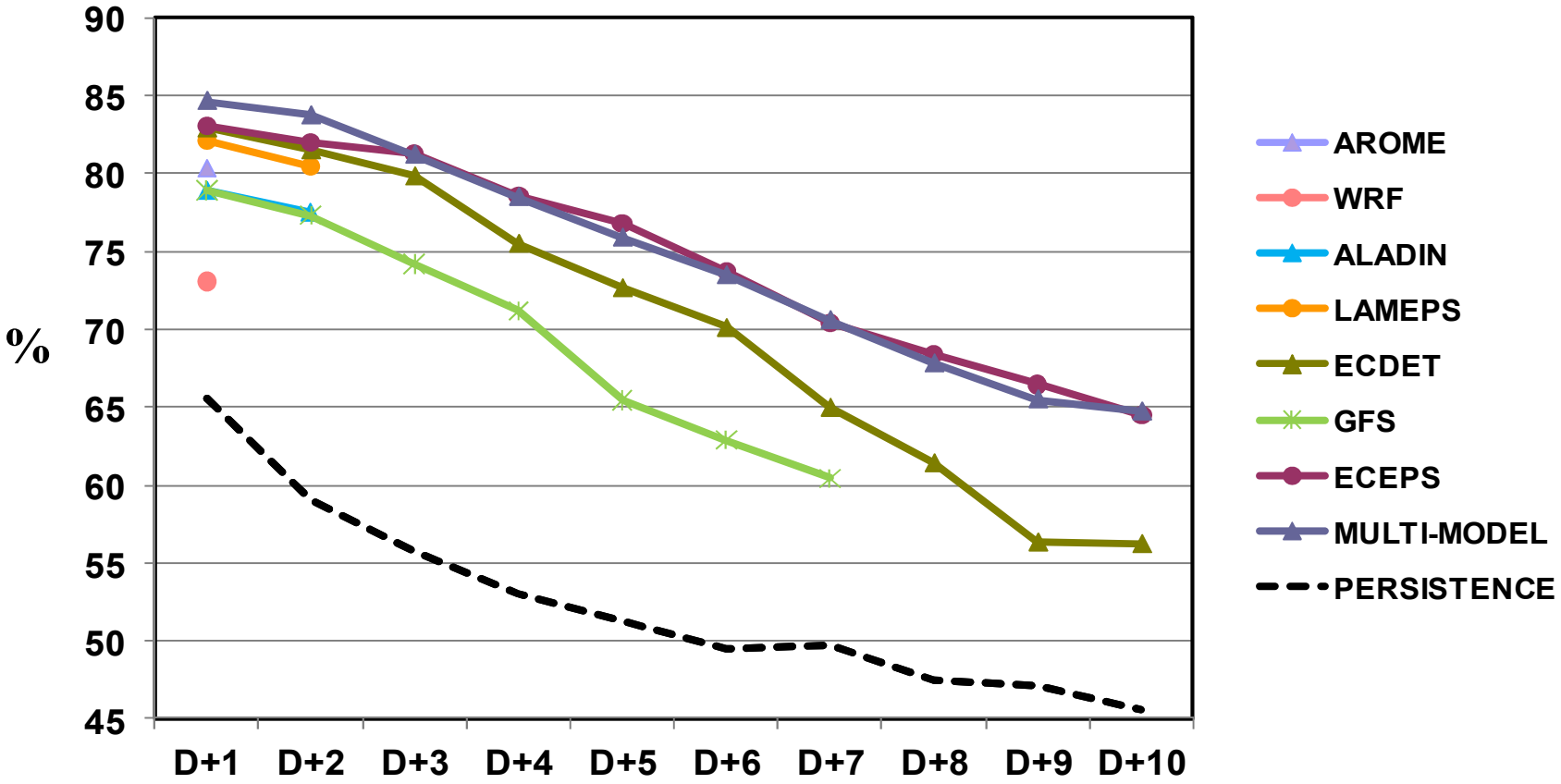
- We performed the verification based on the derived SFC forecast files as the verification system is not updated yet to the requirements of the new system
  - 13 Hungarian subareas
  - 12-hour day time and night time forecast periods
  - Forecasts represent an area over a period – mean/occurrence/min/max)
  - Verification is done against SYNOP observations (~100 stations including ~15 manned stations with visual observations)



Model performance in the new FOCUS system

06 UTC – 18 UTC (day time)

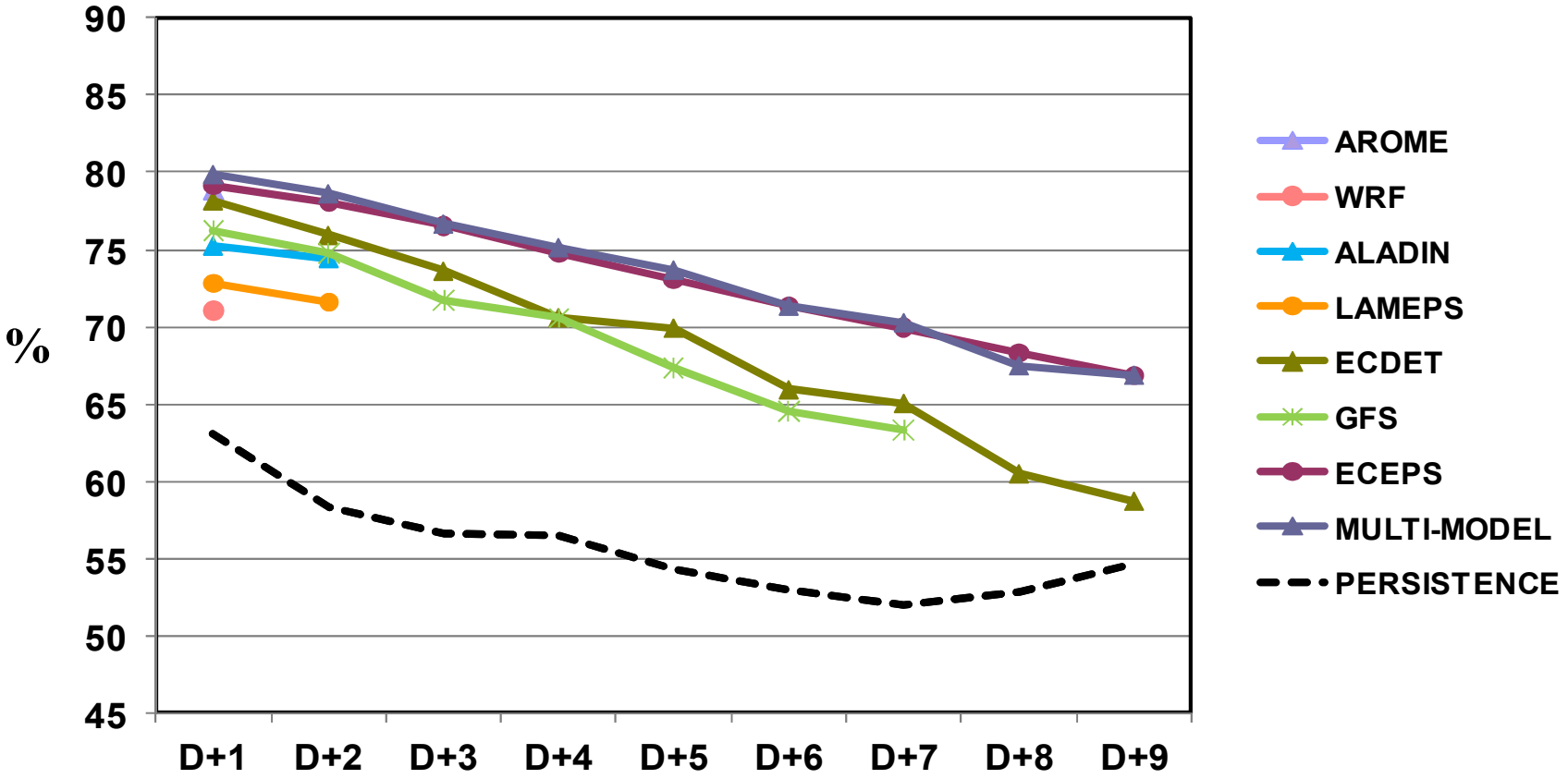
Summary Score – combination of cloud cover, precipitation, wind and temperature performance in one value (%)



Model performance in the new FOCUS system

18 UTC – 06 UTC (night time)

Summary Score – combination of cloud cover, precipitation, wind and temperature performance in one value (%)



Summary and plans

- A rather fundamental change of the forecast production is being carried out at the Hungarian Meteorological Service
- The main goal of this project is to increase the efficiency in practical utilisation of the huge amount of NWP data we are dealing with in operational forecasting (help the forecaster as much as possible)
- The core element of the new system is the reconfigured FOCUS database with unified, gridded forecast data, where all forecast product data is served from this database
- The system is highly automated, human intervention is possible only at two important stages in the data flow from raw NWP data to products
    - The role of the forecasters is being shifted with the arrival of the new system
    - As more emphasis is put on evaluation of the weather situation and decision making about the “best guess” for the forecast production
    - Grid editing possibility is kept, but in a simplified way, with more emphasis on the “weather outcome”

Summary and plans

- A very important attribute of the new system is that ensemble models (and therefore multi-models) with higher overall skills can be processed into traditional/categorical forecasts and therefore utilised in a very practical way
- By using the framework of the new system it is relatively easy to implement new ways of combining models, clusterings, representative members, etc. into the forecast production chain
- We plan to extend the FOCUS database with detailed probabilistic information in the very near future
    - The best guess value, finalised by the forecaster, will be complemented with quantile information originating from the ensemble distribution
- Comprehensive verification package is also planned as an integral part for monitoring each part of the system, including all stages of the production, along with the performance of the forecasters

Thank you!