Probabilistic forecasts for ATM: Potential, Conditions and requirements for complementary information

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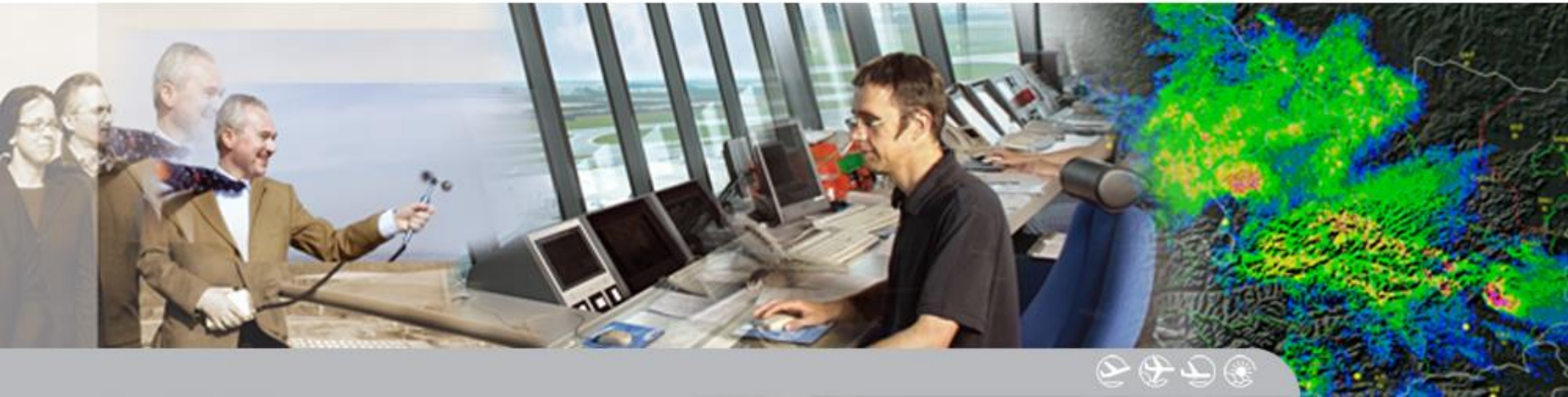


Rationale for probabilistic forecasts/now-casts

- High Impact weather situations are typically linked to smaller scales and contain stochastic elements
- Safety and capacity related ATM applications require information and decision making on the timescale of a few minutes to a few hours, with an increasing demand for reliable outlooks to several days
- , high-resolution ensemble prediction systems may provide useful information, e.g. by quantifying the MET uncertainty at the local level and on short time-scales, and estimate the risk of high impact, small-scale weather phenomena.
- Benefits in looking at outliers?
- Alternative solutions to be explored? (Nearest neighbour, MOS)

Ensemble vs probability forecast

- An Ensemble Prediction System (EPS) has two possibilities of output:
  - A probability forecast; or,
  - An Ensemble forecast.
- For a *probability forecast*, the output would typically be a percentage risk of a certain event, often relative to a specific threshold.

Aviation users of ensemble information may be able to use the full range of forecast data directly to calculate a range of ATM impacts, to be entered in a decision support system

Are all phenomena and parameters equally predictable?

- HR, non-hydrostatic models better represent topographically-driven effects in dynamic situations
- Local forcing depending on interactive processes (soil moisture, evaporation, role of plant cover) create uncertainty super-imposed on processes modeled
- HR model ensembles may represent the spread and range of this additional undcertainty reasonably well where a meso-scale „driver“ constrains outcomes
- Complex interactions between radiation and cloudiness create local convergence/ divergence of moisture fluxes, which are difficult to model explicitly or in parametric form

***:Evaluating Soil Moisture Feedback on Convective Triggering: Roles of Convective and Land-Model Parameterizations**

- Ian N. Williams, **JGR Volume124, Issue1,** 16 January 2019

Needs and Methods for calibration of forecast probabilities

extended calibration period for stable relationship between observed and forecast probabilities

extreme values for high impact weather parameters-

large samples required)

- proof of predictability

The crucial issue of defining thresholds…

Use in Risk assessment

Complex cost-loss situations – Multi-stakeholder situation

Resulting thresholds can be „off-center“)

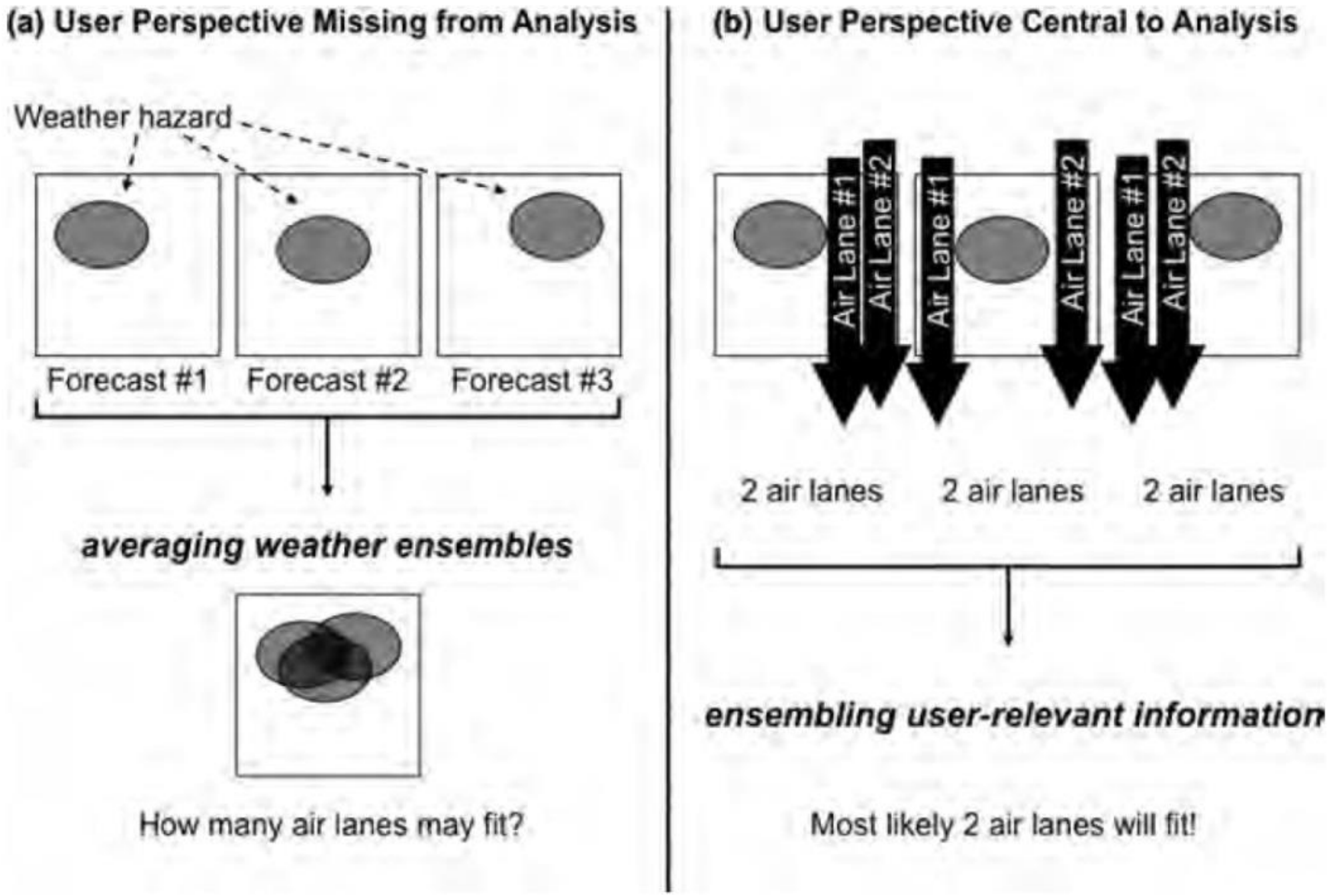
Spread and chance of “hitting the significant event”

- Individual, deterministic forecasts may miss a significant event
- “Shotgun approach” has higher chance of identifying the risk of an extreme event, but
  - Multi-model ensembles may have a higher chance of hitting the target (if single model has a systematic weakness)
  - The rarer the event, the harder calibration becomes
  - Larger spread of IC increases likelihood of identifying, but not necessarily exact estimate of risk
  - Best suited for reasonably homogenous domain
- Use of “mean” forecast likely to eliminate information about small, but important risks
- Use of “translated impact” tempting for end users, requires rather good understanding of underlying principles

Example of ATM ensemble prediction

- NextGen (Steiner et. al., 2010) approach of using high-resolution, ensemble-based numerical weather prediction model data for weather-related, probabilistic aviation impact forecasting.
- Ensembles of aviation-relevant information (e.g. maps of potential throughput as measured by the available flow capacity ratio). EPS output with statistical analysis (left); and, secondly, creating aviation-relevant EPS output.

EPS output with statistical analysis (left); and, secondly, creating aviation-relevant EPS output.



Weather (and related..) elements to be considered

- Visibility, often combined with Cloud Base as LVP conditions
- Wind)Speed, Intensity,Direction (head,crosswind) and gusts
- Icing Conditions (Need for de-icing, snow clearing)
- Precipitation (heavy, freezing, solid)
- Snow/slush
- Braking action
- Duration of weather events (onset, cessation)
- Thunderstorm/hail
- Lightning (shut down of ground operations)

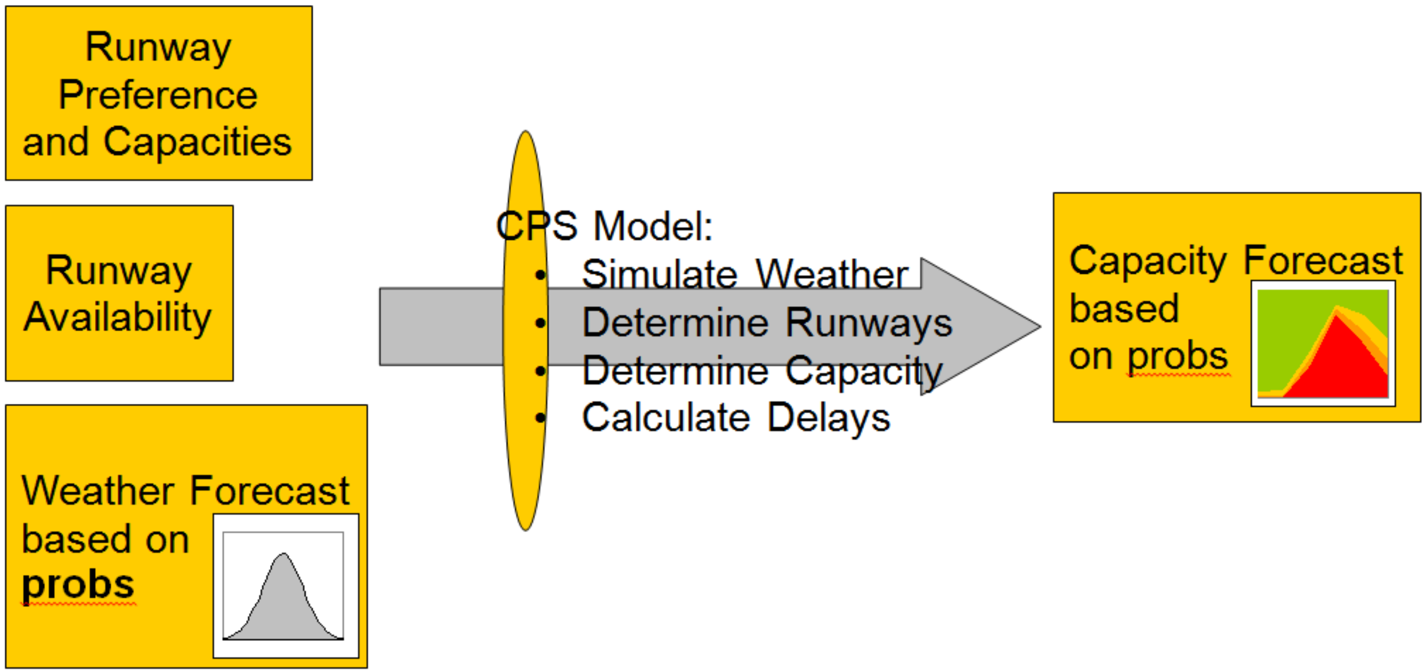
Examples of practical application of probability

- Winter Operations:
  - Nowcasting scale: Timely warning of fzra/fzdz (Application of de-icing agent useless after ice shield has formed)
  - VSRF: De-icing capability for aircraft: Number of de-icing stations, holdover time, intensity of event, DCB
  - VSRF - SRF: Snow accumulation for staff & equipment, rwy temperatures, ops procedures (early rwy clearing)
  - SRF-MRF: Likelihood of sev event out to several days for early staff planning, NM information
  - No two airports the same!

Examples cont.

- LVP (Low visibility procedures)
  - Depending on No of RWY, RWY configuration (Short exit possibility, Distance btn parallel rwy
  - Criteria strongly dependent on local OPS procedures
  - Availability of GND Radar
  - Onset as important as cessation of event
  - Typical accuracy required + / - 10 min
  - Examples: Schiphol , SFO, VIE

Use of probabilities at SCHIPHOL (AMS)



KNMI PROBABILITY FORECAST SCHIPHOL

Sunday 20 January 13 UTC till Monday 21 January 18 UTC

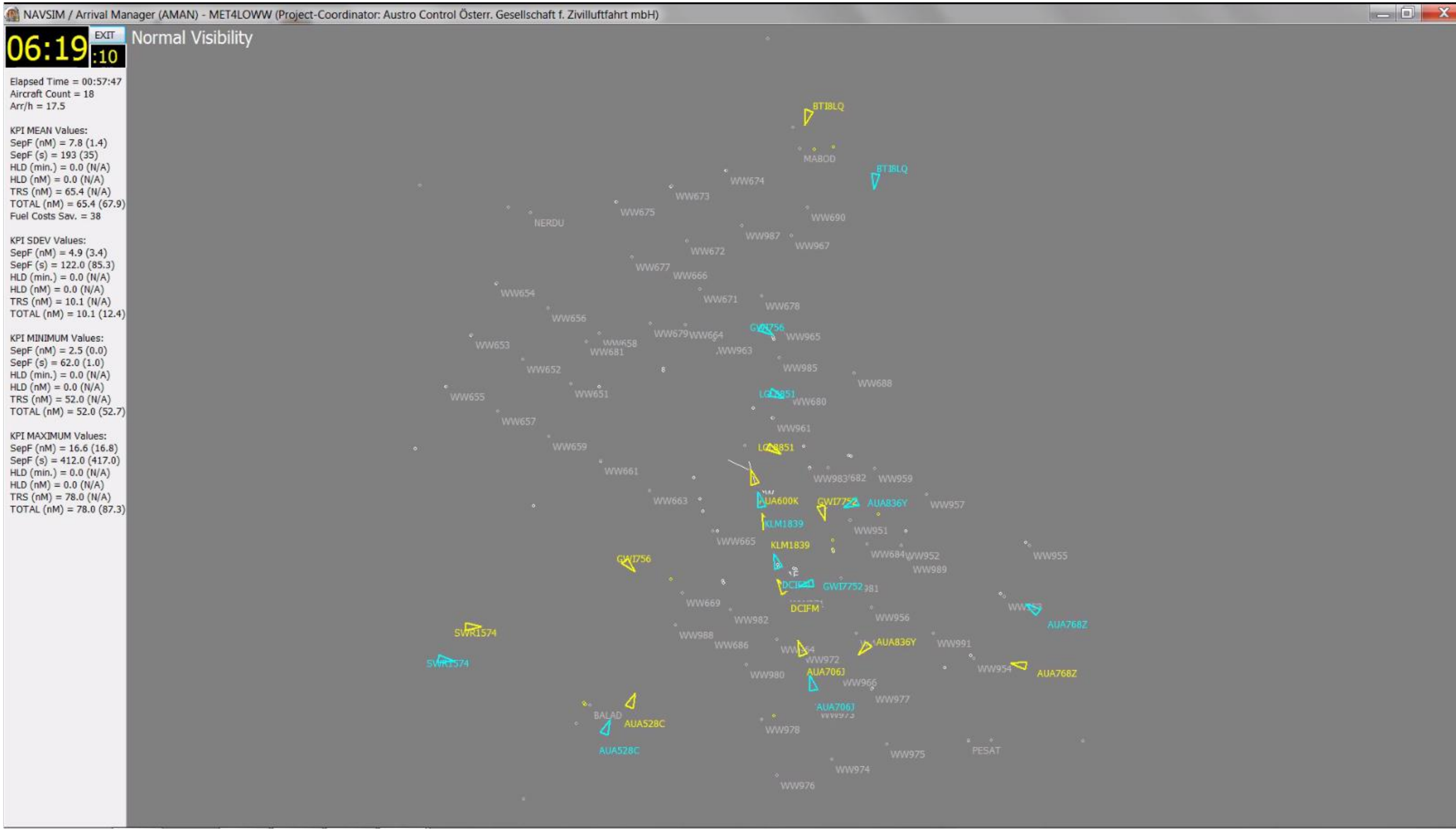
Last update: Short term: 10.03 UTC Long term: 11.24 UTC

	13	14	15	16	17	18	21	00	03	06	09	12	15	18
Visibility < 5 km and/or ceiling < 1000 ft (%)	45	55	75	80	80	85	85	85	85	85	80	65	60	65
RVR < 1500 m and/or ceiling < 300 ft (%)	20	30	40	40	40	40	40	40	40	10	5	5	5	10
RVR < 550 m and/or ceiling< 200 ft (%)	0	0	0	0	0	0	5	5	5	0	0	0	0	5
RVR < 350 m (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winddirection (deg)	↙ 070	↙ 070	← 080	← 080	← 080	← 080	← 090	← 090	← 100	← 100	← 100	↖ 120	↖ 110	↖ 110
Windspeed (kt)	17	18	17	16	17	17	14	11	12	12	12	11	11	10
Gusts (kt)	24	24	25	25	24	24	20	18	17		17	16		
Standarddeviation winddirection (deg)	10	10	10	10	5	15	10	20	30	15	20	20	15	15
Standarddeviation windspeed (kt)	2	2	3	3	2	3	2	2	3	3	3	3	3	3
CB (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorm (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (C)	-5	-5	-5	-5	-5	-4	-3	-3	-2	-2	-3	-3	-2	-3
Dewpoint (C)	-8	-8	-8	-7	-6	-6	-6	-4	-4	-3	-3	-3	-3	-4
Relative humidity (%)	79	79	79	86	93	86	80	93	86	93	100	100	93	93
Windchill	-13	-13	-13	-13	-13	-12	-10	-9	-8	-8	-9	-9	-8	-9
Snow (%)	45	55	75	90	90	80	80	80	80	45	30	30	30	35
Moderate or heavy snow (%)	0	5	30	30	30	30	30	30	30	5	0	0	0	0
Freezing precipitation (%)	5	5	5	5	5	5	5	5	5	0	0	0	5	0
	13	14	15	16	17	18	21	00	03	06	09	12	15	18

MET4LOWW – research project
MET potentials in arrival and departure management

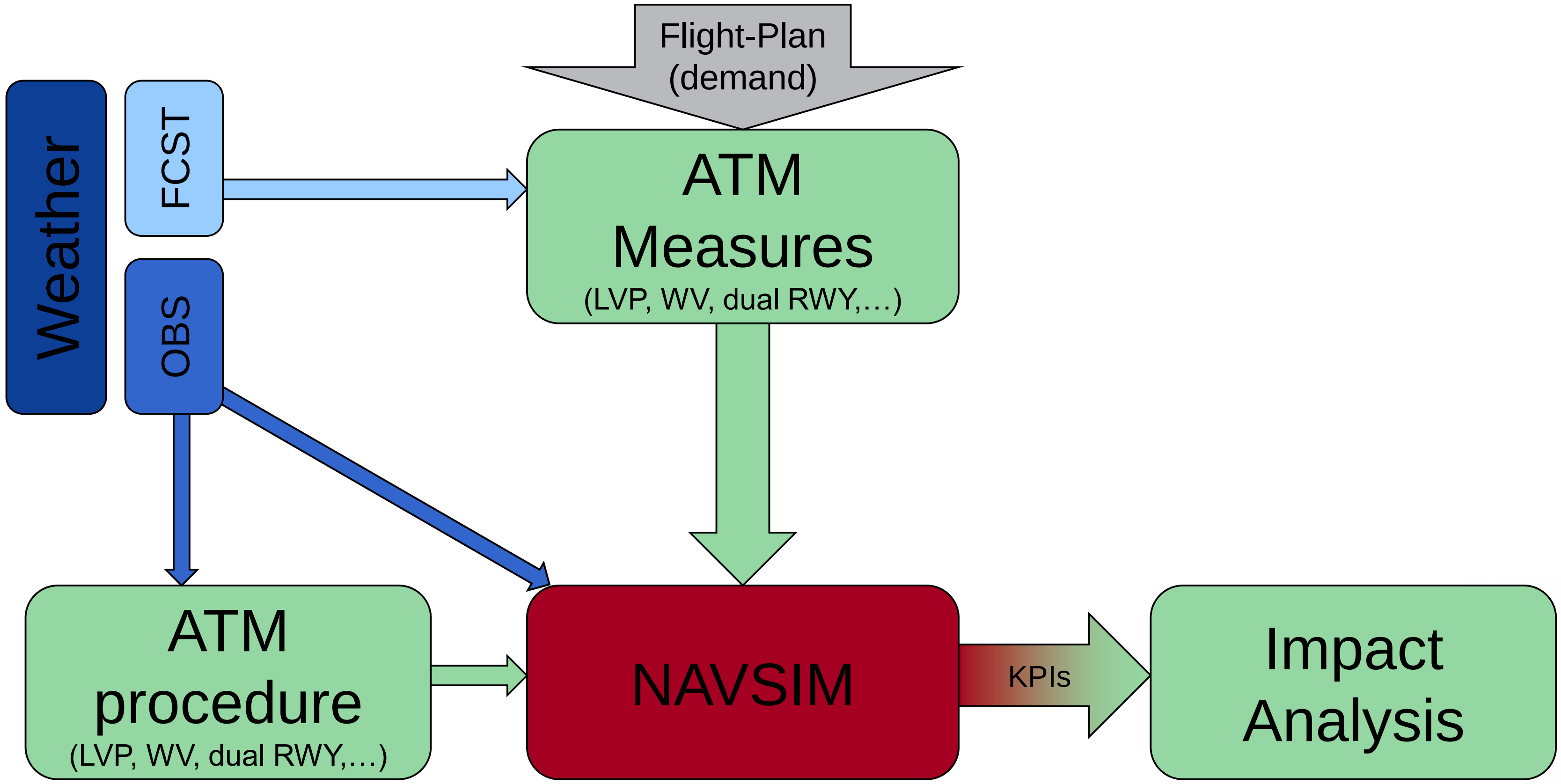
- Funded by the Austrian Research Promotion Agency (FFG)
- Participants
  - Austro Control
  - Uni Salzburg, Aeronautical Digital Communications Group
  - DLR Institute of Atmospheric Physics
- Objective: Evaluate the potential of a holistic ATM/MET approach:
  - Final approach
    - Time Based Separation
    - Low Visibility Procedures
    - Wind shifts (=RWY direction changes)
  - Arrival management
    - Thunderstorms
  - Departure management
    - MET input to CDM

Simulator evaluation
snapshot



yellow: CPR; blue: simulated

Weather impact analysis



Weather impact analysis

- Following a similar approach to using contingency table and cost matrix

		Observed	
		Yes	No
Forecasted	Yes	***h**it*	***f**alse alarm*
	No	***m**issed*	Correct ***n**egative*
		o = h + m	1 - o

		Observed	
		Yes	No
Take action	Yes	$C + L - L_1$	C
	No	L	0

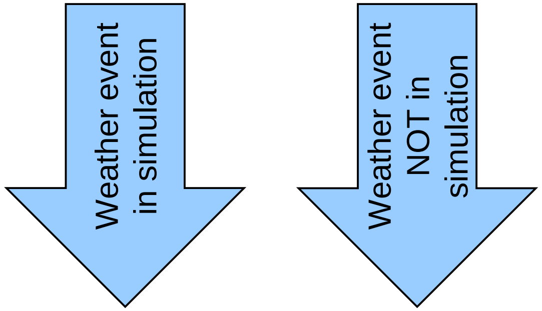
- A contingency table and a KPI matrix can be used to assess the forecast value

		Observed	
		Yes	No
Forecasted	Yes	***h**it*	***f**alse alarm*
	No	***m**issed*	Correct ***n**egative*
		o = h + m	1 - o

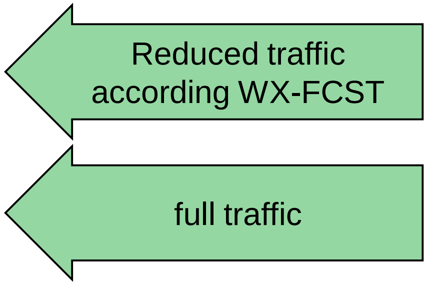
		Observed	
		Yes	No
Take action	Yes	KPI_h	KPI_f
	No	KPI_m	KPI_n

Weather impact analysis

- The KPI matrix can be filled using the air traffic simulator

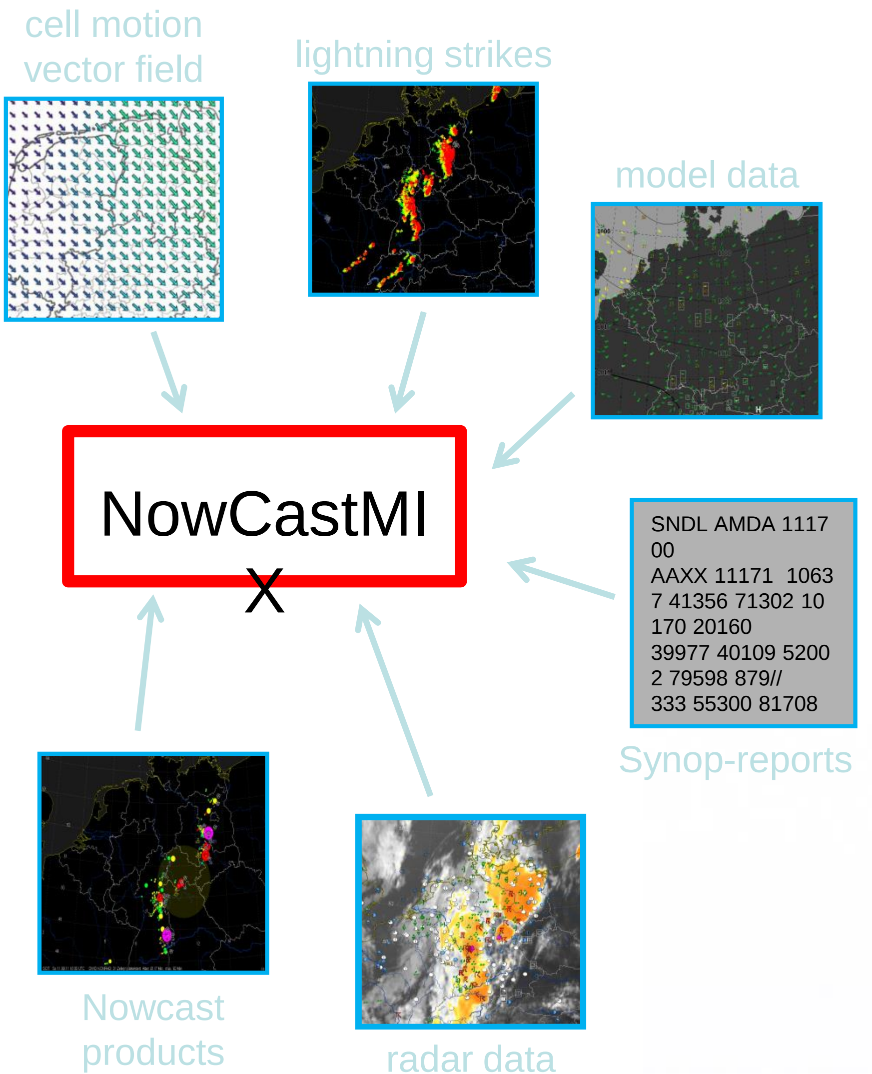


		Observed	
		Yes	No
Take action	Yes	KPI_h	KPI_f
	No	KPI_m	KPI_n



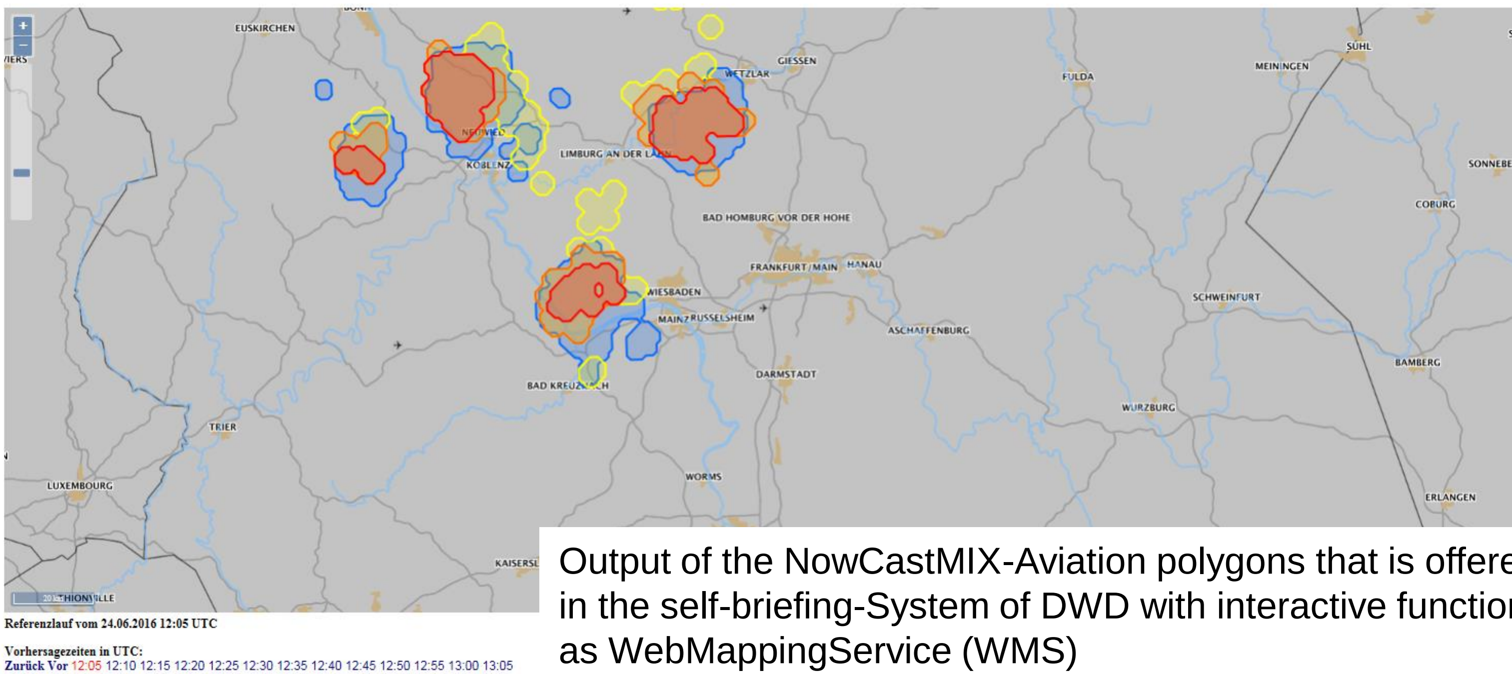
Nowcasting tool NowCastMIX

- NowCastMIX is a fuzzy logic based nowcasting tool for estimating convective events and their respective phenomena
- NowCastMIX combines different types of datasets, such as radar data, lightning strikes and model data
- The severity of the events are functions of the presence and intensity of the attributes hail, wind gusts and strong rain



NowCastMIX-Aviation

- Spatial resolution: the whole of Germany in a region of 900 km x 900 km with 1 km x 1km grid resolution
- Temporal resolution: 5 min time steps with forecasts up to 1 hour on a 5 min update rate
- The output is offered in GRIB format and as polygons



Output of the NowCastMIX-Aviation polygons that is offered in the self-briefing-System of DWD with interactive functions as WebMappingService (WMS)

ETCIS:
Ensemble based Tail and Cross wind Informaton System

- development of probabilistic wind forecasting tool for the airport Frankfurt / Main for handling of runway in use

- Model: COSMO-D2-EPS , the high-resolution, short-range numerical weather ensemble prediction model with 20 members running at DWD

- customer-orientated forecasting products: threshold-exceedance probabilities and quantiles for cross and parallel wind vectors

Products

- Forecasts for 10 m wind and at glide path points up to 1500 m

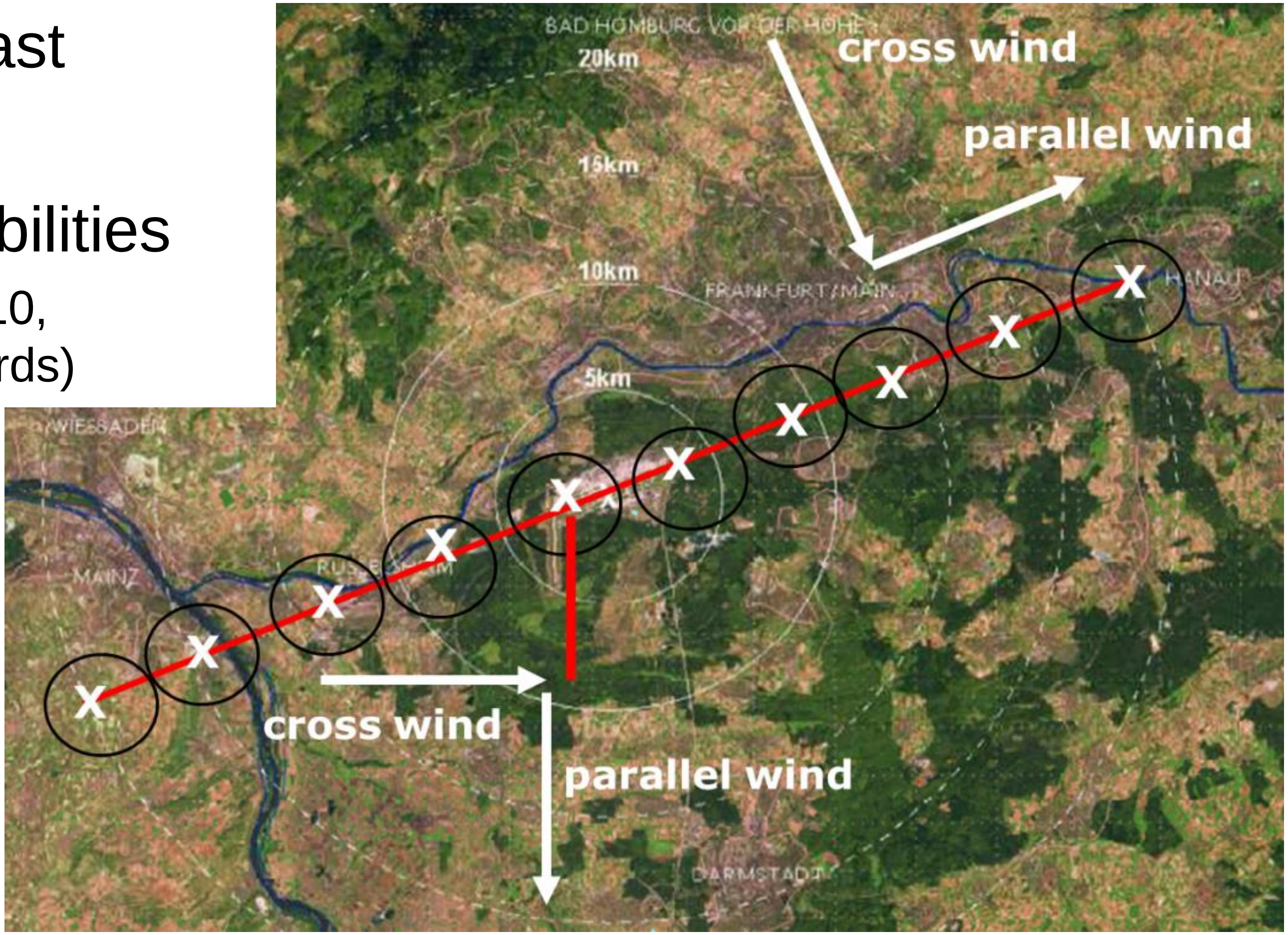
Ensemble mean as deterministic forecast

Exceedance probabilities

Tailwind +5, -5, -8, -10, -15 kn (ICAO standards)

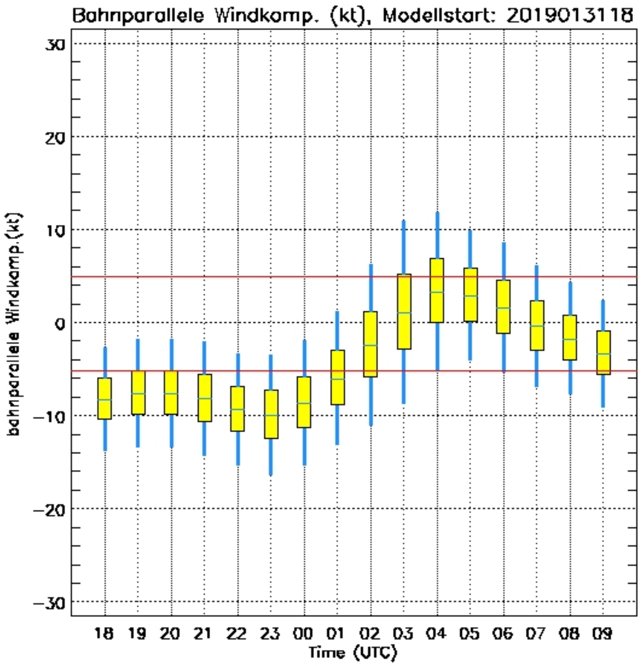
Crosswind ± 20 kn

Selected quantiles

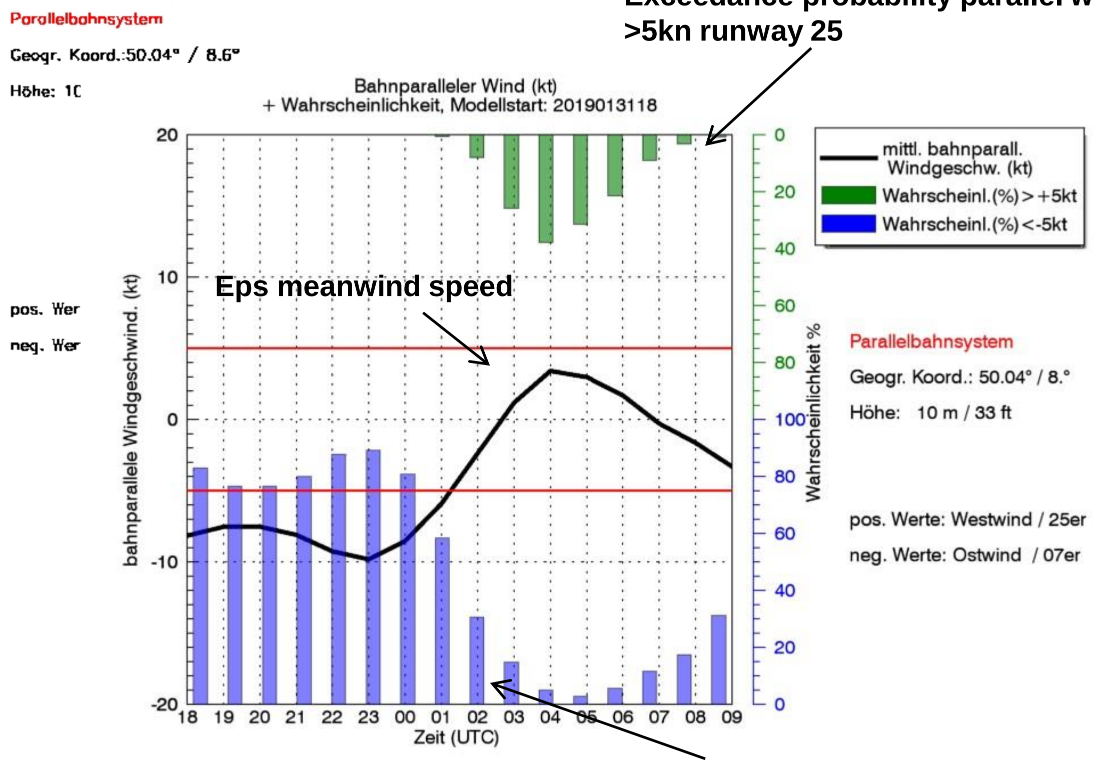


Example of products

box-whisker-plots parallel wind



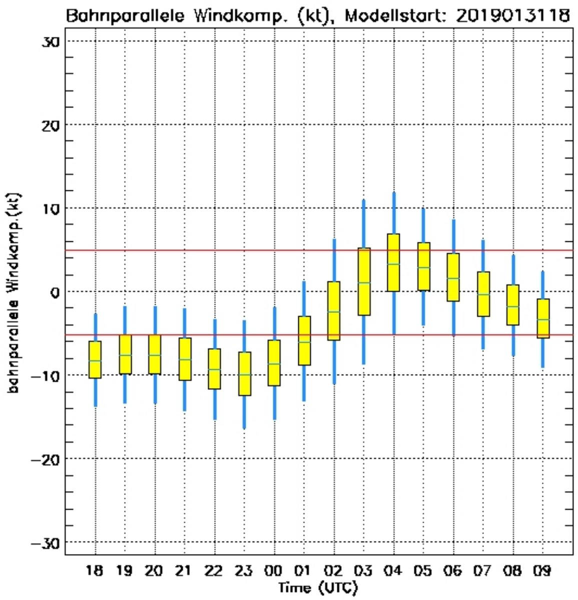
Exceedance probability parallel wind >5kn runway 25



Eps meanwind speed

Exceedance probability parallel wind >5kn runway 07

Example 31.01.2019



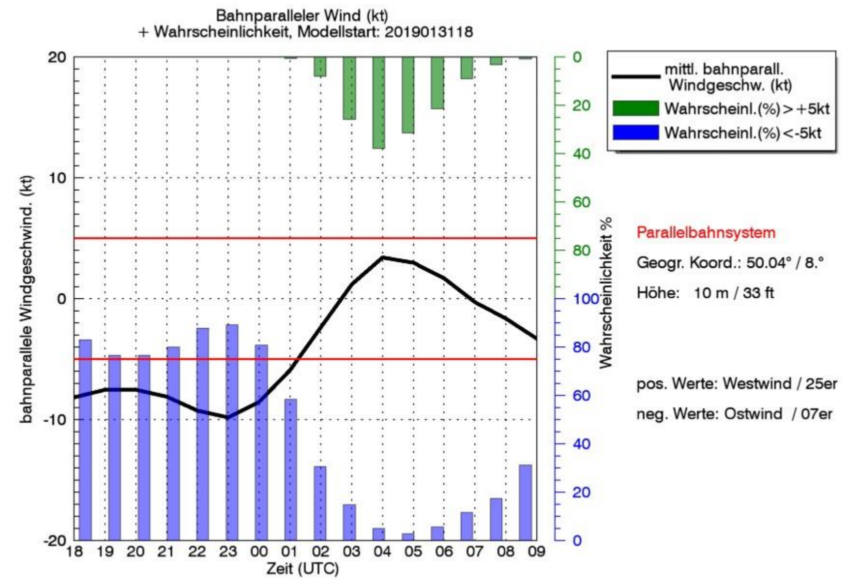
Parallelbahnsystem

Geogr. Koord.:50.04° / 8.6°

Höhe: 10 m / 33 ft

pos. Werte: Westwind / 25er

neg. Werte: Ostwind / 07er



t 18 19 20 21 22 23 00 01 02 03 04 05
06 07 08 09

Role of Synoptic-scale Flow and shear

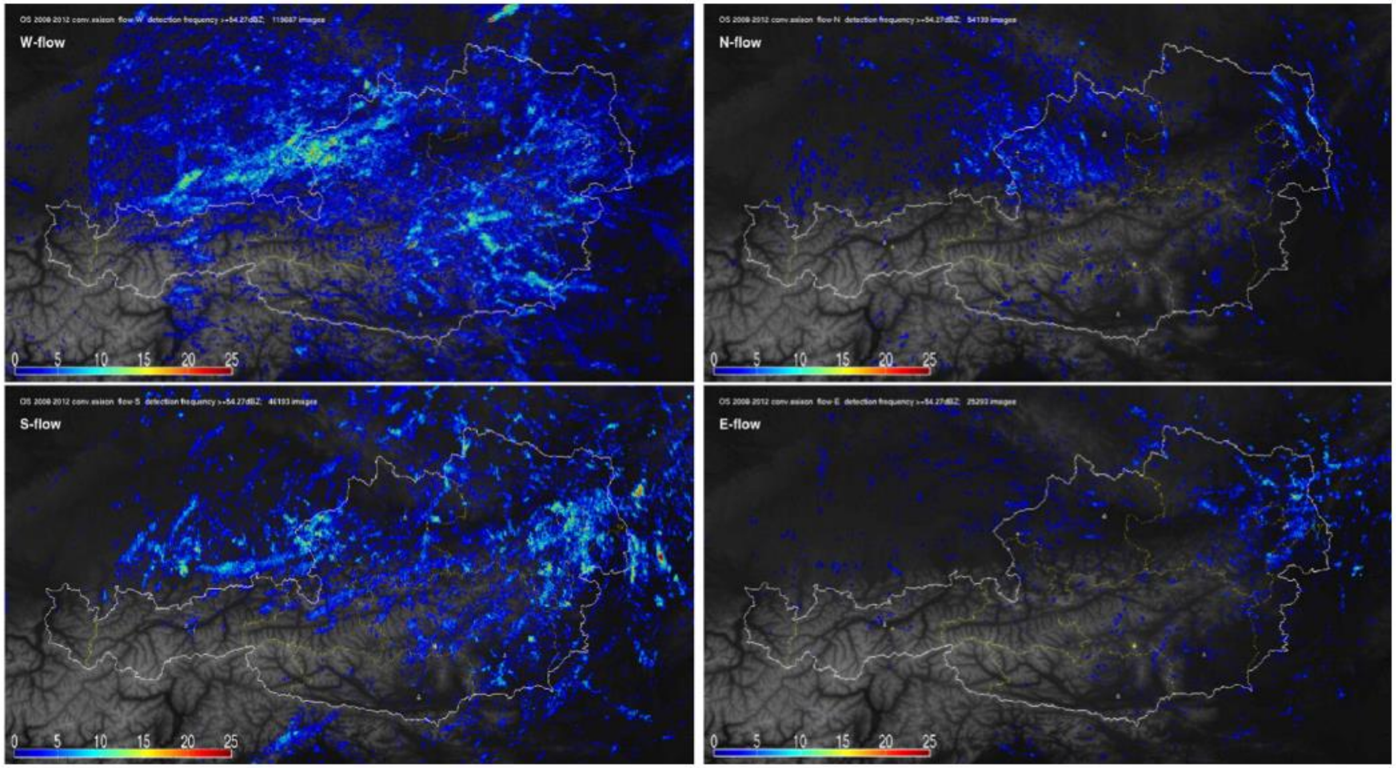
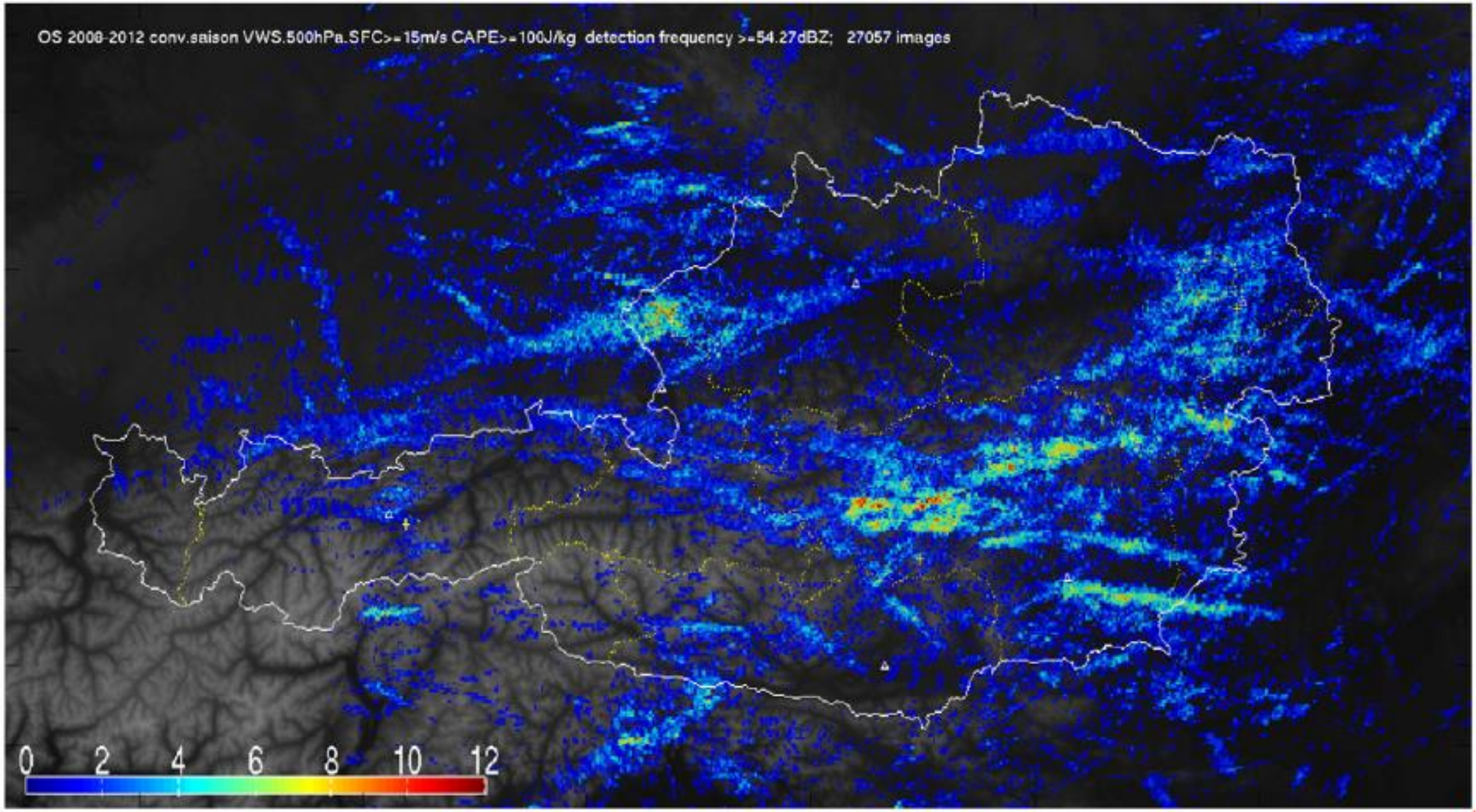
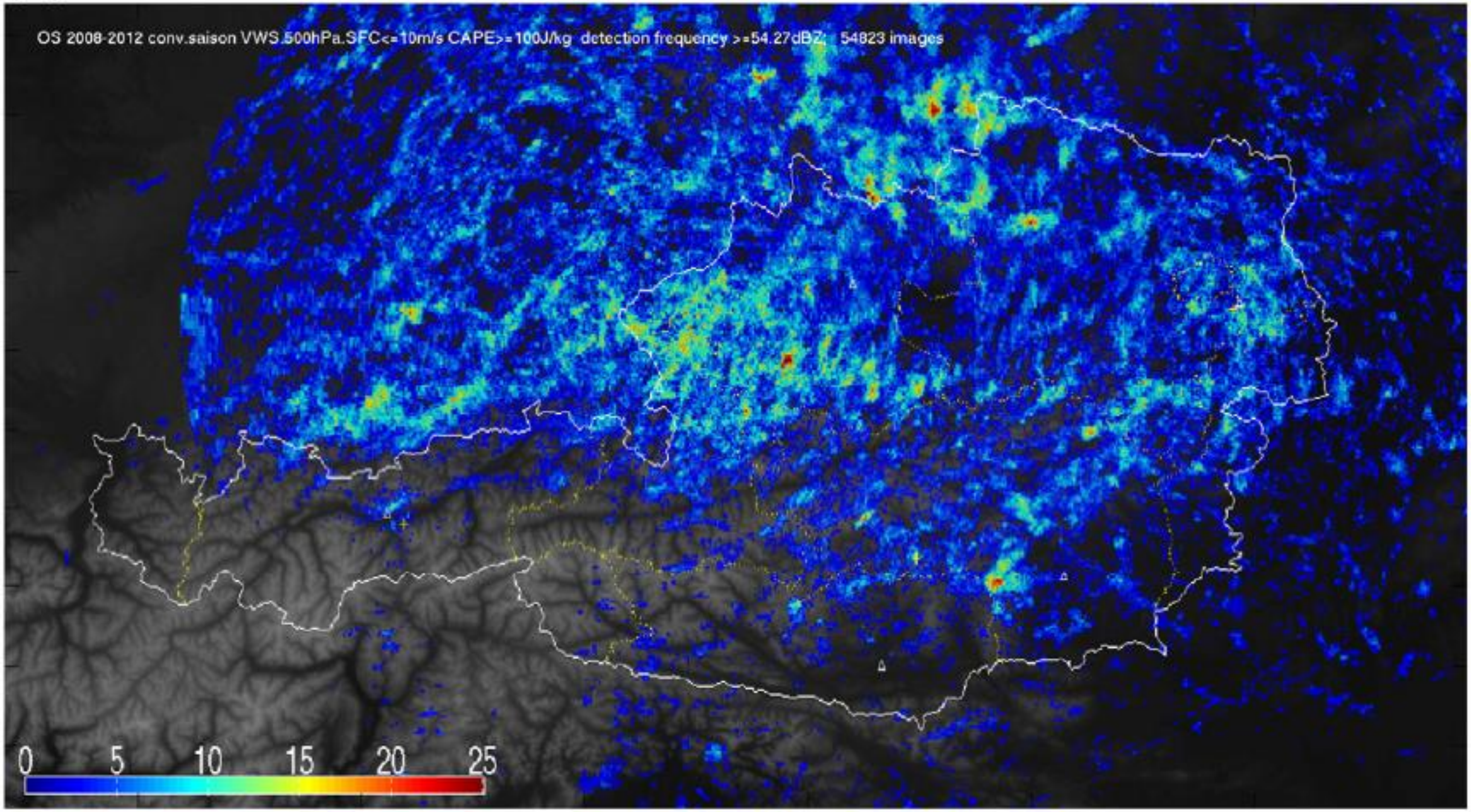


Fig. 6. As Fig. 2 but for frequency distributions of $Z \geq 54$ dBZ (absolute numbers) for different flow configurations (500 hPa) during the convective seasons 2008–2012 derived from Austrian composite consisting of 4 weather radars. From upper left to lower right: W-, N-, S- and E-flow.

Strong shear case

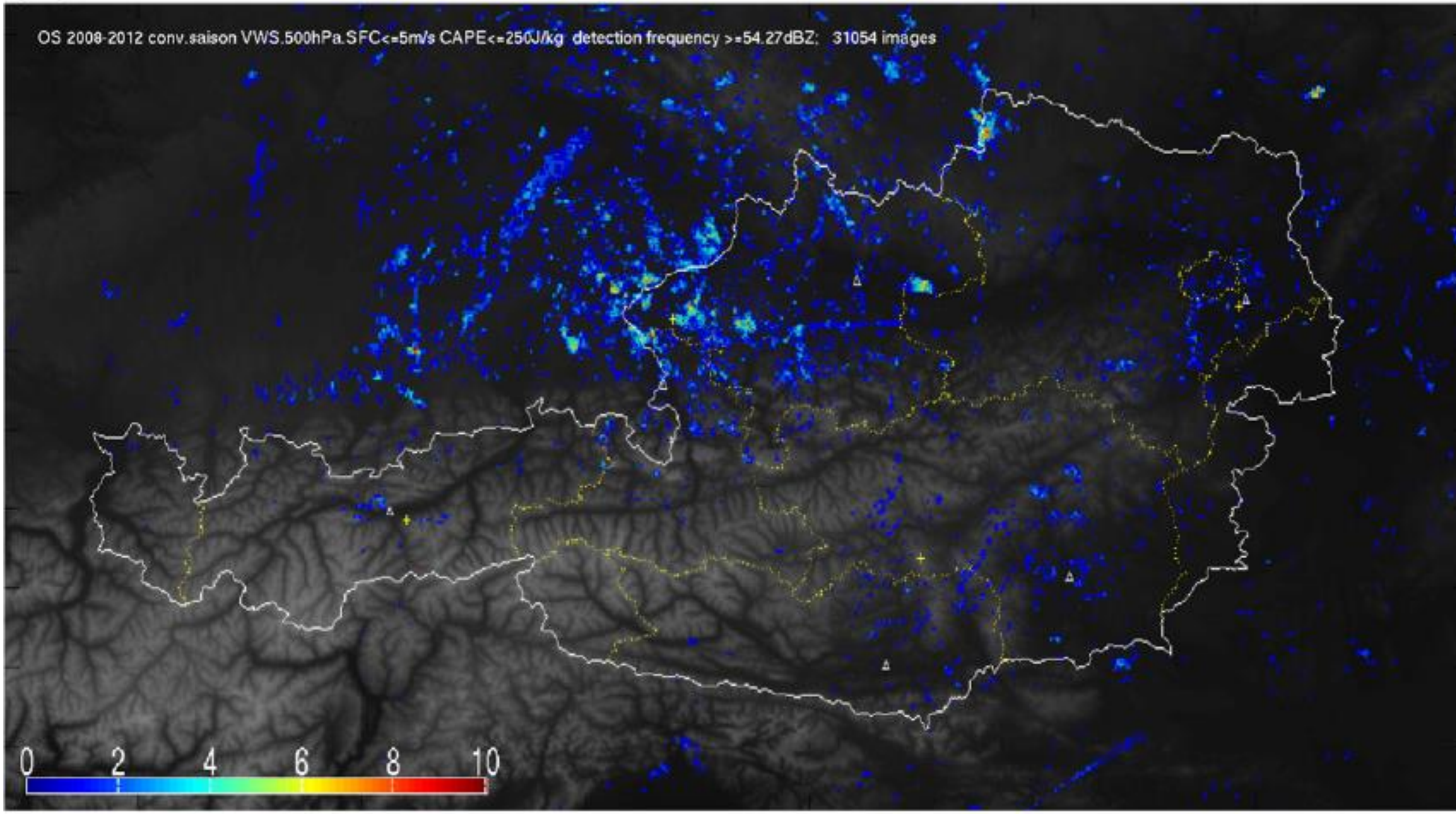


1



OS 2008-2012 conv.saison VWS.500hPa.SFC<=10m/s CAPE>=100J/kg detection frequency >=54.27dBZ; 54823 images
0 5 10 15 20 25

2



OS 2008-2012 conv.saison VWS.500hPa.SFC<=5m/s CAPE<=250J/kg detection frequency >=54.27dBZ: 31054 images
0
2
4
6
8
10

Use of probabilistic forecasts (ensemble prediction scheme) in Trajectory Based Operations (TBO)

- Two options:
- A representative statistical meteorological forecast is derived (e.g. the mean solution) from the output from the EPS. A trajectory prediction is then based upon this outcome i.e. a single ‘best’ solution.
- Based upon the multiple forecasts from the EPS, a trajectory prediction is derived for each meteorological outcome. This then gives an ensemble of ‘MET-trajectory’ predictions which could also be combined with all other non-meteorological factors to determine a range of trajectory solutions.

Schematic of Prob-Based TBO