Funded by: FFG TAKE OFF bmvit

Air traffic management and weather: the potential of an integrated approach

WMO WWRP 4th International Symposium on Nowcasting and Very-short-range Forecast 2016
25-29 July 2016, Hong Kong

Martin Steinheimer, Carlos Gonzaga-Lopez, Christian Kern, Markus Kerschbaum, Lukas Strauss

austro CONTROL

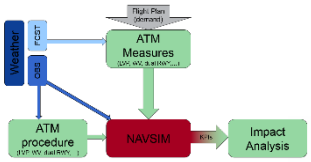
Kurt Eschbacher, Martin Mayr, Carl-Herbert Rokitansky

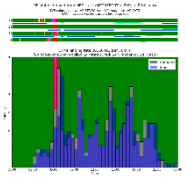
UNIVERSITÄT SALZBURG

SICHERHEIT LIEGT IN DER LUFT

Outline

- The Motivation
  - Why are we doing it…
- The Project
  - Who is doing it…
- The Method
  - How are we doing it…
- The Tool
  - What do we use to do it…
- The First Results
  - What we did so far…
- The Outlook
  - What are we doing next…





The Motivation

Weather impact on Air Traffic Management

- Weather especially wind, thunderstorms and low visibility have big impact on airport capacity

- Weather cannot be changed but accurate forecasts help to be prepared and to minimize weather impact

- Weather impact in numbers:
  - Vienna International airport:

Delays LOWW ARR Oct. 2015 - Mar. 2016			
	minutes	min/flight	percentage
Weather	66 214	0,59	89%
Total	74 121	0,66	

  - Winter 2015/16 weather delays mainly due to low visibility (almost no snow at Vienna airport)

Weather impact on Air Traffic Management
Low Visibility Procedures

- What are **L**ow **V**isibility **P**rocedures

LVP state	RVR	Ceiling	Separation	Capacity
normal			2.5NM	>40
LVP	< 600m or	BKN < 200ft	4NM	25
LVP CATIII	< 350m		6NM	18

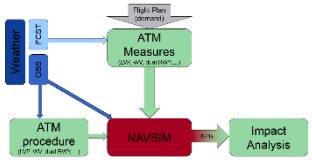
- LVP seen from the cockpit:
  https://www.youtube.com/watch?v=mSNE3SmYA-8

The Project

MET4LOWW – research project
MET potentials in arrival and departure management

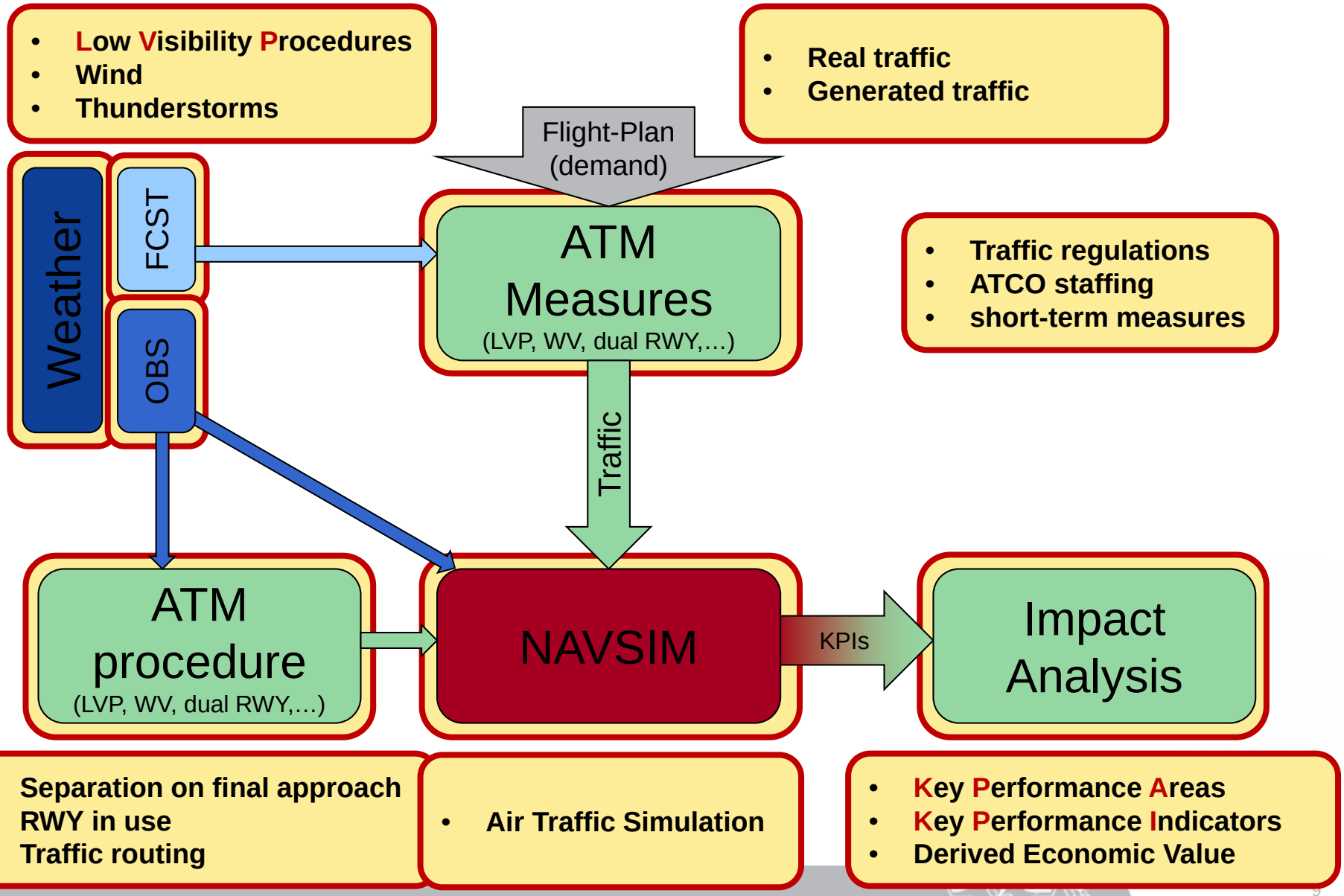
- Funded by the Austrian Research Promotion Agency (FFG)
- Participants
  - Austro Control (ATM and MET department)
  - Uni Salzburg, Aerospace Research Group
  - DLR Institute of Atmospheric Physics
- Objective: Evaluate the potential of a holistic ATM/MET approach:
  - Final approach
    - Time Based Separation (pair-wise/weather dependant separation)
    - **L**ow **V**isibility **P**rocedures
    - Wind shifts (=RWY direction changes)
  - Arrival management
    - Thunderstorms
  - Departure management
    - MET input to Airport **C**ollaborative **D**ecision **M**aking

The Method


Weather
FCST
OBS
Flight Plan (demand)
ATM Measures
ATM procedure
NAVSIM
KPIs
Impact Analysis

Weather impact analysis

Flow chart



Weather impact analysis
KPAs / KPIs

- **K**ey **P**erformance **A**reas considered
  - Capacity
  - Environmental Impact / Flight efficiency
  - Cost-effectiveness
  - Traffic complexity

    As proxy for Safety (safety can not be measured with perfect simulations)
- Each KPA is represented by one or more Key Performance Indicators, which should meet following criteria:
  - Specific
  - Measurable
  - Drive the desired behaviour
  - Accountable/manageable
  - Compatible with ICAO guidelines
  - **Proper with regard to weather forecasts**

According to EUROCONTROL 2011 technical note: Measuring Operational ANS performance at Airports

Weather impact analysis
Forecast value

- 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

(e.g.: Richardson, D. S., 2000: Skill and relative economic value of the ECMWF ensemble prediction system. *Q.J.R. Meteorol. Soc.*, **126**, pp. 649-667.)

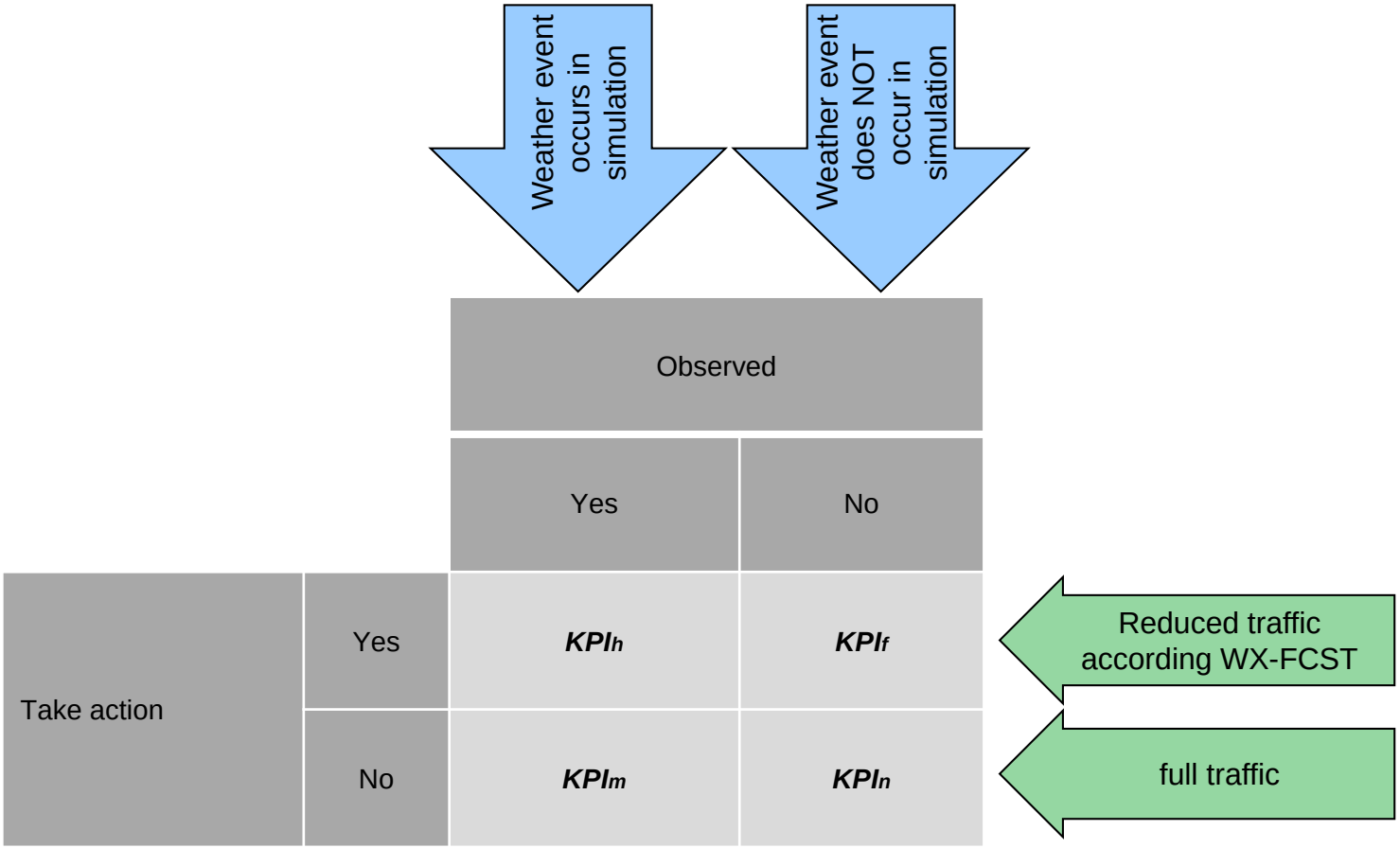
- A contingency table and a KPI matrix can be used to assess the forecast value

		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
Forecast value

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



Weather impact analysis
Forecast value

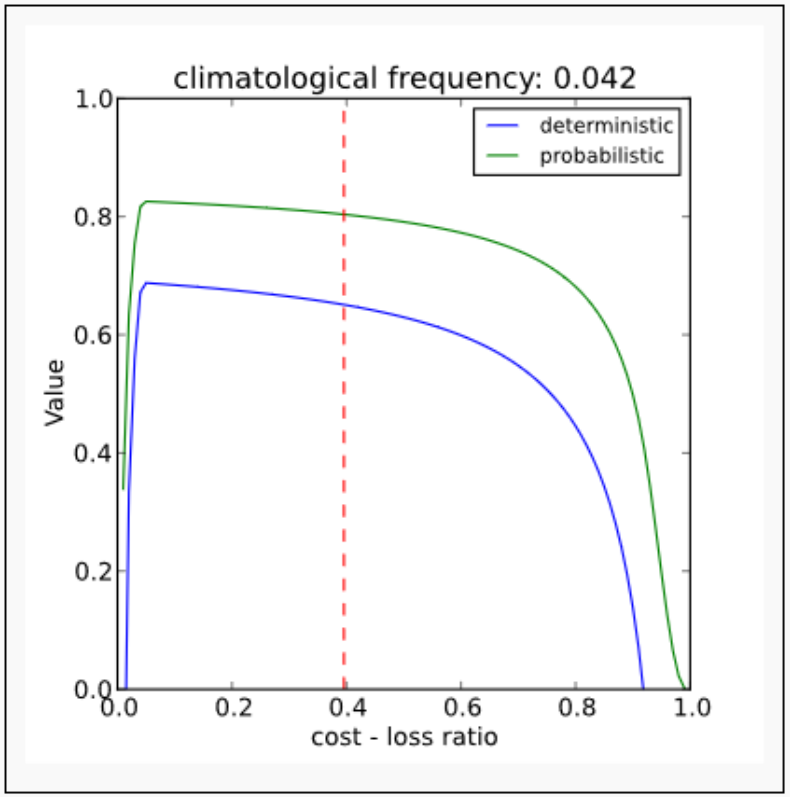
- Cost/Loss ratio can be derived from the KPI matrix
- Economic value can be derived from contingency table and KPI-matrix (similar to potential economic value)

Deterministic forecast:
(2h LVP forecasts at LOWW in 2015)
POD and FAR:

POD (probability of detection):	0.69106
FAR (false alarm ratio):	0.00269

Resulting KPI for N forecasts:
Probability threshold for which to protect/do not protect (C/L): 0.40

Frequency:	0.042
KPI for always protect:	0.5476
KPI for never protect:	0.8514
perfect forecast:	0.8733
"perfect" probabilistic forecast:	0.8690
deterministic forecast:	0.8656
climatology:	0.8514



NOTE:
probabilistic curve is not based on actual verification results
C/L derived from estimates not actual evaluation

NOTE: KPI values and C/L derived from estimates not actual evaluation

Weather impact analysis
Challenges

- KPIs contradictory, e.g.:
  - trade-off between maximizing capacity and optimizing workload
  - trade-off between optimizing workload and minimizing flight delays
  - etc…
- Different stakeholders (ANSP, airlines, airports,…) associate different priorities to KPAs/KPIs
  - e.g. ATM workload is not airlines' first priority
- In order to quantify the impact on the overall air traffic management system:
  - The various KPAs/KPIs need to be combined
  - That requires appropriate normalization and weighting considering all stakeholders' requirements
- A detailed analysis on this topic was done in an Eurocontrol commissioned research study

(Bert De Reyck, B., Degraeve, Z. and Grushka-Cokayne, Y., 2006: Decision Support Using Performance Driven Trade-Off Analysis. *EEC Note: EEC/SEE/2006/001*)

The Tool

Building Blocks – NAVSIM

ATM/ATC/CNS Simulator – Main Characteristics

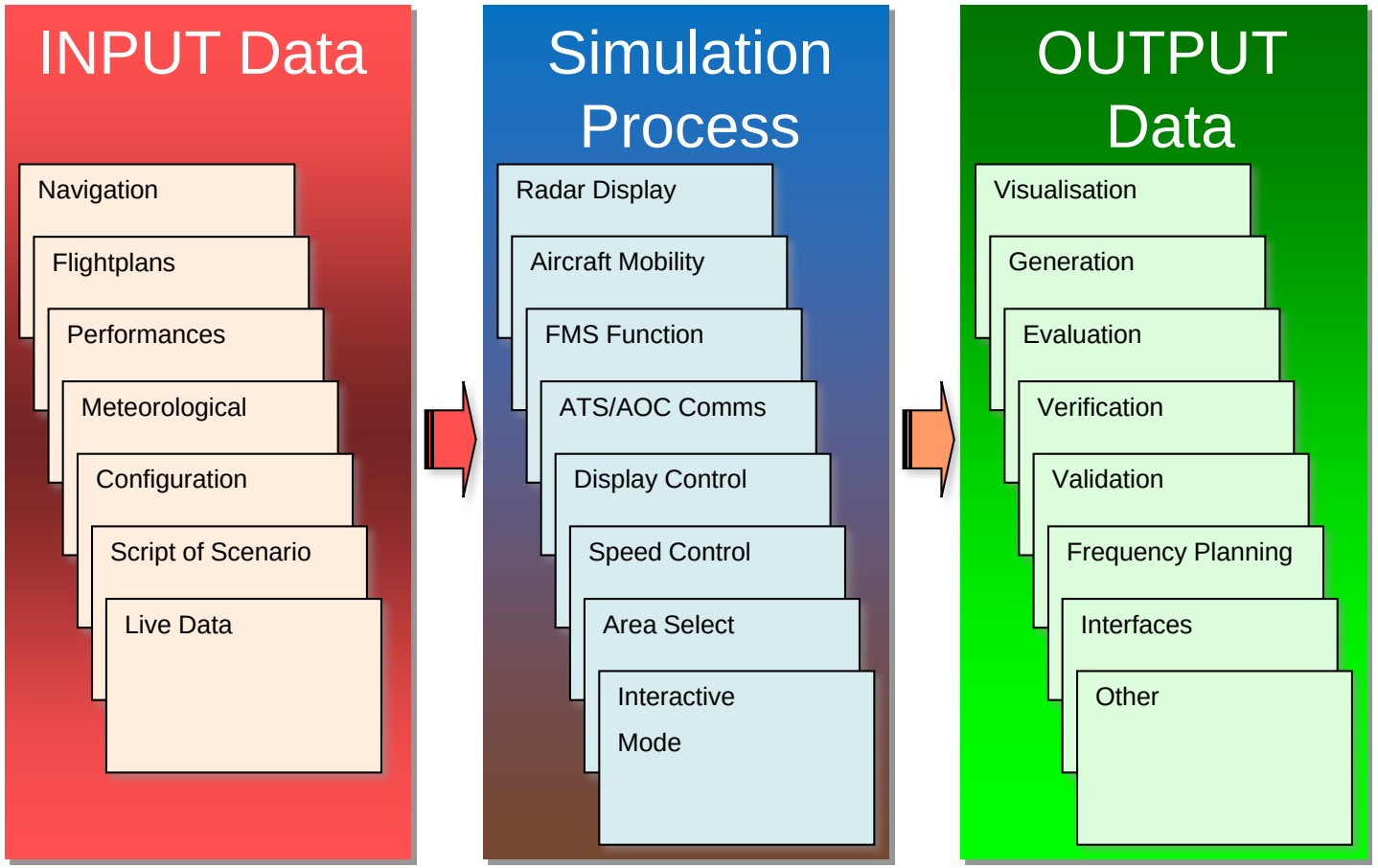
- Detailed world-wide Runway-to-Runway (or Gate-to-Gate) Air Traffic Simulation
- Using detailed Aircraft Performances
- Based on around 1 million Nav-data (as used for FMS)
- Using sophisticated Simulation Techniques
- Simulate more than 10.000 Aircrafts (AC) simultaneously – generic FMS for each AC
- Displaying today's and any future predicted Air Traffic
- Simulation running in Real time or Fast Time mode
- Inclusion of third party test equipment and products
- Supports Evaluation of NextGen / SESAR concepts

UNIVERSITÄT SALZBURG

Note: NAVSIM ATM/ATC/CNS Tool developed by Mobile Communications Research & Development Forschungs GmbH in co-operation with USBG

Building Blocks – NAVSIM

Architecture



NAVSIM / AMAN
Advanced Arrival Management

NAVSIM/AMAN Advanced Arrival Manager includes the following features & functions for ATC performance analysis and evaluation of MET-potentials:

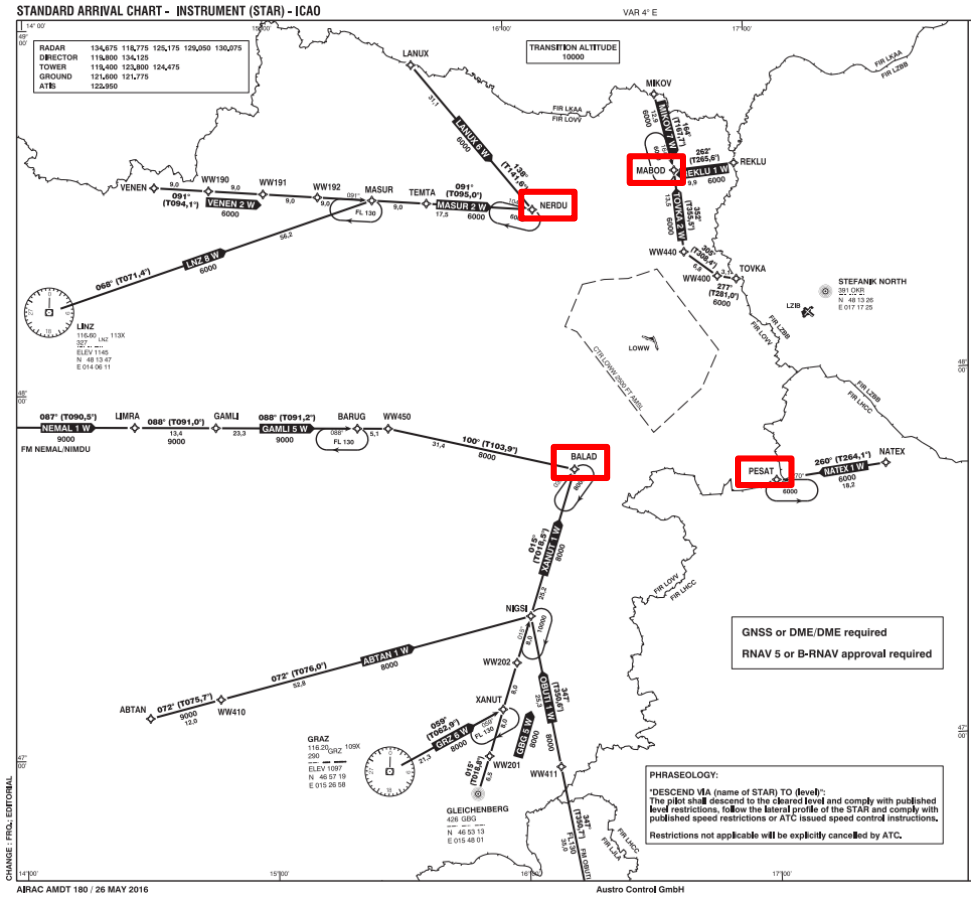
- Detailed Arrival Management of all aircraft (starting calculation about 200 nM to 80 nM ahead of destination aerodrome at "entry point")
- Detailed Merge Point Calculation (e.g. IF or Final Approach Fix FAF) overfly time based on 3 basic modes: Direct Mode (no transition required), Transition Mode and Holding Mode (if required)
- For each flight the flight path geometry, length and Calculated Time of Arrival (CTA) is computed at entry point and remains stable (unless adjustments to flight behavior and or current weather situation becomes necessary) until touch down on arrival runway
- Continuous Descend Approach (CDA, glide slope 3 degrees) is calculated and executed at entry point
- For Wake Turbulence calculation for each aircraft type the wake category according to ICAO rules or (new) RECAT rules is assigned and taken into account during Departures, within TMA and on Final Approach

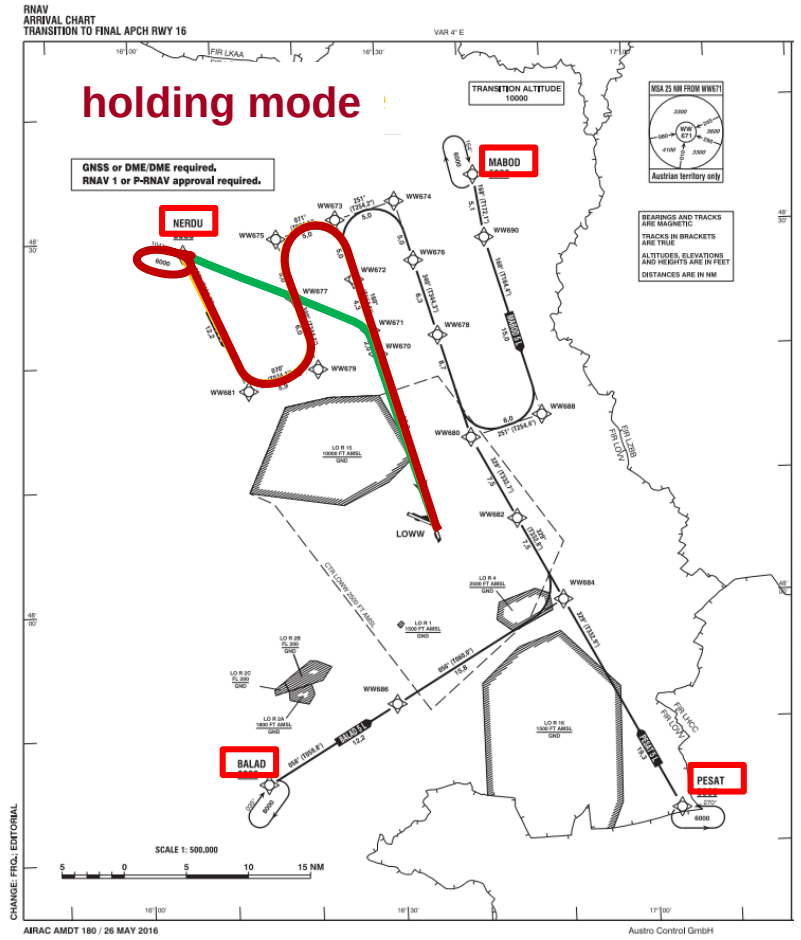
NAVSIM / AMAN
Advanced Arrival Management

- Distance Based or Time Based Minimum Separation on Final Approach are selectable and taken into account in Arrival Management calculations
- Low visibility procedures (increased Minimum Separation distances or time) are taken into account in all Arrival Management calculations
- Wind profiles per runway / within area taken into account
- Optimized Weather Avoidance path is calculated (based on Current and Nowcast data) in case of adverse weather (CBs)
- Harmonization between departing and arriving air traffic is taken into account by NAVSIM/AMAN
- Synchronous arrivals on parallel and/or crossing runways are possible
- NAVSIM/AMAN allows comparison between optimized flights and “best practices” based ATCO controlled flights (based on track/CPR data)
- Detailed performance analysis (in terms of Key Performace Indicators (KPIs)) are calculated & recorded of optimized NAVSIM/AMAN calculated flight paths / time taking all of the above rules and features into account !

NAVSIM / AMAN
Validation

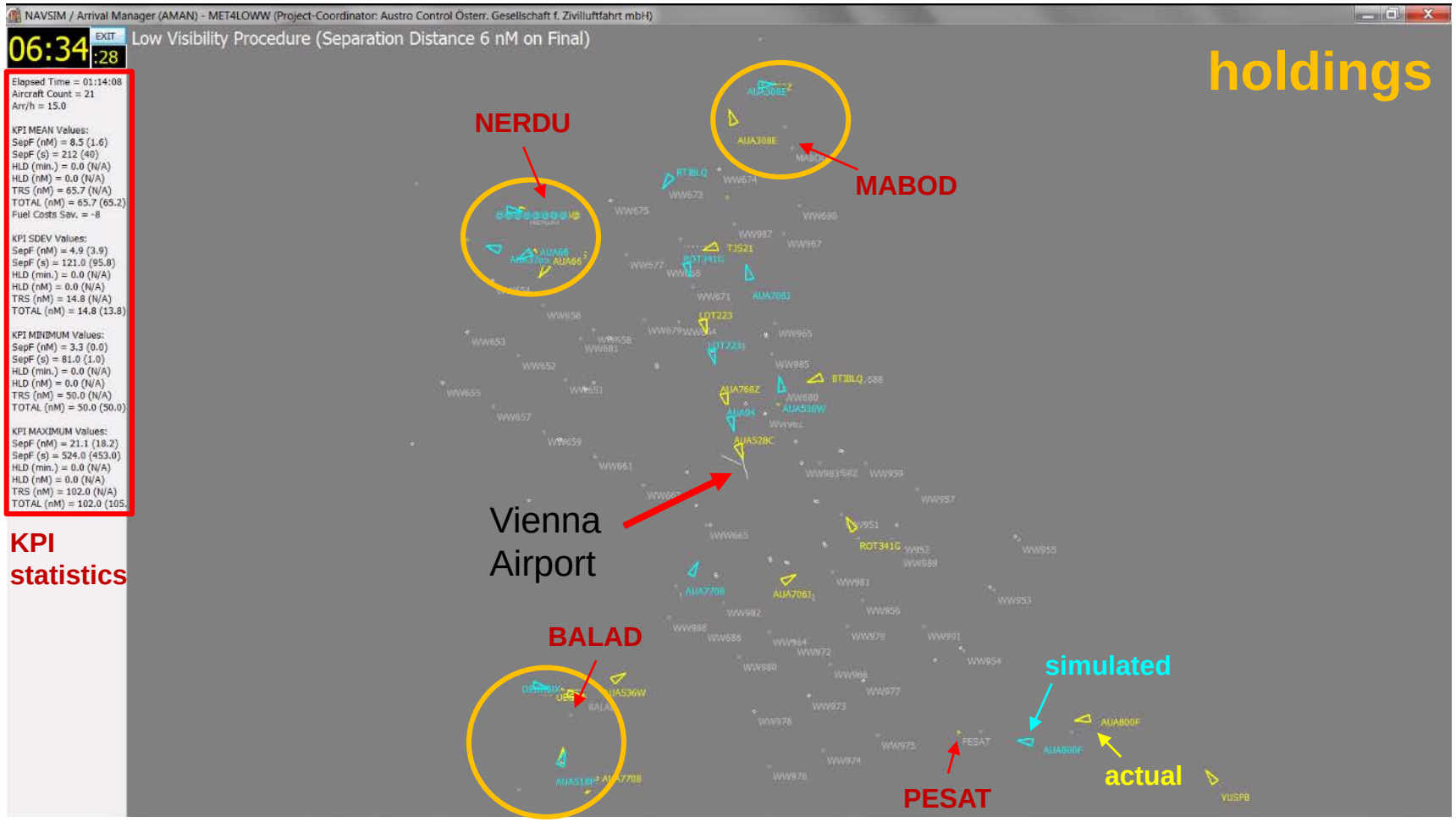
- Compare actual flight path to simulated flight path
  - Simulation is initialized with actual traffic at STAR endpoints
  - Compare simulation and actual flight paths between STAR endpoints and touchdown





NAVSIM / AMAN
Validation

- Validation experiments show very good agreement between simulation and actual flight tracks
  - ATCOs certify widely realistic behaviour of simulator

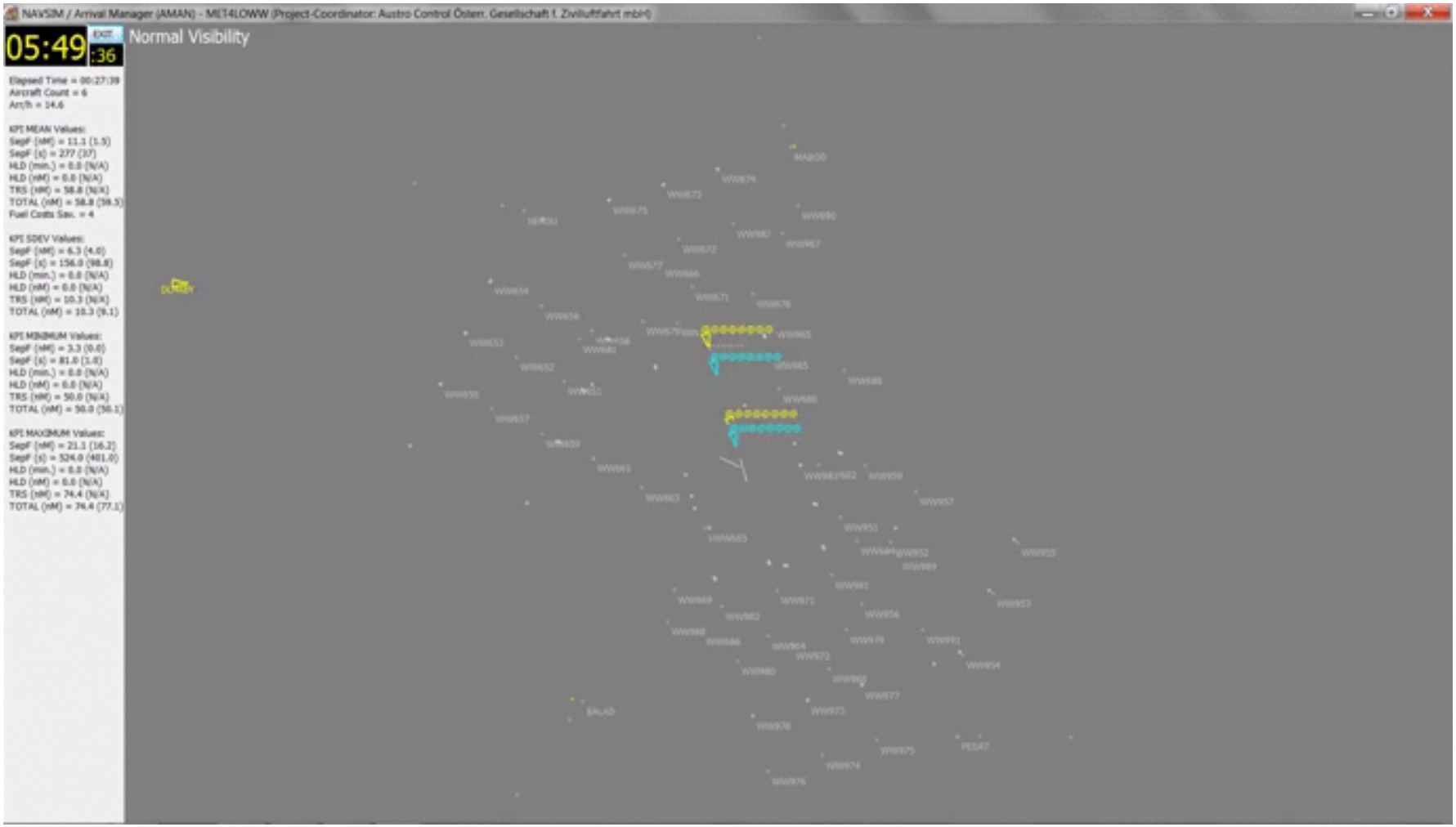


yellow: CPR; blue: simulated

NAVSIM / AMAN

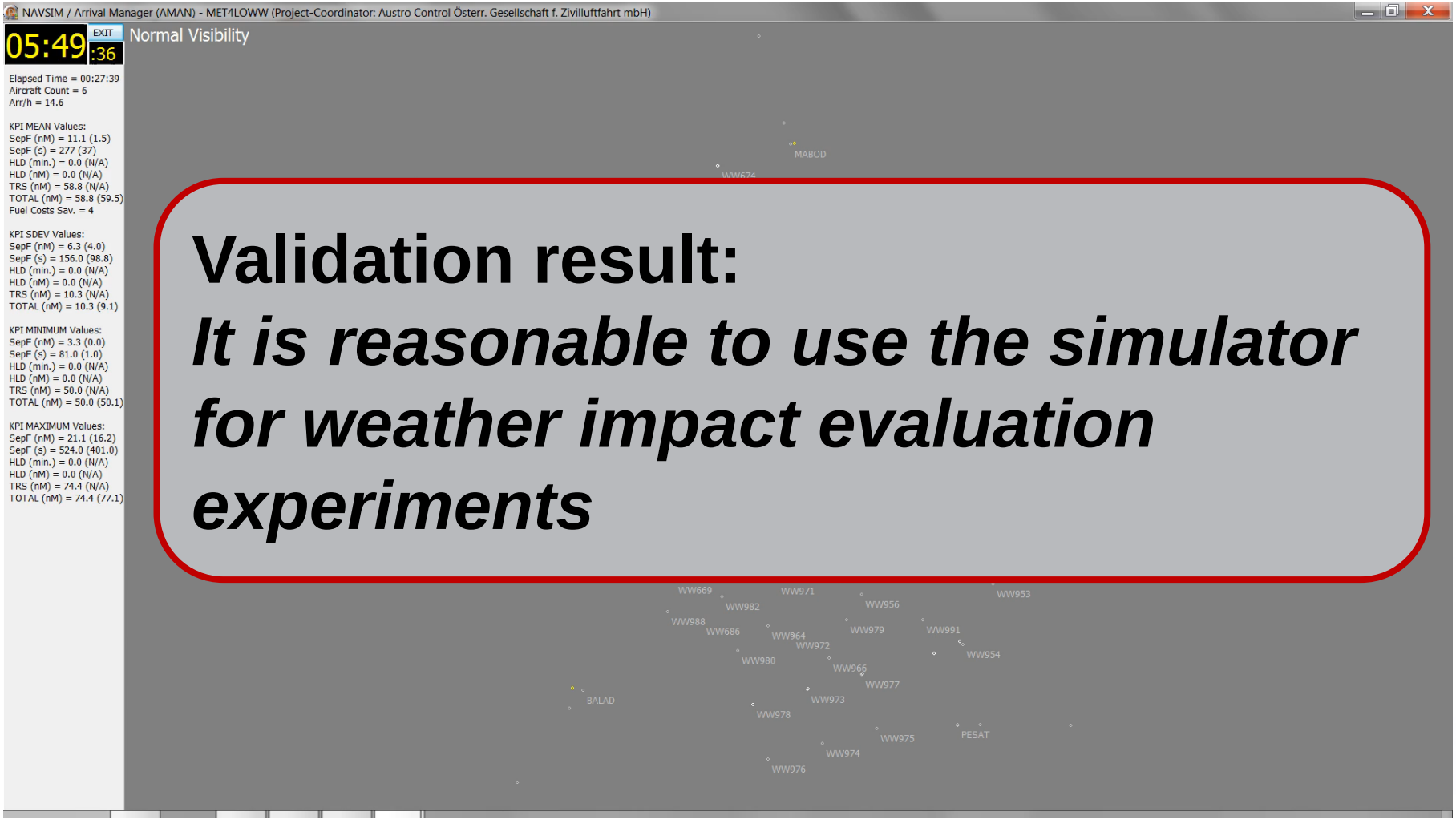
Validation - video

- Low Visibility Procedures (LVP) during morning rush hour



NAVSIM / AMAN
Validation - video

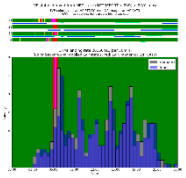
- Low Visibility Procedures (LVP) during morning rush hour



Validation result:
It is reasonable to use the simulator for weather impact evaluation experiments

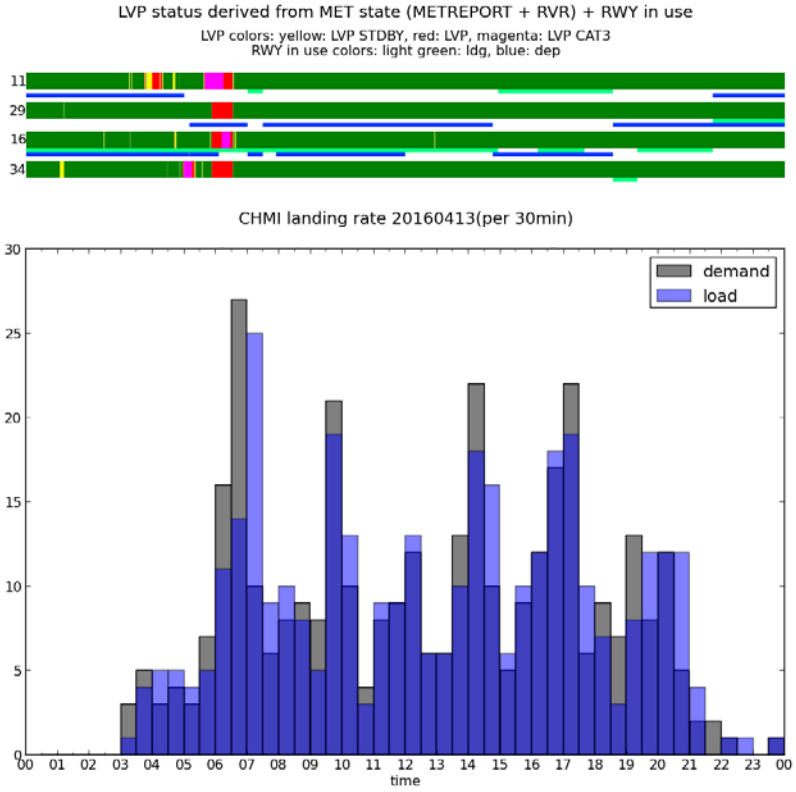
yellow: CPR; blue: simulated

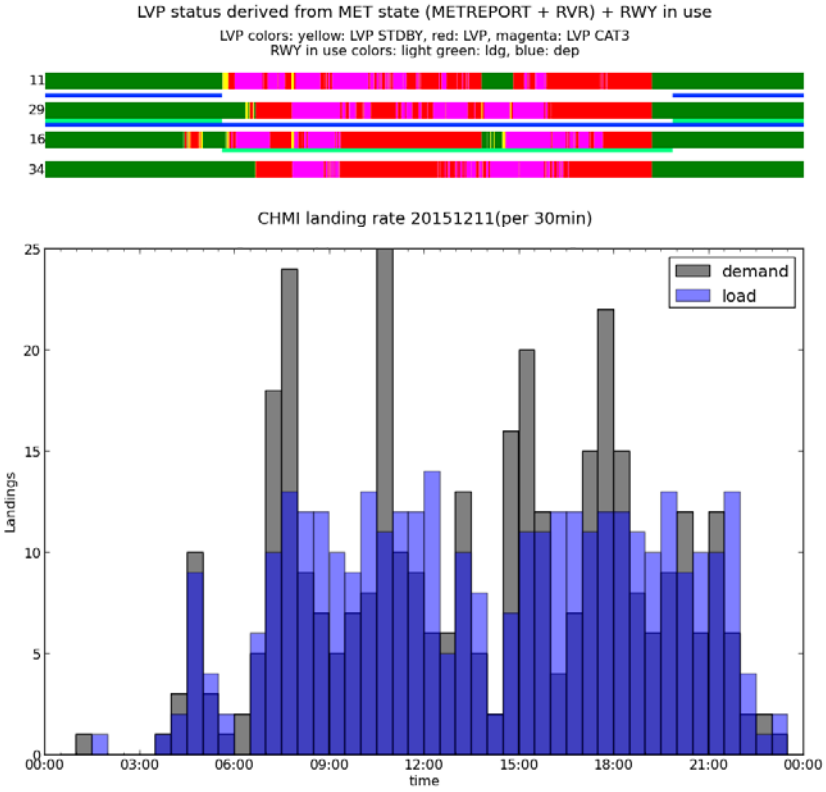
The First Results



Case studies
Low Visibility Procedures

- Simulation of two scenarios
  - Short period (1.5h) of LVP during morning peak
  - Long period (13h) of LVP during daytime





Case studies
Low Visibility Procedures

- For both scenarios multiple variations (weather + traffic) were simulated:
  - n: No LVP observed and none forecast (i.e. full traffic)
  - f: No LVP observed, but forecasted (i.e. traffic regulated)
  - m: LVP observed, but not forecasted. Traffic is regulated once LVP observed
  - h: LVP observed and forecasted. Traffic regulated according forecast.

		Observed	
		Yes	No
Take action	Yes	***h***	***f***
	No	***m***	***n***

Case studies

Low Visibility Procedures - KPIs

Short event:

1.5 hours
103 flights

	n	f	m	h
Trackmiles / flight	60.1	59.5	59.8	58.8
Holding time [min]	8	10	6	4
Holding time / flight [min]	0.08	0.10	0.06	0.04
Delay [min]	0	175	215	187
Delay / flight [min]	0	1.7	2.1	1.8
ATCO phrases	1069	1074	1069	1065

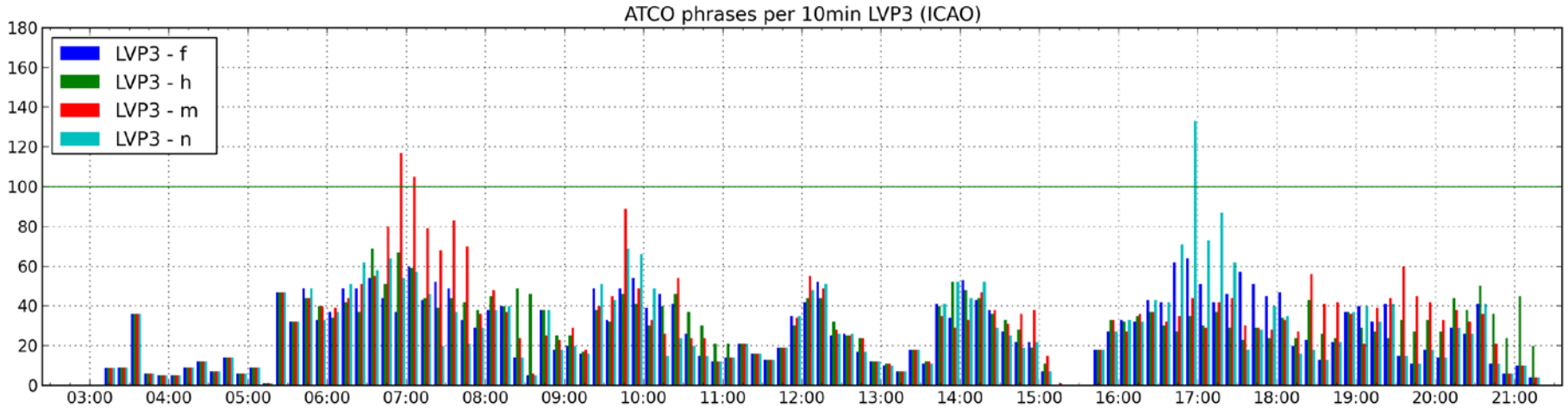
Long event:

13 hours
314 flights

	n	f	m	h
Trackmiles / flight	62.4	60.8	69.2	65.4
Holding time [min]	52	18	327	94
Holding time / flight [min]	0.17	0.06	1.04	0.30
Delay [min]	0	899	3744	5594
Delay / flight [min]	0	2.9	11.9	17.9
ATCO phrases	3159	3076	3515	3236

Case studies
Low Visibility Procedures

- Temporal variation of KPIs must be considered too
  - e.g. **A**ir **T**raffic **C**ontrol **O**fficer commands as a measure of frequency occupation



The Outlook

Outlook
What are we doing next…

- Refine impact analysis
- Run simulations of other weather dependant scenarios
  - Time Based Separation / pairwise separation / weather dependant separation (incl. DLR Wake Vortex-model)
  - thunderstorms in approach sectors
- Derive potential for optimized holistic ATM/MET procedures
  - How can weather forecasts be improved
  - What is the potential of using probability forecasts
  - Can ATM procedures be adapted to make better use of the forecasts
- Extensive validation and evaluation incorporating Air Traffic Controllers
- Validation workshops with other stakeholders
- Possible collaboration with other Air Navigation Service Provider and aviation MET services

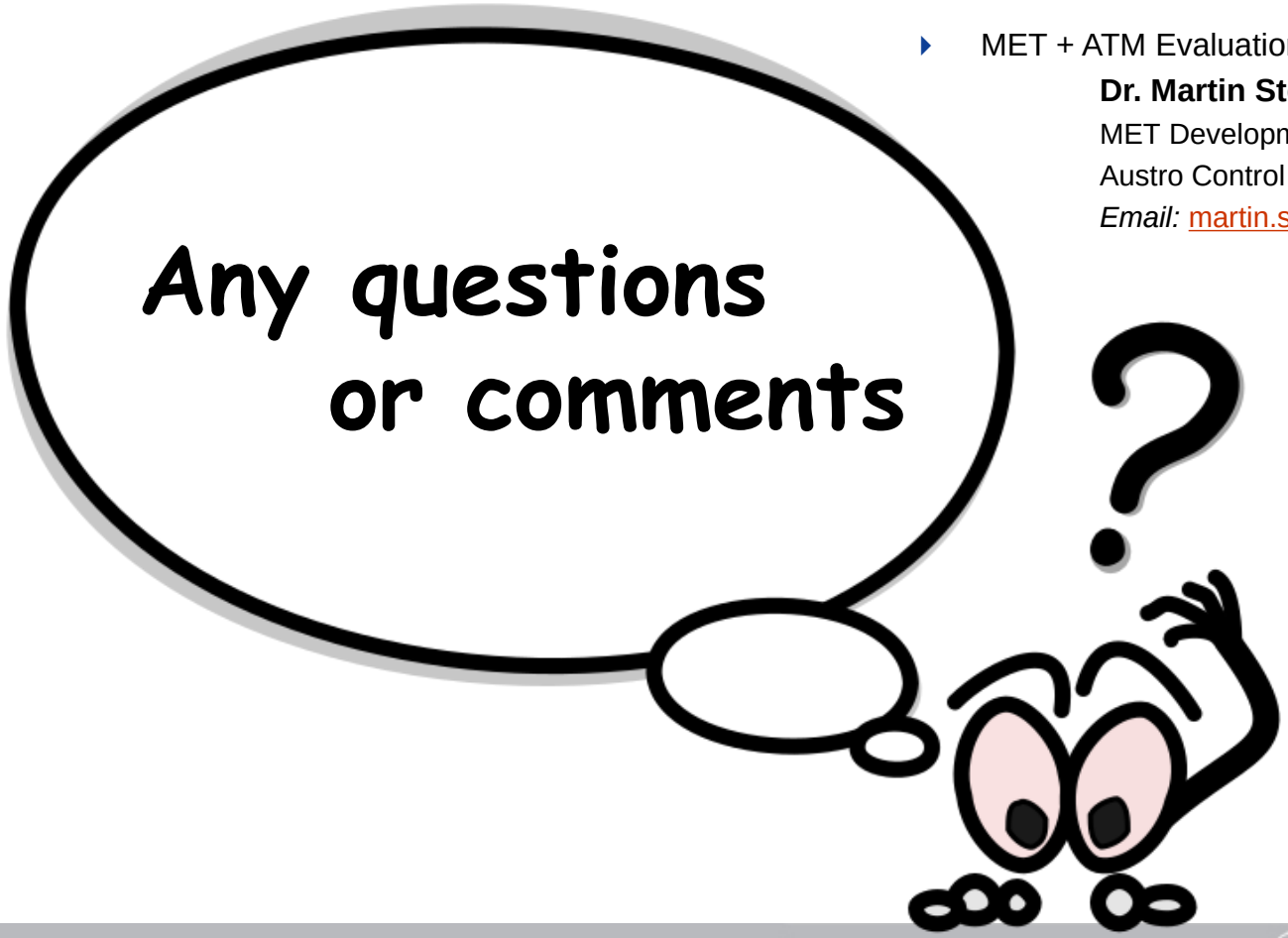
Contact:

- Air Traffic Simulator

Prof. Dr. Carl-Herbert Rokitansky
Computer Sciences Department / Aerospace Research
University of Salzburg
Email: roki@cosy.sbg.ac.at
Web-Info: www.aero.sbg.ac.at

- MET + ATM Evaluation

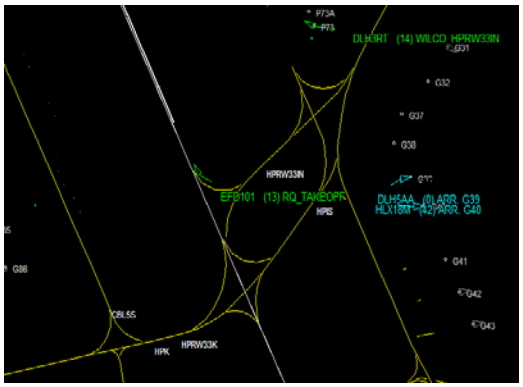
Dr. Martin Steinheimer
MET Development and Innovation
Austro Control GmbH
Email: martin.steinheimer@austrocontrol.at



Additional Information

NAVSIM
MET4LOWW – AMAN/DMAN Optimization

- Research topics:
  - Human-in-the-loop simulation of MET4LOWW TMA operations.
  - Evaluation of MET4LOWW optimization support tools.



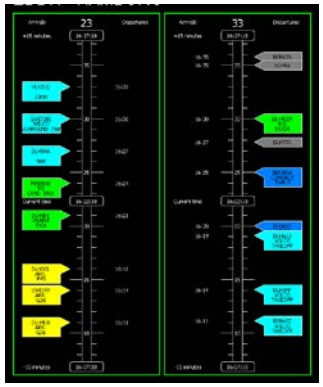


Image Frequentis.

UNIVERSITÄT SALZBURG

NAVSIM
Data Exchange

- All tools interconnected by SWIM-like XML protocol (X23)
  - USBG's distributed human-in-the-loop simulation environment at the "Aviation Competence Center Salzburg" (ACCS) can also include 3rd party functions and tools (via TCP/IP)