Nowcasting: Fundamentals, methods and applications

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Zentralanstalt für Meteorologie und Geodynamik

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Outline

- *Why nowcasting?*
- *Nowcasting systems*
- *Some deeper insights into a nowcasting system*
- *The role of NWP in nowcasting*
- *Nowcasting Ensembles*

What is Nowcasting

- Originally defined by Browning for the 1st Nowcasting Conference in 1981 as:
- **Nowcasting definition** – description of the current state of the weather in detail and the prediction of changes in a few hours
- 0-6 hr forecasting by any method
- spatial scale of no more than a few kilometers (1-3 km) with frequent updates (5-10 min)
- Heavy emphasis on observations

Why Nowcasting

Only on the nowcasting time and space scale there is sufficient forecast skill, for convective storms, that people can take actions to save life, property, and human inconvenience.

Aviation

Source: www.wiwo.de

Construction

Source: www.nzz.ch

Civil Protection

Source: www.thelocal.it

Concerts

Source: www.vegetarianbuffalo.com

Sport events

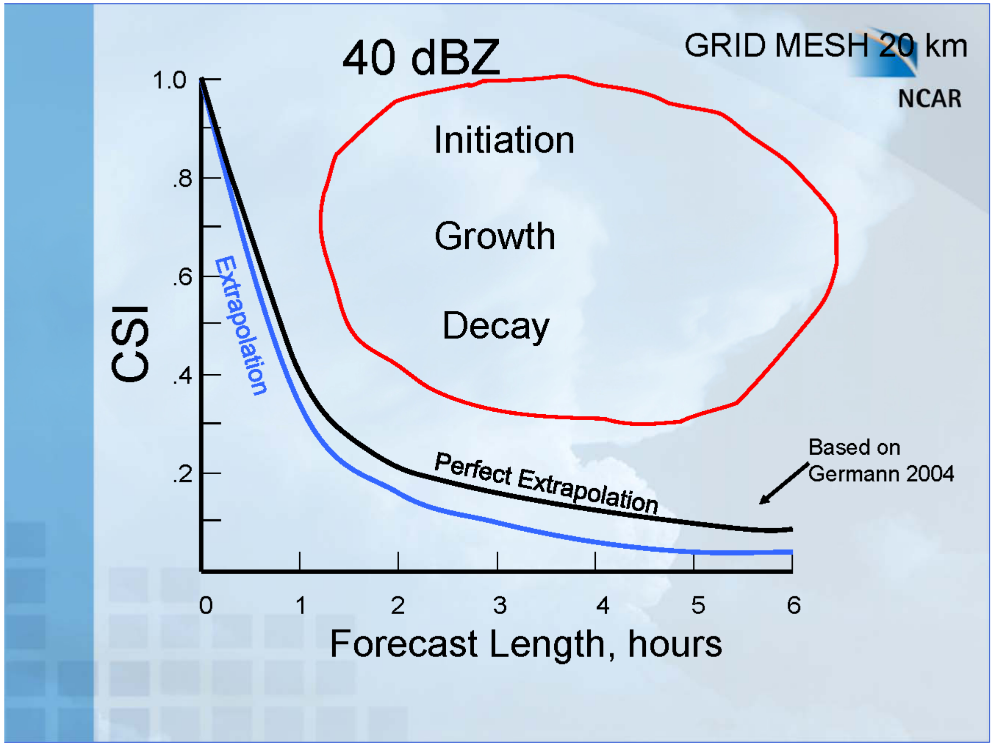
Source: www.tt.com

Winter road maintenance

Source: www.land-oberoesterreich.gv.at

Nowcasting and History …

- Thunderstorm nowcasting started approx. 50yr ago with extrapolation of radar echoes
- Firstly proposed by H. Lidga, 1953



(Wilson, 2011)

Nowcasting systems

- A variety of nowcasting methods and systems exist, mainly based on different needs (users), different data availability and different local conditions/environments.

- Most of them focus on thunderstorms and precip

- Output from **EUMETNET Nowcasting Activity**: Inventory of the nowcasting systems in Europe: (Bañon, 2014)
  - Multi-parameter nowcasting systems
  - Radar-based QPF
  - Object-oriented nowcasting approaches

Nowcasting systems

Multi-parameter systems

Name	Member	Based on	Update frequency	Products	Time range forecast Horizontal resolution
INCA	ZAMG Austria	RAD, SAT, AWS, NWP (ECMWF/ALARO)	5-15 min for Precip 15 min for CLDN 60 min for the rest	Precip, CLDNS, The rest: Temp, W, Gust, RH, global radiation, snowline, 0 ºC line, surface Temp, Info about convective cells and associated products (convective Precip and gusts) each 15 min. A probabilistic nowcasting system is currently under development and based on LAM-EPS information.	2h: extrapolation 2 to 6h: blending 6 to 48h: NWP 1x1 km
	OMSZ Hungary	RAD, AWS, NWP (ECMWF/non-hydrostatic WRF)	60 min	Precip, Temp, W, Gust, convective parameters	6 hours 1x1 km
	CHMI Czech	RAD, SAT, AWS, NWP (ALADIN), SOUNDING	10 min	For catchments: QPE: Precip 10 min and 1, 3, 6 and 24 hours. QPF: Also: Temp, W	QPF up to 3 hours 1X1 km
	ARSO Slovenia	RAD, SAT, AWS, NWP (ALADIN), NWCSAF, AMV	60 min 30 min for Precip	See ZAMG INCA-CE	12 hours
	MeteoSwiss	RAD, AWS, NWP (COSMO-2)	10 min for Precip 60 min for others	To general public with smartphone application. Convection indices and Precip type and QPF for the next 6 hours. Temp, RH, W, Gust	1h: extrapolation (Precip) 1 to 6 h: blending >6 h: ? 1x1 km
	OSMER, FVG Italy	RAD, AWS, NWP (ALARO-5 LAM)	60 min	Precip in 15 min time steps	24 hour 1x1 km
MEANDER	OMSZ Hungary	RAD, SAT, AWS, NWP (non-hydrostatic WRF, ECMWF)	15 min	Precip., Temp, W, Gust, MSLP, CLDNS, Vis. Cell detection and tracking (TITAN) tested. The system issues warnings on severe weather.	3 hours (interpolation: analysis/WRF-BETA) 1x1 km

(Bañon, 2014)

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Multi-parameter systems

Name	Member	Based on	Update frequency	Products	Time range forecast Horizontal resolution
HIRLAM U11 RUC	KNMI Netherlands	AWS, MODES (obs. air traffic control RAD, transponders: Temp)	60 min	Normal NWP output with 10 min time steps To aid air traffic control forecasts of arrival times of airplanes	24 hours (10 min first 6 hours)
DMI HIRLAM Slippery road	DMI Denmark	SAT, AWS, NWP, GNSS, potentially ModeS, road stations. RAD close to operational	10min for selected fields 60 min for standard	All standard NWP output plus extra data for road and energy sector	6-12 hour benefits Rest until 24 hours
LAPS	FMI Finland	RAD, SAT, AWS, NWP (ECMWF), SOUNDING, LIDAR, Aviation reports, LTG soon	60 min	Precip, Temp, W, Gust, MSLP, CLDNS, Vis, RH, Icing, severe weather, Fire-weather Index etc.	Analysis and first guess Plans: 6 hours (HARMONIE) 3x3 km
	ISAC-CNR Italy	RAD (soon), SAT, AWS, NWP (ECMWF/GFS), GPS, SOUNDING	60 min	(for the analysis of single case studies) the BOLAM model initialized with the LAPS analysis (time range forecast 9 hours)	Planned RUC 1-3 hours
	Univ. Athens	RAD (soon), SAT, AWS, NWP, SOUNDING, AMDAR, buoys	60 min 30 min in its operational mode	All standard NWP output	60 min (near-to-analysis forecast, for first guess fields)

(Bañon, 2014)

Radar-based extrapolation algorithms

Name	Member	What is it?	What is based on?	Update frequency	Products	Time range of the forecast
RAVAKE (blended for precipitation)	FMI Finland	A high-resolution nowcasting algorithm for probability of rainfall by combining seamlessly radar and NWP information	RAD, NWP (HIRLAM, HARMONIE)	Two components: 1) 15 min for probabilistic radar-based nowcasts (forecast time steps 5 min) 2) 1 hour for nowcasts and forecasts combining radar and NWP information	1) Probability of Precip. Extrapolation based ensembles only. 2) Blended probabilistic forecasts combination of radar-based and NWP-based ensembles A sms-based alert tool uses this system as background information	1) 180 min (for radar-based ensemble nowcasts) 2) 30 hours (for blended NWP and radar ensemble nowcasts)
TULISET	FMI Finland	Radar-based extrapolation algorithm of precipitation pattern	RAD	10 min with 5 min time steps	Precip single output but is an ensemble mean of 51 samples that illustrates the uncertainty related to the NWC	180 min
COTREC	CHMI Czech	Precipitation extrapolation system	RAD, AWS?, NWP (ALADIN): motion fields as a first guess	5 min	MAX_Z, CAPPI 2km, etc. Precipitation fields extrapolated: Precip, Precip for catchments	90 min for tracking of radar echo features. 180 for precipitation forecasts.

(Bañon, 2014)

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Radar-based extrapolation algorithms

Name	Member	What is it?	What is based on?	Update frequency	Products	Time range of the forecast
RADCAST	ARSO Slovenia	Detection, tracking and extrapolation of precipitation systems. Focused on time-of-arrival to a specific location (mainly airports)	RAD Based in COTREC with improvements	10 min	Extrapolated radar images: MAX	1 hour
2piR scheme	Metéo-France	Extrapolation of radar image. Rainfall nowcasting	RAD	5 min	Displacement fields extrapolated Z images and R. R around each city. Description of convective areas (aeronautical). Probabilistic description of the QPF (based on the variability of the rainfall on the vicinity of each grid point)	1 hour
CombiPrecip	MeteoSwiss	Geostatistical raingauge-radar combination for production, in real-time, of rainfall fields	RAD, AWS	10 min	QPE of 5 min, 1, 3, 6, 12, 24 hours in real-time precipitation maps	

(Bañon, 2014)

Nowcasting systems

Significant weather / object oriented thunderstorm nowcasting

Name	Member	What is it?	What is based on?	Update frequency	Products	Time range of the forecast
NowCastMIX	DWD Germany	Identification on hazard zones	**RAD**, SAT, AWS, LTG, NWP, other (**KONRAD, Cell-MOS, Meso Detection, RadVor-OP**)	5 min	PoC, CSD, PSW, PoH. Precip, W Gust, snow height. Deterministic solution for the forecast cell. Probabilistic for the classification and extrapolation.	Up to 2 hours for extrapolation cells
3D	AEMET Spain	ITF of convective cells	**RAD (3D,)** SAT (quality control and background), LTG, NWP	10 min	PoC, CSD, PSW, PoH, automatic warnings	60 min
2D	IPMA Portugal	ITF of convective cells	**RAD (2D)**, AWS (raingages calibration with RAD rainfall field)	5 min: rainfall int. 10 min: 2D + warnings	PoC of flash flood prone systems, PSW, PoH and other forms of severe weather.	Variable time span for extrapolation cells
CELLTRACK	Czech H. Institute	ITF of convective cells	**RAD**	5 min	PoC. Precipitation forecasts for predefined catchments.	30 min for tracking 180: catchments
SIGOONS	Metéo-France	CONO: IT SIGOONS: blending system:CONO + AWS+Precip+WS +NWP	**RAD** (Z, R, WS), SAT CTH SAFNWC, AWS, LTG, NWP	5 min	PoC, cell motion vector, significant weather associated (LTG, rainfall rate, W Gust, PoH). Cloud top Temp. Risk of Thunderstorm Warning	60 min
TRT	Meteo Swiss	ITF of convective cells	**RAD**, LTG, NWP	5 / 2.5 min (different RAD scan strategies)	PoC, CSD, PoH, Maximum Expected Severe Hail Size (MESHS), PSW, etc PoC takes into account the spread of the velocity vectors from the last three 5 min time steps.	60 min for cells extrapolation

(Bañon, 2014)

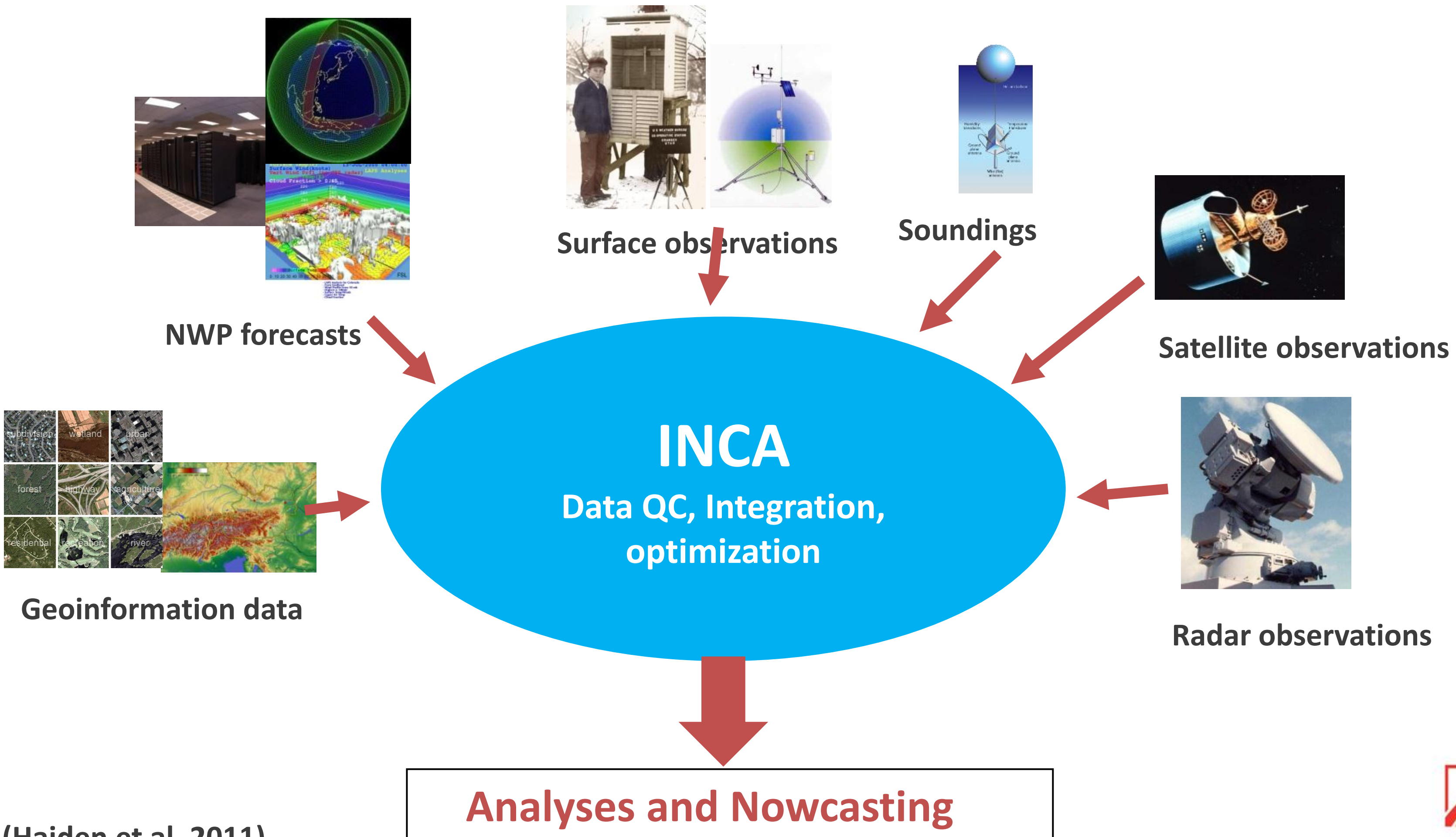
Nowcasting systems

Significant weather / object oriented thunderstorm nowcasting

Name	Member	What is it?	What is based on?	Update frequency	Products	Time range of the forecast
COALITION	Meteo Swiss	Early identification of severe convective cells	**RAD, SAT,** LTG-climatology (not real-time), NWP, topography	5 min	PoC from those with probable intensification / severe thunderstorm development. An object based forecast for the VIL and CTT. Does not provide any extrapolation of the cell.	15 min for CTT 30 min for VIL
A-TNT	ZAMG Austria	ITF of convective cells	**RAD**, **LTG**, NWP	5 min	PoC. Hail warning	1 hour with temporal resolution of 15 min
FeWIS	Meteo Lux	Warning info system (DWD) -Current weather and forecast -Forest fire Index, -ITF, etc	**KONRAD (** Radar 2D, LTG)	5 min	PoC, CSD, POH, tracking	60 min
RDT SAF-NWC	Metéo-France	ITF of convective cells	**SAT**, LTG, NWP, other SAF products (cloud products and CRR)	5 / 15 / 30 min	PoC, extension, motion vector, cooling rate, etc. Cloud cell phase, maximum convective rain rate, overshooting detection, etc.	Up to now: analysis Developing a NWC up to 1 hour
NEFODINA	CNMCA Italy	ITF? of convective cells	**SAT,** LTG, NWP, HSAF products	15 min	PoC, slope index, Precip, cloud's temp, CLDNS, cloud's height, LTG, fire?	?

(Bañon, 2014)

Integrated Nowcasting through Comprehensive Analysis (INCA)



(Haiden et al, 2011)

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INCA-CE – A Central European Nowcasting Initiative

INCA-CE Nowcasting for Central Europe

CENTRAL EUROPE COOPERATING FOR SUCCESS.

EUROPEAN UNION EUROPEAN REGIONAL DEVELOPMENT FUND

- **EU funded Nowcasting project**
- 16 partners from 8 CE countries
  - Weather services
  - Research institutions
  - Public authorities
- Project budget: 4.7 million US$
- Project duration: Apr 2010 – Sep 2013
- ZAMG leading
- www.inca-ce.eu

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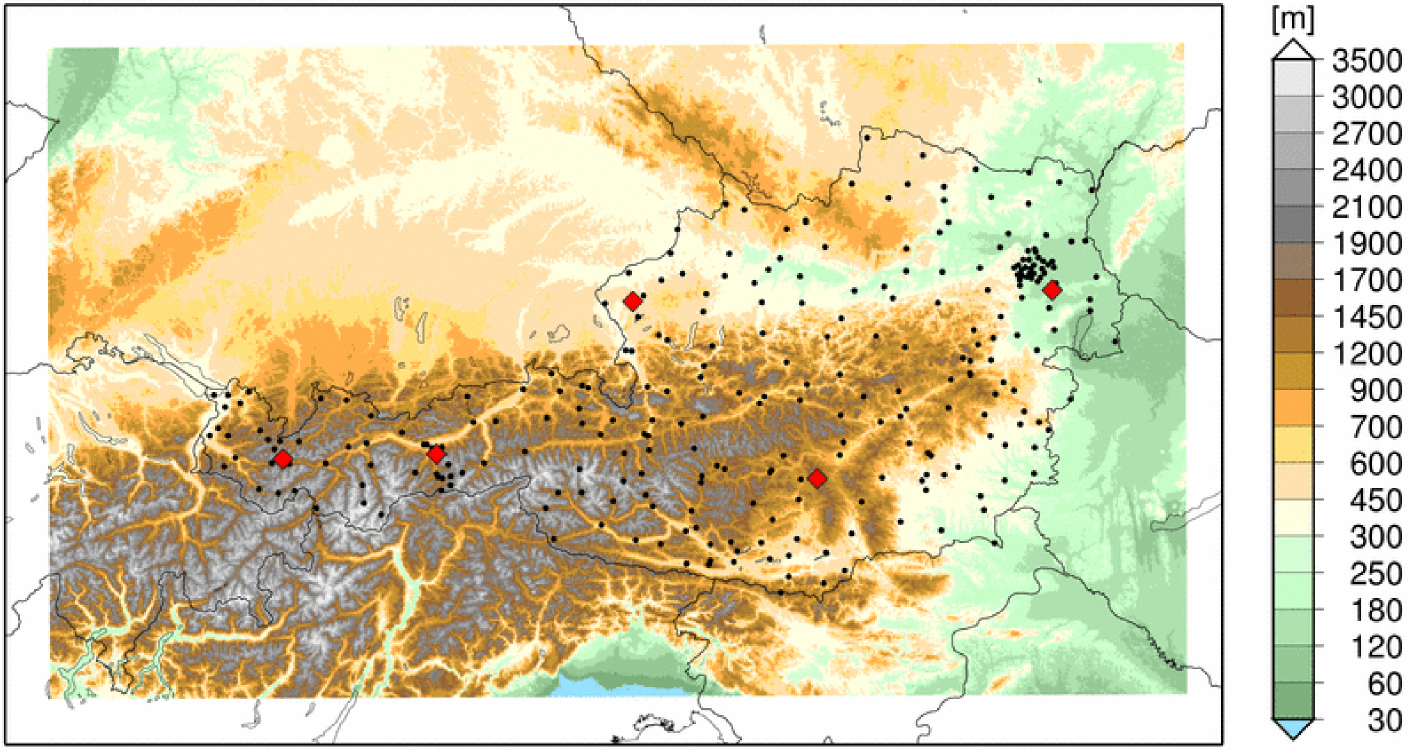
INCA configuation and topography

Domain size
700 x 400 km

Elevation range
100 - 4000 m

Resolution
Horizontal: 1 km
Vertical: 150 - 200 m
Time: 15 min – 1h

Update frequency
5 min – 1h



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INCA strategy

Observations are always reproduced!

	Precipitation	Cloudiness	Temperature & Humidity	Wind
Analysis background	Radar data	Satellite data	NWP forecast (ALARO5)	NWP forecast (ALARO5)
Nowcasting method	Extrapolation with motion vectors	Extrapolation with motion vectors	Persistence + NWP trend	Persistence + NWP trend
NWP forecast	ALARO5 + ECMWF	ALARO5	ALARO5	ALARO5
Nowcasting limit	6 hours	6 hours	3 to 12 hours (depending on stability)	6 hours

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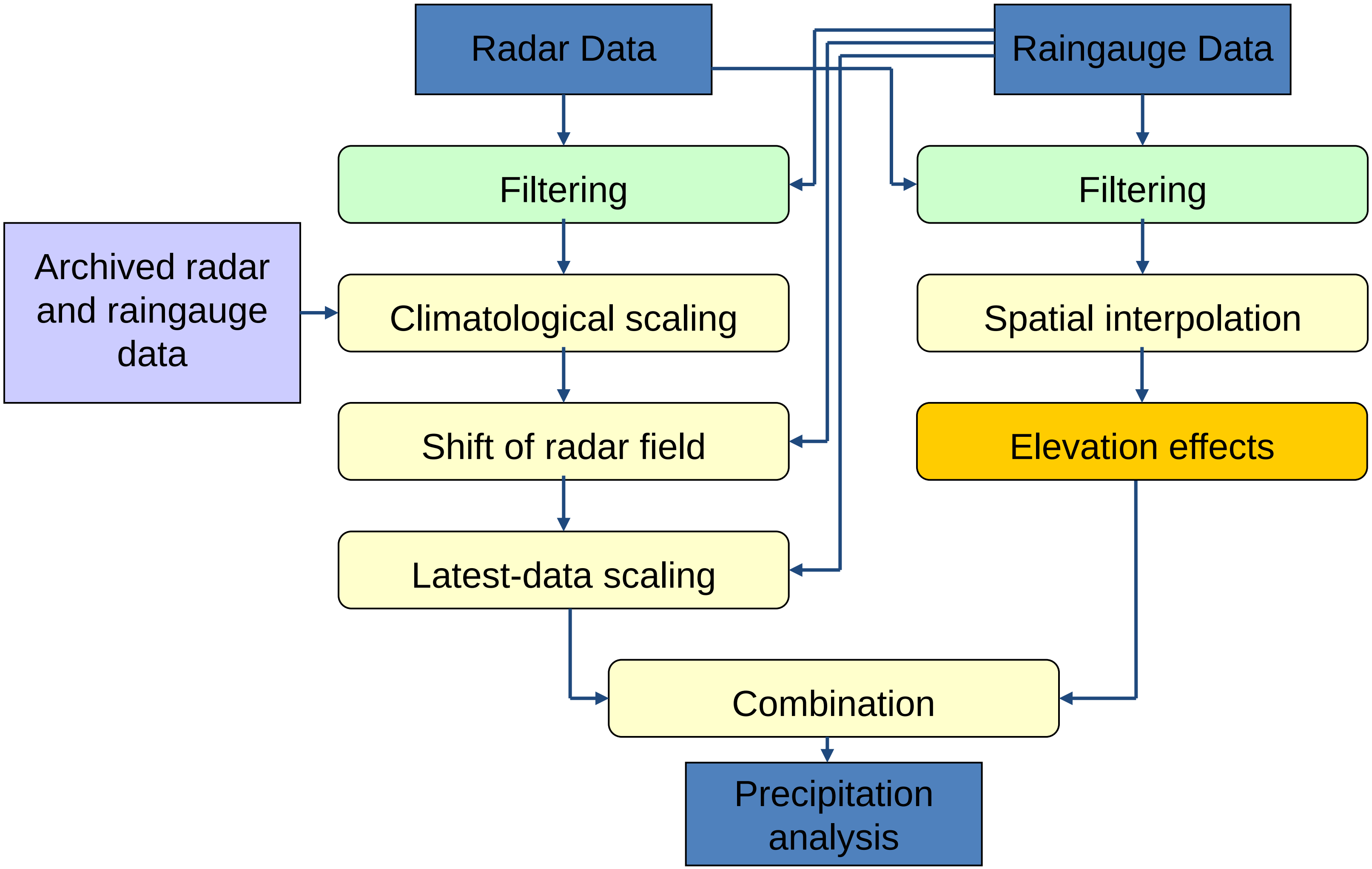
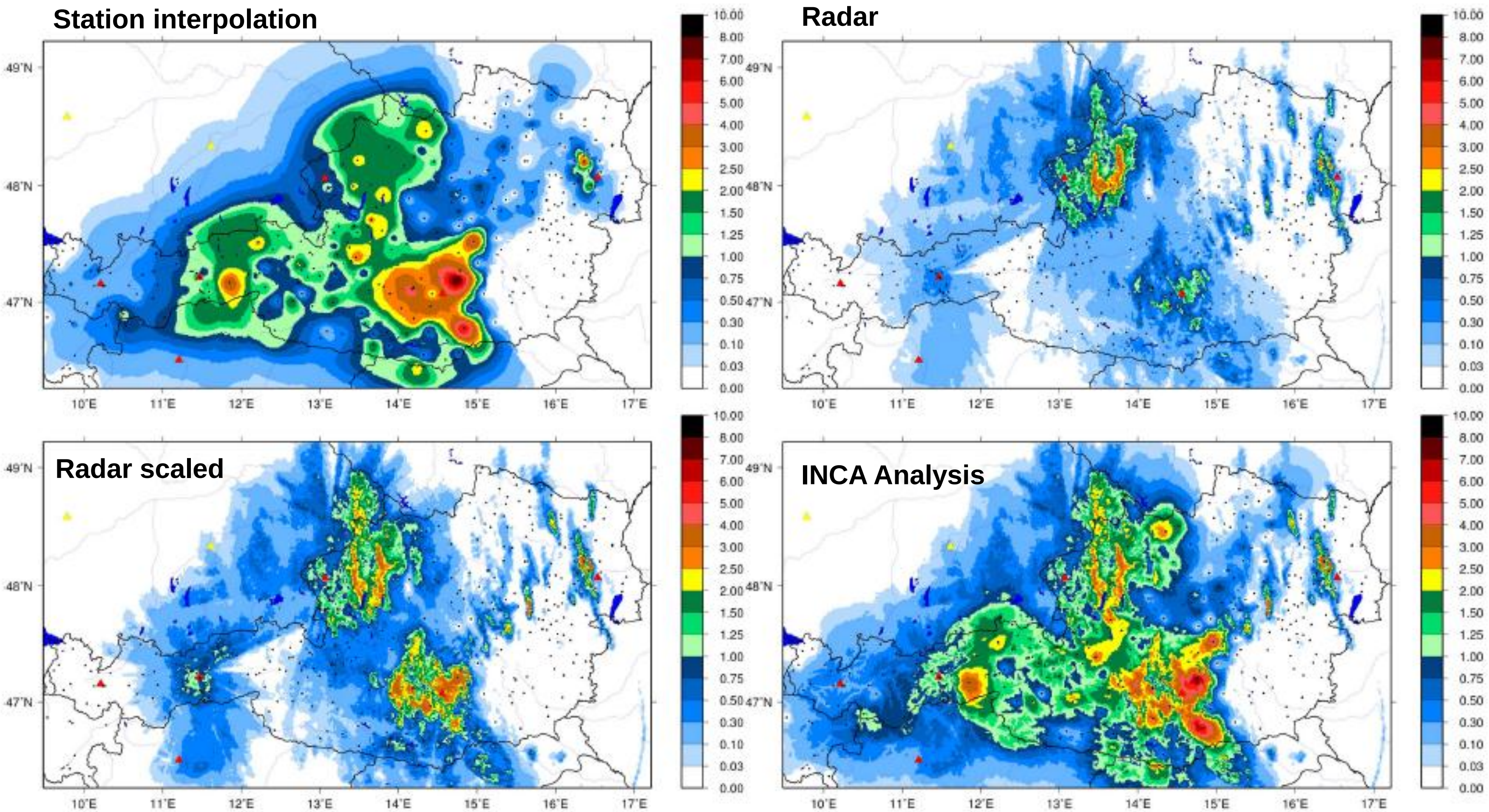
Precipitation analysis: Merging radar and raingauge data



Components of INCA precipitation analysis



18 July 2009, 07:30 UTC

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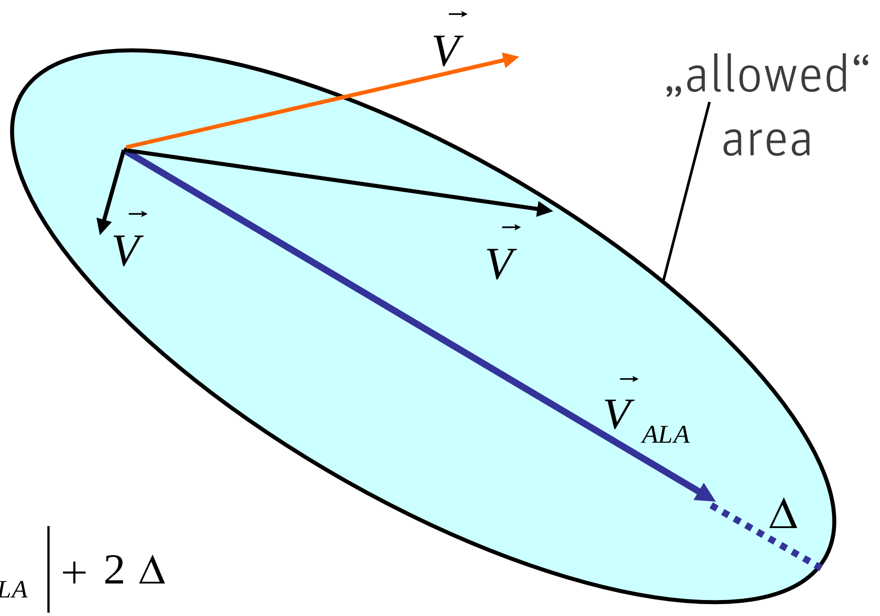
INCA precipitation nowcasting

- INCA Motion Vectors (IMVs) computed from two consecutive analyses
- Plausibility check with ALARO 700 and 500 hPa wind field
- Extrapolation of precipitation analysis



$$\left|\vec{V}\right| + \left|\vec{V} - \vec{V}_{ALA}\right| \le \left|\vec{V}_{ALA}\right| + 2\,\Delta$$

$\Delta = 5$ m/s

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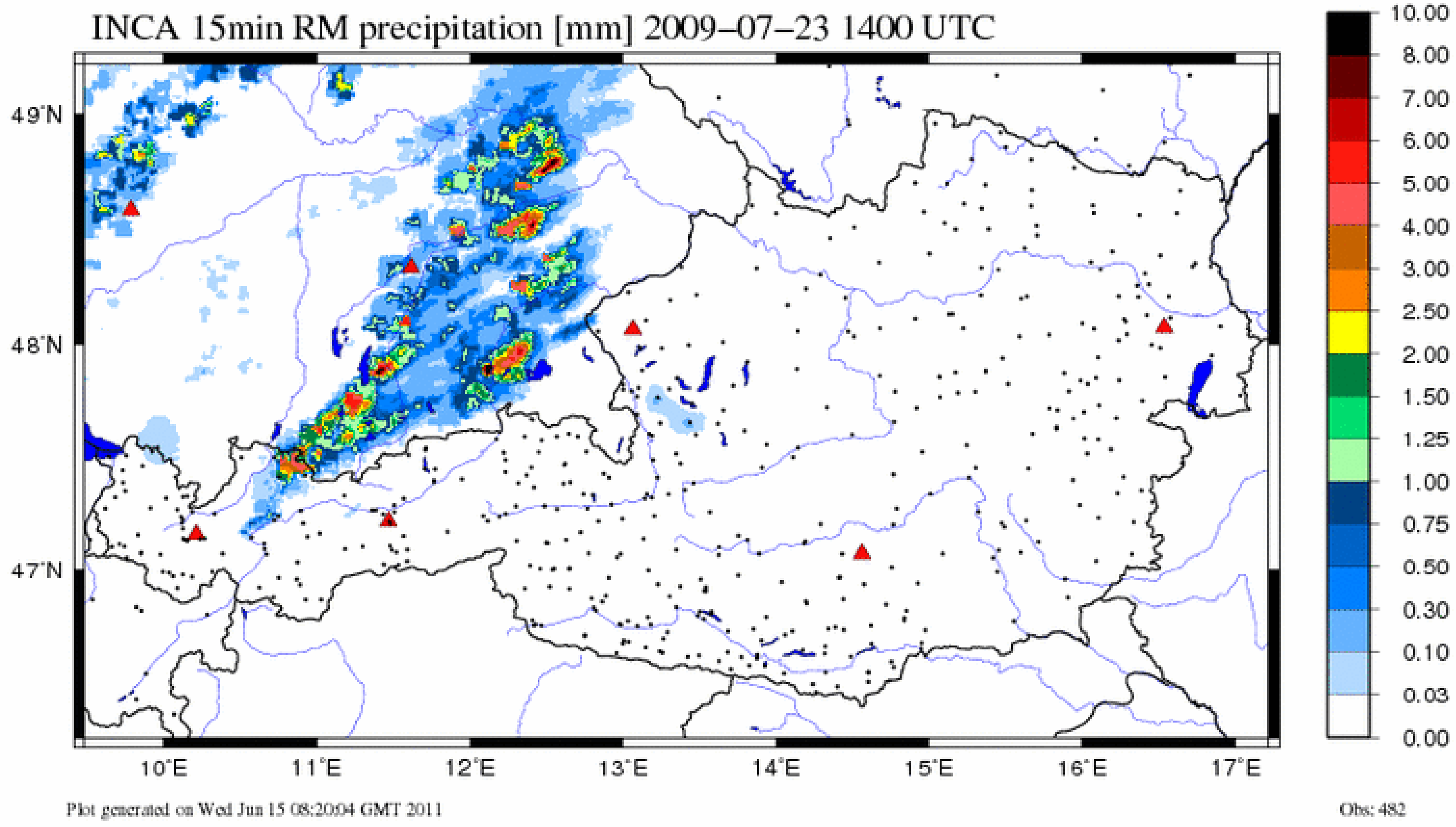

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Quality control and filter mechanisms

Improvements of the precipitation analysis fields by applying quality control

1. **Station data consistency check**
   e.g. compare 10min precipitation to aggregated 1min obs / sunshine data
2. **Plausibility filter**
   Detect unrealistically high/low values, NaNs, etc.
3. **Climatological limits**
   defined according to time of the year and accumulation period
4. **Flatfilter**
   Identify and remove suspicious series of constant values
5. **Singlefilter**
   Identify and remove single "outliers" (i.e., values that appear suspiciously high / low compared to neighbourhood or radar data)
6. **Accumulation filter**
   same as 5) but for longer accumulation periods
7. **SP filter**
   Cross check with cloudiness
8. **Radar filters**
   Remove artefacts in the radar fields
9. **Blacklist**
   Permanently exclude bad stations from analysis

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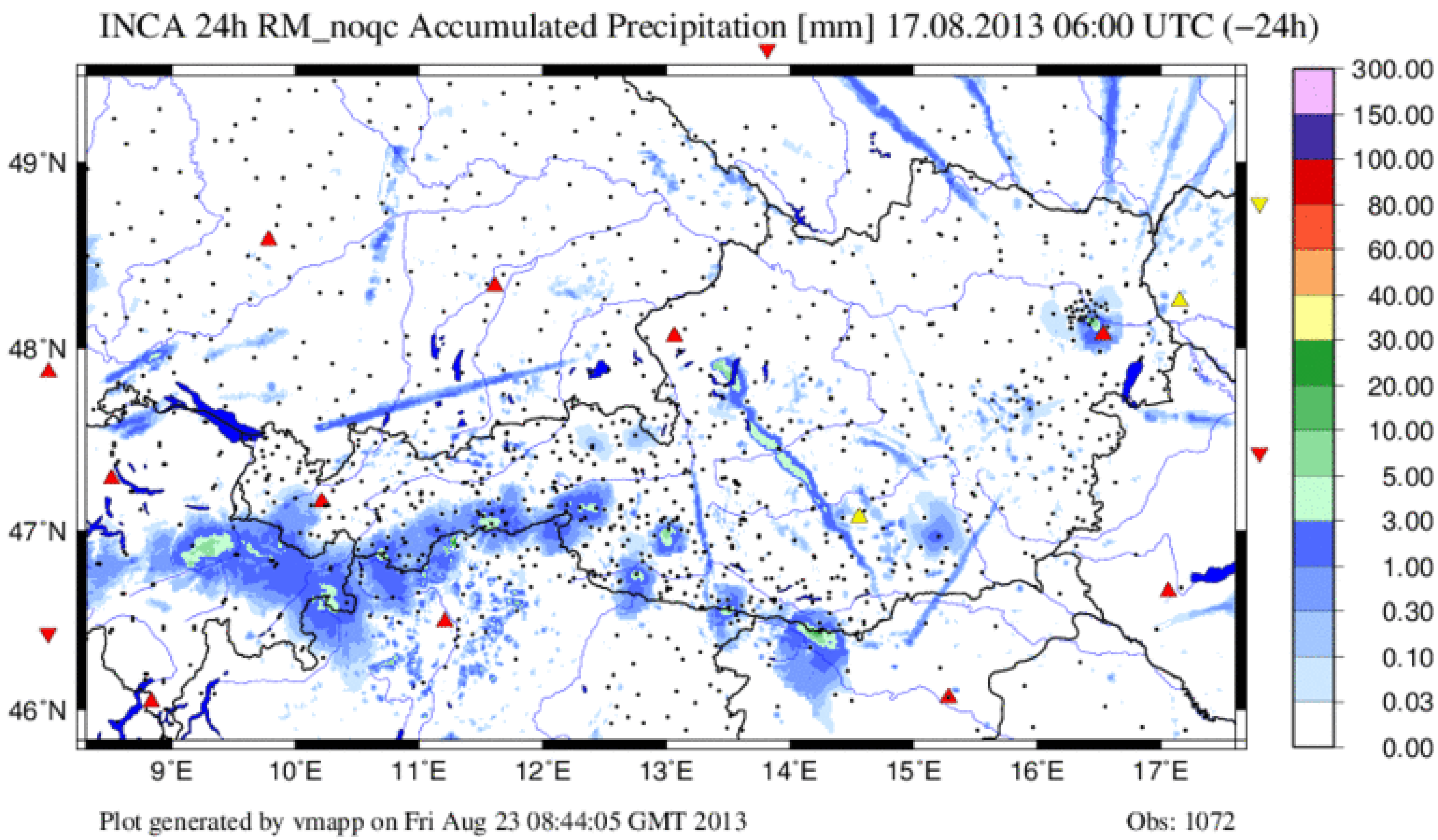
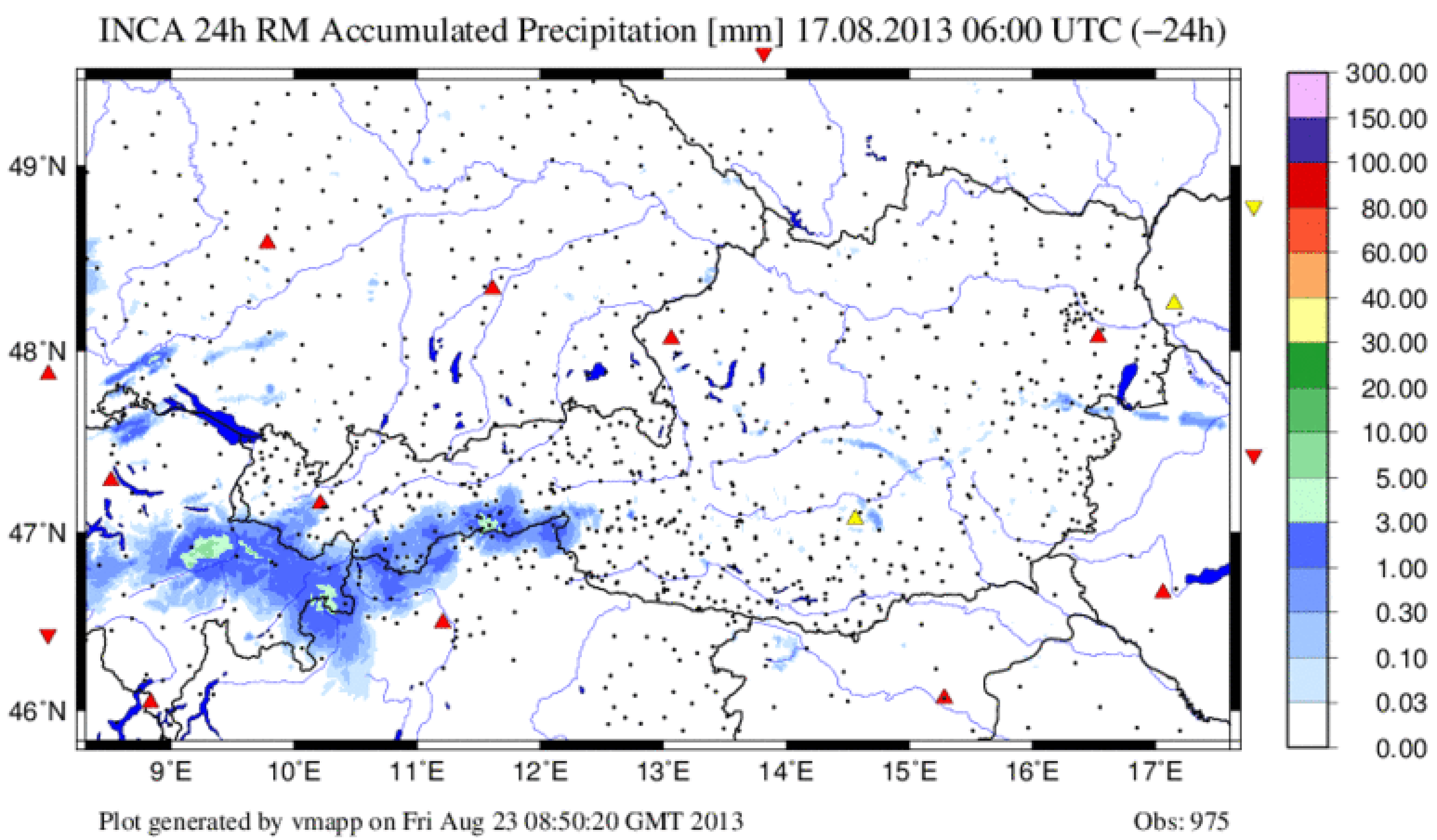
INCA precipitation without advanced quality control



Daily precipitation analysis without Quality Control

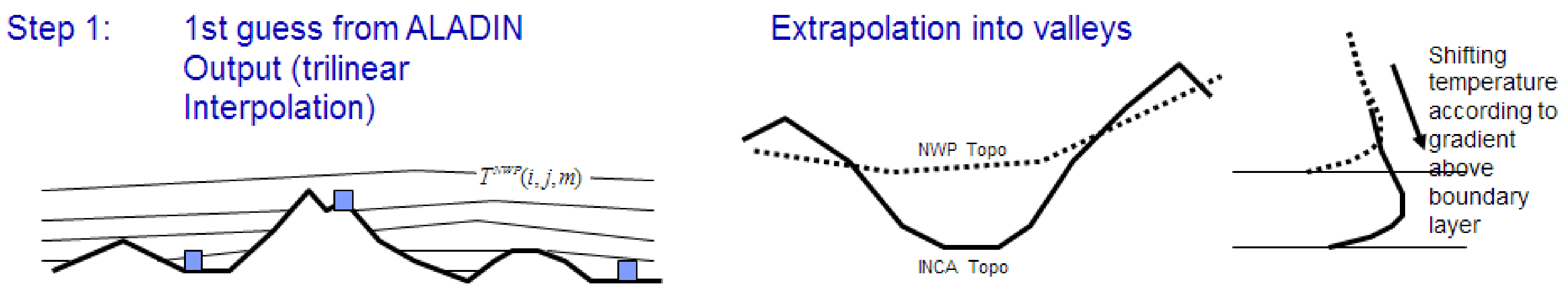
INCA precipitation with advanced quality control



Daily precipitation analysis with Quality Control

Observation analysis in INCA: Temperature

- The analysis of temperature starts with an NWP short-range forecast as a first guess, which is then corrected based on observation–forecast differences.



- Corrections to the first guess are computed based on the differences ΔT_k between the observed and NWP temperatures at station locations.

- Similar to Temperature , NWP forecasts are used as first guess in humidity and wind analysis.

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On the use of NWP for nowcasting purposes

NWP is widely used in Nowcasting systems indirectly:

- Observation analysis and nowcast products
- Blending
- Nowcast including advection, initiation, growth and decay of convection
- Ensemble Nowcasting

Progress in NWP in the last years, e.g. advanced data assimilation technique, comprehensive model physics and cloud resolving model; assimilation of very dense observations in time and space, like radar, GPS etc., there will be more and more use of NWP directly and indirectly in Nowcasting.

(Wang et al., 2013)

On the use of NWP in nowcasting: Blending

The blended forecast is calculated as the weighted sum of the extrapolation and NWP. The forecast values are combined using a time-varying weighting function which is derived from the measured performances.

$$P_{blend}(\tau) = \omega_{nowcast,i}(\tau) \cdot P_{i,nowcast}(\tau) + \omega_{NWP,j}(\tau) \cdot P_{j,NWP}(\tau)$$

To choose an appropriate quality measure is crucial. The weighting method can be linear, exponential, or the introduction of stochastic noise.

Overview of blending

Different blending techniques are presented in the literature. Here is described the evolution of blending technique by enumerating several article highlighting the novelty of each methodology developed.

- The first operational blending technique was developed by Golding (1998). Their technique is based in a simple weight of both NWP and radar-based extrapolation fields. The weights are computed by calculating the correlation coefficient from the previous hour.
- The next step was to include a Object Oriented Model (OOM) that reproduces the life cycle of a shower cloud. It was incorporated into GANDOLF system (Pierce, 2000) which would choose OOM forecast during episodes of air mass convection, whereas Nimrod would be selected in any other episode.
- A decomposition of the problem into component processes was proposed by Ganguly and Bras (2003). They have developed an hybrid model that require alternative tools ranging from simple interpolation to statistical time series models and artificial neural networks.

(Atencia and Germann, 2010)

Overview of blending

- The first ensemble-based probabilistic precipitation forecasting scheme has been developed by Bowler et al (2006) that blends an extrapolation nowcast with a downscaled NWP forecast. They are combined in a scale-dependent way using several levels on cascade processes. The small scales nor represented accurately by the model are injected into forecast using stochastic noise.
- During 2009 three new approaches are published. All of them have introduced a phase and intensity model correction before the blending technique. Both of them (Wong et al, 2009; Dufran et al, 2009) correct the phase and intensity model error by minimising a cost function. The another procedure (Chiang and Chang, 2009) has corrected the model by applying a back-propagation neural network between radar observation, NWP meteorological variables and gauge measurement.
- Within the IMPRINTS project a blending procedure has been developed by the SMC group (Atencia et al, 2010). It is mainly based on several existing techniques but a novelty approach has been included. A spatial dependence of weight as distant function to precipitation structures has been introduced into the weight computation.

Blending in B08FDP

NIWOT Fusion Algorithm. It is assumed that the radar based extrapolation is the best method for rainfall zone forecasting, numerical models have certain skills for capturing precipitation coverage. If an echo exceeds 35 dBZ at the time of forecast, the echo based extrapolation is used to forecast the future location of the echo, and then based on the echo zone[1] from model, the forecasted echo area through the echo extrapolation is re-delineated. If no echo exceeds 35dBZ at the time of forecast, and the model forecasts a future echo, then the model output shall be used. In addition, NIWOT permits manual corrections of the blended forecast.

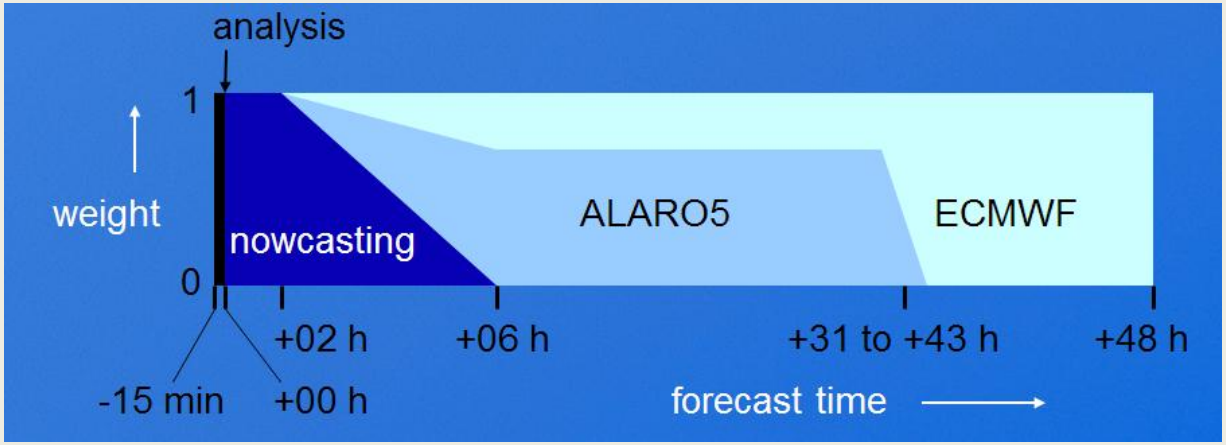
SWIRLS Blending Algorithm. The technique of "phase correction" is used to correct an error in rain-belt location prediction by the NWP model, and at the same time the model based rainfall intensity is re-adjusted based on the actual measurements before converged with the echo extrapolation. By this blending algorithm, the weighting factors used for the echo extrapolation-based hourly rainfall forecast and corrected model prediction are determined by a hyperbolic function to increase the validity of model rainfall prediction from 1 to 6 hours. This algorithm can be dynamically re-adjusted according to the echo extrapolation and the most recent squall line forecast.

GRAPES Blending Algorithm. The fuzzy logic is used to blend the displacement vector of COTREC algorithm with the horizontal wind field forecast by the hourly updated and assimilated NWP model GRAPES-CHAF to obtain an extrapolation vector field. Taking into account the error in extrapolation due to the limited resolution of COTREC vector and the truncation error in the echo pixel location forecasts, a grid point compensation scheme is used in radar reflectivity forecasts (Feng et al, 2007a).

(Wang J. et al, 2009)

Blending in INCA

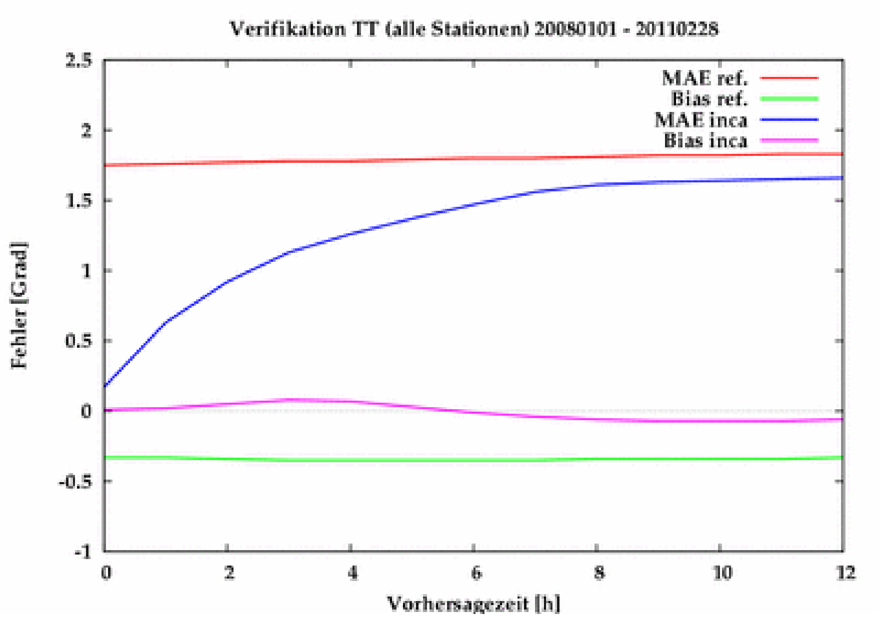
- **To obtain a continuous sequence of forecast fields, a transition from the extrapolation forecast to the NWP forecast is constructed through a prescribed weighting function that gives full weight to the extrapolation forecast during the first 2 h and decreases linearly to zero at 6 h.**
- **Attempts to improve upon the fixed weighting by making the time scale of the transition dependent on the magnitudes of NWP and nowcasting errors has as yet not shown any benefit.**

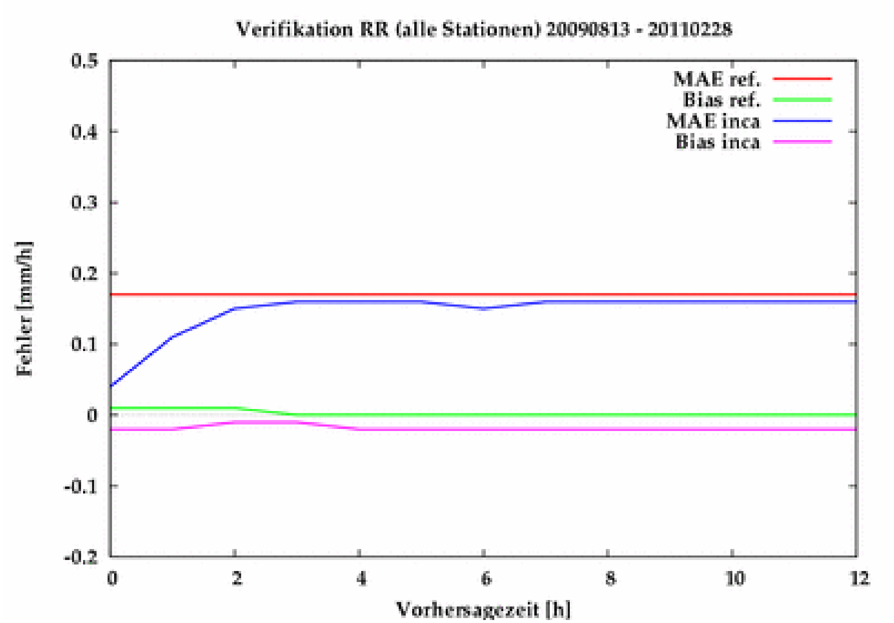


Update frequency:

ECMWF	12 h	(available at +9 h)
ALARO5	6 h	(available at +5 h)
Nowcasting	5,15 min	(available at +20…25 min)

Blending in INCA





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Nowcast in INCA: temperature and humidity

- In the case of **temperature** and **humidity**, Lagrangian persistence explains only a small part of the total temporal variation, and variations due to the diurnal cycle become dominant.
- The temperature nowcast is based on the trend given by the NWP model and computed for each grid point from a recursive relationship.

$$T_{\mathrm{INCA}}(t_i) = T_{\mathrm{INCA}}(t_{i-1}) + f_T[T_{\mathrm{NWP}}(t_i) - T_{\mathrm{NWP}}(t_{i-1})]$$

$T_{\mathrm{INCA}(t_0)}$ temperature at the analysis time

- Thus, the INCA temperature nowcast is the latest analyzed temperature plus the temperature change predicted by the NWP model, multiplied by f_T.
- This factor is parameterized as a function of the cloudiness forecast error of the NWP model.
- If the NWP model underestimates the cloudiness compared to the INCA cloudiness analysis and nowcast, it will tend to overpredict temperature changes, and vice versa.

Examples of INCA applications

INCA

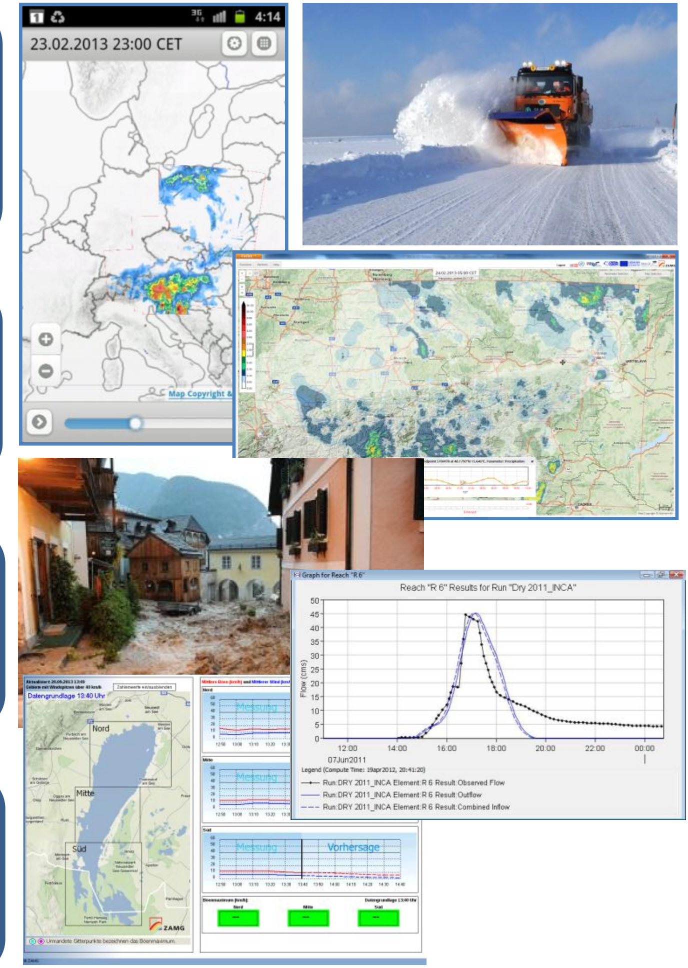
Road Safety
- Winter road maintenance
- Preventive salt spraying
- Precipitation, -type, wind, TG
- Metro road weather model

Hydrology
- Input for hydrological models
- Input for flash flood models
- Part of flood warning system

Civil Protection
- Storm alert monitor
- Organisation of large events
- National/regional alarm centers

Energy providers
- Global radiation, wind
- Input for power supply models
- Wind climatology, re-analysis

Landslide modeling, dispersion modeling (of dangerous goods), …



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Road safety: Special focus on (surface) temperature

- 3D temperature analysis starts with the ALADIN / ALARO5 forecast as a first guess
  - First guess is corrected based on differences between observation and forecast at surface station locations.
  - The model 2m-temperature forecast is conceptually and computationally separated into a '3-d' or model-level part, and a 2-d surface-layer contribution.

- Surface temperature is a derived parameter, based on observations of the +5 cm air temperature, -10 cm soil temperature, and 2 m air temperature.
  - Outside the nowcasting range, the NWP forecast of ground surface temperature is used (corrected for the actual terrain height based on 2 m temperature).
  - INCA surface temperature serves as a main input for INCA precipitation types.

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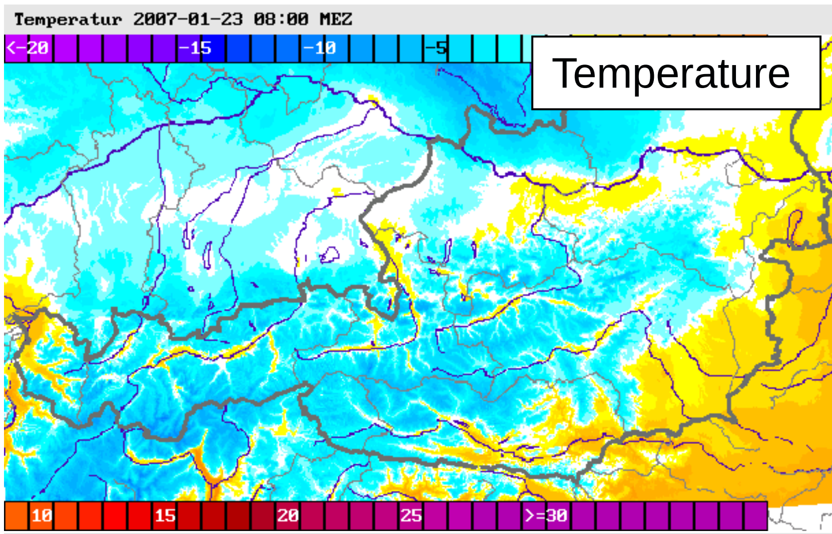
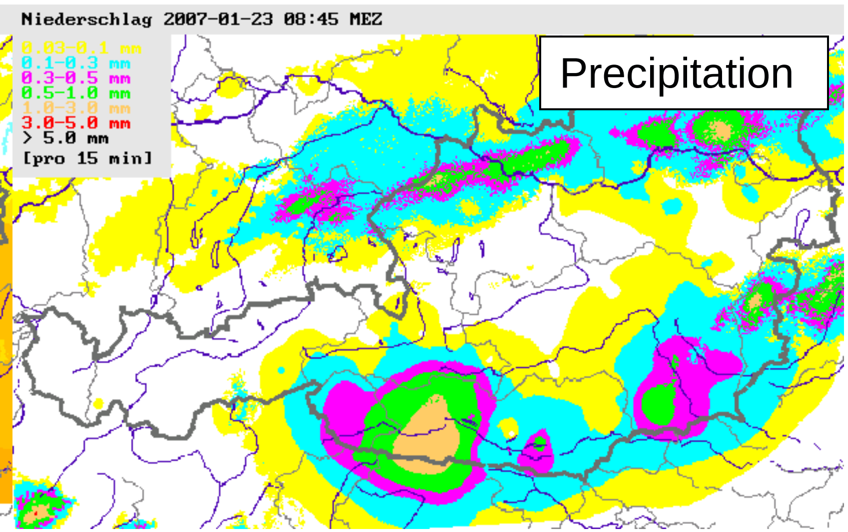
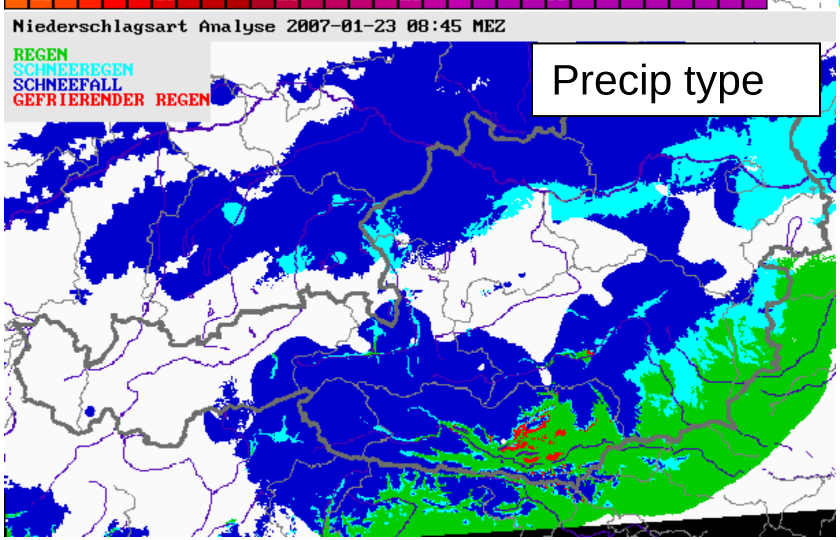
Precipitation type

In INCA the distinction between rain and snow is based on the vertical profile of the wet-bulb temperature at each grid point, derived from the 3D temperature and humidity fields.







Snowfall
Snow/Rain mix
Rain
Freezing rain

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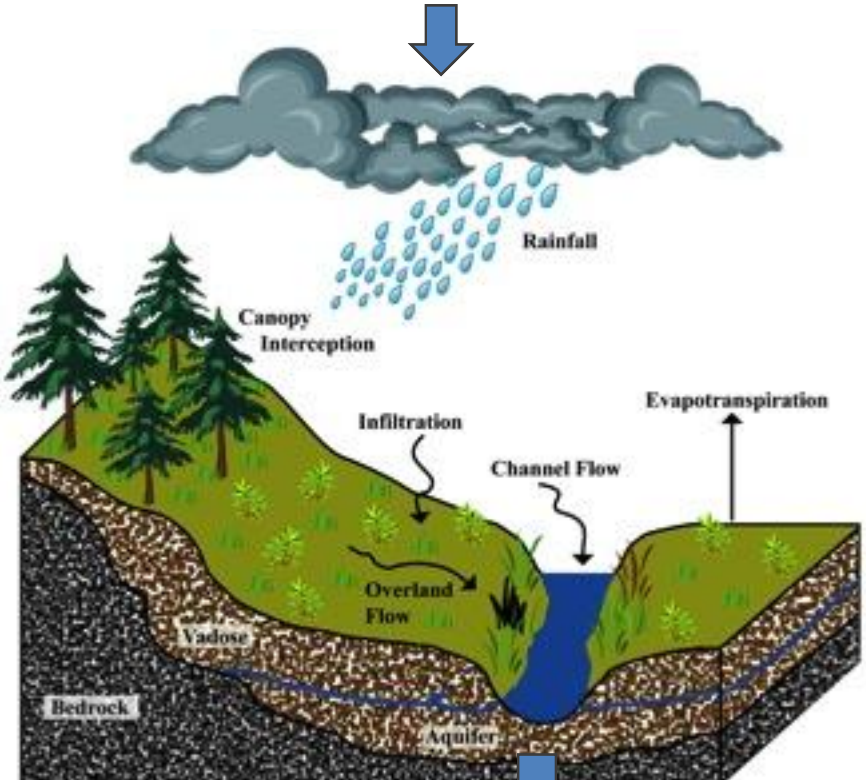
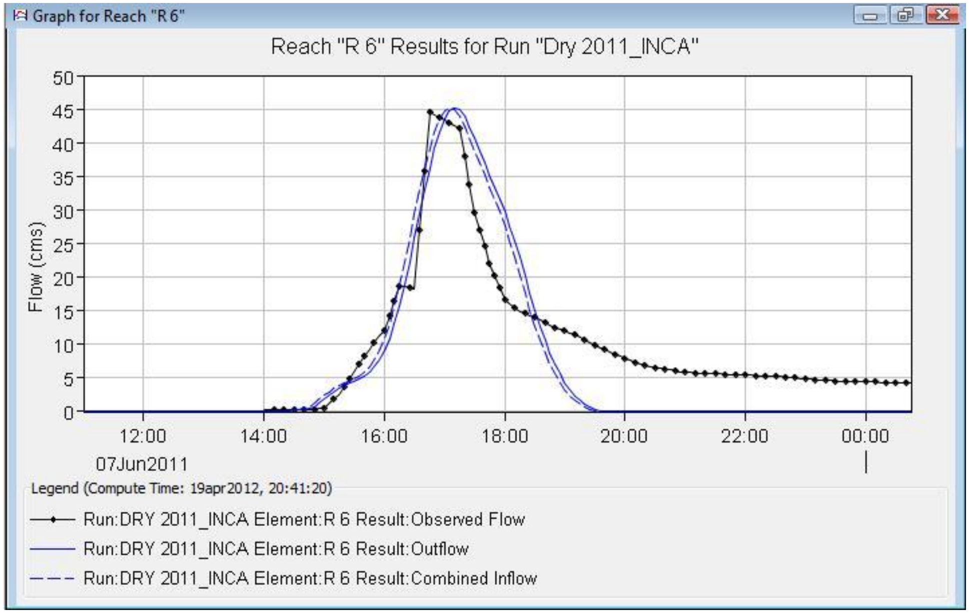
Hydrology

INCA



- Very high update frequency of RR (5min)
- Information about uncertainty would be beneficial



Improved output (flash flood forecasting)

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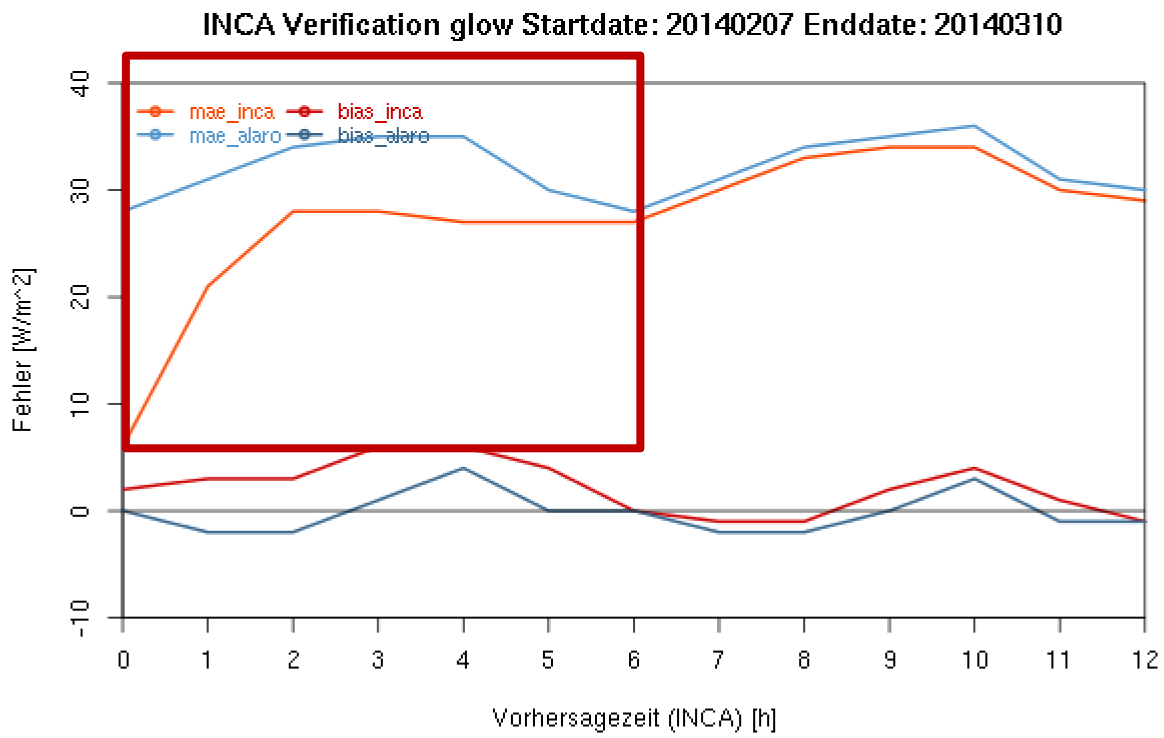
Photovoltaic: Solar radiation

- For sites with photovoltaics: improved radiation forecasts for power supply especially in the nowcasting range (~ up to 6 h)



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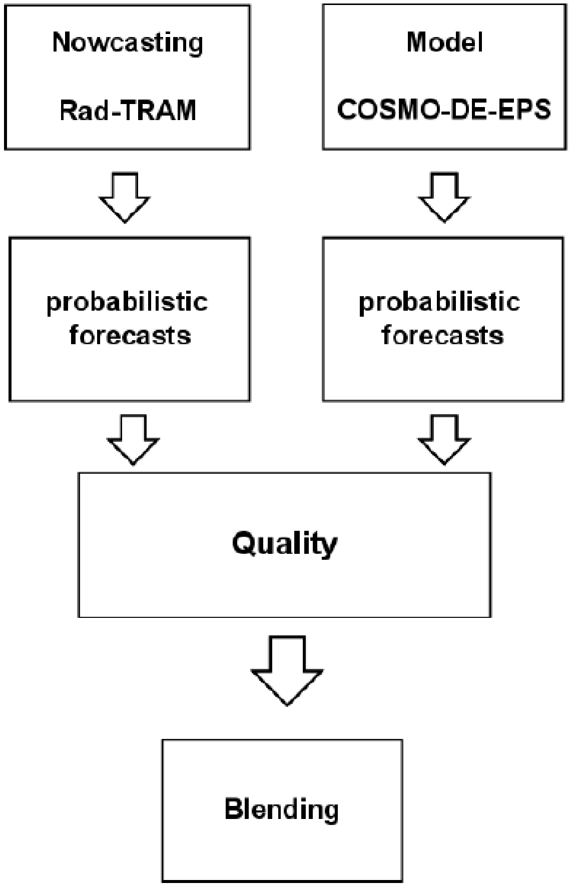
Ensemble Nowcasting based on det. NWP

- Decompose NWP into a cascade
- Decompose the rainfall field into a cascade
- Use radar field to estimate stochastic model parameters
- Calculate the skill of the NWP at each level in the cascade using the correlation between NWP and radar
- Blend each level in the radar & NWP cascades using weights that are a function of the forecast error at that scale and lead time
- For each forecast
  - Add noise component to the deterministic blend, the weight of the noise is calculated using the skill of the blended forecast
  - Combine the cascade levels to form a forecast

(Seed, 2011)

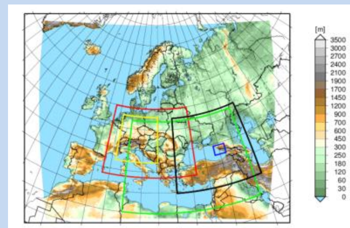
Ensemble Nowcasting based on NWP EPS



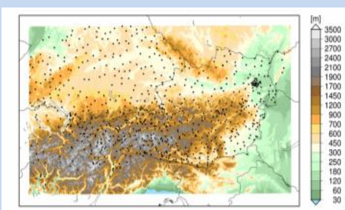
(Kober et al, 2010)

Ensemble INCA: Overview

ALADIN-LAEF
(limited area ensemble system)

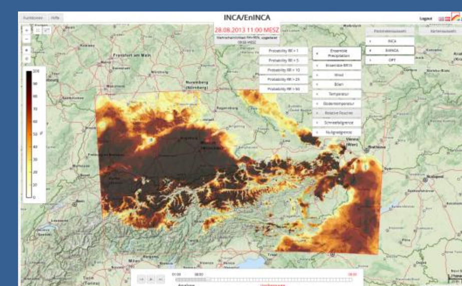


INCA
Integrated Nowcasting through Comprehensive Analysis



Uncertainties
- Measurement errors
- Radar errors
- Interpolation errors
- …

Ensemble INCA
ensemble forecast in the nowcasting range



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Ensemble INCA: Details

Precipitation

Analysis

- Measurement error *
- Representation error *
- Radar error *
- Interpolation error *

Nowcasting

- Extrapolation error
- Convective effects*

blending

NWP

- NWP errors / uncertainties
- and/or „Multi-Model-approach“*

Temperatur, wind

Analyse

- Measurement error*
- Representation error *
- Interpolation error *
- Ensemble background fields

Nowcasting

Error in NWP-trend
-> LAEF

Stochastical blending with LAEF

blending

NWP

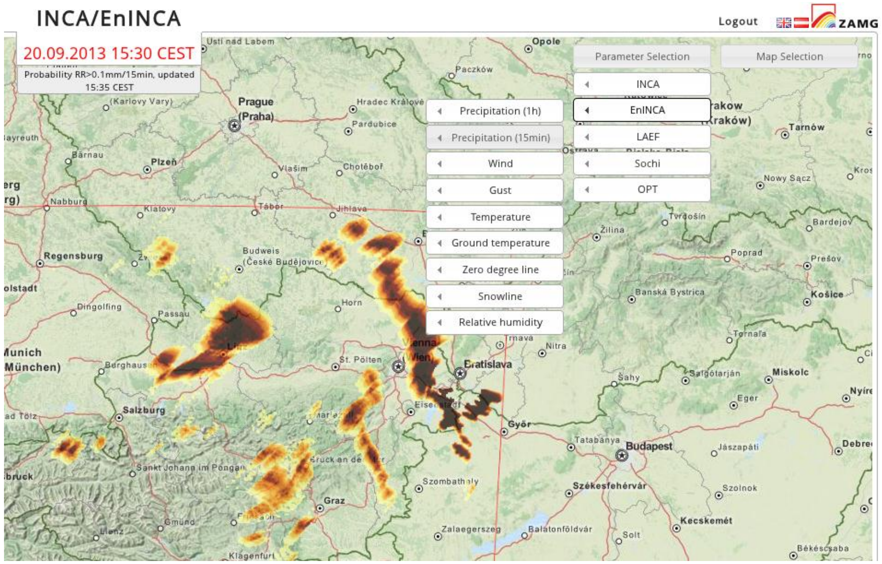
- NWP errors / uncertainties
- ALADIN-LAEF and/or multi-system EPS *

* planned

Ensemble INCA

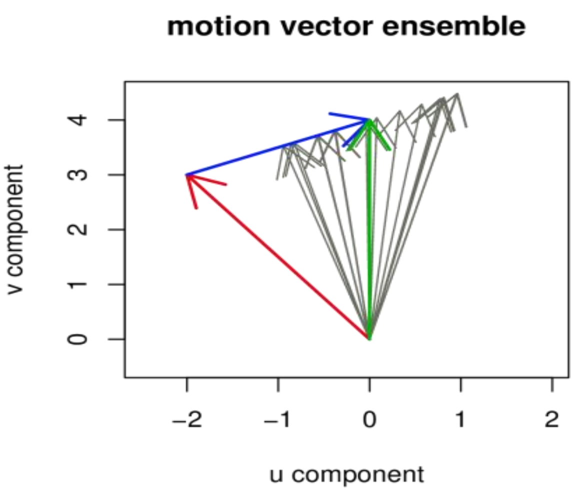
Ensemble based on LAEF:

- Use of LAEF EPS as input for INCA to derive probabilistic nowcasts
- Precipitation, wind, gust, temperature, ground temperature, …



Error motion vectors (precipitation):

- Ensemble based on error motion vectors (blue)
- Error in motion vectors estimated from past analyses
- Motion vector (red) corrected by error yields the corrected motion vector (green).
- A sample of motion vectors is drawn



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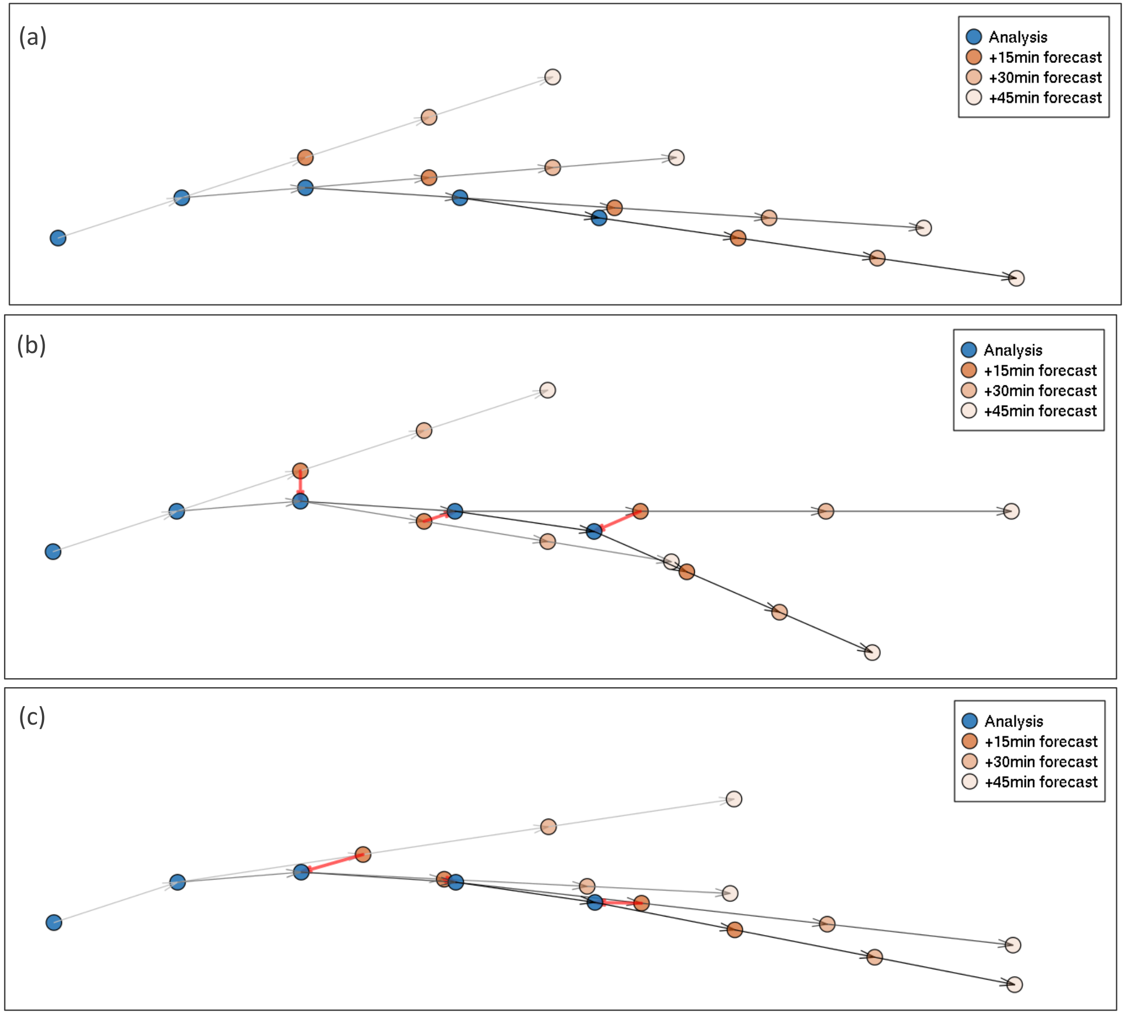
Error motion vectors



Kinematic extrapolation in the course of one hour. Blue dots show the position of an idealized area of precipitation, brown dots their extrapolated positions (with the more transparent ones lying further in the future) along the corresponding motion vectors (black/grey shades). For panel (a) no error motion vectors were used at all, for panel (b) the current error motion vectors alone were used, and for panel (c) the current error motion vectors and a climatological error motion vector were used.

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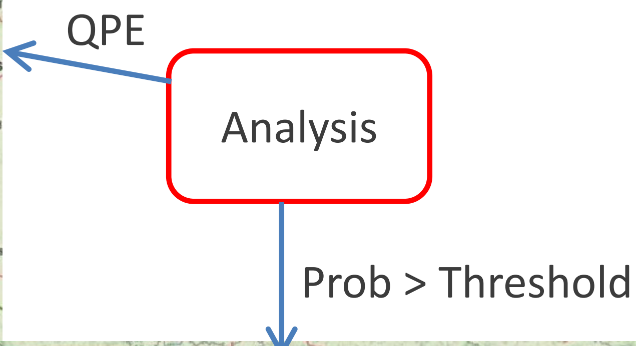
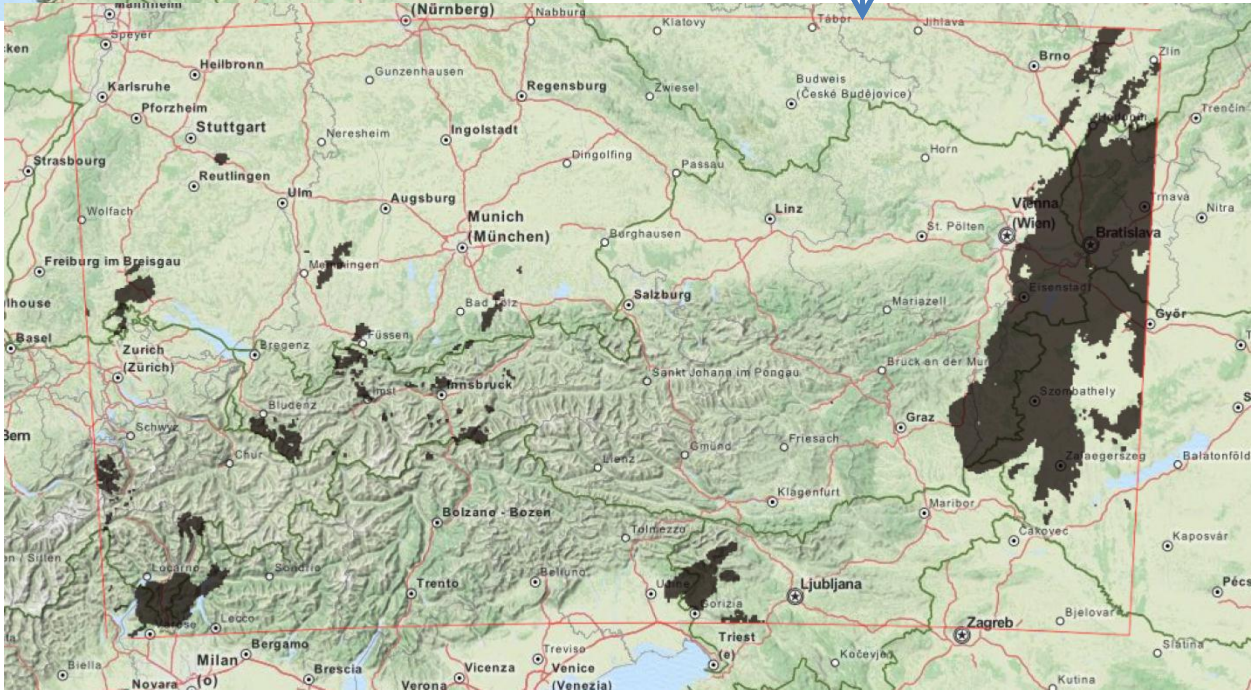
Comparison: Deterministic INCA and En-INCA



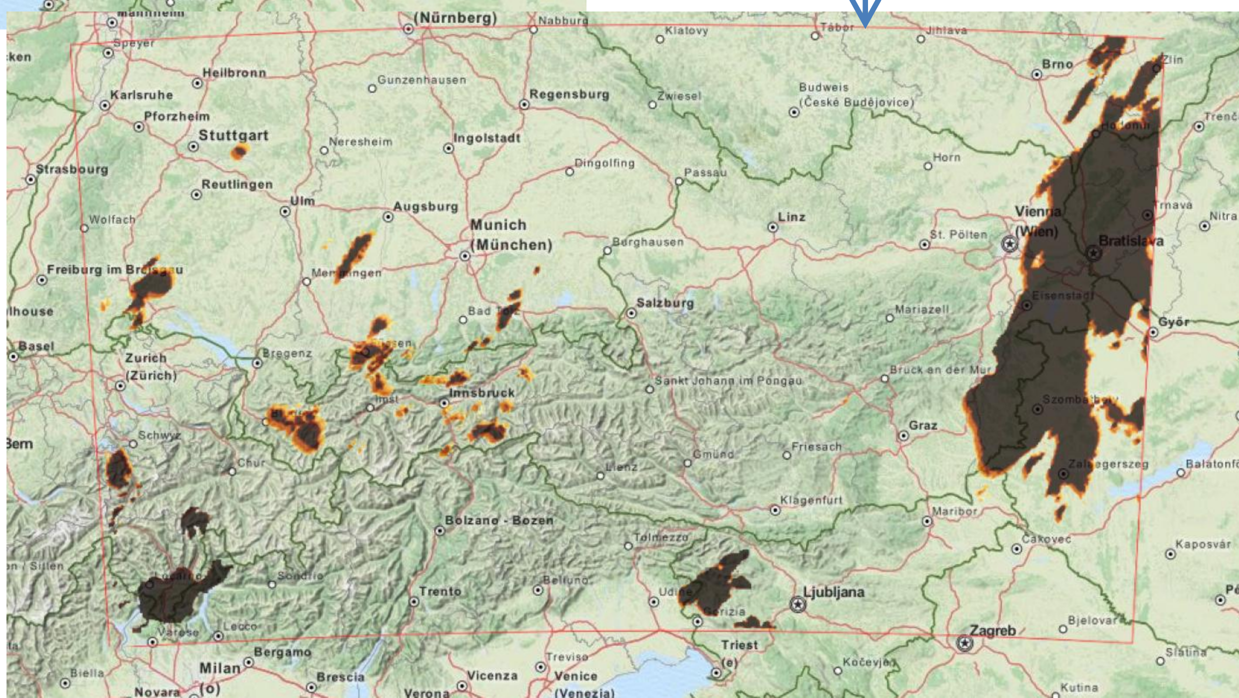


Comparison: Deterministic INCA and En-INCA

QPF

Forecast:
+15 min

Prob > Threshold

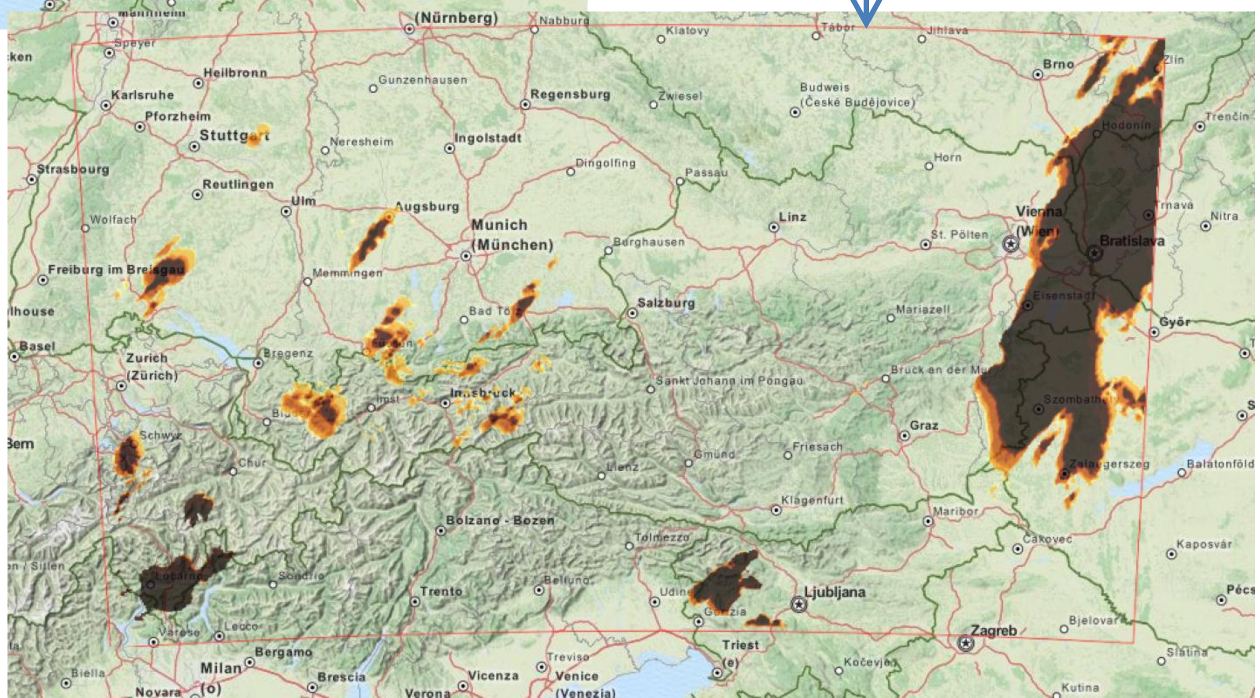


Comparison: Deterministic INCA and En-INCA

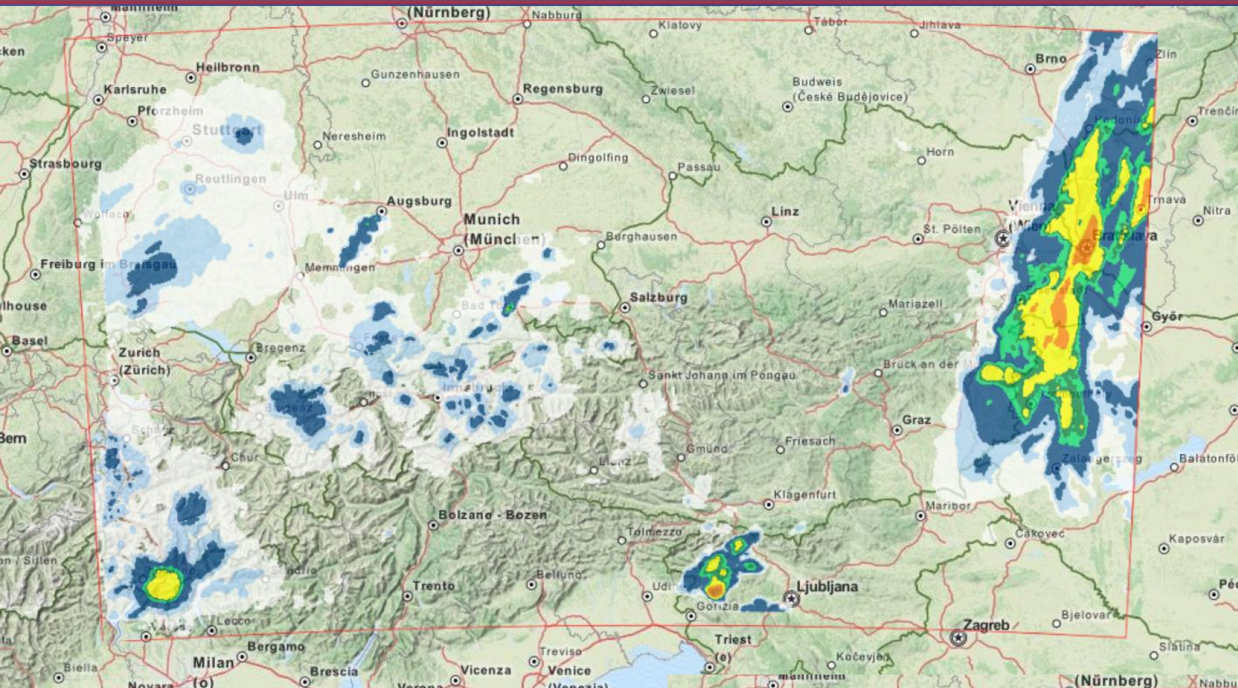
QPF

Forecast: +30 min

Prob > Threshold



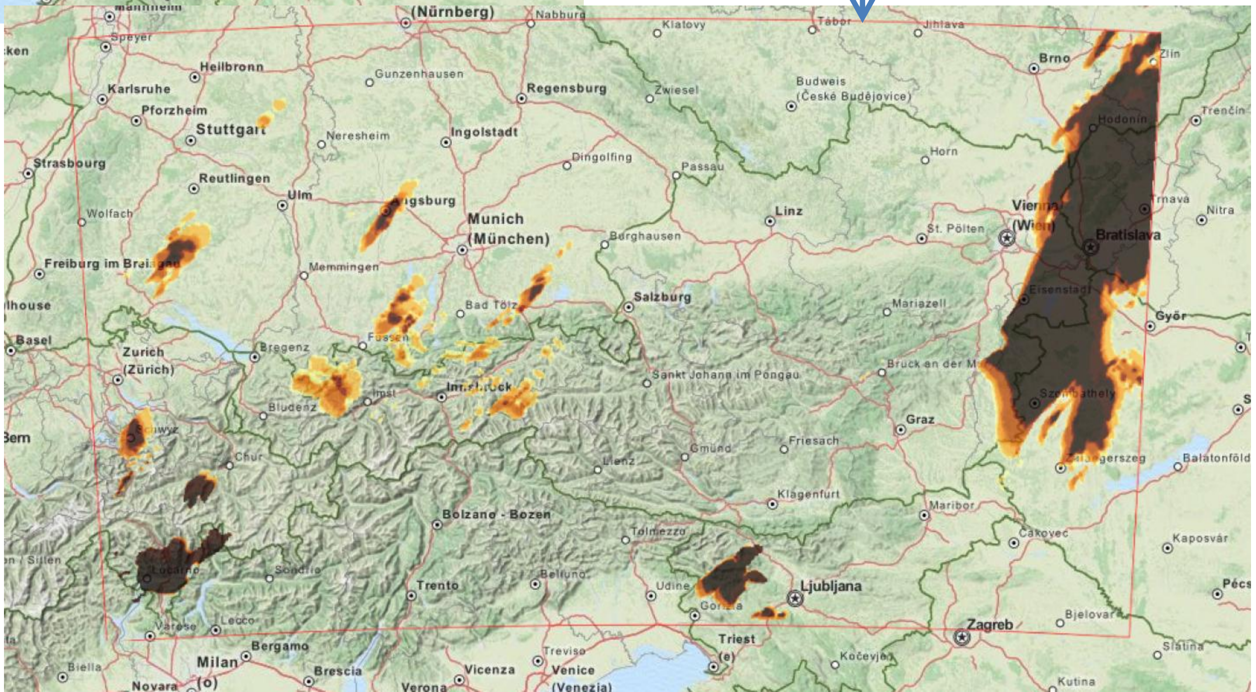
Comparison: Deterministic INCA and En-INCA



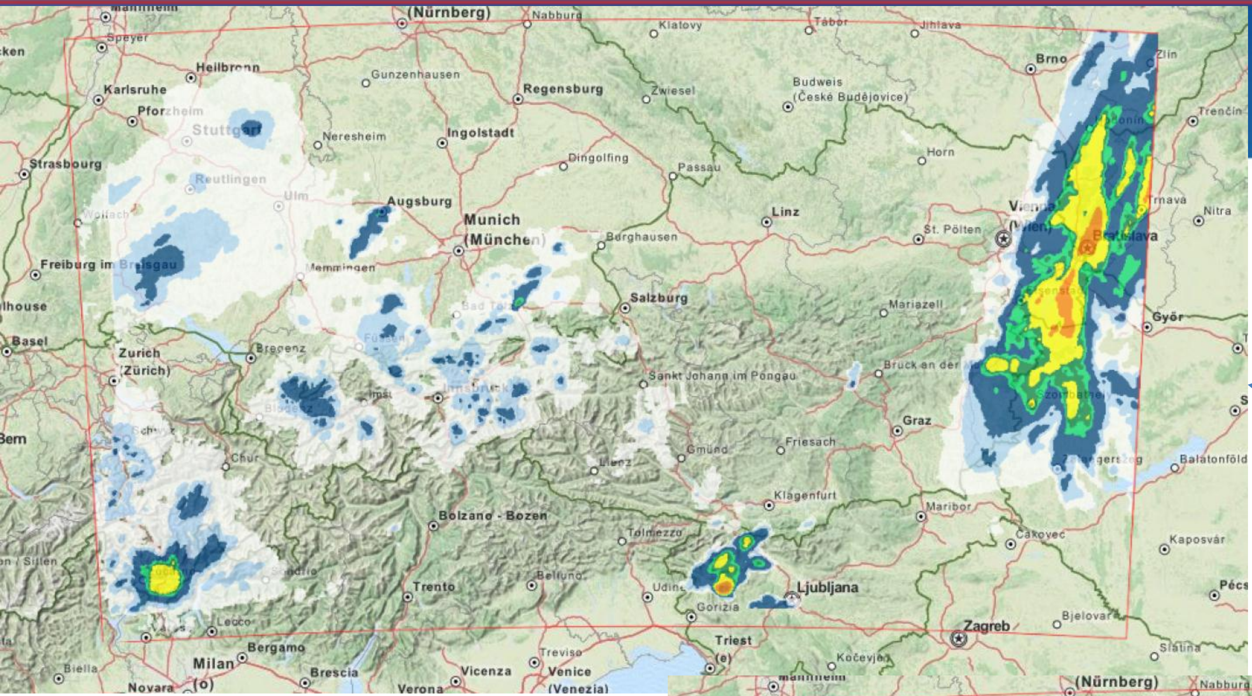
QPF

Forecast:
+45 min

Prob > Threshold



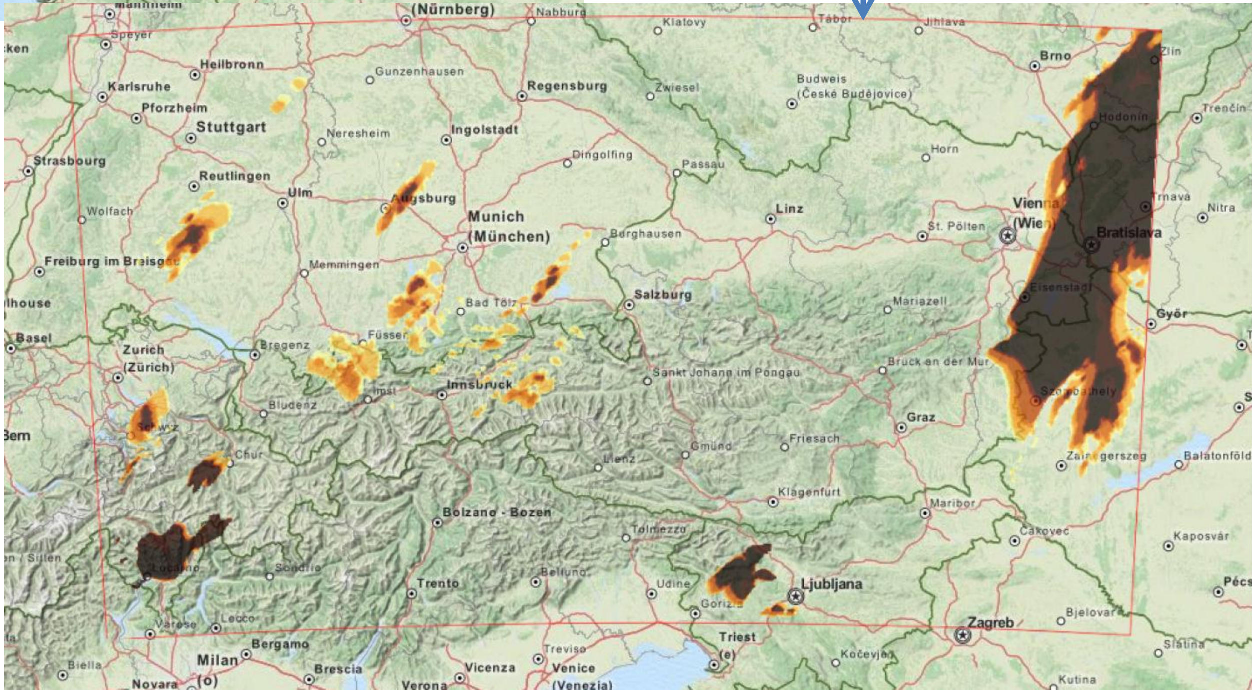
Comparison: Deterministic INCA and En-INCA



QPF

Forecast:
+60 min

Prob > Threshold

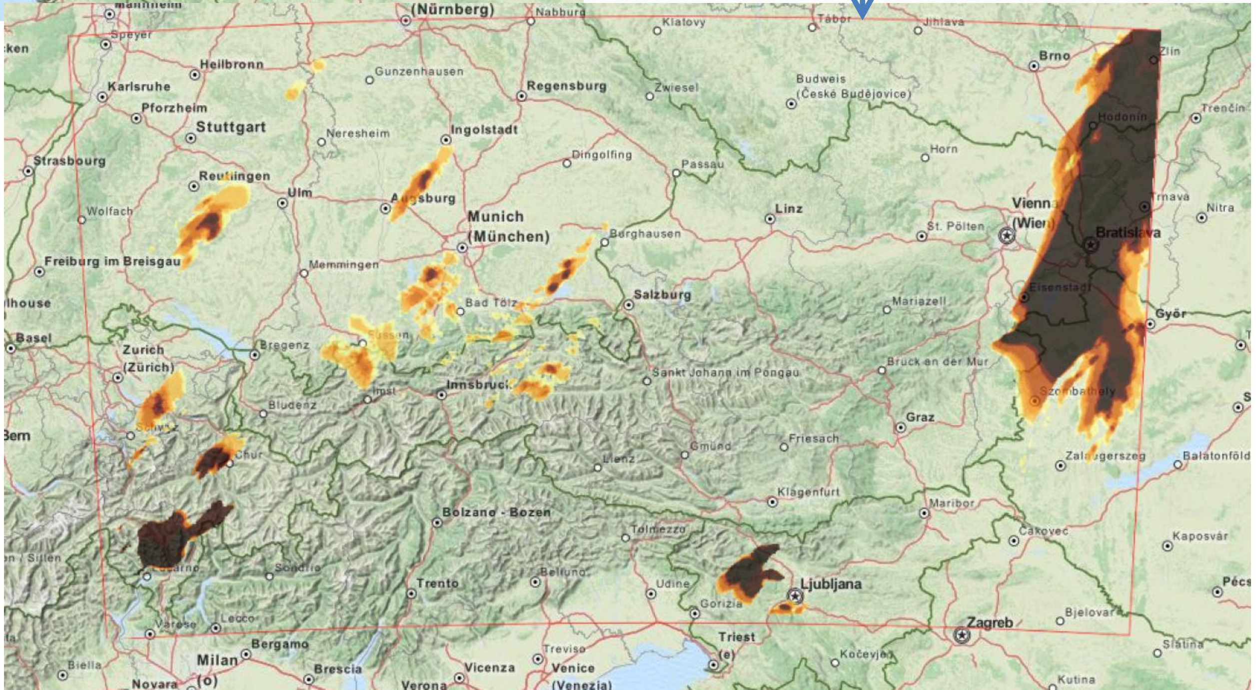


Comparison: Deterministic INCA and En-INCA

QPF

Forecast:
+75 min

Prob > Threshold

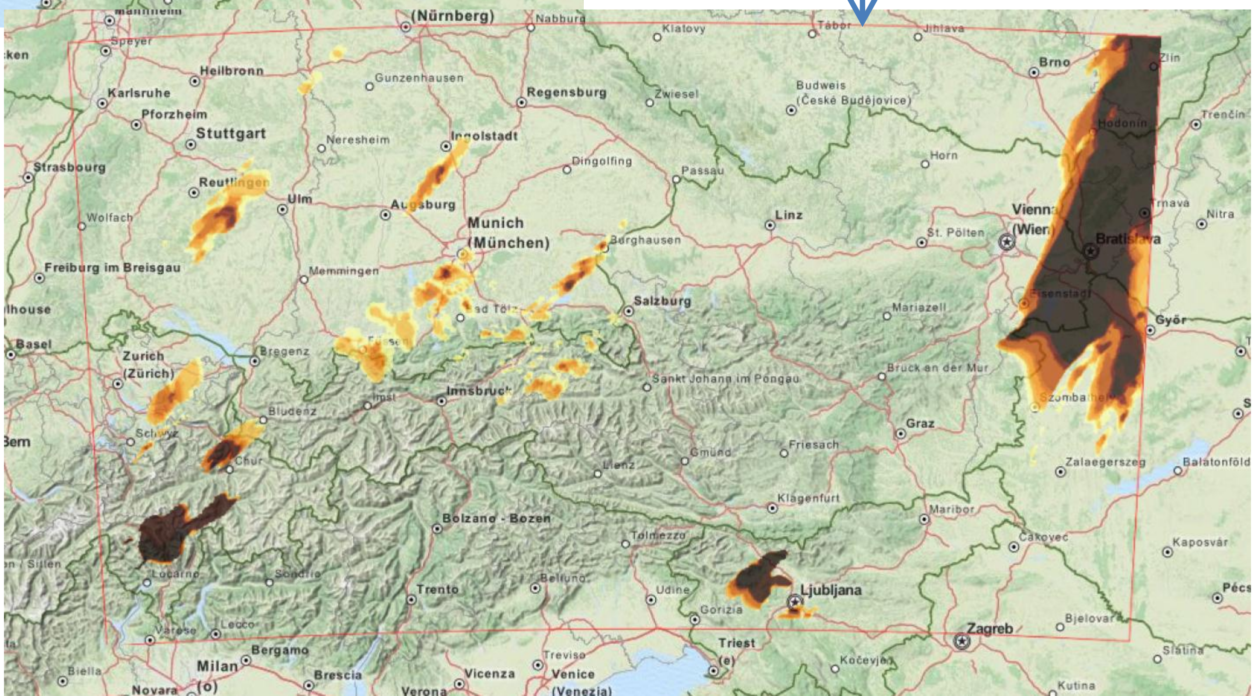


Comparison: Deterministic INCA and En-INCA

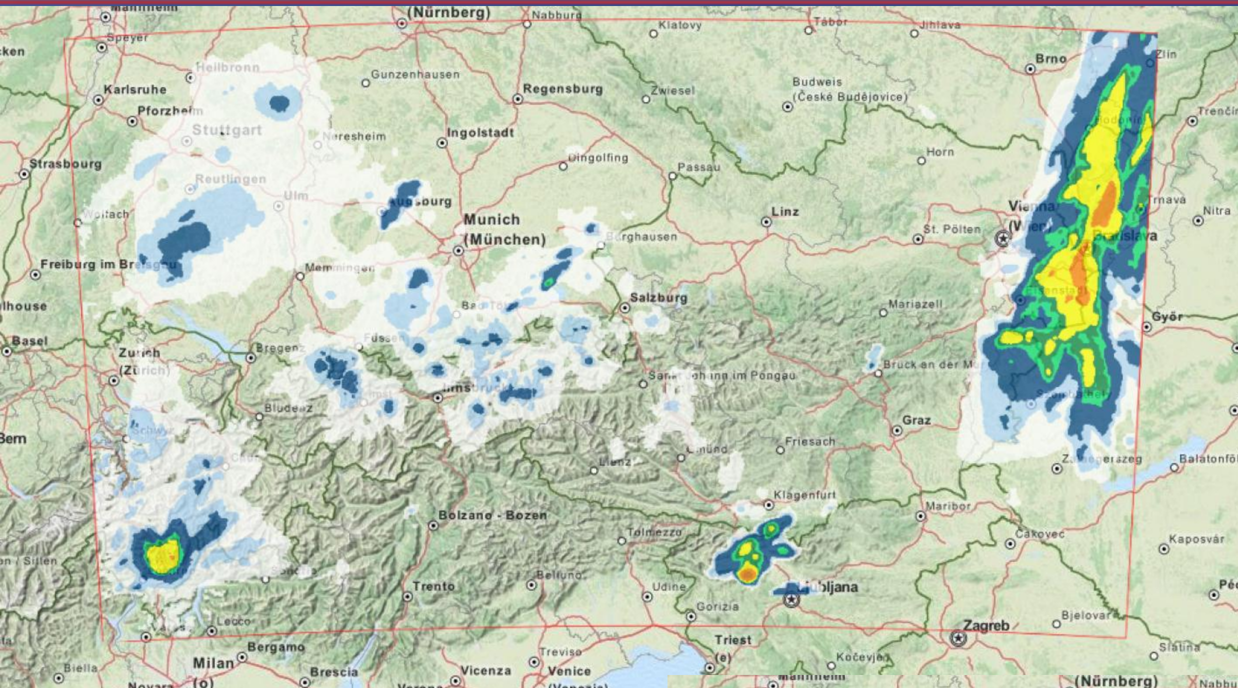
QPF

Forecast:
+90 min

Prob > Threshold



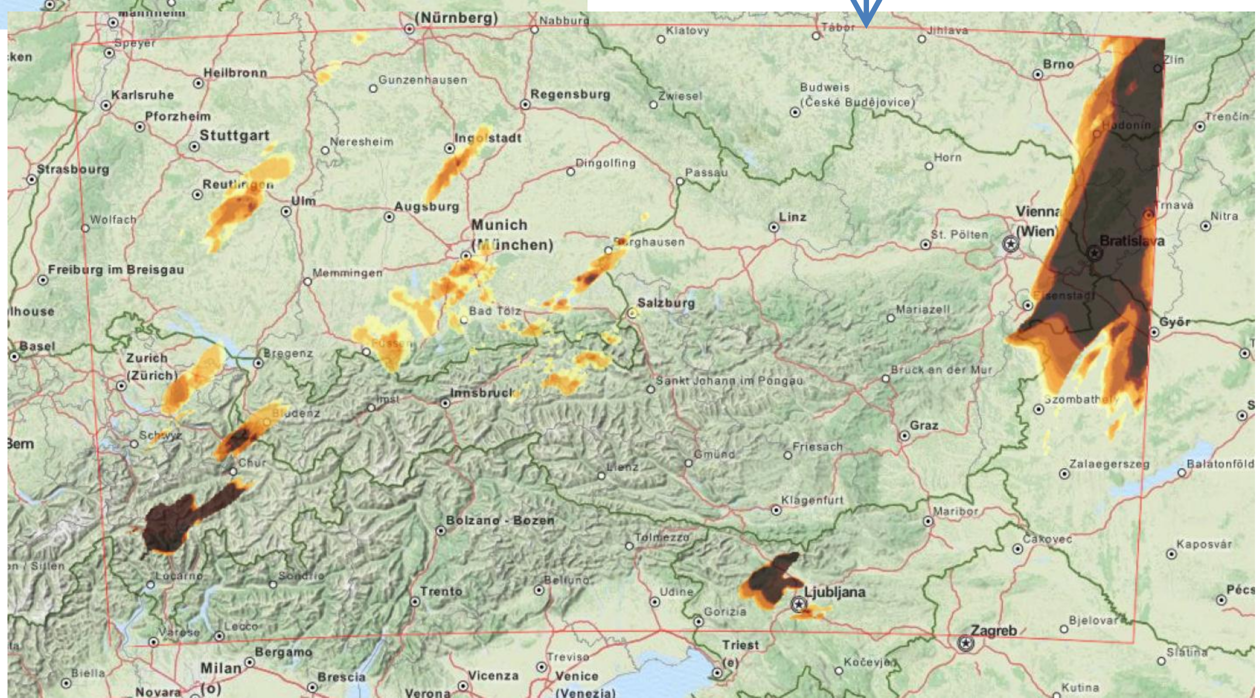
Comparison: Deterministic INCA and En-INCA



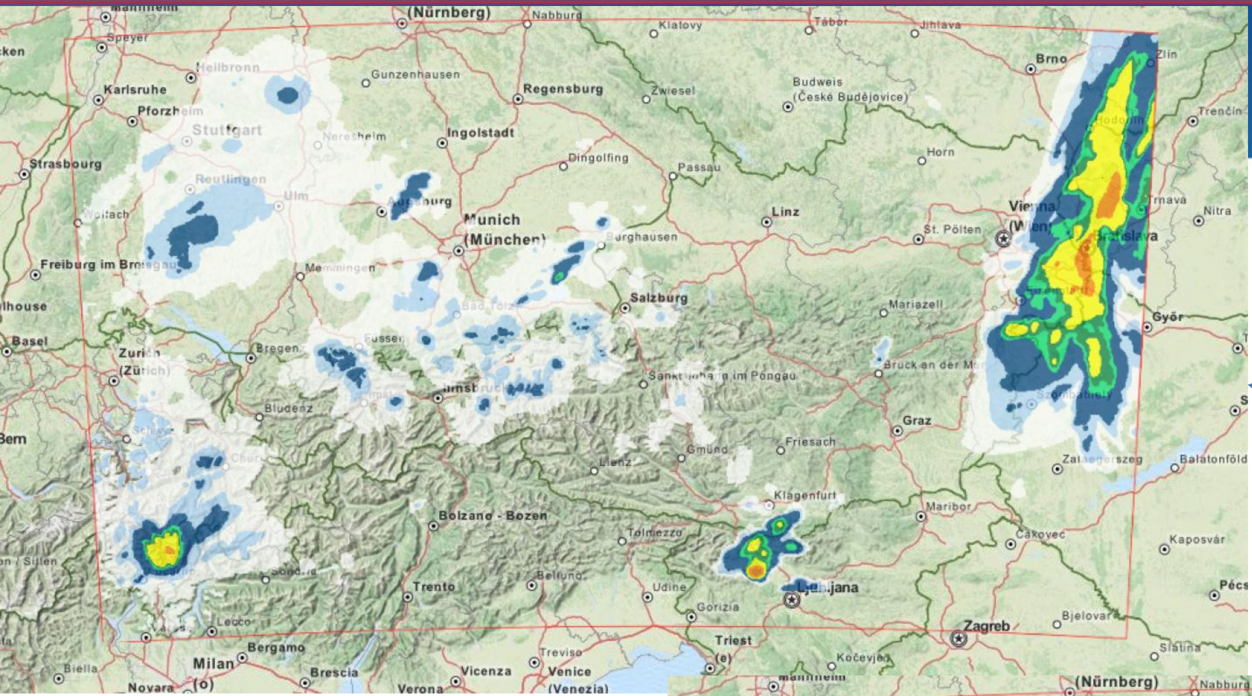
QPF

Forecast:
+105 min

Prob > Threshold



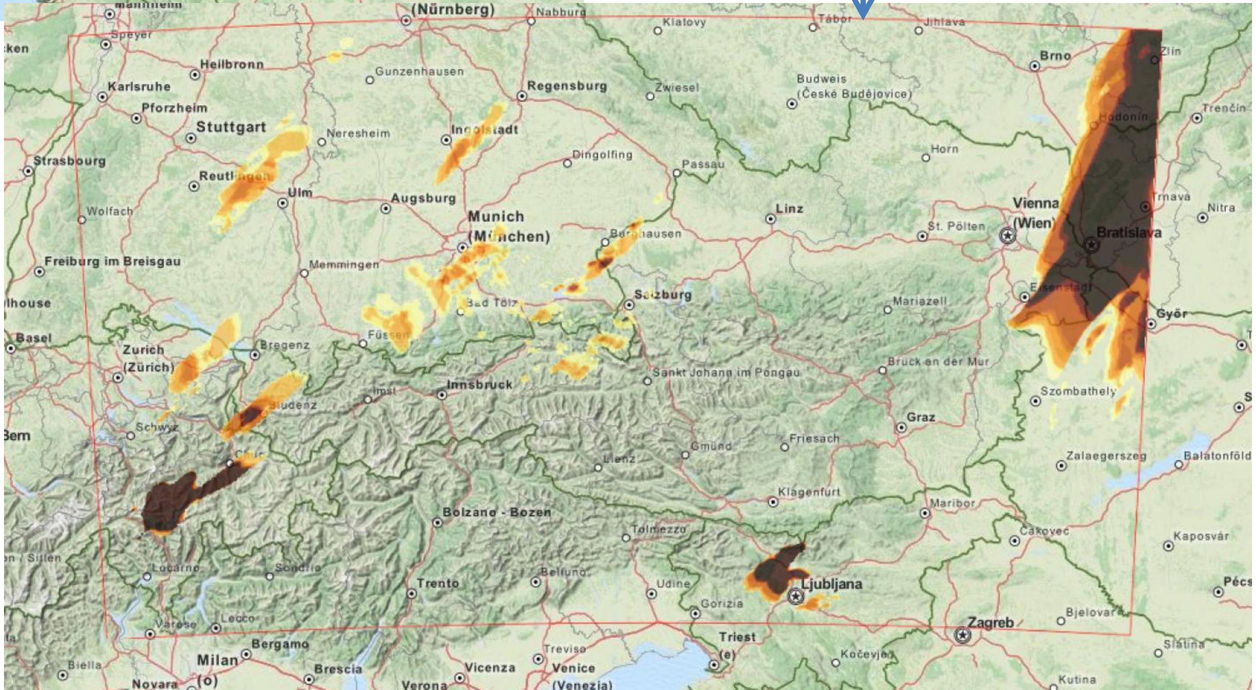
Comparison: Deterministic INCA and En-INCA



QPF

Forecast:
+120 min

Prob > Threshold



Final Remarks

1. Nowcasting: although basic idea rather old, still beneficial and often superior to NWP within the first hours
2. Originally mainly/only thunderstorm nowcasting, nowadays for many applications (warnings, road, civil protection, hydrology, renewable energies, …)
3. Many different methods/systems/algorithms, but often with similar concepts
4. Uncertainty assessment becomes more and more important (Ensemble Nowcasting), also for end-users
5. NWP models on the convection permitting scale become more and more attractive to be used for nowcasting, indirectly or directly.
6. Since nowcasting is (and will always be) observation-based (regardless of the method), the QC and assimilation of all new and available data sources will be crucial (satellites, GPS, radar, aircraft, …)

Thanks for your attention!