Recent developments in the INCA analysis and nowcasting system

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EGU Sharing Geoscience Online | Monday, 4 May 2020, 08:30–10:15

Overview

- Numerical weather prediction models at ZAMG
- INCA Motivation and concept
- Classification of INCA among NWP products

- INCA system overview
- Operational service: relevant aspects at a NWS
- International collaboration + Winter Olympics

- Ongoing code revision and upgrade / the new precipitation module
- Current research and development within and around INCA

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Models used in operational products at ZAMG

ECMWF seasonal forecast

ECMWF monthly forecast

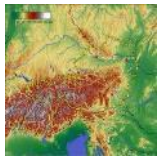
ECMWF EPS

ECMWF HRES

C-LAEF (ex ALARO-LAEF, ex ALADIN-LAEF)

AROME-AUSTRIA (ex ALARO, ex ALADIN)

AROME-RUC



INCA

En-INCA

+ 00 + 12h + 1d + 2d + 3d ... + 15d + 6m

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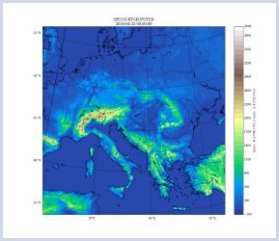
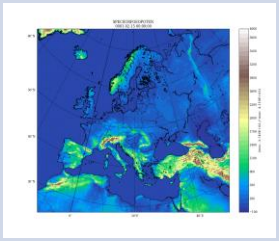
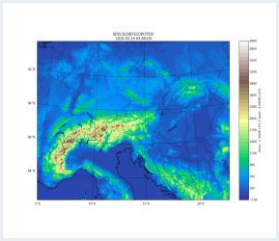
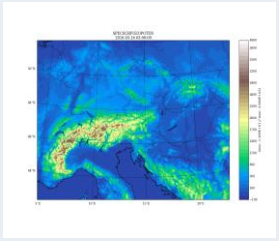
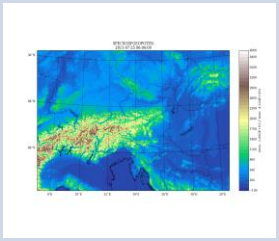
Models used in operational products at ZAMG

	deterministic		probabilistic
	ALARO (4.8km, +72h, 4x / day		ALADIN – LAEF (10.9km, +72h, 2x / day)
	AROME (2.5km, +60h, 8x / day)		C-LAEF (2.5km, +48h, 2x / day)
	AROME – RUC (1.2km, +12h, 24x / day)		

... to be turned off ...
... operational (established) ...
... operational (new) ...

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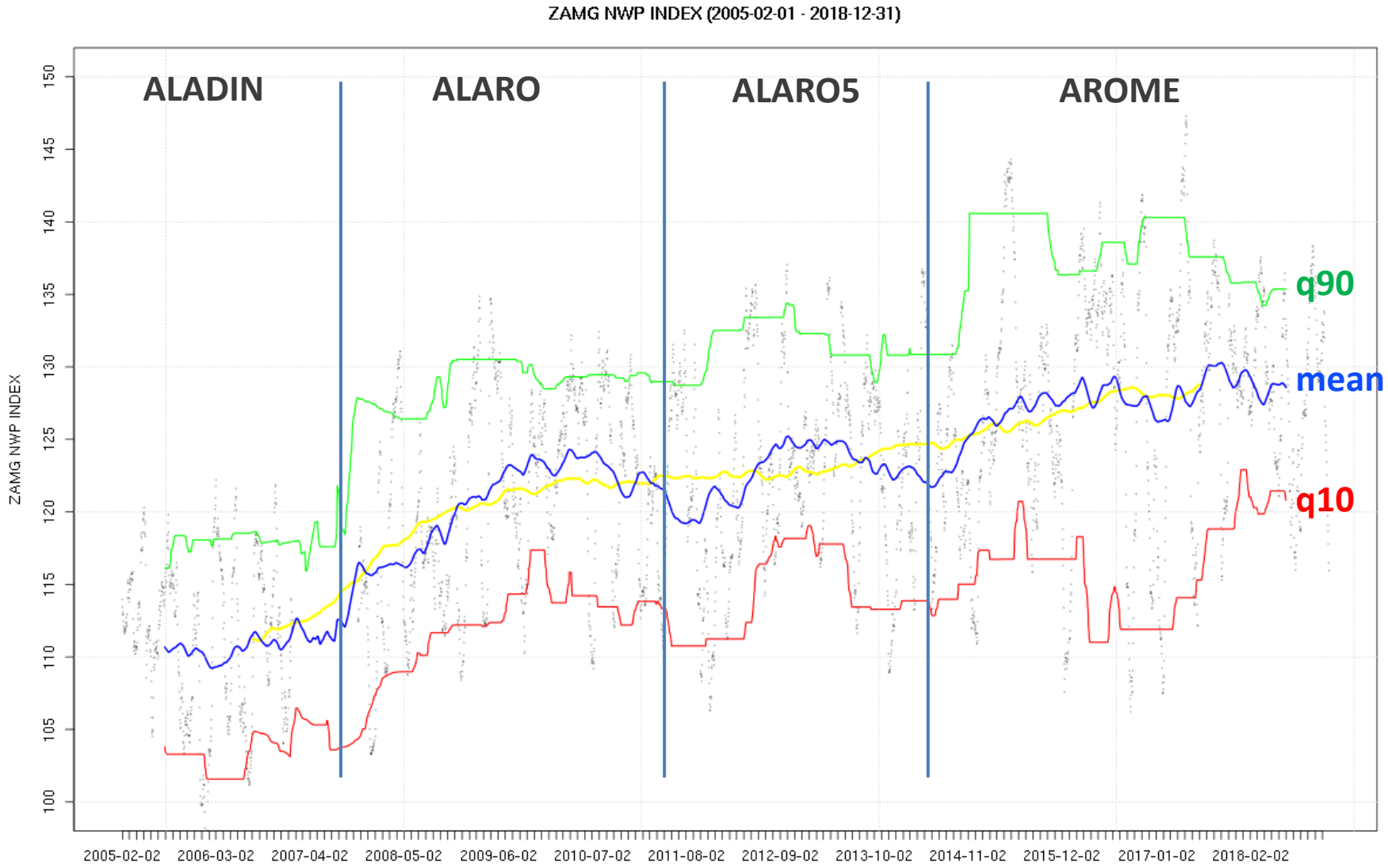
ZAMG NWP Index 2005 - 2018

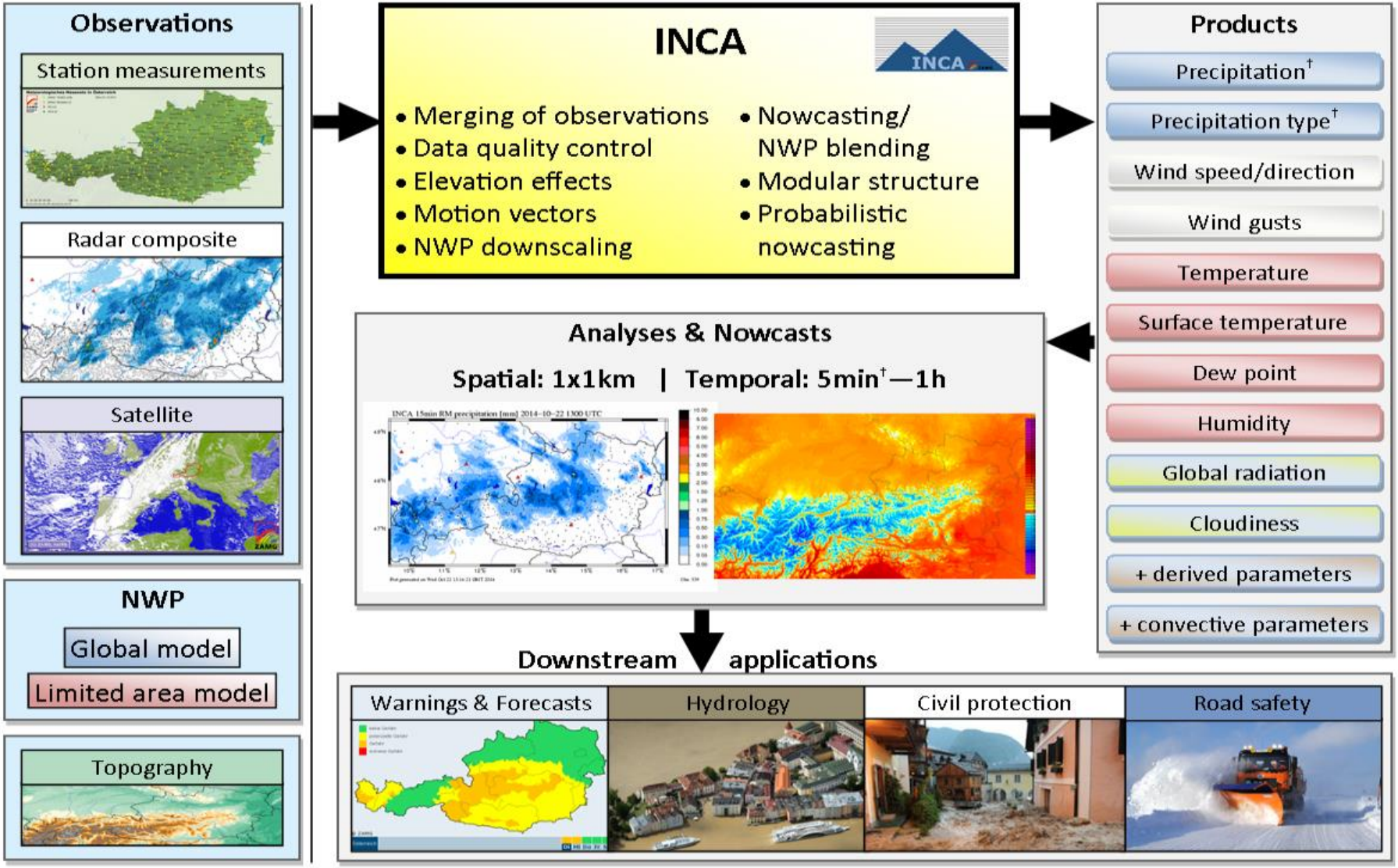


2005

© Christoph Wittmann

2018

INCA system overview



INCA strategy

	Precipitation	Cloudiness	Temperature & Humidity	Wind
Analysis background	radar data	satellite data	NWP forecast	NWP forecast
Nowcasting method	extrapolation with motion vectors	extrapolation with motion vectors	persistence + NWP trend	persistence + NWP trend
NWP forecast	AROME + ECMWF	AROME	AROME	AROME
Blending method	Local weights (variational method)	Global weights (fixed)	Global weights (adaptive)	Global weights (fixed)
Nowcasting limit	4 hours	6 hours	3 to 12 hours (depending on stability)	6 hours

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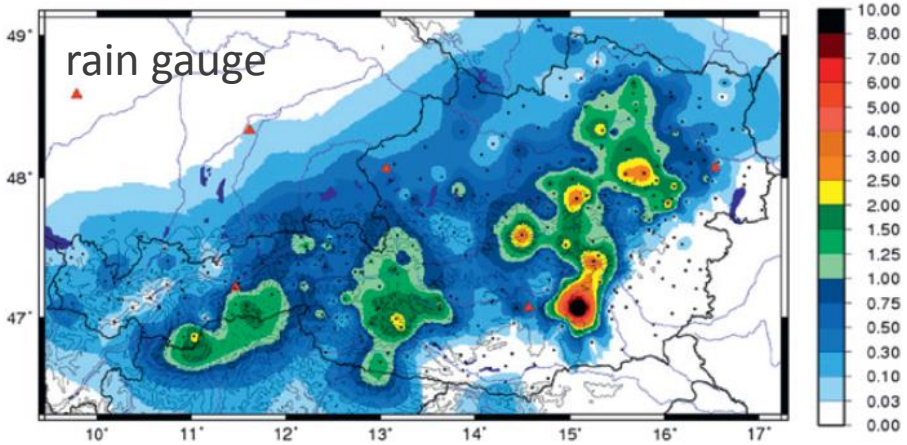
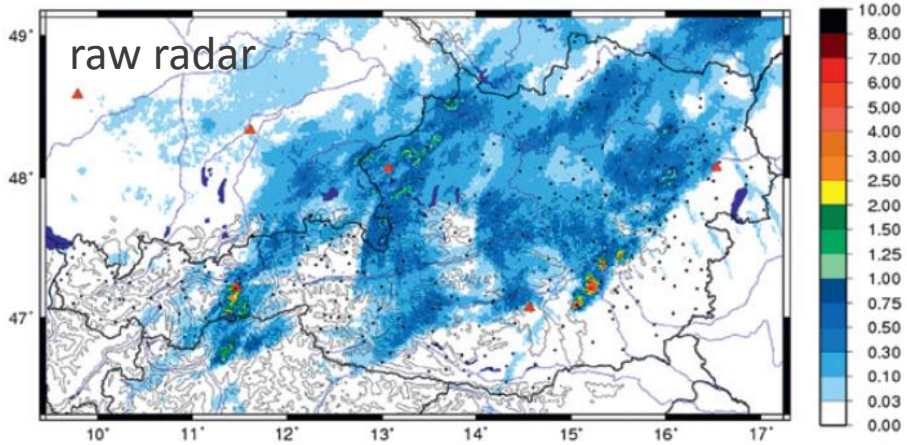
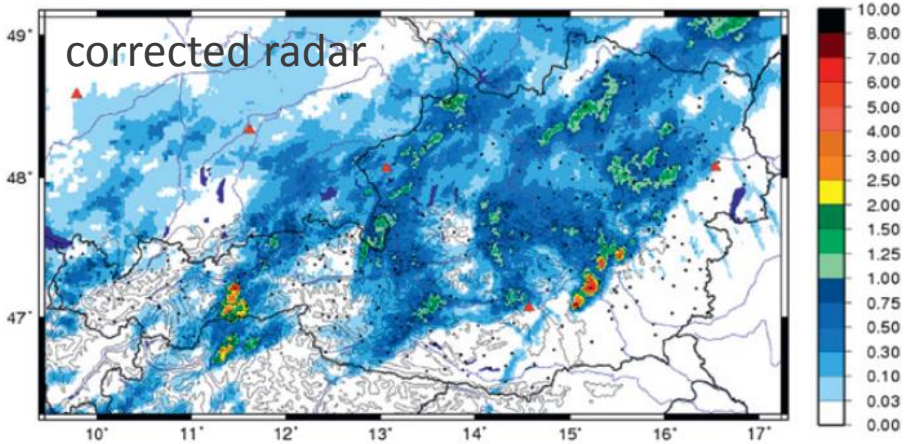
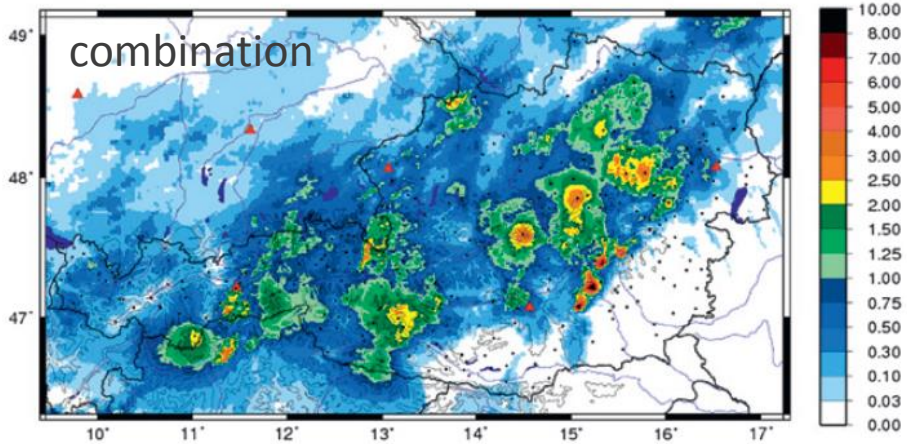
INCA precipitation analysis (operational approach)









$$P_{INCA}(i,j) = P_{STA}(i,j) + w(i,j) \times [P^{**}_{RAD}(i,j) - P^{**}_{RST}(i,j)]$$

+ QC + elevation dependence + blocking effects + convection + ...

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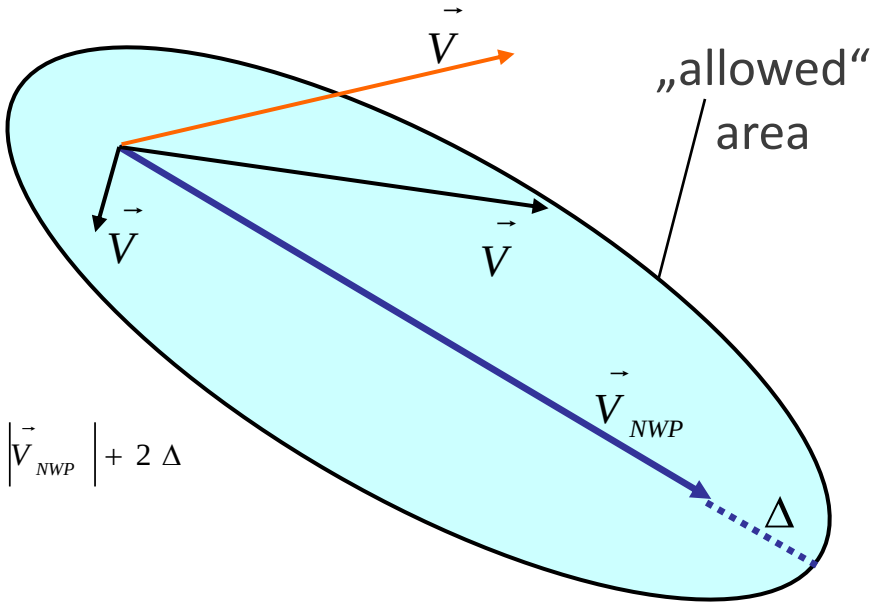
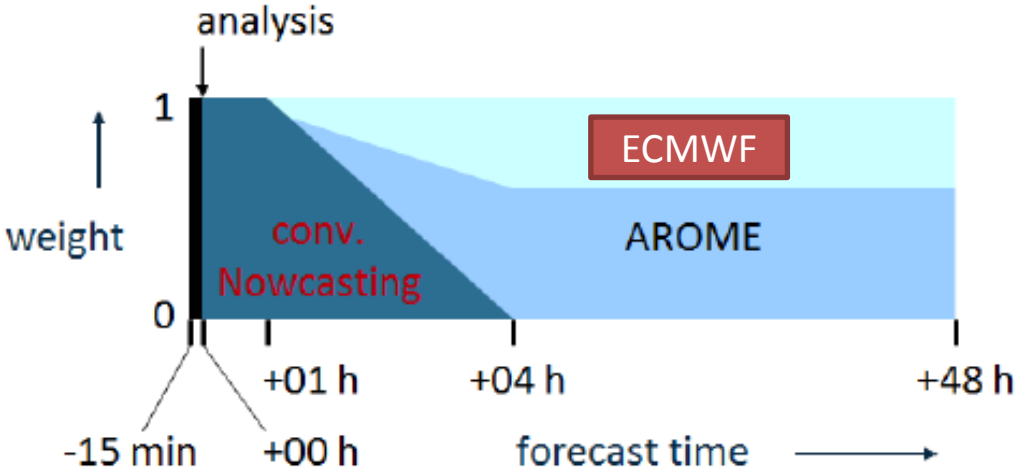
Operational INCA precipitation nowcasting based on motion vectors Blending into NWP

- Motion vectors computed from two consecutive analyses
- Plausibility check with NWP 700 and 500 hPa wind field
- Extrapolation of precipitation analysis



$$\left|\vec{V}\right| + \left|\vec{V} - \vec{V}_{NWP}\right| \leq \left|\vec{V}_{NWP}\right| + 2\,\Delta$$

Δ=5 m/s



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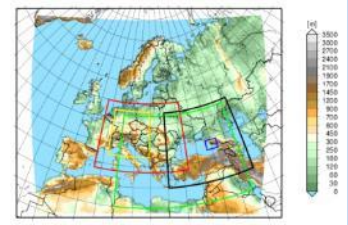
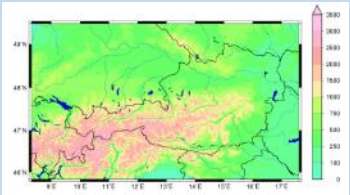
Ensemble INCA

LAEF
Limited Area Ensemble Forecasting



INCA
Integrated Nowcasting through Comprehensive Analysis



Observation-related uncertainties

- site measurement errors
- radar uncertainties
- interpolation errors
- …

En-INCA
Ensemble Forecasting in the Nowcasting range

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INCA applications

INCA ZAMG

Road Safety

- Winter road maintenance
- Preventive salt spraying
- Precipitation, -type, wind, ground and road surface temperature, and hoar frost

Hydrology

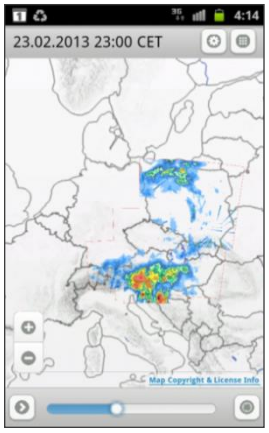
- Input for hydrological models
- Input for flash flood models
- Part of flood warning system

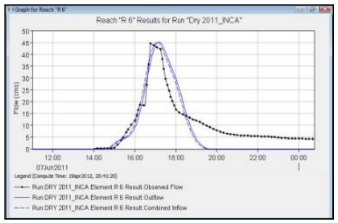
Civil Protection

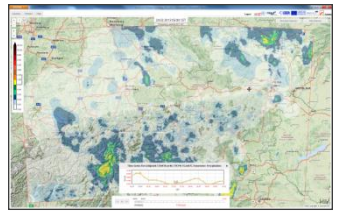
- Storm alert monitor
- Organisation of large events
- National/regional alarm centers

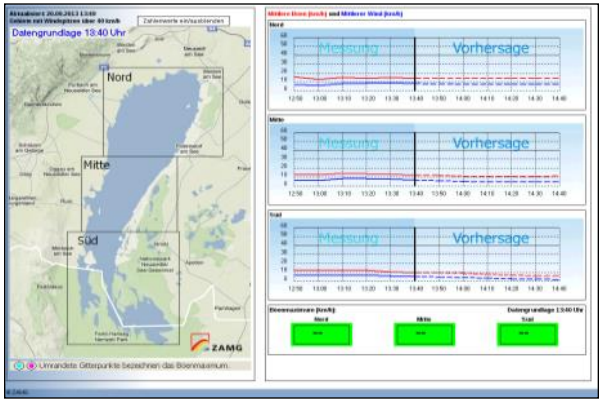
Energy providers

- Global radiation, wind
- Input for power supply models
- Wind climatology, re-analysis, Machine learning









Landslide modelling, debris flow warnings, snow cover, ...

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NWS challenges & operational issues

- ZAMG is classified as „critical infrastructure“
- Forecast products are delivered to authorities, customers and to the public
- INCA is used for flood forecasting, automated warnings, etc.

- Requirements
  - Excellent quality
  - Reliability: No service breaks
  - Availability: No delay in dissemination

- Challenges
  - Handling large amount of incoming and outgoing data
  - Highly complex system, multiple parameters
  - Insufficient data quality
  - Missing input data
  - Deficient metadata
  - Server upgrades
  - Software updates
  - etc.

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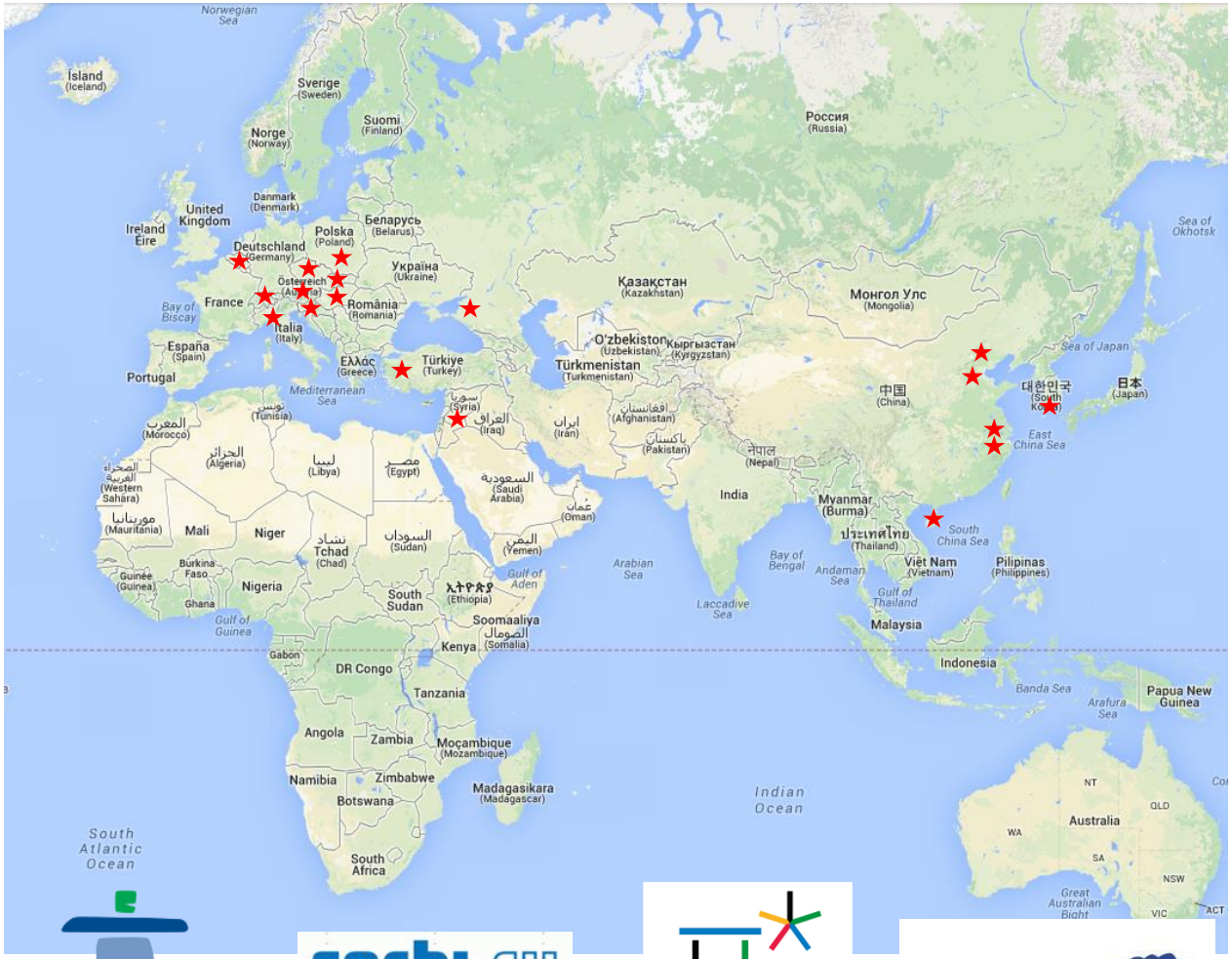
INCA International Collaboration



vancouver 2010

sochi.ru 2014

PyeongChang 2018

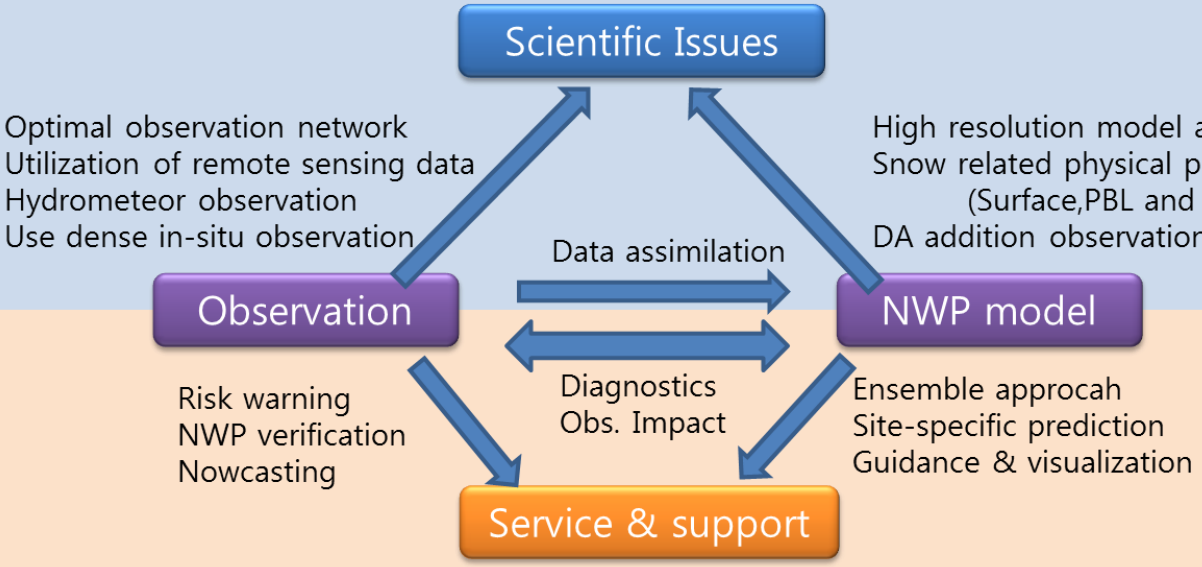
INCA-CE
Nowcasting for Central Europe

ICE-POP 2018: Goal and scientific challenges

Lead agency: KMA (Dong-Kyou Lee, Sangwon Joo)
10 participating countries (AU, **AT**, CA, CN, FI, RU, KR, ES, CH, US)
16 participating organisations
WMO/WWRP RDP/FDP endorsement since 27 Nov 2015
Goal: Advance prediction of winter weather based on intensive observations

RDP

1) Orographic effect in complex terrains (wind flow, vertical structure/phase changes)
2) Ocean effect (heat and moisture exchange, rolling cloud over ocean due to cold air surge)
3) Improve wind, visibility & precipitation (amount/type) forecast (physical processes, data assimilation)



FDP

1) To provide & interpret high resolution model results for forecasters (Verification)
2) To demonstrate the usefulness of remote sensing observation in nowcasting
3) To evaluate the benefit of RDP/FDP (Societal impact)

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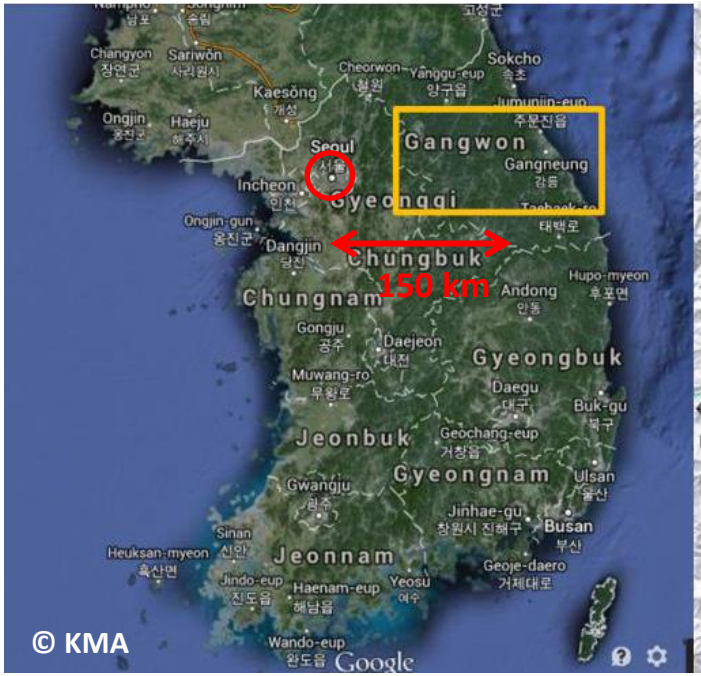
PyeongChang 2018 venues



Austria: 83.879 km^2
South Korea: 100.284 km^2

Pyeongchang Mountain Cluster: Alpine climate (773 m a.s.l., -5.5°C, 53 mm in Feb.)
Gangneung Coastal Cluster: Coastal climate (26 m a.s.l., 2.2°C, 69 mm in Feb.)

13 competition venues in total: 7 existing, 6 new

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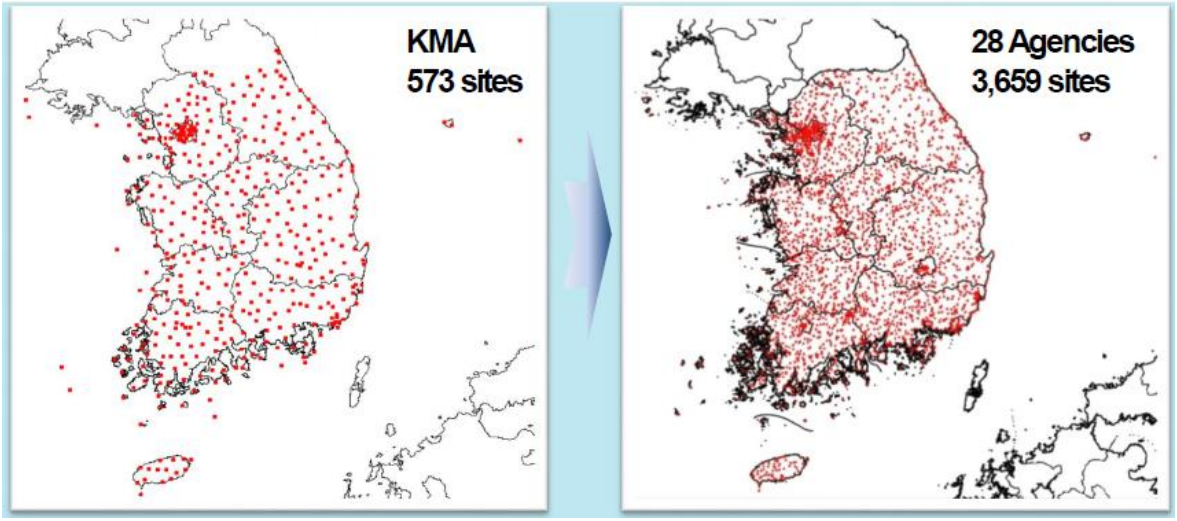
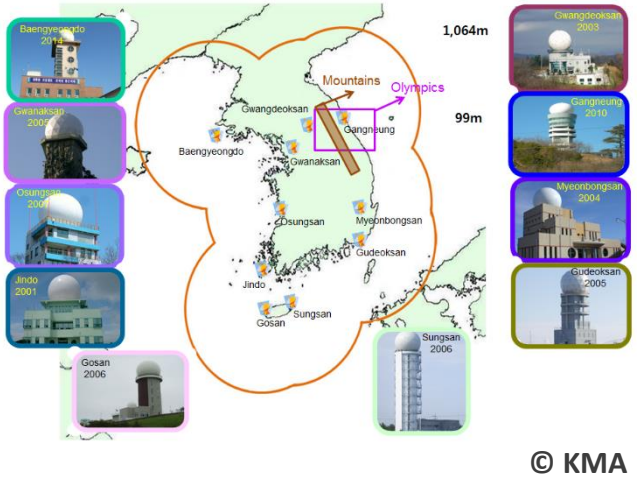
Observation network





© KMA

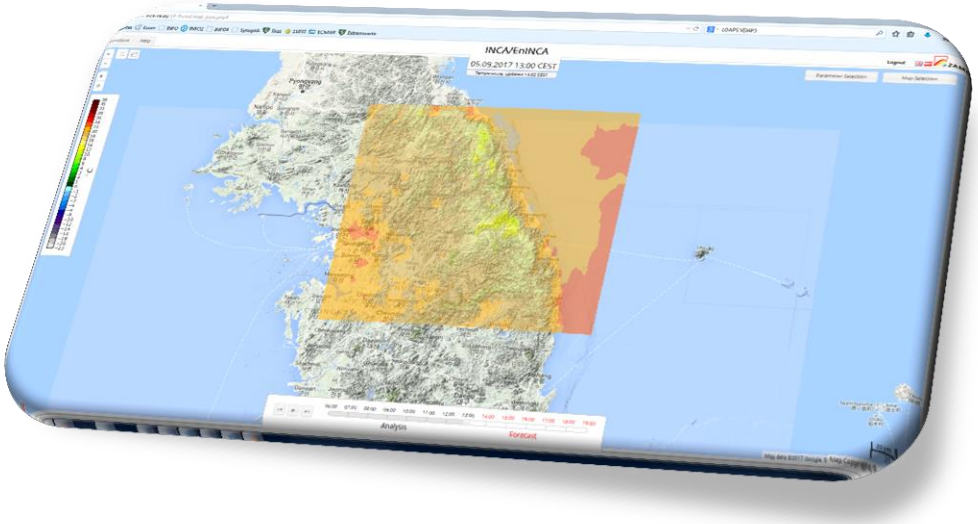
- Ground station network, 11+16 WXs
- Upper level network: 8 Radio soundings, 12 wind profilers, 105 ceilometers, 238 visibility sensors, ...
- Ocean network: 110 sites + 1 ship
- Satellite, Aircraft, Observation vehicle

Ideal setting for NWP development and evaluation

Nation	Institution	Instrument
Canada	ECCC	Lidars, Precipitation Occurence Sensor System (POSS)
South Korea	KNU	VertiX, TEAM-R
Spain	UCLM	Snow radar, Parsivels
Switzerland	EPFL	Snow and cloud radar
USA	NASA	Pluvio, Parsivel, PIP, MRR, D3R
USA	SUNY	Cloud radars

INCA specifications for ICE-POP 2018

- **INCA settings**
- Parameters: **T2m (1.5m), RH2m (1.5m), wind, gusts, visibility, precipitation, precipitation type**
- Lambert conformal conical projection, Bessel 1841 ellipsoid; Reference latitudes λ_0=128.28; ϕ_1=30; ϕ_2=60
- Domain extension: λ_{min}=126.68, ϕ_{min}=36.62, λ_{max}=129.93, ϕ_{max}=38.85
- Mesh size: **1 km x 1 km**
- Grid points: **NX=272, NY=251**



- Vertical levels: From 0 to 1600 m, with equal spacing of 200 m for all parameters except wind (125 m)
- Time resolution and update frequency: **1h**, except for precipitation products in **10min** resolution
- Analyses and Nowcasts up to **+6h leadtime**
- Output: **Analysis and forecast fields in grb2 format; point forecasts in ascii format**
- Graphical visualisation: KMA and ZAMG

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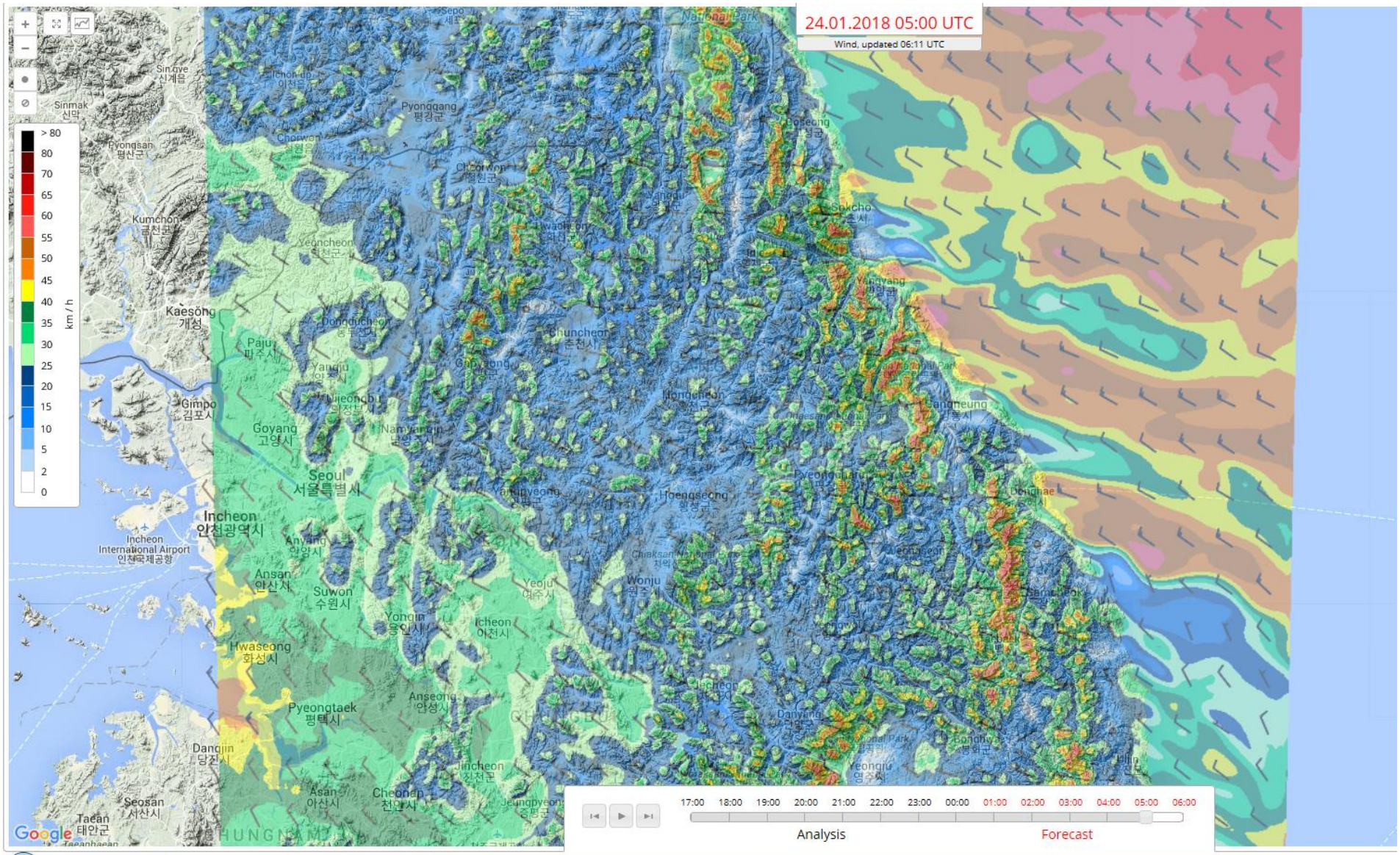
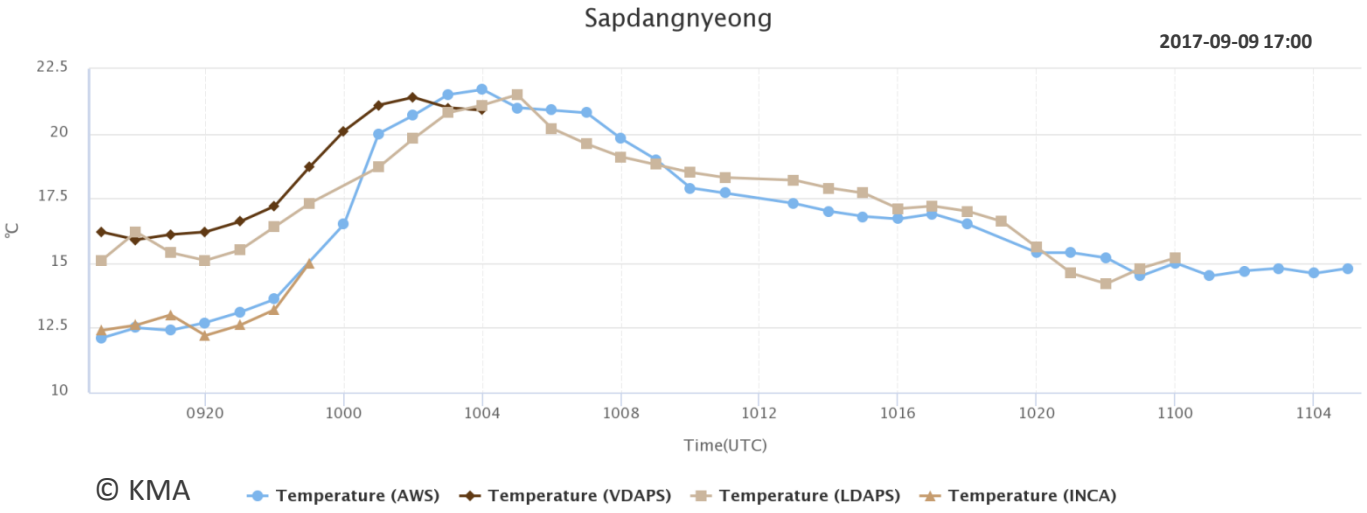
INCA wind – 24 Jan 2018 05 UTC



Point forecast locations for Pyeongchang 2018

Venues	id no.	위치		altitude(m)	Desciption
		lat	lon		
Alpensia Ski Jumping Centre	2575	37.662208	128.680462	785	Ski Jumping Landing
Alpensia Biathlon Centre	2557	37.663755	128.687290	757	Biathlon Start
Alpensia Cross-Country Skiing Centre	2577	37.663897	128.684789	764	Cross-country Start
Alpensia Sliding Centre	2554	37.654353	128.681965	813	Sliding Finish
Yongpyong Alpine Centre	2560	37.612989	128.671767	1,414	Alpine GS Start
	2579	37.618446	128.668860	1,180	Alpine GS Middle2
	2561	37.621578	128.664814	975	Alpine GS Finish
Jeongseon Alpine Centre	2584	37.445418	128.598923	1,370	Alpine DH Start
	2586	37.457433	128.601828	919	Alpine DH Middle
	2587	37.464385	128.603100	680	Alpine DH Finish
Bokwang Snow Park(C)	2580	37.578527	128.312698	856	Cross Start
	2581	37.584330	128.322039	664	Cross Finish
Bokwang Snow Park(P)	2588	37.574346	128.323211	874	Slopestyle Start
	2583	37.579428	128.324778	709	Slopestyle Finish
Gangneung	105	37.75147	128.89098	26	
Olympic stadium	미정	37.666900	128.707500	735	



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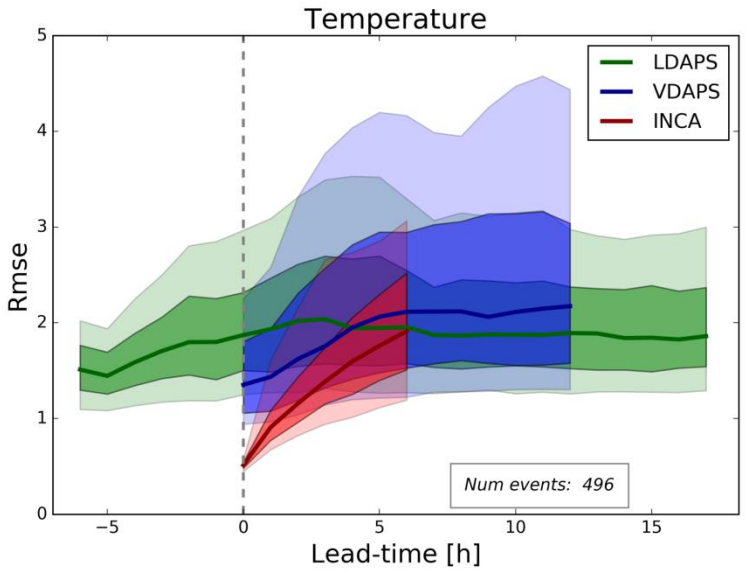
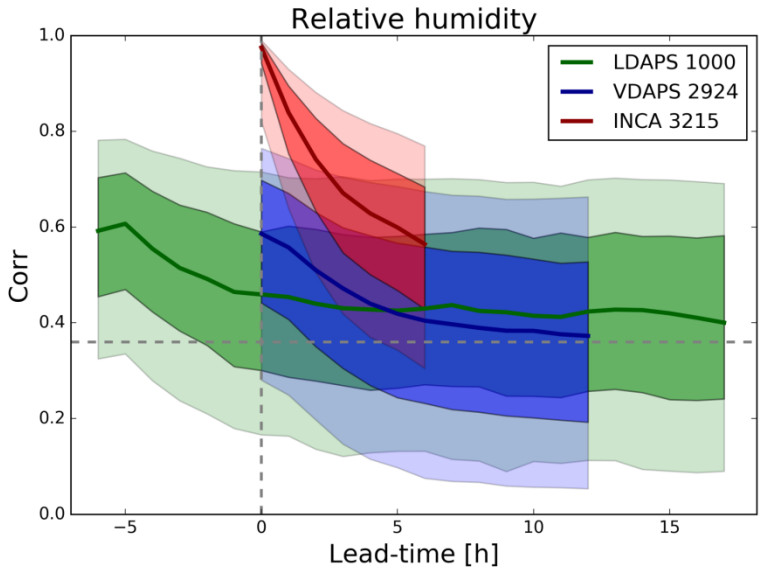
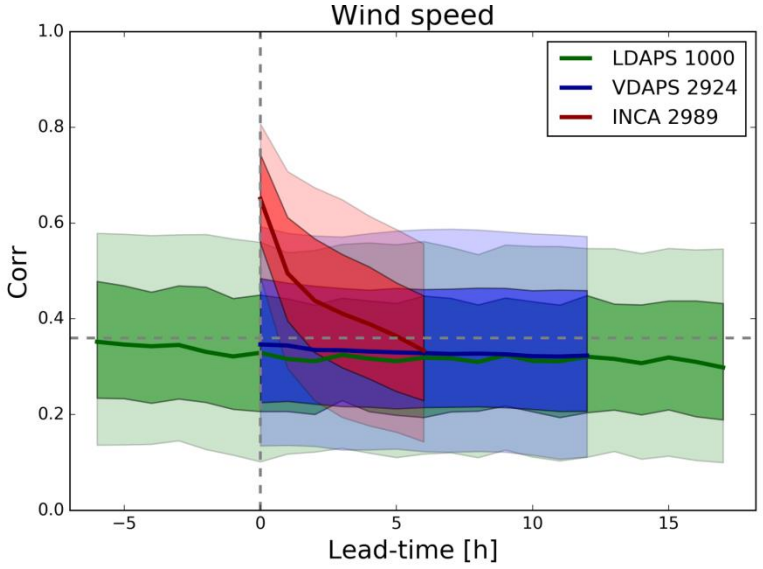
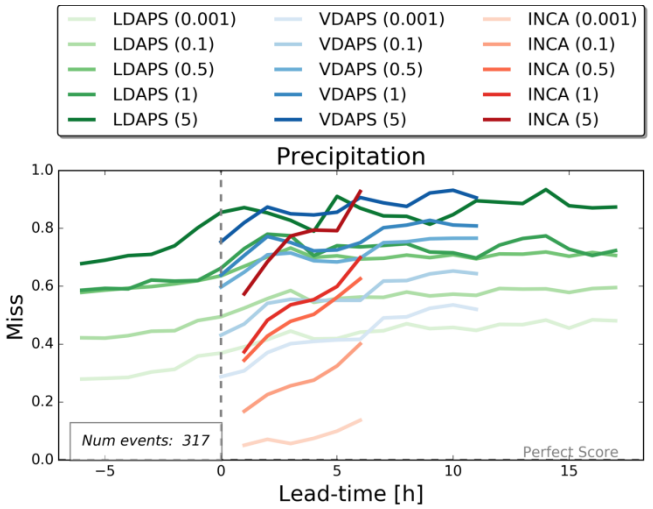
Verification Jan 2017 – Sept 2017









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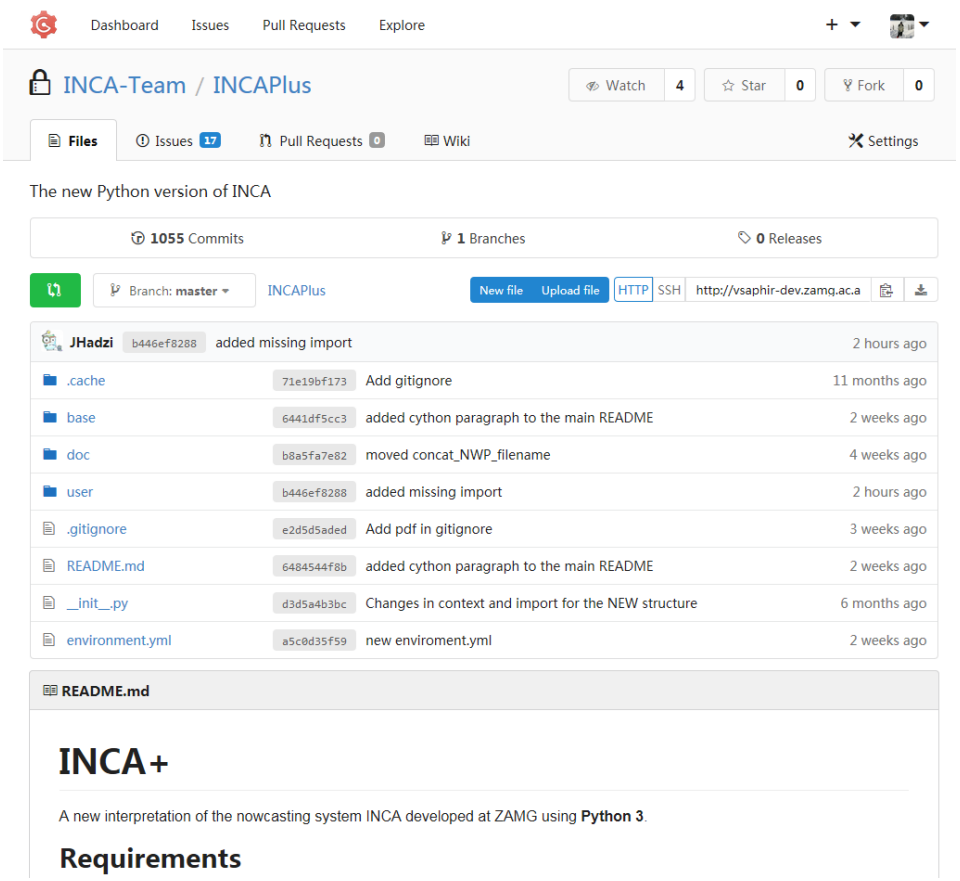
INCA code revision

- 2005-2018: Old code has become increasingly hard to handle
- Basic decisions, assumptions, code fragments unknown or hard to retrace
- C, f90, f77, ksh, csh, sh, GMT, R
- Very specific data formats
- Multiple interfaces
- Hard to apply changes, handle requests, answer questions

- New Code in Python 3
- New precipitation methodology and code
- Code rewritten for all other paramters
- Operational version == „Export version“
- Version control and documentation



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New Precipitation Analysis, Nowcasting and NWP Blending

- Set projection, destination grid, radar grid
- Retrieve raingauge data from database
- Interpolate raingauge data to destination grid

- Enhanced data quality control (including lightning data)
- Compute station density

- Interpolate radar data to destination grid
- Radar QC
- Compute minimum beam height

- Merge raingauge and radar data based on station density and minimum radar beam height

- Motion vectors derived from optical flow
- Remapping of motion vector field on to current analysis

- Blending of Nowcasts into a weighted combination of NWP models („OPT-Forecast“)

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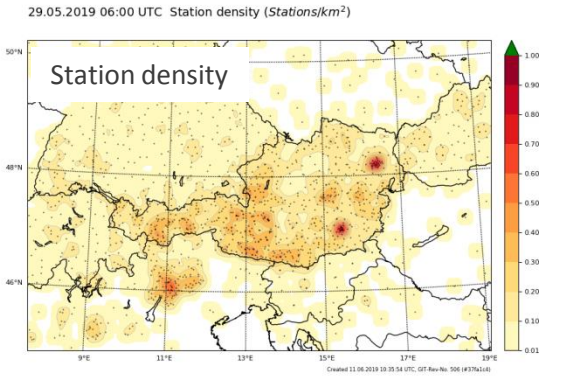
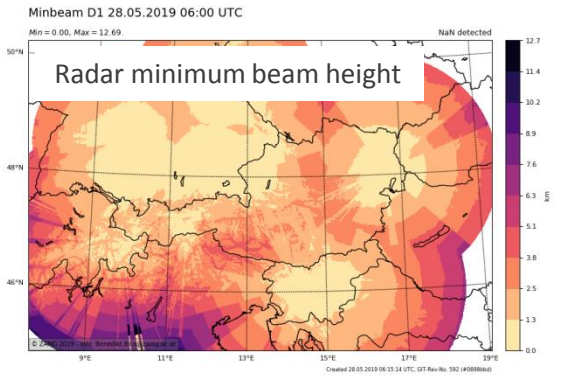
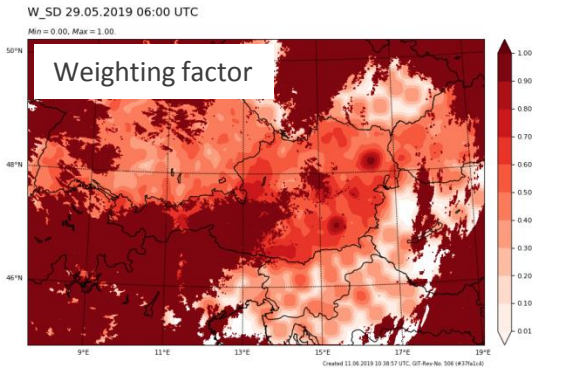
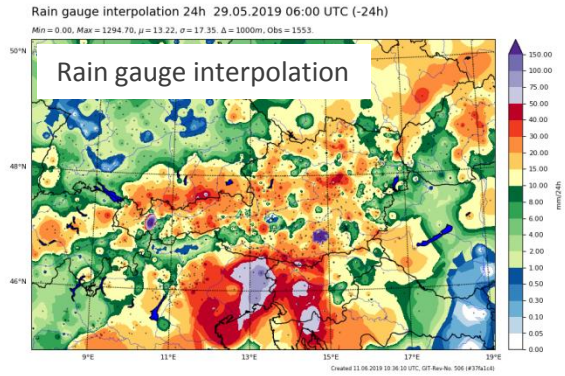
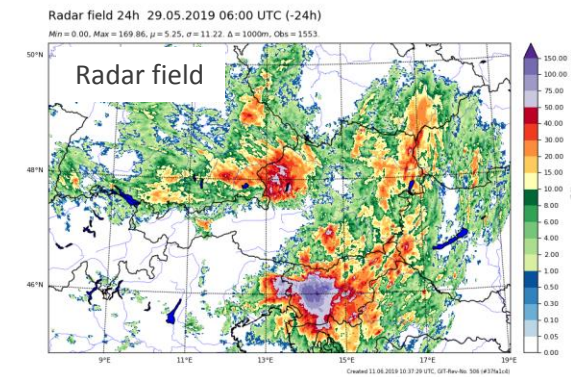
Radar – raingauge merging

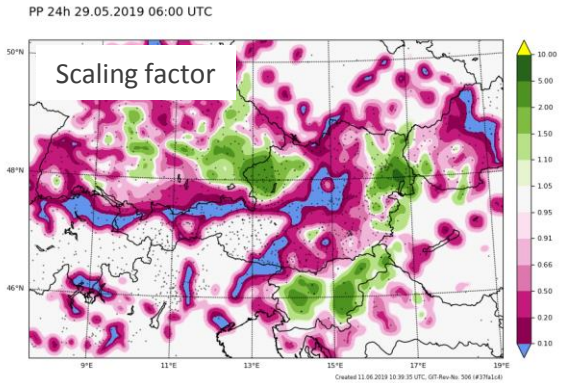


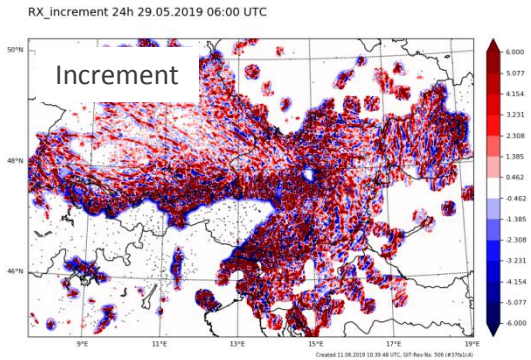


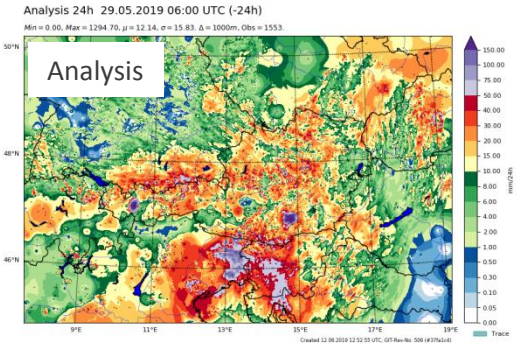












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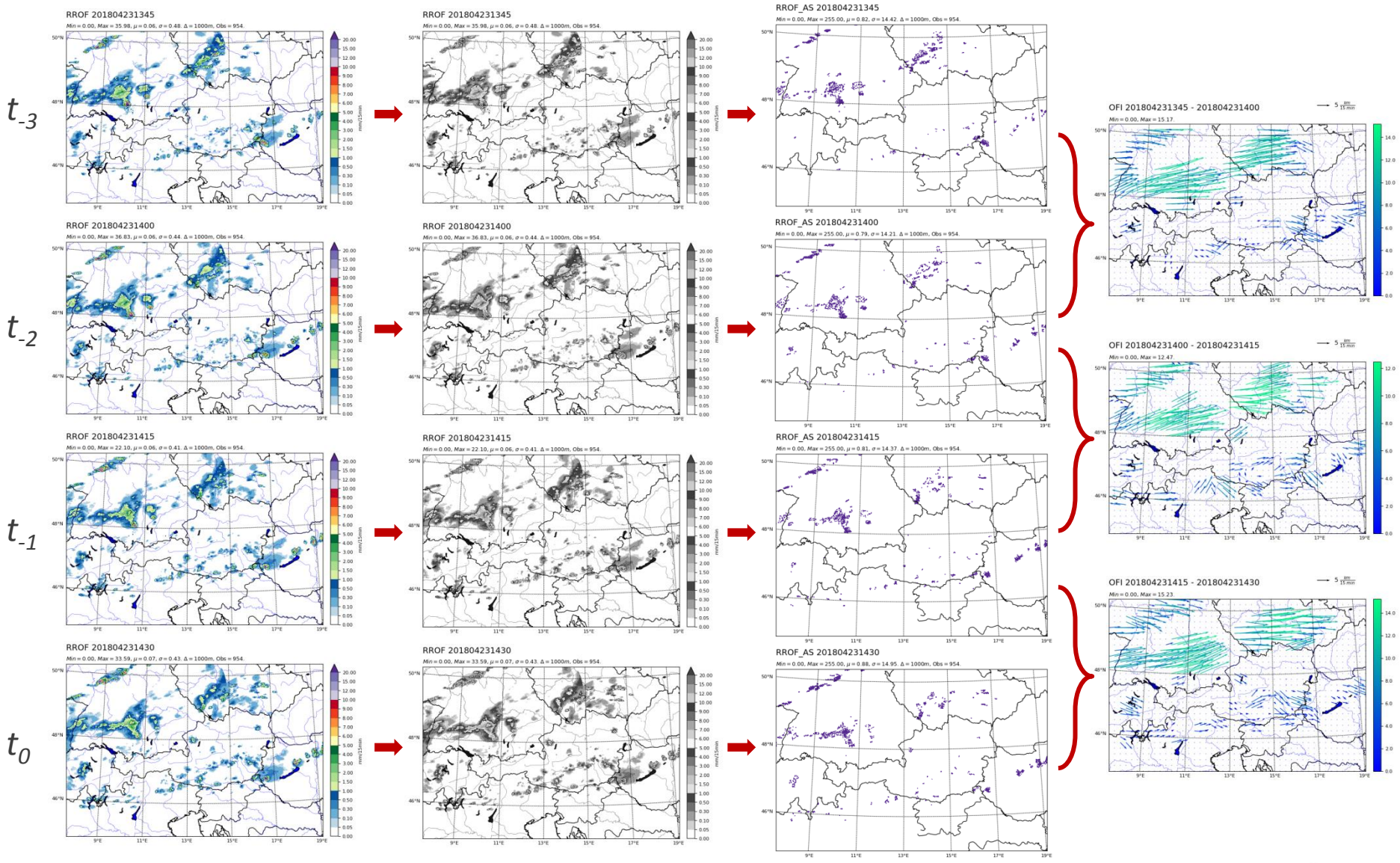
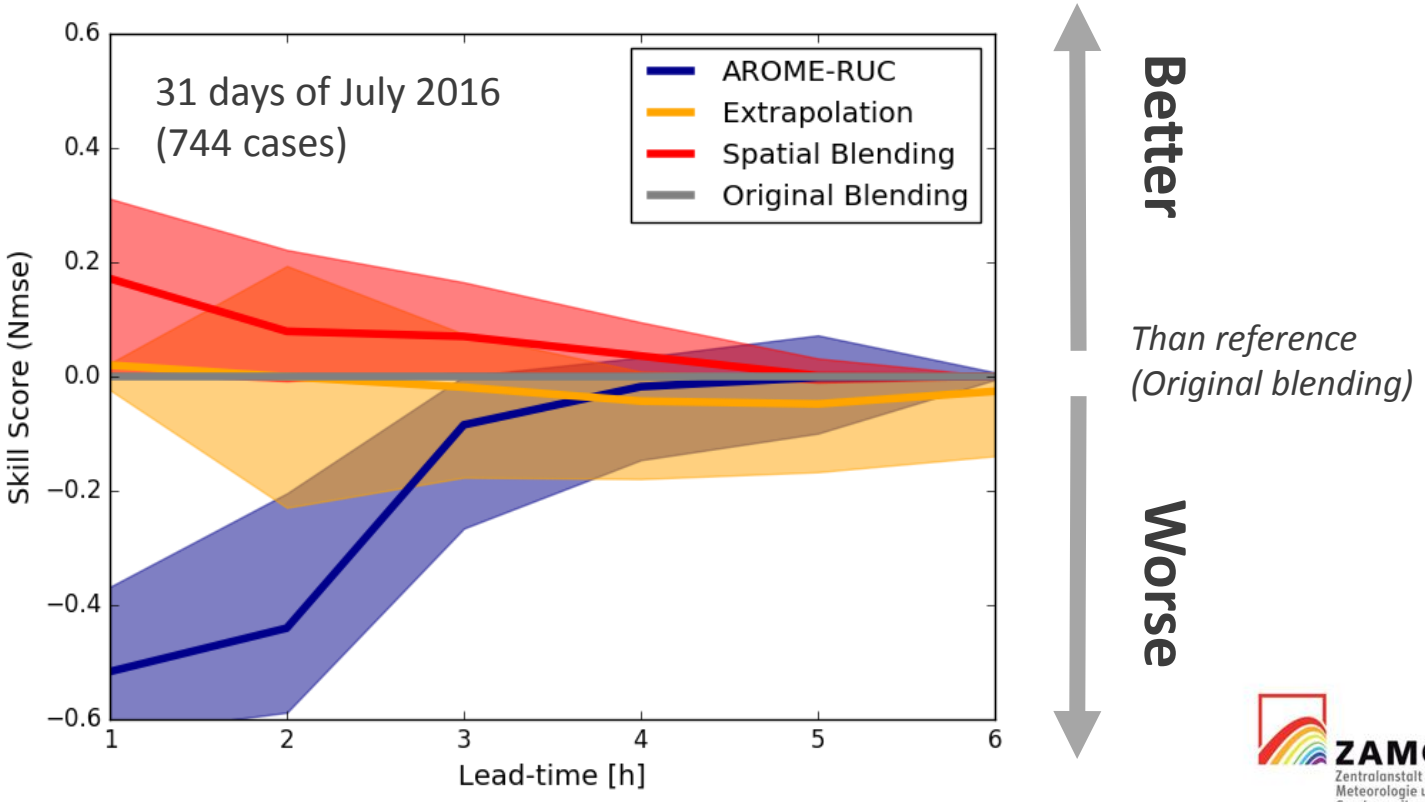
Optical flow nowcasting



NWP Blending

New SPATIAL blending: The previous error distribution and location are extrapolated into future time steps to compute the weights in a more advanced way.

- The distribution of values is closer to the observed one due to the different weights
- The weight is location-dependent and the nowcasting can still be present in later lead-times.



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Status quo and outlook

- Models operated at ZAMG in 2020:
  - Deterministic: AROME, AROME-RUC
  - Probabilistic: C-LAEF

- Short range (deterministic and probabilistic): INCA
- INCA is part of the model chain, aiming at adding value to the first few hours of lead time

- A new system is being developed, implementation in 2020
- New methodology for precipitation:
  - new data management, new QC
  - new analysis algorithm based on station density and radar minimum beam height
  - new nowcasting algorithm based on OF
  - new spatial blending
  - arbitrary domain, projection and resolution
  - Currently running for 5min, 10min, 15min, 1h, 24h temporal resolutions

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