ExOb Seminar
06. Sept, 2021

MIA (UL): Improving High-Impact Numerical Weather Prediction with Lidar and Drone Observations (Leuenberger et al.)

TN: Talk DA/REA Symposium

LP: Talk EMS

& further org. aspects…

ExOb outing day

Improving High-Impact Numerical Weather Prediction with Lidar and Drone Observations (Leuenberger et al.)

https://doi.org/10.1175/BAMS-D-19-0119.1

Examples from
- Severe convection (pre-conv. Environment)
- Fog forecasting

→ References why PBL obs. important, especially for convective-scale NWP

Goals:
- Present: obs. to fill observation „gap“: Raman lidar and UAVs
- Demonstrate: improvement for convective-scale NWP forecasts of high-impact weather

↓

MeteoSwiss: COSMO (2.2 km) with KENDA (40 ensembles)

Table 1. List of WMO OSCAR requirements for the lower troposphere and global/high-resolution NWP application areas. Each parameter has three requirement levels: goal (G), breakthrough (B), and threshold (T) (see text for an explanation).

Variable	Application area	Level	Uncertainty	Horizontal resolution	Vertical resolution	Observation cycle	Timeliness
Temperature	Global NWP	G	0.5 K	15 km	0.3 km	60 min	6 min
		B	1 K	100 km	1 km	6 h	30 min
		T	3 K	500 km	3 km	24 h	6 h
Humidity	Global NWP	G	2%	15 km	0.3 km	60 min	6 min
		B	5%	50 km	1 km	6 h	30 min
		T	10%	250 km	3 km	12 h	6 h
Wind	Global NWP	G	1 m s^{-1}	15 km	0.5 km	60 min	6 min
		B	3 m s^{-1}	100 km	1 km	6 h	30 min
		T	5 m s^{-1}	500 km	3 km	12 h	6 h
Temperature	High resolution NWP	G	0.5 K	0.5 km	0.1 km	15 min	15 min
		B	1 K	2 km	0.25 km	60 min	30 min
		T	3 K	10 km	1 km	6 h	2 h
Humidity	High resolution NWP	G	2%	0.5 km	0.1 km	15 min	15 min
		B	5%	5 km	0.2 km	60 min	30 min
		T	10%	20 km	1 km	6 h	2 h
Wind	High resolution NWP	G	1 m s^{-1}	0.5 km	0.1 km	15 min	15 min
		B	2 m s^{-1}	2 km	0.2 km	60 min	30 min
		T	5 m s^{-1}	10 km	0.4 km	12 h	2 h

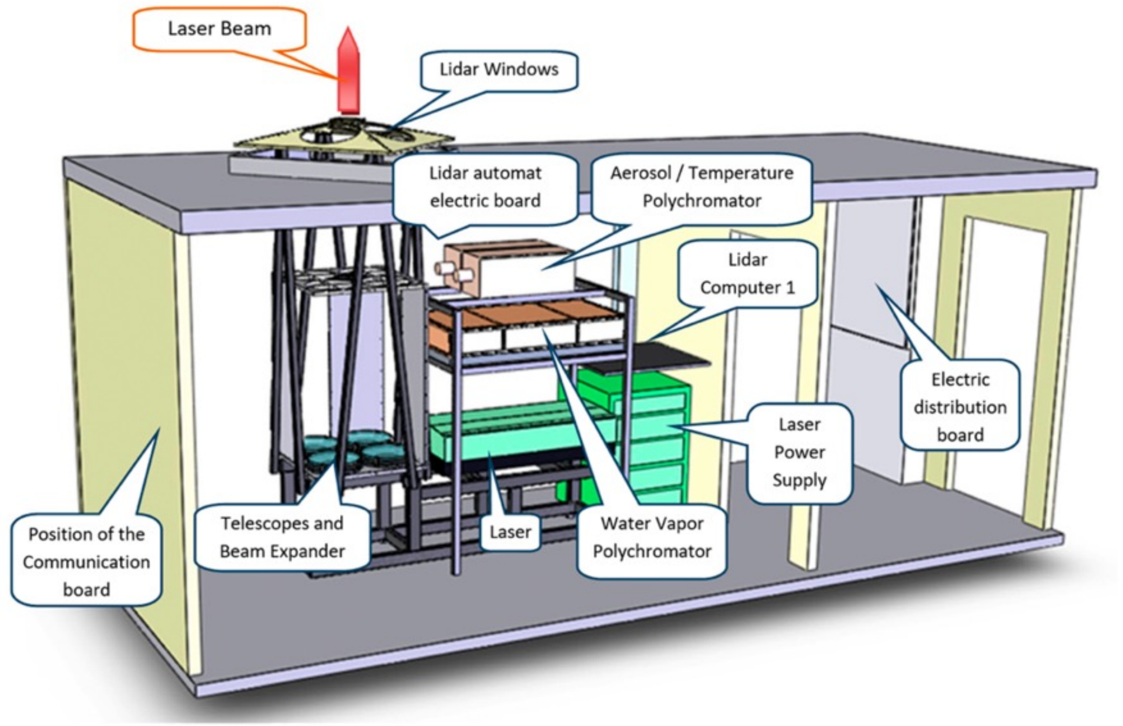


Fig. 1. Schematic picture of the Raman lidar for Meteorological Observations (RALMO) with its main elements (adapted from Dinoev et al. 2013).

RALMO @ Payerne & O-B statistics

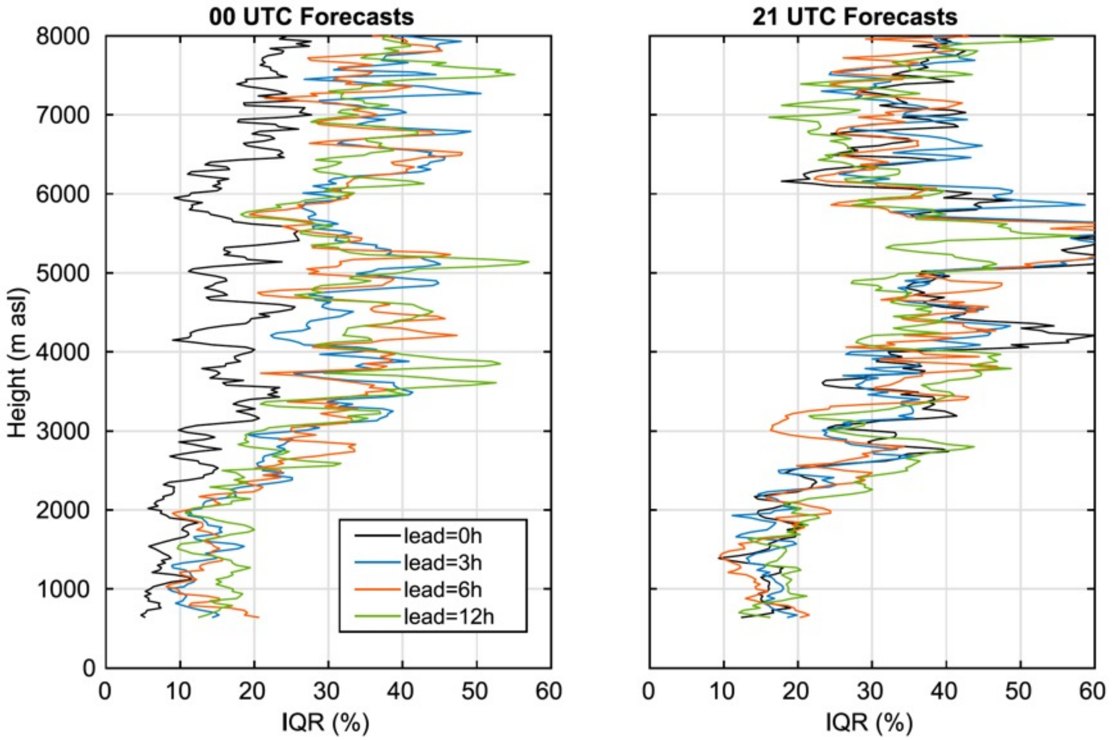
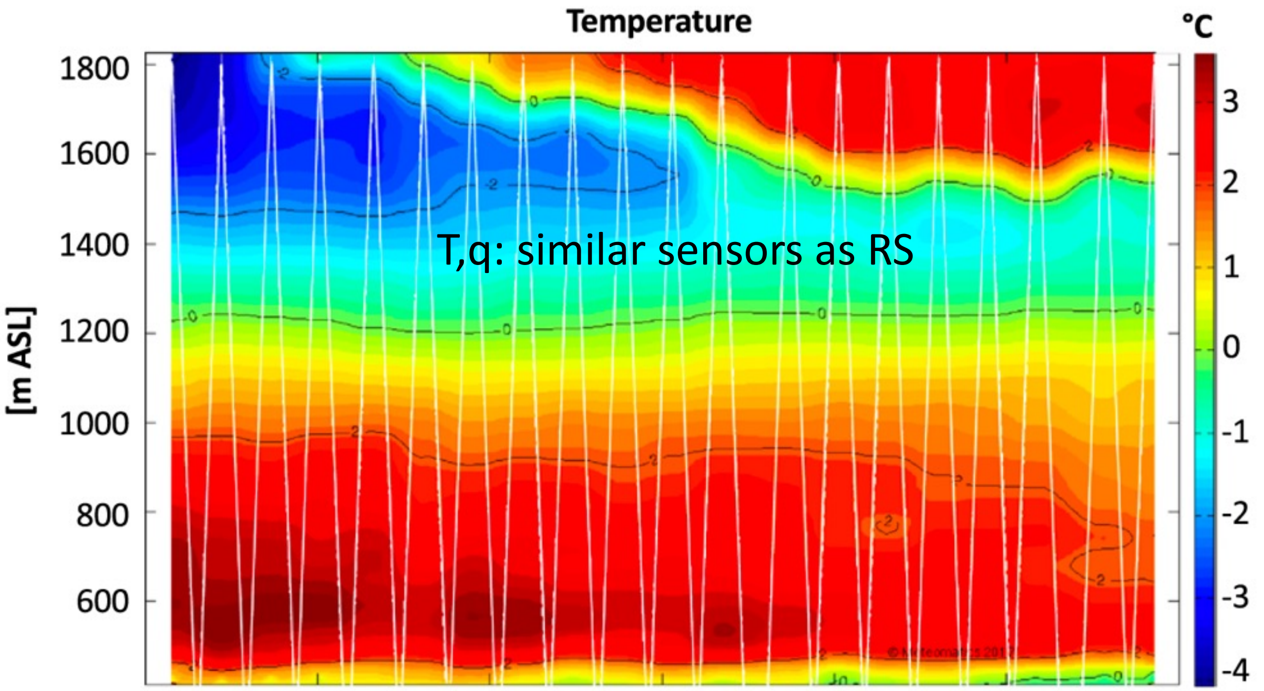
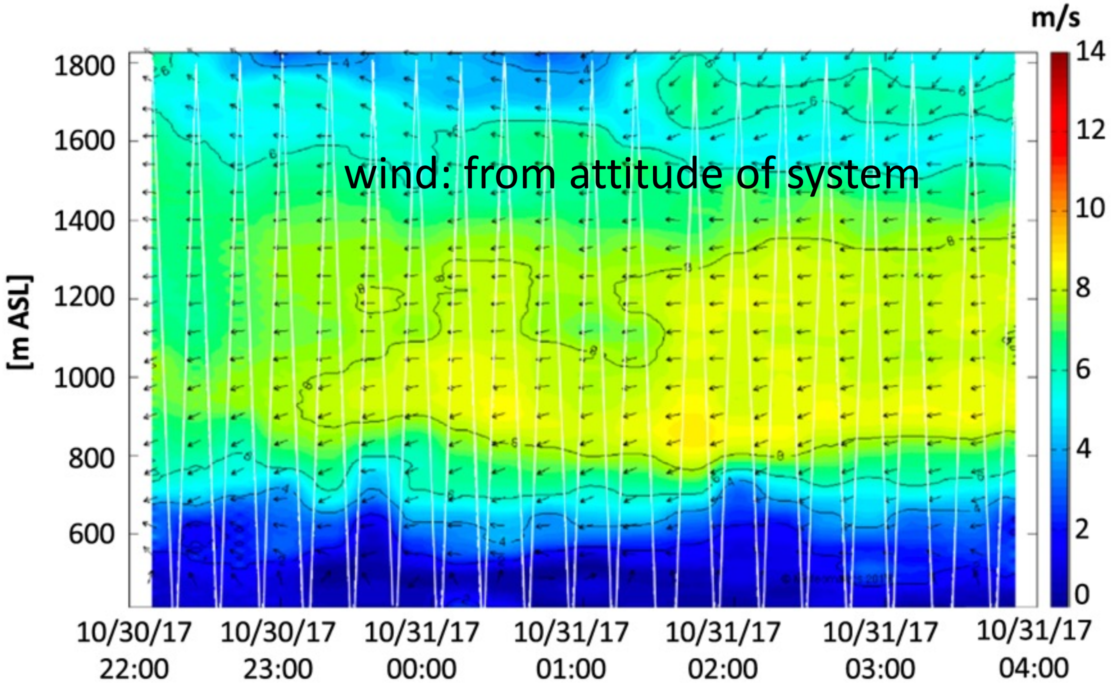


Fig. 3. Normalized interquartile range of observation minus model differences for specific humidity for forecasts initialized at (left) 0000 UTC and at (right) 2100 UTC and for lead times 0 (analysis), 3, 6, and 12 h. The interquartile range has been normalized to the average modeled specific humidity and the statistics were obtained from a period of 31 days starting on 1 Jul 2019.

Meteodrones: BVLOS mode, up to 3 km (6 km planned), each launch with NOATM

Fig. 5. Meteobase: The recently developed, fully automated launch and recharge system for the Meteodrones. The UAVs fly straight up, take their measurements, and land on the base for recharging via a connector.





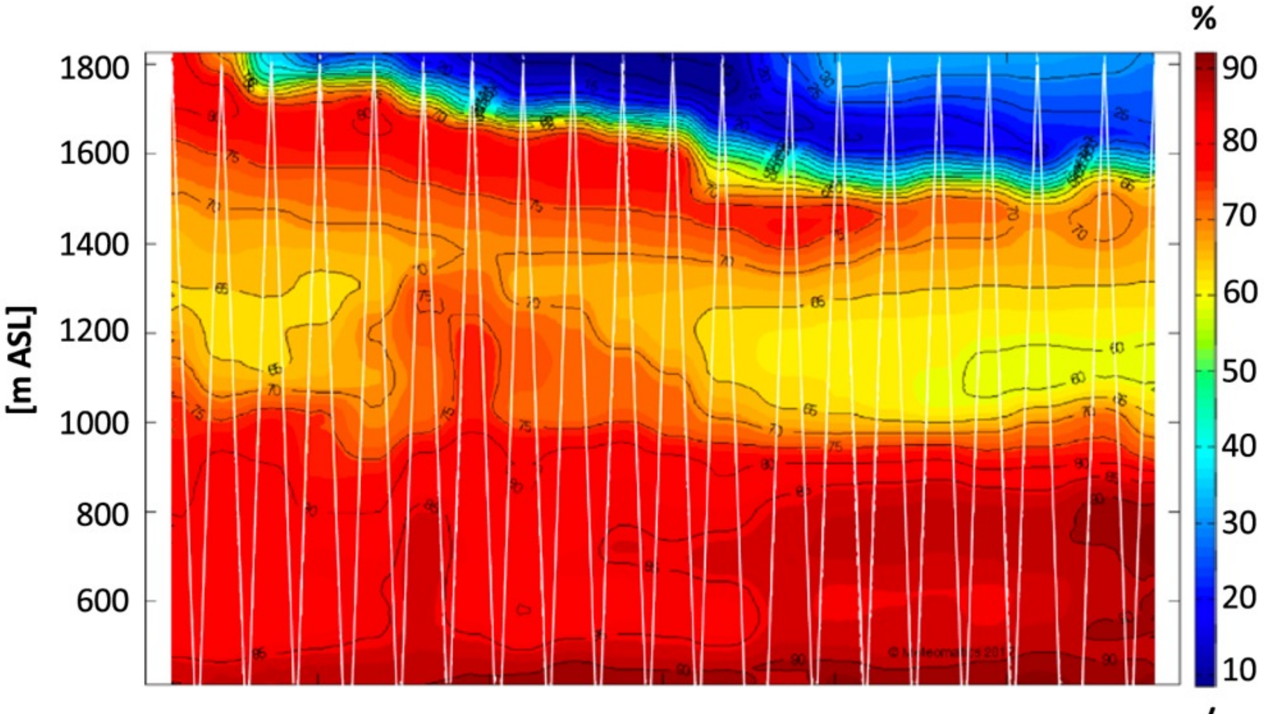


Fig. 6. Example of a Meteodrone observation time series: (top) temperature, (middle) relative humidity, and (bottom) wind speed and direction evolution in Amlikon, Switzerland, during the night of 30–31 Oct 2017. A temperature inversion at 1,200–1,800 m ASL, high relative humidity, and weak winds favored fog development in the PBL.

- PBL profile every 20min
- Breakthrough requirements in PBL met

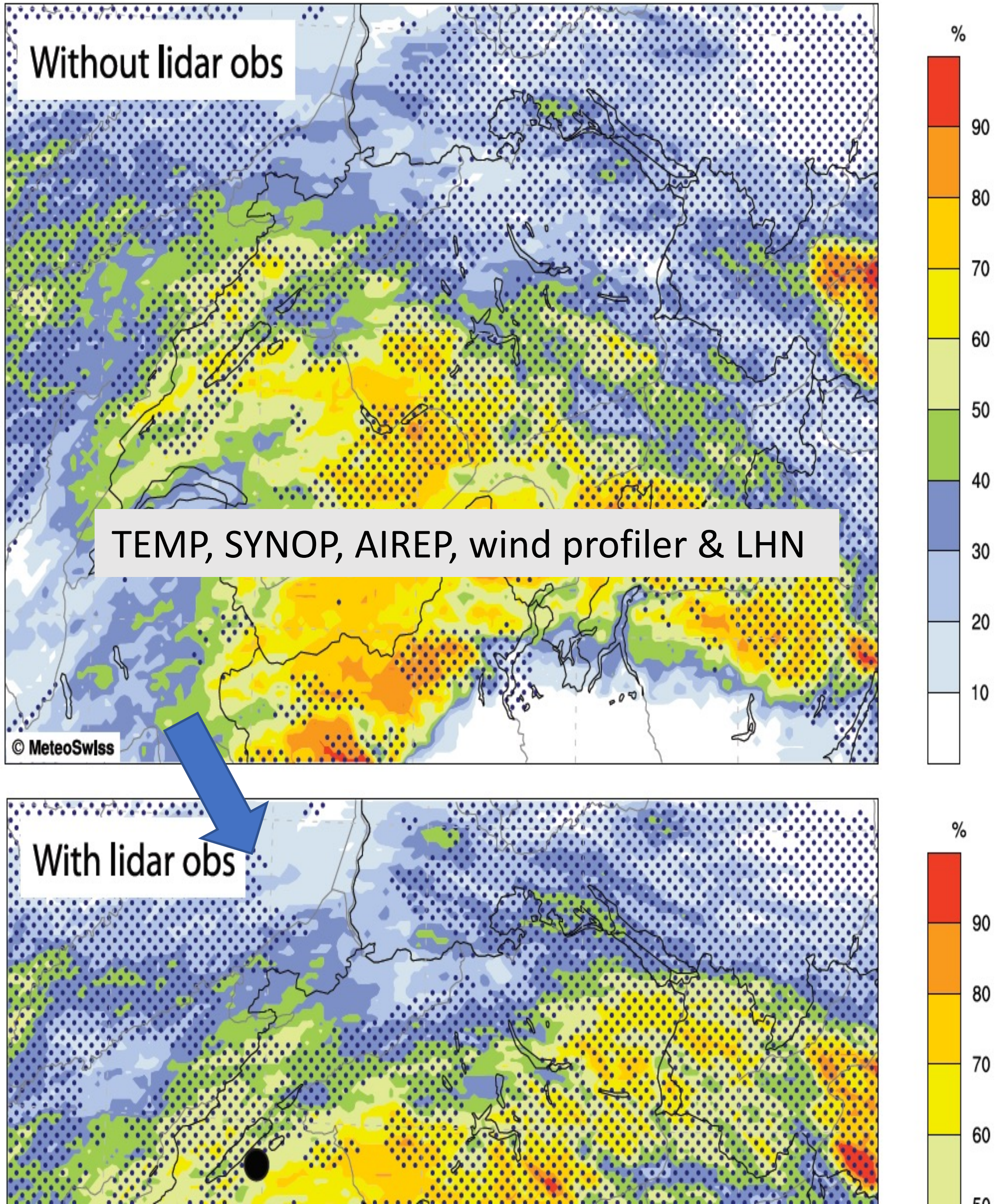
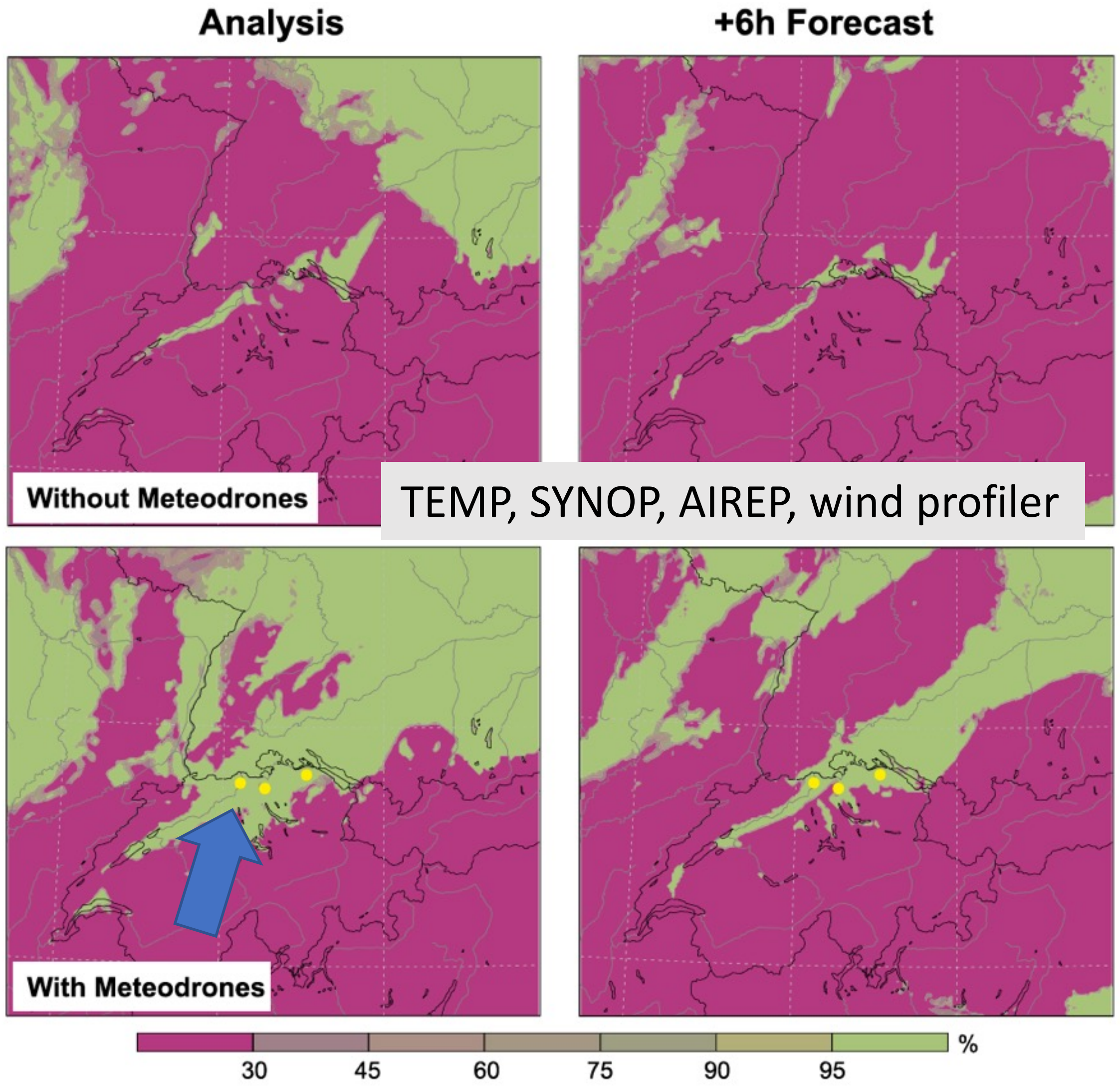


Fig. 7. Forecasted probability of the 24-h accumulated precipitation ending at 0000 UTC 9 Jul 2017 to exceed 1 mm 24 h^{-1} (color shading). Stippled shading denotes regions where the observed precipitation exceeds 1 mm 24 h^{-1}. Top (bottom) panel shows the forecast without (with) lidar observations included. A good forecast is characterized by a high probability in the stippled areas. The measurement location of Payerne is marked with a black dot in the lower panel. The forecast with lidar measurements assimilated has a better agreement of high probabilities and observed precipitation, than the one without lidar data.

Convective case, SW flow with cold front passage, locally severe 24h precip.



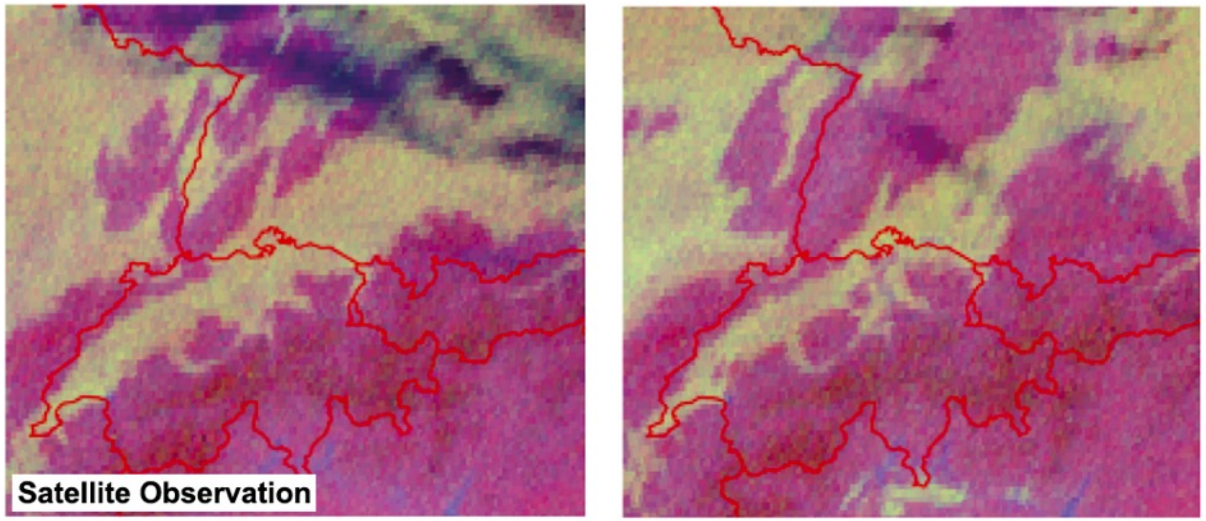


Fig. 8. Cloudiness at (left) 0000 UTC and (right) 0600 UTC 7 Dec 2017 from the COSMO ensemble mean (top) without and (middle) with the assimilation of Meteodrone observations. (left) Analysis time, and (right) +6-h forecast time. (bottom) Corresponding cloudiness as observed by satellite. Bright colors denote cloudy, purple colors cloud-free regions. The measurement locations of the Meteodrones are marked with yellow dots on the middle panels. The forecasts with Meteodrone observations assimilated shows a clearly improved cloud distribution at both, analysis and +6-h forecast time, compared to that without Meteodrone observations.

Winterly high-pressure system, two hourly assimilation cycles with drones from 22:00-0:00 UTC, six locations in 60x60 km^2 area, **drones cooling and moistening PBL**

Some statements from the summary:

For lidars, the arrival of diode pumped lasers for Raman applications (Lange et al. 2019) and frequency stabilized diode lasers for elastic applications (Spuler et al. 2015) are about to bring automated systems to a maturity level that makes them fit for network applications. We expect acquisition costs of a Raman lidar device to be on the order of \$100,000 to \$500,000 (U.S. dollars) depending on system performance and annual operating costs on the order of \$10,000 to \$50,000.

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UAVs are still a very young technology and flight regulations differ from country to country, so far hindering the establishment of a broad network. An important step toward harmonization of regulations in Europe was made by the European Union Aviation Safety Agency (EASA) with the aim of a common ground across Europe. Besides, the UAV community is on a steep learning curve concerning the technology and the variety of applications (e.g., Chilson et al. 2019). Another challenge for an UAV network is the ability for an automatic operation. The Meteobase described above is an important step toward an operational application of UAV in meteorology. The estimated costs for the automated systems are on the order of \$100,000 per Meteobase and year, including hardware and operation costs.

The design of a future network of lidars and drones depends on a variety of factors, such

Chilson, P. B., and Coauthors, 2019: Moving towards a network of autonomous UAS atmospheric profiling stations for observations in the Earth's lower atmosphere: The 3D mesonet concept. *Sensors*, **19**, 2720, https://doi.org/10.3390/s19122720.

Cooney, J., 1972a: Measurement of atmospheric temperature profiles by Raman

OSSEs with drones

Some more organizational aspects

- This week: EMS (Wednesday session)
- Next week DA/REA symposium: https://symp-bonn2021.sciencesconf.org/
- Tomorrow: AWARES seminar (Chile, Jose)
- Working in presence: discussion rounds, seminar in semester
- Update Inferno “Waschzettel” (working guide) to ExOb (TN)
- Thematic seminars: KENDA, Lidar, … other?