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Towards the Assimilation of KITcube data in COSMO-KENDA

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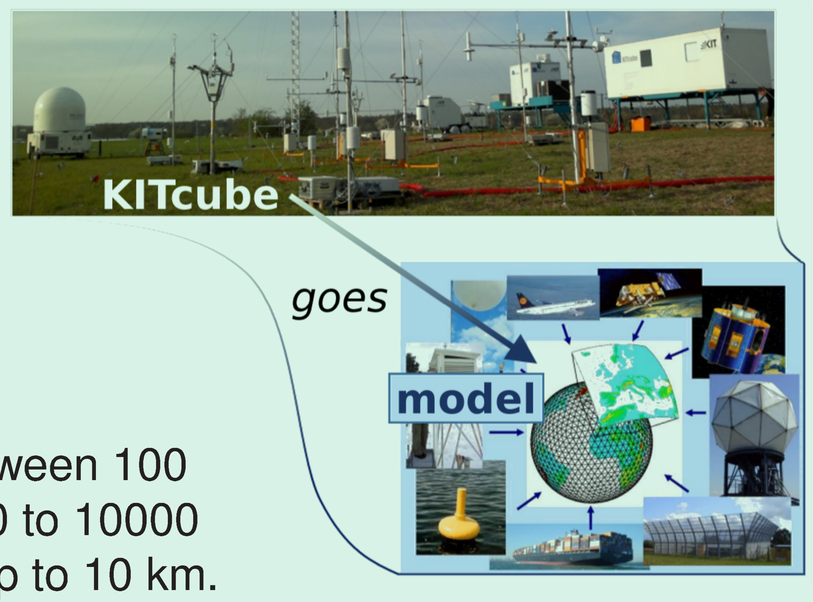
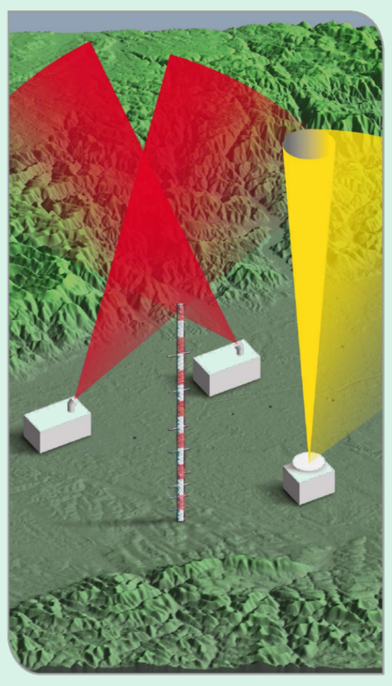
Introduction

- Including a suite of remote sensing instruments such as cloud and precipitation radars and Doppler lidars, the KITcube allows temporally and spatially highly resolved measurements within a volume of about 10 × 10 × 10 km^3.
- In simulations with grid spacings between 100 and 1000 m, KITcube data cover 100 to 10000 horizontal grid points and all levels up to 10 km.





(Corsmeier et al. 2010)

- The combination of measurements and simulations with such high resolutions allows for new insights into and a better understanding of the processes on these scales.
- The recent development of the Kilometer-Scale Ensemble Data Assimilation (KENDA) for COSMO at the German Weather Service offers a great opportunity to integrate KITcube data into this system.
- An ensemble Kalman filter (KENDA-LETKF) provides 40 ensemble states, complemented by a deterministic simulation → 40 + 1 members.
- KENDA enables the usage of high-resolution observations (cloud, precipitation, etc.) for convective-scale simulations.

KITcube Instrumentation

- KITcube is a portable measurement platform.
- High-quality measurements from field campaigns, e.g., HyMeX: Mediterranean, 2012 HEADS: Dead Sea, 2014 DACCIWA: West Africa, 2016

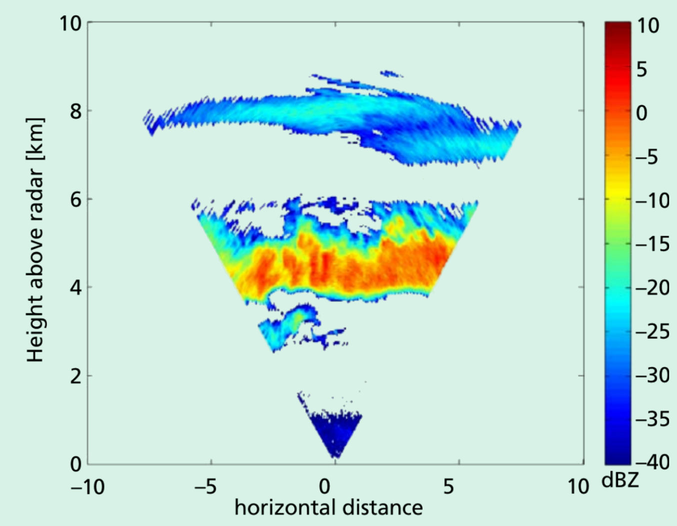


Figure 1: Example for reflectivity measured by cloud radar (Corsmeier et al. 2010).

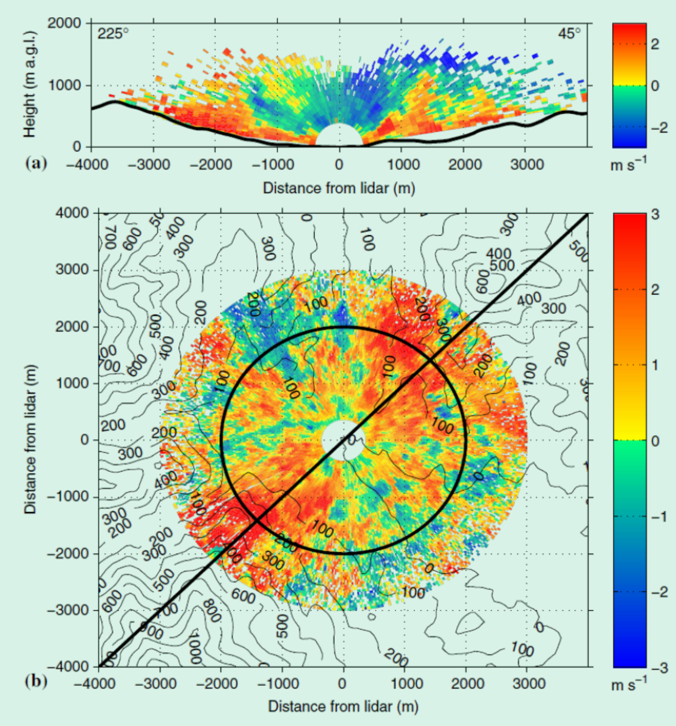


Figure 2: Examples for radial velocity (a) and radial velocity minus mean radial velocity during azimuthal scan at 10° elevation angle (b) measured by wind lidar. (Adler & Kalthoff 2014)

Device (Manufacturer)	Quantity	Derived parameters	Temporal resolution of derived parameters (raw data)	Measurement heights (m AGL)
Surface energy exchange and near-surface observations				
Energy balance stations (Different manufacturers)	2	Temperature	10 min (1 s)	3
		Humidity	10 min (1 s)	3
		3-d wind	10 min (0.05 s)	4
		Humidity	10 min (0.05 s)	4
		Temperature	10 min (0.05 s)	4
		Air pressure	10 min (1 s)	0.1
		Precipitation	10 min	1
		Radiation temperature of surface	10 min (1 s)	0
		Solar and reflected irradiance	10 min (1 s)	3
		Long wave incoming and outgoing radiation	10 min (1 s)	3
		Sensible and latent heat and momentum fluxes	30 min (0.05 s)	4
		Soil heat flux	10 min (1 s)	−0.05
		Soil moisture	10 min	4 variable depths
		Soil temperature	10 min	4 variable depths
Flux stations (Different manufacturers)	7	Temperature	10 min (1 s)	1, 2, 4
		Humidity	10 min (1 s)	1, 2, 4
		3-d wind	10 mm (0.05 s)	5
		Temperature	10 min (0.05 s)	5
		Air pressure	10 min (1 s)	0.1
		Sensible heat and momentum fluxes	30 min (0.05 s)	5
Scintillometer (Scintec)	1	Sensible heat flux	1 min	2–3
20-m tower (Different manufacturers)	1	Temperature	10 min (1 s)	0.5, 1, 2, 4, 8, 16, 19
		Humidity	10 min (1 s)	0.5, 1, 2, 4, 8, 16, 19
		Wind speed	10 min (1 s)	0.5, 1, 2, 4, 8, 16, 19
		Wind direction	10 min (1 s)	20
		Temperature	10 min (0.05 s)	20
		Soil temperature	10 min (1 s)	0.02, 0.04, 0.08, 0.16, 0.32, 0.64
		3-d wind	10 min (0.05 s)	20
		Sensible heat and momentum fluxes	30 min (0.05 s)	20
Mobile towers (Young)	3	Temperature	10 min	2
		Humidity	10 min	2
		3-d wind	0.03 s	4
		Temperature	0.03 s	4
		Air pressure	10 min	1
		Precipitation	10 min	1
		Sensible heat and momentum fluxes	30 min (0.03 s)	4
Mean and turbulent atmospheric conditions				Measurement range (m)
Radiosonde system (Graw)	2	Temperature	2–8* (1 s)	0:x:15000
		Humidity	2–8* (1 s)	0:x:15000
		Wind velocity and direction	2-8* (1 s)	0:x:l5000
Microwave radiometer (Radiometer Physics)	1	Temperature	10 s	0:50:1200, 1200:200:5000, 5000:400:10000
		Humidity	10 s	0:200:2000, 2000:400:5000, 5000:800:10000
		IWV	10 s	–
		LWP	10 s	–
		Infrared temperature	10 s	–
GPS receiver (JAVAD)	1	IWV	15 min	–
Sodar (Scintec)	1	Wind velocity and direction	30 min	30:10:1000
		Vertical velocity variance	30 min	30:10:1000
Wind lidar, WindTracer (Lockheed Martin)	2	Radial velocity	0.1–1 s	375:x:12000
		Aerosol backscatter	0.1–1 s	375:x:12000
		Wind velocity and direction	scan dependent	75:50:8475
Wind lidar, Windcube (Leosphere)	1	Radial velocity	1.6 s	40:20:600
		Wind speed and direction	10 min (7 s)	40:20:600
Measurements of clouds and precipitation properties				
Cloud camera (Mobotix)	2	Hemispheric photo	2 min	–
Cloud radar (Metek)	1	Radial velocity	1–10 s	150:30:14460
Ceilometer (Jenoptik)	1	Cloud base heights	1 min	150:15:15000
X-band radar (Gematronik)	1	Precipitation	5 min	125:250:100000
Micro rain radar (Metek)	1	Precipitation, Drop size distribution	1 min, 1 min	100:100:3200, 100:100:3200
Disdrometer (KIT)	1	Precipitation, Drop size distribution	1 min, 1 min	1, 1
Disdrometer (Distromet)	1	Precipitation, Drop size distribution	1 min, 1 min	0.1, 0.1
Rain gauge (EML)	2	Precipitation	1 min	1

*height dependent

Table 1: Measurement systems included in KITcube and main derived parameters, typical settings, and measurement ranges of instruments. The measurement range column includes the minimal and maximal distance and spatial resolution. (Kalthoff et al. 2014)

Conclusions & Next Steps

- KITcube provides high-resolution measurements from field campaigns.
- KITcube's SYNOP and TEMP data can now be assimilated by COSMO.
- The assimilation improves the simulation of near-surface data.

- Automatic data conversion for more instruments (e.g., GPS, wind profiler).
- Development/usage of new forward operators for "non-standard" instruments (e.g., wind lidars, cloud and X-band radars).
- Use KENDA for ensemble data assimilation.
- Assimilated forecasts during field campaigns (DACCIWA in summer 2016).

Status Quo

- First test data set: HOPE field campaign in Jülich in April 2013
- Automatic conversion of measurements to COSMO-readable "Observation Input Files" (`cdfin`-files) is ready for SYNOP and TEMP data.
- First simulations are performed with and without assimilating surface data (PS, T2M, TD2M, V10M) for 24.-27. April 2013 with COSMO's standard DA and the nesting setup shown in Figure 3.

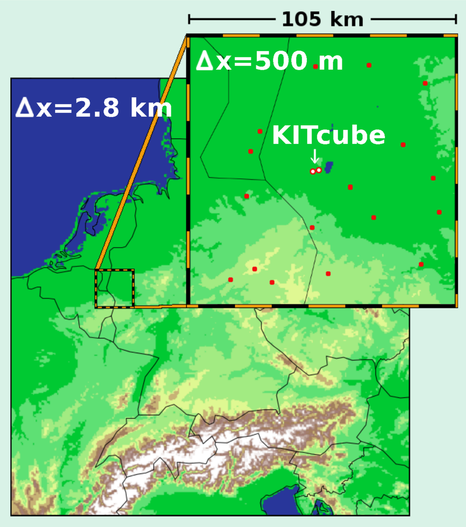


Figure 3: Model domains with SYNOP and KITcube stations.

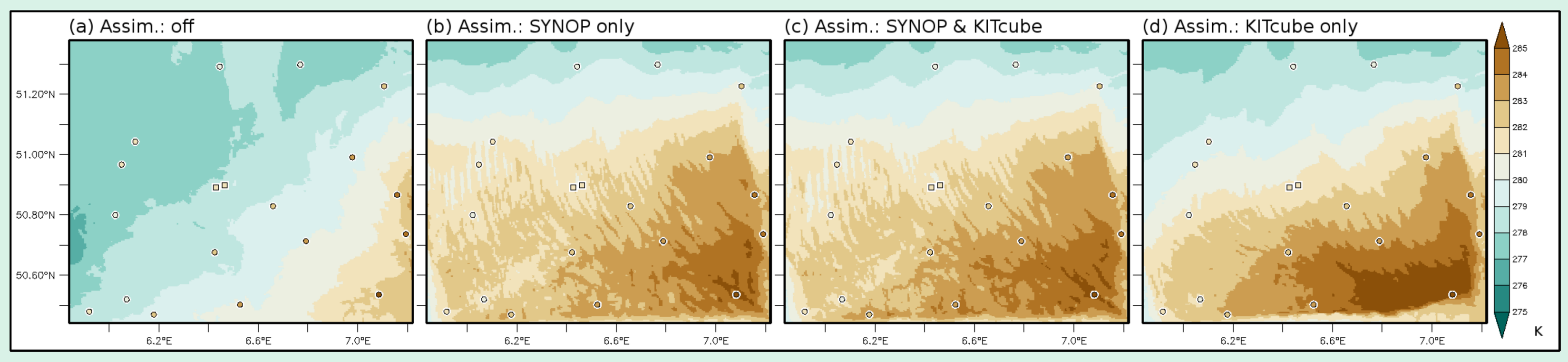


Figure 4: 2 m dew-point temperature at forecast hour 63. Dots show SYNOP, squares KITcube stations used for assimilation.

- Assimilation increases mean dew-point temperature by about 2° C (Fig. 4).
- The difference between assimilating all data or only SYNOP or KITcube data, respectively, is comparable small (about 0.2° C on average, Fig. 4).

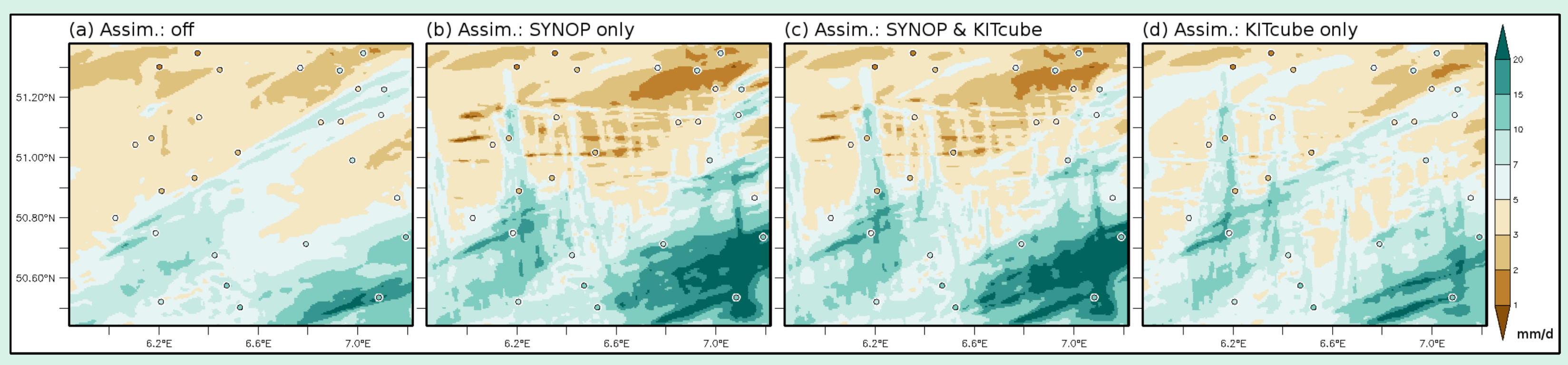


Figure 5: 24 h accumulated precipitation at 27. April, 06 UTC. Dots show measured precipitation by SYNOP stations.

- Assimilating SYNOP data causes increased (decreased) precipitation in the southeastern (northeastern) part of the model domain (Fig. 5).
- These patterns are similar when assimilating only KITcube data but the impact is smaller (Fig. 5).
- Comparison with the SYNOP observations in Figure 6 reveals smaller RMSE of the 2 m dew-point temperature in the assimilated simulations.
- This comparison is not independent for simulations with assimilation of SYNOP stations, which have the smallest RMSE.
- Assimilation of only KITcube data also shows a positive effect, i.e., reduced RMSE.
- Effect of assimilating SYNOP data and KITcube data additionally is small.

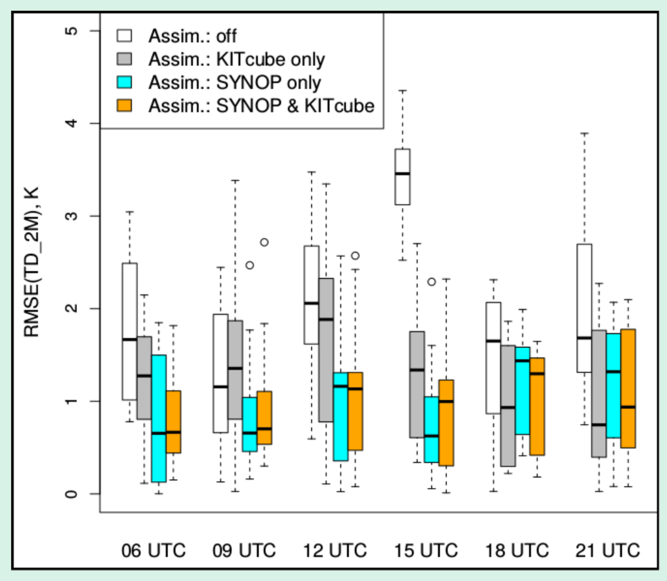


Figure 6: RMSE of 2 m dew-point temperature on 26. April for all 17 SYNOP stations inside the COSMO domain.

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