Lidar-based Water Vapor, Temperature and Wind Measurements with Turbulence Resolution during the EUREC4A Field Campaign onboard R/V Merian



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Modular Observation Solutions for Earth Systems











EUREC4A (ElUcidating the RolE of Clouds-Circulation Coupling in Climate)



- Campaign timeframe: 20 Jan. 2020 20 Feb. 2020
- R/V Maria S Merian departed from Barbados on 17 Jan. 2020, and came back on 20 Feb. 2020
- More info: <u>http://eurec4a.eu/index.php?id=4201&L=0</u>





Credits: <u>http://eurec4a.eu/index.php?id=5154</u>

Bony, S., Stevens, B., Ament, F. et al. EUREC4A: A Field Campaign to Elucidate the Couplings Between Clouds, Convection and Circulation. Surv Geophys 38, 1529–1568 (2017). <u>https://doi.org/10.1007/s10712-017-9428-0</u>



Lange et.al. EGU 2020 - EUREC4A



EUREC4A (ElUcidating the RolE of Clouds-Circulation Coupling in Climate)



Instruments involved:

- → ARTHUS (Atmospheric Raman Temperature and Humidity Sounder)
 - UV Raman lidar:
 - Lange et.al. GI4.2, Display D719 EGU2020-12164, Thursday, 7 May 2020 14:00 15:45 https://doi.org/10.5194/egusphere-egu2020-12164
 - Observes temperature, moisture, aerosol particle backscatter and extinction coefficients profiles over the ocean with turbulence resolution of up to 10 s and 7.5 m temporal and range resolution respectively
 - Can derive also higher-order moments of turbulent fluctuations of water-vapor mixing ratio and temperature, aerosol optical thickness, marine atmospheric boundary layer depth and cloud base
 - Geophysical Research Letters paper: <u>https://doi.org/10.1029/2019GL085774</u>

→ Doppler lidar (vertical pointing)

- Observes vertical wind, backscatter ratio, cloud base, all of them up to 1 s and 30 m temporal and range resolution respectively
- Can derive higher-order moments of turbulent fluctuations of vertical wind, TKE dissipation rate and momentum flux

→ Doppler lidar (scanning mode)

- Observes slant 6-bin profiles, backscatter profile, cloud base, LOS wind, all of them up to 1 s and 30 m temporal and range resolution respectively
- Can derive horizontal wind, wind shear

→ Synergy between instruments

• Provides Latent heat flux, molecular destruction rates of humidity variances, sensible heat flux, buoyancy, temperatura variance, molecular destruction rate of temperatura variance, correlation between water-vapor and temperature fluctuations





R/V Maria **S** Merian, instruments location









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NRE

R/V Maria S Merian Versität nomenmen



R/V Maria S Merian and some other platforms involved in EUREC4A







Preliminary results



- Given data copyrights, only preliminary results can be shown
 - → The data was not quality controlled
 - \rightarrow Its rights belongs to the authors
 - Real-Time Control: LabView Panels for all the instruments
 - → ARTHUS
 - Only temperature, water-vapor mixing ratio and backscatter ratio
 - → Vertical DL
 - Only backscatter and vertical velocity





Example case 1, ARTHUS – Vertical DL ARTHUS - 10 s, 7.5 m



ENHEIM

- 07.02.2020, 00:03 01:13 UTC (70 minutes)
- Local time: 20:03 21:13
- 1. Convective Marine Boundary Layer, with a minimum height of 300 m
- 2. Cloud layer, cloud base at around 800 m
- 3. Short rain event. Note that the lidar can observe the temperature and WV mixing ratio even while it is raining (drizzling rain)
- Red dashed box will be zoomed out in the next slide



Example case 1, ARTHUS – Vertical DL (cont.)

Vertical DL - 1 s, 30 m

ARTHUS - 10 s, 7.5 m



Example case 2, ARTHUS – Vertical DL ARTHUS - 10 s, 7.5 m



Temperature (K) Resolution: 10 s, 7.5 m 1000 m • 295.0 292.0 -289.0 -286.0 0.5 -283.0 0.3-200 m 0.2. 45 35 40 50 55 Water-vapor Mixing ratio (g/kg) 2000 m 1 16.8 12.0 ₩ 0.6--7.8 0.5--4.6 0.4 200 m 340 360 380 400 Backscatter ratio (a.u.) Resolution: 10 s. 7.5 m 2000 m 1 0.9-

0.7 ge (m)

0.5

200 m

0.4

OHENHEIM

- 07.02.2020, 12:32 13:42 UTC (70 minutes)
- Local time: 08:32 09:42
- 1. Cloud layer, cloud base at around 600 m
- Sudden change in moisture and aerosol content
- Red dashed box will be zoomed out in the next slide



-6.4

-2.8

Example case 2, ARTHUS – Vertical DL (cont.)

ARTHUS - 10 s, 7.5 m



Vertical DL - 1 s, 30 m

- Humid air mass updrafts from the ocean to the atmosphere
- After that event, there are still updrafts until a cloud is formed



Conclusions & Outlook



- First ship based campaign with ARTHUS
- Despite the "problems" we faced, like ship motion, ship vibration, high elevation of the sun over the horizon, or salty atmosphere, the lidar behaved extremely stable, so none of those issues can be seen in the data products (temperature, WV mixing ratio and backscatter ratio for now)
- The measurements were successful and our instrument concept was proven
- High resolution ARTHUS (10 s, 7.5 m) and DL (1 s, 30 m) data acquired
 - Thermodynamic measurements in the surface layer, atmospheric boundary layer and free troposphere up to the turbulence scale with very high resolution achieved, more info:
 - Behrendt et.al. GI4.2 D734 EGU2020-7191 Thursday, 7 May 2020 14:00 15:45 https://doi.org/10.5194/egusphere-egu2020-7191
- More info about ARTHUS, today afternoon:
 - Lange et.al. GI4.2, Display D719 EGU2020-12164, Thursday, 7 May 2020 14:00 15:45 <u>https://doi.org/10.5194/egusphere-egu2020-12164</u>
 - → Geophysical Research Letters paper: <u>https://doi.org/10.1029/2019GL085774</u>
- Data analysis still on going



Conclusions & Outlook (cont.)



- What comes next...
- Horizontal wind
 - → Scanning DL
- Latent heat flux, sensible heat flux, buoyancy, etc.
 - → Synergy between ARTHUS and vertical DL
- Water vapor flux inside the clouds
 - Synergy between Doppler cloud radar (Uni of Cologne) and ARTHUS in the bottom of the clouds
- Cloud microphysics such as the mean droplet radius at the cloud bottom
 - → Synergy between ARTHUS, DL, Doppler cloud radar (Uni of Cologne) and Cloudkite (MPI)
 - Acquistapace et.al. AS1.26, Display D3125 EGU2020-6265, Thursday, 07 May, 08:30 10:15 <u>https://doi.org/10.5194/egusphere-egu2020-6265</u>
- Ocean atmosphere interaction, influence of the Sea Surface Temperature (SST) over the temperature in the atmosphere, while the ship was chasing eddys
 - → Synergy with Thermosalinograph (GEOMAR)

