Comparing trade-wind cloudiness in *realistic* LES and observations shows despite a deficit of clouds at the inversion height the capability of LES to reproduce the variability of trade-wind cloudiness

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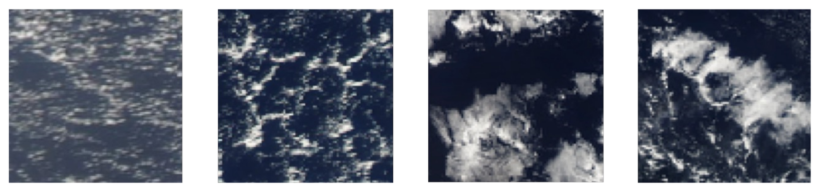
Abstract

- **Organization of shallow convection** has been identified to **influence the top-of atmosphere radiation budget** (Bony et al. (2019))
- The spatial extent and frequency of occurrence is **expected to change in a warming climate** caused by the change in environmental factors that particular shallow cloud formations favour (Schulz et al. (2021)
- Four meso-scale cloud formations of shallow convection have been identified to represent the **building blocks of the observed variability in cloudiness** in the downstream trades (Stevens et al. (2020))



Sugar *Gravel* *Flowers* *Fish*

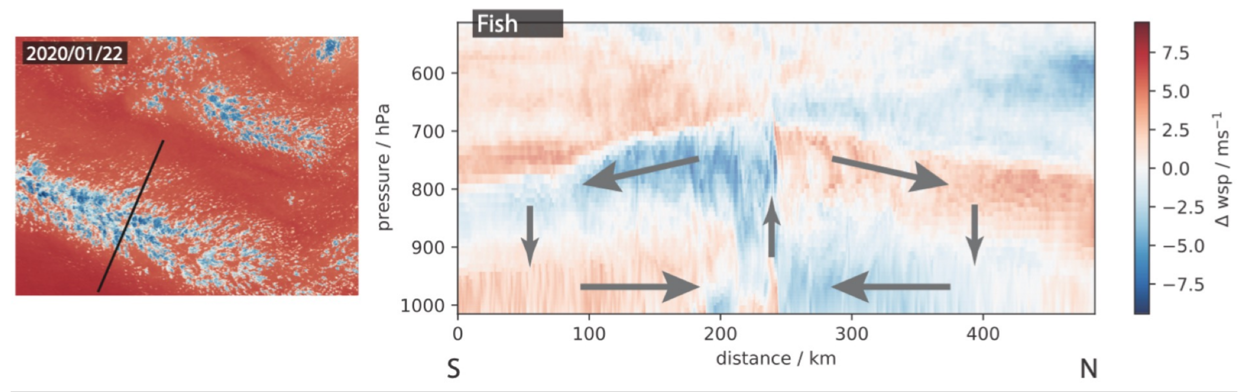
To understand how these patterns contribute to the **shallow cloud feedback** a **process-understanding** is needed. To do, so, we ask the following questions:

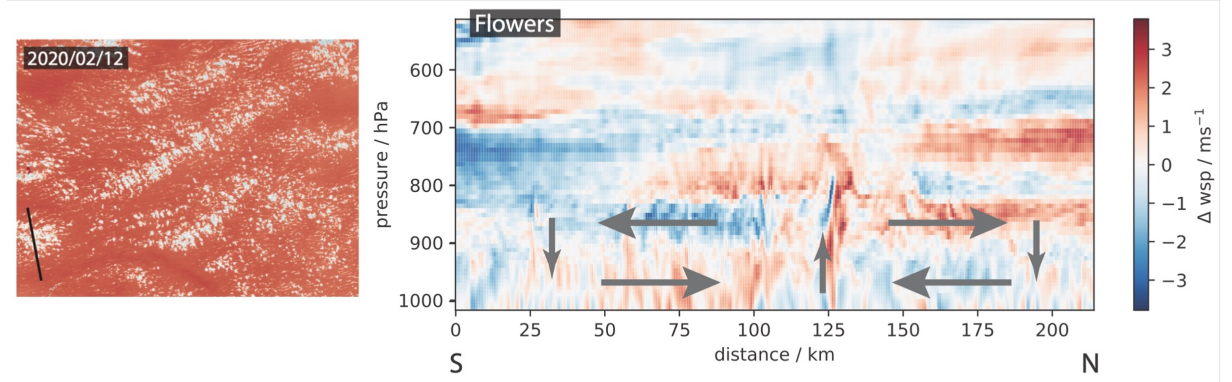
How well do large-eddy simulations capture the observed co-variability of trade-wind cloudiness and its environment?

Can large-eddy simulations help to gain a process understanding of the pattern morphology?

Process understanding of pattern morphology

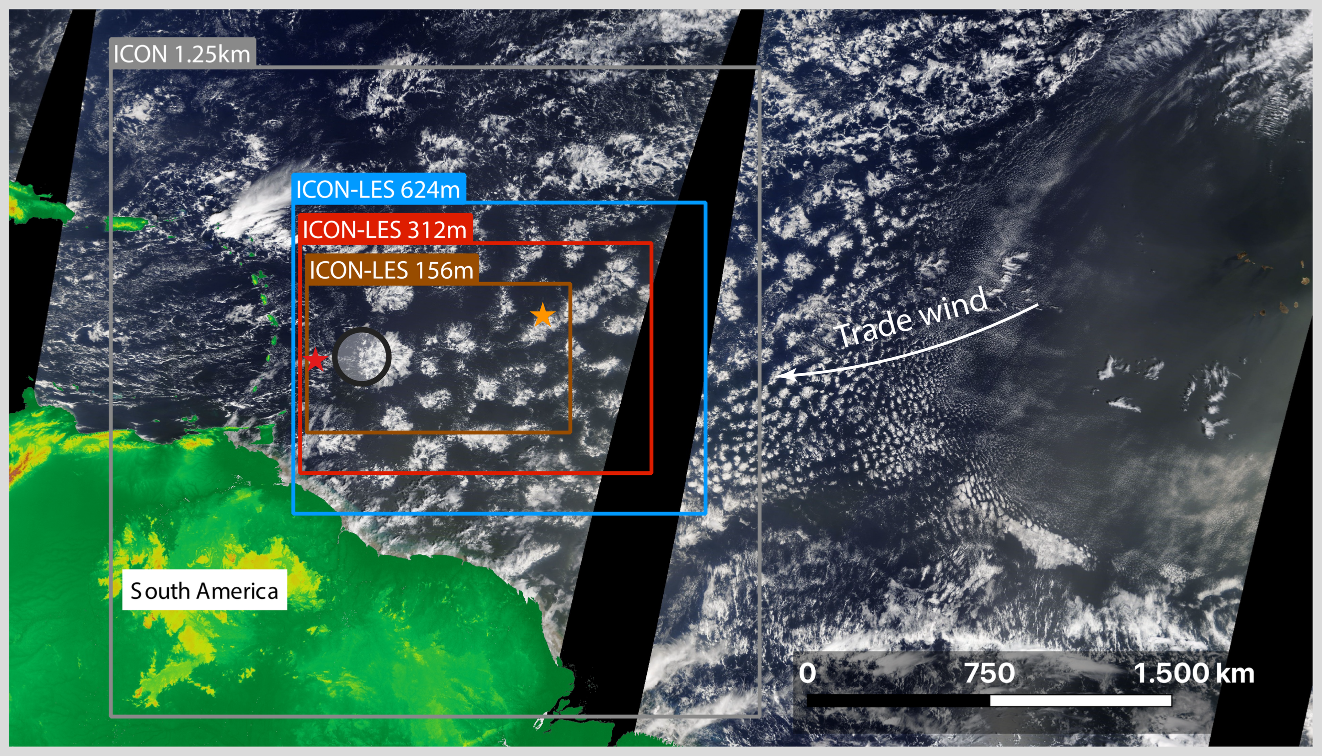
- Large-eddy simulations of meso-scale extent are capable to represent the cloud formations to some degree
- The stratiform layer of Flowers are hardly represented
- Meso-scale circulations are however visible in patterns whose entities are of meso-scale extent





Example simulated cloud scenes (left) with wind-speed anomalies along the marked cross-sections (black line) on the right.

Realistic large-eddy simulations

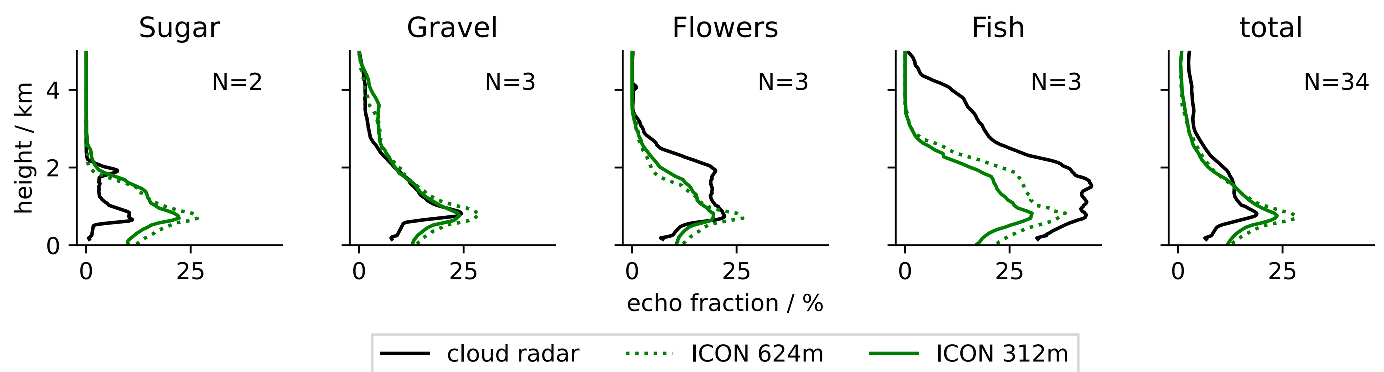


- Model: ICON-LES
- Initialized and bounded by ICON-SRM (1.25 km resolution)
- Nested domains of 624m, 312m and for specific days 156m grid-spacing
- SST: ERA5 skin temperatures
- Two-moment microphysics
- Temporal coverage: Jan 9th to Feb 19th 2020 (EUREC4A/ATOMIC period)

Further details at howto.eurec4a.eu/icon_les.html

Too frequent precipitation and too little stratiform cloud amount

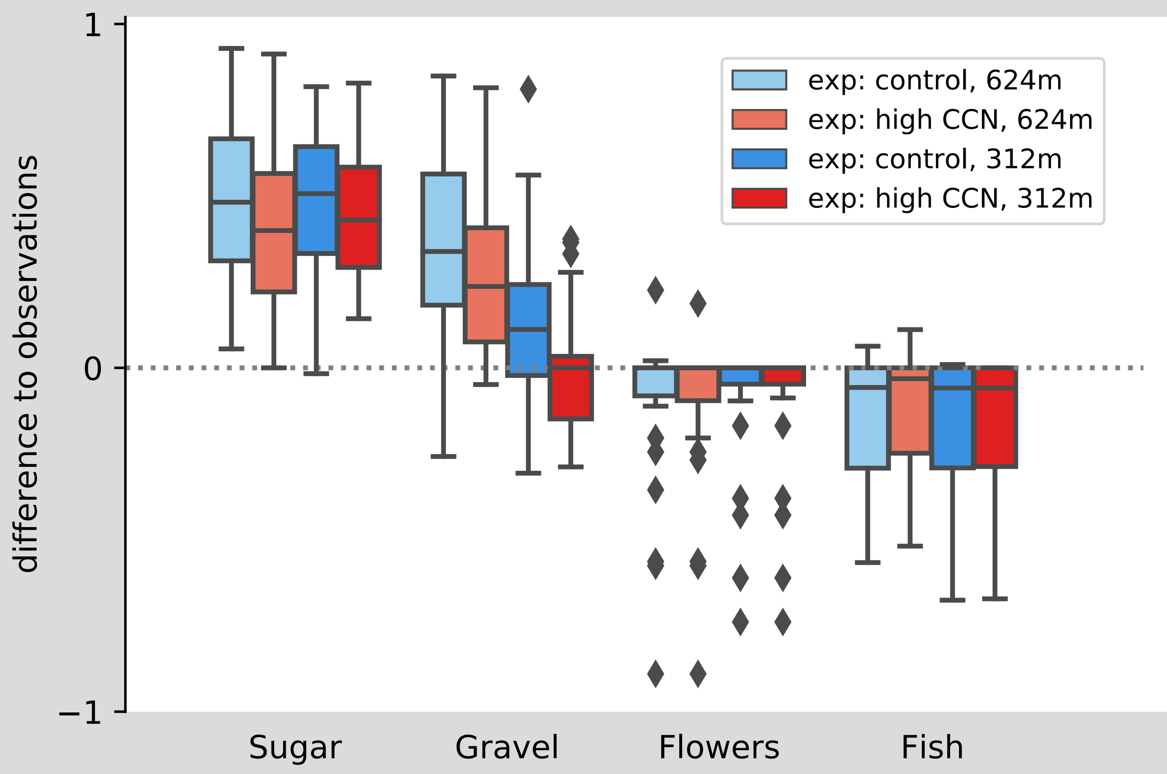
- Echo fraction (cloud fraction + rain fraction) measured at the Barbados Cloud Observatory exemplifies daily variability of cloudiness in the downwind trades.
- Echo fraction derived with the PAMTRA forward radar forward operator reveals a deficit of the ICON-LES in capturing the variability in the stratiform cloud component and a general overestimation of the cloudiness at the lifting condensation level (LCL).
- Overestimation of CF increases with horizontal resolution
- Precipitation fraction is on average overestimated by the simulations



Comparison of echo fraction from cloud radar (black) and for two ICON-LES (green).

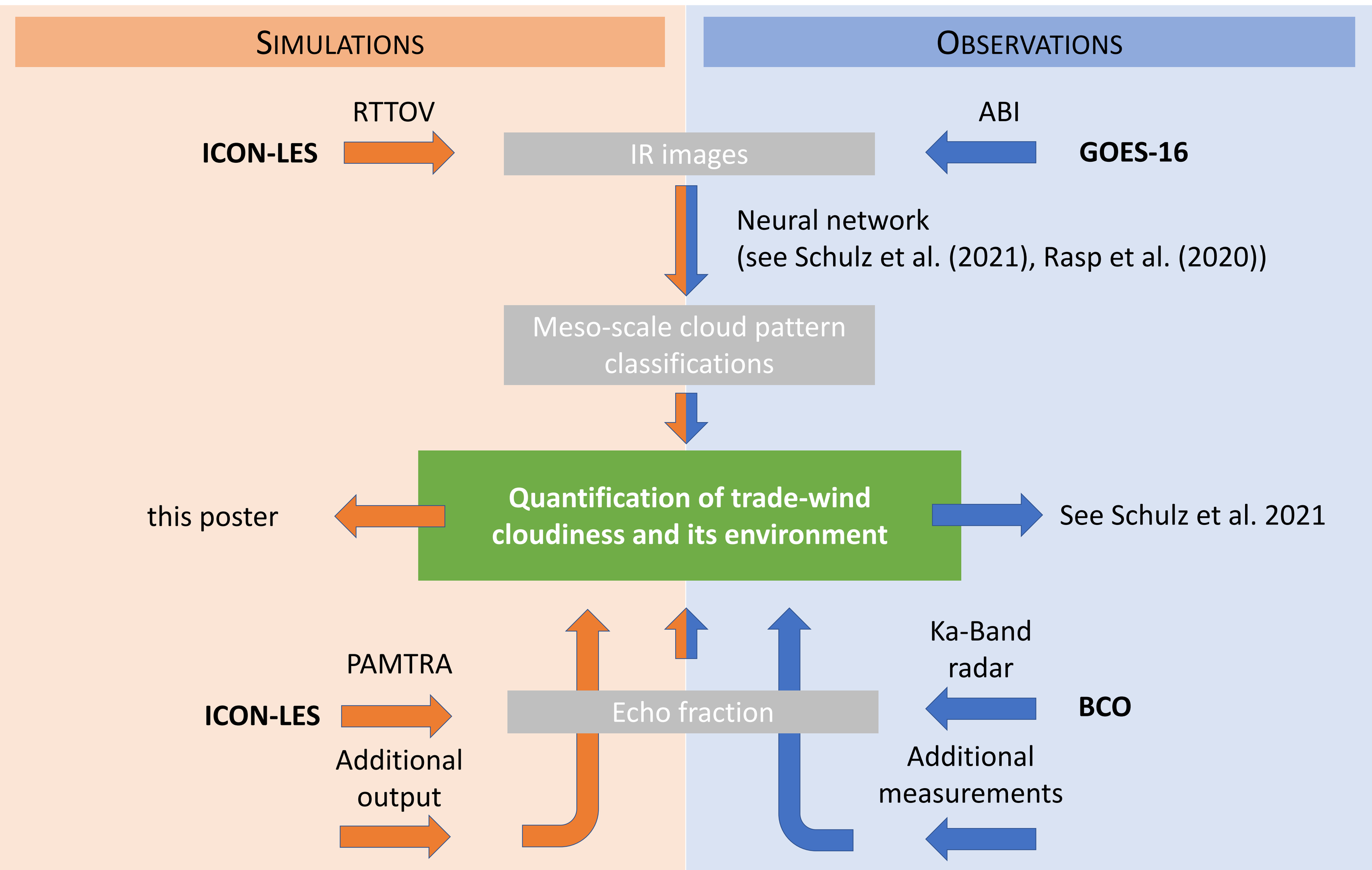
Aerosol concentration impacts structure of frequently raining cloud patterns

- ICON-LES has been repeated with cloud-condensation nuclei (CCN)-concentration of 1300 cm-1



- The mesoscale cloud pattern *Gravel*, characterized by frequent cold pool structures, shows the strongest dependence on CCN concentration changes, but even more so on horizontal resolution.

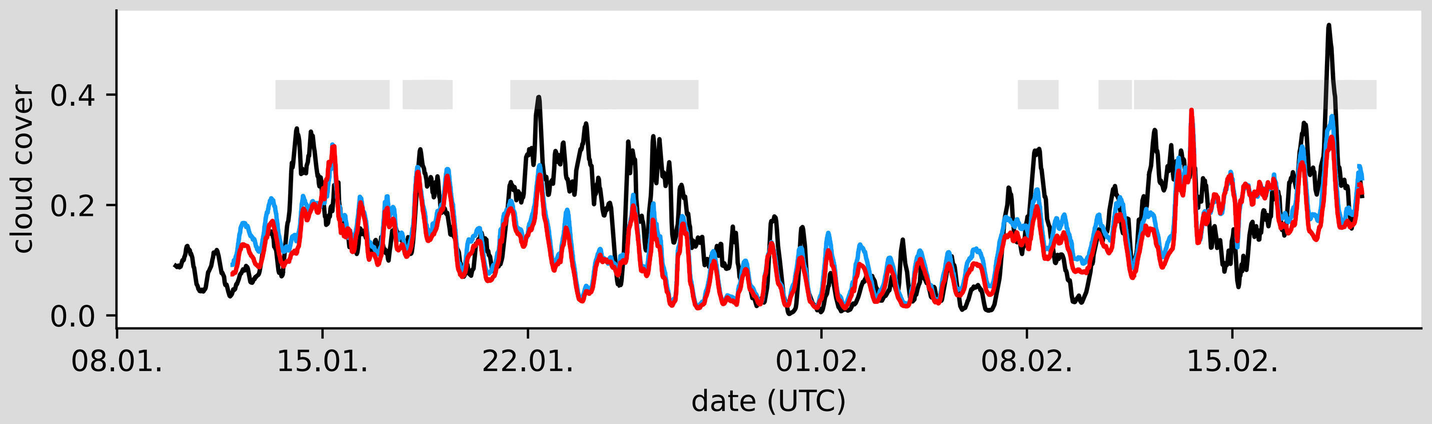
Methods



- Quantitative comparison of Barbados Cloud Observatory measurements to LES output by using forward simulators
- Application of same neural network classification method to both datasets
- Fair comparison of cloud characteristics

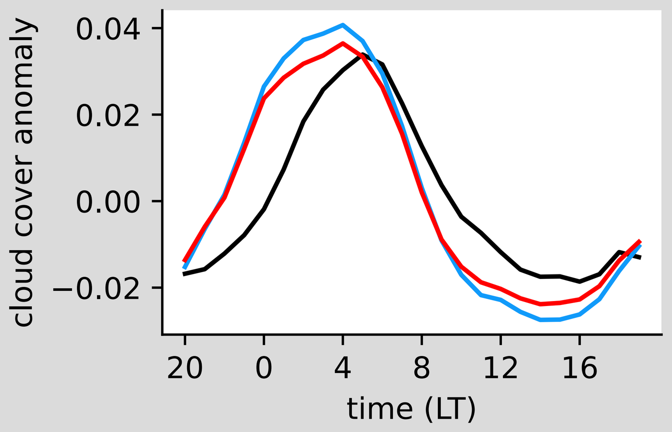
Cloud cover and its diurnal cycle are well represented

- Simulations and observations cover the typical observed meso-scale variability in the downstream North Atlantic trades (Schulz (2022))
- Cloud cover is well represented (when excluding high clouds)



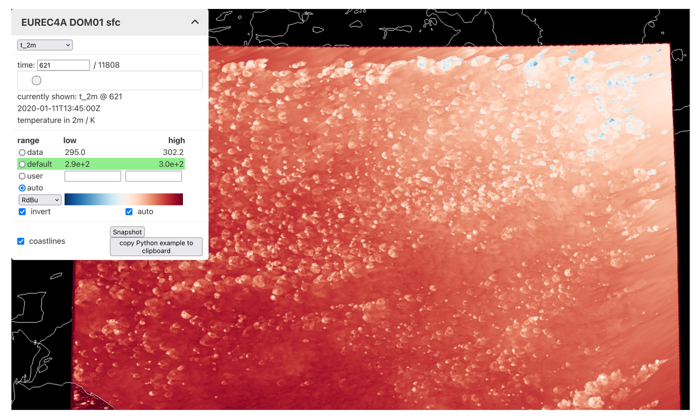
Cloud cover for observations (black) and simulations (624m: blue; 312m: red) over 10deg x 10deg area based on brightness temperatures. Grey indicators mask times with high cloud cover.

- Diurnal cycle agrees well in amplitude and phase.
- Absolute values are generally higher in the simulations (here anomaly to mean cloud cover is shown)



Get a hand on the data! #OpenScience

- Simulation output is increasingly made available online
- Simulation can be interactively explored at https://s.gwdg.de/puTB0p



- Accessing the simulation output is straight-forward thanks to the EUREC4A – intake catalog

```
from intake import open_catalog
cat = open_catalog("https://raw.githubusercontent.com/eurec4a/eurec4a-intake/master/catalog.yml")
cat.simulations.ICON.LES_CampaignDomain_control.surface_DOM01.to_dask()
```

- Please have a look at HowTo.Eurec4a.eu for further description and examples of how to explore the EUREC4A/ATOMIC field data and simulation output.
- You have a dataset or simulation output that you would like to share with the community? Get into contact and join our efforts to make data access become a quick and easy process before starting your analysis.

References:
Stevens et al. (2019) *QJRMS*. https://doi.org/10.1002/qj.3662
Bony, S., Schulz, H., Vial, J., & Stevens, B. (2020). *GRL* https://doi.org/10.1029/2019GL085988
Schulz, H (2021) *JGR: Atmospheres* https://doi.org/10.1029/2021JD034575
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