Observing clouds & their large-scale[a] environment (through the lenses of NARVAL2 & EUREC4A)

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WHAT IS OUR OBJECTIVE? WHAT IS NOVEL?

- On climate scale, we know many factors in the large-scale environment, both thermodynamic and dynamic, that control cloudiness. On the **process scale** or on **sub-synoptic scales**, however, this is not so clear.
- As NARVAL2 (August, 2016) provides first-of-its-kind estimates of divergence (and subsequently, pressure velocity, ω ; *from Bony and Stevens, 2019*), a comprehensive understanding of **how different large-scale parameters affect clouds, especially on short-time scales,** can be obtained.
- We use these **estimates of observed large-scale vertical motion and co-located cloud measurements** (see Figure-2) to showcase for the first time, how large-scale vertical motion influences tropical clouds and **how dynamics have a more instantaneous control on clouds than thermodynamics.**

Figure- 1

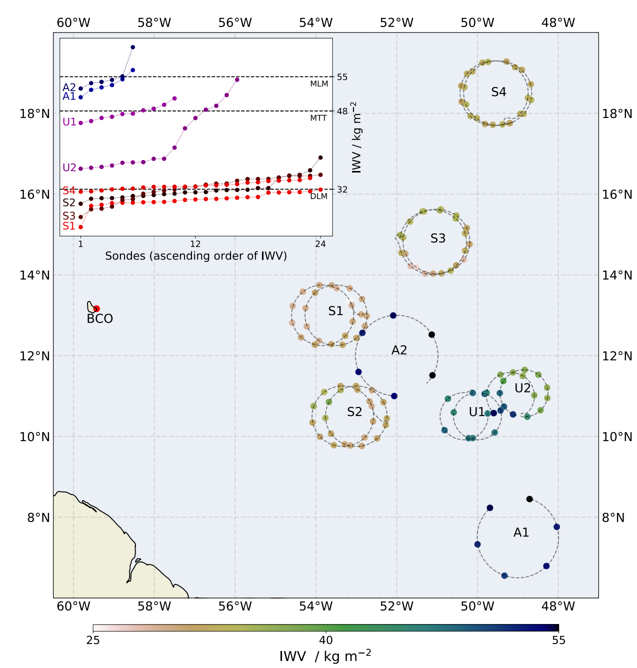
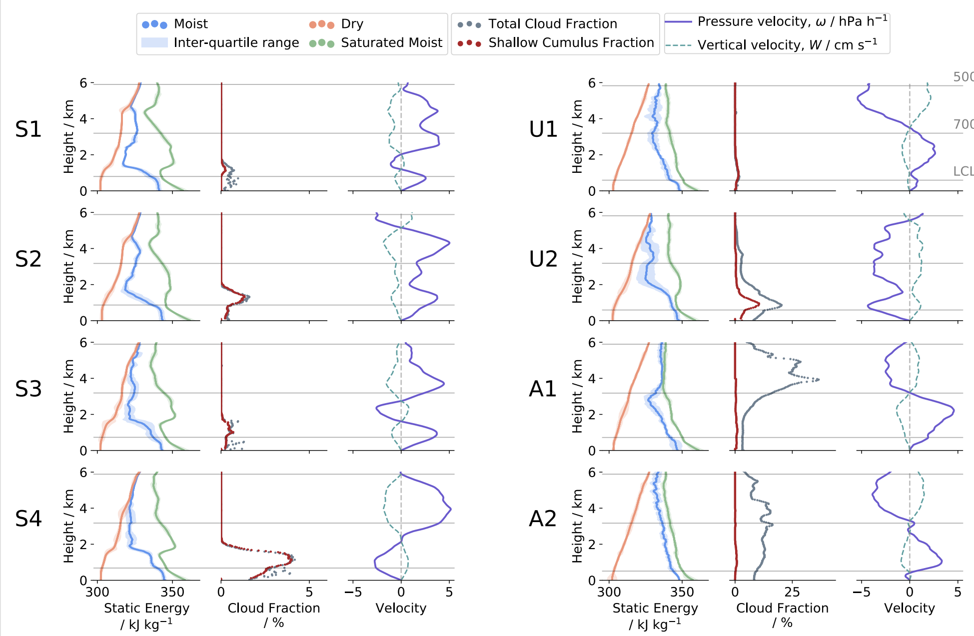


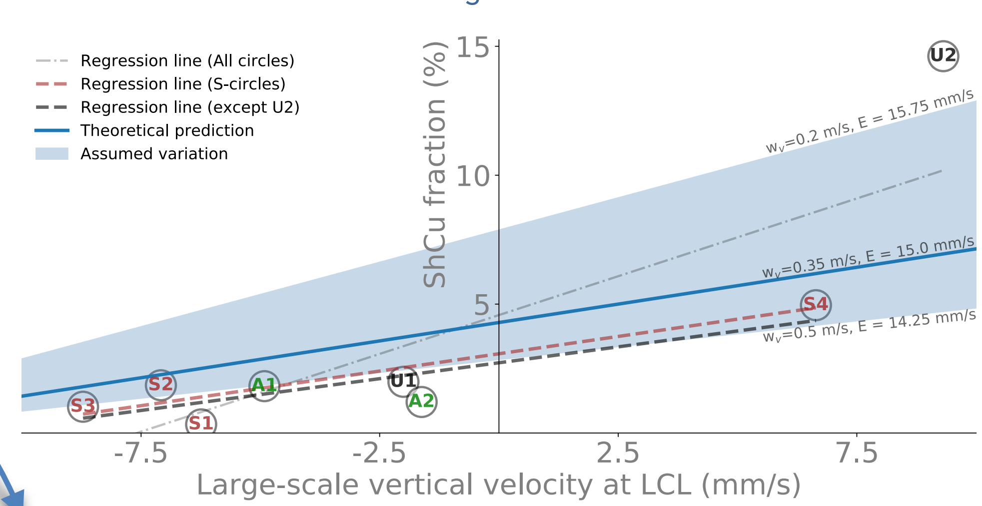
Figure- 2



INFLUENCE OF LARGE-SCALE VERTICAL VELOCITY ON CLOUDS

- Figure-2 shows for S-circles, how the thermodynamics in the environment can be consistent, even when there is significant variation among the cloudiness in the these environments. The only difference is the **subsidence regime in the lower layers of the atmosphere**.
- S4, with significantly high cloudiness, also stands out as the only circle with a boundary layer experiencing large-scale rising motion. Conventional controls of ω_{700} **and** ω_{500} **do not explain the variability in cloudiness in these short time-scales** (see Figure-4).
- With a simplistic, theoretical mass-flux estimate (based on *Vogel et al (2020)*), we show that **large-scale vertical velocity in the shallow layers of the atmosphere can be used to estimate cloud fraction of shallow cumuli,** with considerable confidence (see Figure-3).

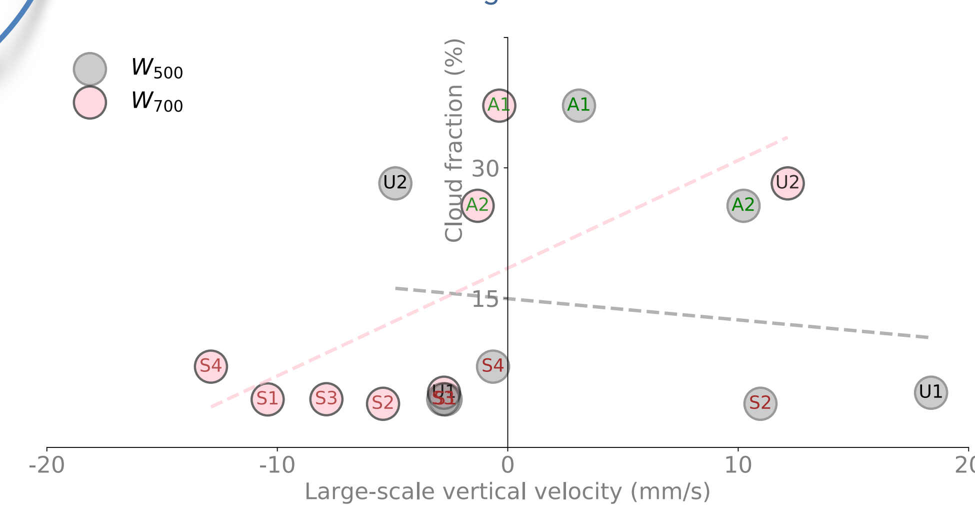
Figure- 3



THE NARVAL2 CASE STUDIES

- **8 dropsonde circles** flown on 4 HALO research flights in **different large-scale environments** (locations shown in Figure-1)
- Based on column moisture thresholds from *Mapes et al (2018)* (see inset in Figure-1) – circles were classified as:
  - **S-circles** : suppressed environment (shallow convection)
  - **A-circles** : active environment (deep convection)
  - **U-circles** : cases at the transition of S & A environments
- Cloud fraction was estimated from the measurements of the HAMP radar onboard HALO. Thermodynamic profiles and estimates of large-scale vertical motion were from dropsondes. (see Figure-2)

Figure- 4



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[a] : For this presentation, the large-scale is 200-250 km; on the same scale as the NARVAL2 and EUREC4A circles by HALO

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Characterising the large-scale environment with EUREC4A

1213 sondes (85 circles) = HALO : 895 sondes (71 circles + 1 clover) + P3 : 322 sondes (14 circles)

Figure- 5

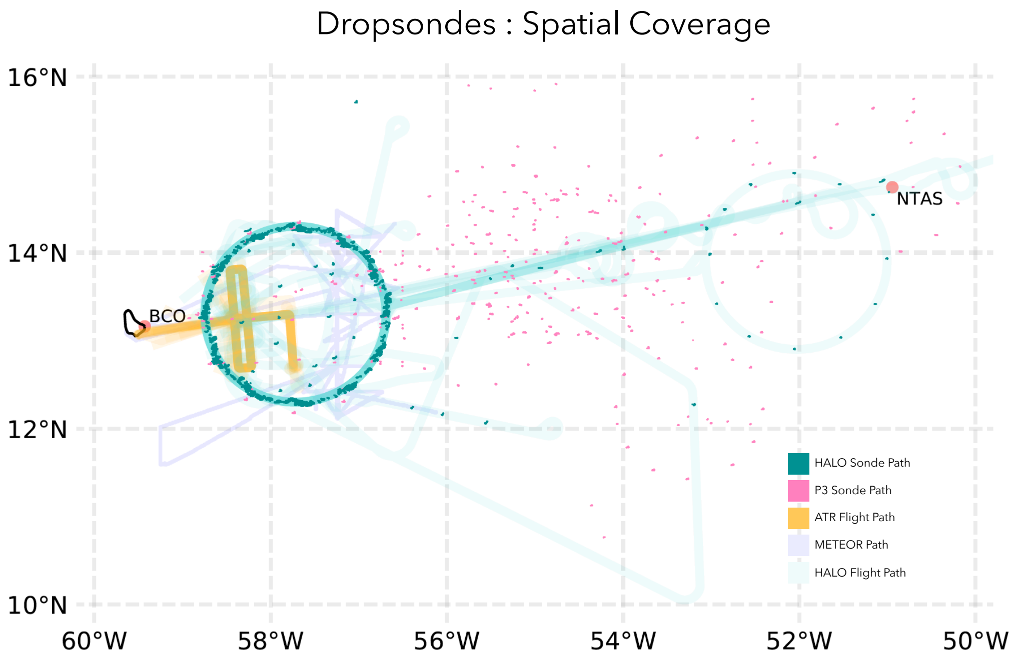
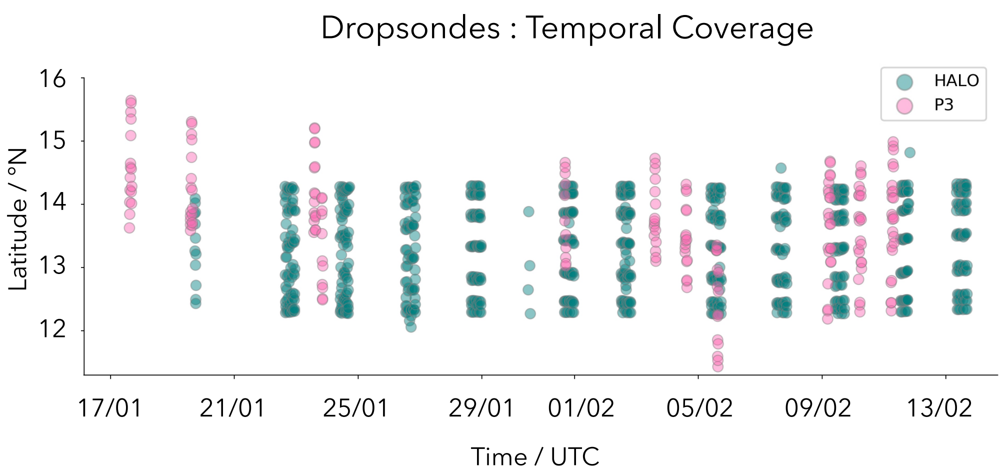


Figure- 6



EUREC⁴A MEASUREMENTS

- To understand how the environment controls cloudiness, it is key to study **the variability of environmental parameters, and their interplay**.
- The intensive dropsonde measurements (see Figs -5 & 6) during EUREC⁴A make this possible.
- The sounding profiles provide valuable information about the thermodynamics of the environment. The circle products add information about dynamics as well as others, such as advection & gradient of parameters.
- A very important parameter is the **large-scale horizontal mass divergence**, due to the impact that it can have in regulating other environmental parameters. With circle measurements, **it is possible to study the variability in divergence on the inter-** (see Figure 7) **as well as intra-day** (see Figure 8) **scale**.
- The atmosphere shows a **stratified structure in the large-scale**, even when averaged over almost a month (Fig -7; left). The daily mean profiles also show oscillations, albeit with higher frequencies (Fig - 7; right). Note that these are preliminary analyses.

Figure- 7

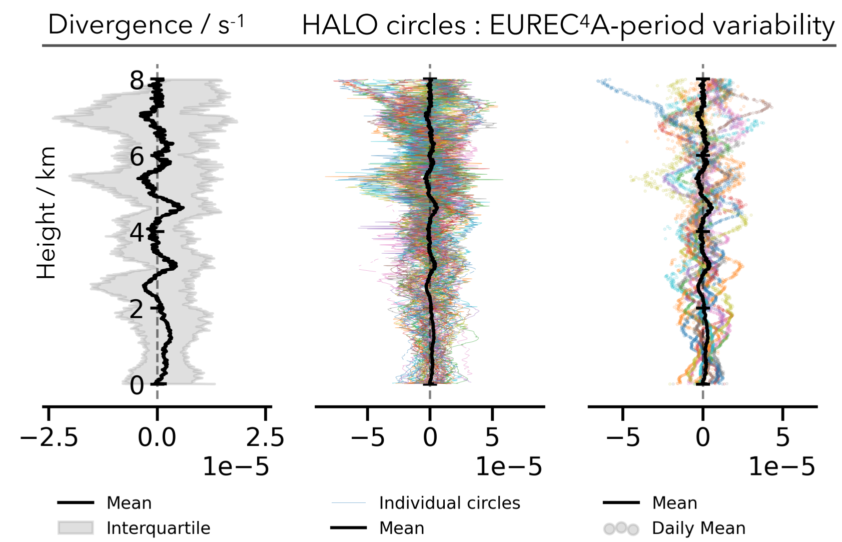
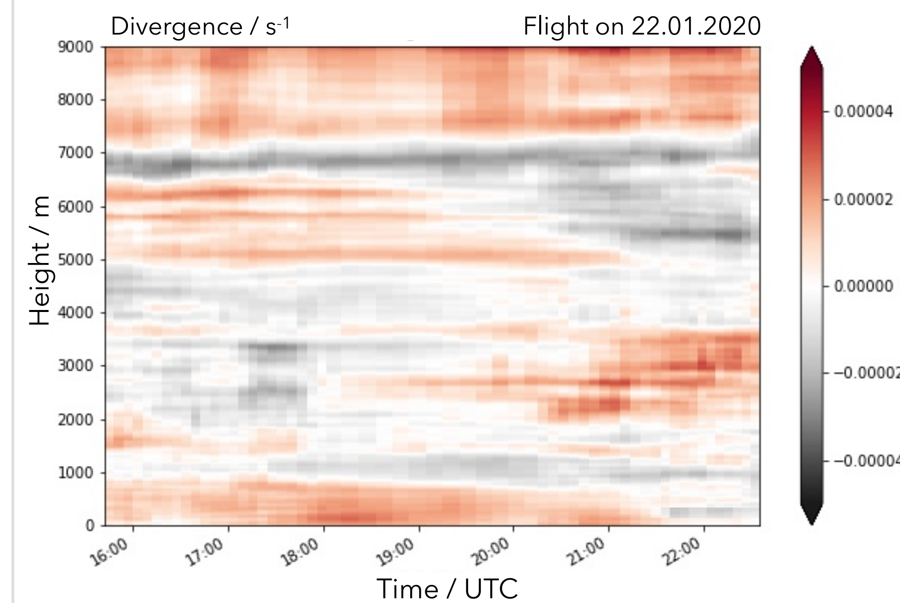


Figure- 8



- **ANSWERING "HOW DOES THE ENVIRONMENT CONTROL CLOUDINESS?"**

– The first step would be to **characterise the environmental parameters** such as humidity, temperature, winds (horizontal and vertical), their gradients and realise the extent of variability within these. This step will also give hints about the interplay between these parameters.

– The second step would be to **quantify the cloudiness** in these observed environments in several forms, i.e. cloud cover, cloud albedo, cloud base fraction, cloud top height, etc. This spread-out approach can help in understanding the mechanisms through which clouds respond to changes in their environment.

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