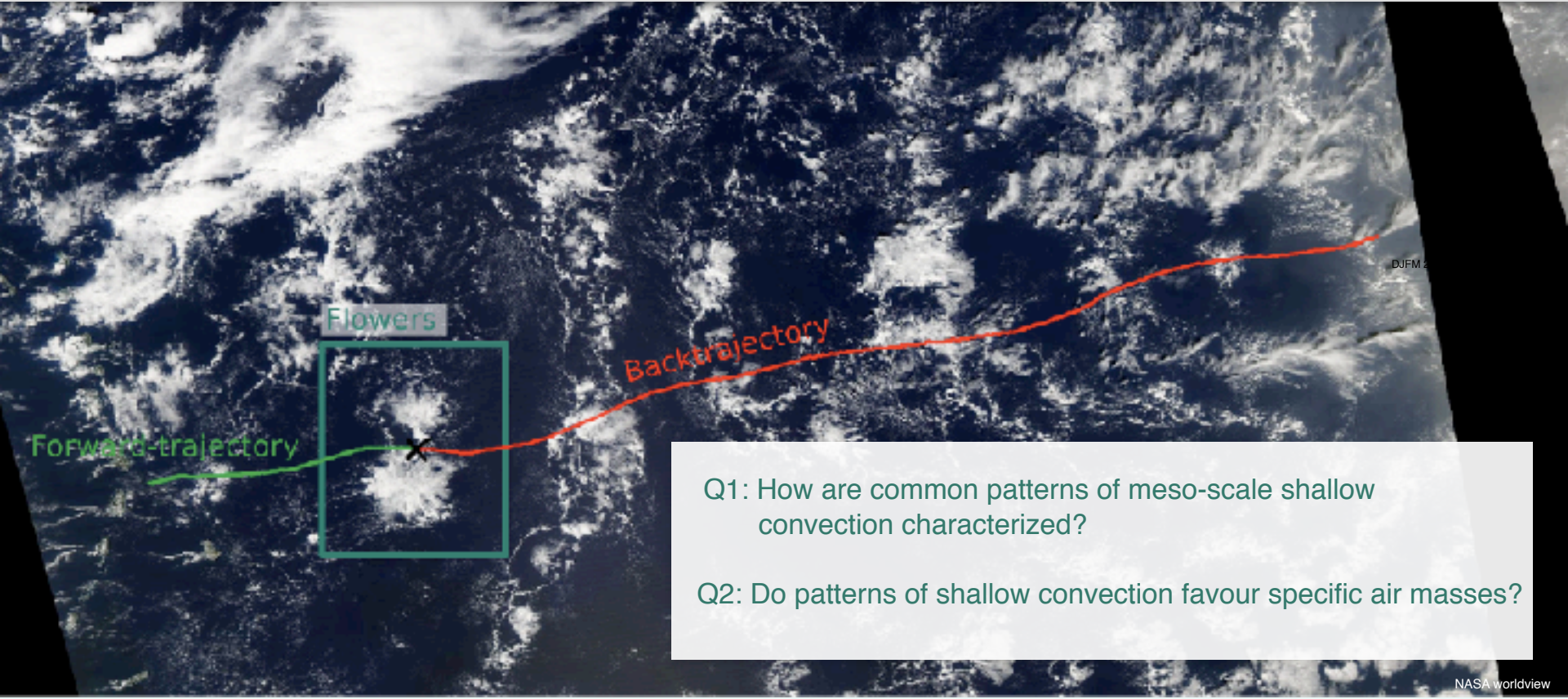
Evolution of Organized Shallow Convection

Hauke Schulz[1] Ryan Eastman[2] Bjorn Stevens[1]
[1] Max Planck Institute for Meteorology, Germany
[2] University of Washington, Seattle



Q1: How are common patterns of meso-scale shallow convection characterized?

Q2: Do patterns of shallow convection favour specific air masses?

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Q1: How are common patterns of meso-scale shallow convection characterized?

- Meso-scale patterns of shallow convection have been defined by analysing satellite observations (Stevens et al. 2020).
- So far, little is known about the vertical structure of these clouds and their thermodynamic environment

- Patterns of shallow convection are frequently passing over the Barbados Cloud Observatory, fuelled by the trade winds
- The comprehensive instrumentation at the site enables together with the automatic detection of meso-scale patterns of shallow convection to characterize the patterns in great detail
- The automatic detection is realised with a neural network (NN) similar to Rasp et al. (2019) but instead of being trained with visible MODIS images the neural network used to create Fig. 1 is trained in the infrared. This way the NN could be applied to temporal high resolution GOES16 infrared imagery.

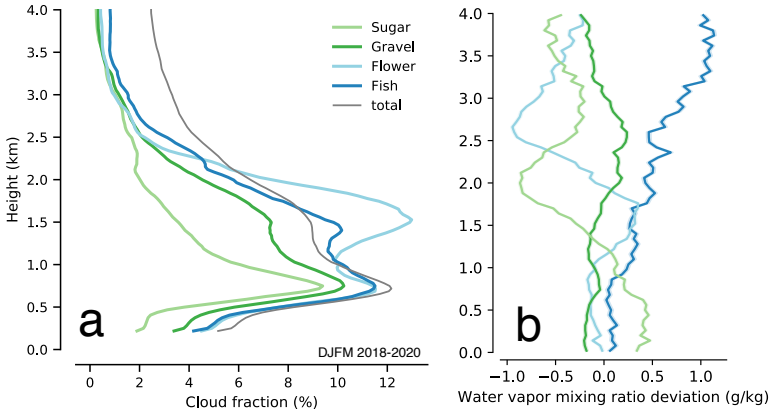

Fig. 1: Observations at the Barbados Cloud Observatory grouped by meso-scale cloud pattern identified by neural network. (a: radar cloud fraction; b: lidar water vapor mixing ratio)

Results

- The cloud fraction at cloud base height is nearly invariant to the apparent pattern, strengthening the results of Nuijens et al. (2014) that clouds at cloud base height are insensitive to changes in meteorology also in the context of meso-scale organization.
- The variability in cloud fraction remains aloft close to the inversion height.
- Flowers and Fish both show a peak in cloud fraction caused stratiform clouds
- The humidity profiles anomalies show the strong inversion present in Flower cases
- —> What causes these patterns to form so differently? Is the difference already inherent in the history of the air mass?

Q2: Do patterns of shallow convection favour specific air masses?

- We analyse back-trajectories that are initialized at the center of identified meso-scale cloud patterns at 925 hPa (example Fig. 1)
- Cloud patterns are detected with a neural network (Rasp et al. 2019) in the downwind Atlantic trades (region C in Fig. 2)
- Mean environmental conditions along the trajectories are extracted from ERA5 and MODIS data (Fig. 3)

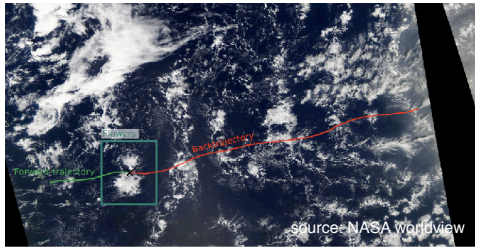

Fig. 1: Example of a identified cloud pattern (green), its center point (X) and the calculated back-trajectory.

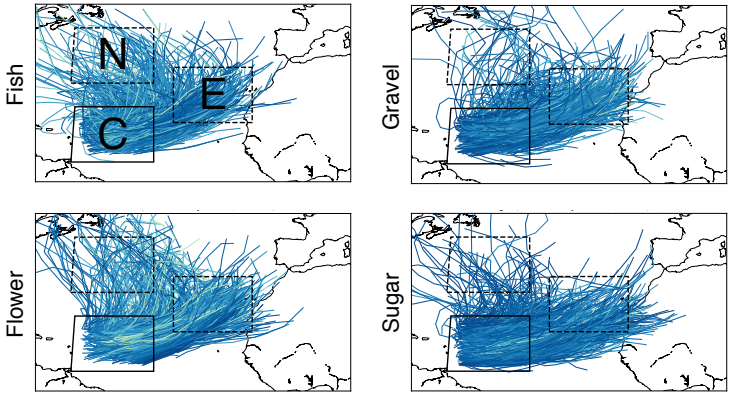

Fig. 2: Back trajectories for meso-scale shallow organizations identified in the downwind trades (region C). Trajectories are coloured by classification size (larger patterns are lighter).

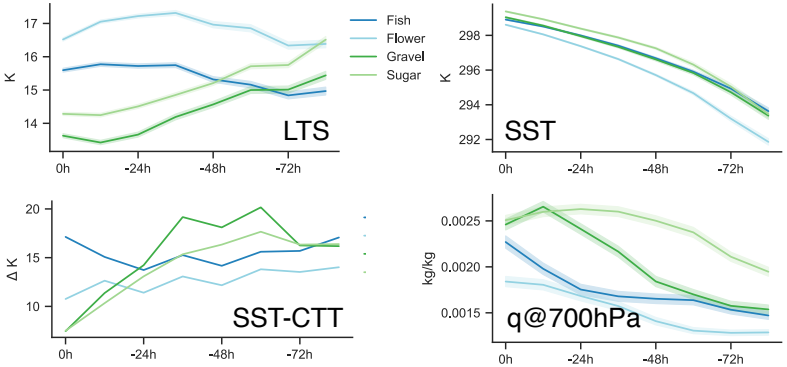

Fig. 3: Mean environmental conditions along the back-trajectories

Results

- Air masses origin mostly from within the trade-winds
- Fish patterns are frequently associated with northern air masses
  - Three times more trajectories pass through region E than through N
  - Other patterns have about 10 times more trajectories through region E
- The environmental conditions are specific to each of the patterns
- The estimated boundary layer height (SST - observed cloud top temperature) shows a deepening for the Fish pattern, while the others are decreasing in depth

Q2: Do patterns of shallow convection favour specific air masses?

- Trajectories entering the trades from the north can be attributed to synoptic disturbances caused by cold air outbreaks
- These outbreaks often result in stationary frontal lines or convergence lines when reaching low latitudes (see example Fig. 1)
- Are these disturbances necessary to create favourable conditions for one or the other pattern? Does Gravel happen to be in the cold sector of a cold air outbreak?

- Cold air outbreak fronts have a strong meso-scale convergence signature relative to undisturbed trade-wind conditions
- Fig. 2 shows the frequency distribution of convergence relative to the center of each detected pattern

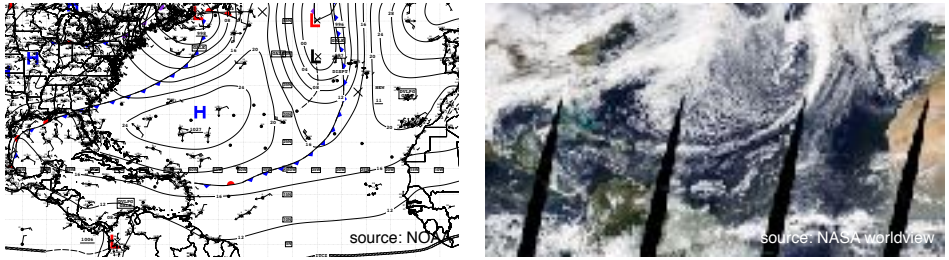

Fig. 1: Cold air outbreak on the 29th of December 2018 (left: surface analysis chart, right: MODIS satellite image)

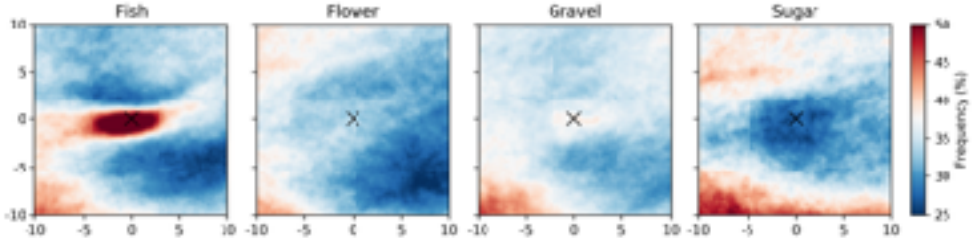

Fig. 2: Frequency distribution of convergence relative to identified pattern centers composited by 10x10 deg domains around each identified pattern. Pattern centers are marked with a “x”.
(convergence@950hPa > 0.1E-5 1/s)

Results

- The Fish pattern is often connected with convergence lines with a latitudinal orientation
- Other patterns show less clear signal in the convergence composites
- Noticeable is the close ITCZ in the south of the composite of Sugar and the deficiency at the pattern center itself

References

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