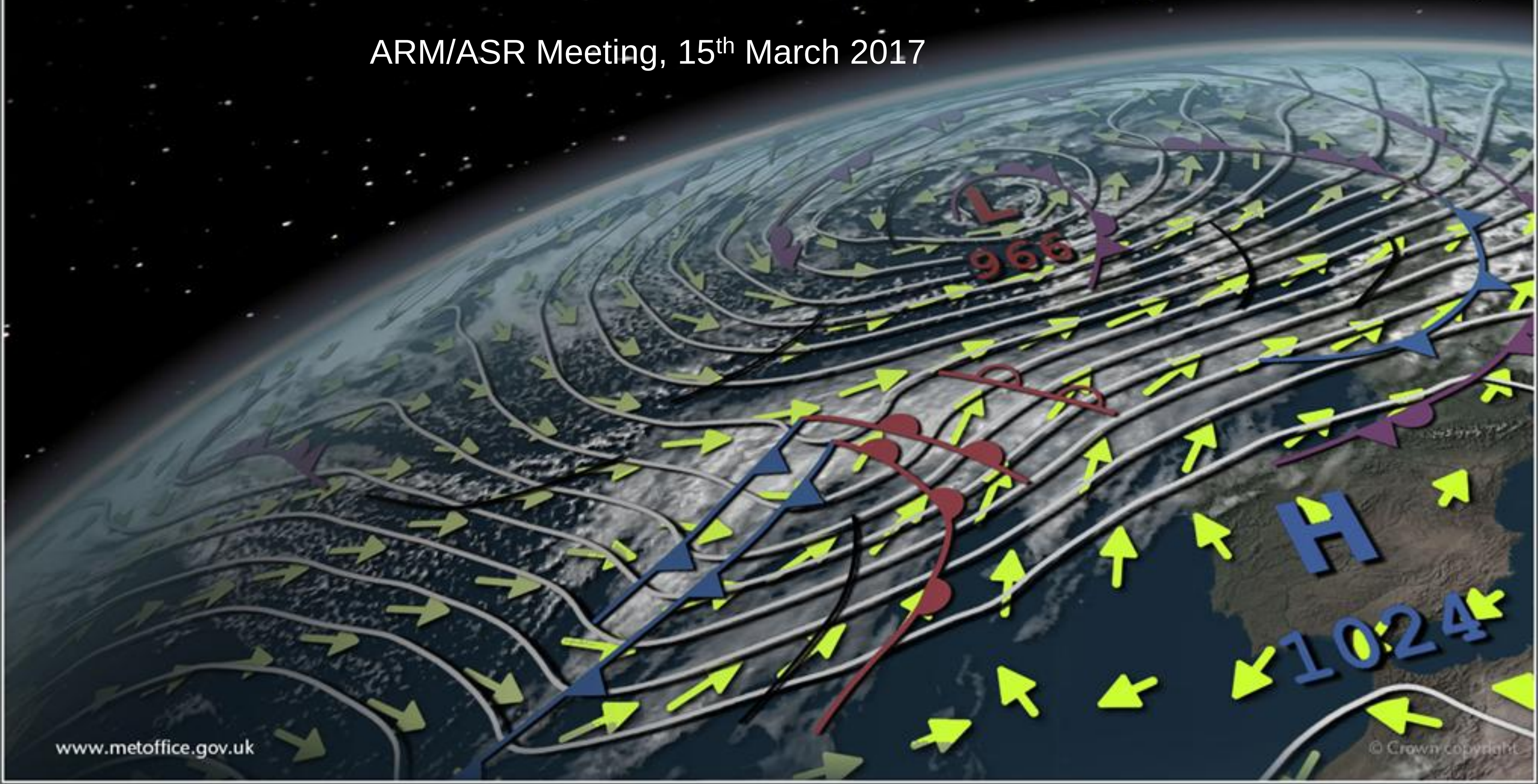
Met Office

Observations and modeling of northern-hemisphere cold-air outbreaks

Steven Abel and Paul Field

ARM/ASR Meeting, 15th March 2017



Motivation

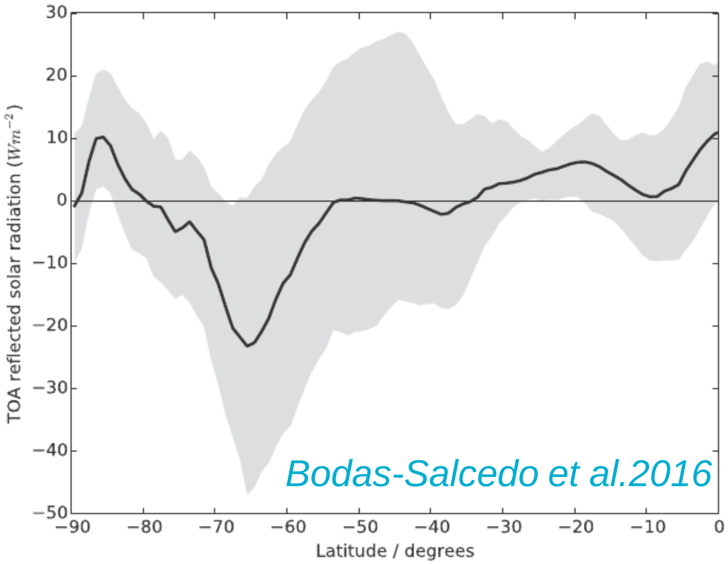


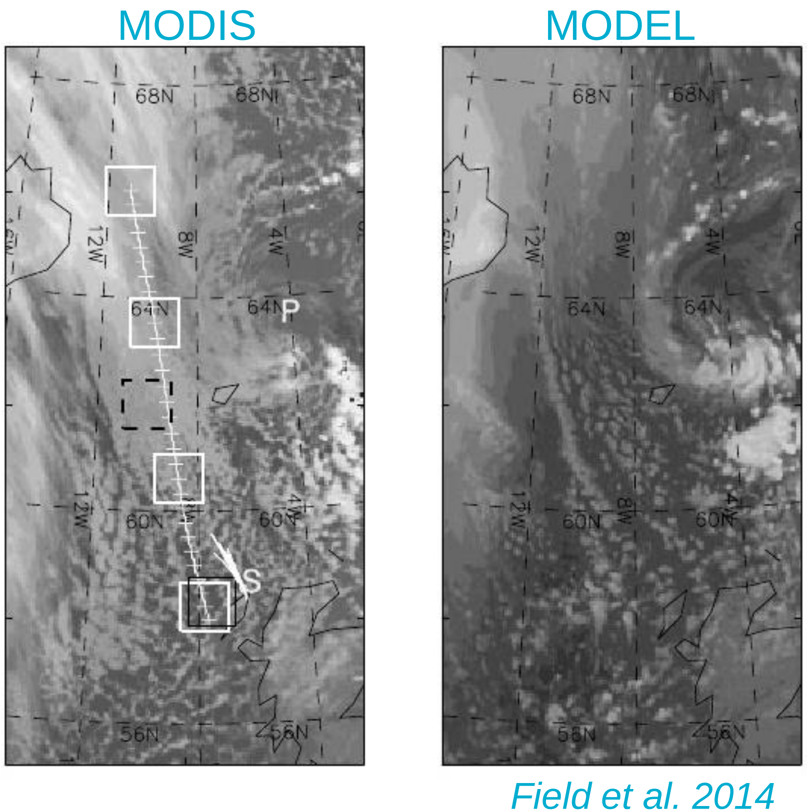
FIG. 6. TOA SW reflected flux error from the CMIP5 AMIP experiments with respect to CERES-EBAF, showing zonal-mean averages for austral summer (DJF). The solid line shows the ensemble-mean bias, and the gray-shaded envelope shows the 10th–90th percentile range.

Reflected shortwave radiation bias in the southern Ocean common to many climate models

Large component attributed to a lack of low level supercooled liquid water clouds on the cold-air side of cyclones

Same results from NWP case studies in similar synoptic conditions (cold-air outbreaks) in the northern hemisphere

Limited in-situ observations to test models.



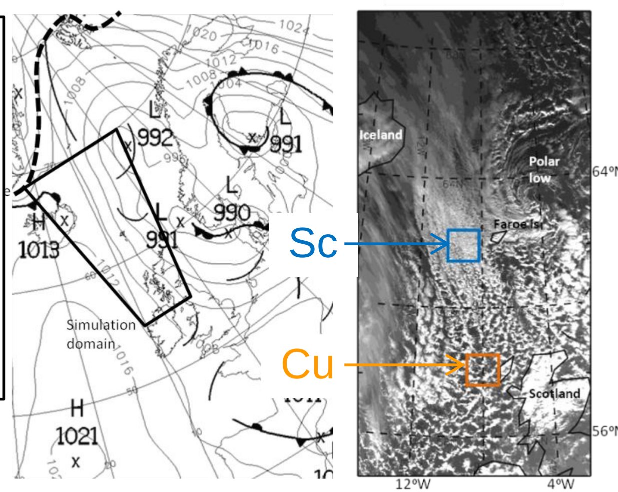
Grey-zone model intercomparison

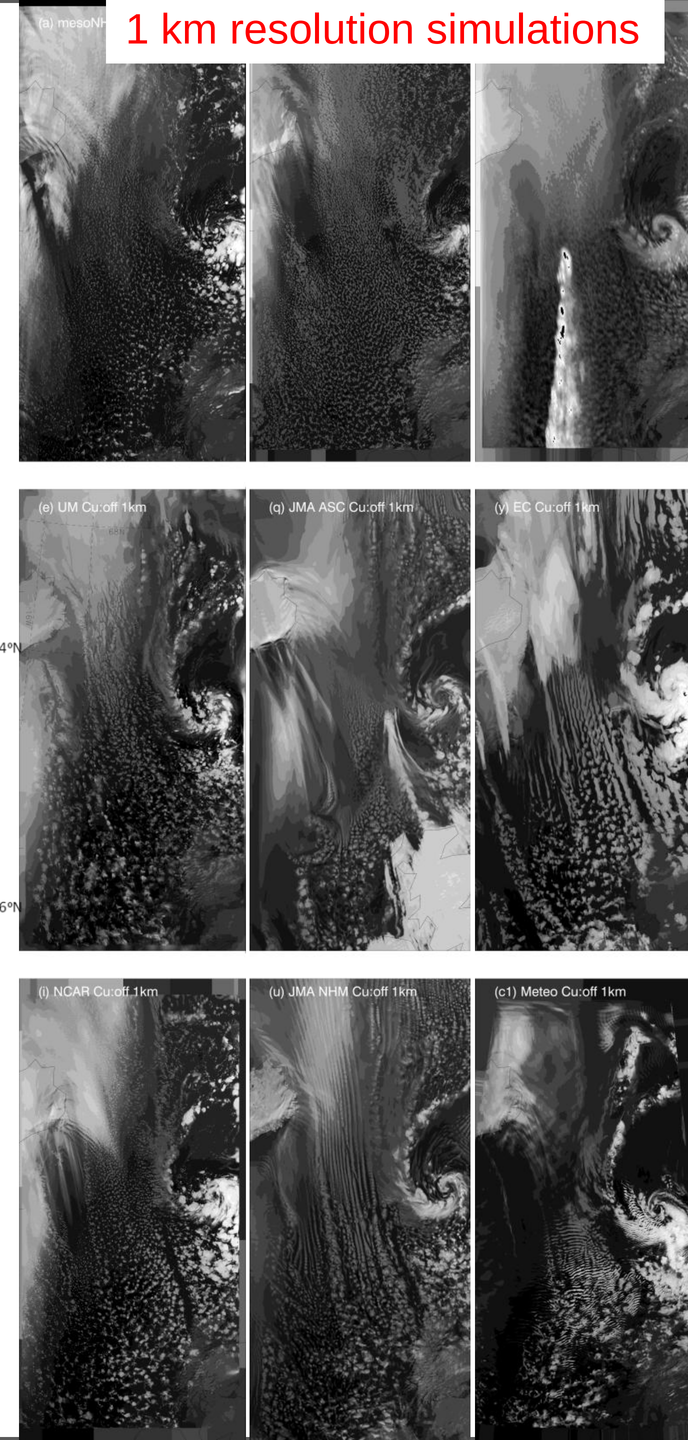
Field et al., submitted

- CONSTRAIN case-study
- 9 regional models
- 1km to 16 km horizontal grid resolution
- Analysis of Sc and Cu regions of the cloud field

31st January 2010 12Z

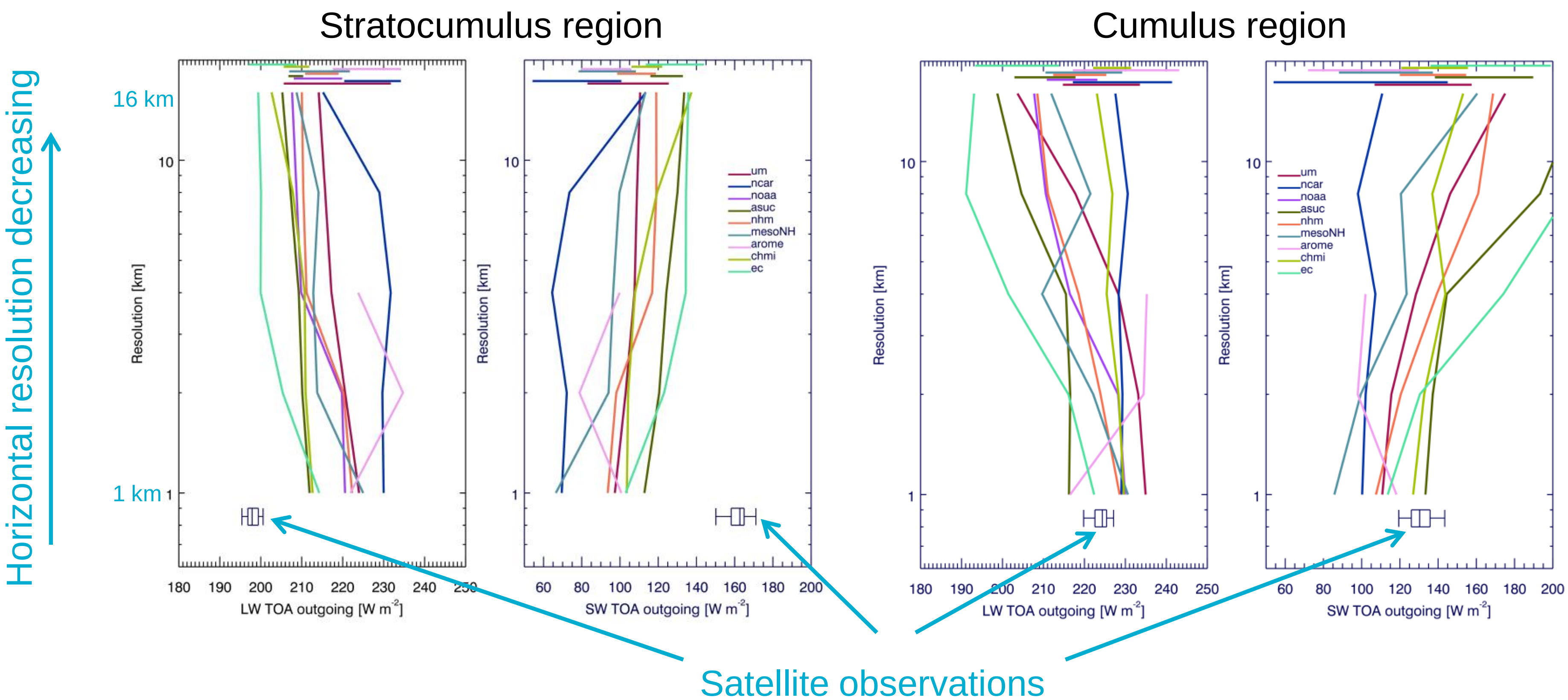
MODIS channel 4





The stratocumulus region is not simulated well by the models, which tend to predict open cell convection

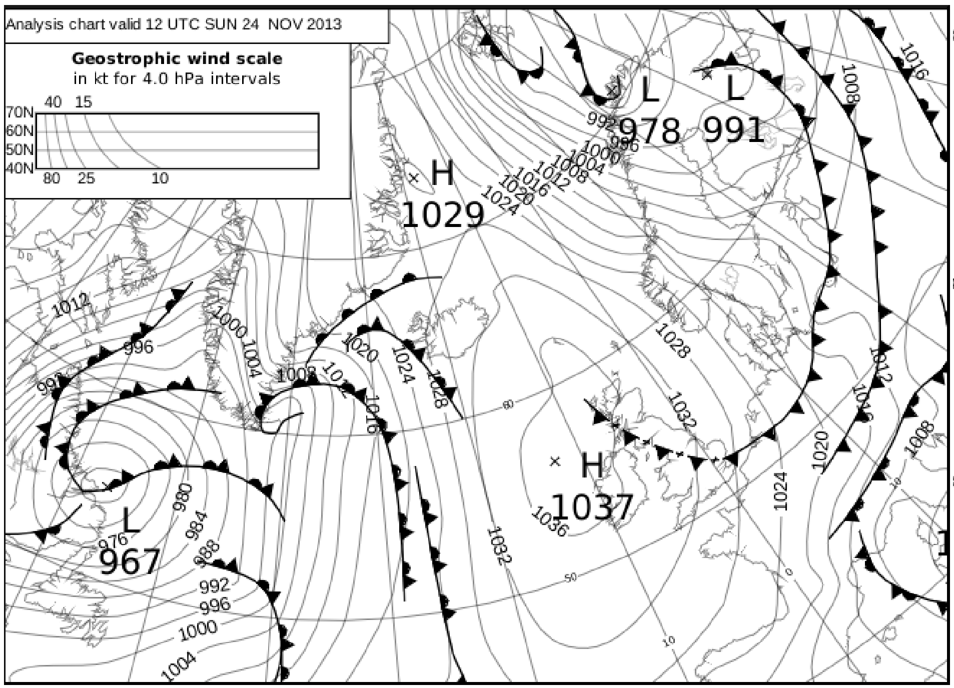
Model intercomparison: outgoing TOA fluxes

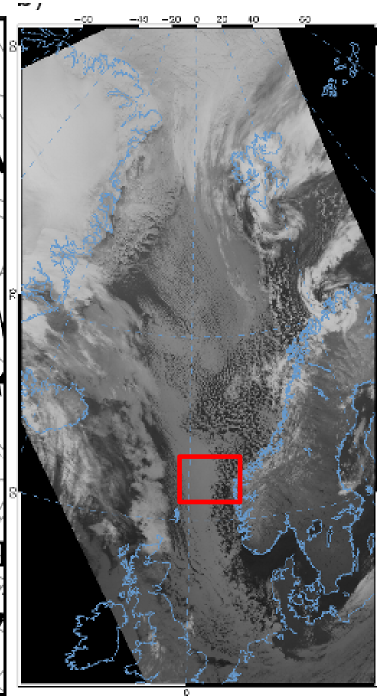


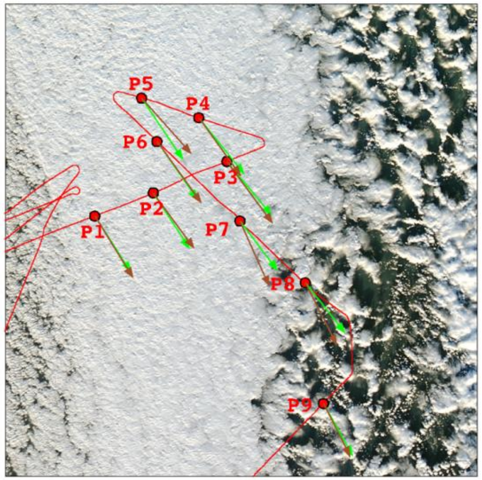
All models underestimate outgoing SW flux (lack of cloud and low LWP) in the Sc region

Models better represent the clouds in the Cu region and converge with observed TOA fluxes at higher grid resolutions

In-situ observations *Abel et al., submitted*





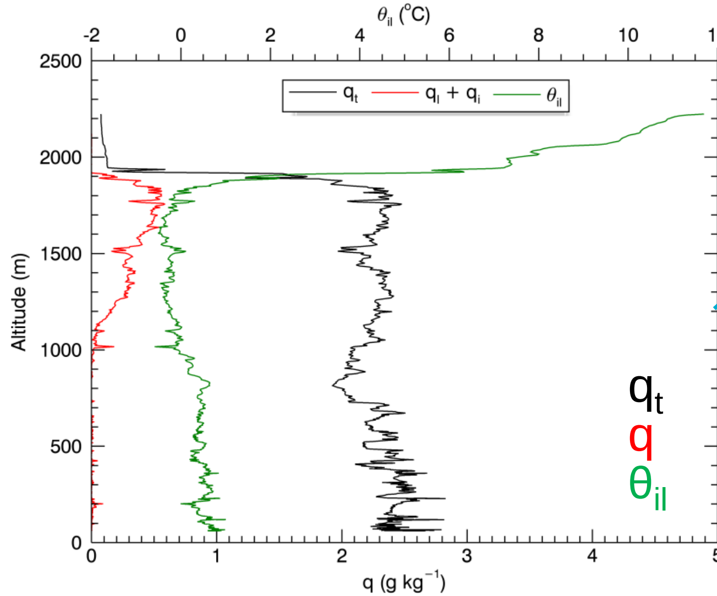


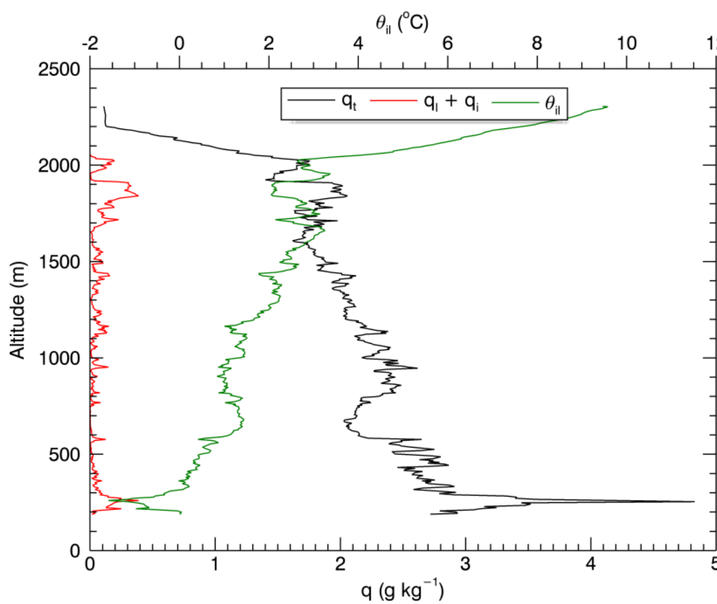
Aircraft observations in the Sc region and across the transition in cloud regime to the Cu region

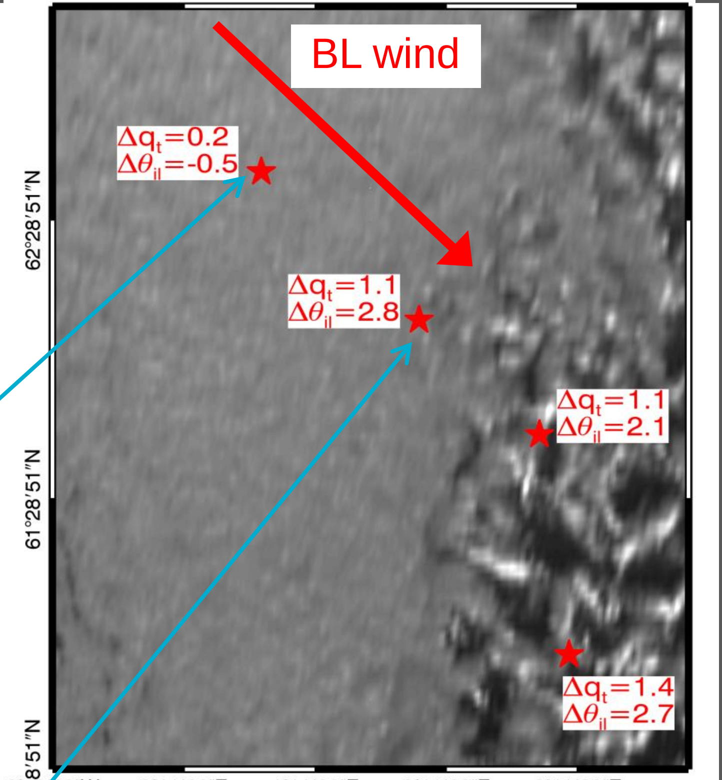
- Boundary layer structure, aerosol and cloud microphysics.
- What drives the transition in cloud morphology?

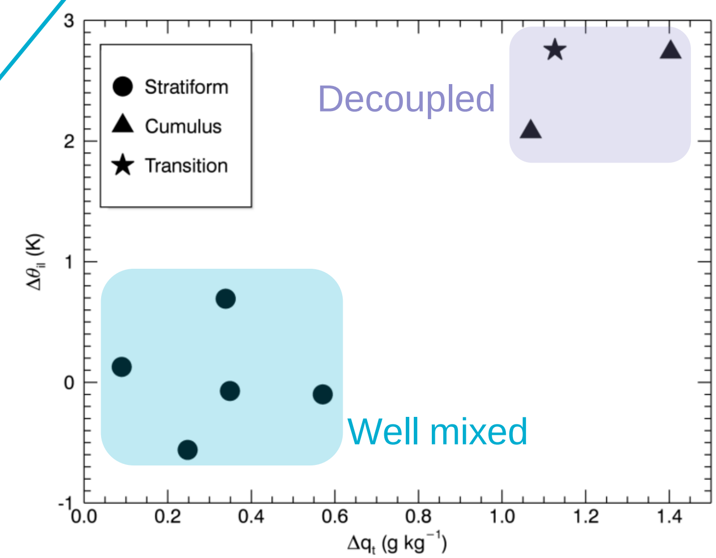
Boundary layer structure

Boundary layer becomes decoupled across the transition in cloud cover





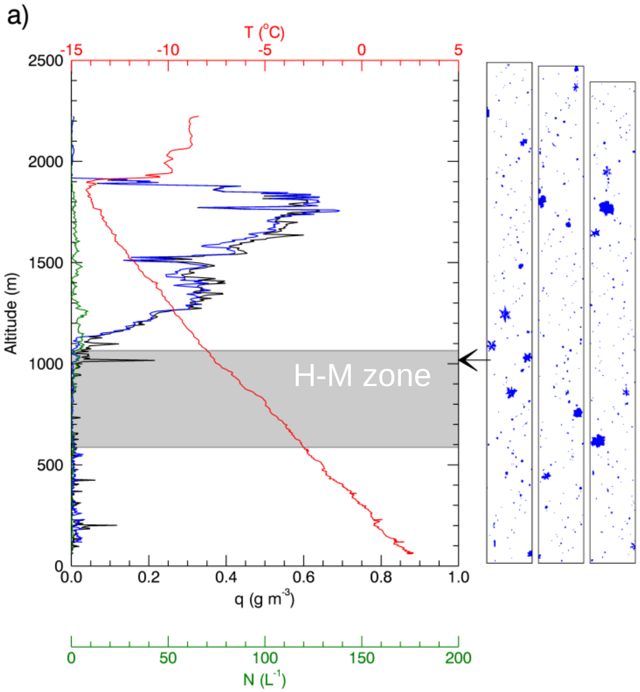




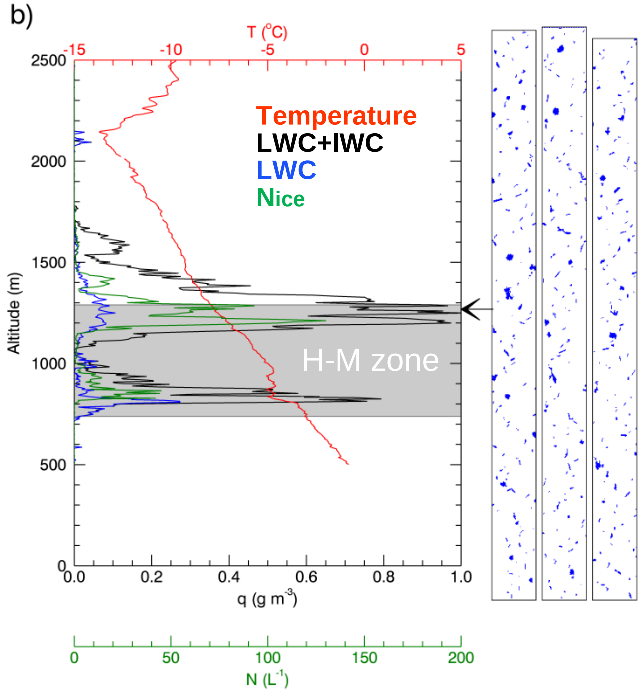
Δq_t and $\Delta\theta_{il}$ are the difference in q_t and θ_{il} between upper 25% and lower 25% part of the boundary layer

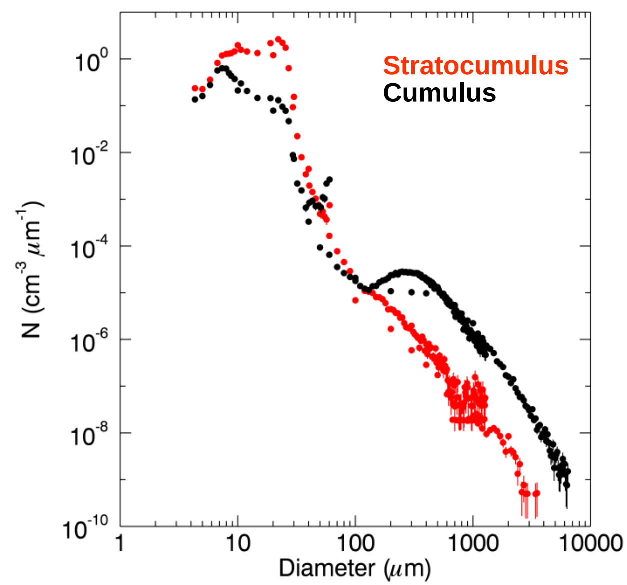
Cloud microphysics

Stratocumulus



Cumulus



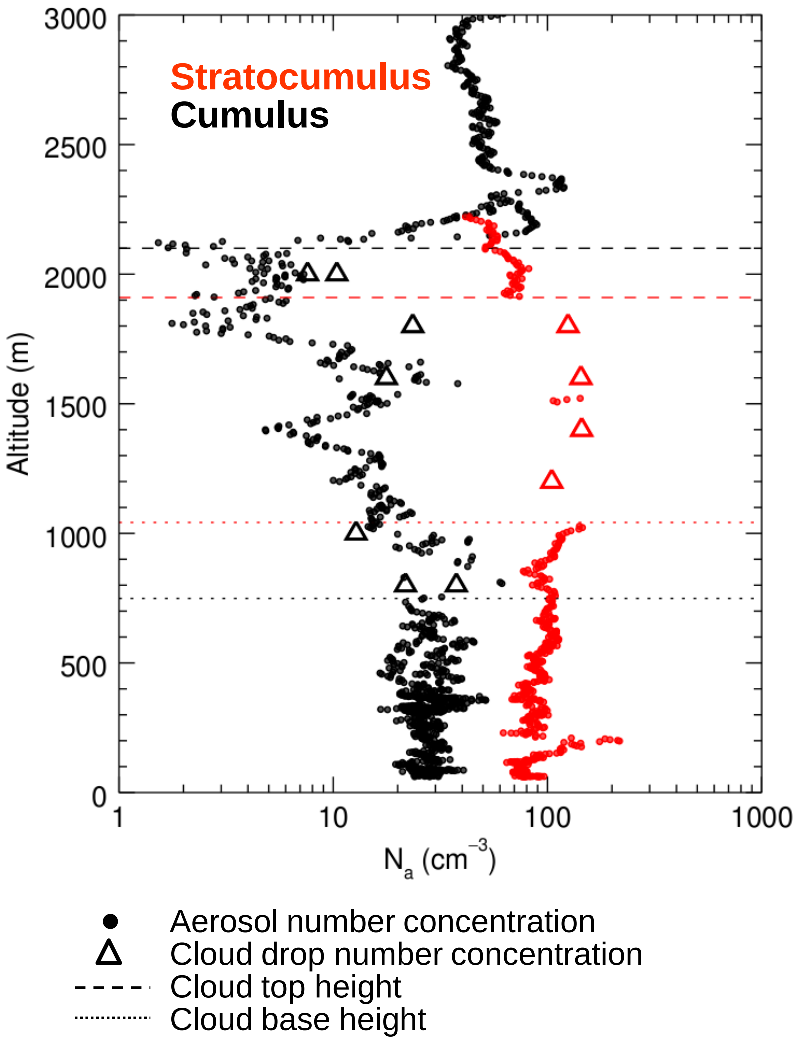


- Supercooled liquid water
- Small concentrations of ice that precipitate below the cloud

- Glaciation of cloud across the transition in cloud cover
- Convection spans the Hallett-Mossop temperature zone and is conducive to secondary ice production.

- Increase in precipitation sized particles (ice) across the transition

Aerosols

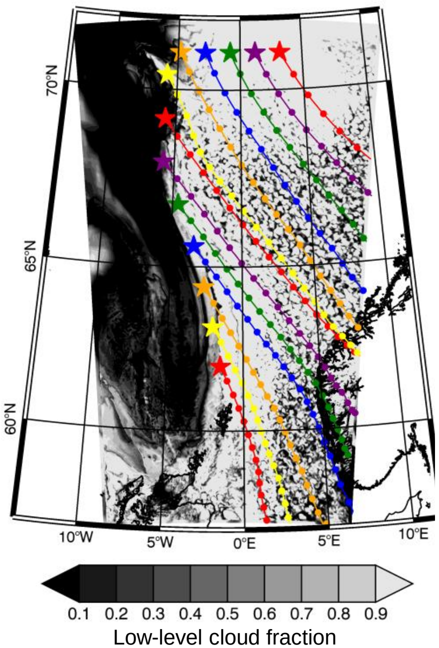


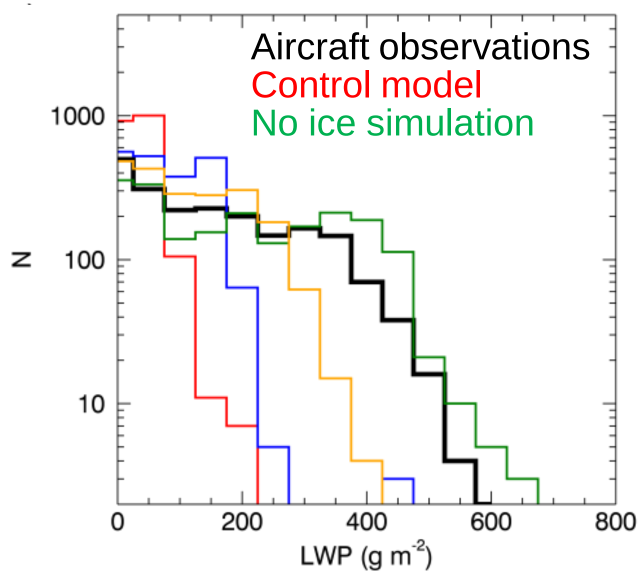
Enhancement in precipitation in the Cu regime leads to a rapid removal of aerosols via collision-coalescence

Ultra-clean layer at the top of the boundary layer in the Cu regime.

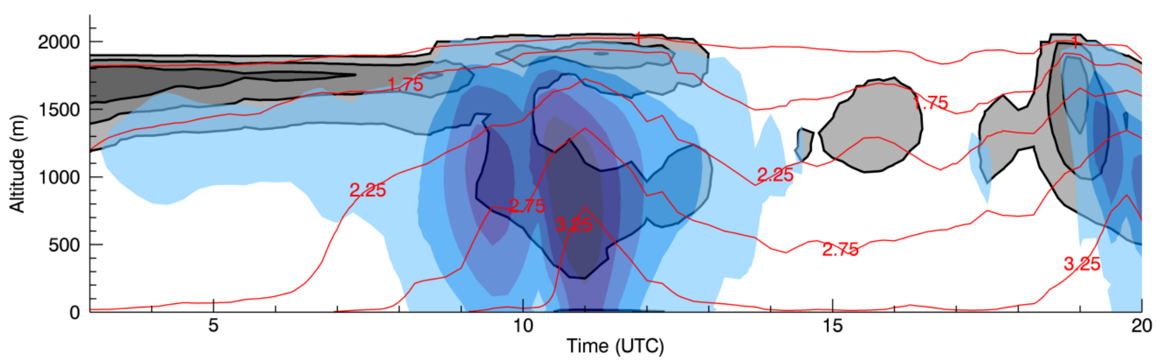
Very similar to observations in Pockets of Open Cells (POCs) in subtropical Sc decks.

Model simulations *Abel et al., submitted*





Ice processes in the model are too efficient at removing liquid water from the stratiform cloud layer.



LWC (grey shading), precipitation (blue shading), q_t (red contours)

Trajectories through the model show that precipitation induced decoupling of the boundary layer plays a key role in the break-up of the stratiform cloud.

Key points

Simulating boundary layer clouds in cold-air outbreaks presents a significant challenge for weather and climate models.

Complex interaction between the dynamics, cloud microphysics and convection in these shallow boundary layers.

Myriad of poorly quantified processes in the mixed phase clouds that need to be parameterized in the models.

Linkages to the southern Ocean problem in climate models (lack of supercooled LWC on the cold-air side of cyclones).