Cloud Trails: Are the clouds important?

Michael Johnston, Dr. Christopher Holloway, and Prof. Robert Plant
From Observations:
Bermuda Weather Service: 2019-07-17 14:36:04 UTC

Island:
~2 km by 25 km

Cloud band:
~2 km by >50 km

Fairly common -> e.g. Johnston et al. (2018) MWR
How small islands organise shallow convection

Strongly heated island creates a turbulent plume

Mixing within turbulent plume warms and dries island wake

Land/sea gradient in surface buoyancy fluxes forces circulation

Matthews et al. (2007)
The Model

- UM10.9 with no convection scheme
- Blended boundary layer scheme
- Smith (1990) cloud scheme
- Periodic boundary conditions in E-W and N-S directions
- Prescribed cooling profile (Radiation)
- Geostrophic forcing (f plane)
- 140 vertical levels to 40 km model lid

- 10-day spin-up of initial conditions on 32x32 horizontal grid with interactive surface fluxes
  -> we get nice initial profiles of theta, RH, and wind, plus ~balanced sea surface fluxes
Experiments

All Experiments:

Periodic boundary conditions

Control Experiment:
100 m grid spacing

Flat 50 km$^2$ island
Diurnal cycle of H and E
Control Experiment

- One domain
- Island Coastline
- Cloud mask
- Cloud Band
- Turbulent Plume

Diurnal Cycle

- $T+0000\text{mins}$
- $H = 0 \text{ W m}^{-2}$, $E = 0 \text{ W m}^{-2}$

Nauru, 30 June 2018
Clouds and circulation

Clouds are a passive signature of the circulation

- Low RH
- No change to warm plume extent
- No change to circulation strength

ν'
How bad could it be?

We want to try out:
Grid spacing of 800 m and 1.6 km

~UKV resolution

... and use the 100 m grid spacing as the “truth”
Expectations from BOMEX

Slope of cloud initiation
~1 sec m\(^{-1}\)

Slope of 10% cloud cover
~2 sec m\(^{-1}\)

Resolved TKE increases with increasing dx

Cloud cover decreases with increasing dx
Coarse Grained Comparison

Increasing $dx$ increases cell size and intensity with subsequent negative feedback on CT organisation.

Control, $dx = 100$ m, $T+0300$ mins, $H_{\text{long}} = 0000$W/m$^2$, $E_{\text{long}} = 0000$W/m$^2$

$dx = 800$ m (coarse grained from 100 m)

$dx = 1600$ m (coarse grained from 100 m)
Total Rainfall between 6AM and 12PM
Mass Flux Evolution

**Mass flux at LCL in 3 hours prior to peak island heating**

- **Control**
- **Control_0800m (cloudy)**
- **Control (cloudy)**
- **Control_1600m**
- **Control_0800m**
- **Control_1600m (cloudy)**

1.6 km experiment overshoots and collapses prior to peak heating (@12hrs)
As dx increases, the amount of deeper cloud increases.

Cloud liquid in solid lines, Cloud ice in dotted lines.
Summary

• Do the clouds matter for cloud trails?

No*

• What happens as we increase to operational grid spacing?

Convective cells get too big
They get too intense
The resulting clouds start to matter*