Gravity waves as a modulator of clouds in the South East Pacific

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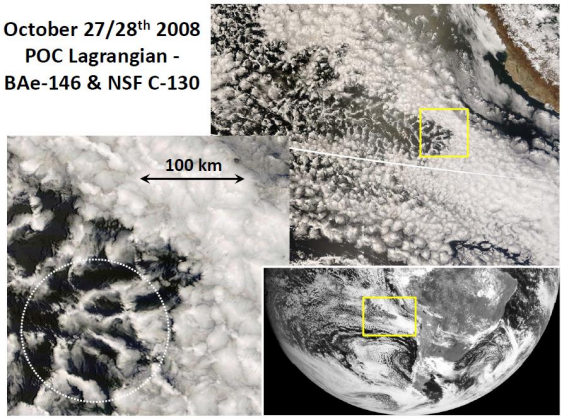
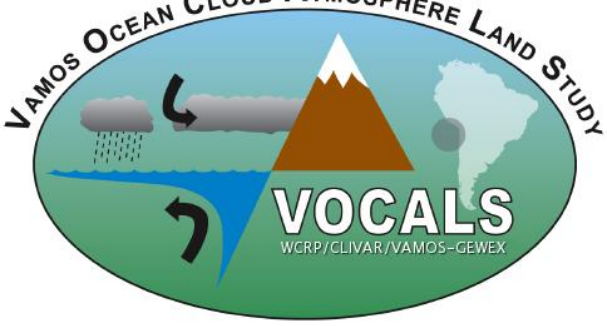
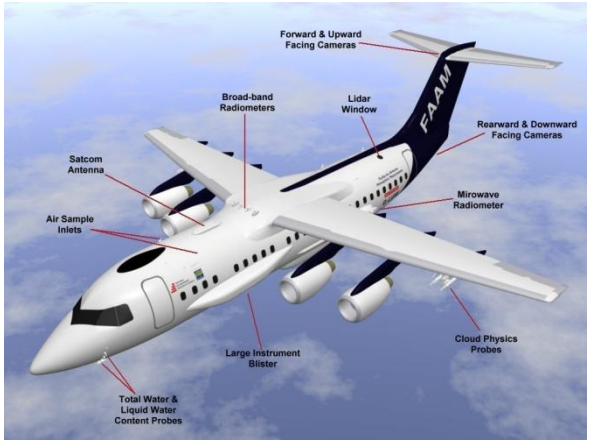
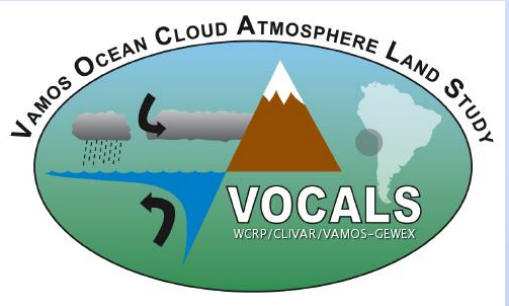






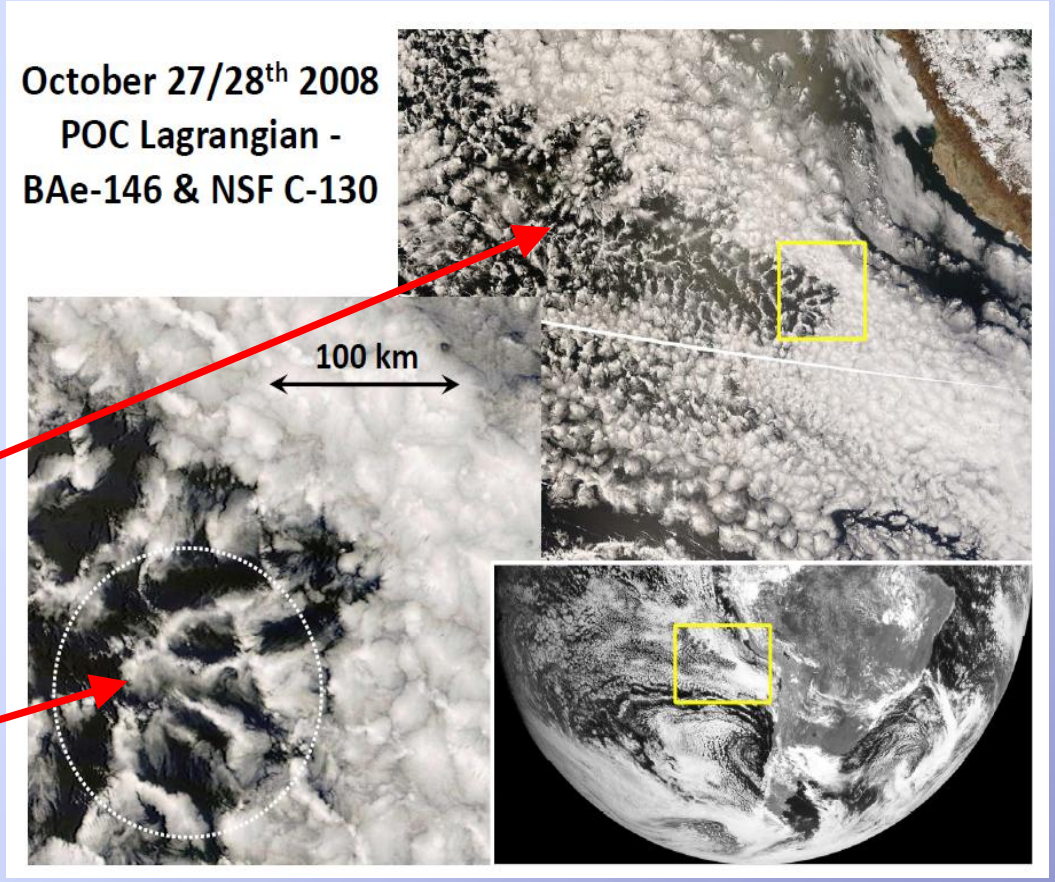
Motivation



- Another source of cloud variability
- Observational case study
  - Satellite analysis
  - Why were they there?
  - Relationship to POCs
- Further work – Other times and places

Pockets of Open Cells (POCs)

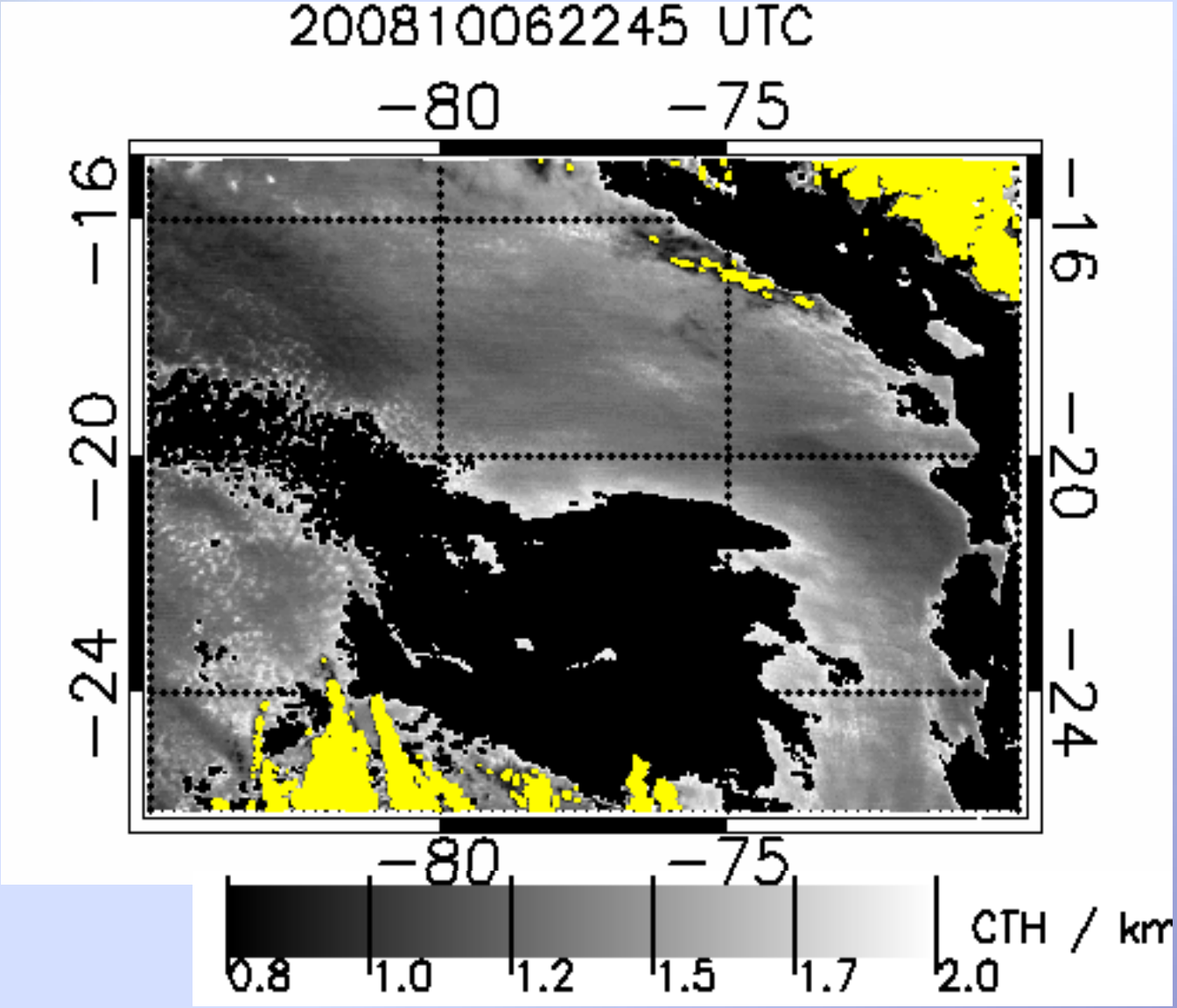
- Episodic appearance of **POCs** –openly convecting, cloud-clear zones
- Always observed well away from the coastline
- **Enhanced drizzle rates** in surrounding wall cloud (Wood et al., 2009; 2010)



Observations of POCs in the SEP

- POCs are not rare
- Mechanisms leading to their formation remain theoretical, yet LES representation looking good
- Drizzle common to all hypotheses but…
  - drizzle may be initiated by a number of different processes e.g. reduced CCN, thermodynamics
- Between 7th Oct – 10th Oct 2008, GOES-10 images show propagation of gravity waves (GWs) across the SEP
  - seen as modulated cloud brightness temperature.
- POCs formed in their wake and advected away with the mean flow.
- Focus here on an observation-led process study

Gravity wave observation

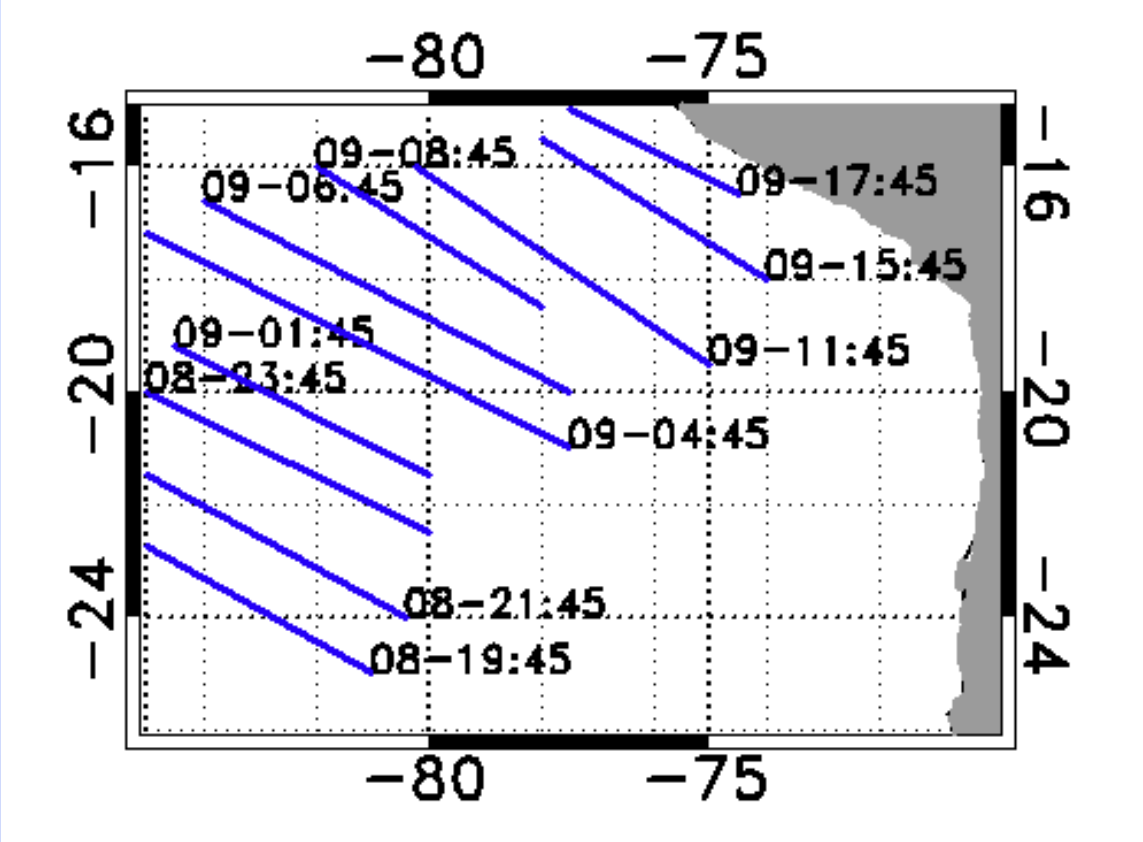


Gravity waves = bright and dark wave fronts in cloud field

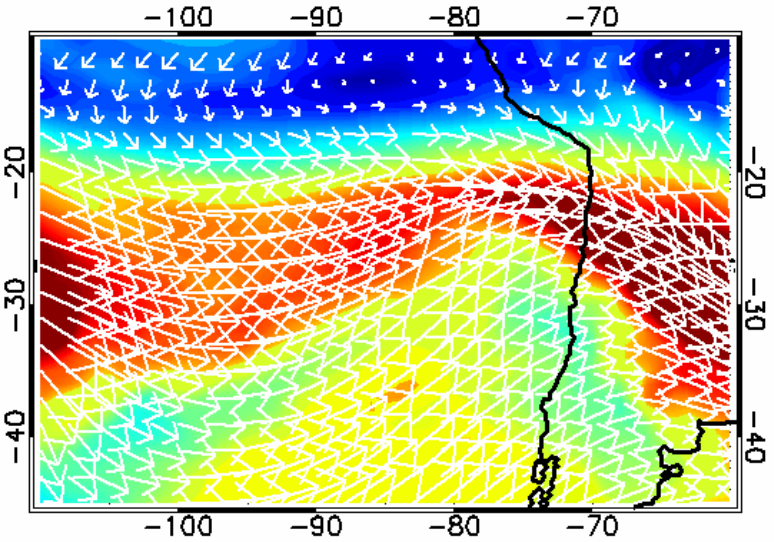
Retrieved CTH from GOES-10

GW Time-line

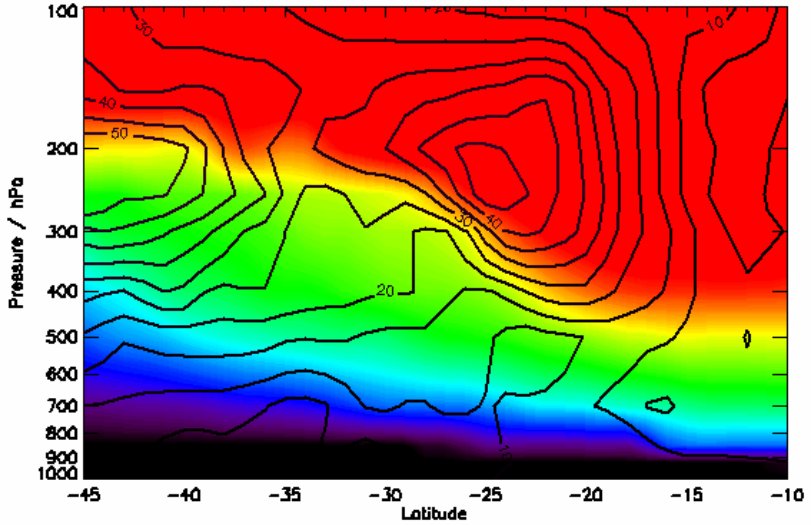
- Waves take 22 hours to reach the coast, travelling ~800 km
- Phase speed ~ 40 km/h
- Wavelength ~ 60 km



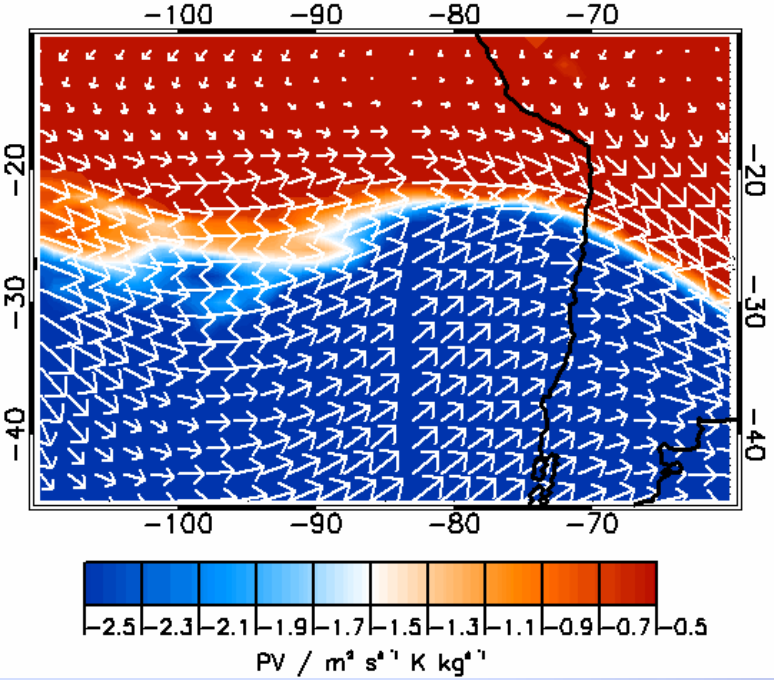
ECMWF Winds at 350 K: 20081004 00:00 UTC



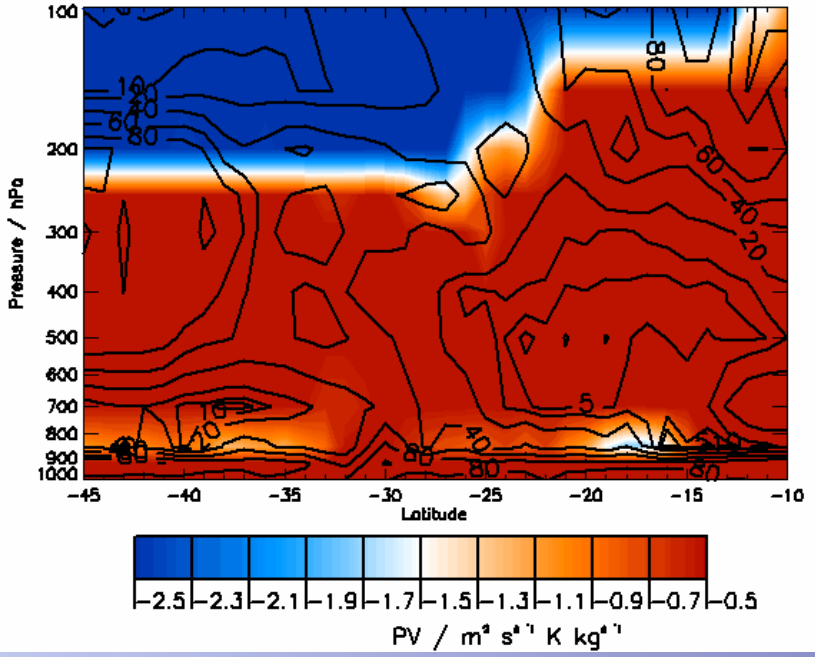
ECMWF section theta/winds at 275E: 20081004 00:00 UTC



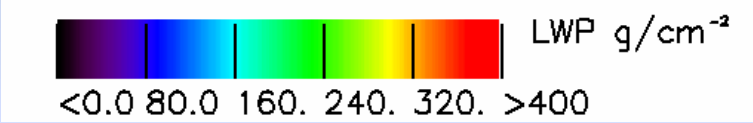
ECMWF PV/winds at 350 K, 20081004 00:00 UTC



ECMWF section PV/RH at 275E: 20081004 00:00 UTC



Satellite retrievals of cloud bulk properties

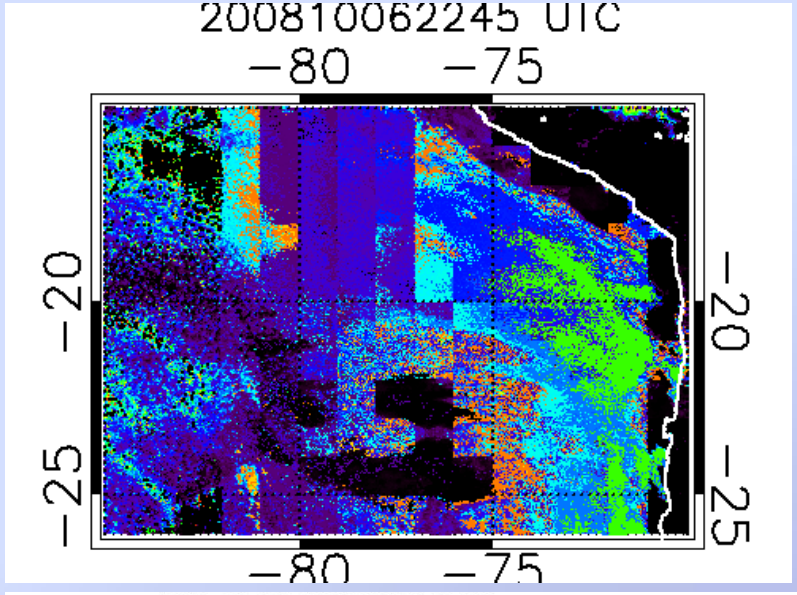


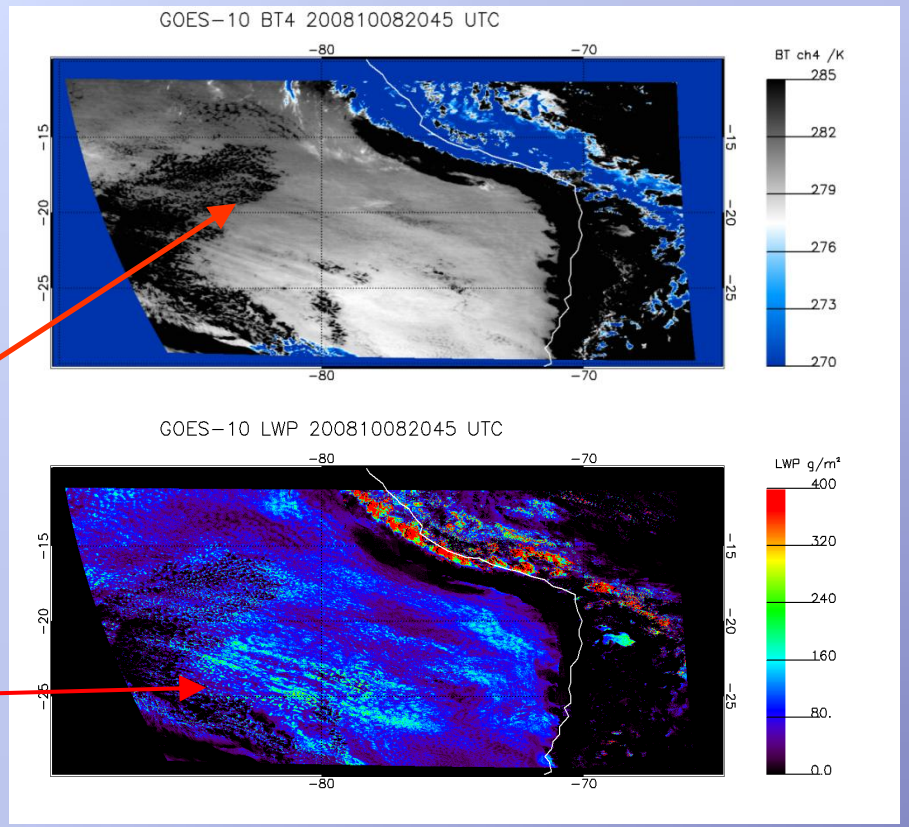
Right: GOES-10 retrieved LWP

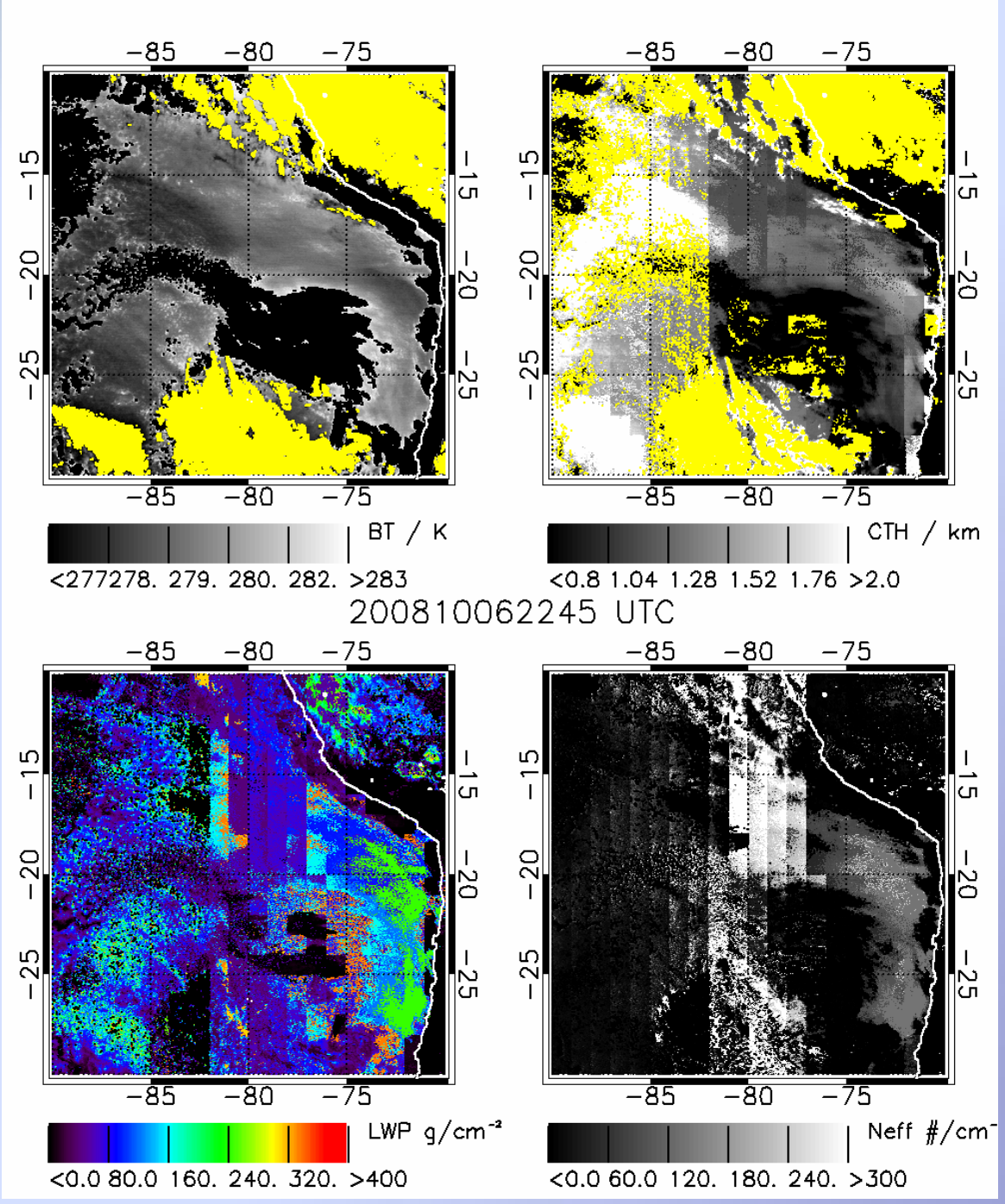
Modulations in cloud Tau, LWP and Re are seen.

Waves moving into pre-existing enhanced LWP areas form POCs

POCs in wake of gravity waves



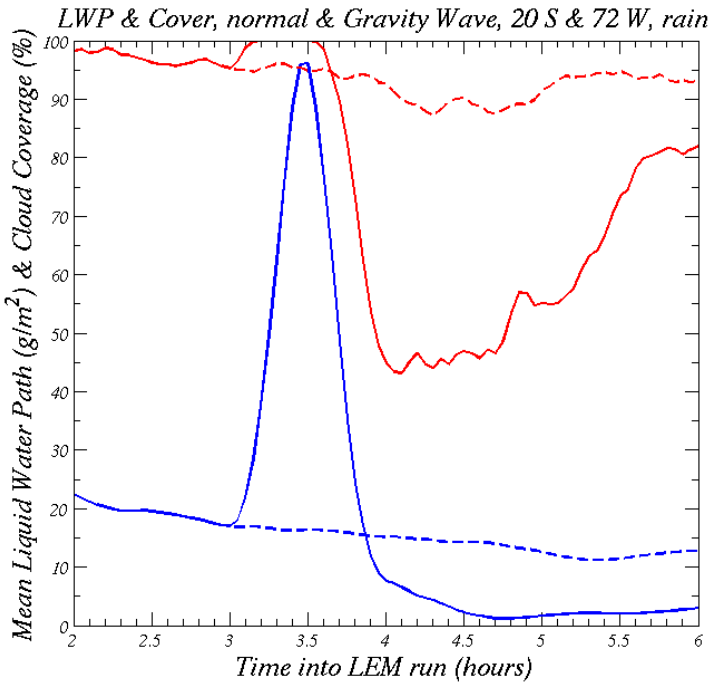


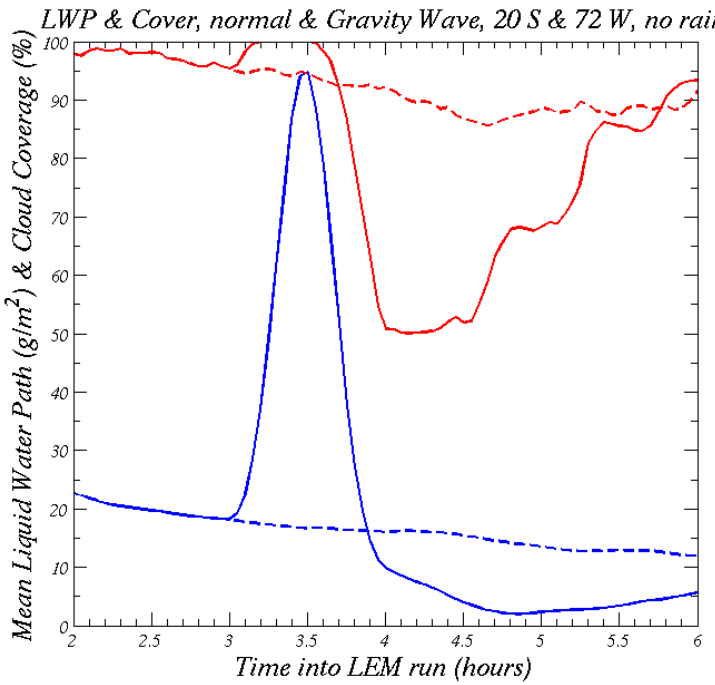

−85 −80 −75
−15 −20 −25
BT / K
<277278. 279. 280. 282. >283
CTH / km
<0.8 1.04 1.28 1.52 1.76 >2.0
200810062245 UTC
LWP g/cm⁻²
<0.0 80.0 160. 240. 320. >400
Neff #/cm⁻
<0.0 60.0 120. 180. 240. >300

LEM modelling of POCs

- Gravity wave simulated using an isentropic perturbation in the vertical wind field of the Met Office Large Eddy Model.
- Vertical velocity field modelled as a vertically symmetric triangular function peaking at cloud top and decaying to zero at the surface.
- Amplitude chosen to match the observed peak-to-trough in satellite-retrieved cloud top height (300 metres)
- Modulated in time by a sine wave with a period of 55 minutes in line with observations
- Fixed locations (and corresponding ECMWF T799 91 sigma level) used to initiate the model at 1200 UTC, concurrent with observations of POC forming zones

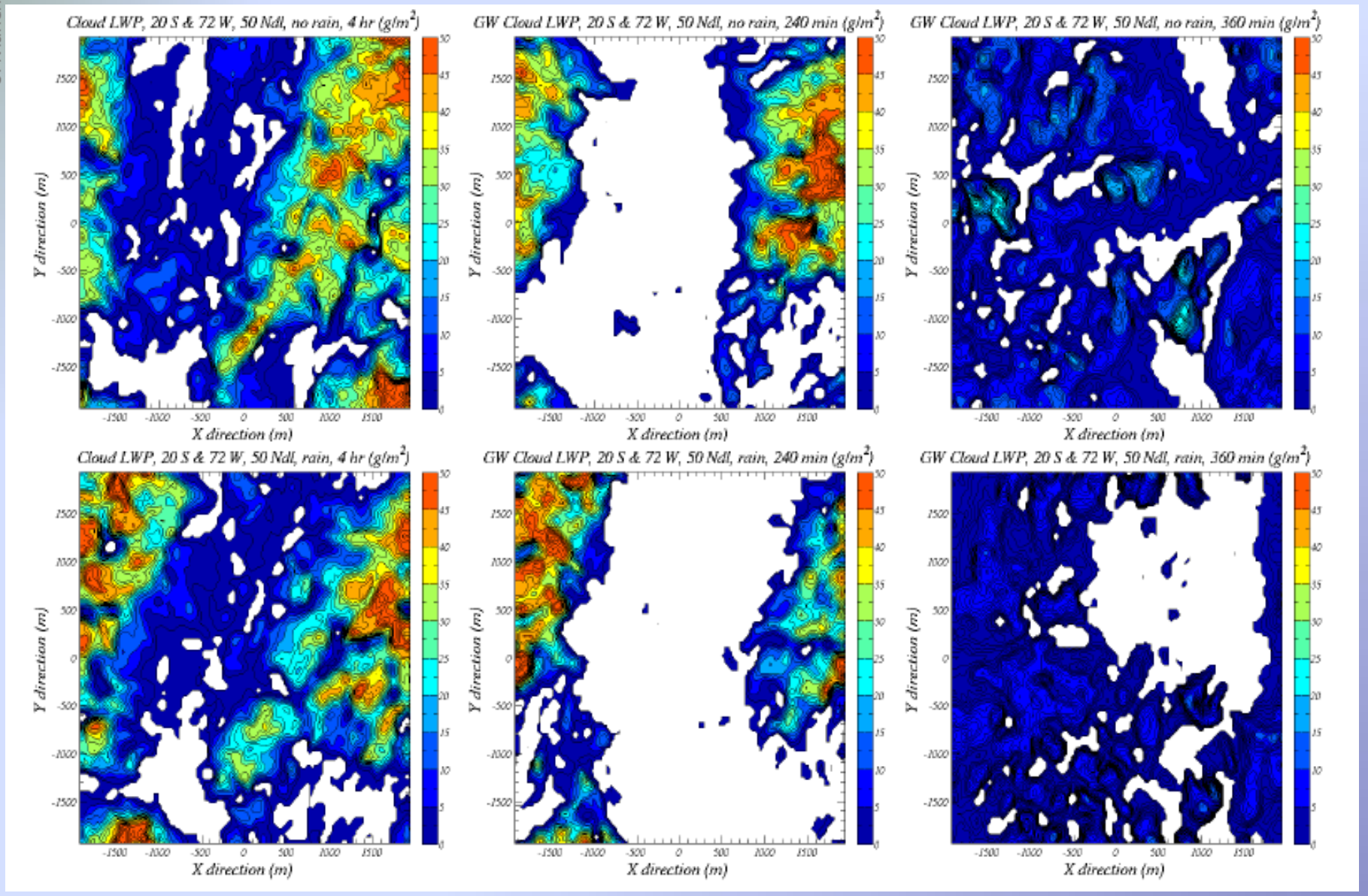
LEM results





Above: Cloud cover percent (red) and cloud liquid water path (blue) with time during the passage of a GW, with (left) and without (right) rain formation. Dashed line = control (no GW) case.

LEM – model liquid water path



Without gravity wave **Just after wave** **2 hrs after gravity wave**

Summary

- Gravity waves are excited in the SEP throughout October 2008 in a STJ disturbance
- These waves propagate across the SEP; and are evident as north-eastward propagating coherent wave-trains in cloud brightness temperature and retrieved cloud bulk properties
- The waves propagate perpendicular to the mean north easterly flow
- On occasion, POCs form in the troughs of these waves, which subsequently advect with the mean flow.
- LEM modelling suggests POCs may be formed by simulated waves through a forced and subsequently self-sustained change in vertical mixing and cloud top entrainment, coupled with a reduction in total water content in the cloud layer due to drizzle formation.
- This mechanism suggest a new additional mechanism which ultimately leads to POC formation in the SEP, playing a significant role in the tropical energy budget.
- POCs and their manifold potential initiative processes remain unresolved in GCMs.