Thermodynamic Boundary Layer profiles

Model and Aircraft data from the VOCALS 2008 Stratocumulus field campaign

Paul Barrett July 2009

2nd VOCALS MEETING Seattle, July 2009

- Thermodynamics θ_{vl}

BEGIN ANALYSIS OF BOUNDARY LAYER

- Sea Surface Temperature Measurements
  - Fluxes
- Thermodynamic profiles
  - Stability
- Summary BL Structure along 20S
  - Diurnal Cycle
  - Variability in Well Mixed Sc cover
  - Decoupling, Drizzle, and Cumulus

Thermodynamic Structure along 20S

Virtual Potential Temperature

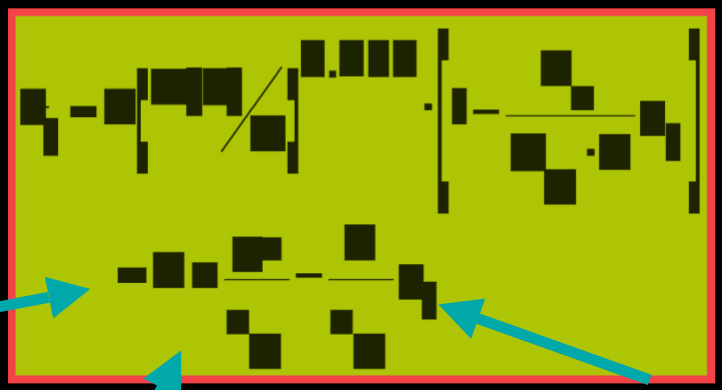
Buoyancy

Liquid Water Virtual Temperature

- Conserved under saturated adiabatic processes in absence of precipitation
- **A measure of the stability of the atmosphere under saturated conditions**
- *c.f.* Potential temperature for un-saturated conditions
- Liquid water acts to reduce Virtual Temperature, and reduce buoyancy
- Atmospheric water vapour adds to buoyancy (reduces density *c.f.* dry air)

Liquid Water Virtual Temperature

Liquid Water Potential Temperature



(1)

Temp

Adiabatic Altitude adjustment

Liquid water reduces potential temperature

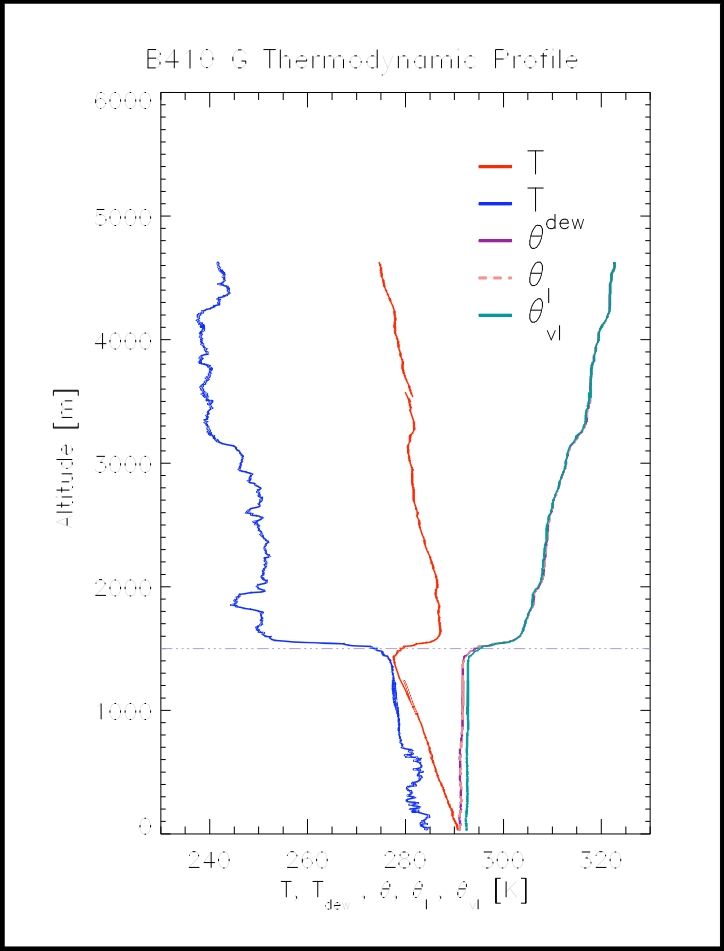
Liquid Water Virtual Temperature

(2)

Reverts to LWPT in unsaturated conditions

Includes atmospheric water vapour

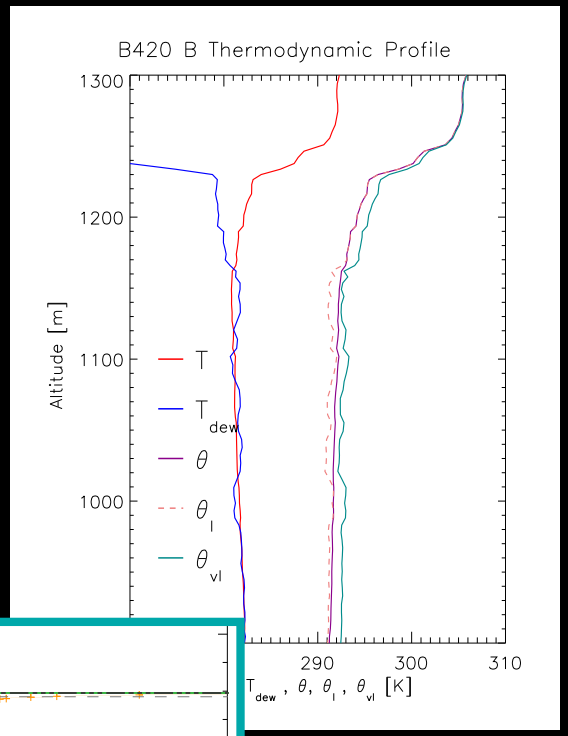
Typical VOCALS Thermodynamic Profile

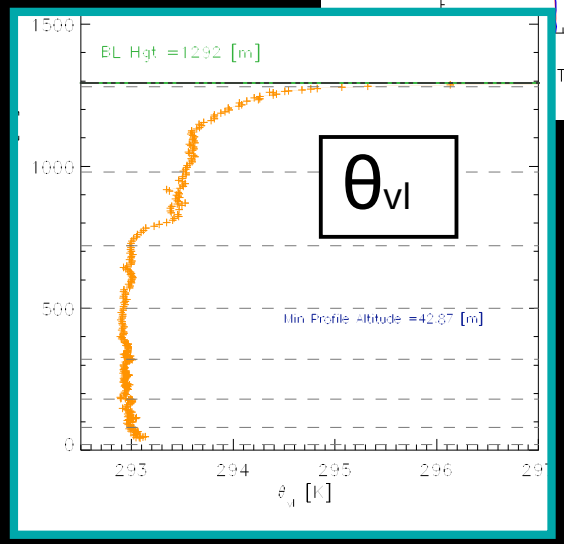


- Large Temperature Inversion
- Very dry aloft (generally)
- Mostly Cloud topped BL
- Stratocumulus
- Some decoupling, and Cu

Well Mixed or Decoupled?

- Liquid water potential temperature reduced by cloud LWC
- Inversion still at BL top
- Can identify decoupled layers – stable layers within BL

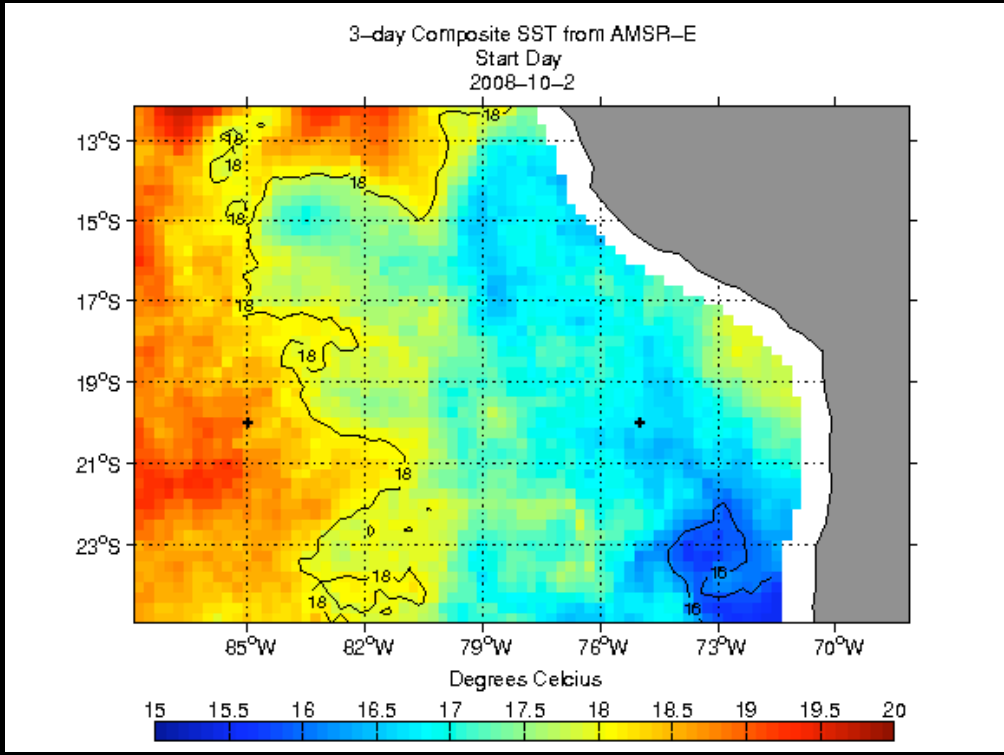




Structure Along 20 South

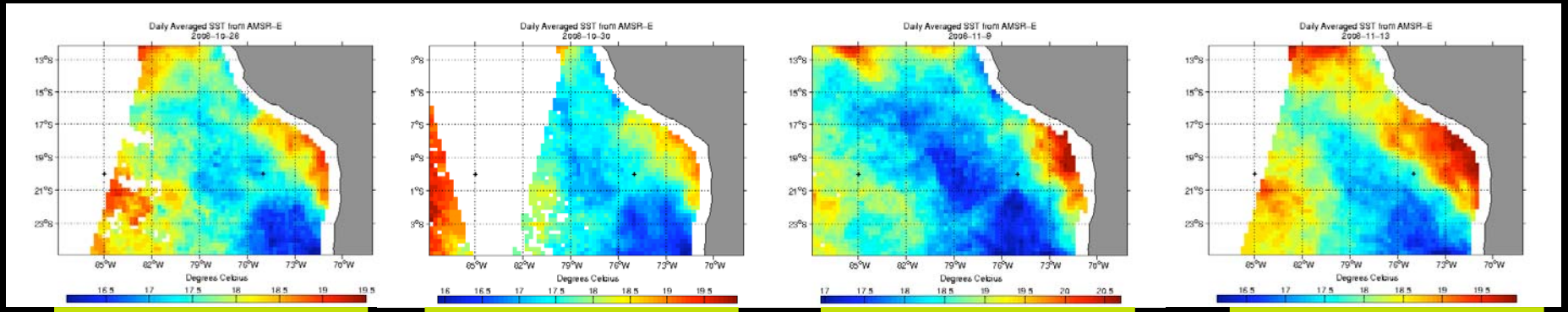
- Sea Surface Temperature
- Thermodynamic Profiles
- Wind
- Cloud Cover

SST VOCALS Animation AMSR-E μ-Wave



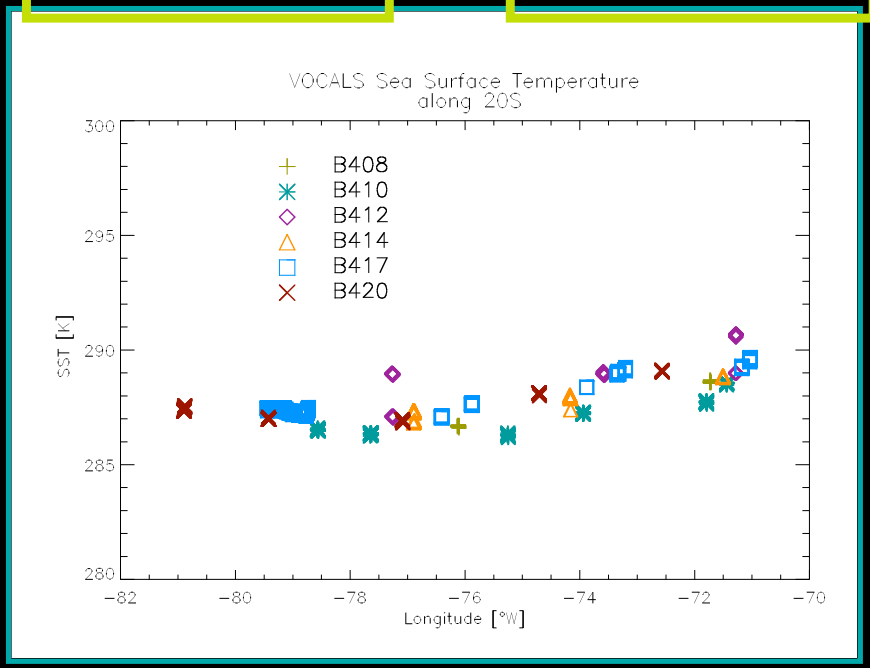
- 3 Day Mean
- Need good SST for surface fluxes
- Satellite, or
- Heinman BT, or
- ARIES, μ-wave Rad

Sea Surface Temperature along 20S - Heinman

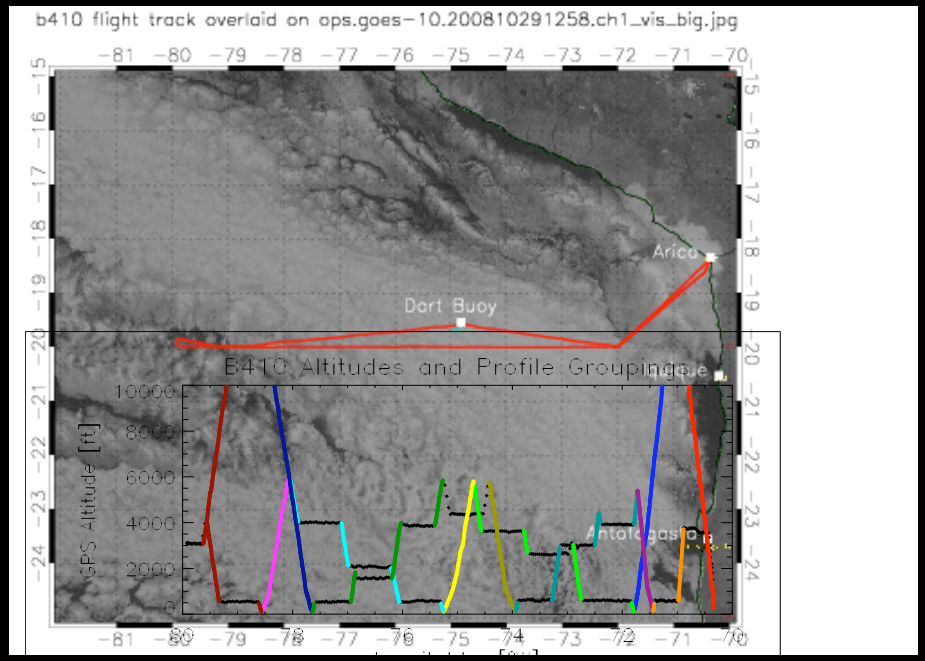


28 Oct | **30 Oct** | **09 Nov** | **13 Nov**

- Warming through the campaign
- Variation through campaign
- Some captured by Heinman BT
- BT measured from 50-100ft altitude
- We always measure under?
- ARIES SST



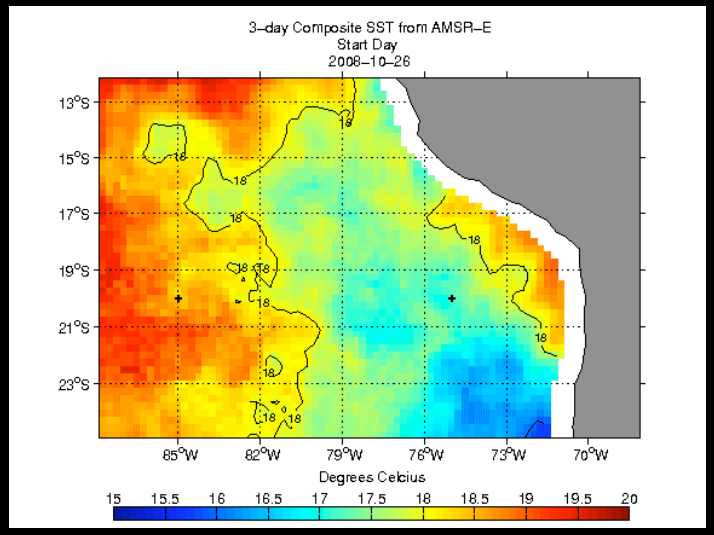
B410 29 Oct



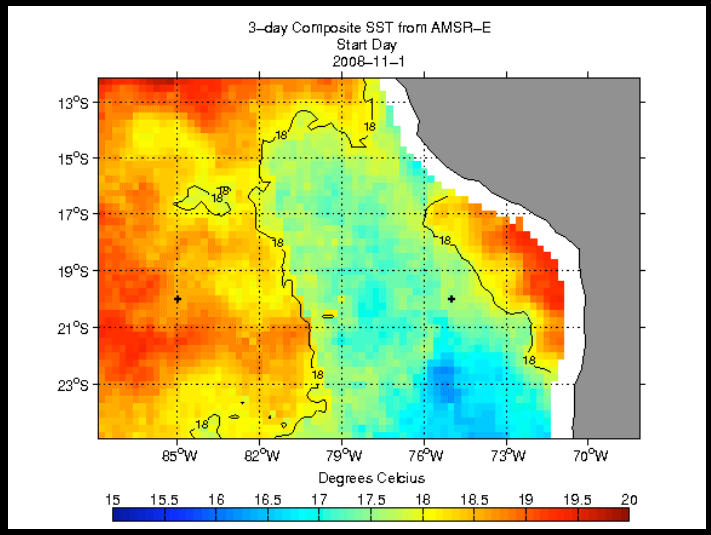
- Coastal Bight apparent
- Cloud is similar from 72W until very far end of track
- Pass into different region
- Return leg at low level
- Deep profiles at either end

Satellite + Flight tracks: S Abel.

No SST data from AMSR-E



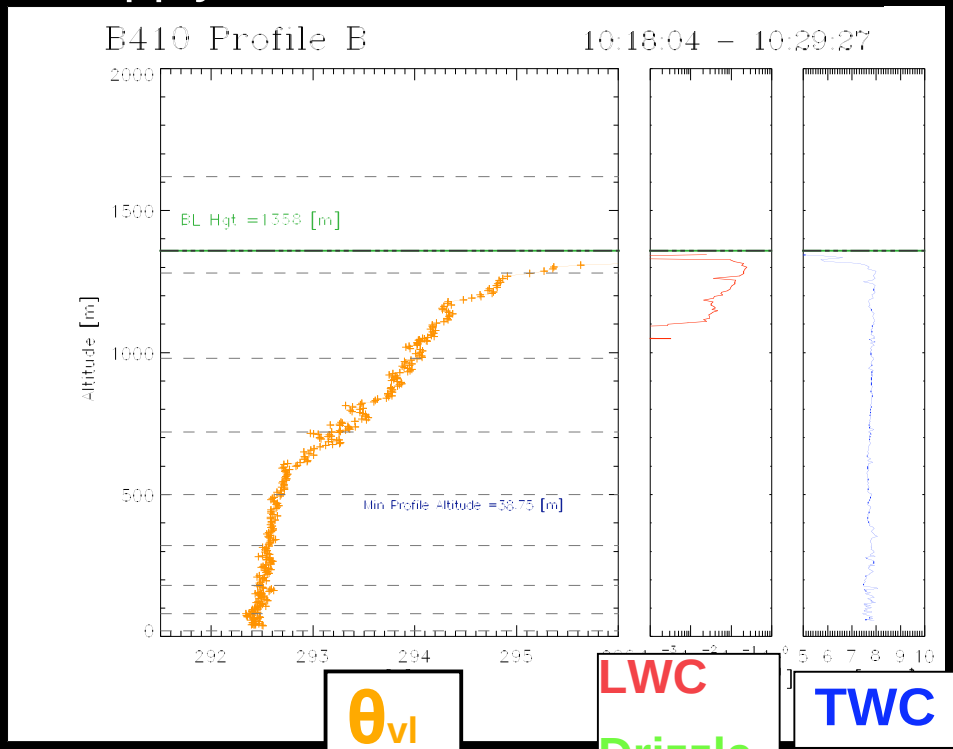
- 26 Oct
- To
- 1 Nov

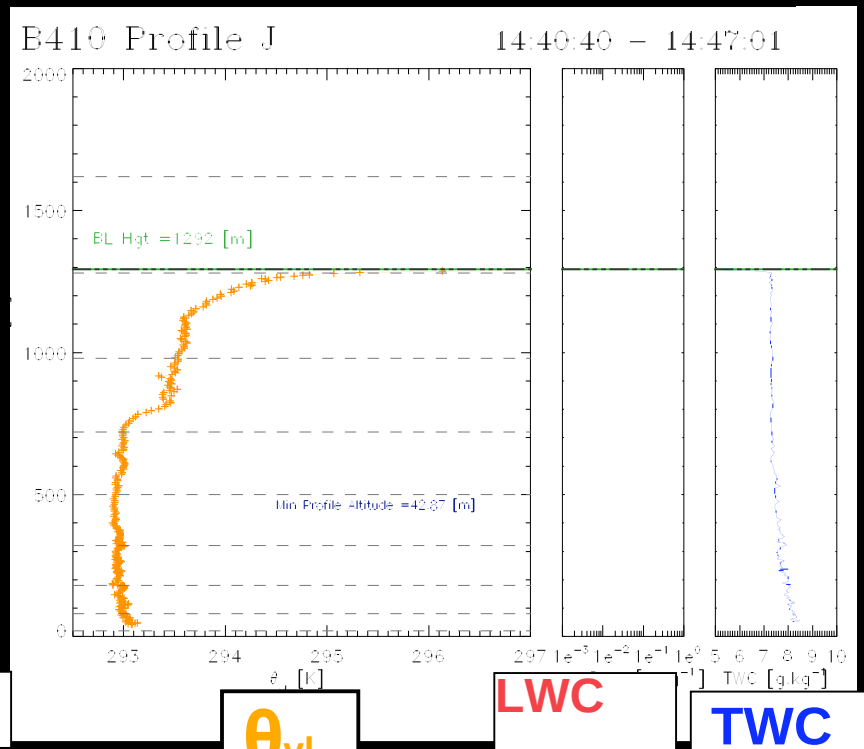


- Some coastal heating
- Cold tongue
- Similar Regime

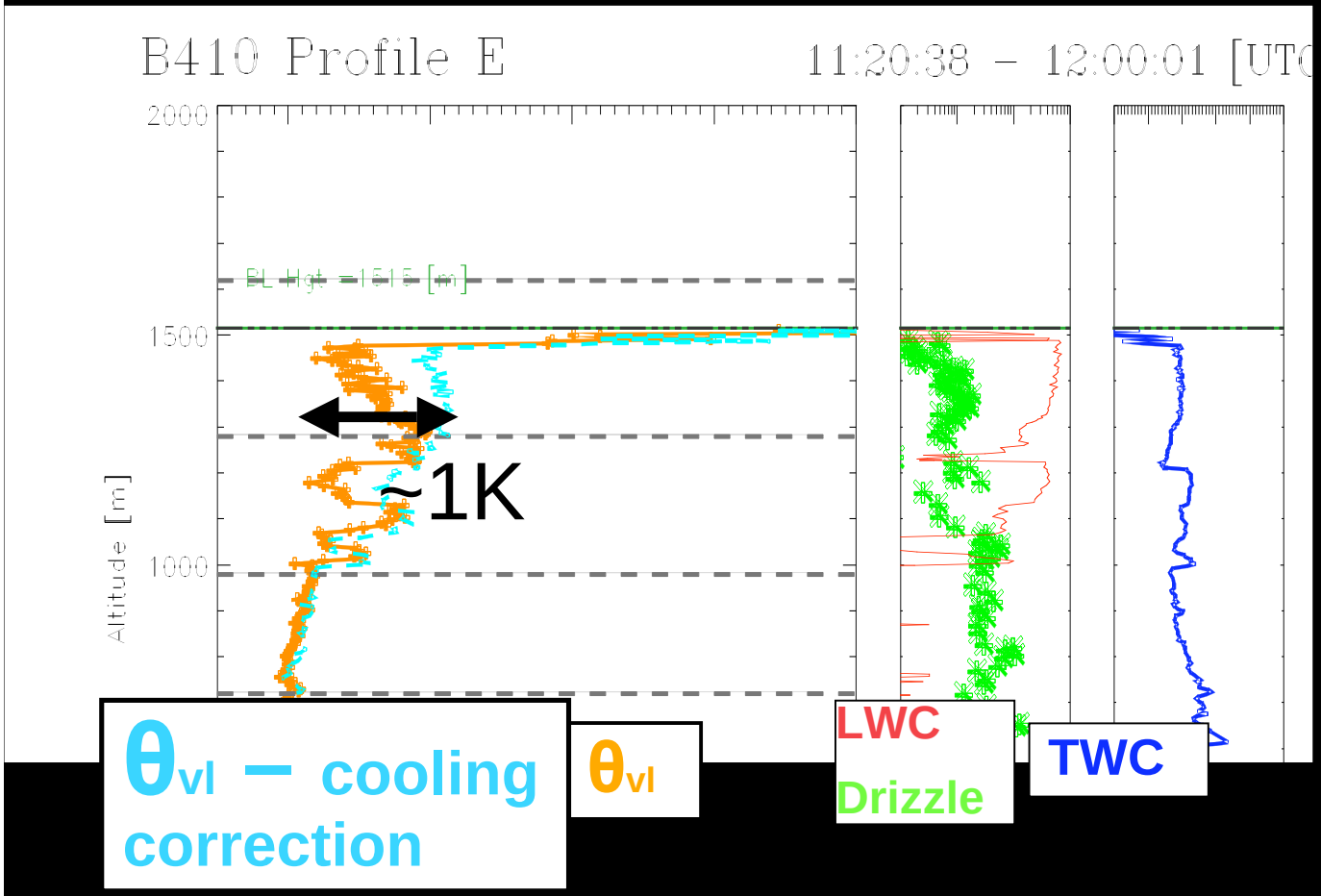
B410 Diurnal Cycle – Sunrise to Midday – Coastal Region

- Cloud – through the night by CTRC(?) gone by midday
- Inversion at ~1350m – falls during day
- Lower inversion at ~650m – builds – cuts off moisture supply





ALL: Wetting of Temp. Sensors – under-reading

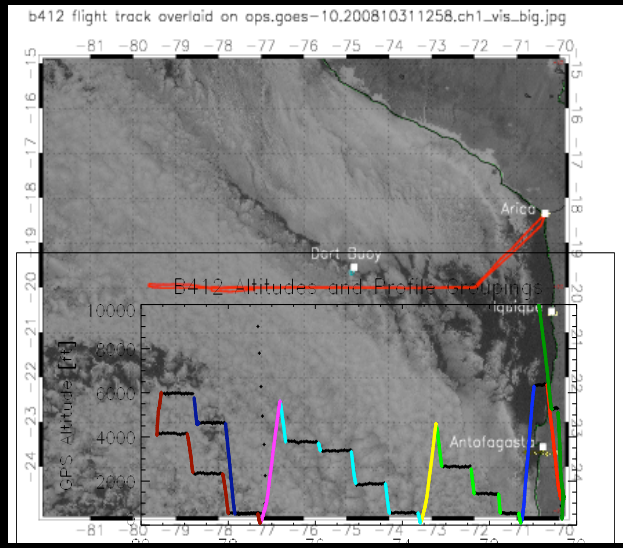


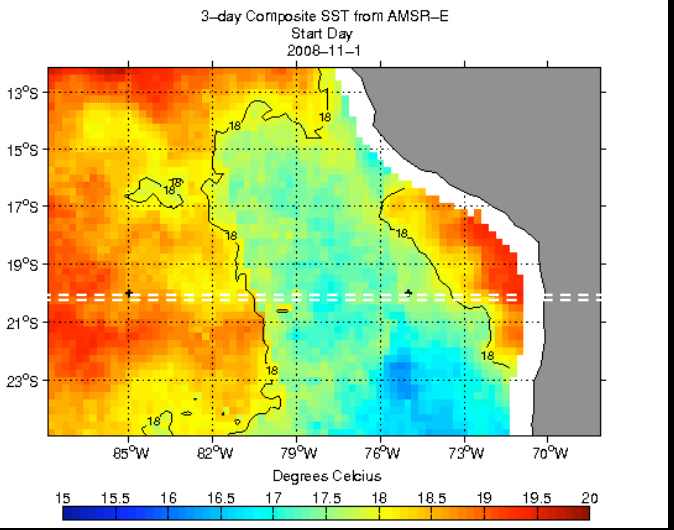
- Rosemount non-deicied temperature is too cool in presence of liquid water
- Need to compare with Ophir Radiometric on C130 when in cloud

B412 and B414 Comparison

- Similar Flight tracks
- C130 follows same track earlier in AM
  - Possibility of extended study 3am - noon
- Similar Conditions
- Differences in Detail

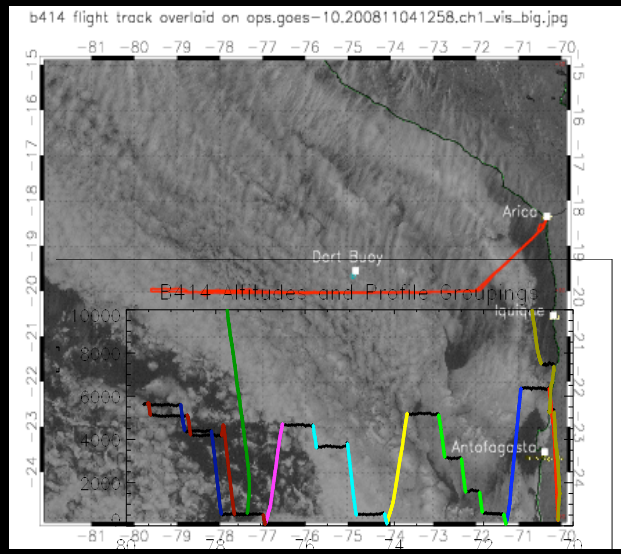
B412
31 Oct

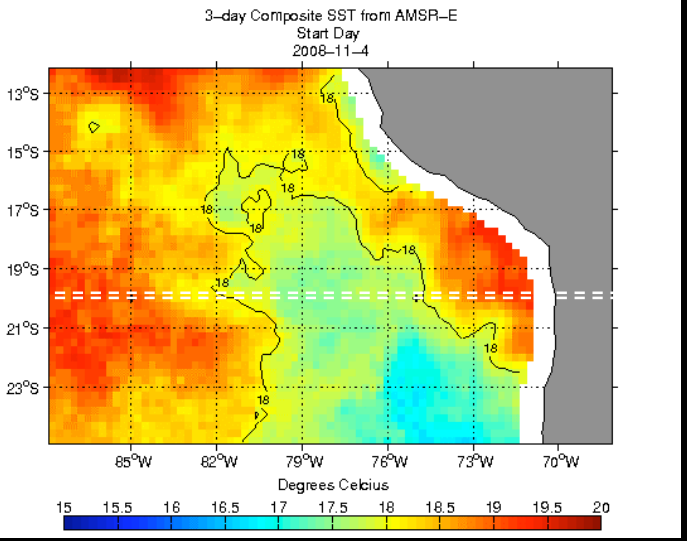




- **BL deepens away from coast**

B414
4 Nov



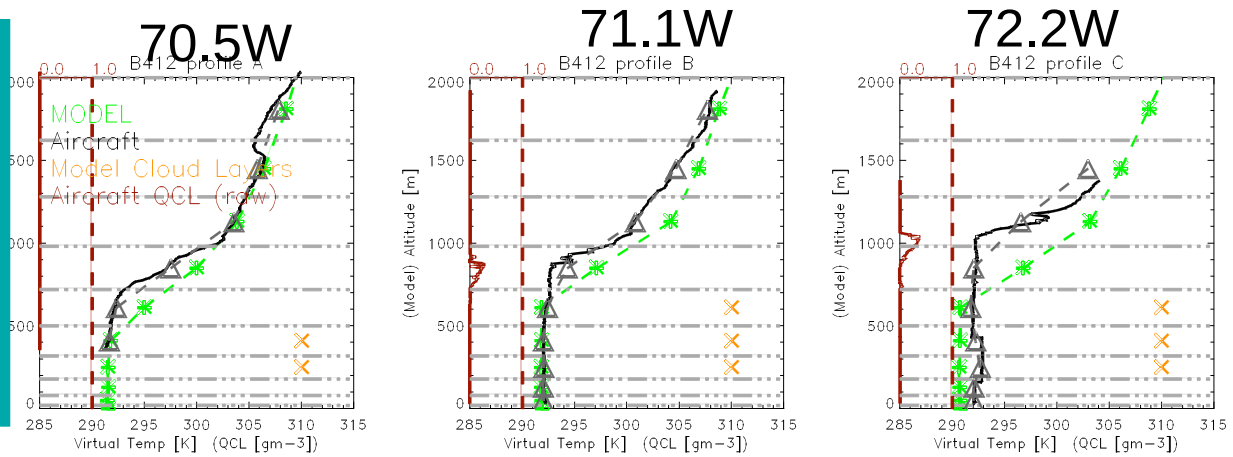


- **Warm SST at cloud break – SW corner and Coastal – not at northern edge**
- **BL height more uniform, Warmer out to 75W**

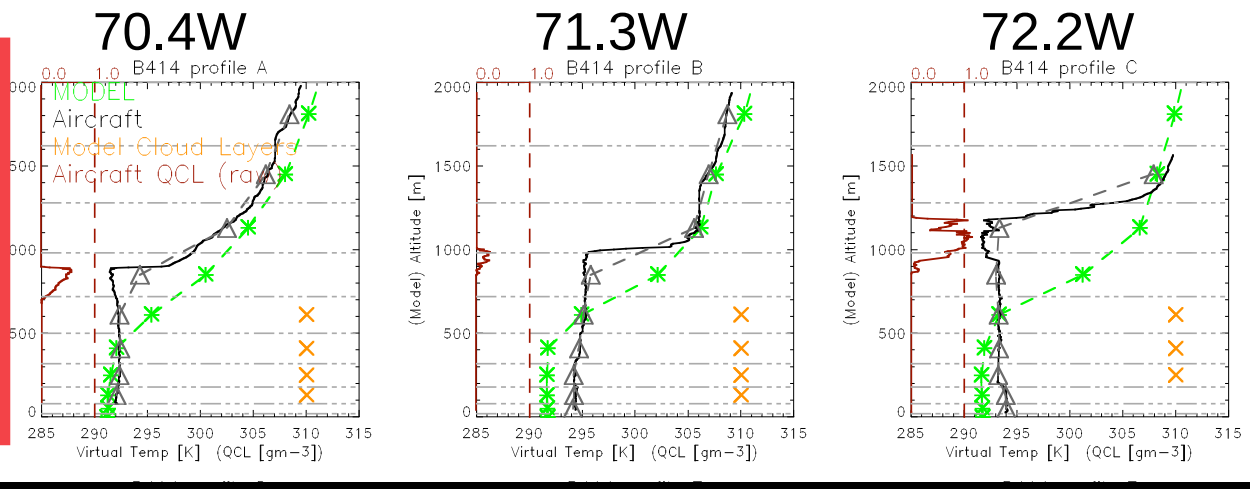
B412 and B414 Profiles Coastal – early AM

- **AIRCRAFT OBS**
- **MODEL**
- **A/c on MODEL**
- **QCL**
- **Model cloud layers**

B412



B414



Close to Coast

More definition to inversion on B414

More cloud on B414

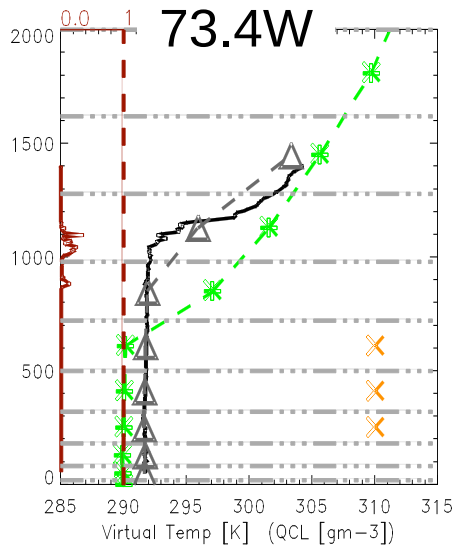
Higher BL at Coast on B414

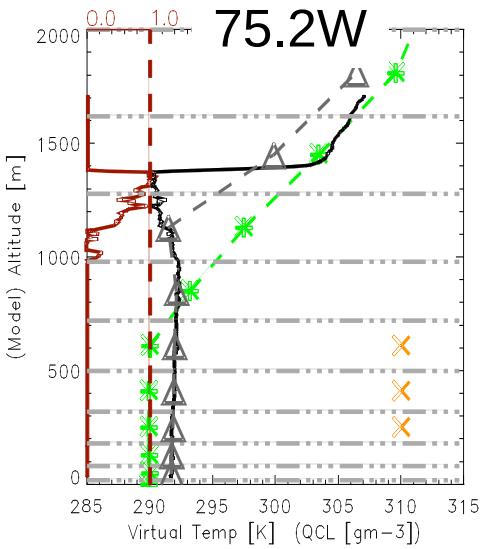
Similar BL heights just off Coast

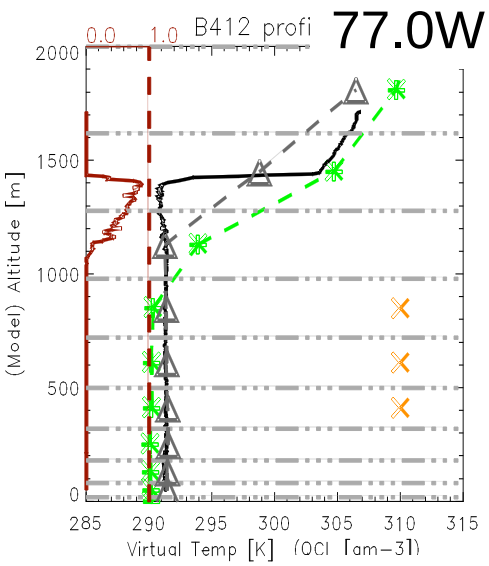
- Clear morning at the coast on B412
- BL deepens away from coast - both
- C130 – along same track but earlier – long time range

B412, B414 – BL increase Mid Region

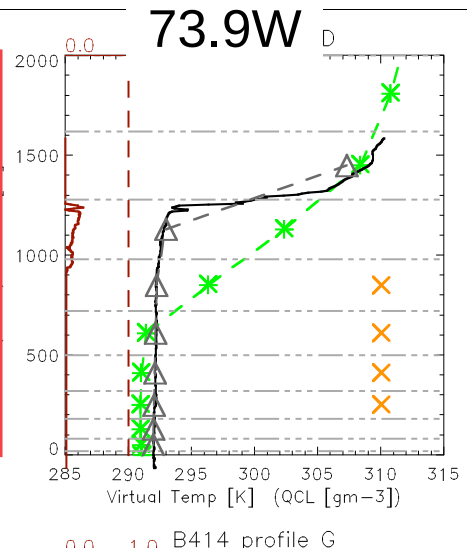
B412

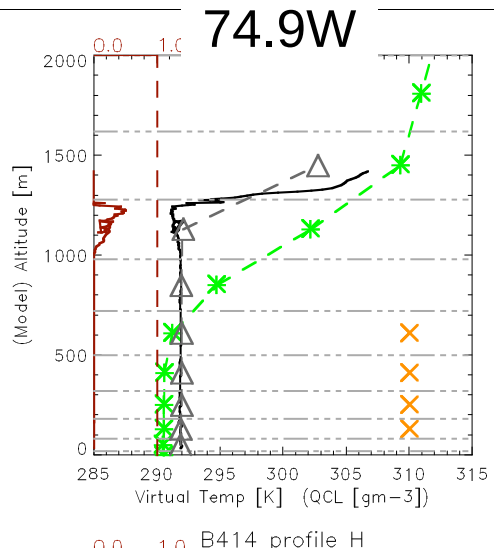


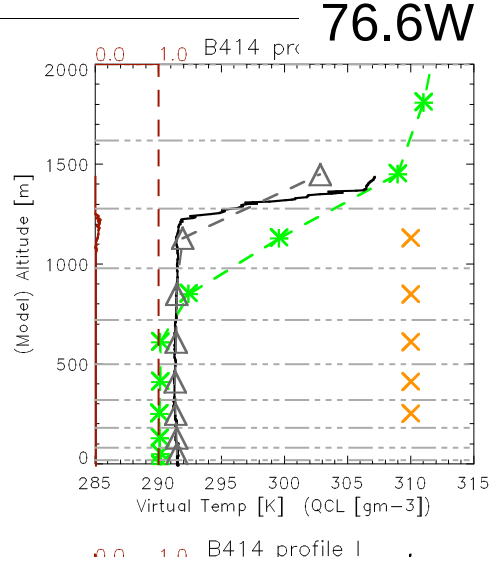




B414







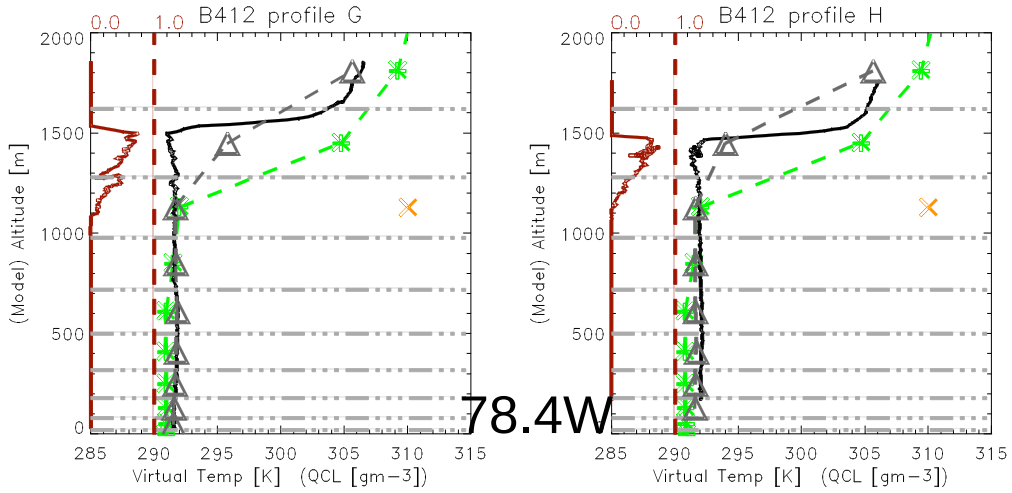
Mid Region

- Thin Cloud B414 and more patchy
- “Regular Sc” on B412 – higher BL to western edge of region

B412, B414 Away from Coast

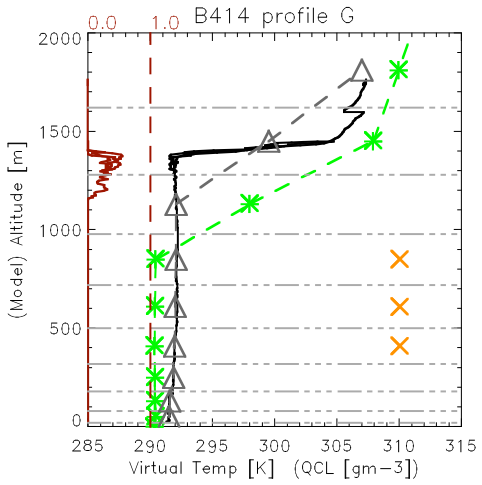
B412

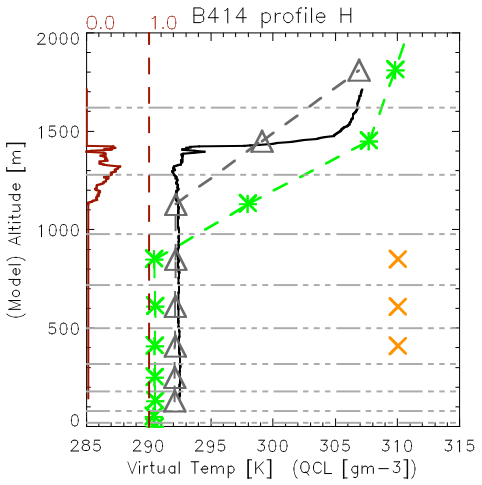
B414

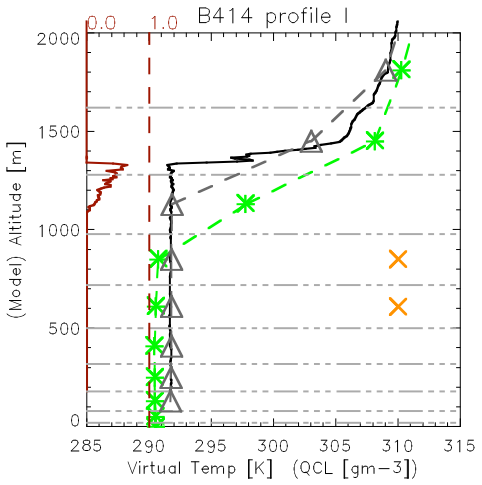


78.4W

- **AIRCRAFT OBS**
- **MODEL**
- **A/c on MODEL**
- **QCL**
- **Model cloud layers**







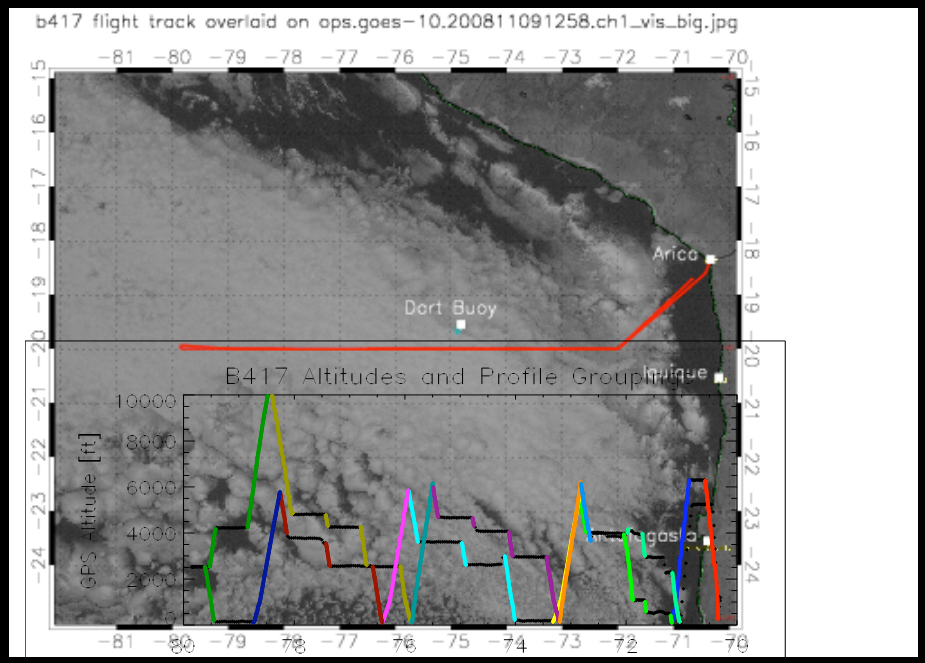
B412, B414 Remote Maritime

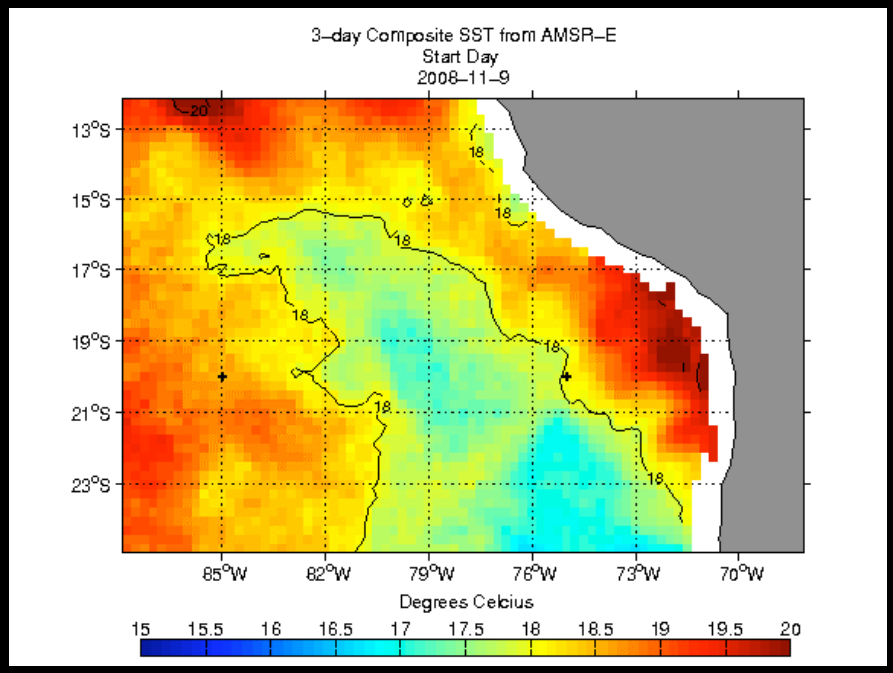
- Typical Well Mixed Layer Away from Coast
- More Cloud on B412
- Hint of Stable surface layer on B414?
- Slightly Higher Inversion on B412

B417 Coastal Bight Difficulties

- **Picture taken around 73W 20S looking out to sea**

B417 Coastal Bight Difficulties

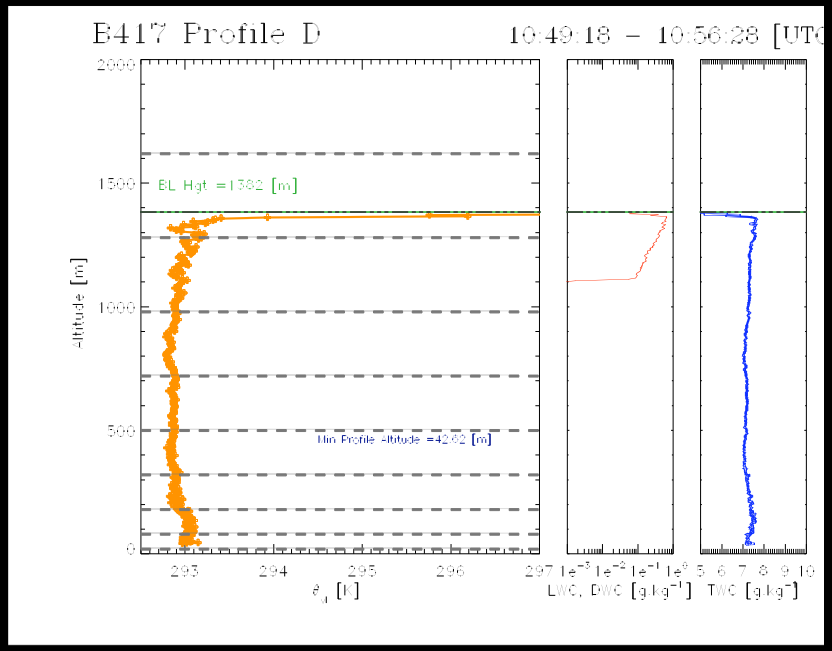




- Large variations in cloud cover and type around the edge of coastal region
- Warmer SST close to coast in this time period

B417 Coastal

- Complexity at edge of Coastal Bight

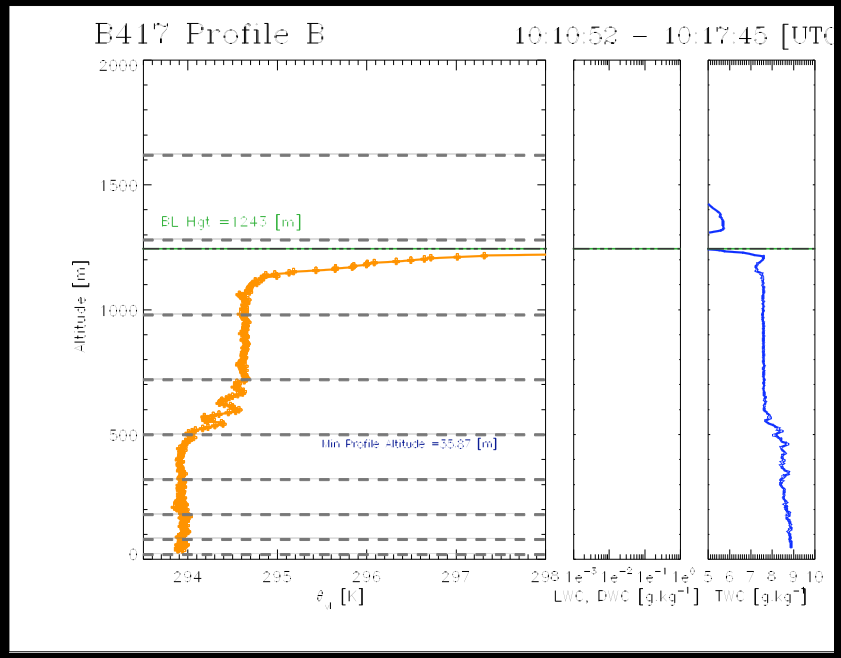


73.0º

Range=0.48º

Well Mixed

Cloud



71.0º

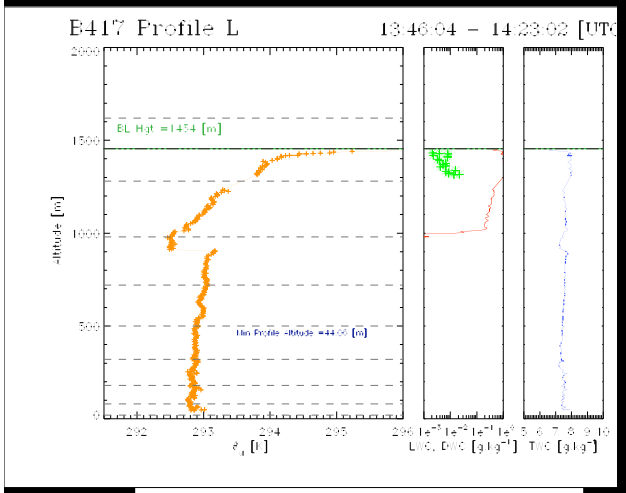
Range=0.31º

Decoupled

Cloud Free

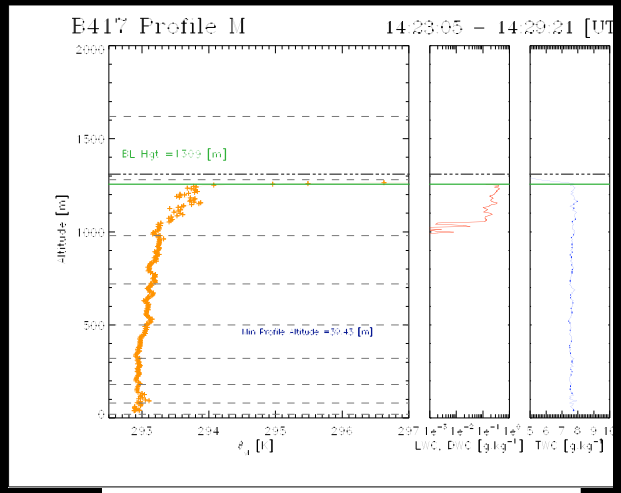
B417 Coastal Afternoon

- Variability



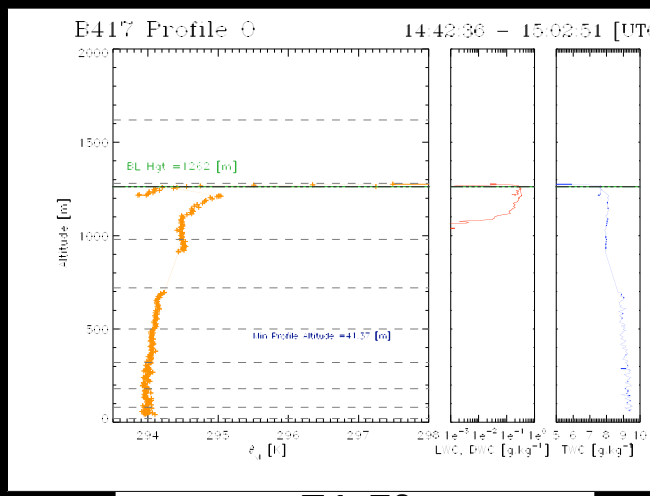
74.3º

Range = 2.2º



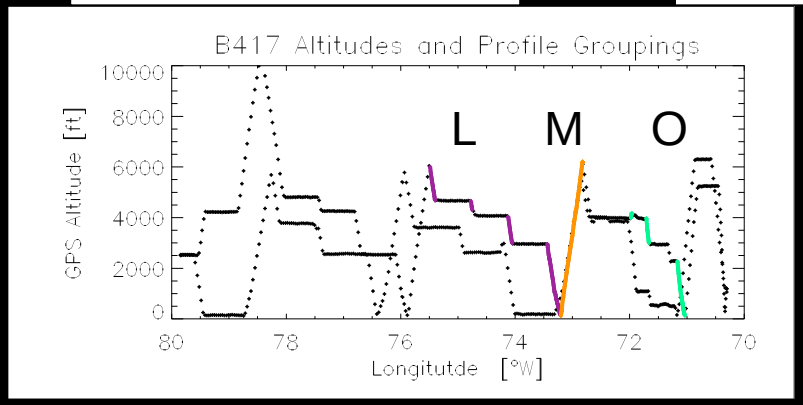
73.0º

Range = 0.38º



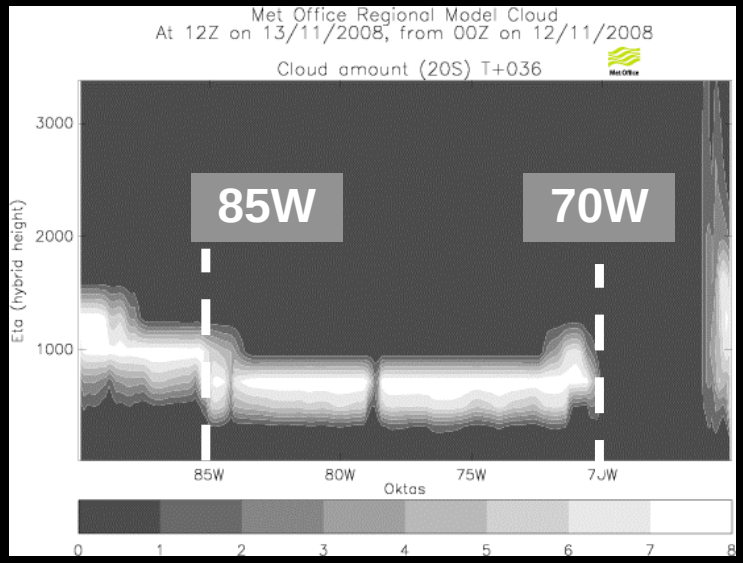
71.5º

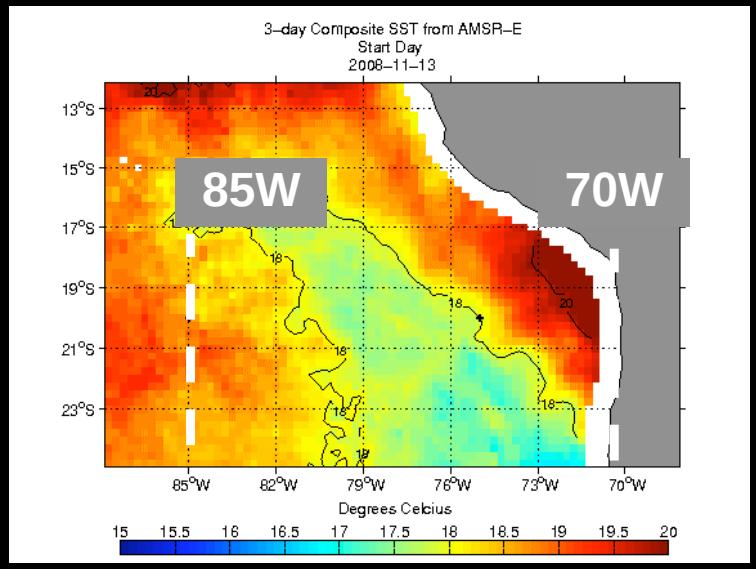
Range = 0.94º



Coastal Transition Study

B420 Decoupling



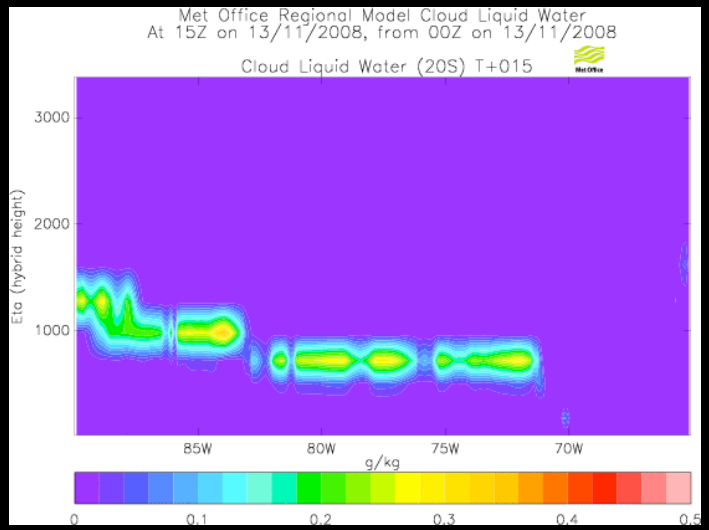


- FORECAST Cloud along 20S
- Model Cloud (17km (T+36))
- Break in Cloud – not at model level change.

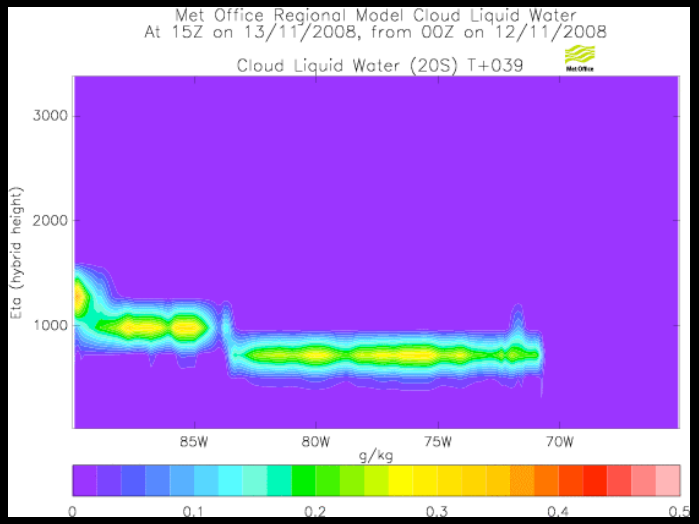
- Gradient in SST
- Much warmer in remote maritime
- Enough Heat for Cu convection?

LAM: D Walters

B420 – Model Cloud LWC from T+15 and T+39 - differences



T + 15

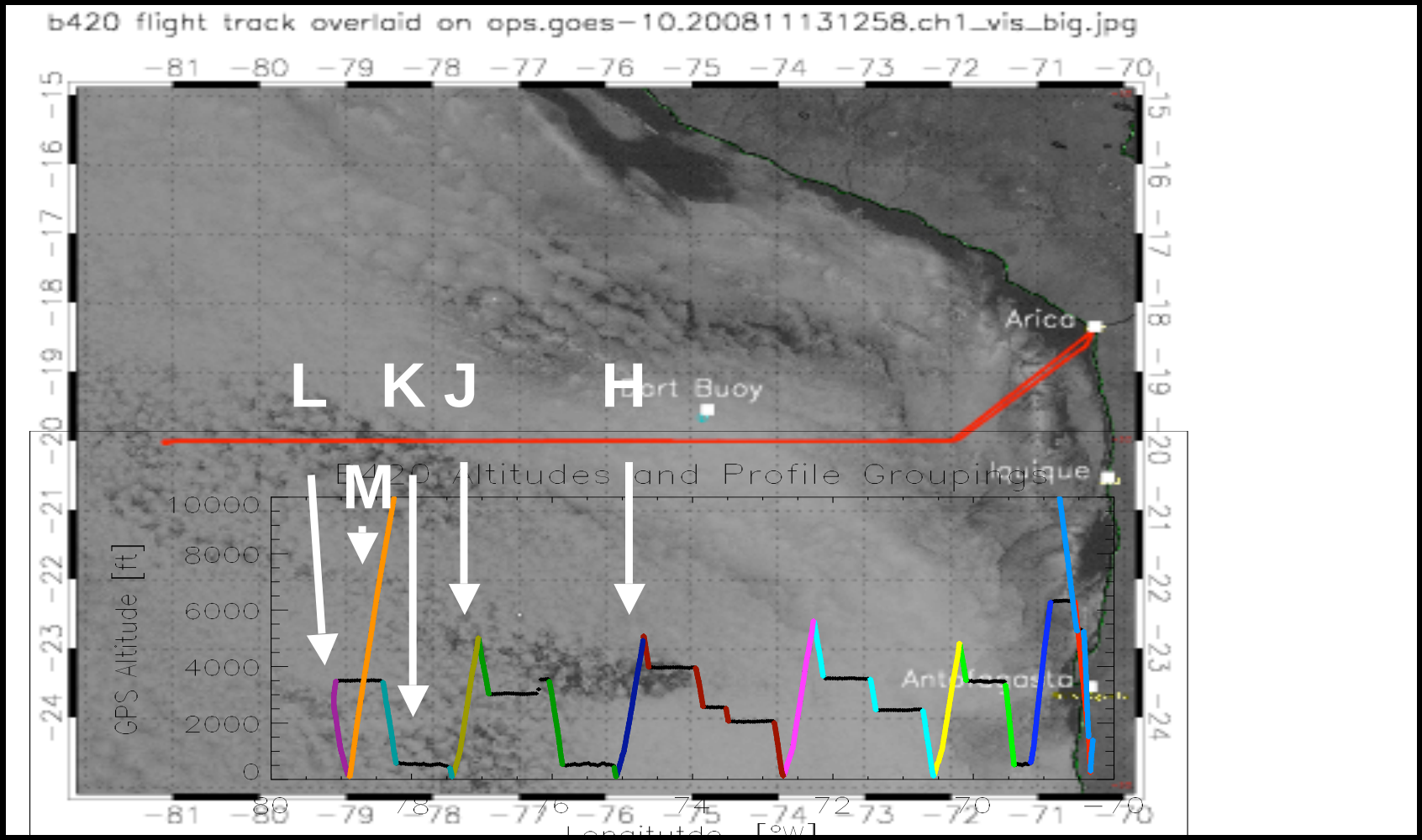


T + 39

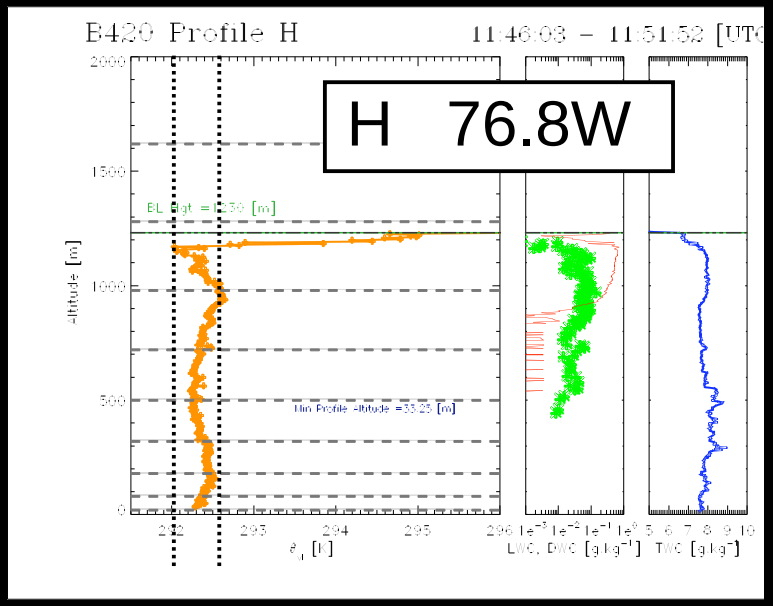
Assimilation of breaks in cloud from satellite?

CWC reduced by drizzle?

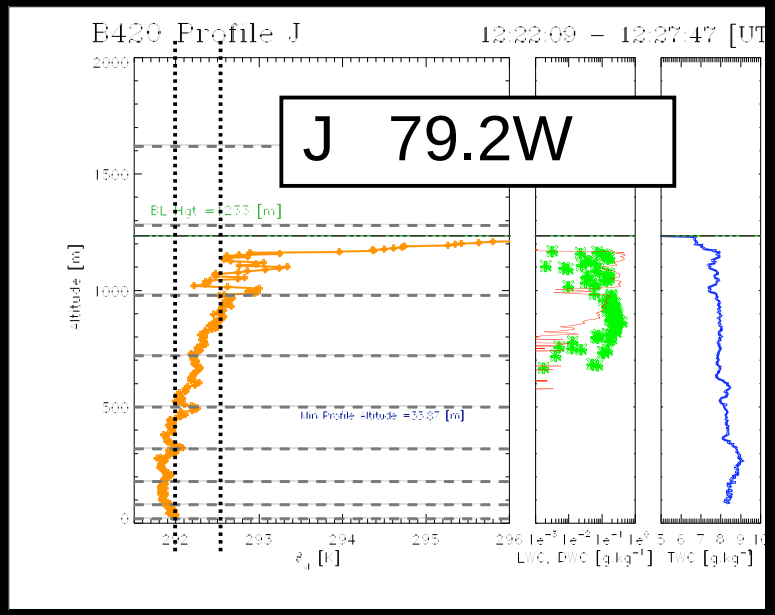
B420 Profile Locations



B420 Transition to Cumulus

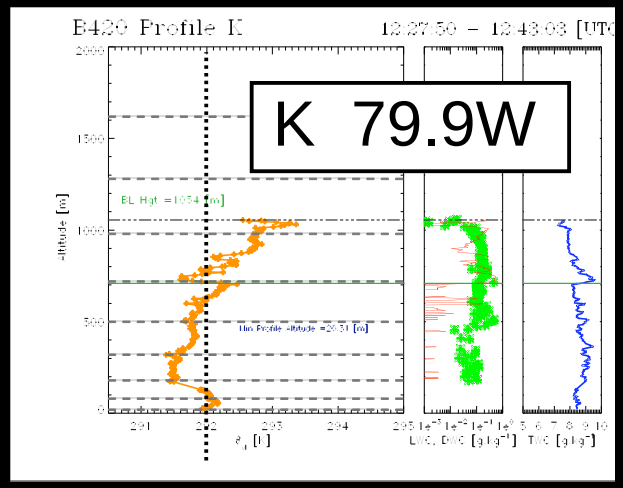


- Well mixed
- Heavy Drizzle

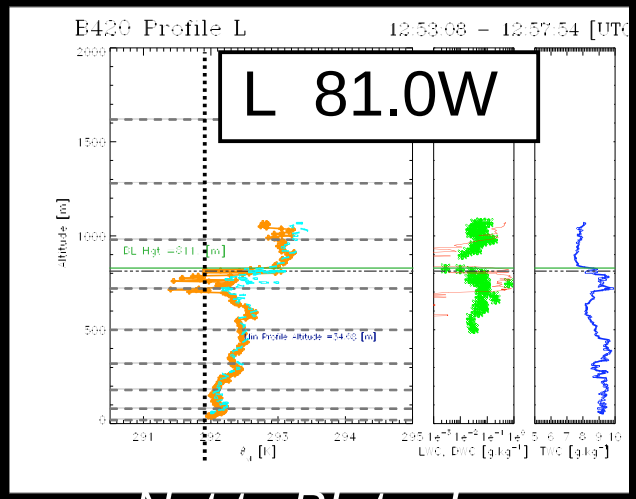


- Cooler sub-cloud
- Warmer cloud layer
- Two cloud layers?
- Heavy Drizzle

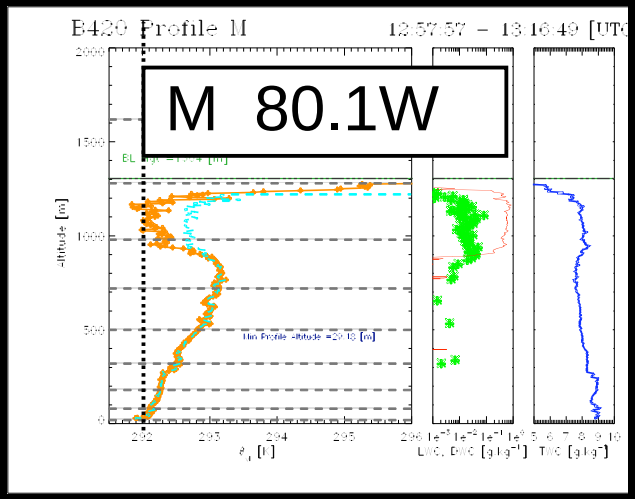
B420 Profiles – Decoupling



Not to BL top!



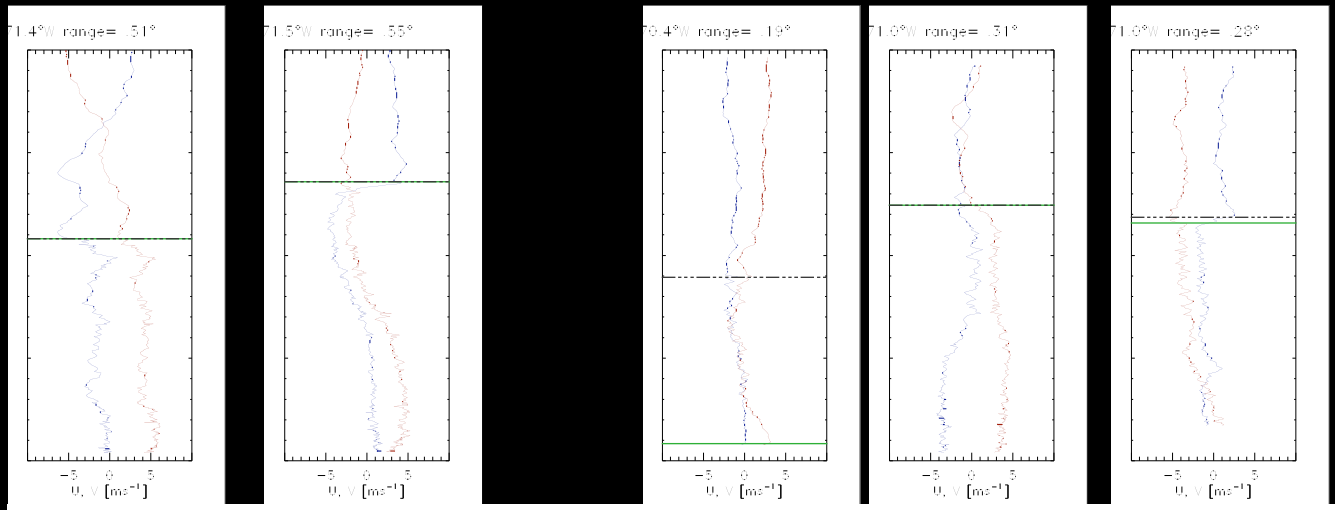
Not to BL top!



- Huge Variability in Short spatial range
- Final profile shows fully decoupled layer
- Wetting Correction shown

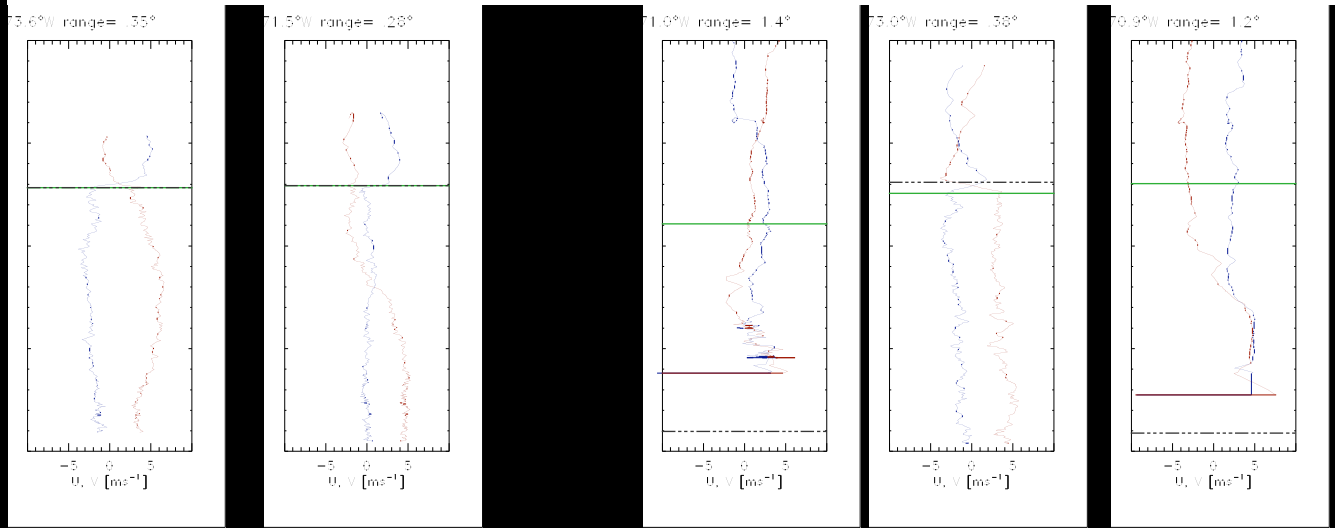
Diurnal Cycle in Winds above BL near coast

- U=blue
- AM



B408 B410 B414 B417 B420

- PM



- N.B – some spatial seperation

Future Work

- Include the C130 20s Cross Section Data for a project climatology
- Generate fluxes from SSTs
- Determine Cloud Top Radiative Cooling

Questions and answers