



# Boundary layer thermodynamics and decoupling in the South Eastern Pacific along 20° South.

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VOCALS 3<sup>rd</sup> All Hands Science Meeting – Miami 2011



# Using VOCALS Observations to assess UKMO model performance

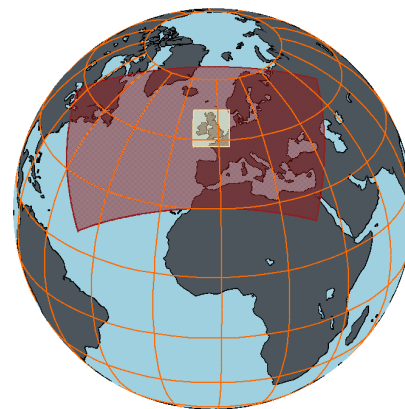
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- 20 South temp. Inversion Statistics, models and Obs.
- High resolution models case study – 12<sup>th</sup> and 13<sup>th</sup> Nov

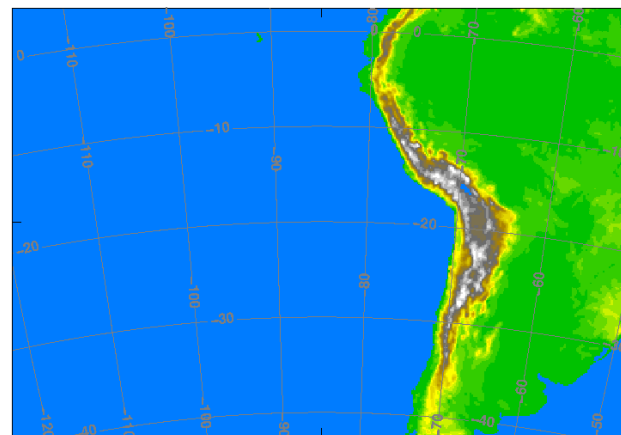
Thanks to: Chris Bretherton (C130 data) Simon De Szoeki (RHB data)  
UKMO modellers

# UKMO VOCALS operational forecasts, and re-runs

- This study uses first 24 hours of forecasts
- Global model – re-run to provide additional diagnostics (*Walters*)
- Limited Area Model (LAM) 0-40S, 110E-60E (Andes is fully in domain) (*Walters*)
- Recent Global model re-run with 40km/70 Levels (*Mulcahy*)
- Fxxx data from 14 Oct to 19 Nov



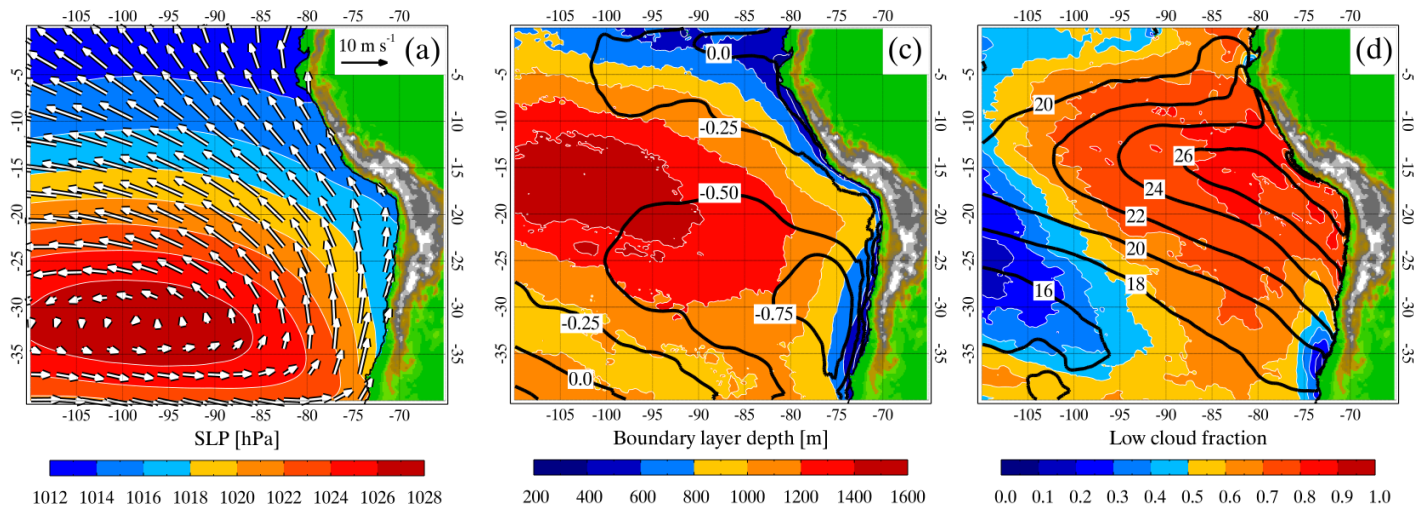
Global 40km/ 50 Levels



LAM ~17km/ 38 Levels

# UKMO Operational model performance – *Abel et al 2010*

- LAM – 17km, 38 Levels
- Anti-cyclonic circulation well represented
- Boundary layer depth increases away from coast
- Low cloud fraction > 70% along 20S



# Temperature Profile Observations



FAAM BAe-146  
Profiles



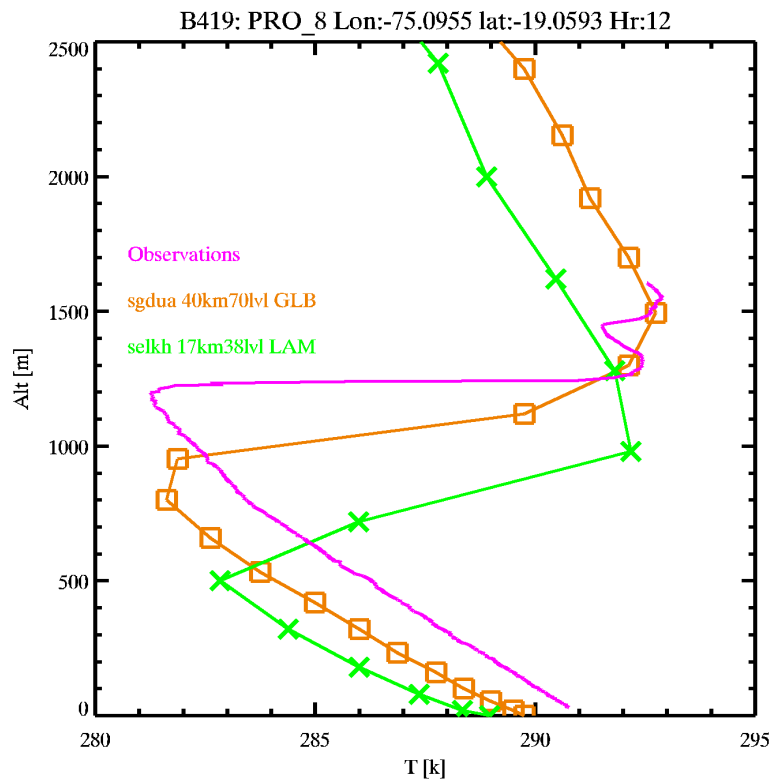
NSF C-130  
Profiles



Ronald H. Brown  
Sondes

- 350 Profiles along 20s (+/- 2 Deg)
- Most inversion crossings are used
- Some shallow profiles are rejected
- Generate **T-inversion\_base** and **Inversion\_Strength**
- Inversion scheme finds max  $dT/dz$
- Use Inversion Base Temperature to allow comparison with model output

# Temperature Profile Example

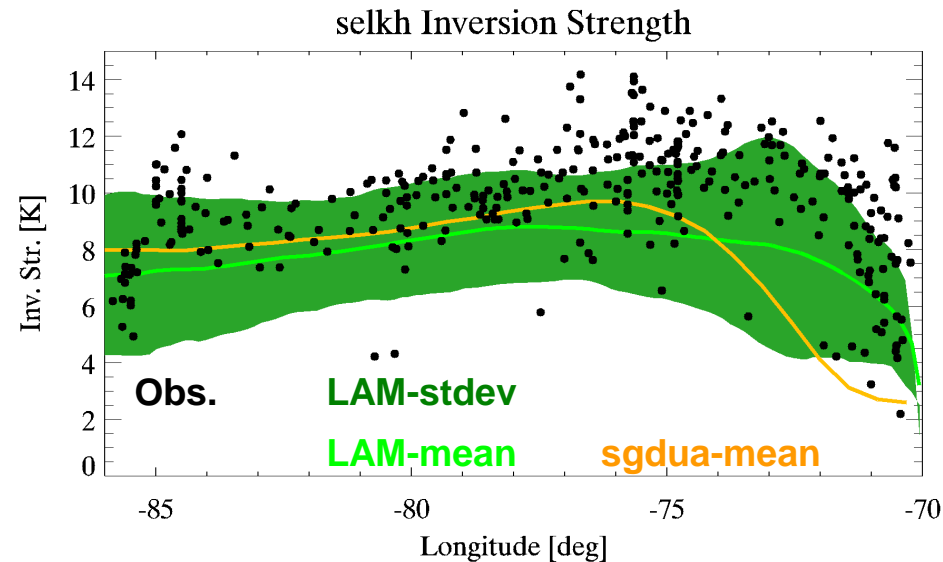
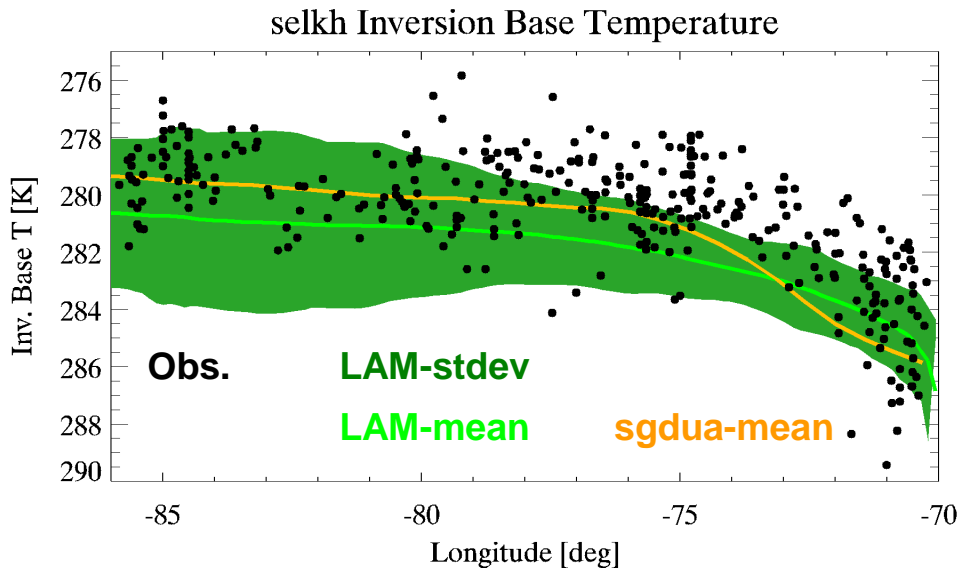


- Inversions have low bias in UKMO: ~200m
- Profiles generally too cold
- **BAe146 B419 Profile at 75W 19S**
- **Selkh-operational local area model (LAM) 17km 38 levels**
- **Sgdua – high vertical resolution re-run – global 40km 70 levels – better**



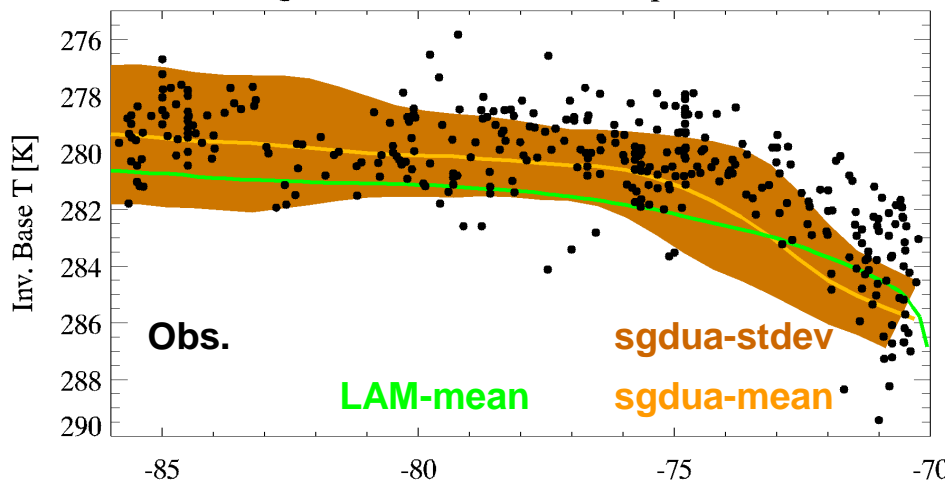
# Cross Section Stats - Inversion T, T(str)

- Observations – C130, BAe146, RHB (c.f. *Rahn and Garraeud ACP2011*)
- LAM 17km 38 Levels
- sgdua 40km 70 levels
- Model stats include data from all campaign
- Observations biased to mornings (aircraft)
- REMOTE: Colder (higher) & stronger inversions in sgdua – closer to Obs.
- COASTAL: Colder (higher) & stronger inversions in LAM – closer to Obs.

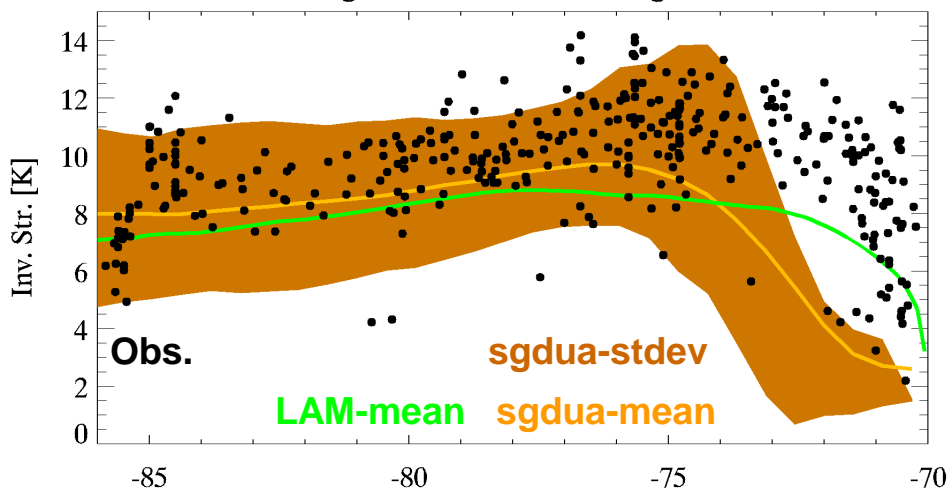


# Cross Section - Inversion T, T(str)

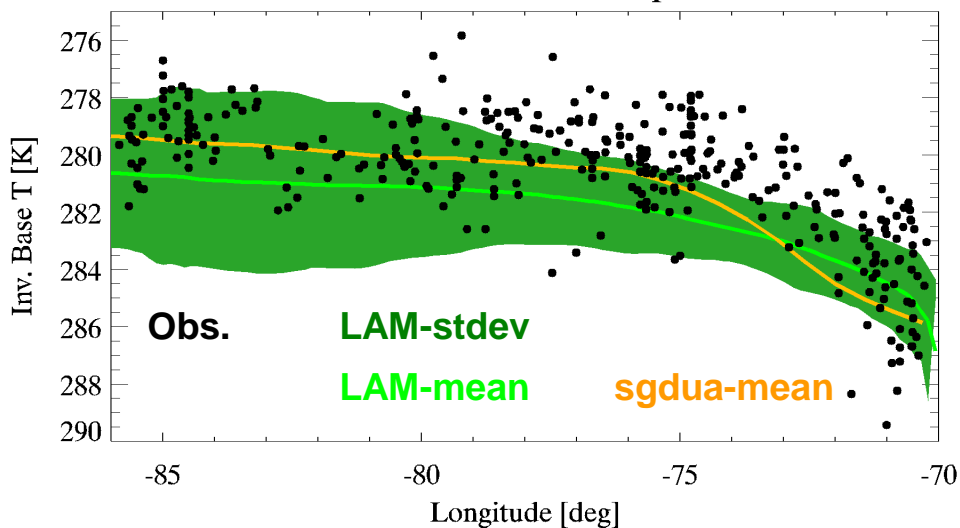
sgdua Inversion Base Temperature



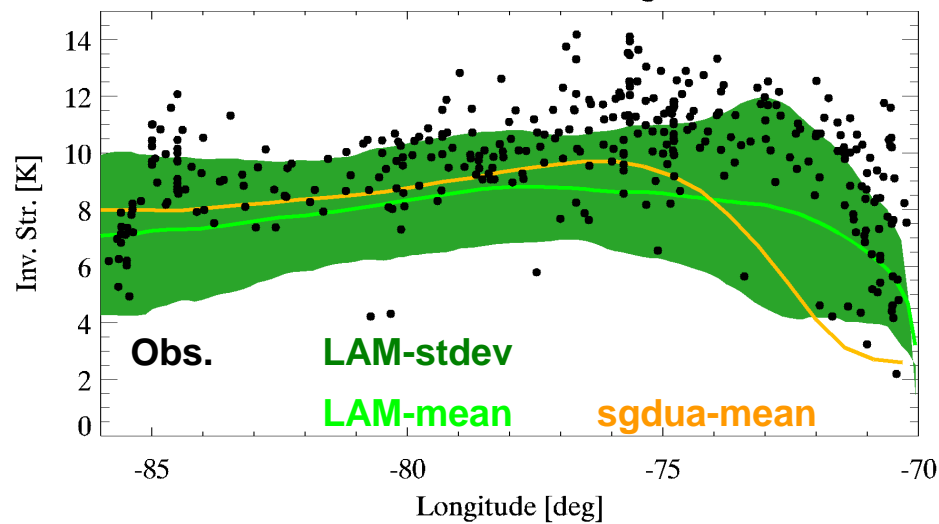
sgdua Inversion Strength



selkh Inversion Base Temperature



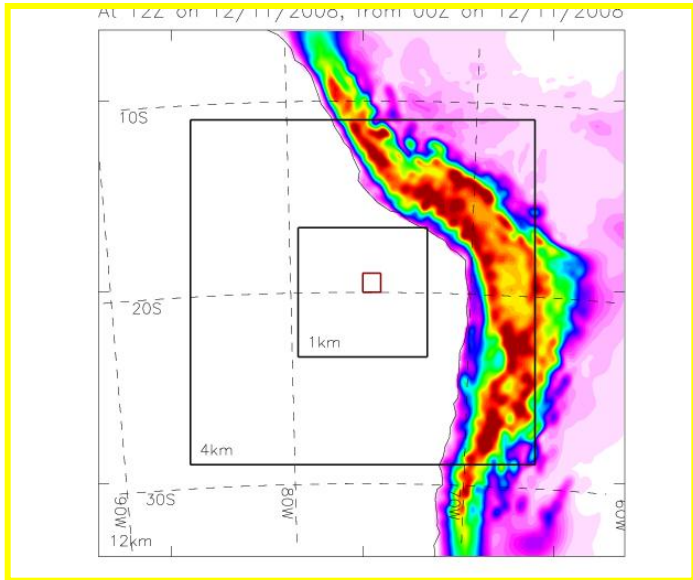
selkh Inversion Strength







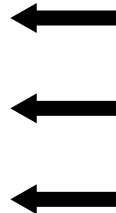
# High Res. Case Study



Model	Location	Gridbox [km]	Vertical Levels	Levels below 4.5km
opfc #	Global	40	50	16
selkh #	SEP	17	38	15
sgdua	Global	40	70	25
akono *	Global	40	70 Glb	25
akonq	SEP	12	70 Glb	31
akons	SEP (subset)	4	70 UKv	31
akonu	75W 20S	1	70 UKV	31

# Operational during VOCALS

\* New Physics



*New runs using the current operational UK model configs.*

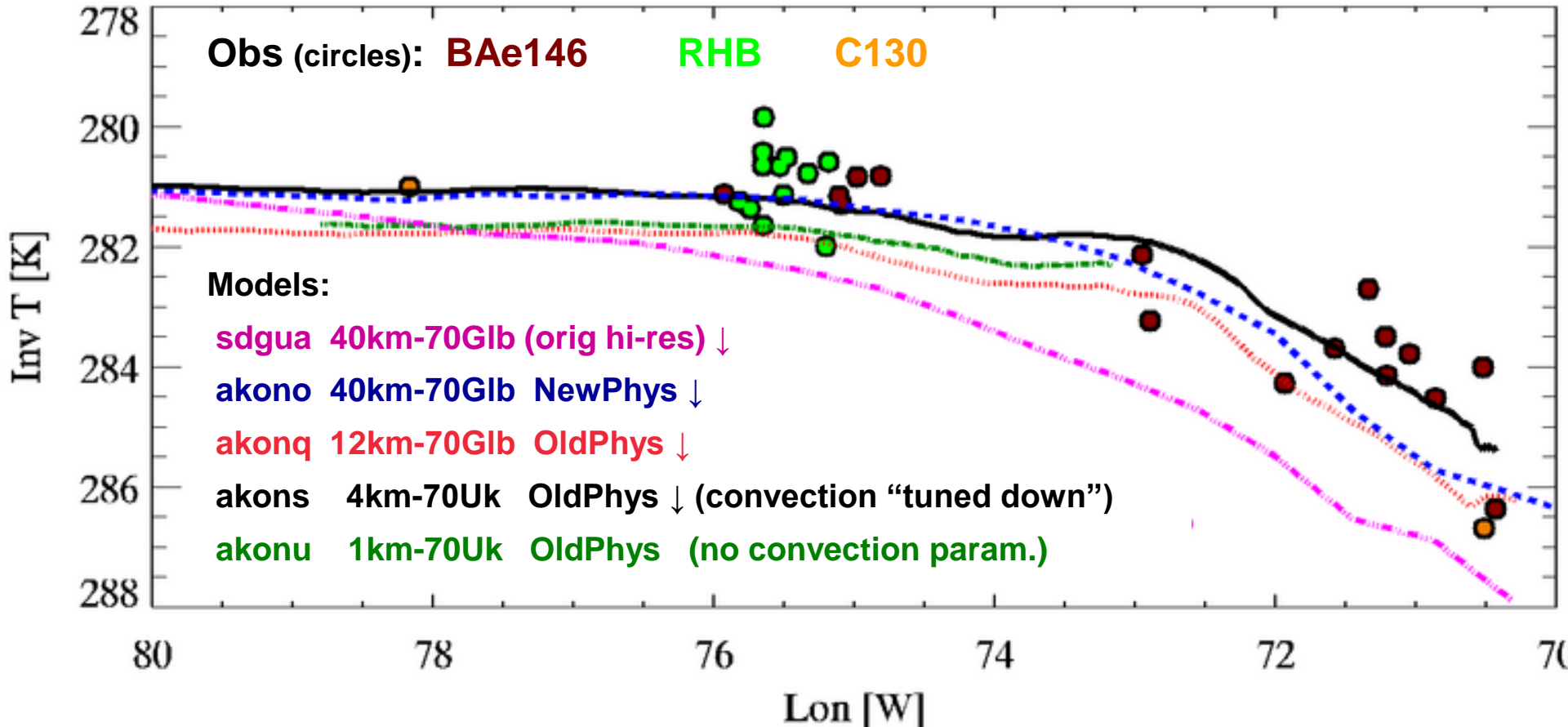
## Model Changes:

- PC2 Cloud Scheme
- New  $\mu$ -physics – Abel and Shipway fall speeds
- Revised BLformulation
- Increased entrainment when decoupling is diagnosed (LES) (*Lock 2009*)



# Case Study Cross Section

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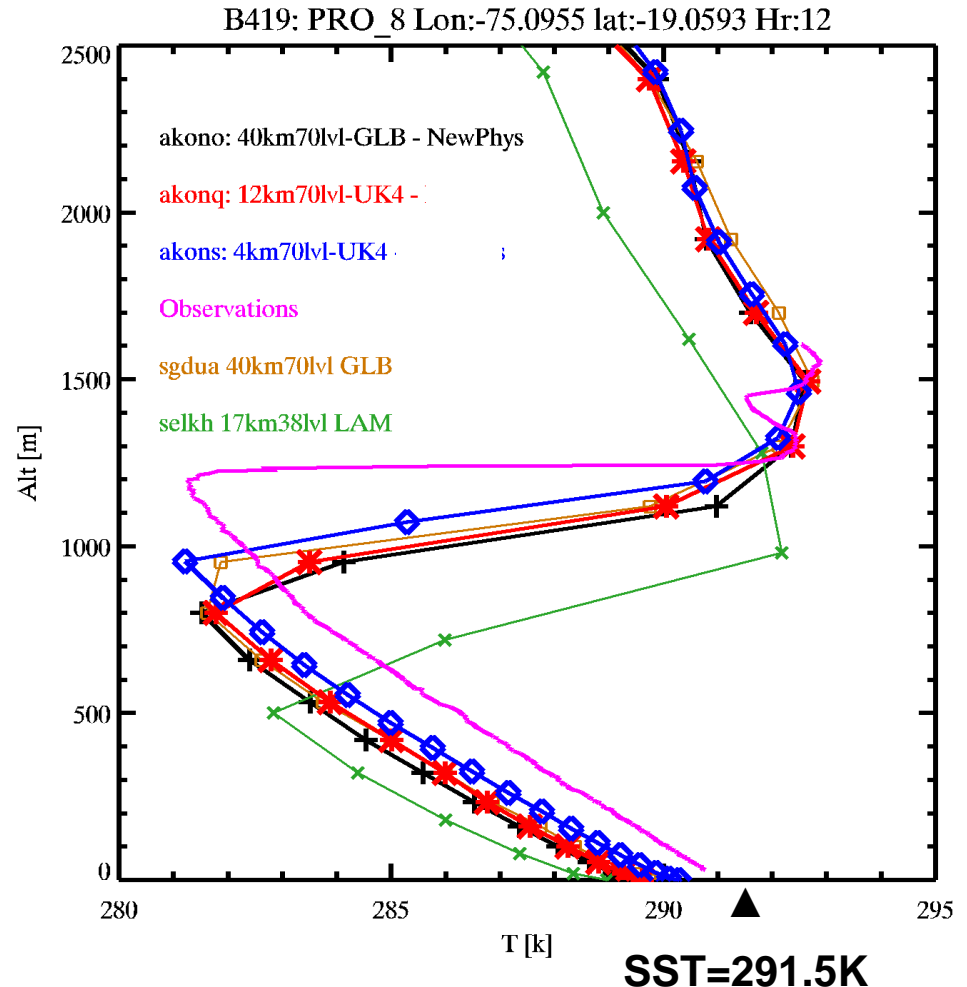
- T(inv) Model Mean for 2 day case study
- Point Observations, BAE146, RHB, C130



Met Office

# 75 West Individual Profile

- All high vertical res. models are similar for this profile
- 4km model can lift inversion height through Fxxx period
- Major improvements from operational LAM
- 1km model has even higher inversion – next slide
- Radiometric SST from subsequent straight and level run
- Model SST from OSTIA re-analysis, downgraded to 40km – source of error?

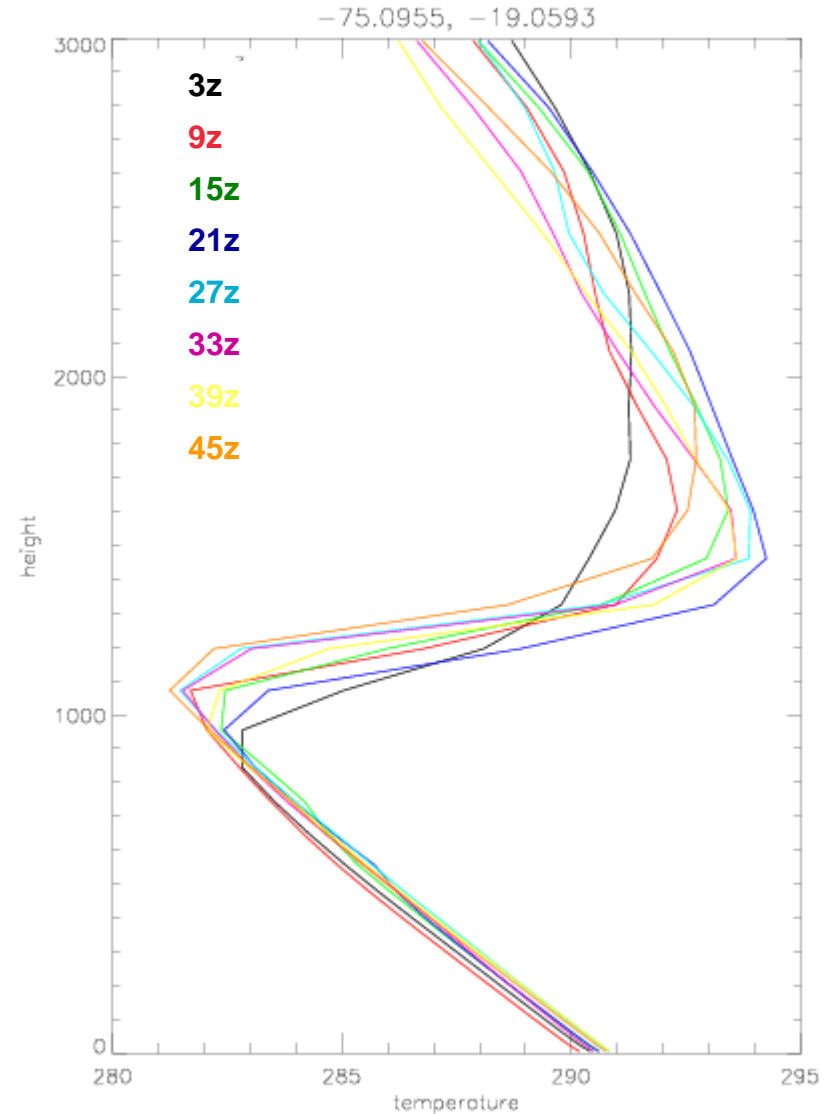




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# Time Series of 1km 70 level

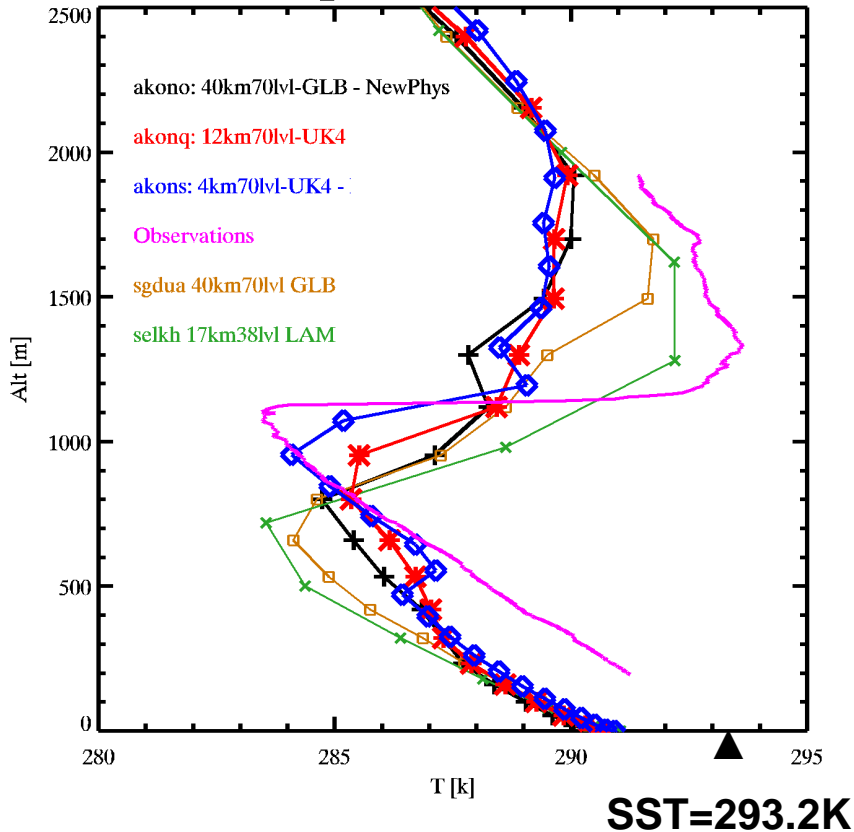
- 1km model at 75W 20S
- Time series of Temp profile
- 1km model can lift the inversion through the model period from the original Global Model profile
- Extra resolution can generate sharper inversions



# 71W – Observed profiles are well mixed B419 B419

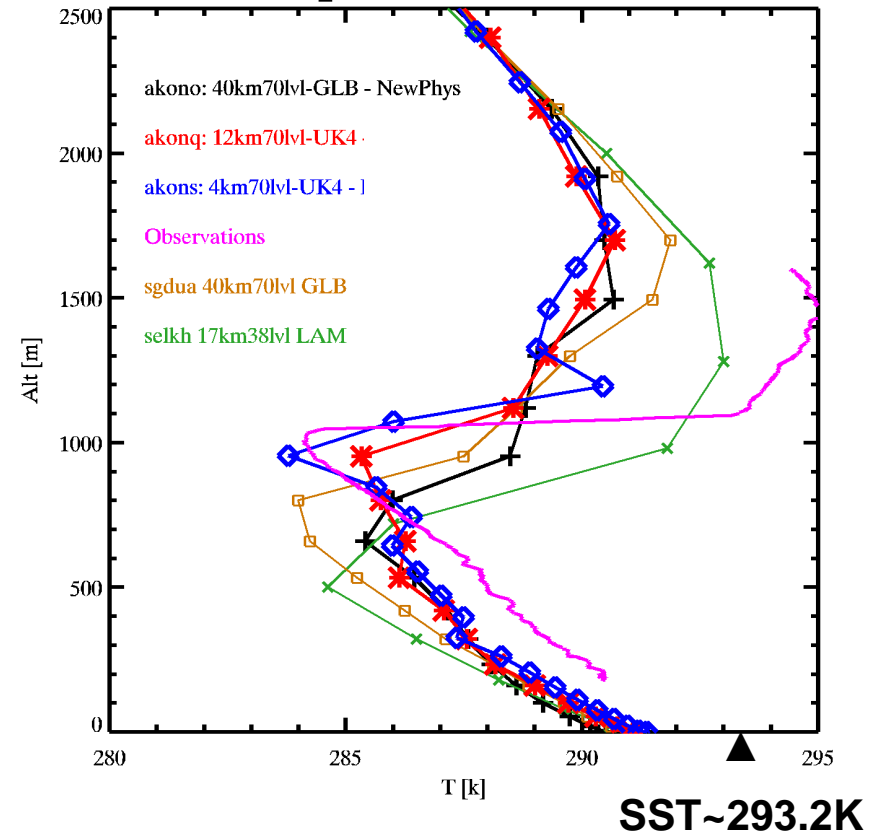
## 71W 18.5S 11z

B419: PRO\_2 Lon:-71.2176 lat:-18.5085 Hr:11



## 71W 18.5S 16z

B419: PRO\_23 Lon:-71.2089 lat:-18.5038 Hr:16z





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# Summary

- Higher vertical res. *(38→70)* improves boundary layer structure in oceanic region west of ~73W
- Higher horizontal res. *(40km→17km)* – improves coastal boundary layer structure
- New improvements from recent physics changes:
  - PC2 cloud scheme
  - New BL formulation
  - Increased entrainment in decoupled cases (higher turbulence)
- Next – add new physics to 12kmn, 4km, 1km - assess relative contribution of physics changes



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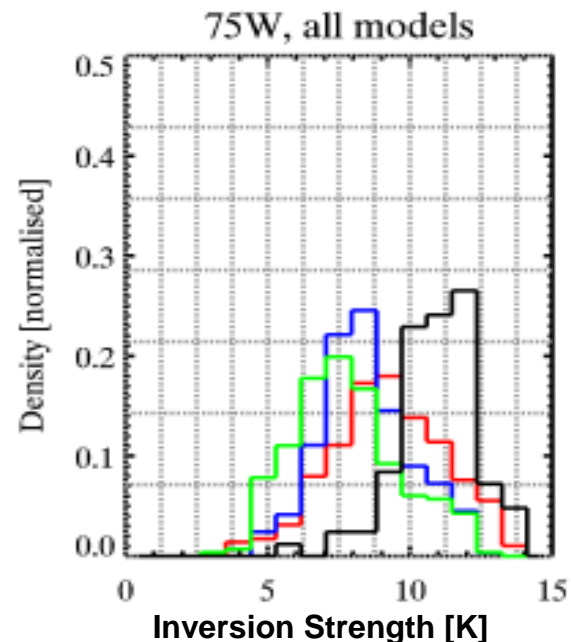
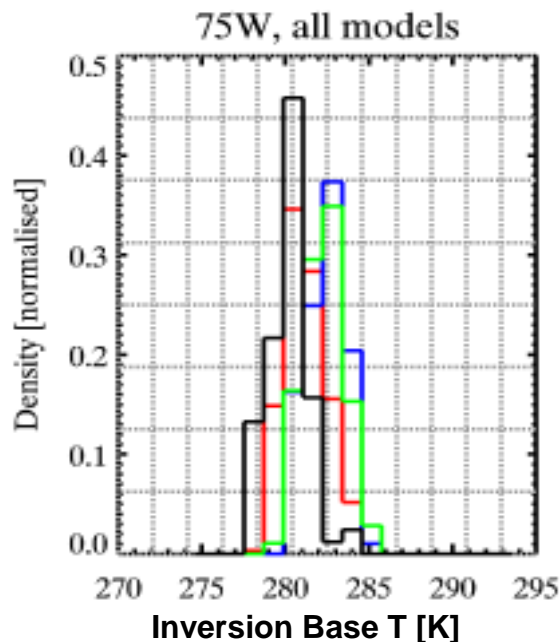


Thank you  
Questions and answers



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# Inversion PDFS at 75W



- In all models  $T(\text{inv})$  is too warm (low). Increasing vertical resolution gives colder (higher)  $T(\text{inv})$
  - All models have weaker inversions than Obs. – but – do we bias the observed sample towards stronger inversions?
- Model inversion altitude is fixed to model levels
  - **Inversion Base Temperature** allows comparison of Obs. and model output
  - Models: all campaign data 37 days, location  $\pm 1$  degree
  - Observations: All suitable profiles, location  $\pm 1$  degree
  - Obs. timing biased to morning Obs. (aircraft)



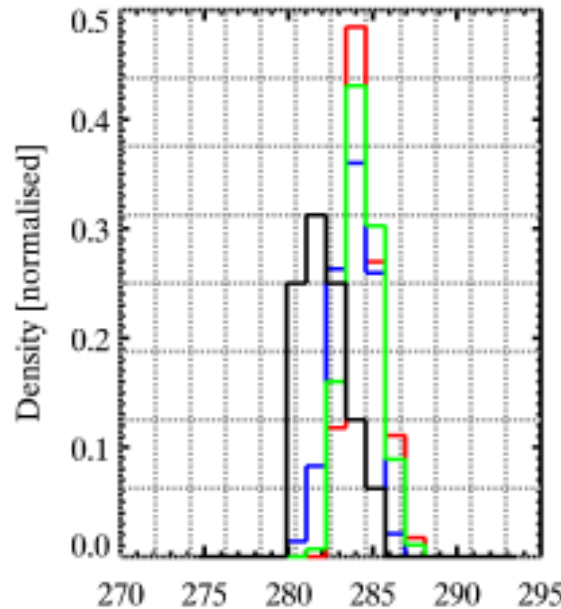


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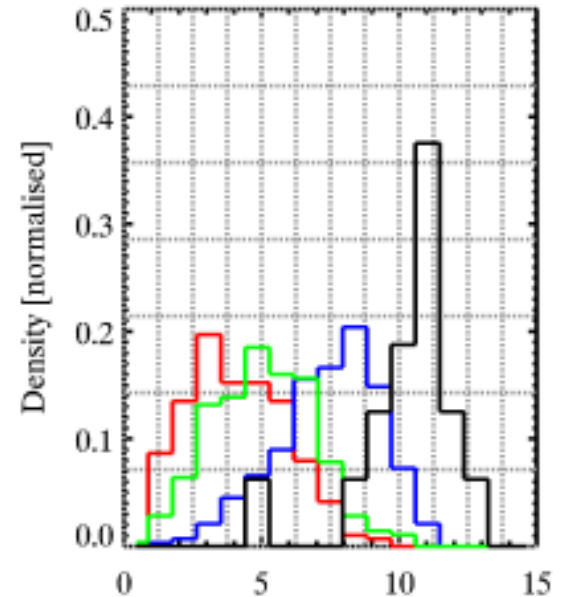
# Coastal Inversion PDFS – 72W

40kmGlb\_70lvl 40kmGlb\_50lvl 17kmLAM\_38lvl VOCALS\_Obs

- Close to coast: 17km LAM performs better than 40km global models
- 17km LAM has most realistic inversions strengths
- Inversions are far too warm (low) in ALL models
- Increased vertical resolution is of no benefit



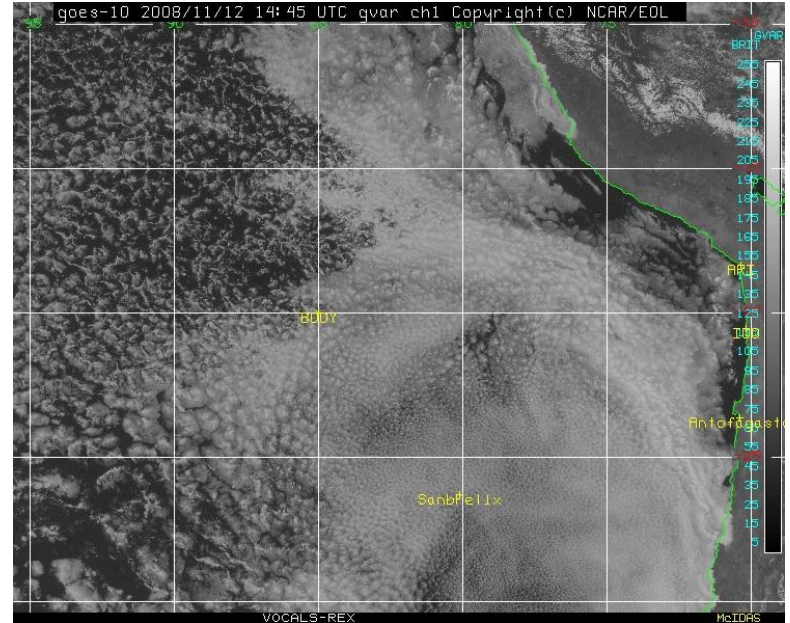
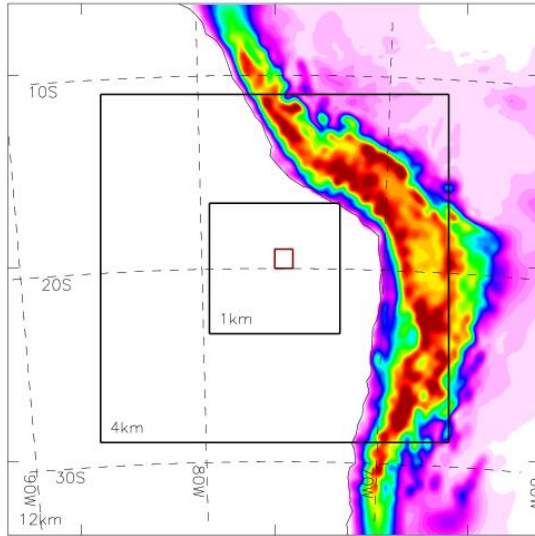
Inversion Base T [K]



Inversion Strength [K]

# High Resolution Modelling

## 12<sup>th</sup> November B419



### Model Changes:

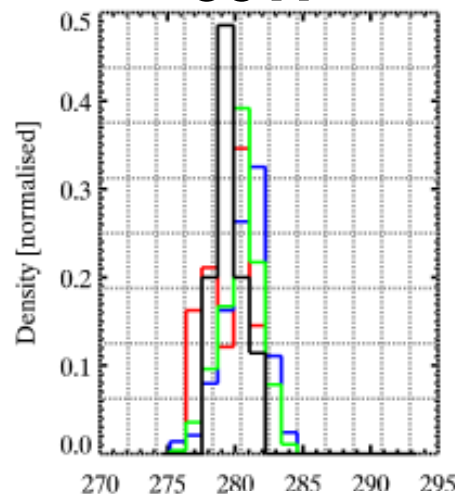
- PC2 Cloud Scheme
- New Boundary layer formulation
- Increased entrainment when decoupling is diagnosed (from LES) (*Lock 2009*)



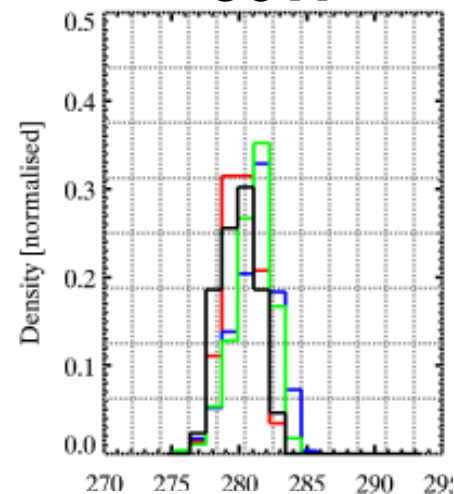
# Inversion PDFS - remote

- Better representation of inversions temps at 80W with 40km 70level
- Mode of inversions strength in 40km 70level is shifted to **STRONGER** inversions at 85W – is this a failure of the model to represent POC type events, where BL structure alters significantly?
- **VERY FEW OBS.**

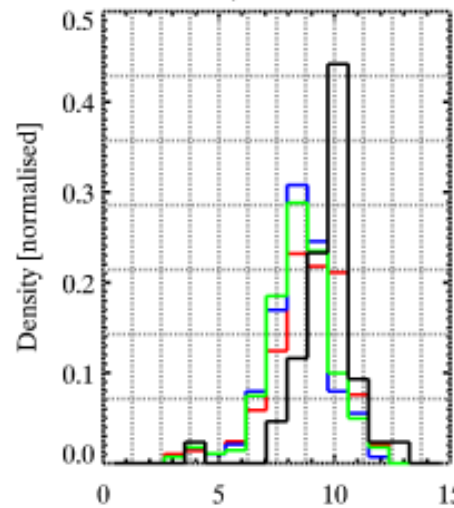
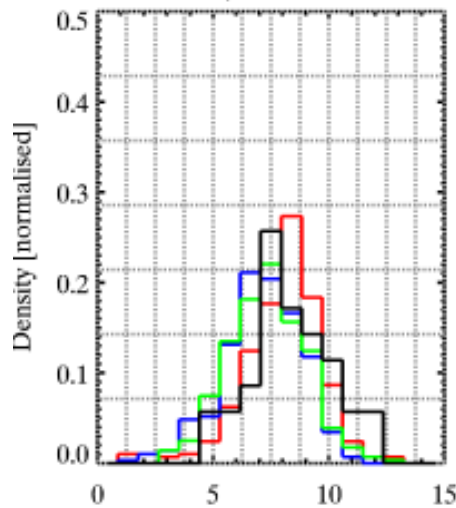
85W



80W



Inversion Base T [K]

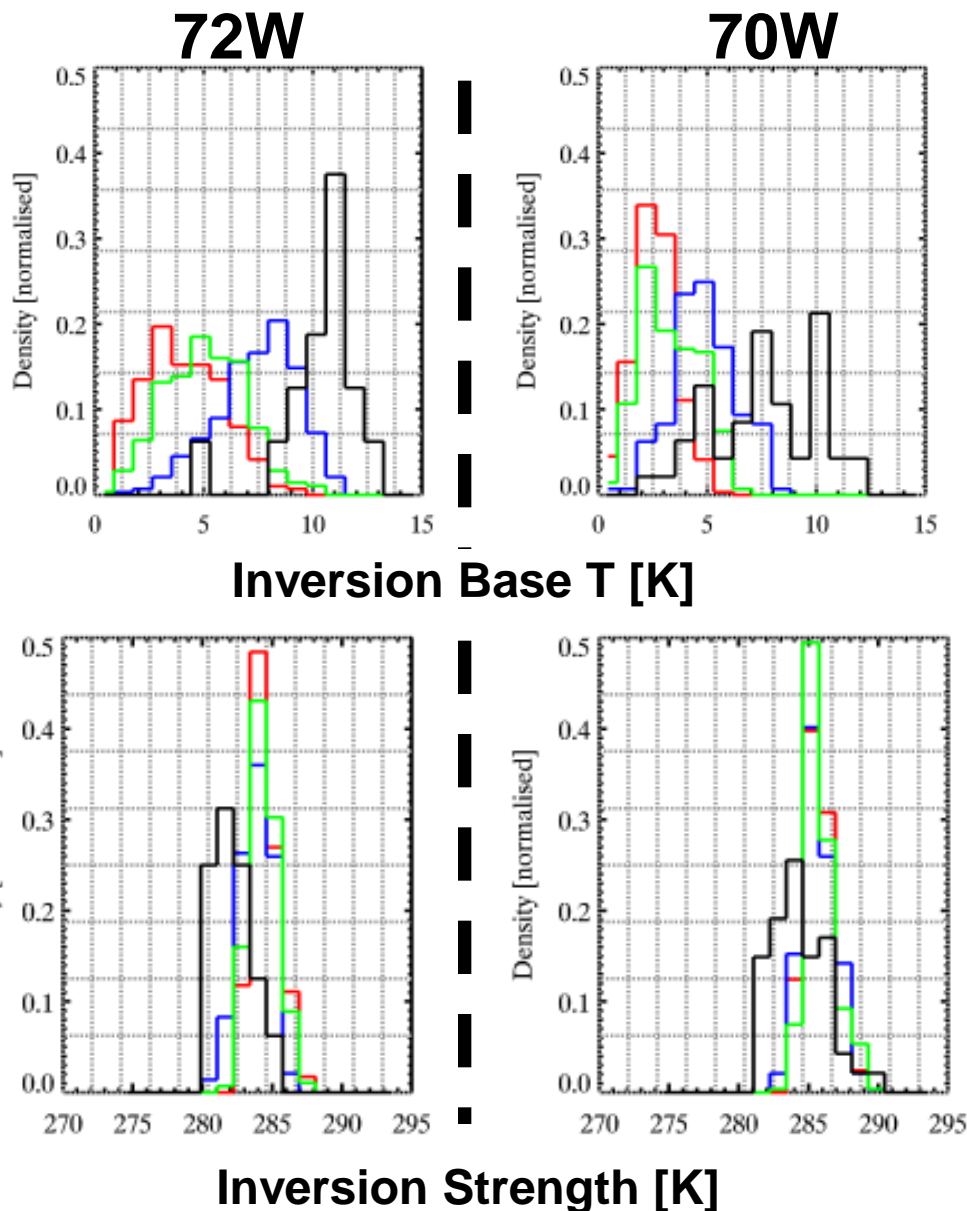


Inversion Strength [K]

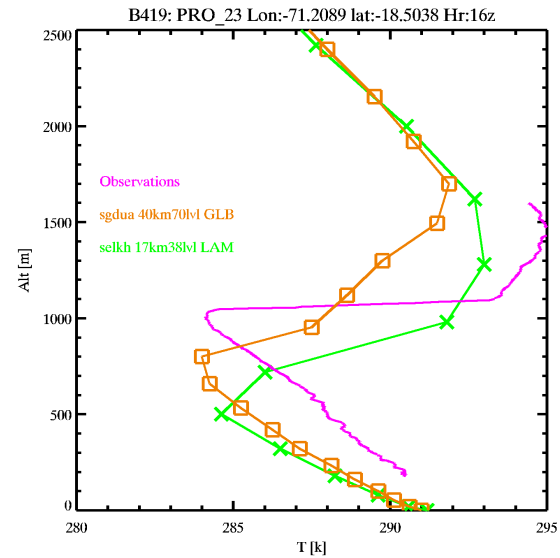
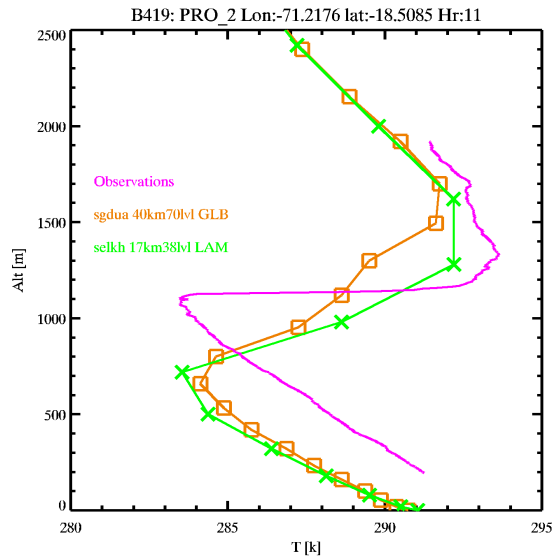


# Inversion PDFS – Coastal

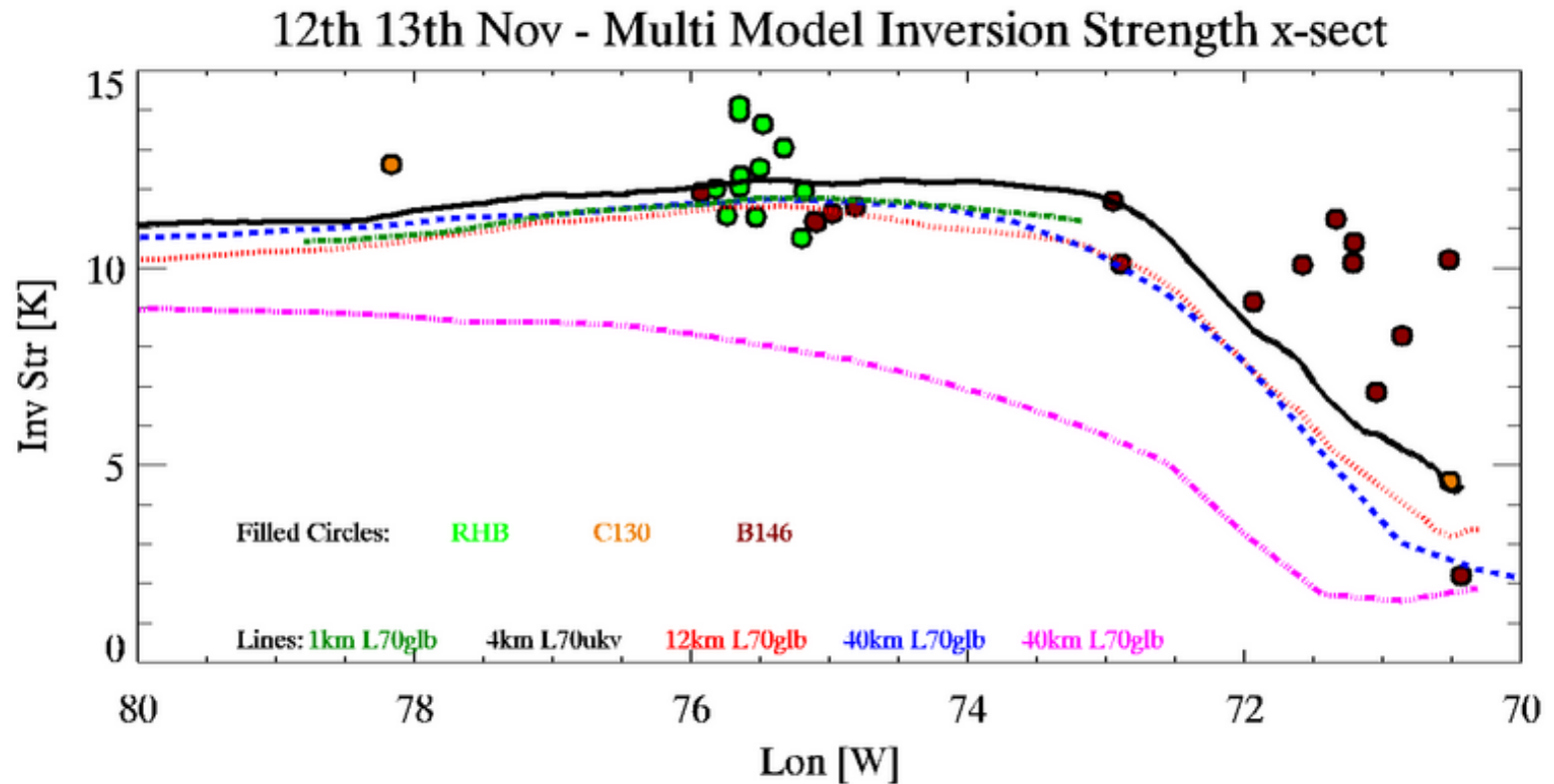
- 40km Global Models are worst
- 17km LAM has most realistic inversions strengths
- Inversions are far too warm (low) in ALL models



# B419 coastal profiles case study

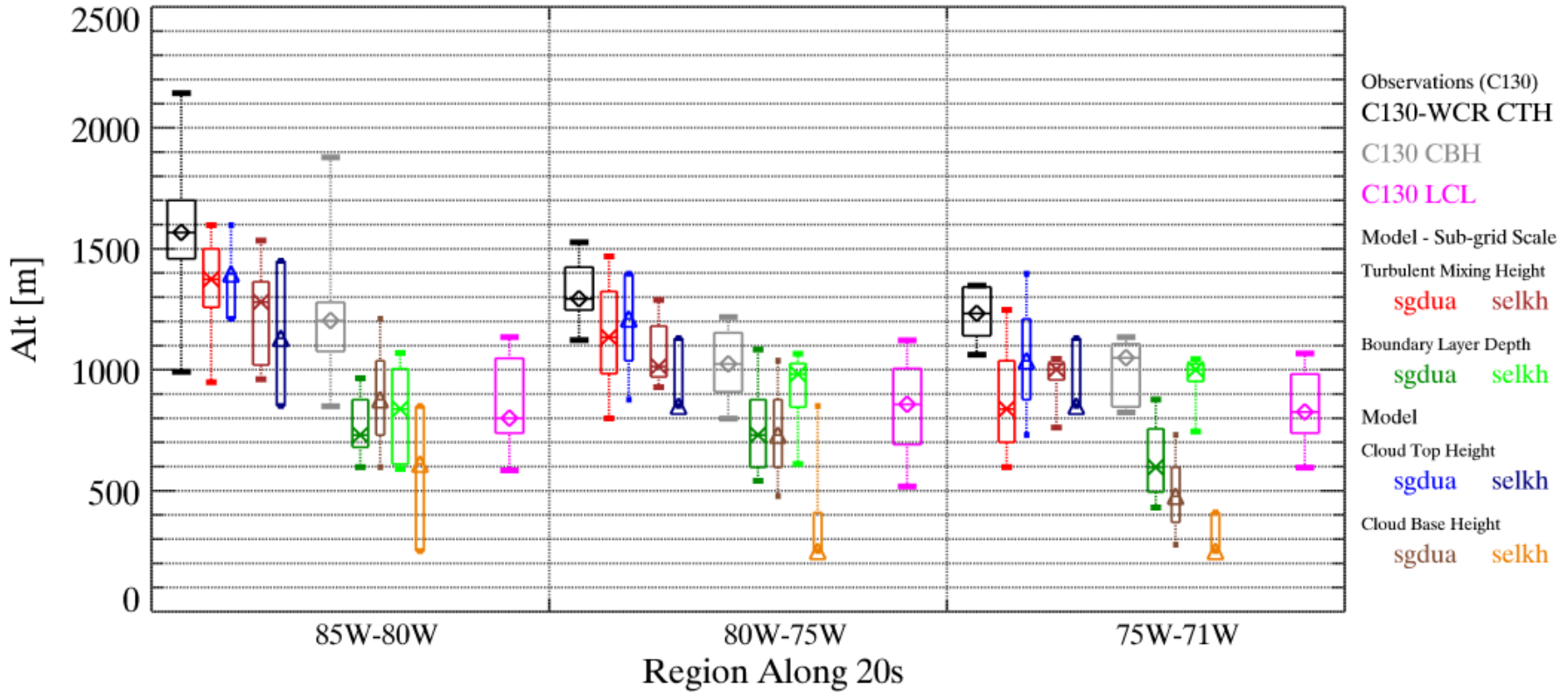


# Inversion Strengths HI-Res





# WCR, TMH, C130 LIDAR, CBH, LCL Percentiles



- Decoupling

# Diurnal Cycle in Inversion Strength from Model

- 40km Global, 70 level model run
- Split the campaign model data into night and day points
- Night – 03z
- Day – 15z
- It appears that the inversion strength has little diurnal cycle in the global model – another avenue for investigation!
- But – observations bias seems not to be an issue

Inversion strength - sgdua  
Diurnal cycle at 75W

