

The role of SCMs and CRMs for investigating biases in NWP and climate models

Tuesday 13 February 2007

WGNE systematic bias meeting

San Francisco, US

Jon Petch

GCSS deep WG case 5 participants

GCSS & the precipitating cloud working group (PCWG)

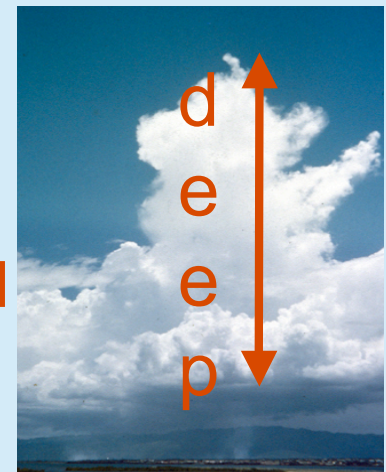


GEWEX **C**loud **S**ystem **S**tudies goals are:

- develop the **scientific basis for the parametrization** of cloud processes
- highlight key issues and **encourage other relevant programs** to address them
- promote the **evaluation and comparison** of parametrization schemes for cloud processes.

The goal of the GCSS PCWG is:

to **improve the parametrization of precipitating convective cloud systems** in global climate models and NWP models **through an improved physical understanding of cloud system processes**



- **Methodologies**
 - frameworks for using SCM and a CRM to identify and address biases in NWP and climate models
- **The case study (GCSS case 5: TOGA-COARE)**
- **Biases in the Met Office NWP/Climate model**
 - Boundary layer humidity
 - Upper mass fluxes
- **A warning from the multi-model comparisons**
- **Summary**

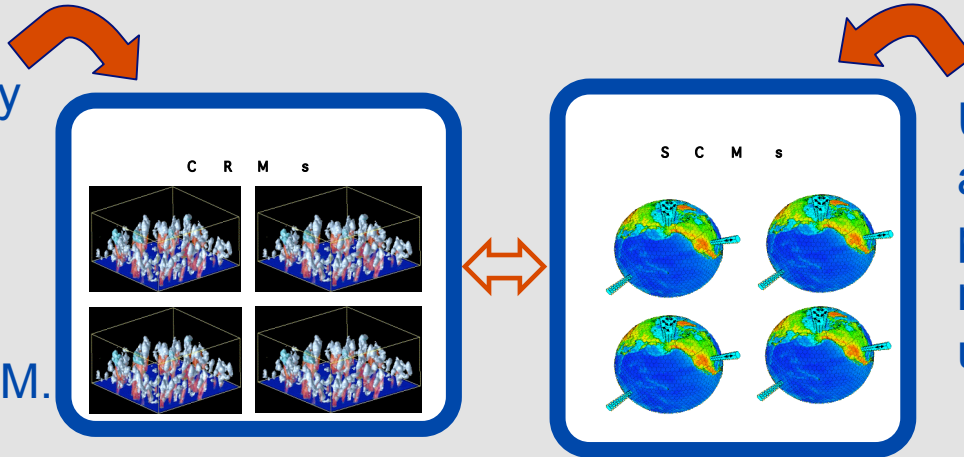


methodologies

Sensitivities in a CRM vs an SCM: “bottom up”

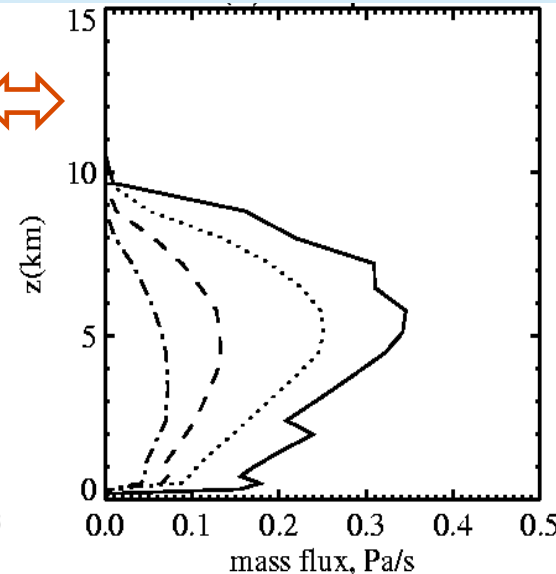
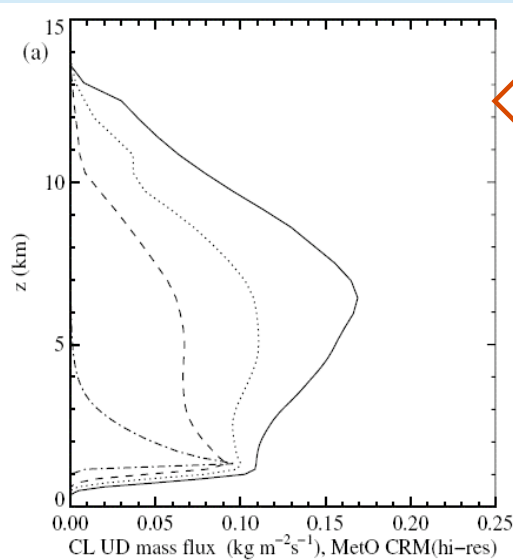


Design a case study which isolates a process and allows us understand this using sensitivity studies within a CRM.



Using SCM tests, attempt to change the parametrizations to reflect this understanding.

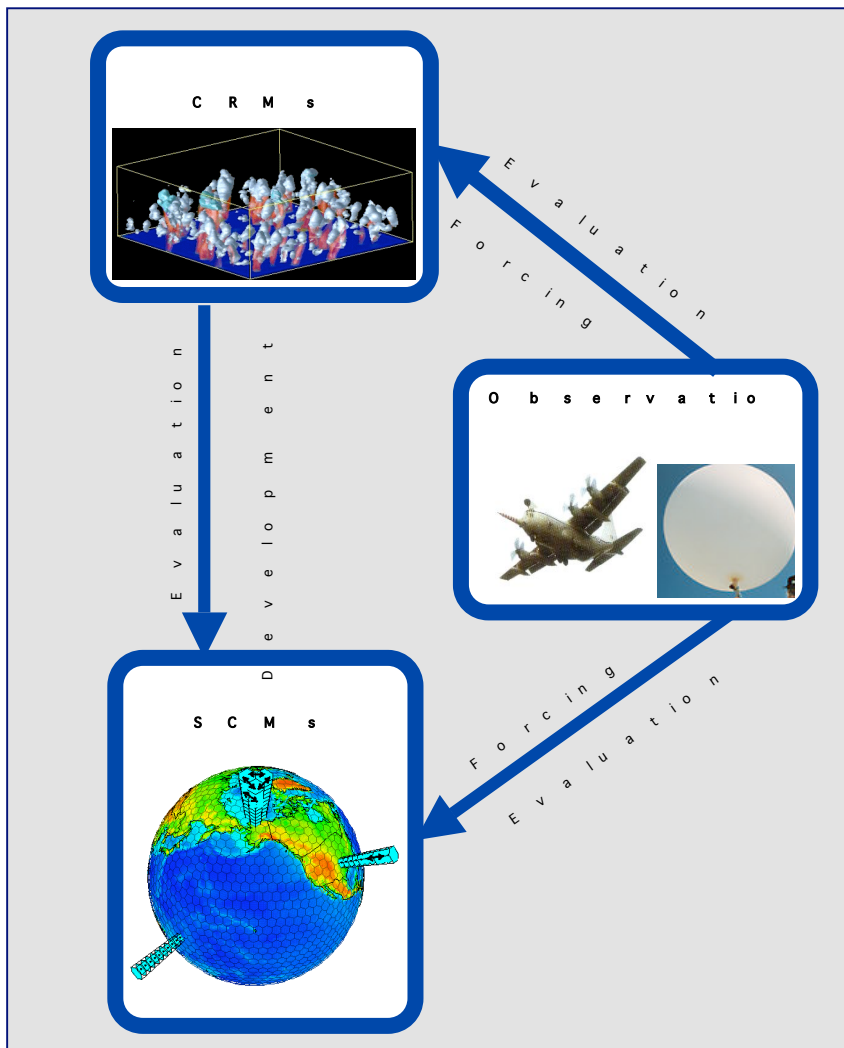
Shape of the CRM mass fluxes respond to changes in the relative humidity



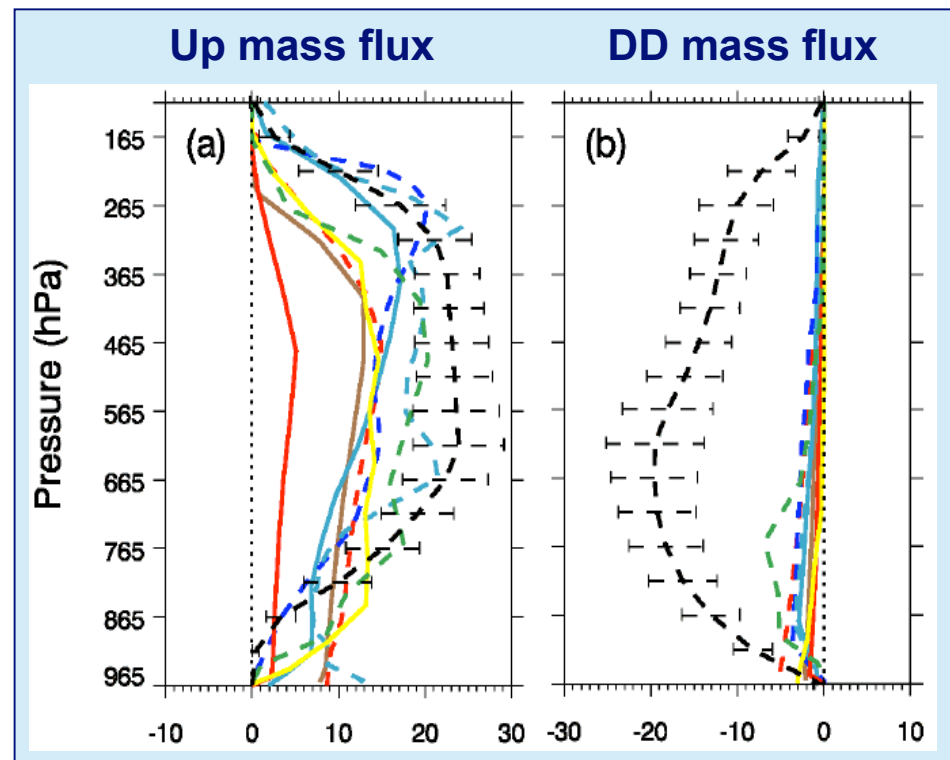
There is no such response in the parametrizations as seen in SCM studies.

Maidens et al 2007
Derbyshire et al 2004

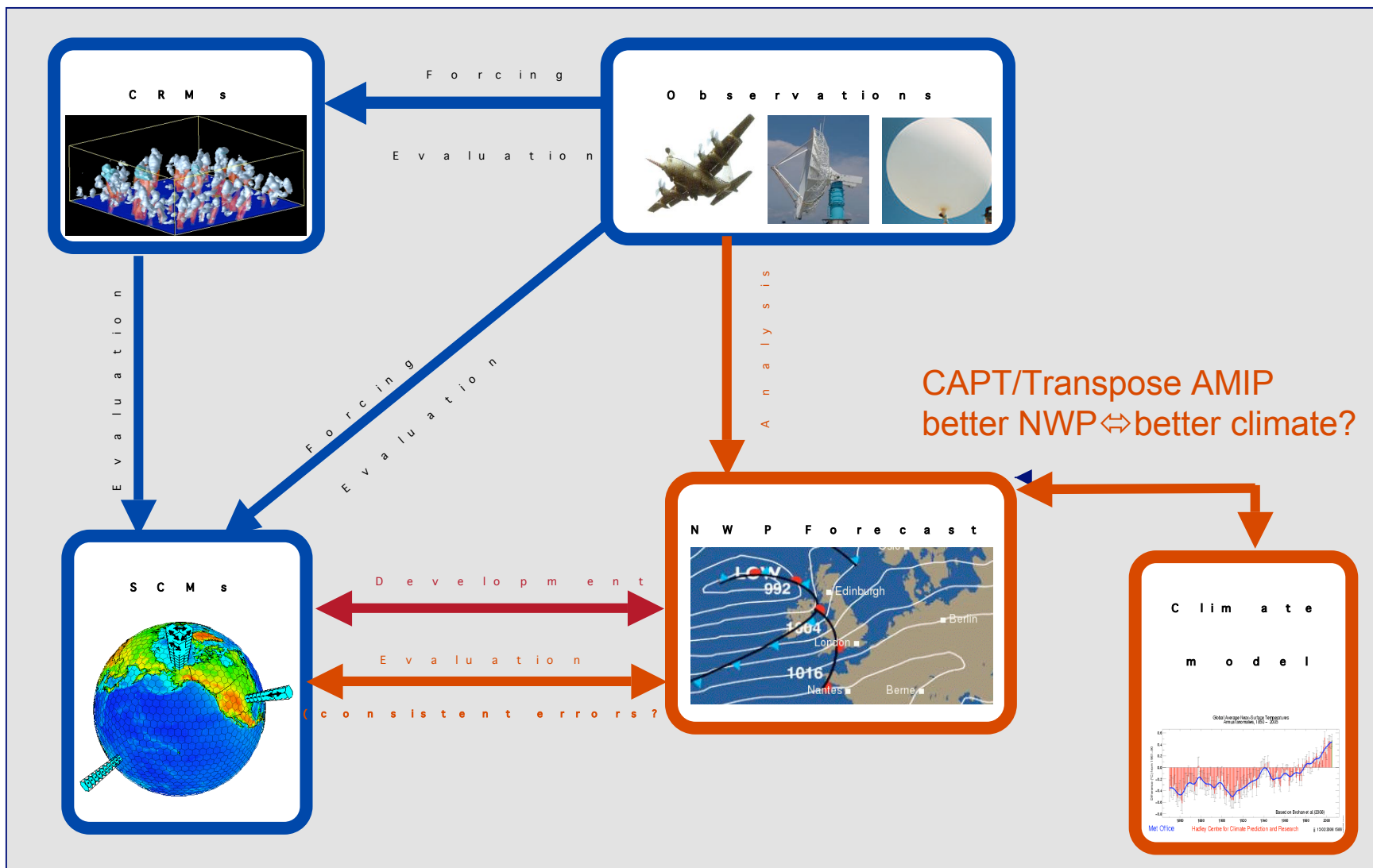
Direct comparison of SCM with CRM and Obs



Another option is to use more realistic cases and look for biases in SCMs when compared to the observations and CRM e.g. Xie et al 2002



What aspects of the SCM are consistent with the full model?

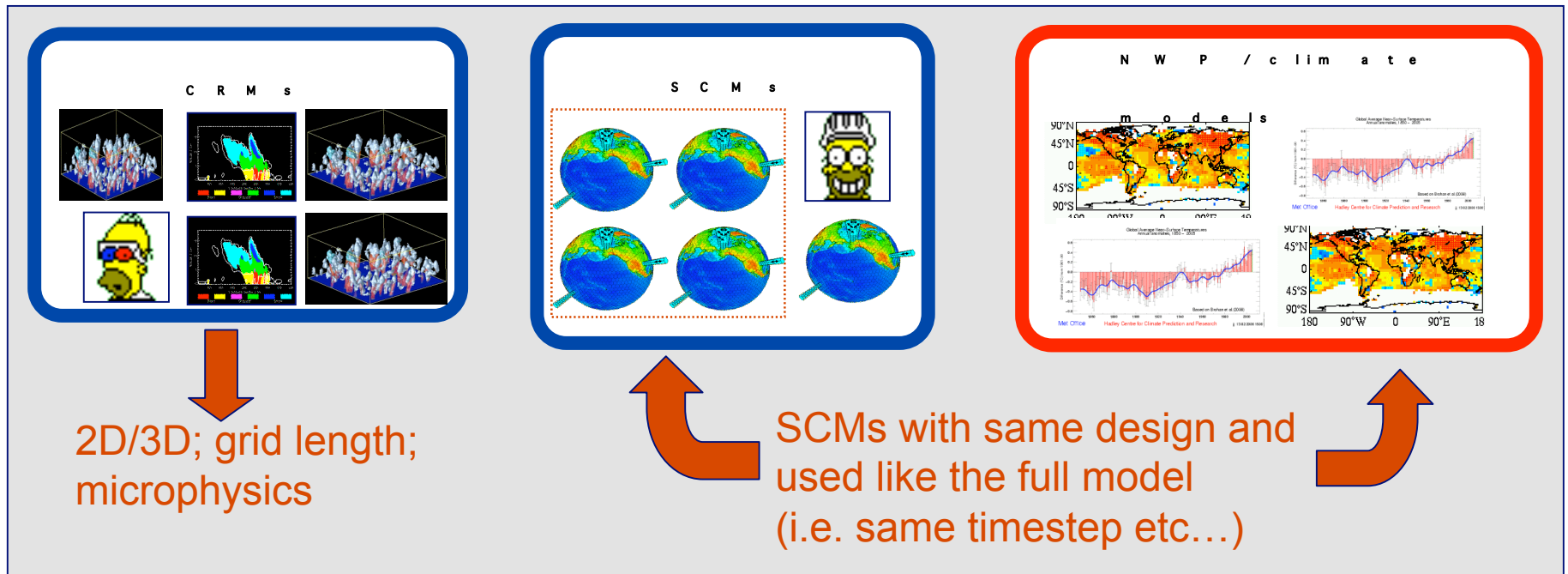


3 categories of “bias”



| Bias | Summary | Reasons/comments |
|--------|-----------------------------|---|
| type A | similar bias in SCM and NWP | The parametrizations are behaving the same in both models so the SCM is a good tool within this framework to study this bias |
| type B | bias in SCM but not in NWP | SCM has formed unphysical profiles (and not typical of the full model) due to lack of dynamical feedback SCM has a bias due to deficiencies with the parametrizations but this is manifested differently in the NWP model due to dynamical feedbacks |
| type C | bias in NWP but not in SCM | NWP bias is due to analysis (e.g. ERA40) differing significantly from the observations NWP error is formed through the feedback of parametrization errors on the large-scale dynamics |

Multi-model comparisons



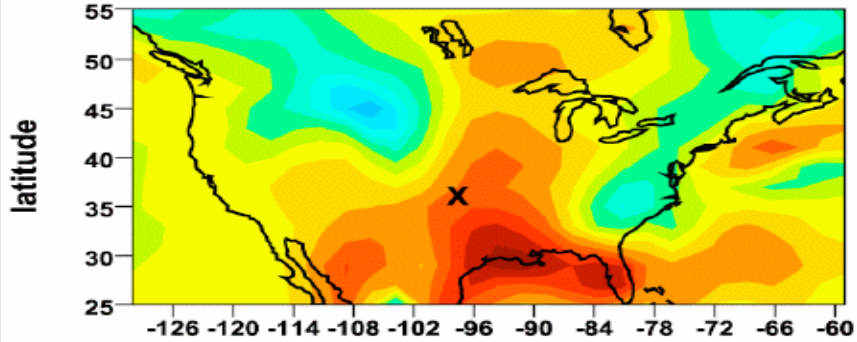
Multiple models:

- **All:** Identify errors in experimental design
- **CRMs:** Better trust in the output as a “truth” when combined with observations
- **SCMs/NWP:** Community wide problem/specific problem in “my” model; issues with analysis

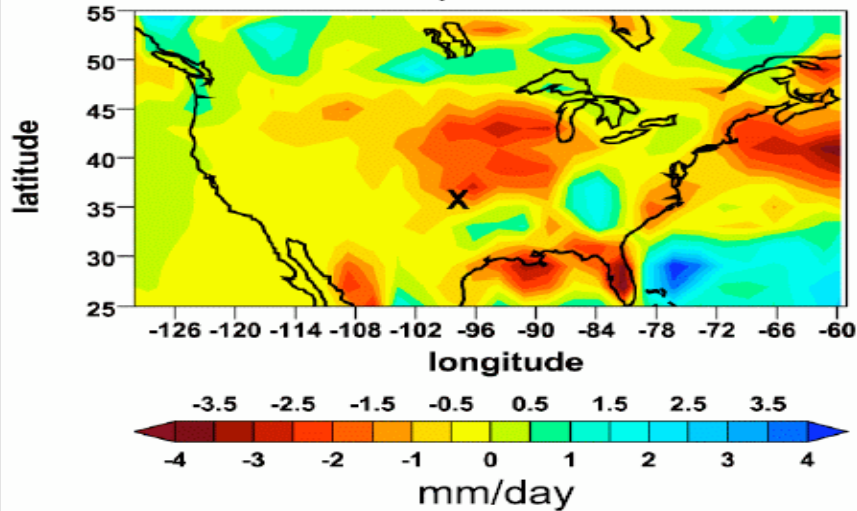
Climate and NWP errors



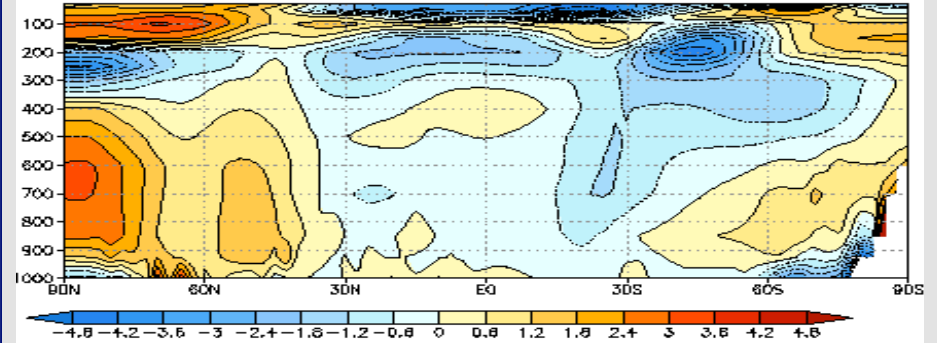
b Climate Precipitation Bias



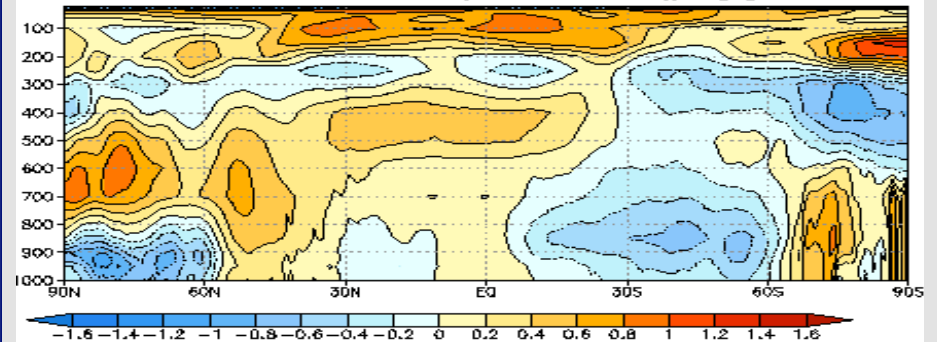
d Forecast Precipitation Bias



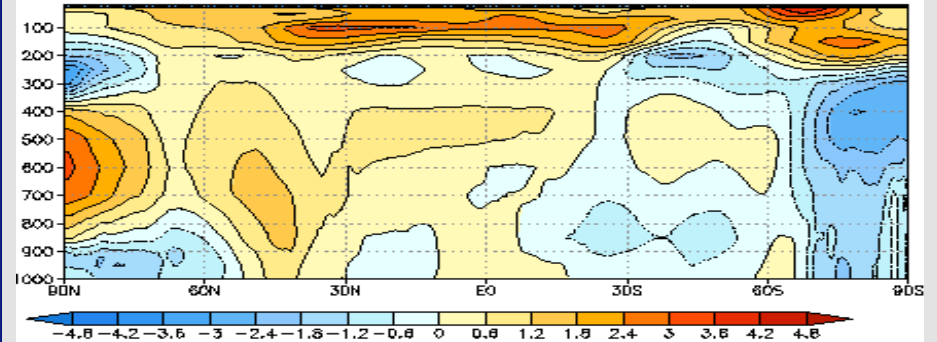
HadGAM1a-ERA40 jja [T]



THORPEX NWP Day 1-5 error jja [T]



THORPEX NWP Day 11-15 error jja [T]



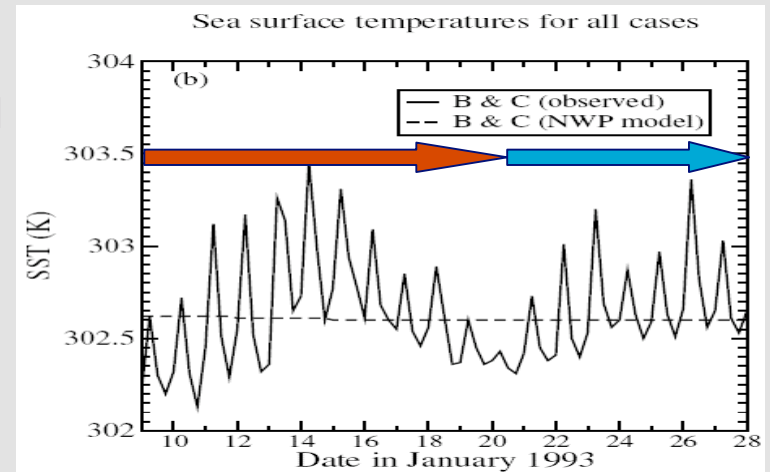
the case study

GCSS case 5: TOGA-COARE

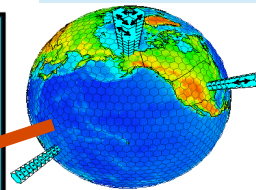
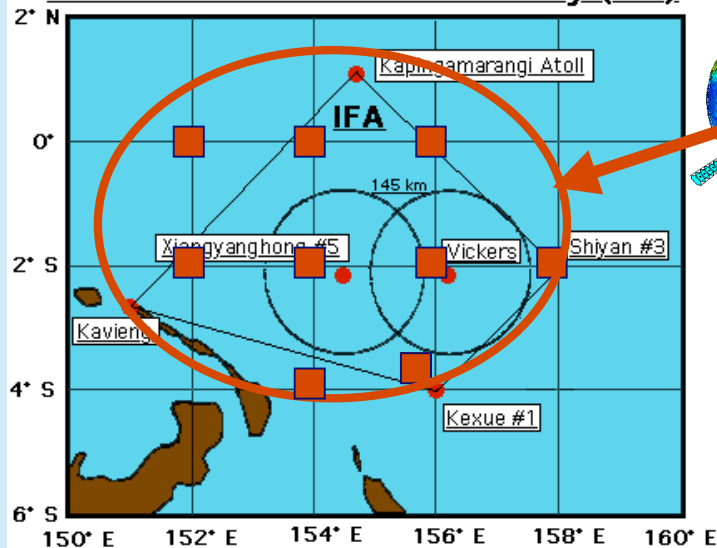
The framework



- Selected periods from TOGA-COARE
 - Strongly forced ► suppressed ► strongly forced
- CRM and SCM forced with an IFA mean derived from observations
- NWP uses ERA-40 with own SSTs
- NWP run multiple 48 hour forecasts (SCM also run this way)

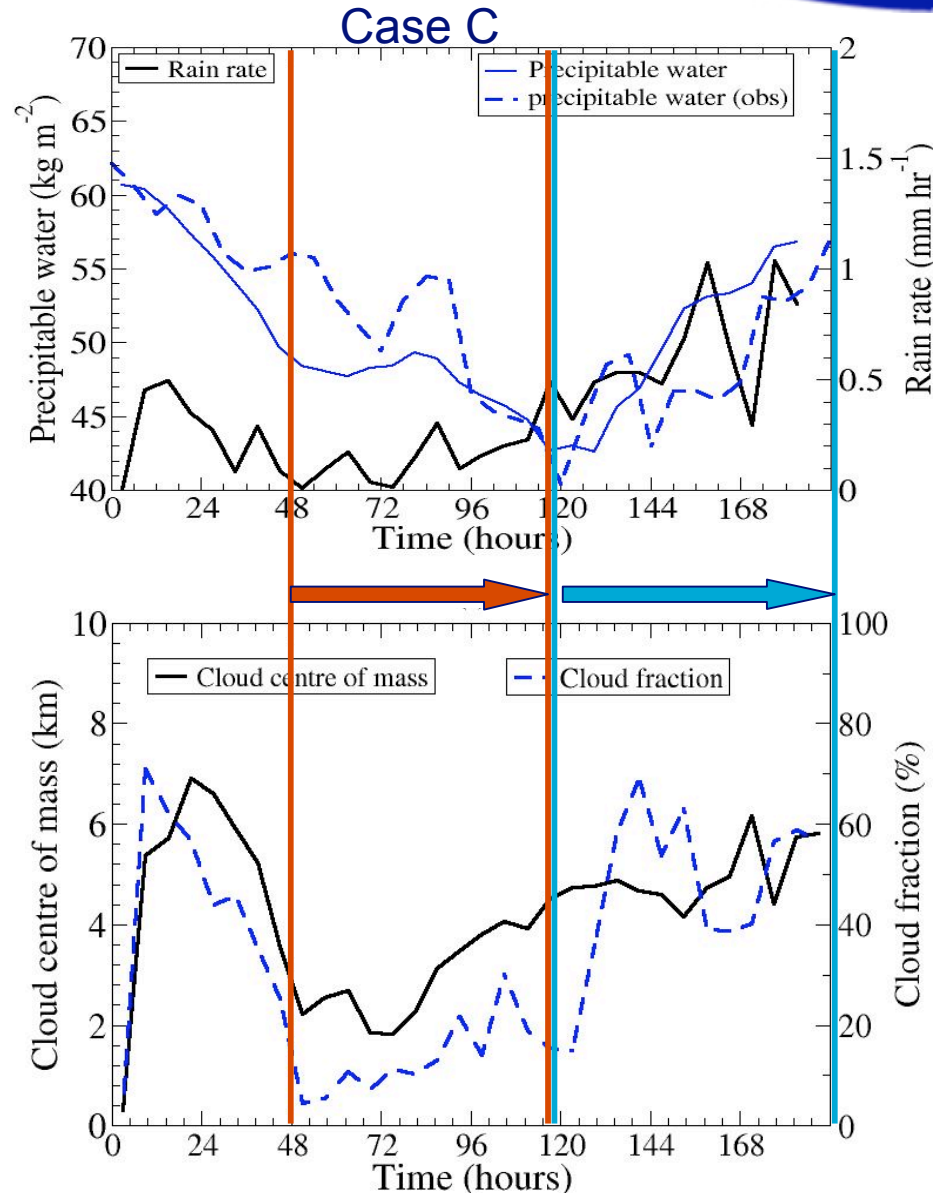
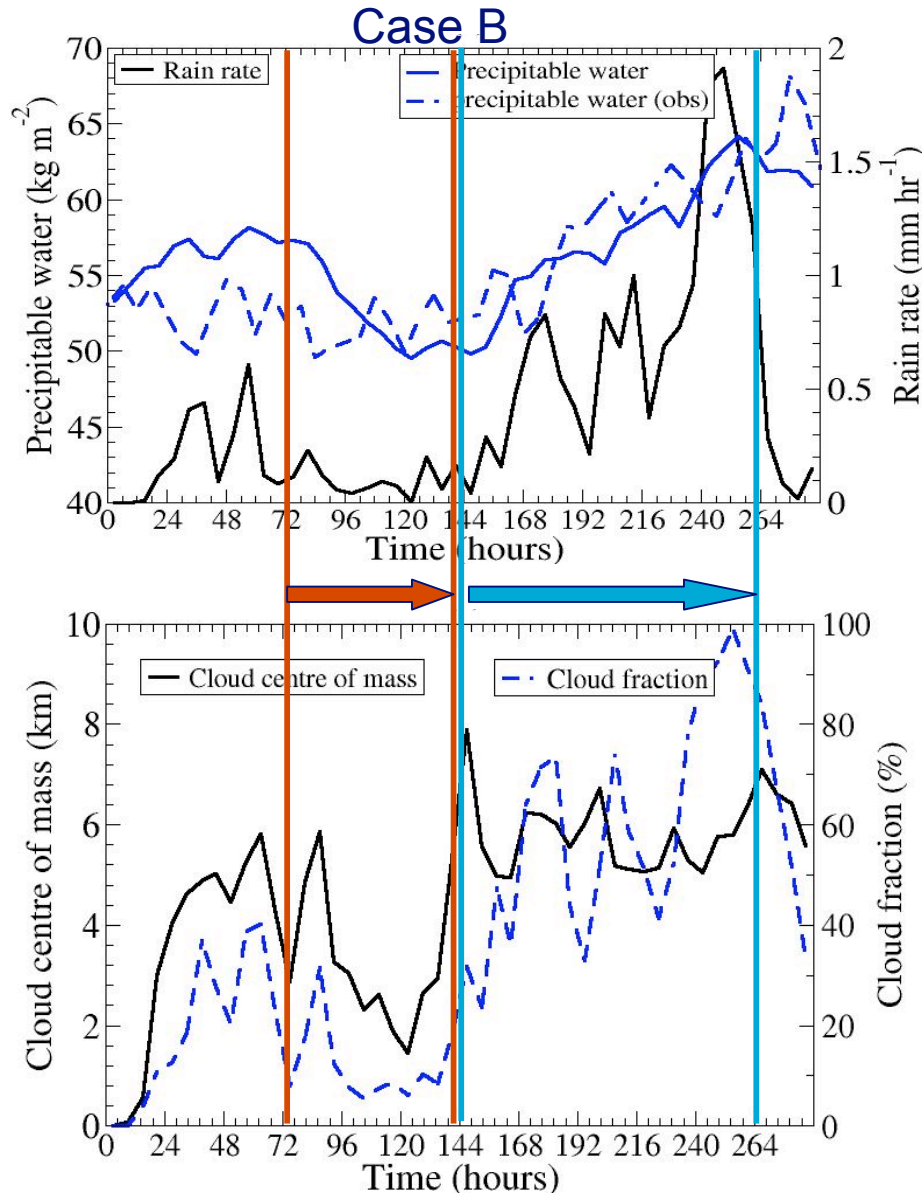


TOGA COARE Intensive Flux Array (IFA)



- Analysis of NWP model uses mean of all points within IFA
- Actual number varies from model to model (UM has 23 grid-points)

Regimes of convection

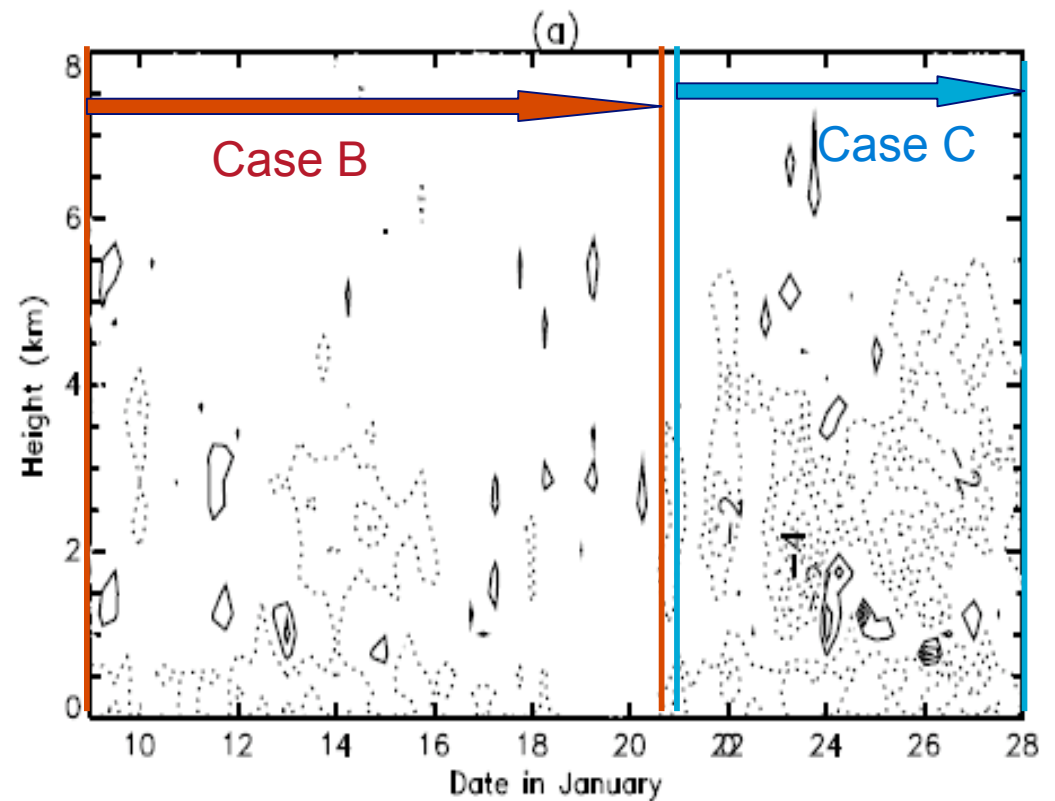
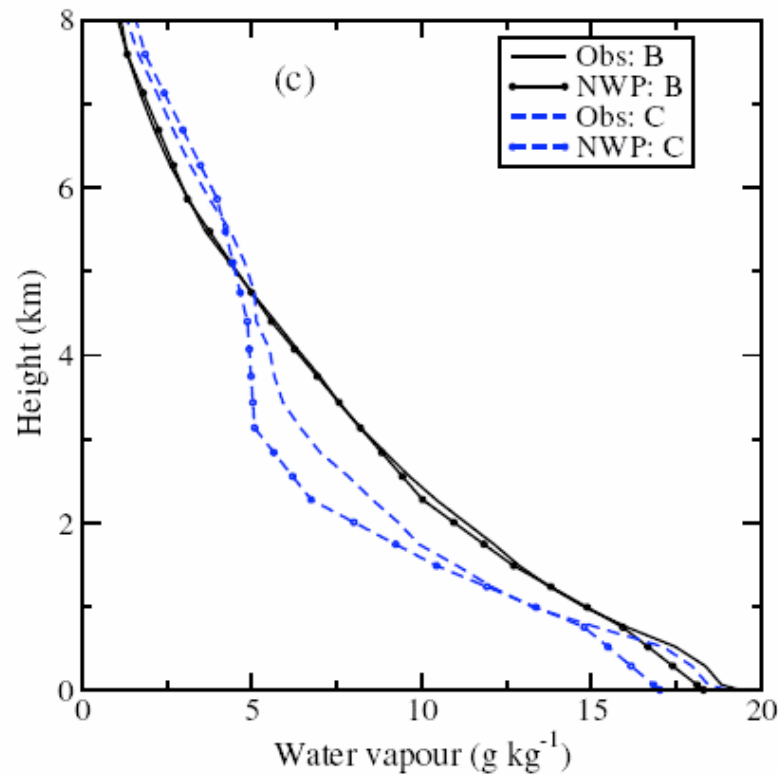


Comparison of observations with analysis



Mean profiles of water vapour for periods B and C from the sondes and from ERA40

Difference in the water vapour (ERA40 – observations) as a time-height plot



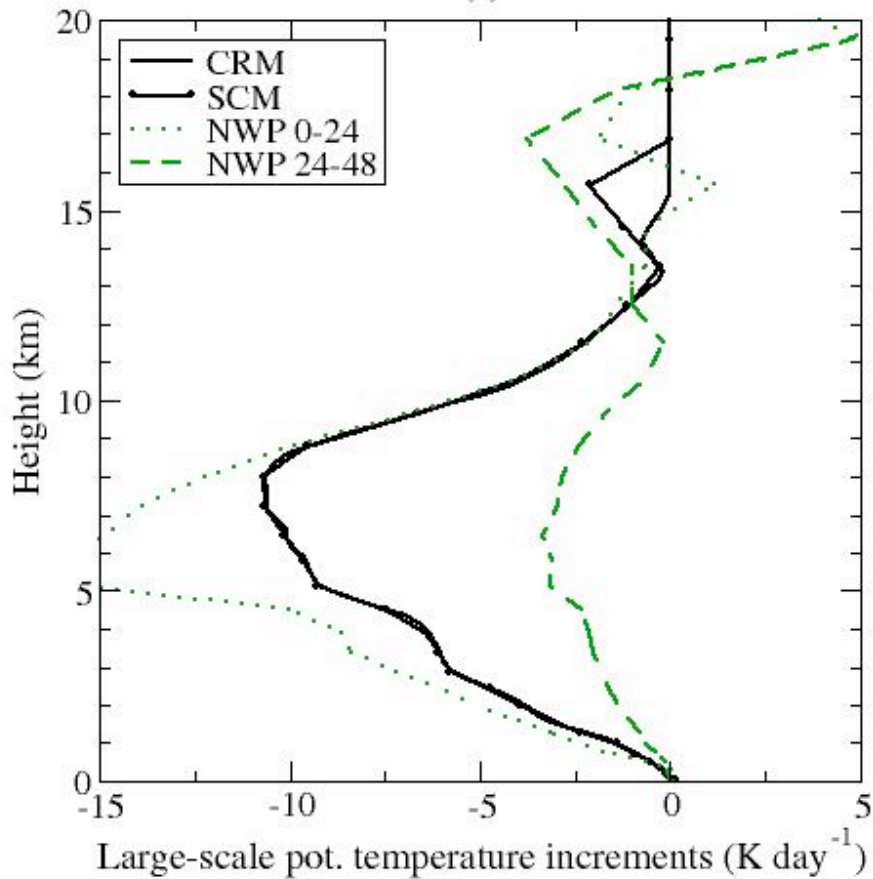


biases in the Met Office model

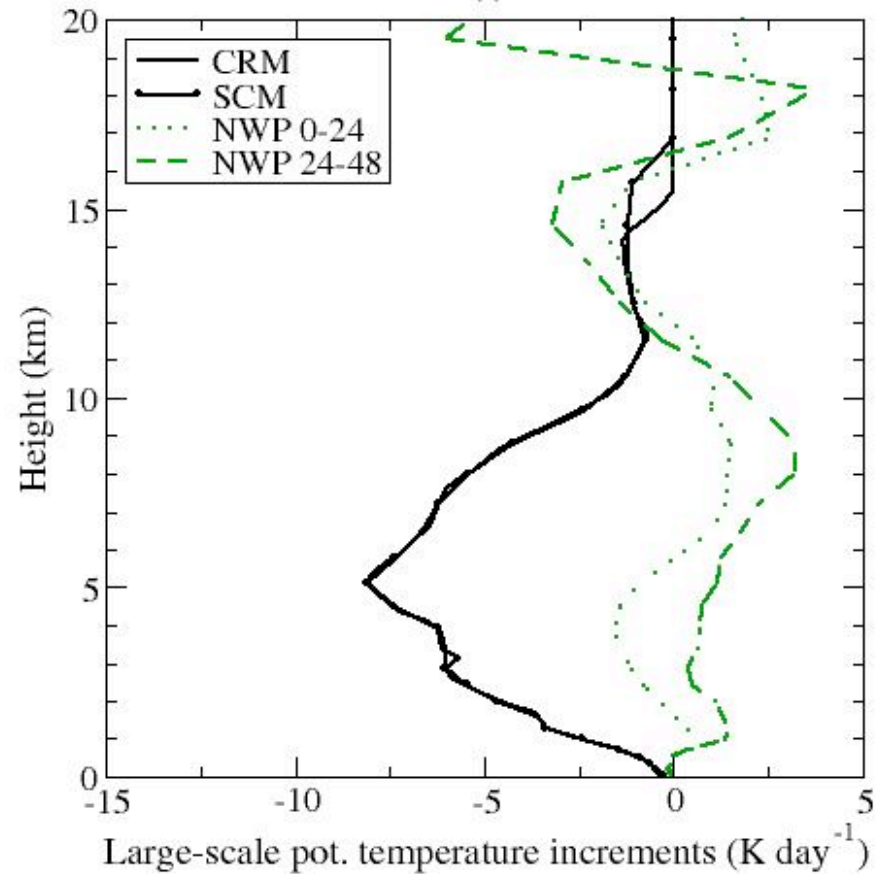
Spin down and a poor match for case C



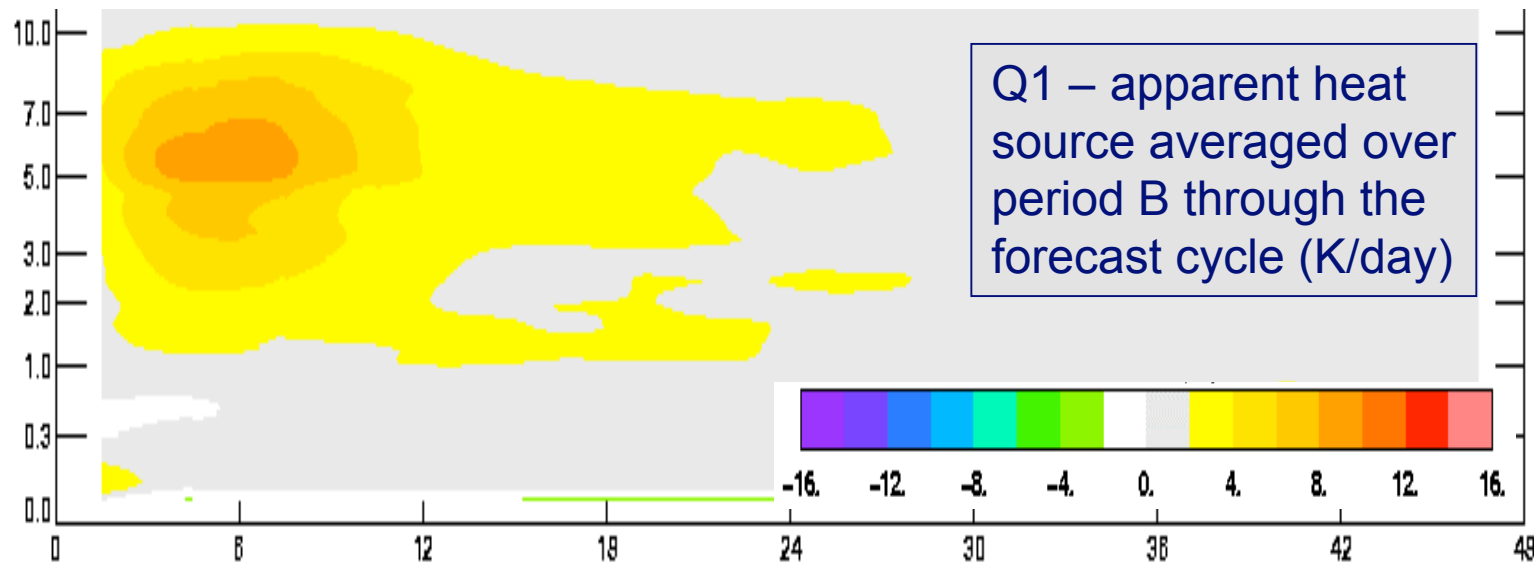
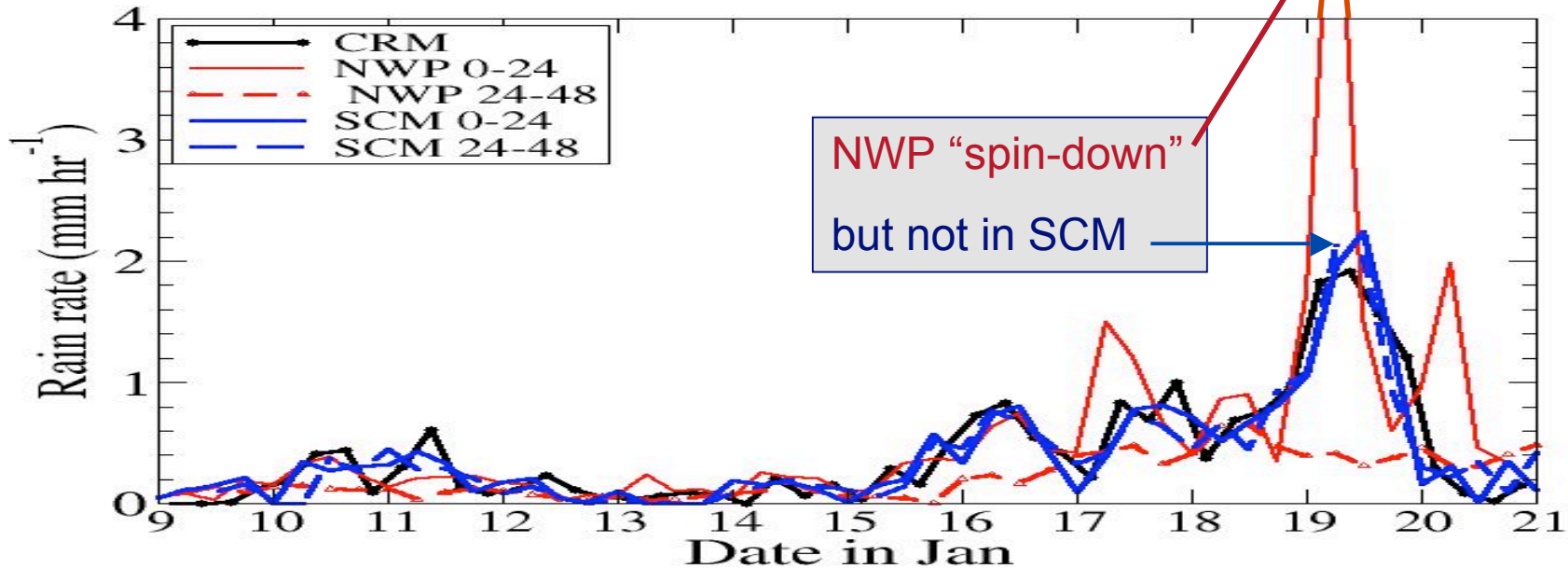
Case B active period



Case C active period



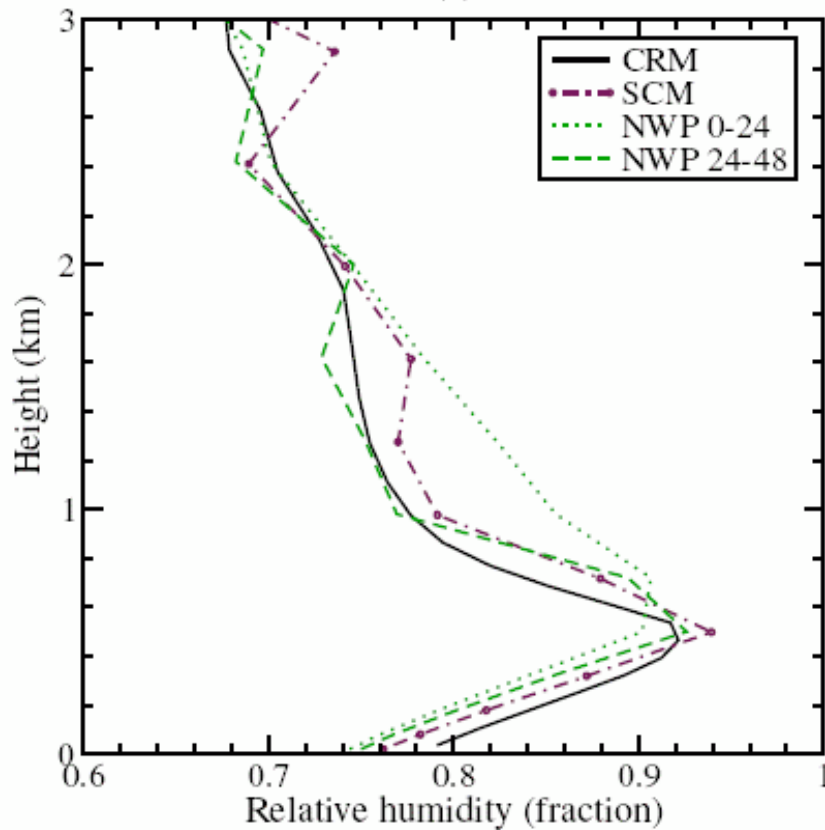
Spin down in the MWP model



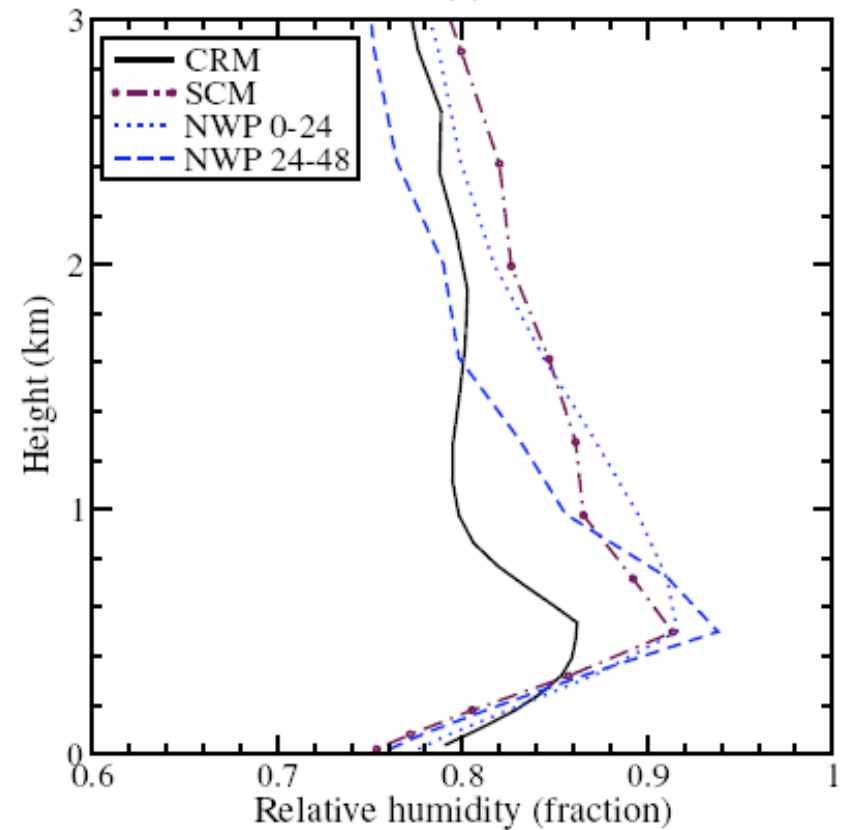
Relative humidity profiles in lower troposphere



The RH profile in the UM/SCM is not very dependent on convective activity but it is in the CRM.

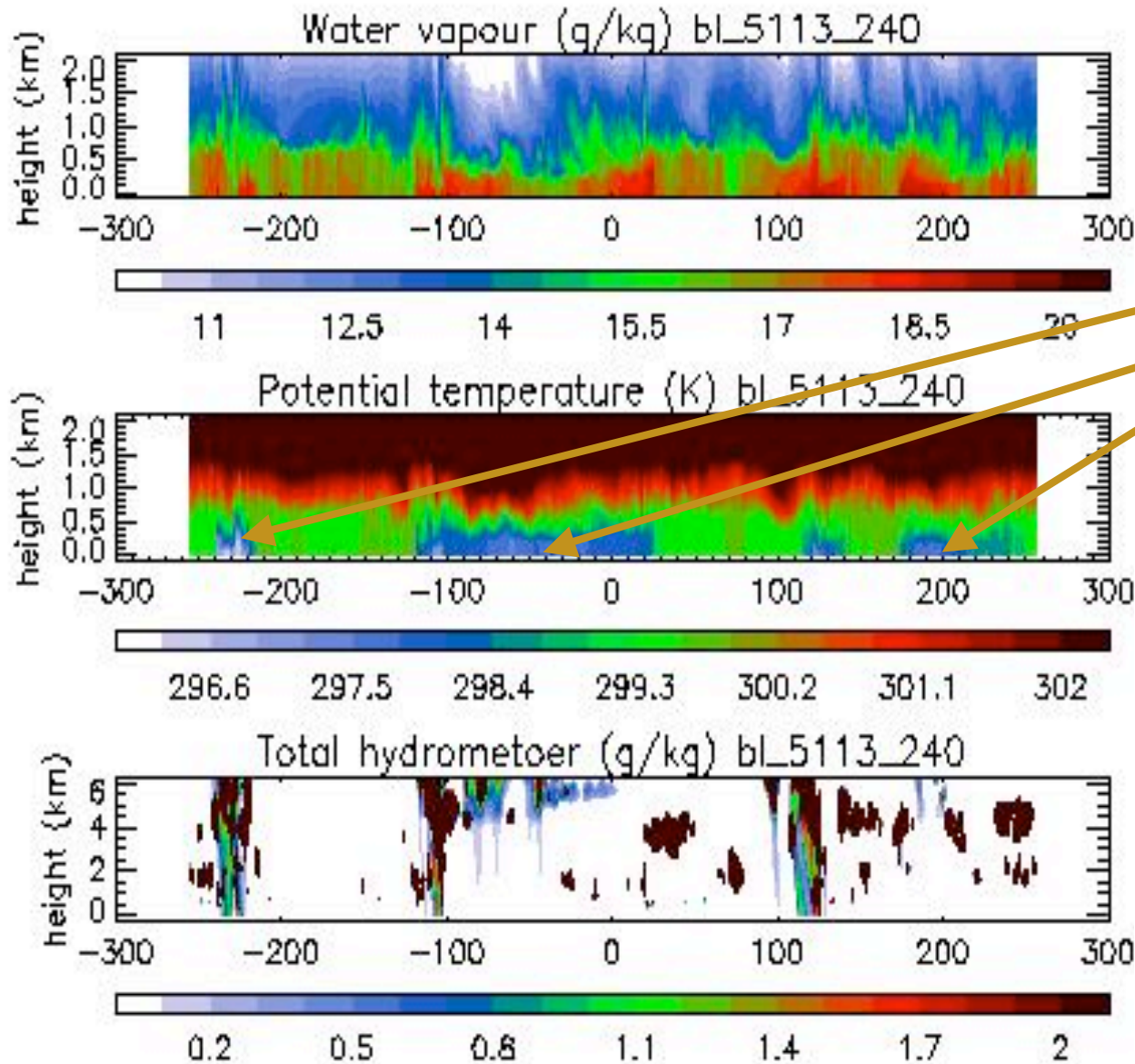


Active period B



Suppressed period B

During a convective period

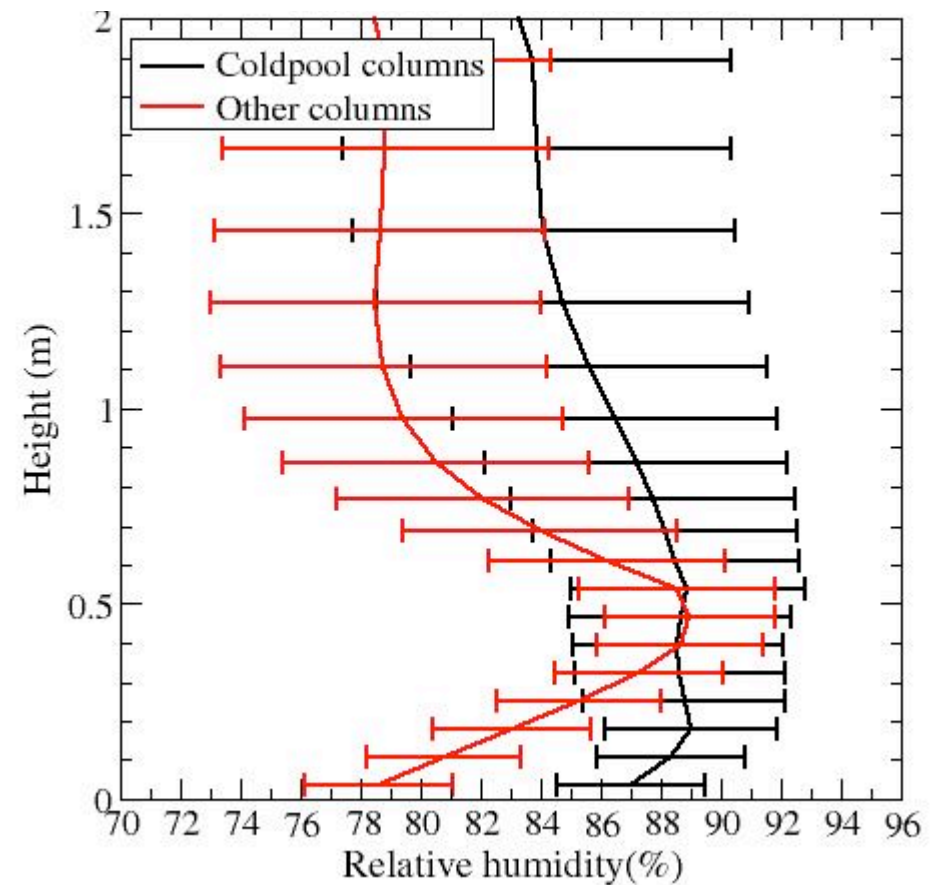
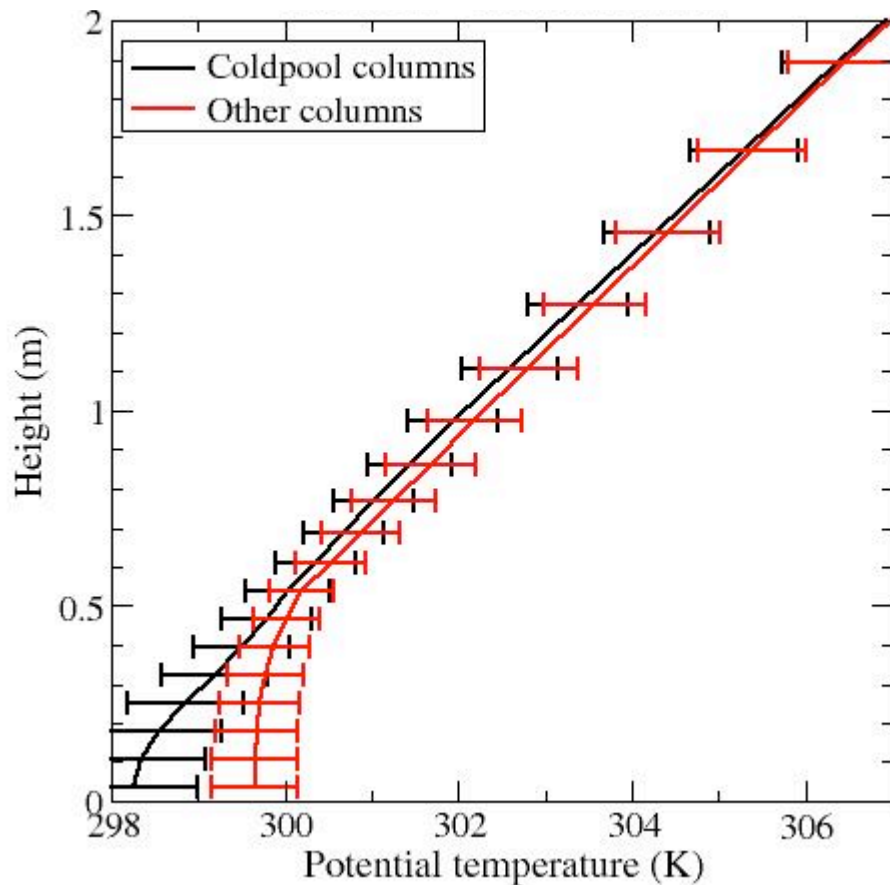


A closer analysis of the CRM shows significant coldpools near deep convective events.

The profiles



The differences in the cold pools relative humidity structures are clear throughout the whole period



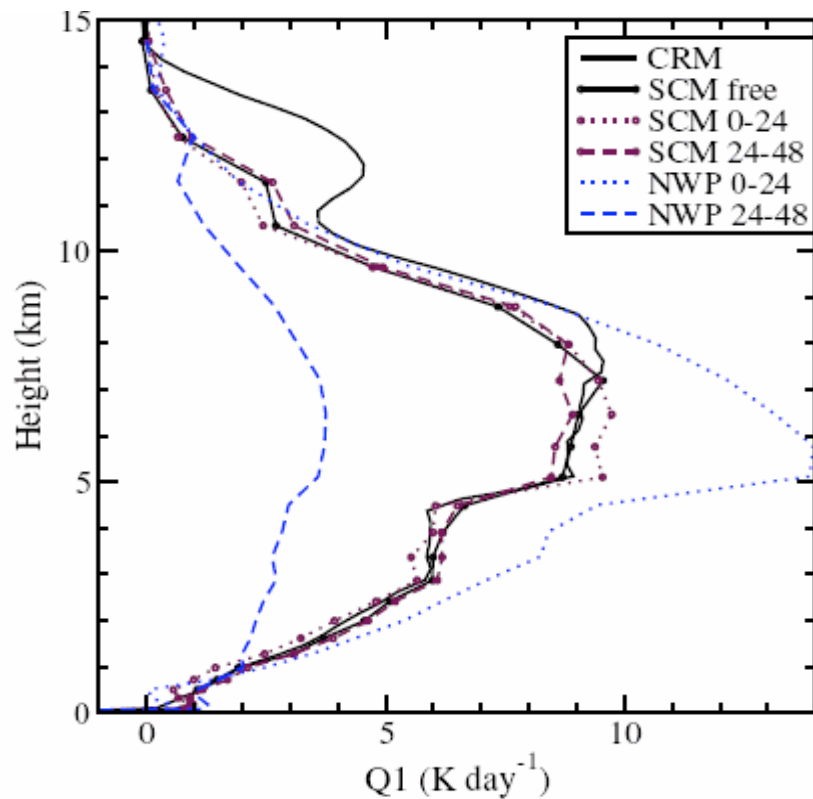


**a warning from the multi-
model comparison**

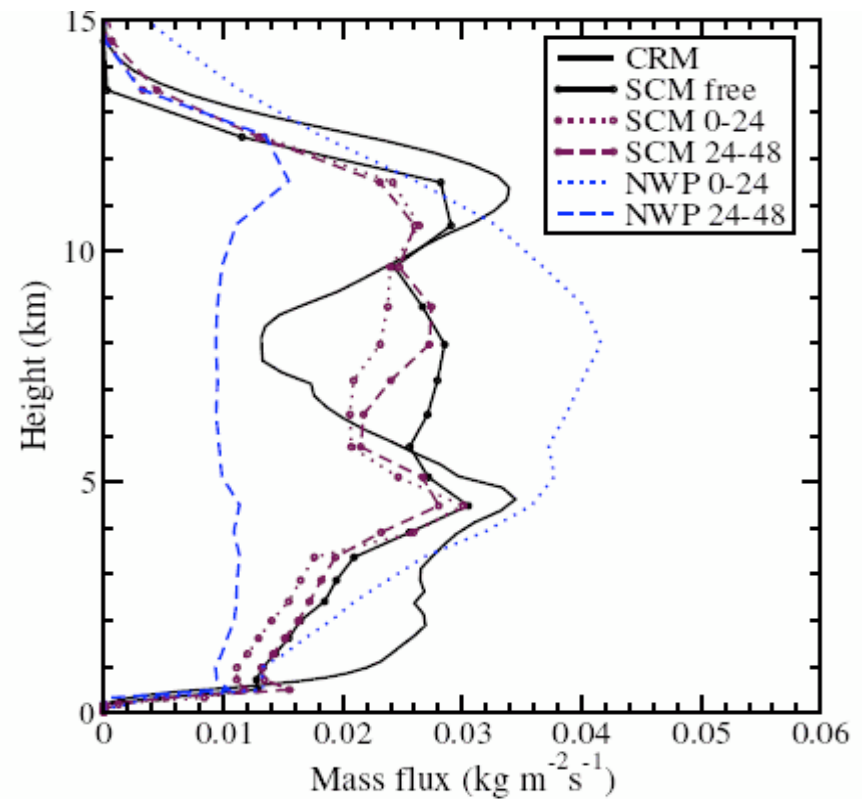
a warning from the multi model comparison



The apparent heat source and convective mass flux at 10-14 km differ significantly from the CRM



Q1

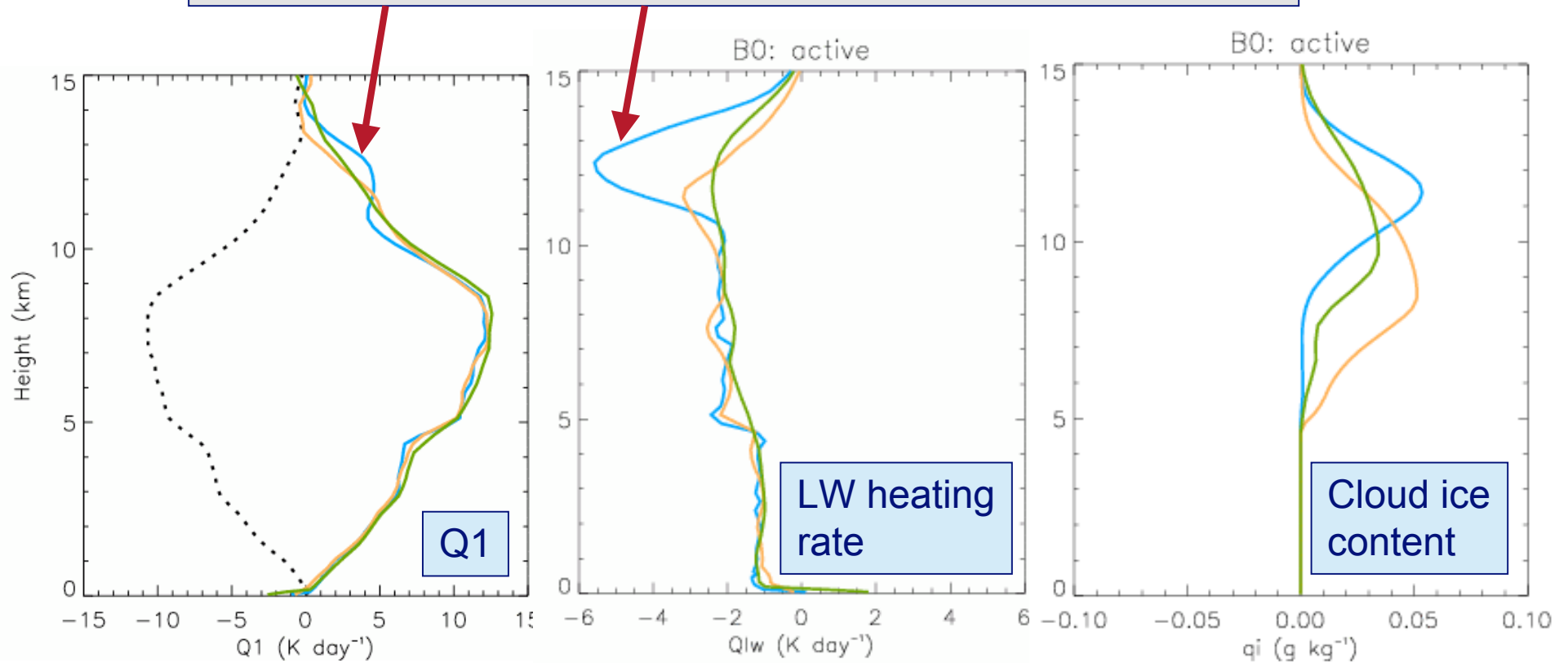


Convective mass flux

a warning from the multi model comparison



The apparent heat source in the Met Office CRM differs from other CRMs involved in the multi-model comparison



The background of the slide features a light blue color with several horizontal, wavy bands of a slightly darker shade of blue. A faint rainbow gradient is visible behind these waves, transitioning from purple on the left to yellow on the right. The word "summary" is centered in a dark blue, sans-serif font.

summary

- A framework involving CRMs, SCMs and NWP models has been used to identify model biases
- Some biases are clear in both the NWP and SCM model, others are may only be seen in one or the other
- The CRM has been used to gain additional information about these biases and will be used to help change the parametrizations
- Idealized tests with SCMs and CRMs can also be used to help identify and address problems with parametrizations

The background of the slide features a light blue gradient with several horizontal, wavy bands of a slightly darker shade of blue. A faint rainbow gradient is visible behind these waves, transitioning from purple on the left to yellow and green on the right.

the end

Models NWP



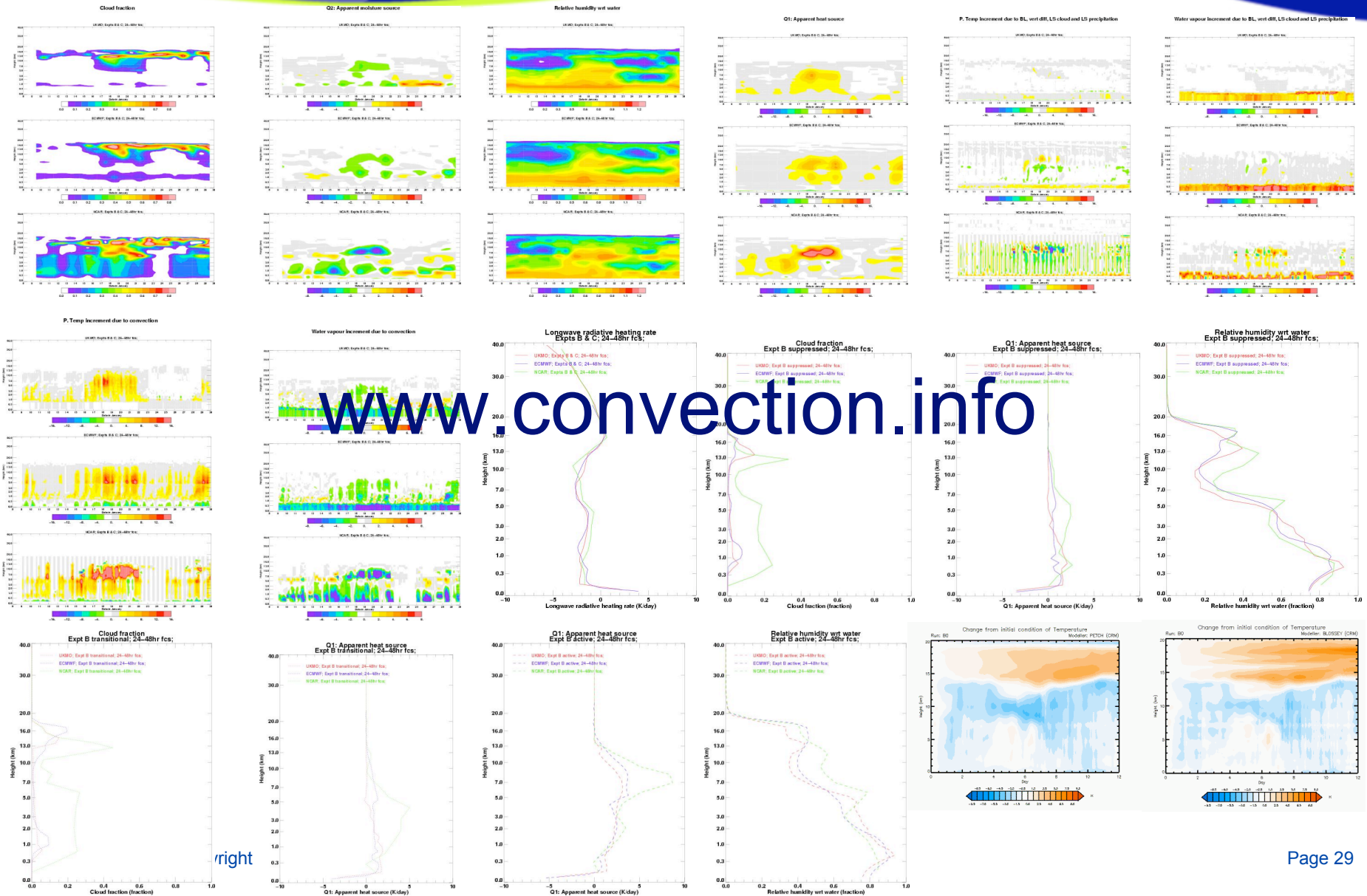
| Modeller | Affiliation | Type | Model |
|-------------------|-------------------|--------------------------|----------------------|
| BECHTOLD | ECMWF | NWP | EC T159 |
| WILLETT | Met Office | NWP | UM N216 |
| WILLIAMSON | CAM | NWP (Climate) | NCAR CAM3 T42 |
| <i>KLEIN</i> | <i>LLNL</i> | <i>NWP (Climate)</i> | <i>GFDL ?</i> |

Models CRM/SCM



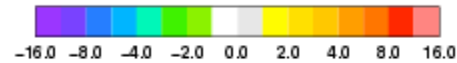
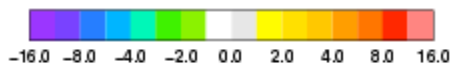
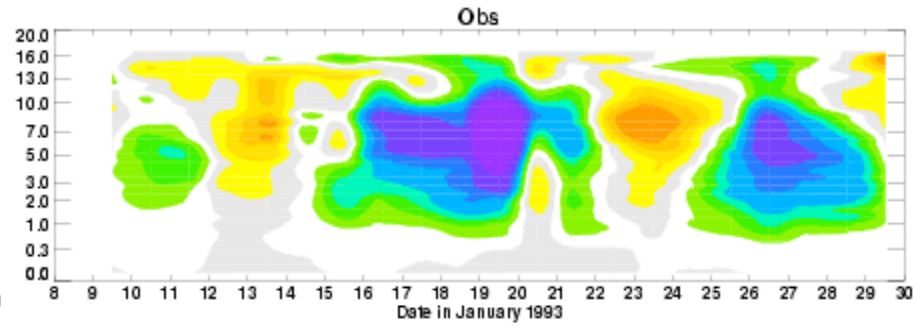
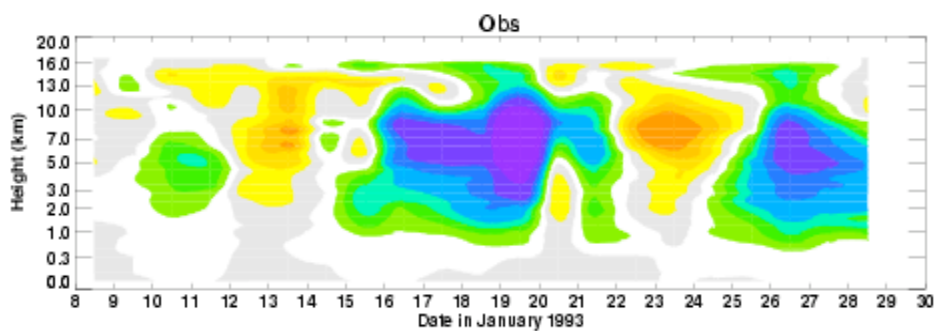
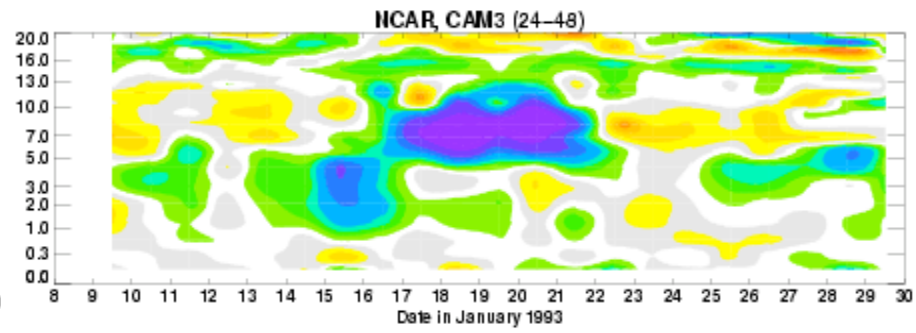
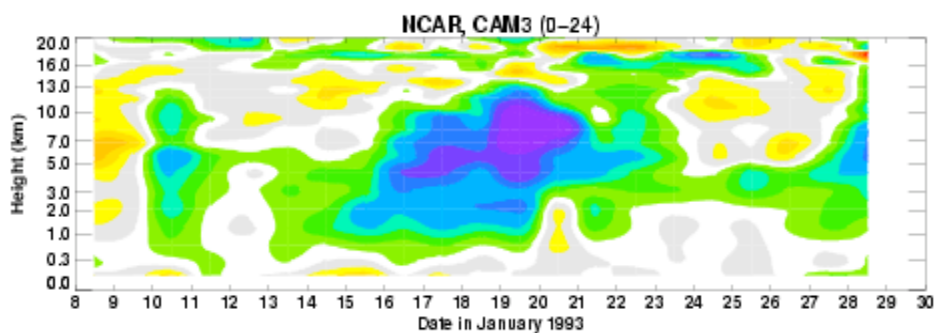
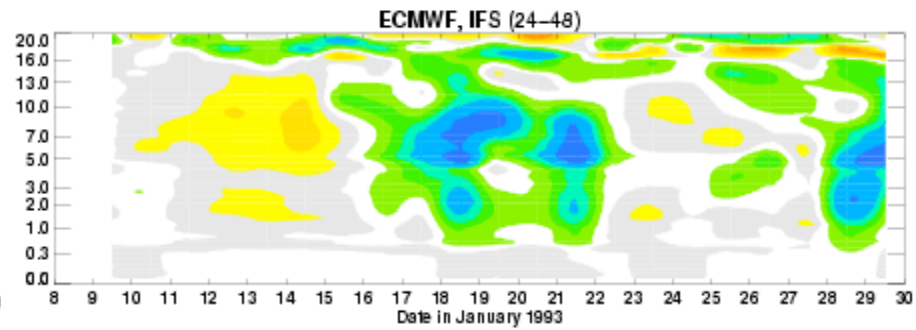
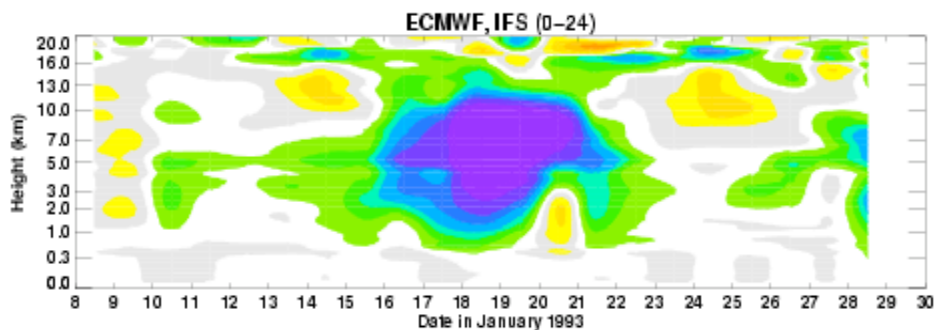
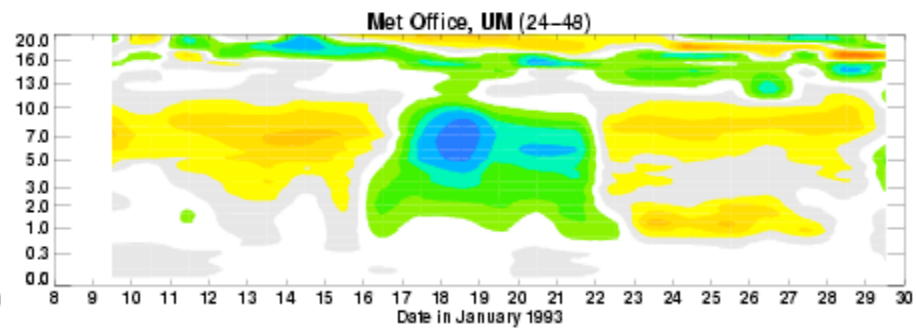
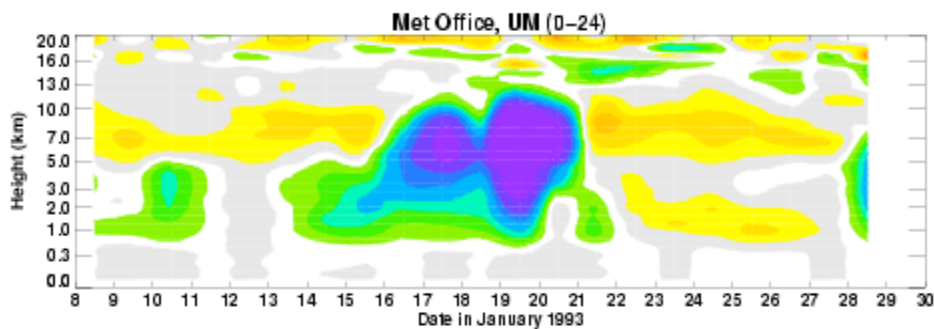
| Modeller | Affiliation | Type | Model |
|-----------------|--|-------------|---------------------------|
| PETCH | Met Office | CRM | Met Office LEM |
| LUO | National Institute of Aerospace | CRM | UCLA/LaRC CRM |
| BLOSSEY | U. Washington | CRM | SAM 6.3 |
| HALLIWELL | Met Office | CRM/ NWP | Met Office UM |
| XIE | LLNL | SCM | NCAR CAM3 |
| BECHTOLD | ECMWF | SCM | EC |
| WONG | Met Office | SCM | Met Office UM |
| IACOBELLIS | Scripps, UCSD | SCM | Scripps |
| HOSOMI | JMA | SCM | JMA Global Spectral Model |
| CHABOUREAU | Laboratoire d'Aérodynamique, Toulouse | SCM | Meso NH |

A wide variety of plots

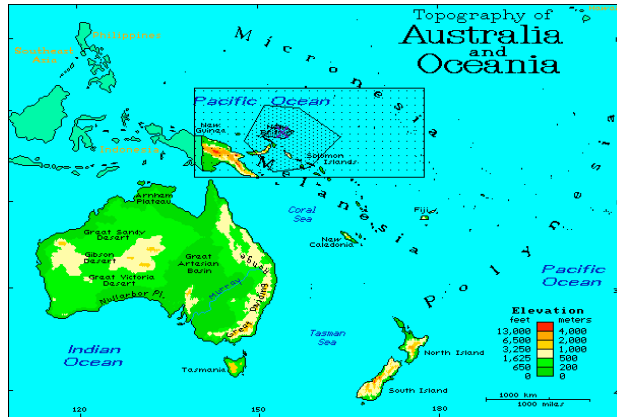


www.convection.info

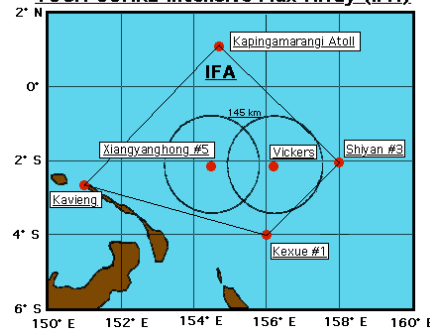
right



Cloud pictures from TOGA-COARE



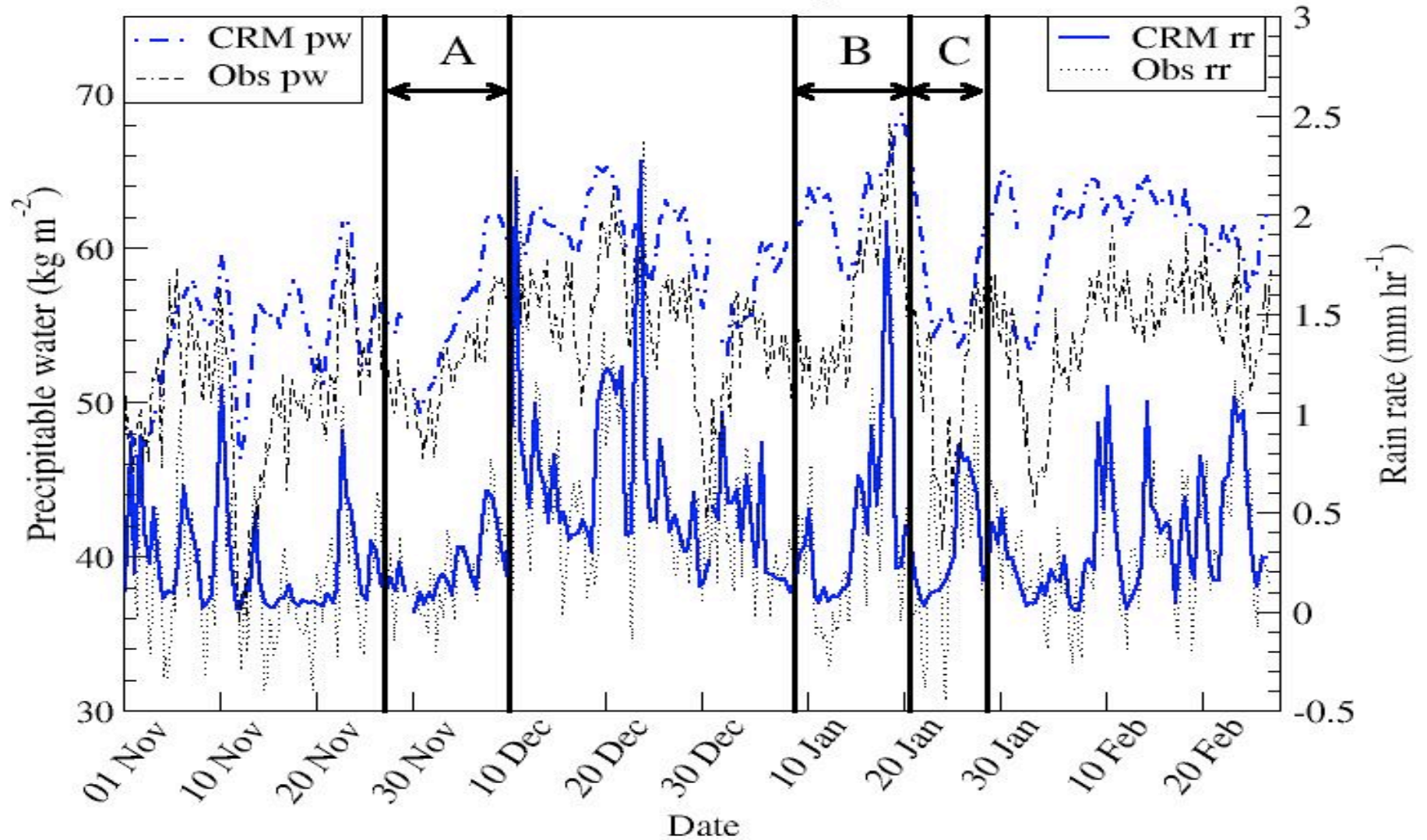
TOGA COARE Intensive Flux Array (IFA)



Choosing the period



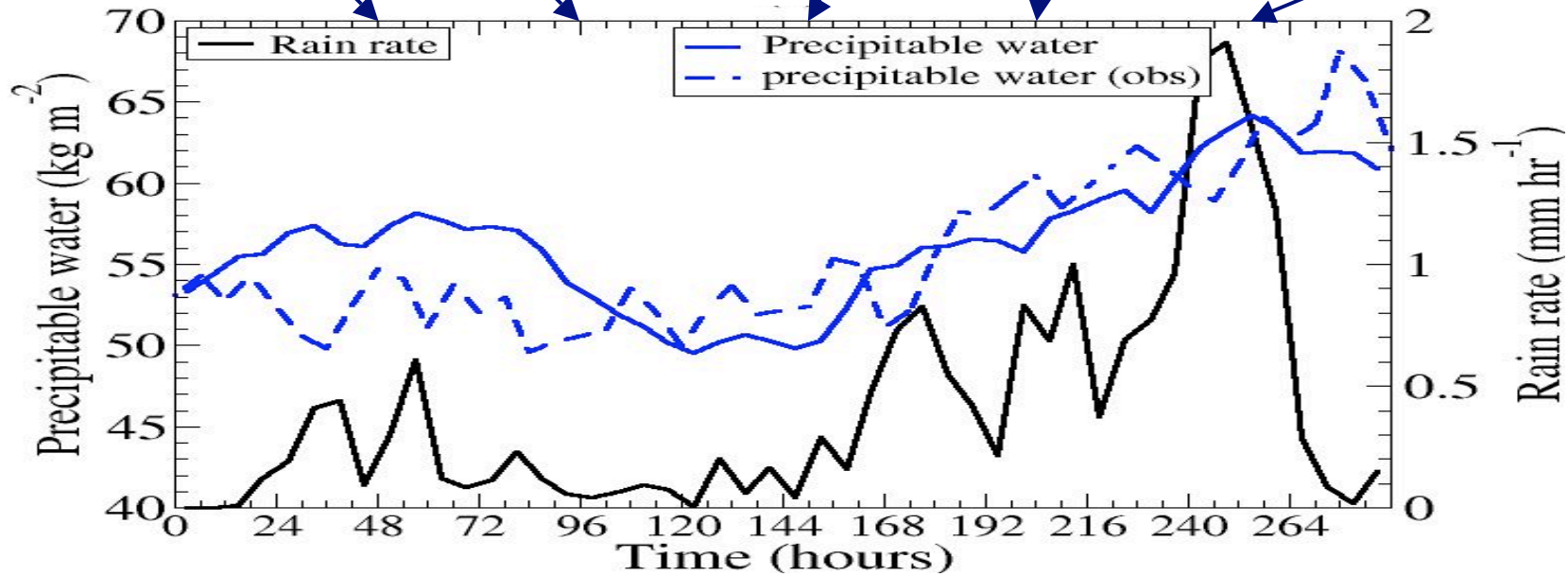
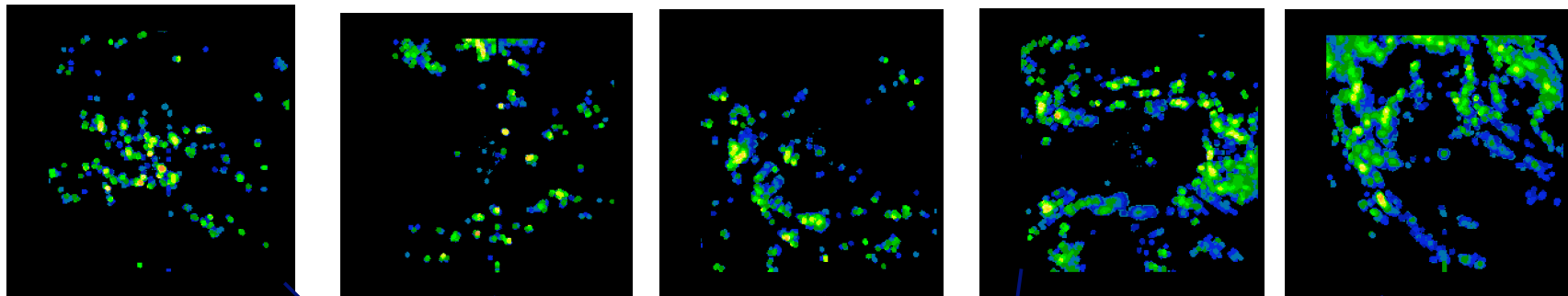
Full 4 month TOGA period



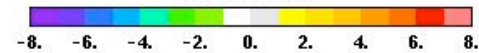
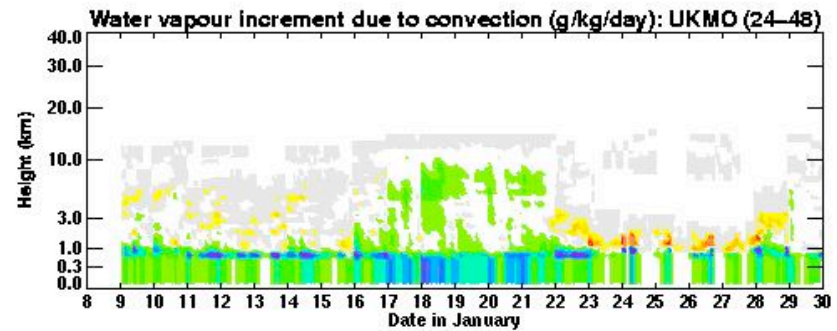
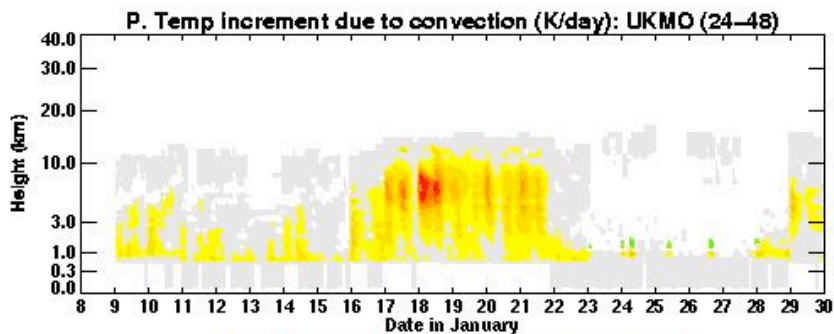
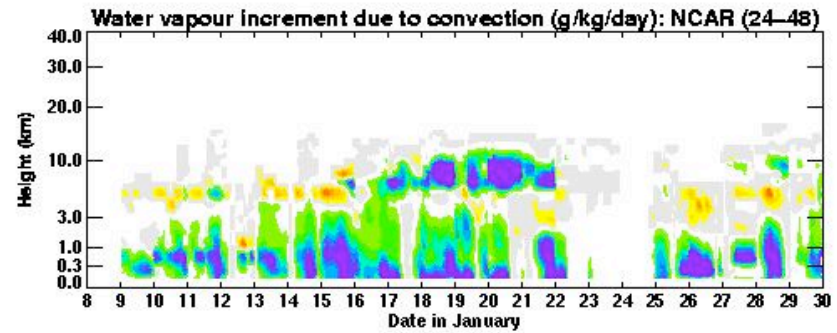
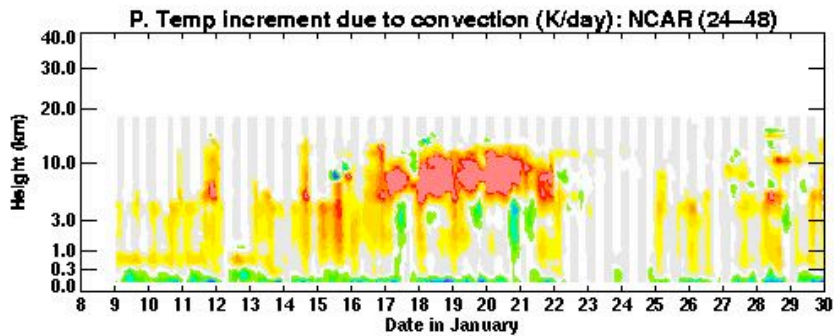
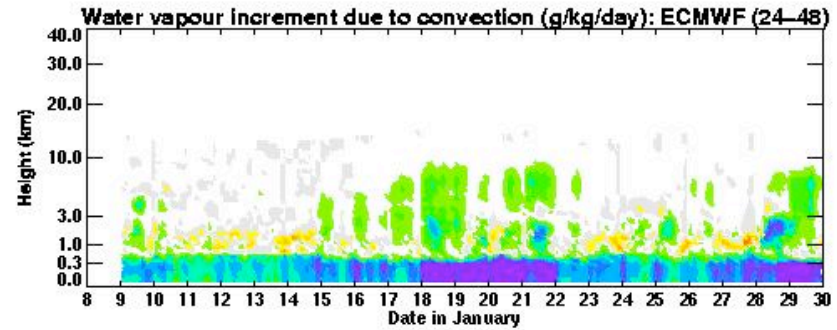
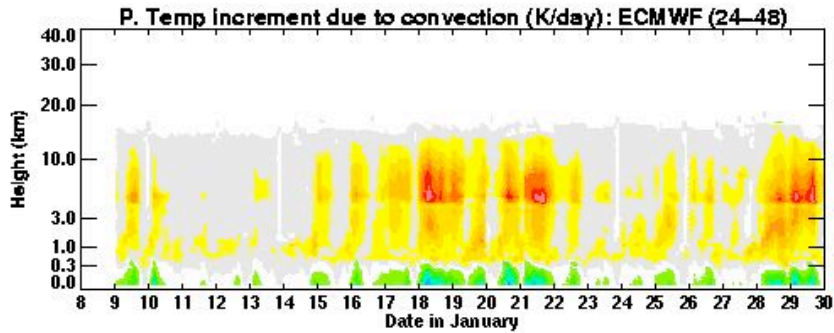
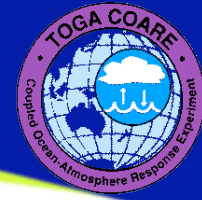
SCM/CRM forcing vs EC analysis



ship based radar



NWP results: T and q increments due to convection

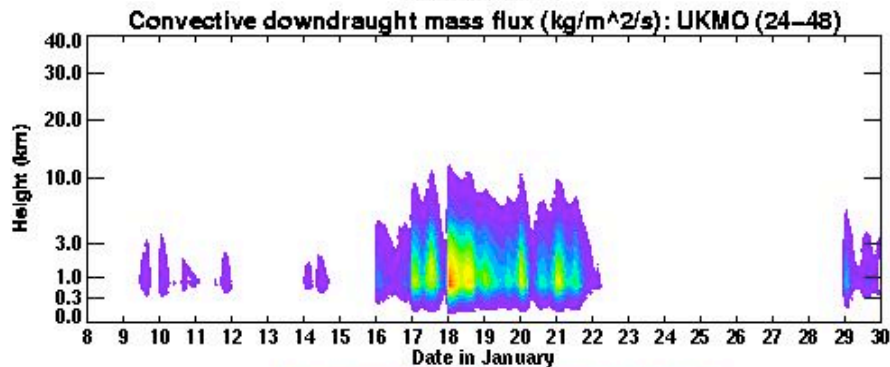
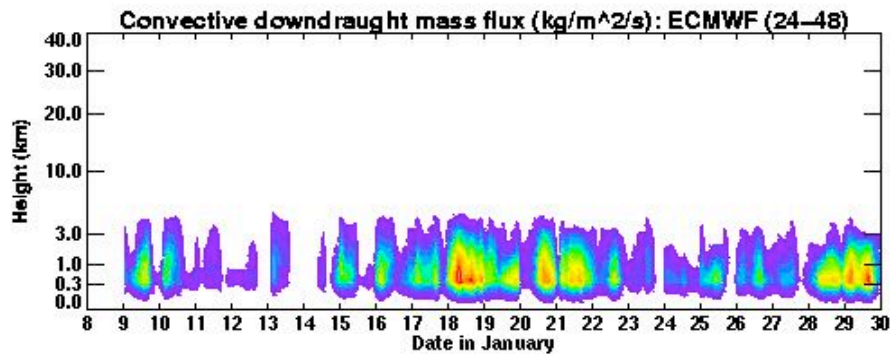


NWP results: convective mass flux (total and DD)

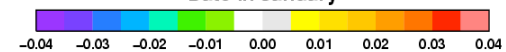
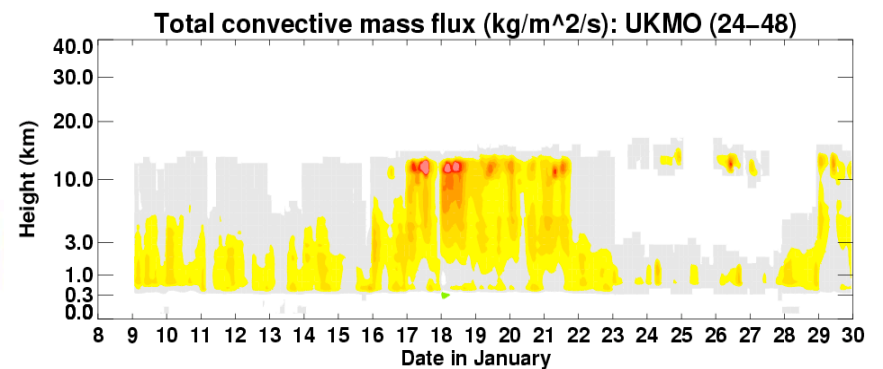
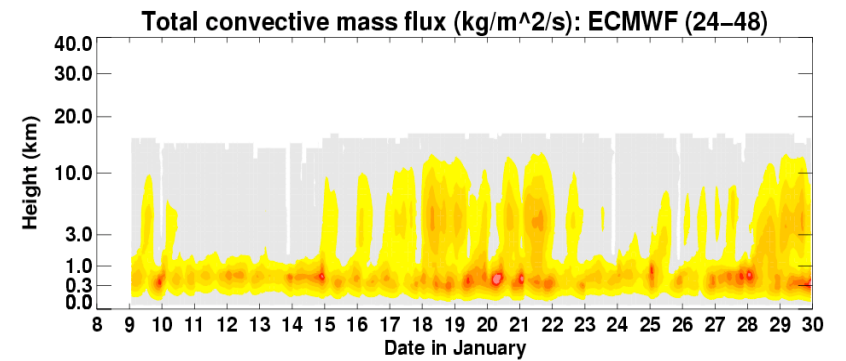


The UM and EC have notably different mass fluxes and downdraught profiles

Downdraughts



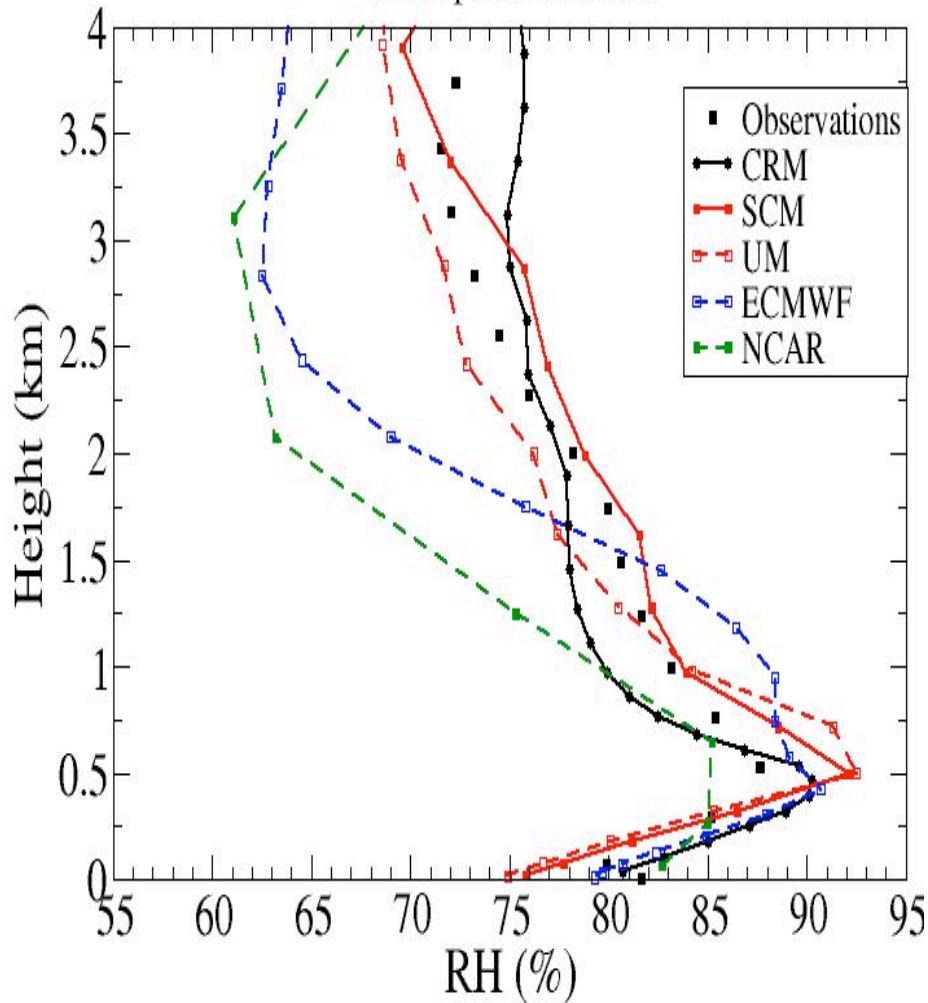
Total mass flux



Relative humidity profiles in lower troposphere



Mean profiles case B

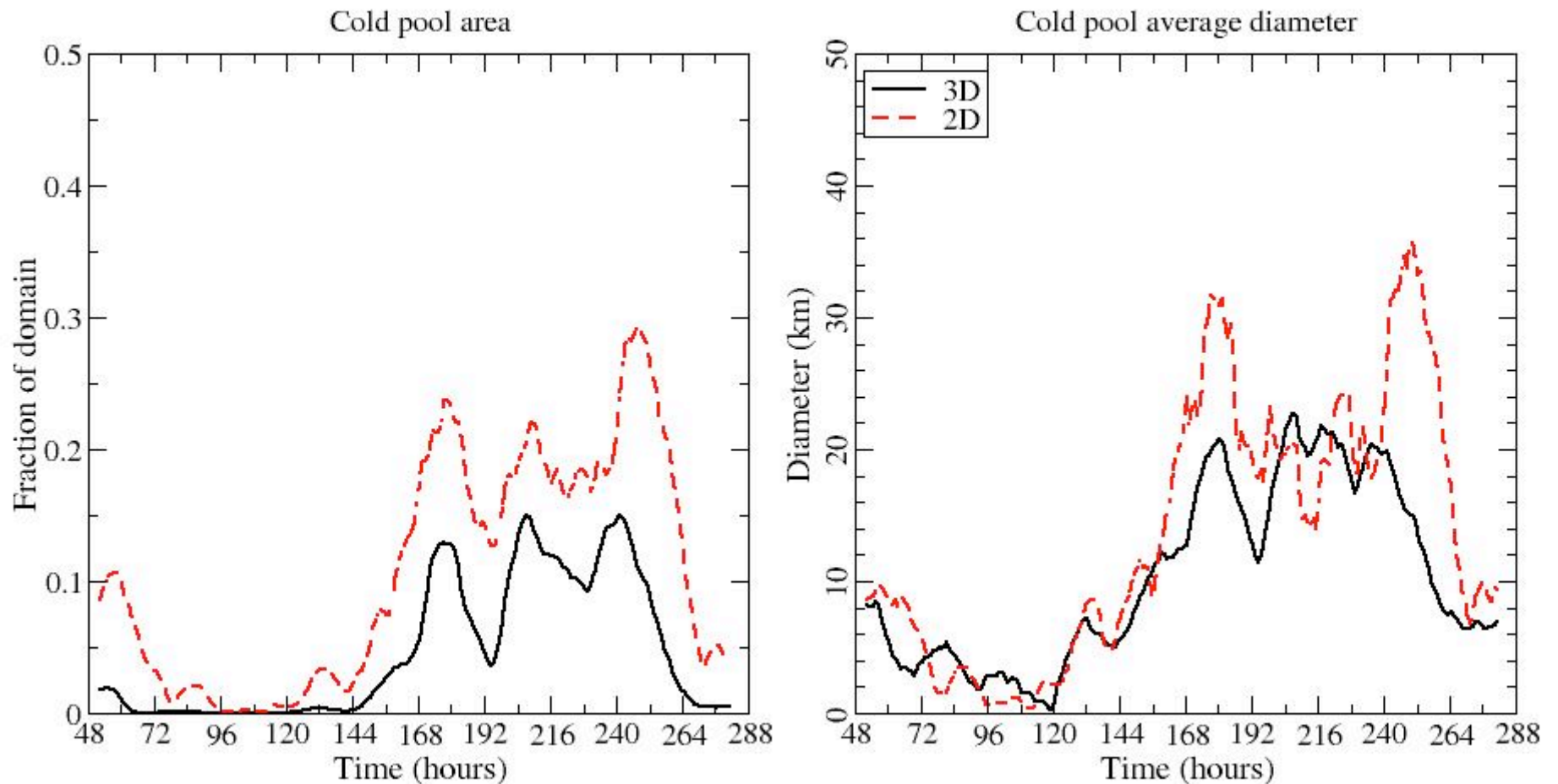


- The SCM and full NWP model have a similar humidity profile in the BL.
- The CRM and EC model look more similar to each other in the BL.
- The overactive shallow scheme in EC can account for the larger humidities between 500 m and 1.5 km.

Cold pool sizes



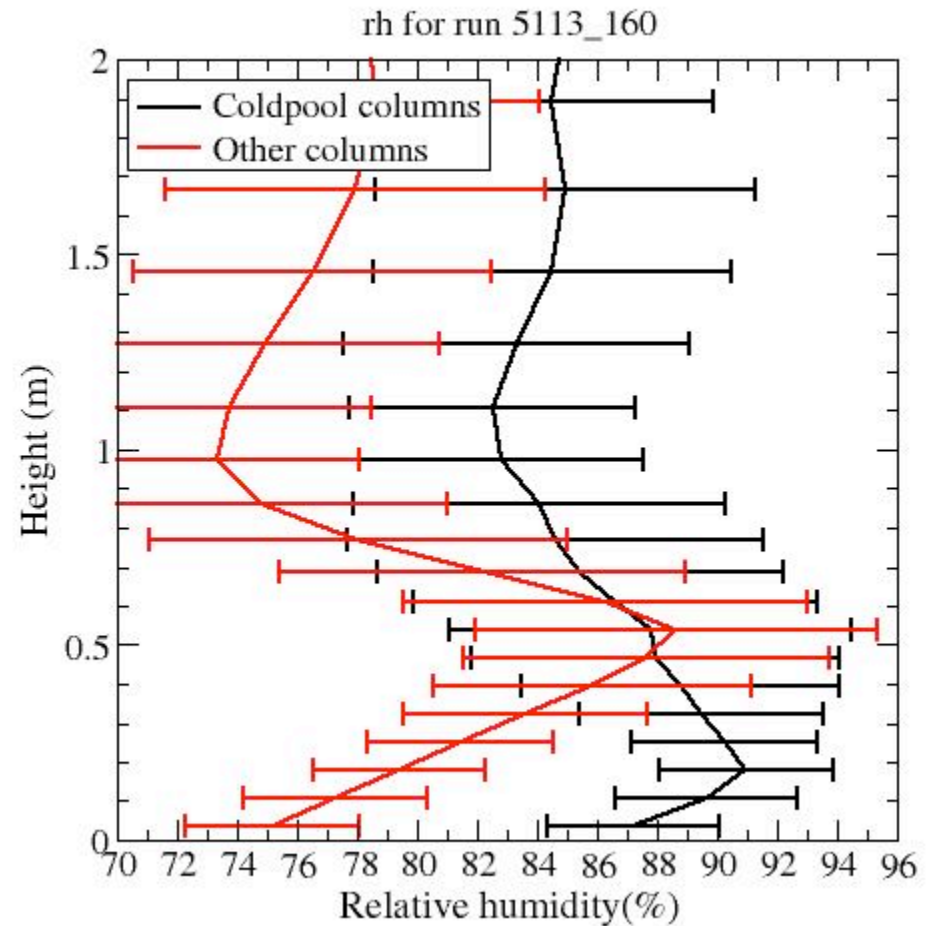
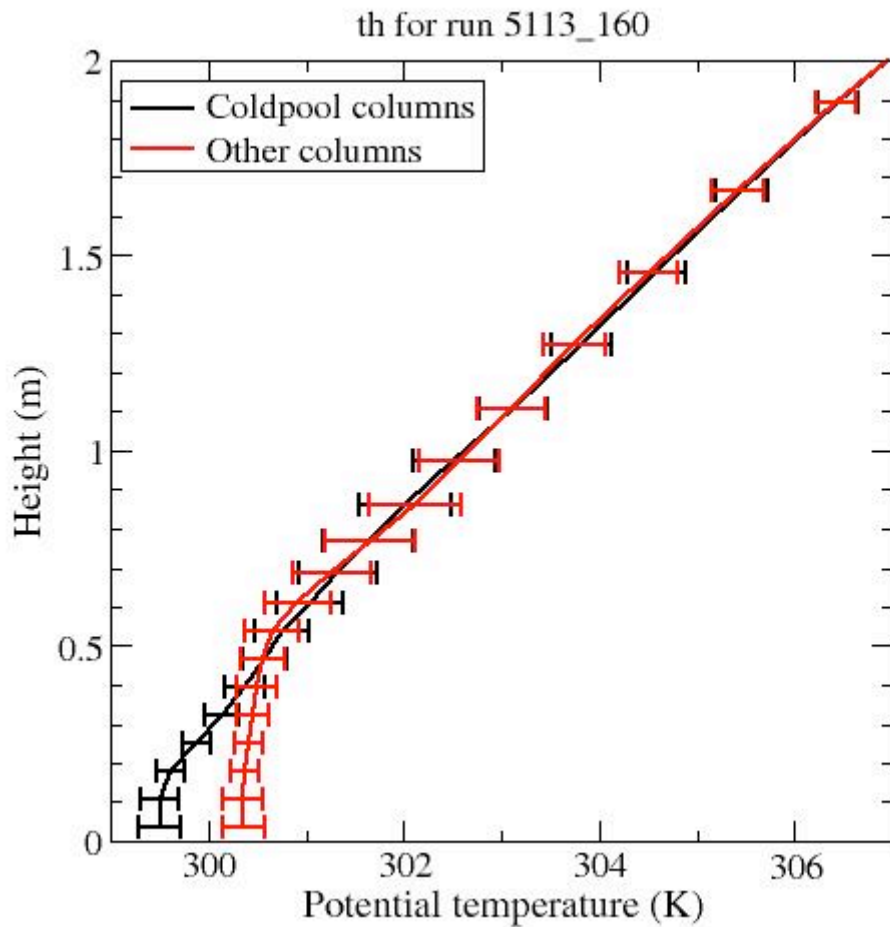
We can count and measure the cold pools in the CRM. Some differences between 2D and 3D runs.



Cold pool structures

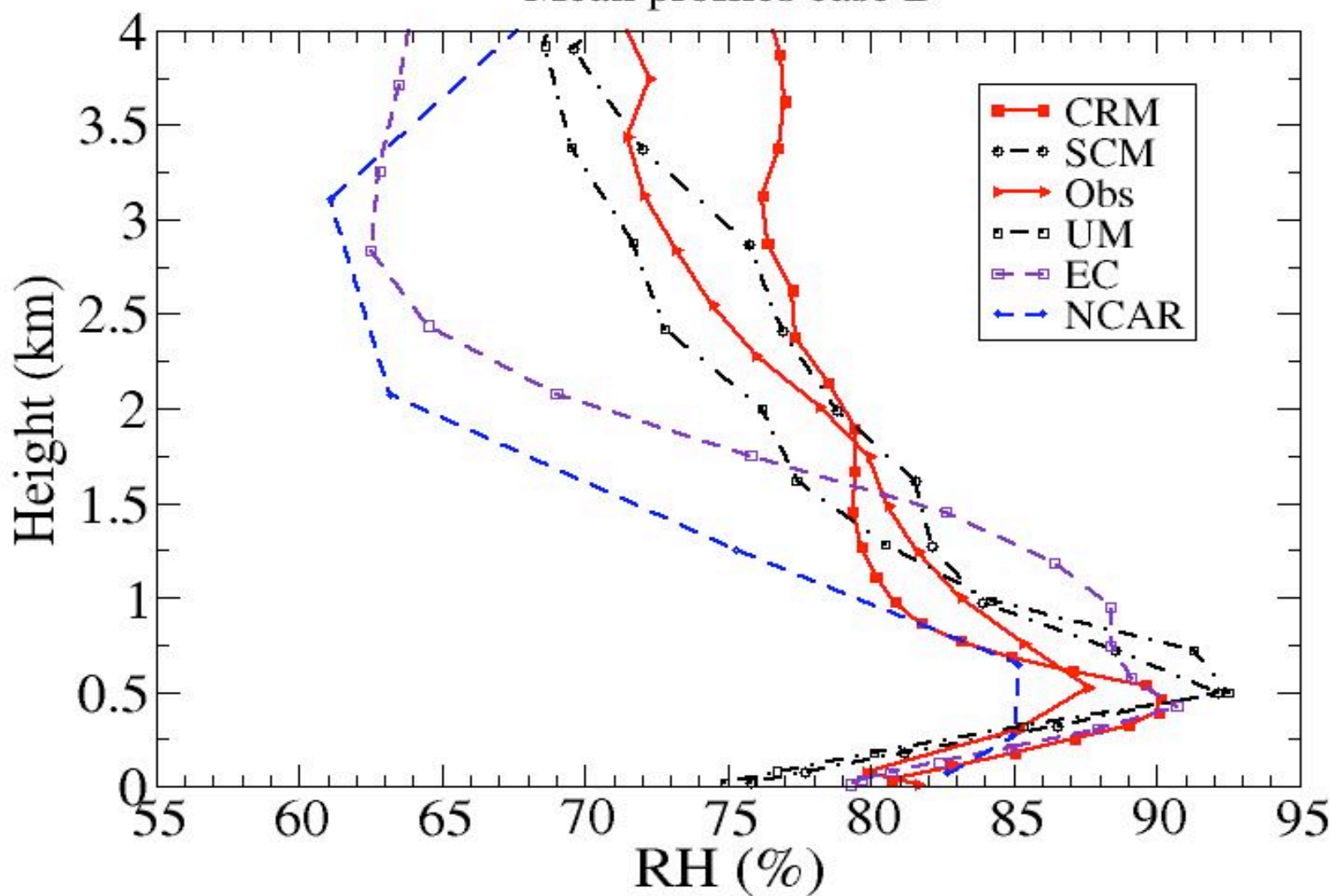


The differences in the cold pools relative humidity structures are clear on any given time



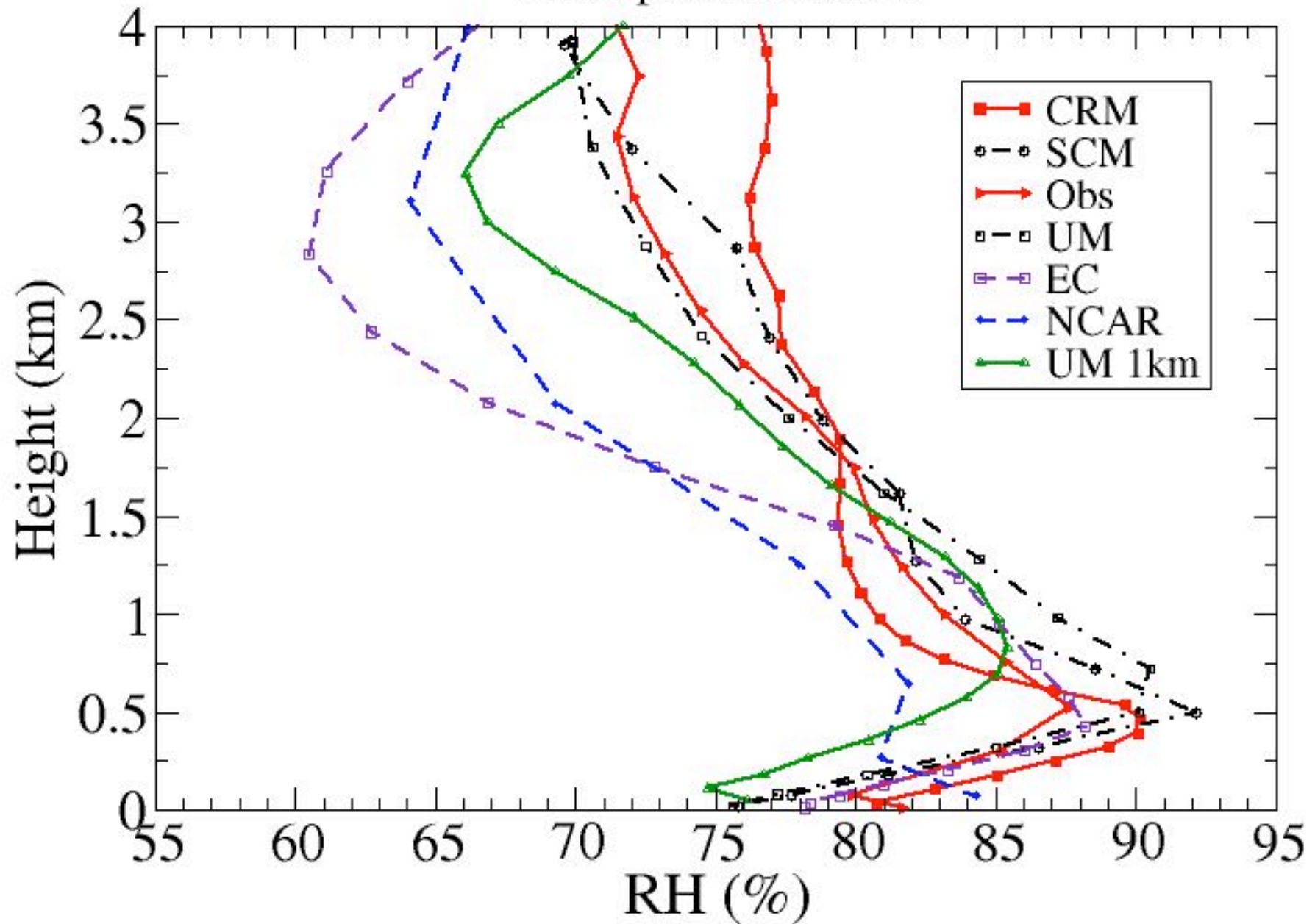
NWP, SCM, CRM and Obs

Mean profiles case B



NWP, SCM, CRM and Obs

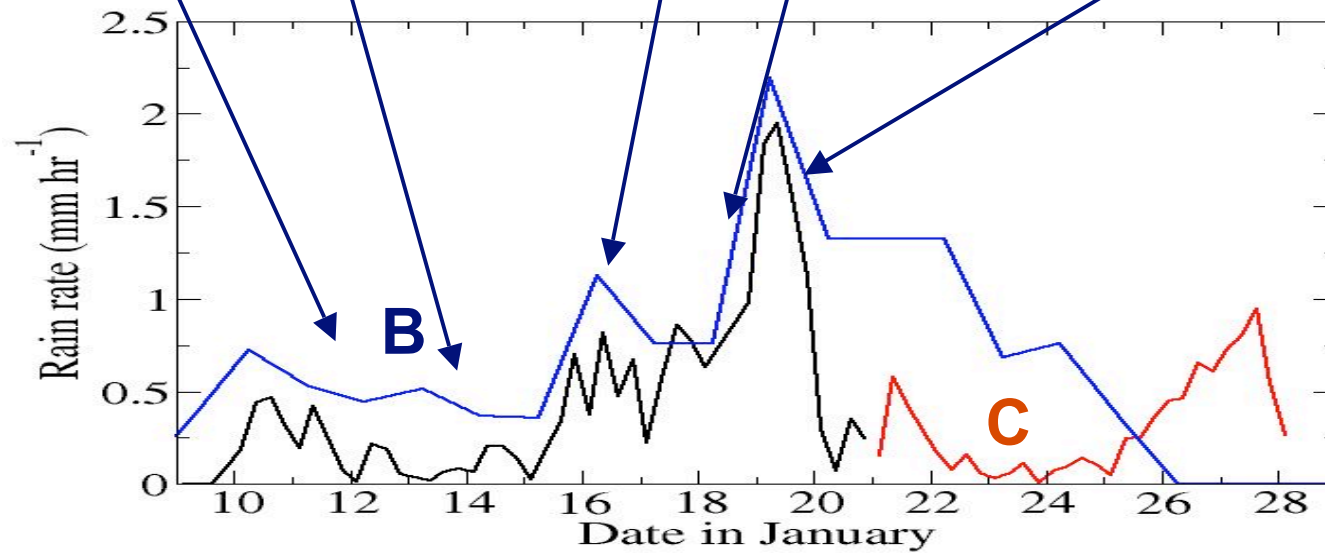
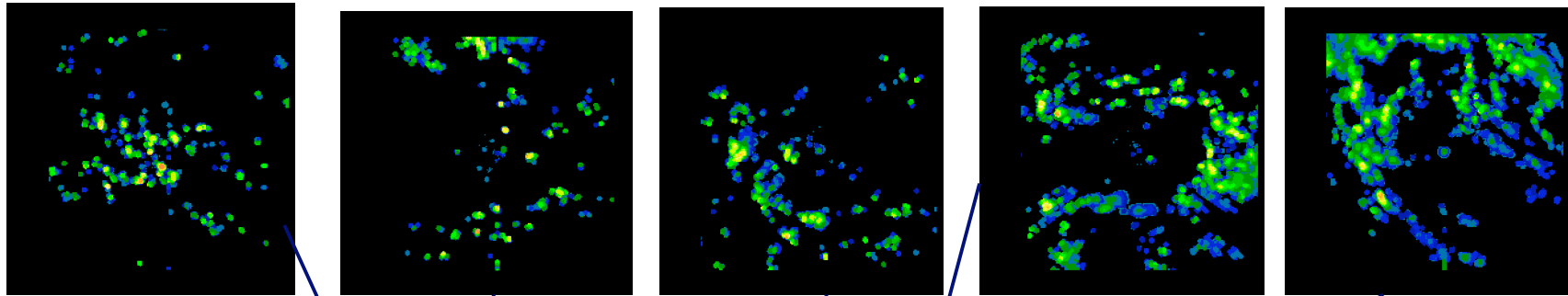
Mean profiles case C



SCM/CRM forcing vs EC analysis



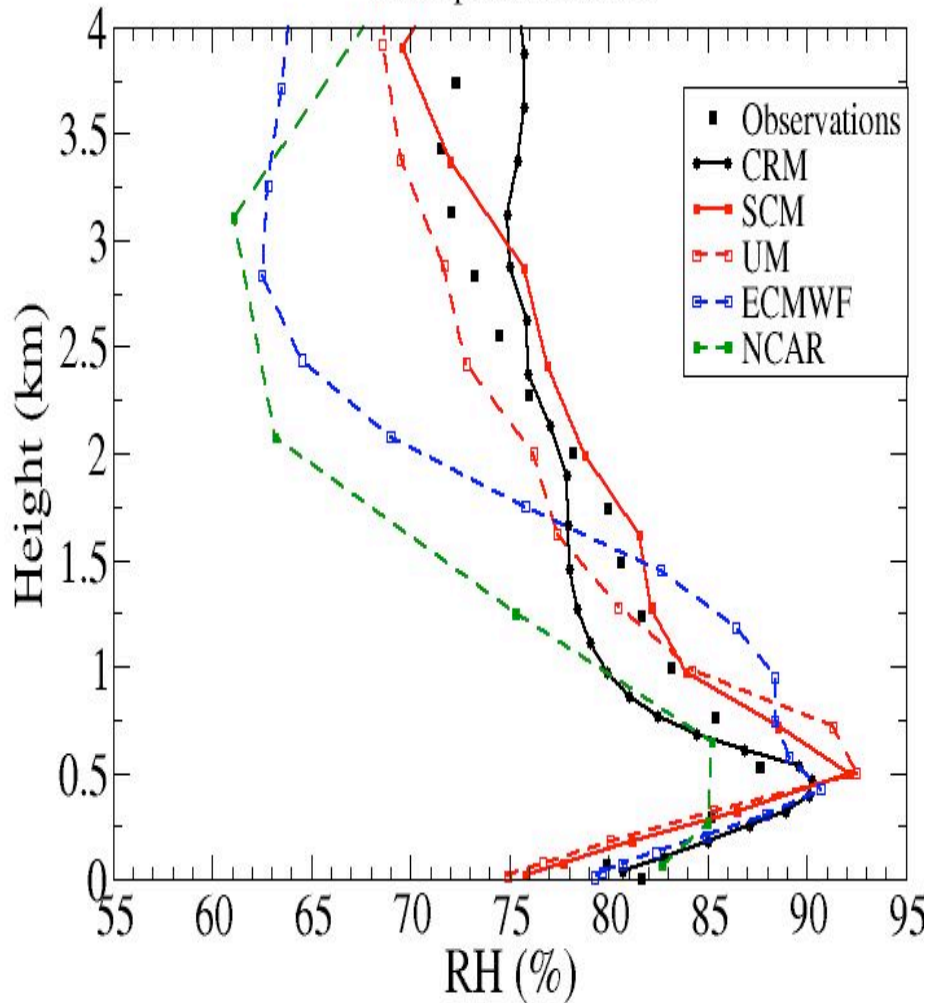
ship based radar



Relative humidity profiles in lower troposphere



Mean profiles case B



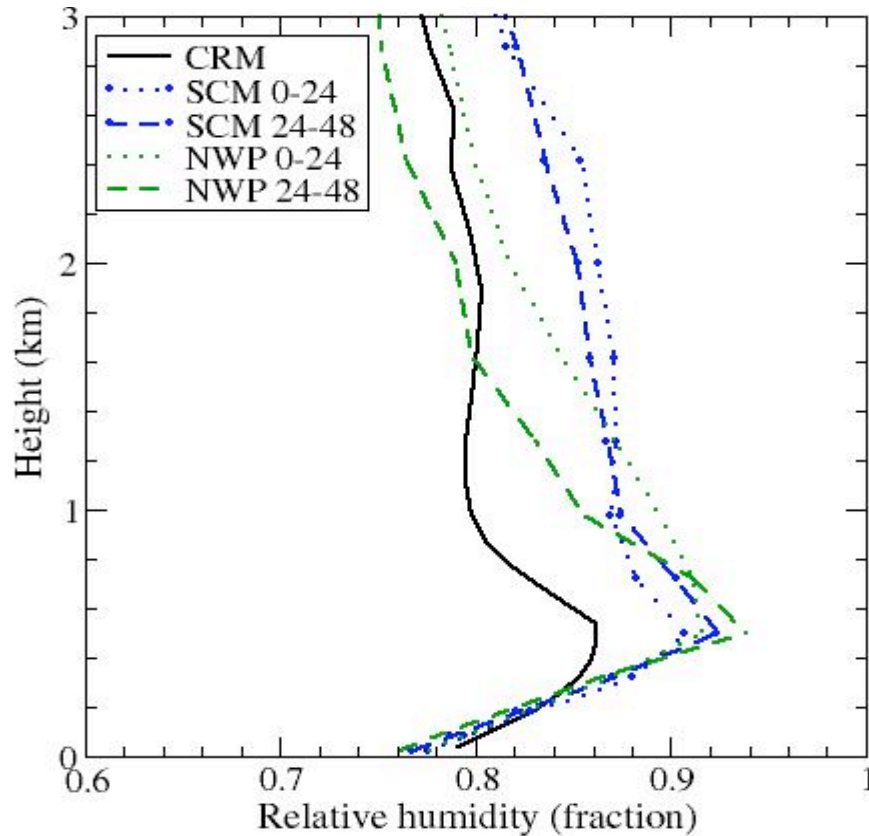
- The SCM and full NWP model have a similar humidity profile in the BL.
- The CRM and EC model look more similar to each other in the BL.
- The overactive shallow scheme in EC can account for the larger humidities between 500 m and 1.5 km.

Relative humidity profiles in lower troposphere

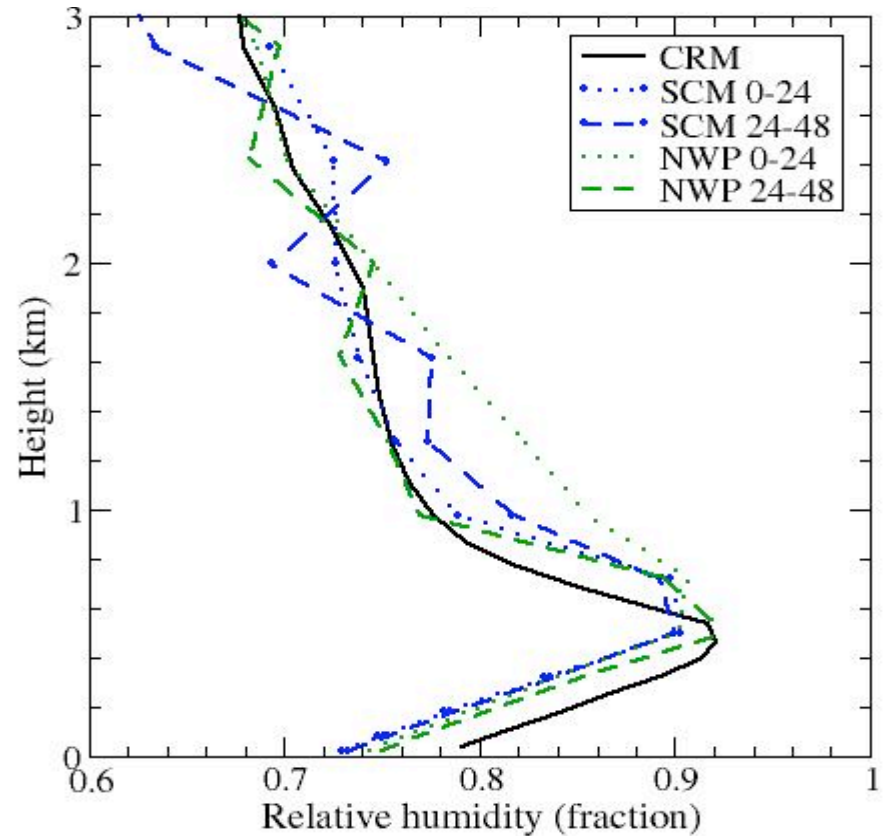


The RH profile in the UM/SCM is not very dependent on convective activity but it is in the CRM.

Active period B



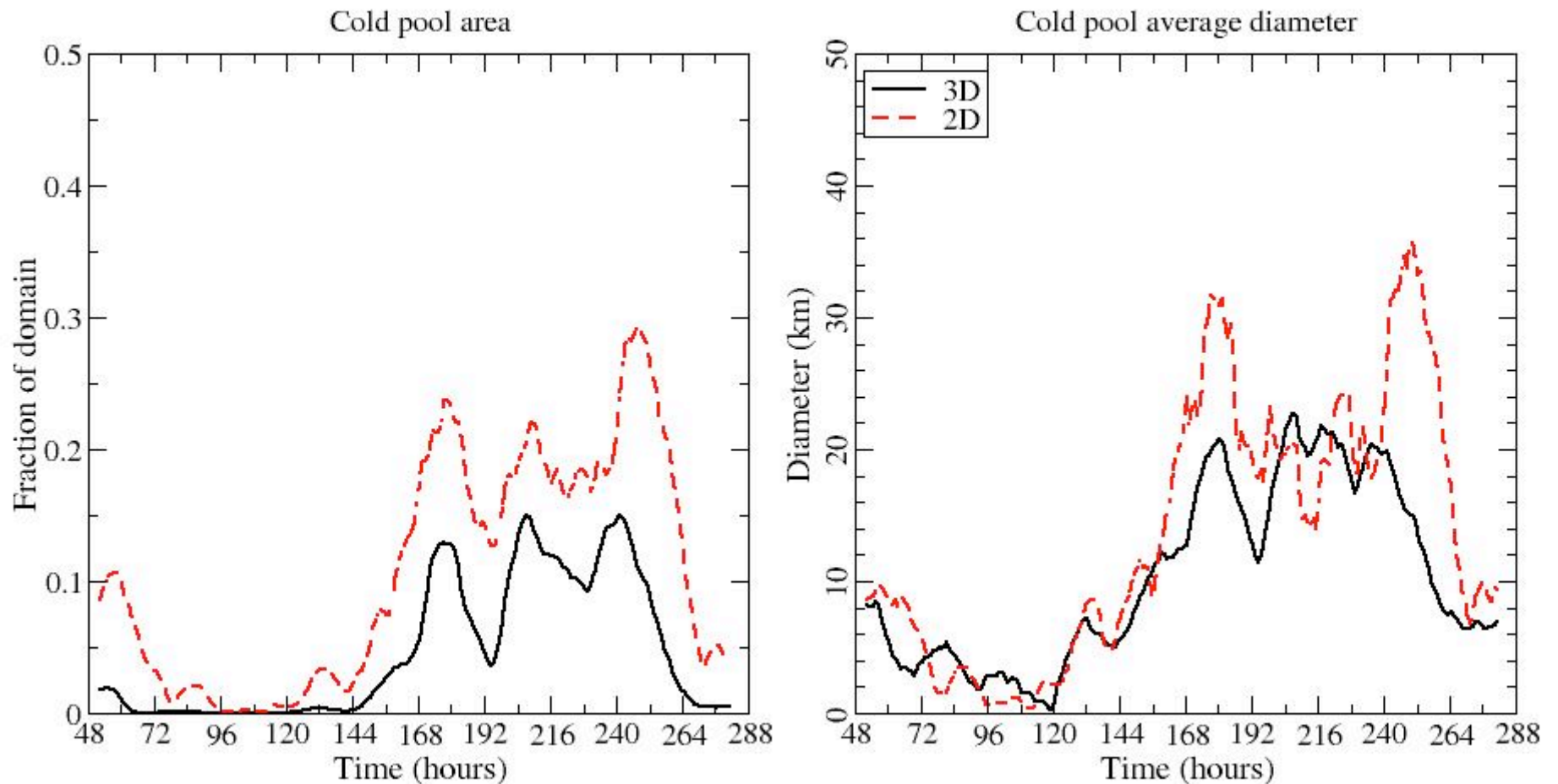
Suppressed period B



Cold pool sizes



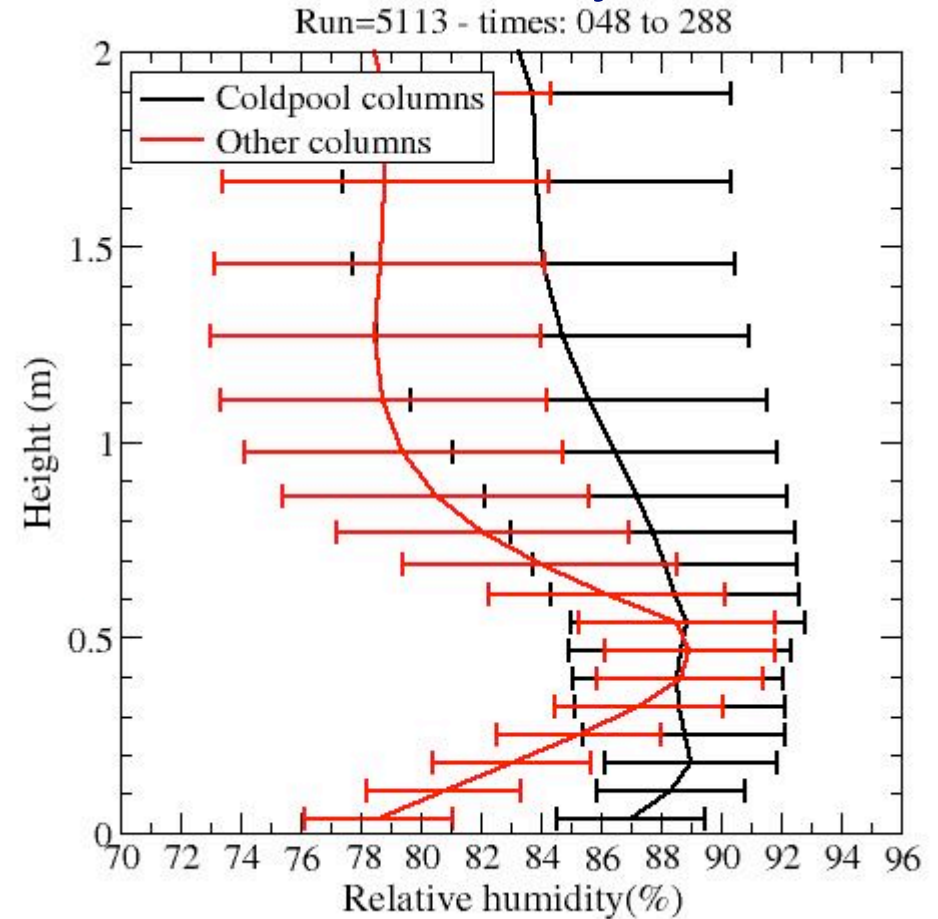
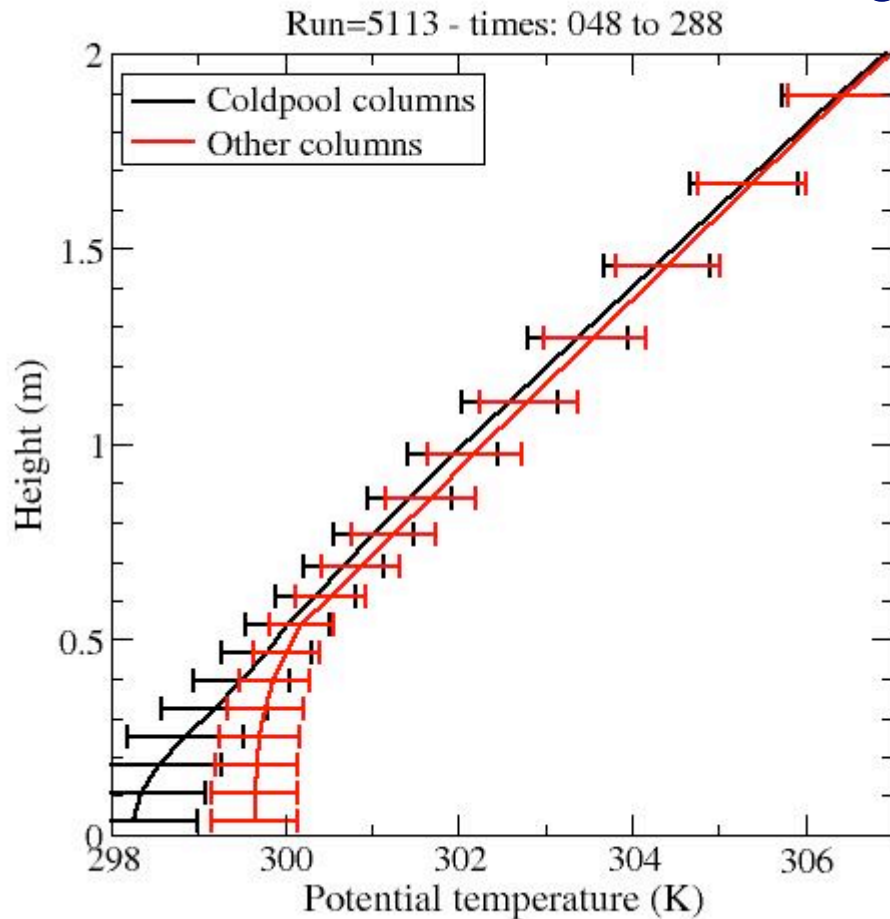
We can count and measure the cold pools in the CRM. Some differences between 2D and 3D runs.



The profiles



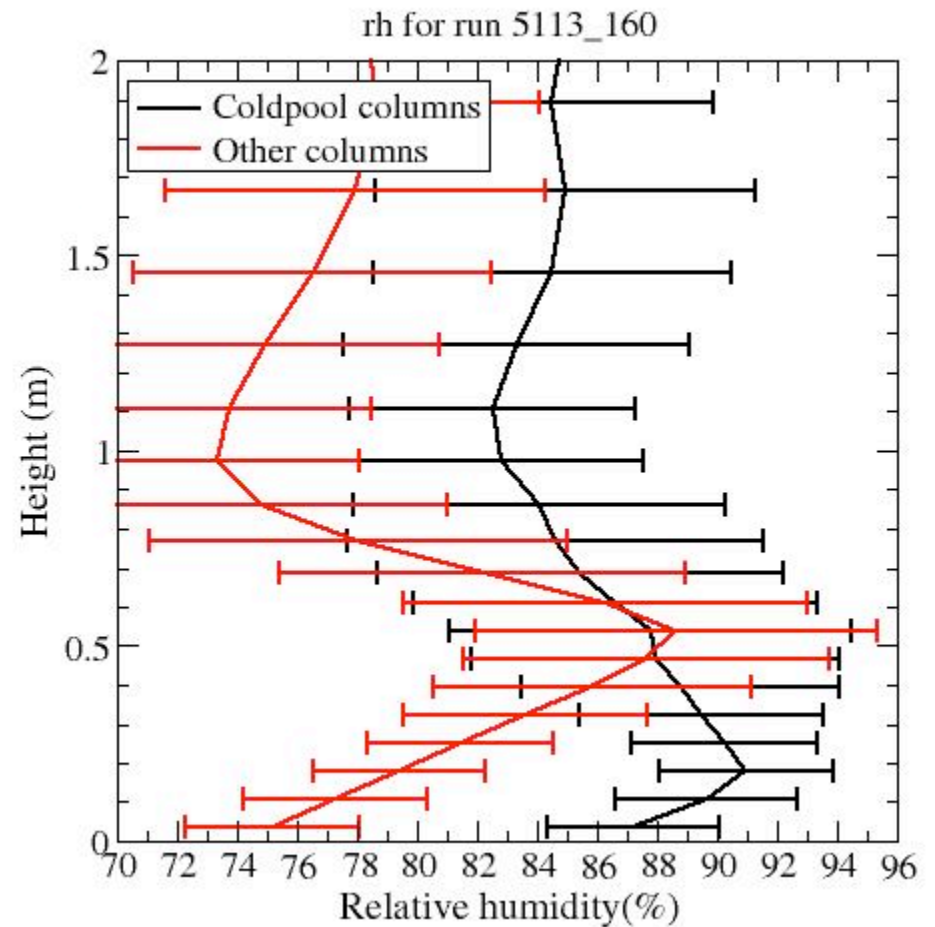
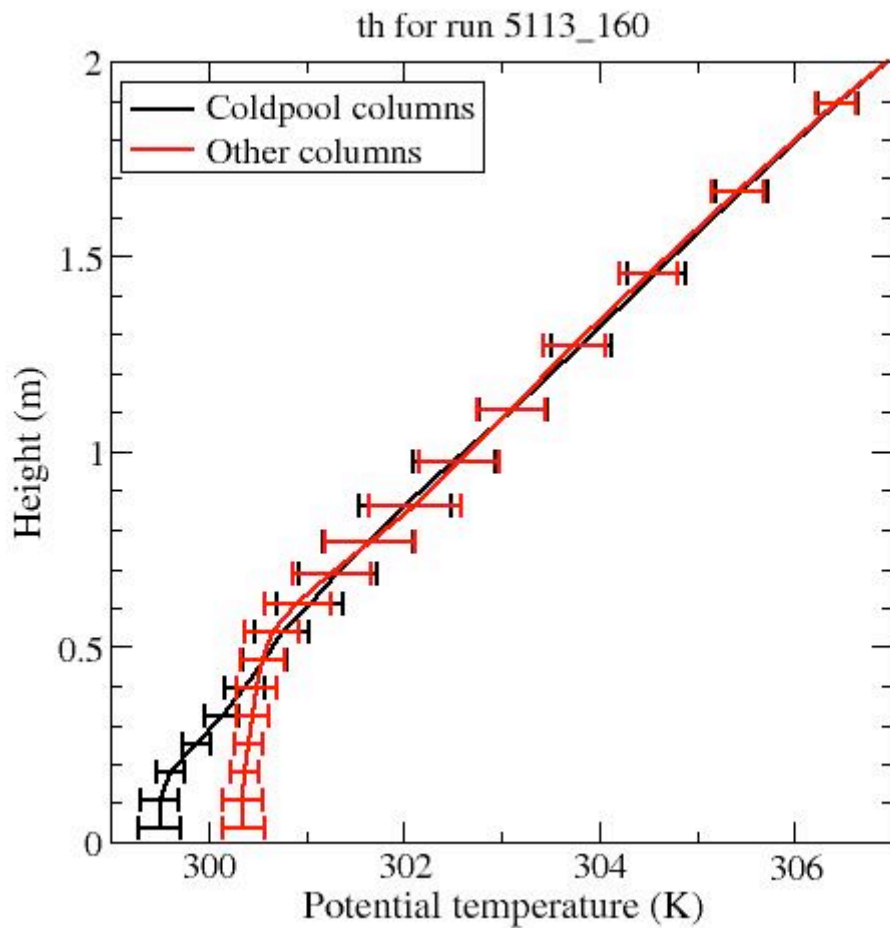
The differences in the cold pools relative humidity structures are clear throughout the whole 10 days



Cold pool structures



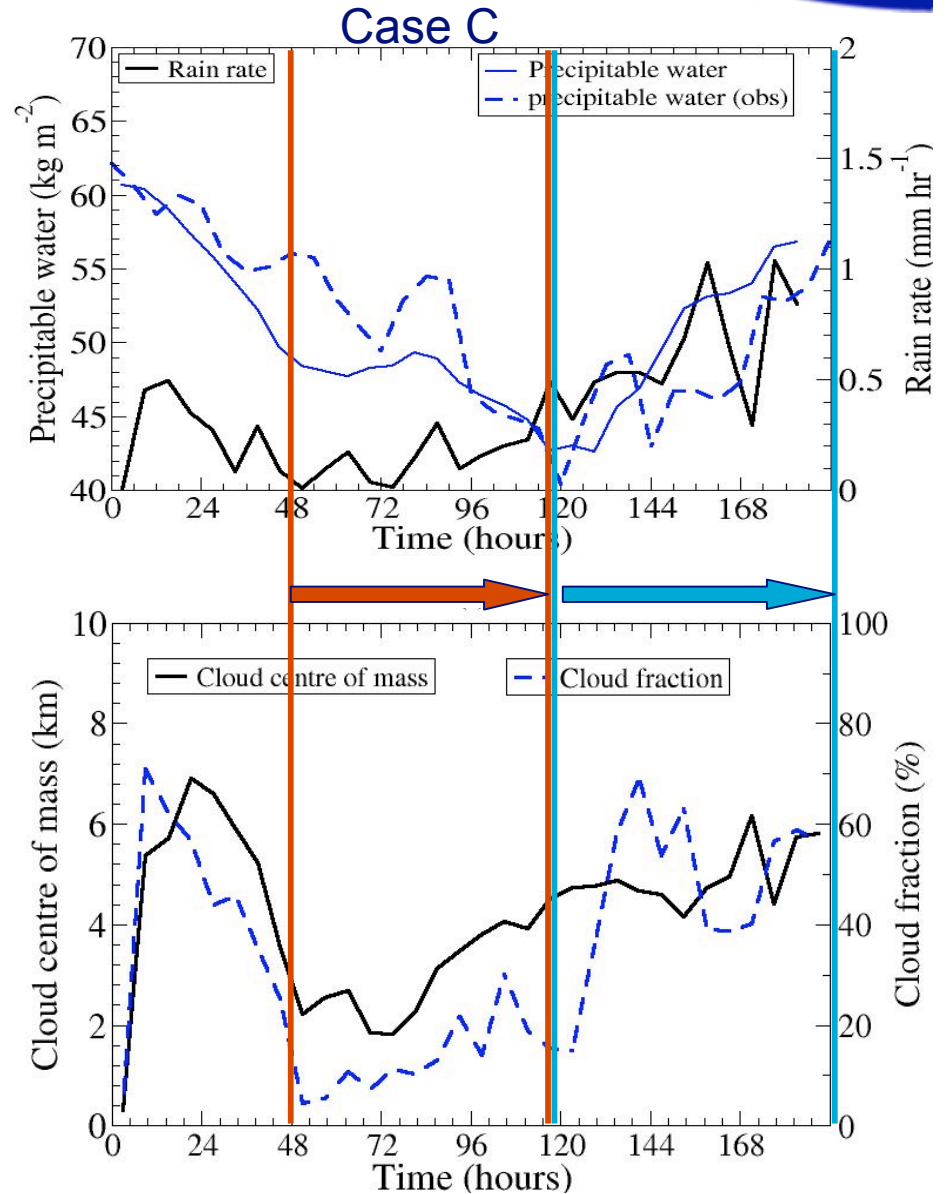
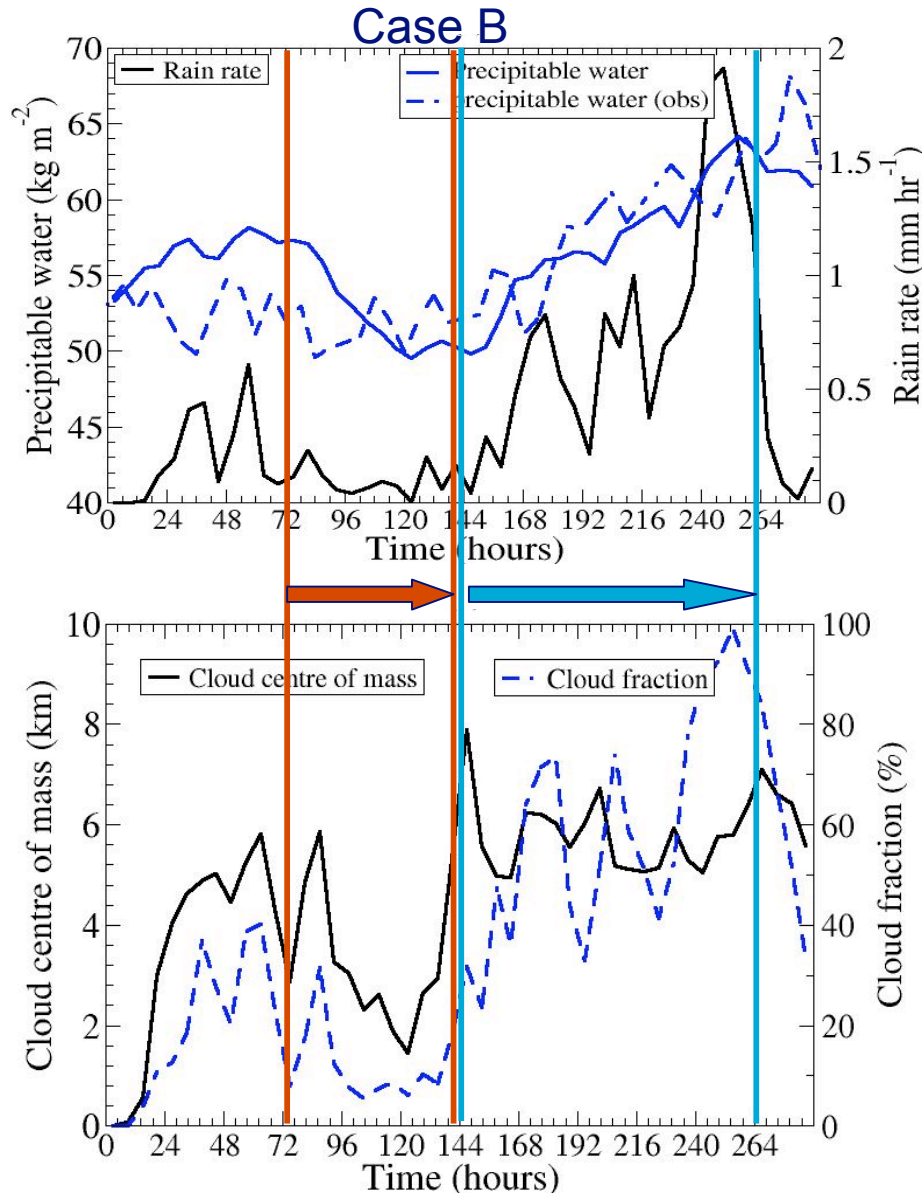
The differences in the cold pools relative humidity structures are clear on any given time



- A range of analysis of coldpools has been done
 - Notably different profiles of T,q & RH
 - 2D does not exaggerate too much
- Interesting results and implications of Conv/BL coupling

- Enough to write up?

Regimes of convection

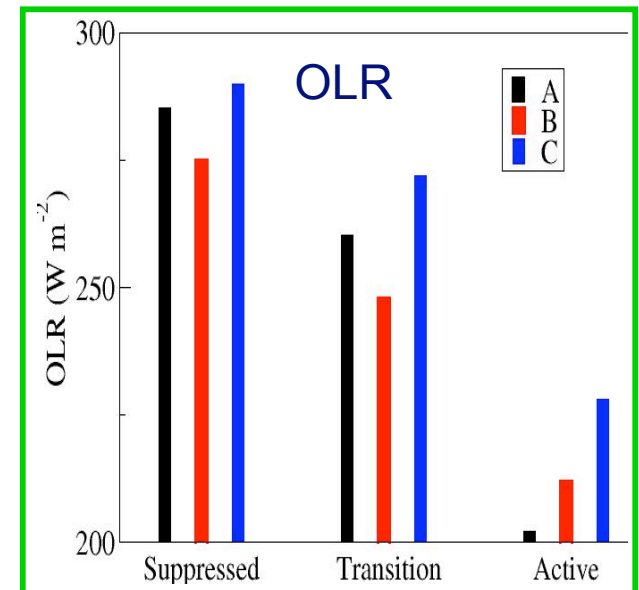
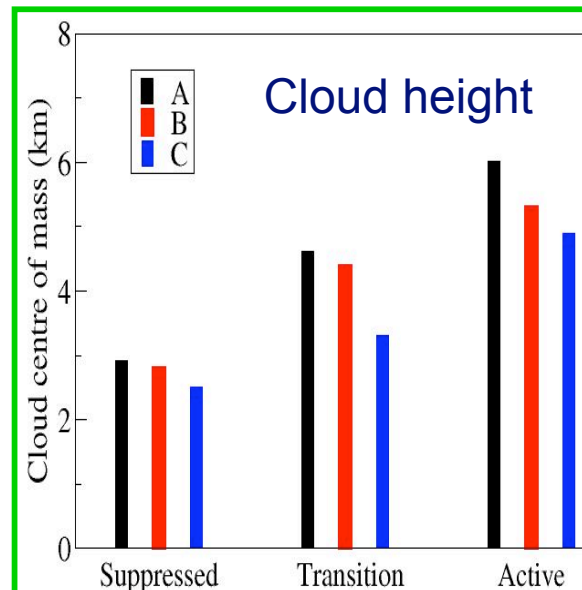
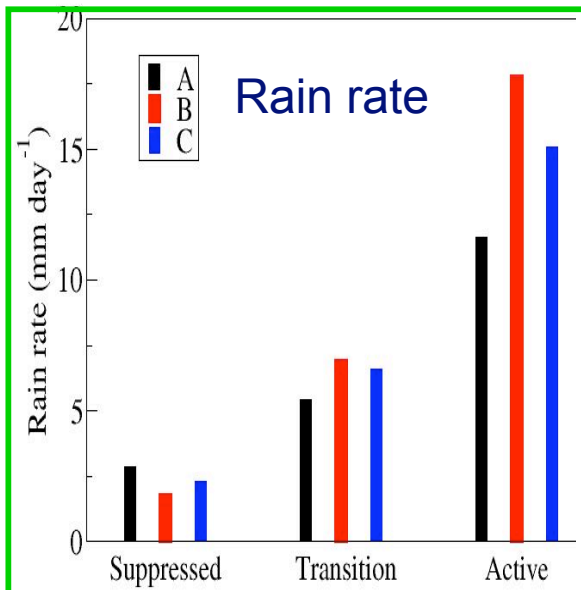


Regimes of convection



| Period | Start date | Length (hrs) | Suppressed (hrs) | Transition (hrs) | Active (hrs) |
|--------|-------------|--------------|------------------|------------------|--------------|
| A | 28 Nov 1992 | 288 | 48-168 | 120-264 | 240-288 |
| B | 9 Jan 1993 | 288 | 72-144 | 120-192 | 144-264 |
| C | 21 Jan 1993 | 192 | 48-120 | 72-144 | 120-192 |

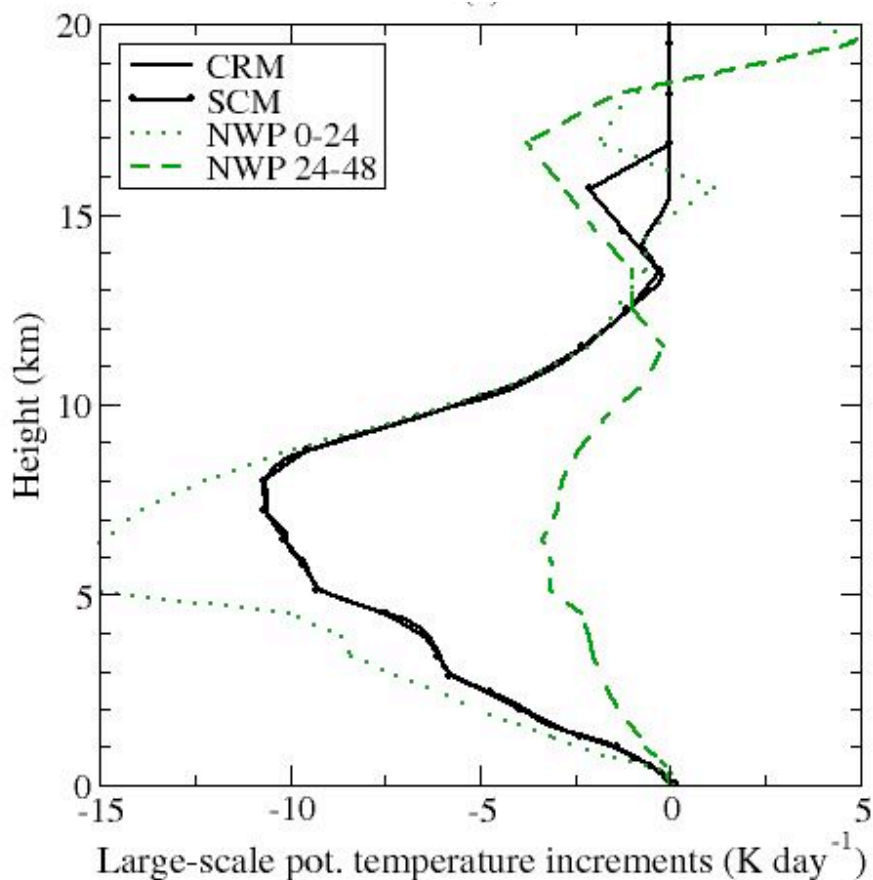
| Diagnostic | Suppressed | | | Transition | | | Active | | |
|---------------------------------------|------------|-----|-----|------------|-----|-----|--------|------|------|
| | A | B | C | A | B | C | A | B | C |
| Rain rate (mm day ⁻¹) | 2.8 | 1.8 | 2.3 | 5.4 | 6.9 | 6.6 | 11.6 | 17.8 | 15.1 |
| Cloud centre of mass (km) | 2.9 | 2.8 | 2.5 | 4.6 | 4.5 | 3.3 | 6.0 | 5.3 | 4.9 |
| Cloud fraction (%) | 7 | 11 | 7 | 23 | 37 | 20 | 66 | 60 | 46 |
| OLR (W/m ²) | 285 | 275 | 290 | 260 | 248 | 272 | 202 | 212 | 228 |
| Surface shortwave (W/m ²) | 305 | 313 | 319 | 290 | 283 | 304 | 237 | 239 | 278 |



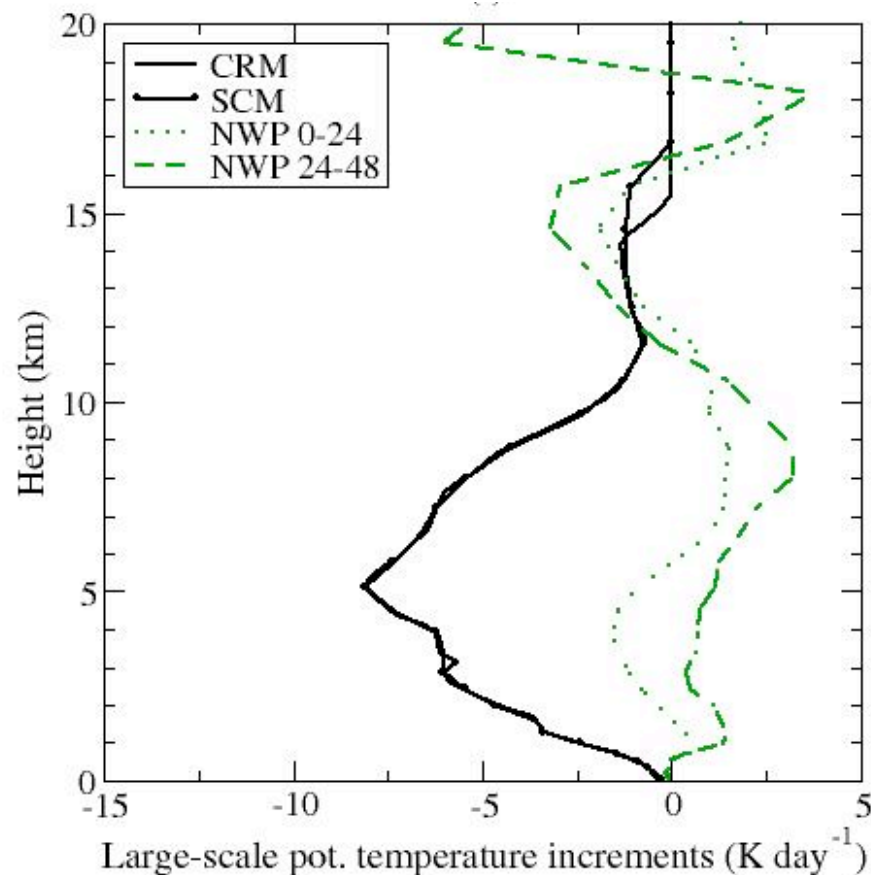
The forcing of the CRM vs the NWP dynamics

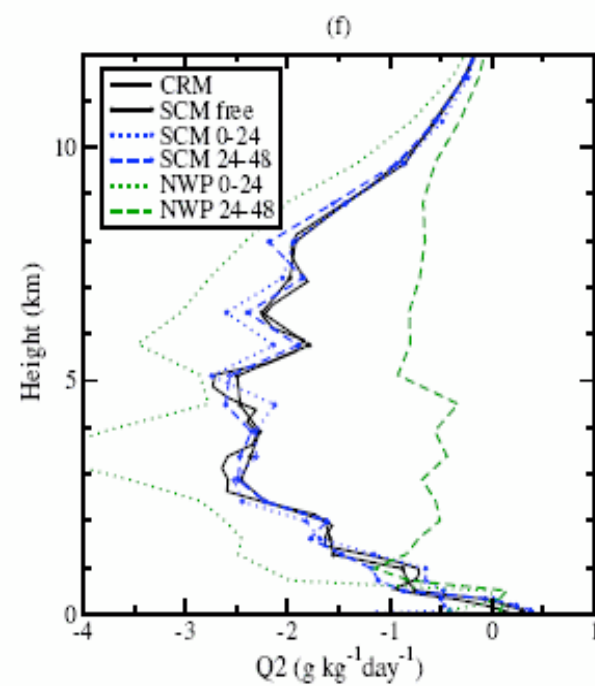
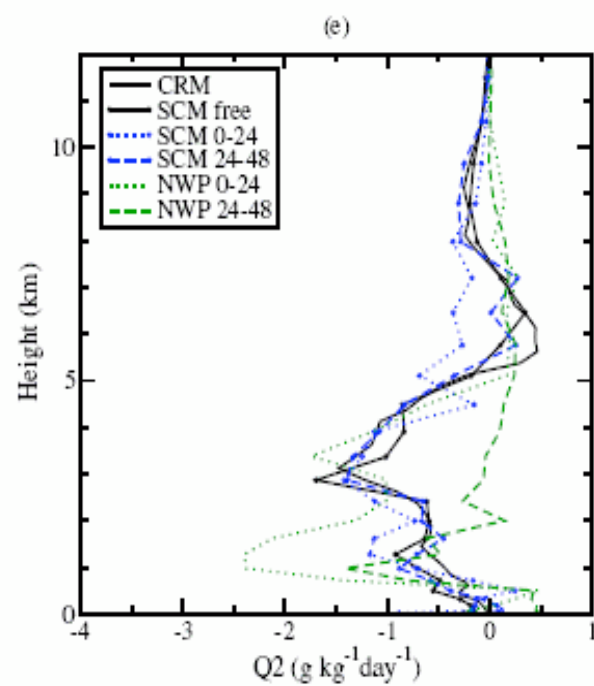
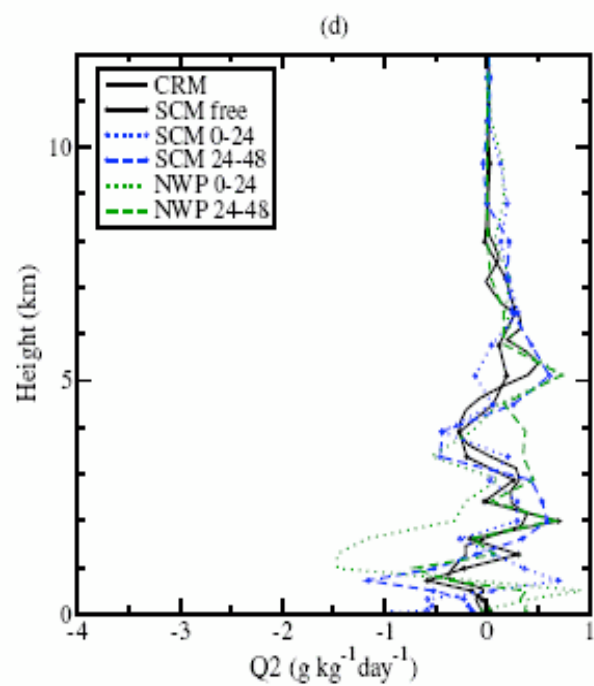
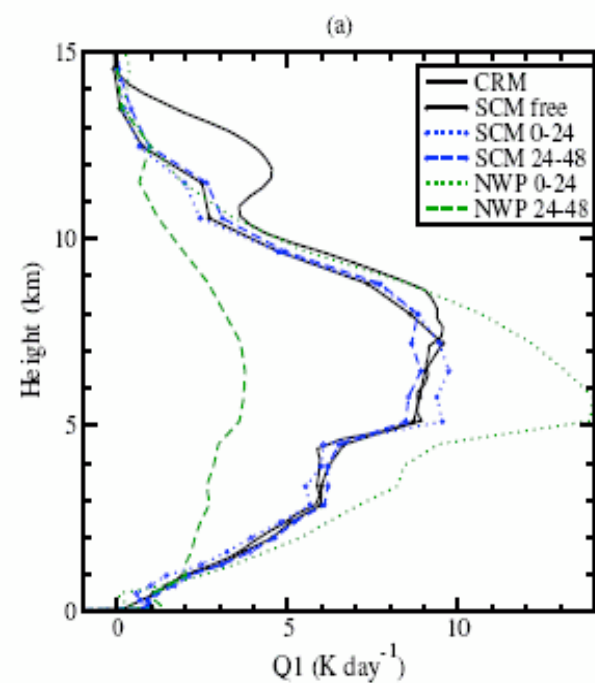
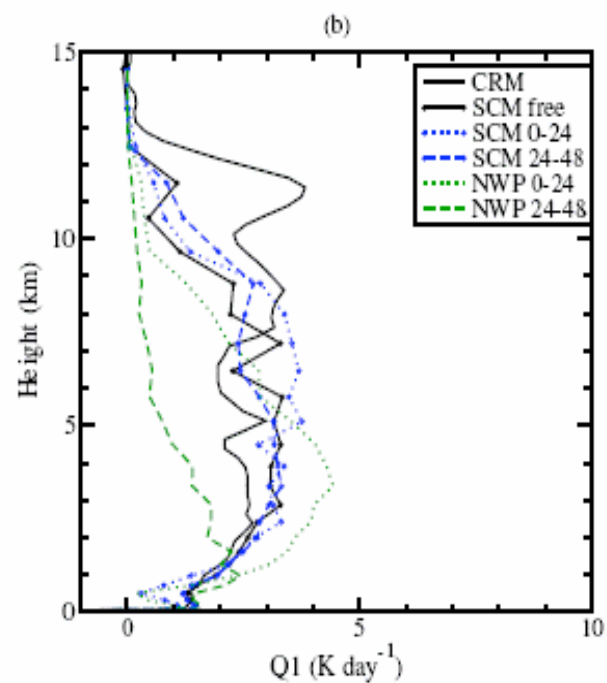
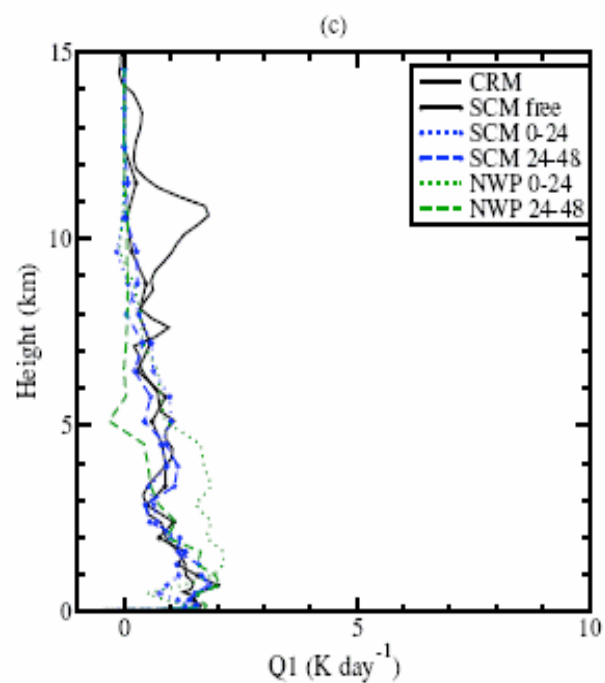


Case B active period

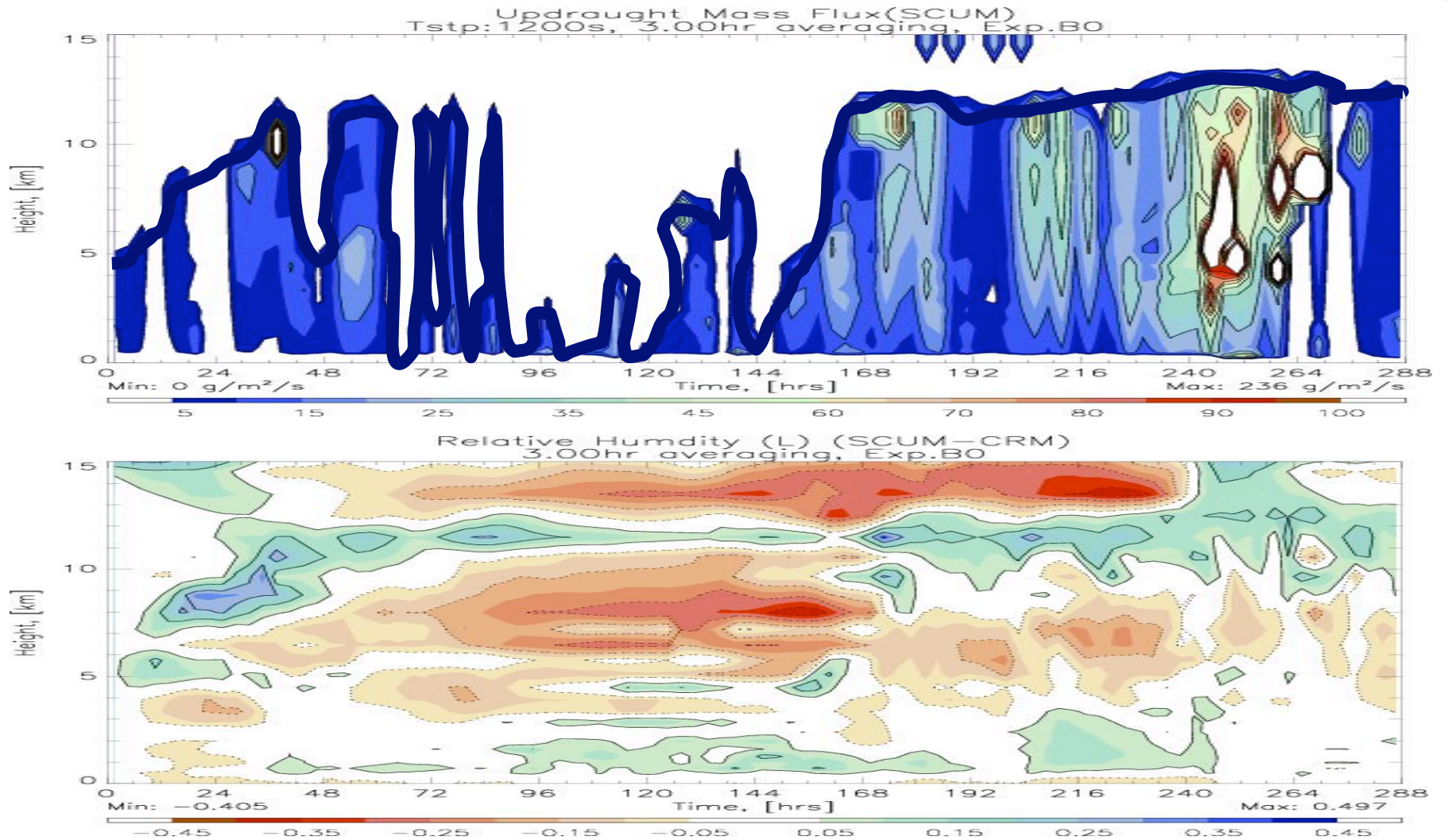


Case C active period

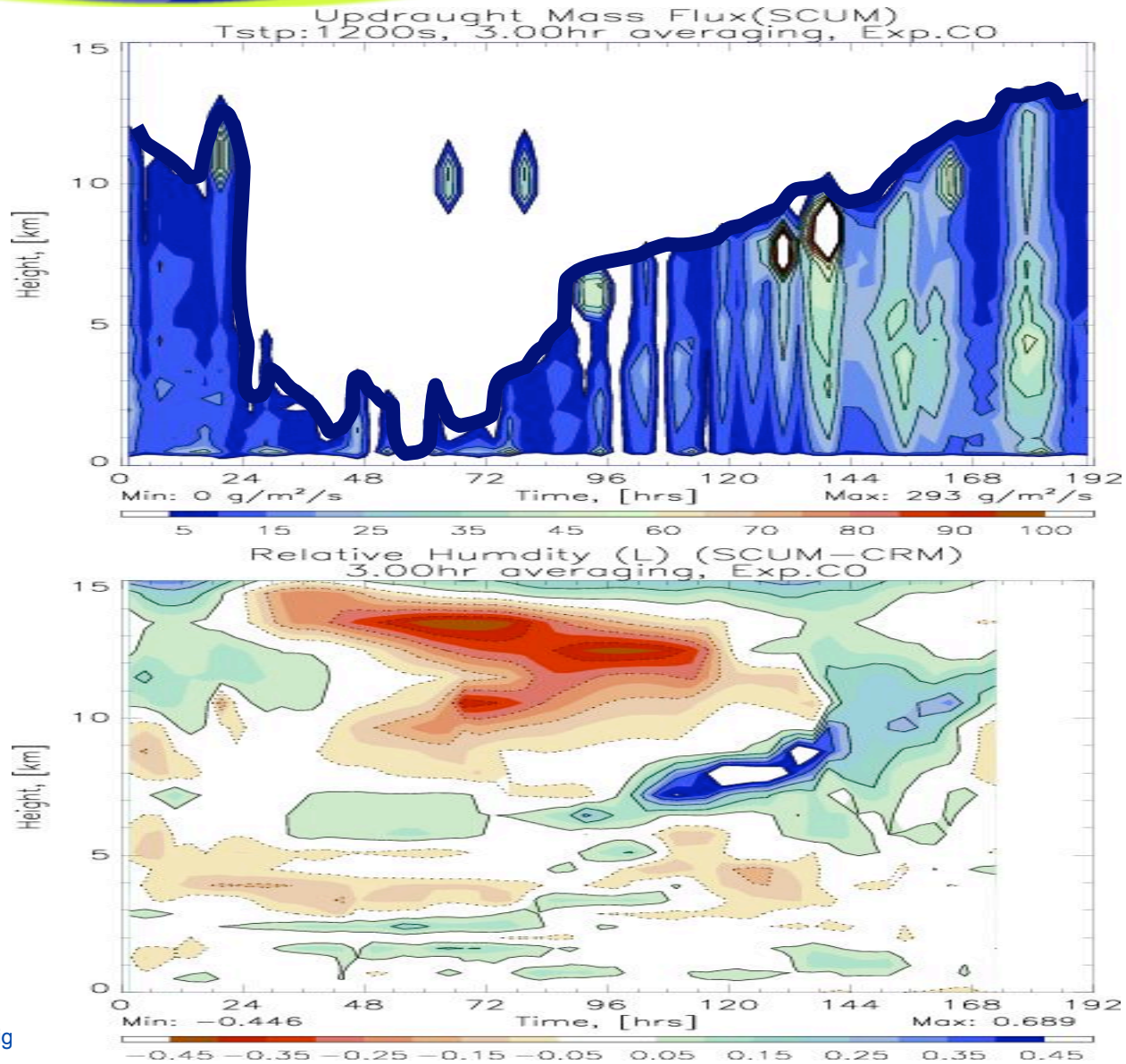




Convection top and RH "error"



Convection top and RH "error"



Convection top diagnostic

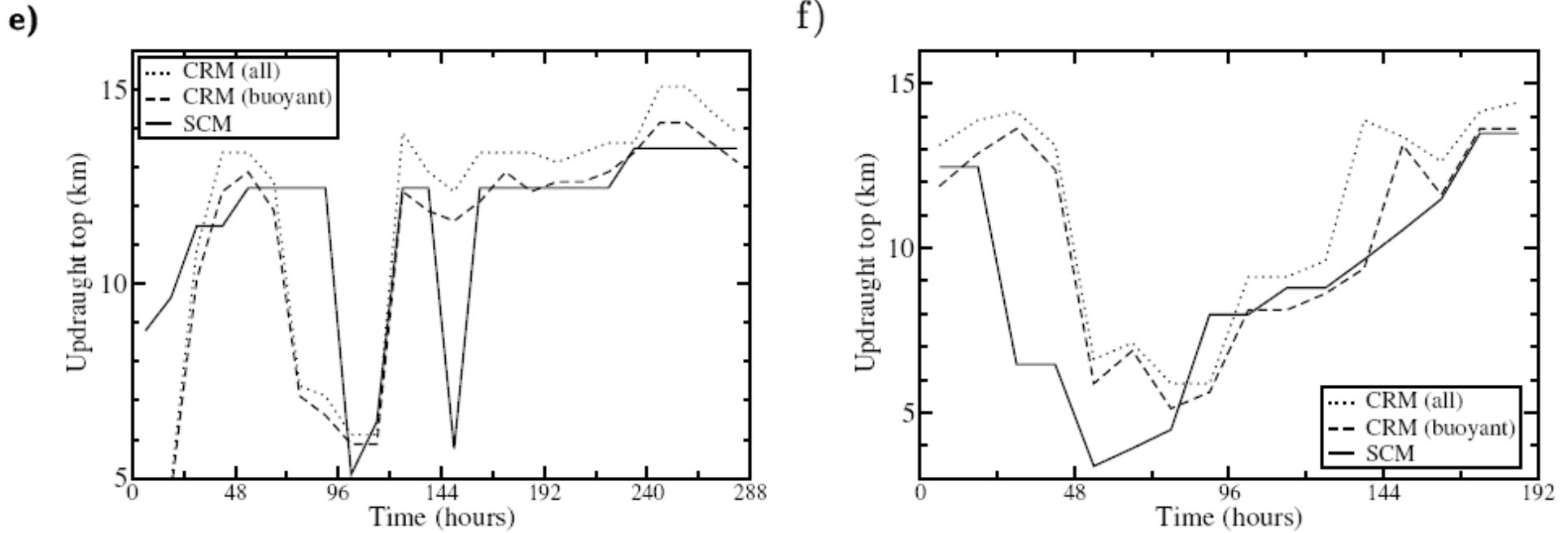


Figure 8. Time height plots of 3 hourly average [lets use 12 for final plots] convective mass flux ($\text{g}/\text{m}^2/\text{s}$) from a) the SCM for case B, b) the SCM for case C, c) the CRM for case B and d) the CRM for case C. and SCM. Would a timeseries of convection top work?

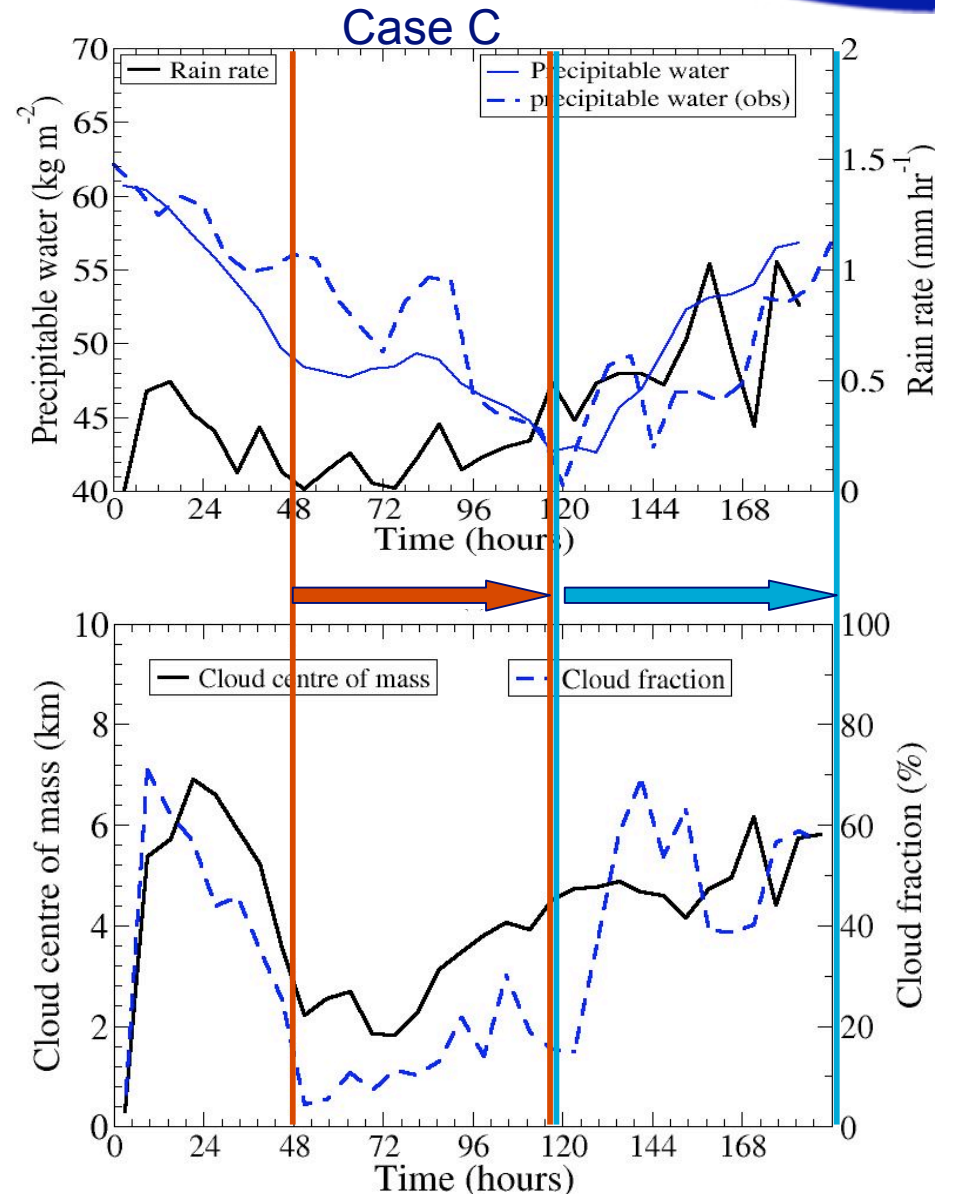
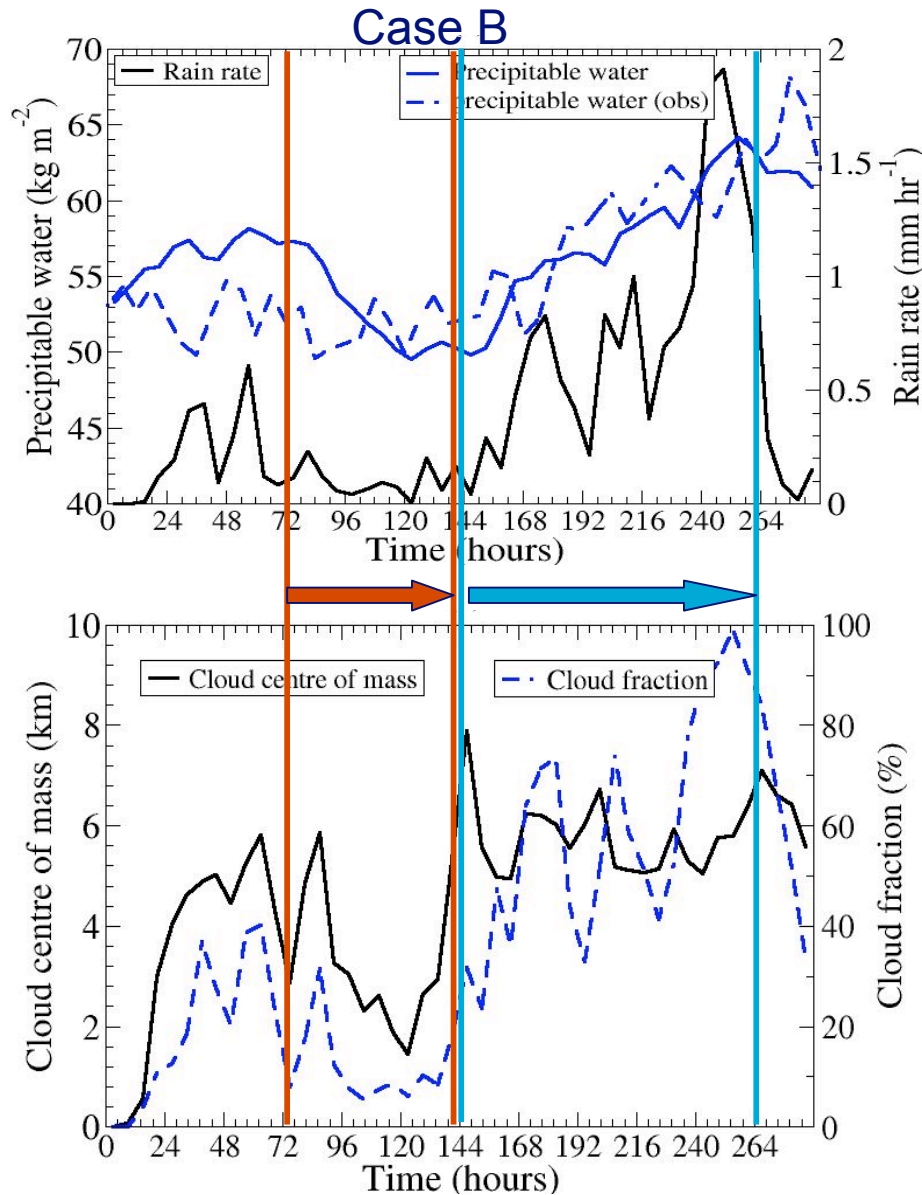
- Overview paper nearly complete. Key points:
 - It's a new method to have NWP, SCM & CRMs so the case is described
 - It is the basis of some multi-model intercomparison papers so is a useful background
 - Examples of where SCMs are useful and where they are not are both highlighted and discussed
 - Focus on suppressed and active periods proves valuable

Does it have enough in it?

I will pass it out in the next few weeks for all to see in next few weeks. Comments welcome...

Should I wait to submit it at the same time as the intercomparison papers? When will these be ready?

Regimes of convection

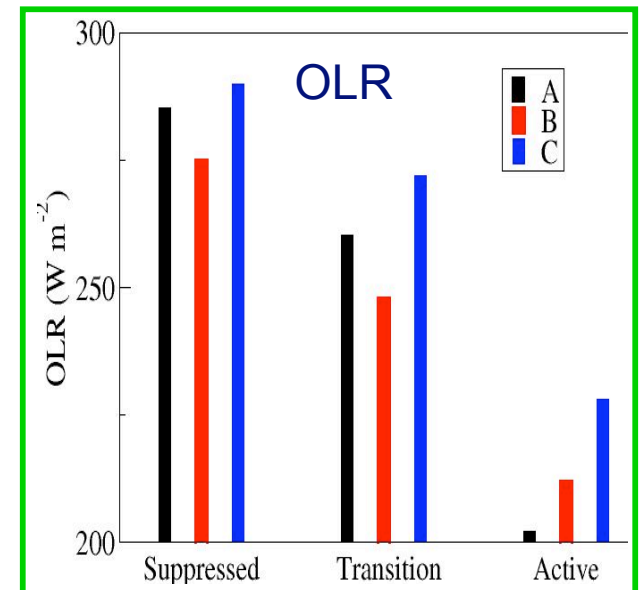
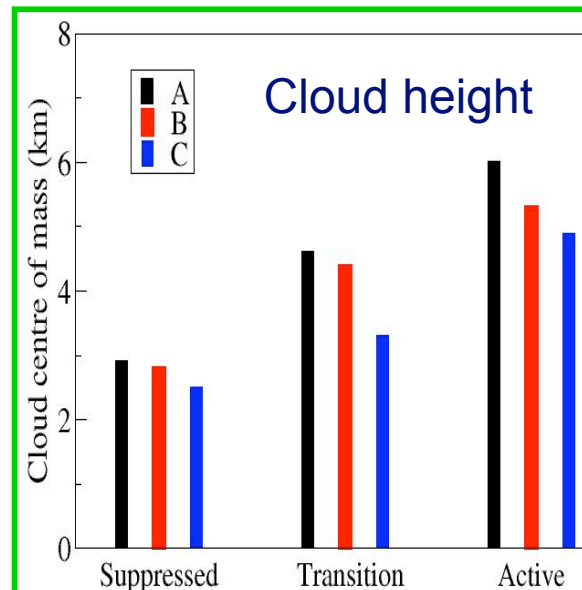
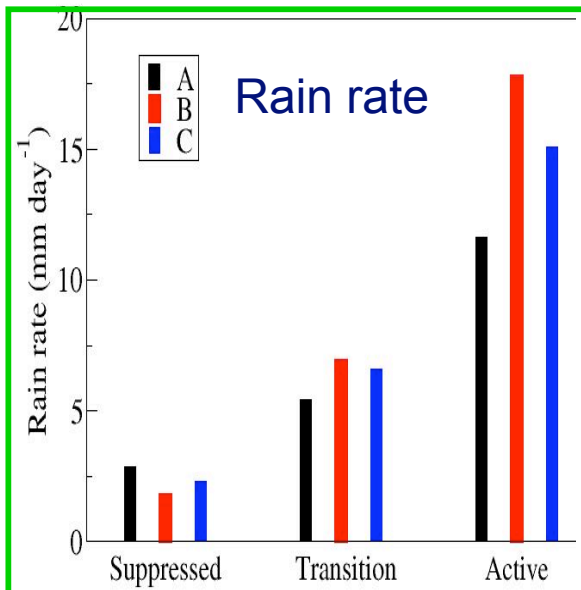


Regimes of convection



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| Diagnostic | Suppressed | | | Transition | | | Active | | |
|---------------------------------------|------------|-----|-----|------------|-----|-----|--------|------|------|
| | A | B | C | A | B | C | A | B | C |
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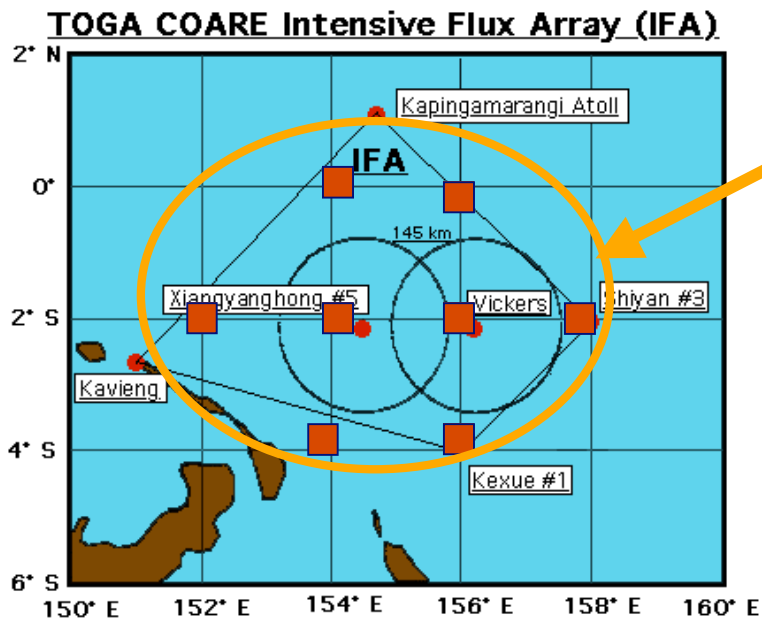
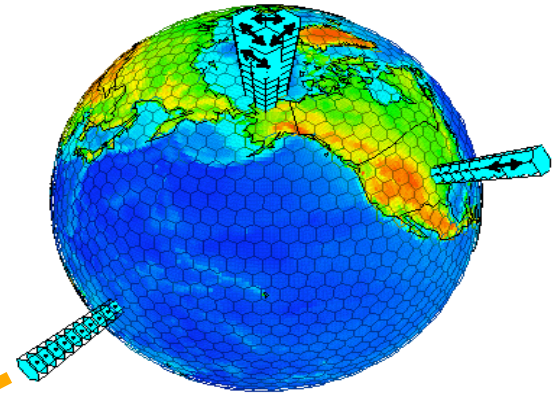
**The current case of the
GCSS DWG: NWP vs
CRM/SCM**



Analysis of the NWP model



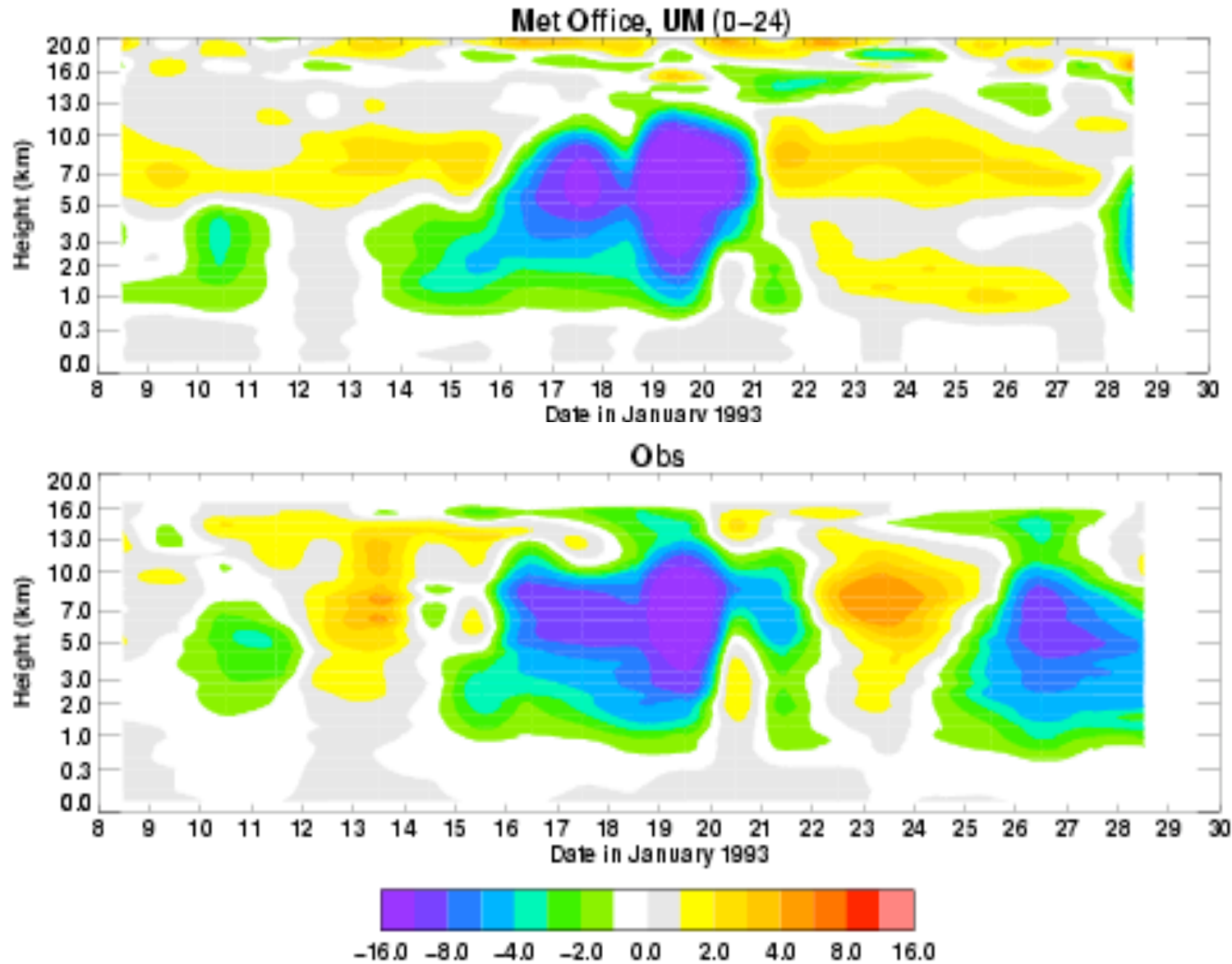
- CRM and SCM forced with mean data over IFA



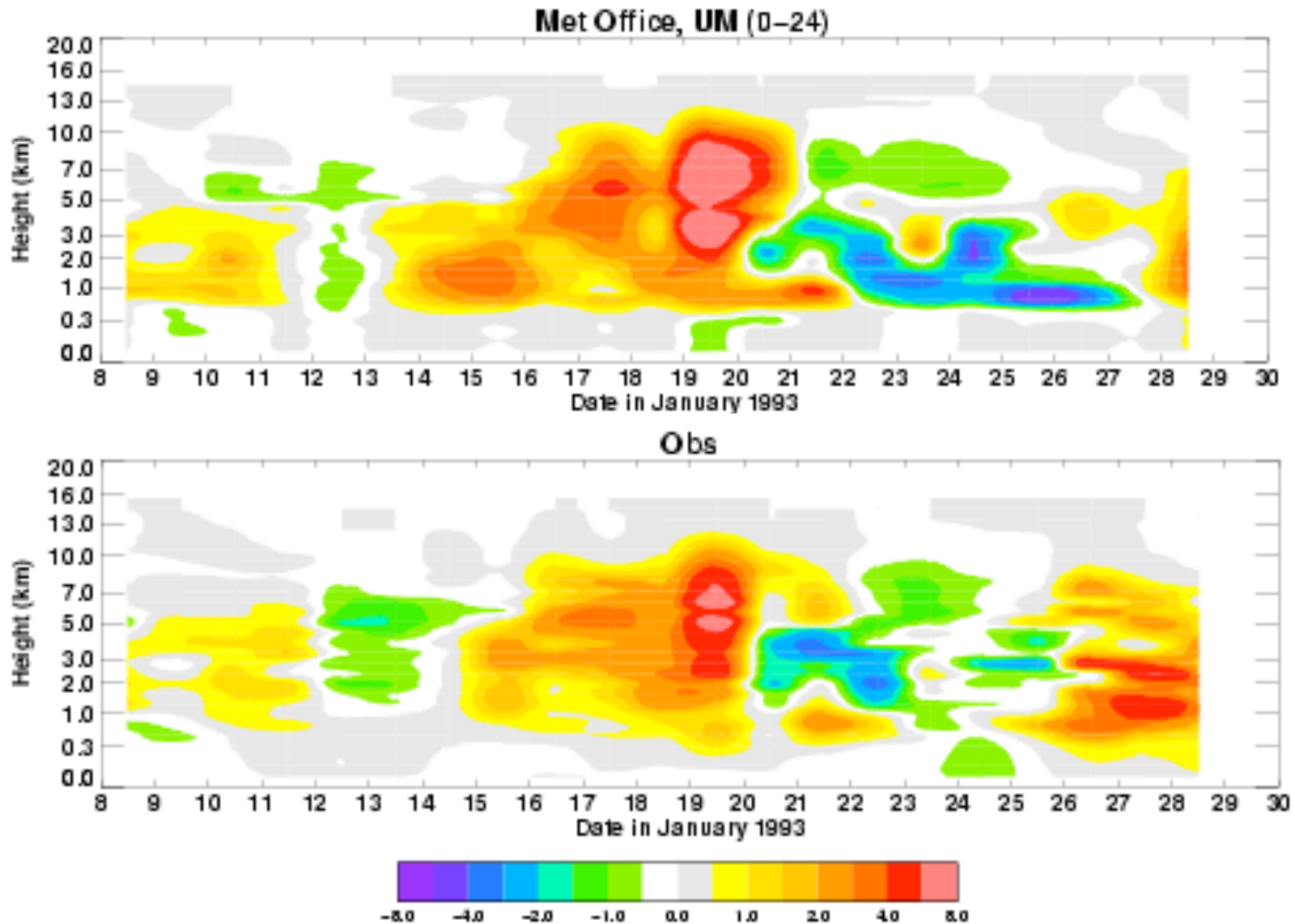
- Analysis of NWP model uses mean of all points within IFA
- Plan to look at individual columns too (relevant for understanding the SCM)

- How does the NWP forcing/runs compare to the observational forcing and SCM/CRM runs?
- How does the NWP forcing change in during the forecast cycle?

Temperature forcing – periods B and C



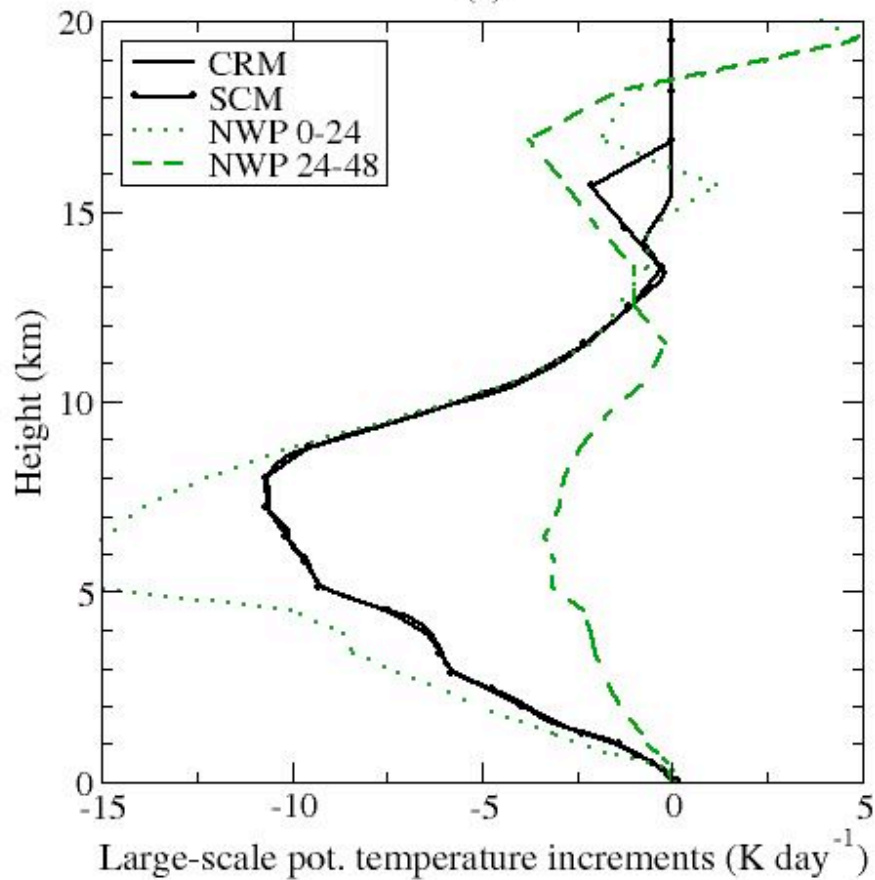
Moisture forcing



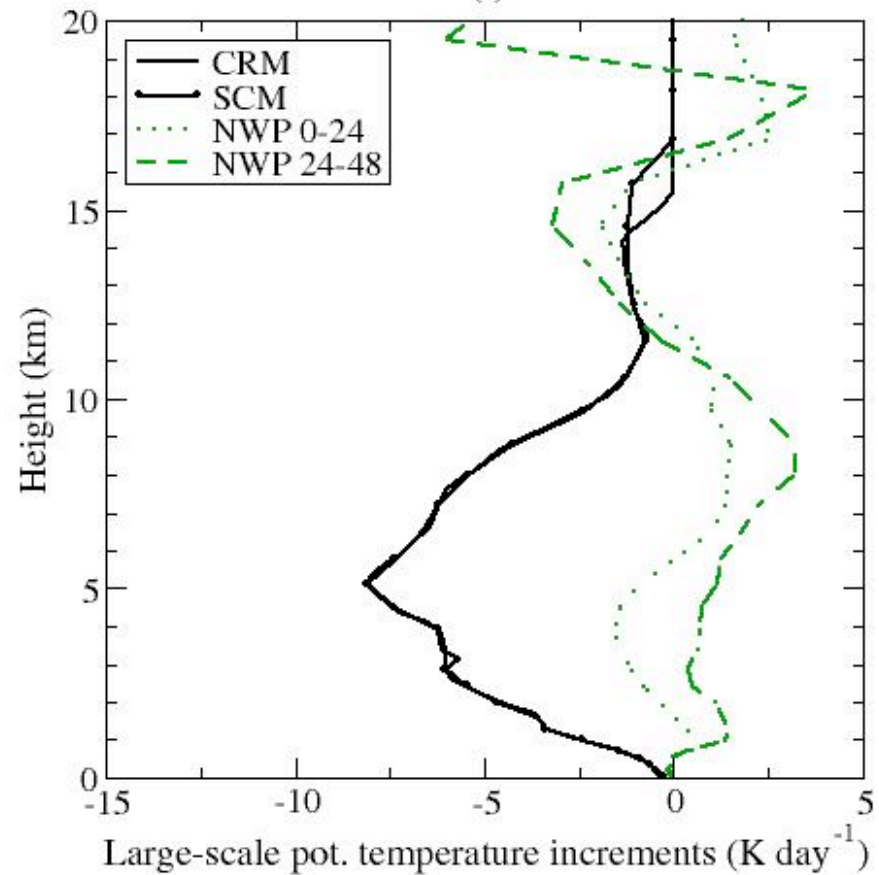
The forcing of the CRM vs the NWP dynamics



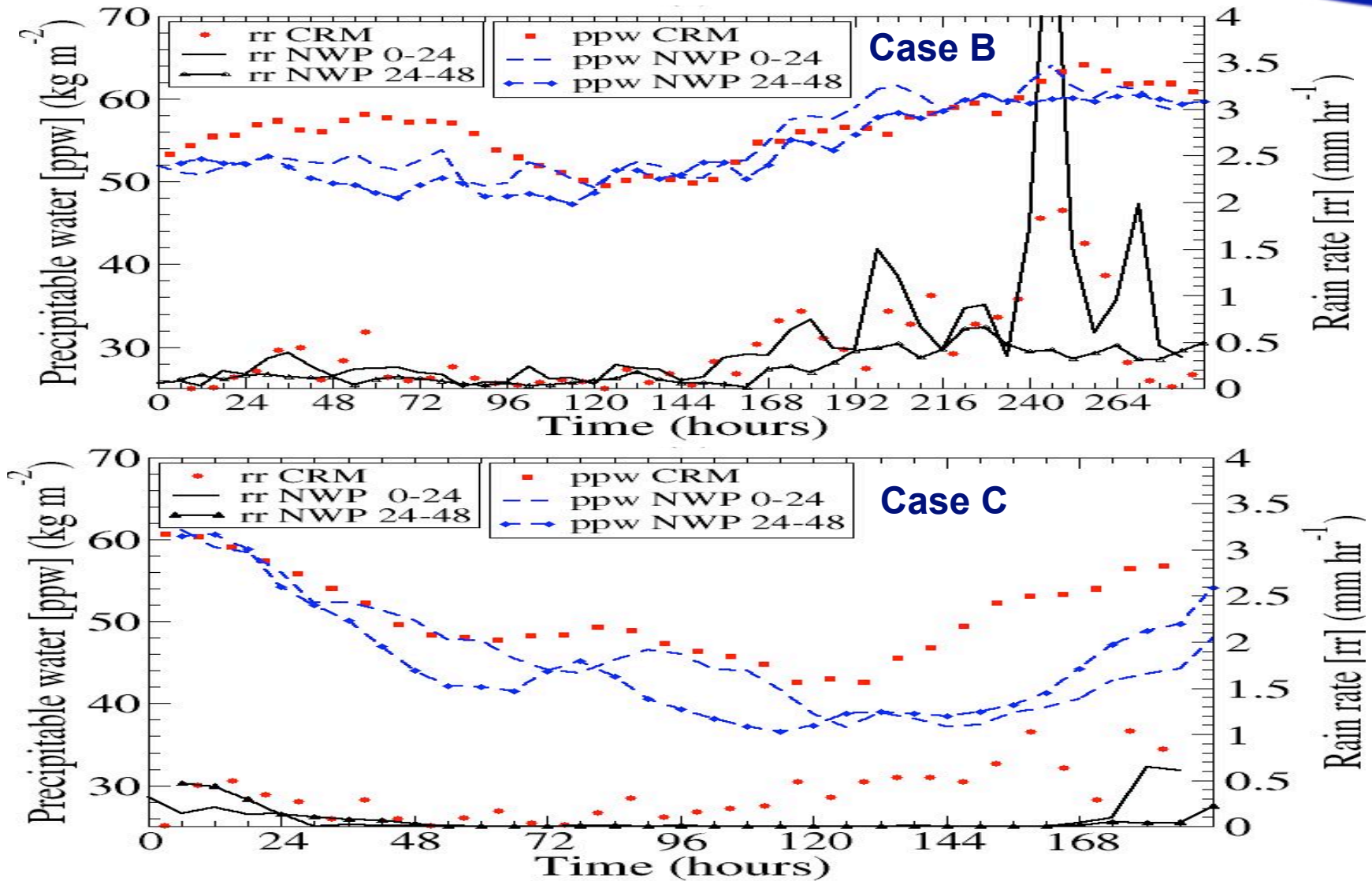
Case B active period



Case C active period



Comparing the NWP model and CRM

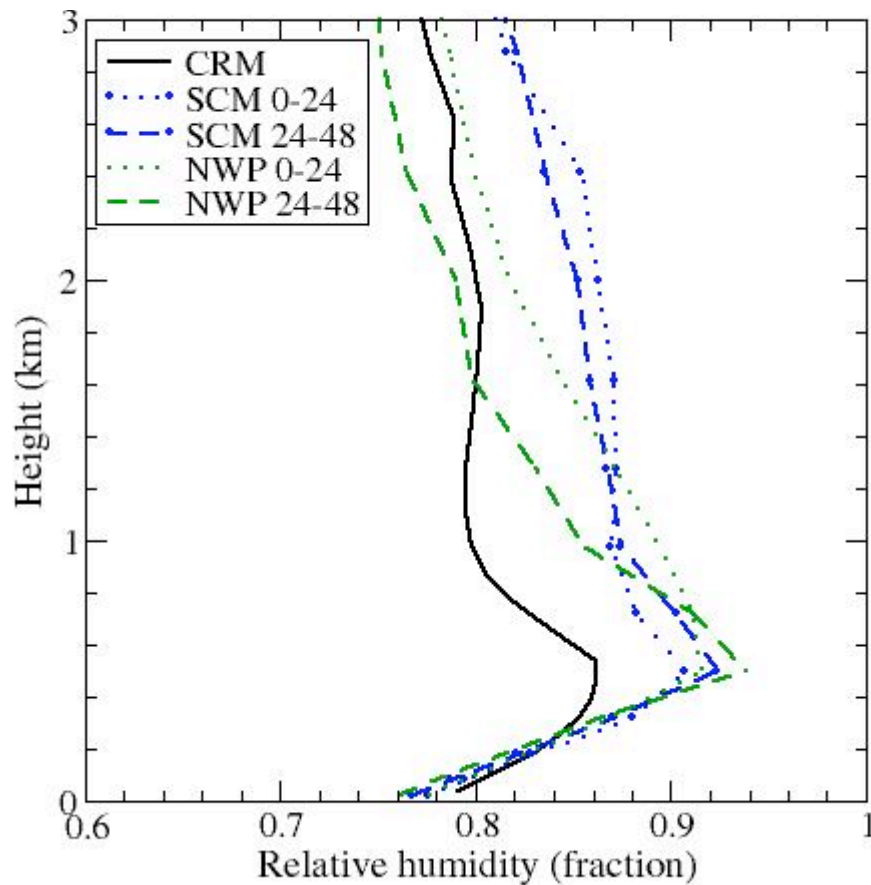


- Does the SCM behave like the full model?
- Can we identify differences between the CRM or obs and the NWP model we believe are due to parametrization issues?

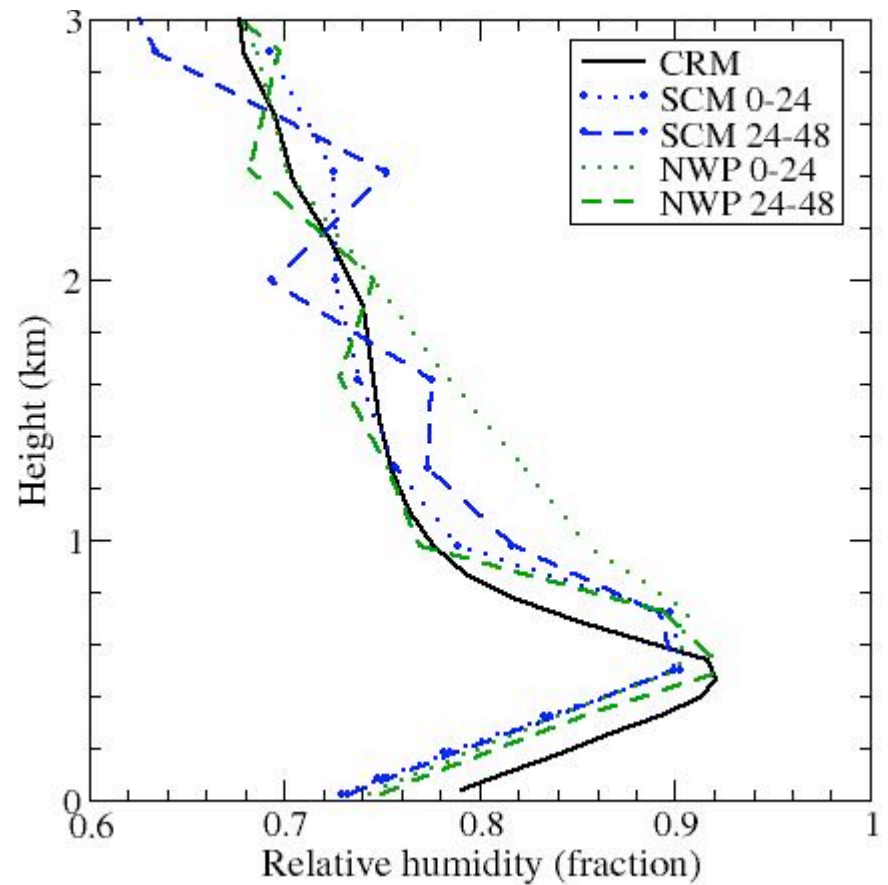
Low level relative humidity



Active period B



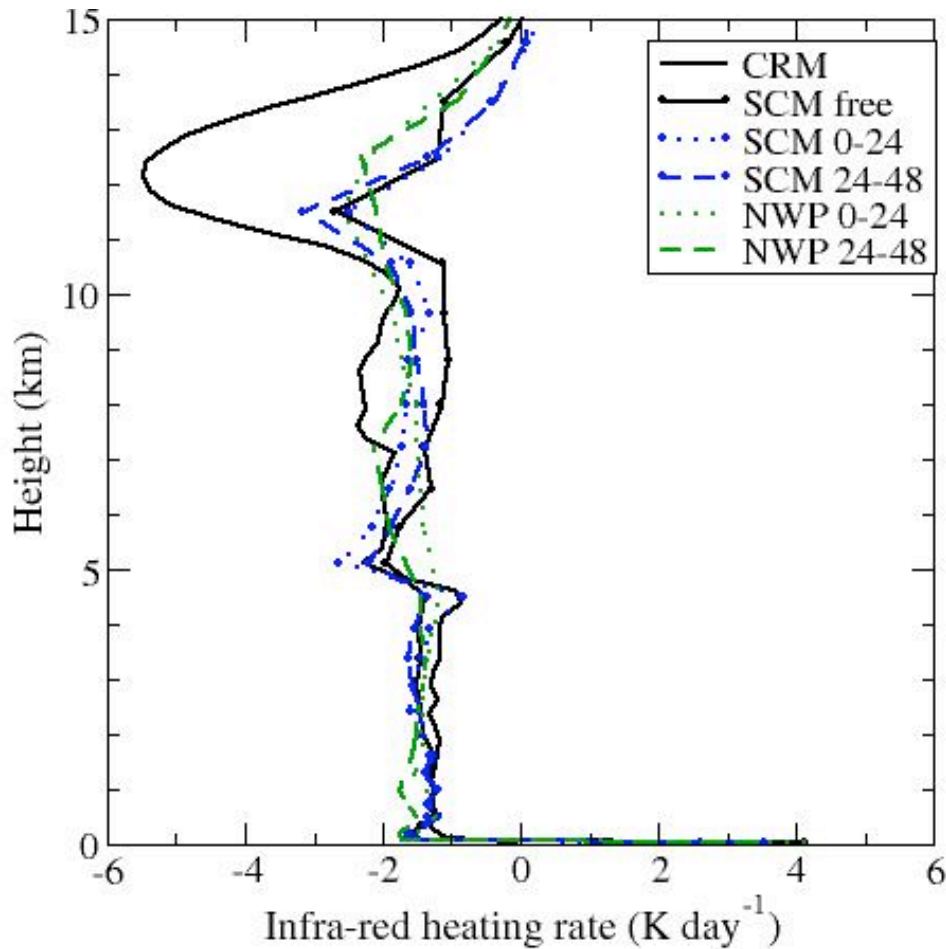
Suppressed period B



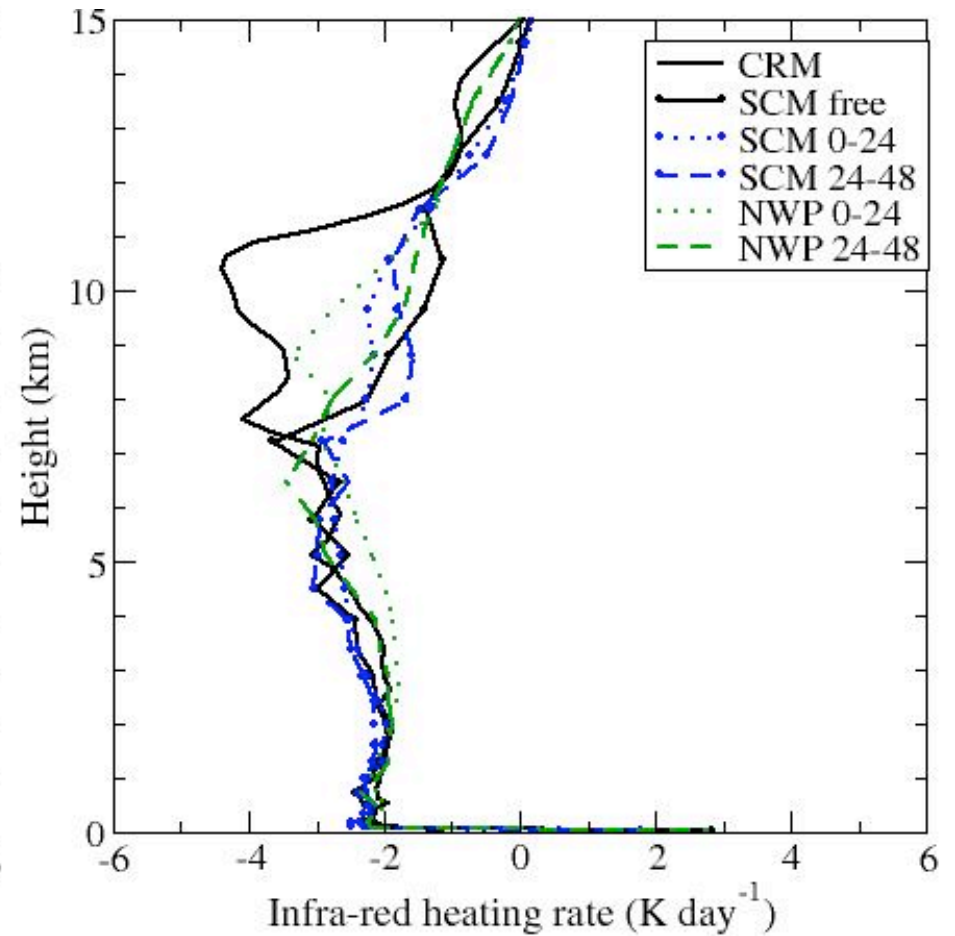
Physics response



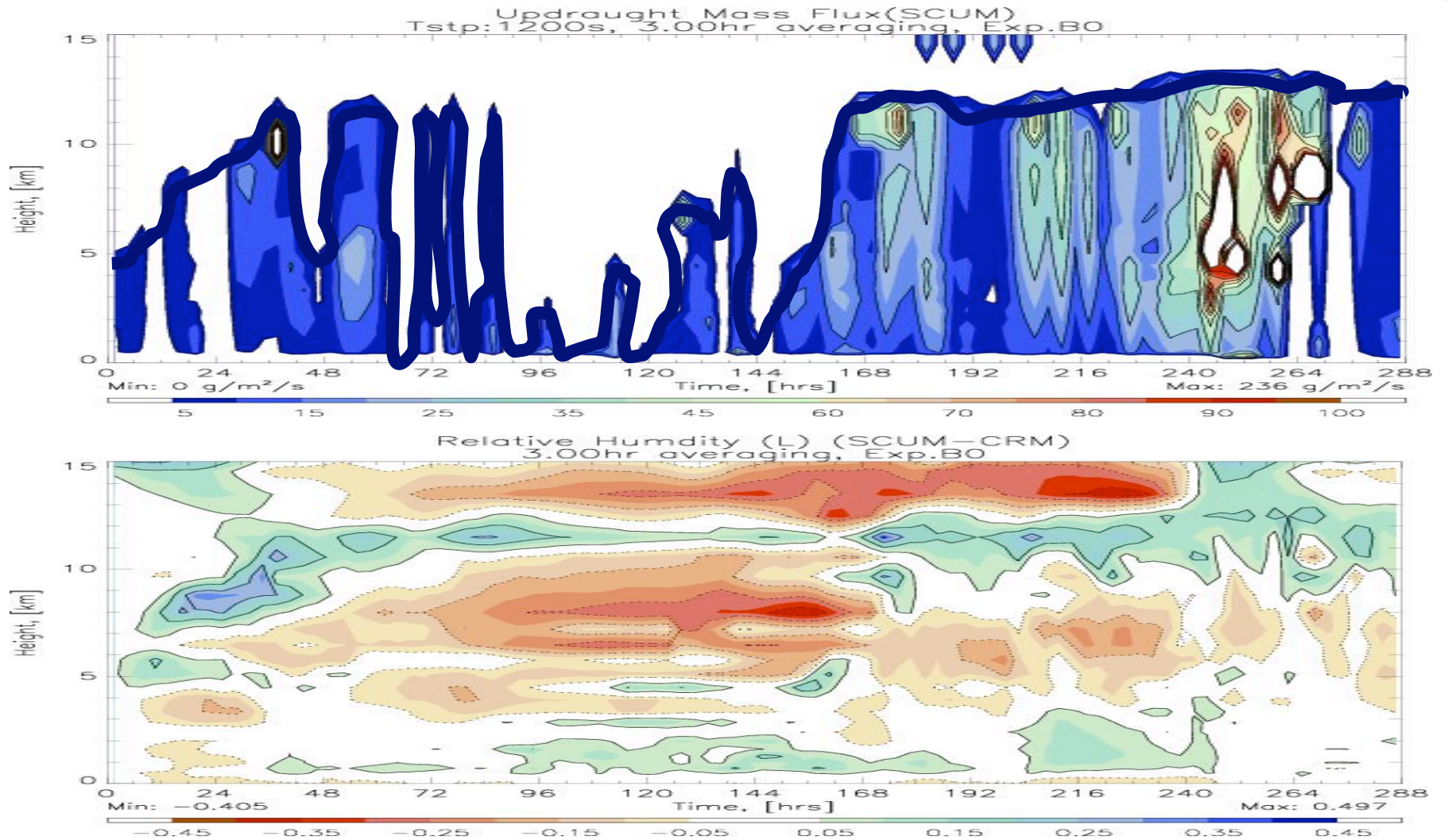
Active period B



Suppressed period B



Convection top and RH "error"



Convection top and RH "error"

