# Model humidity biases during the NAWDEX campaign from radiosondes

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Supervised by Suzanne Gray, John Methven and Richard Forbes (ECMWF)

# Control of cloud and moisture on extratropical cyclone evolution

- Identify systematic humidity biases in operational models
- Characterise these biases according to coincident conditions
- Study the causes of these biases
- Consider the effect of any misrepresentation of moisture on evolution of cyclones downstream

# What I will cover in this talk

- The methods I have been using to identify biases so far
- The lower stratospheric moist bias (which we know about already from studies such as Dyroff et. al. 2014 with CARIBIC data)
- How the moisture bias differs between ridges and troughs
- How this might be related to temperature biases (which we also know about, from the ECMWF Report on Stratospheric task force)

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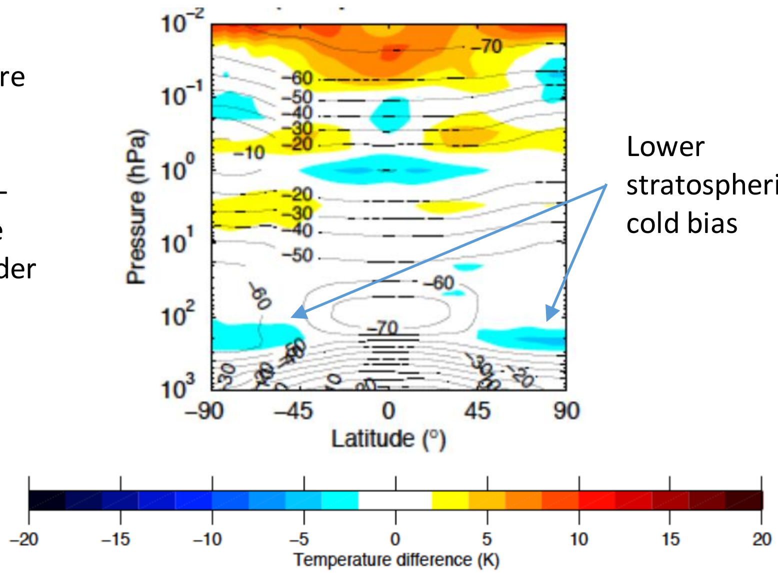
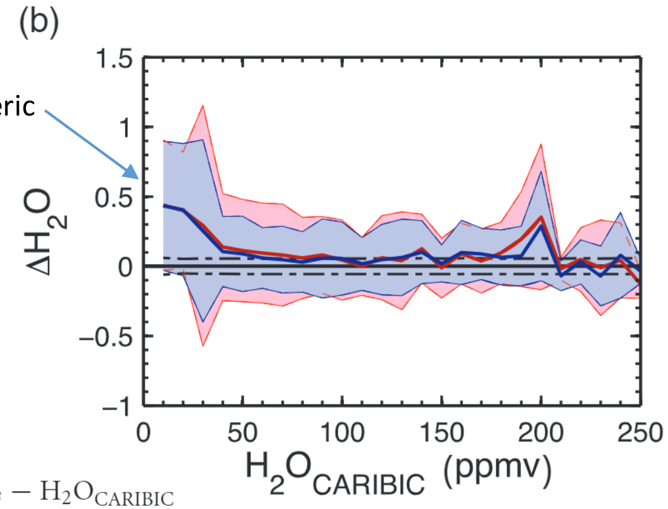
Temperature biases relative to Aura MLS – Microwave Limb Sounder




Lower stratospheric cold bias

Lower stratospheric moist bias




Average relative differences between ECMWF analyses and CARIBIC observations

$$\Delta H_2O = \frac{H_2O_{ECMWF} - H_2O_{CARIBIC}}{H_2O_{CARIBIC}}.$$

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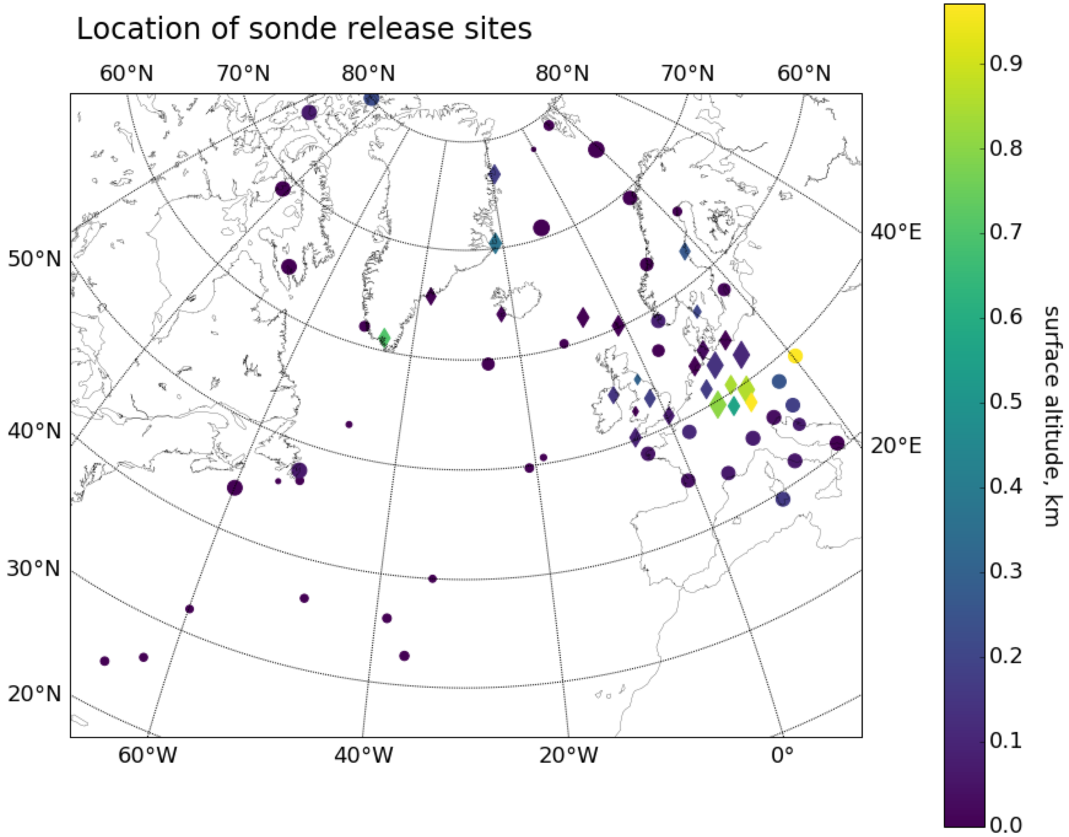

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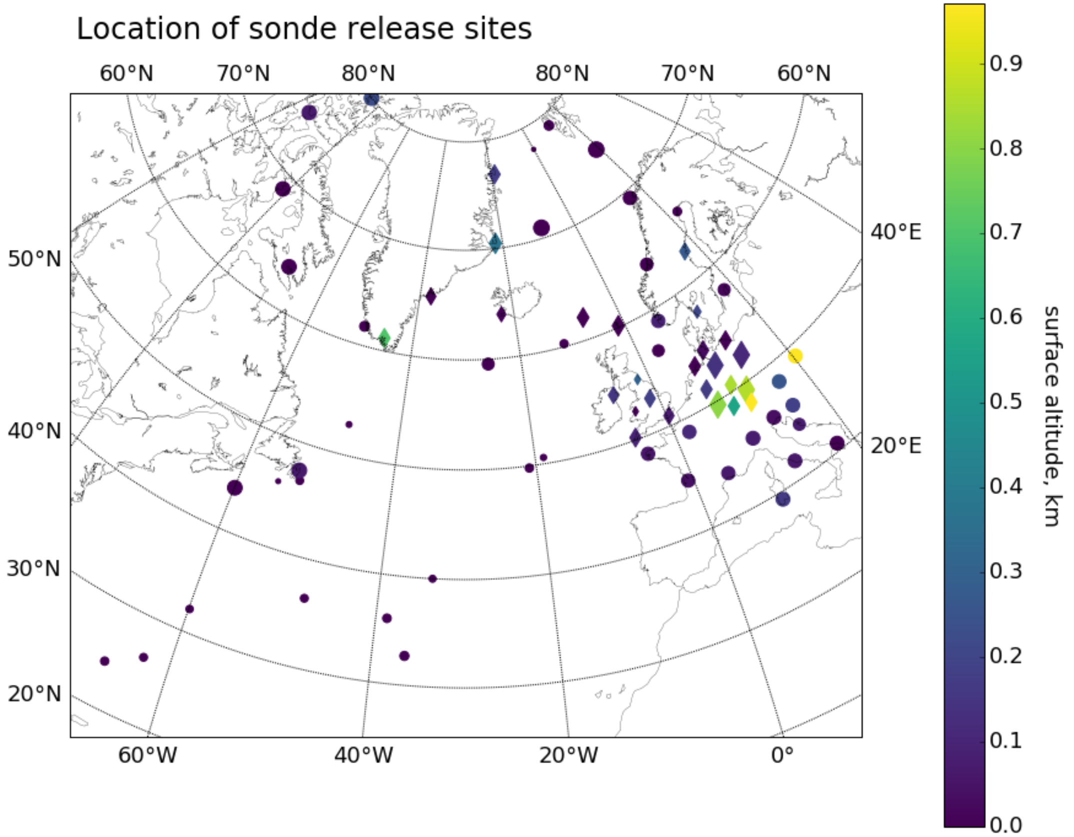


Vapour pressure is calculated from dew point temperature using the Sonntag numerical approximation.
Specific humidity (q) is then calculated from the expression:

$$q = \frac{\epsilon e}{\max(p, e) - (1 - \epsilon)e}$$

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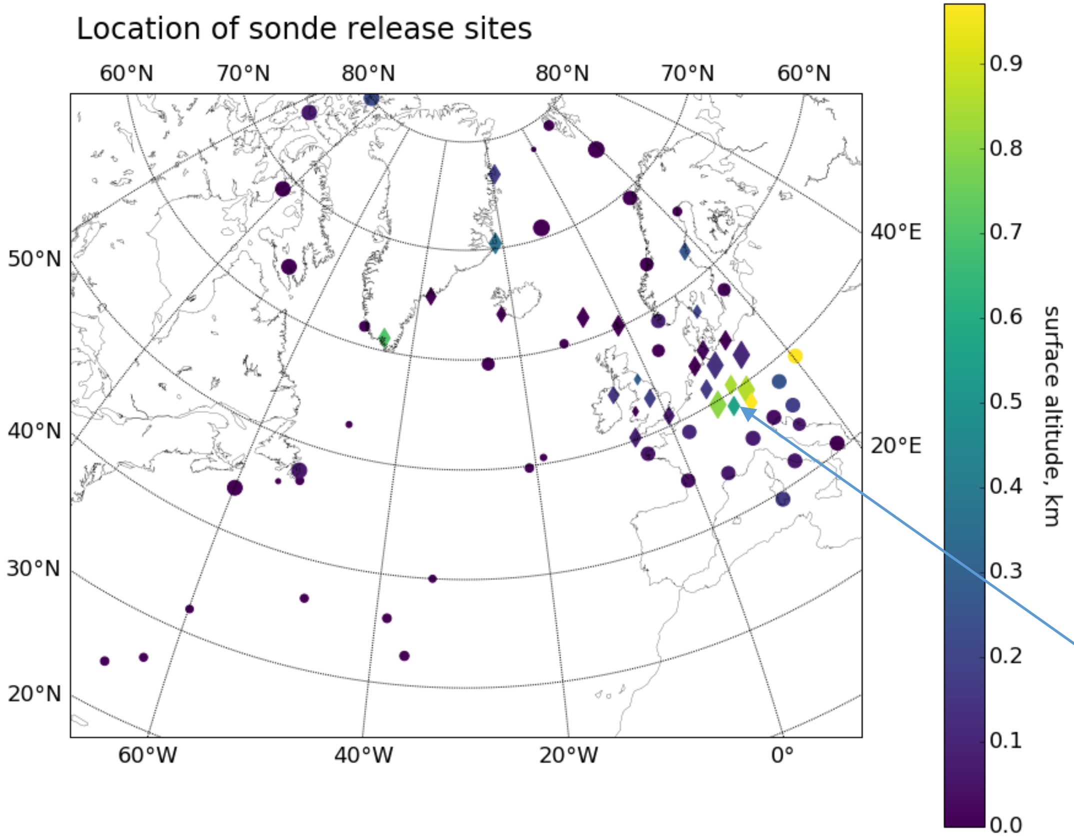


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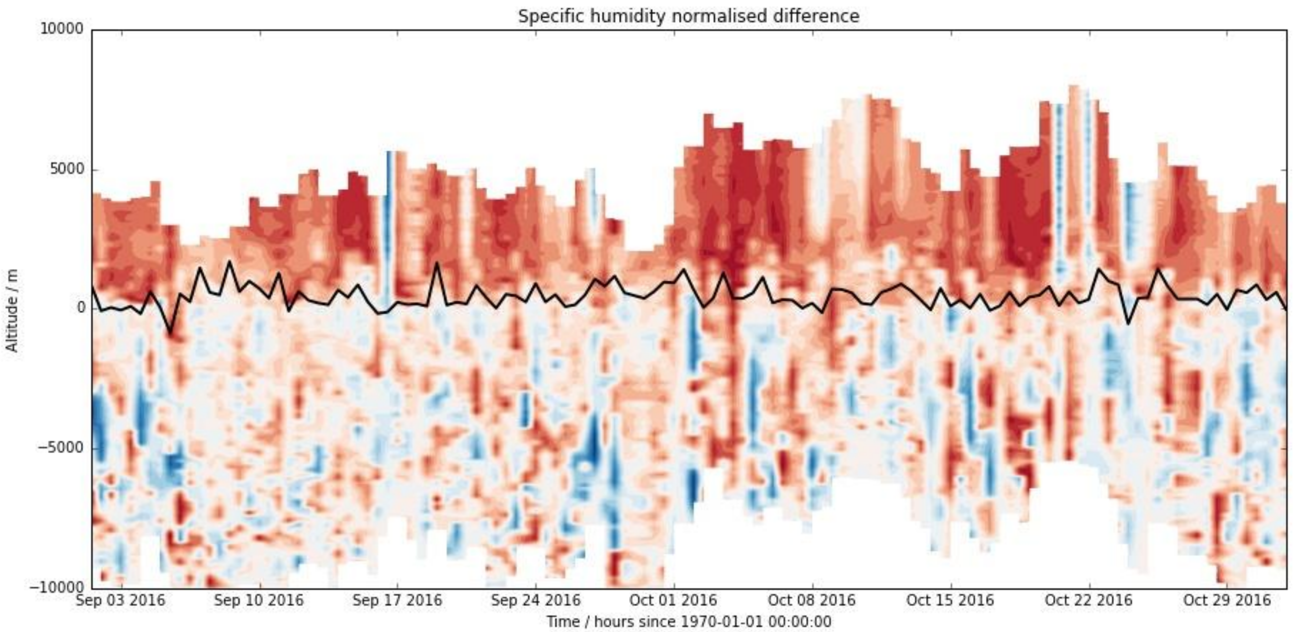
Consider all radiosondes released from this site




Model: ECMWF IFS

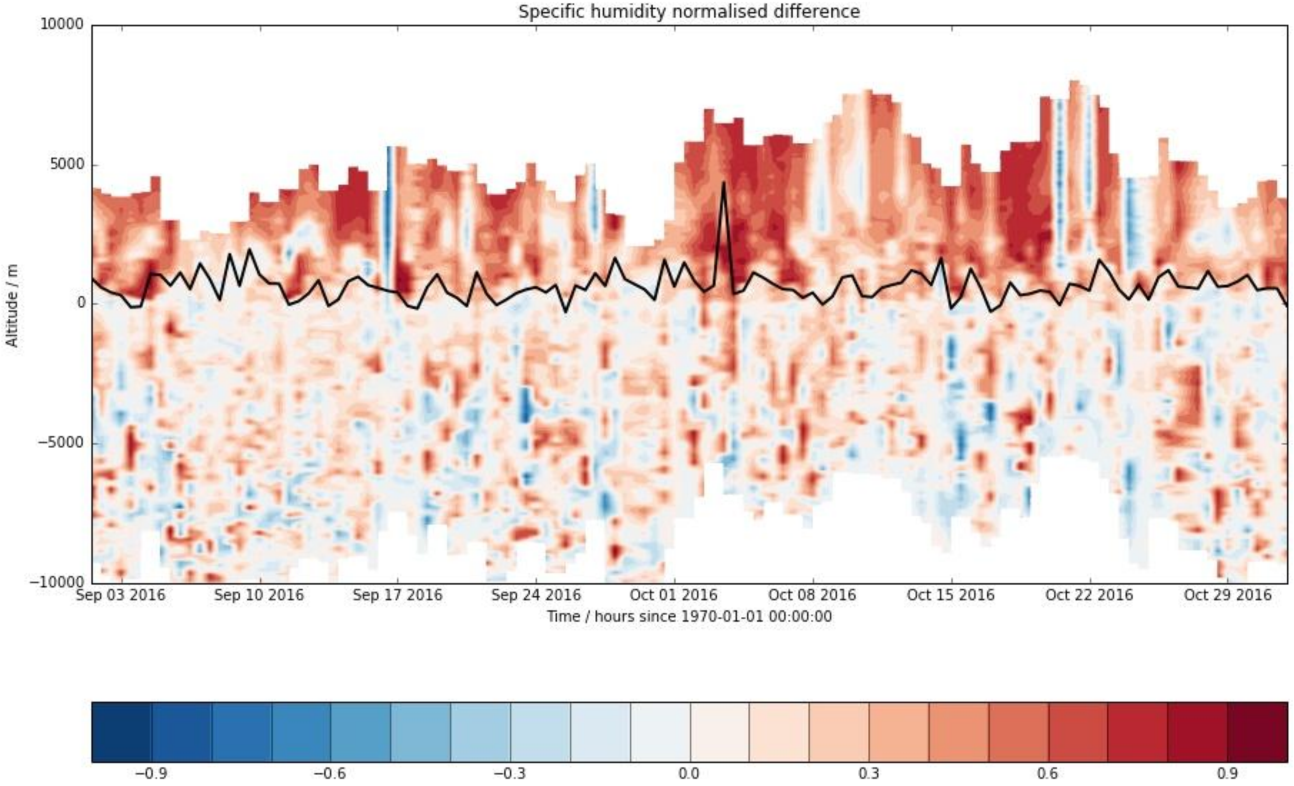
Normalised difference:

$$\frac{q_{model} - q_{observed}}{\sqrt{q_{model}^2 + q_{observed}^2}}$$

- Tropopause relative vertical coordinate – 0 is the height of the tropopause as calculated from radiosonde temperature profile

- Variable distribution of normalised difference in troposphere
- Persistent signal of model being more moist than radiosonde observations in lower stratosphere

Model: UK Met Office UM



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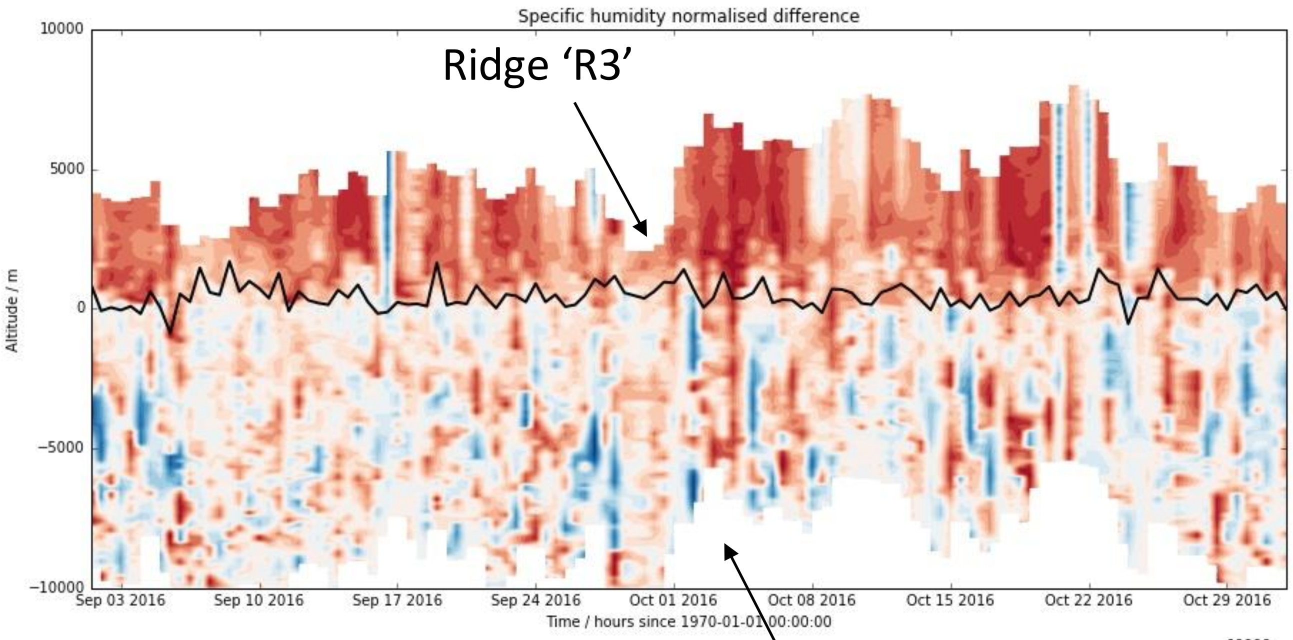
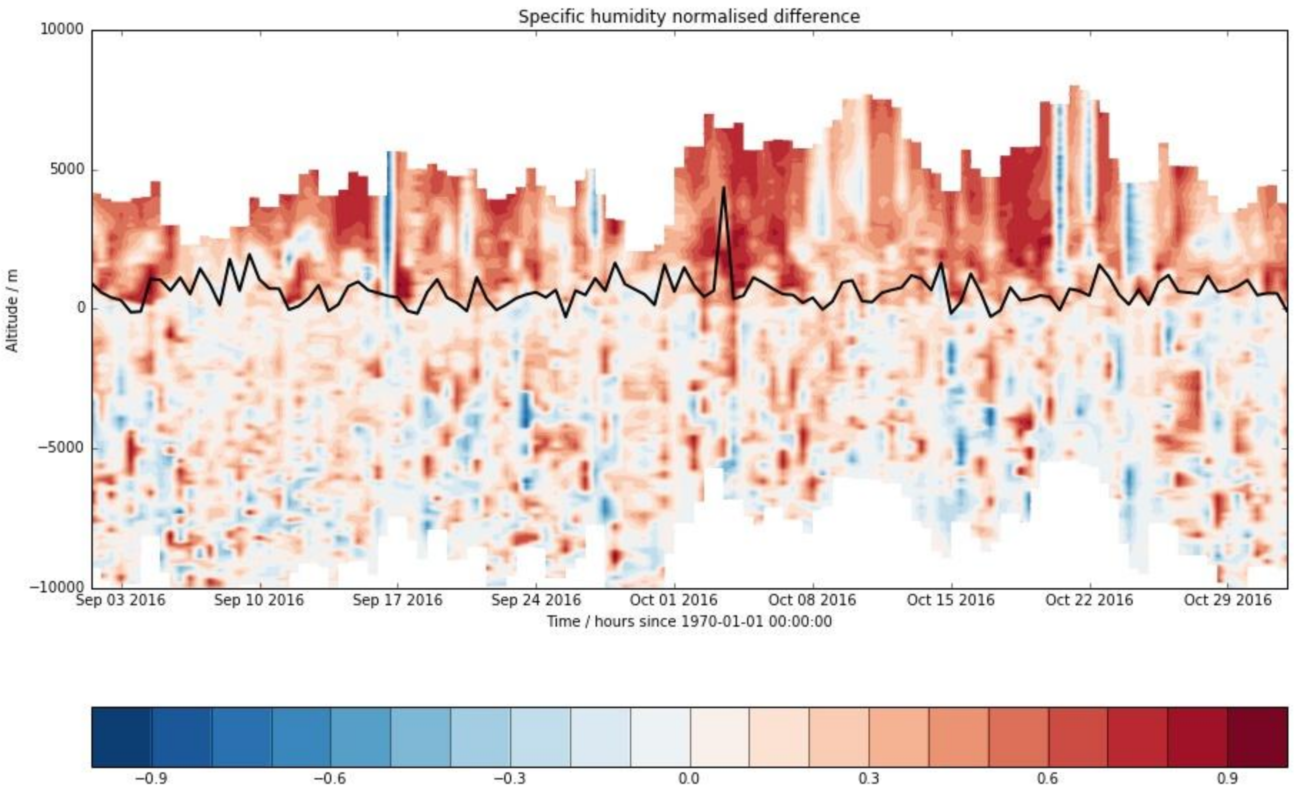



Model: ECMWF IFS

Troughs downstream of ridges ‘R5’ and ‘R6’

Model: UK Met Office UM

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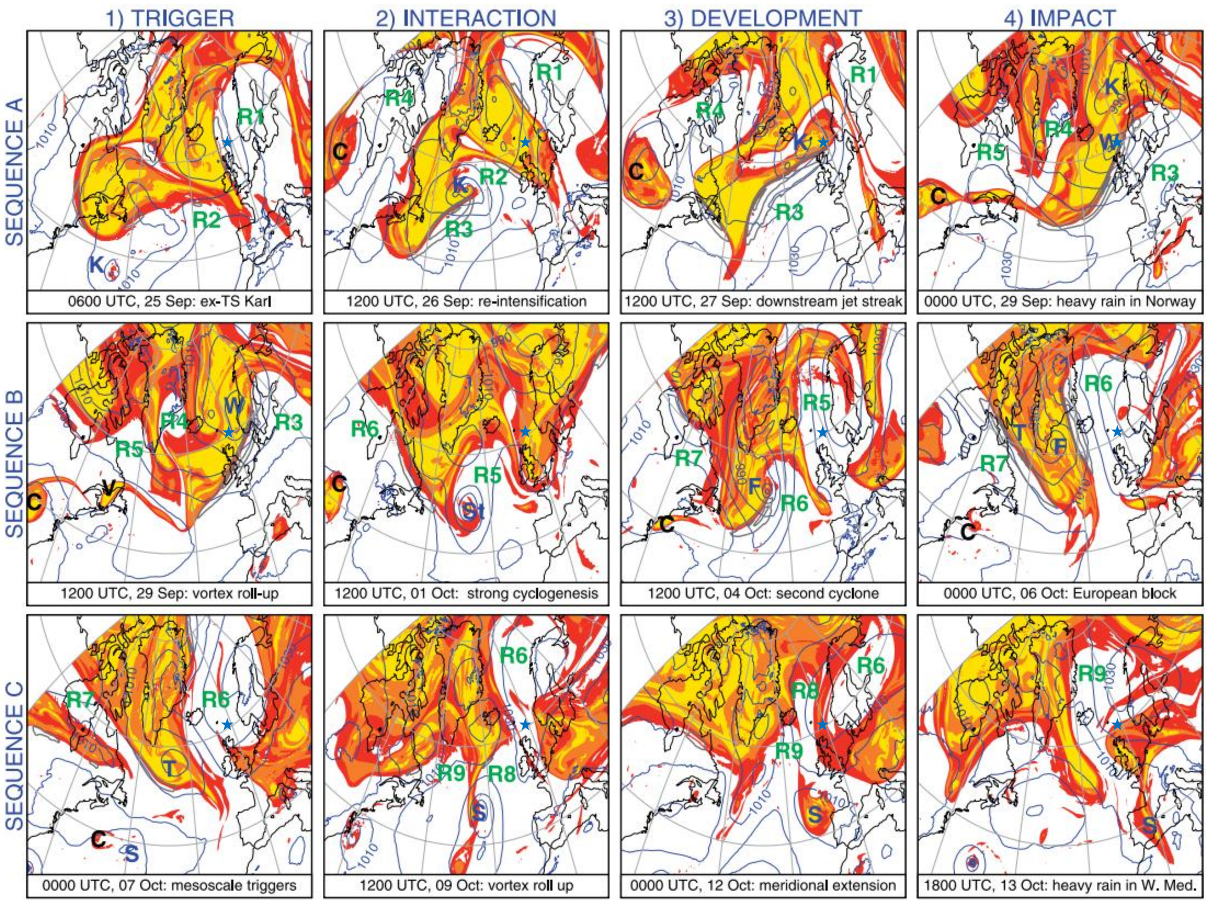
1) TRIGGER
2) INTERACTION
3) DEVELOPMENT
4) IMPACT
SEQUENCE A
SEQUENCE B
SEQUENCE C
0600 UTC, 25 Sep: ex-TS Karl
1200 UTC, 26 Sep: re-intensification
1200 UTC, 27 Sep: downstream jet streak
0000 UTC, 29 Sep: heavy rain in Norway
1200 UTC, 29 Sep: vortex roll-up
1200 UTC, 01 Oct: strong cyclogenesis
1200 UTC, 04 Oct: second cyclone
0000 UTC, 06 Oct: European block
0000 UTC, 07 Oct: mesoscale triggers
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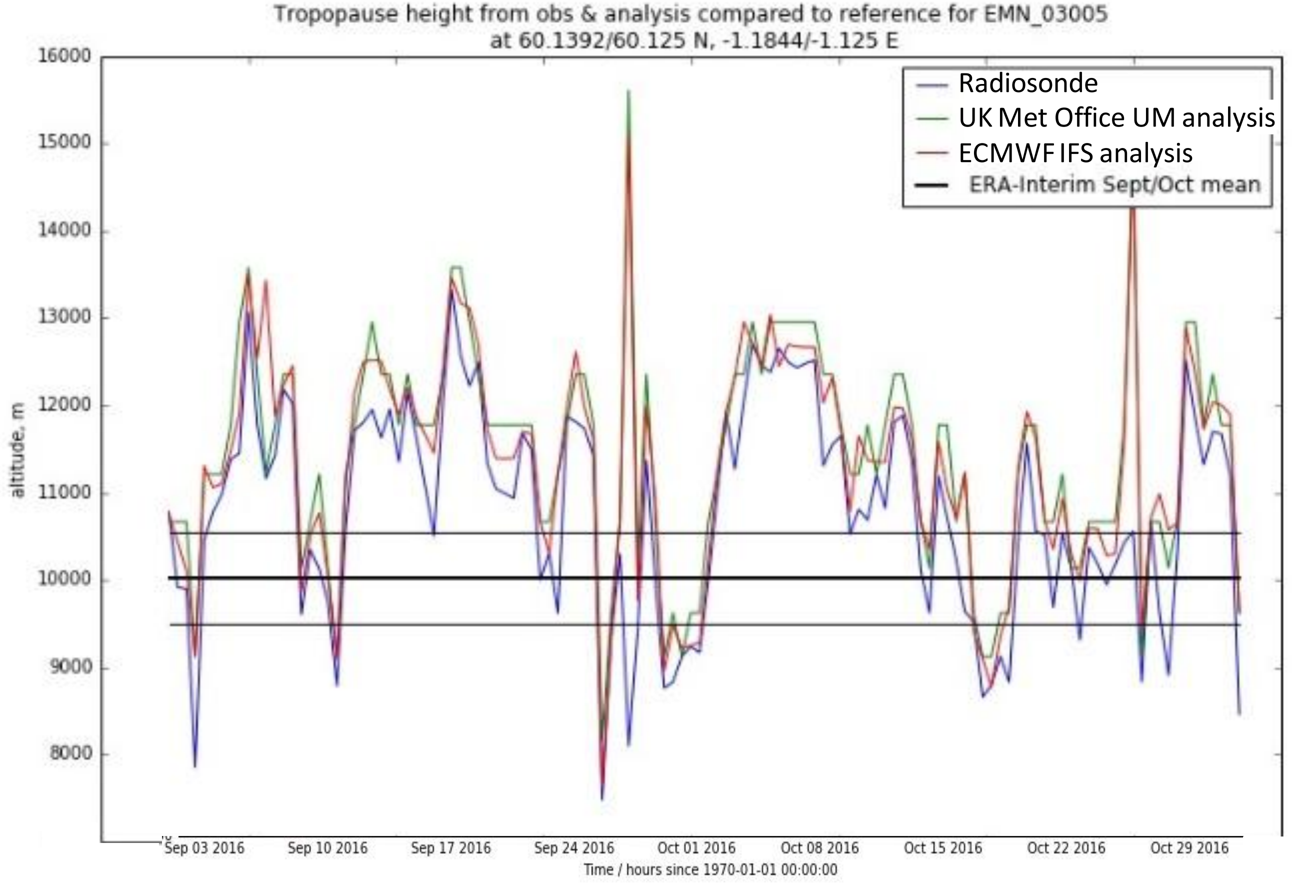
Tropopause height from obs & analysis compared to reference for EMN_03005
at 60.1392/60.125 N, -1.1844/-1.125 E
Radiosonde
UK Met Office UM analysis
ECMWF IFS analysis
ERA-Interim Sept/Oct mean
altitude, m
16000
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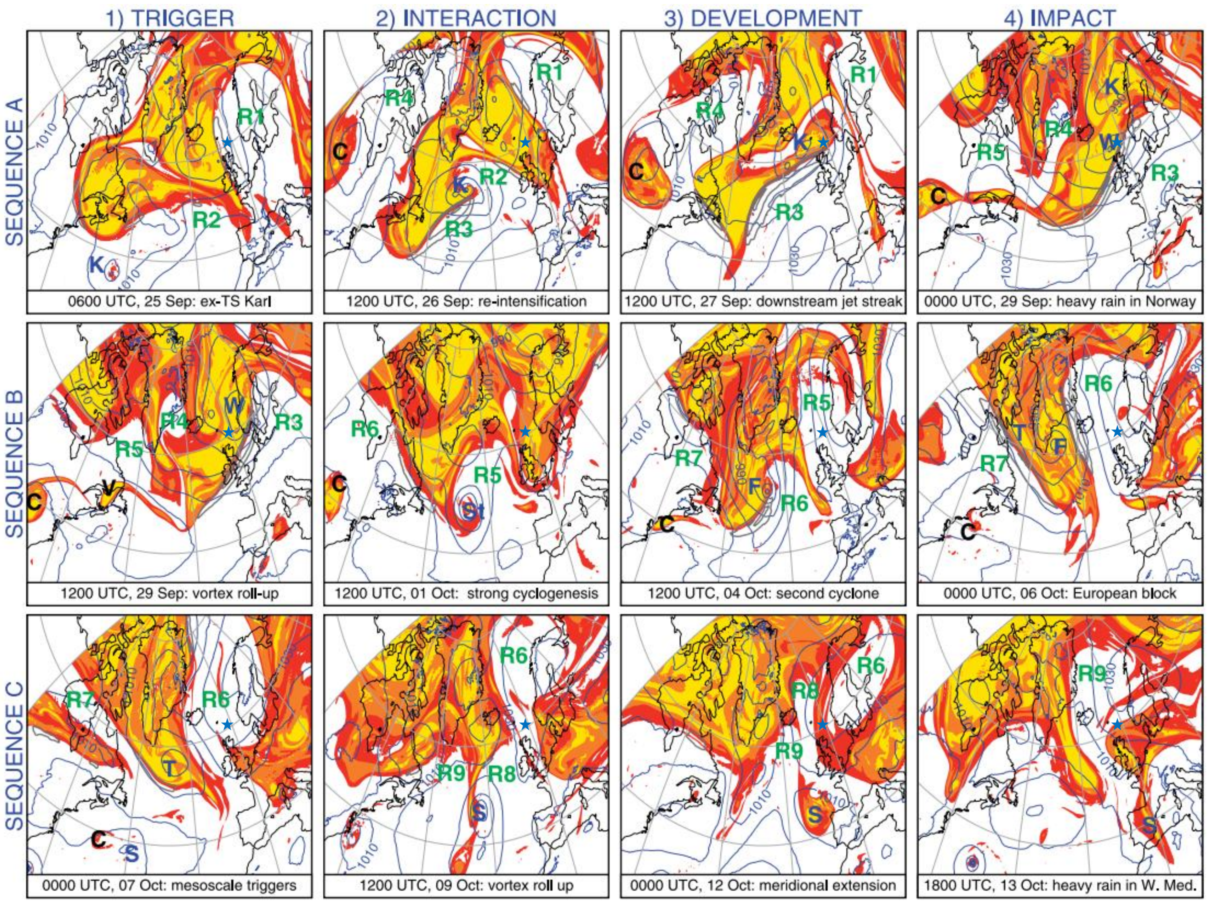
13000
12000
11000
10000
9000
8000
Sep 03 2016
Sep 10 2016
Sep 17 2016
Sep 24 2016
Oct 01 2016
Oct 08 2016
Oct 15 2016
Oct 22 2016
Oct 29 2016
Time / hours since 1970-01-01 00:00:00



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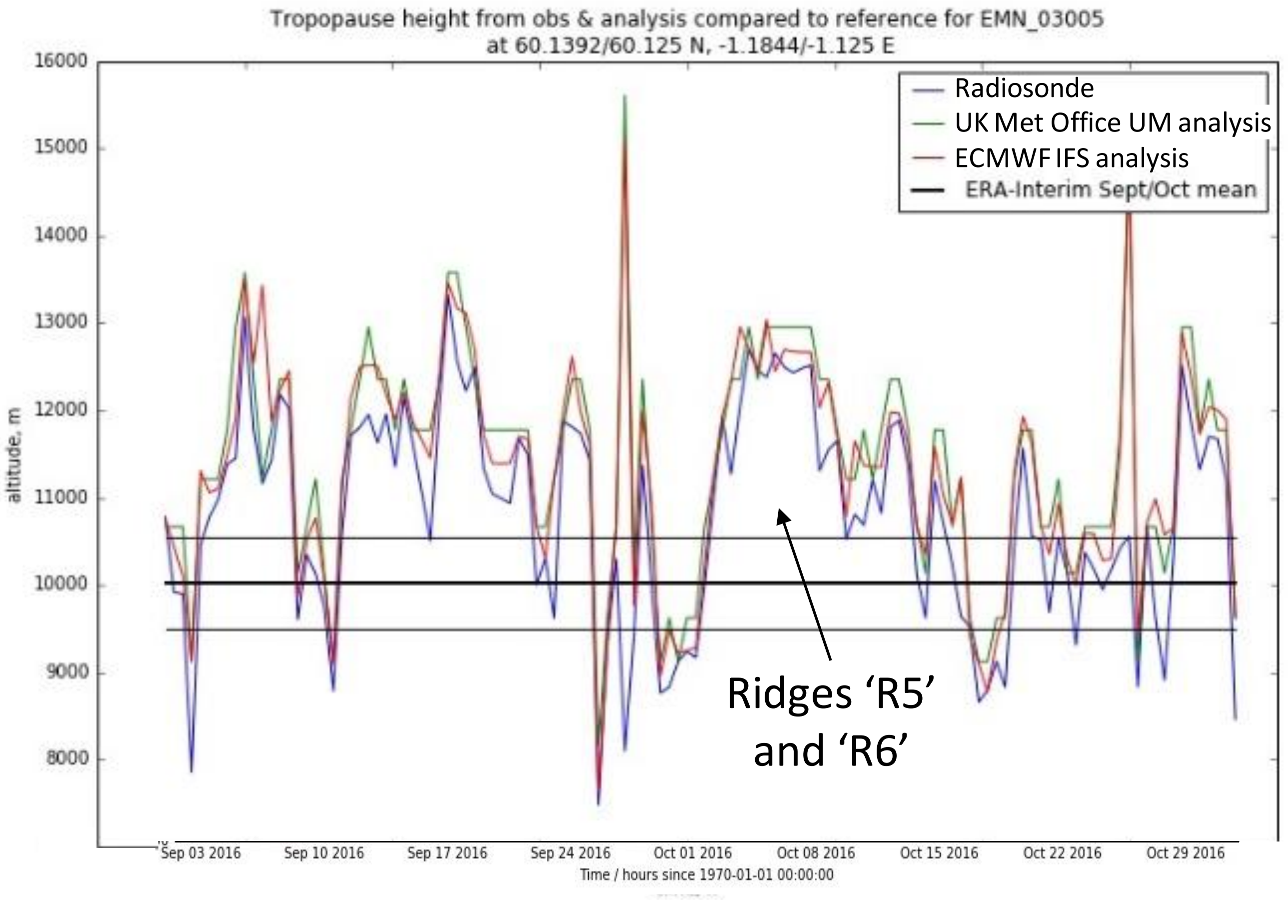

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Ridges 'R5'
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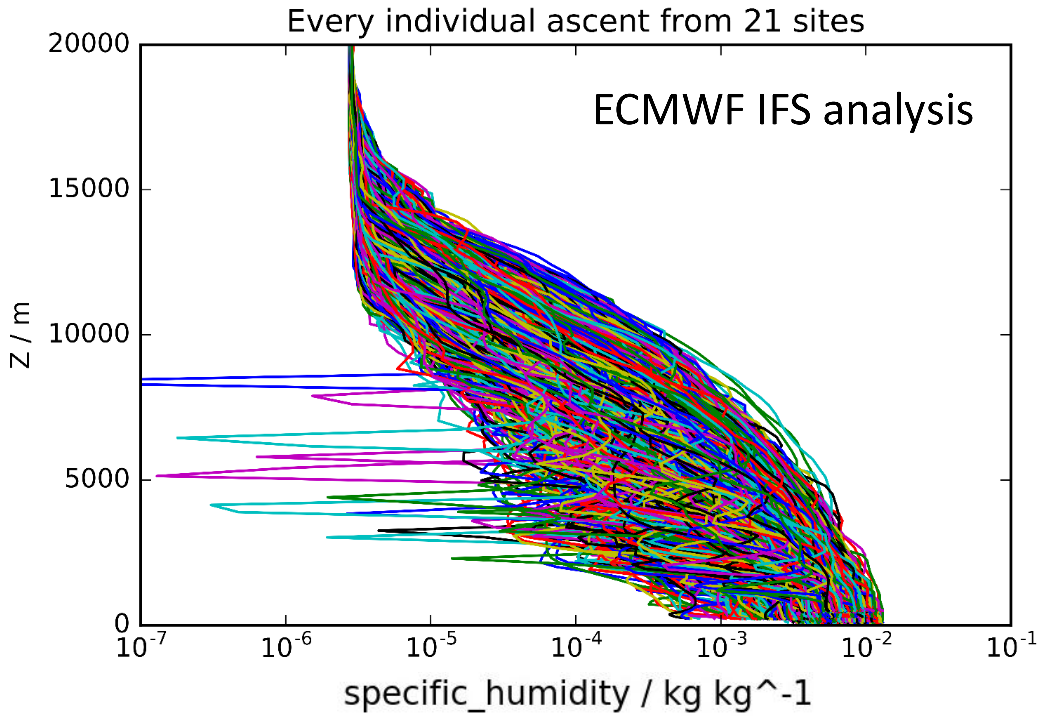
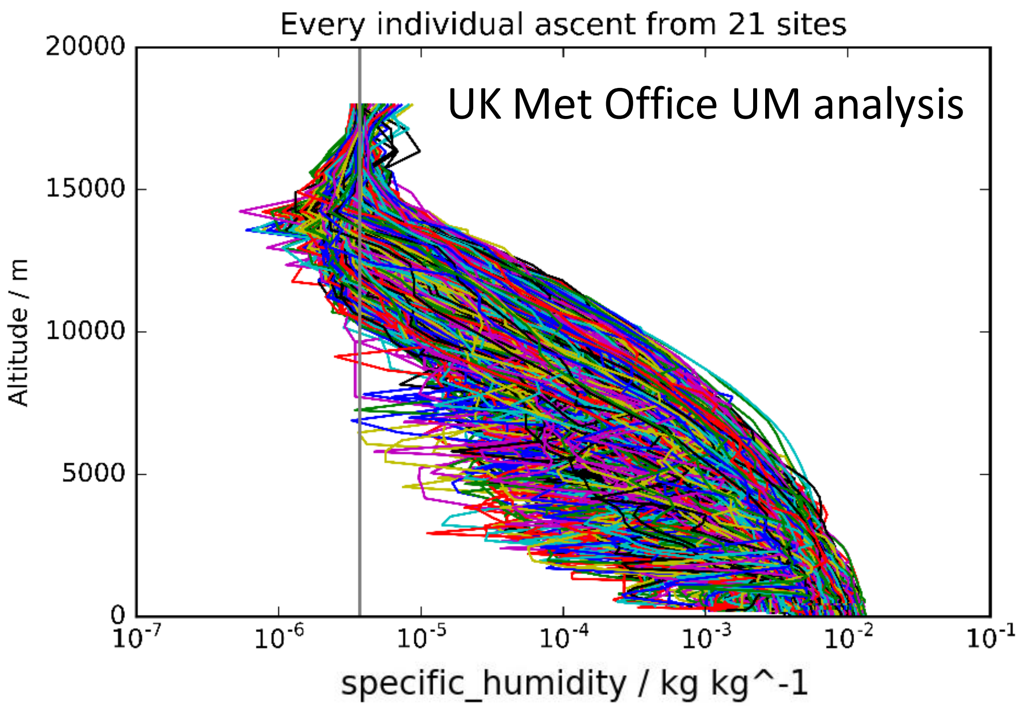
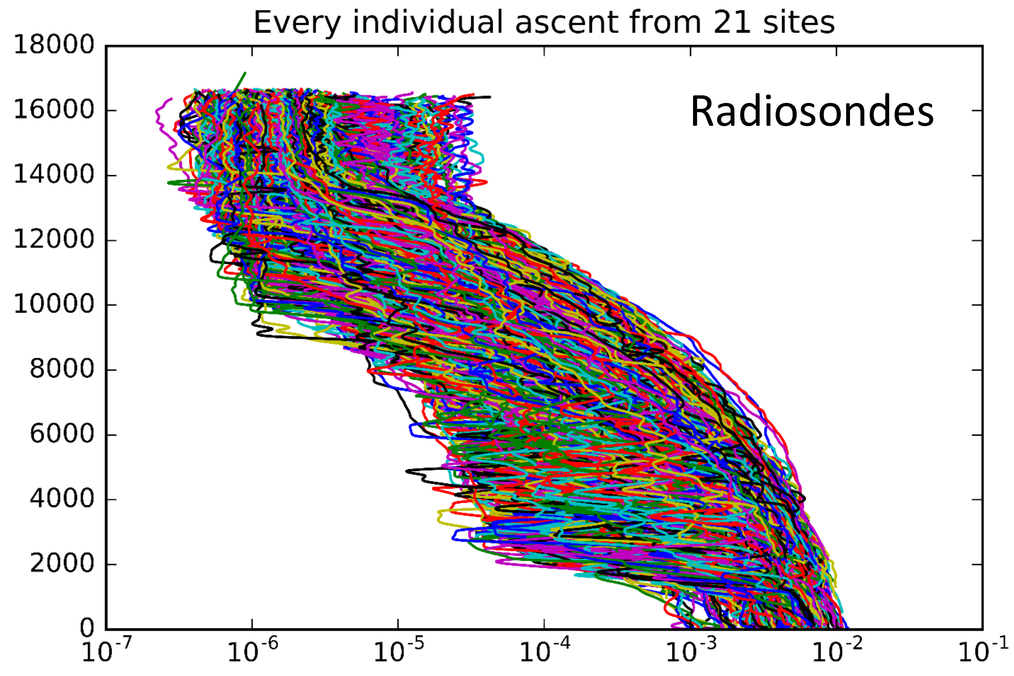
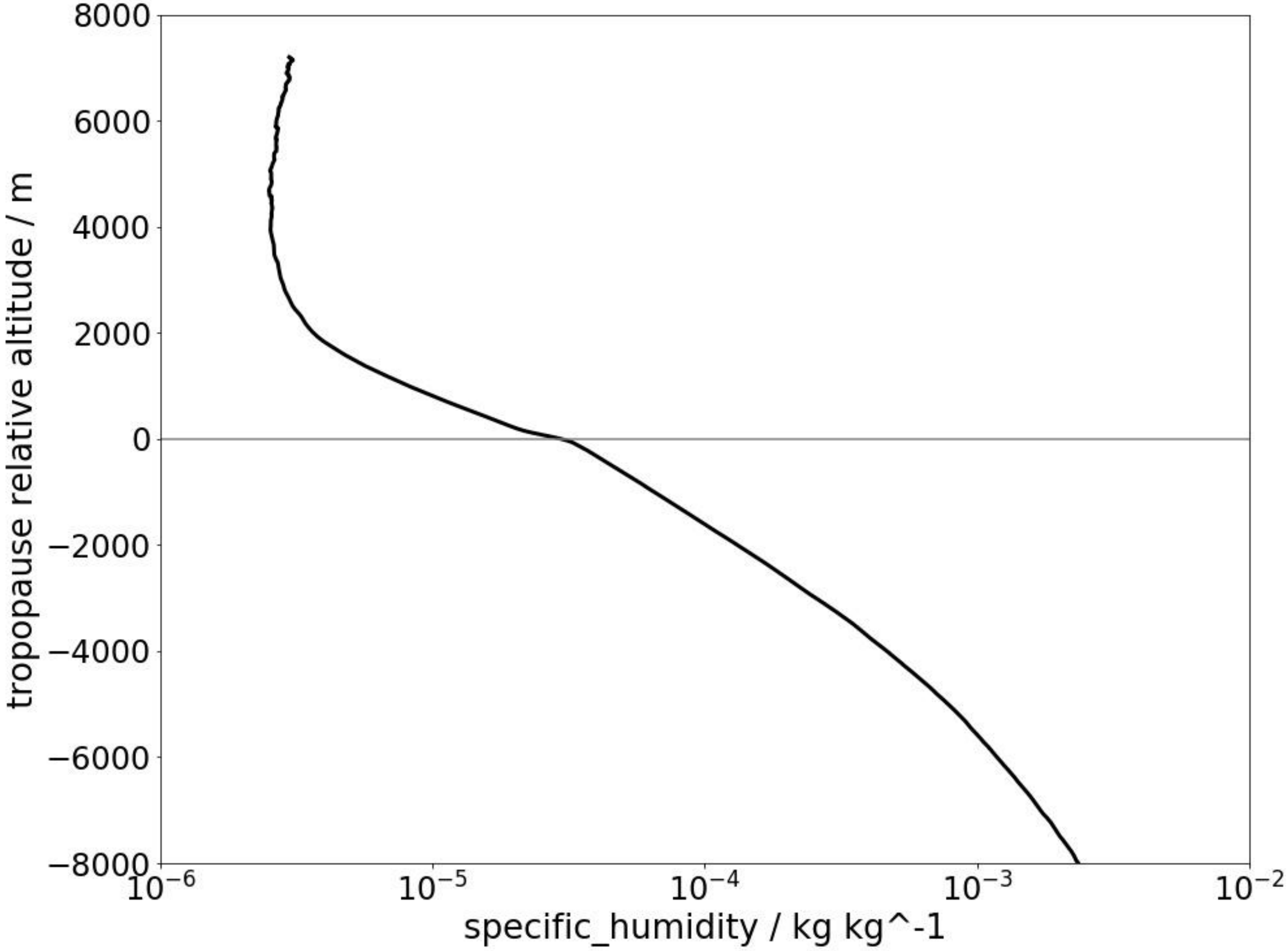



- Observations show much greater variability than the model analyses
- Unsure why there is apparent minima in some UM vertical profiles at ~14km

Comparison between radiosonde specific humidity and the IFS analysis




Solid line – observation
Dashed line -- analysis

At each site a mean is taken over all times, and the vertical profile is the mean of this over all sites
- The mean is only taken if there are at least 10 times/sites with data at a given vertical level

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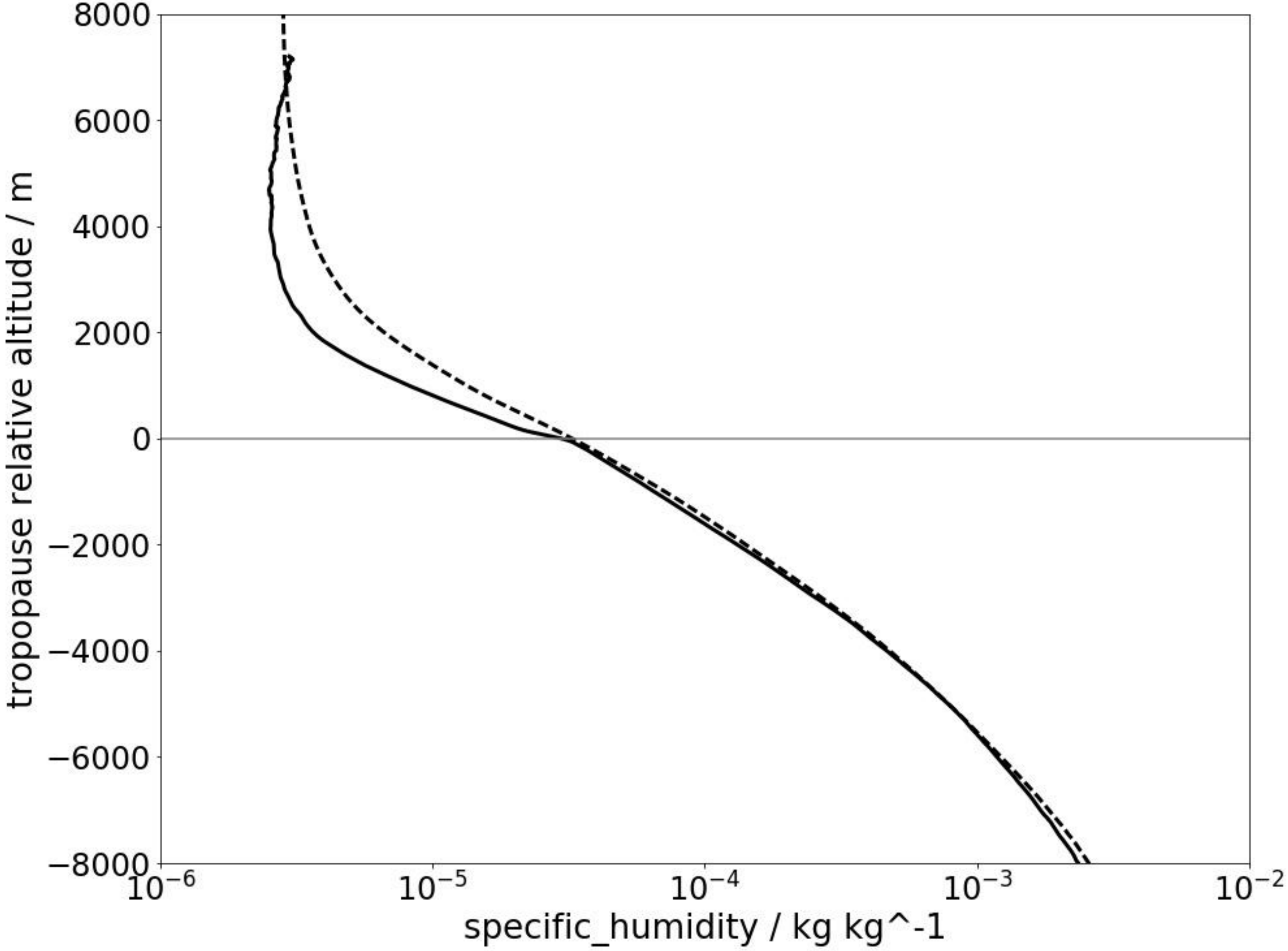


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Lower stratospheric moist bias

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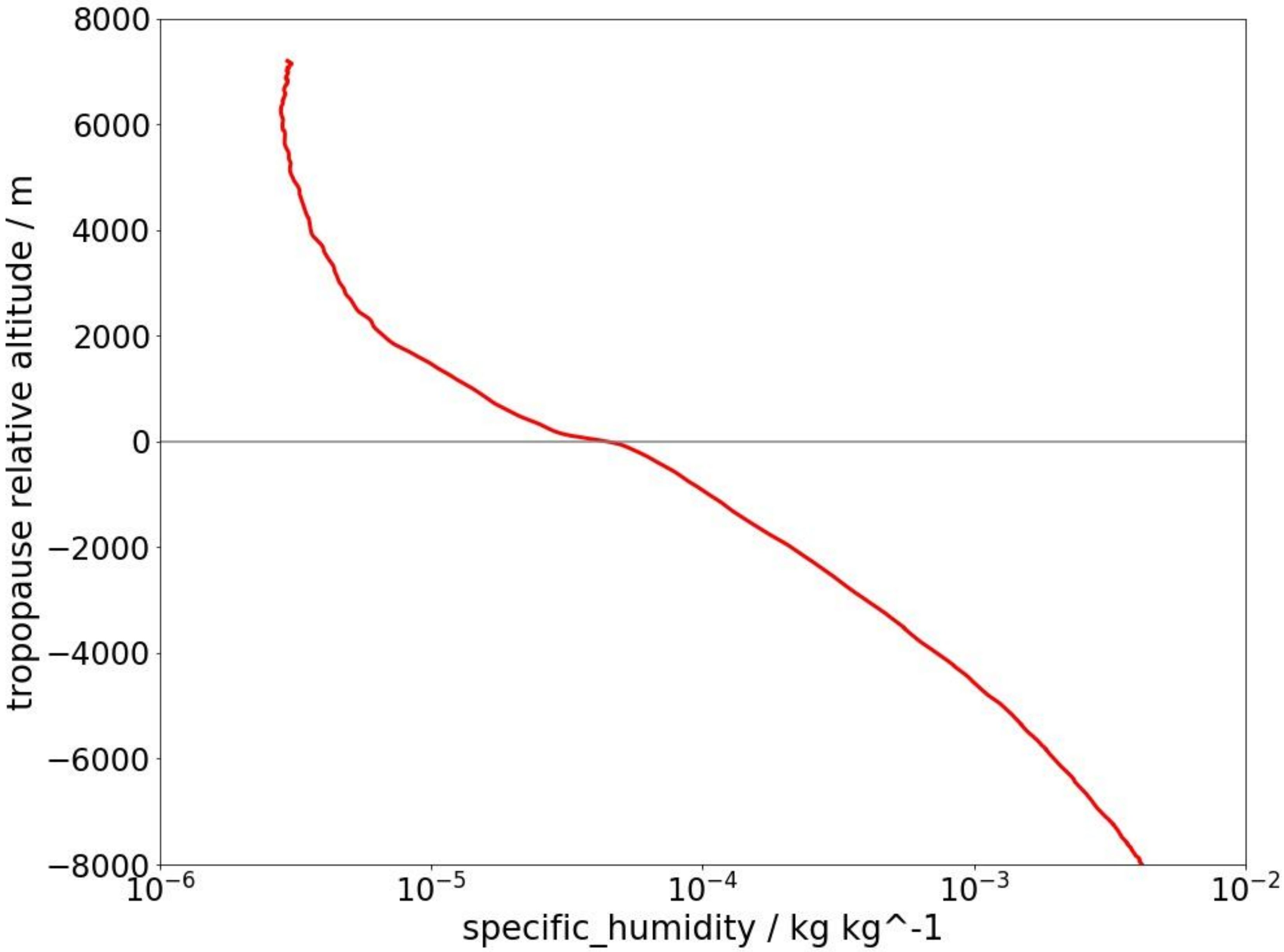


Solid line – observation
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At each site a mean is taken over all times at which the profile was identified as being in a trough, and the vertical profile is the mean of this over all sites
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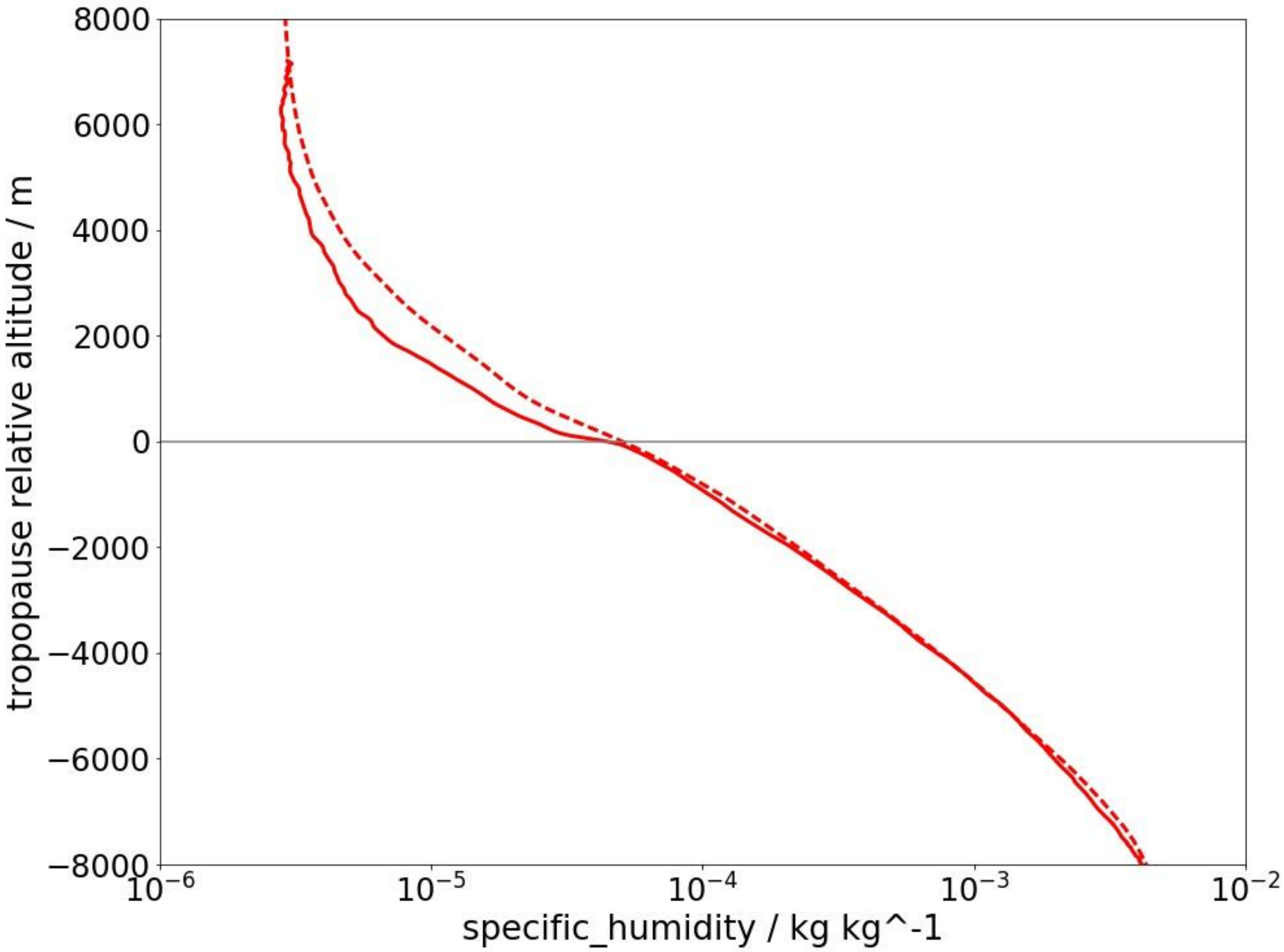


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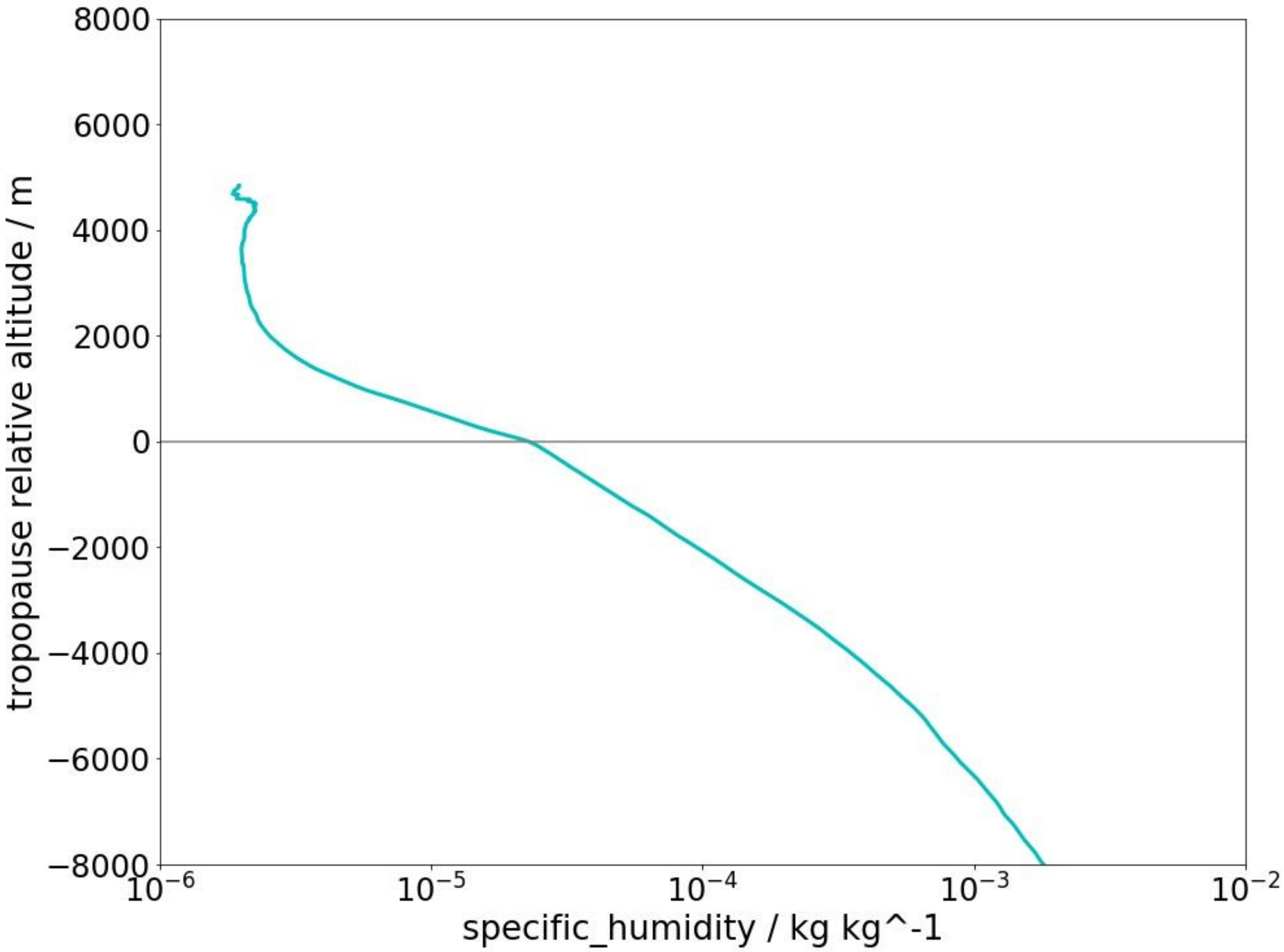


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At each site a mean is taken over all times at which the profile was identified as being in a ridge, and the vertical profile is the mean of this over all sites

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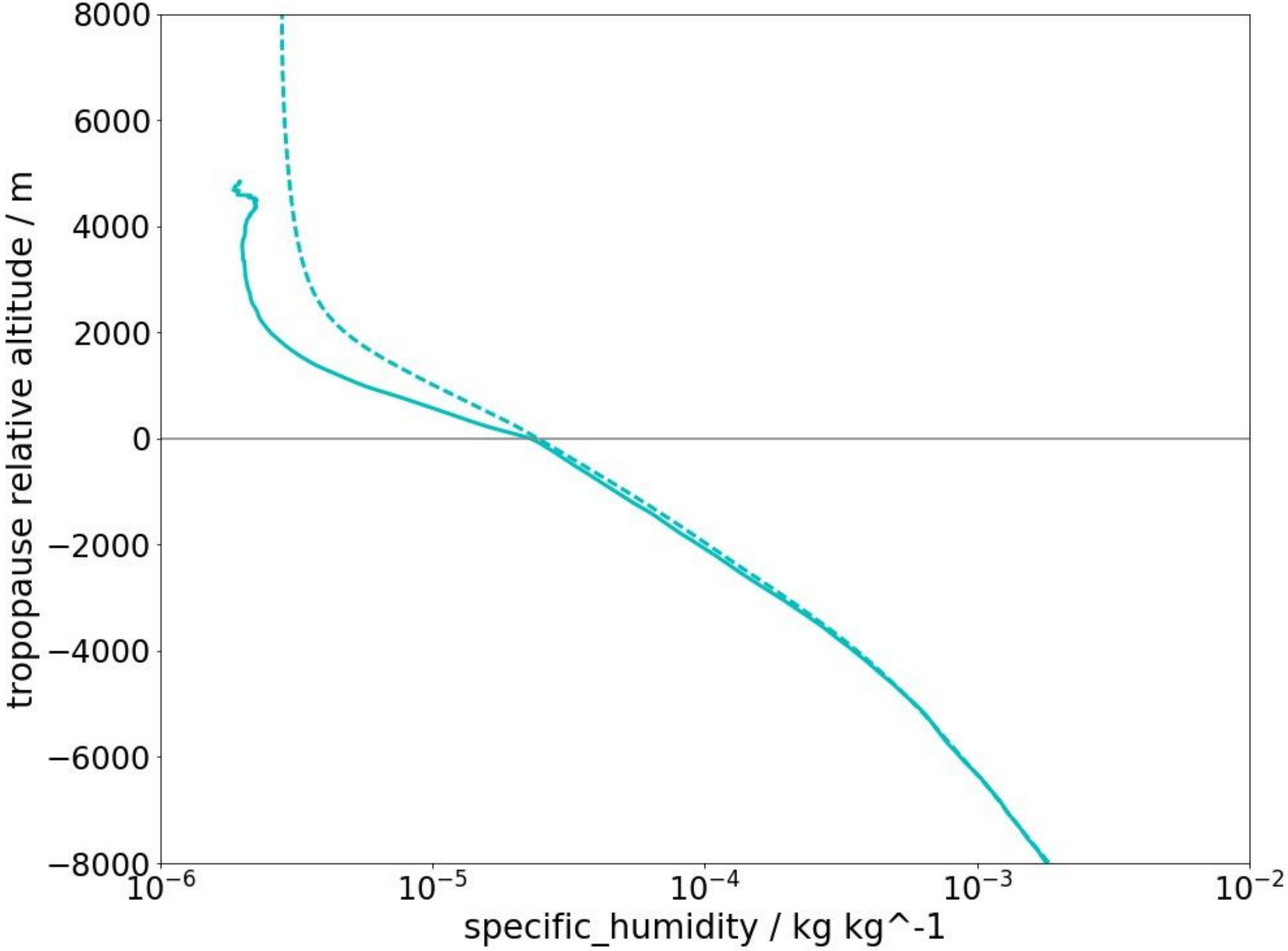


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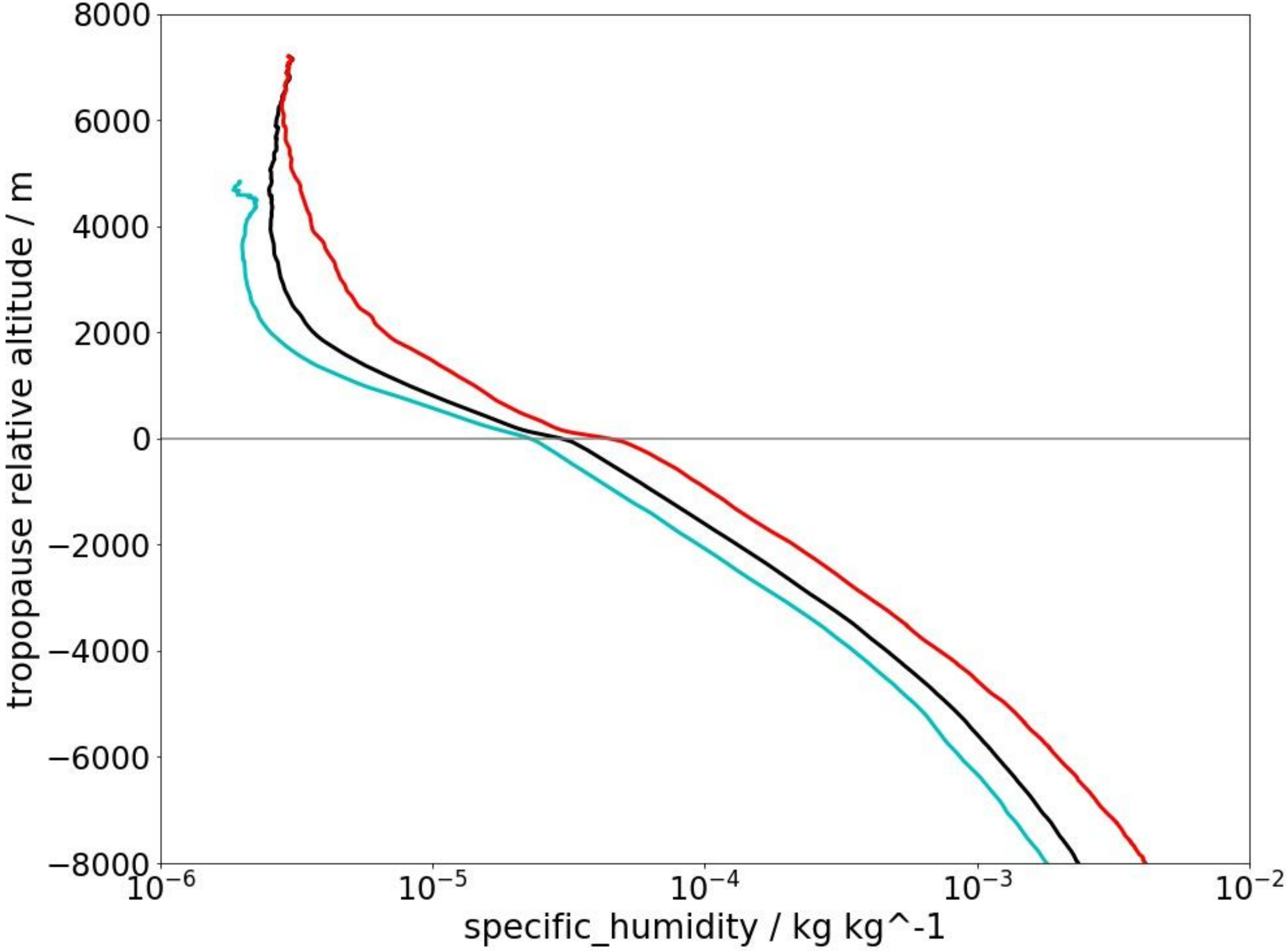


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At higher tropopause relative altitudes, there is no radiosonde data from ridges, so the mean over all ascents (black solid) tends towards the mean over all ascents in troughs (red solid)

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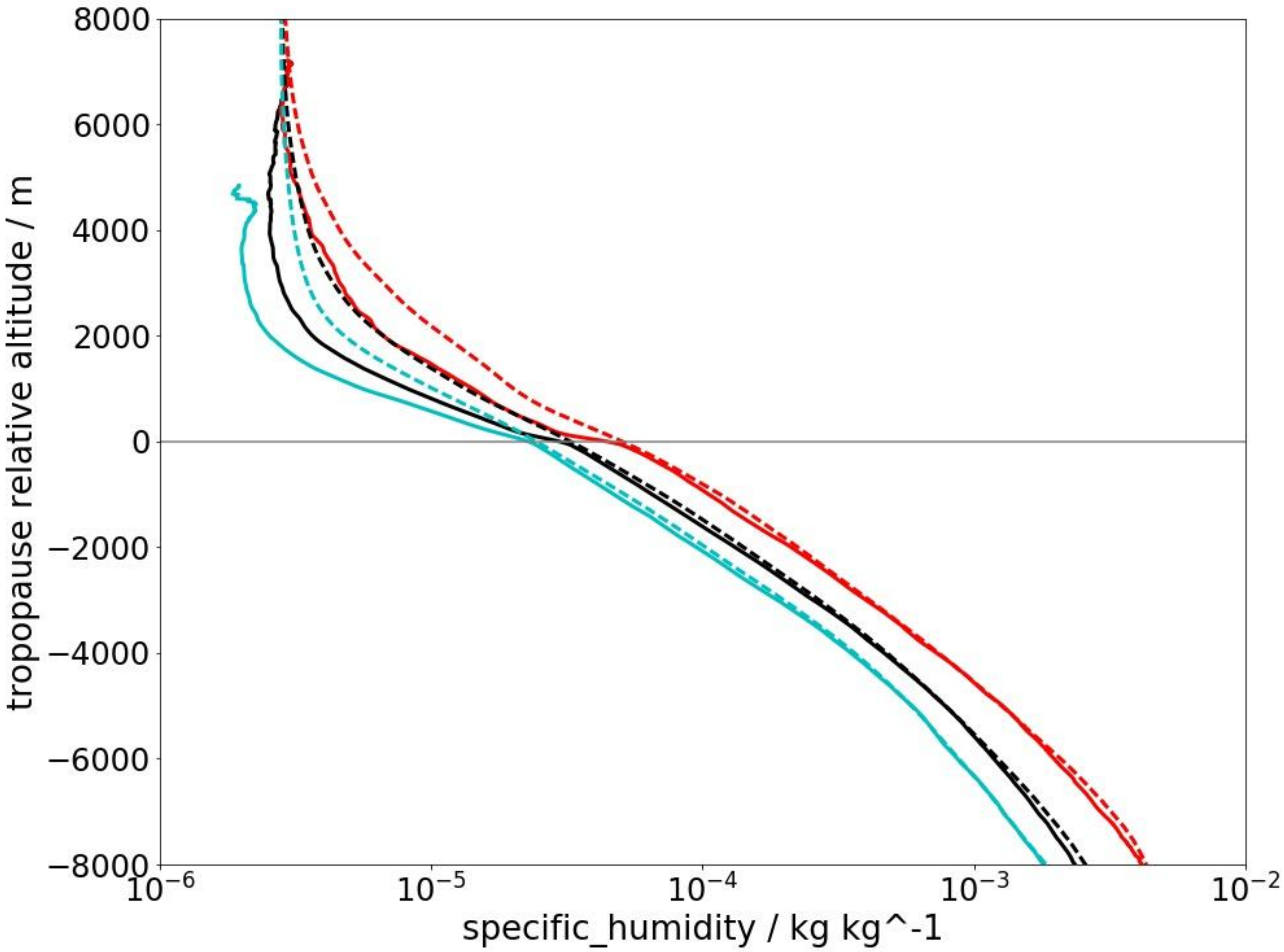


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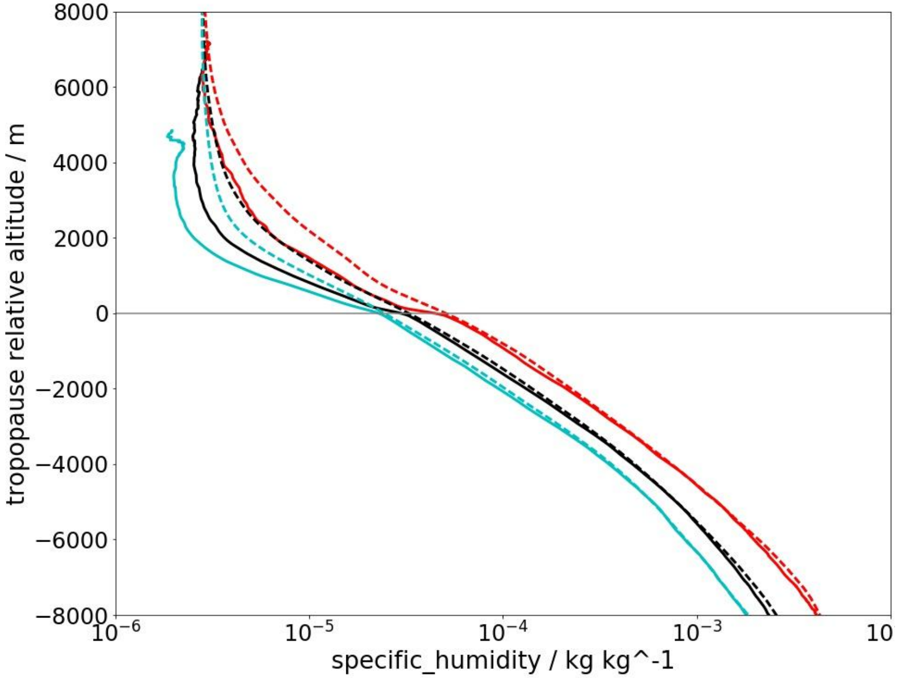
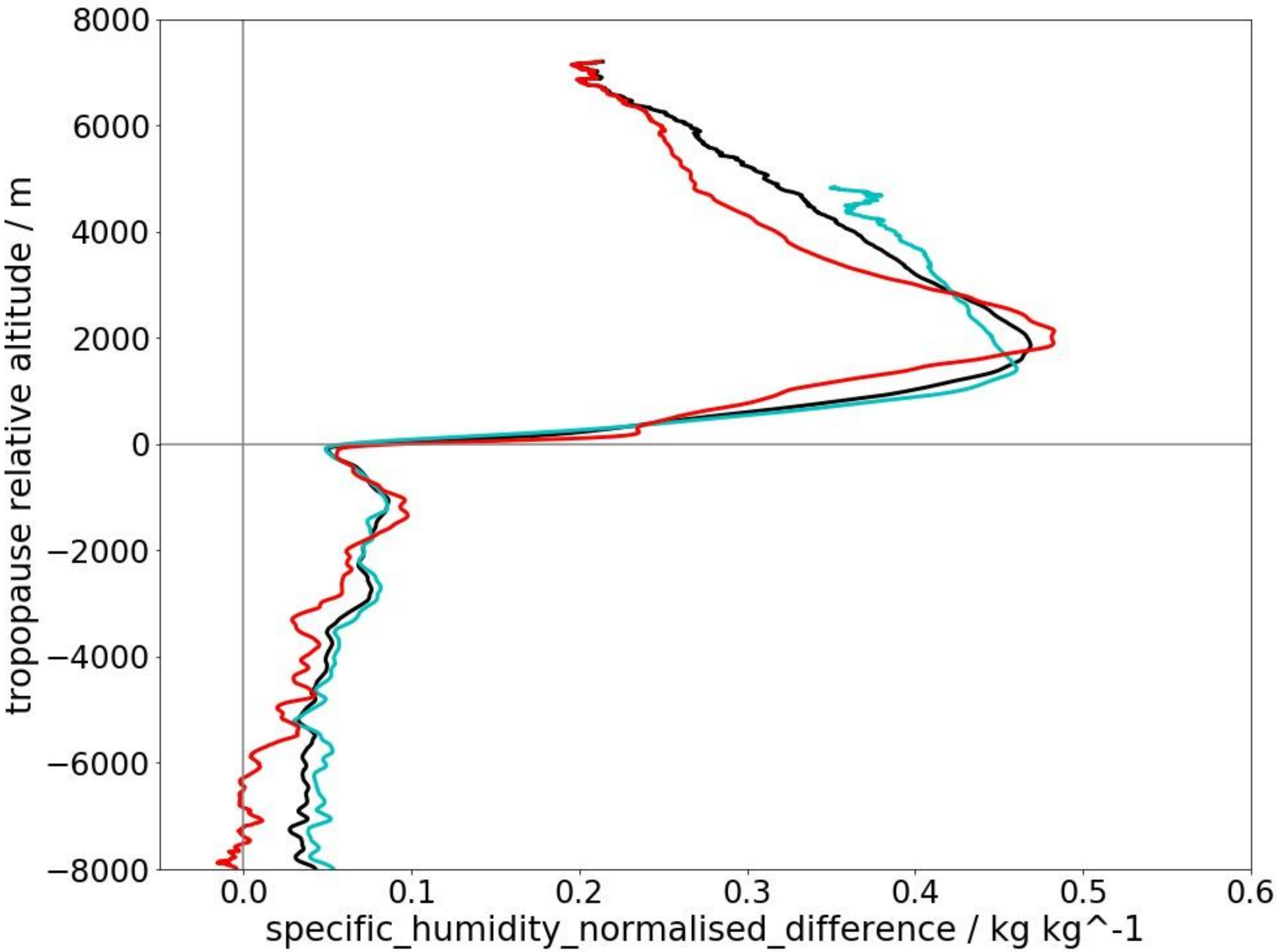
This is not the case for the IFS analysis data

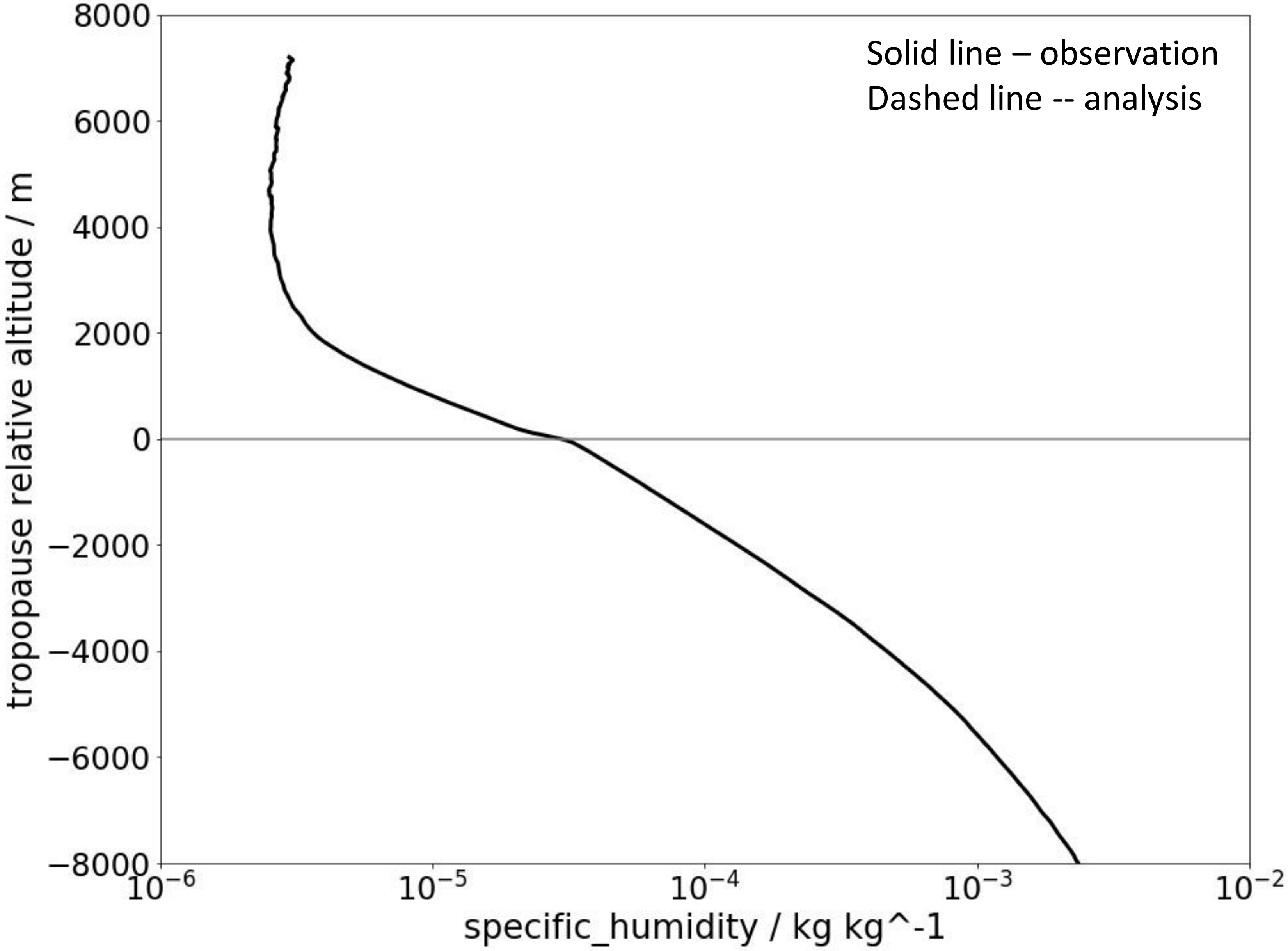
# Comparison between radiosonde specific humidity and the IFS analysis

A clear ~50% moist bias in the lower stratosphere, slightly larger in ridges than in troughs.



Comparison between radiosonde specific humidity and the UM analysis



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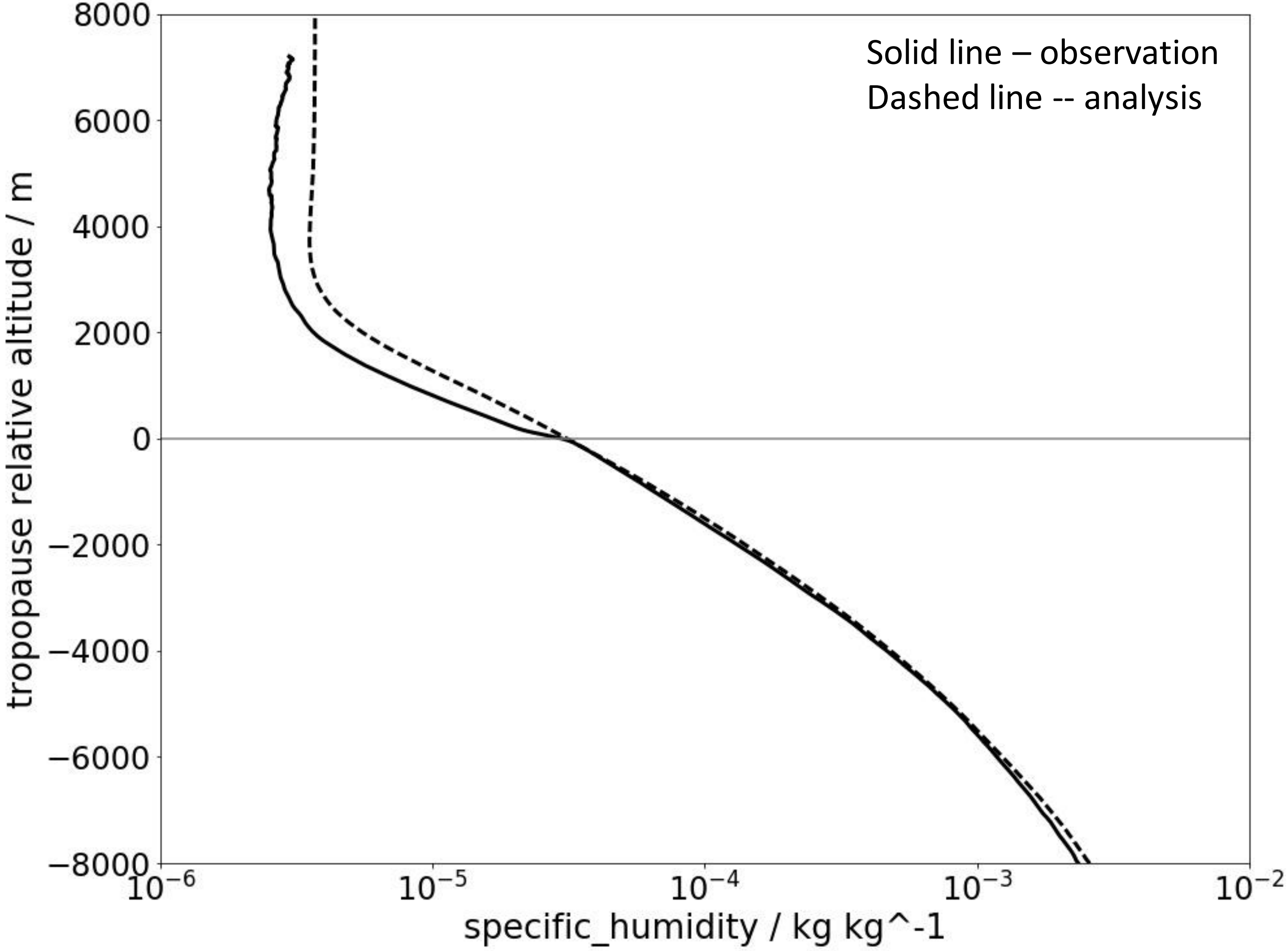


Sharp decrease in specific humidity across the tropopause in the observations is not reproduced in the analysis

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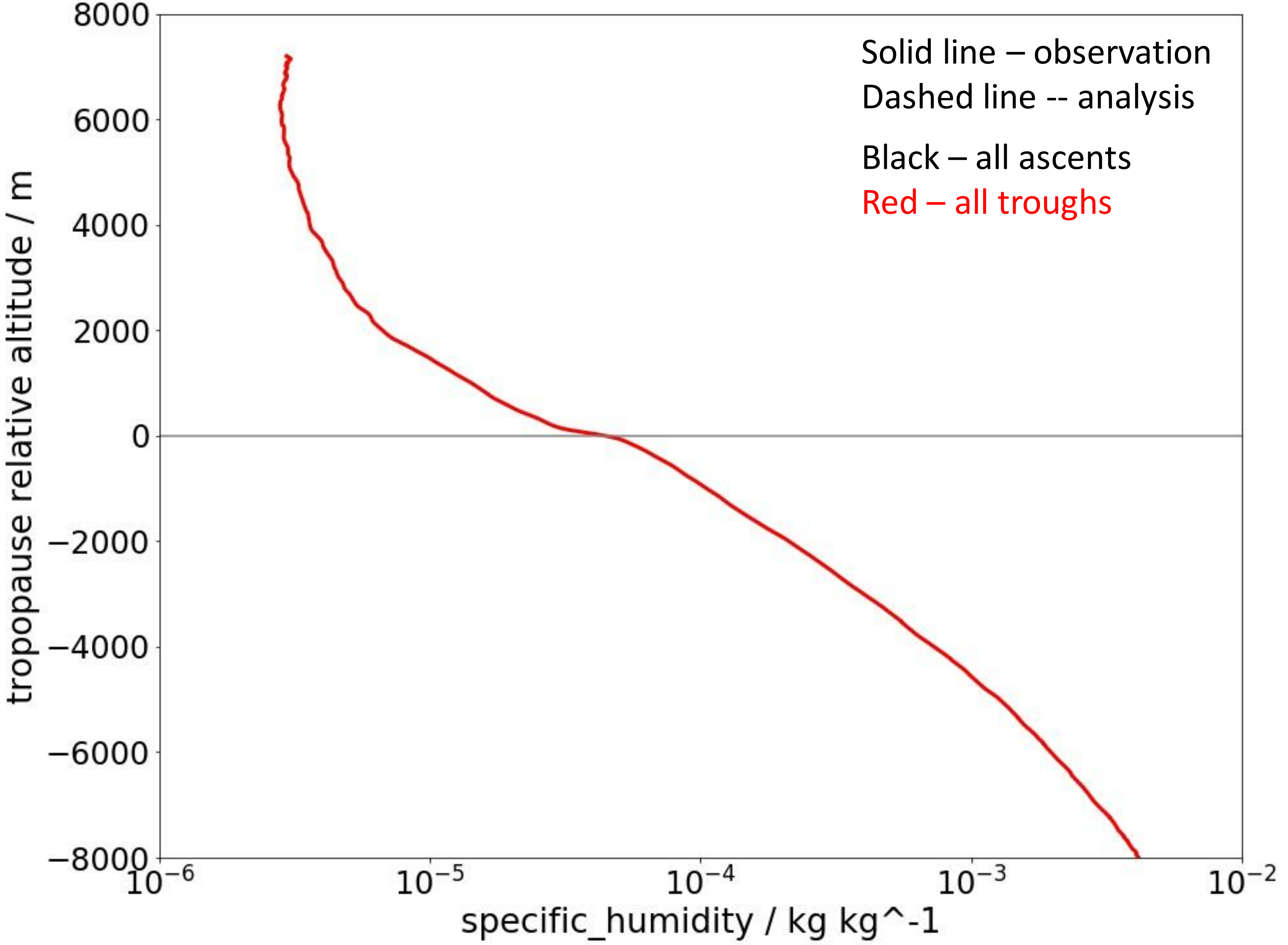

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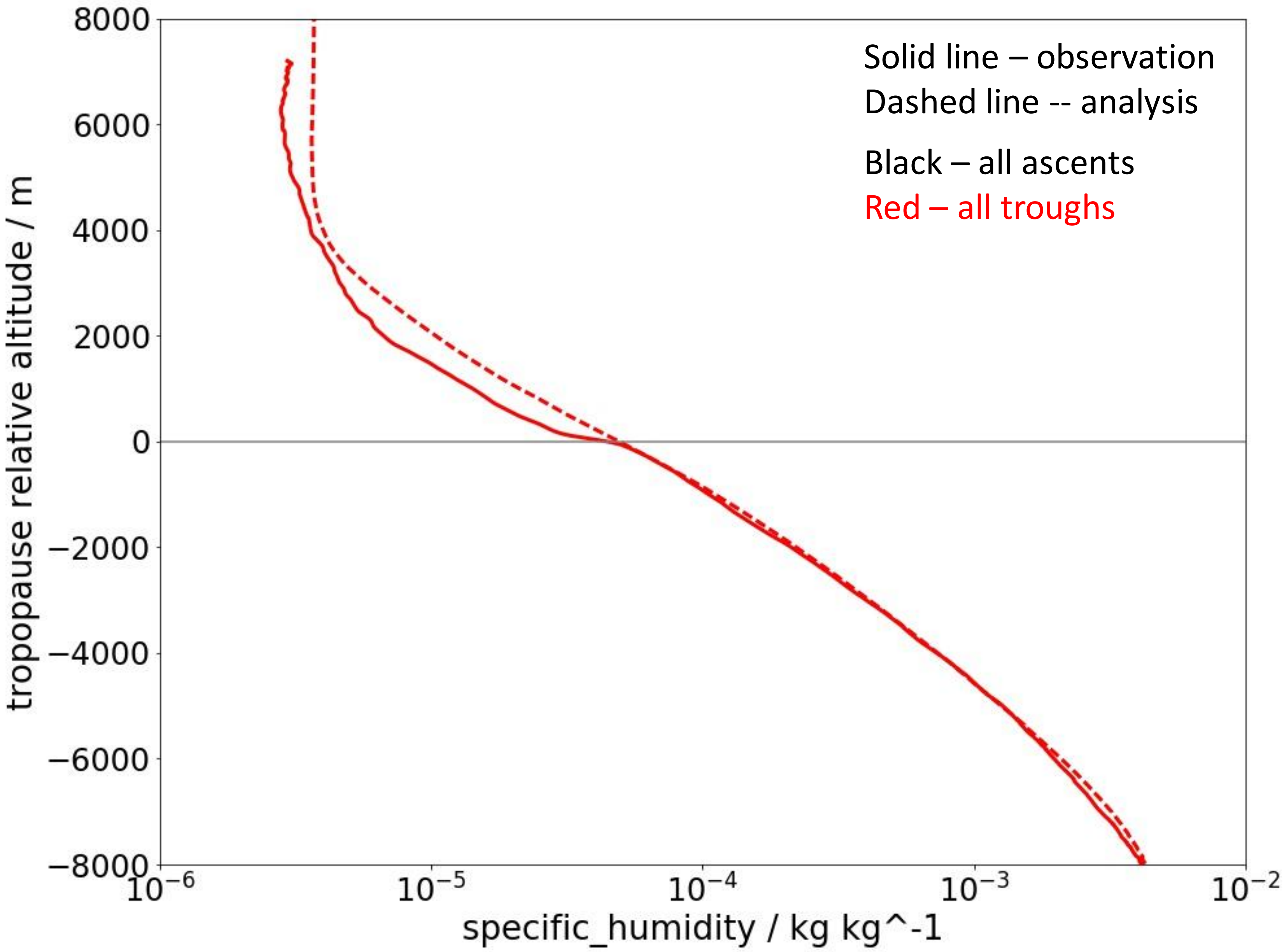

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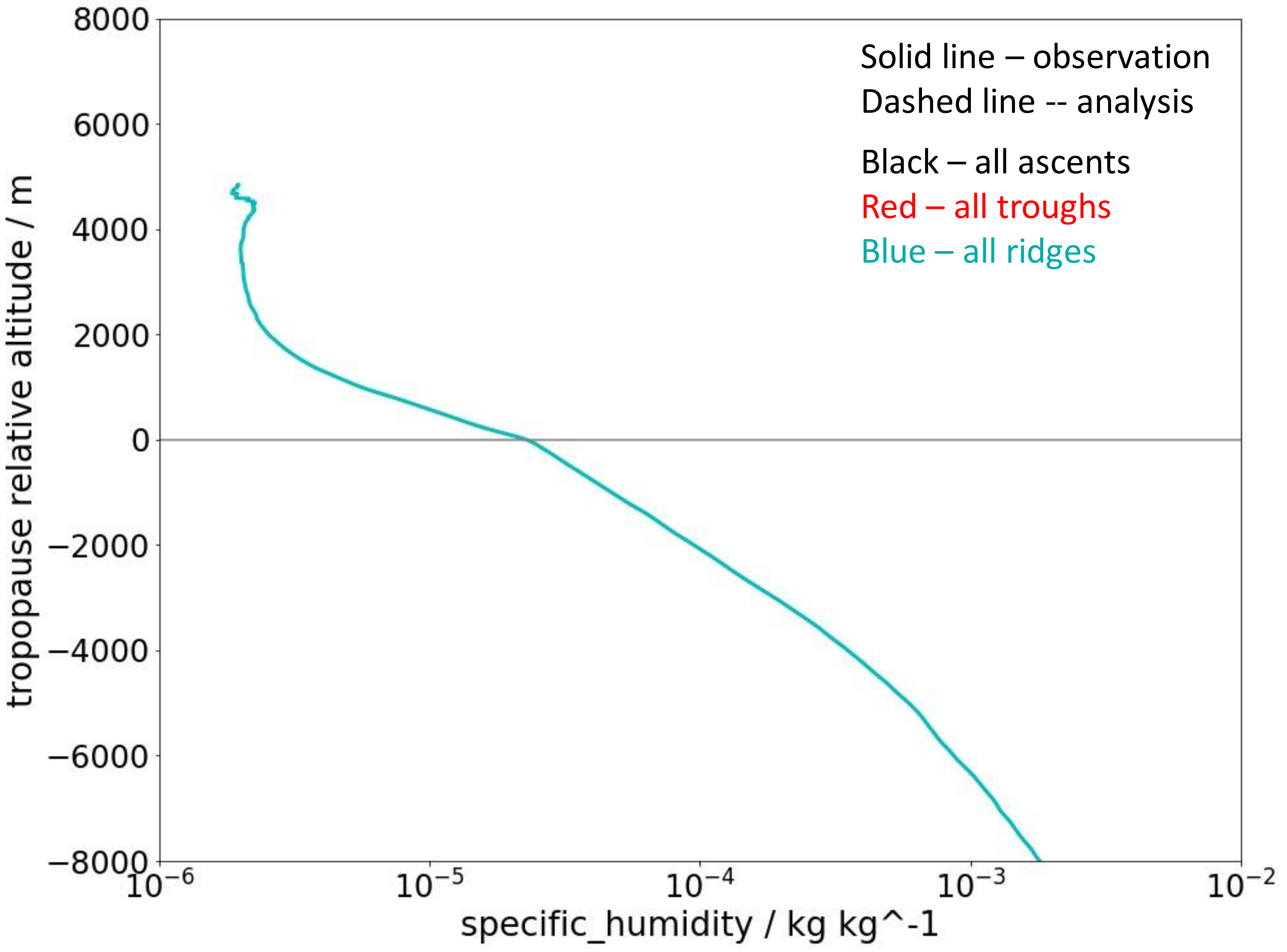

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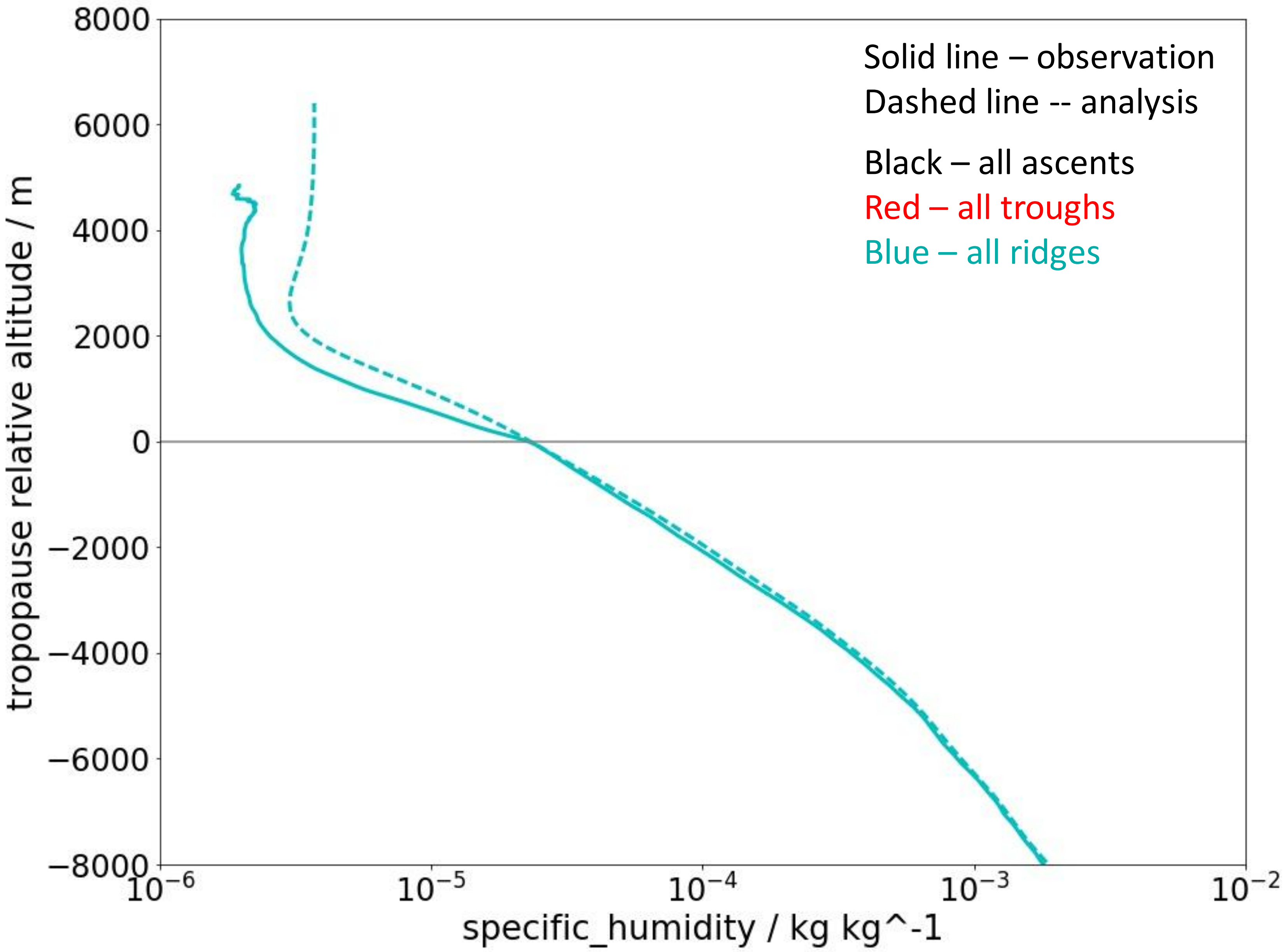

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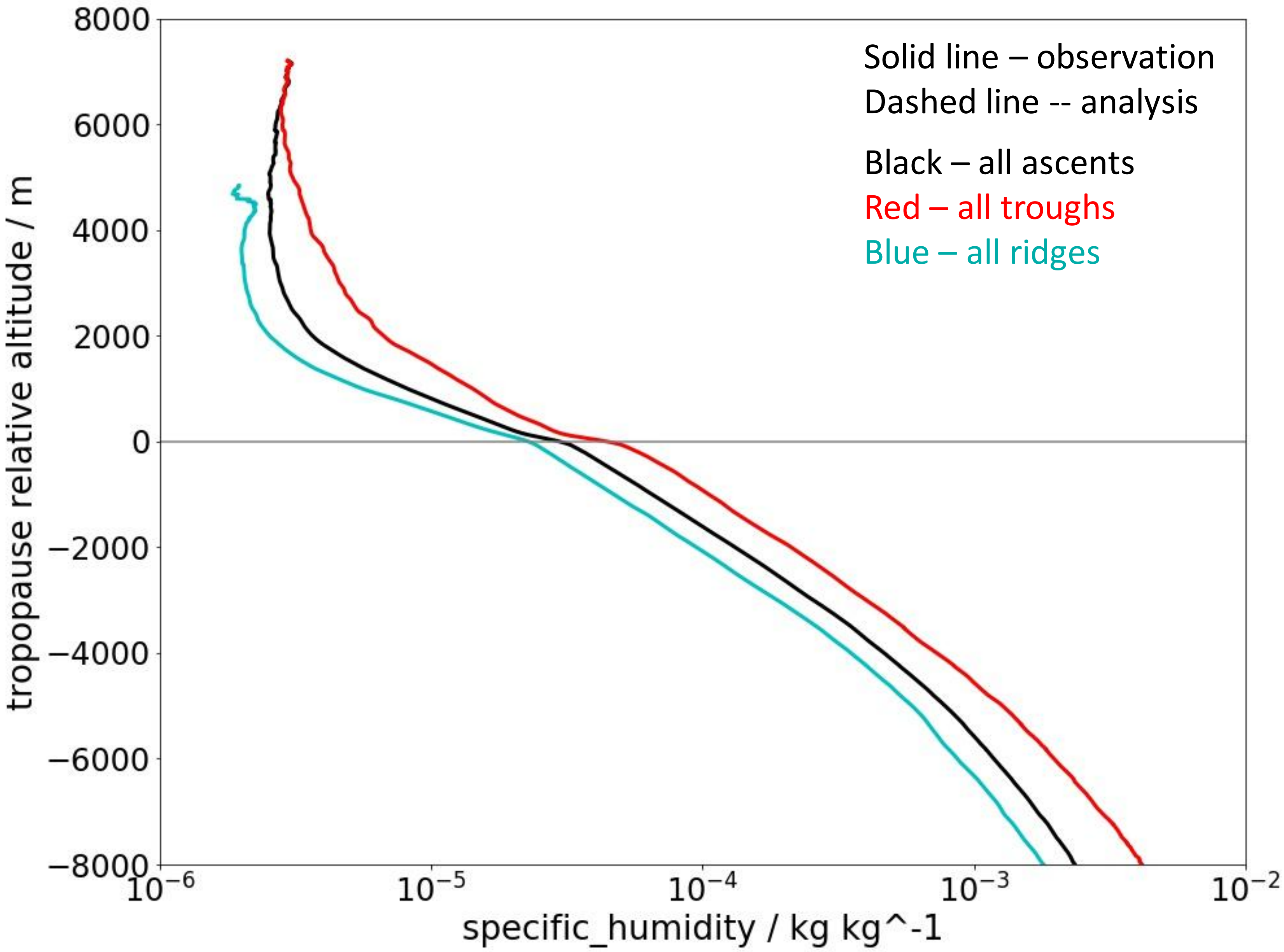

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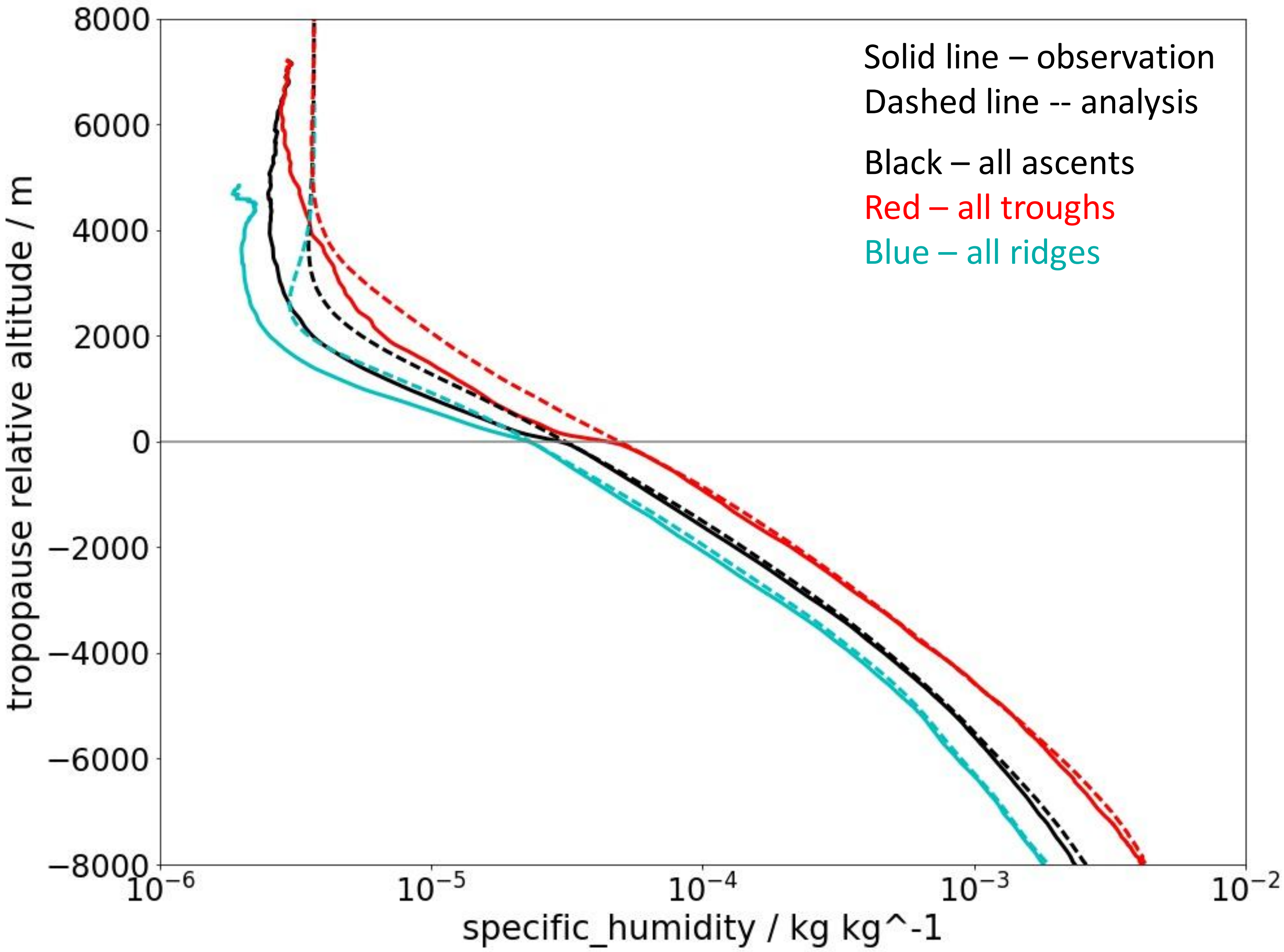

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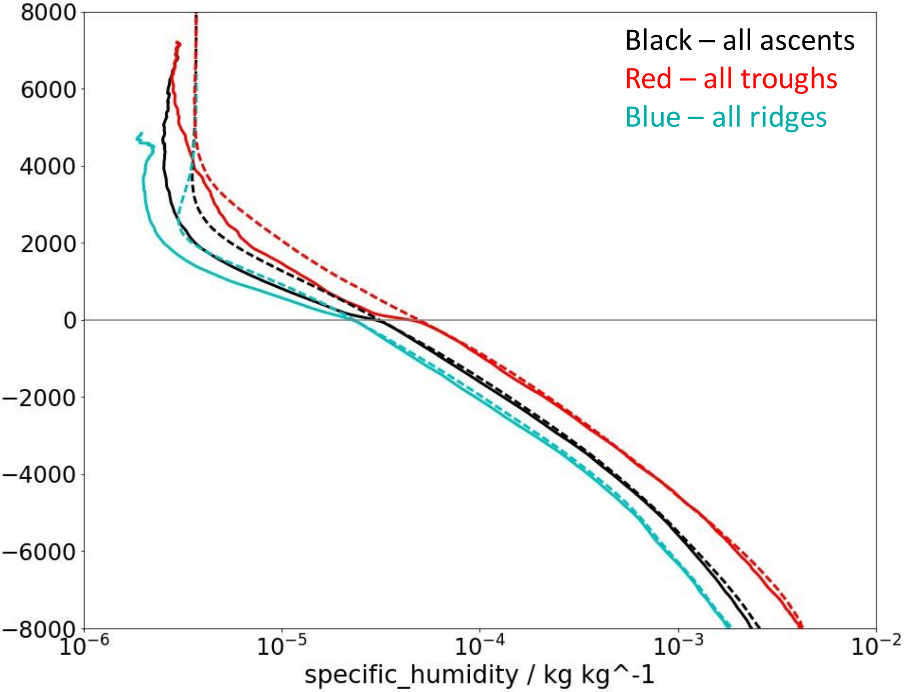
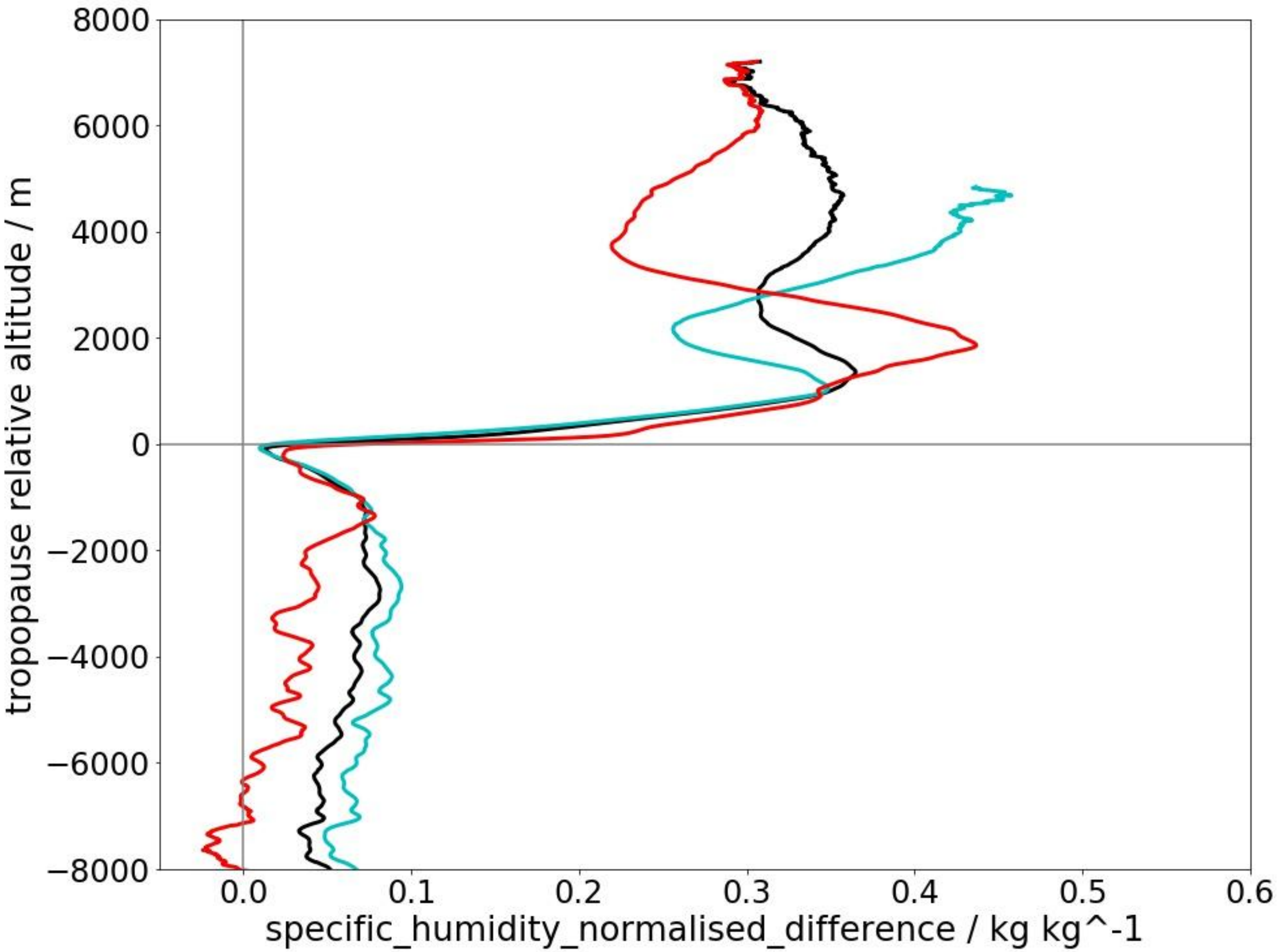
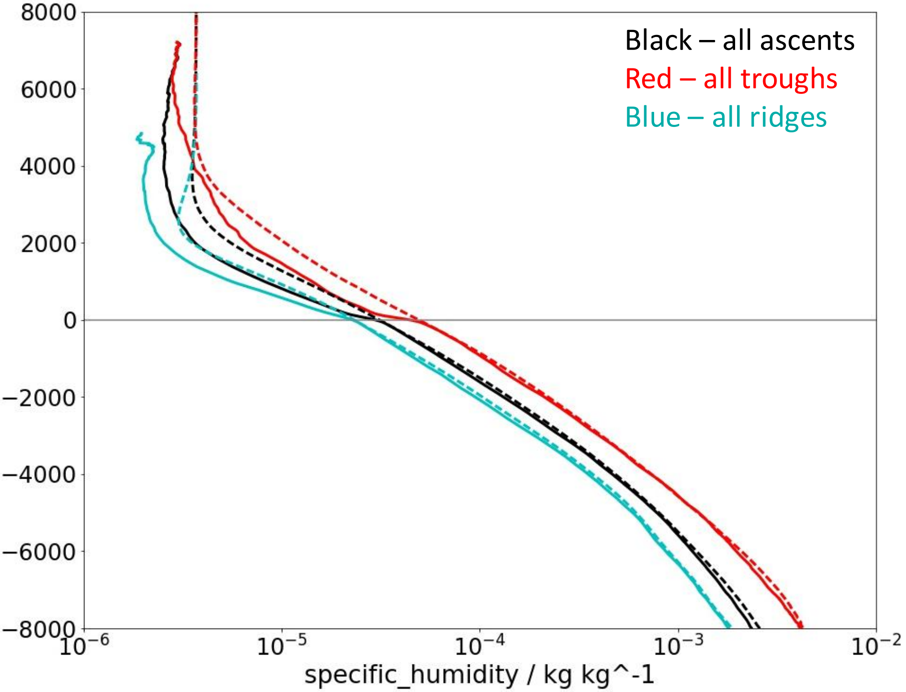
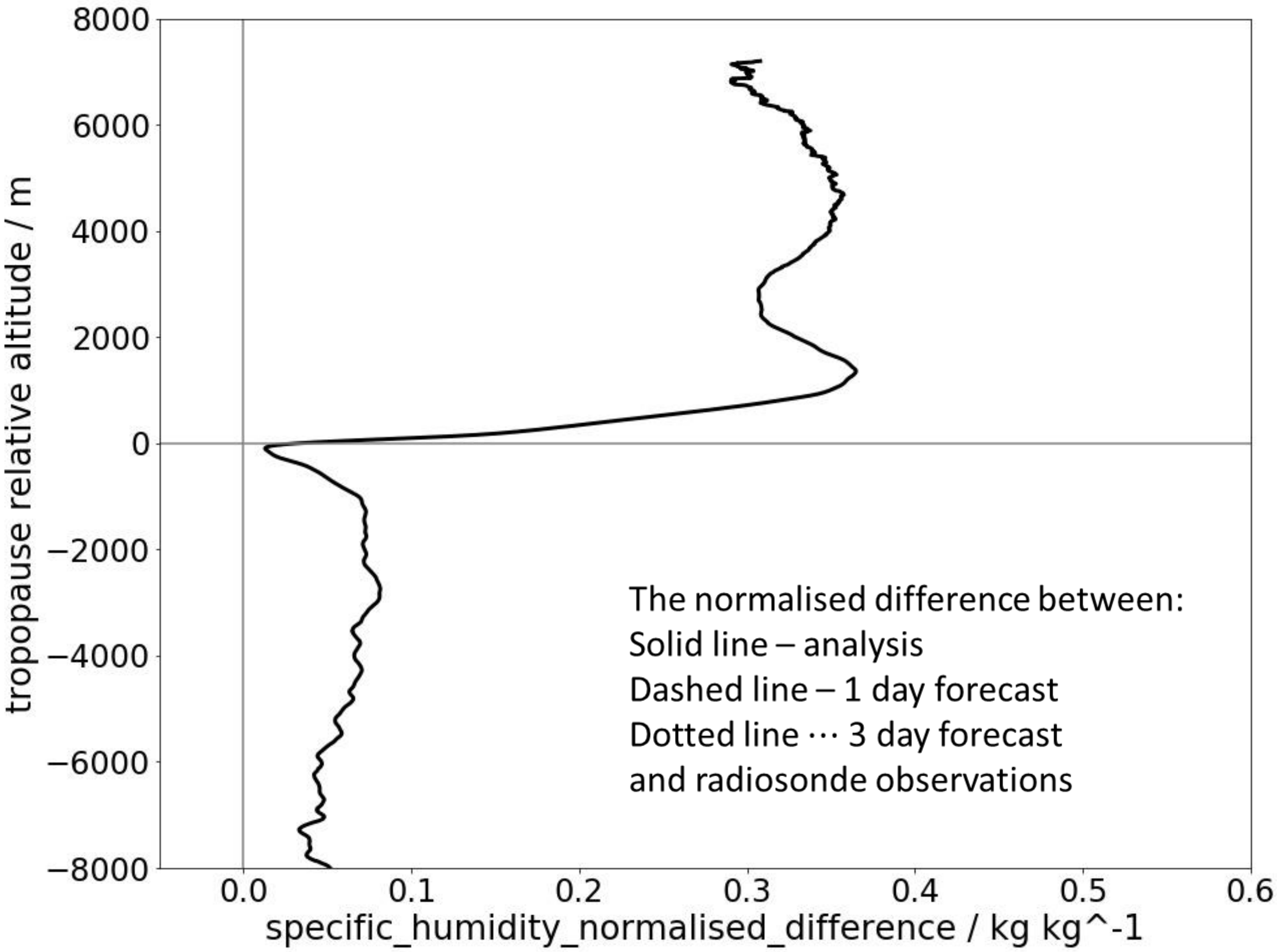


Comparison between radiosonde specific humidity and the UM analysis and forecast



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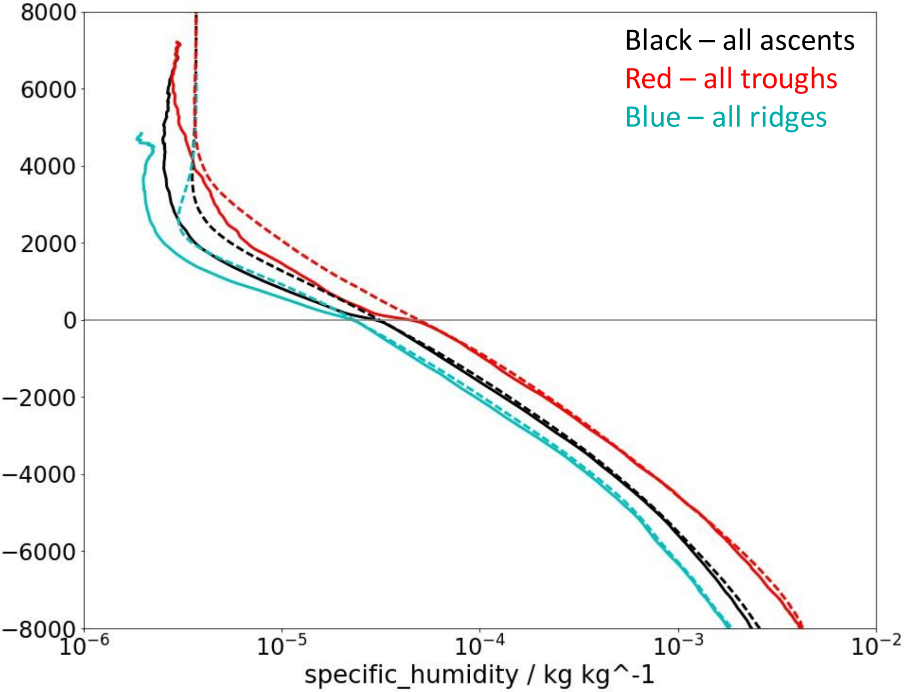


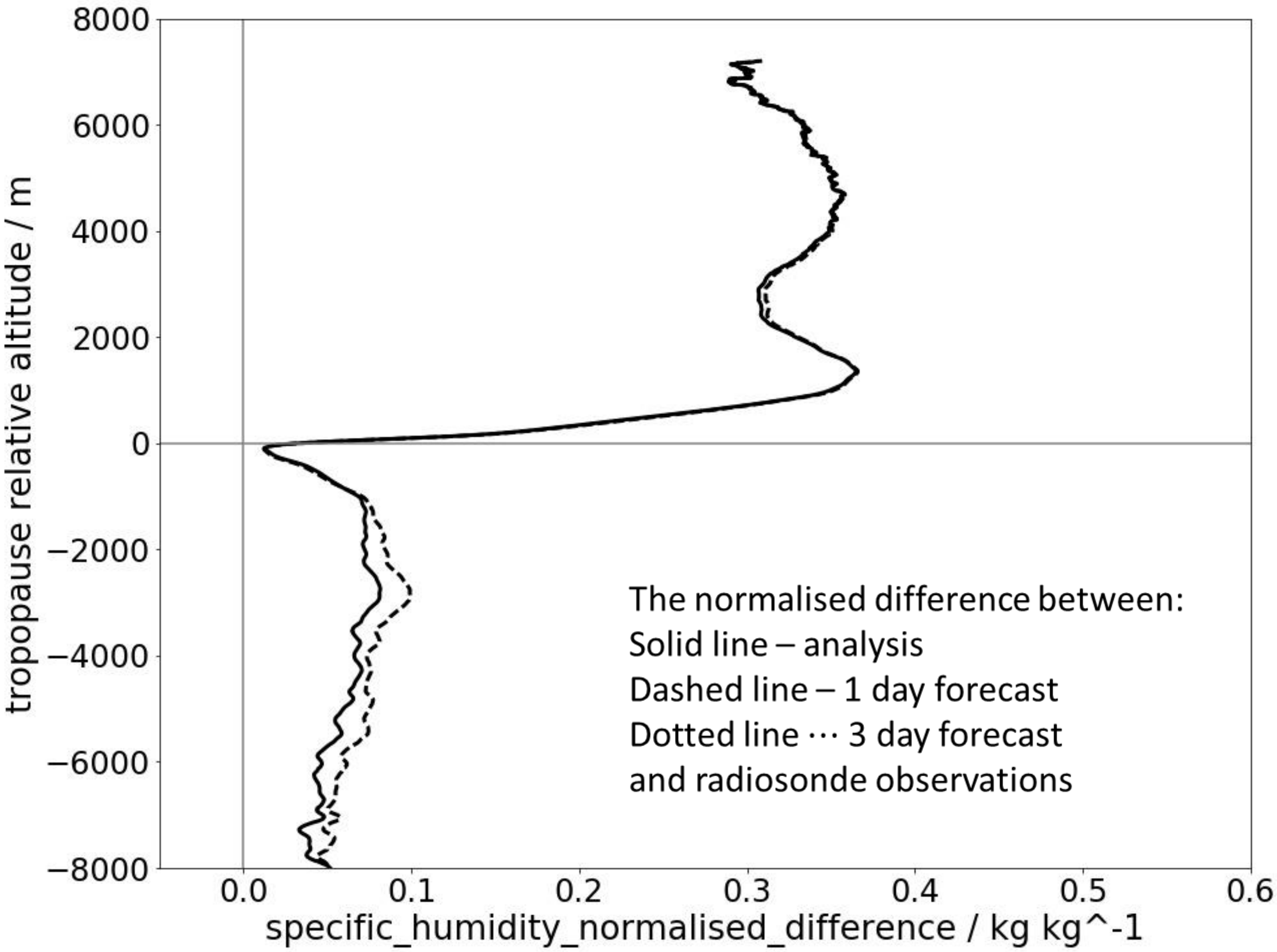

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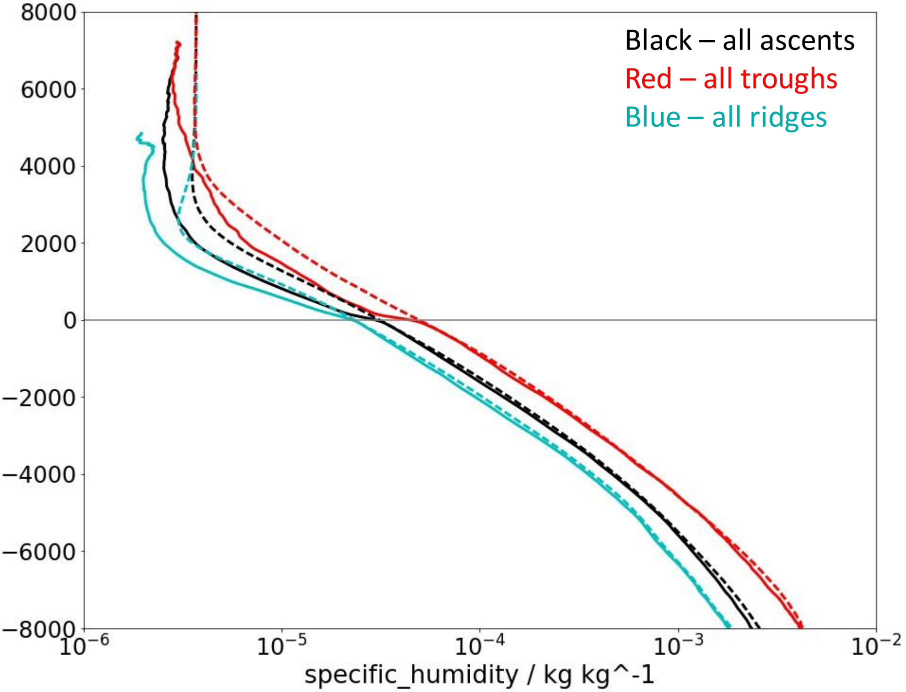


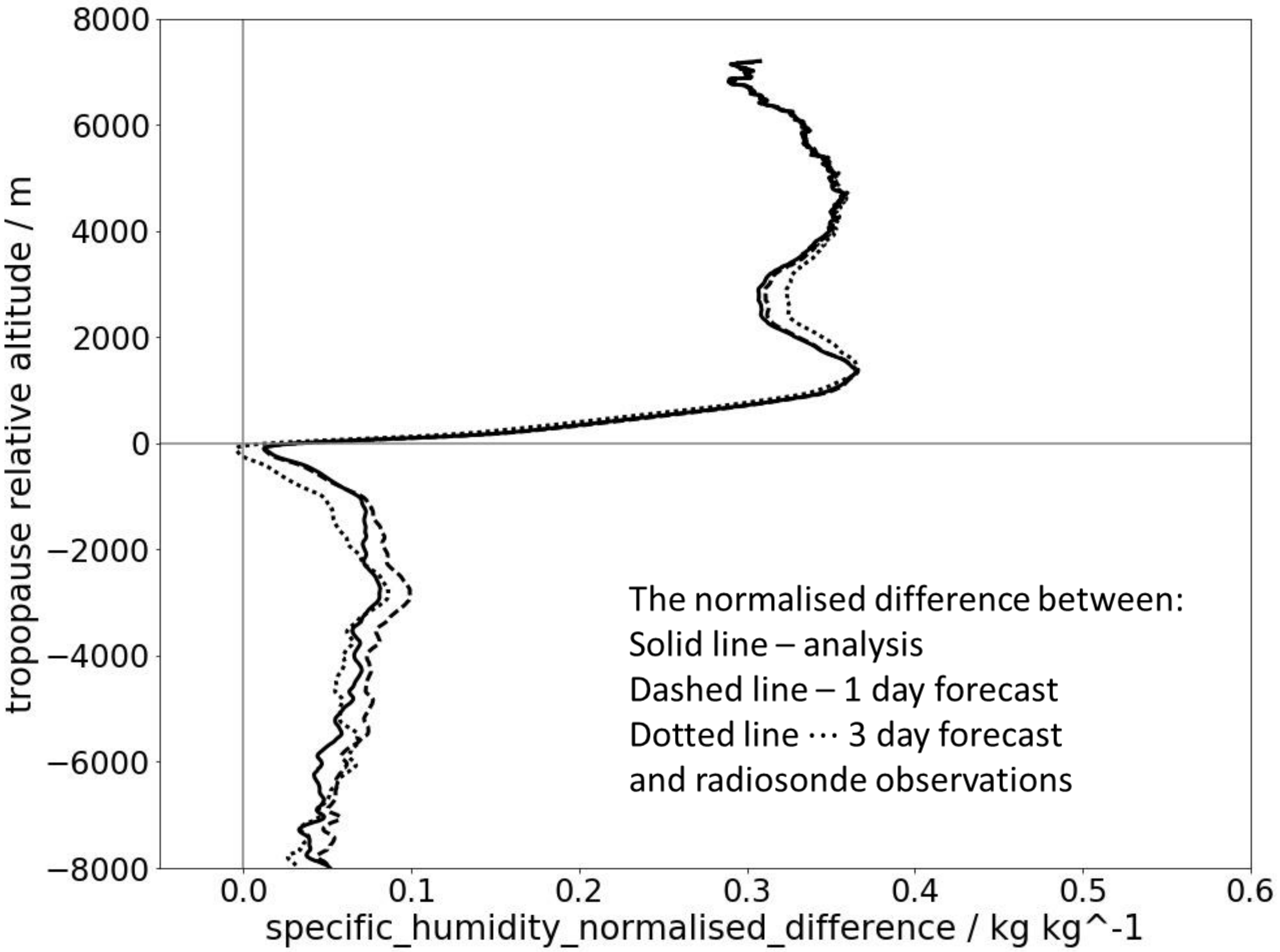

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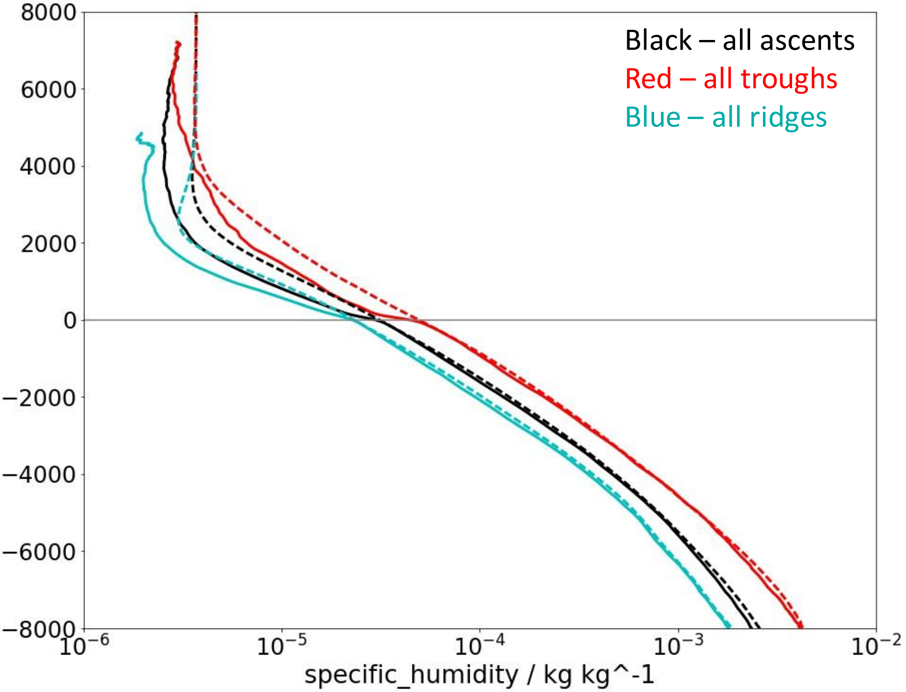


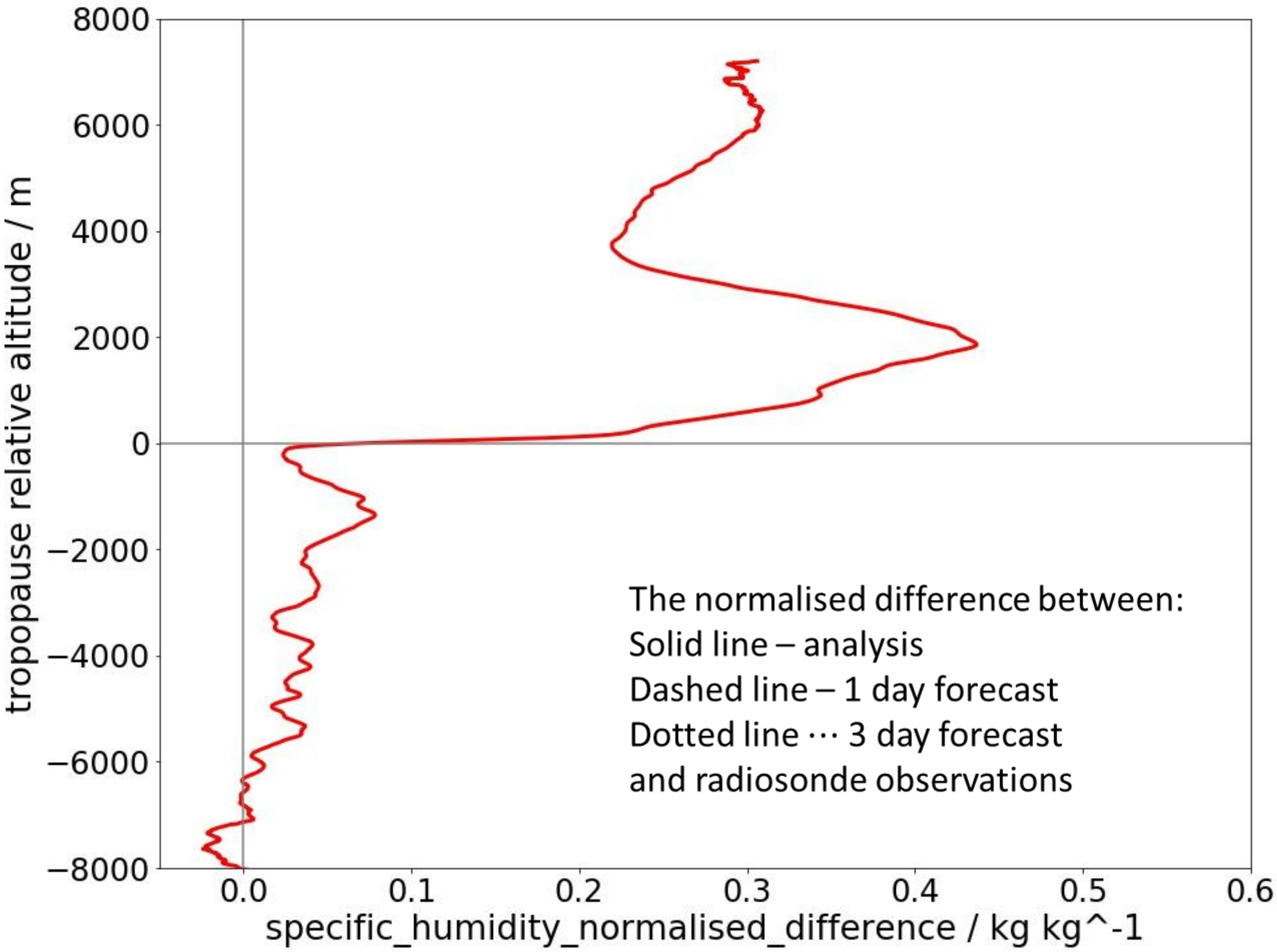

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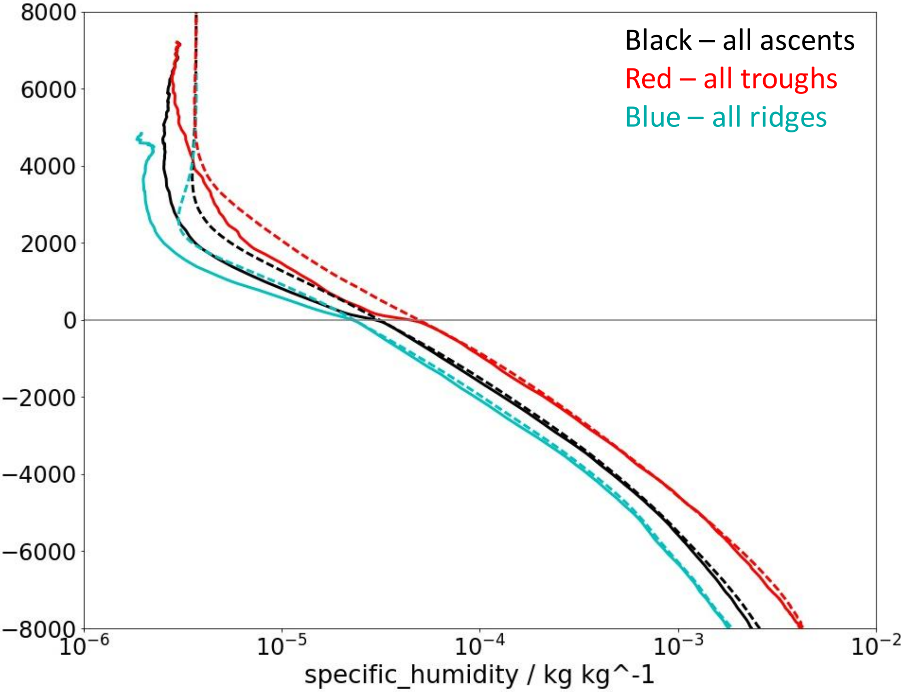


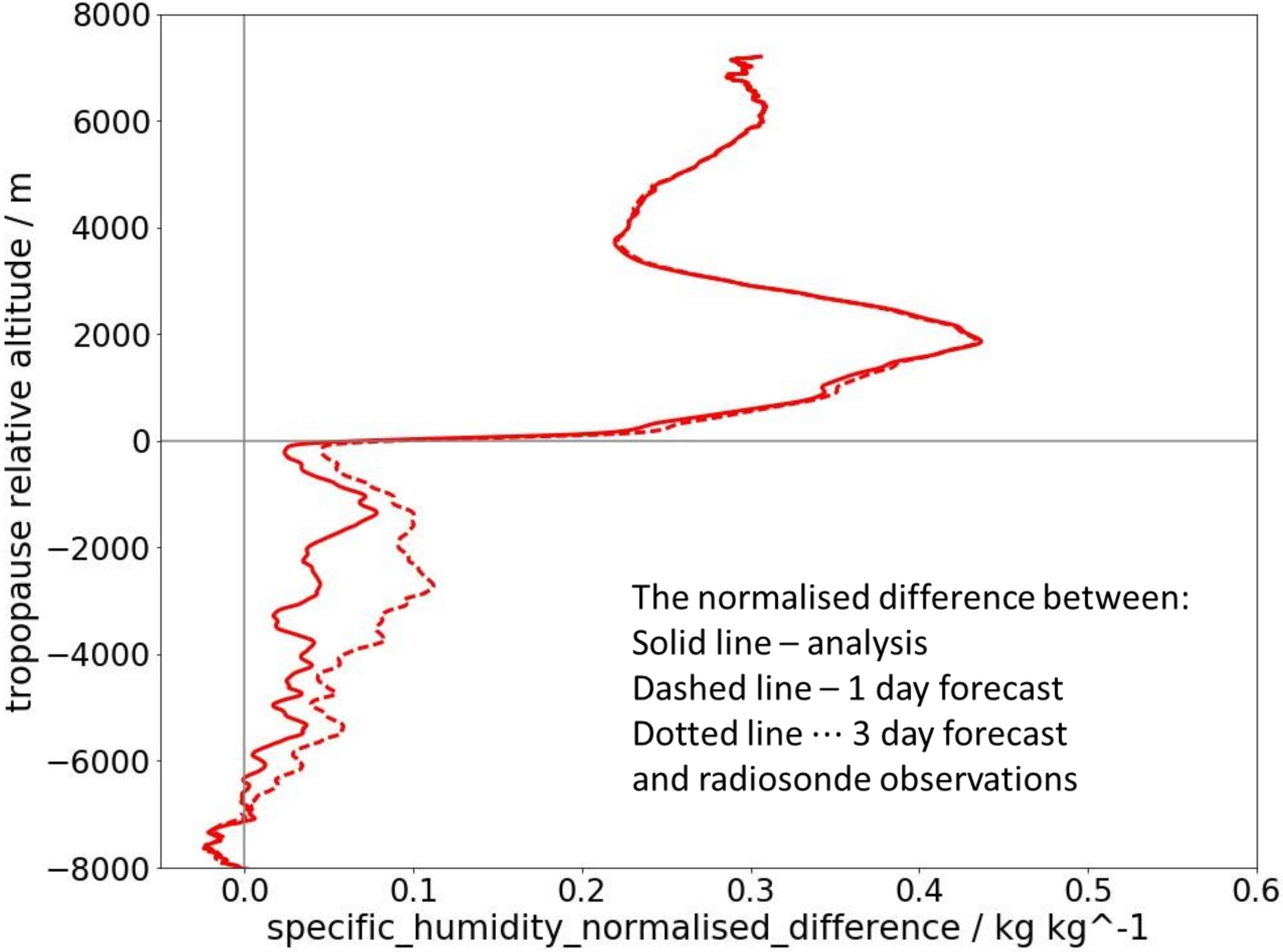

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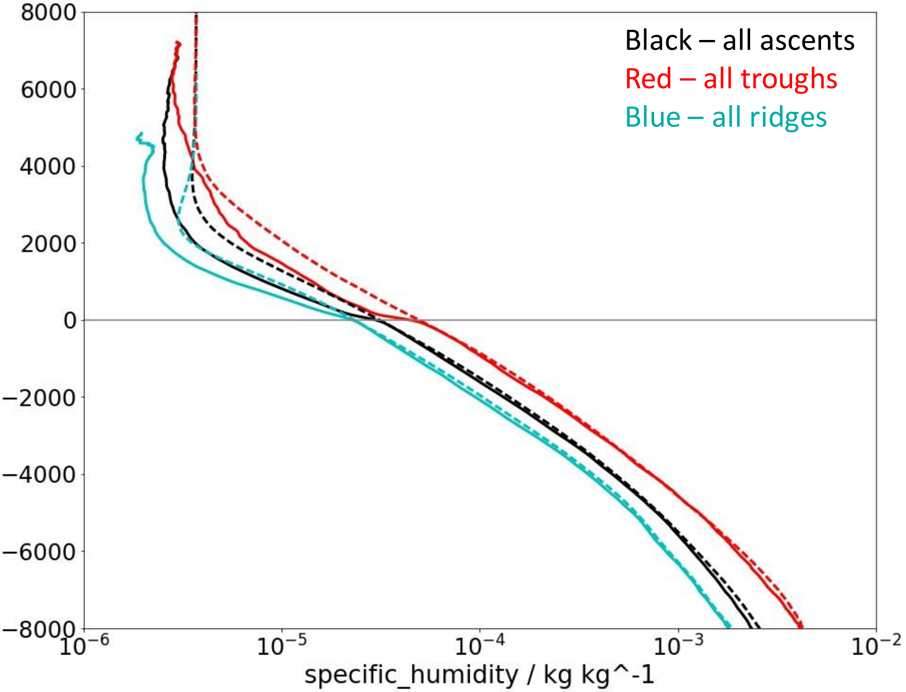


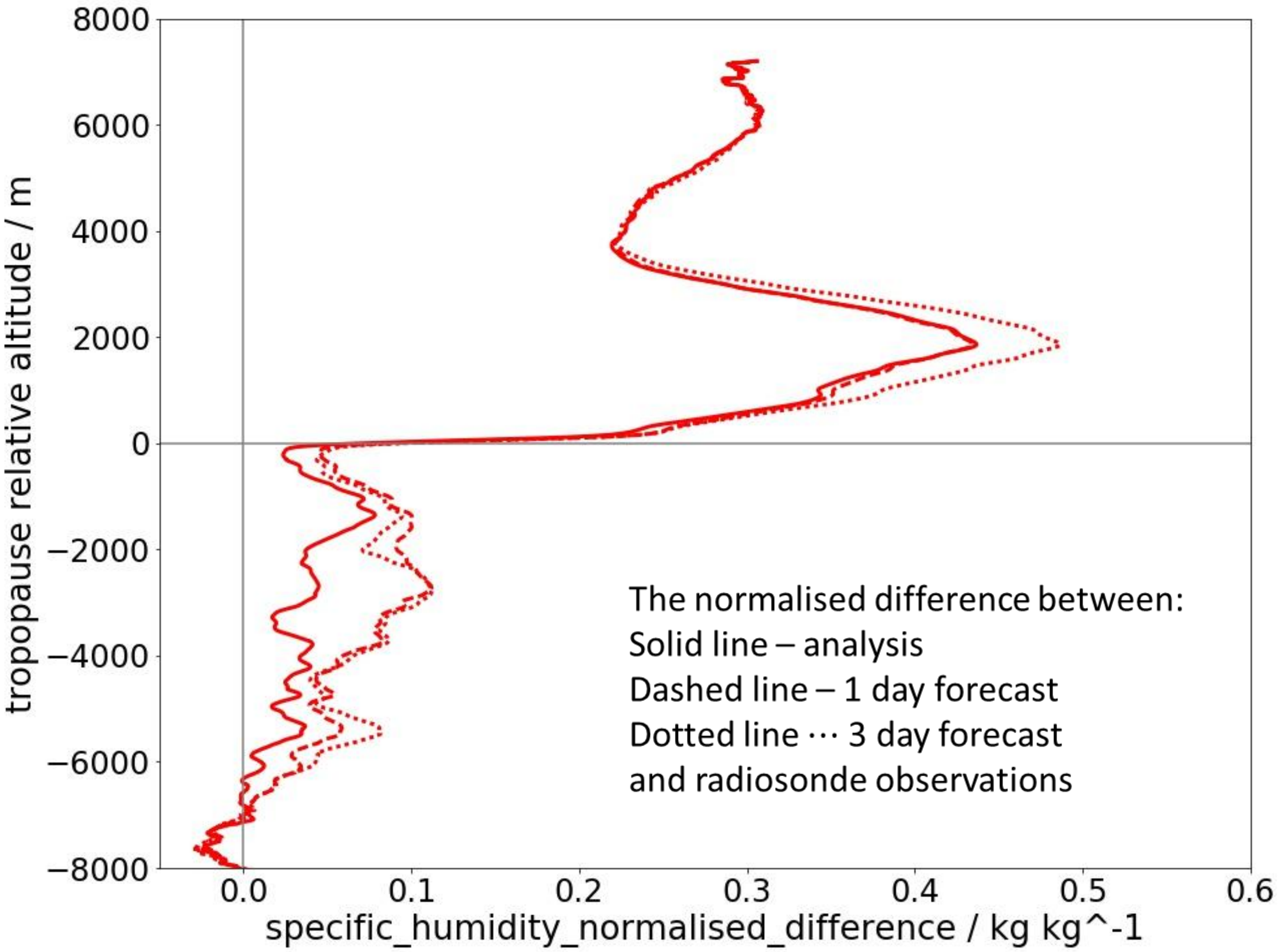

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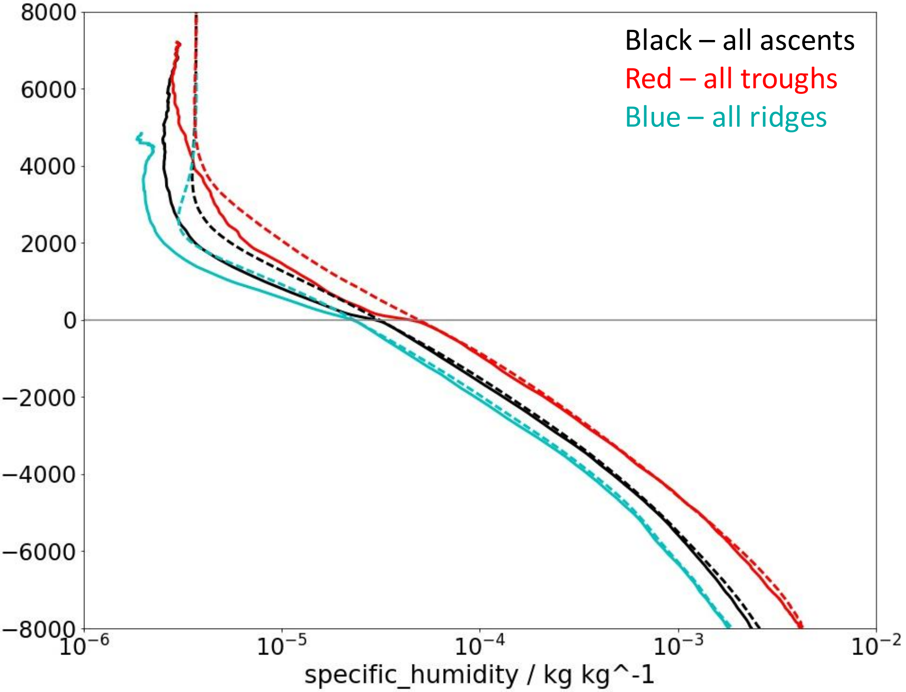


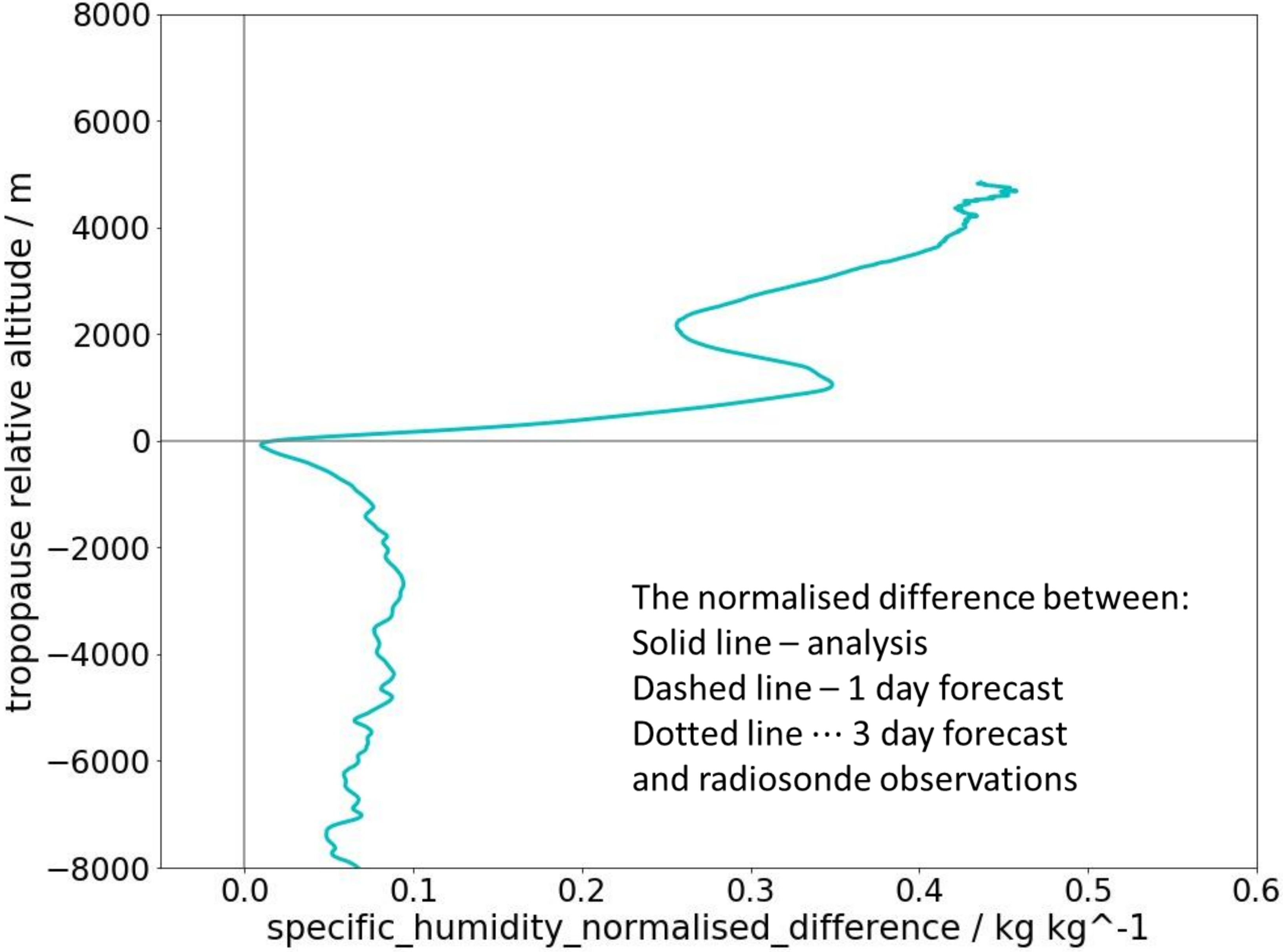

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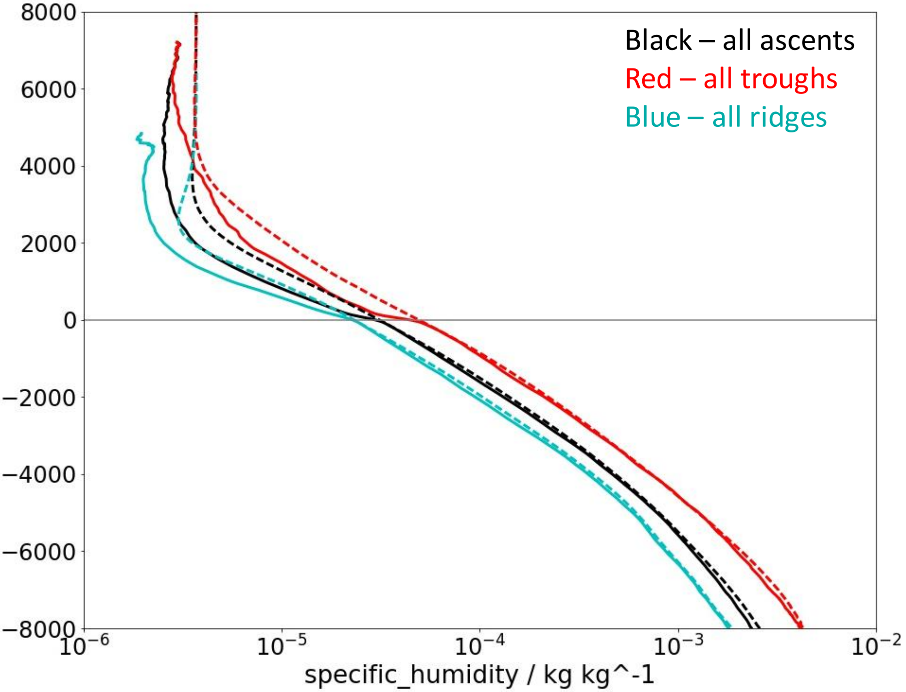


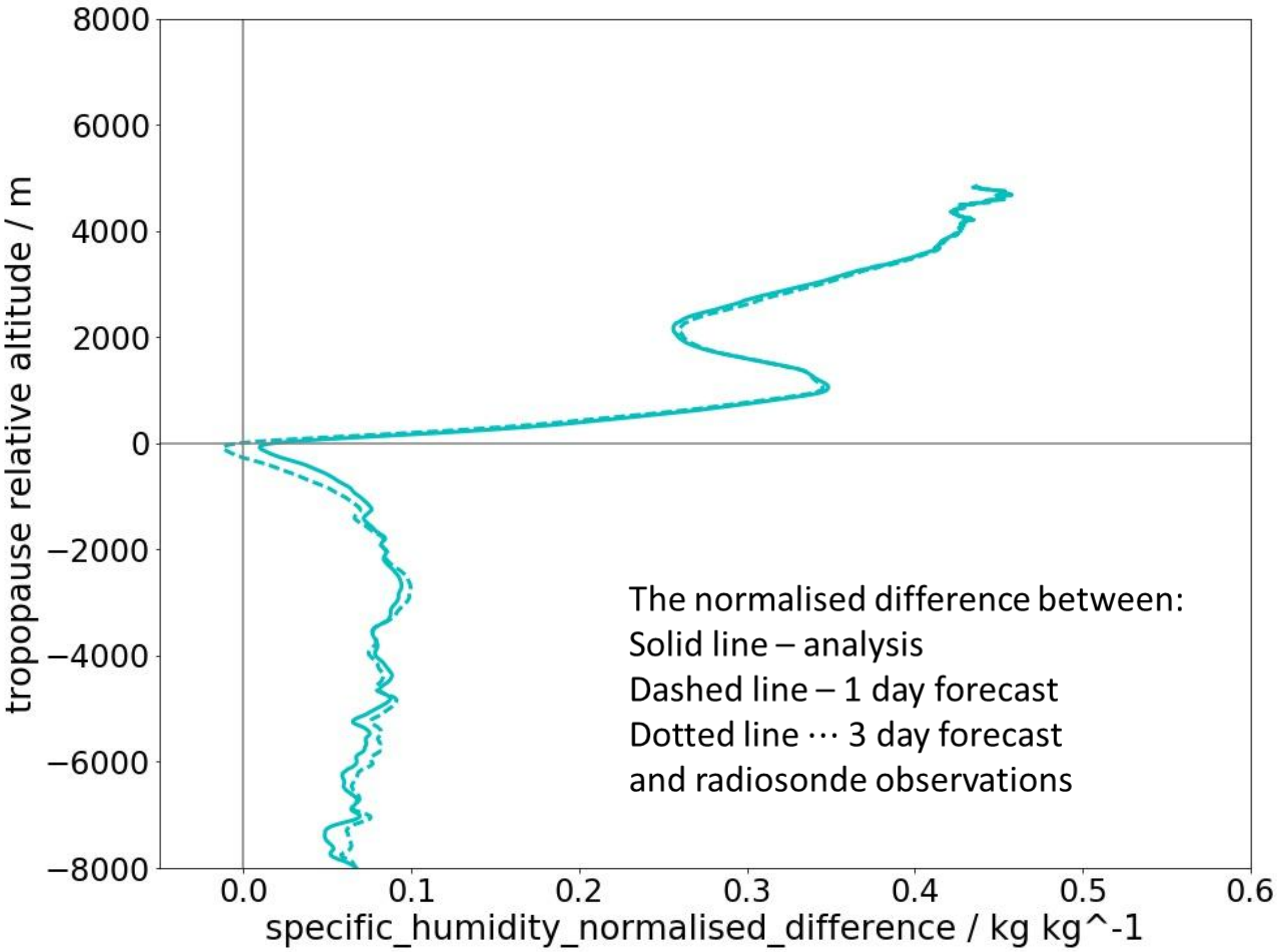

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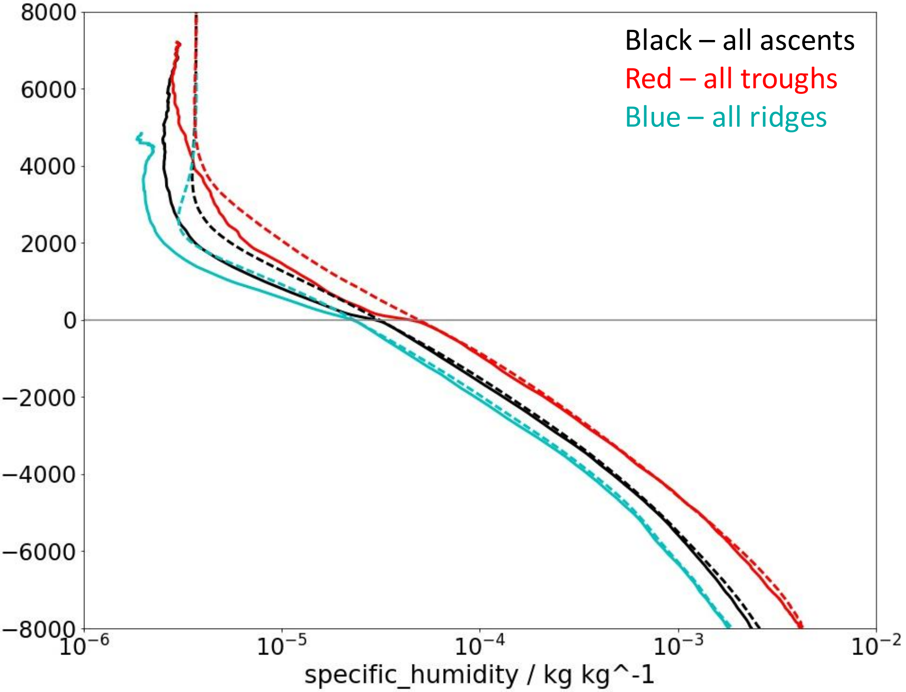


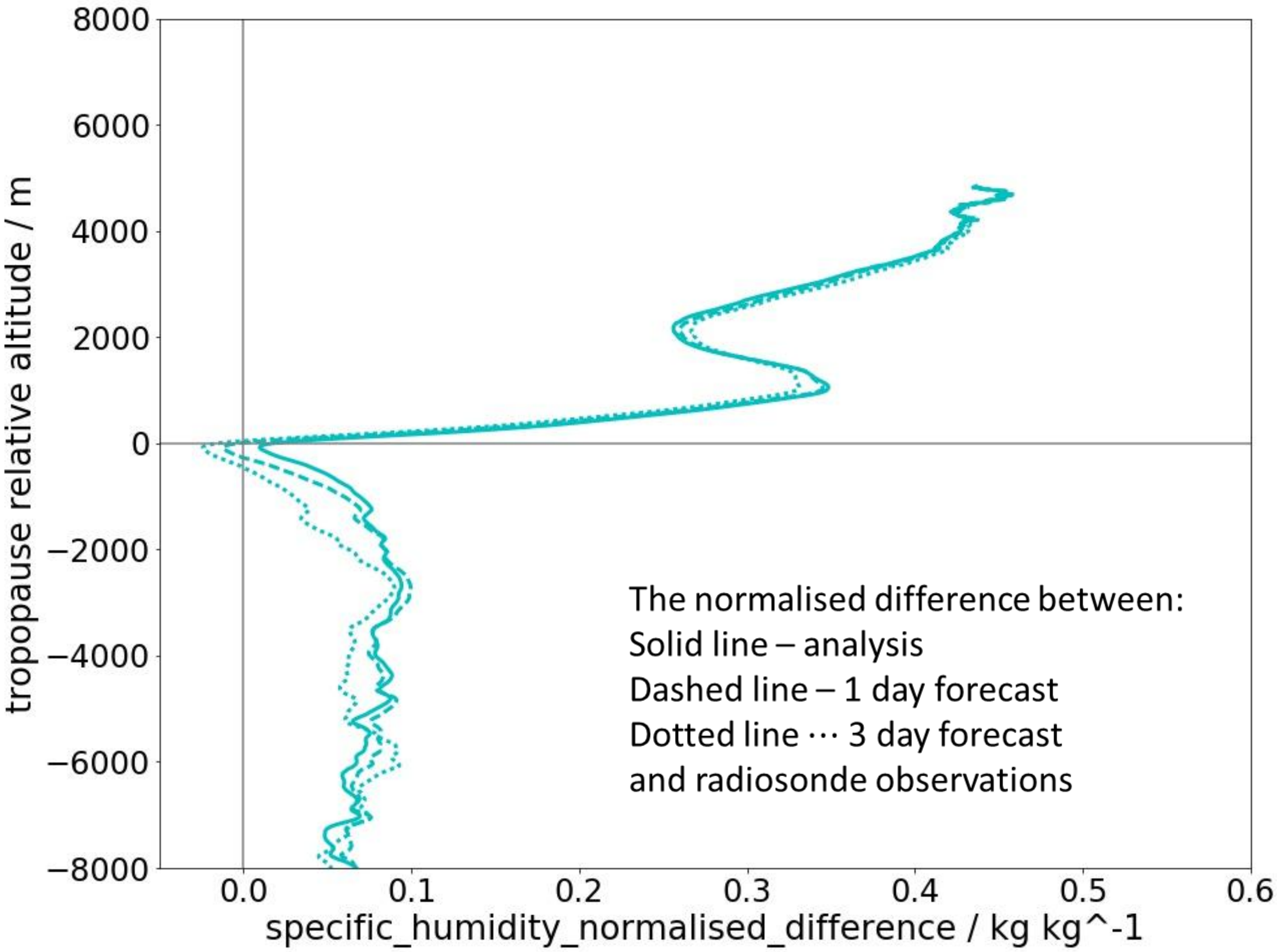

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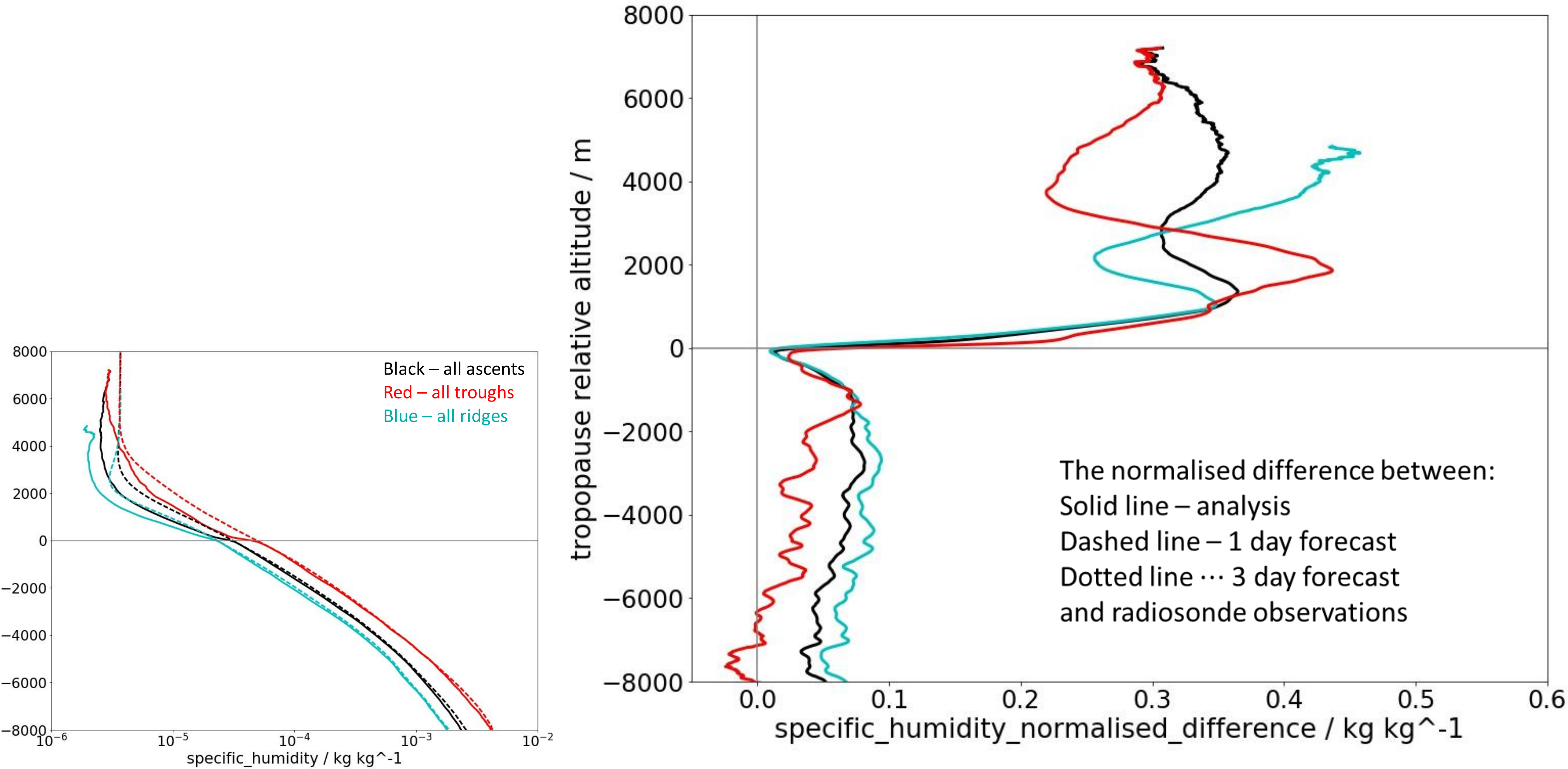
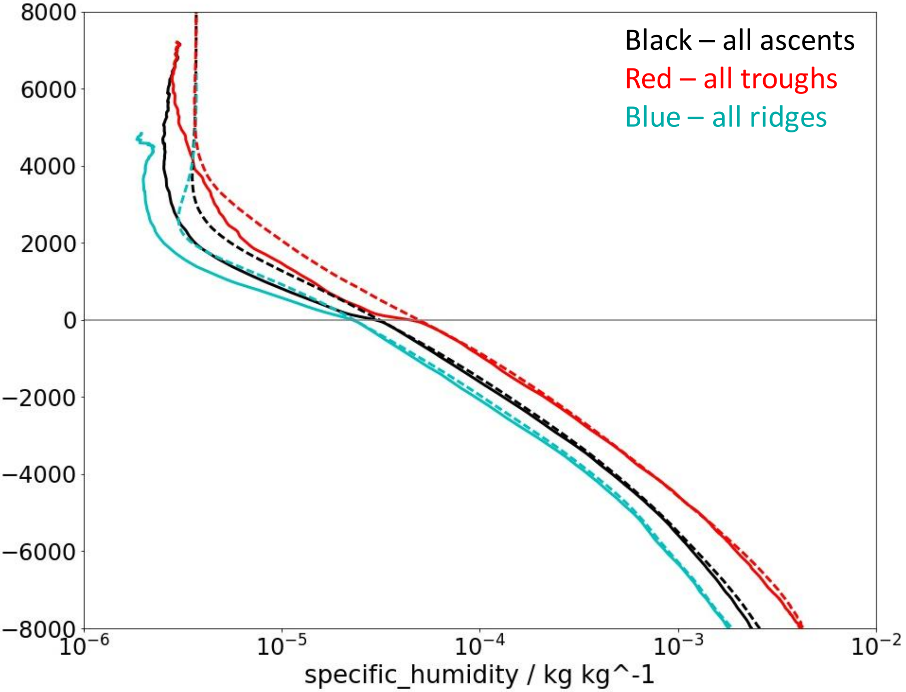
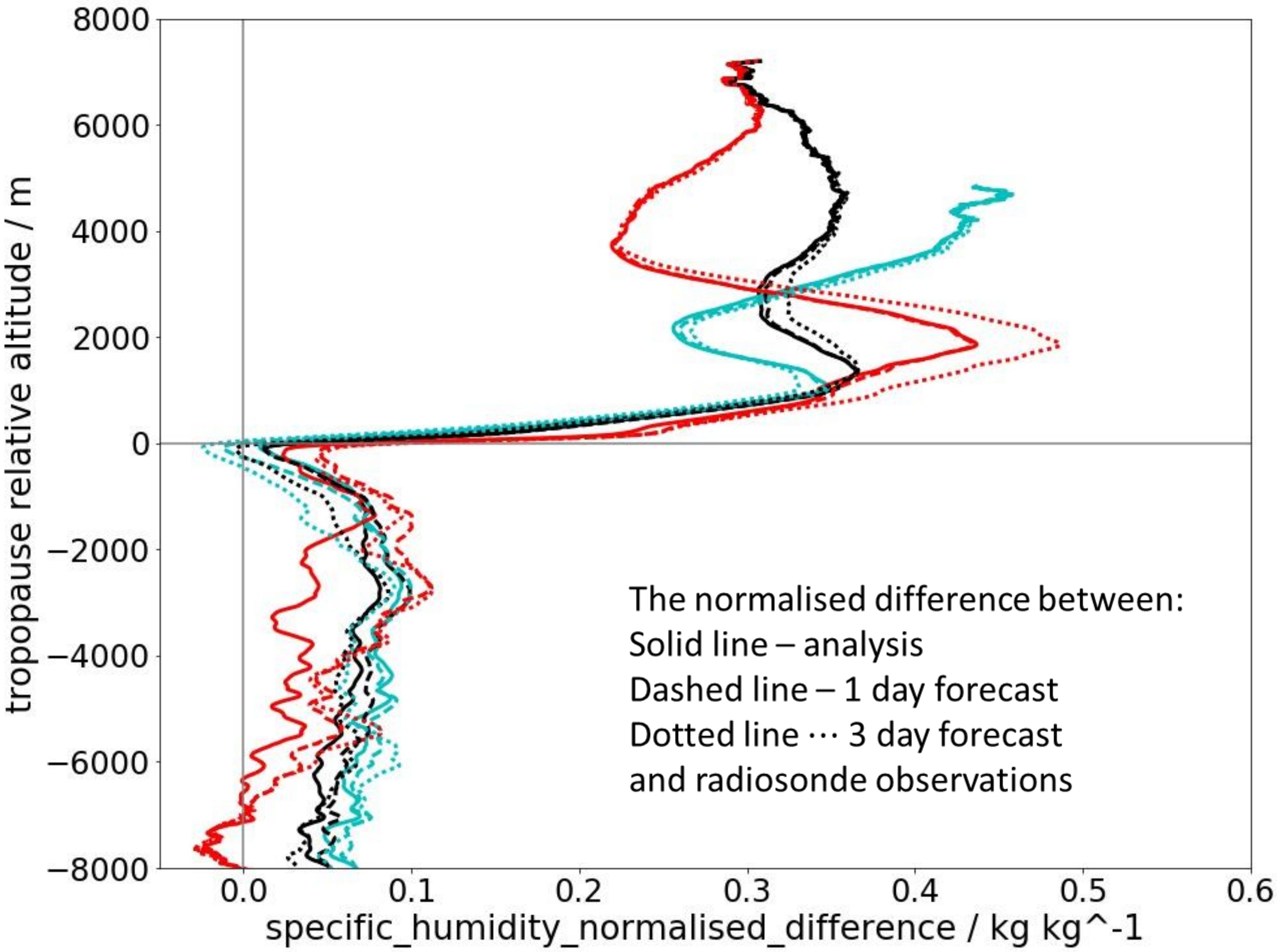


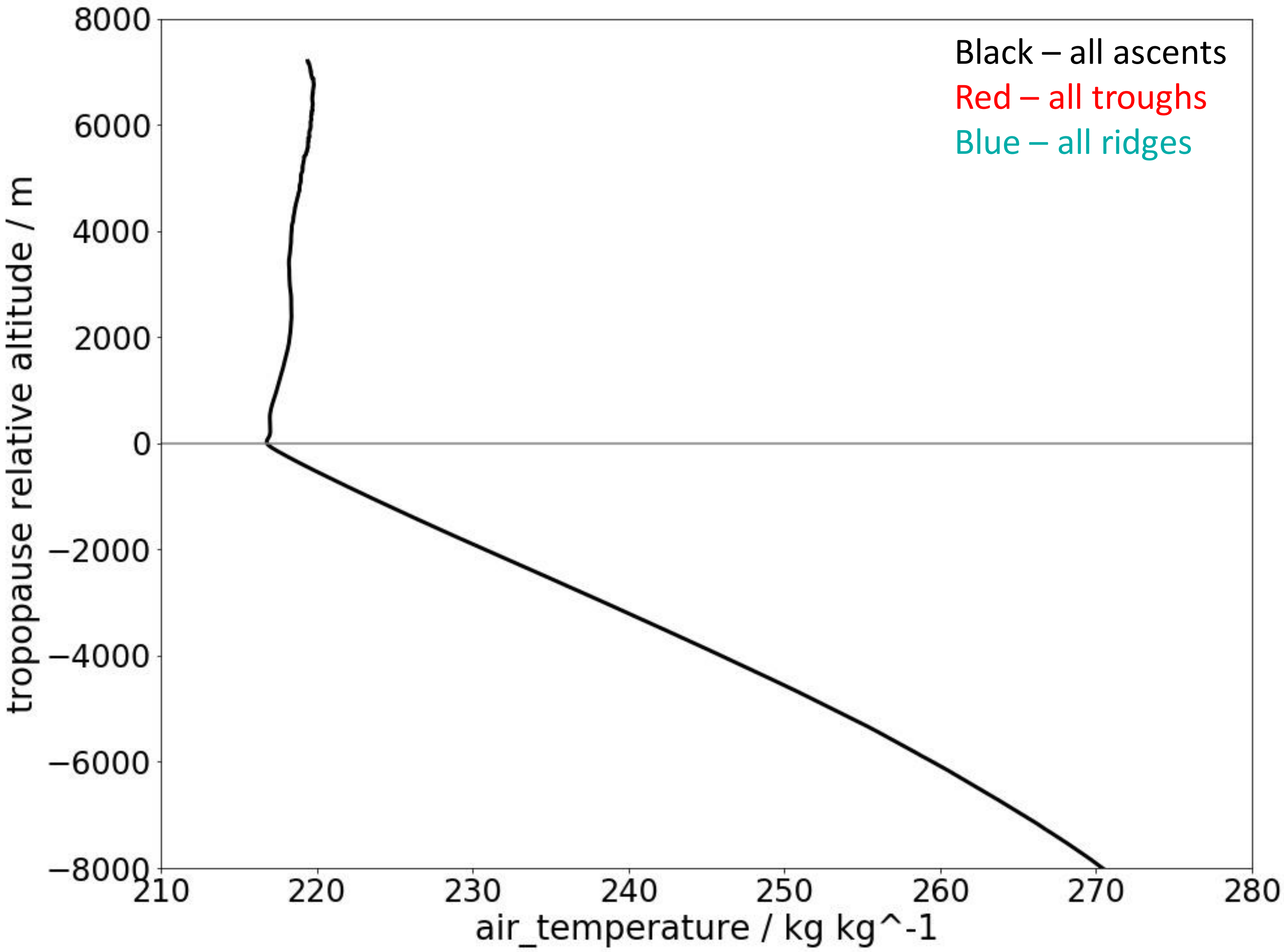
# Comparison between radiosonde specific humidity and the UM analysis and forecast

The humidity bias in the lower stratosphere increases slightly with lead time, with the largest increase in troughs, where the bias was largest in the analysis

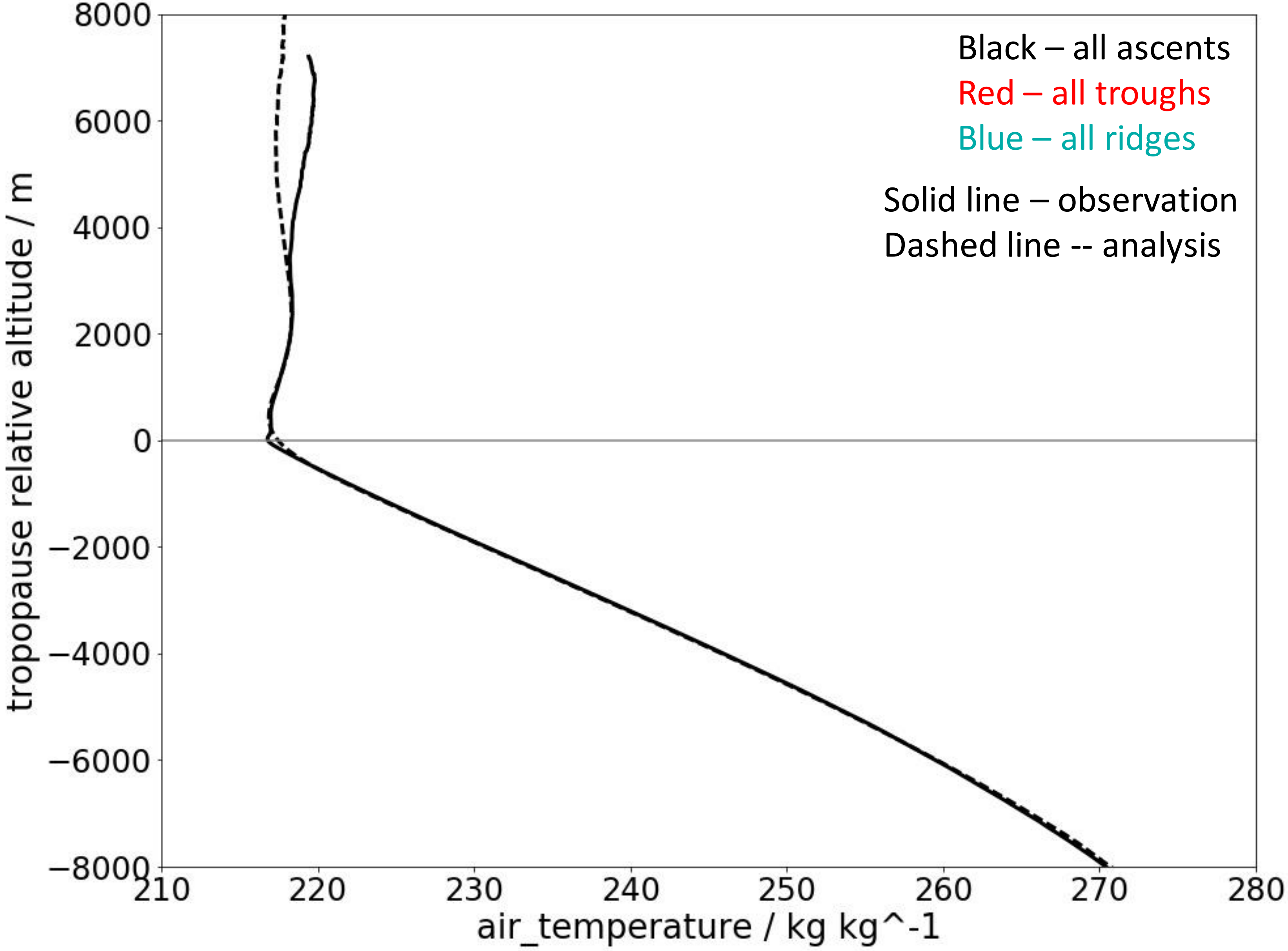


radiosonde temperature

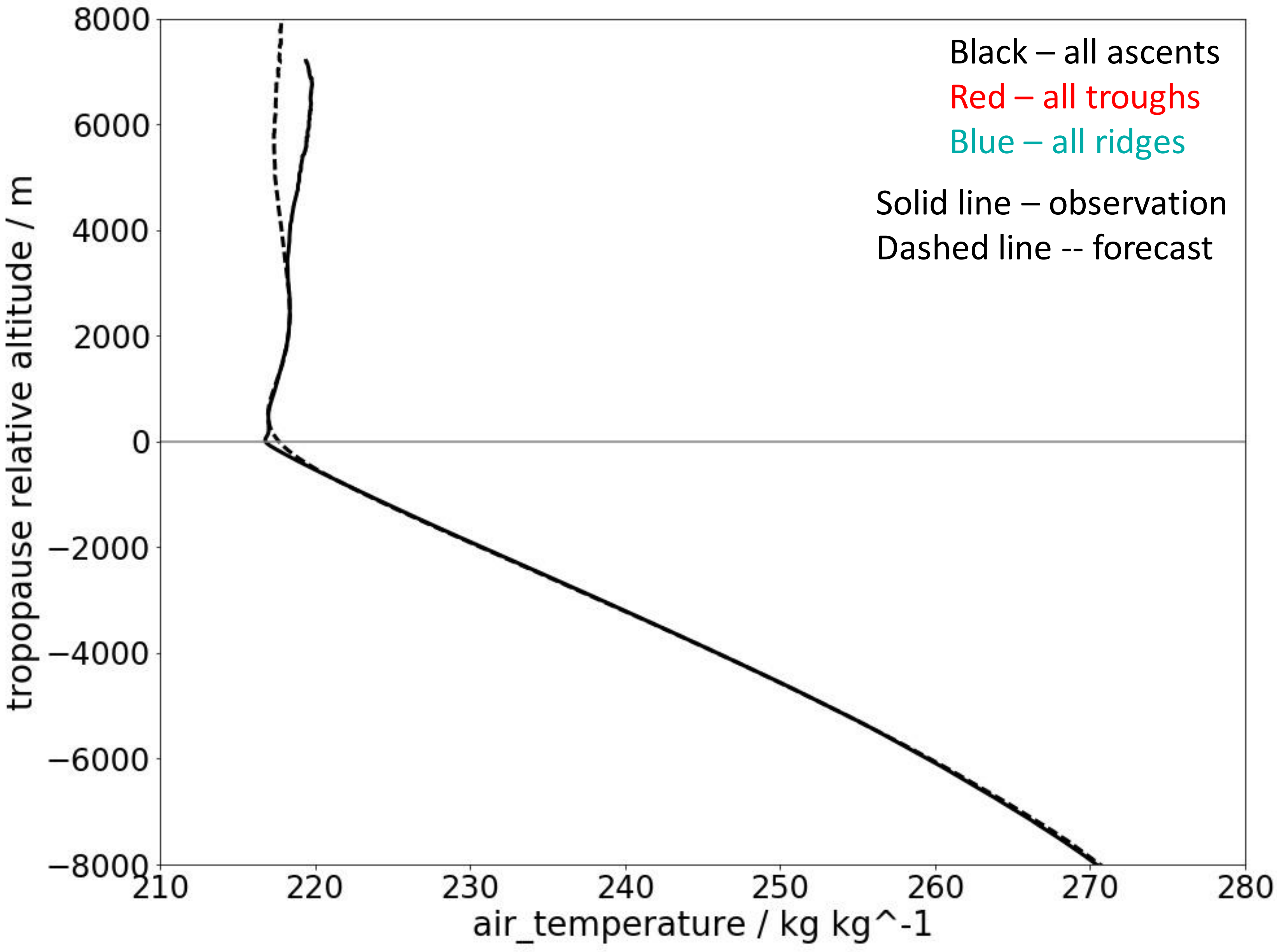


Comparison between radiosonde temperature and the UM analysis




Sharp changes in lapse rate at the tropopause in observations are more smoothed out in the model

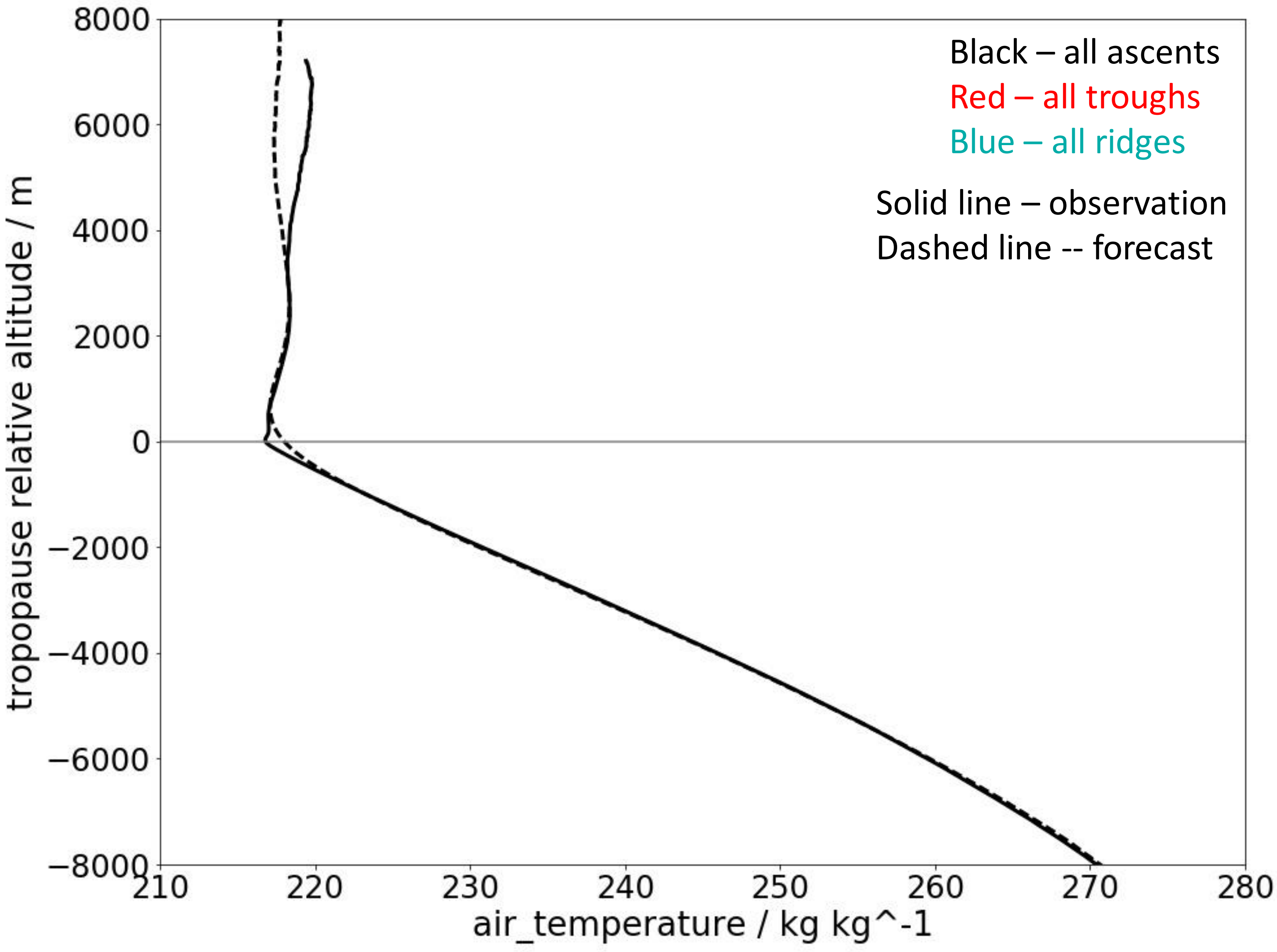
Comparison between radiosonde temperature and the UM 1 day forecast




Sharp changes in lapse rate at the tropopause in observations are more smoothed out in the model

This increases with lead time

Comparison between radiosonde temperature and the UM 3 day forecast




Sharp changes in lapse rate at the tropopause in observations are more smoothed out in the model

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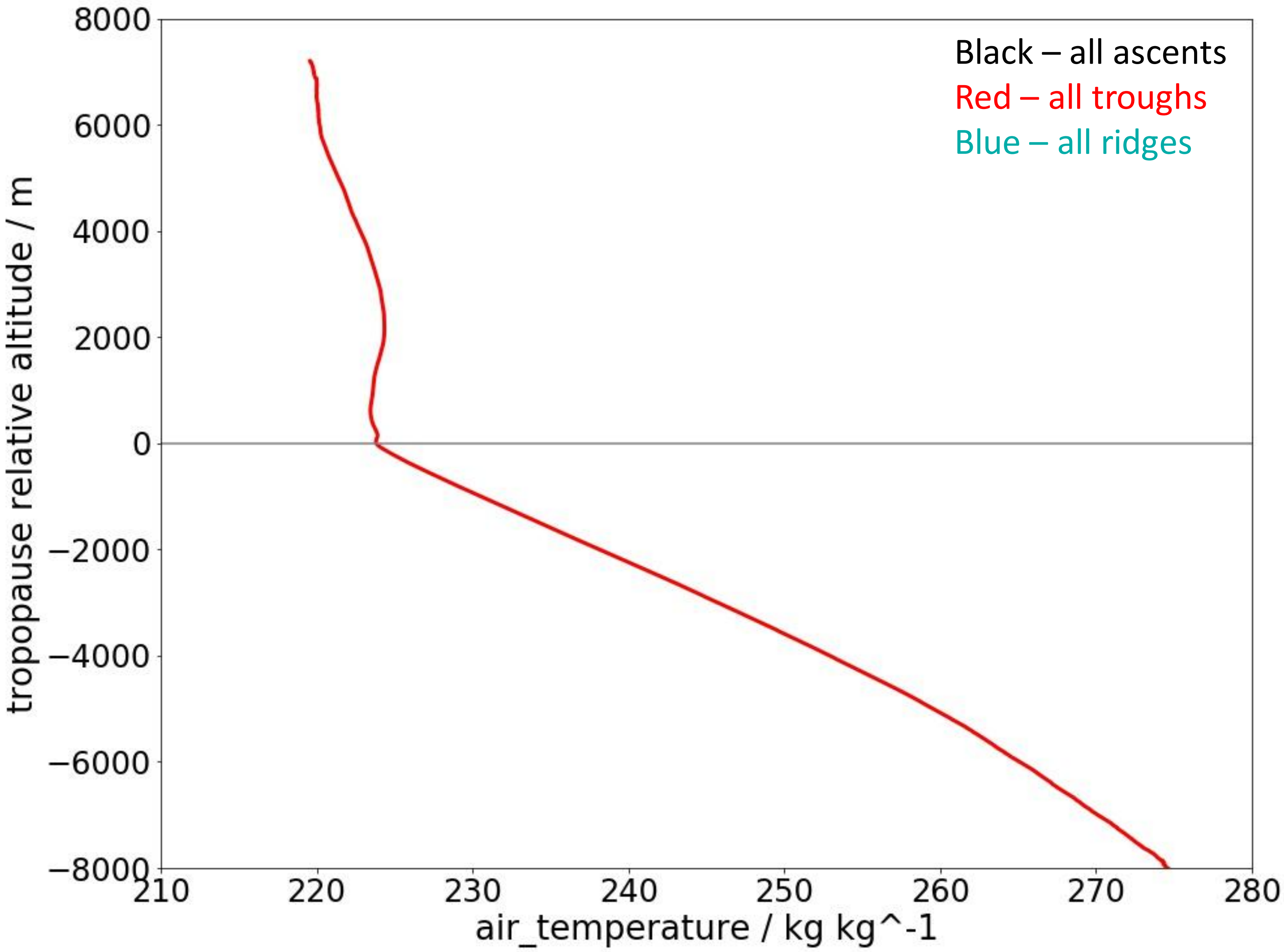
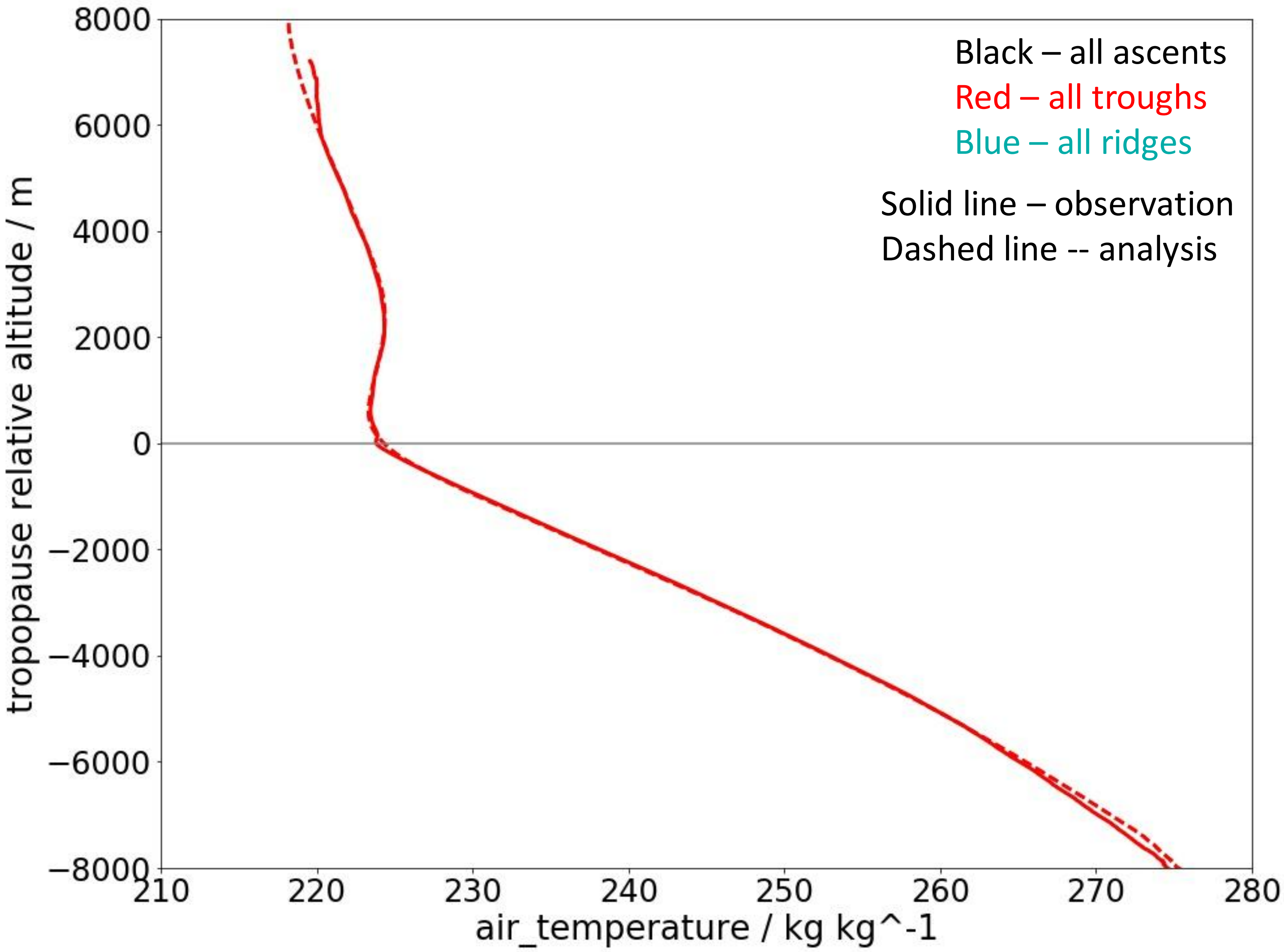
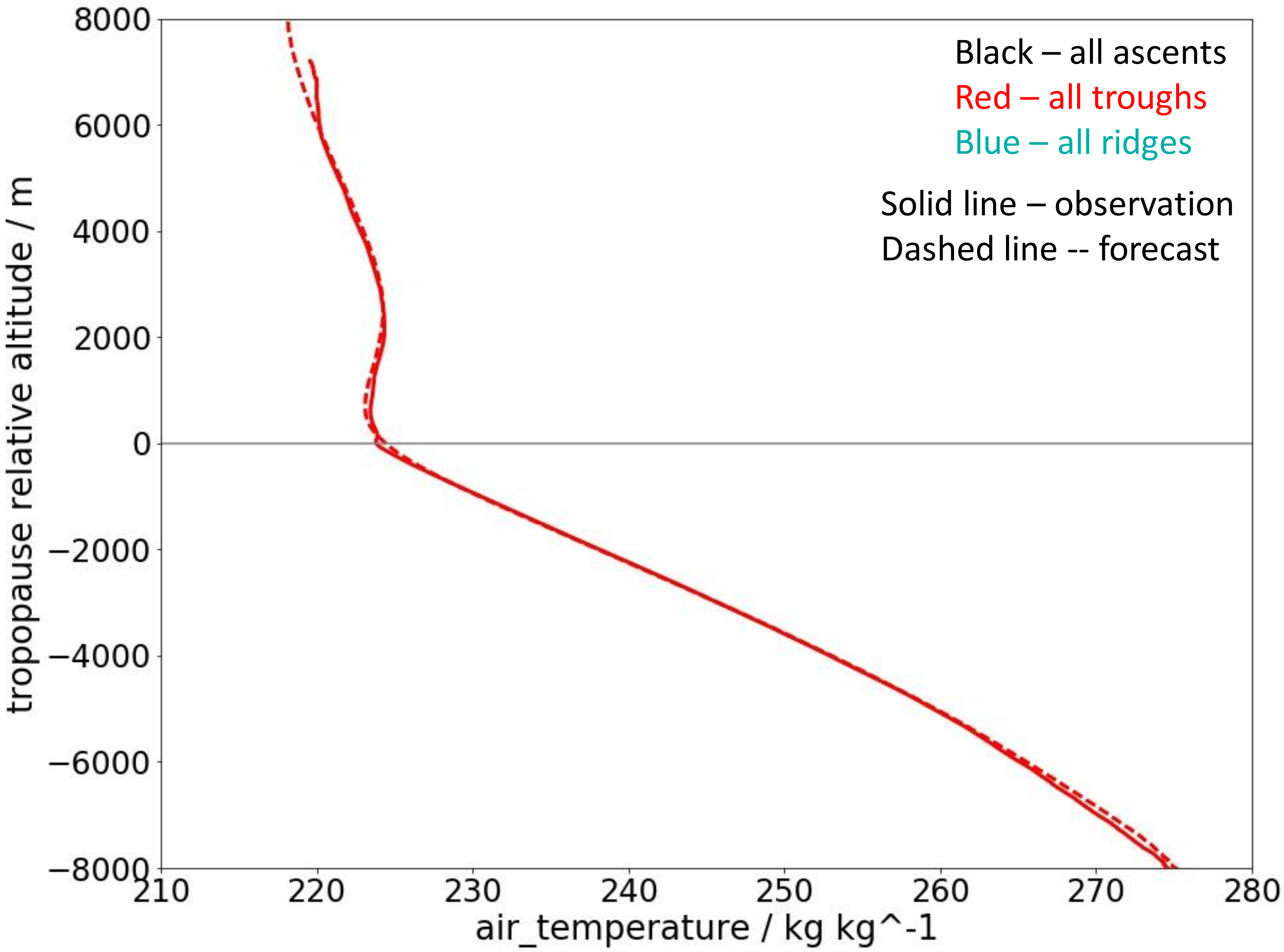
radiosonde temperature



Comparison between radiosonde temperature and the UM analysis



Comparison between radiosonde temperature and the UM 1 day forecast



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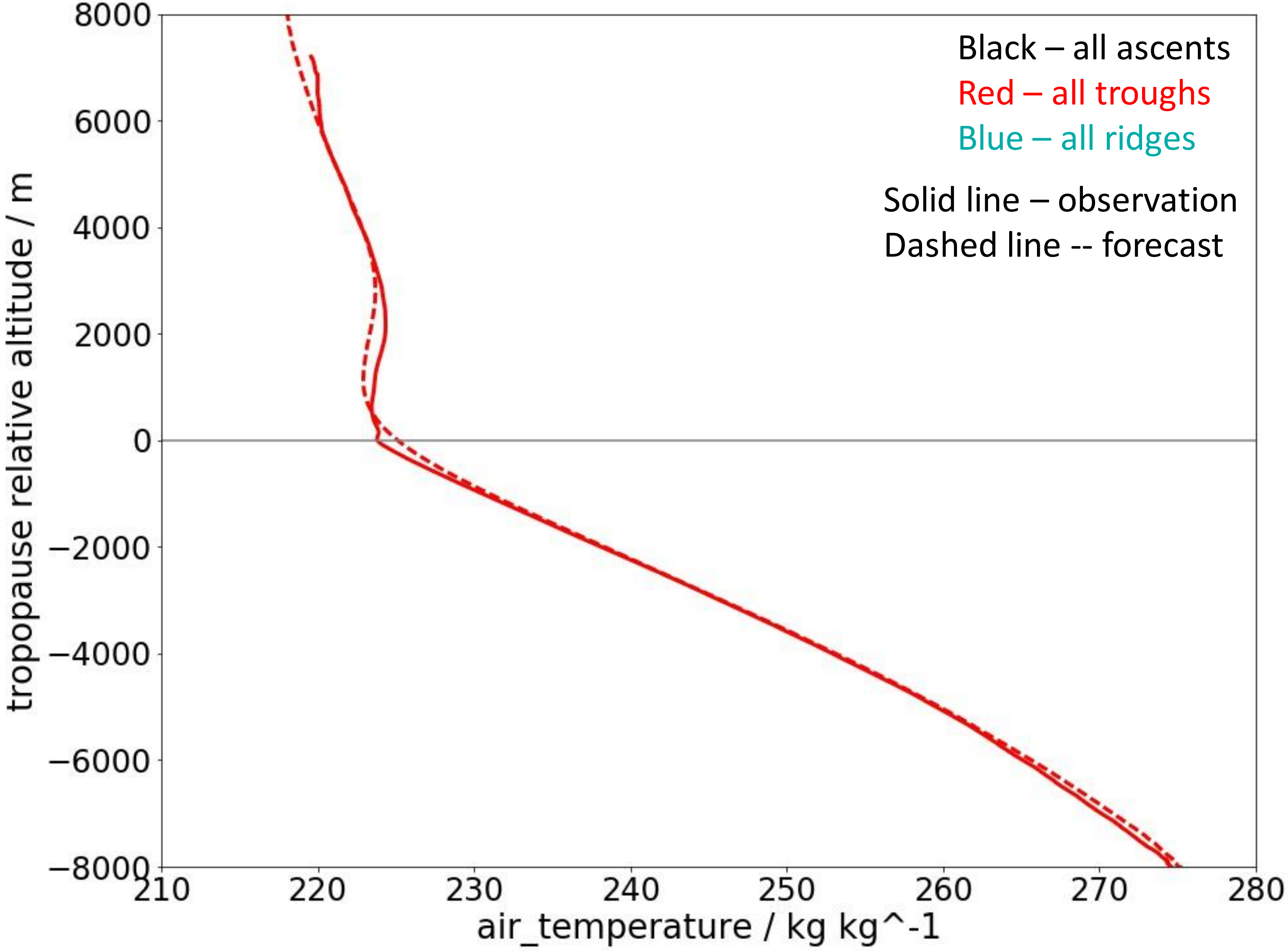
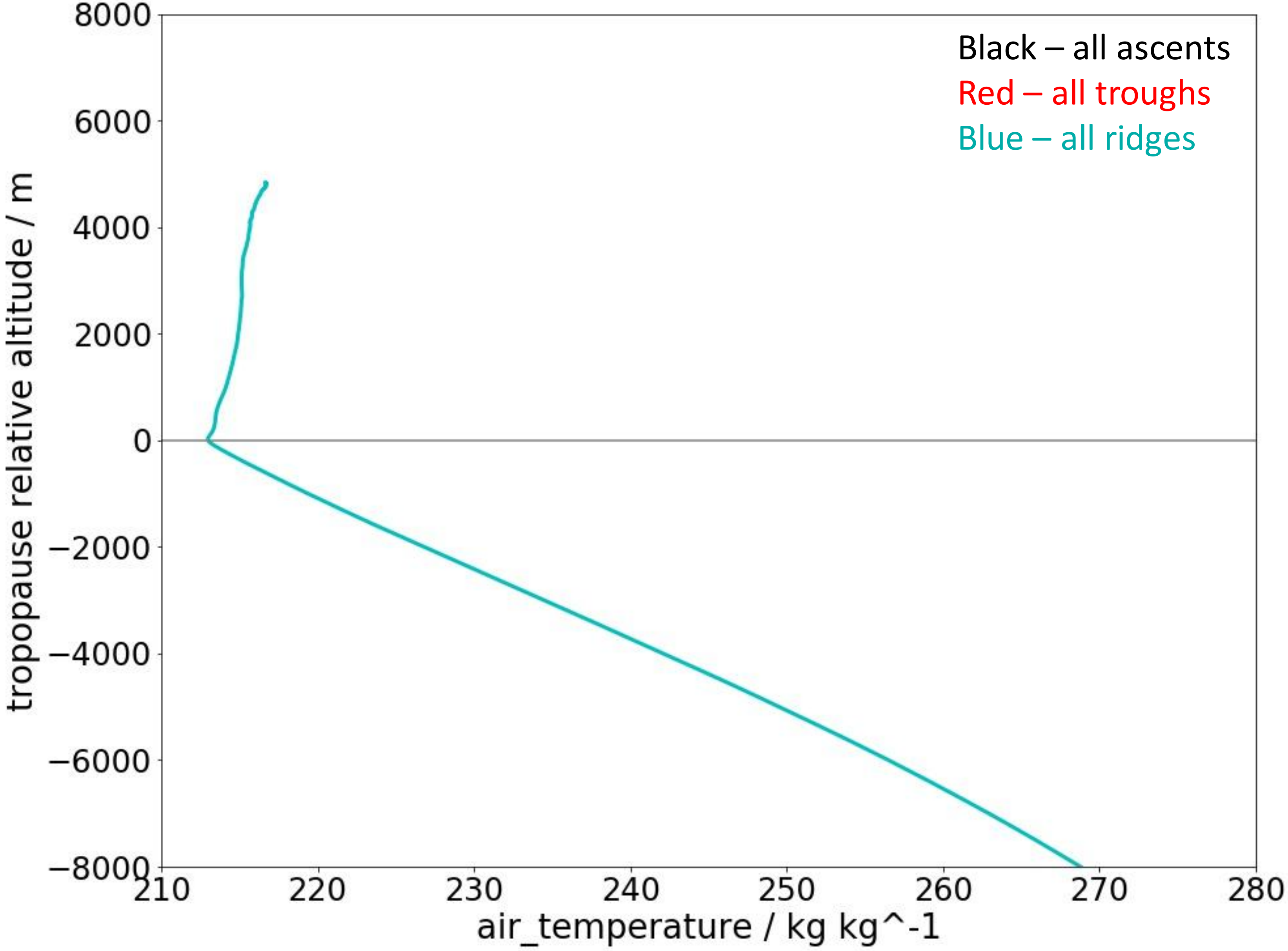


radiosonde temperature



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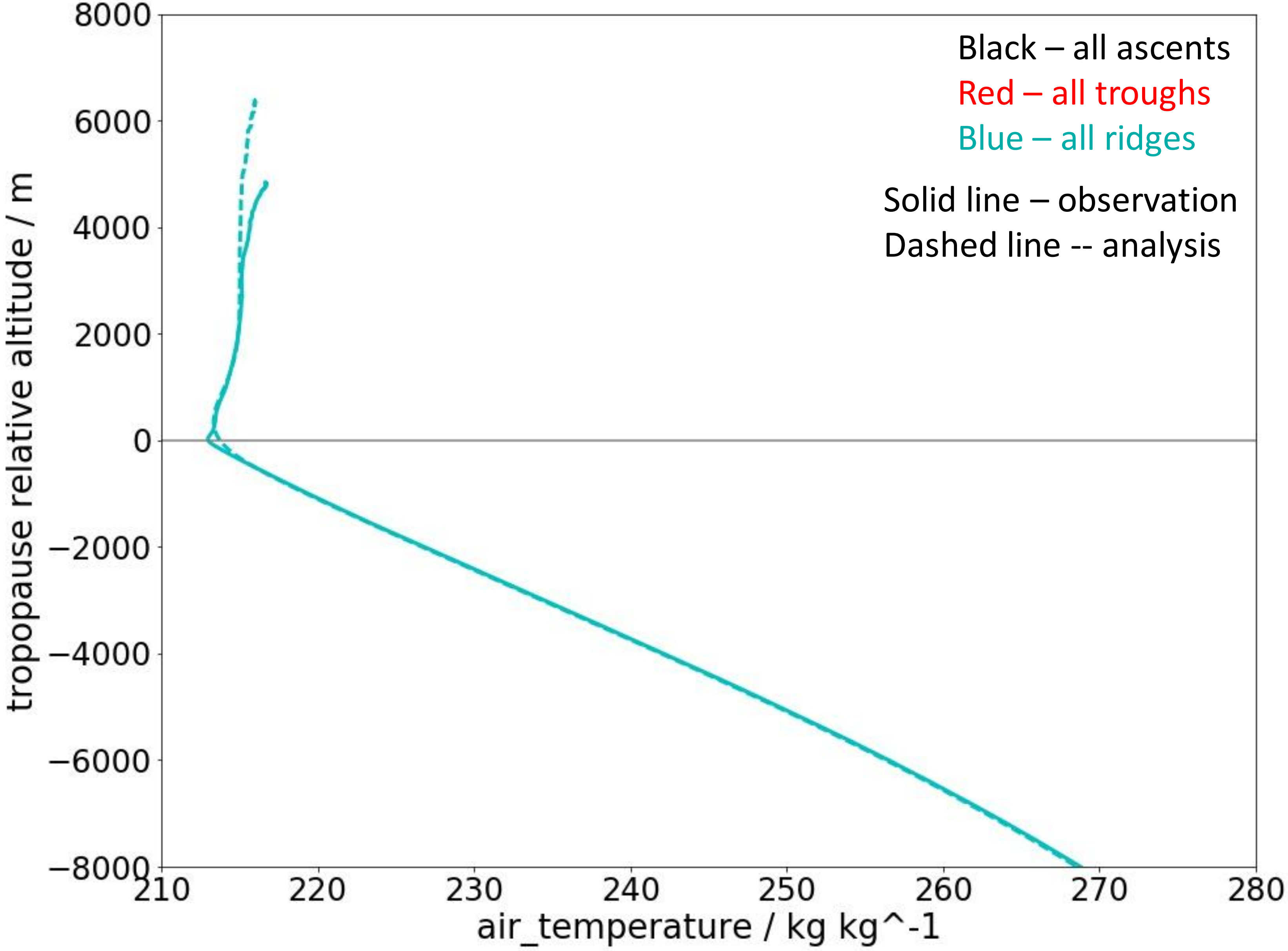

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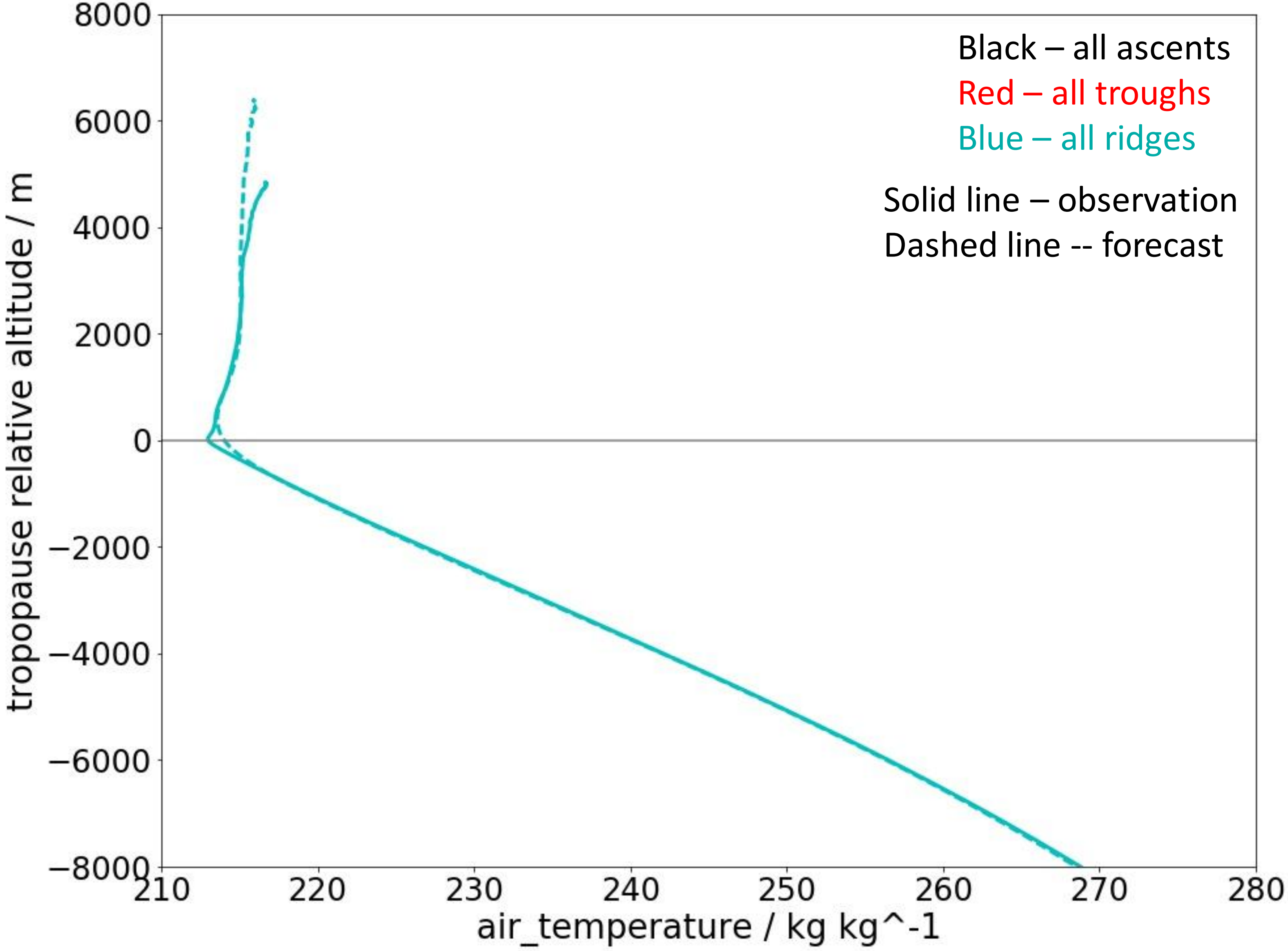

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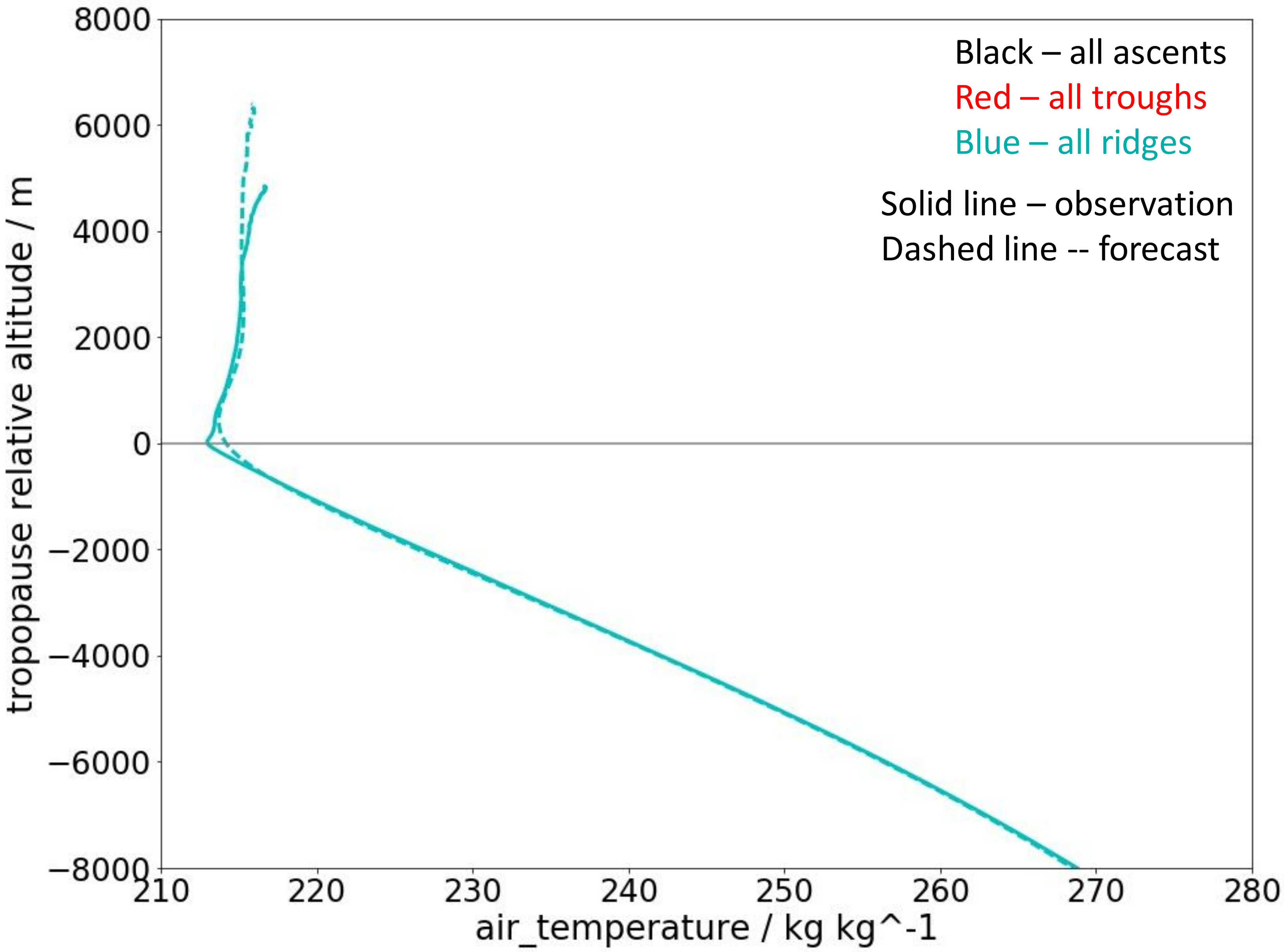
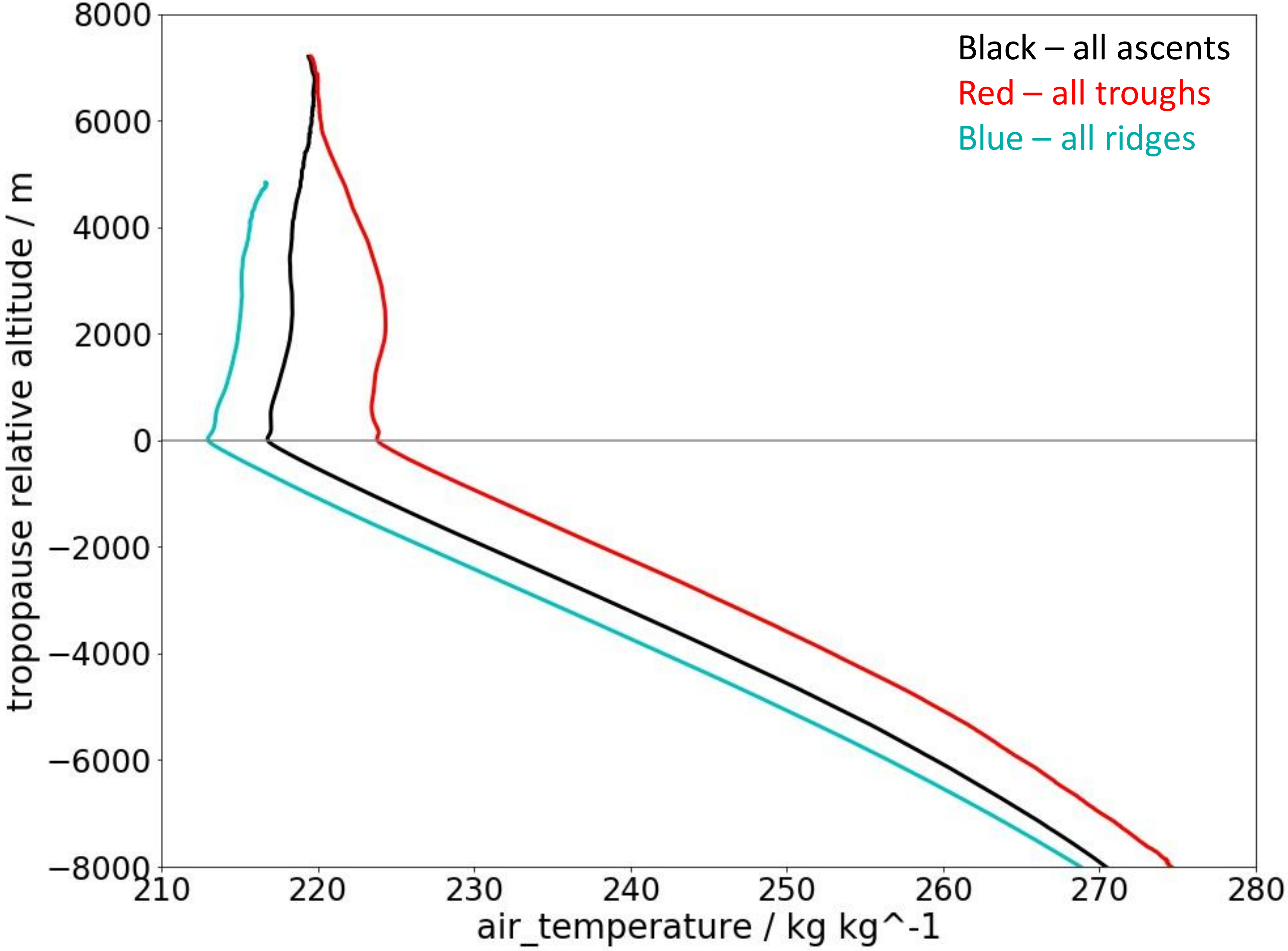
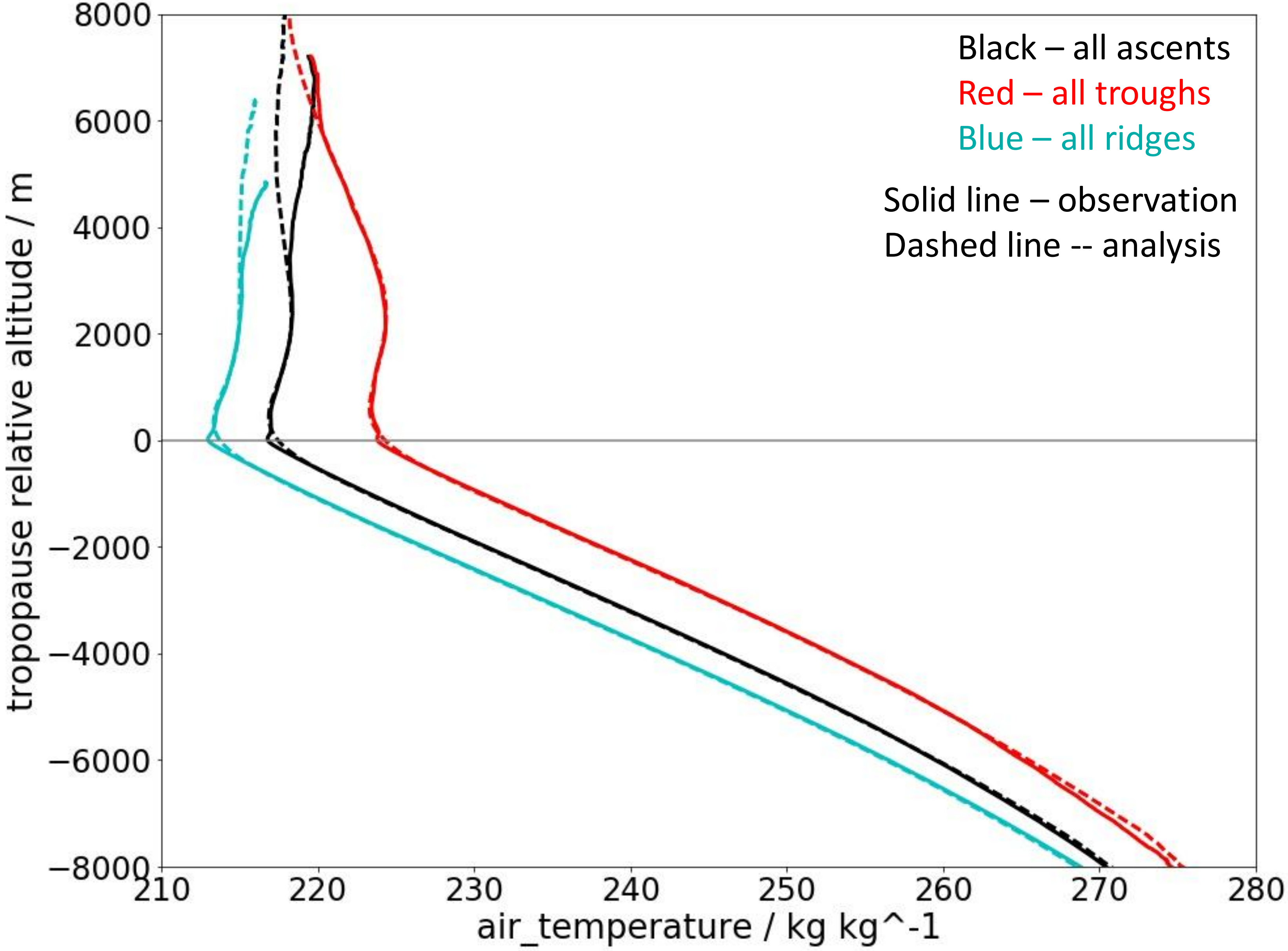


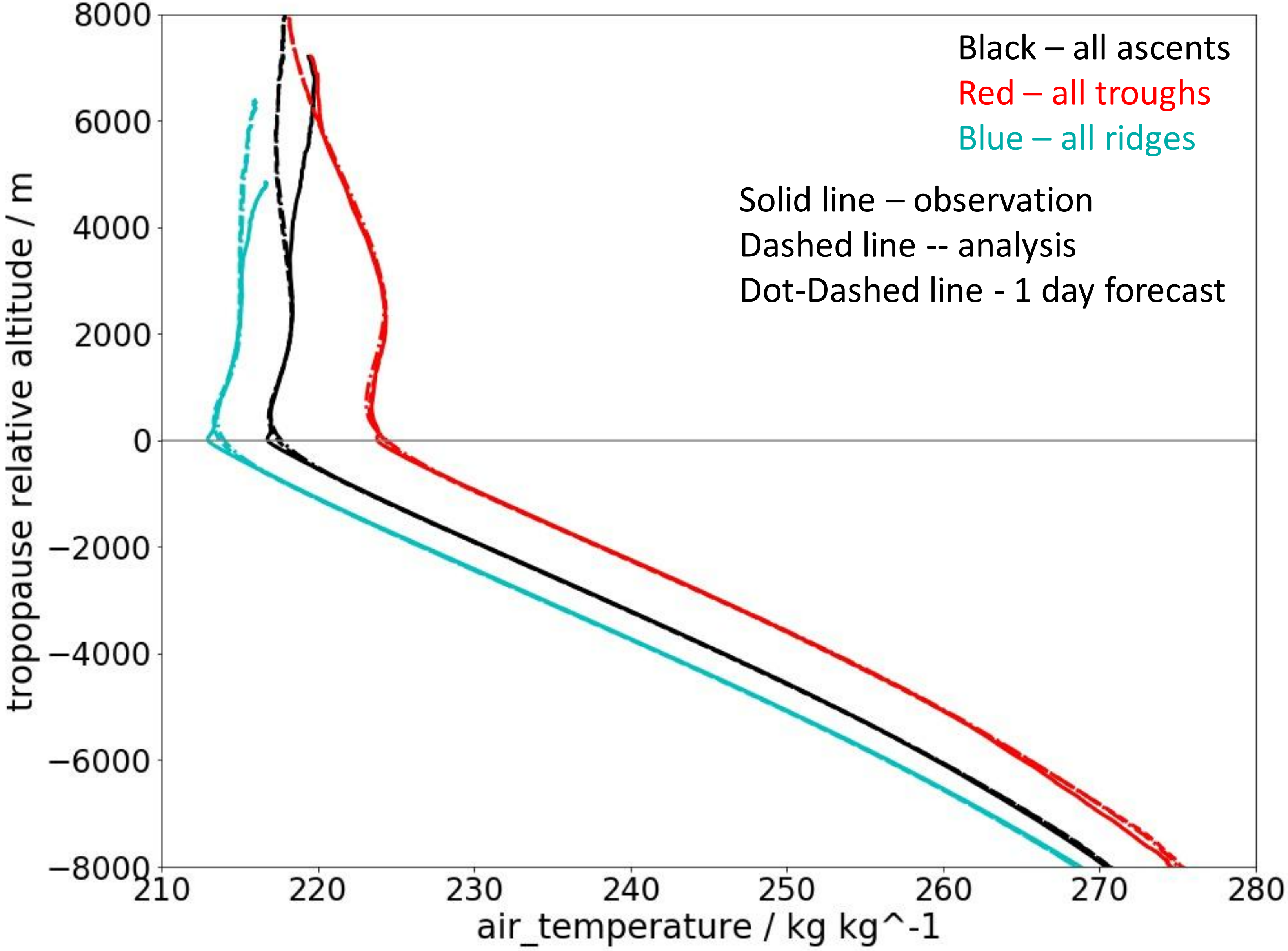
radiosonde temperature



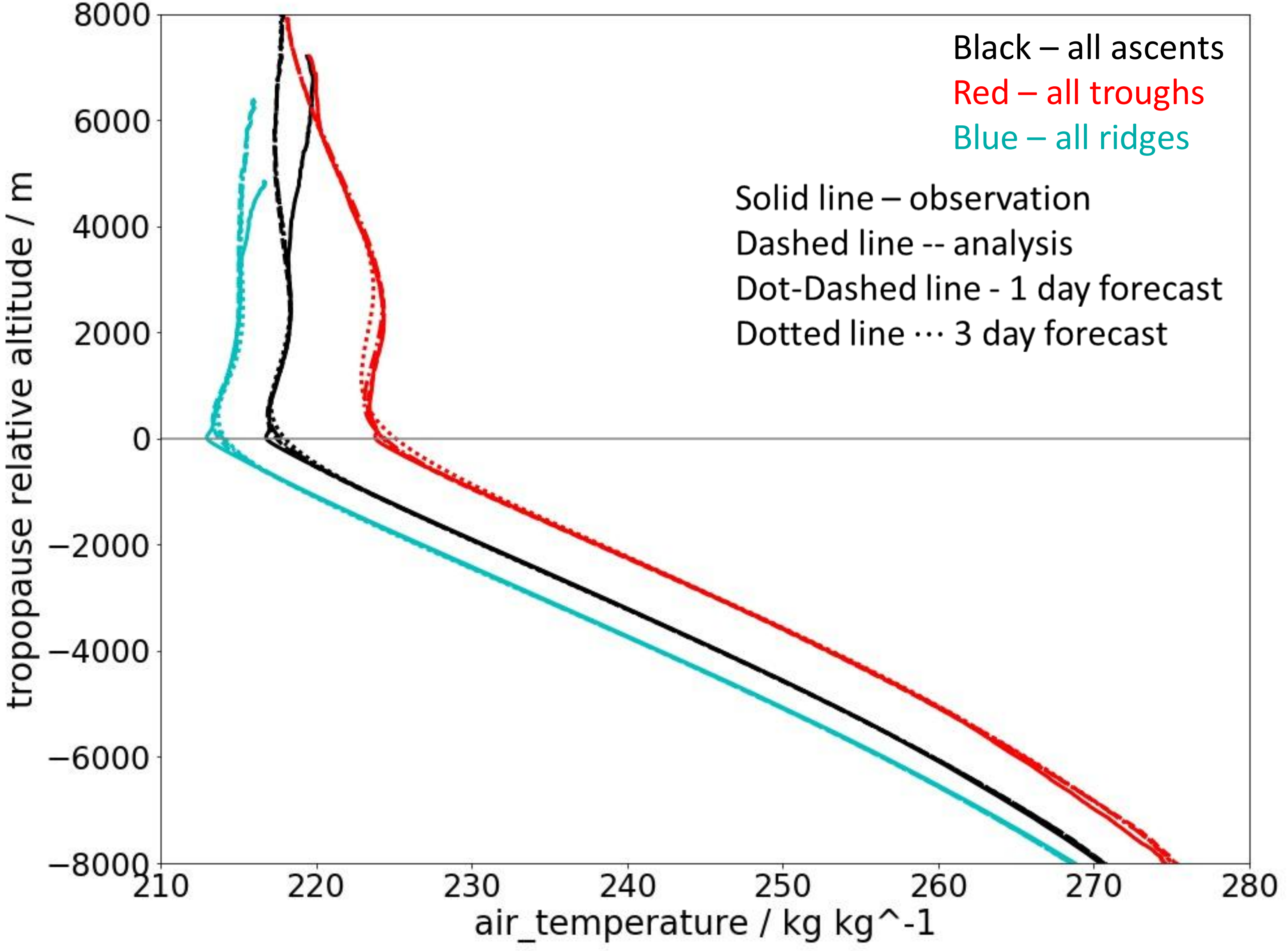
Comparison between radiosonde temperature and the UM analysis



Comparison between radiosonde temperature and the UM analysis and forecast

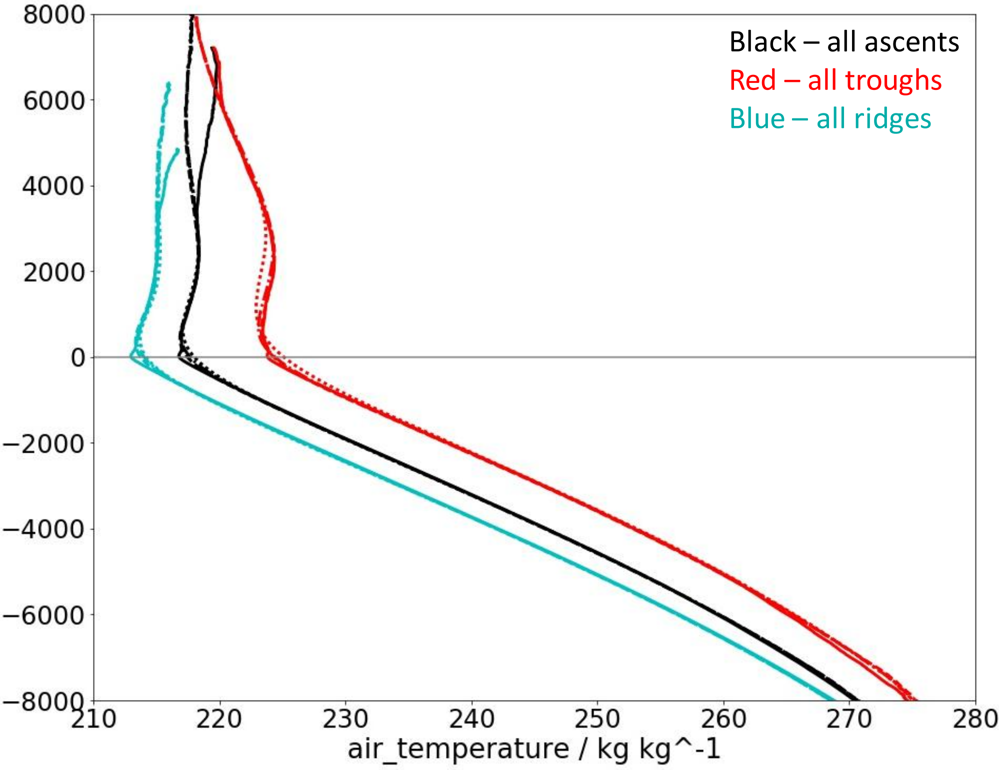


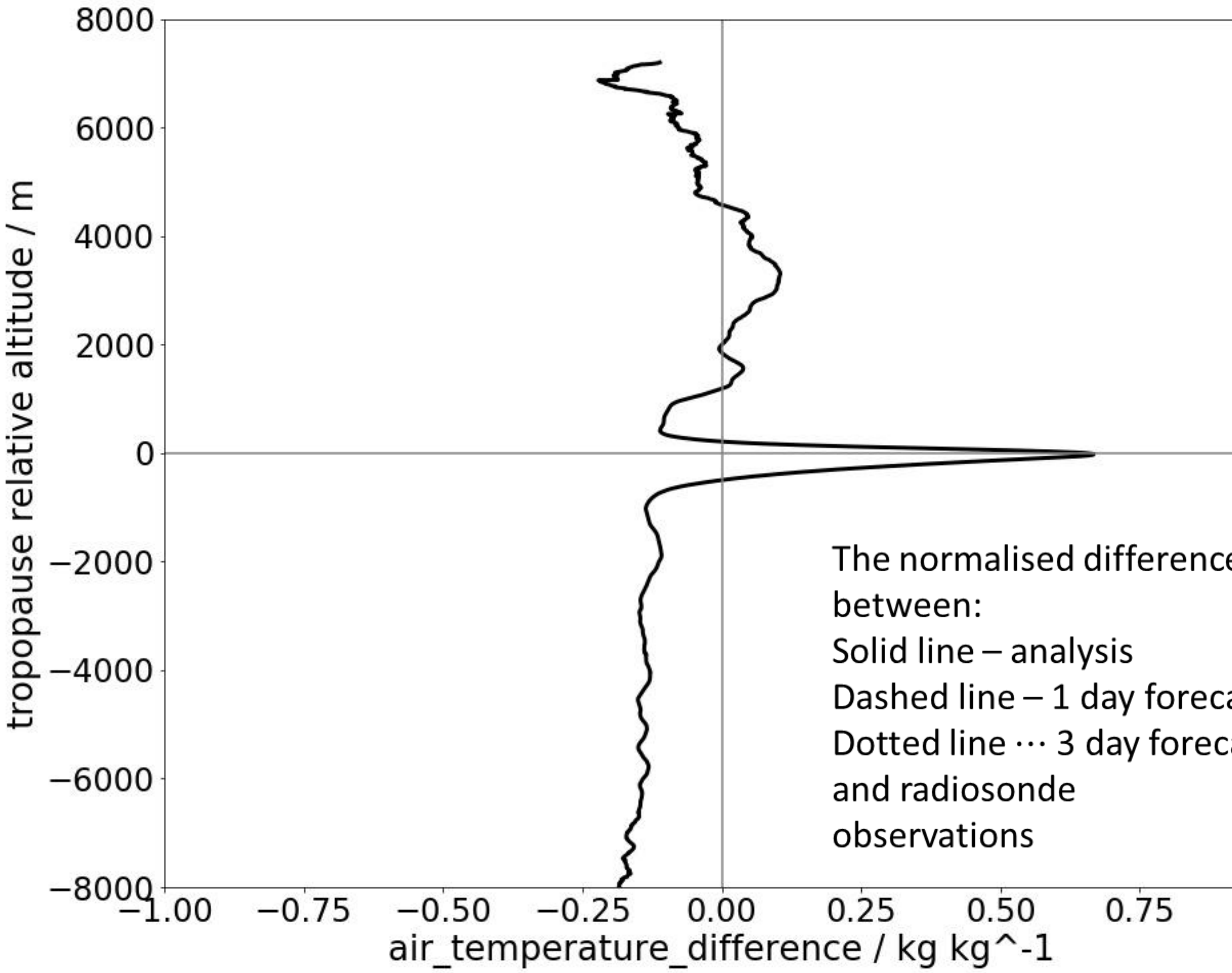
Comparison between radiosonde temperature and the UM analysis and forecast



# Comparison between radiosonde temperature and the UM analysis and forecast

A result of the smoothing of the temperature profile at the tropopause is the spike in air temperature difference around the tropopause.

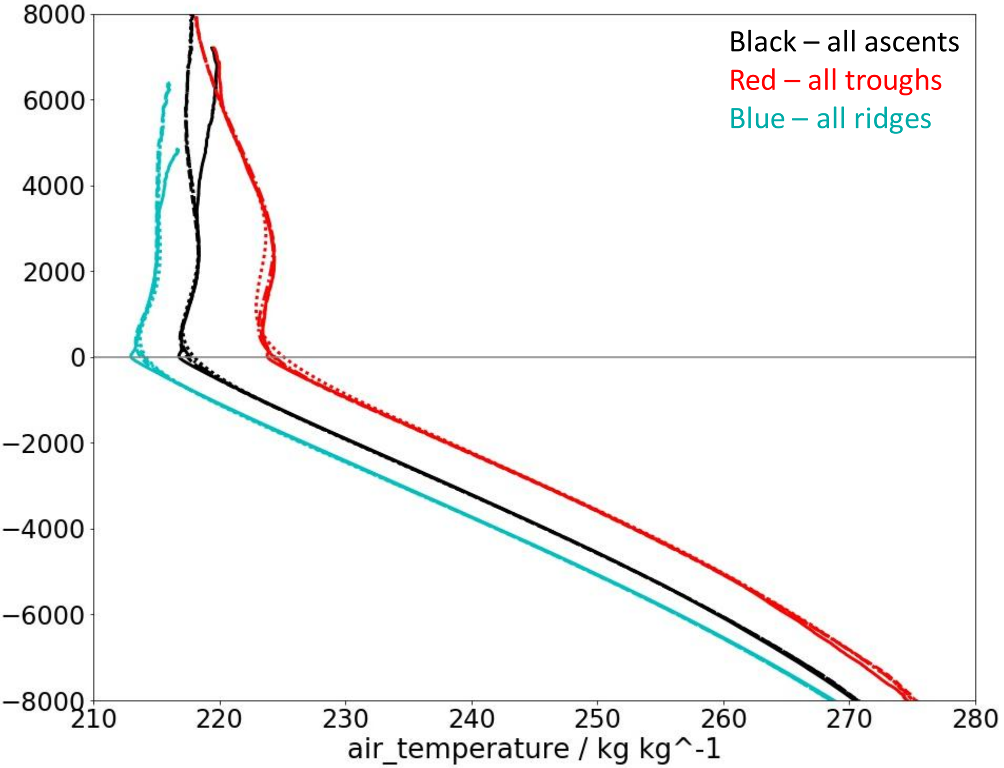


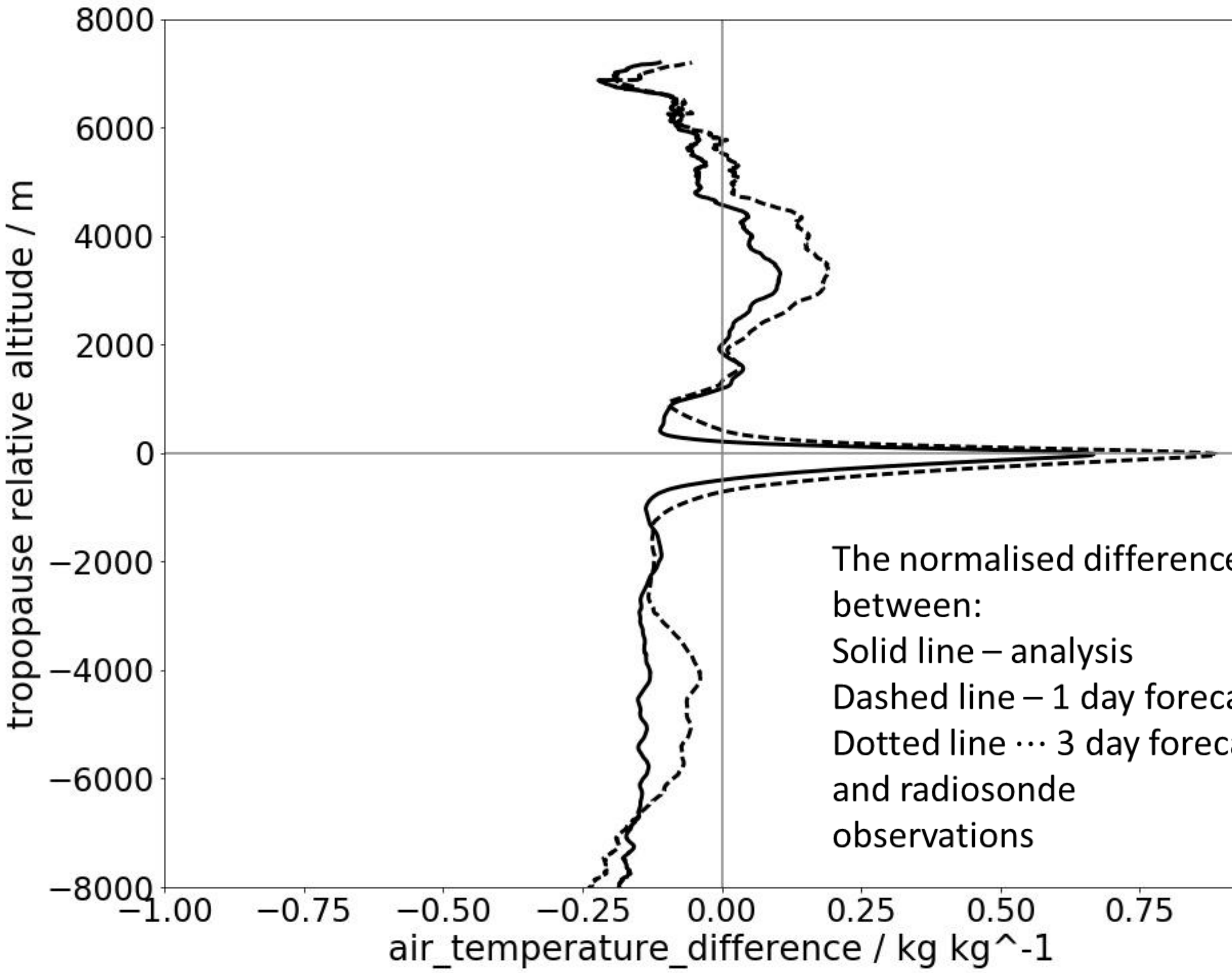



# Comparison between radiosonde temperature and the UM analysis and forecast

A result of the smoothing of the temperature profile at the tropopause is the spike in air temperature difference around the tropopause.

Which also grows with forecast lead time.



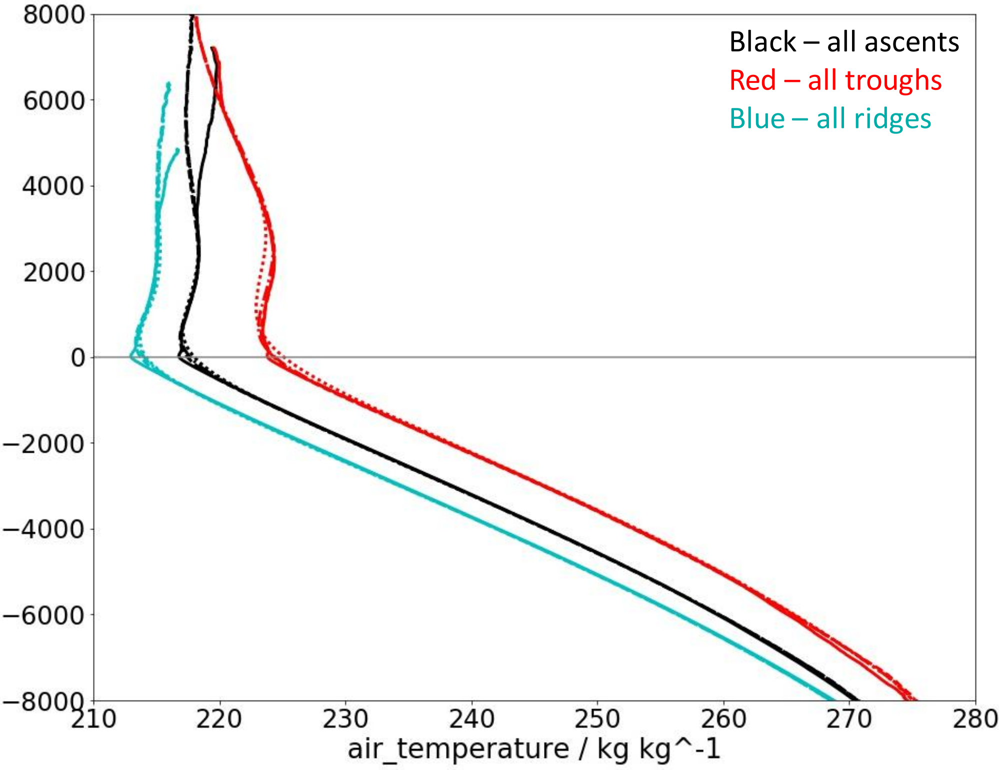



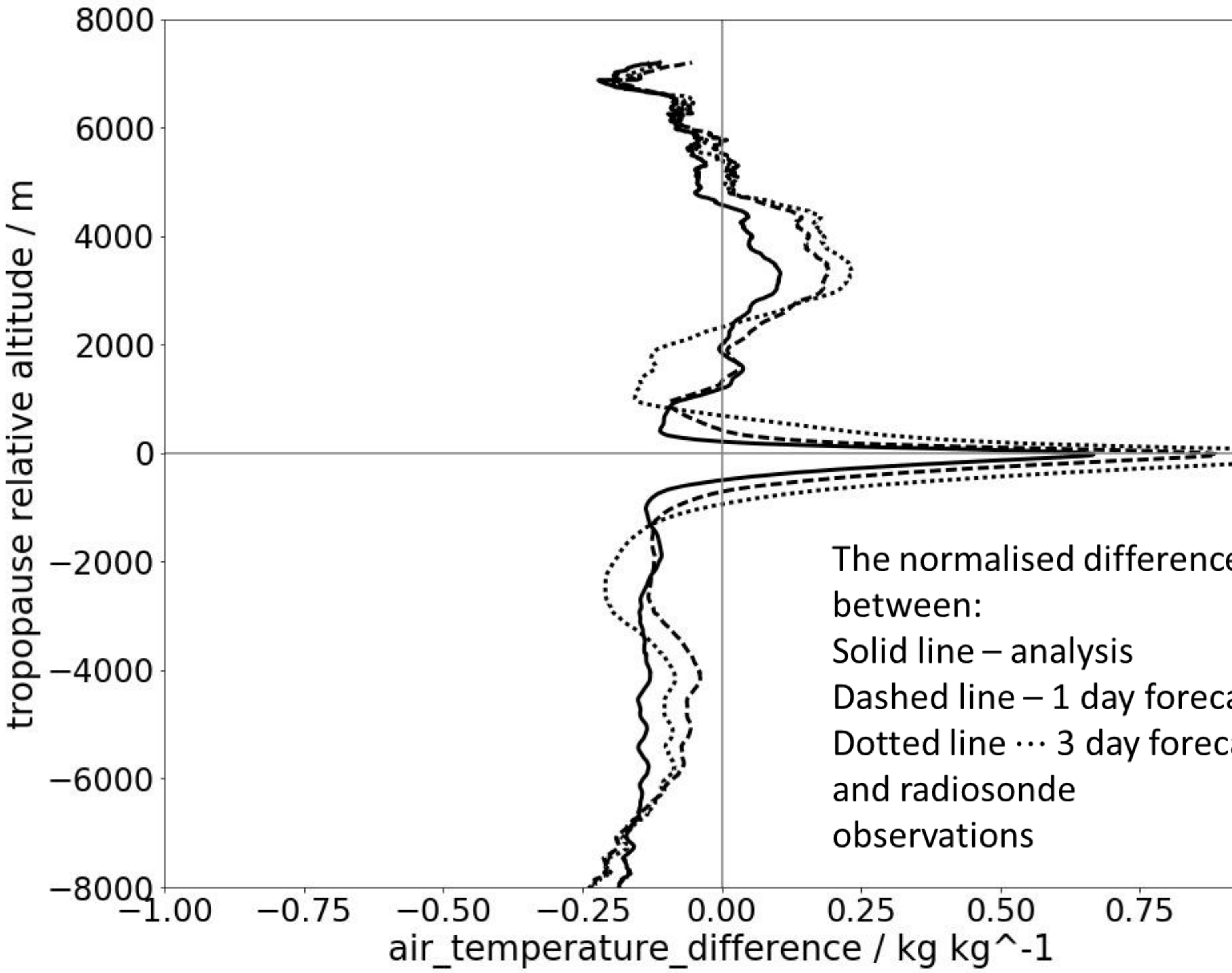
# Comparison between radiosonde temperature and the UM analysis and forecast

A result of the smoothing of the temperature profile at the tropopause is the spike in air temperature difference around the tropopause.

Which also grows with forecast lead time.

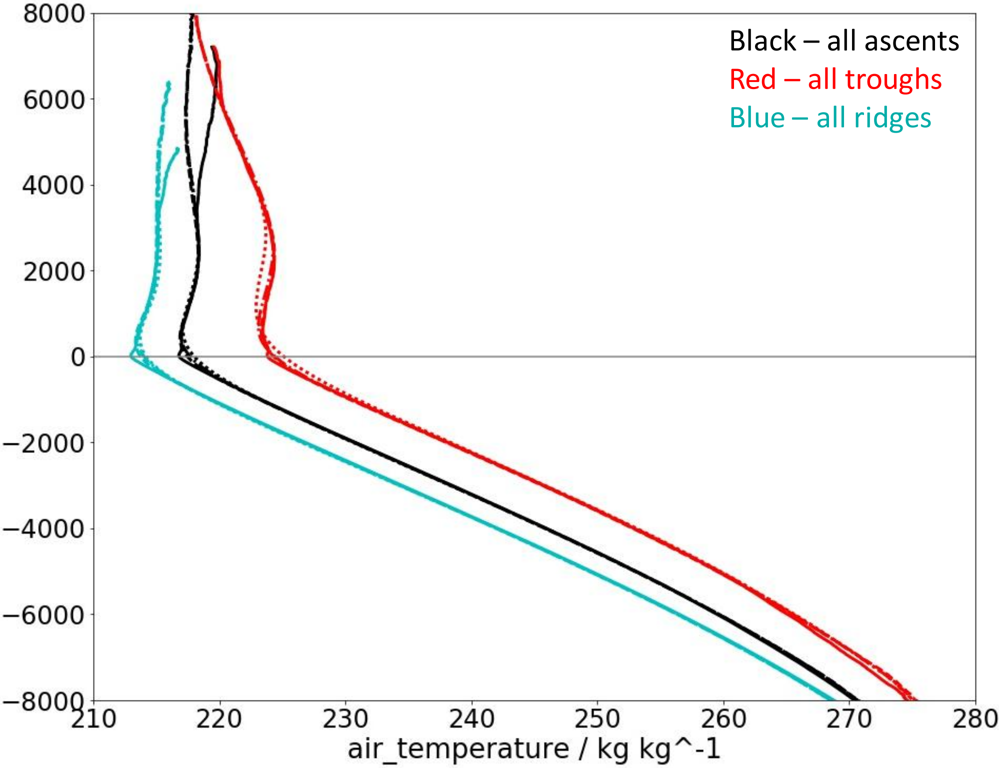
We can also see the growth of the lower stratospheric cold bias.

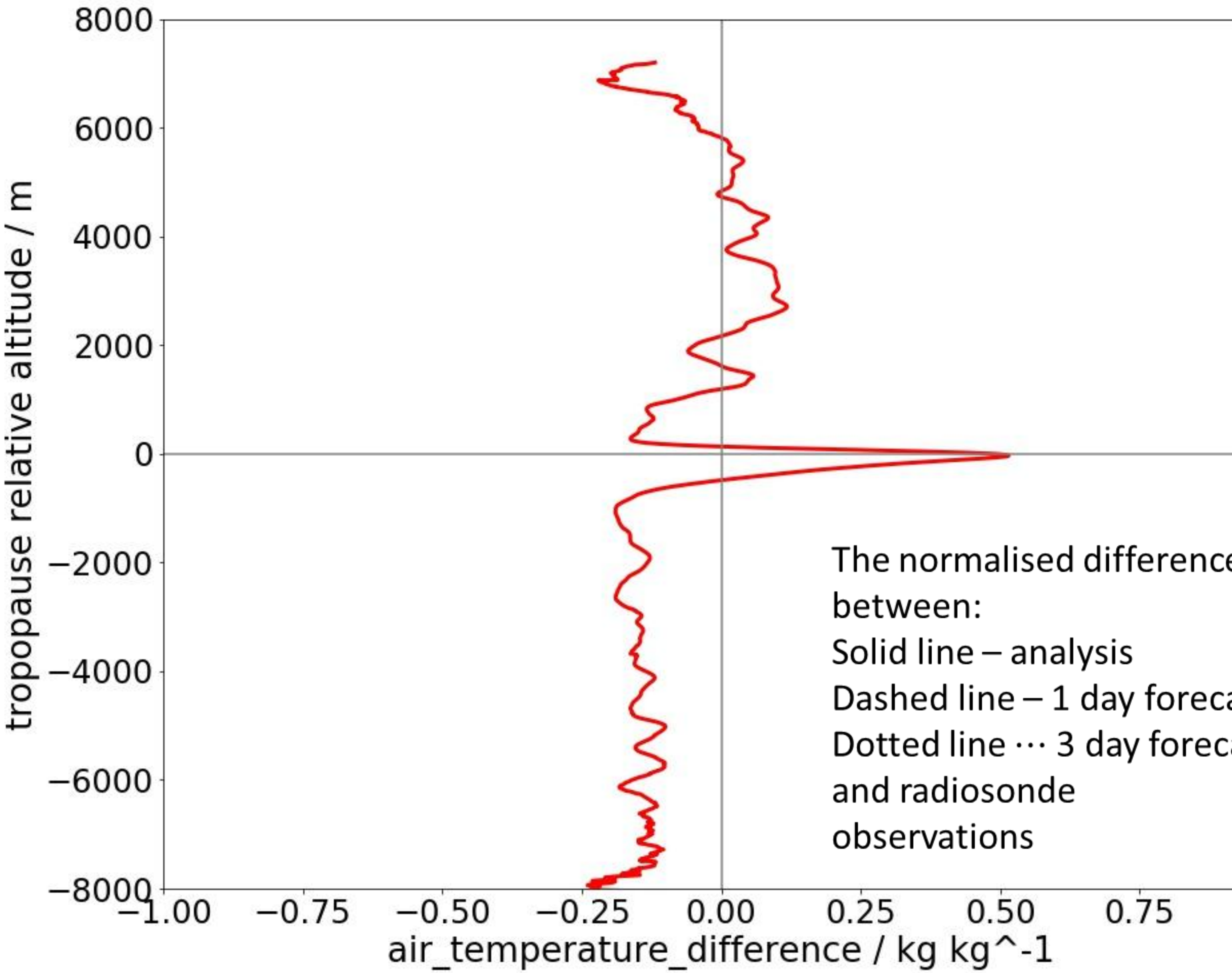


# Comparison between radiosonde temperature and the UM analysis and forecast

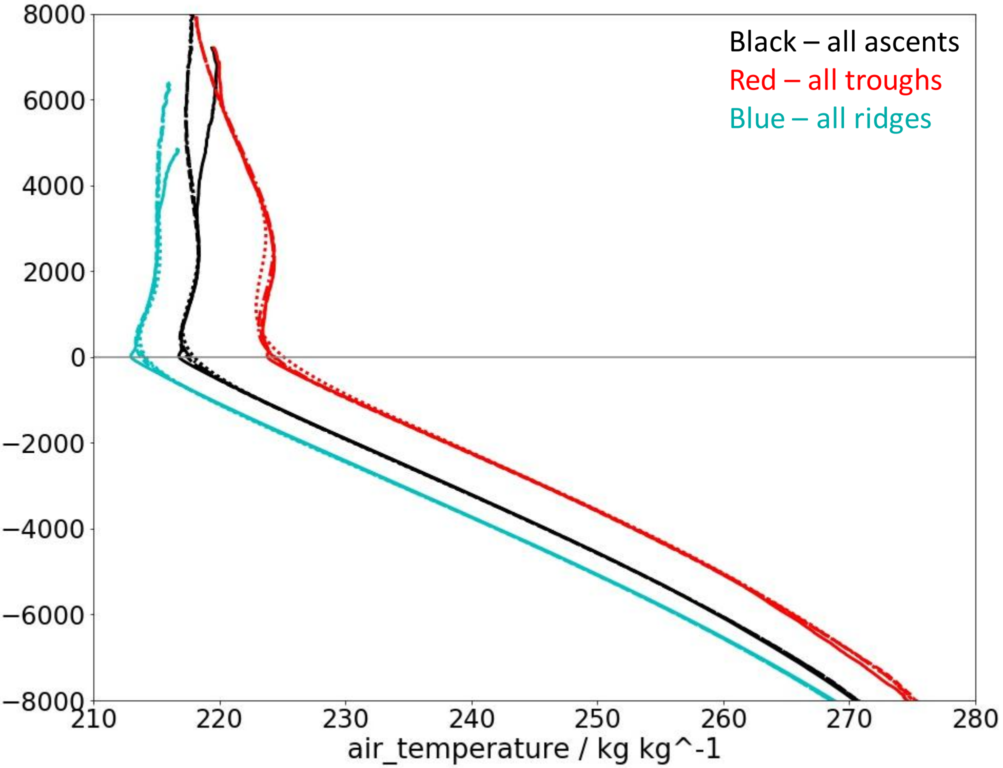
In troughs we see a larger lower stratospheric cold bias

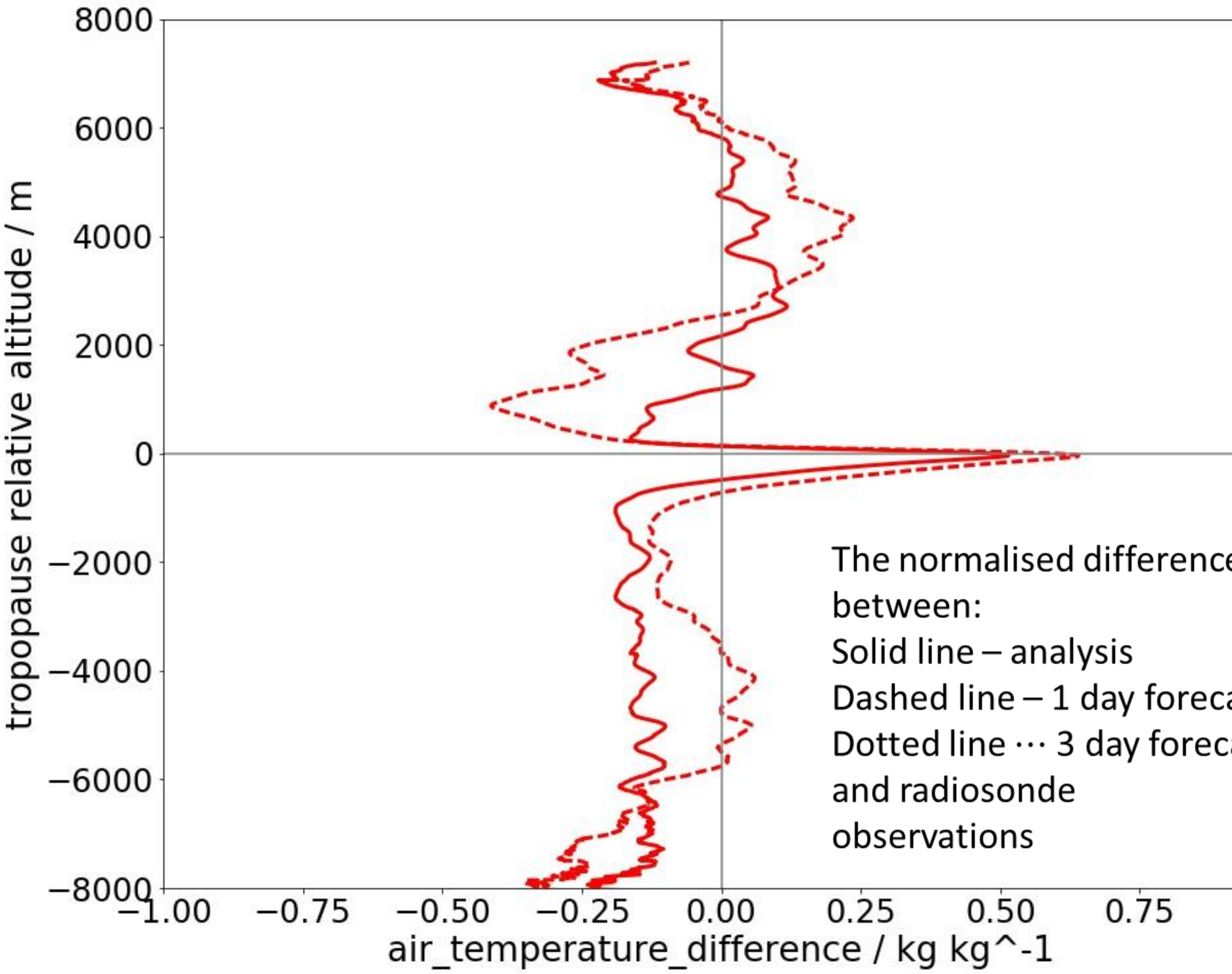


Comparison between radiosonde temperature and the UM analysis and forecast

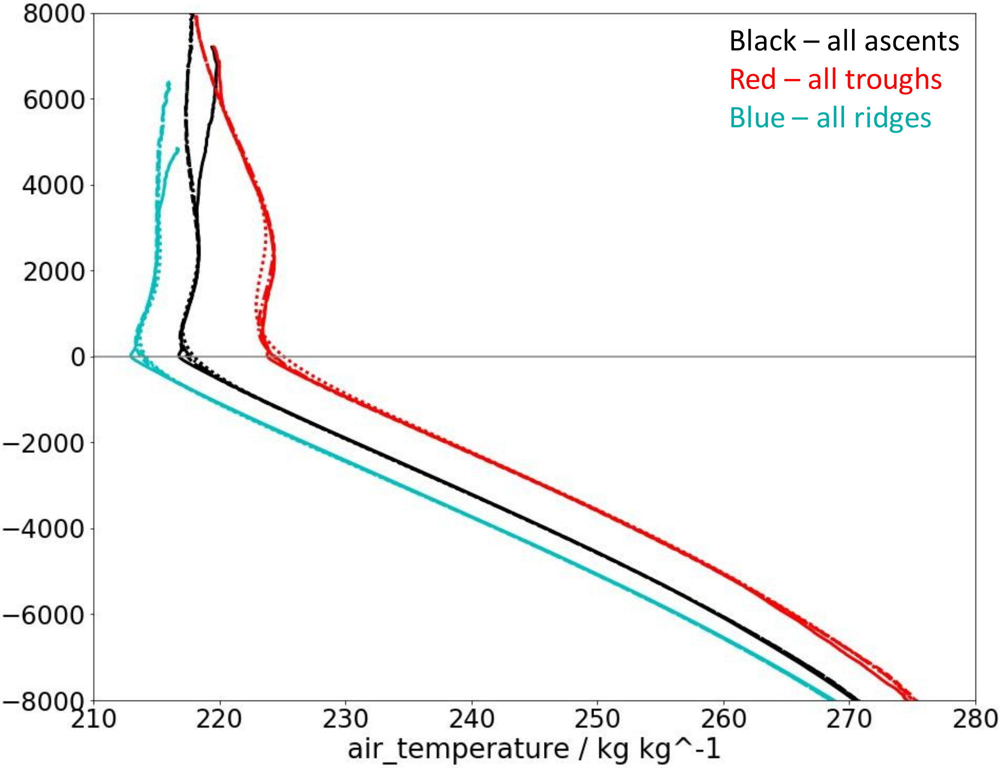
In troughs we see a larger lower stratospheric cold bias, which grows to ~.5K in the 1 day forecast

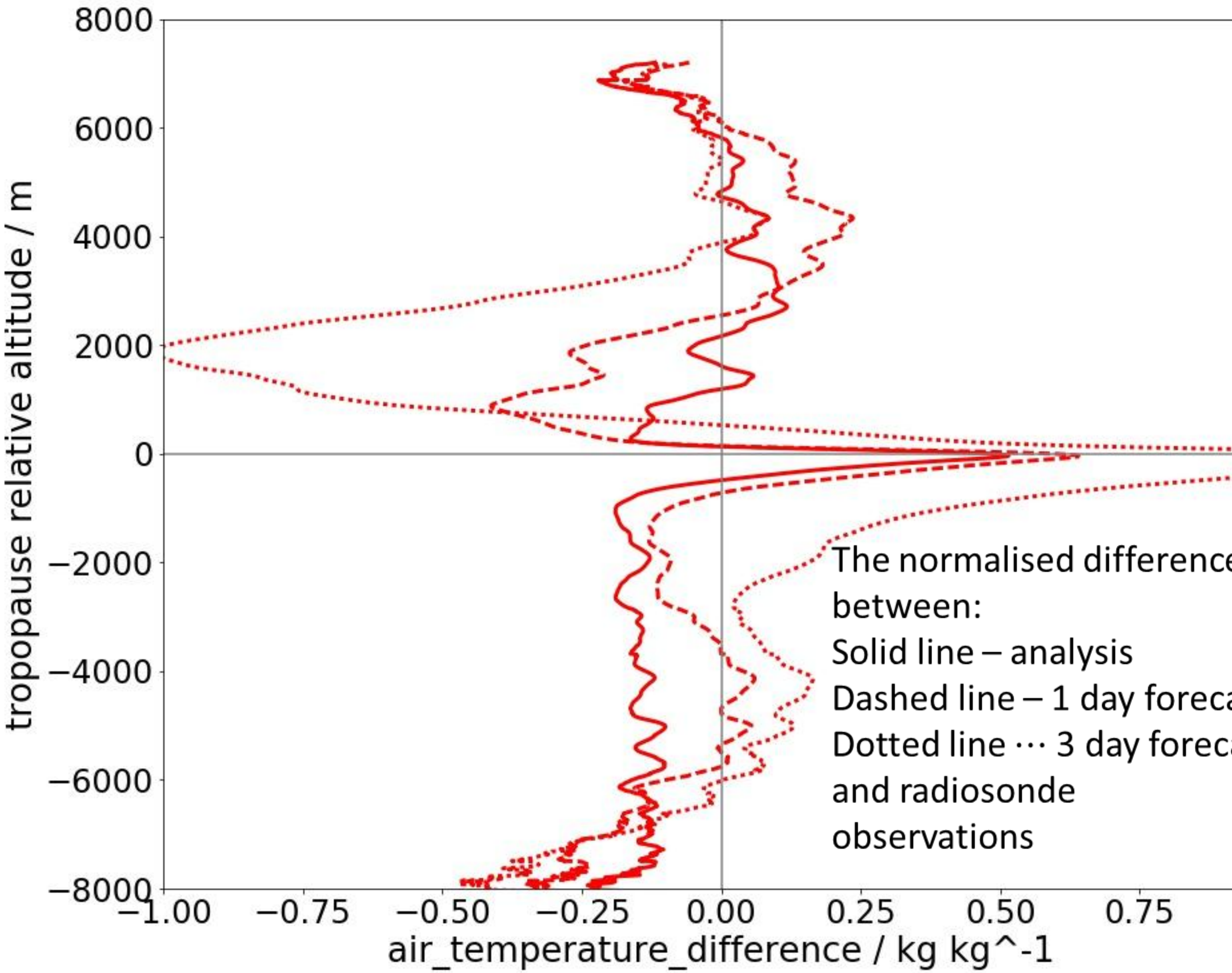


Comparison between radiosonde temperature and the UM analysis and forecast

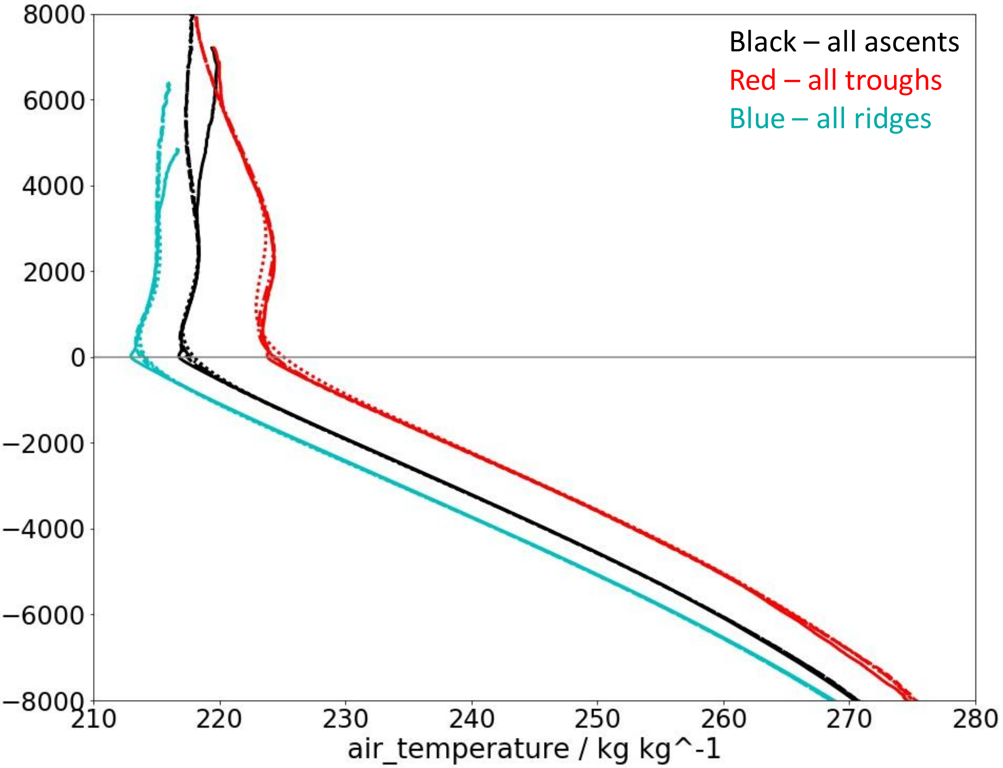
In troughs we see a larger lower stratospheric cold bias, which grows to ~.5K in the 1 day forecast, and ~1K in the 3 day

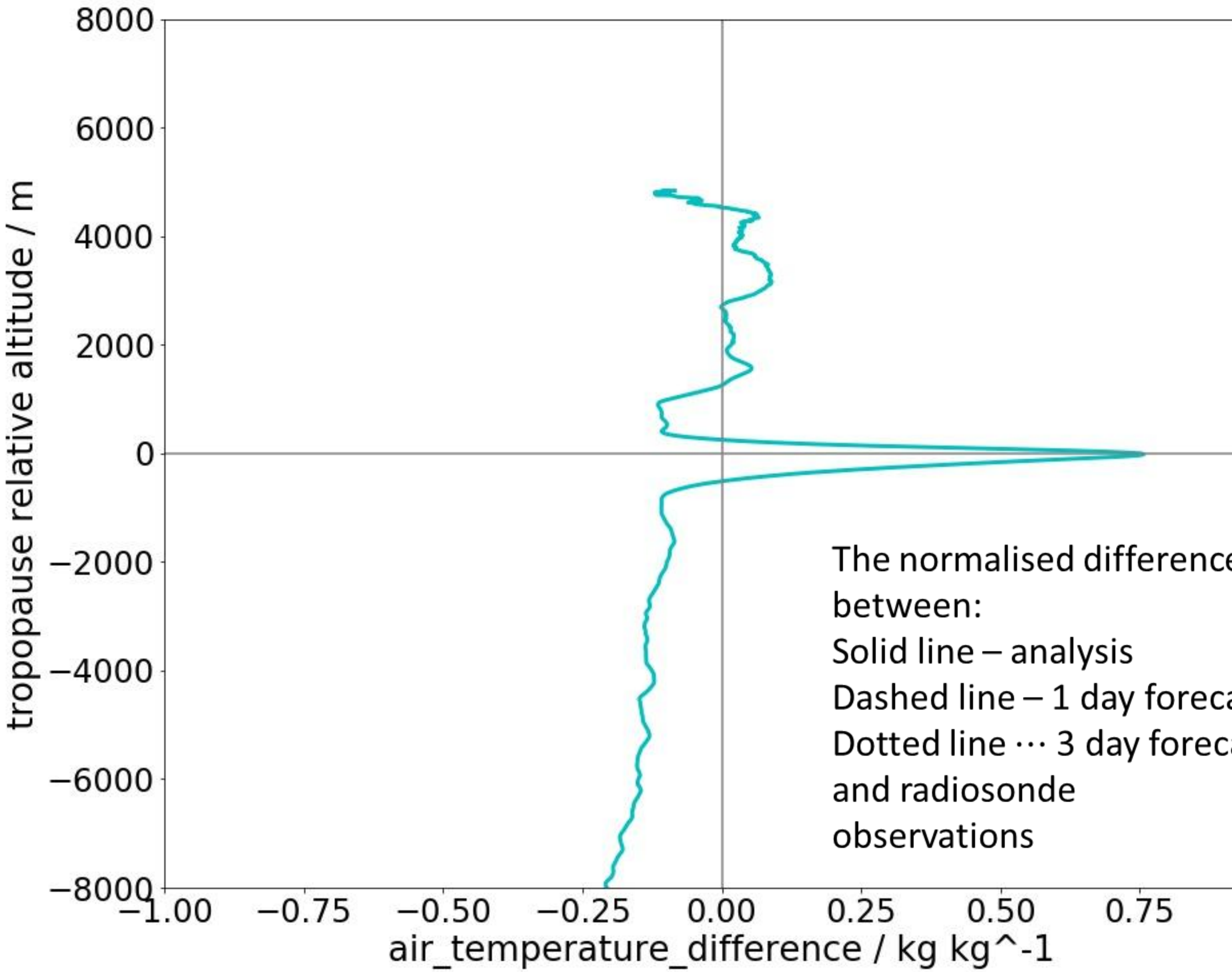


# Comparison between radiosonde temperature and the UM analysis and forecast

Ridges also have a lower stratospheric cold bias in the analysis

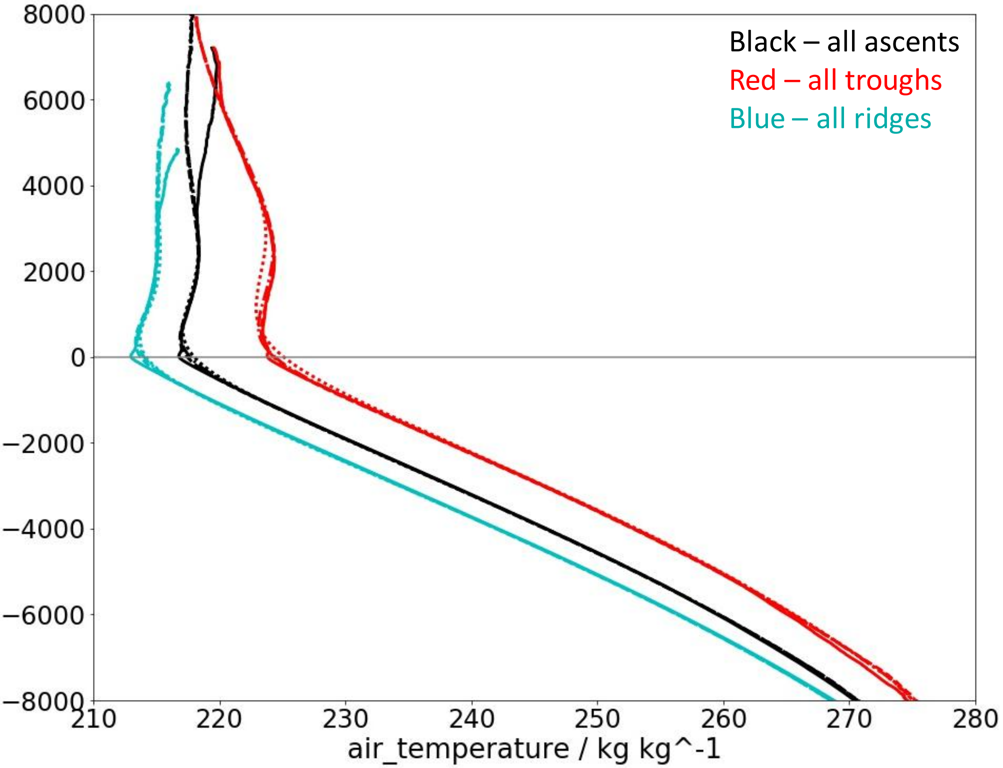


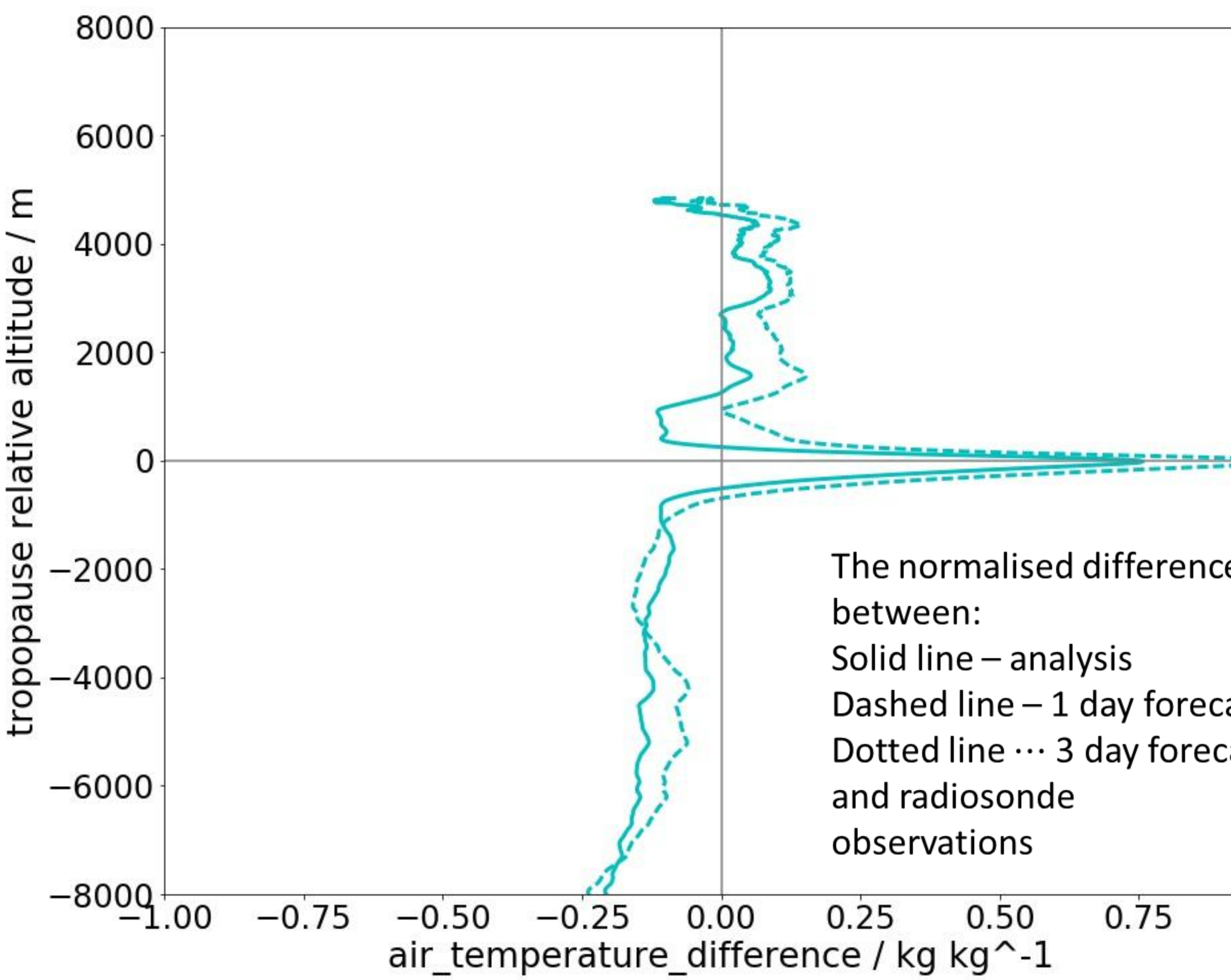




The normalised difference between:
Solid line – analysis
Dashed line – 1 day foreca
Dotted line ··· 3 day foreca
and radiosonde observations

# Comparison between radiosonde temperature and the UM analysis and forecast

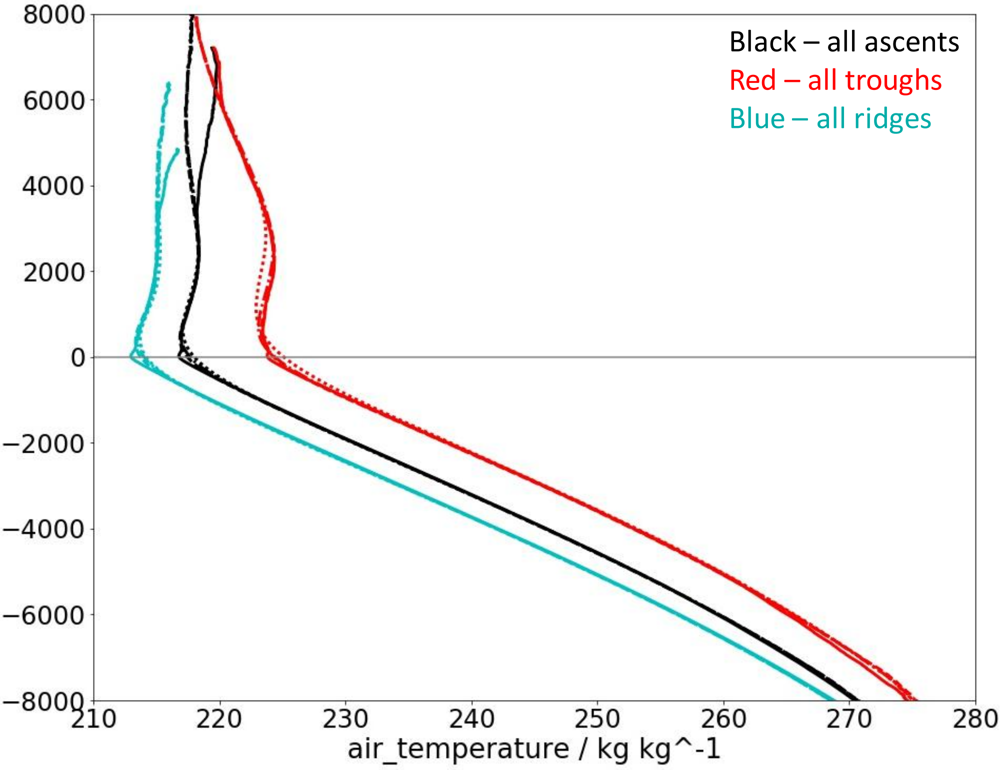
Ridges also have a lower stratospheric cold bias in the analysis, but as the forecast evolves this warms

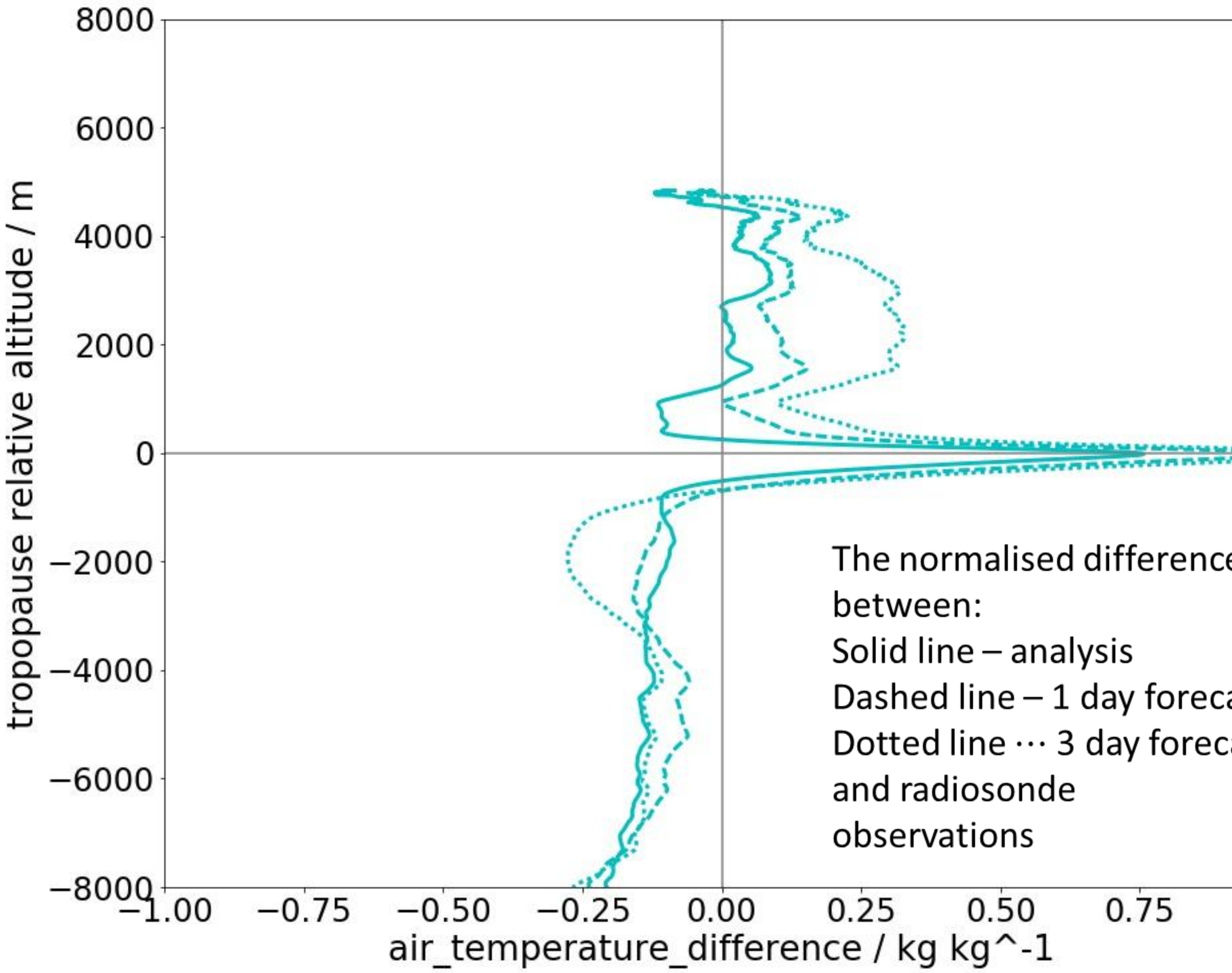


# Comparison between radiosonde temperature and the UM analysis and forecast

Ridges also have a lower stratospheric cold bias in the analysis, but as the forecast evolves this warms, and there is instead a small warm bias in the lower stratosphere



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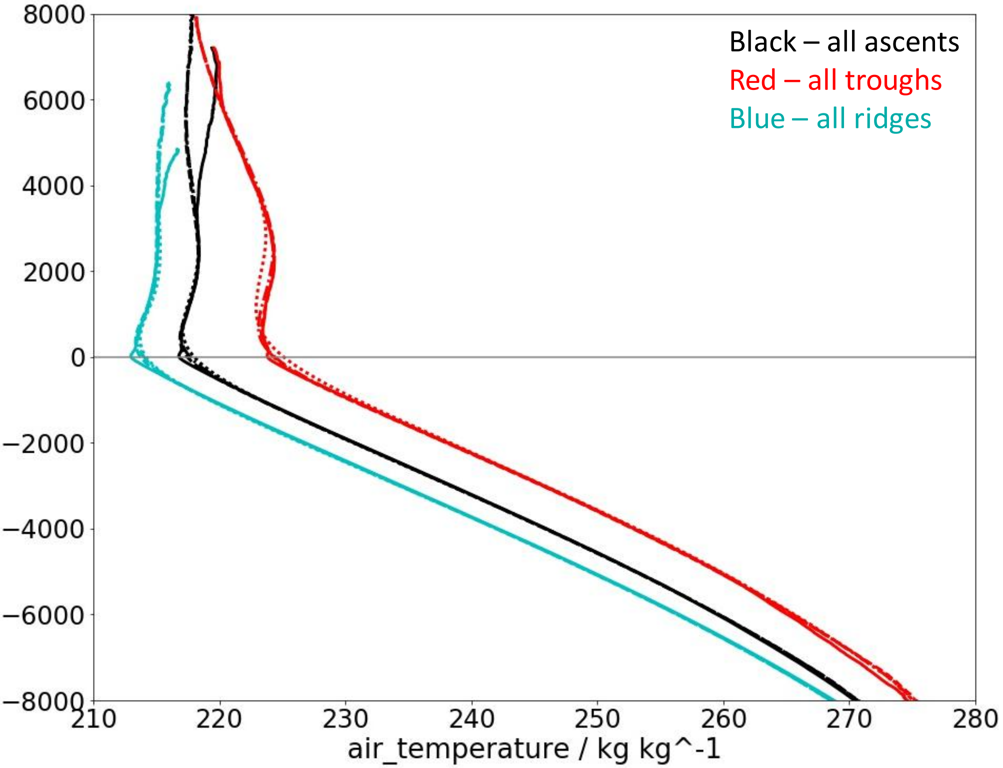
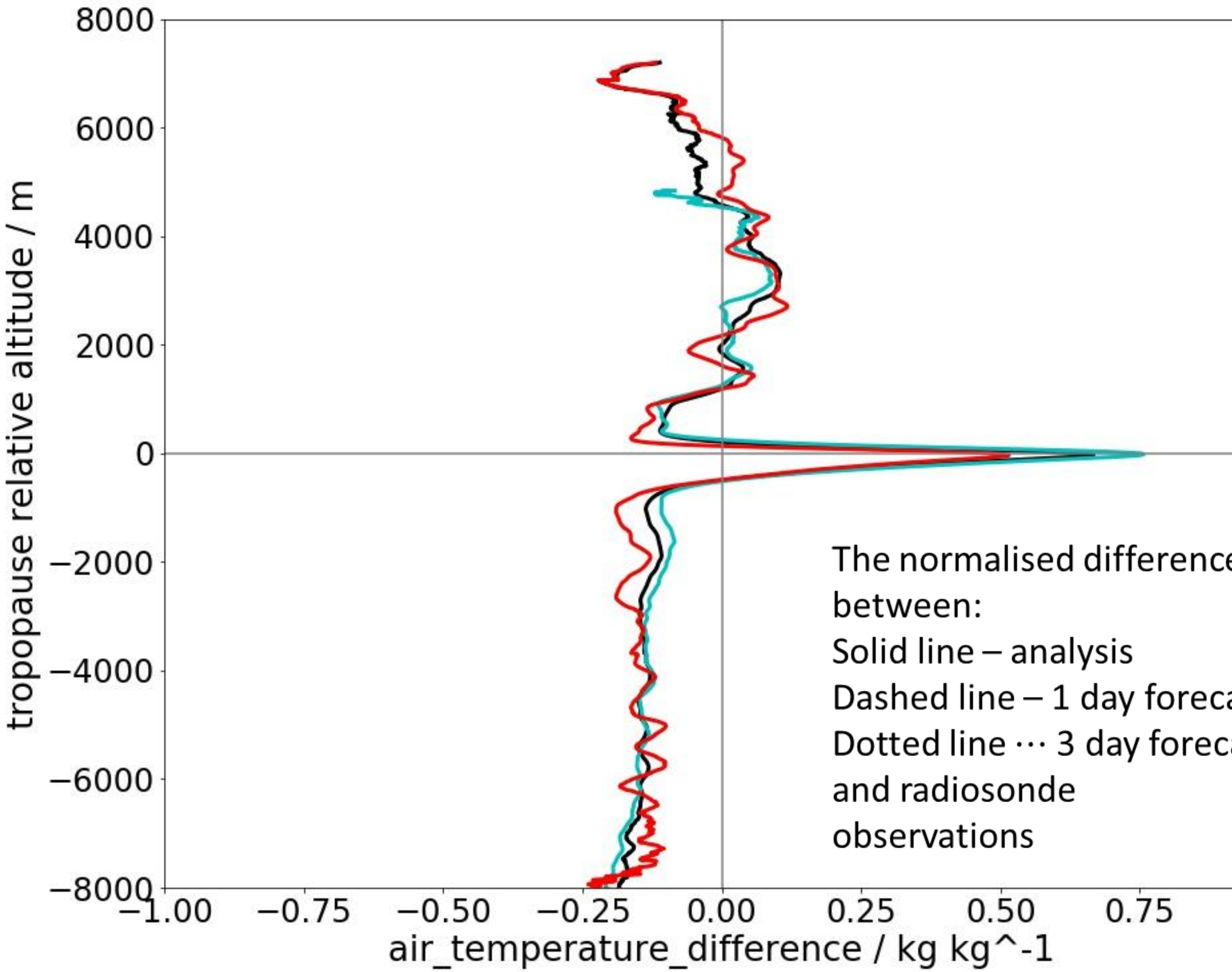
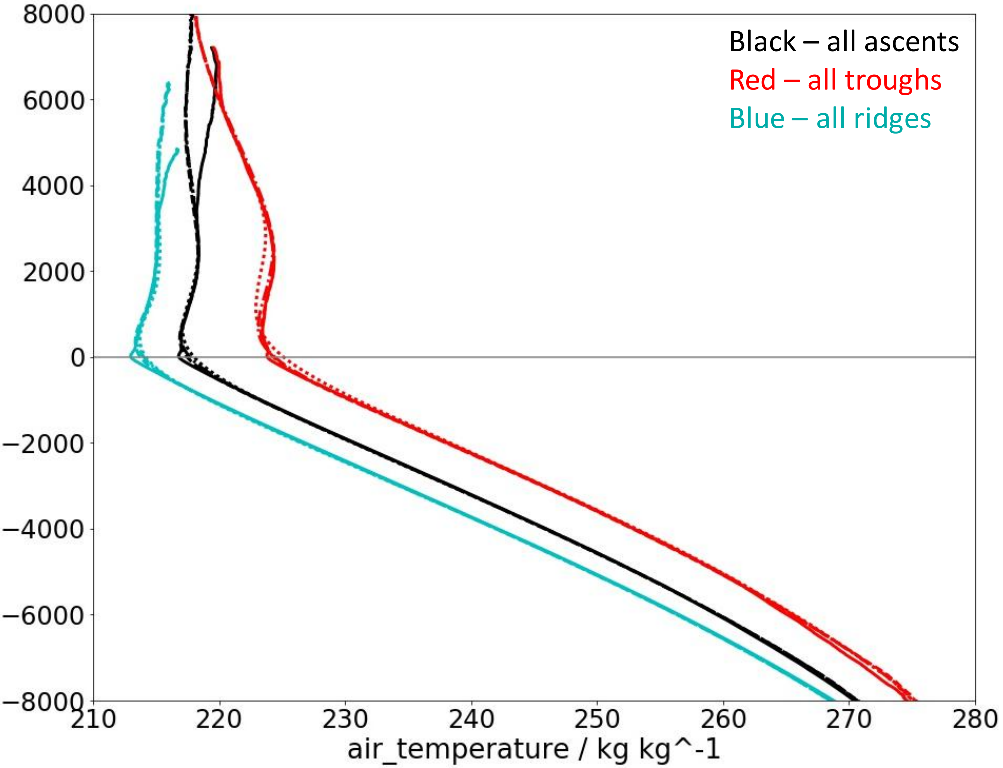
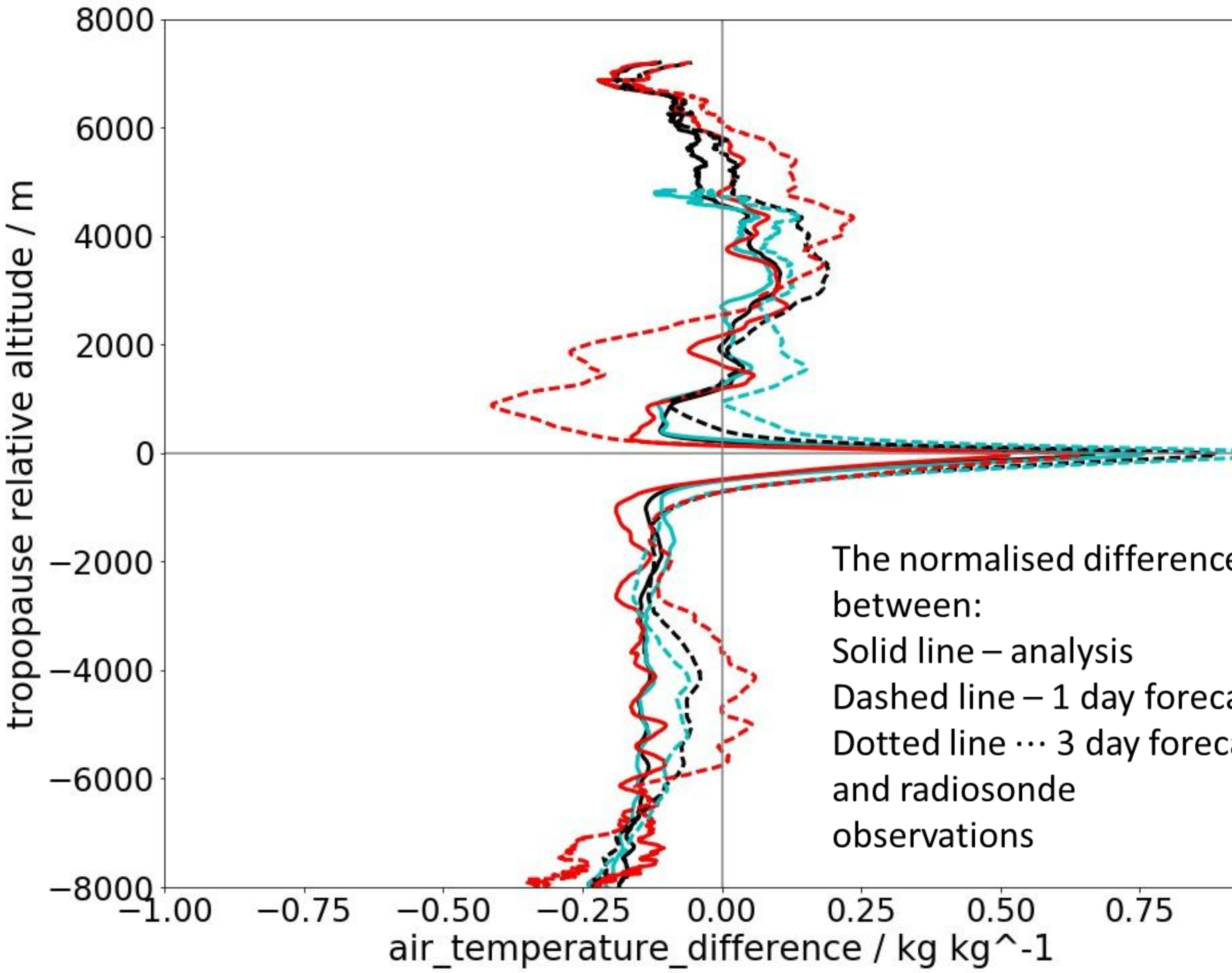


Comparison between radiosonde temperature and the UM analysis and forecast

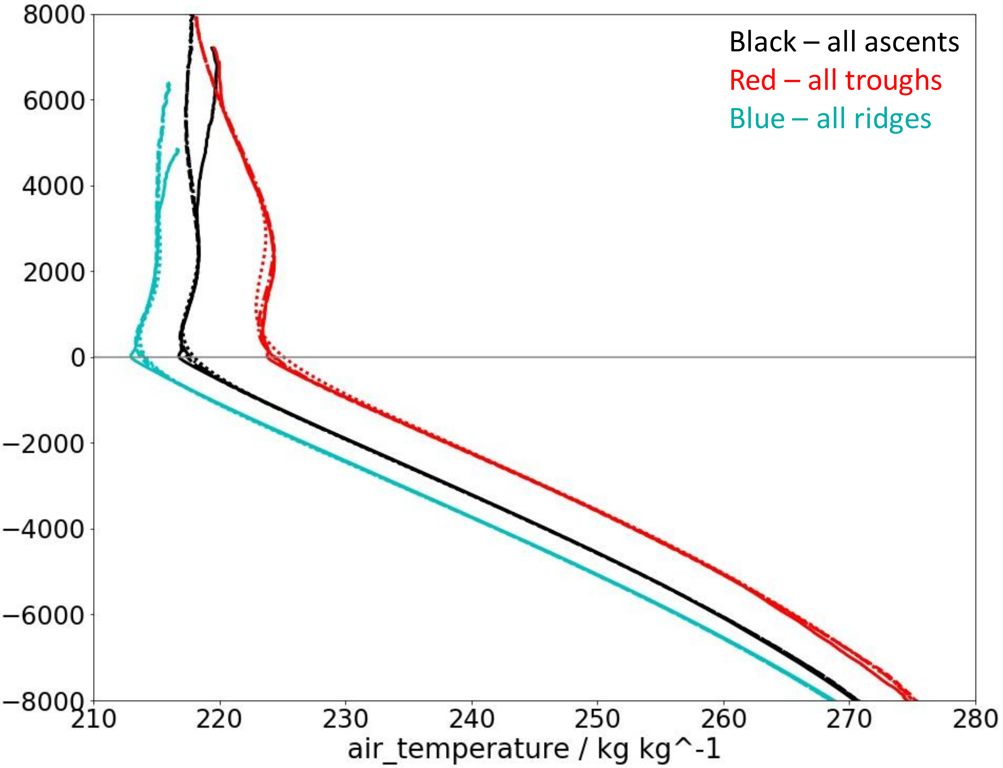


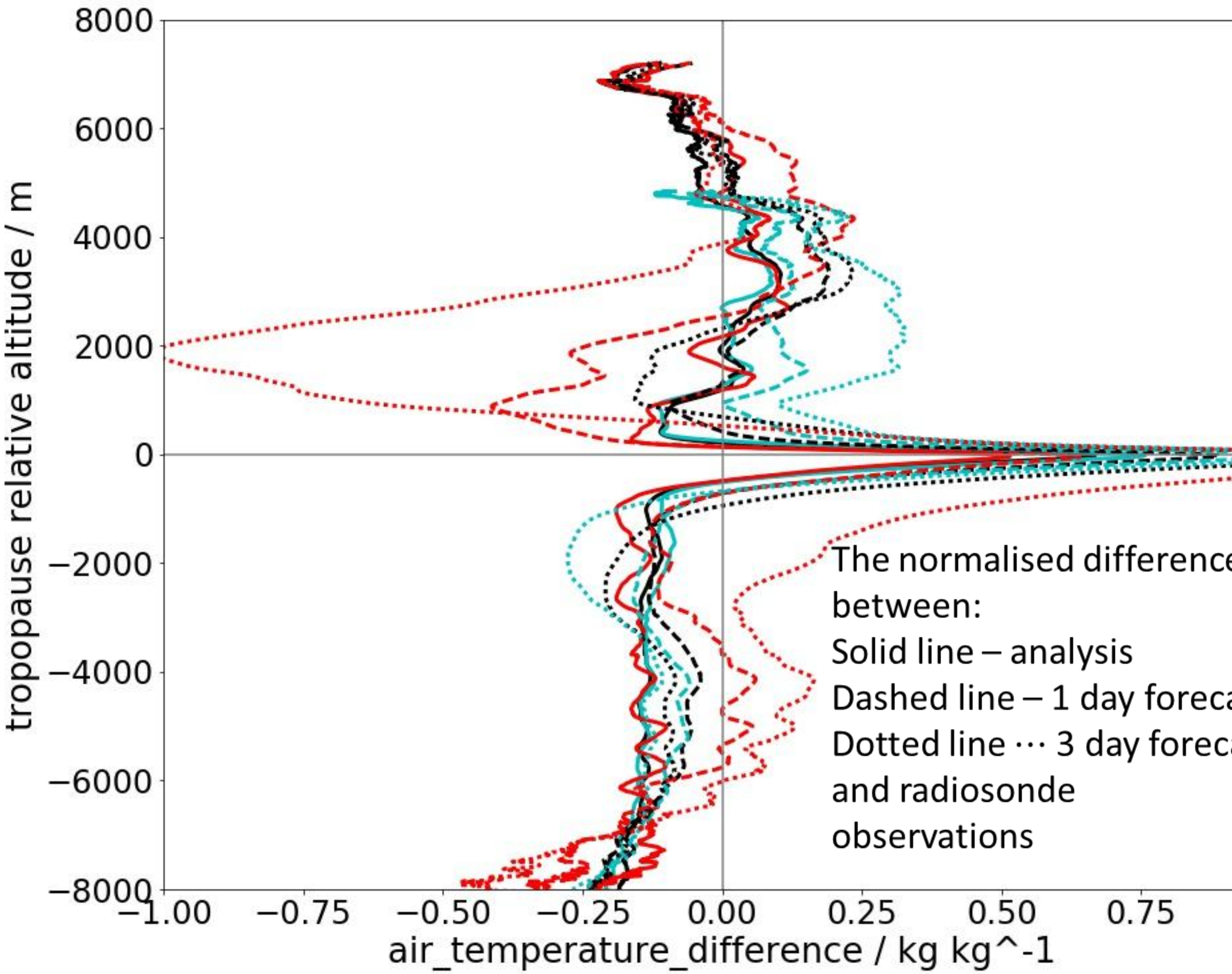



Comparison between radiosonde temperature and the UM analysis and forecast

Expect temperature to be linked to specific humidity through radiation: more humidity = more radiative cooling

Is the reversal of the humidity gradient in ridges inhibiting radiative cooling despite still being more moist



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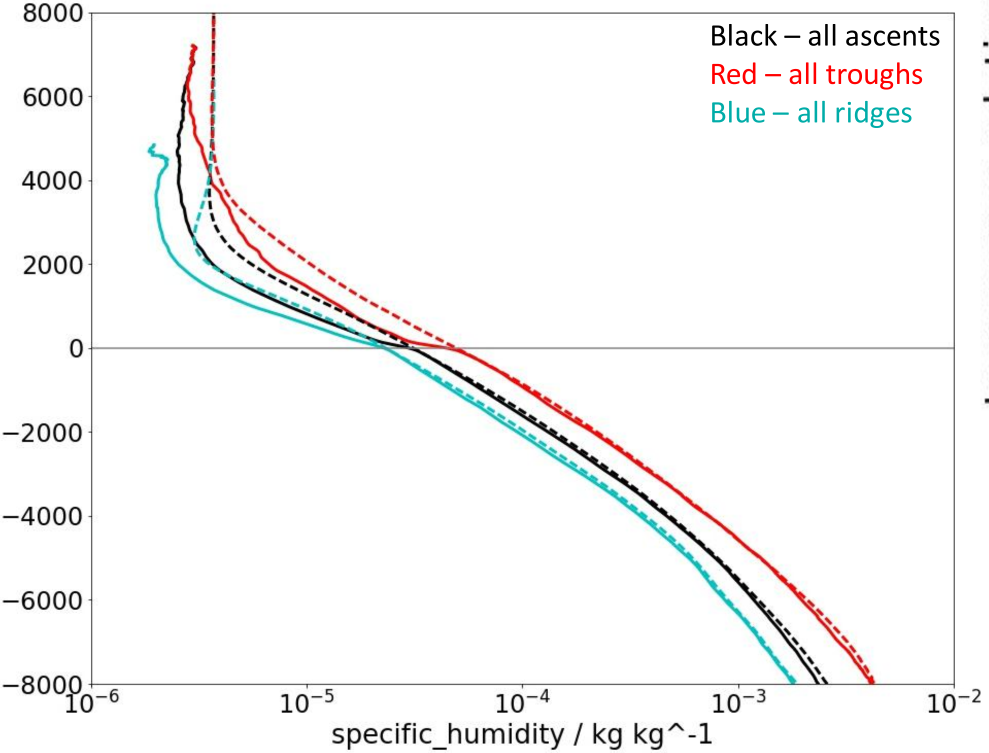


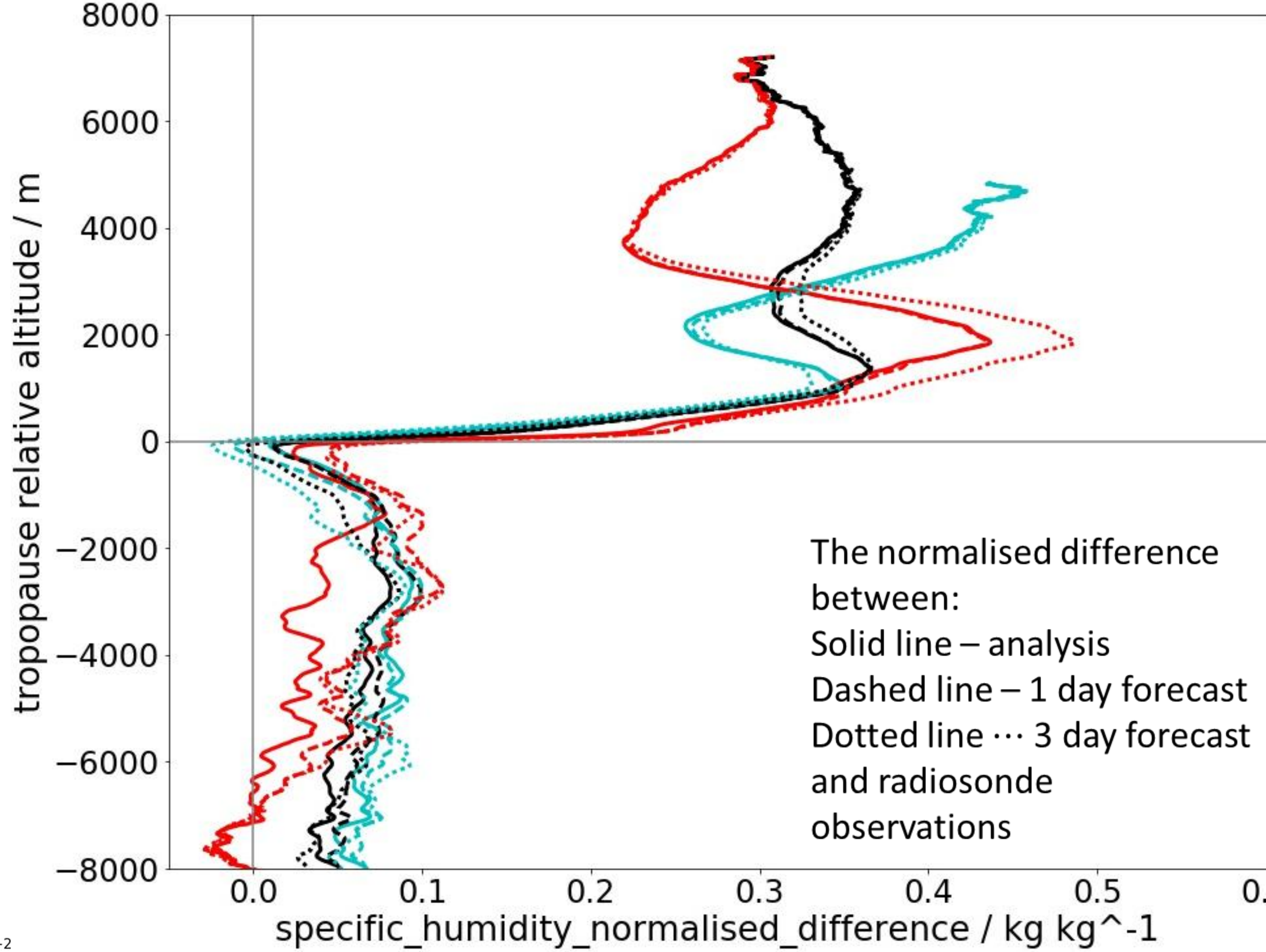

# Summary

- Humidity and temperature biases found in comparisons to other observations are also found in comparison with radiosondes
- Separating ascents in ridges and troughs is used as an example of the method used to try to better understand these biases
- We expect temperature biases to be linked to humidity biases through radiation

# Future work

- Attempt to understand what is going on in ridges in the UM
- Apply a similar method to other conditions – such as presence of cloud, low static stability layers
- Calculate the expected temperature bias growth from the observed humidity bias – see if it matches with observed
- Produce similar comparisons to IFS forecasts

Longer term

- Use modelling informed by this to investigate the processes causing any biases, and the impact of these on the downstream evolution of cyclones

References


- Dyroff, C. , Zahn, A. , Christner, E. , Forbes, R. , Tompkins, A. M. and van Velthoven, P. F. (2015), Comparison of ECMWF analysis and forecast humidity data with CARIBIC upper troposphere and lower stratosphere observations. Q.J.R. Meteorol. Soc., 141: 833-844
- Shepherd T., Polichtchouk I., Hogan R. and Simmons A. (2018) Report on Stratosphere Task Force. ECMWF Technical Memoranda
- Schäfler, A. and Coauthors, 2018: The North Atlantic Waveguide and Downstream Impact Experiment. *Bull. Amer. Meteor. Soc.,* **99**, 1607–1637

# OpenIFS 5th User Workshop 2019

## Department of Meteorology, University of Reading

## 17-21st June 2019

17th June: Lectures & training on OpenIFS
18-21st June: Scientific programme

OpenIFS is the ECMWF outreach programme that provides a version of the ECMWF forecast model to research institutes and universities. This 5th user workshop is an opportunity for researchers to meet and learn about the ECMWF modelling system and applications, and meet other users of the OpenIFS/IFS models.

**Workshop theme:**

**The impact of moist processes on weather forecasts**

## CALL FOR ABSTRACTS and REGISTRATION

https://confluence.ecmwf.int/x/FFsVBw

Abstracts are sought on:

- Topics related to the workshop theme
- Other research applications of OpenIFS/IFS
- Education and training using OpenIFS/IFS

Registration is free and open to all interested scientists. Early career scientists are encouraged. The workshop includes social networking events. Places are limited.

The workshop includes keynote presentations from invited speakers and contributed presentations. The scientific programme will include practical sessions exploring a case study on the workshop theme. OpenIFS training is aimed at both new and existing users to learn about the latest model version.

**Workshop keynote speakers**

C. Grams, KIT, Germany
J. Methven, University of Reading, UK
M. Rodwell, ECMWF, UK
V. Sinclair, University of Helsinki, Finland
C. Thorncroft, University of Albany, USA
H. Wernli, ETH, Switzerland
K. Williams, Met Office, UK
K. Wyser, SMHI, Sweden
N. Žagar, University of Ljubljana, Slovenia

**Deadlines**

Requesting financial support:
**15th March 2019**

No financial support request:
**31st March 2019**

**Contact**
openifs-support@ecmwf.int

**Supported by:**

European Geosciences Union
University of Reading
ECMWF
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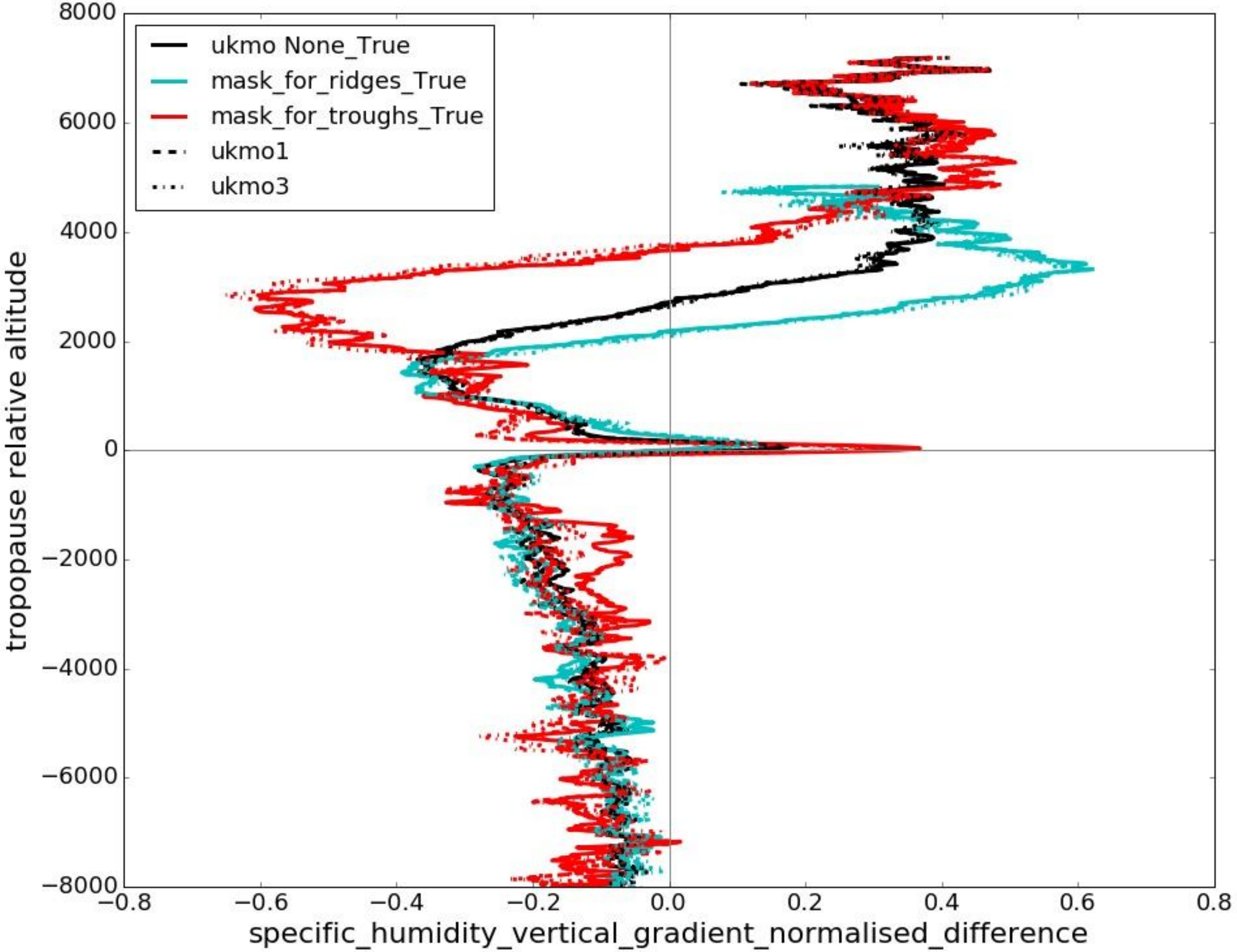
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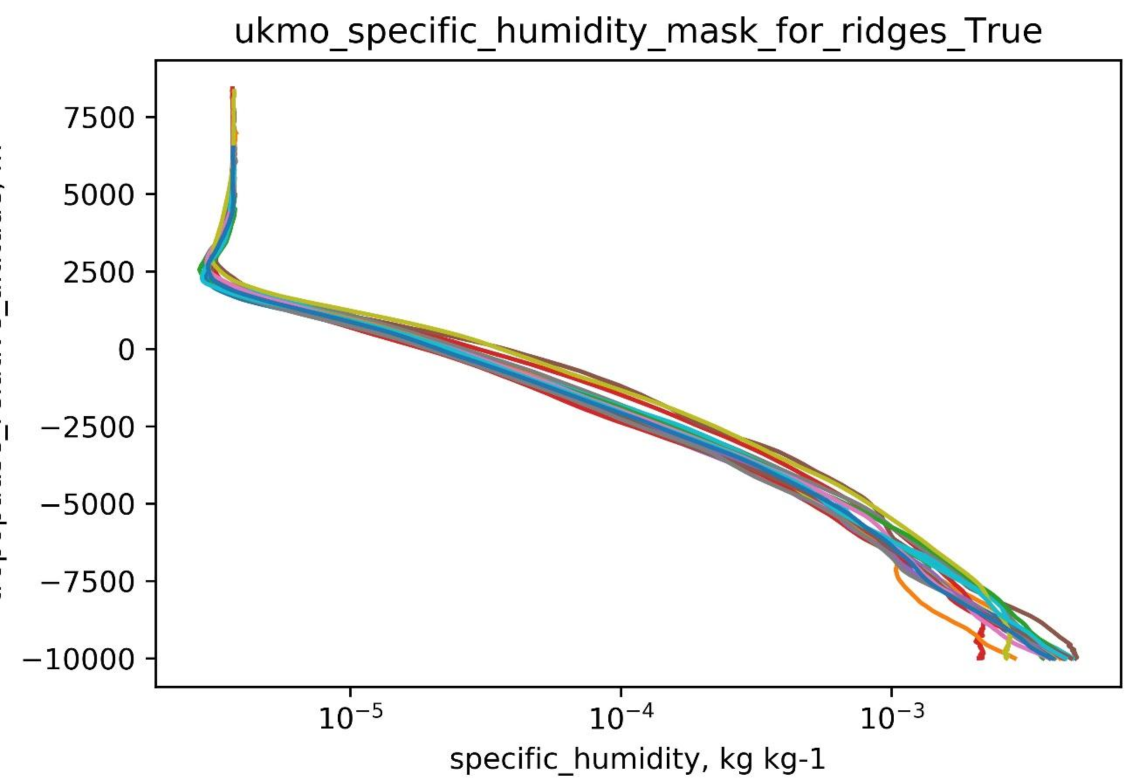
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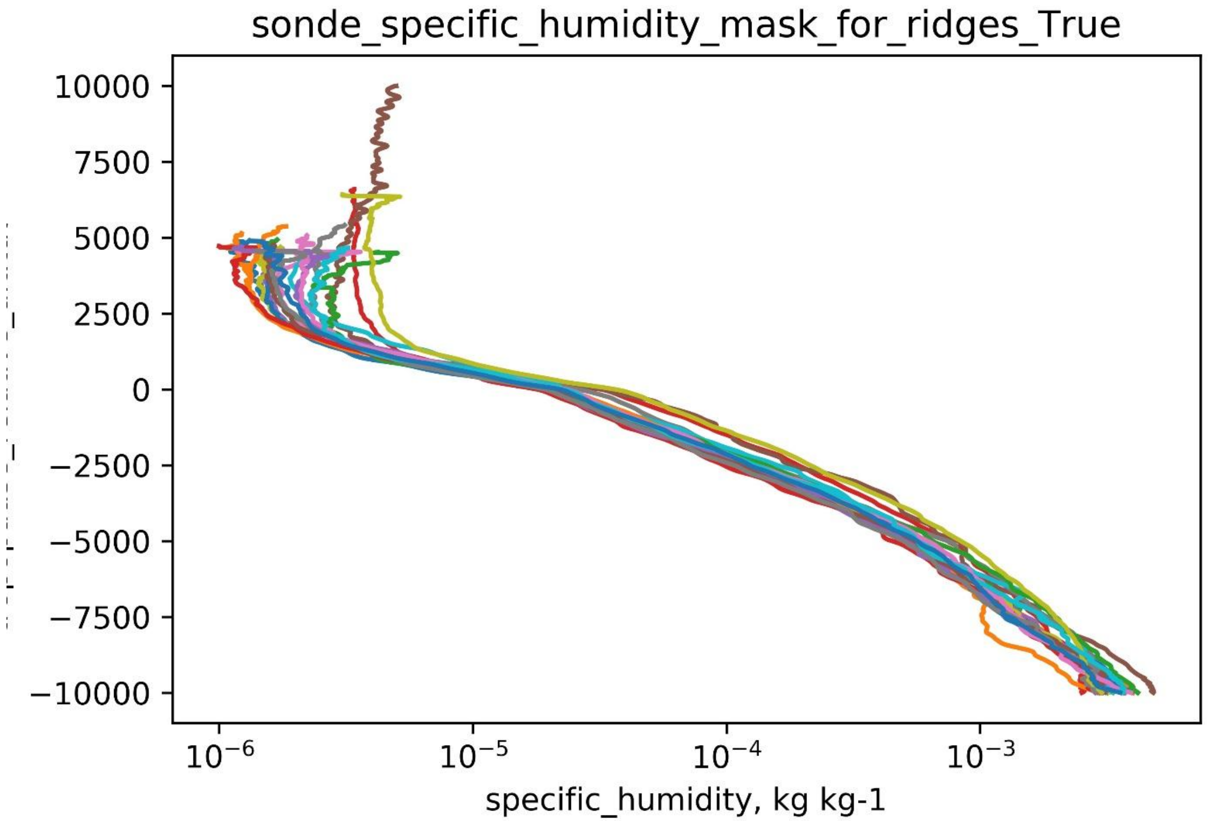
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