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paths emerge in that we walk them

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Atmospheric Remote Sensing and Climate System Research Group
ARSCliSys

Evaluation of Climate Models Using RO Observations – Tropical Convection Regimes in the HadGEM Model

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Outline

- Motivation and background
- Data sets
- Comparison method
- Results
  - classification
  - distribution
  - differences in temperature
- Conclusions and outlook

Motivation

- Spread of climate model uncertainty arises mainly from differences in feedback processes (*IPCC* 2007).
- Water vapor feedback constitutes the strongest feedback followed by the negative lapse rate feedback (*Soden and Held* 2006).
- The net effect of the water vapor/lapse rate feedback results in the amplification of a warming.
- Change is largest in the tropical middle and upper troposphere and is not yet well understood.
- *"Given the complexity of processes controlling tropical humidity* a *combination of modeling and observational studies are needed to assess the reliability of model water vapor feedback* (*IPCC* 2007)".

Background

- Evaluation of climate model data with RO observations
- First study using Met Office Hadley Centre HadGEM2 model
- Focus on processes in the tropics, convection regimes
- We take the approach of classification of moist and dry tropical regimes through distinction between dynamical up- and downdraft regions.
- Regions of rising motion (upper level divergence) are closely tied to regions of deep convection.
- Regions of sinking motion (convergence) represent mean clear sky conditions (*Lau et al.* 1997).
- For the classification of vertical motion (ascending/descending air) associated with large-scale tropical circulation we use the pressure vertical velocity at 500 hPa (ω500) and Sea Surface Temperature, following *Ringer and Allan* (2004).

Data

- **RO observations**
  temperature profiles from multiple satellites
  CHAMP, SAC-C, GRACE-A, F3C
  200 m vertical grid
  Wegener Center processing OPSv5.4
  www.wegcenter.at/globclim

- **HadGEM2 AMIP model (CMIP5)**
  pressure vertical velocity (ω500) – daily means,
  near surface temperature (Ts) – daily means
  air temperature – 6 hourly
  model resolution:1.25 lat x 1.875 lon, 38 levels
  ftp.badc.rl.ac.uk

- **ERA-Interim**
  daily mean ω500 and
  6 hourly 2m-temperature (T2m)
  proxy for RO to classify the profiles
  ERA land-sea mask

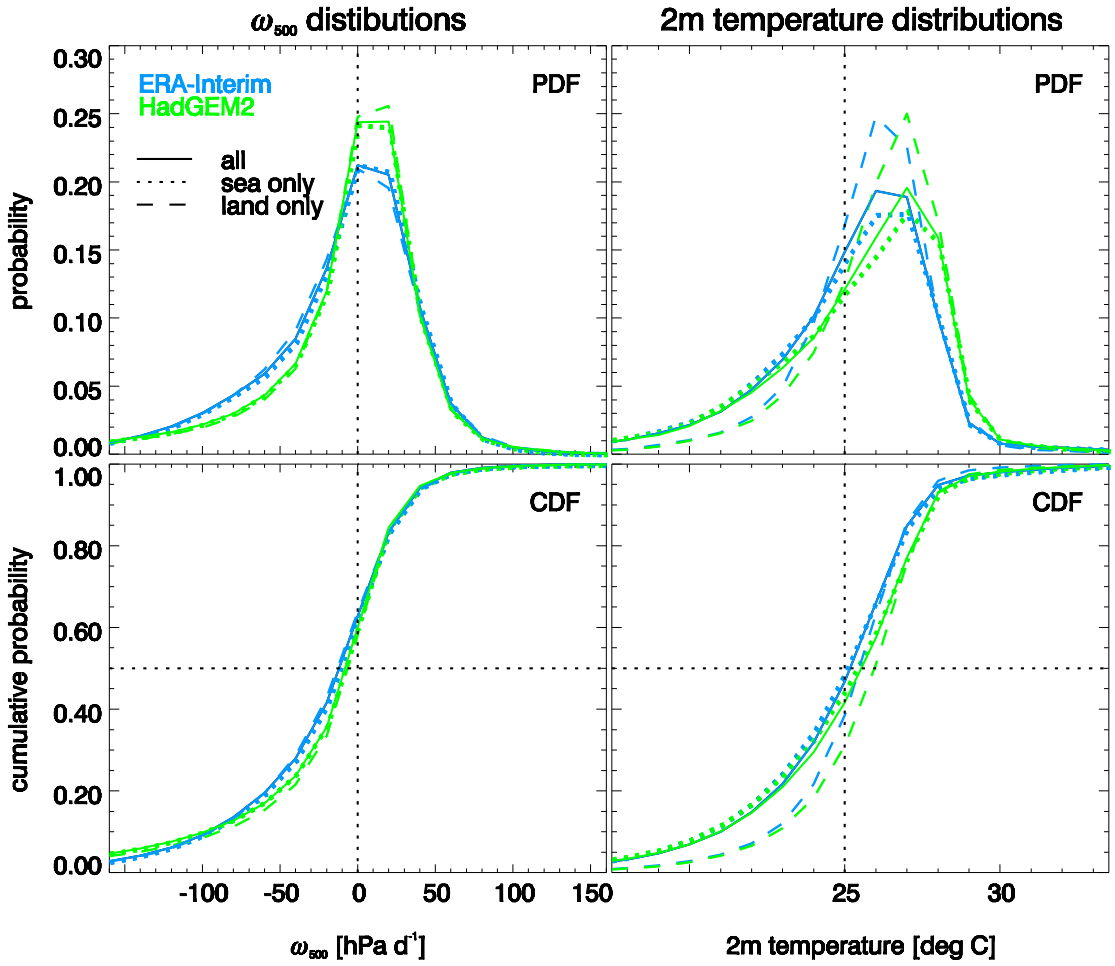
- **Nino 3.4 index**
  El Niño, La Niña conditions (N3.4 index values above/below 0.4)
  www.esrl.noaa.gov/psd/forecasts/sstlim/global/indices_global

Method

- **Period 2001 to 2008**
- **Tropics** 20S to 20N,
  4 pressure levels: 250 hPa, 100 hPa, 50 hPa, 10 hPa
  18 altitude levels: 5 km to 33 km
- **Moist and dry tropical regimes**
- Classification of **dynamical up- and downdraft** regions by **pressure vertical velocity at 500 hPa** and **surface temperature** from ERA-Interim for RO profiles and
  from the HadGEM2 model itself for the model
- **Sort RO and collocated HadGEM2 profiles into vertical velocity classes** for a systematic comparison
- Classified **temperature** data are investigated wrt differences over **land and sea** and
  El Niño/La Niña conditions

Distribution – ERA-Int and HadGEM2

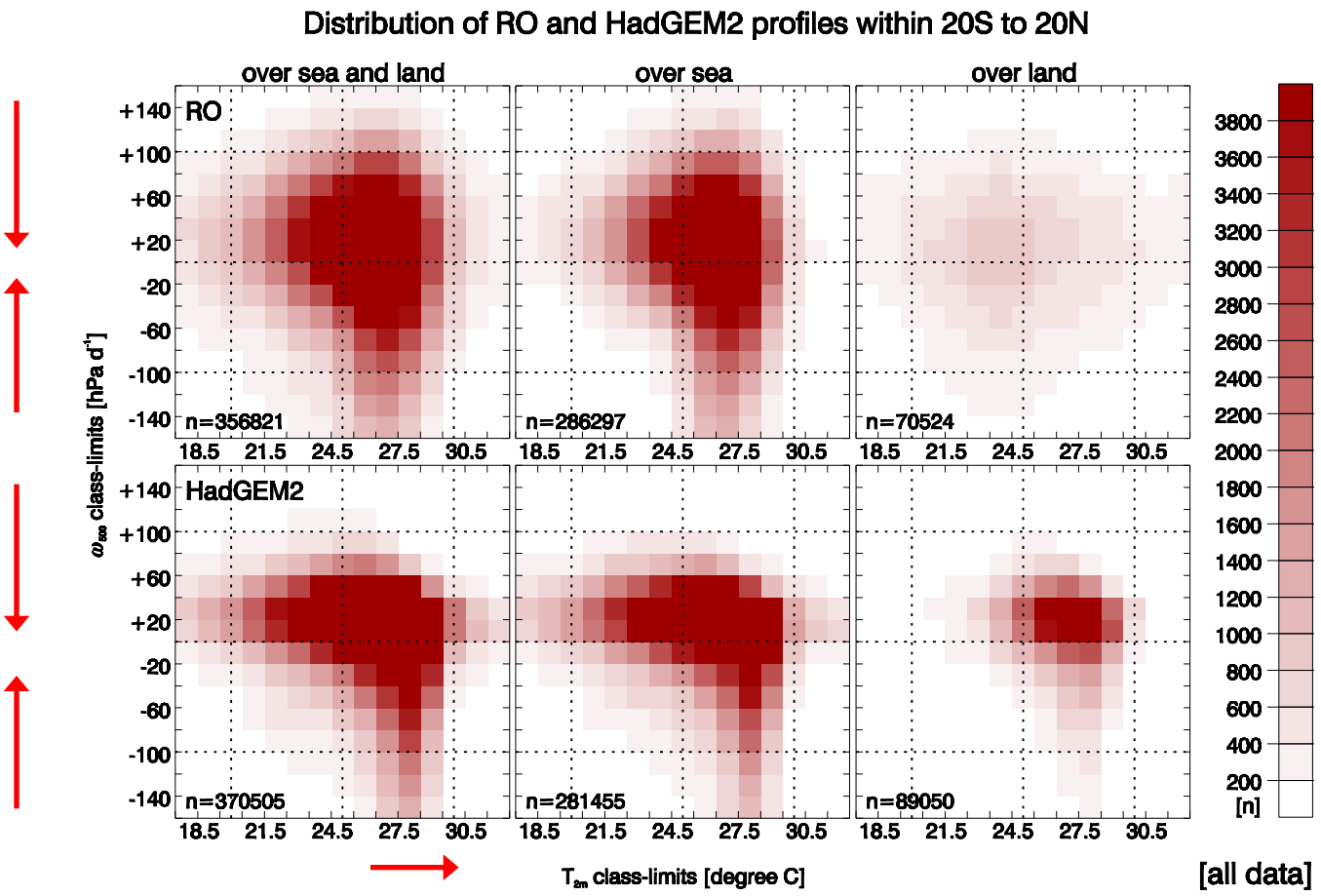
- **ERA-Int** and **HadGEM2: Distribution of ω500 and T2m**



- Distribution of HadGEM2 less broad than ERA-Int
- Agreement in T2m (both use SST)
- Use ERA-Int ω500 and T2m as proxy to classify RO

Distribution of RO and HadGEM2

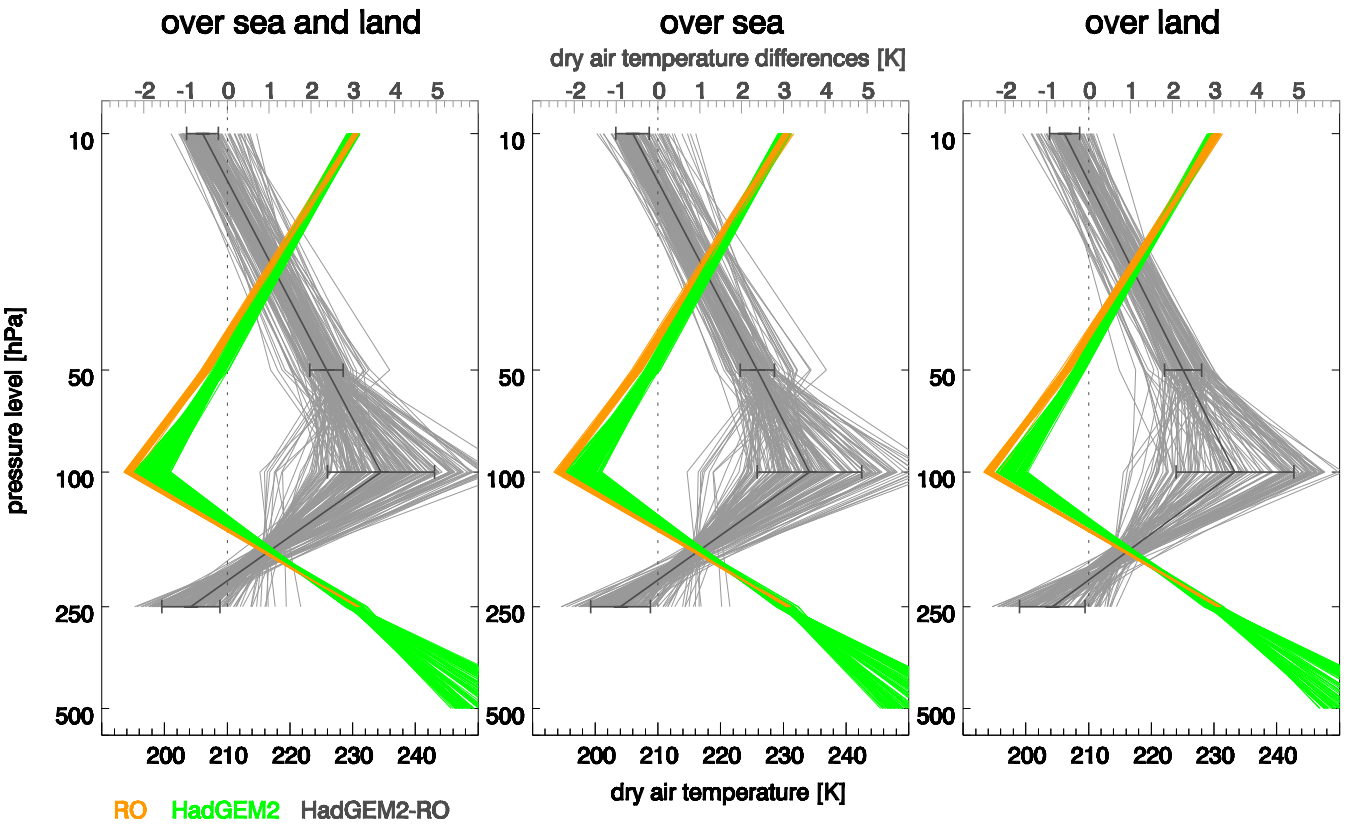
Distribution of RO and HadGEM2 profiles in ω500 and T2m



- RO profiles cluster in classes between (-60 to 80)hPa/d and between (23 to 28)°C
- HadGEM2 profiles cluster narrower in ω (-40 to 60)hPa/d and broader in T2m (21 to 29)°C
- Over land RO profiles cluster at lower temperatures than HadGEM2

Mean Temperature Profiles – RO and HadGEM2 (1)

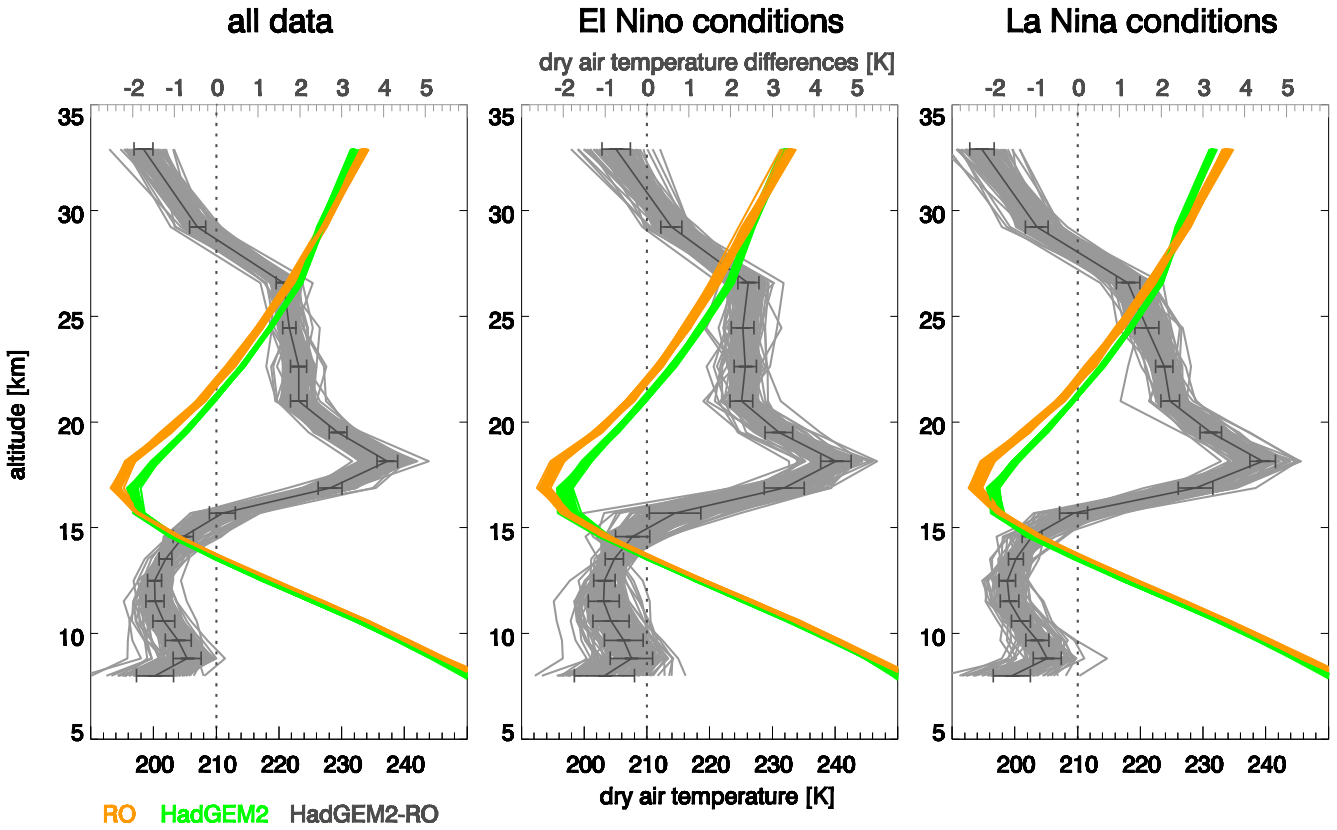
- **Classified RO and HadGEM2 mean dry temperature profiles – 4 p-levels**



- Temperature profiles of all class means and differences HadGEM2 minus RO
- HadGEM2 shows warmer tropopause (~3 K) – coarse altitude resolution?
- HadGEM2 colder than RO below at 250 hPa and at 10 hPa

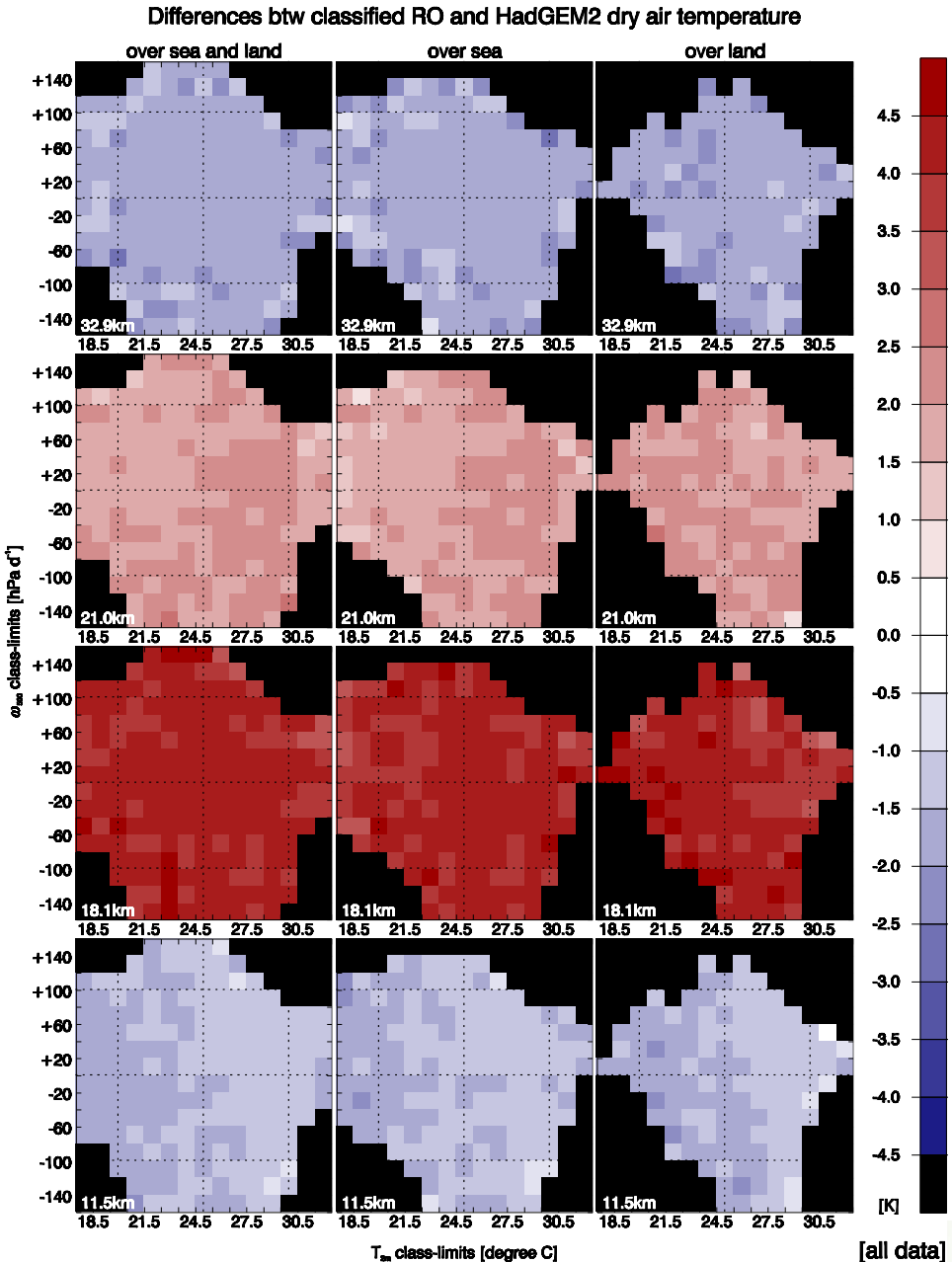
Mean Temperature Profiles – RO and HadGEM2 (2)

- **Classified RO and HadGEM2 mean dry temperature profiles – 18 alt-levs**



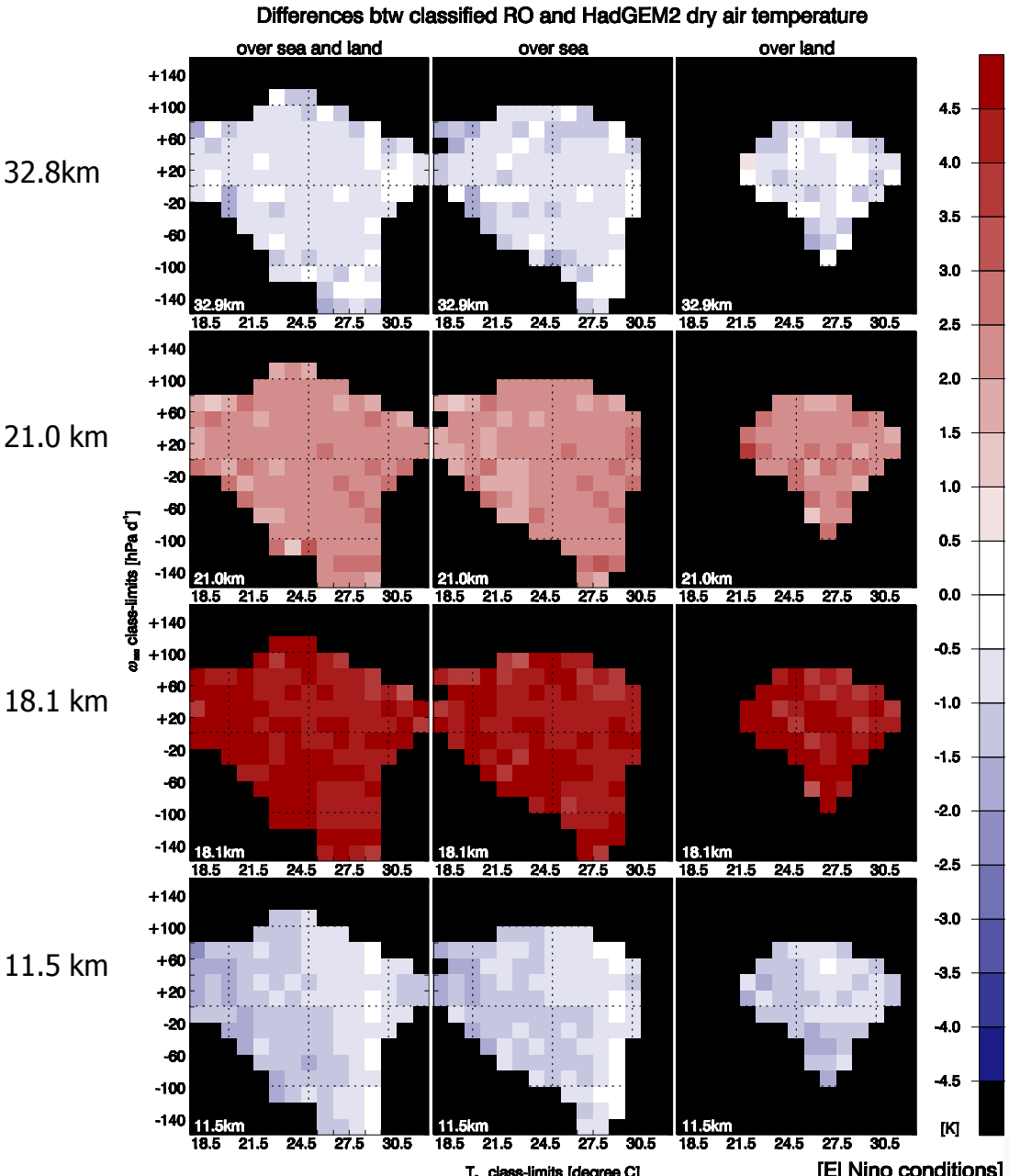
- HadGEM2 shows warmer tropopause ~4 K and LS, lower variability than at p-levels
- HadGEM2 colder than RO below ~15 km and above ~28 km
- Difference El Niño (-1 K in UT; 2.5 K in LS) and La Niña (-1.5 K in UT; 1 to 2 K in LS)

Temperature Difference – RO and HadGEM2 (1)



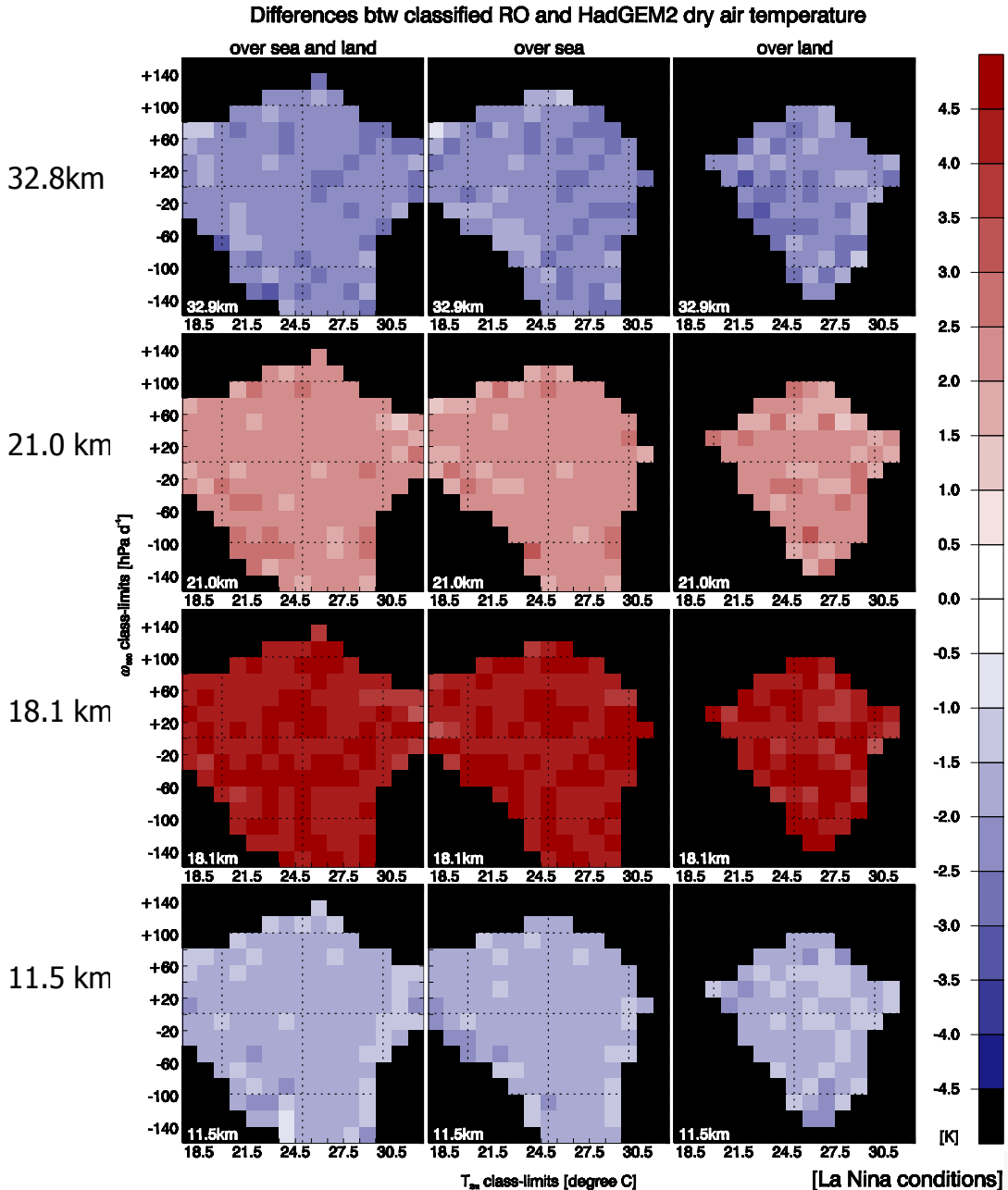
- **Differences of classified RO and HadGEM2 dry temperature profiles**
- Distribution of differences in classes
- 4 altitude levels
  11.5 km
  18.1 km
  21.0 km
  32.8 km
- HadGEM2 colder in UT<15 km
- Maximum difference to RO above the tropopause
- HadGEM2 warmer in LS
- HadGEM2 colder >28 km
- No difference over land/sea

Temperature Difference – RO and HadGEM2 (2)



- **Differences of classified RO and HadGEM2 mean dry temperature profiles**
- **El Niño**
- Troposphere larger differences at lower surface temperatures and larger ω500 values
- Different distribution over land and over sea

Temperature Difference – RO and HadGEM2 (3)



- **Differences of classified RO and HadGEM2 mean dry temperature profiles**
- **La Niña**
- Difference of HadGEM to RO is larger at highest levels
- Difference of HadGEM2 in tropospheric levels about -1 K

Conclusions

- First results on representation of UTLS temperature in RO and HadGEM
- Systematic deviation of HadGEM2 from RO was found depending on altitude and atmospheric conditions
- HadGEM2 is warm biased around the tropopause and in the LS
- HadGEM2 is cold biased in the troposphere below ~15 km
- HadGEM2 is cold biased in the stratosphere above ~ 28 km
- Differences in the distribution of up-, downdraft regimes in troposphere

Outlook

Further investigations

- zoom into differences in distribution in the troposphere
- compare refractivity profiles
- compare temperature and refractivity gradients
- HadGEM3 model with higher resolution, higher top level
- other CMIP5 models

Comparisons of RO observations with model data might be useful for the improvement of parameterization in climate models.

THANK YOU !

Thanks for funds to