From the west African monsoon up to planetary climate change: synergy between Earth radiation budget measurements

University of Reading

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Thanks: Chunlei Liu, Norman Loeb

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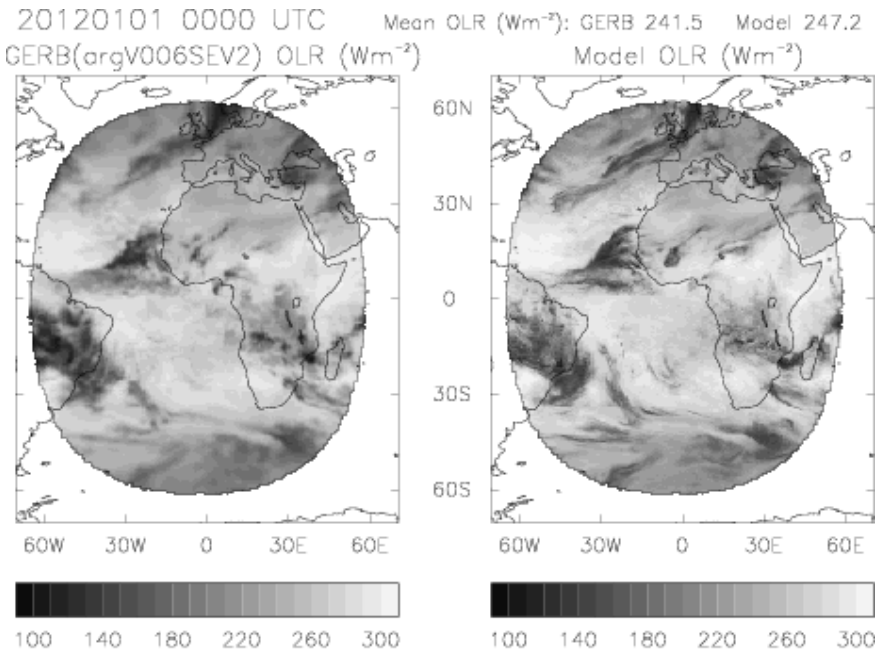
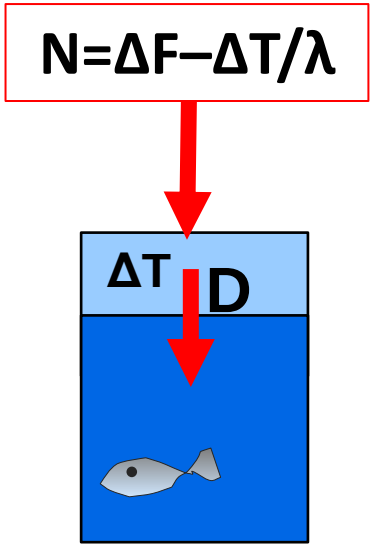
Joint CERES-GERB and SCARAB Earth Radiation Budget workshop

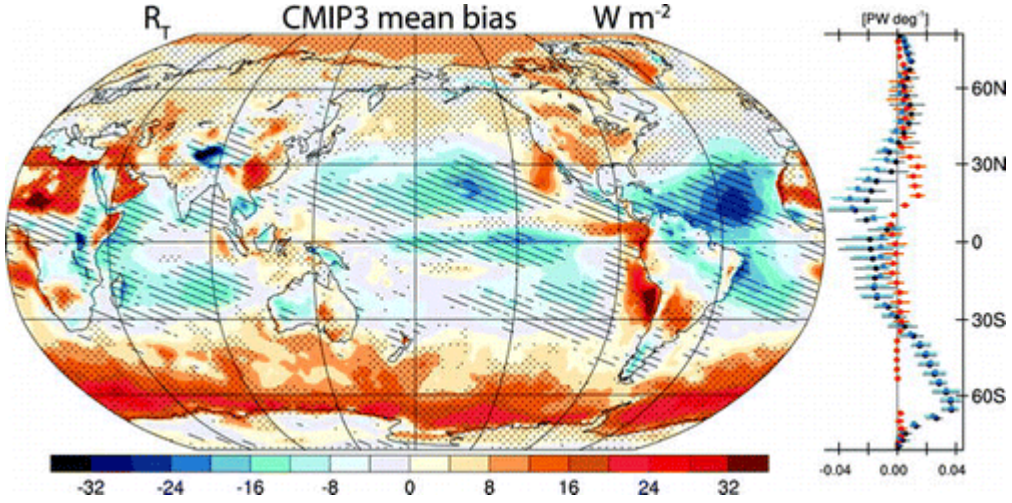
7-10 Oct 2014 Toulouse (France)

Earth's Energy budget: a key variable…

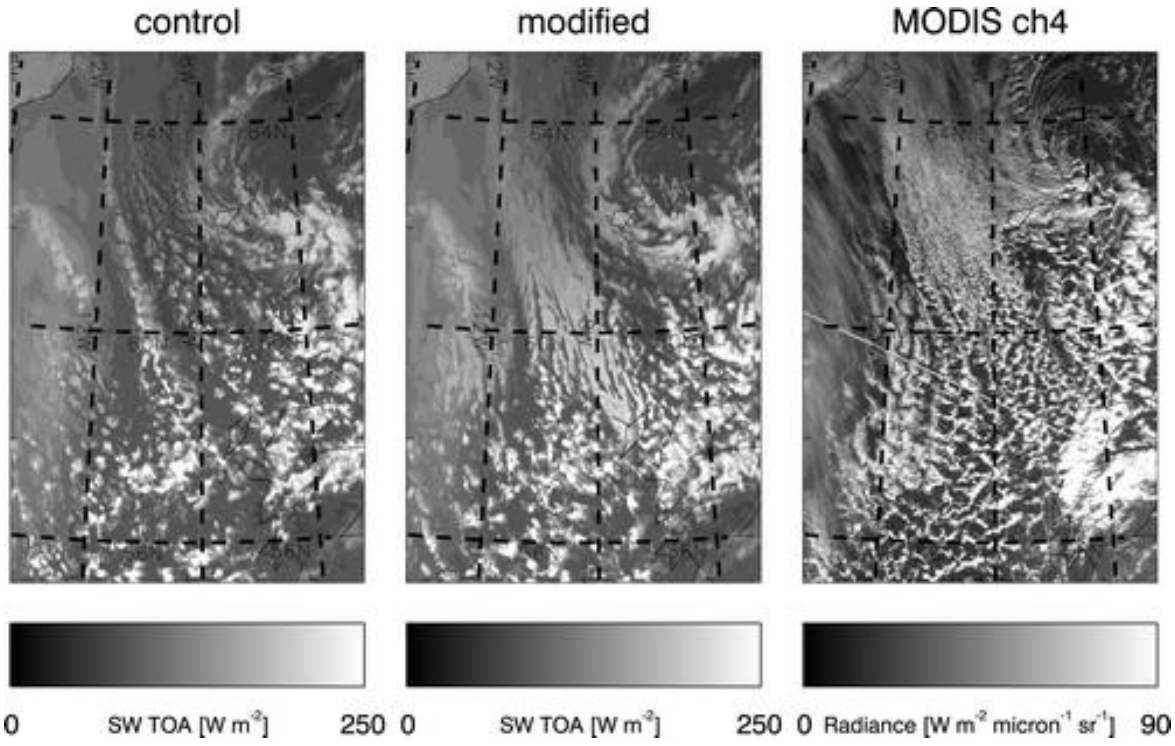
- Evaluation of weather and climate model processes
- Radiative forcing/feedbacks and ocean heat uptake
- Coupling of global energy and water cycle







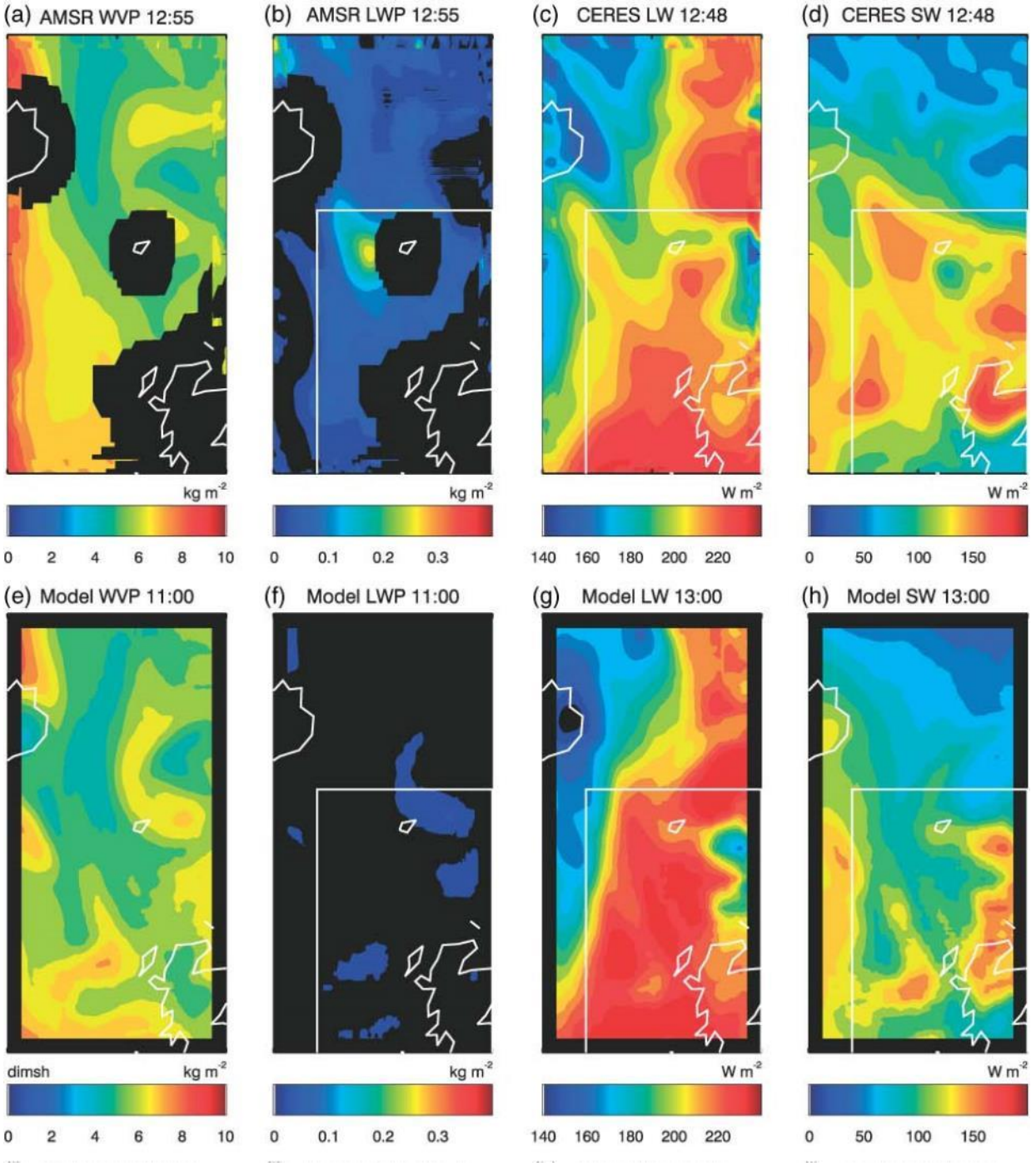
Systematic cloud radiative model biases



Systematic model biases in cloud radiative forcing relating to cold air outbreaks (e.g. Trenberth & Fasullo, 2010; Karlsson & Svensson, 2011; Bodas-Salcedo *et al.*, 2012)

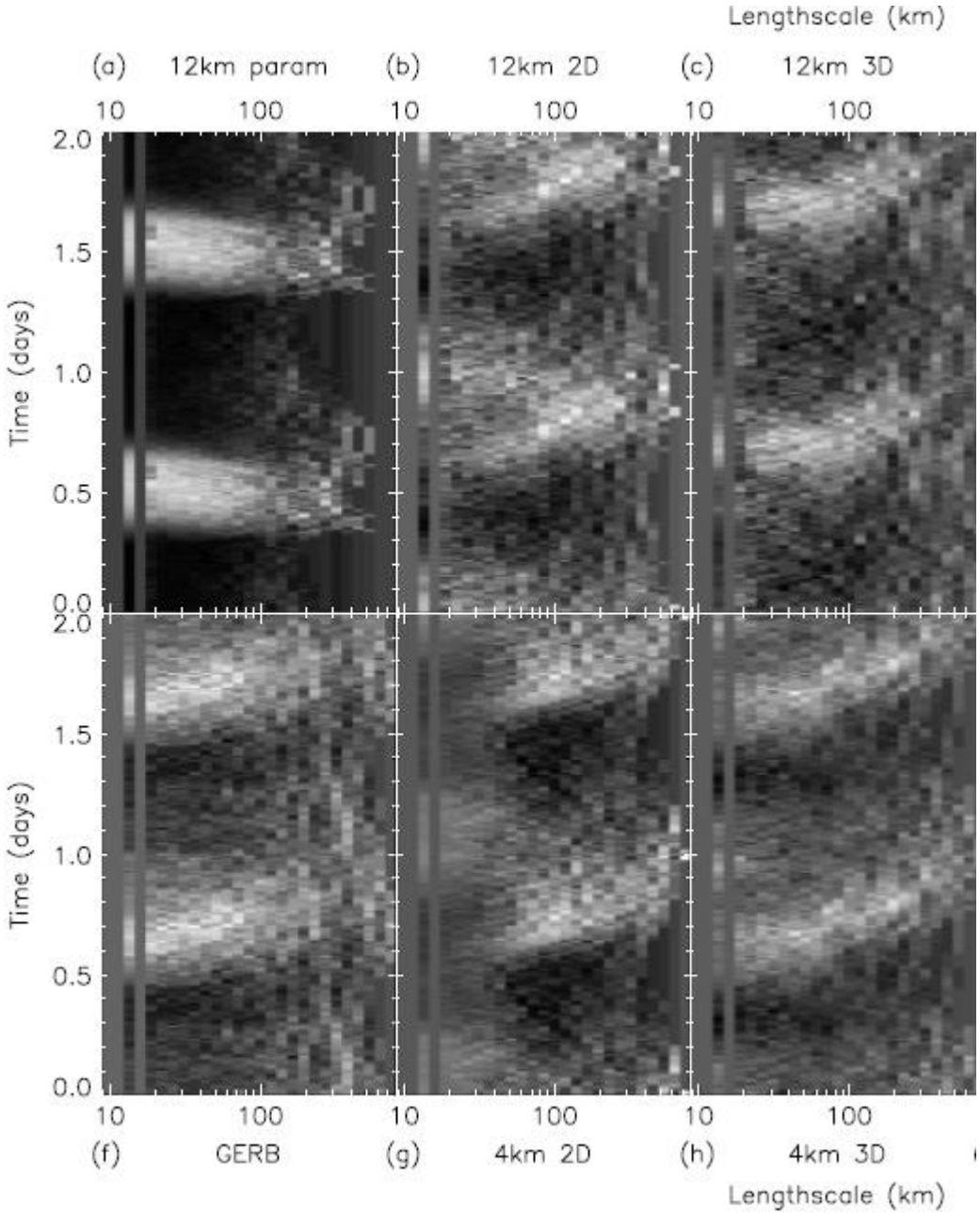
Evaluating model cloud processes

Right: combining AMSR and CERES satellite data to evaluate simulations of a cold air outbreak: [Field et al. (2014) QJRMS]



Evaluating diurnal cycle of convection in models

Right: Use of GERB in evaluating simulation of diurnal cycle of convection over W. Africa in the “grey zone” of convective parametrization (4-12km)



Pearson et al. (2014) QJRMS

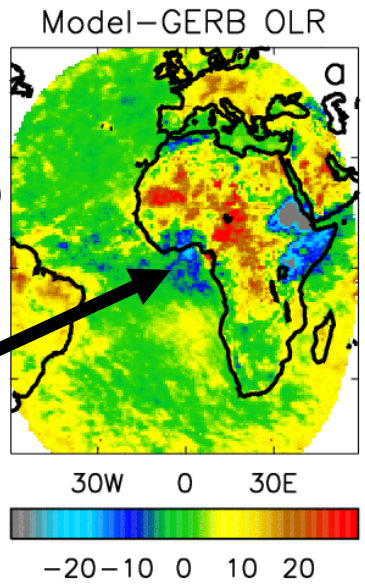
Convective outflow

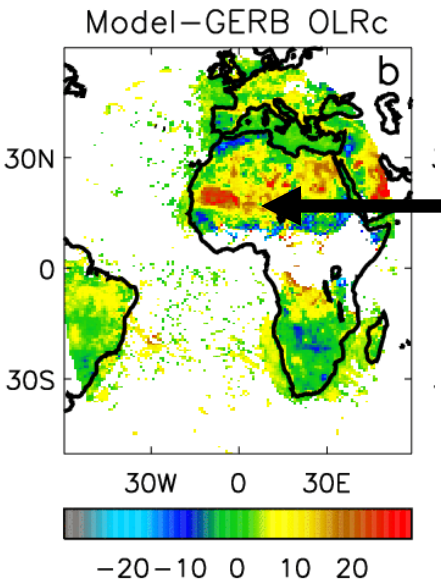
Improving model physics using GERB data

Marine stratocumulus

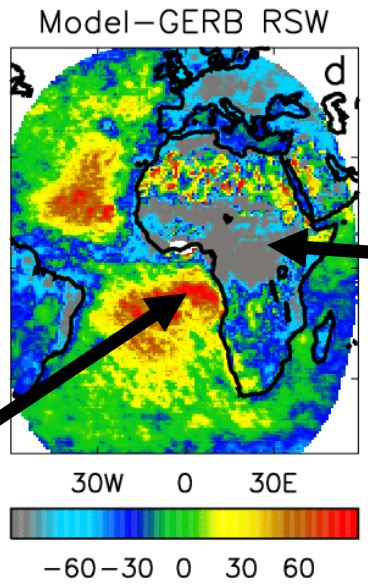
All-sky **Clear-sky**

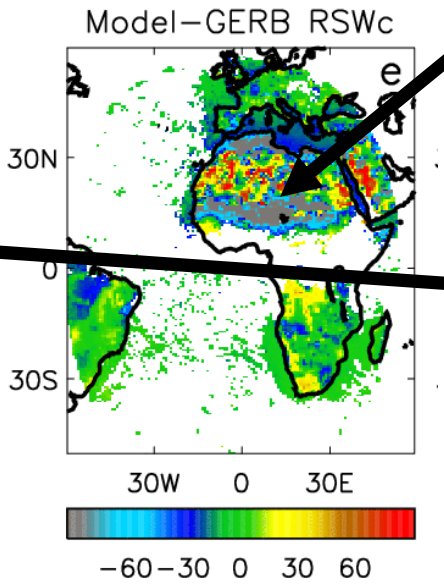
Longwave





Shortwave





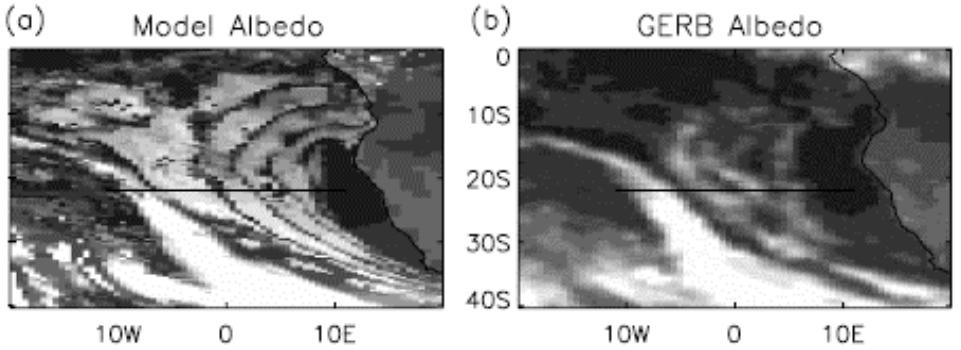
Mineral dust

Surface albedo

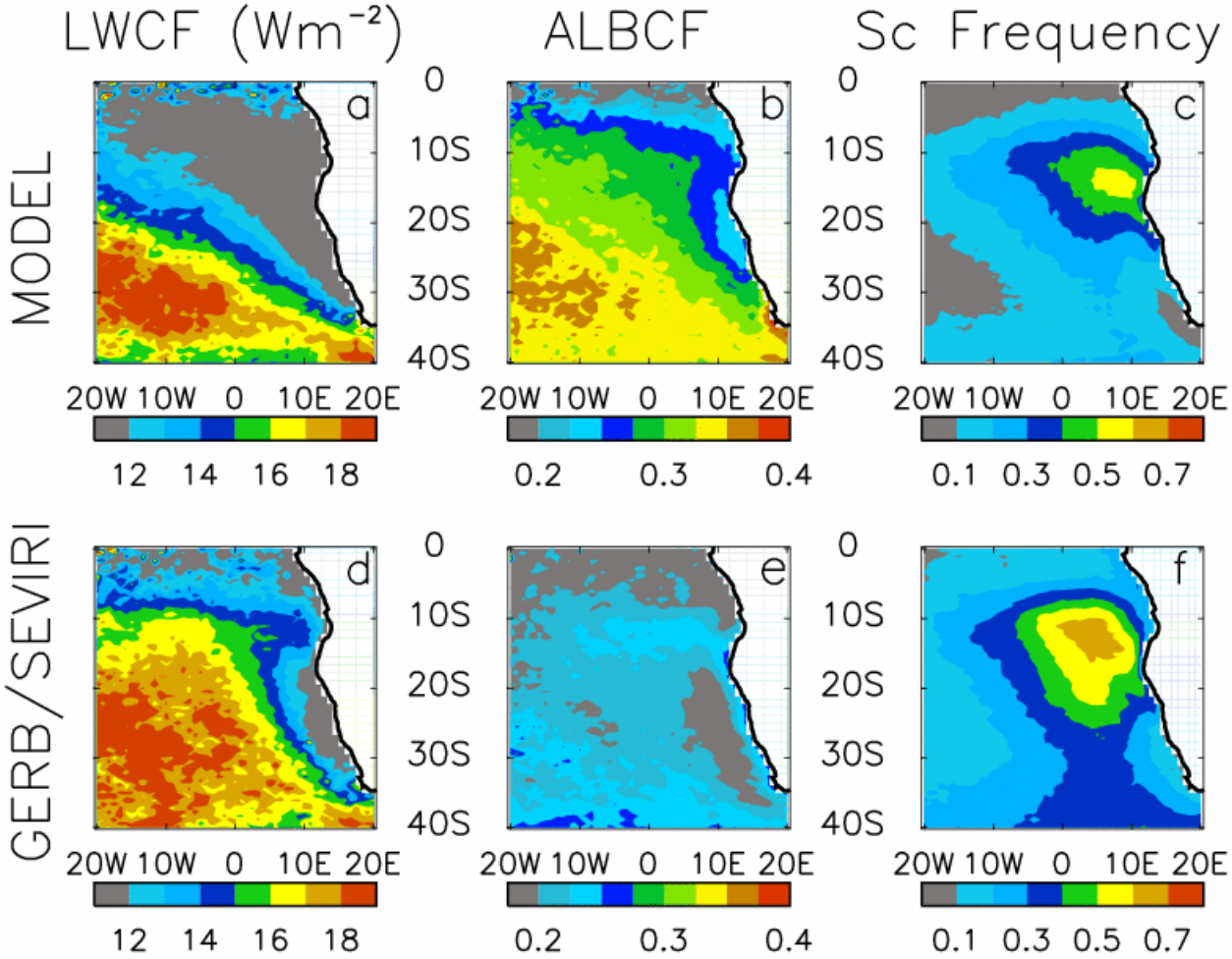
Convective cloud

Allan et al. (2007) QJRMS

NWP model cloud radiative bias

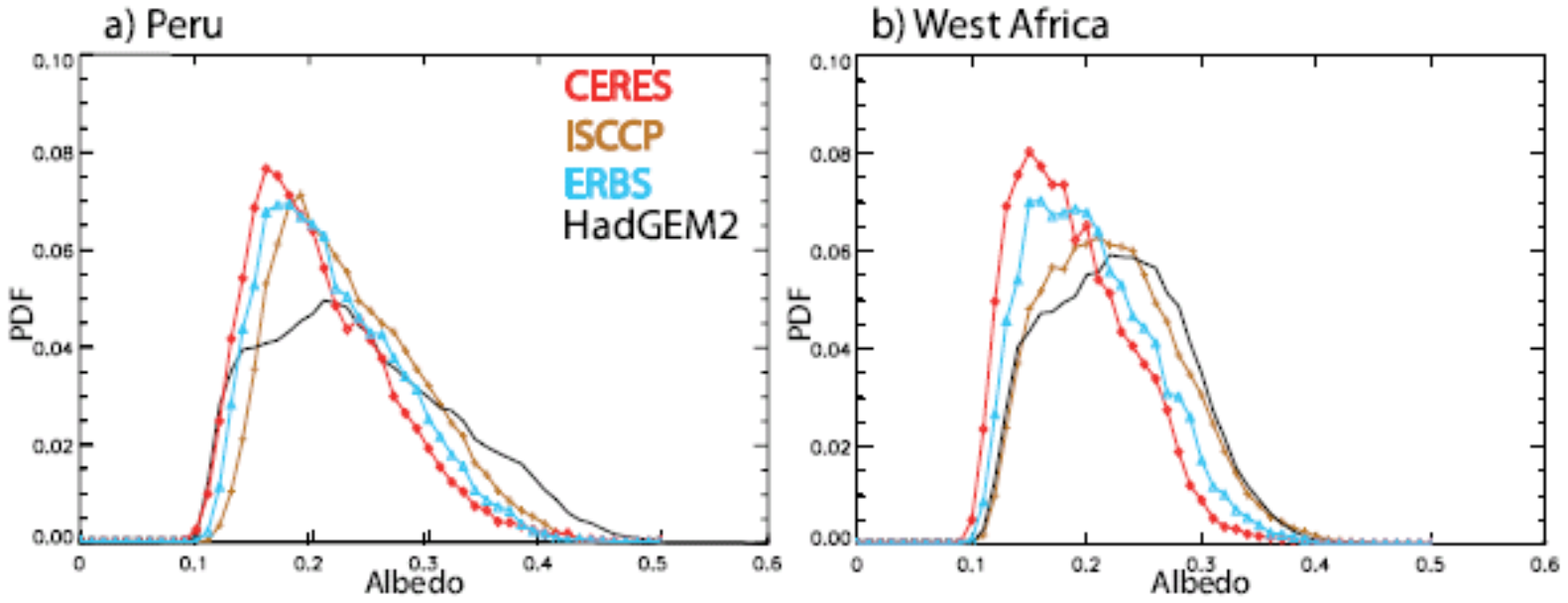


- LW cloud effect too small by about 5 Wm^{-2}
- SW cloud effect too large...
- ...yet too little stratocumulus cloud cover
- Too few too bright e.g. [Nam et al. (2012) GRL]



Overcast Sc-cover pixels only (2003-2010) [Allan et al. (2007) QJRMS]

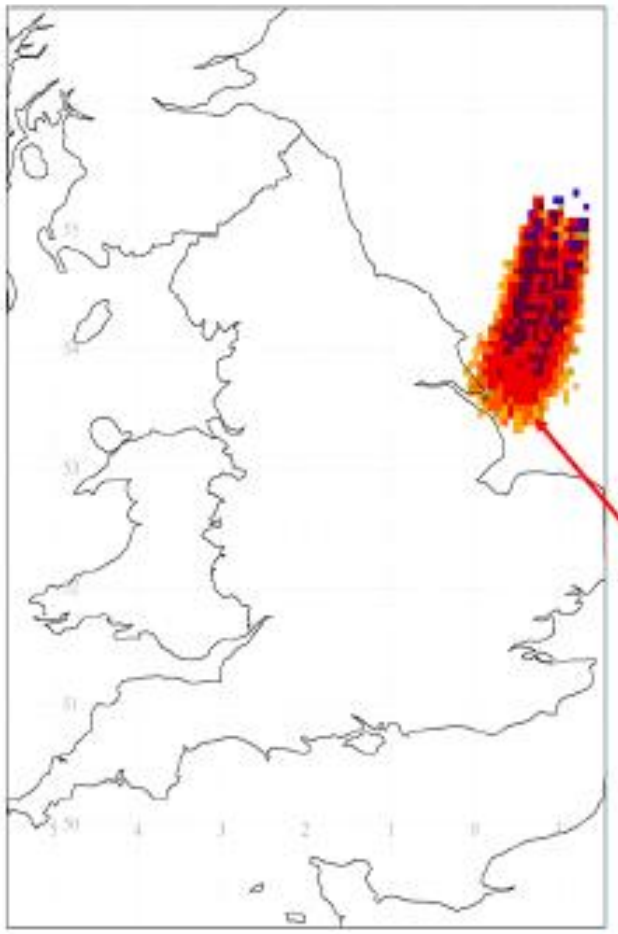
Albedo probability distribution over stratocumulus regions

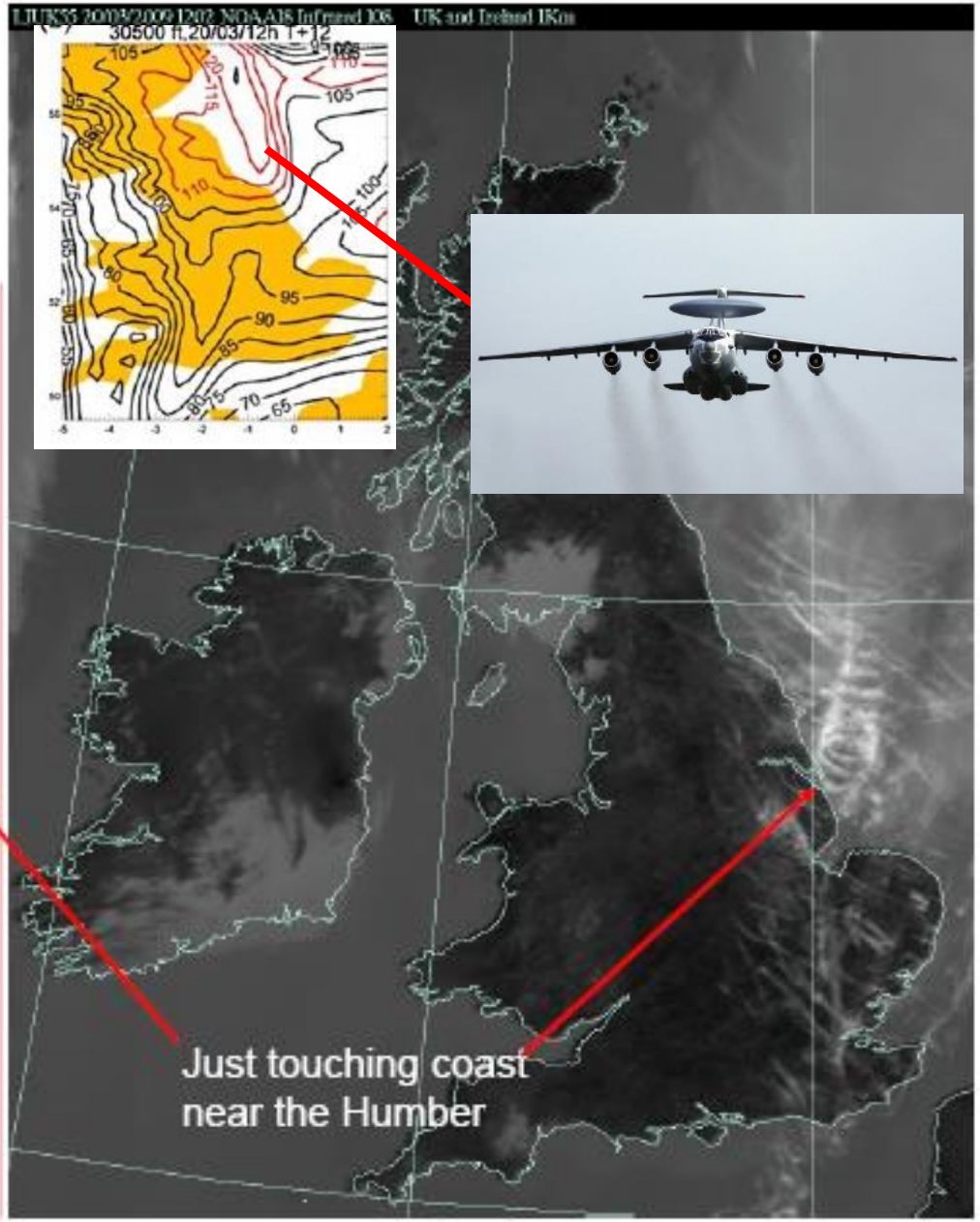


- Positional errors/natural variability
- Amount/microphysical characteristics

Claire Barber PhD

Radiative forcing: contrail cirrus



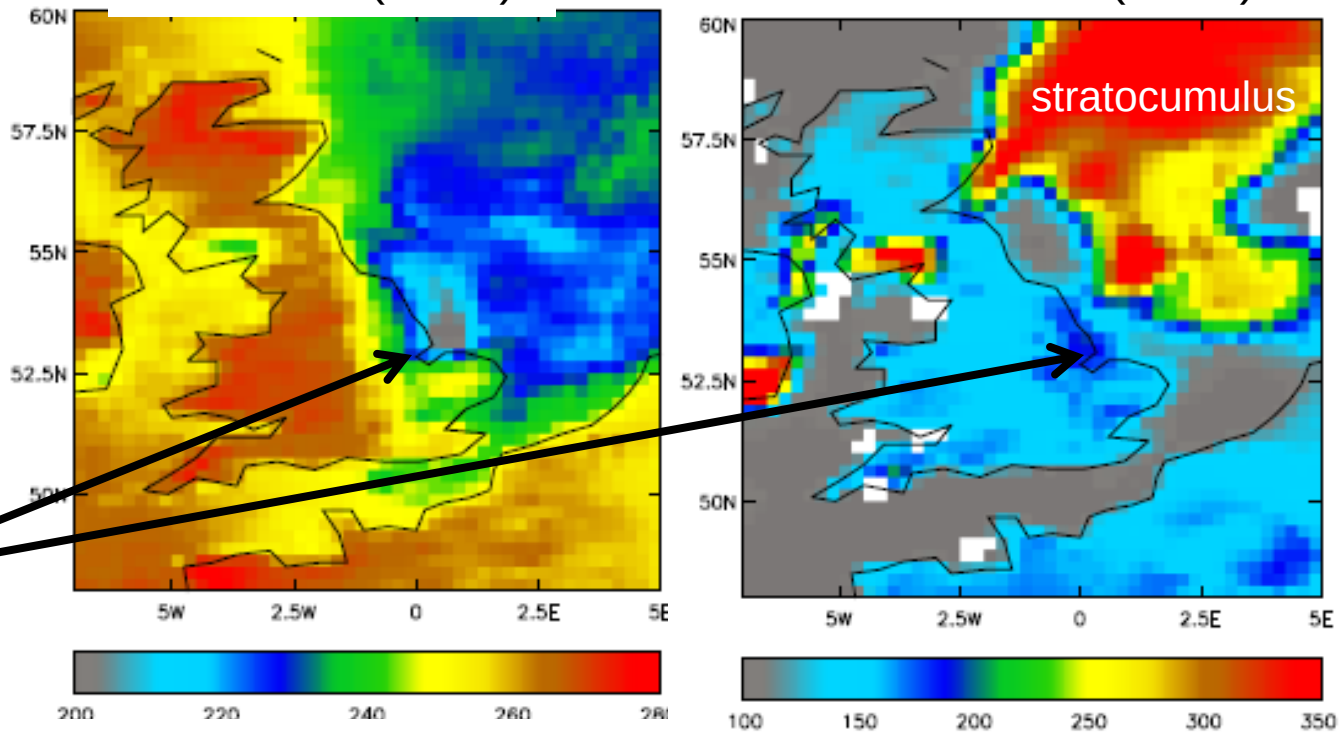


Courtesy of Jim Haywood

CERES FM3 (Aqua) fluxes 13:25

LW fluxes (Wm^{-2})

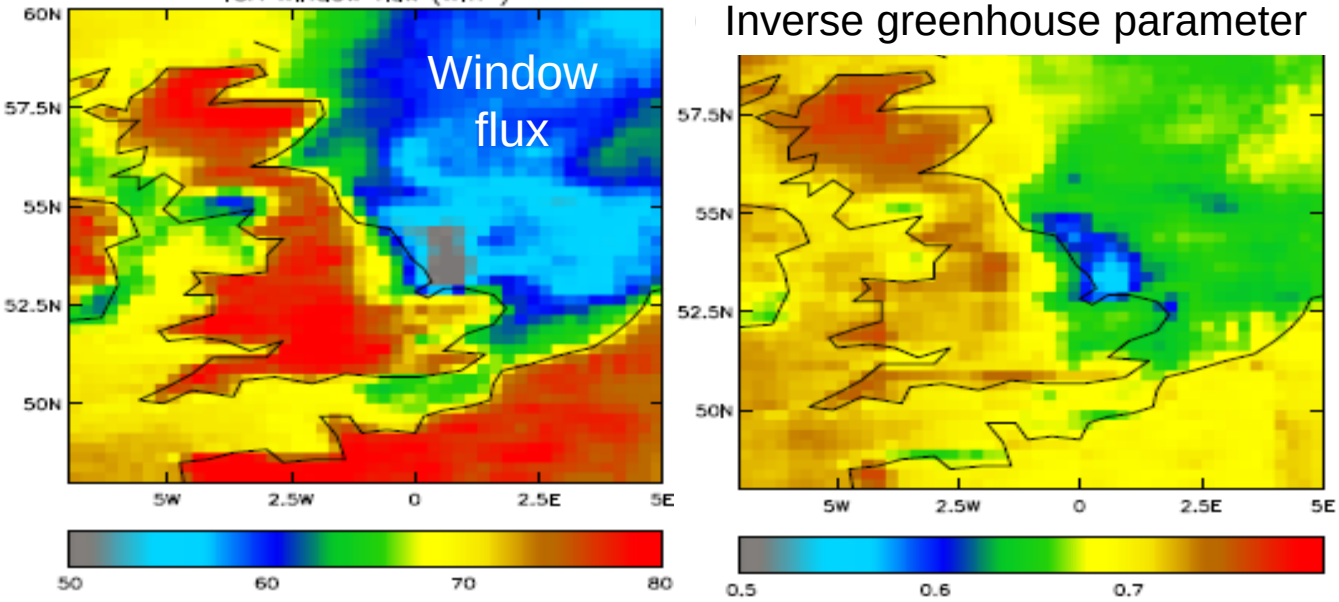
SW fluxes (Wm^{-2})



Contrail induced cirrus

TOA Window flux (Wm^{-2})

Inverse greenhouse parameter

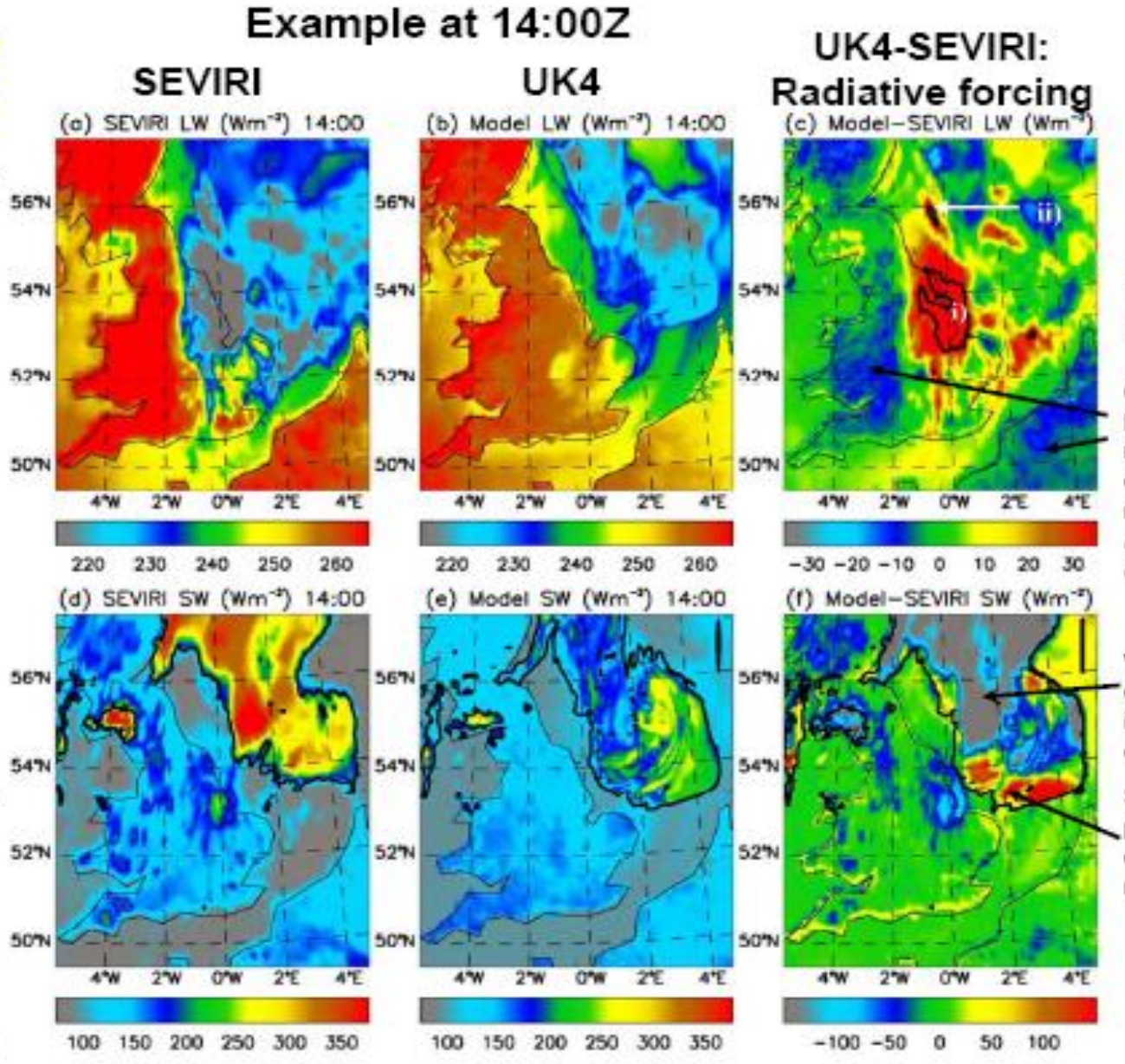


Using GERB/NWP model estimate radiative effect of contrail cirrus:

LW ~ 40 Wm^{-2}

SW up to 80 Wm^{-2}

Using GERB-like/SEVIRI to quantify contrail radiative effects



LW

(no cloud screening)

SW

(cloud mask shown)

i) & ii) Areas > 40Wm^{-2}

Cold bias over land in UK4 model in cloud free regions (*John Edwards, pers comm*)

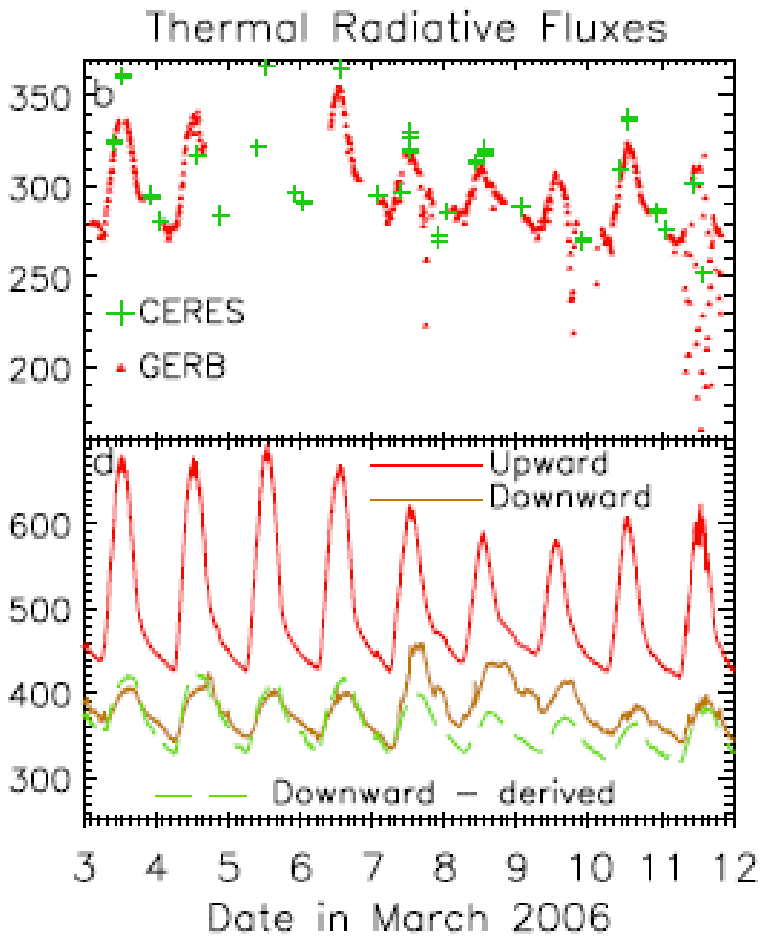
Very large differences in brightness of Sc.

Some positional errors of the model Sc

Haywood et al. (2009) JGR

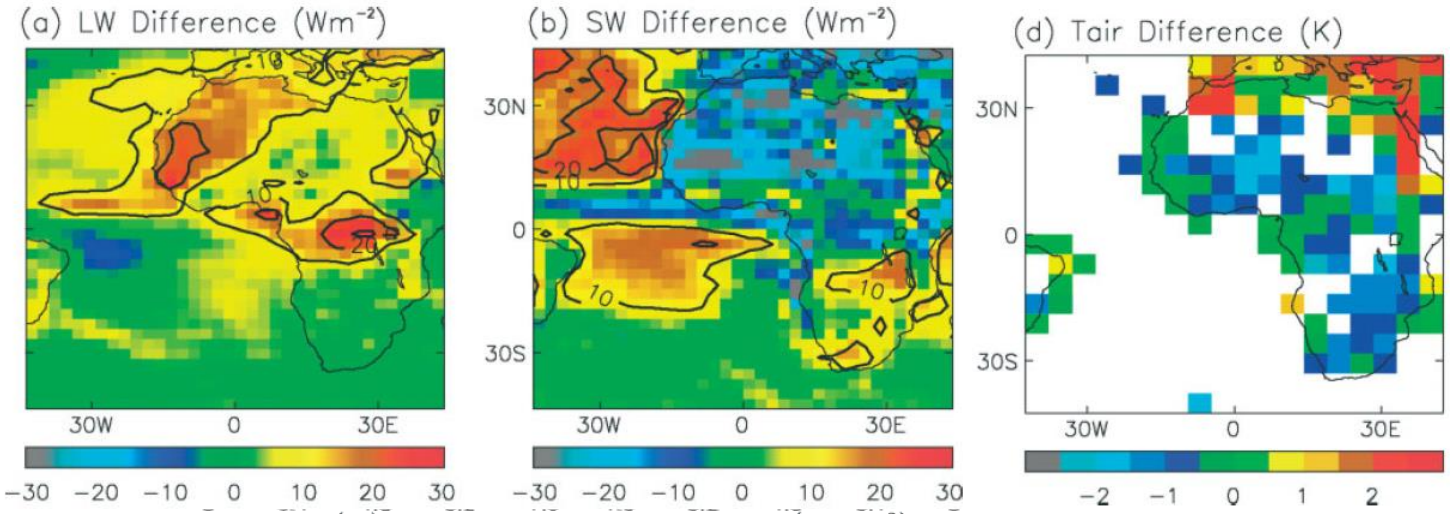
Combining satellite and surface data: RADAGAST

- Combining GERB/CERES and ARM
- Example: substantial radiative effect of mineral dust aerosol →
- Model LW biases up to 40 Wm^{-2}
- e.g. Haywood et al. (2005); Zhang and Christopher (2003)

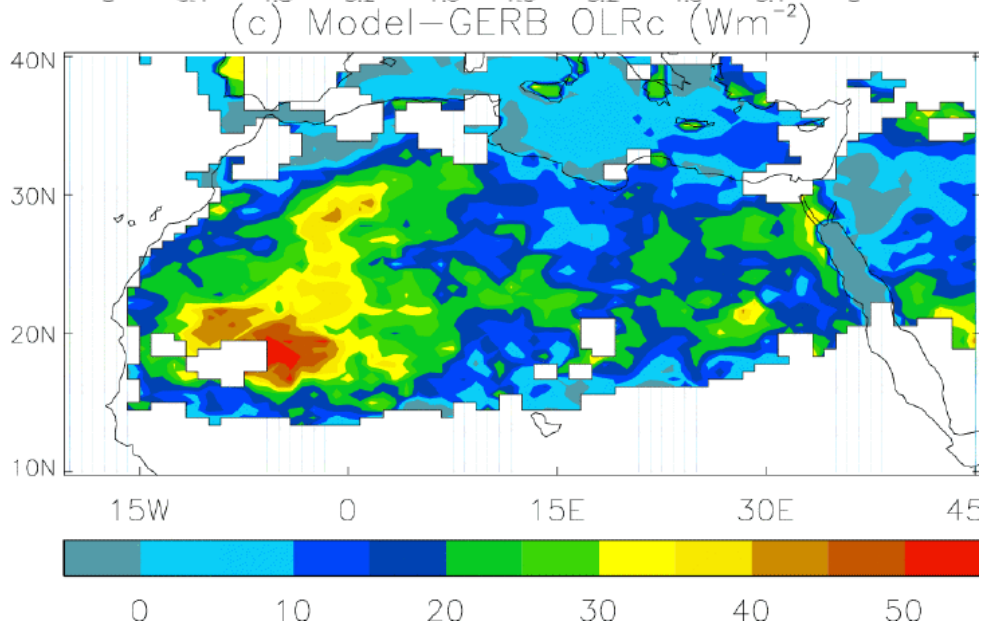


Slingo et al. (2006) GRL

Evaluating Systematic Model Errors in north Africa



Systematic biases in climate model radiation (models-CERES) and temperature

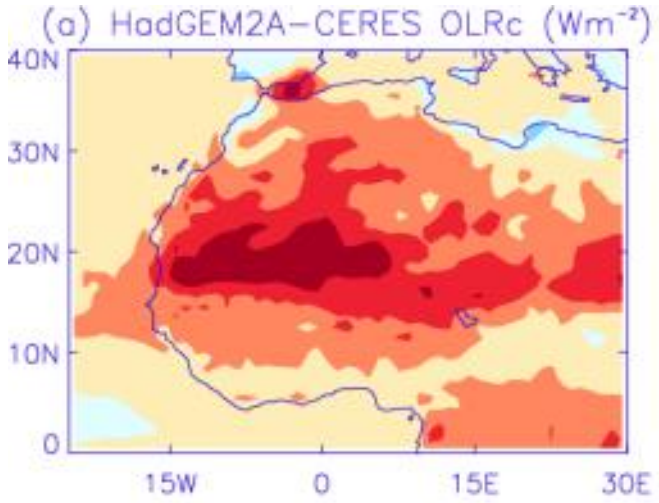


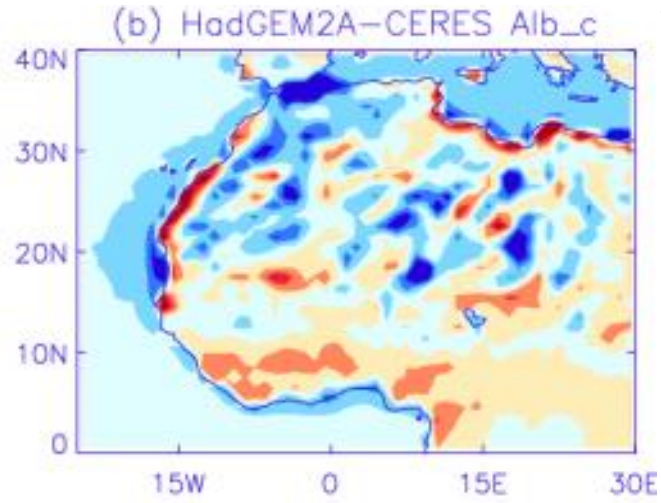
Longwave radiation over-estimated over Saharan Heat Low (model-GERB)

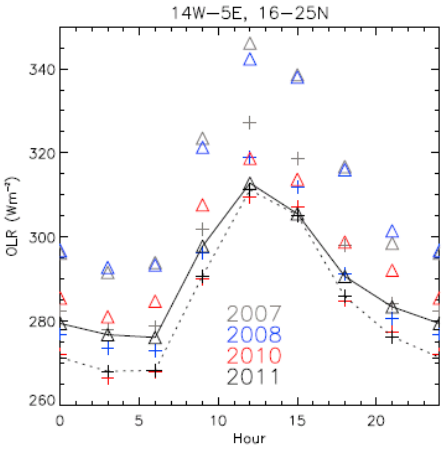
Haywood et al, 2005 JGR

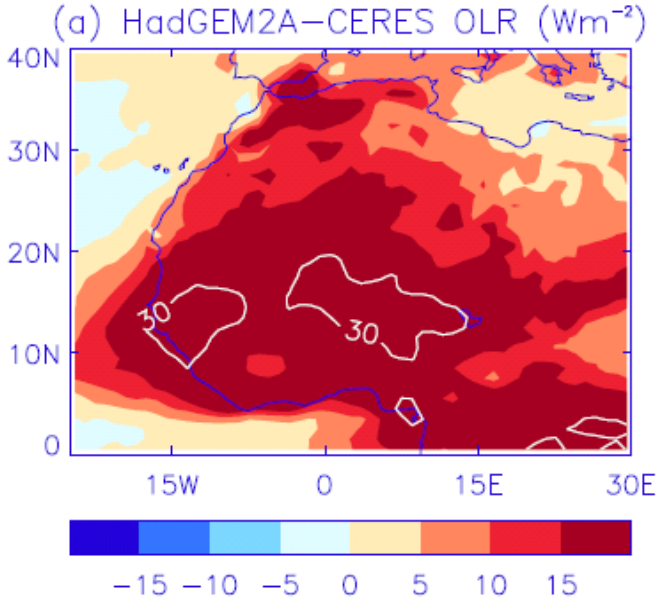
Allan et al. 2011, QJRMS

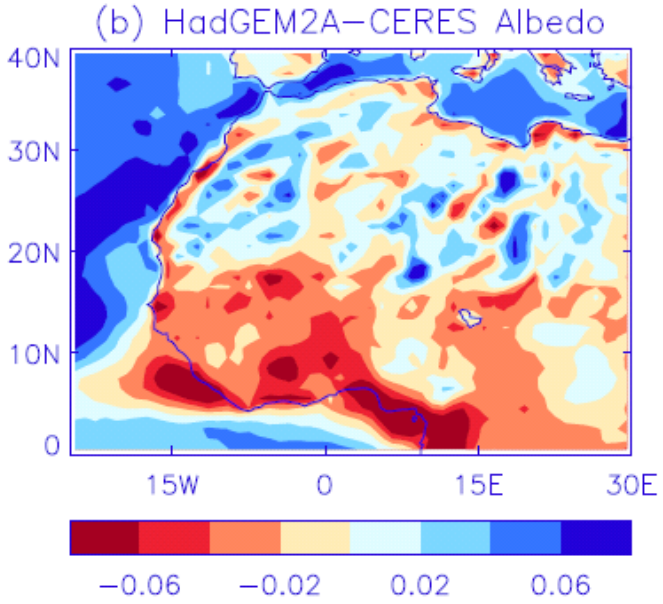
HadGEM2 biases vs CERES











DACCIWA - Dynamics-aerosol-chemistry-cloud interactions in West Africa

EU consortium lead by Peter Knipperts

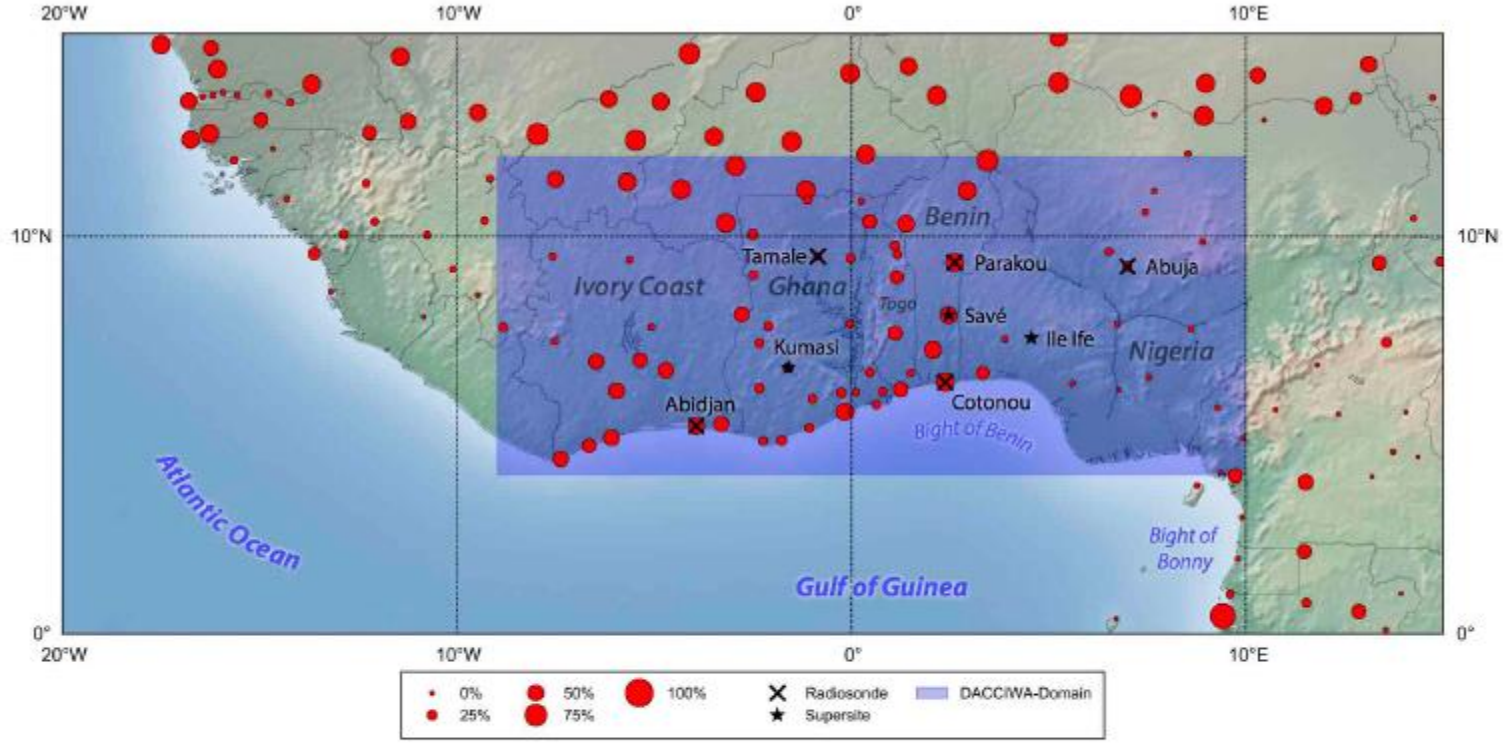
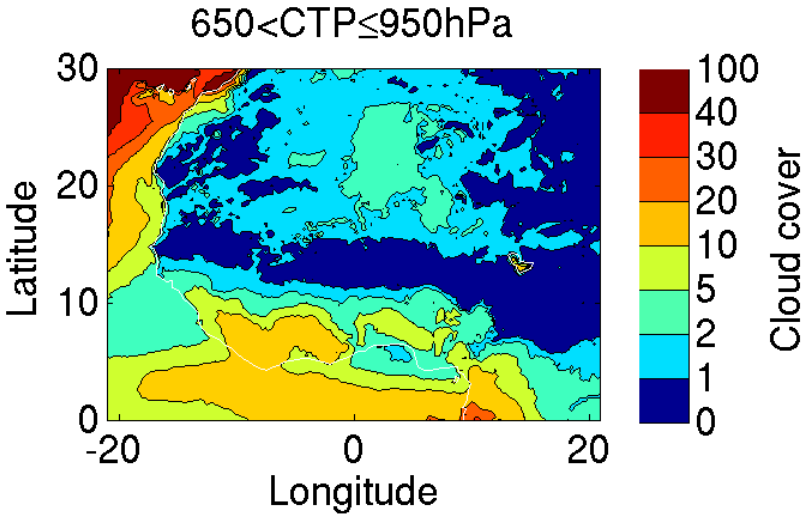
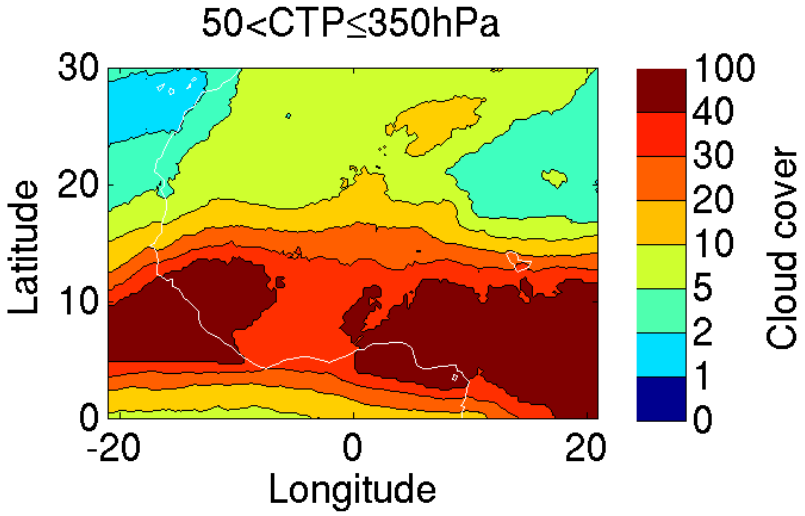
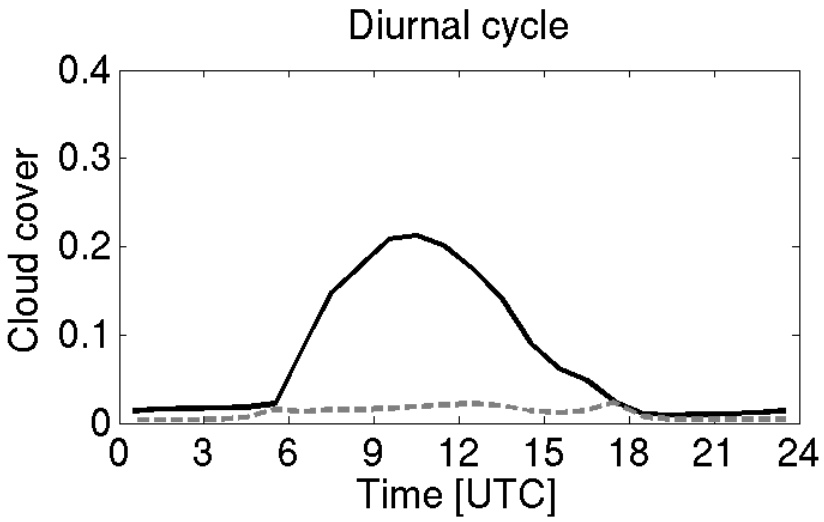


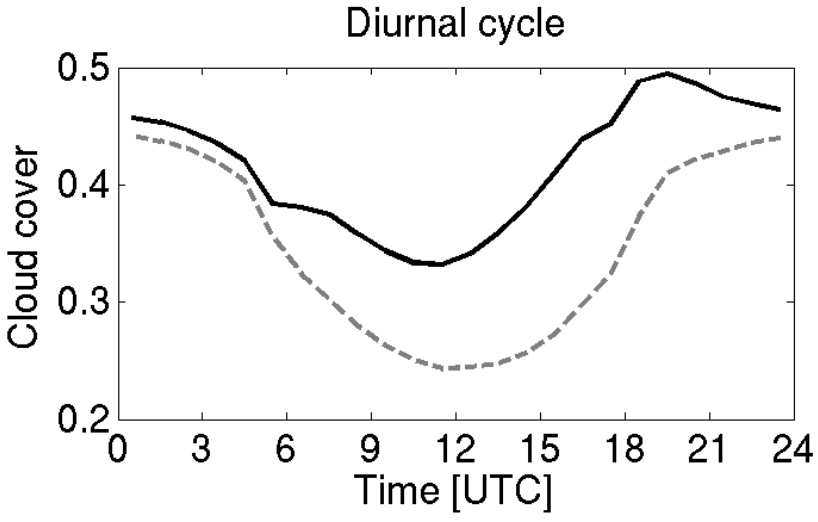
Figure 1.4: Geographical overview of the DACCIWA study area highlighted in blue. Supersites and planned radiosonde stations (black markers) and synoptic weather stations (red dots, proportional to available number of reports in the WMO Global Telecommunication System from 1998–2012).

DACCIWA preliminary analysis of cloud cover



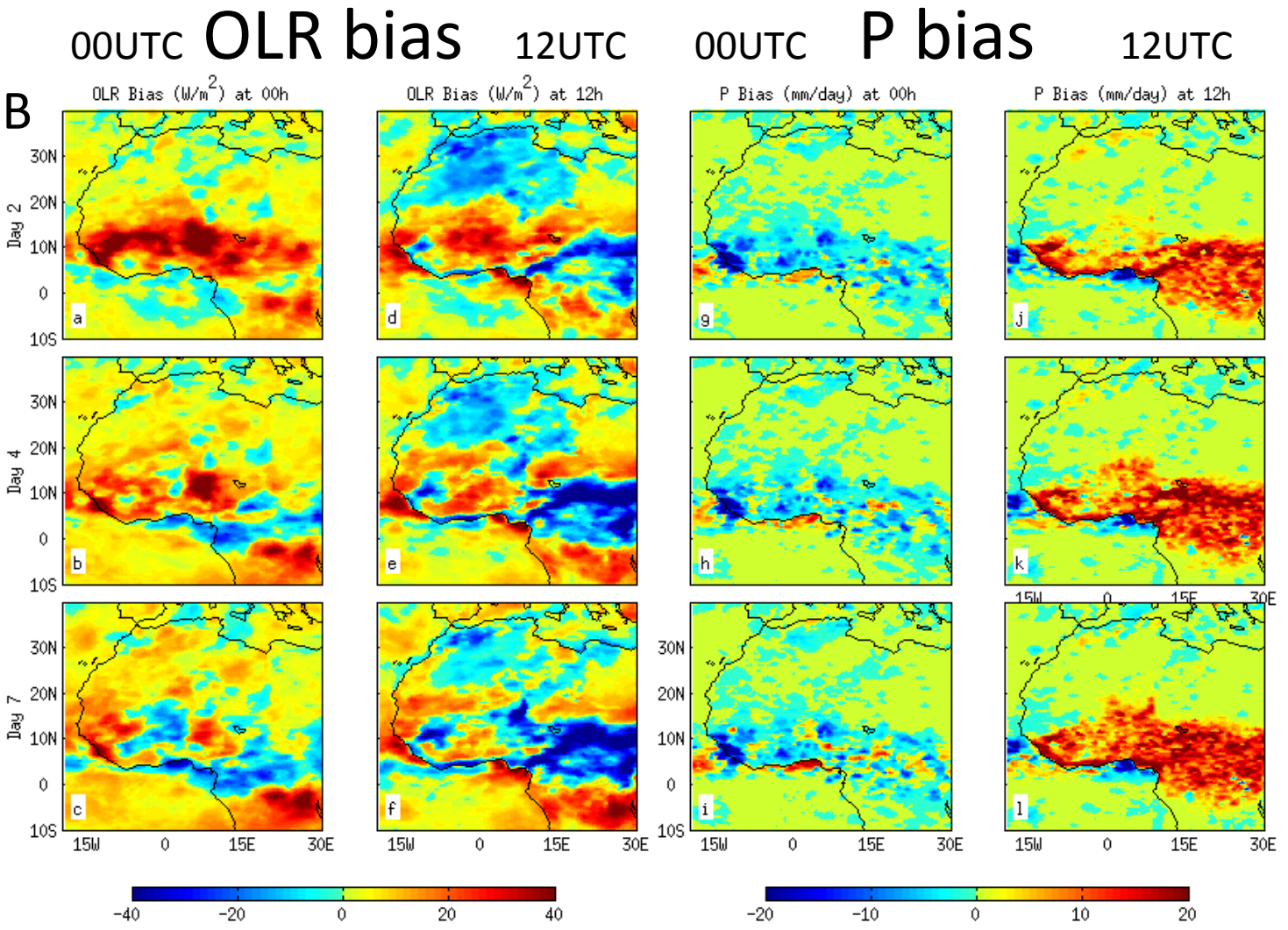






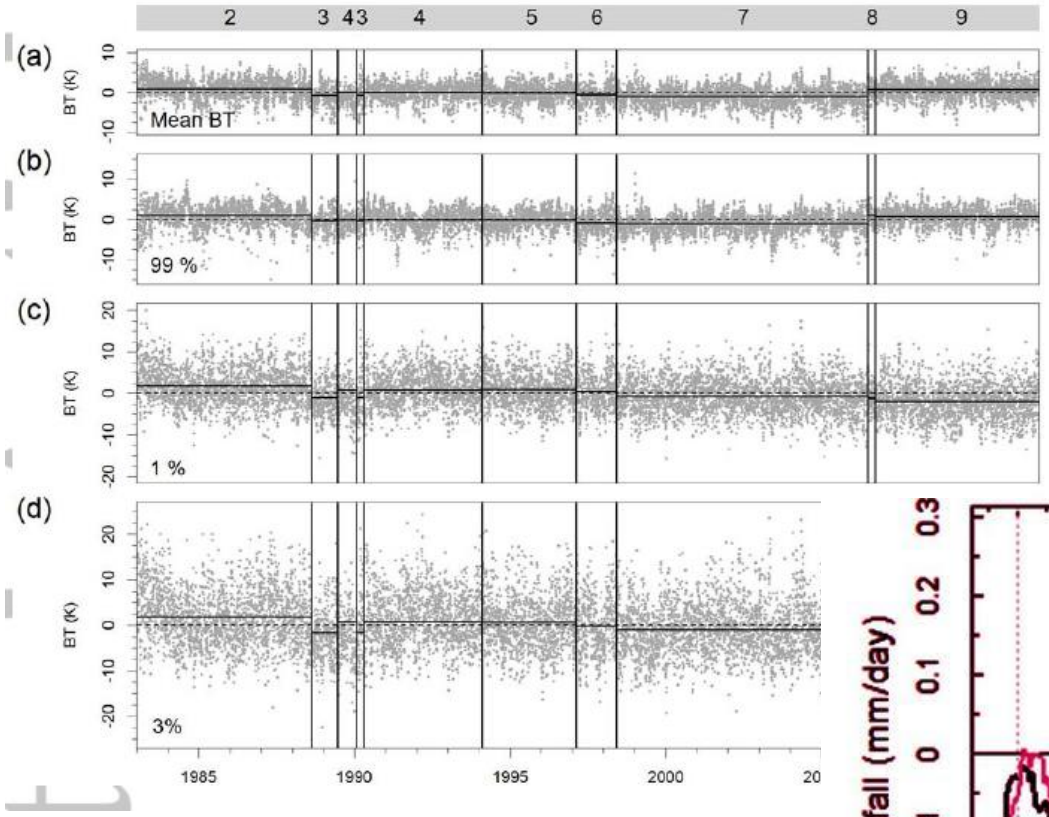
Thorwald Stein, University of Reading

Emerging Weather Forecast Model Biases in Radiation and Precipitation



See also [Liu et al. (2014) JAMC]

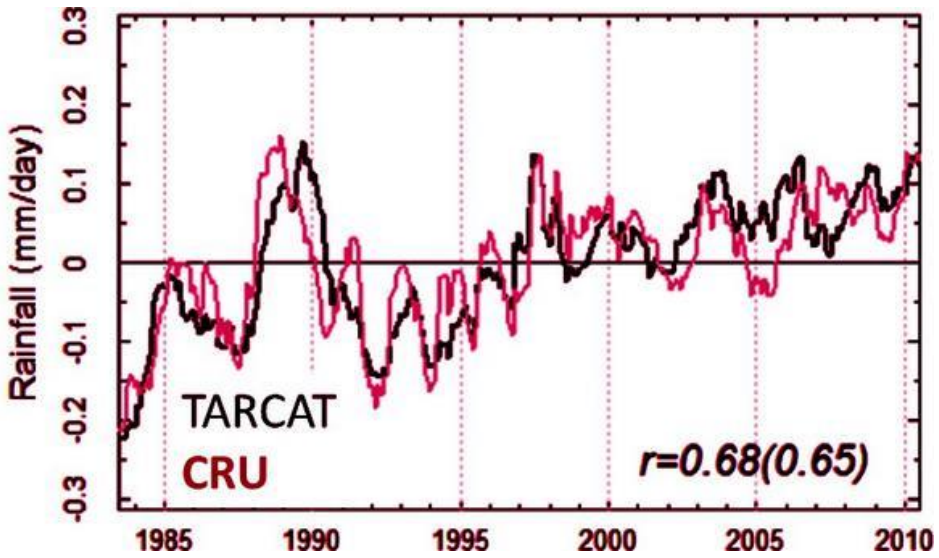
Homogeneous Africa rainfall record from Meteosat



- 30yr Meteosat window channel BT record
- CCD rainfall proxy

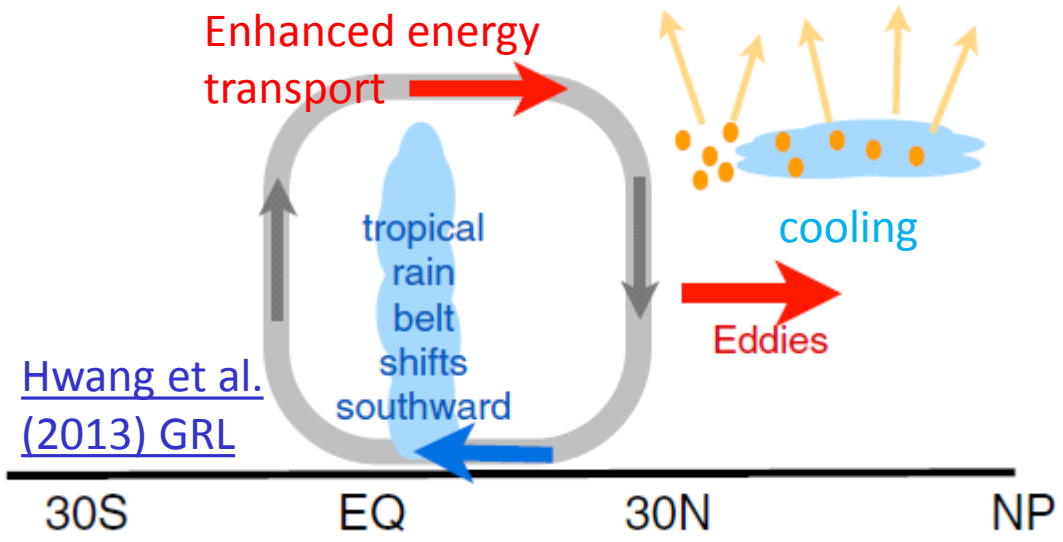
Maidment et al. (2014) JGR

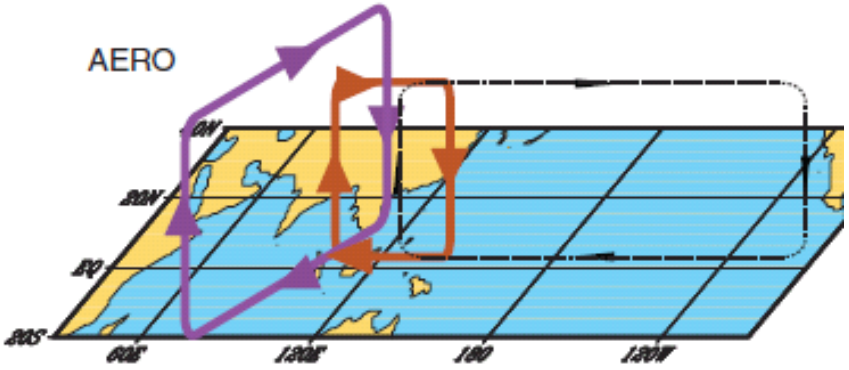
Rain-gauge (CRU) variability captured by TAMSAT →



Interhemispheric heating and the water cycle

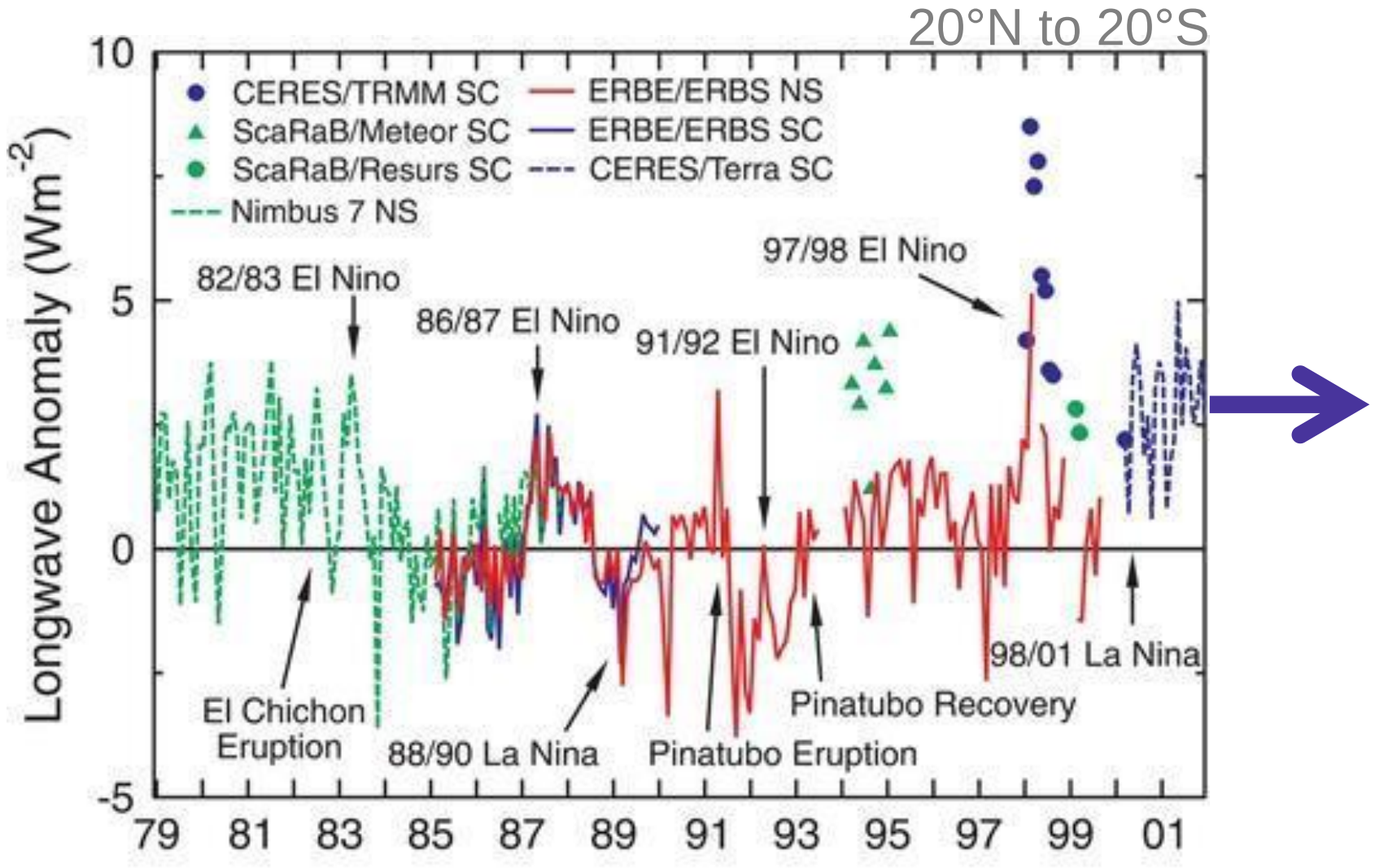
- N Hemisphere Aerosol cooling 1950-1980s
- Induces southward movement of ITCZ
- Reduced Sahel rainfall →
- Recovery after 1980s e.g. Wild 2012 BAMS
- +Asymmetric volcanic forcing e.g. Haywood et al. (2013) Nature Climate





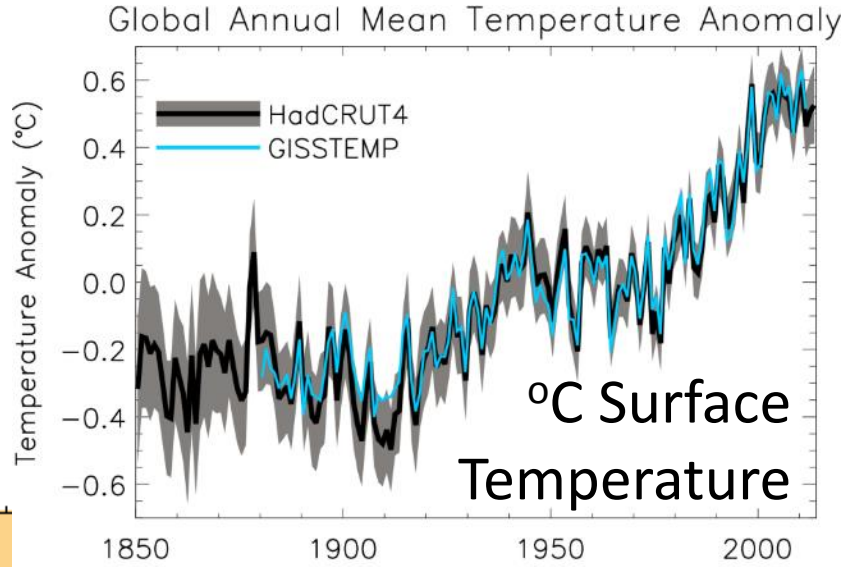
- Sulphate aerosol effects on Asian monsoon e.g. Bollasina et al. 2011 Science (left)
- Links to drought in Horn of Africa? Park et al. (2011) Clim Dyn
- Recovery in Sahel rainfall e.g. Maidment et al. (2014) JGR

Changes in Earth's radiative energy balance

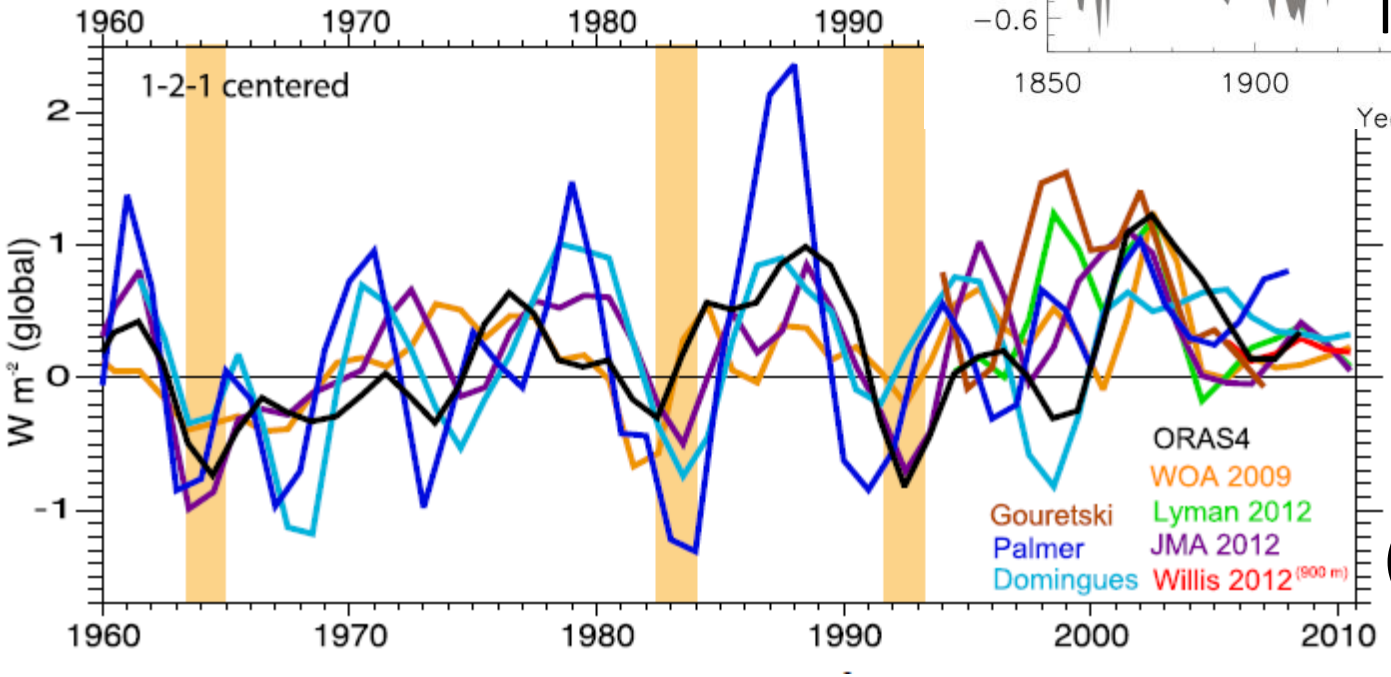


Wong et al. (2006) J Clim; Wielicki et al. (2002) Science

At what rate is Earth heating?



°C Surface Temperature

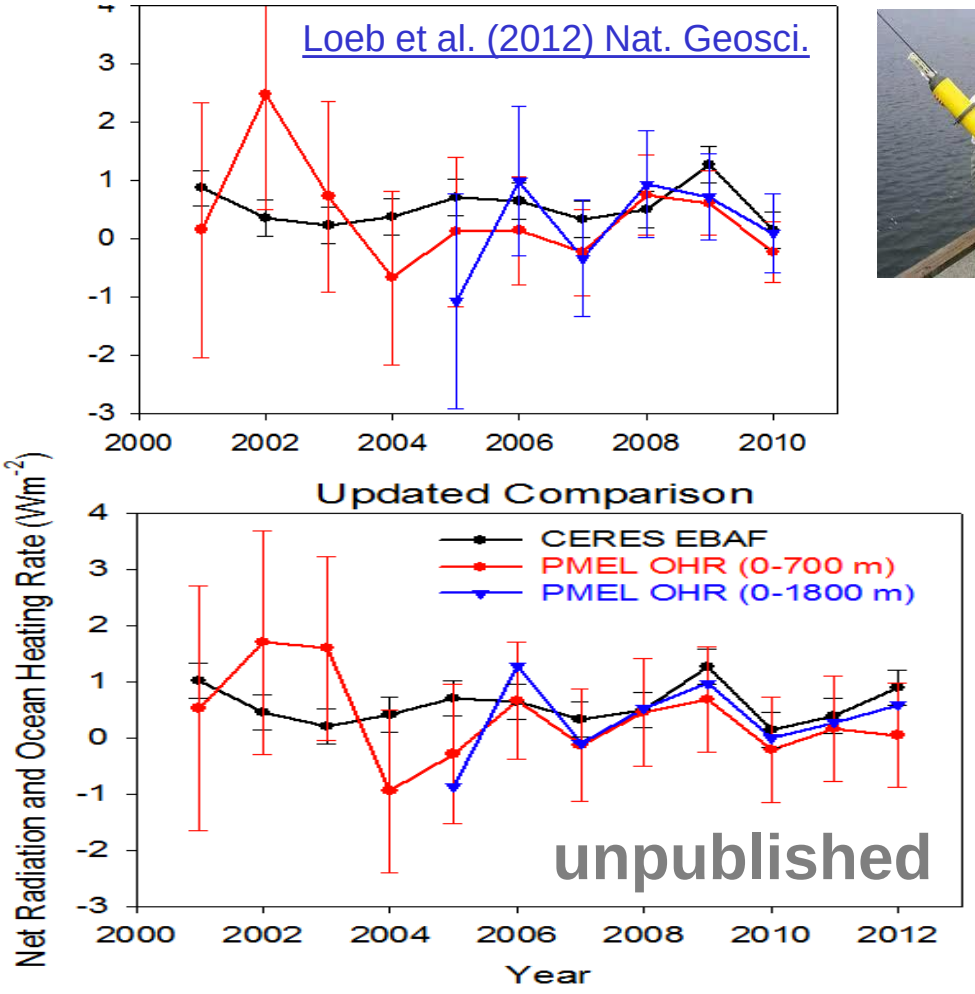


Upper ocean (Wm^{-2})

Trenberth et al. (2014) J Clim

Combining Earth Radiation Budget data and Ocean Heat Content measurements

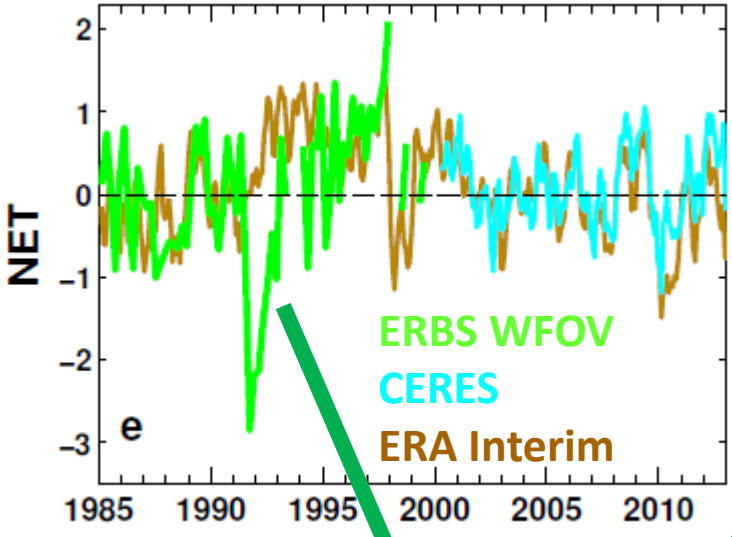
- Tie 10-year CERES record with SORCE TSI and ARGO-estimated heating rate 2005-2010 + minor additional storage terms
- Variability relating to ENSO reproduced by CERES and ERA Interim
- Ocean heating rate sensitive to dataset and sampling
- What about prior to 2000?



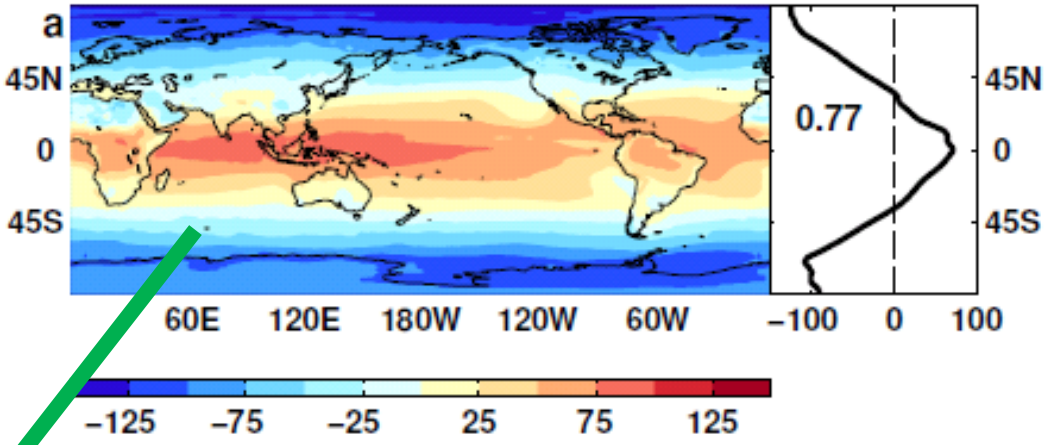
Loeb et al. (2012) Nat. Geosci. See also Hansen et al. (2011) ACP

Reconstructing global radiative fluxes prior to 2000

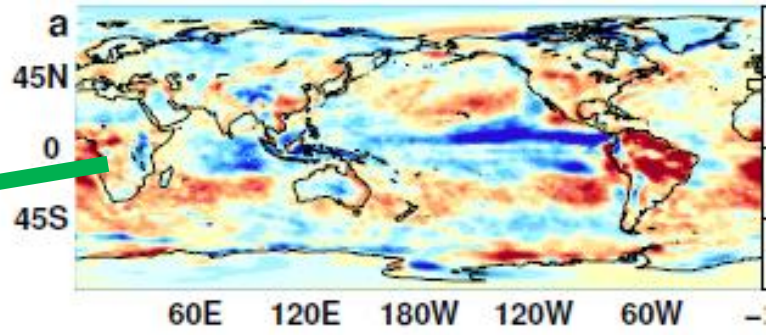
ERBS/CERES variability



CERES monthly climatology



ERA Interim spatial anomalies

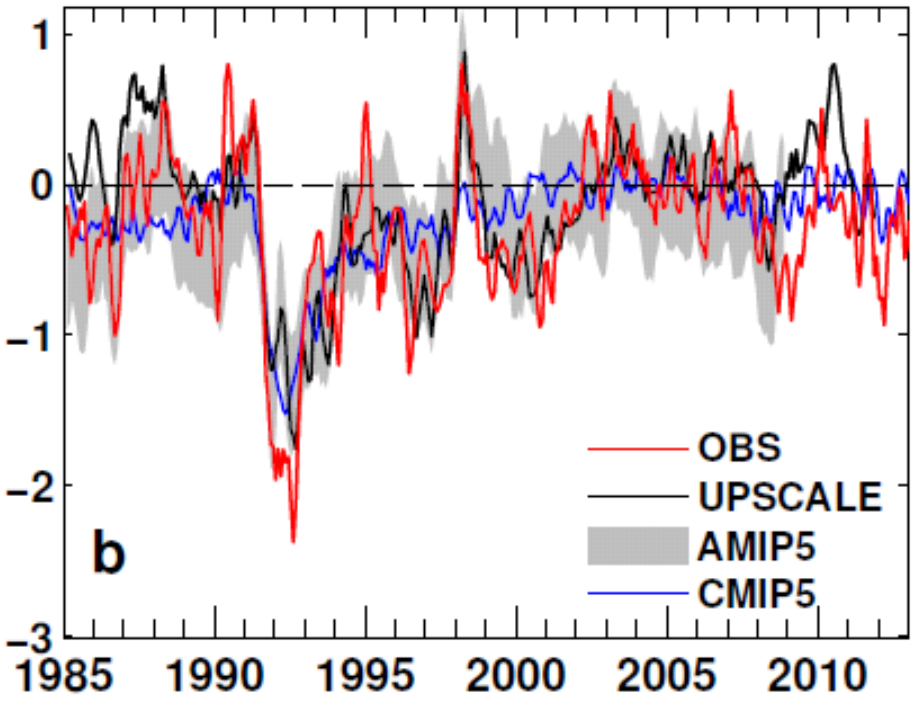


Combine CERES/ARGO accuracy, ERBS WFOV stability and reanalysis circulation patterns to reconstruct radiative fluxes

Use reanalyses or models to bridge gaps in record (1993 and 1999/2000)

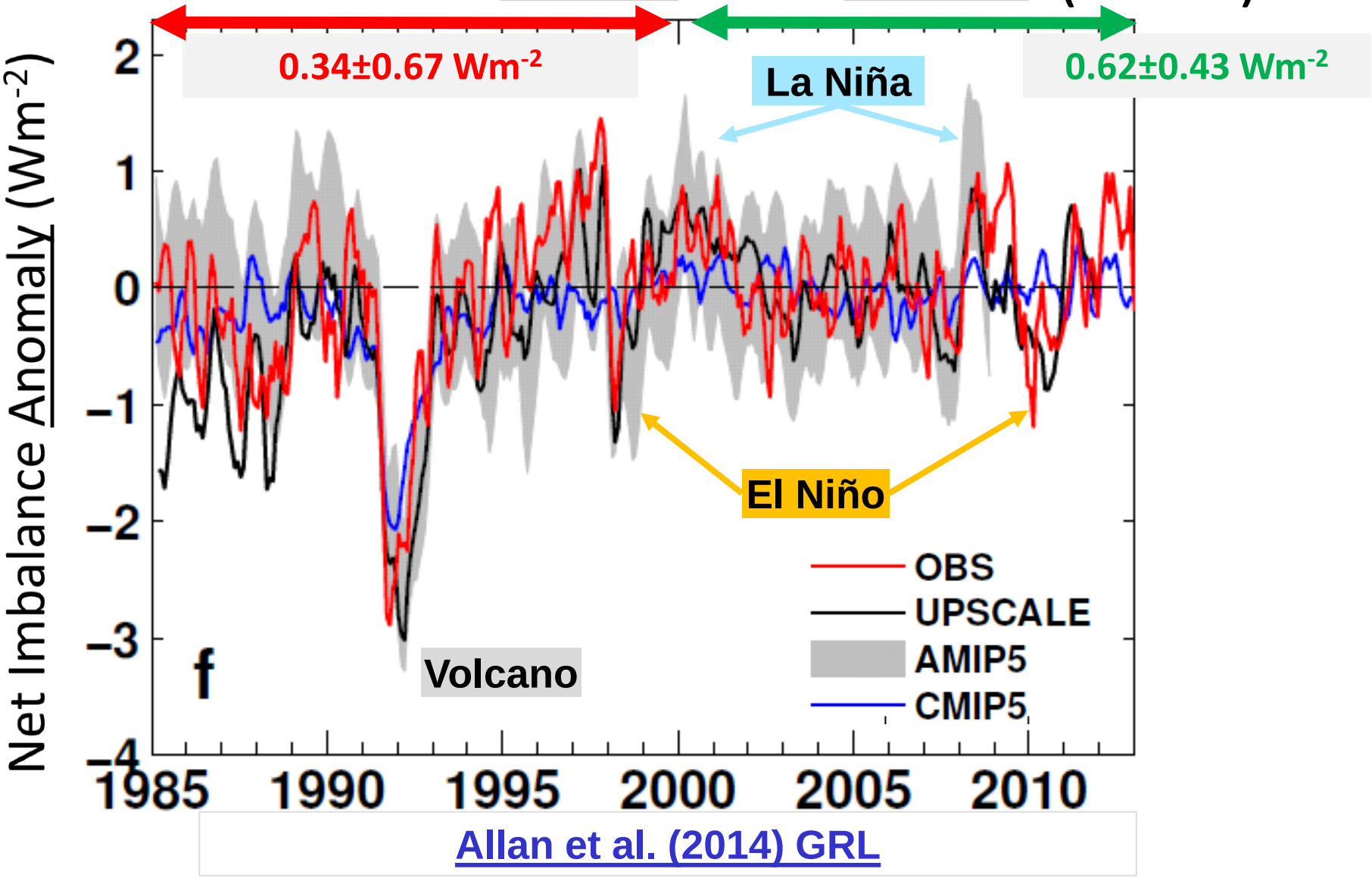
- ERA Interim trends suspect. Use model…
- **UPSCALE** simulations (obs. SST, sea ice & realistic radiative forcings) "**OBS**"
- Net less sensitive to method than OLR/ASR

Outgoing Longwave Radiation Anomalies (Wm^{-2})



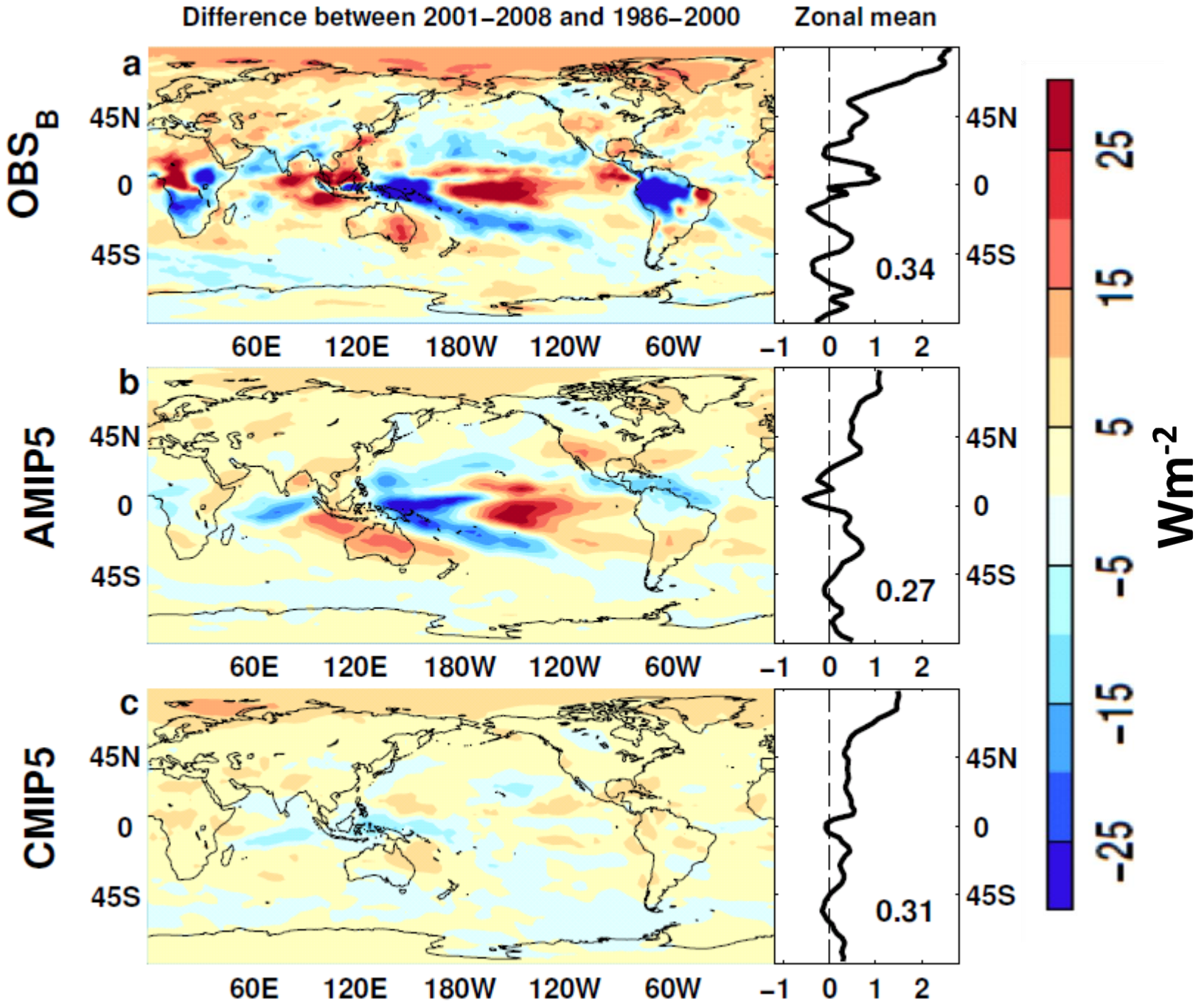
Changes in imbalance in models & observations

Imbalance: 0.23 | 0.00 | 0.78 | 0.63 | 0.63 (Wm^{-2})

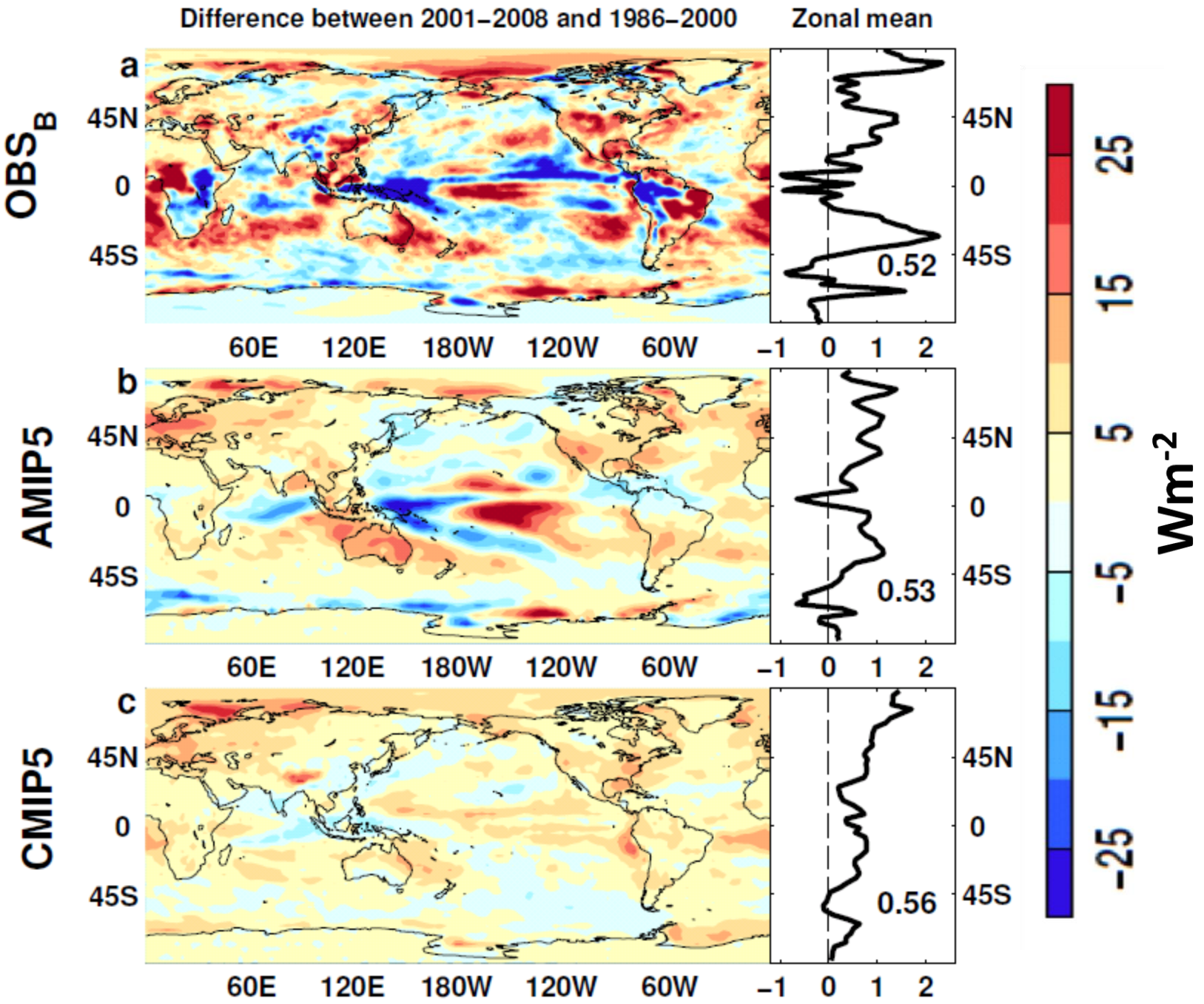


Allan et al. (2014) GRL

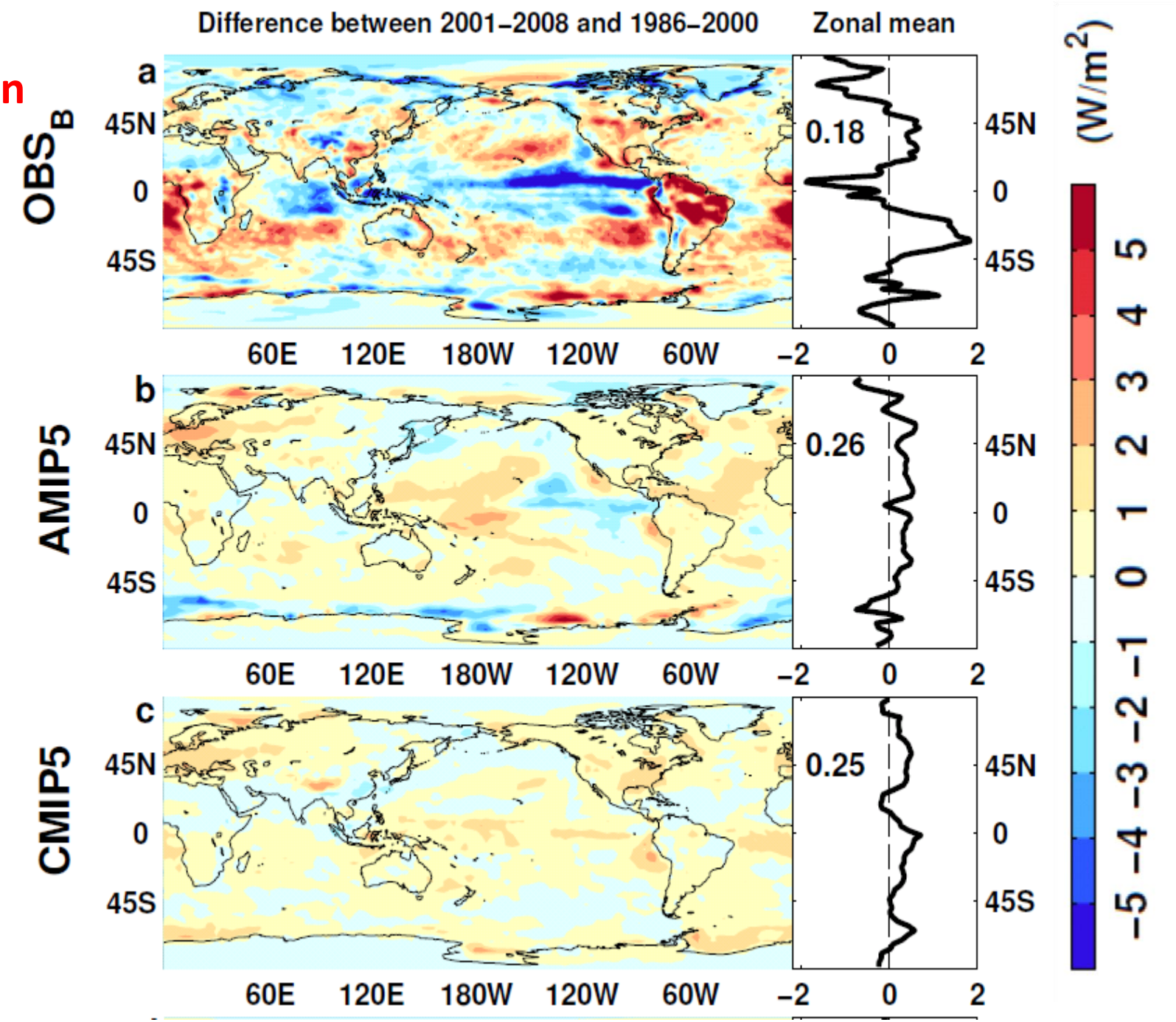
Outgoing Longwave Radiation

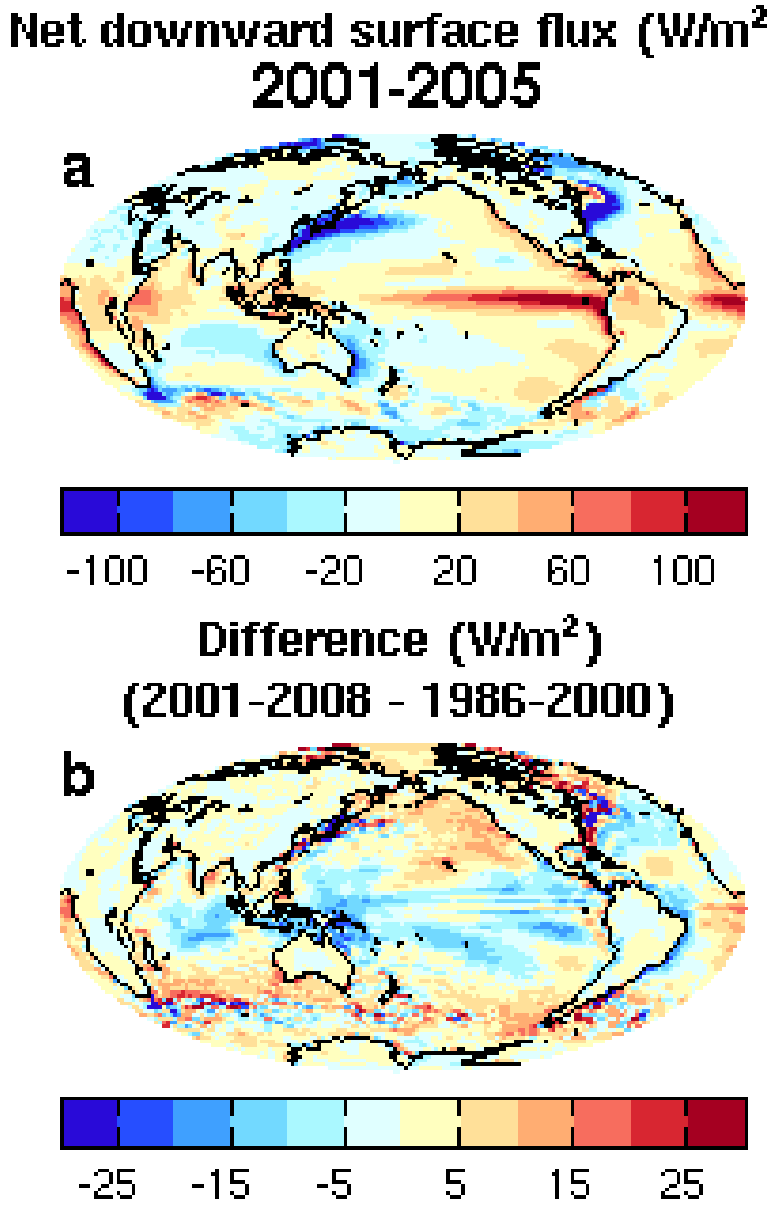


Absorbed Shortwave Radiation

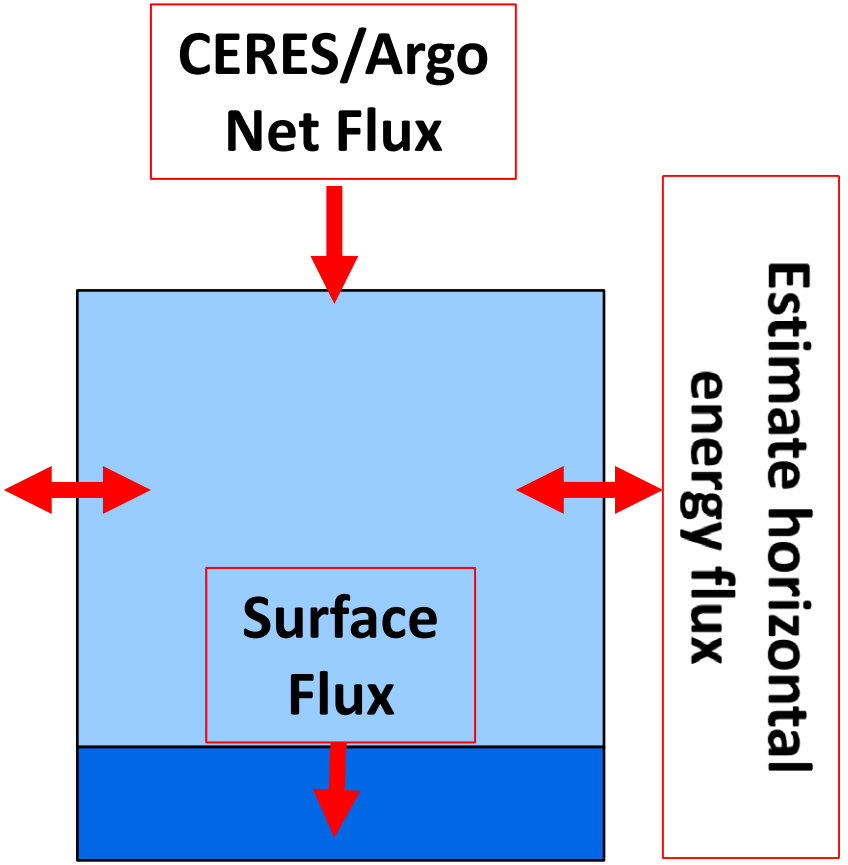


NET Radiation





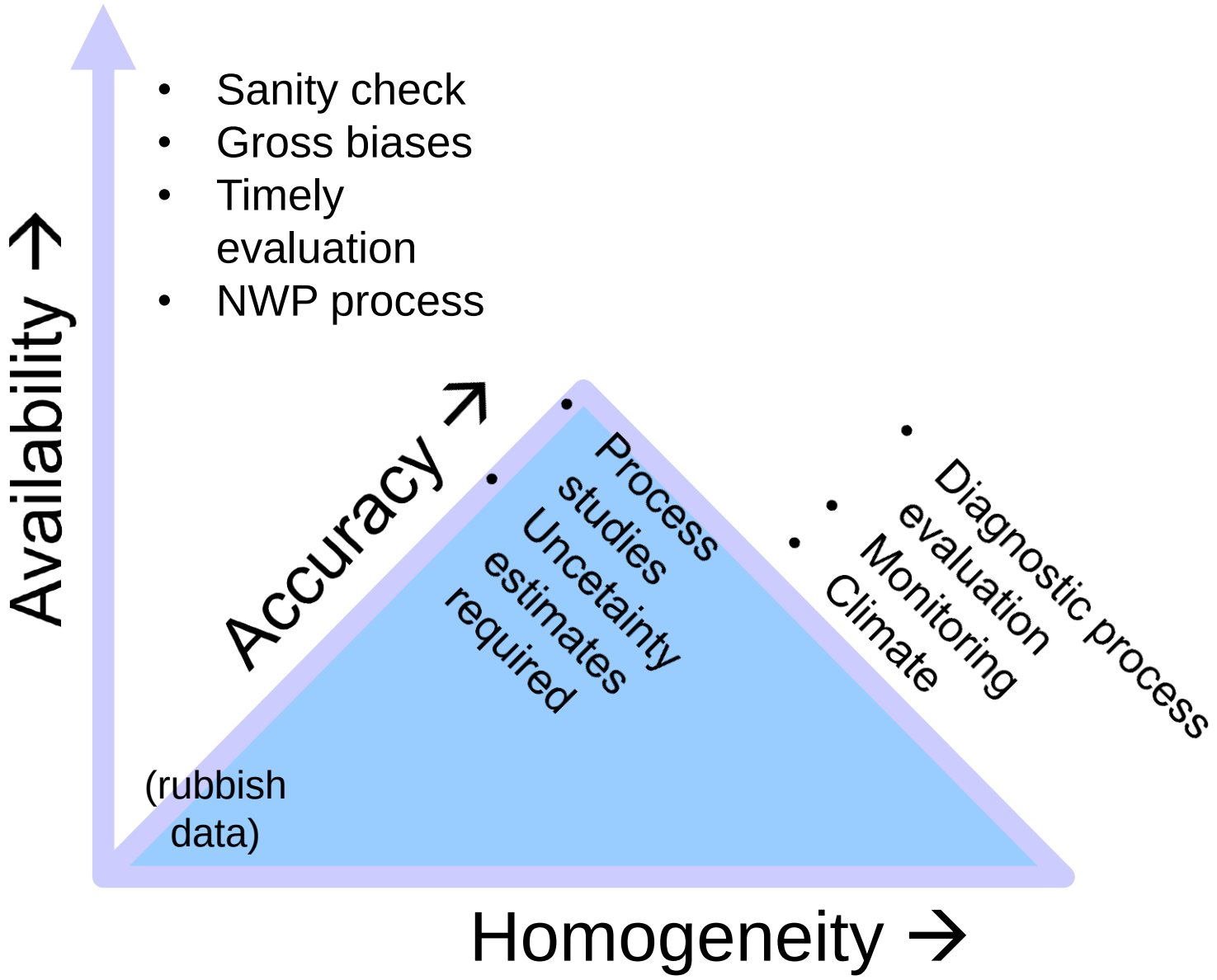
Next steps: estimates of Surface Flux



$$F_{SFC} = F_{TOA} - \frac{\partial TE}{\partial t} - \nabla \cdot \frac{1}{g} \int_0^1 V(Lq + C_p T + \varphi_s + k) \frac{\partial p}{\partial \eta} d\eta$$

Conclusions

- Synergy between different ERB and other sensors
  - Essential in understanding processes
  - Confirming biases in models… or data
- Different challenges, different problems…
  - Bottom up: evaluation at model time-step required in understanding & improving process representation
  - Top down: diagnosing and understanding climate change
- Net radiative flux imbalance fairly stable ~0.6 Wm^{-2}
  - Requires anchoring to ARGO ocean heating rate + minor terms
  - Influence of Pinatubo and ENSO
  - Radiative forcing alone can't explain surface warming slowdown: internal variability important
  - Reliability of CERES/GERB decadal trends?


Availability →
Accuracy →
Homogeneity →
• Sanity check
• Gross biases
• Timely evaluation
• NWP process
• Process studies
• Uncetainty estimates required
• Diagnostic process evaluation
• Monitoring
• Climate
(rubbish data)