The relative humidity of the subtropical free troposphere

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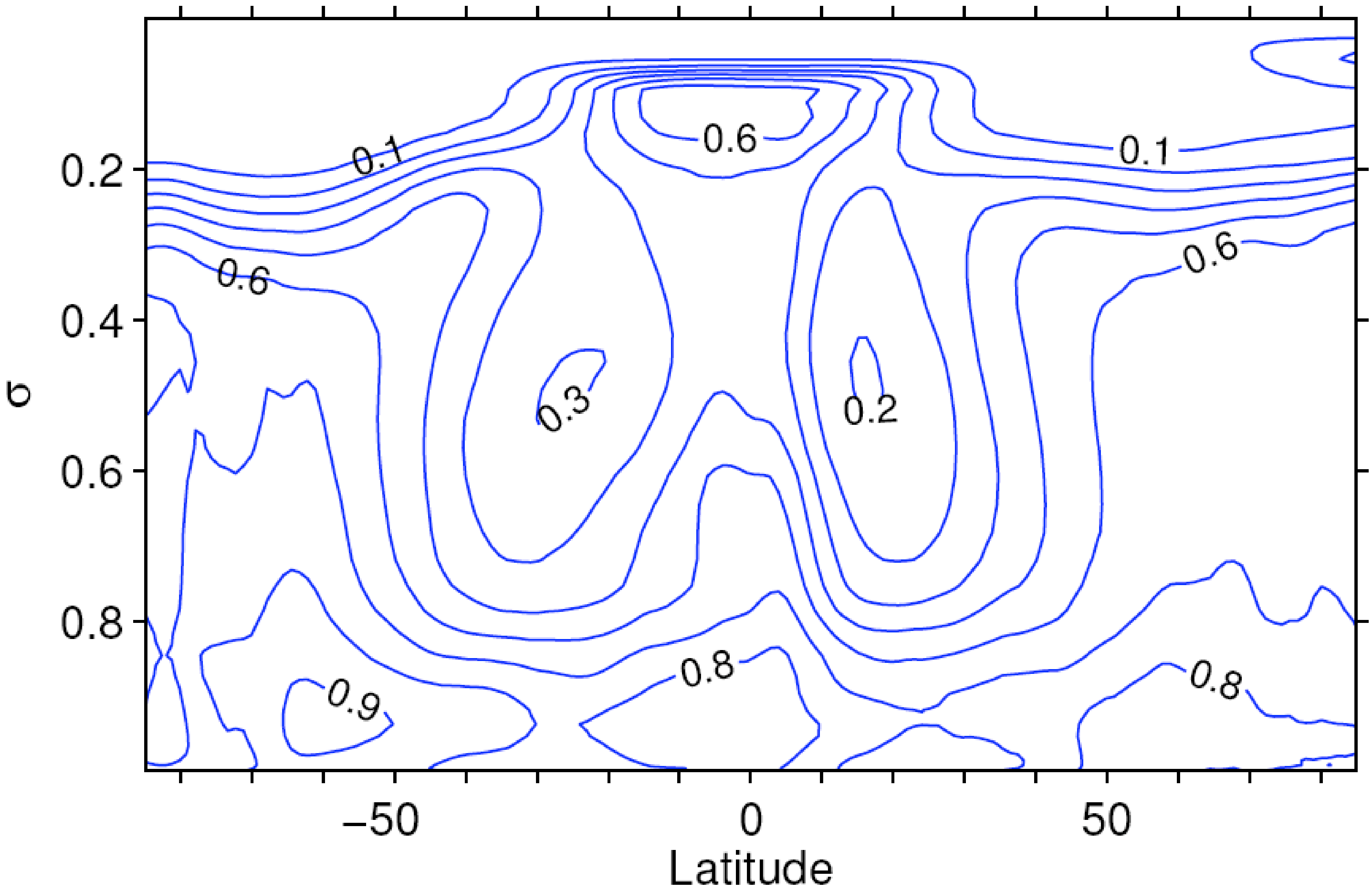
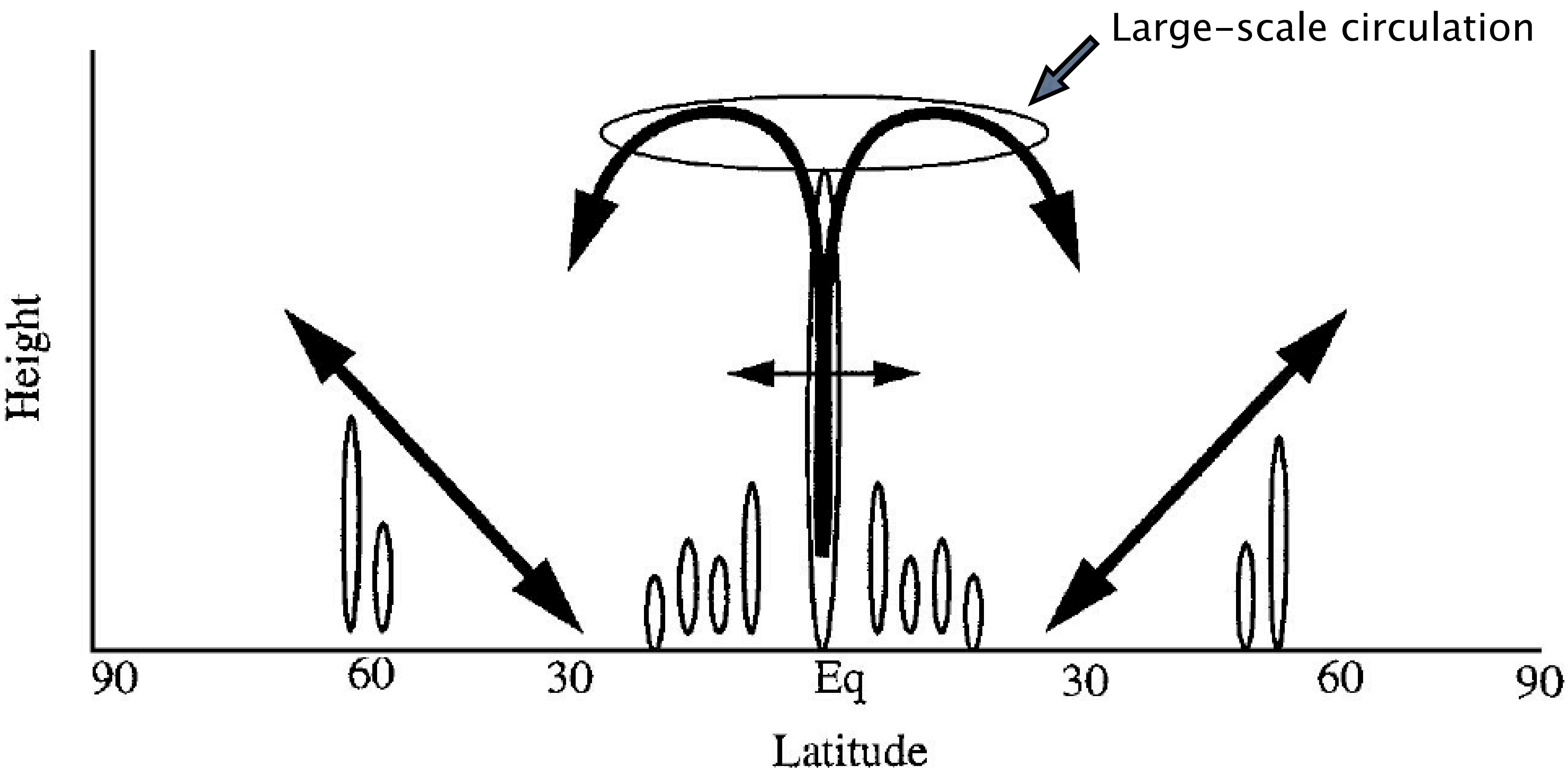
(with Alexandre Couhert, Karen Smith, Juilin Li, Paul O'Gorman, Adrian Tompkins, Duane Waliser, and Chris Walker)

Relative humidity (annual mean)



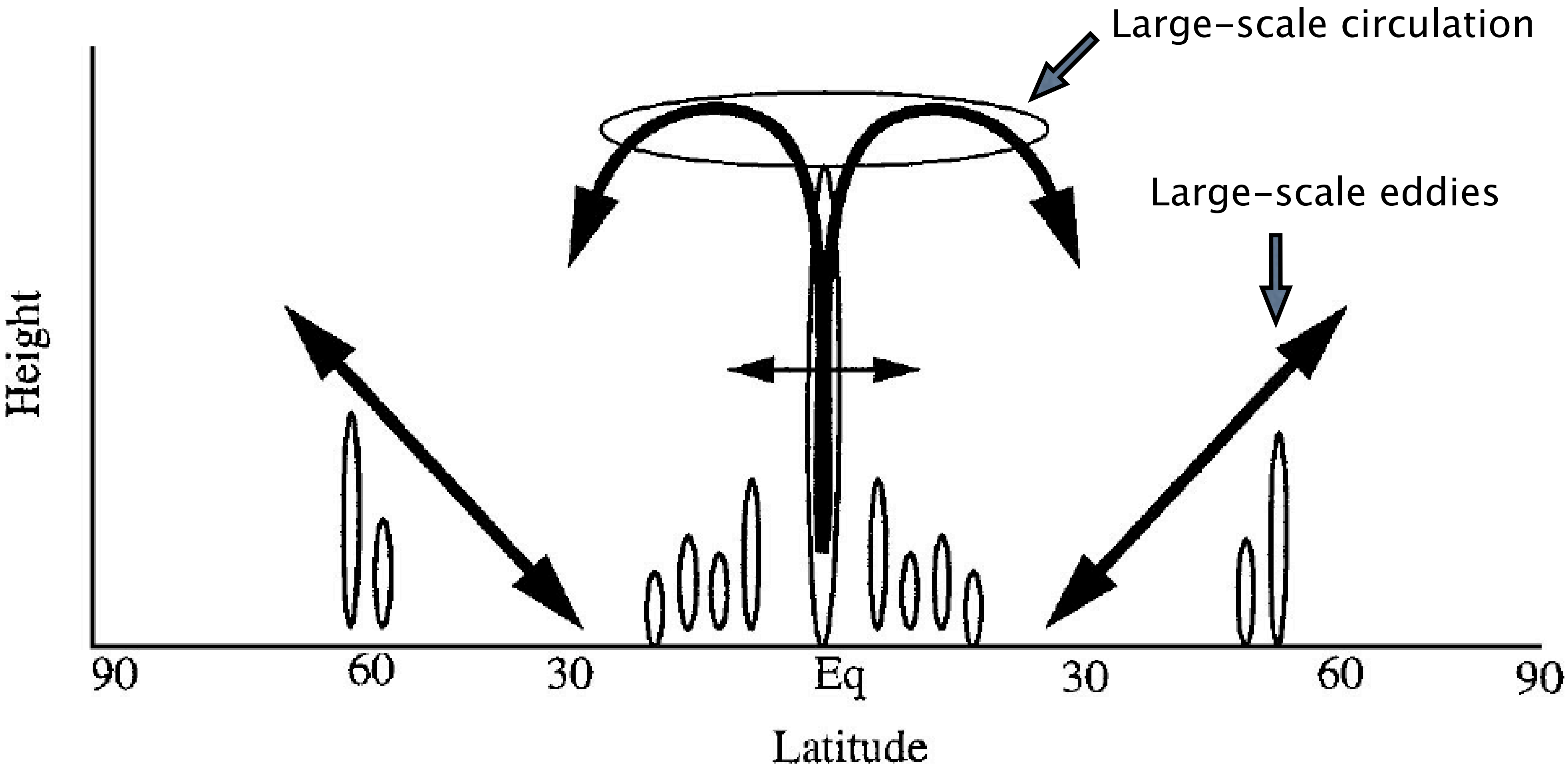
(*Data source*: ERA-40)

Processes influencing humidity distribution



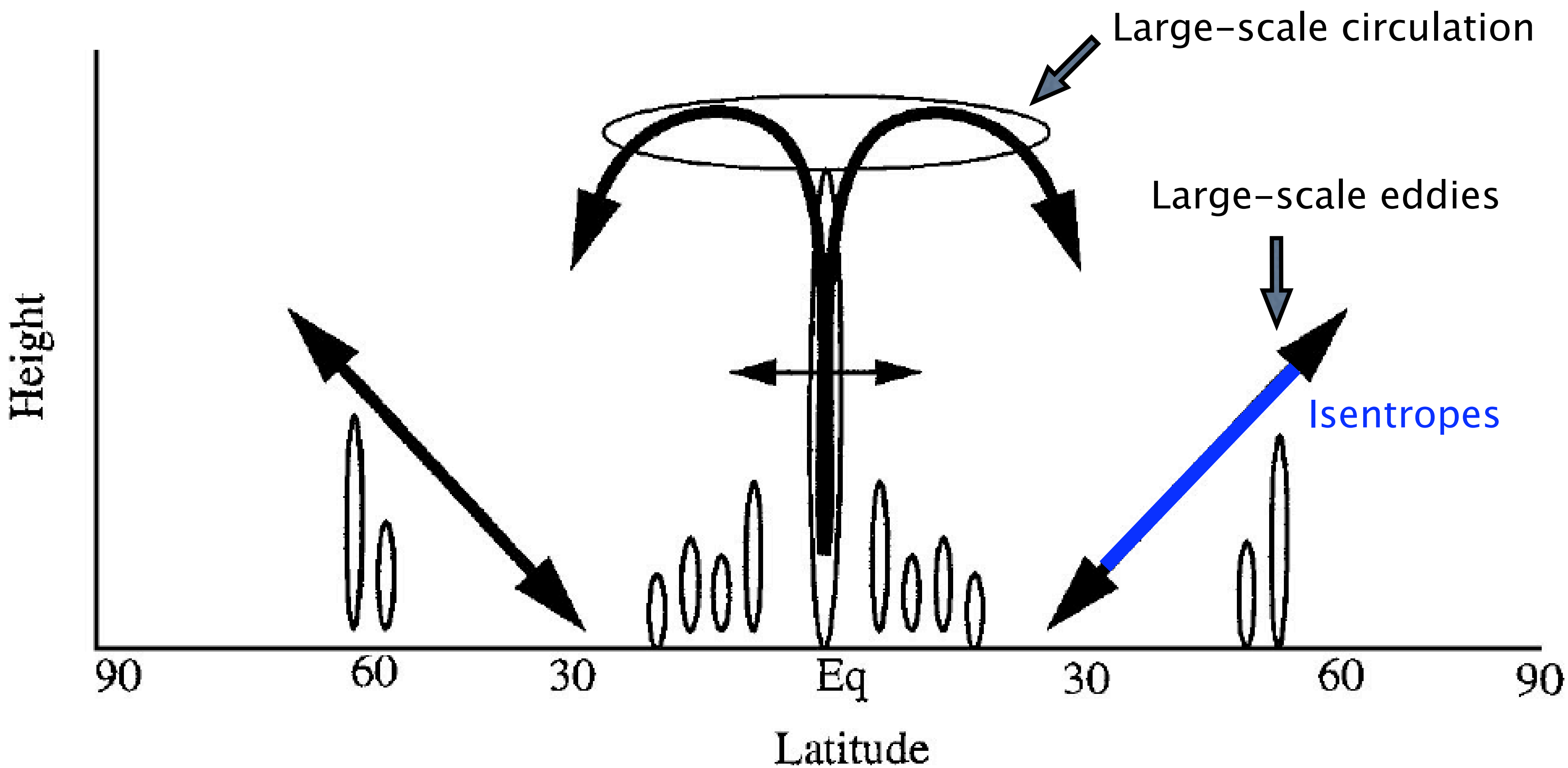
(Held & Soden 2000)

Processes influencing humidity distribution



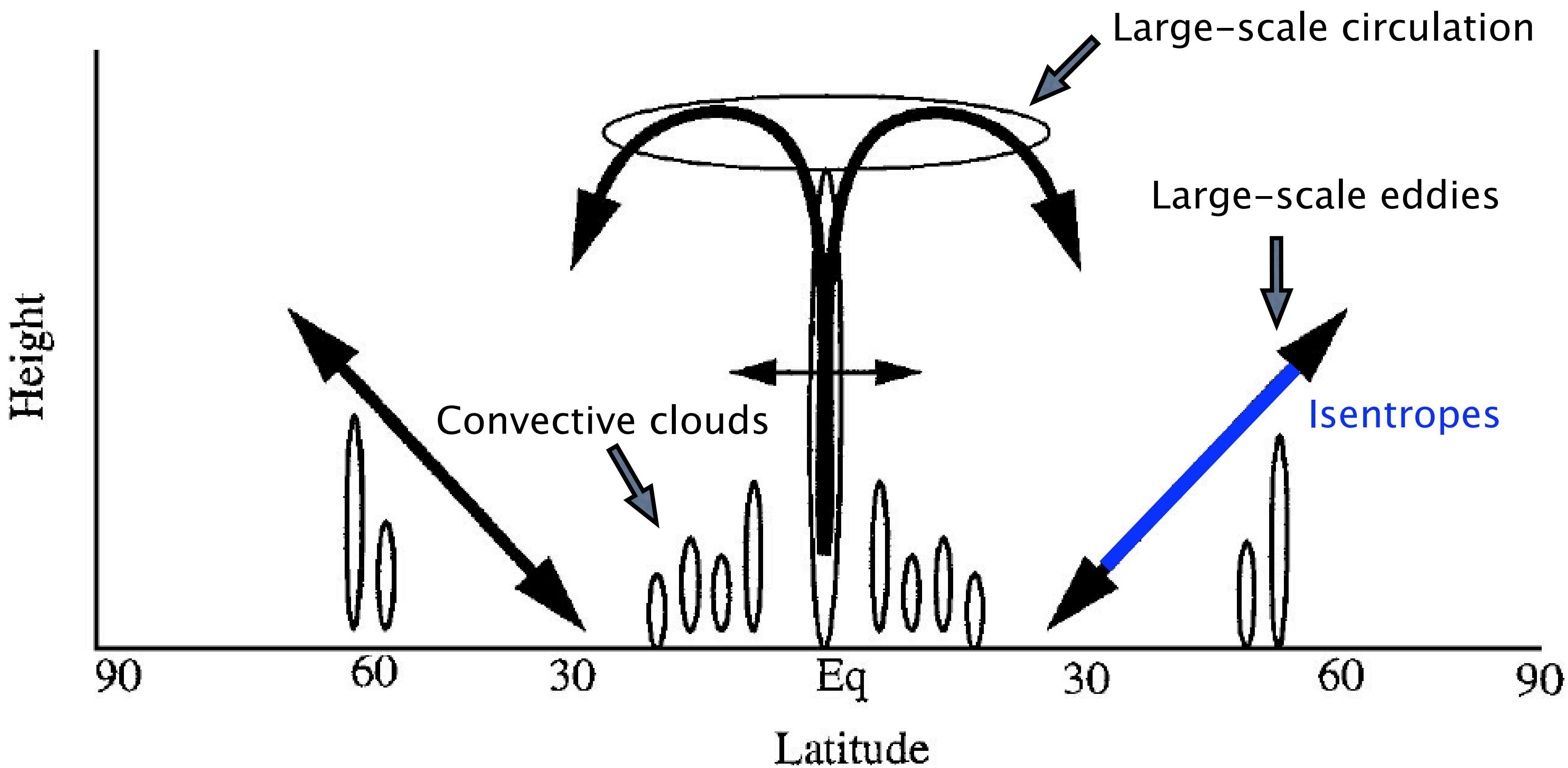
(Held & Soden 2000)

Processes influencing humidity distribution



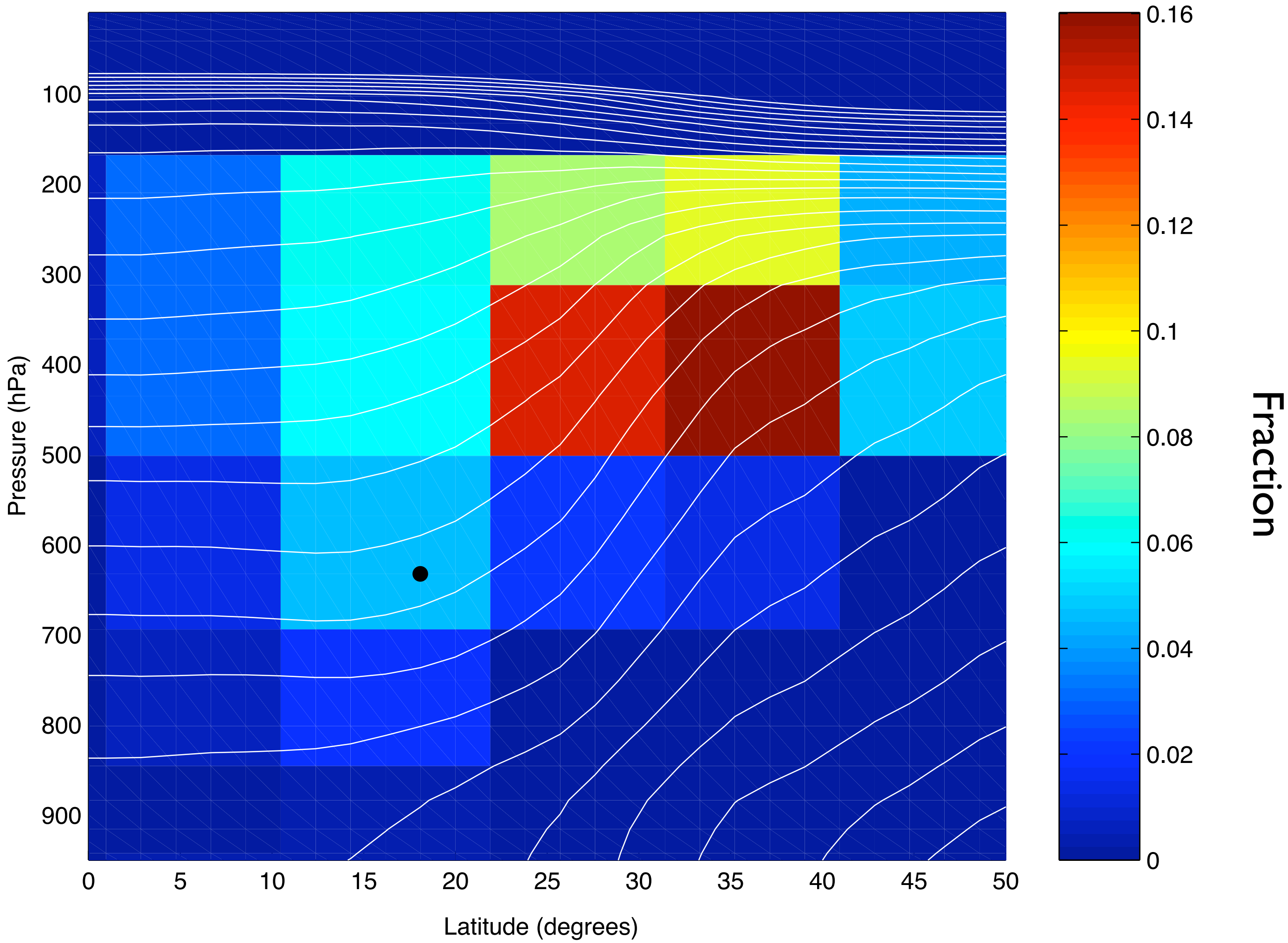
(Held & Soden 2000)

Processes influencing humidity distribution



(Held & Soden 2000)

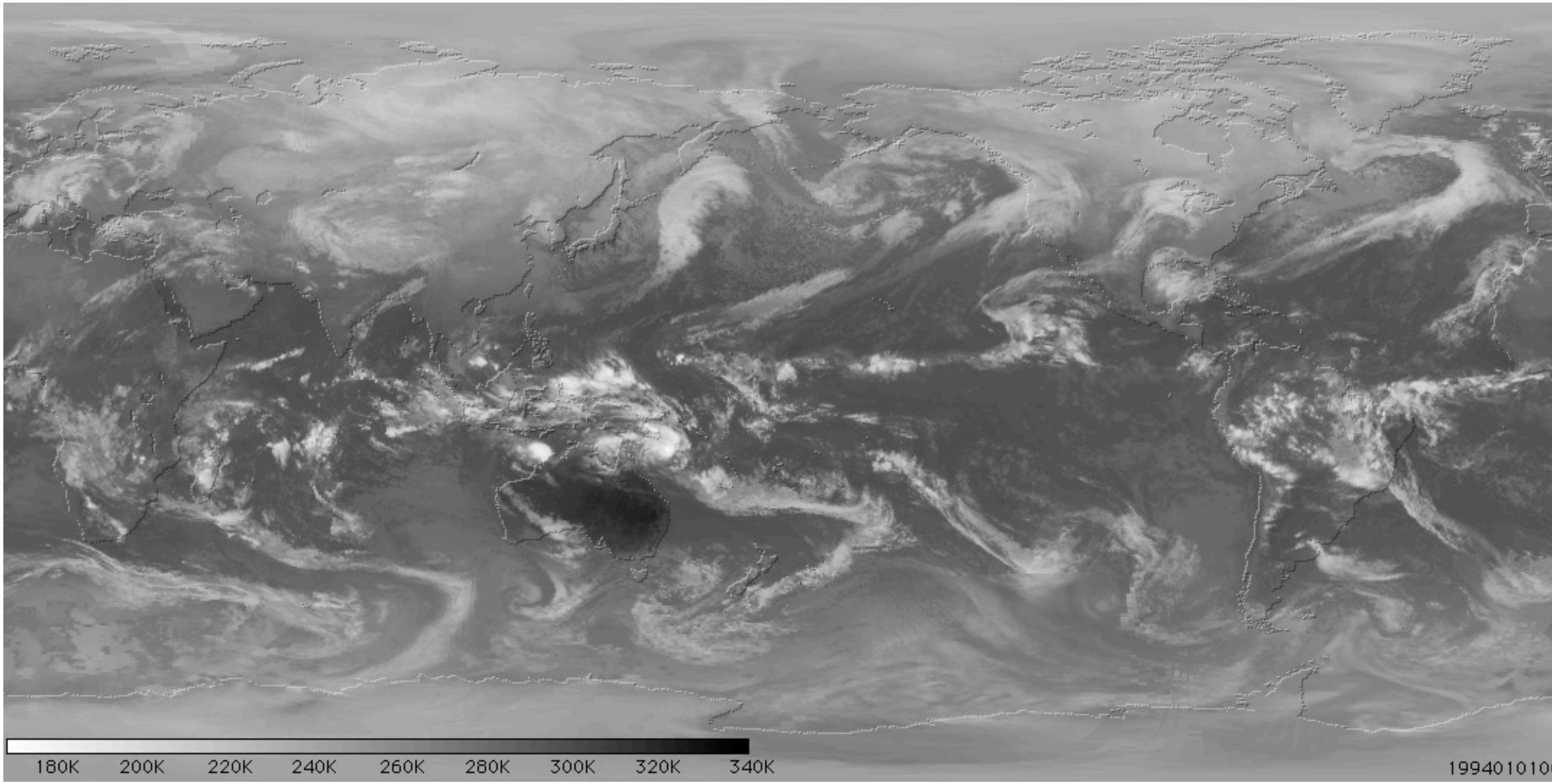
Last saturation of subtropical air masses



(NCEP/NCAR Reanalysis, JFM 1997)

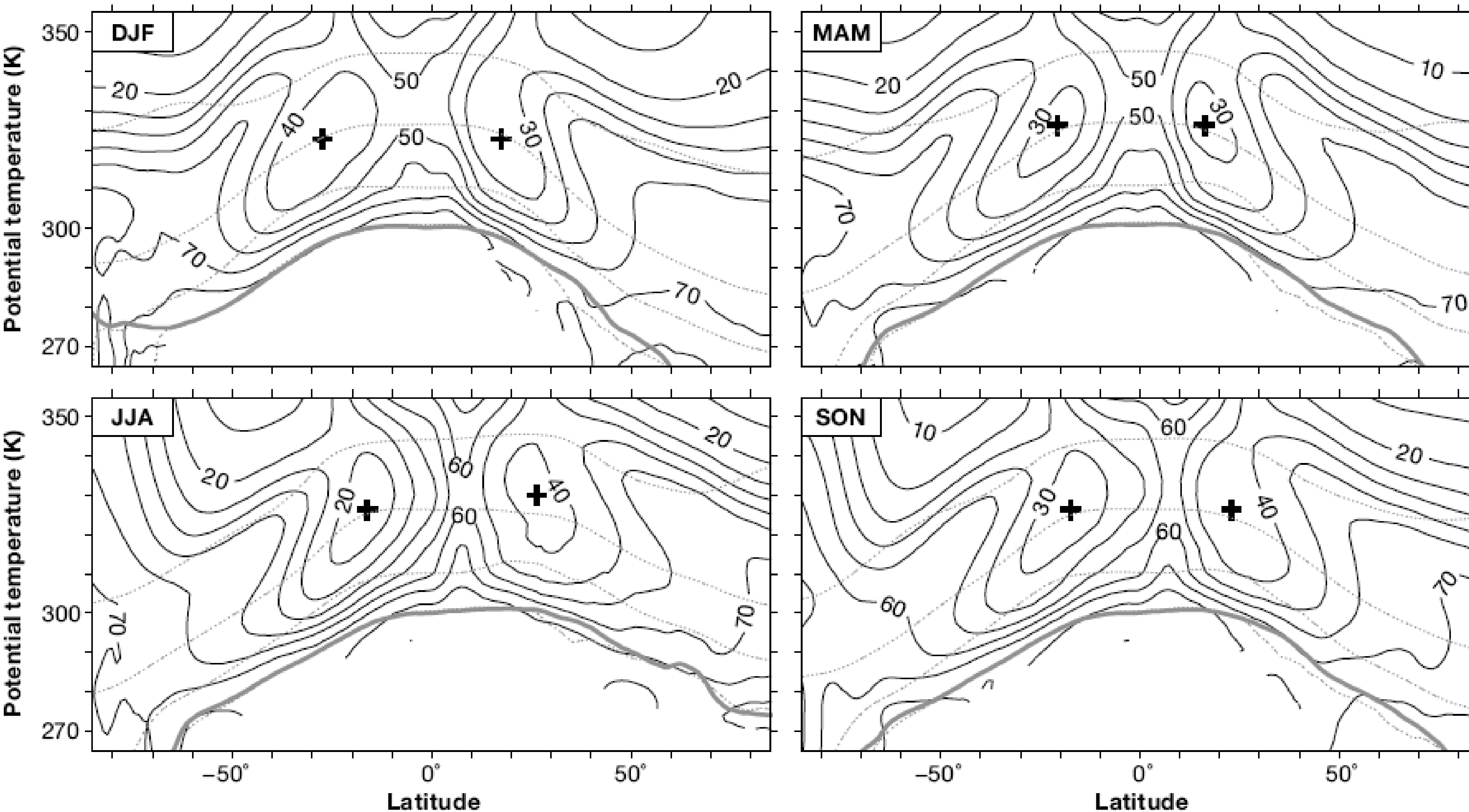
(Galewski, Sobel & Held 2005)

Brightness temperature January 1994



(Courtesy of CLAUS: http://badc.nerc.ac.uk/data/claus/)

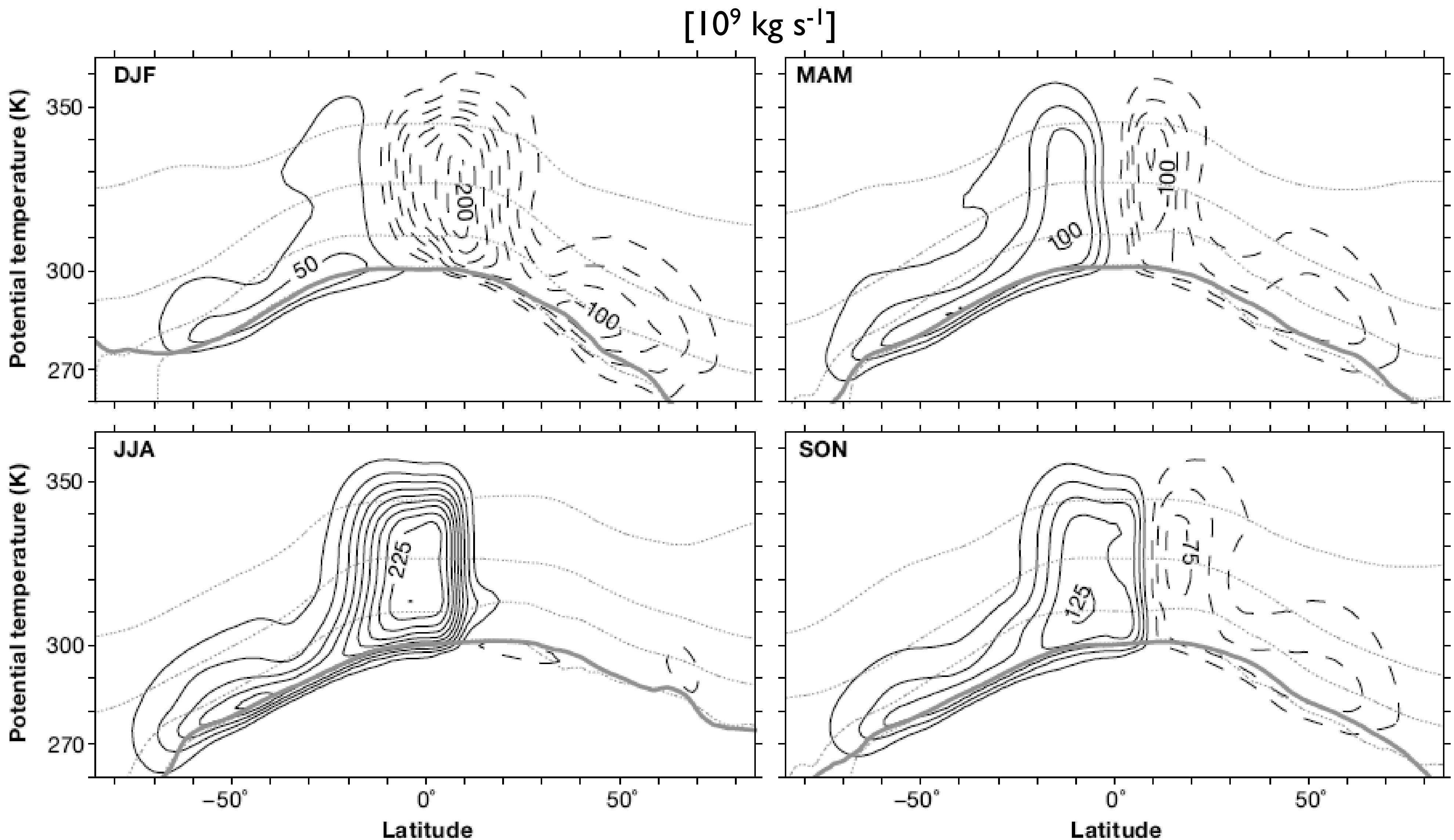
Relative humidity in isentropic coordinates



Dotted lines: 250, 500, 750, 925 hPa pressure contours

(*Data source*: ERA-40; Schneider et al. 2006)

Isentropic mass flux streamfunction

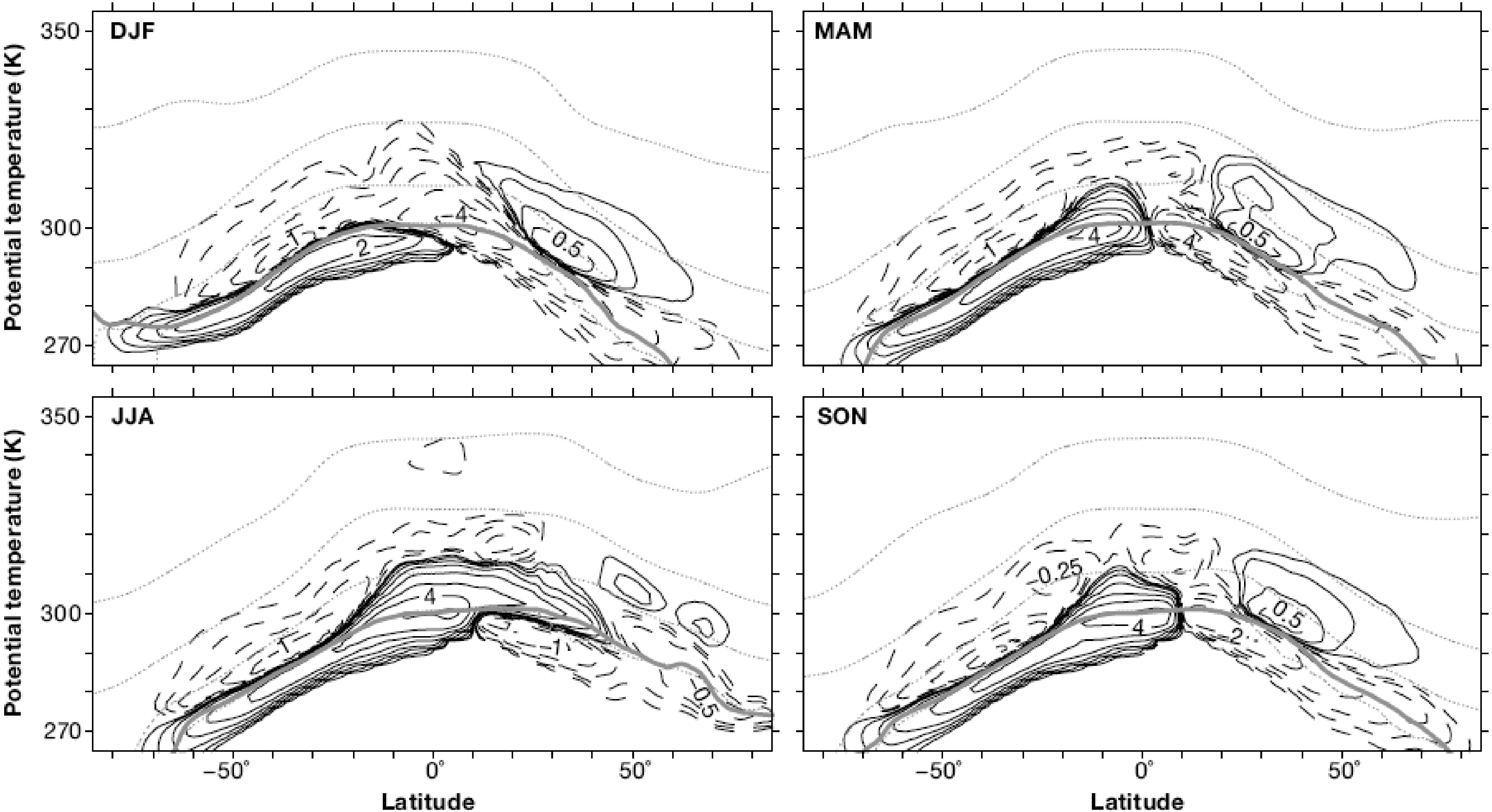


Dotted lines: 250, 500, 750, 925 hPa pressure contours

(Schneider et al. 2006)

Mean meridional flux of water vapor

[±(2^{-4}, 2^{-3}, ...) ×1 kg m^{-1} K^{-1} s^{-1}]

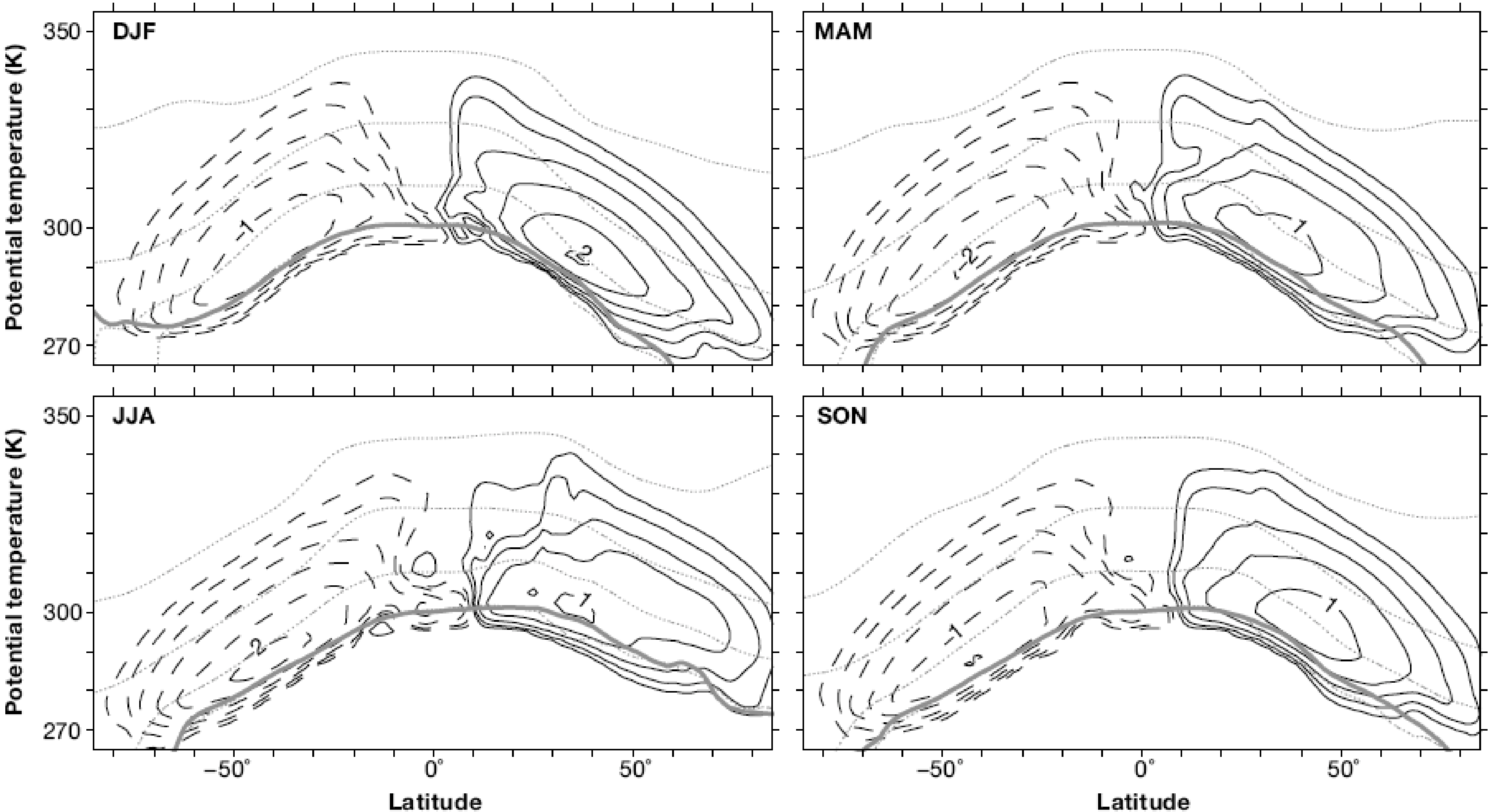


Dotted lines: 250, 500, 750, 925 hPa pressure contours

(Schneider et al. 2006)

Meridional eddy flux of water vapor

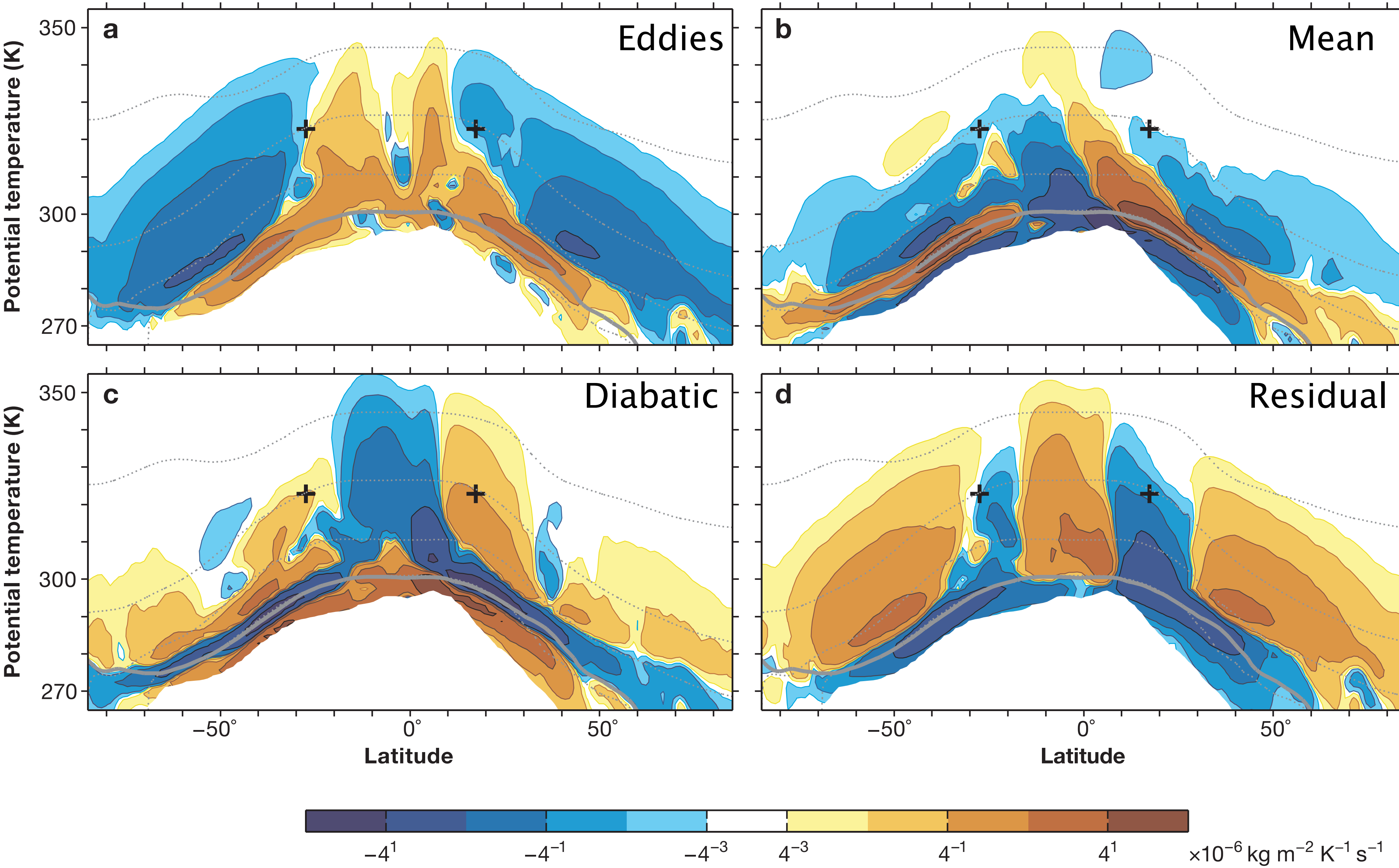
$[\pm(2^{-4}, 2^{-3}, \ldots) \times 1 \text{ kg m}^{-1} \text{ K}^{-1} \text{ s}^{-1}]$



Large-scale eddies dominate meridional water vapor flux deep into Tropics

(Schneider et al. 2006)

Divergence of flux components (DJF)



(Schneider et al. 2006)

Water vapor fluxes in the zonal mean

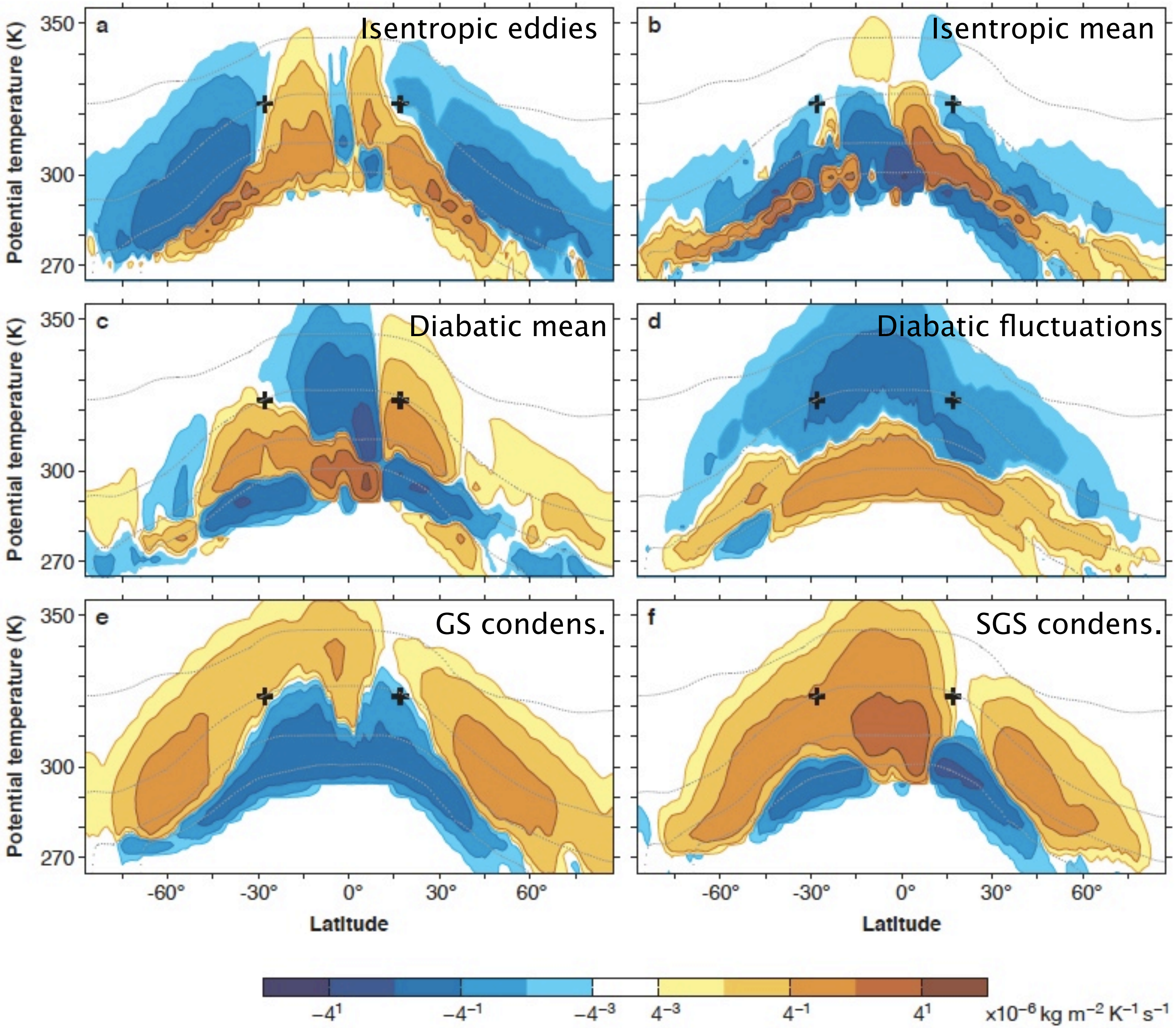
- Isentropic eddy fluxes dominate meridional flux in free troposphere
- Isentropic mean fluxes play secondary role in free troposphere but are important near surface
- Isentropic eddy fluxes diverge in the tropics, convergence in the extratropics, without strong net import to or export from subtropics
- Near RH minima, dominant divergence is mean descent, balanced primarily by cross-isentropic fluxes (plus possibly re-evaporation)

What moistens the subtropics?

- Use ECMWF Integrated Forecast System (IFS) hindcasts for DJF 1998/1999 to get breakdown of diabatic processes affecting water vapor balance.
- T511 horizontal resolution, 60 vertical levels, 4D variational data assimilation

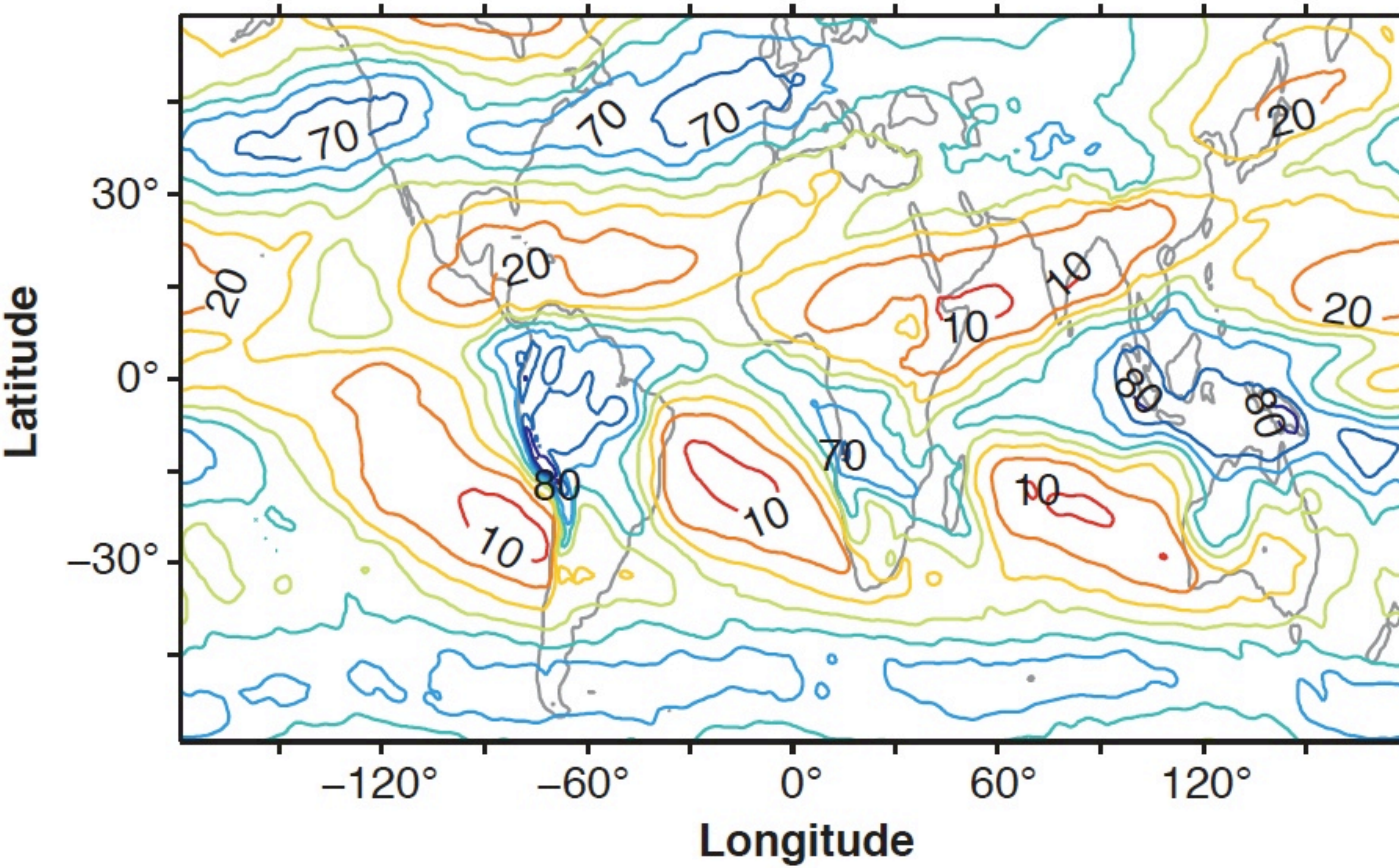
(Data from Tompkins, Li, Waliser)

Divergence of flux components (DJF)



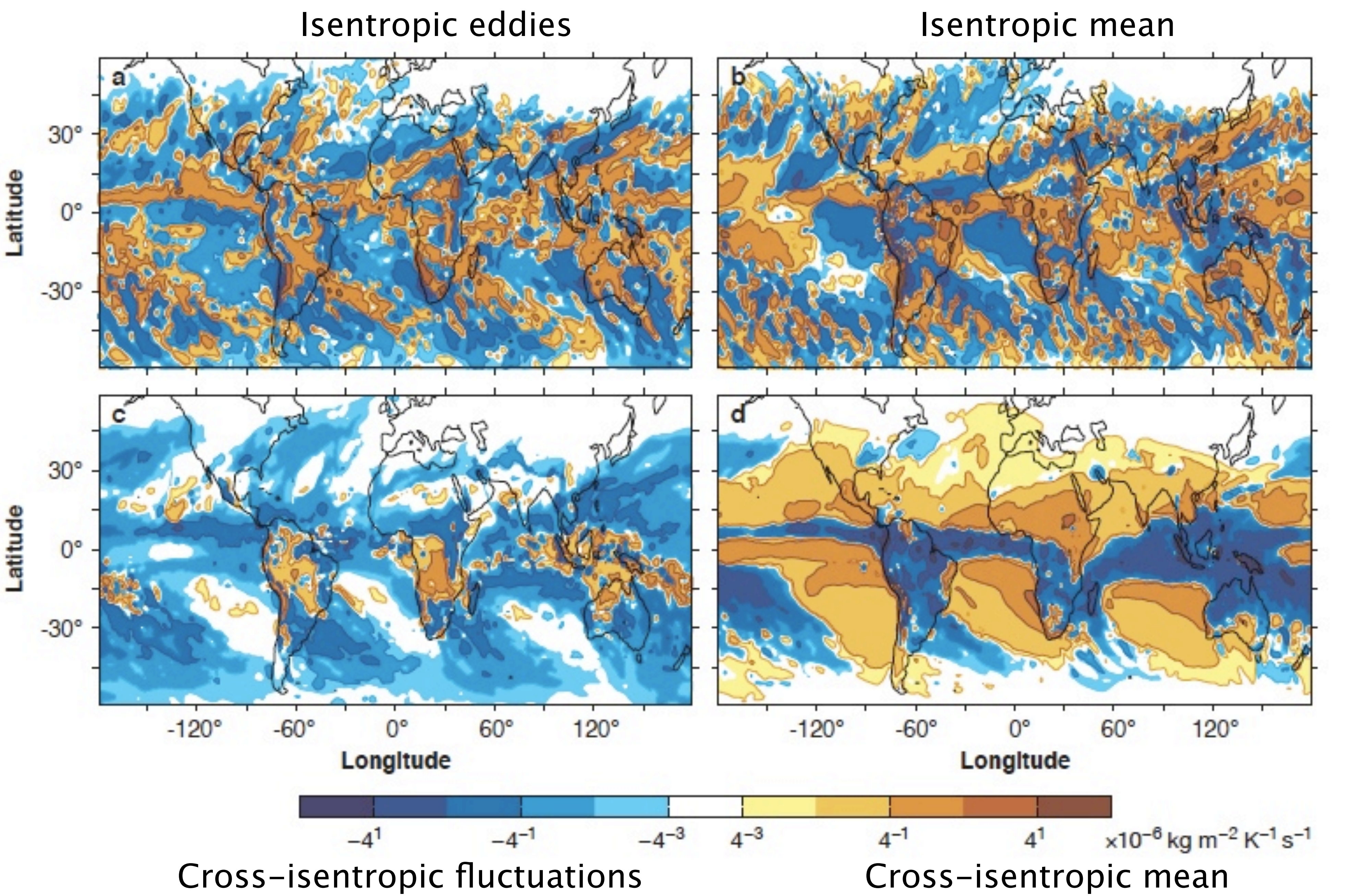
(Couhert et al., *J. Climate*, in press)

Relative humidity on 323-K isentrope



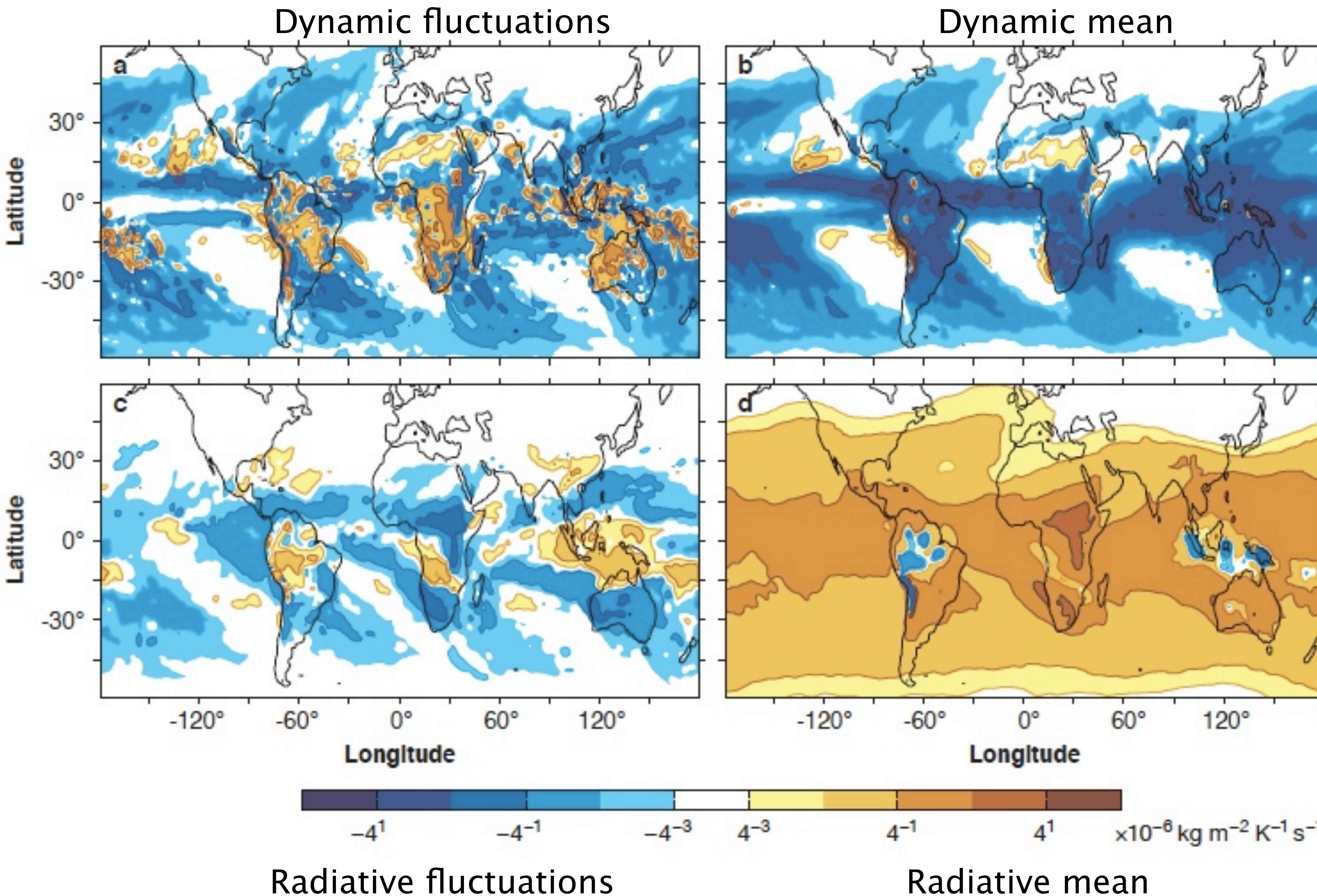
(Couhert et al., *J. Climate*, in press)

WV flux divergence on 323-K isentrope



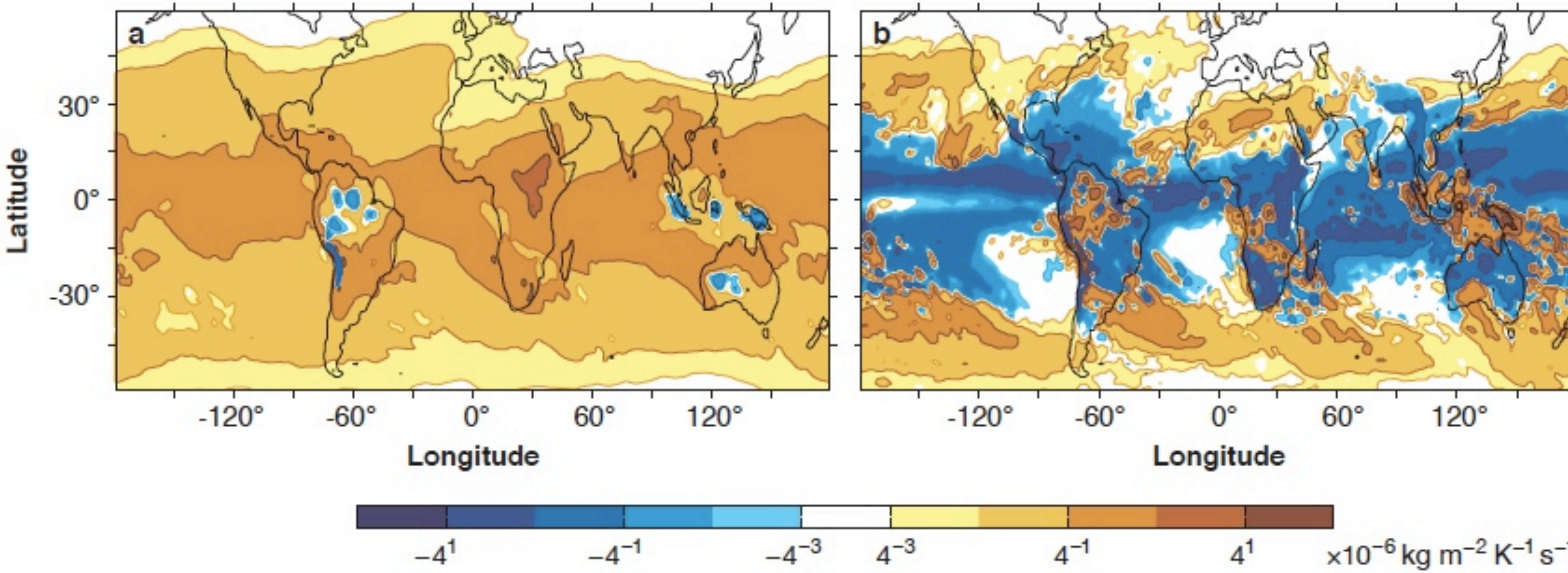
(Couhert et al., *J. Climate*, in press)

Divergence of cross-isentropic fluxes



(Couhert et al., *J. Climate*, in press)

Drying owing to cross-isentropic fluxes and net condensation



Radiative $\partial_\theta(\bar{\rho}_\theta \, \overline{Q_R q}^*)$ Dynamic $\partial_\theta(\bar{\rho}_\theta \, \overline{Q_d q}^*) - \bar{\rho}_\theta \, \overline{S}^*$

(Couhert et al., *J. Climate*, in press)

Conclusions for subtropical free troposphere

- Isentropic eddy fluxes transport wv through subtropics, but do not lead to substantial import or export in the zonal mean
- Dominant moistening process balancing drying by (radiative) subsidence is cross-isentropic convective flux, e.g., over summer hemisphere continents or western ocean basins
- Evaporation of condensate is secondary moistening process at lower levels
- Regional imbalance between subsidence drying and cross-isentropic moistening controls regional relative dryness (e.g., over eastern ocean basins)
- Isentropic eddy fluxes transport wv from moister into drier regions within the subtropics (transport wv downgradient)

Ocean-Atmosphere Energy Transport

November 5 – 7, 2009 California Institute of Technology

Invited Speakers

David Battisti
University of Washington, Seattle

Harry Bryden
University of Southampton

Paola Cessi
UC San Diego, Scripps Institution of Oceanography

Isaac Held
Princeton University, GFDL/NOAA)

John Marshall
Massachusetts Institute of Technology

Lynne Talley
UC San Diego, Scripps Institution of Oceanography

Robert Toggweiler
Princeton University, GFDL/NOAA

Eli Tziperman
Harvard University

Kraig Winters
UC San Diego, Scripps Institution of Oceanography

Carl Wunsch
Massachusetts Institute of Technology

The observed climate depends crucially on the poleward transport of energy by the oceans and atmosphere. Much progress has been made in understanding the dynamics of energy transport in the atmosphere. But it remains an open question what the key processes are that control the energy transport in the ocean, and it is unclear how ocean and atmosphere energy transports are coupled. The wealth of new data from global observation systems and our improved ability to simulate ocean and atmosphere dynamics numerically put us in a position to resolve these questions.

This three-day conference will bring together oceanographers and atmospheric scientists, with expertise in observations, theory, and modeling, to assess the current state of our understanding of ocean-atmosphere energy transport and outline directions for future research. About one half of the conference will be devoted to invited overview talks, with the rest allocated to contributed talks and posters.

Organizers

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www.eas.caltech.edu/oaet2009

Please contact Nora Oshima with questions at nora@gps.caltech.edu

The Conference is being hosted by the Division of Geological and Planetary Sciences and the Division of Engineering and Applied Science of the California Institute of Technology and is made possible through the generous support of Richard H. Cox.