Ten Years of Measurements of Tropical Upper-Tropospheric Water Vapor by MOZAIC: Climatology, Variability and Relation to Deep Convection

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MOZAIC Project and Data

MOZAIC is a project, funded by the European Union, for the measurement of the large-scale distribution of water vapor and ozone from board of commercial Airbus aircraft during schedule flights [Marenco et al. 1998].

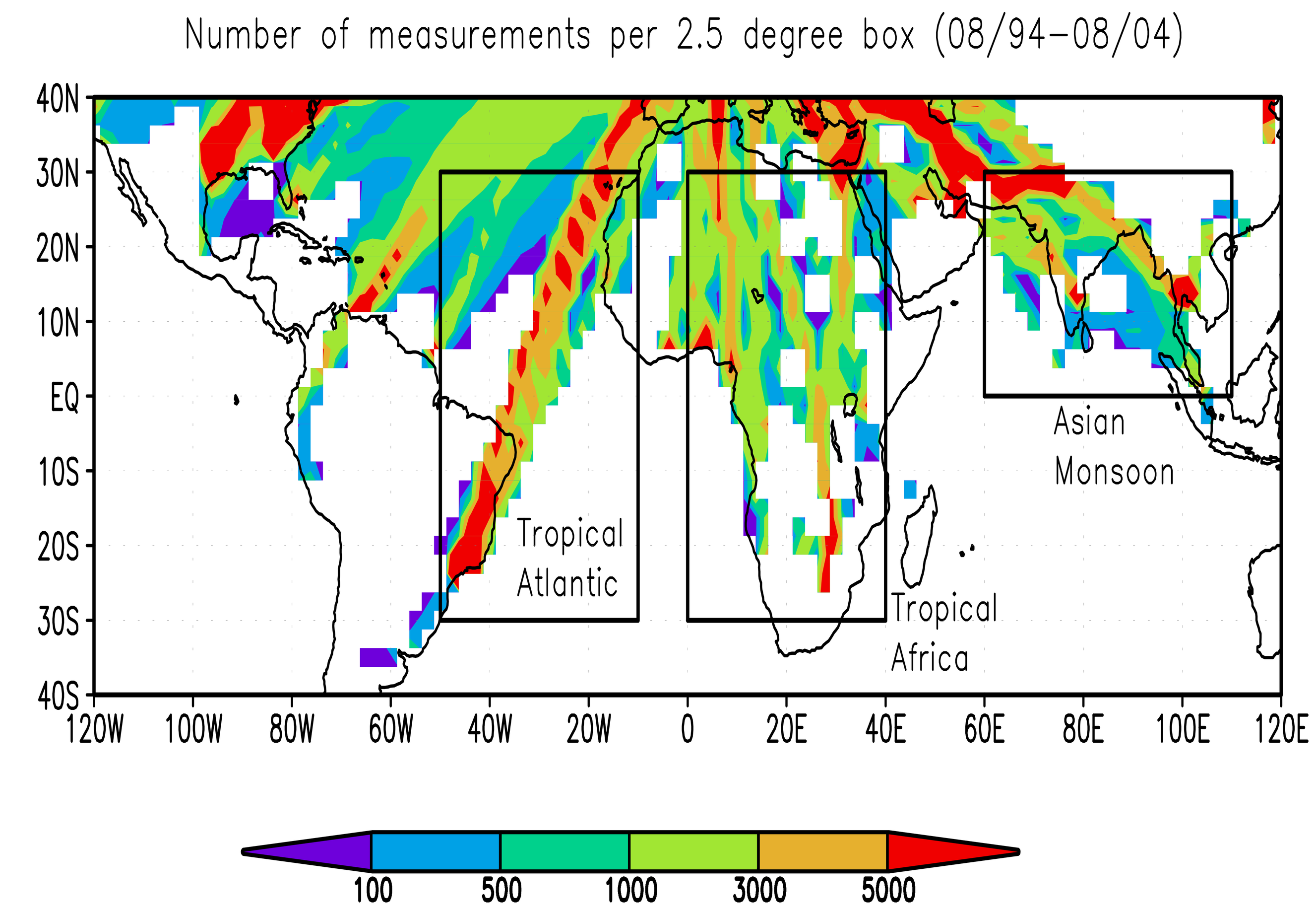
Five A340 long-range passenger aircraft are equipped with semi-automated instrumentation to measure relative humidity, ozone, temperature and to record aircraft data such as position, pressure, temperature, wind speed, Mach number etc.

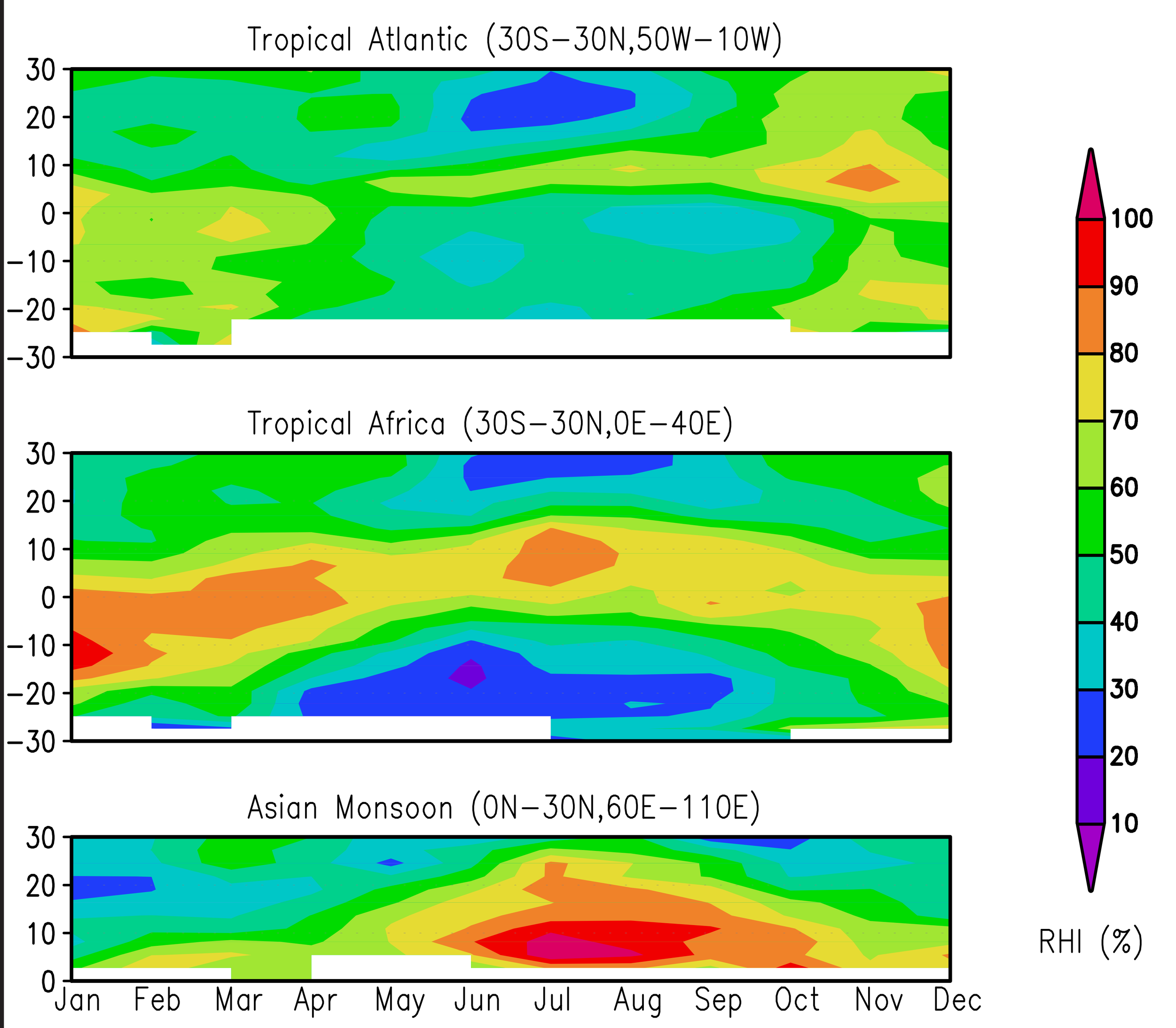
MOZAIC equipment is flown during scheduled flights by several European airlines. MOZAIC has been operational since August 1994. Data exist since its inception. More than 2,500 flights/year with a total of about 125,000 flight hours of measurements were made by December 2003. The flights cover all continents, except Australia, and all oceans except the Pacific.

Roughly 32% of the flights cover the three tropical regions that are selected for analysis: Tropical Africa, Asian Monsoon region and Tropical Atlantic. The time resolution of the MOZAIC humidity measurements in the upper troposphere is 1 min which, at cruising speed, corresponds to a spatial resolution of 15 km.

In the tropical regions, MOZAIC Aircraft, at cruise altitude, fly at five discrete pressure levels of 288, 262, 238, 217 and 197 hPa with a preponderance of 238and 262 hPa. The humidity and temperature measurements provide an unexcelled depository of accurate (to 5%) and quality-assured relative and specific humidity data [Helten et al. 1998].

We analyse ten years (1994 – 2004) of measurements of tropical upper-tropospheric water vapor (UTWV) to determine the UTWV climatology and variability on multiple scales. The full analysis is reported in Luo et al. [2006].

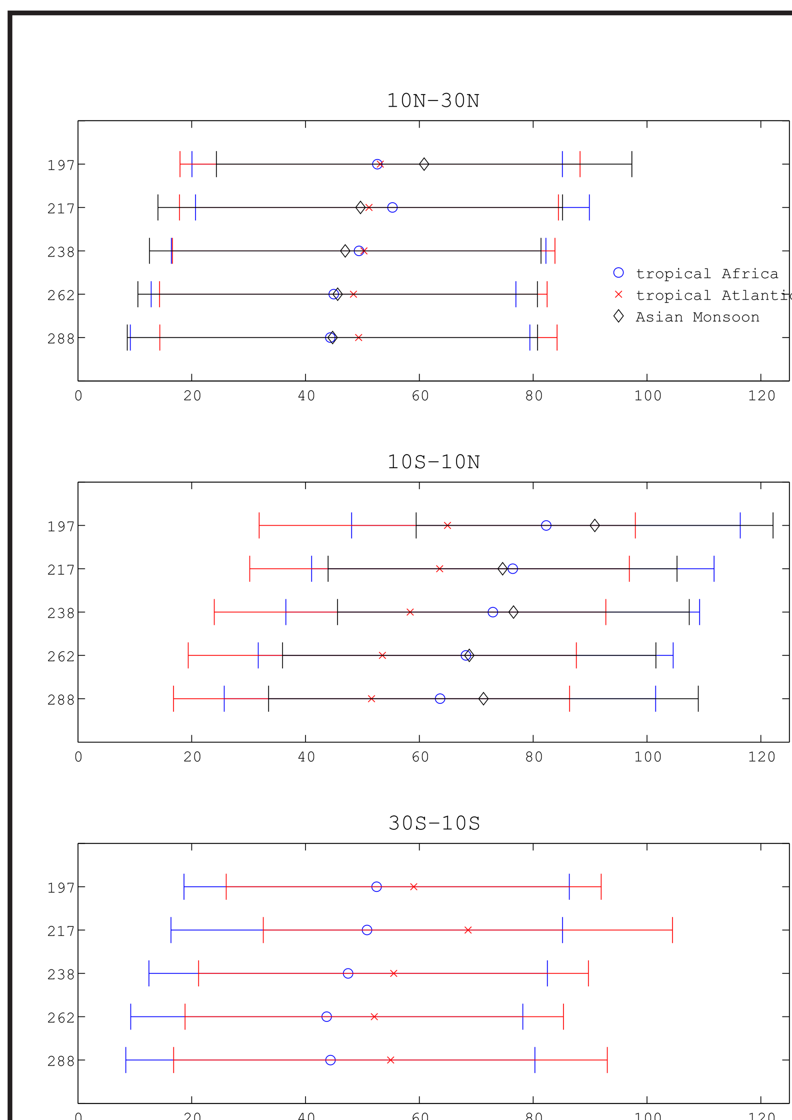




Annual Cycle

Left figure shows the composite UTH annual cycle with respect to ice, (RHi) as a function of latitude. All flight levels are included. It is seen that the seasonal migration of the UTH pattern keeps pace with that of the ITCZ in the corresponding region, indicating the convective influence on the UTH distribution. Some significant regional differences are identified:

- The magnitude of the UTH seasonal cycle is large for the South Asian Monsoon region and the tropical Africa; it is comparatively weak for the tropical Atlantic.
- The moistest upper troposphere is found in the Asian Monsoon region during the wet season (with the monthly mean RHi greater than ice saturation), followed by the tropical Africa during the local summer.
- Subtropical Africa south of the equator (10S – 30S) experiences the driest upper troposphere for the most prolonged period during the local winter (i.e., the boreal summer) with values of RHi of only around 20% and is much drier than the Sahara desert region.



Vertical Structure

The long-term, near global, vertical structure of tropical relative humidity is shown in left figure.

RHi generally increases with height: mean RHi is about 10 – 20 % (in absolute values) higher at the 197-hPa level than the 288-hPa level.

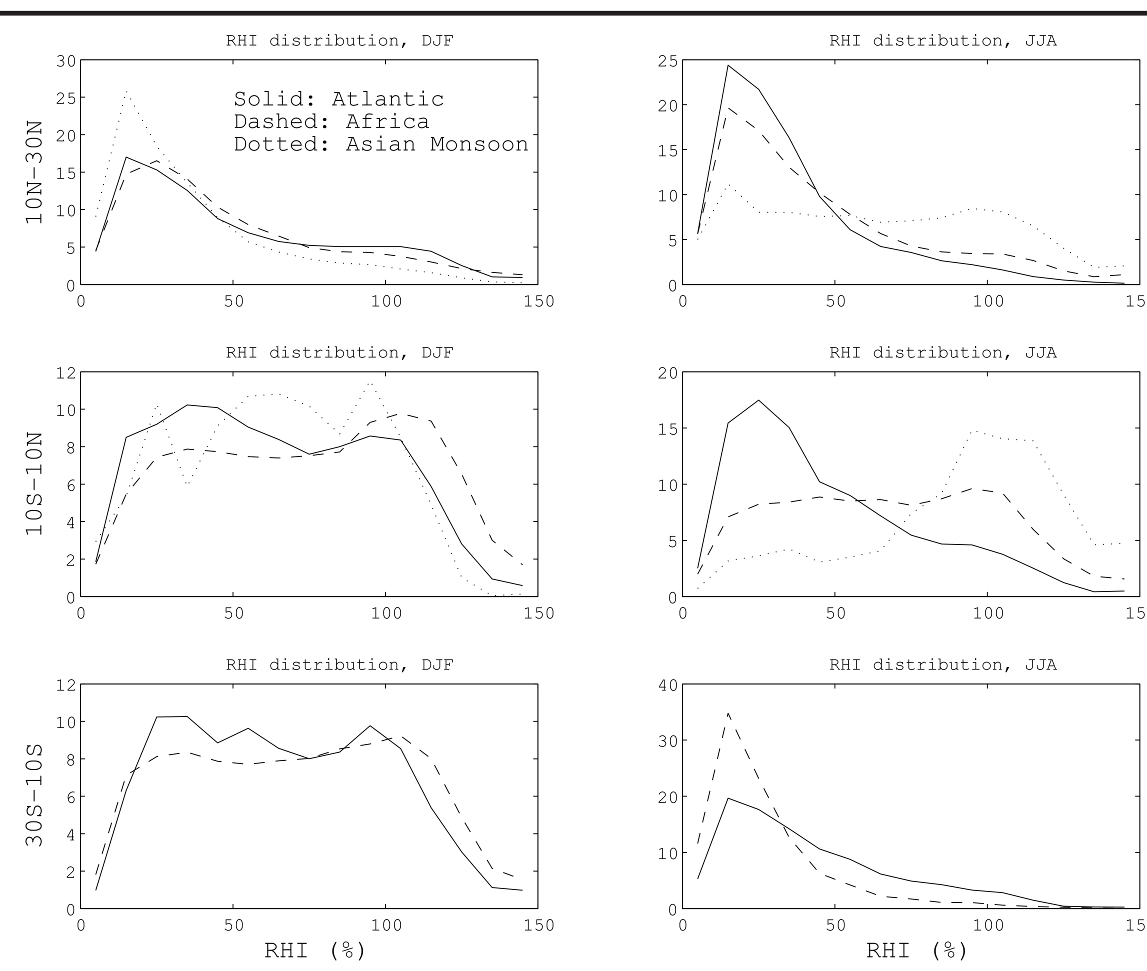
A natural explanation for the observed height dependence of tropical UTH is that the upper levels correspond more closely to the convective detrainment layer, where there is an ejection of both saturated air and condensate serving as moisture source whereas the lower levels are subjected more to drying by subsidence.

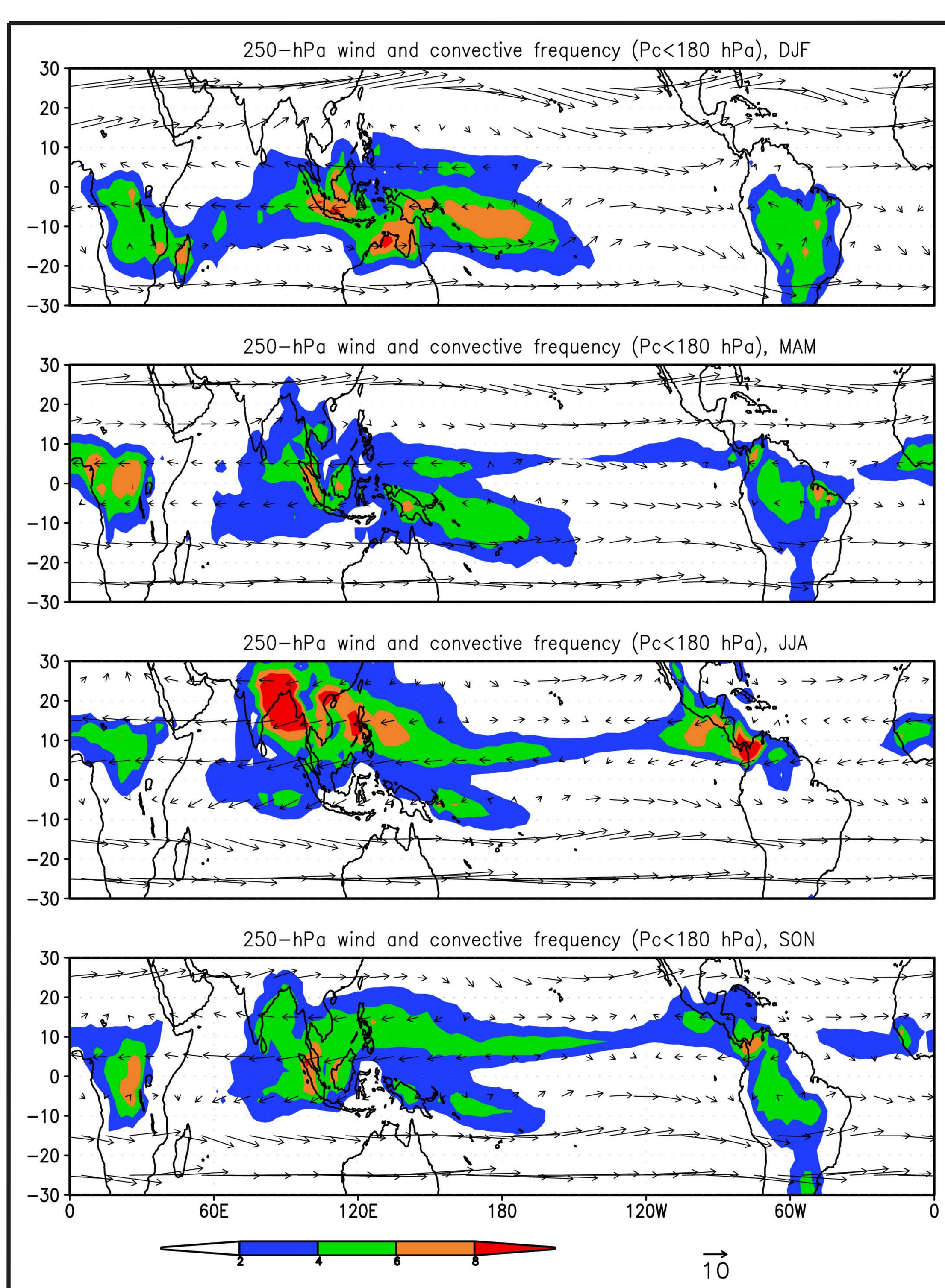
Probability Density Functions – PDF

The probability density function (PDF) of tropical UTH is bimodal. The figure shows the RHi PDFs sorted by latitude and season. MOZAIC measurements over the tropical Atlantic [Nawrath 2002] and their extension to other tropical regions show the ubiquitous nature of the bimodality distribution.

In the deep tropics (10S – 10N), the moisture level frequently reaches ice supersaturation and even approaches saturation over liquid [Nawrath 2002]. The shape of the moist mode is nearly Gaussian, suggesting that processes which generate this mode have about equal probability of forming higher or lower RHi about a mean of 100%.

The two modes of this bimodal distribution stay rather constant; suggesting that they probably are a manifestation of two key processes that have controlling effects on UTH, namely convective moistening and subsidence drying.





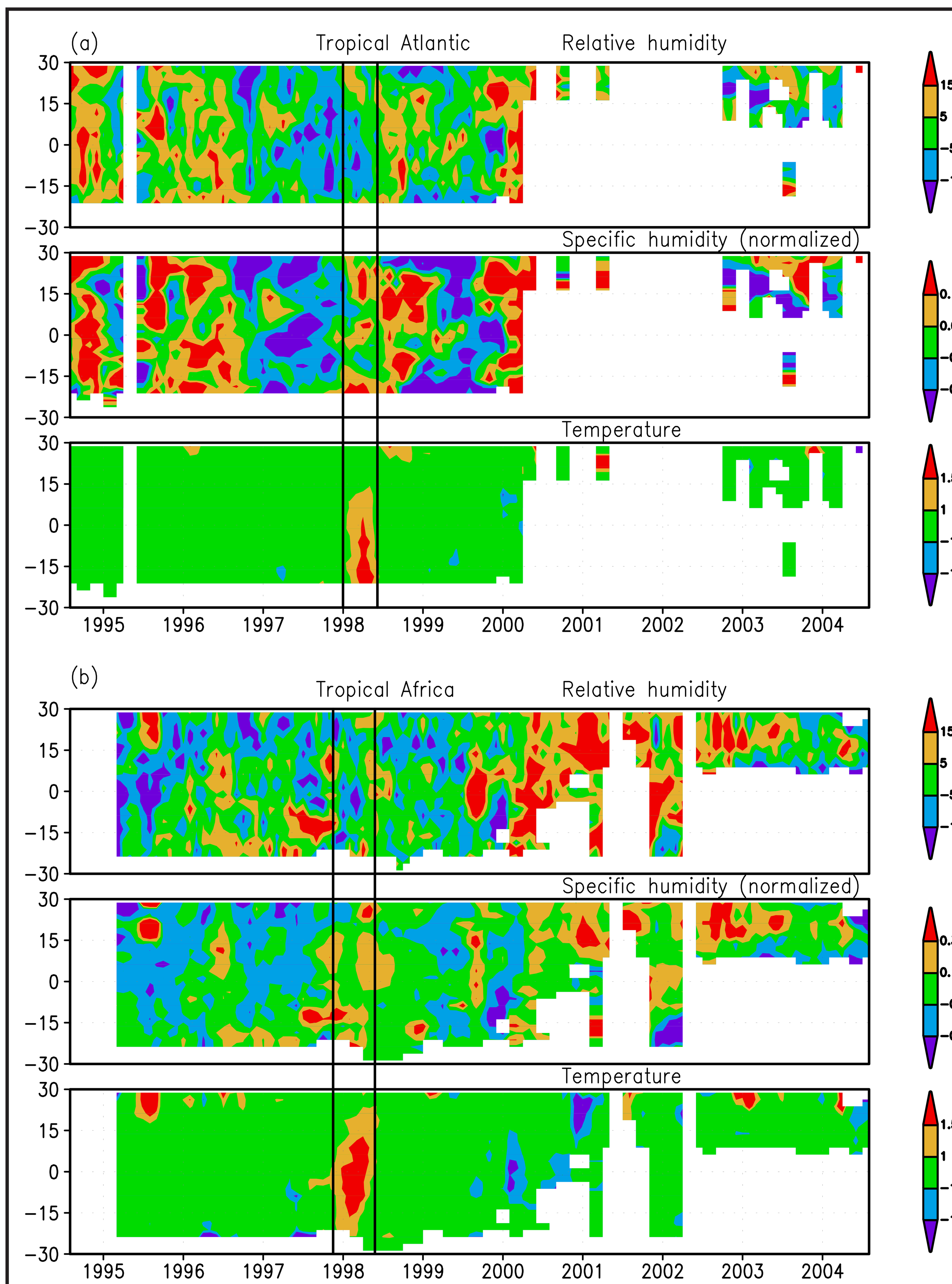
Relation to Deep Convection

The MOZAIC climatology and variability in relation to deep convection, using 1994 – 2004 ISCCP data. Cloud properties of high clouds with cloud top pressures between 310 and 180 hPa (type I) are derived from analyzing infrared (≈ 11 µm) radiances measured by the imaging instruments on operational weather satellites [Luo and Rossow 2004].

The Figure left shows the 1994 – 2004 period climatology of high clouds.The regional differences in MOZAIC UTH climatology are closely connected to the differences in the distribution of deep convection.

The tropical Atlantic has the driest upper troposphere because it has the least amount of deep convection reaching the MOZAIC cruise levels.

The Asian Monsoon region has the moistest upper troposphere during the wet season and also the most abundant deep convection.



Interannual Variability

An analysis of interannual variability in UTWV can be made with the MOZAIC data due to the fact that the same instrumentation with known and assured accuracy is used throughout. Figure above shows the monthly mean UTH (in RHi) variations for the period of 1994 – 2004 without seasonal cycles. Also shown are the interannual variations of specific humidity and temperature.

In general, UT temperature experiences little temporal variation, whereas moisture variability (both specific humidity and relative humidity) is large. The small temperature perturbation makes RHi variation closely follow that of the specific humidity except during the 1997/1998 ENSO event.

The figure shows also an increase in UTH over tropical Africa from around 2000 to 2002, and probably beyond. The increase in UTH mainly comes as a result of the rise in specific humidity rather than changes in temperature.

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Acknowledgement

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