

The Available Energy and its Trends

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Available Energy

- AE is **not** the APE of Lorenz
- Formulation by Gibbs: improves on APE
- Maximum amount of work a system can do
 - Also called 'Free Energy' or 'Exergy'
- $AE = TPE - TPE_0$ where $\delta S_{sys} = 0$
- $APE = TPE - TPE_A$ where $\delta s_{particle} = 0$

Atmospheric Available Energy

Minimize an availability function to uniquely determine the equilibrium temperature and thus the available energy:

$$\delta a_j = \delta h_j - T_0 \delta s_j - \delta p_j / \rho_{j0}$$

specific available
energy

specific enthalpy

specific entropy

equilibrium temperature

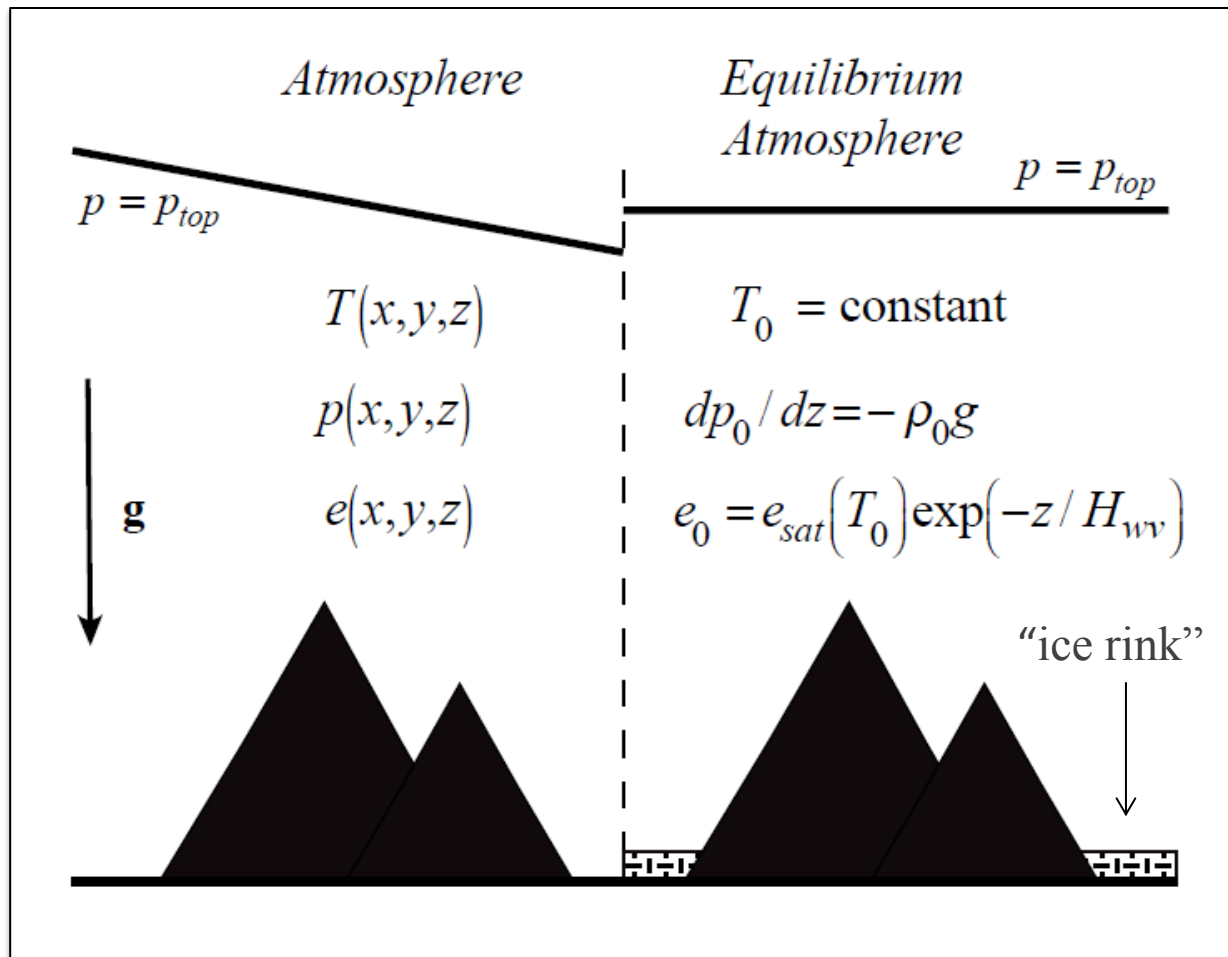
partial pressure

partial
equilibrium
density

δ indicates a finite difference between actual atmosphere and the equilibrium atmosphere

$j = d, v$ for dry air and water vapor

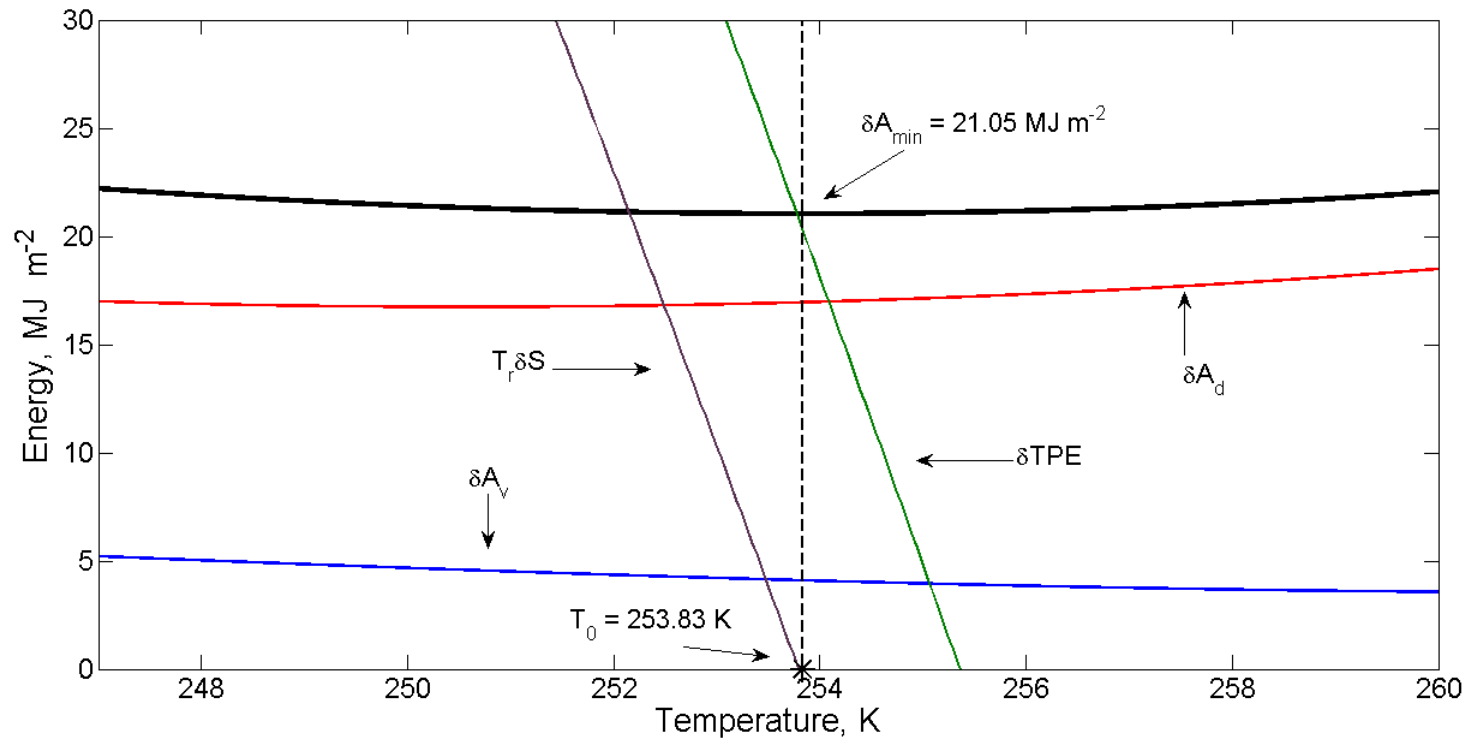
The Equilibrium Atmosphere



ERA-Interim Reanalysis

- 1.5 by 1.5 degree horizontal grid
 - All 37 pressure levels from 1000 to 1 hPa
 - Monthly mean data
 - 34 years (1979-2012)
-
- Equilibrium temperature and available energy determined for each month.

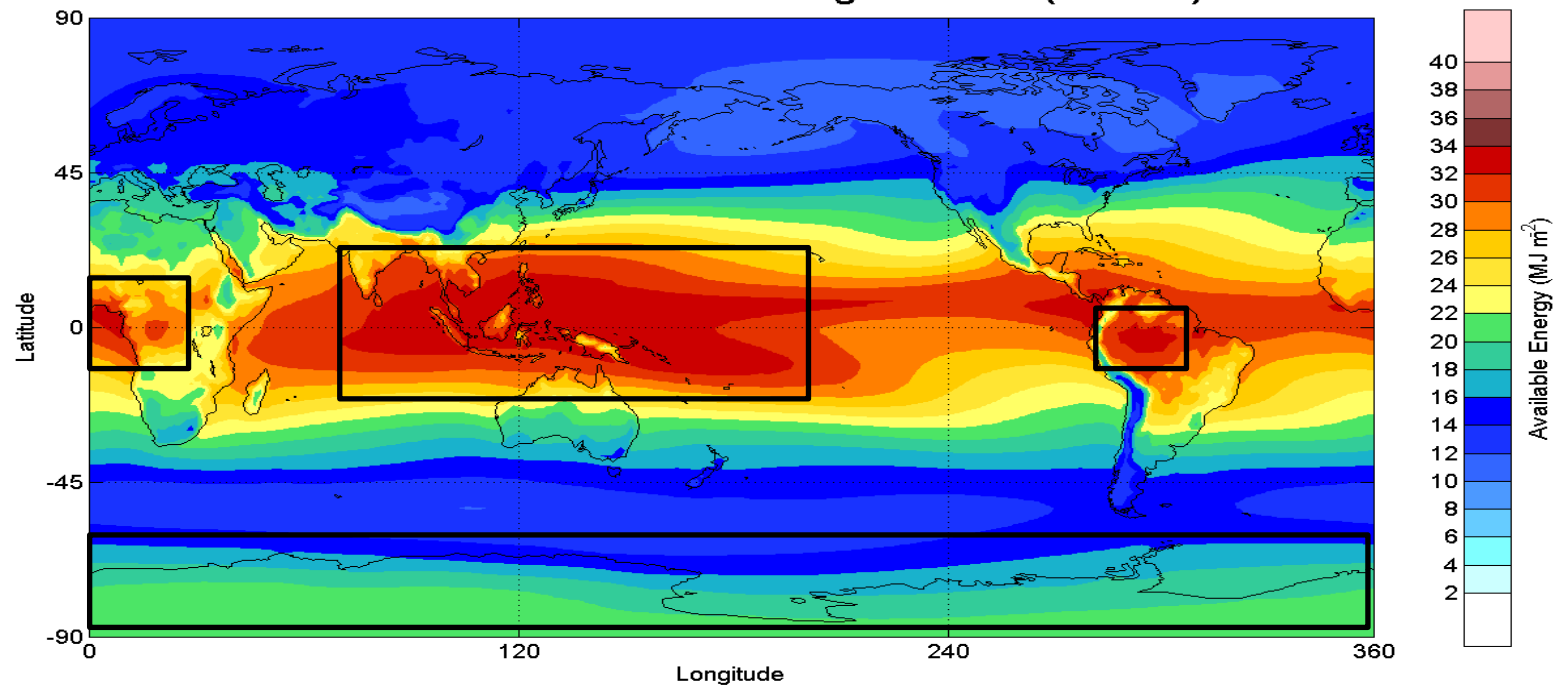
Minimization of the Availability Function



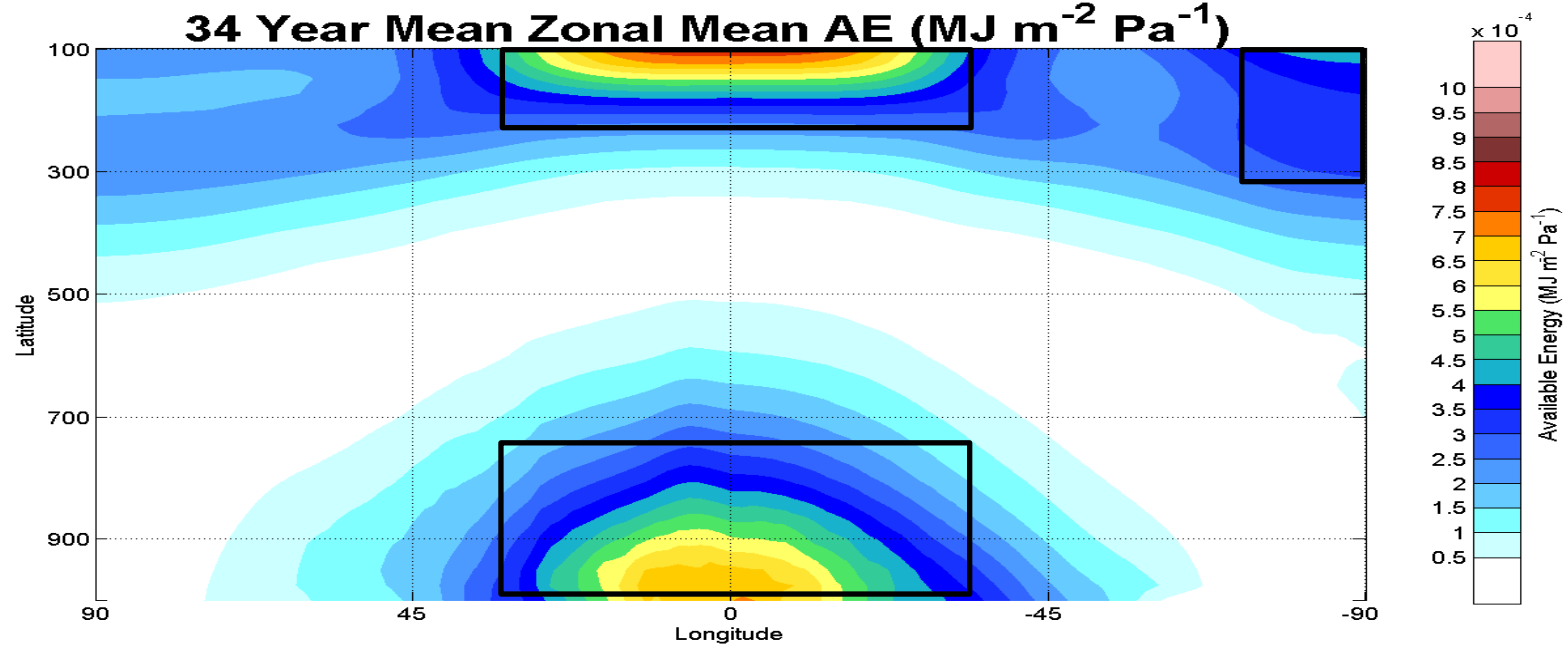
$$AE = \delta A(T_0) = \delta TPE$$

$$\delta S = 0$$

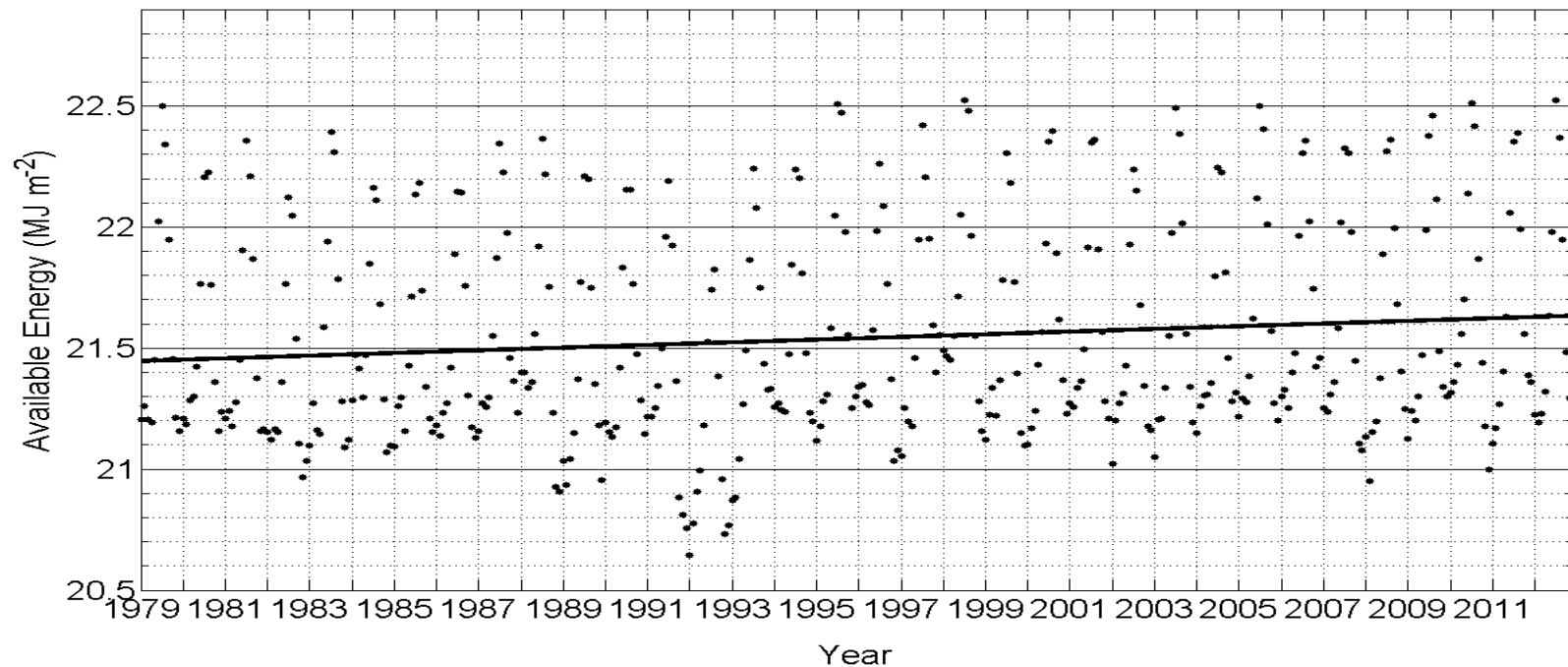
34 Year Mean Column Integrated AE (MJ m^{-2})



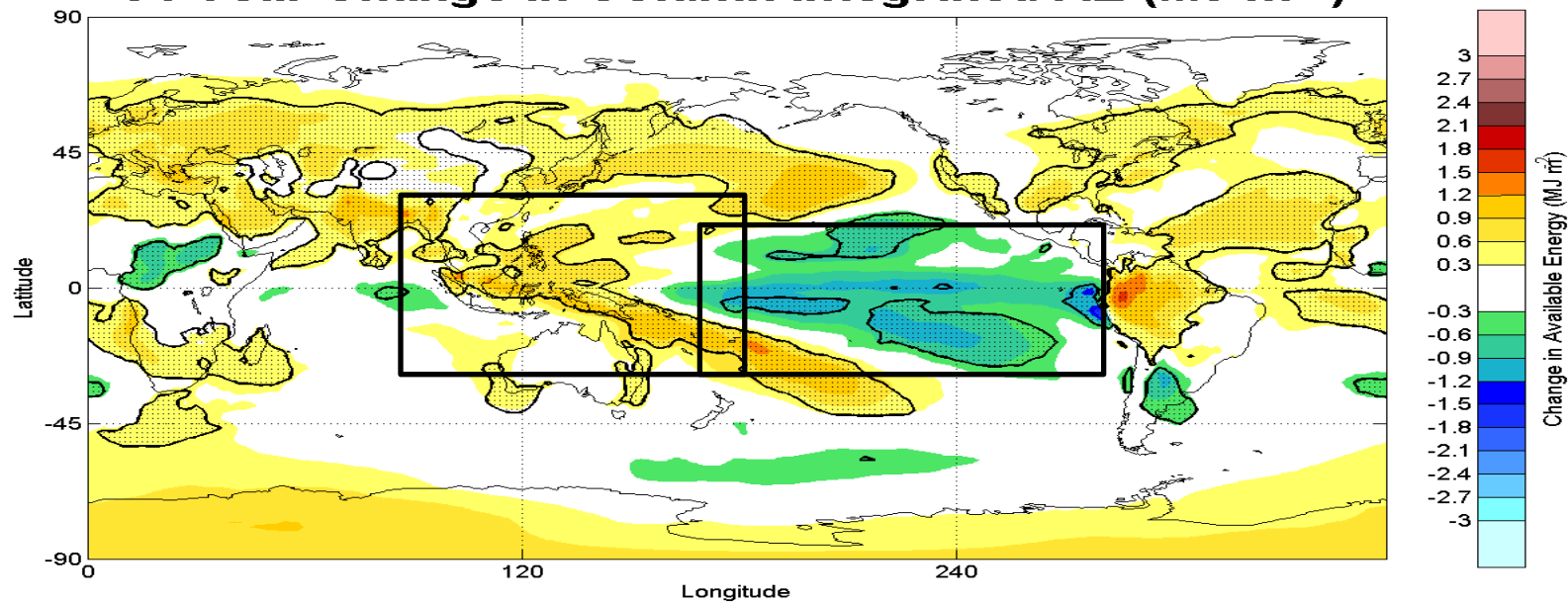
34 Year Mean Zonal Mean AE ($\text{MJ m}^{-2} \text{ Pa}^{-1}$)



Monthly Global Available Energy (MJ m^{-2})



34 Year Change in Column Integrated AE (MJ m^{-2})



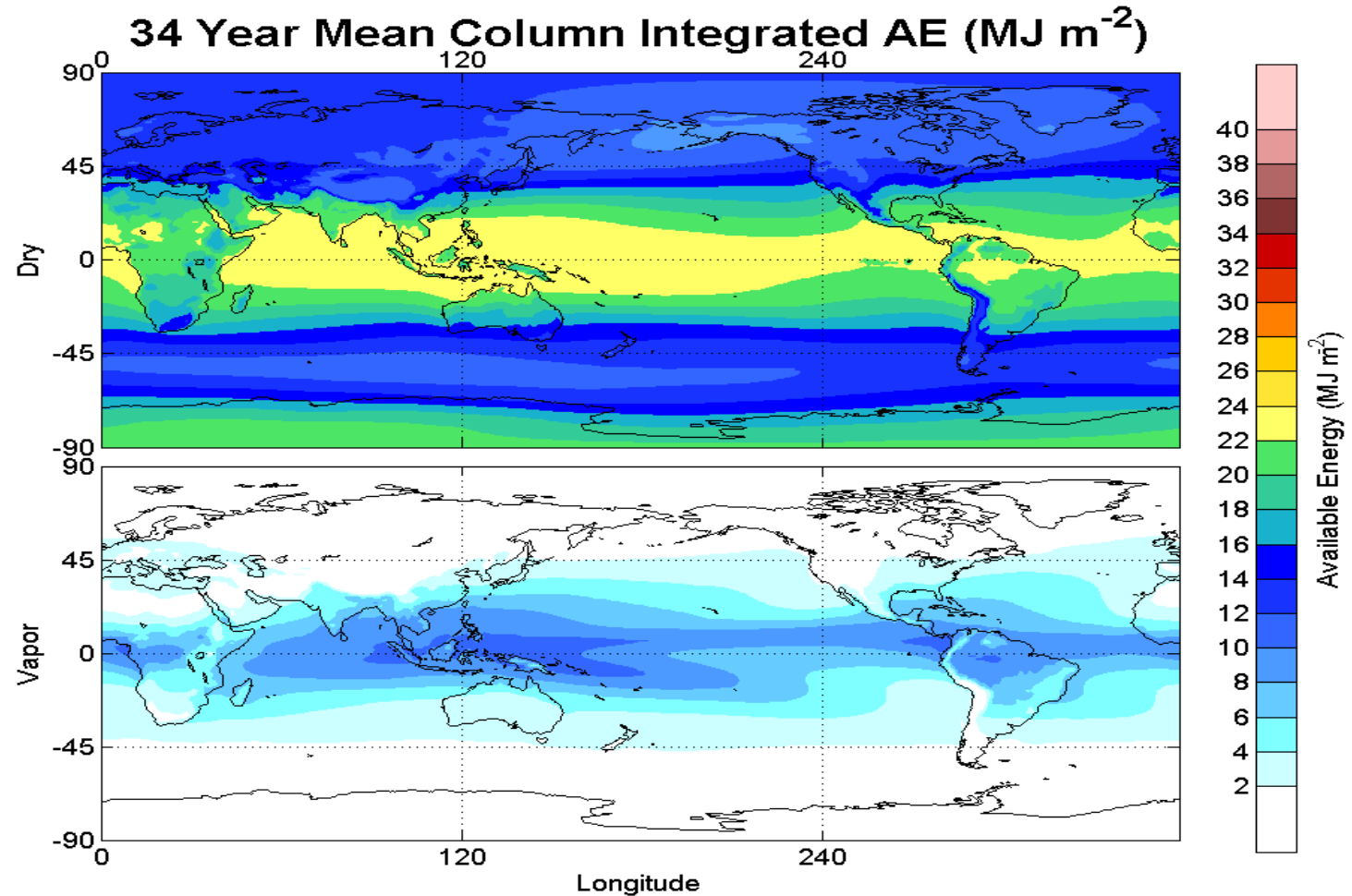
Summary

- Available Energy measures the maximum available kinetic energy
 - Dry air and water vapor included
 - Baroclinic and convective contributions
 - Terrain effects included
- Globally, AE 5 times as large as APE
- Dry air contribution dominates the available energy
- In the tropics, water vapor component is equally large

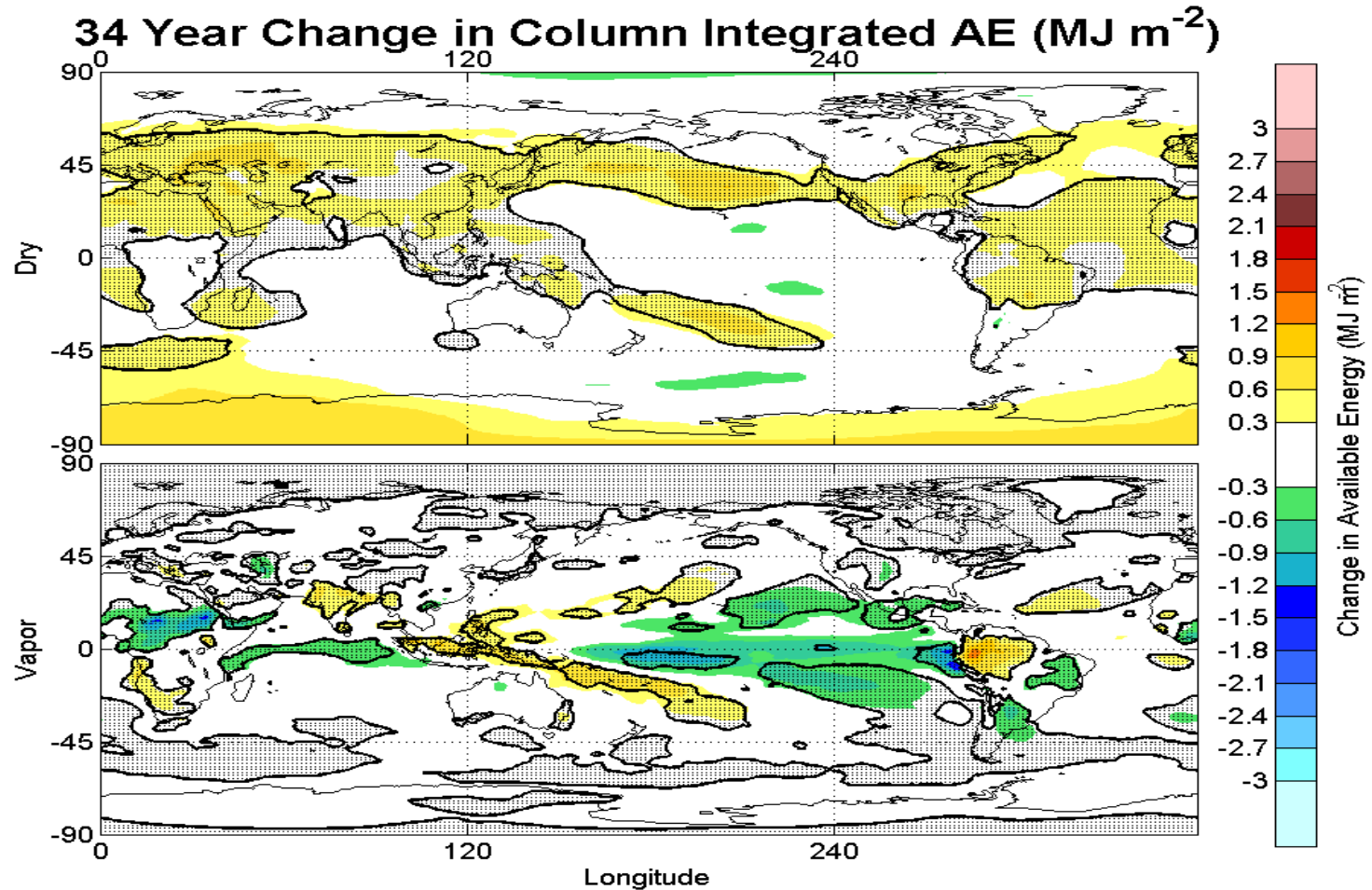
Conclusions

- Globally, AE is increasing in ERA-Interim Reanalysis data
 - AE of dry air is increasing
 - AE of water vapor is decreasing
 - AE is increasing in West Pacific, decreasing over Central Pacific
- consistent with strengthening of Walker circulation

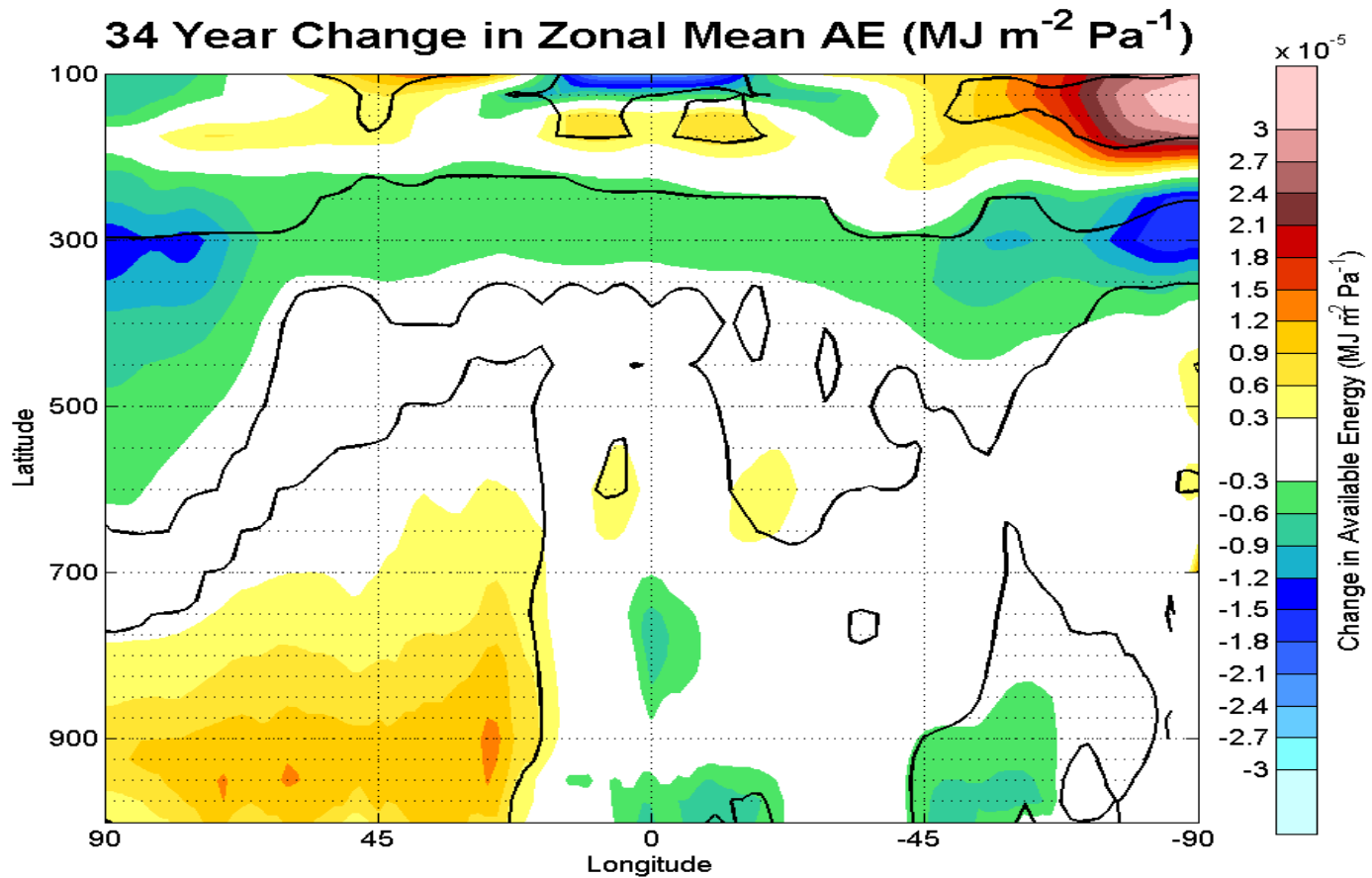
Column Integrated Mean



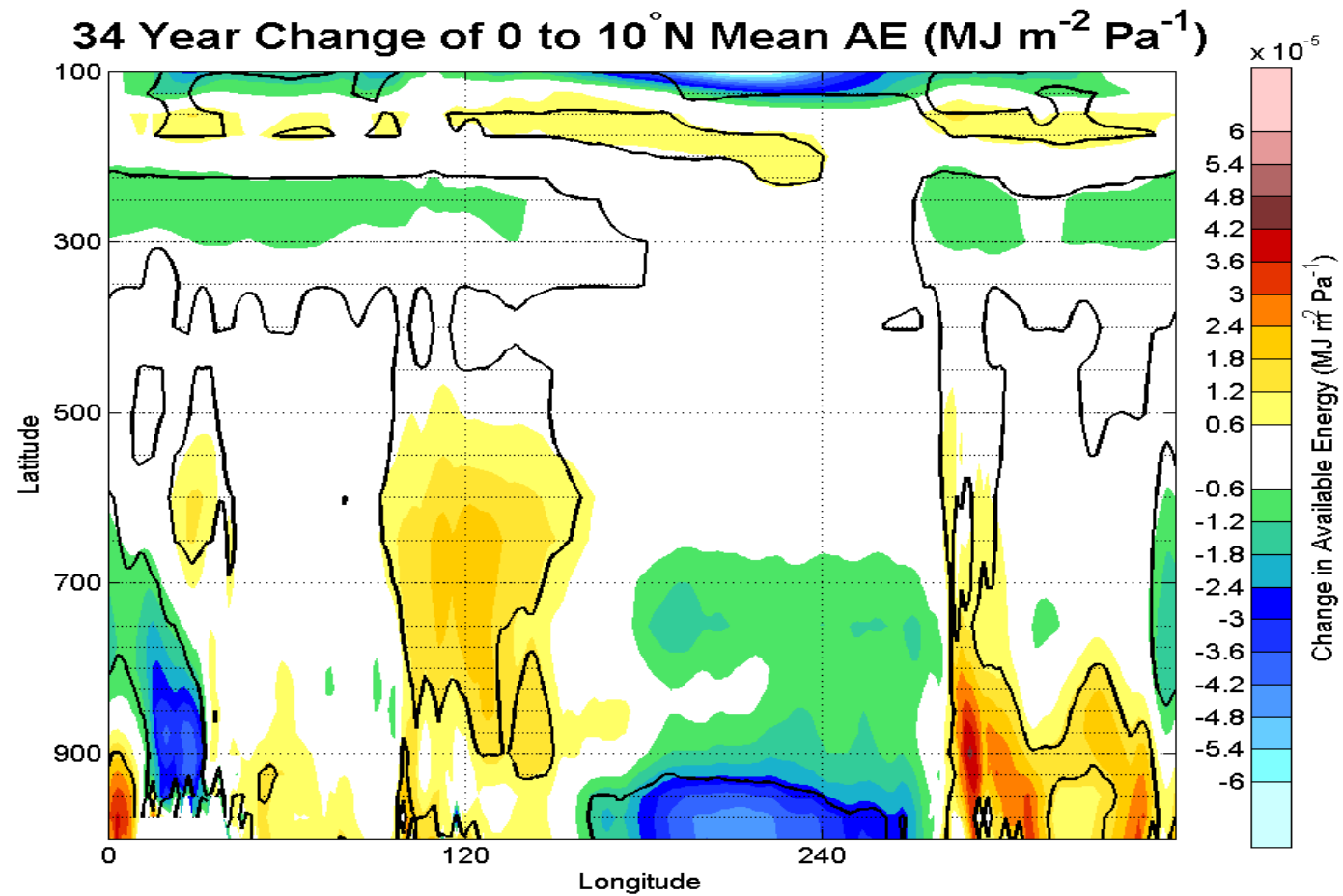
Column Integrated Trend



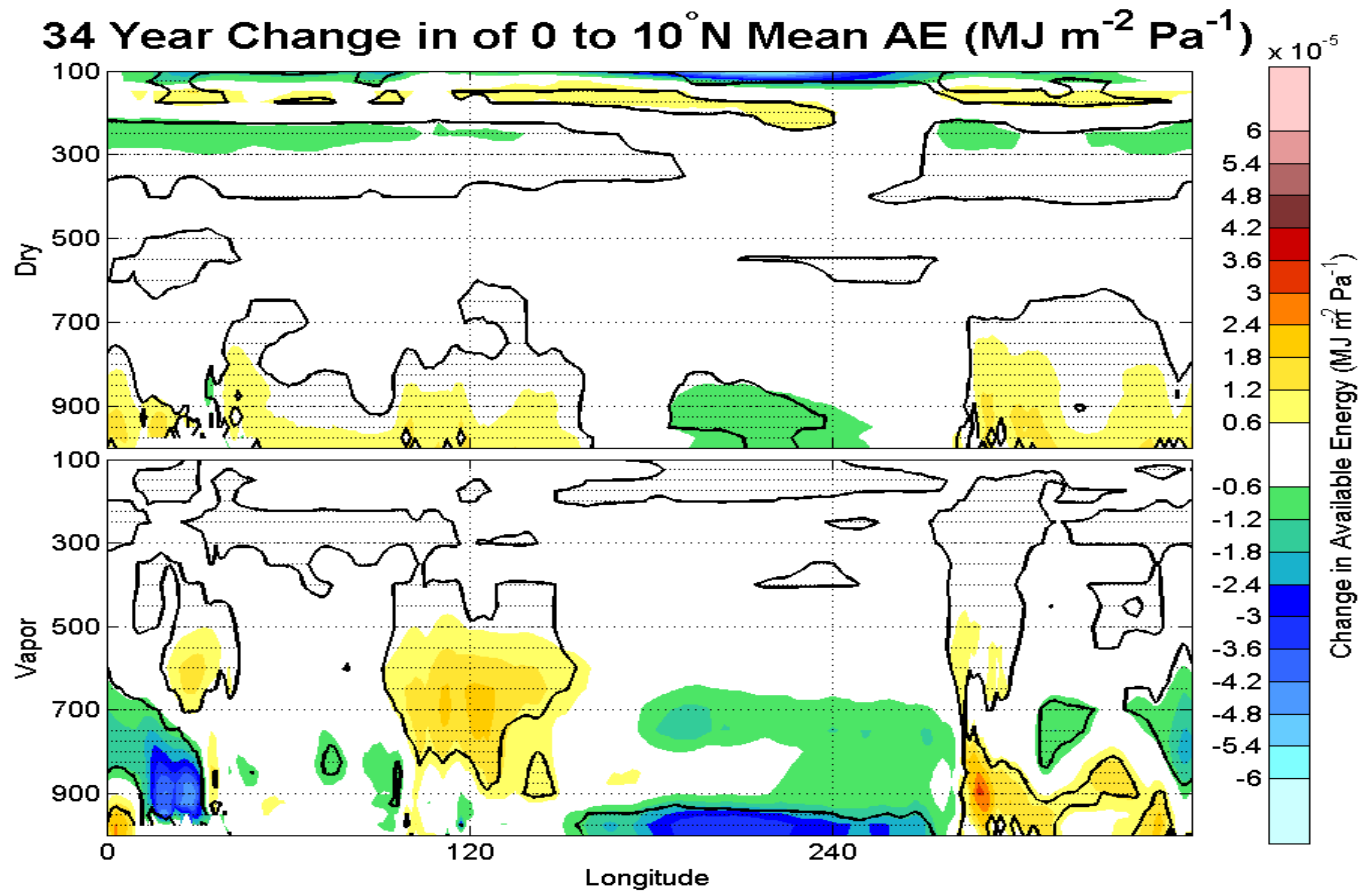
Zonal Mean Trend



Tropics Total Trend



Tropics Trend Components



Global Components

