

The energy density per unit volume of the atmosphere is the sum of **internal**, **potential**, and **kinetic** energies: $\rho(C_v T + gz + v^2/2)$.

Internal and potential energies are closely coupled. When air in a hydrostatic atmosphere is heated, it expands, doing work against the local pressure, and converting some of the heat into potential energy. Raising the temperature of a parcel by δT requires $C_v \delta T$ of internal energy and $R \delta T$ of work. The sum $(C_v + R) \delta T \equiv C_p \delta T$ is called the **enthalpy**.

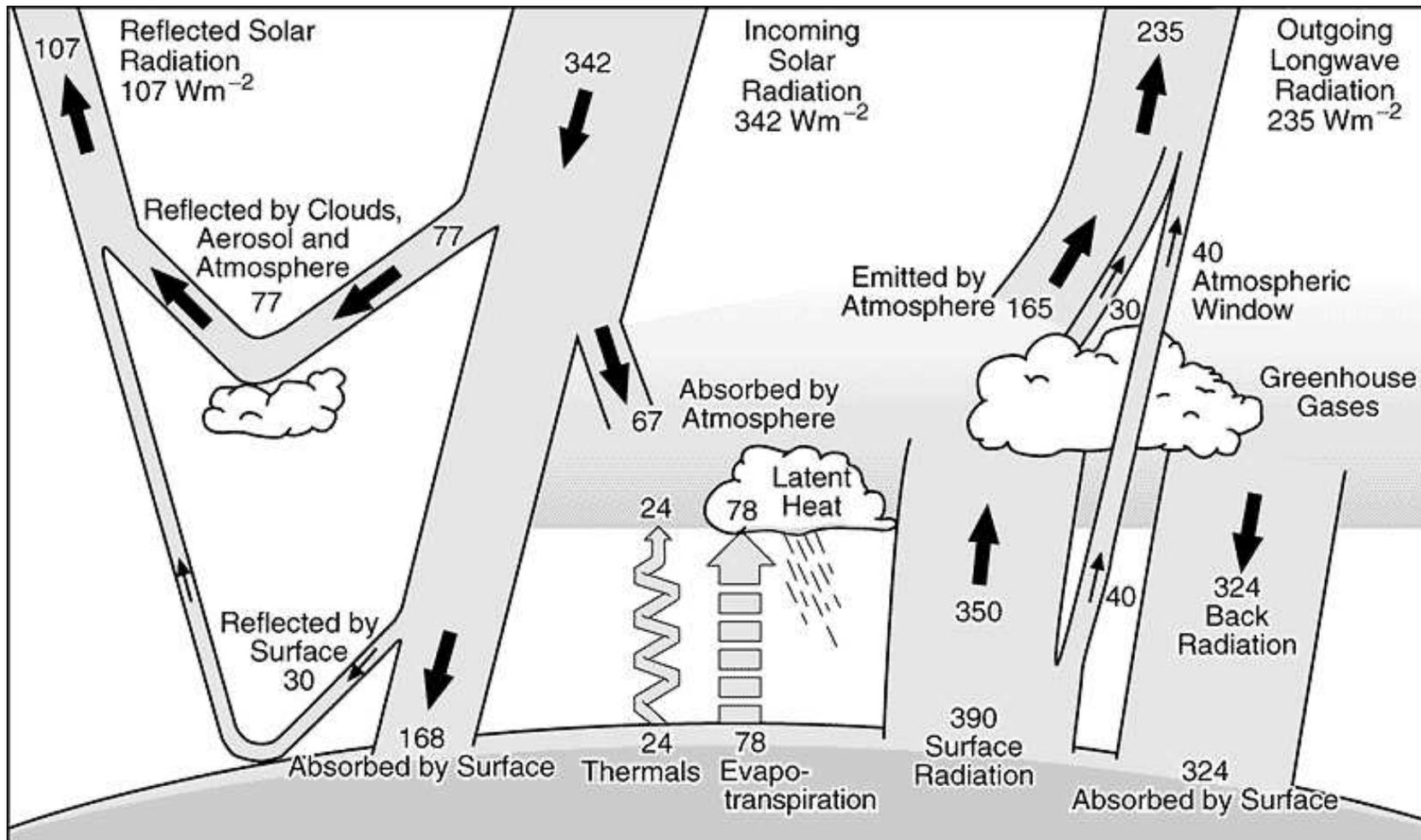
The quantity which is conserved by a parcel moving in a hydrostatic atmosphere is the **dry static energy**. It includes the enthalpy rather than the internal energy. The energy flux is the product of the dry static energy and the velocity vector: $\rho(C_p T + gz + \frac{1}{2}v^2)\vec{v}$.

The conservation law for atmospheric energy density says that the rate of change of energy in a volume plus the flux out of the volume equals the diabatic heating rate Q

$$\frac{\partial}{\partial t} \left\{ \rho \left(C_v T + gz + \frac{1}{2} v^2 \right) \right\} + \nabla \cdot \left\{ \rho \left(C_p T + gz + \frac{1}{2} v^2 \right) \vec{v} \right\} = \rho Q$$

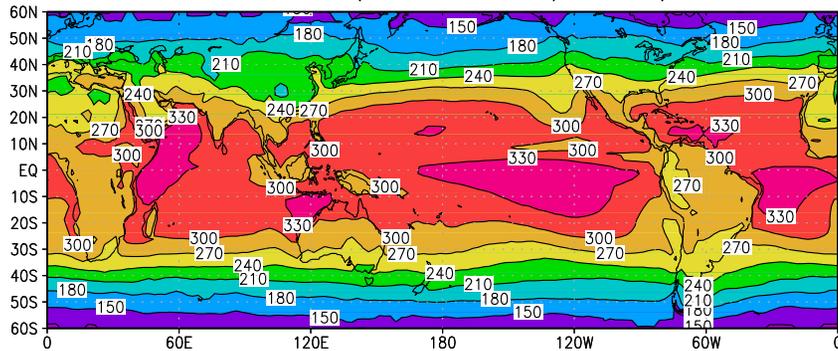
Energy budget of the Earth and conversion of heat in different forms.

The greenhouse effect of the atmosphere is due to its particular radiative properties: almost transparent for solar radiation, but almost opaque for the infrared terrestre radiation.

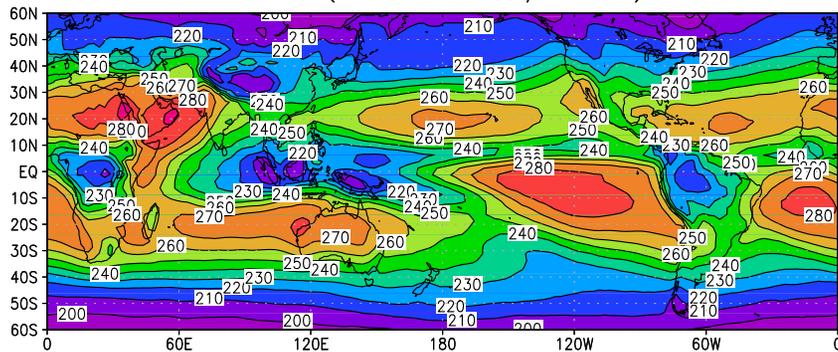


Radiative budget at the top of the atmosphere

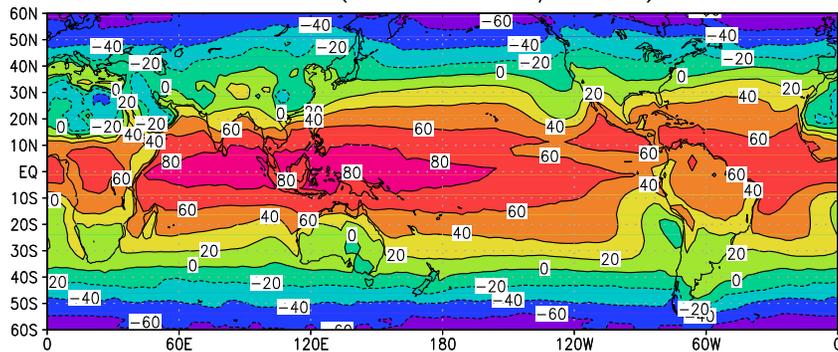
Solar radiation (ERBE 1985/1990) annual



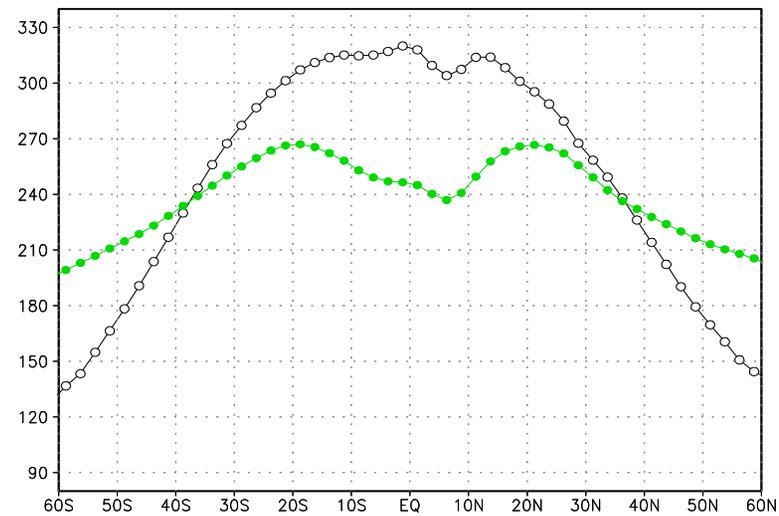
IR radiation (ERBE 1985/1990) annual



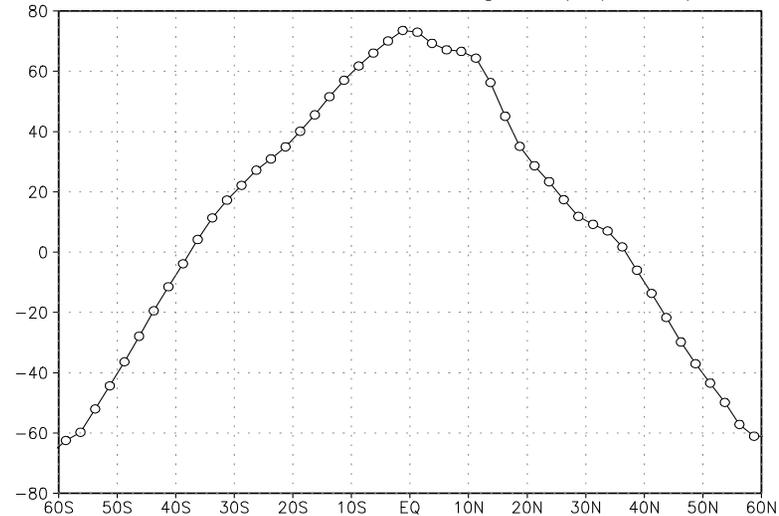
Net radiation (ERBE 1985/1990) annual



ERBE radiative budget (W/m²)

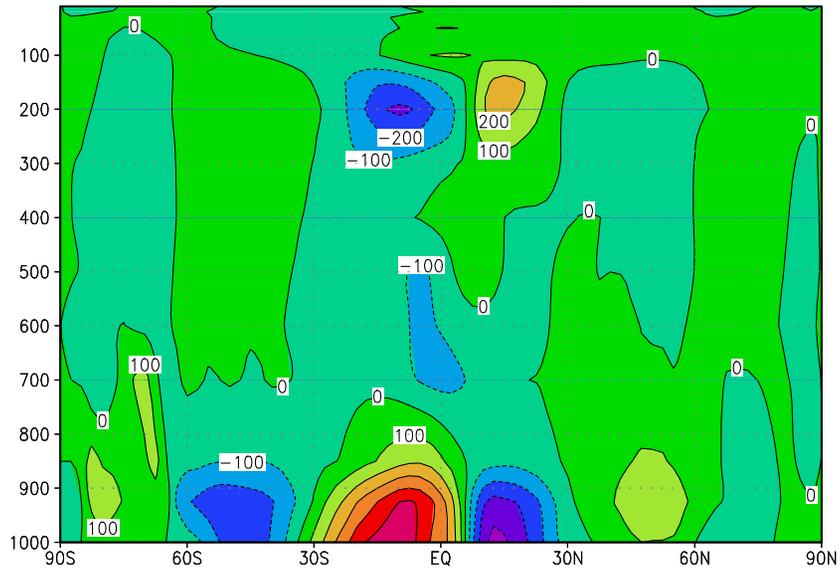


ERBE radiative budget (W/m²)

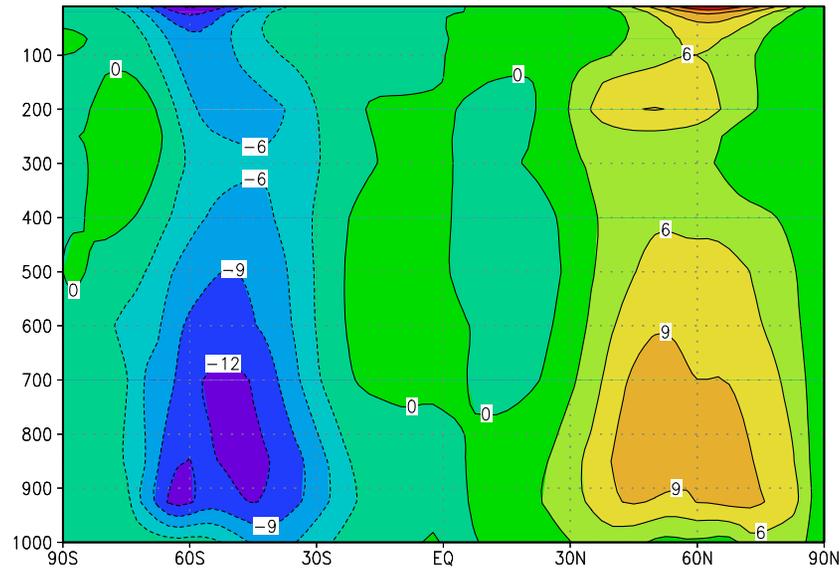


Zonally and annually averaged of vT

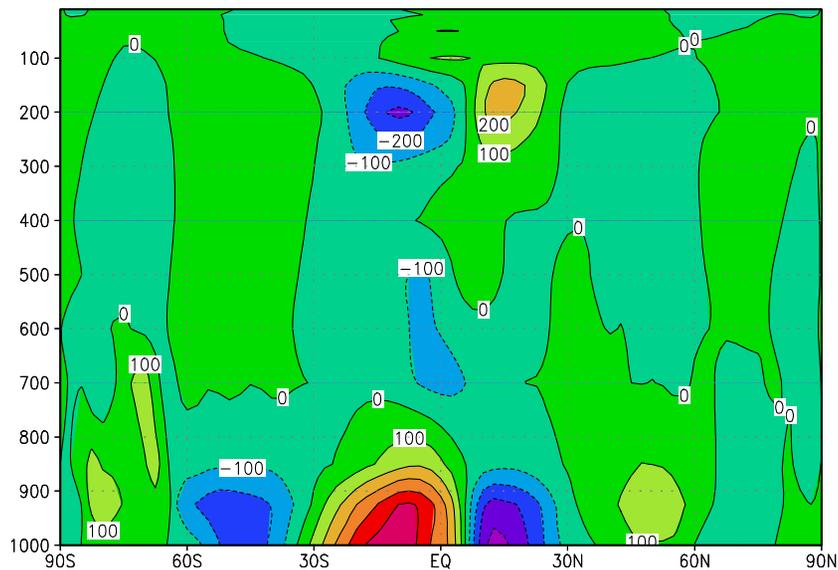
Northward VT transp. (total) (K m/s)



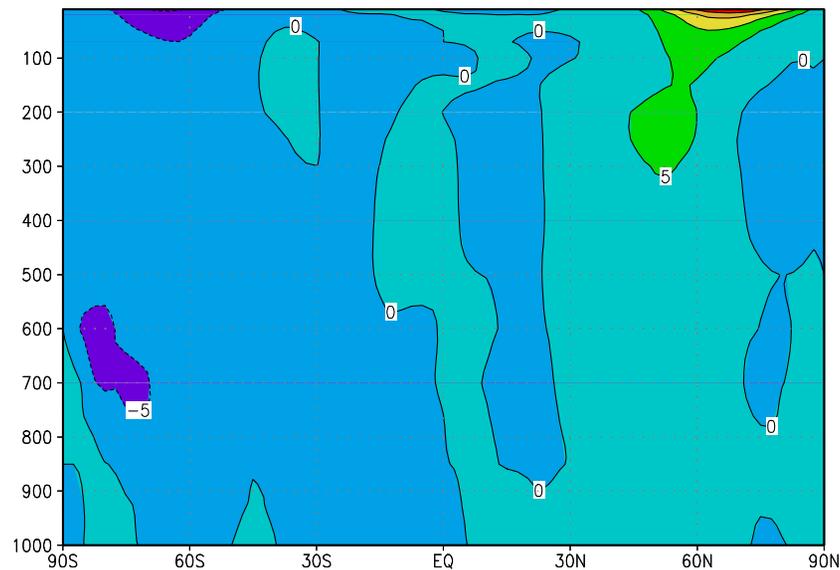
Northward VT transp. (trans) (K m/s)



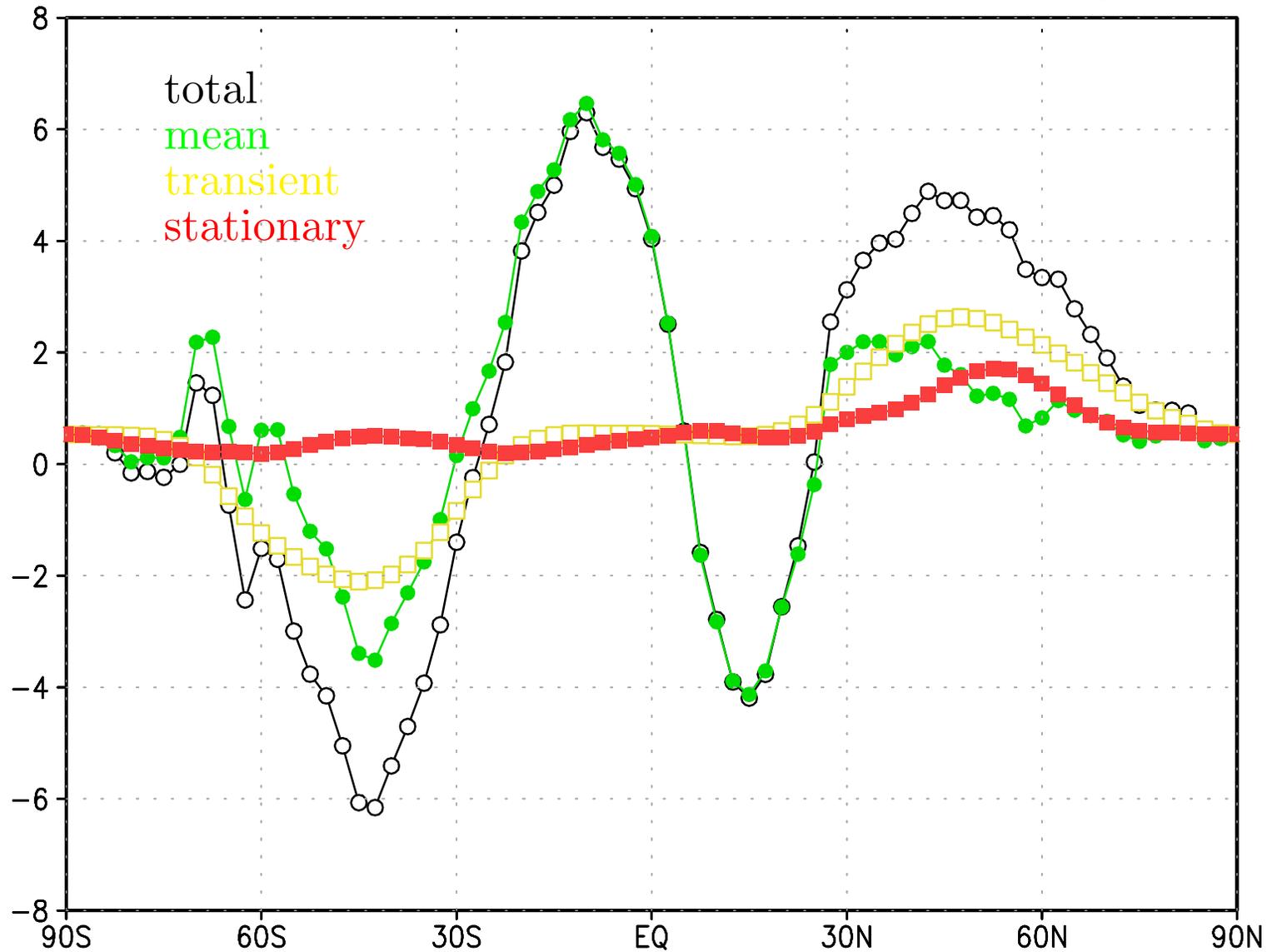
Northward VT transp. (mean) (K m/s)



Northward VT transp. (stati) (K m/s)

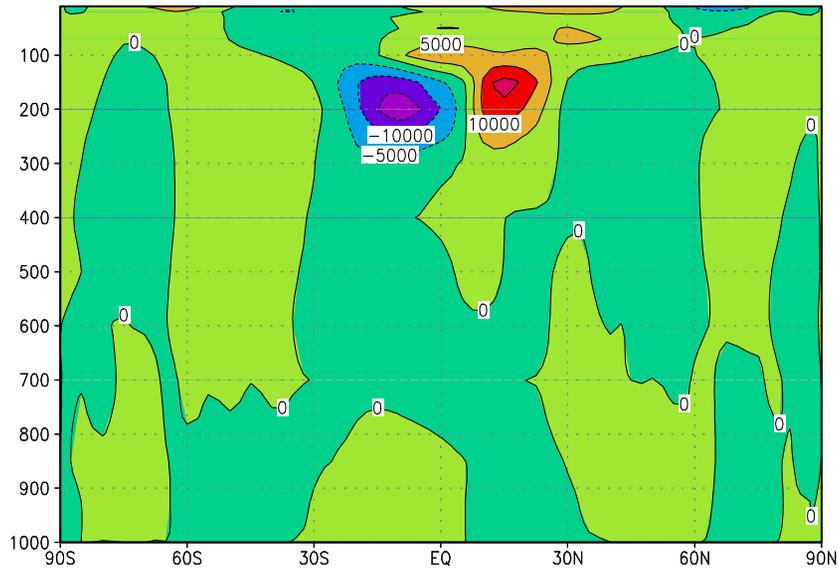


Vertical integration of vT , annual average
Northward transport vT (e12 Kkg/s)

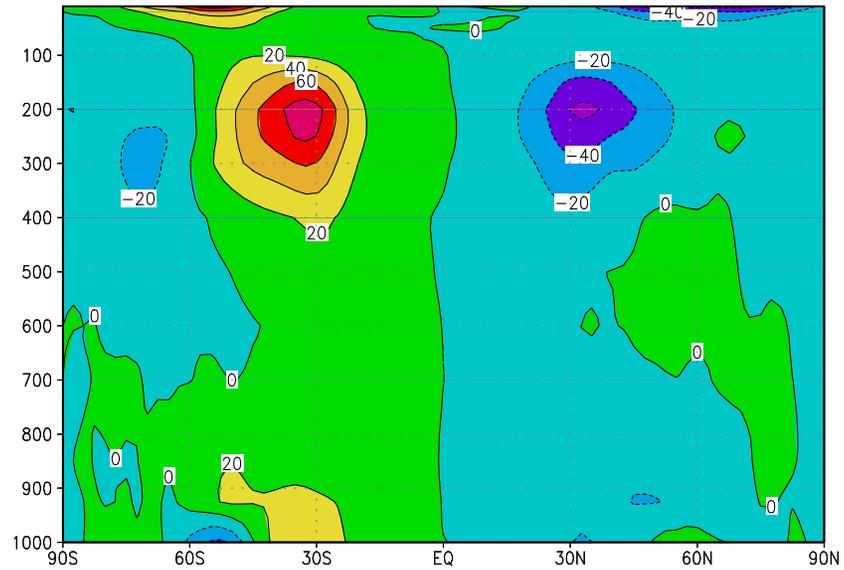


Zonally and annually averaged of vZ

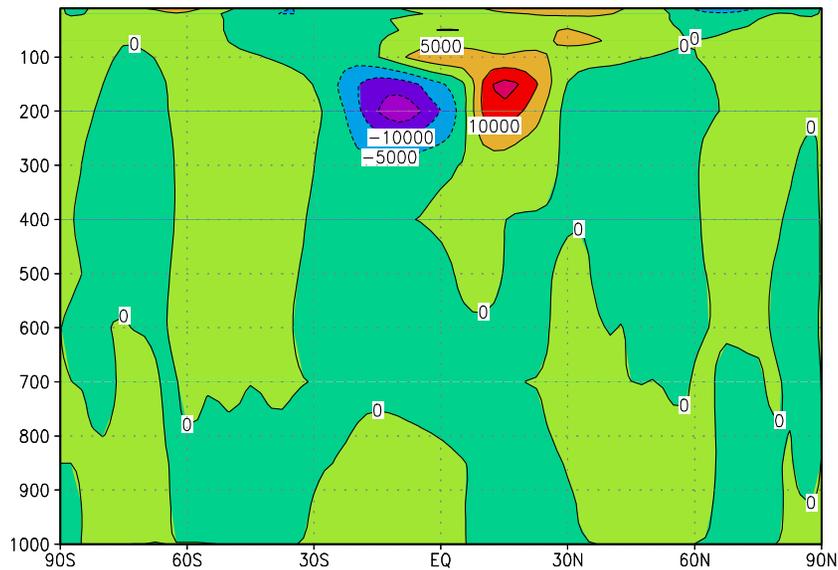
Northward VG transp. (total) (m m/s)



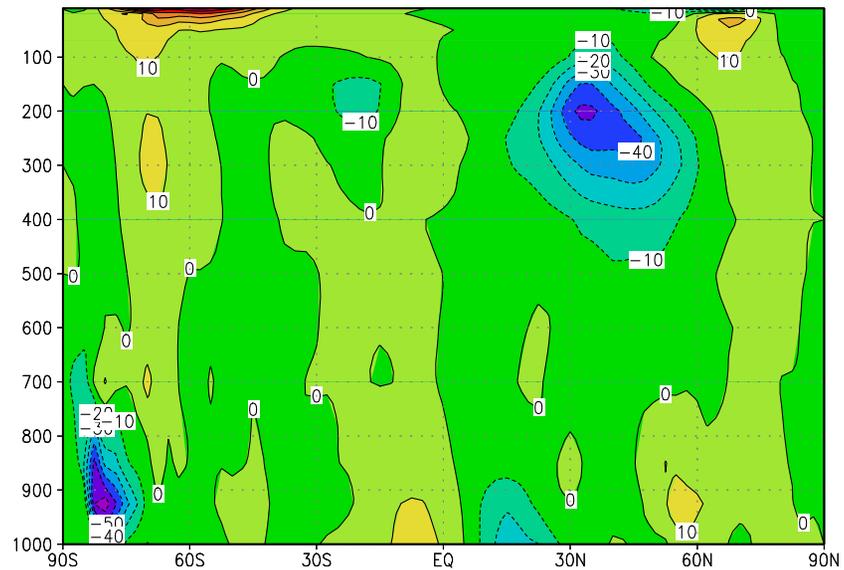
Northward VG transp. (trans) (m m/s)

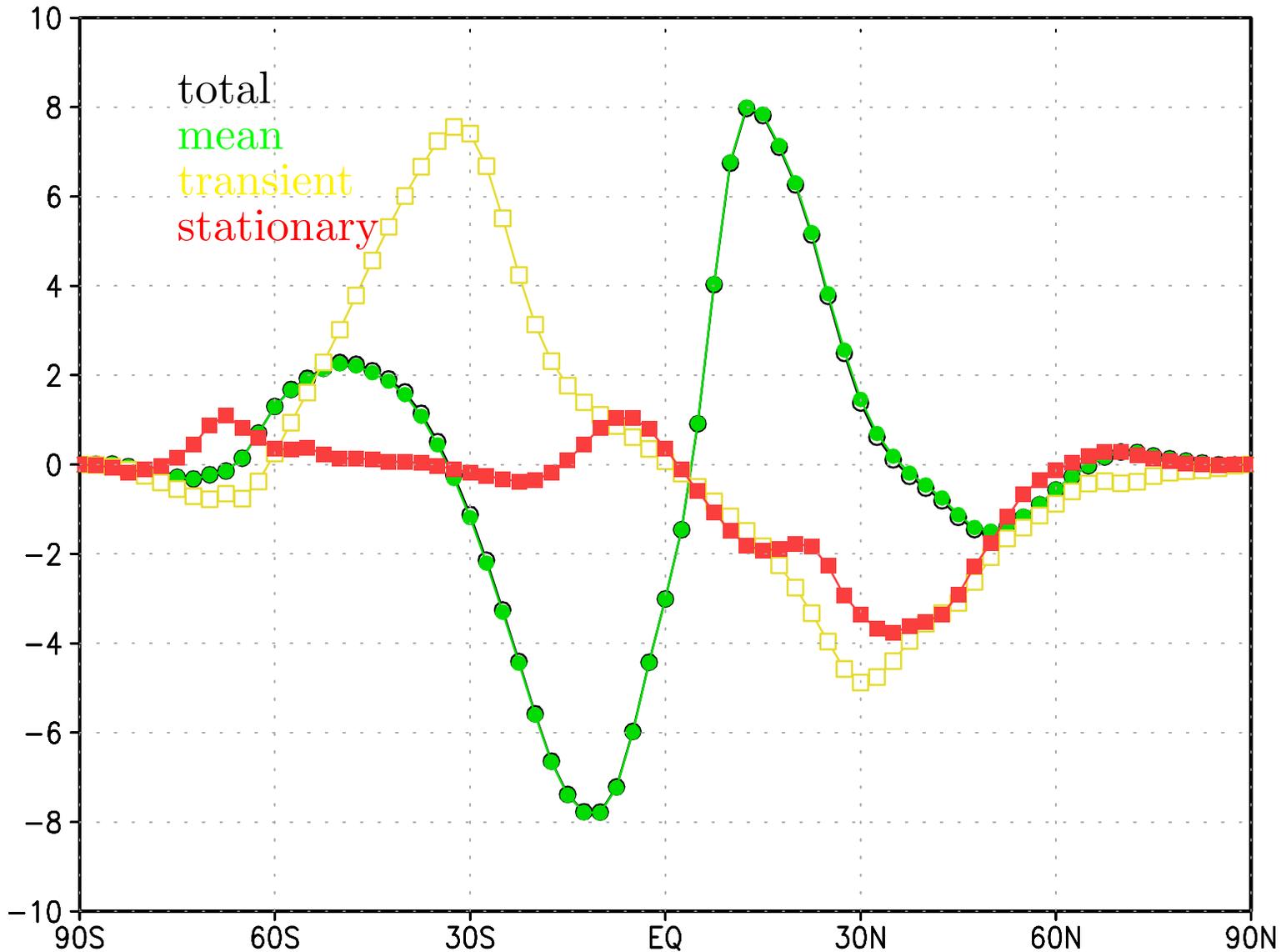


Northward VG transp. (mean) (m m/s)



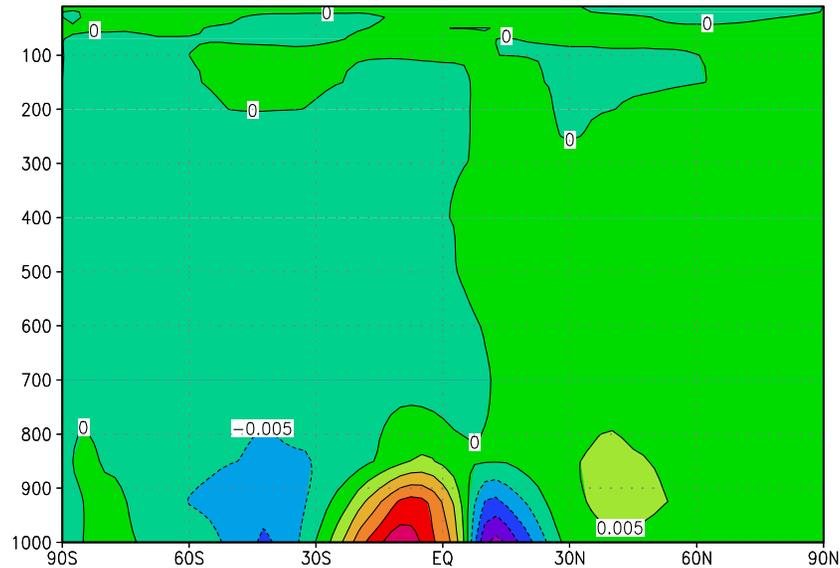
Northward VG transp. (stati) (m m/s)



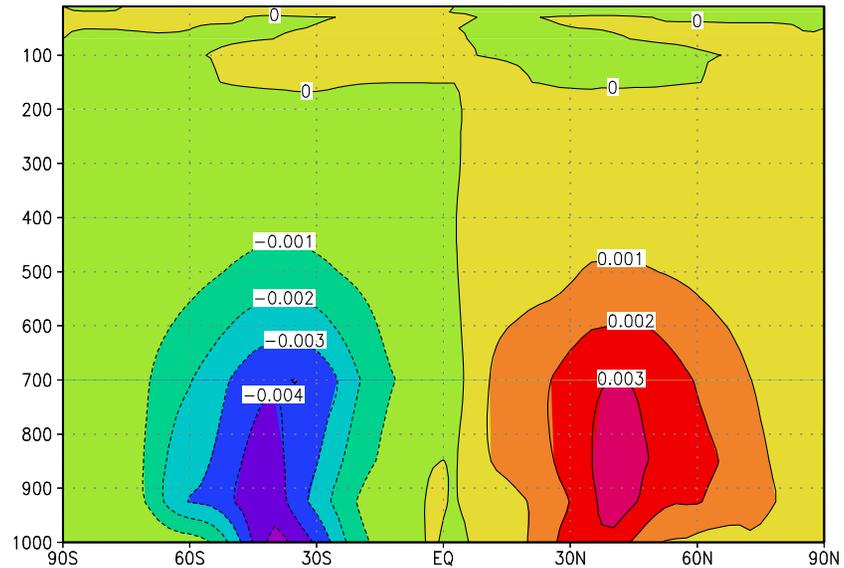
Vertical integration of vZ , annual averageNorthward transport vG ($e14/e12$ Kkg/s)

Zonally and annually averaged of vq

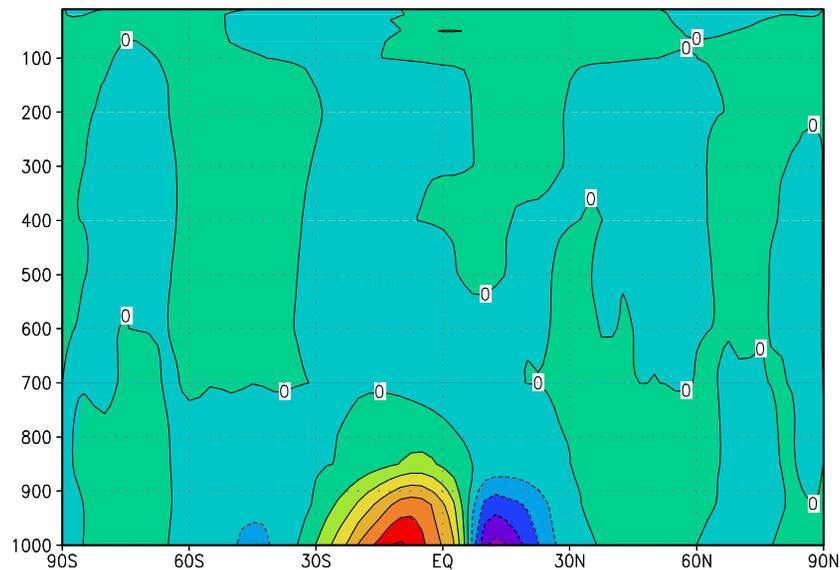
Northward VQ transp. (total) (kg/kg m/s)



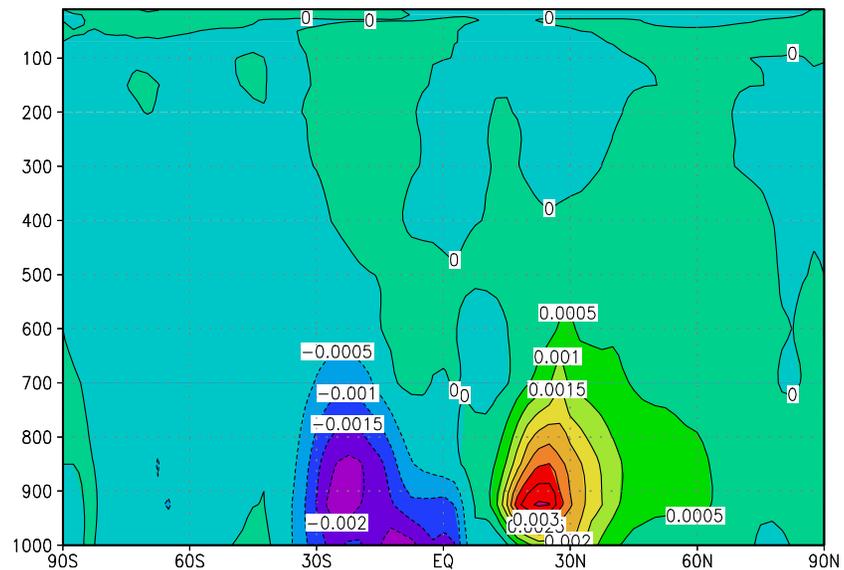
Northward VQ transp. (trans) (kg/kg m/s)



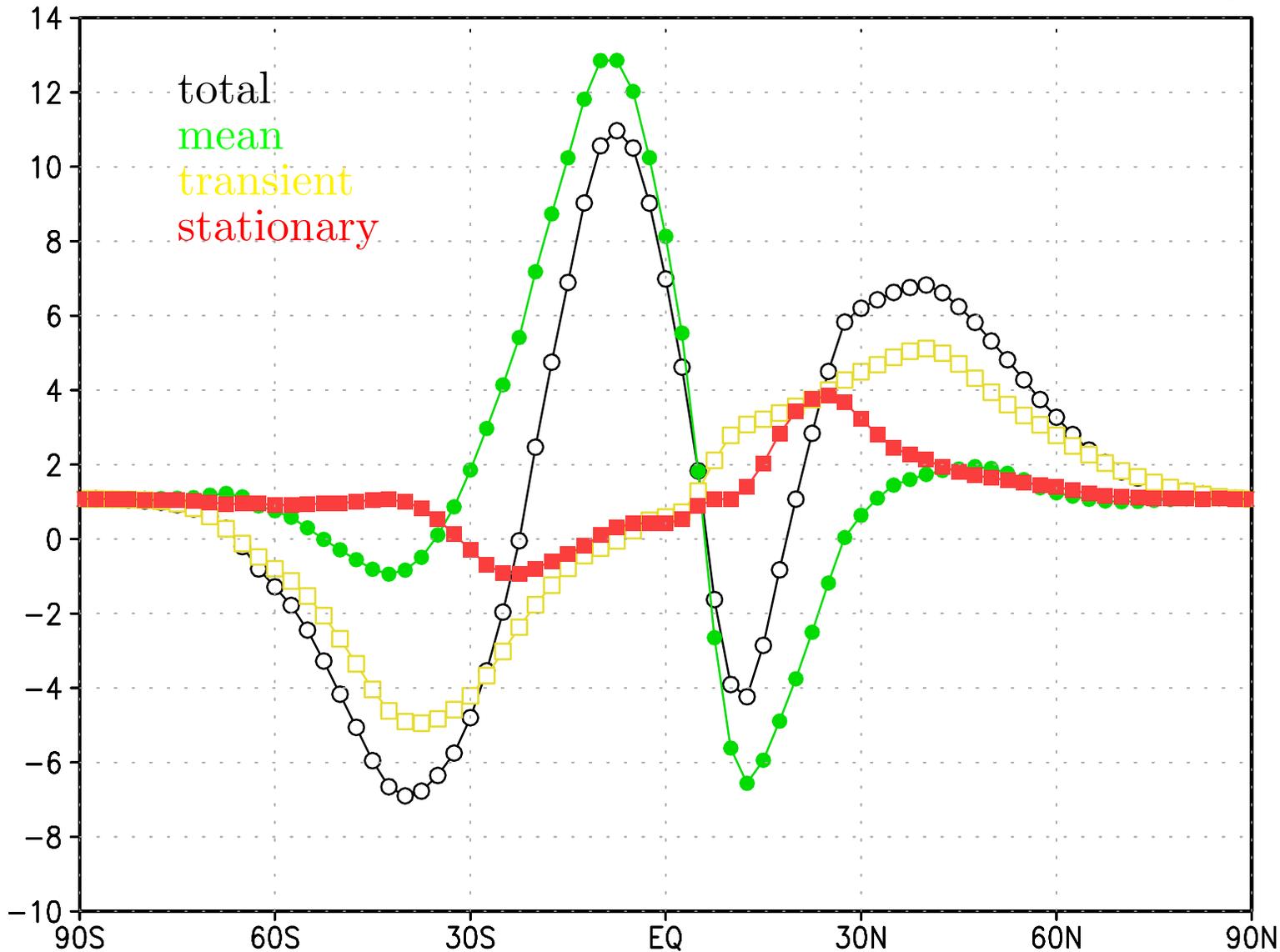
Northward VQ transp. (mean) (kg/kg m/s)



Northward VQ transp. (stati) (kg/kg m/s)

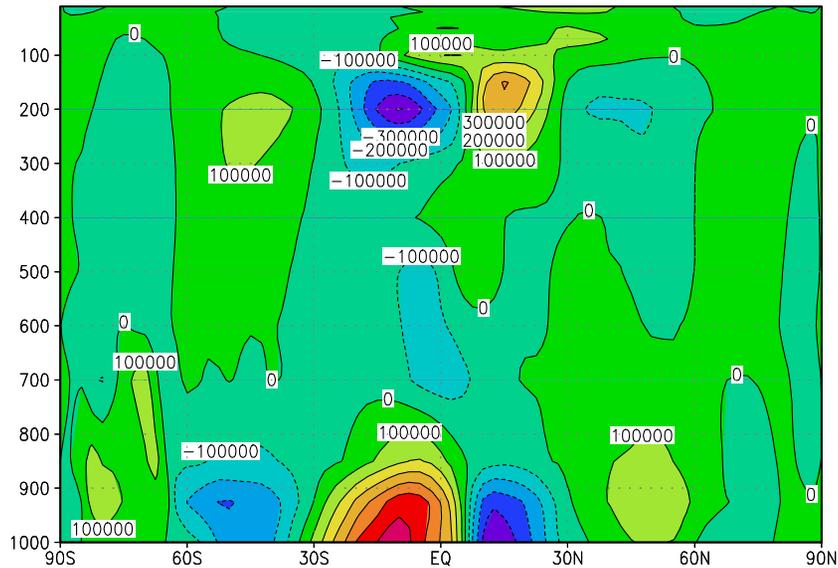


Vertical integration of vq , annual average
Northward water vapor transport (e8 kg/s)

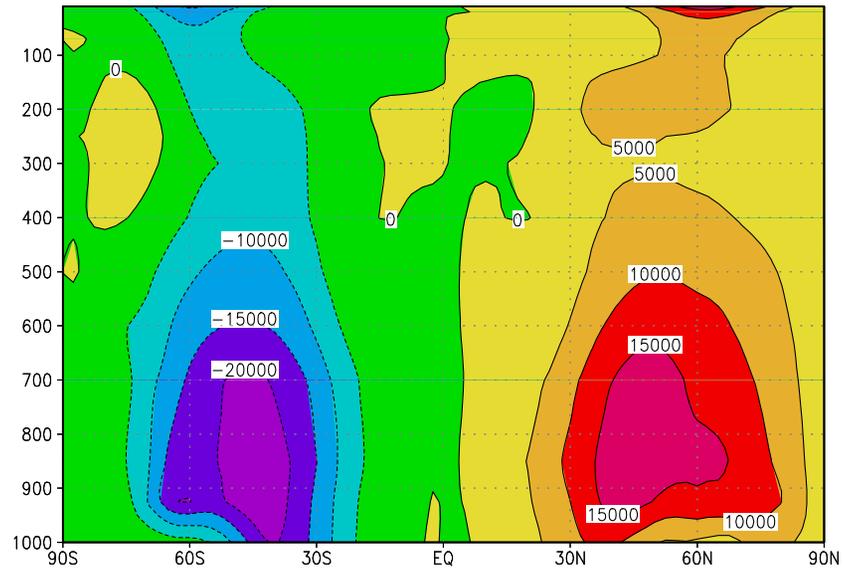


Zonally and annually averaged of vE

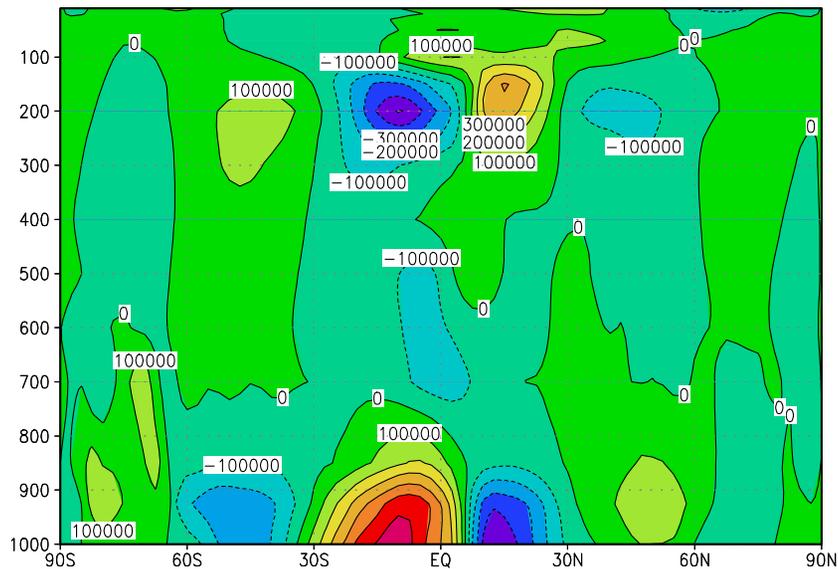
Northward VE transp. (total) (J/kg m/s)



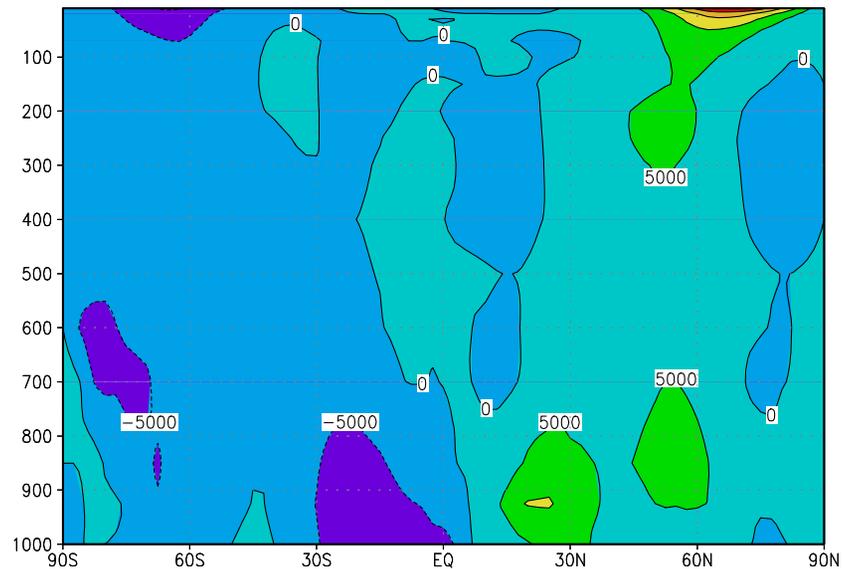
Northward VE transp. (trans) (J/kg m/s)



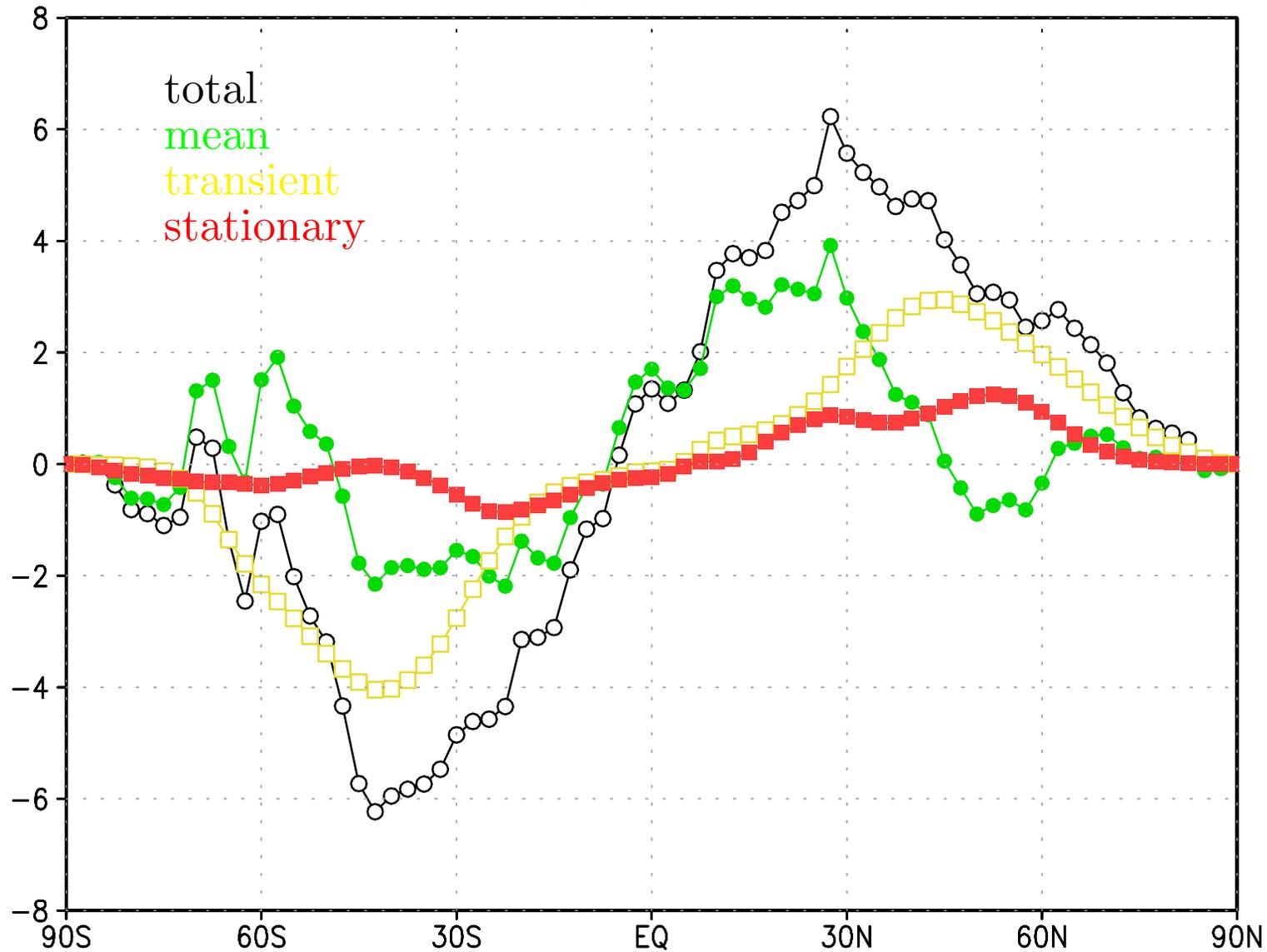
Northward VE transp. (mean) (J/kg m/s)

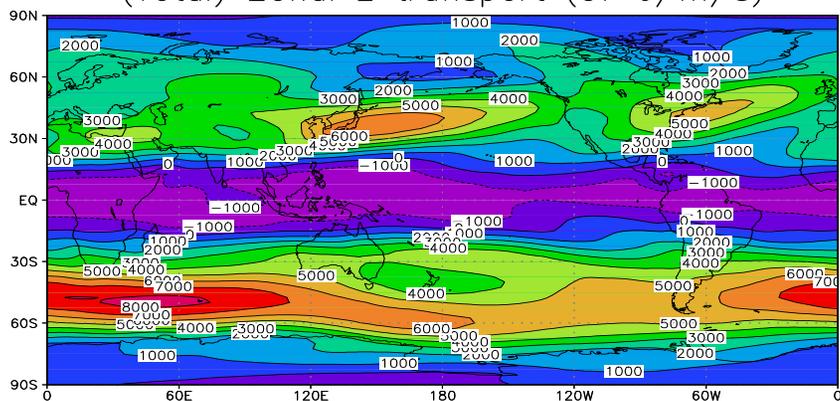
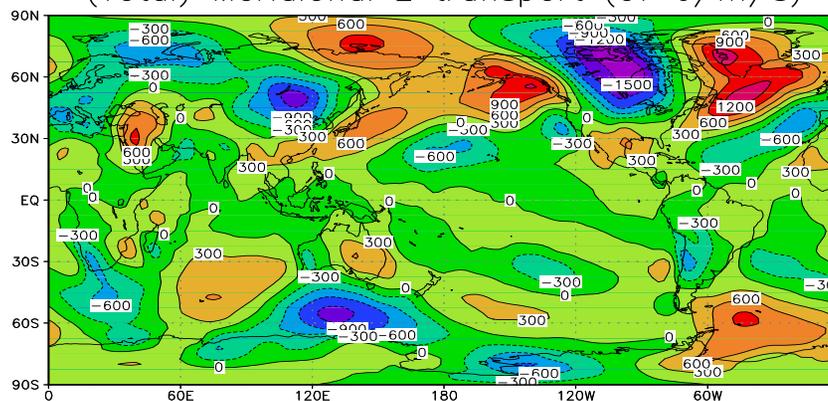
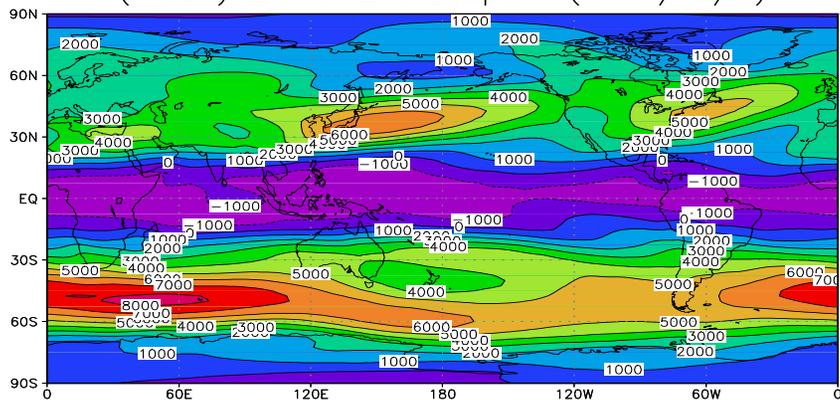
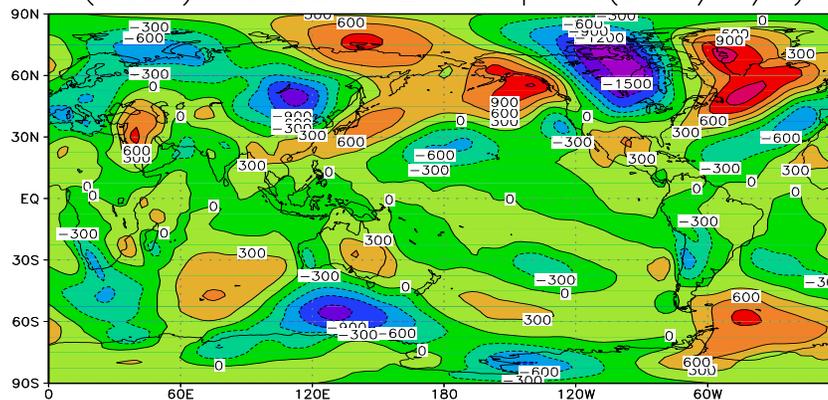
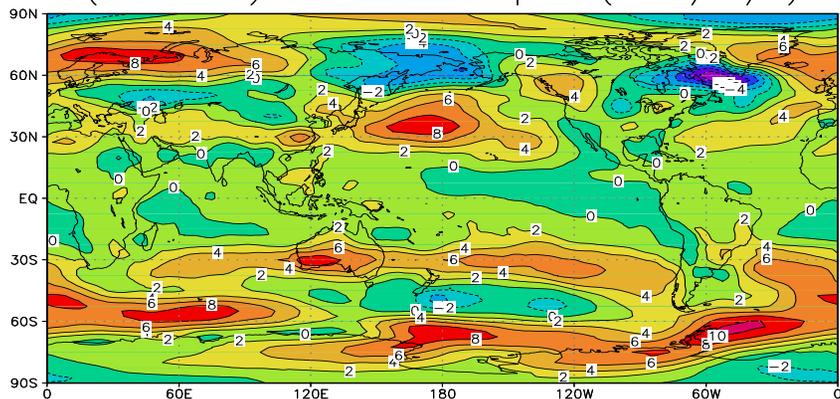
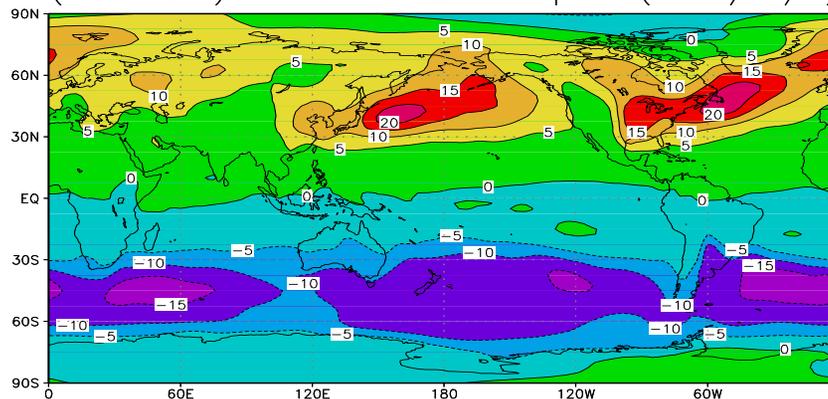


Northward VE transp. (stati) (J/kg m/s)



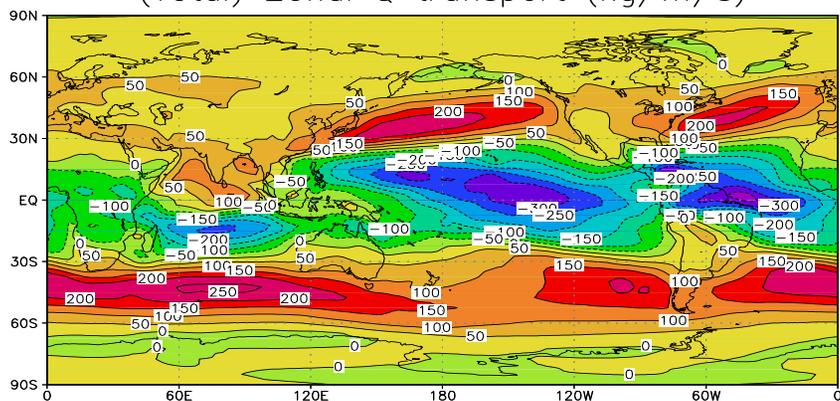
Vertical integration of vE , annual average
Northward energy transport (PetaW)



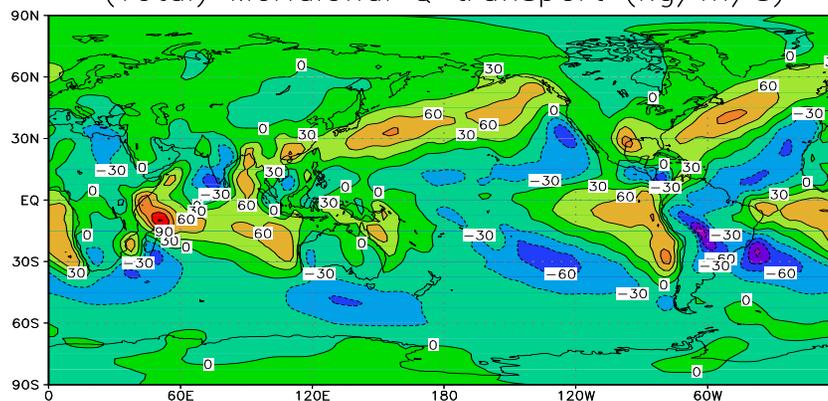
Vertical integration of E transport, annual average(Total) Zonal E transport ($e7$ J/m/s)(Total) Meridional E transport ($e7$ J/m/s)(Mean) Zonal E transport ($e7$ J/m/s)(Mean) Meridional E transport ($e7$ J/m/s)(Transient) Zonal E transport ($e7$ J/m/s)(Transient) Meridional E transport ($e7$ J/m/s)

Vertical integration of q transport, annual average

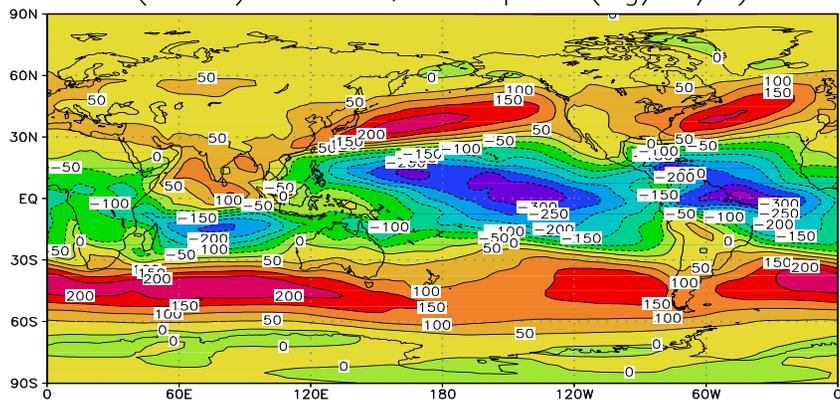
(Total) Zonal Q transport (kg/m/s)



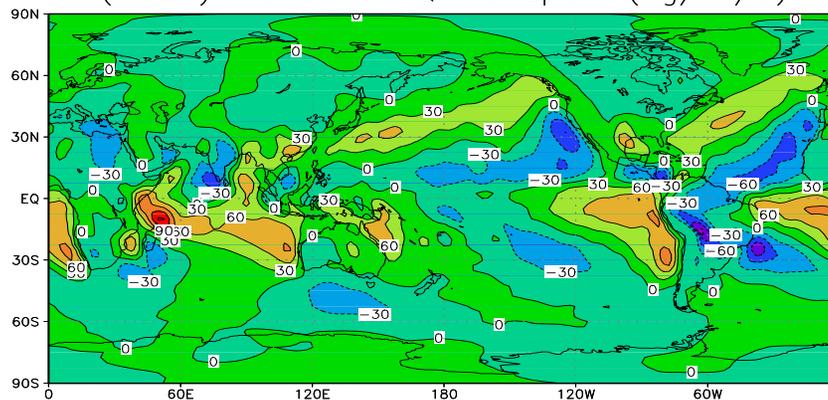
(Total) Meridional Q transport (kg/m/s)



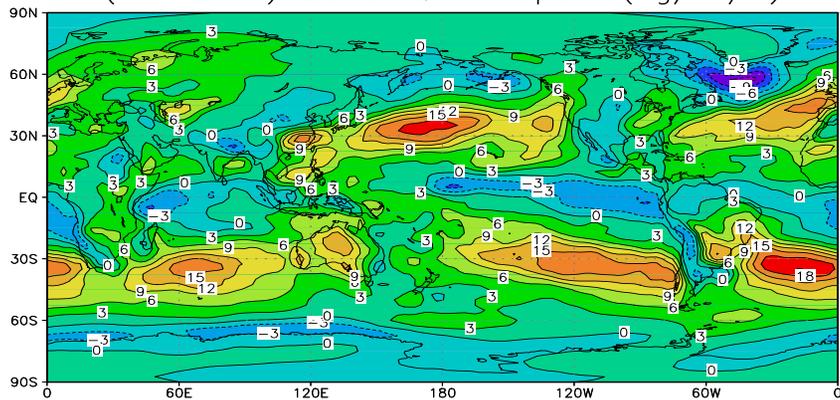
(Mean) Zonal Q transport (kg/m/s)



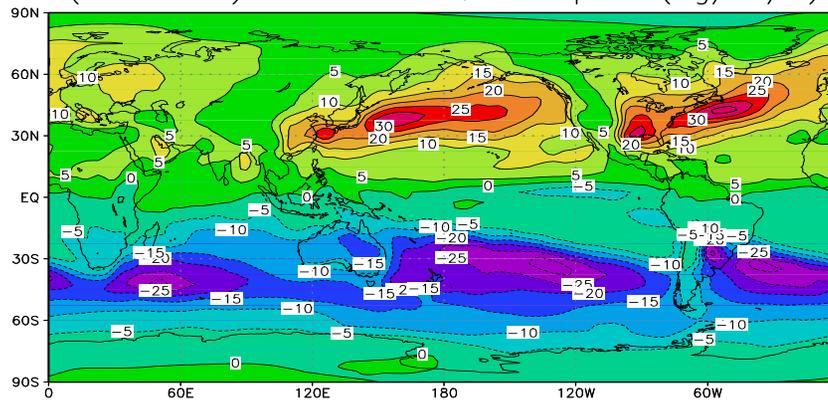
(Mean) Meridional Q transport (kg/m/s)

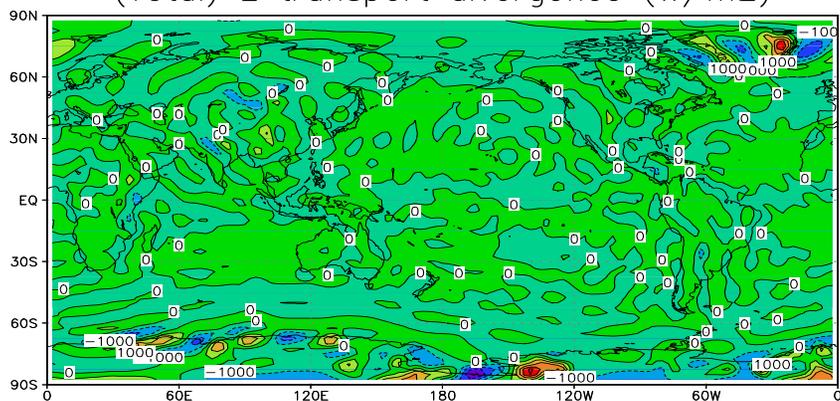
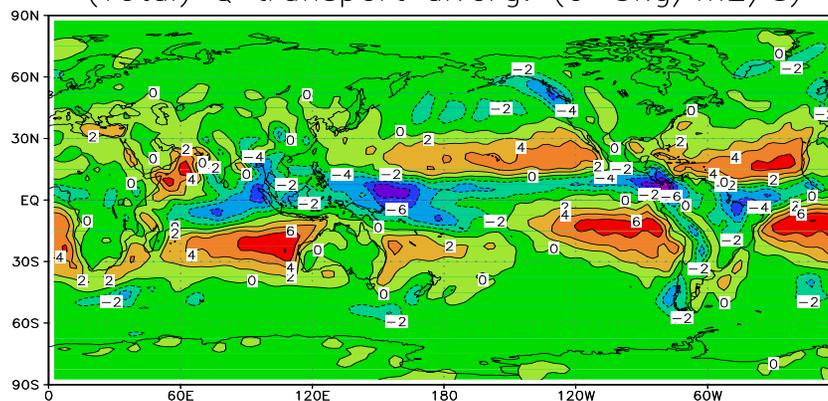
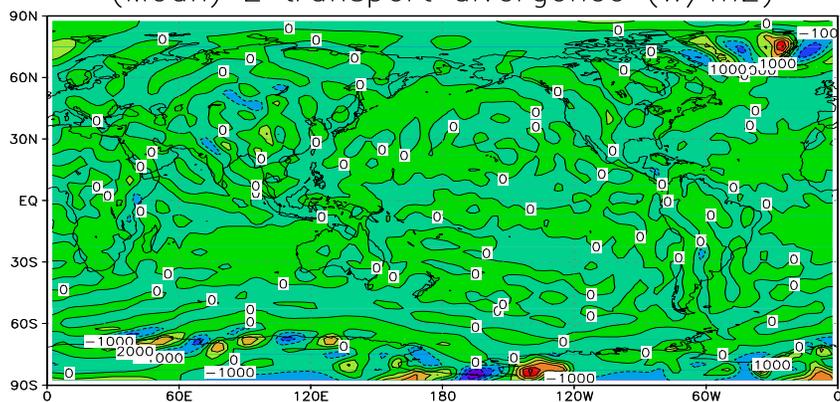
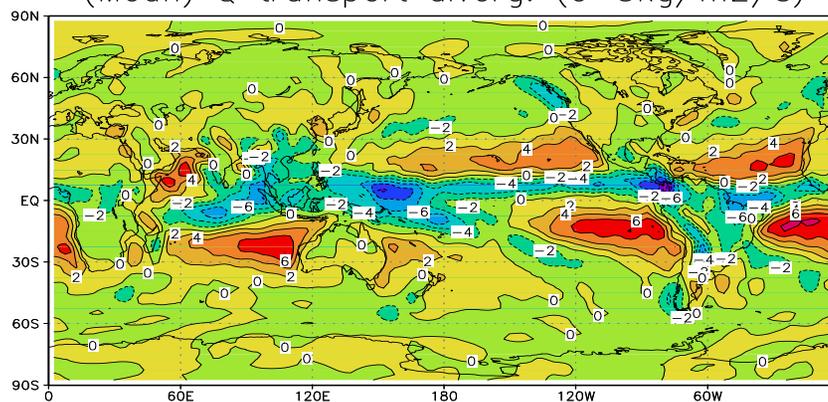
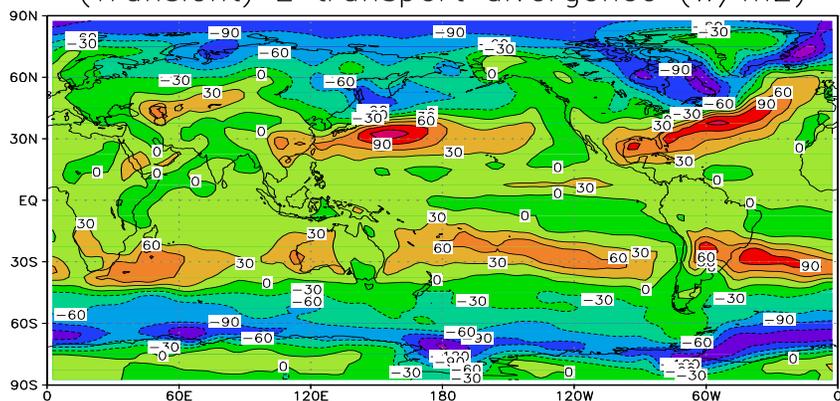


(Transient) Zonal Q transport (kg/m/s)



(Transient) Meridional Q transport (kg/m/s)



Divergence of E transport and q transport, annual average(Total) E transport divergence (W/m^2)(Total) Q transport diverg. ($e-5kg/m^2/s$)(Mean) E transport divergence (W/m^2)(Mean) Q transport diverg. ($e-5kg/m^2/s$)(Transient) E transport divergence (W/m^2)(Transient) Q transport diverg. ($e-5kg/m^2/s$)