Ekman Transport and Depth-integrated Ocean Meridional Transport
Preliminary Results

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- Heat Transport
- Water Transport
- Long Term Variability
Ekman water transport

$$EWT(\theta) = \int_{x_1}^{x_2} -\frac{\tau_x}{\rho f} \, dx$$

$\tau_x$: Zonal stress

$T_e$: Potential temp. of Ekman layer

$\overline{T}$: Mean potential temp. of the water column

Ekman heat transport

$$EHT(\theta) = -c_p \int_{x_1}^{x_2} \frac{\tau_x}{f} (T_e - \overline{T}) \, dx$$

Sato, Polito, & Liu, 2002: GRL, 29(17)

Sprintall & Liu, 2005: Oceanography, 18(4)
Intensification of poleward Ekman heat transport since 1998 in the tropics
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Ekman heat transport in the subtropical Atlantic is correlated with NAO
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Ekman heat transport anomaly 5N-12N
SSM/I QuikSCAT

SSM/I EHT anomaly (PW) 5N-12N Pacific
-Nino 3 index

SSM/I EHT anomaly (PW) 12S-5S
QuikSCAT
-Nino 3 index

5S-12S
Impact of ENSO on Ekman water transport in the equatorial Pacific
Meridional Heat Transport (MHT)

Conservation of heat

\[
\frac{\partial H}{\partial t} + \nabla \cdot \zeta = SW - LW - LH - SH
\]

By Green’s theorem

\[
MHT(\theta) = \int_{\theta}^{\theta_0} \int_{x_1}^{x_2} \left( \frac{\partial H}{\partial t} - SW + LW + LH + SH \right) dx dy
\]

H: Heat content
\zeta: Horizontal heat flux
SW: Short wave radiation
LW: Long wave radiation
LH: Latent heat
SH: Sensible heat
Meridional Water Transport (MWT)

Conservation of water mass

\[ \frac{\partial M}{\partial t} + \nabla \cdot \psi = P - E \]

By Green’s theorem

\[ \text{MWT}(\theta) = \int_{\theta}^{\theta_0} \int_{x_1}^{x_2} \left( \frac{\partial M}{\partial t} + E - P - R \right) dx dy \]

P: Precipitation
E: Evaporation
\( \psi \): Horizontal mass flux
R: River discharge
Atlantic total northward water transport

Peak poleward transport in winter in the tropics
Summary

- Spacebased data provide almost continuous spatial and temporal coverages for Ekman and total meridional transport for a decade.
- Reality checks are needed.
- What is the relation between surface Ekman transport in the total meridional transport need physical interpolation.
REPORT OF THE JSC/CCEO

'CAGE' EXPERIMENT: A FEASIBILITY STUDY

WCP - 22
MAY 1982
backup
Intensification of poleward Ekman water transport from 1998 in the tropical Pacific.
Intensification of poleward Ekman heat transport from 1998 in the tropical Pacific
Red - divergence of water vapor transport integrated over depth of the atmosphere
Black - sum of climatological river discharge across all coastline
Green - loss rate of water stored in all oceans from GRACE
---- difference between fresh water flux and river input

Green - subtracting climatological steric change from altimeter
HYDROLOGIC BALANCE

$$\frac{\partial W}{\partial t} + \nabla \cdot \Theta = E - P$$

$$\Theta = \frac{1}{g} \int_{0}^{p_0} q Ud\rho$$

$$W = \frac{1}{g} \int_{0}^{p_0} q d\rho$$

$$\Theta = U_e W$$

$U_e = f(U_s)$  Liu (1993)-polynomial
Liu & Tang (2005) - Neural Network

$U_e = U_{850mb}$  Heta & Mitsuta (1993)
Both $U_s$ & $U_{850mb}$  Xie et al. (2007) - SVR
Subtropical South Pacific

CC = 0.856

15–100 days

E–P

CC = 0.913

10–14 months

180–160W, 20S–10S