Evaporation and Water Transport Dynamics over the Oceans Derived from Satellites

Frank Wentz and Kyle Kilburn
Remote Sensing Systems, Santa Rosa, CA, USA

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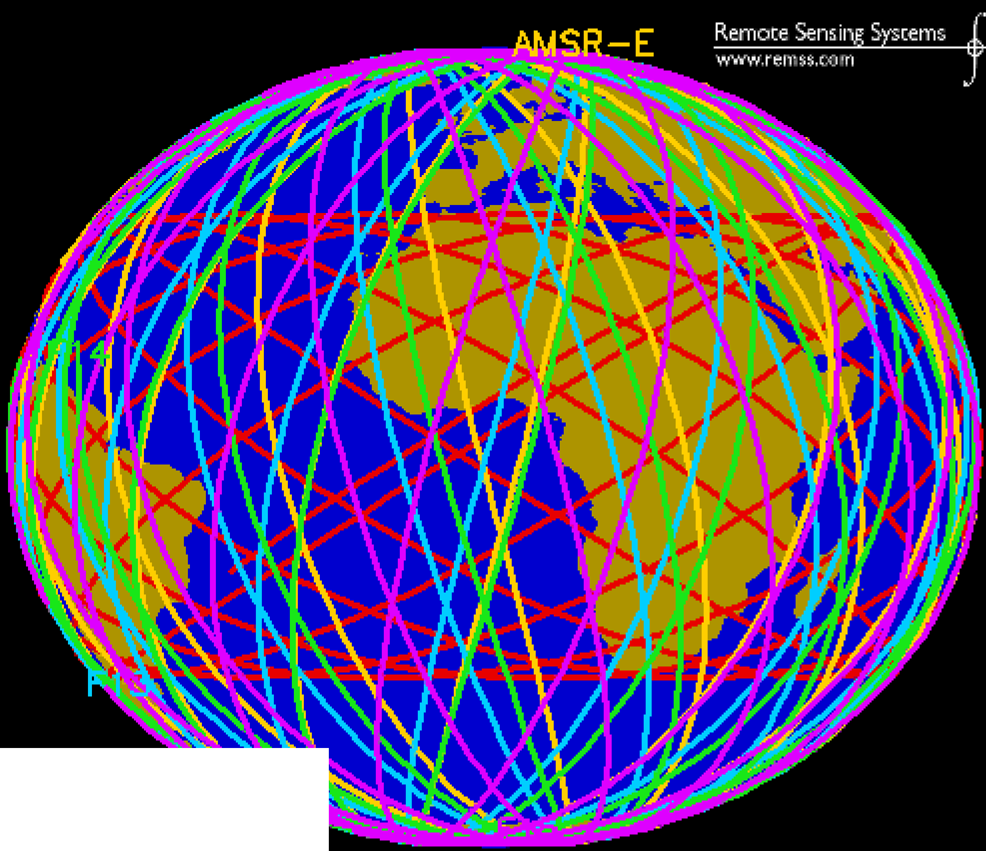
Earth Observation with a Constellation of Radiometers

SSM/I: F13, F14, F15 ; TMI ; AMSR-E



No wind direction
No winds in storms
Long-term Calibration Challenging

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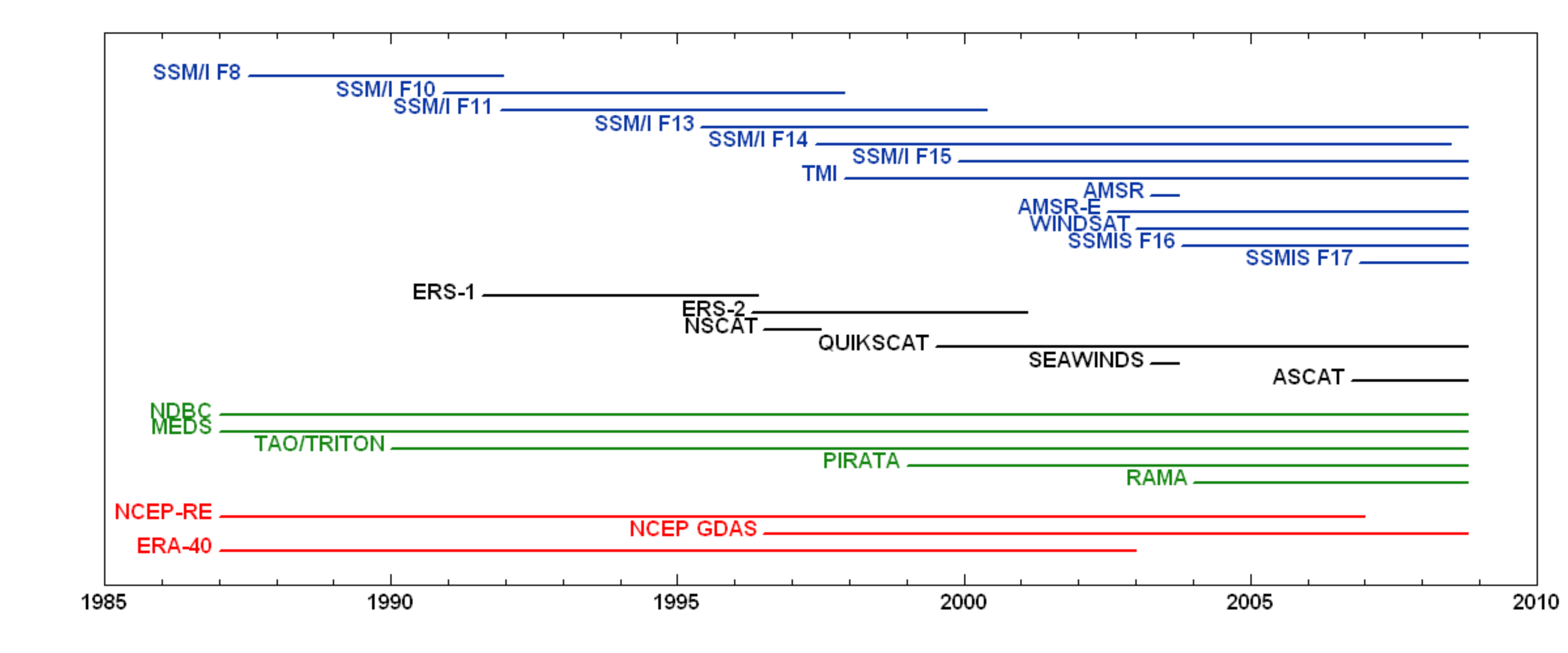
Cross-Calibrated, Multi-Platform (CCMP) Winds

Vector Wind Fields from 1987 to Present

- RSS does intersatellite calibration and wind retrievals (approaching 100 satellite years)
- Atlas & Ardizzone assimilate RSS wind products into numerical model and generate 6-hour wind vector maps for 1987 to present.
- Satellite winds receive a very heavy weight



DFS Can be Assimilated in a Similar Way rather than Viewing as Standalone

- Need Global fields (diurnal effects)
- One Component of a Larger Satellite Network (pros and con).
- This analysis is in part an evaluation of the CCMP Winds

Required Parameters for Vapor Transport

- Surface wind vector **W** (CCMP Atlas/Wentz)
- Water Vapor **V** (Satellite)
- Precipitation **P** (Satellite + rain gauges over land)
- Evaporation **E** (satellite winds and SST, COADS RH, Hadley Center Tair)
- Water Vapor Transport **Q** (a vector)
- Water Vapor Transport Divergence (**div Q**)

The Constraint

- Averaging over time (~month) at a particular location we have (balance equation for water vapor):

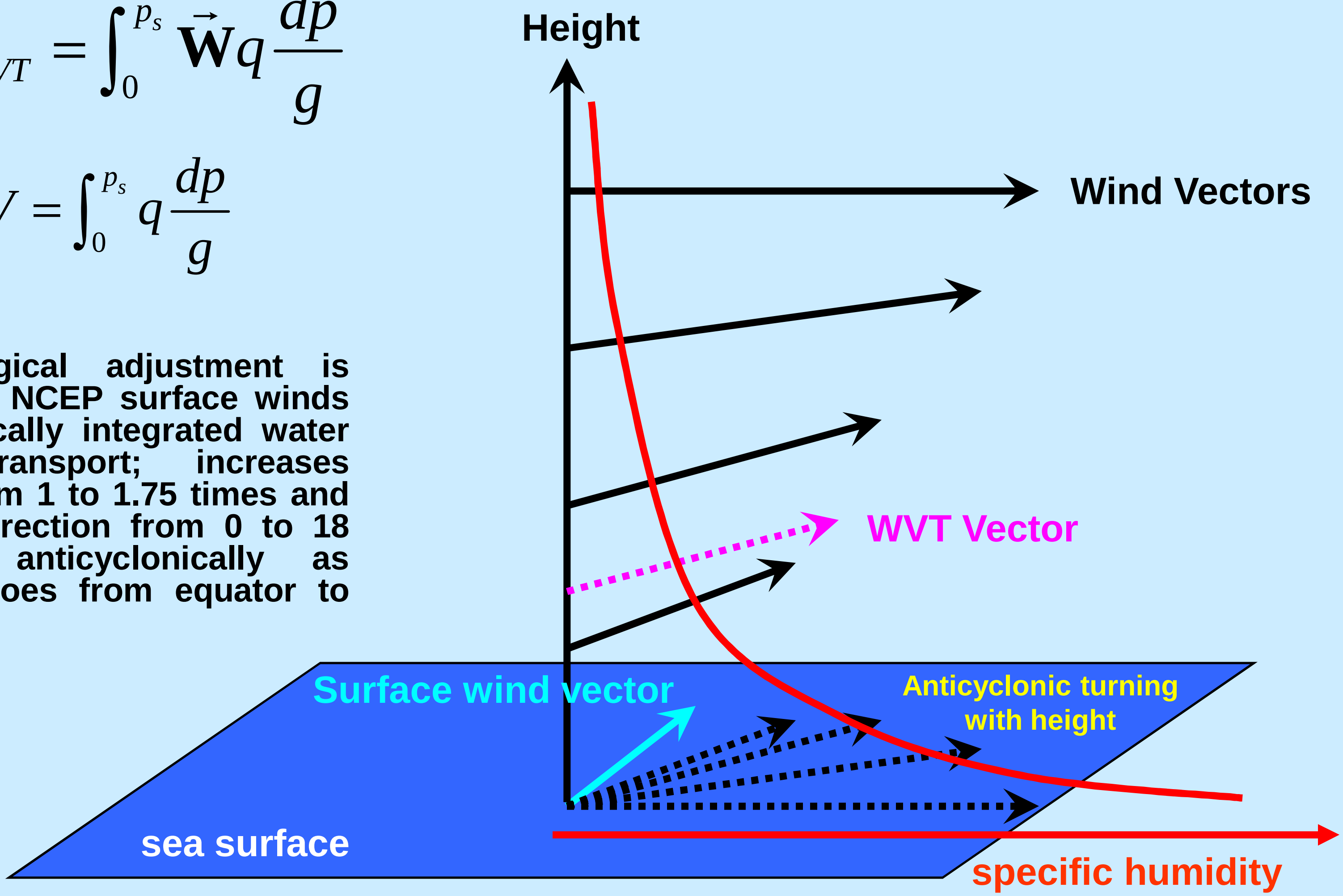
div Q = E – P

Surface Winds to WV Tranport Adjustment (Weakest Link?)

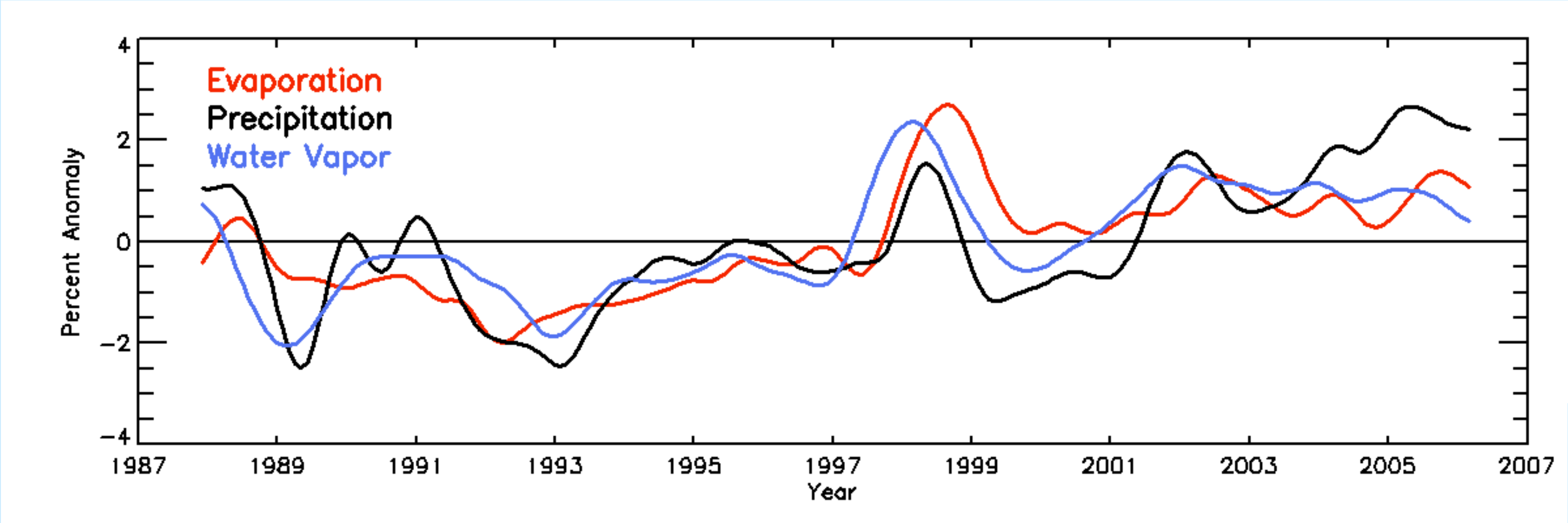
$$\vec{\mathbf{Q}}_{WVT} = \int_0^{p_s} \vec{\mathbf{W}} q \frac{dp}{g}$$

$$V = \int_0^{p_s} q \frac{dp}{g}$$

Climatological adjustment is based on NCEP surface winds and vertically integrated water vapor transport; increases speed from 1 to 1.75 times and rotates direction from 0 to 18 degrees anticyclonically as latitude goes from equator to pole



Global Results on Monthly Time Scales
div Q=0 ➔ E = P



- Global evaporation balances global precipitation (with a static, latitude-dependent adjustment to rain)
- Average evaporation: 962 mm/year
- Average precipitation: 951 mm/year
- Imbalance on the order of 1%

- Trends in evaporation and precipitation have the same magnitude as trends in water vapor, in contrast with climate models
- **Evaporation trend: + 1.3 % / decade**
- **Precipitation trend: + 1.5 % / decade**
- **Water Vapor trend: + 1.4 % / decade**

Climate prediction models predict a muted response by precipitation see Wentz et al., 2007, *Science*.

Wind trend similar to 0.1 m/s/decade

QuikScat and buoys track extremely well

Scatterometers are extremely stable

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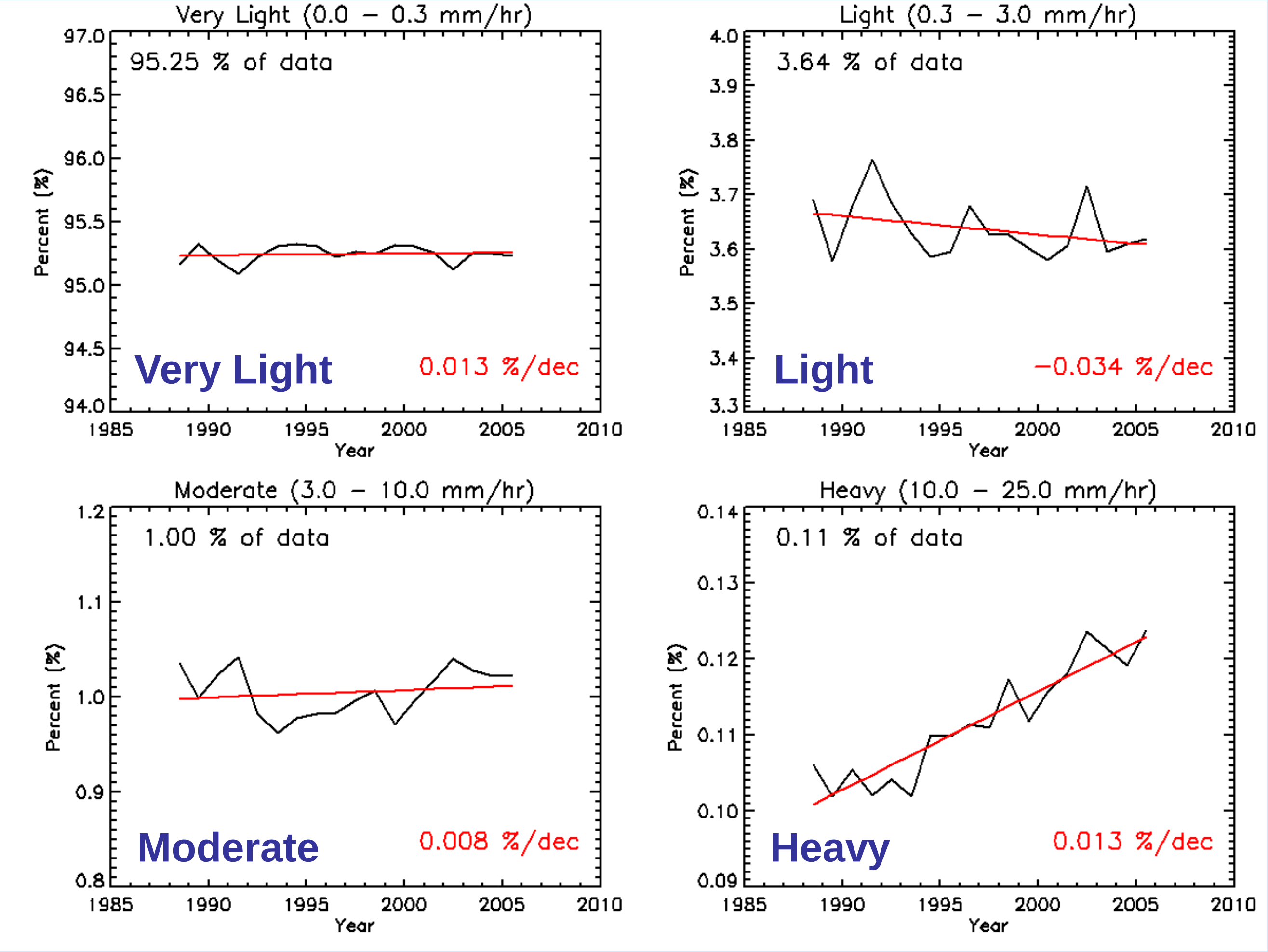
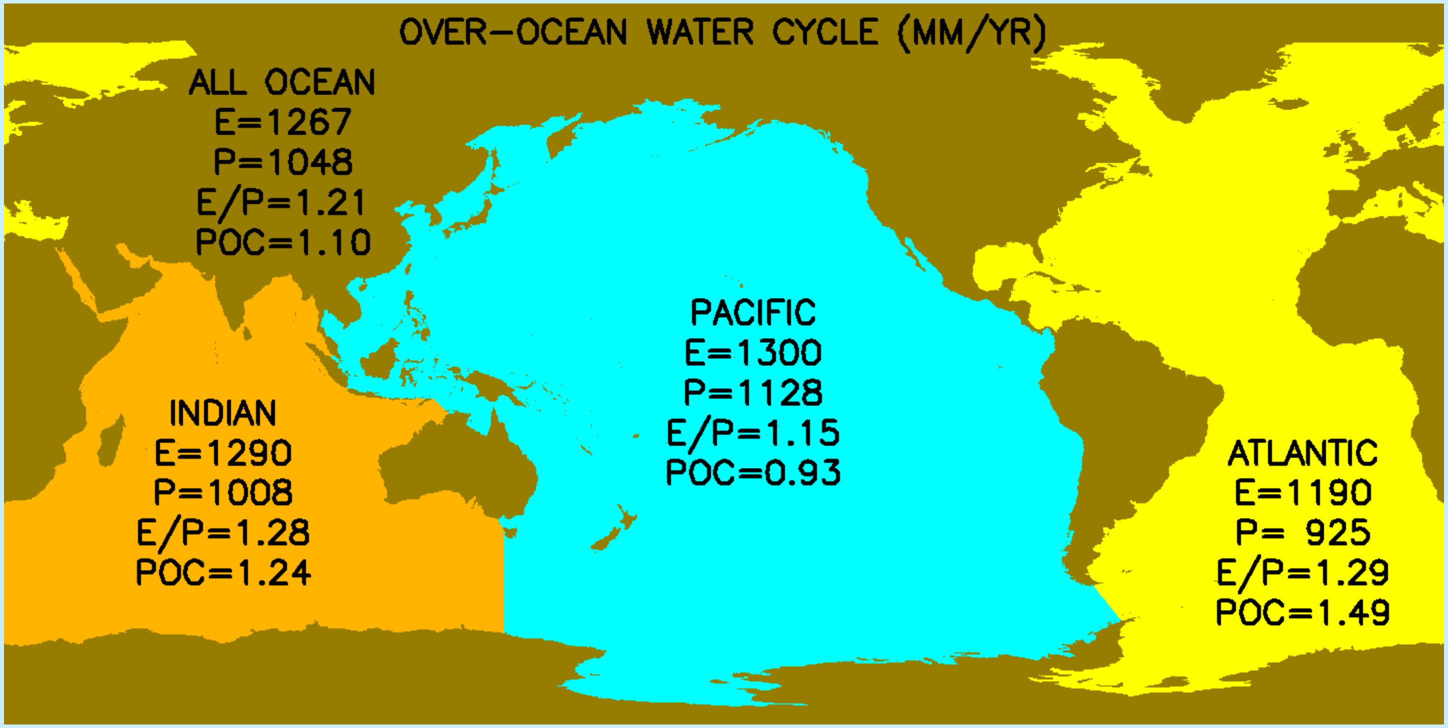
Precipitation Trend Due to Increase in Heavy Rain



consistent with Trenberth and Soden

These are for global oceans, tropical oceans the same

Regional-Scale Water Balance



- **Our evaporation ratios (E/P) are more consistent from basin to basin than previous estimates (values from "Physics of Climate" (POC) shown here)**
- **For a sufficiently large area, evaporation is about 20% larger than precipitation; with the excess finding its way onto land**

Attempt at Deriving Water Vapor Transport Q Independently

- **Feature Tracking to deduce the transport velocity**

  Problems with non-conservation of water vapor and the optical flow aperture problem, also issues near coastlines

  Monthly average transports are ok... but the divergence field lacks proper structure

- **Ardizzone/Atlas/RSS Surface Winds + ECMWF Cross-Calibrated, Multiple Platform (CCMP)**

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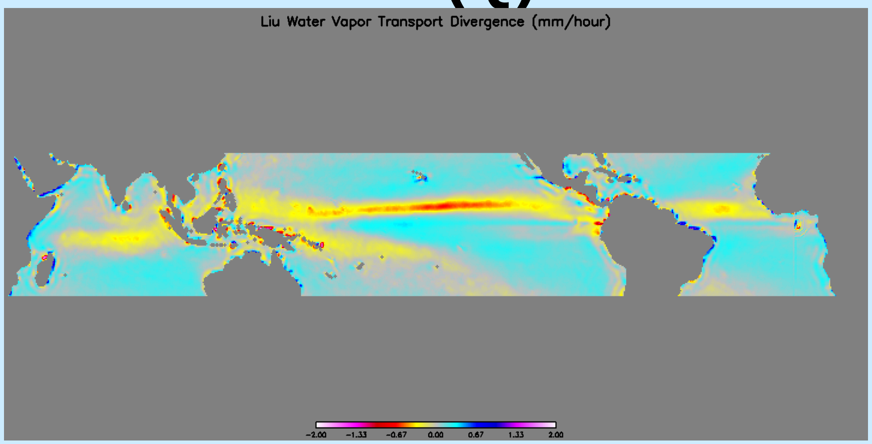
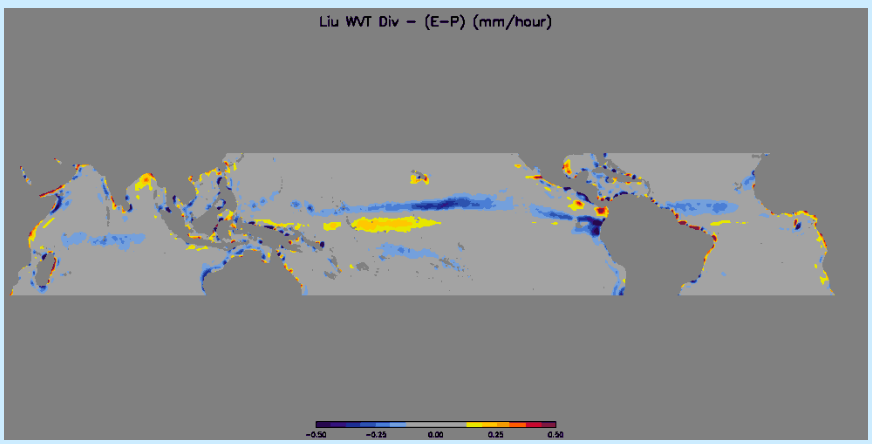
  NCEP Climatology used to convert surface wind to transport wind (rotated and increased, varies with latitudes)

Water Vapor Transport Divergence

No Constraint on Q

Div(Q)

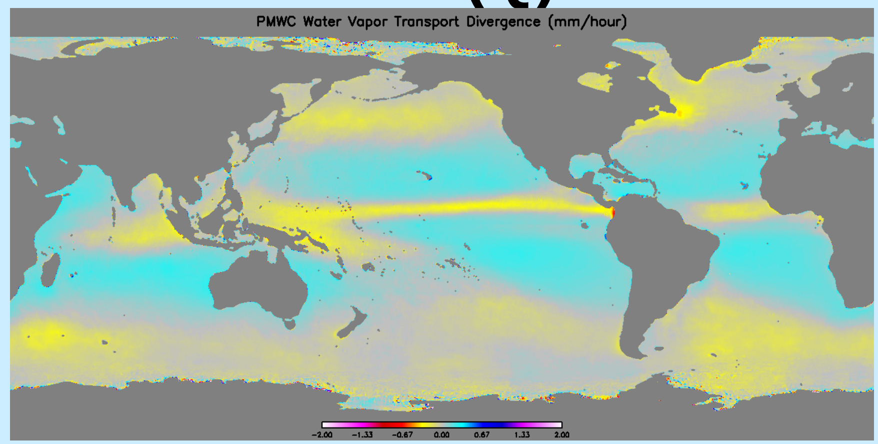


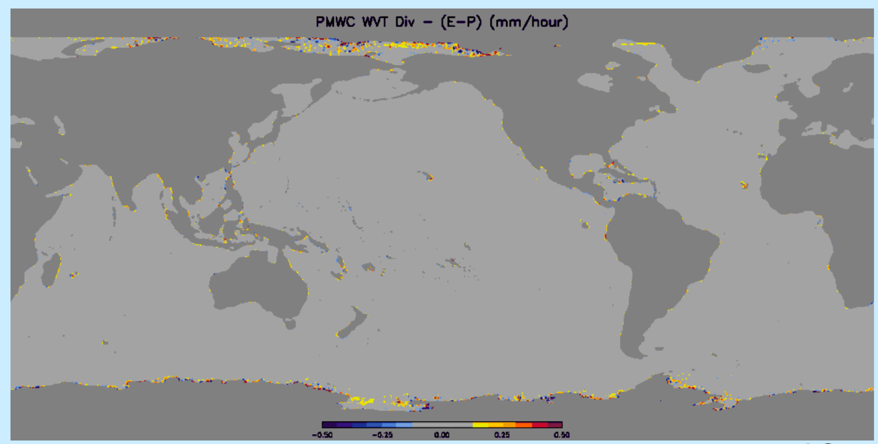


Div(Q) – (E-P)

Div(Q) constrained to = E-P

Div(Q)





Div(Q) – (E-P)

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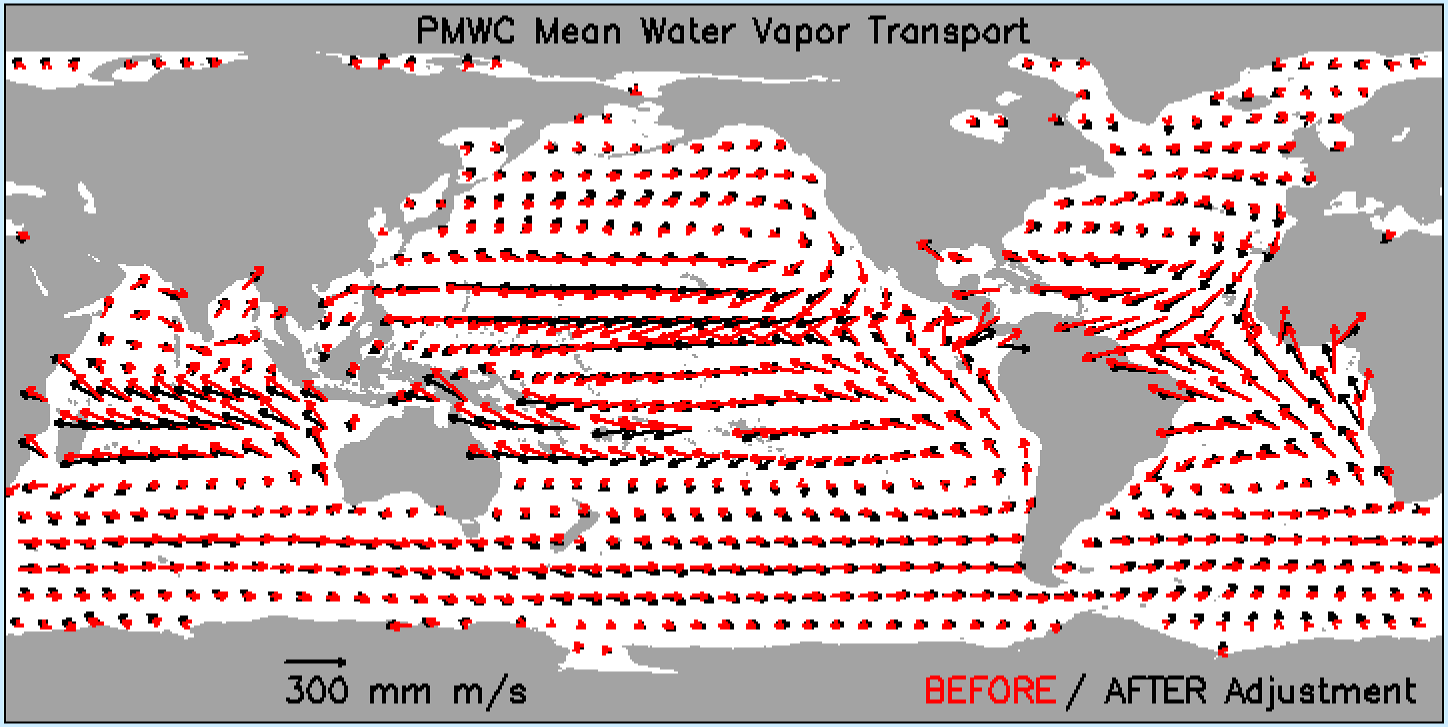
Example of WVT (Q) Adjustment



- **Final Water Vapor Transport (WVT) requires the following inputs**
  - **Surface Wind Field**
  - **Columnar Water Vapor**
  - **Evaporation**
  - **Precipitation**
  - **NCEP Climatology to relate surface wind to transport wind**
- **Divergence of Q constrained to be E - P**
- **Net effect of constraint: mostly rotate direction of vectors; median rotation of 12 degrees**

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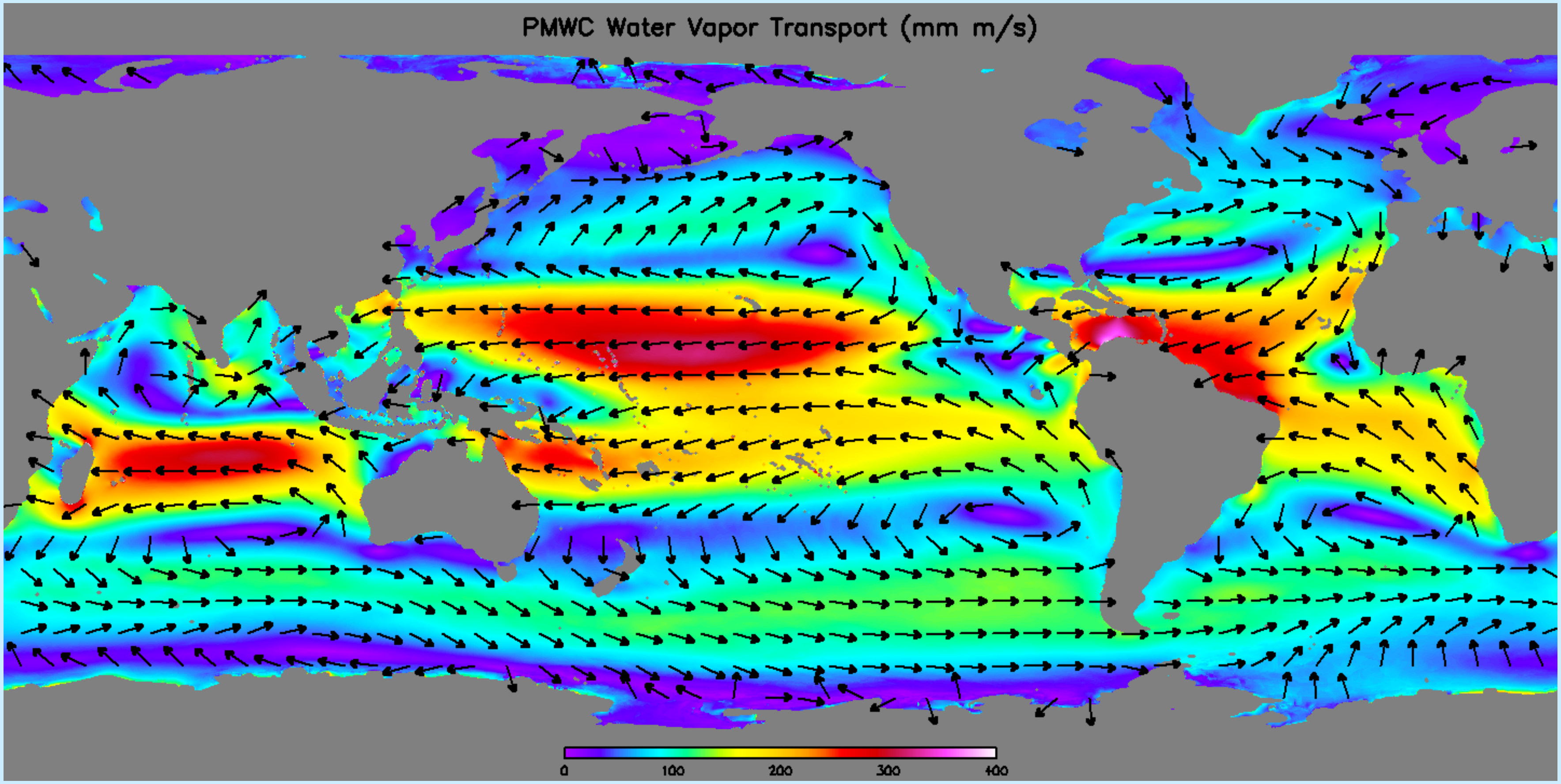
Water Vapor Transport

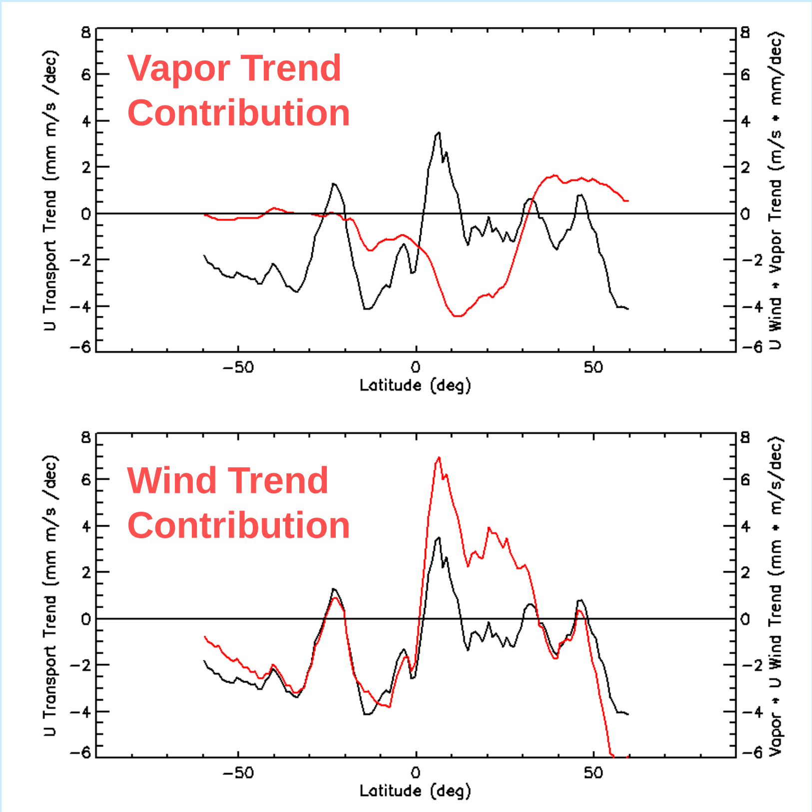
2000-2005



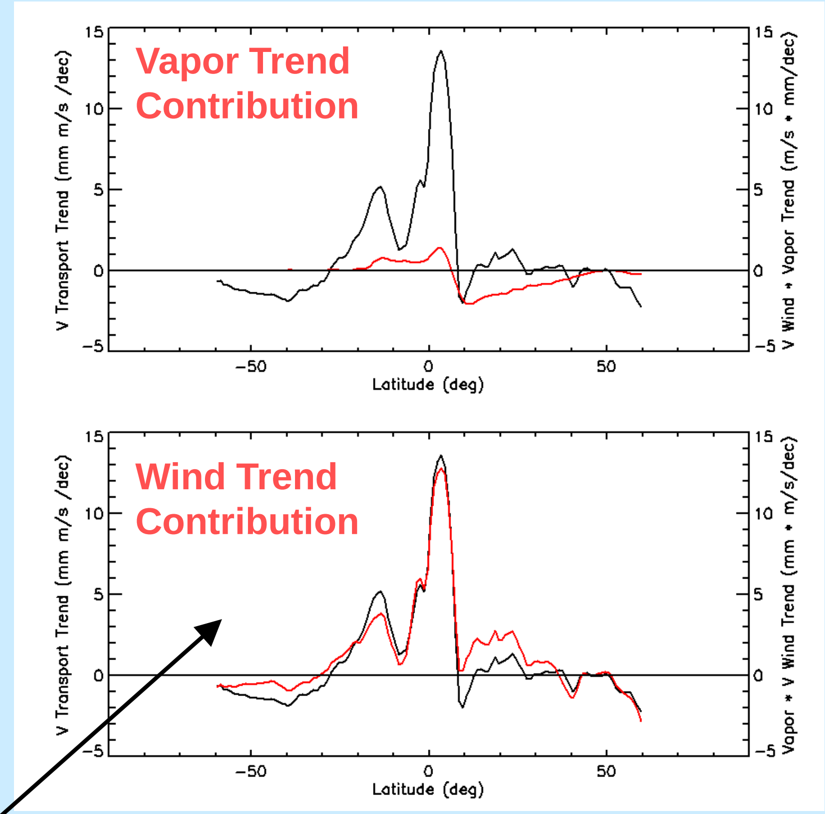
Transport Trends

Black line: transport trend

Zonal Vapor Transport



Meridional Vapor Transport



(Trend in meridional wind) * (Mean vapor) = (Trend in vapor transport)

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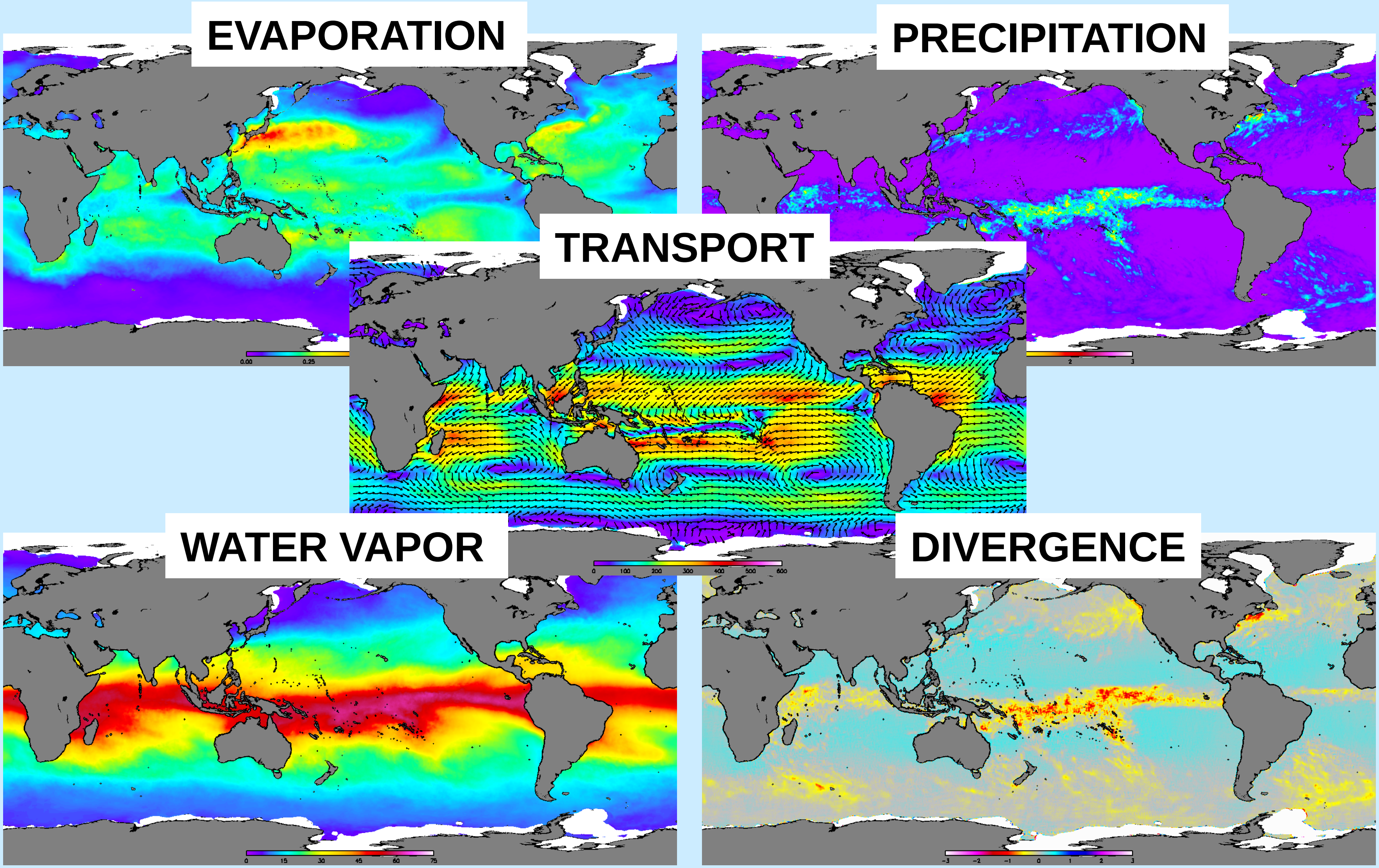
1987-2006, monthly, ¼ deg. resolution



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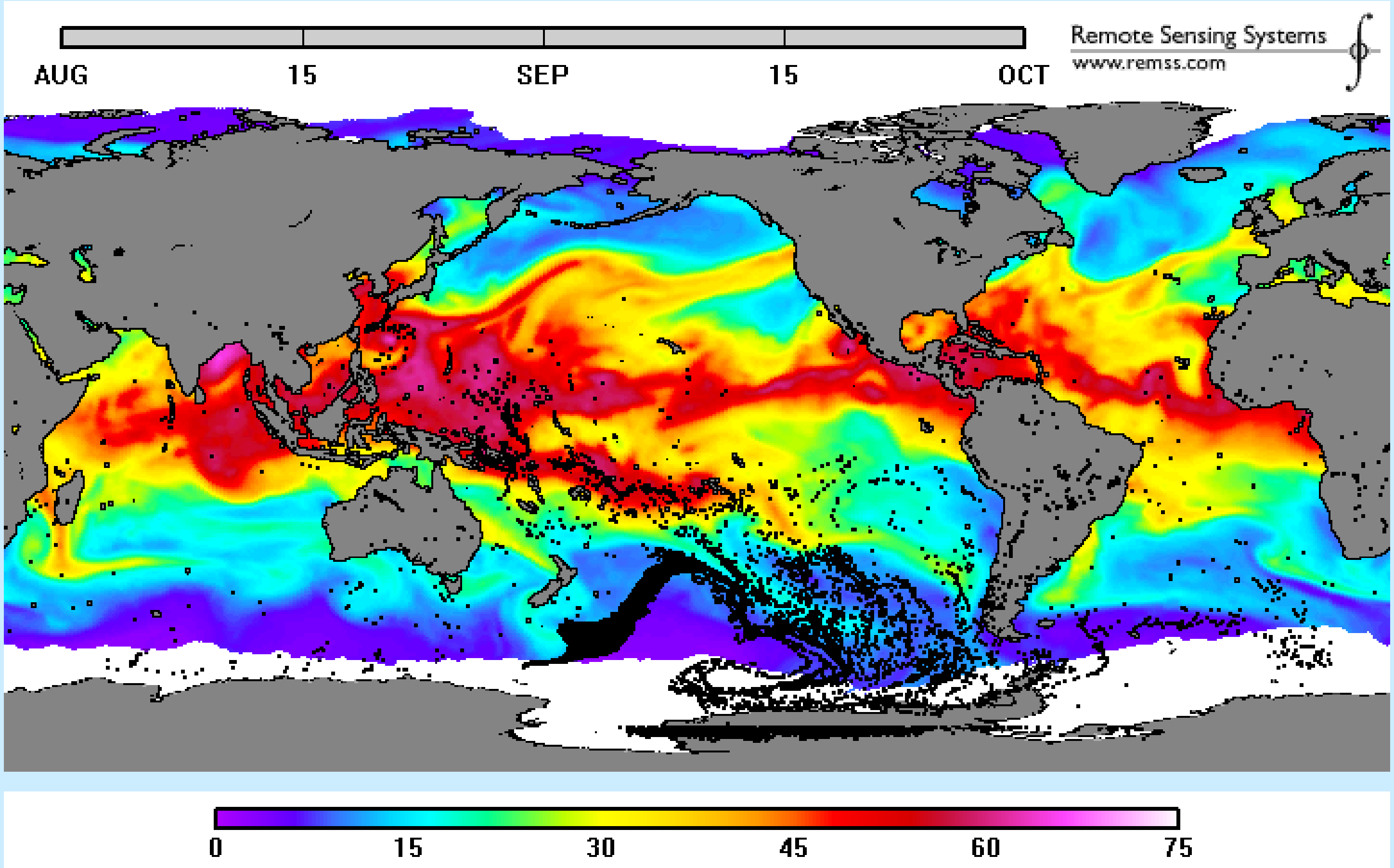
Trajectory Analysis with Surface Winds

Note that particle positions line-up with water vapor



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Color: **water vapor (mm)**

Aug-Sep 2005