Trends and Inter-annual Variations in Surface Temperature, Water Vapor and Precipitation and the Impact of ENSO and Volcanoes

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**Objective:**
To understand the large-scale variations of and inter-relationships among temperature, water vapor and precipitation on both the inter-annual and inter-decadal scale and the similarities and differences thereof.

**Approach:**
Analyze global observational data sets using ENSO and volcano indices to separate those signals from linear changes (trends).

**Global (1988-2008)**
- **Surface Temp.** (Amplitude ≈ 0.2°C)
- **Water Vapor** (~7%/C for ENSO, ~6%/C for volcano)
- **Precipitation** (~2%/C for ENSO, ~4%/C for volcano)

**Trends**
- **Surface Temp.** (1.5°C/10yr)
- **Water Vapor** (~7%/C, taking into account MERRA trend bias)
- **Precipitation** (~0%/C)

**For global scale:** Inter-annual ENSO and volcano water vapor variations ~ C-C, while precipitation variations smaller (~2%-4%/C); trend changes similar to inter-annual with precipitation near zero.

**Inter-annual Lag Correlations With ENSO/Volcano Effects**
- Water vapor correlated with surface temperature over both land and ocean over both tropics and globe, even when ENSO and volcano effects removed.
- Precipitation positively correlated with temperature over ocean, negative over tropical land; correlations near zero when ENSO and volcano effects removed.

**Summary:**
ENSO and volcano signals can be determined for tropical and global fields of surface temperature, column water vapor and precipitation. Removal of these inter-annual signals allows for a clearer determination of the inter-decadal/trend signals and allows for a clear comparison of the two time scales.

For ENSO inter-annual variations, temperature and water vapor signals remain “strong” when integrated over the globe, while precipitation signals become muted. Water vapor follows C-C (7%/C), precipitation 2%/C.

For volcanoes the precipitation signal (4%/C) is more similar to that of water vapor.

For trends, temperature and water vapor increase, while precipitation trend is close to zero—similar to ENSO variations. However, while precipitation variations are globally weak relative to water vapor and temperature, there are key regional variations due probably to stronger dynamical influence for precipitation and because of energy budget constraints.

For the inter-annual signal with ENSO/volcano removed, water vapor still correlated strongly with temperature; precipitation correlation near zero—may be closest analogy to trend processes.