Causes and Impacts of the 2005 Amazon Drought

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Supplementary Information

1 Precipitation analysis

The raingauge stations used in our analysis are from the Global Historical Climatology Network[1] (GHCN). Only stations with more than 50% temporal coverage over the period 1979-2005 and with more than 6 months during year 2005 were used. Thus one needs to be very careful in interpreting the data if spatially averaged because such sparse coverage may be too coarse to resolve the typical interannual climate anomaly patterns. This dataset is referred to as GHCN50.

In addition, we have analyzed 9 precipitation datasets produced by other groups, and many of them are widely used global datasets. These datasets are based on gauge, satellite, or merged satellite and gauge. Altogether, we used 10 datasets to analyze the 2005 Amazon drought (the numbering is consistent with Fig.S1 and Fig.S2):

(a) Satellite measured outgoing longwave radiation (OLR; [2]);

(b) OPI[3], outgoing longwave radiation precipitation index for real-time monitoring at NOAA/NCEP/CPC;

(c) TRMM TMI+PR [4] version 3B31 with satellite microwave and precipitation radar combined;

(d) Our own station gauge analysis GHCN50;

(e) CAMS Gauge only[3];

(f) CPC station, an analysis at CPC based on daily station data from South America[5];

(g) CMAP, the Climate Mapping and Analysis Project[6], longwave satellite-gauge blended;

(h) GPCP, the Global Precipitation Climatology Project[7], longwave satellite-gauge blended;

(i) GPCC, a station-based gridded product from the Global Precipitation Climatology Centre[8];

(j) PRECL, a land-only station-based precipitation dataset[9].

While all other 9 datasets are provided as precipitation rates (in mm d^{-1}), the OLR is outgoing longwave radiation flux (in W m^{-2}) seen from space that was not converted to precipitation.

The conversion of OLR to precipitation rate requires nontrivial calibration that may be location and season dependent[3], as in the case of the blended/merged datasets [6, 7].

We have included OLR as an important dataset here because the interannual variability (in terms of relative change) from OLR still provides reliable (possibly more so than many other methods as discussed below) information on the year to year change of interest here, and it is not subject to uncertainties in the gauge data. These advantages are also applicable to TRMM/TMI+PR satellite microwave based measurements.

These datasets are often not independent of each other because the main input sources are only three: gauge, satellite longwave, and satellite microwave (precipitation from space radar is not yet mature enough to be used in global applications). For instance, two of the widely used global precipitation datasets CMAP and GPCP both use the quality-controlled gridded dataset of GPCC which is in turn based on over 6000 synoptic stations. The CPC South America analysis apparently uses a larger number of stations from South America than what is available in GHCN and GPCC and is a relatively new dataset. Obviously the analysis procedure including the selection of station data can also make a major difference.

The reason we put major emphasis on satellite-only data is that, unlike some midlatitude regions such as western Europe, US, China where station data networks are dense and reliable, the remote Amazon region has few stations and some of them are known to be not reliable. The outcome can thus be sensitive to the choices in station and other procedures in producing the final dataset. Such regional issues are not necessarily dealt with in the best way possible in these datasets because the analysis procedures are generally globally applicable, whose choices may be dominated by considerations for other regions such as those areas with large direct ENSO influence because it is the largest global interannual signal. It is thus likely that satellite-based datasets may be better at depicting interannual variations in tropical land rainfall than a network of sparse gauge data with uncertain quality (P. Arkin, J. Janowiak, personal communications). Because outgoing longwave radiation detects mostly cloud top temperature, and microwave is most sensitive to ice cloud, satellite data may not capture warm cloud rainfall such as those occurring in northeastern Brazil when trade wind is lifted by low topography (D. Vila, personal communication). But such effects may be minimum inside the Amazon basin where deep convection dominates.

It is revealing to compare 2005 Amazon rainfall anomalies from these 10 datasets. In Fig. S1 and S2, they are grouped according to how they depict the 2005 drought: Group 1, moderate drought; Group 2, severe drought; Group 3, no clear drought signal. The differences between Group 2 and Group 3 are striking, especially in northern Amazon. A close look suggests that the differences can be attributed to only few stations. For instance, one station at Iquitos, Peru (3.44°S, 73.15°W) in northwestern Amazon further upstream of the Solimões River, shows large wet anomaly in Group 3 but large dry anomaly in Group 2. Thus, serious doubts are raised about the reliability of these station data. A thorough analysis station by station may be able to reveal the reasons behind such disagreement, but this is beyond the scope of this paper.

In contrast to the large uncertainties in the gauge data, the satellite precipitation based on infrared and microwave show general agreement (Fig.S1a-c and Fig.S2a-c). More importantly, the satellite datasets appear more consistent with streamflow data (Fig.S2k,l). For instance, the slow decrease of streamflow at Obidos during 2002-05 (Fig.S2k) is consistent with a modest but long-lasting negative rainfall anomalies seen in OLR (Fig.S2a), OPI (Fig.S2b) and TRMM (Fig.S2c). In contrast, this slow decrease in Obidos streamflow is difficult to reconcile with the positive (albeit small) above-normal rainfall in Group 3, and with the extremely large 2005 drop seen in Group 2 datasets, which was significantly larger than the 1997-98 El Niño drought. Despite the limitations with satellite datasets, given the reasons discussed above, we conclude that for the Amazon, the satellite datasets are more reliable in depicting the interannual rainfall variability. Subsequent analysis in the main text is thus based on the OPI dataset.

2 Monthly timeseries

See Fig.S3.

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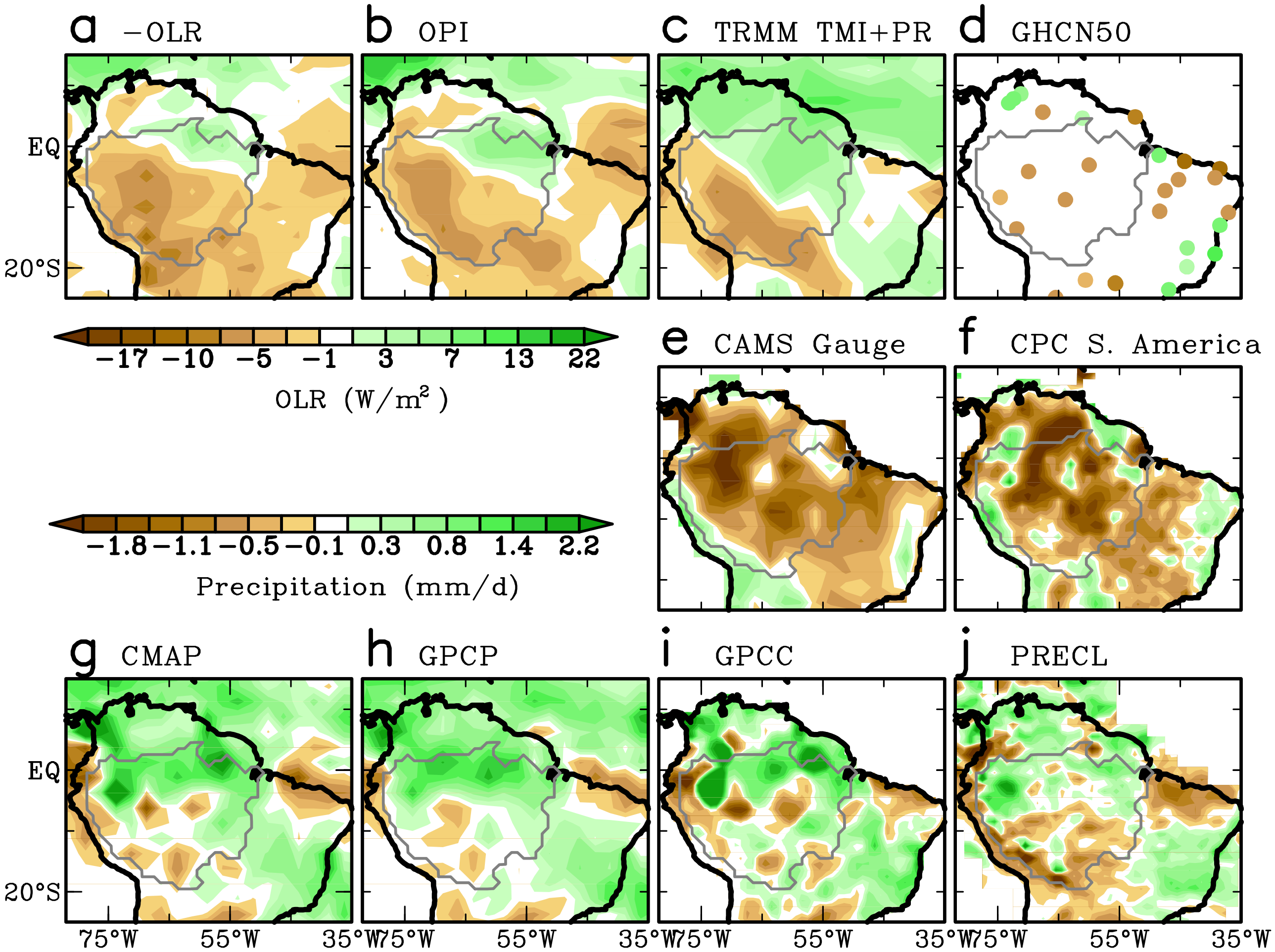

Figure S1: Anomalies for January-December 2005 from the 10 precipitation datasets analyzed. The horizontal plots are grouped according to how they depict the 2005 drought: Group 1 (first row), moderate drought; Group 2 (second row), severe drought; Group 3 (third row), no clear drought signal.

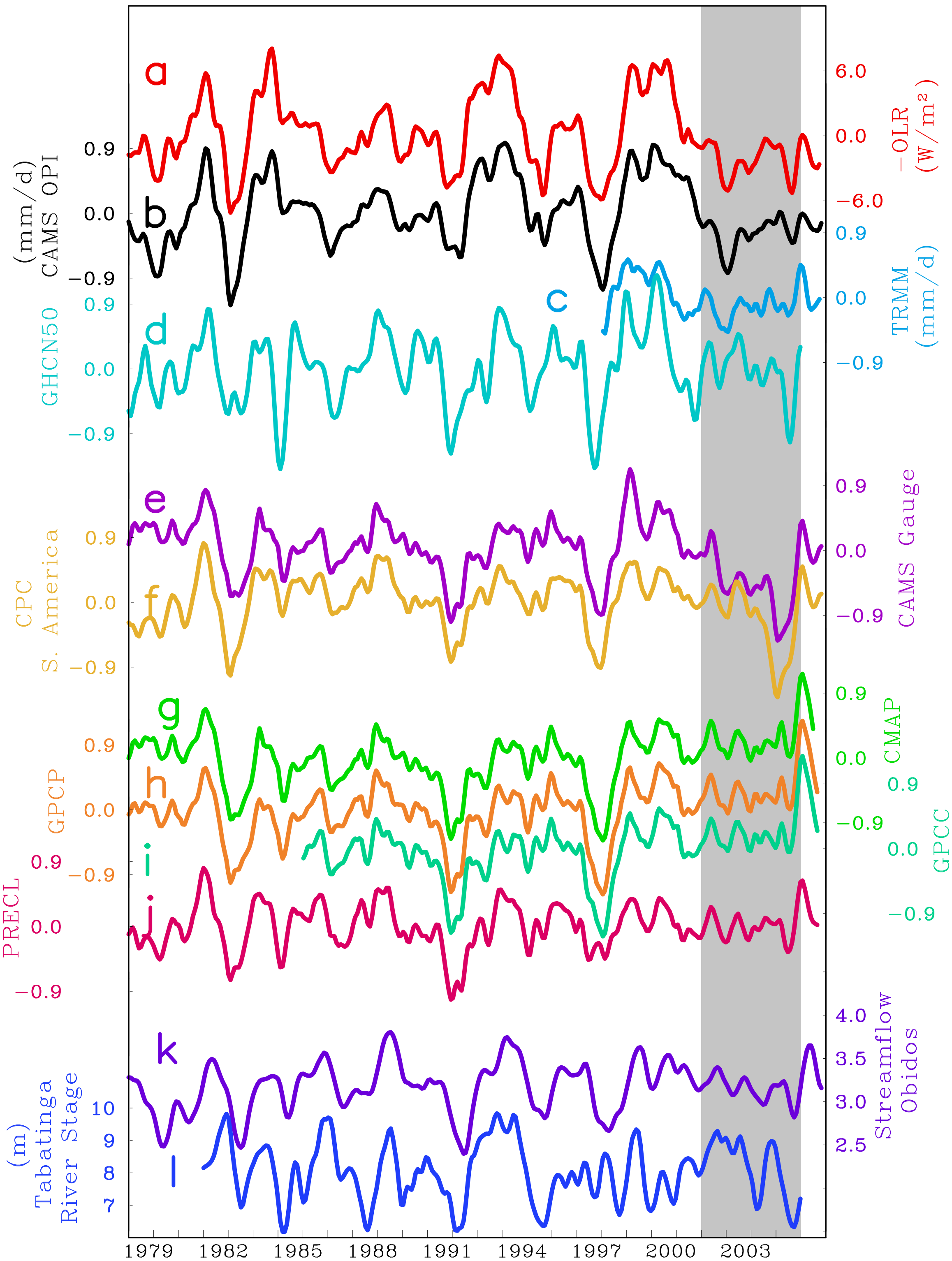

Figure S2: Amazon precipitation from the 10 datasets for Jan1979-Dec2006 and the Obidos streamflow and Tabatinga river stage data. The same low-pass filter as in Fig.2 was applied to all. The curves are grouped according to how they depict the 2005 drought, similar to Fig.S1.

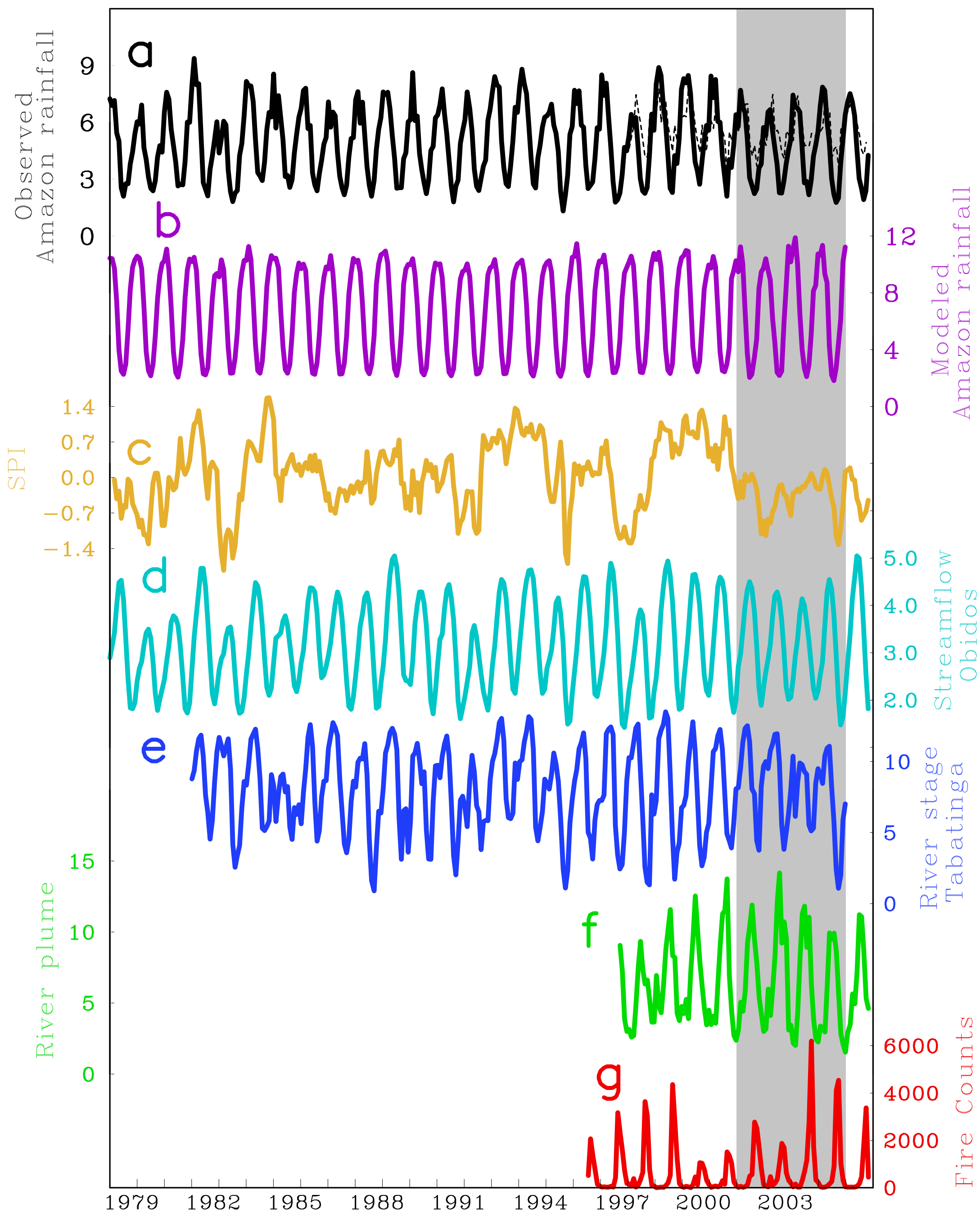

Figure S3: Similar to Fig.3, but the monthly data without low-pass filtering. The SPI here was calculated for a 3 month timescale.