Fig. 6. Total linear changes (*A* and *C*) and S/N ratios (*B* and *D*) in column-integrated water vapor. Results are from 49 realizations of the CMIP-3 20CEN experiment, obtained from 12 ALL models with combined anthropogenic and natural external forcing (SI Table 2). Total linear changes in *W* were estimated over 1980–1999 (*A*) and 1900-1999 (*B*). For each model and at each grid-point, $\overline{b}_j$ is the ensemble-mean total linear change of the *j*th model (or an individual realization of the total linear change, for models with only one 20CEN realization). The multimodel average change, $\overline{b}$, is given by $\overline{b} = 1/N\sum_{j=1}^{N} \overline{b}_j$, with sample size *n* = 12. The S/N is simply $\overline{b}/s$, where *s* is the intermodel standard deviation of $\overline{b}_j$. Because the major anthropogenic forcing (increases in well mixed GHGs) is much larger over the full 20th century than over 1980–1999, use of model data for 1900–1999 provides a more reliable estimate of the "true" pattern of water vapor response to GHG forcing. This is why S/Ns for the total linear changes in *W* are much higher in *B* than in *D*.

Fig. 7. Raw and optimized fingerprints of externally forced changes in column-integrated water vapor over near-global oceans. Multimodel averages of the 20th century changes in W_o were used for estimating the raw (nonoptimized) ALL and ANTHRO fingerprints, $\vec{F}_{ALL}$ and $\vec{F}_{ANTHRO}$ (*A* and *B*), that we search for in the observations. The optimized counterparts of these fingerprints are $\vec{F}^{*}_{ALL}$ and $\vec{F}^{*}_{ANTHRO}$ (*C* and *D*). For full details of the calculation of raw and optimized fingerprints, refer to *SI Text* sections 4.2 and 4.4, respectively. Data from the concatenated ANTHRO control runs was used for optimizing the ALL fingerprint; the ANTHRO fingerprint was optimized with ALL control run data. All optimization was performed with a truncation dimension *m* = 15.

Fig. 8. Example of the method used for estimation of detection time. The signal (*A*) and noise (*B*) components of the S/N (*C*) used for estimating detection time are fully described in *SI Text* section 4.5 and in the caption for Fig. 4*F*. The horizontal green and blue lines are the stipulated 1% and 5% significance thresholds for a one-tailed test,

assuming a Gaussian distribution of noise trends. The dashed vertical lines denote the detection times for the raw and optimized fingerprints (1999 and 2002, respectively), based on the 5% significance threshold.

Fig. 9. The effect of temporal filtering on the S/Ns used for estimating detection time. The "No filtering" results are for the projection of the observations and the concatenated ANTHRO control run data onto the raw ANTHRO fingerprint and are identical to the nonoptimized S/N ratios shown in SI Fig. 8*C*. S/N ratios were also calculated after prefiltering of all observational and model data with three different filter types: (*i*) a 13-term Gaussian filter, (*ii*) a 13-term moving-average filter, and (*iii*) a 5-term binomial filter. Temporal filtering consistently leads to earlier detection of the ANTHRO fingerprint in the SSM/I data. For example, use of the 13-term moving-average filter leads to fingerprint detection in 1997, 5 years before the detection time for unfiltered data.

Fig. 10. Monthly-mean anomalies of $<W_o>$, the column-integrated water vapor over near-global (50°N–50°S) oceans in the MIROC3.2(medres) single-forcing experiments with changes in well mixed GHGs (*A*) and volcanic aerosols (*B*). There are four realizations of each single-forcing experiment. Results are shown for January 1988 to December 2000, the period of overlap between the MIROC experiments and the SSM/I $<W_o>$ data. The same period was used for calculation of climatological monthly means used for the definition of anomalies. In each of the four MIROC realizations with volcanic forcing only, recovery from the Pinatubo eruption leads to a short-term (3- to 4-year) increase in $<W_o>$ but actually yields a slight decrease in $<W_o>$ over 1988–2000.

Fig. 11. Projection of noise data from the concatenated ALL model control runs, $\vec{C}_{ALL}(t)$, onto the unrotated fingerprint $\vec{F}_{ALL}$ estimated from the multimodel average of the ALL model 20CEN runs. This is the "signal-free" time series $N(t)$ used for determination of detection times. For each of the 12 ALL model control runs, annual-mean anomalies of W_o were defined relative to the climatological annual mean of the control. Residual control run drift was not subtracted. The effects of drift and/or intermodel differences in

the variability of W_o are readily apparent at some of the "transitions" between the concatenated control runs. The start date (1800) is nominal and bears no relation to "real time."

Fig. 12. As for SI Fig. 11, but for the projection of noise data from the concatenated ANTHRO model control runs, $\vec{C}_{ANTHRO}(t)$, onto the unrotated fingerprint $\vec{F}_{ALL}$ estimated from the multimodel average of the ALL model 20CEN runs.

Fig. 13. Response function for the Lynch/Huang digital filter for a window width $K = 21$ months and a half-power point of 25 months (1).

1. Lynch P, Huang X-Y (1992) *Mon Weather Rev* 120:1019–1034.