Notes: GGMT presentation, Jeju, 2019

1. Introduction: We began hosting webpages with updated CO2 trends in 2008. We have a number of trends products, but here I focus on monthly updates of global trends based on weekly samples from our cooperative air sampling network.

2. NOAA Trends products: Our most popular trends page is for MLO, from which CO2 obs are presented at hourly to annual time scales. We also have a global CO2 deseasonalized trend based on in situ measurements at NOAA’s 4 baseline observatories (BRW, MLO, SMO, and SPO), updated daily. Finally, we have global trends originally only for CO2, and more recently for CH4 too, based on flask-air measurements from our cooperative air sampling network, updated monthly. It was development of CH4 trends, and N2O and SF6 in the future that led to this analysis.

3. Cooperative global air sampling network: We use a subset of BG sites from the ones indicated in red on the map to calculate zonal averages with our data extension methodology.

4. Example data: Here are CH4 data from BRW. Retained values are in red filled circles; blue and green data are flagged. We fit curves to retained data to get smooth curve and deseasonalized trend. They can be thought of as running means, 6 weeks for the SC and 12 months for the trend. Extract values from each SmCrv at synchronized time intervals with 48 time steps per year.

5. Latitude fits: A new curve is then fitted to these synchronized values as a fn of latitude at each time step. The values are weighted based on the RSD of the smooth curve fitted to the original measurements. Here are examples for CH4 of curve fits at the same time step from 2000 and 2002.

6. Surface: Taken together, the fits as fn of latitude result in a matrix of GHG values as fn of time (48 t-steps per year) and equal volume latitude bands (spacing sine(lat) =0.05. We want to report values as recent as possible, but there are two concerns. 1) Because of the nature of our network, there is a lag between sampling and analysis, and the magnitude of the lag varies depending on the site. 2) Although we want to offer results that are as current as possible, we also know there is potential for end effects from the curve fitting methods.

7. Use these “web runs” to update global trends for CO2 and CH4 about the 5th of each month (URL given) where we report updated annual mean for the previous years, monthly means, and annual increases. Uncertainties are estimated annual based on non-parametric statistical methods, the MC and resampling methods once data are QC’d and finalized 7 or 8 months into a year. These uncertainties are NOT appropriate for the initial estimates from the web runs.

Currently have global trends pages for CO2 and CH4 (shown as an example), but hope to add N2O and SF6, too. These pages are very popular getting many views each month.

8. What issues are we addressing and how? Because monthly updates of data extension started only recently, so back-calculated web runs for 5th of each month from 1990-2017; extracted data from DB based on analysis date to mimic real web runs. We want to make our global trends page as current as possible w/o posting significantly biased results. Why is this a concern? First, there is a significant lag between sampling and analysis, so at the time of a web run, we will only have a fraction of the data we will ultimately have by the 5th of the month. Second, because we are using curves based on smoothed data, we need to assess how well constrained a particular curve is for that parameter. Then, if we do have biases, how do we best address them? I am doing this to avoid potential claims we are exaggerating changes in GHG burdens.

9. Start with annual means: In January of each year, we calculate an annual mean for the previous year, and we want to track how it changes with each subsequent monthly update relative to a stable value, in this case that same parameter at the end of the experiment. We do that by comparing it with the annual mean for the same year at the end of the experiment. Here, that difference is plotted for each color-coded year based on subsequent monthly web runs from 1990 through 2017. As it turns out, the initial estimate isn’t biased by too much, roughly ±0.1 ppm. Average behavior is shown in the RH plot, in this case the mean Abs val of differences and SD for all years. Again, biases are small and converge quickly, but I’m sure you noticed the abrupt changes in cyan and green. Look more closely at these.

10. Both these cases are related to conditions we put on the length of record before a site is included; once two years of data are present, the full record is added. Between Feb and Mar web runs in 1994, we met the two-year condition, and measurements of CO2 from CRZ starting in Mar., 1991 were added causing a change of 0.06 ppm in global annual mean. You can see how it affects the matrix of values here where the latitude gradients are plotted for the Feb and Mar web runs and their difference as the dashed dotted line. There was likely a bias in early measurements from CRZ.

11. Monthly means: Here are similar plots to before, but rather than how an annually averaged parameter changes, how CH4 MMs change for a single year, 2010. There can be large biases, up to 10 ppb, much larger than we saw for annual means. The main problem is that the global average as represented by the smooth curve is not well-constrained at the end of the web run. This was no surprise. But, we can use the results of this analysis to assess how much lag is necessary between the web run and the MM released. So the line shows for CH4 what adding a lag of 4 months does. It is now close to being within the typical uncertainty.

Aside: The step in April, 2010 MMs occurs as weights for Pacific Ocean shipboard samples change. Weights depend on SD of residuals and temporal density of samples.

12. Here is a similar plot for CO2, but for 2009. For CO2, the bias in initial estimates are significantly greater than the typical uncertainty assigned to MMs, so, as with CH4, we add a delay, 3 months in this case, to ensure they are well-constrained before release.

13. Annual increase for CO2: There is a lot of interest in updates of annual increase, so this is clearly a climate metric we do not want to seem to be exaggerating. LH plot: Annual increases, color-coded by year for 1990-2016. RH plot: Average absolute values of differences as subsequent web runs refine the calculation of annual increase. Given annual increases of 1.6 to 3 ppm/yr over past 10 years, the magnitude of the initial bias is significant.

14. Figures as for CO2 but for CH4; bias is larger than CO2 relative to its recent annual increases of 4.6 to 12.7 ppb during past 10 years.

15. Annual increase first calculated in Jan.; subsequent web runs refine it. Here are trend curves. While the start of the year remains well-defined and fixed, as more data are added, the end-point changes. This is not surprising; the smoothing we use smooths variability over a year or so.

16. Conclusions: Initial estimates of annual means are reasonably close to “finalized” values, but monthly means and annual means can have large biases, significantly larger than the uncertainties we typically apply. For MMs, we can decrease initial bias for CH4 MMS with different weighting of the 4 values per month, as we do with CO2. For the global annual increase, there is no advantage of one processing method over the other in terms of bias; the best we can do is delay the release of annual increase until we are certain the trend curve is somewhat stable at the endpoint.

**Bullet points:**

1. Introduction:

- We’ve been offering various monthly updates of CO2 for ~10 years.

- Here the focus is on global trends determined from our cooperative global air sampling network.

2. Brief summary of DEI method:

- Map of network on TL:

- 5th of each month, use subset of sites to calc glob and zonal averages by smooth dat in t and lat: web run.

- Result is matrix of values as function of t (48 t-steps/yr ) and sine(lat) (shown).

- Lag between sampling and analysis and curve fitting end effects affect initial estimates of params.

3. Use results to update “Trends” web pages.

- Report updated annual mean and annual increase for prev yrs, and MMs.

- Uncertainties reported based on MC and resampling methods, but are they appropriate for initial estimates?

- So far, have trends pages for CO2 and CH4 – will extend to N2O and SF6.

- >30,000 views per month (although not possible to separate global, only)

4. What issues will I address?

- Start with pseudo-web runs…. 1990-2017.

- Are there biases in initial estimates that fall outside our uncertainties?

- How can we improve reliability of results? Methods evolved for CO2 – can this be exploited for CH4+?

5. Two methods used to process output from web runs described here.

- Rather than describe in detail, better to illustrate their differences with figures.

6. Difference in how MMs calculated.

- Both methods use same output, 48 t-steps/yr, but weight them differently.

- MMs calculated with both plotted, red-classic and blue-alt. Differences in cyan.

- ALT likely more realistically represents actual monthly mean.

7. Difference in how trend calculated (critical because trend used to calculate ann inc):

- As before, diff between methods plotted: ALT more variable.

- Also difference in annual increase: More variability with PPT.

8. Annual means:

- Since “web runs” are recent, then created pseudo-web runs from 1990-2017 based on a-date.

- In Jan, calc initial ann mn for previous yr. It, and val from subsequent runs, compared with final val.

- Differences are color coded by yr. RH: avg over all yrs. Relatively small changes.

- Makes since, since at time of calc, most of year well-defined by data.

- Not green and cyan – what’s happening there?

9. Network influence on annual mean:

- Related to conditions necessary for inclusion – once 2 yrs present, full record included.

- Between Feb and Mar 1994 web runs, condition met for CO2 at CRZ, and data included back to Mar 91.

- See impact on CO2 vs lat w/ and w/o CRZ – results in 0.06 ppm change in annual mean.

10. Ann mean CH4:

- Similar to CO2; small bias with initial estimates and found no change with method.

11. Monthly means: plots similar to before, but for single year color-coded by month.

- For CH4, large biases, up to 10 ppb (compare with *u*). Fundamental problem is, not surprisingly, that the global average is not well constrained at the end of the web run. So, we add a lag, here using the alternate method.

- Another abrupt change; this one related to how POC data are weighted.

12. Monthly means, CO2: already using PPT for CO2. Bias in initial est can be outside *u*.

13. Summarize MMs for CH4 and CO2 using current method for each:

- For CH4, there are large biases in initial estimates of MM, but can be improved using PPT.

14. Annual increase:

- Everyone interested in ann inc. Sometimes get requests for it before the year ends! Highlight of GHG Bull.

- LH: ann inc color-coded by yr for PPT (little dif betw methods); RH: average over all years.

- Init est can be biased by much more than u; given inc of 1.6 – 3 ppm/yr, bias can be significant.

15. Similar plots for CH4:

- Again, given recent increases, 4.6 to 12.6 ppb/yr, these biases can be large.

16. End effects: network vs curve fits.

- LH: ann inc from web runs based on a-date, as we’ve done before. RH: same, but based on sample date.

- Changes are comparable, although net + crv a bit worse.

17. Causes of end effects:

- Start of year (Jan. 1) changes little from run to run.

- W/ each web run, because of the way the data are smthd, end point (Jan1., yr+1) can change significantly.

18. Summary and conclusions:

- Annual means reasonably close to final values.

- MMs and aninc can have large biases, significantly larger than uncertainty.

- The different weighting used in the PPT method decreases bias in initial estimates of MMs for CH4.

- For aninc, meths yield similar bias. Best can do: wait until sufficient data to constrain trend, delaying release.