Comment

January 16, 2021

1 Comment on Authors' Definition of Final Stratospheric Warming in Southern Hemisphere

Author: Nick Byrne

It's been well established in the literature (e.g. [1]) that ozone depletion has led to a delay (i.e. a positive trend) in the date of the final warming of the Southern Hemisphere stratospheric polar vortex, prior to the early 2000s at least. I was surprised by Figure 1c as there does not appear to be a visible trend in the authors' data. I performed some basic analysis to confirm this statement (see below), and also compared it against another definition that has been used in the literature ([1]). This analysis would appear to confirm that evidence for a positive trend is much weaker using the authors' data than in data previously used in the literature.

I wonder if this is because the authors use 10hPa in their definition for the final warming - perhaps this is a little high to use as a definition for the final warming? And given that the final warming in the Southern Hemisphere has been so closely tied to ozone depletion/a positive trend in the date of occurrence, I wonder if it might be confusing to introduce a new definition where this relationship is not so clearly visible?

On the other hand, I agree that it is attractive to be able to use the same level to define stratospheric events (FSW or SSW) in both hemispheres. I think there is a balance here between simplifying a definition and also maintaining the key properties attached to the original definition. Perhaps the authors could comment a little on where they think this balance lies? (There are convincing arguments for both sides. I think the most important thing is that the authors include some discussion in their paper about how their definition impacts previous work on long-term trends. Some related questions have also been raised by Reviewer 1.)

1.1 Inspection of Data

[1]:
```
# Day of year of FSW according to Butler & Domeisen definition.
SFW_DATES_BUTL_DOM = [322, 322, 321, 323, 312, 310, 329, 317, 336, 300, 315,
                      339, 319, 325, 327, 316, 328, 338, 322, 341, 339, 308,
                      341, 305, 319, 320, 314, 337, 331, 335, 320, 345, 329,
                      310, 306, 326, 345, 314, 313, 328]
```

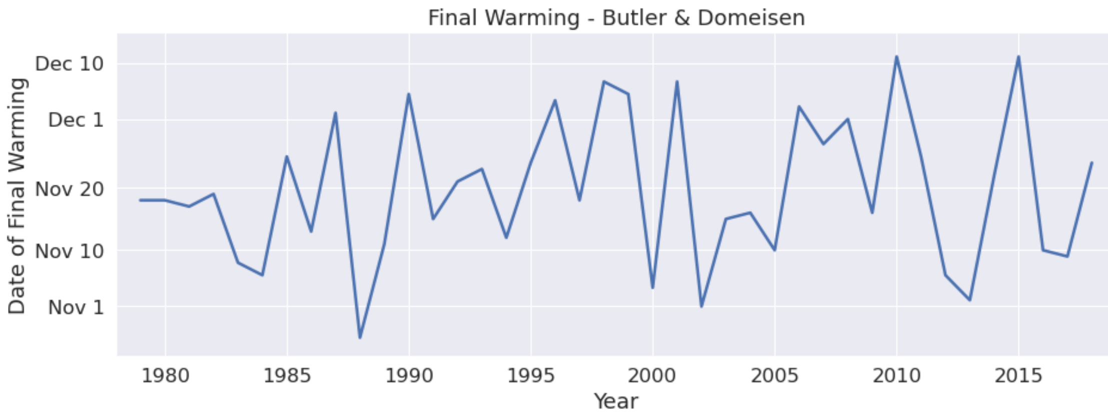
[2]:
```
# Day of year of FSW according to Black & McDaniel definition (see [1]).
# NOTE: 2017 and 2018 datapoints have not been calculated
SFW_DATES_BLA_MCD = [324, 326, 337, 333, 340, 335, 345, 339, 345, 322, 341,
                     348, 323, 341, 340, 328, 353, 344, 336, 356, 368, 331,
```

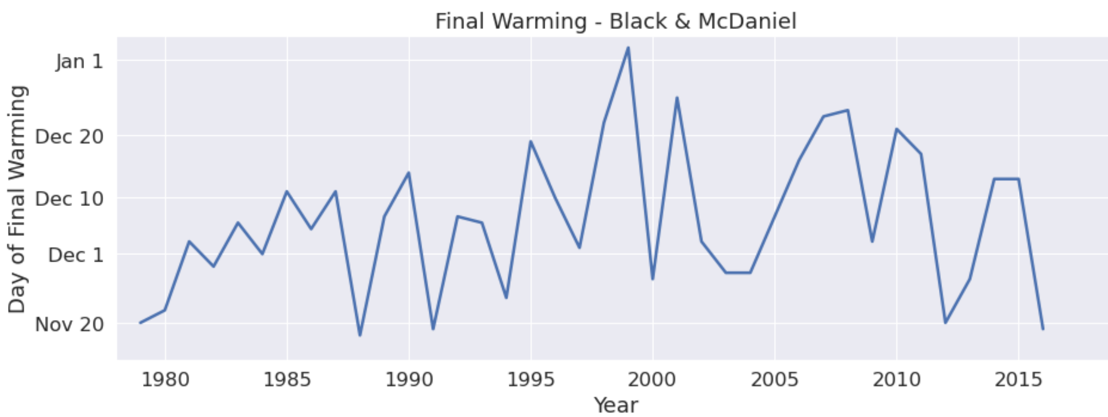
```
                    360, 337, 332, 332, 341, 350, 357, 358, 337, 355, 351,
                    324, 331, 347, 347, 323]
```

[3]:
```
years = [1979 + x for x in range(40)]
```

[4]:
```
from my_utils import plot_dates
```

[5]:
```
plot_dates(years, SFW_DATES_BUTL_DOM, SFW_DATES_BLA_MCD)
```





1.2 Trend Analysis

We estimate the slope of the regression line, and its standard error, for subsequences of the full data. For example, the subsequence denoted by 1990 contains all FSW dates from 1979 - 1990 (inclusive). Similarly, the subsequence denoted by 2016 contains all dates from the original data, 1979 - 2016. (2017 and 2018 are not included as I do not have these datapoints for the Black & McDaniel time series.)

[6]:
```
from scipy.stats import t, stats
```

Trend analysis for Butler & Domeisen timeseries:

[7]:
```
tinv = lambda p, df: abs(t.ppf(p/2, df))
```

[8]:
```
res_butl_dom = [stats.linregress(years[:i+2], SFW_DATES_BUTL_DOM[:i+2]) for i
                in range(36)]
```

[9]:
```
slope_butl_dom = [x.slope for x in res_butl_dom]
ci_butl_dom = [tinv(0.05, idx)*x.stderr for idx, x in enumerate(res_butl_dom)]
```

Trend analysis for Black & McDaniel timeseries:

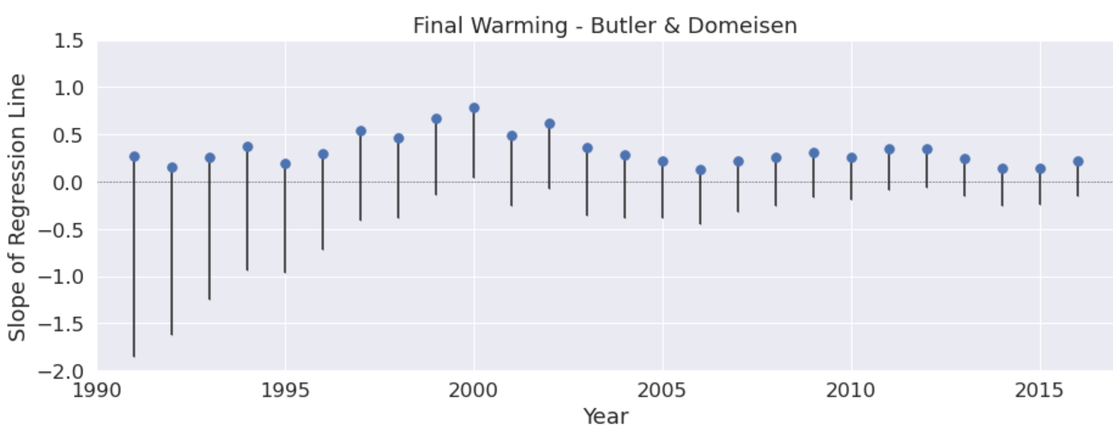
[10]:
```
res_bla_mcd = [stats.linregress(years[:i+2], SFW_DATES_BLA_MCD[:i+2]) for i
               in range(36)]
```

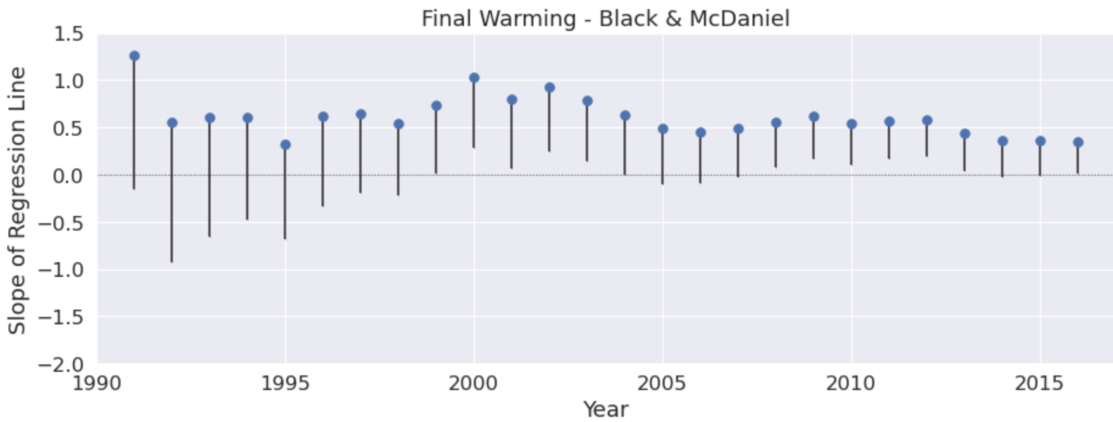
[11]:
```
slope_bla_mcd = [x.slope for x in res_bla_mcd]
ci_bla_mcd = [tinv(0.05, idx)*x.stderr for idx, x in enumerate(res_bla_mcd)]
```

The blue dots represent the slope of the regression line (i.e. the trend) for a particular subsequence, and the black lines represent the 5% confidence thresholds. If a black line crosses the y=0 line, this means that the null hypothesis that the slope is zero (i.e. no trend) cannot be rejected at the 5% level for a given subsequence. This is a common test for checking for the existence of a trend in a timeseries.

[12]:
```
from my_utils import plot_trend_coef
```

[13]:
```
plot_trend_coef(years, slope_butl_dom, slope_bla_mcd, ci_butl_dom, ci_bla_mcd)
```





What the analysis indicates is that there is only one statistically significant subsequence using the definition of Butler & Domeisen whereas the more common definition of Black & McDaniel has many statistically significant subsequences i.e. evidence for an underlying trend is much stronger using the Black & McDaniel data.

1.3 References

[1] *Interannual Variability in the Southern Hemisphere Circulation Organized by Stratospheric Final Warming Events*, Black & McDaniel 2007, **JAS**