Trends of UV Radiation in Antarctica

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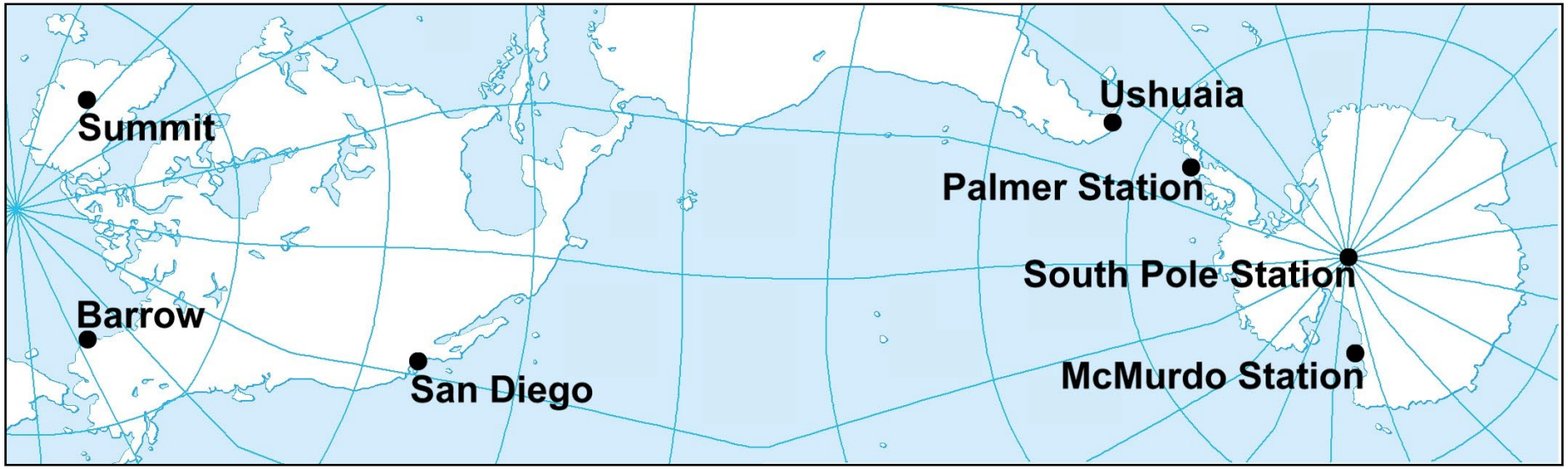
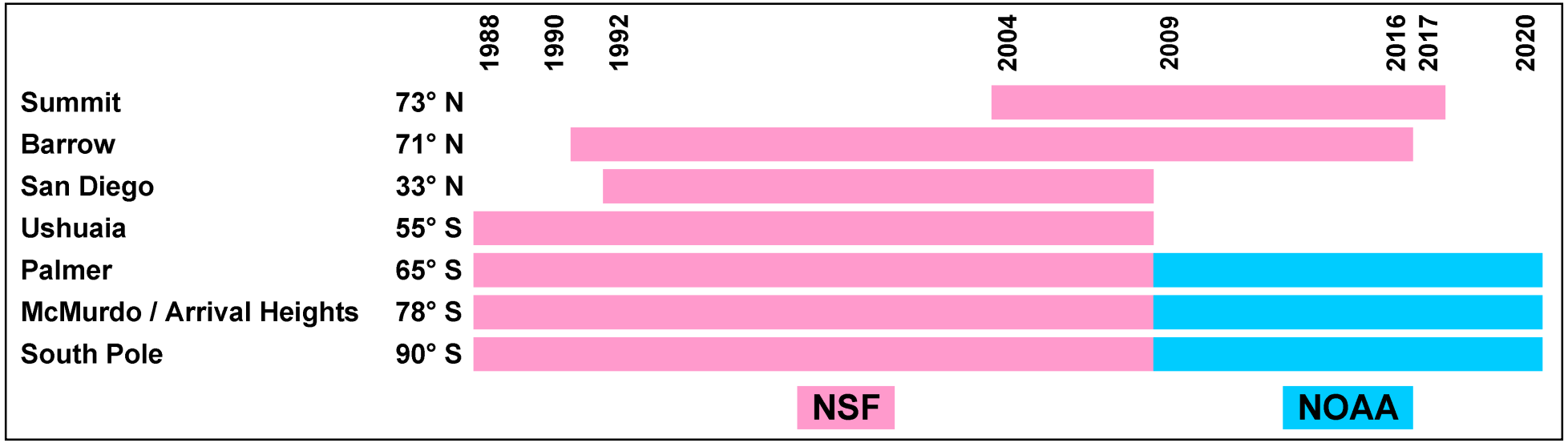
Outline

- History of observations
- Instrumentation and data products
- Success of Montreal Protocol in curbing UV
- Corrections for drifts in calibrations
- New trend estimates
- Conclusions

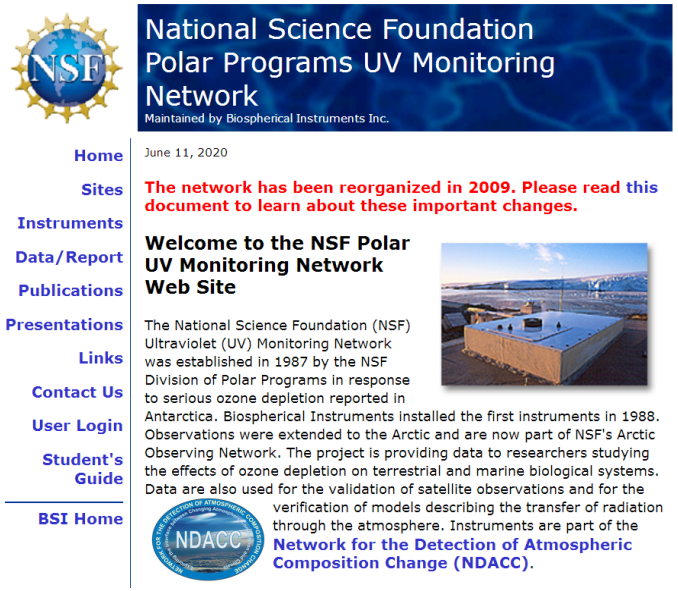
History and Milestones





Websites

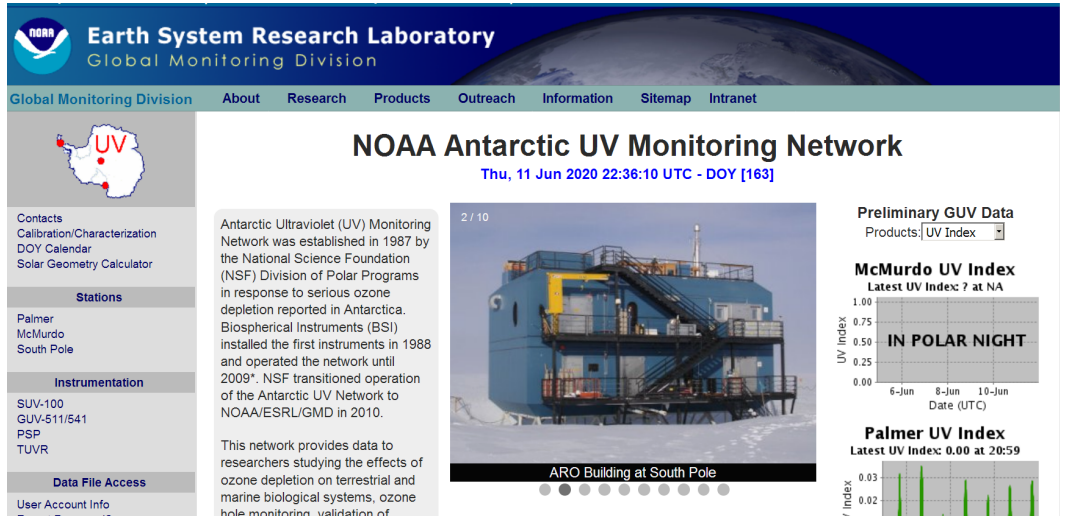
NSF Polar UV Monitoring Network



http://uv.biospherical.com

Data up to 2008

NOAA Antarctic UV Monitoring Network

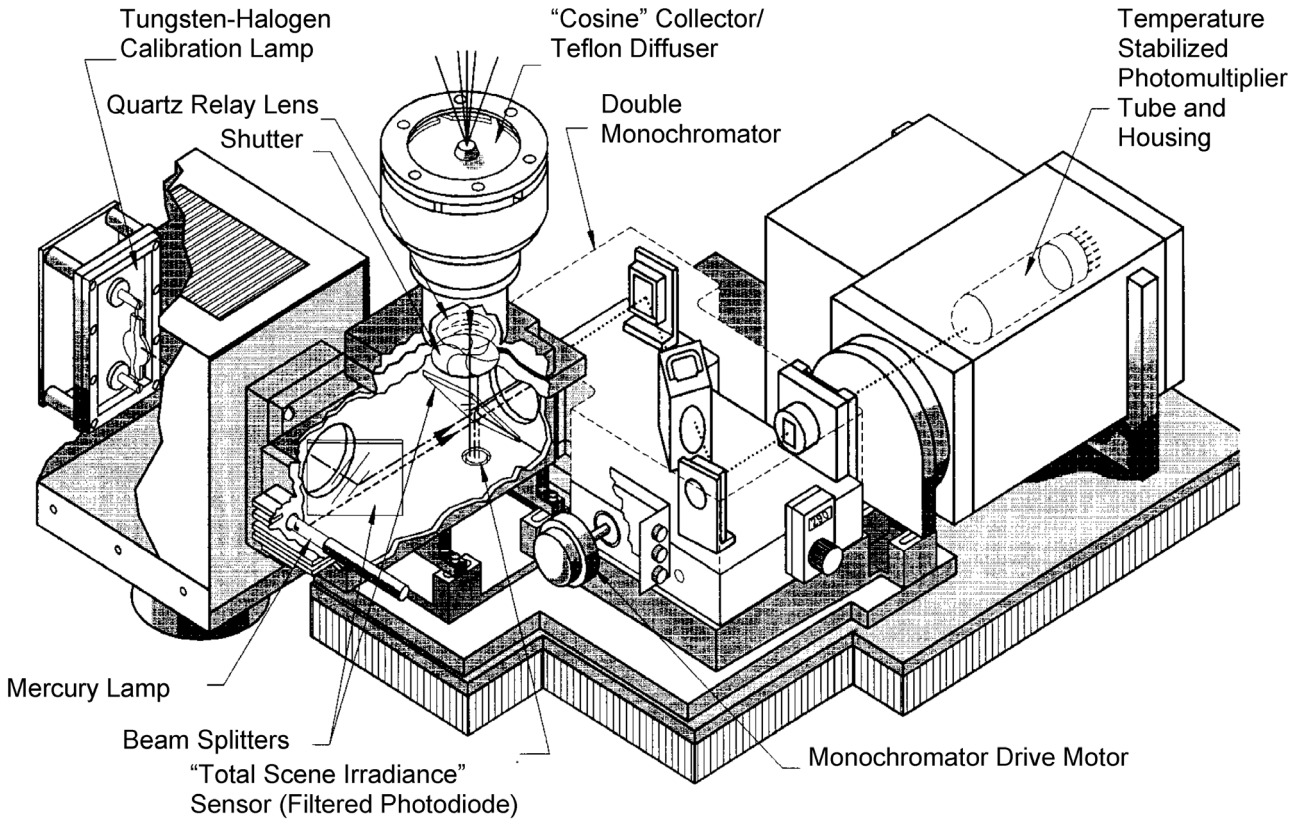


https://www.esrl.noaa.gov/gmd/grad/antuv/

Data from 2009

Instrumentation / Data Products

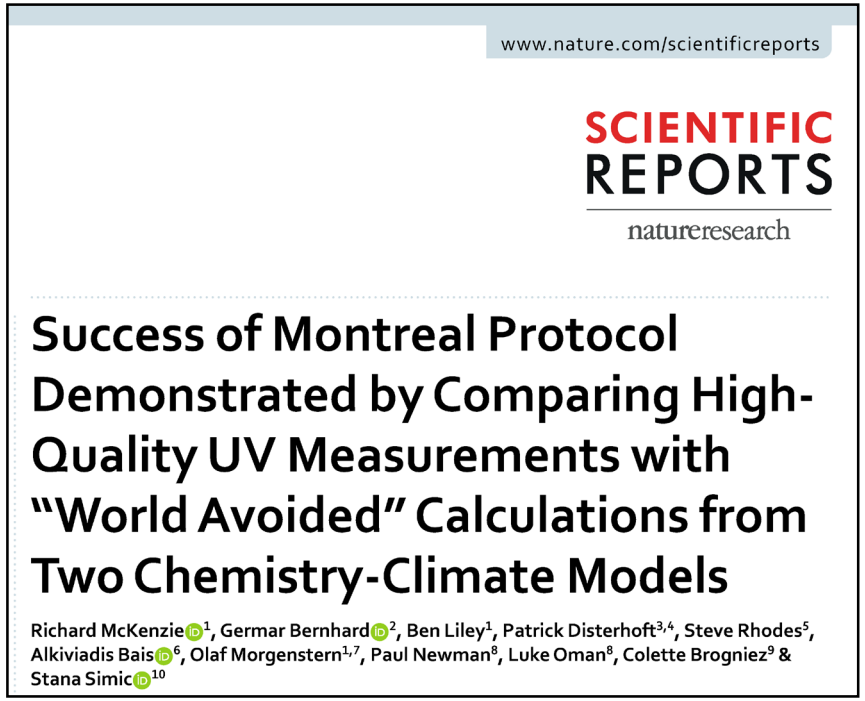
SUV-100 scanning spectroradiometer



Data Products

- Global spectral irradiance ("power per area and per wavelength") between 280 and 600 nm
- Biologically effective radiation levels (UV Index, Vitamin D synthesis, UV-B, UV-A)
- Total ozone
- Cloud optical depth
- Effective surface albedo
- Modeled spectra
- Actinic flux and photolysis rates
  $[O_3 \rightarrow O(^1D) + O_2;\ NO_2 \rightarrow NO + O(^3P)]$
- Ozone profiles (vertical distribution of ozone)

Success of Montreal Protocol in Curbing UV Radiation



McKenzie, R., G. Bernhard, B. Liley, P. Disterhoft, S. Rhodes, A. Bais, O. Morgenstern, P. Newman, L. Oman, C. Brogniez and S. Simic (2019). Success of Montreal Protocol demonstrated by comparing high-quality UV Measurements with "World Avoided" calculations from two chemistry-climate models, *Scientific Reports*, *9*, 12332, doi: https://doi.org/10.1038/s41598-019-48625-z.

Method:

Compare high-quality UV Index measurements at 17 sites with UV Index data that were:

- calculated from total ozone measurements;
- estimated from a chemistry-climate models (CCM) that represent "**World Expected**" scenario;
- estimated from CCMs that represent the "**World Avoided**" scenario.

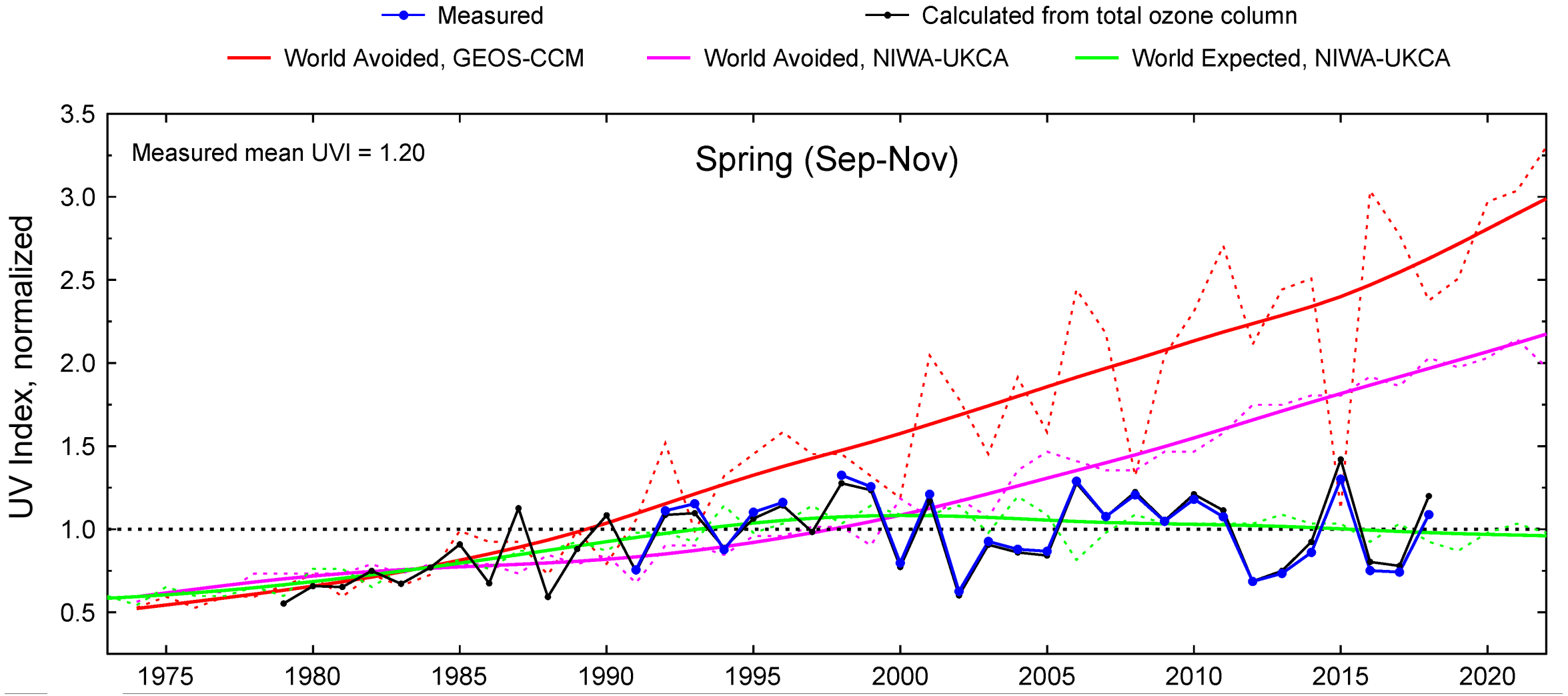
World Expected: Emissions of ozone-depleting substances are curbed in compliance with Montreal Protocol

World Avoided: Emissions of ozone-depleting substances continue to rise unabated without being controlled by the Montreal Protocol

Rationale:

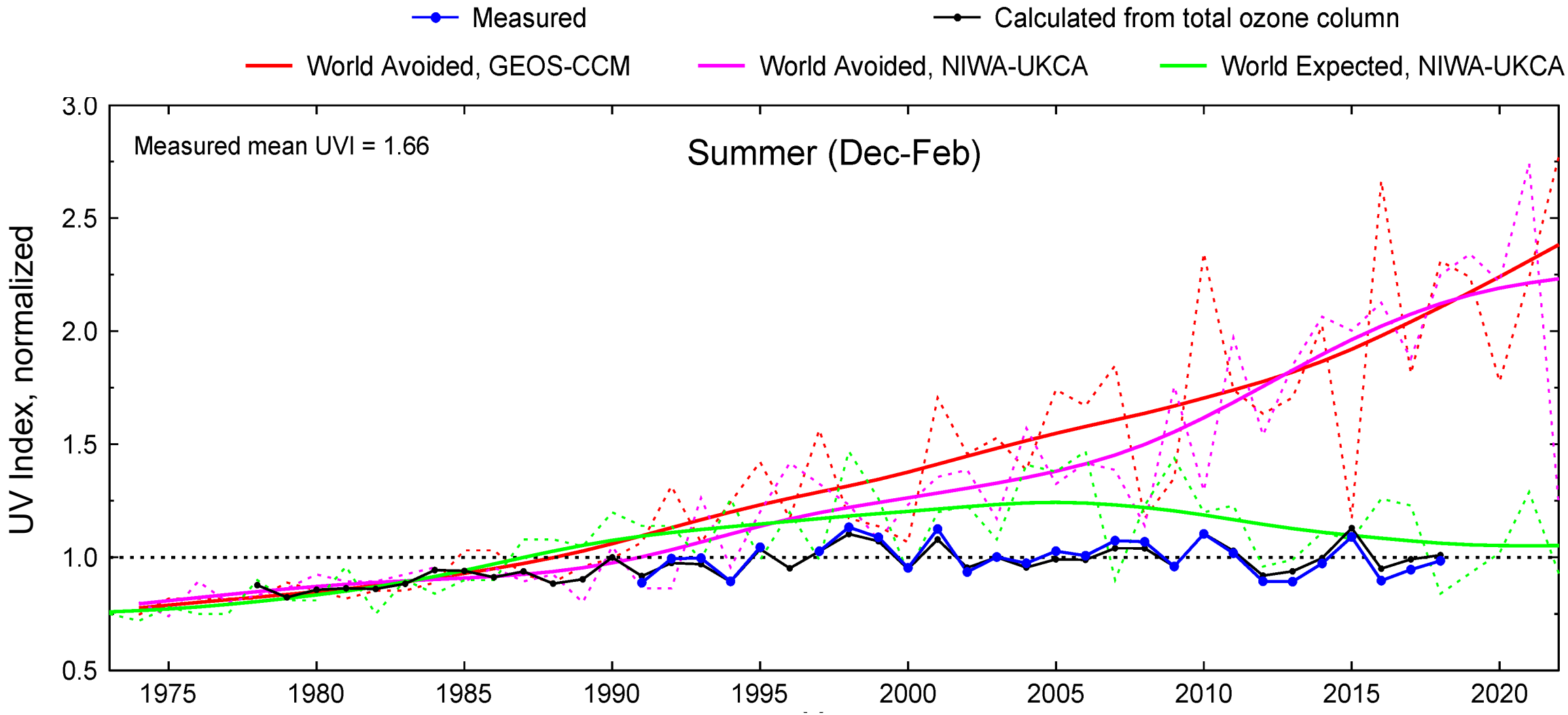
➔ Good agreement between measurements and World Expected simulations would give credibility to the World Avoided projections.

UV Measurements and Projections for South Pole, Spring



Part of Supplement of McKenzie et al. (2019), doi: https://doi.org/10.1038/s41598-019-48625-z.

UV Measurements and Projections for South Pole, Summer



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Decadal UV Index Trends since 1996, Spring

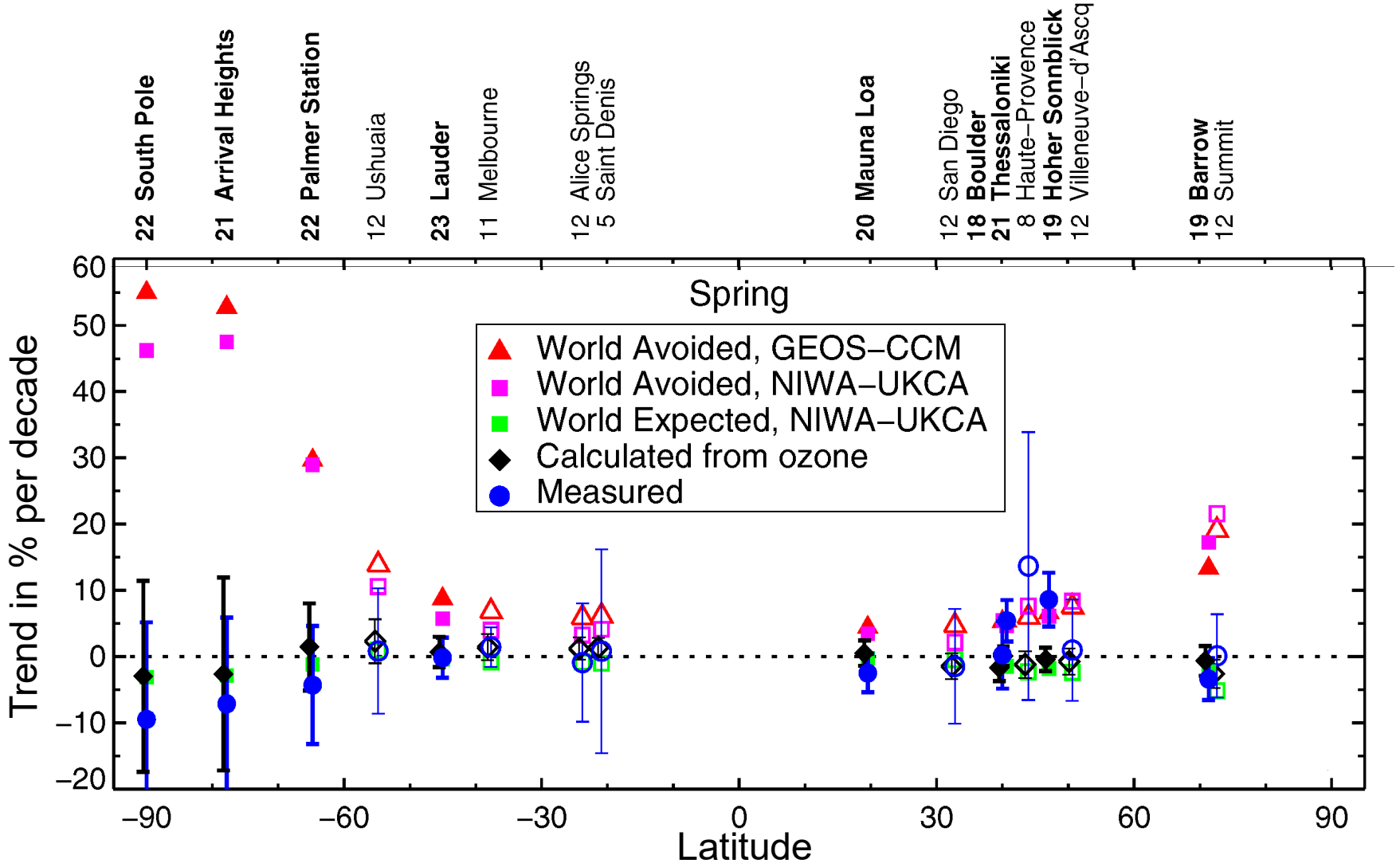


Figure 6 of McKenzie et al. (2019), doi: https://doi.org/10.1038/s41598-019-48625-z.

Decadal UV Index Trends since 1996, Summer

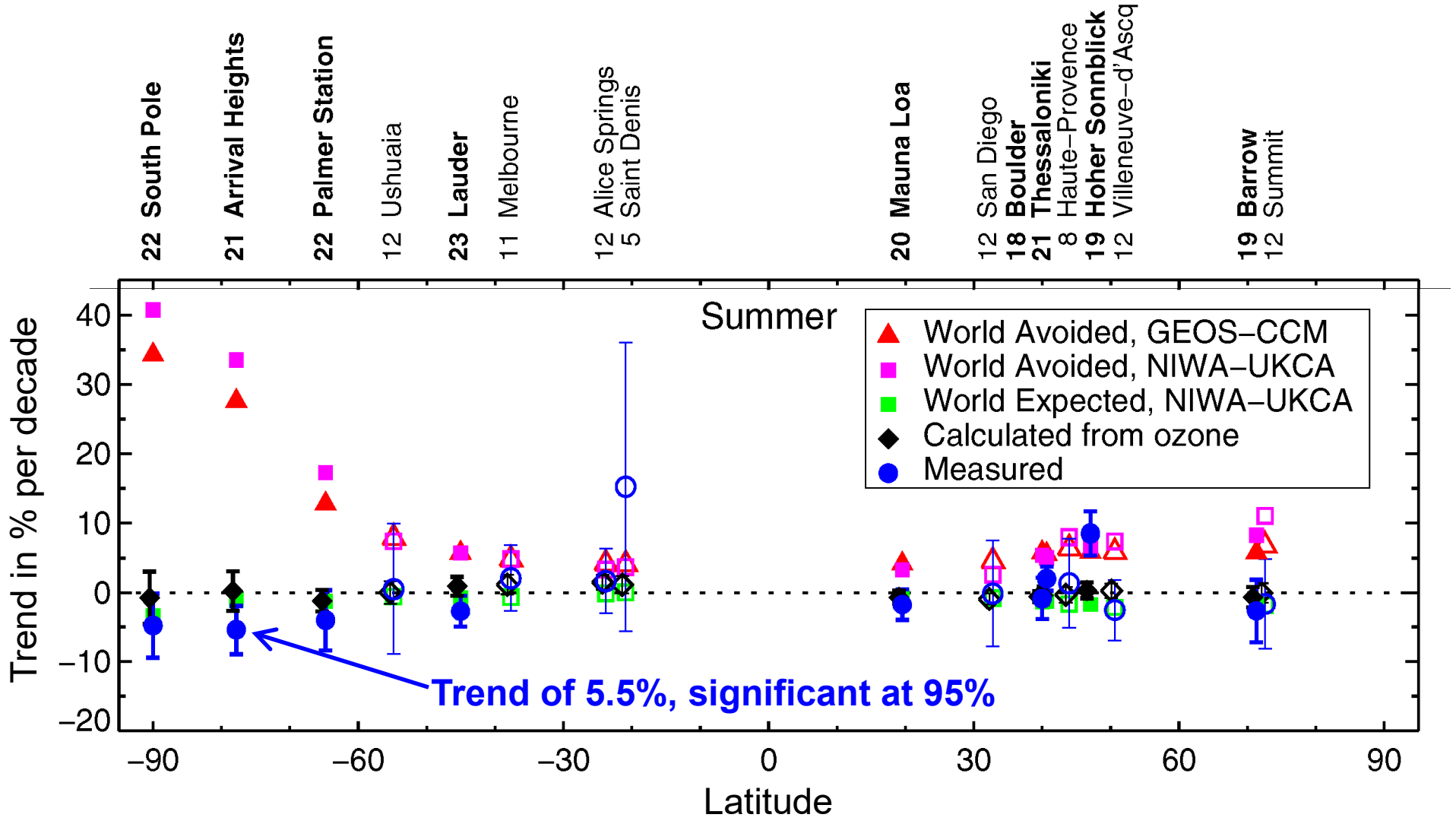


Figure 6 of McKenzie et al. (2019), doi: https://doi.org/10.1038/s41598-019-48625-z.

Drift of Calibrations?

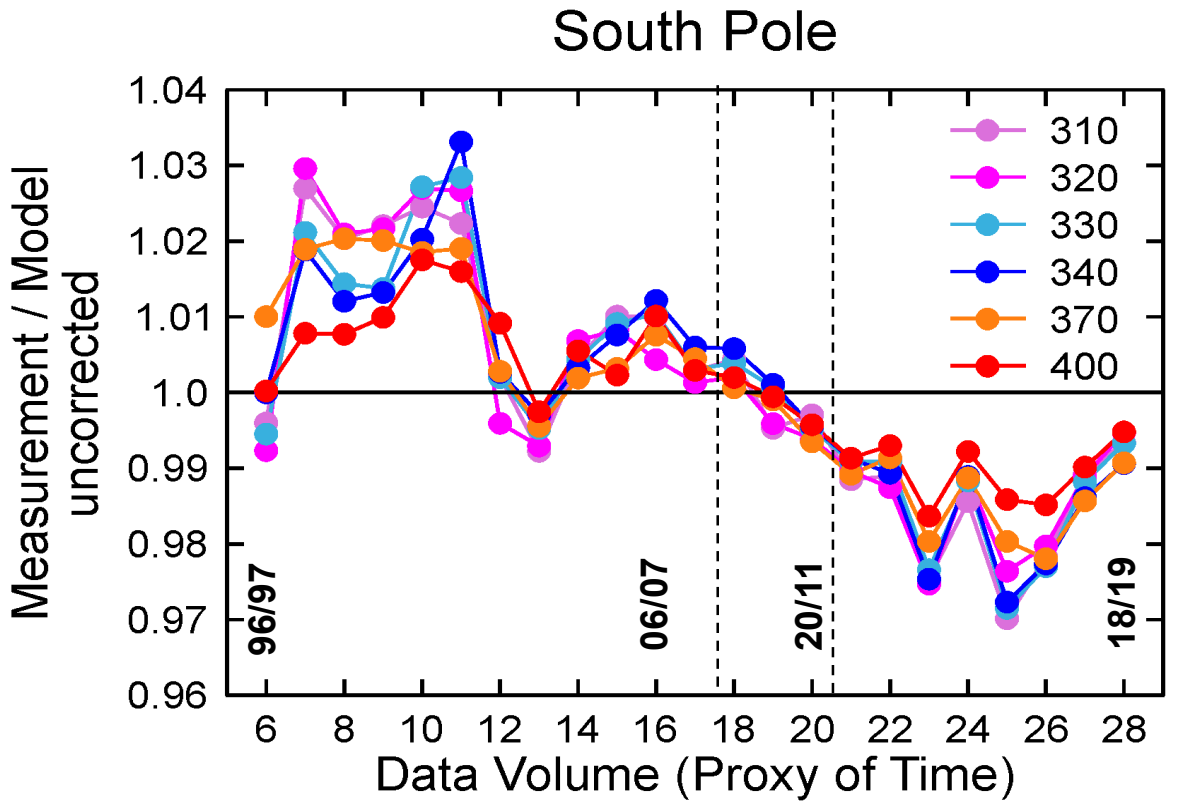
Caveat stated in *McKenzie et al.* (2019) paper:

"We also note that measurements at South Pole, Arrival Heights and Palmer Station are potentially affected by long-term drifts of approximately 1% per decade, which are associated with hardware modifications and changes in calibration standards."

Ratio of measured and modeled clear sky irradiance is decreasing since ~2006/2007

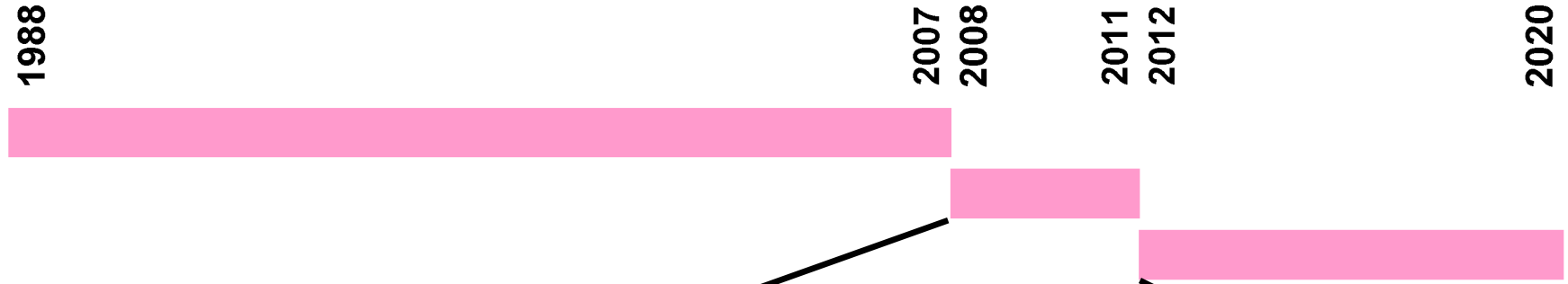
- Each data point is median of measurement / model of clear sky spectra for each Data Volume
- Model: libRadtran/UVSPEC radiative transfer model
- Model considers: total ozone, ozone profiles, pressure
- Surface albedo and aerosols are fixed

➔ Decrease in ratio could be explained by drift in calibrations or changes in albedo and aerosols

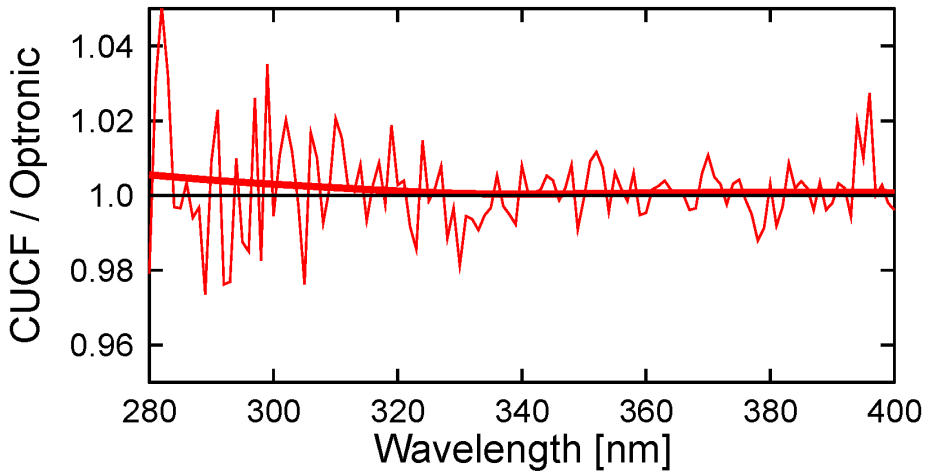


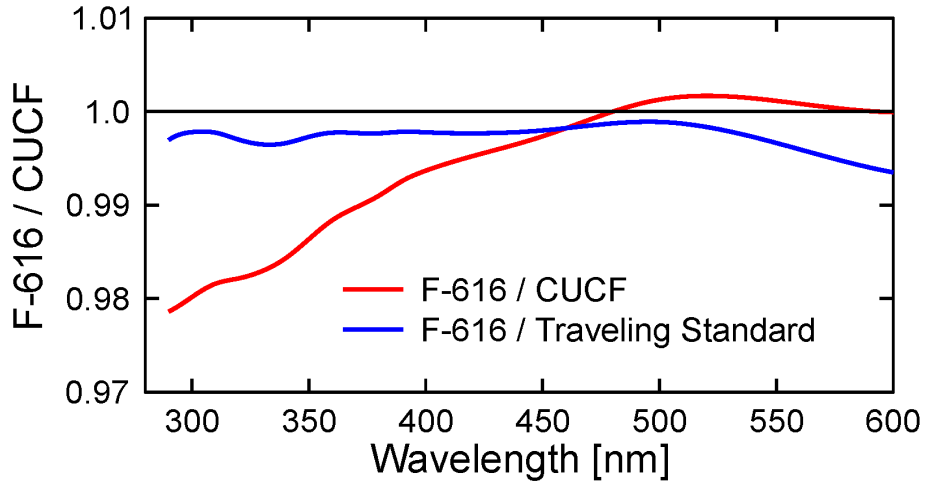
Change in Calibration Scale

Primary Scale of Spectral Irradiance over time



FEL Lamp

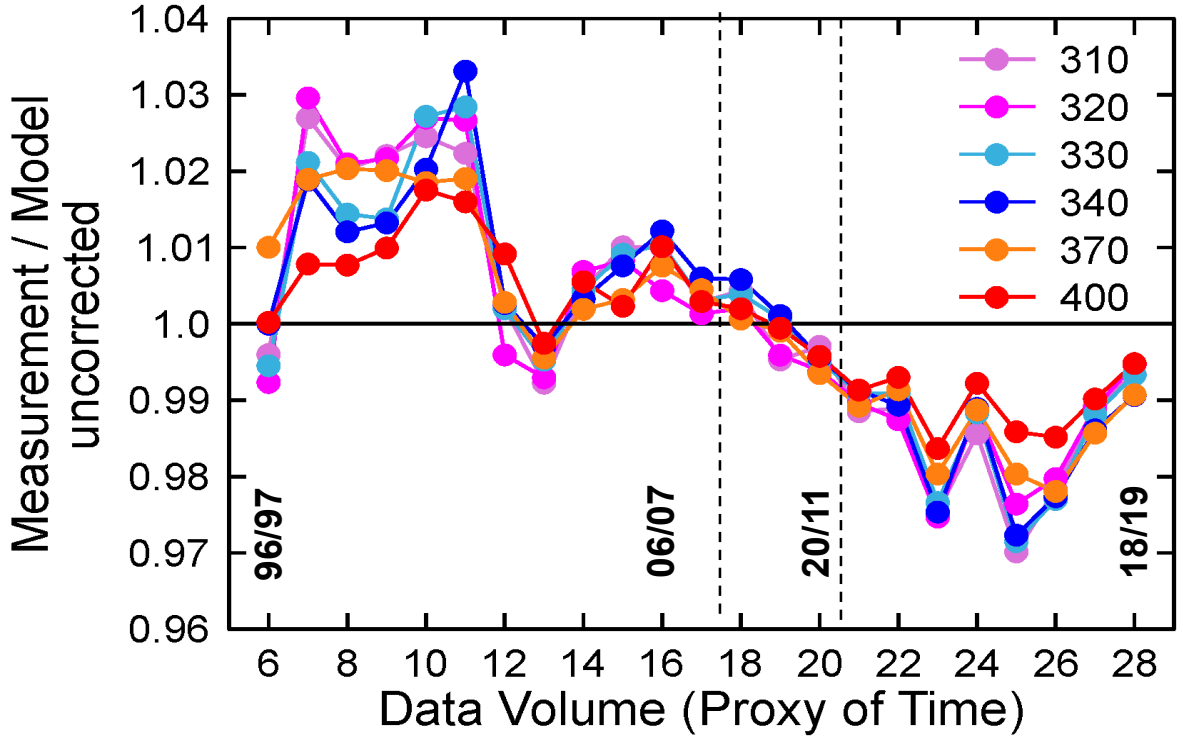




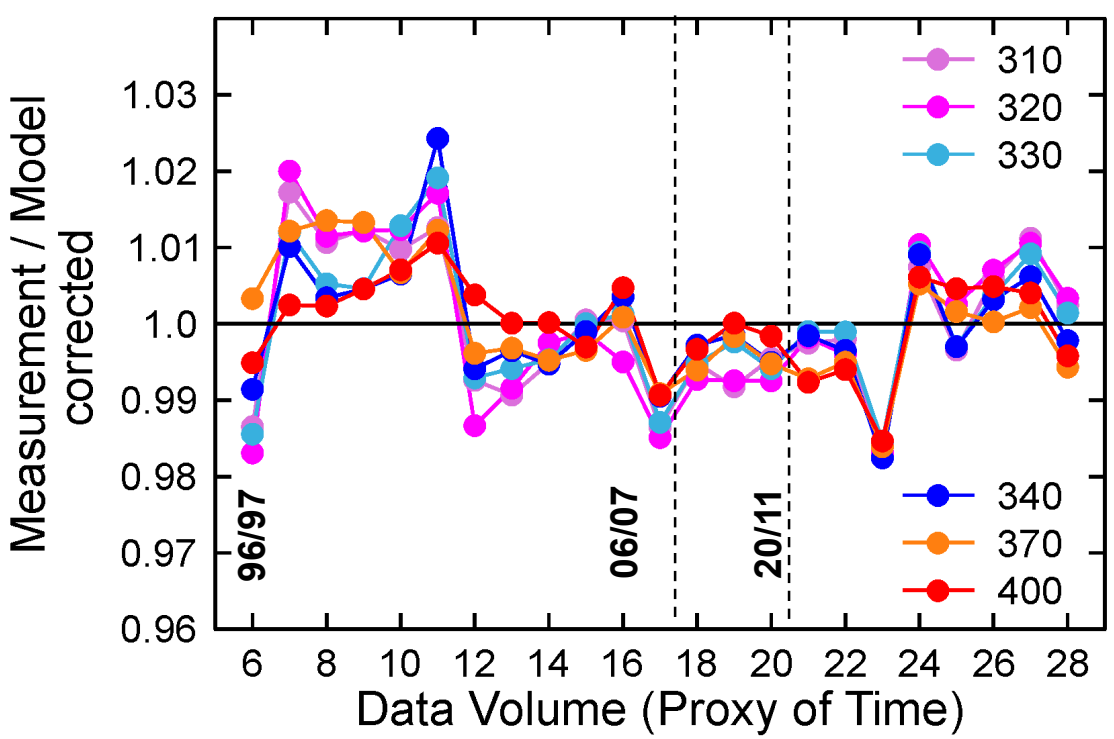
➔ UV Index with F-616 is low by 1.7%

Effect of Correction of Irradiance Scale

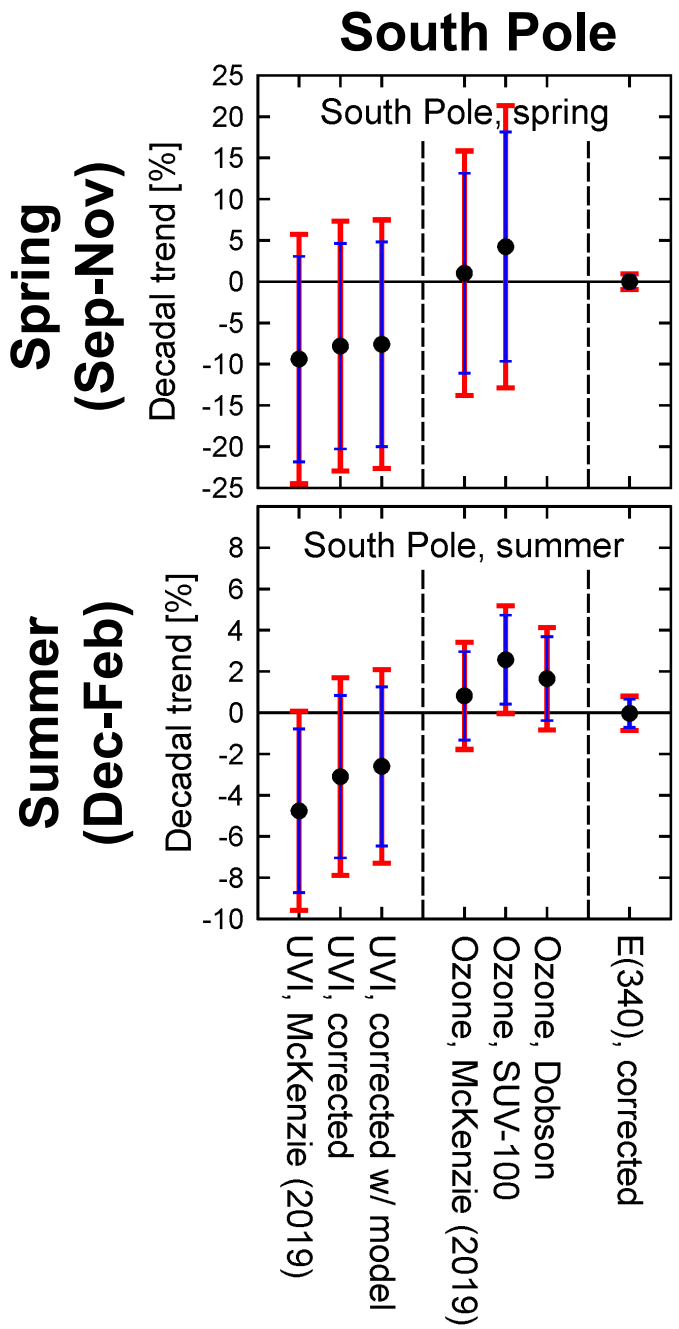
Uncorrected



Corrected



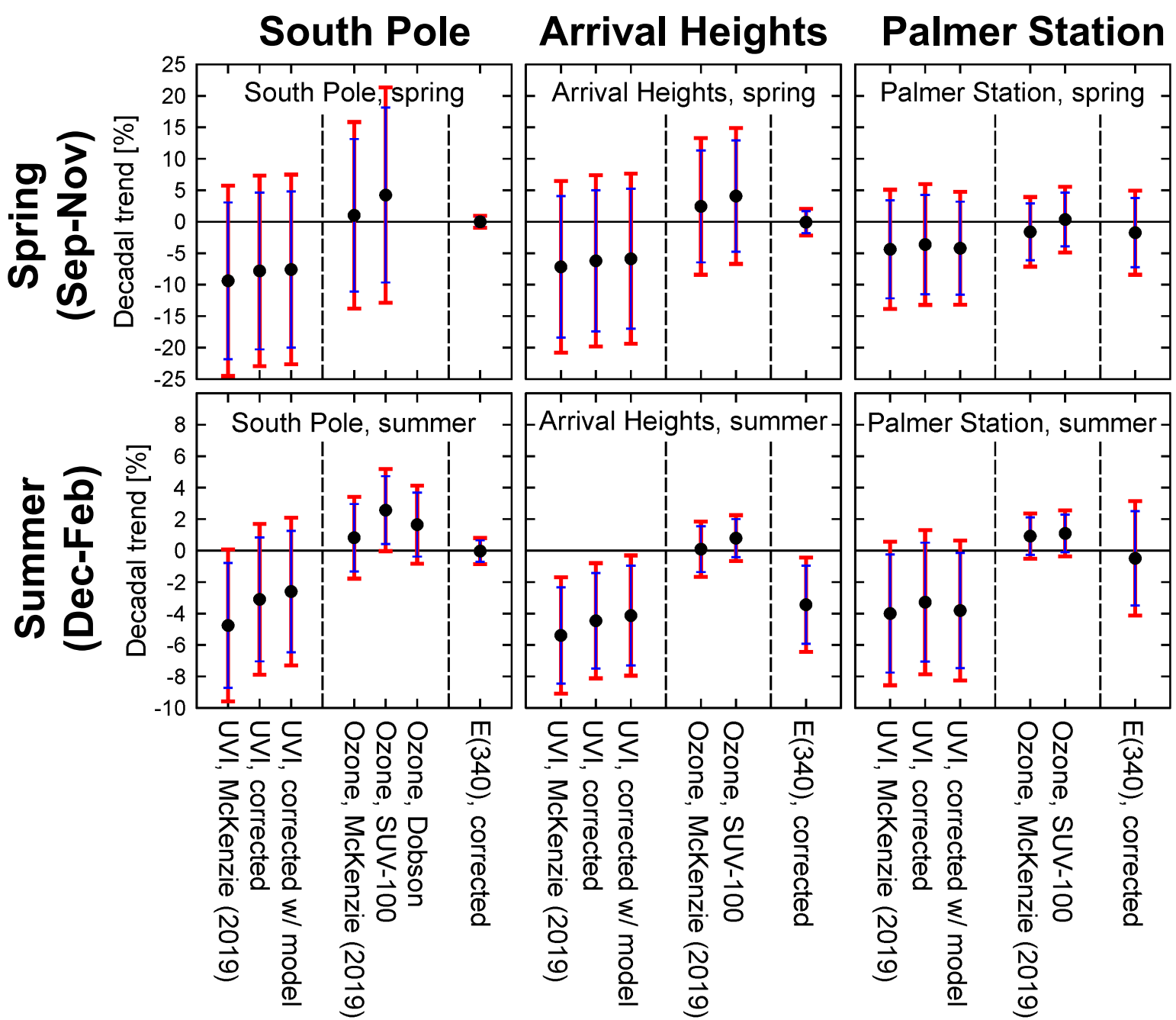
Trends, recalculated



Explanation of datasets

- UVI, McKenzie (2019)
  Trend in UV Index as published by McKenzie et al. (2019)
- UVI, corrected
  Trend in UV Index, corrected for drift in calibration scale
- UVI, corrected w/ model
  Trend in UV Index, corrected using RT model
- Ozone, McKenzie (2019) :
  Trend in total ozone data used by McKenzie et al. (2019)
- Ozone, SUV-100:
  Trend in total ozone measured by SUV-100 radiometer
- Ozone, SUV-Dobson:
  Trend in total ozone measured by Dobson at South Pole
- E(340), corrected:
  Trend in spectral irradiance at 340 nm, corrected for drift in calibration scale

Trends, recalculated



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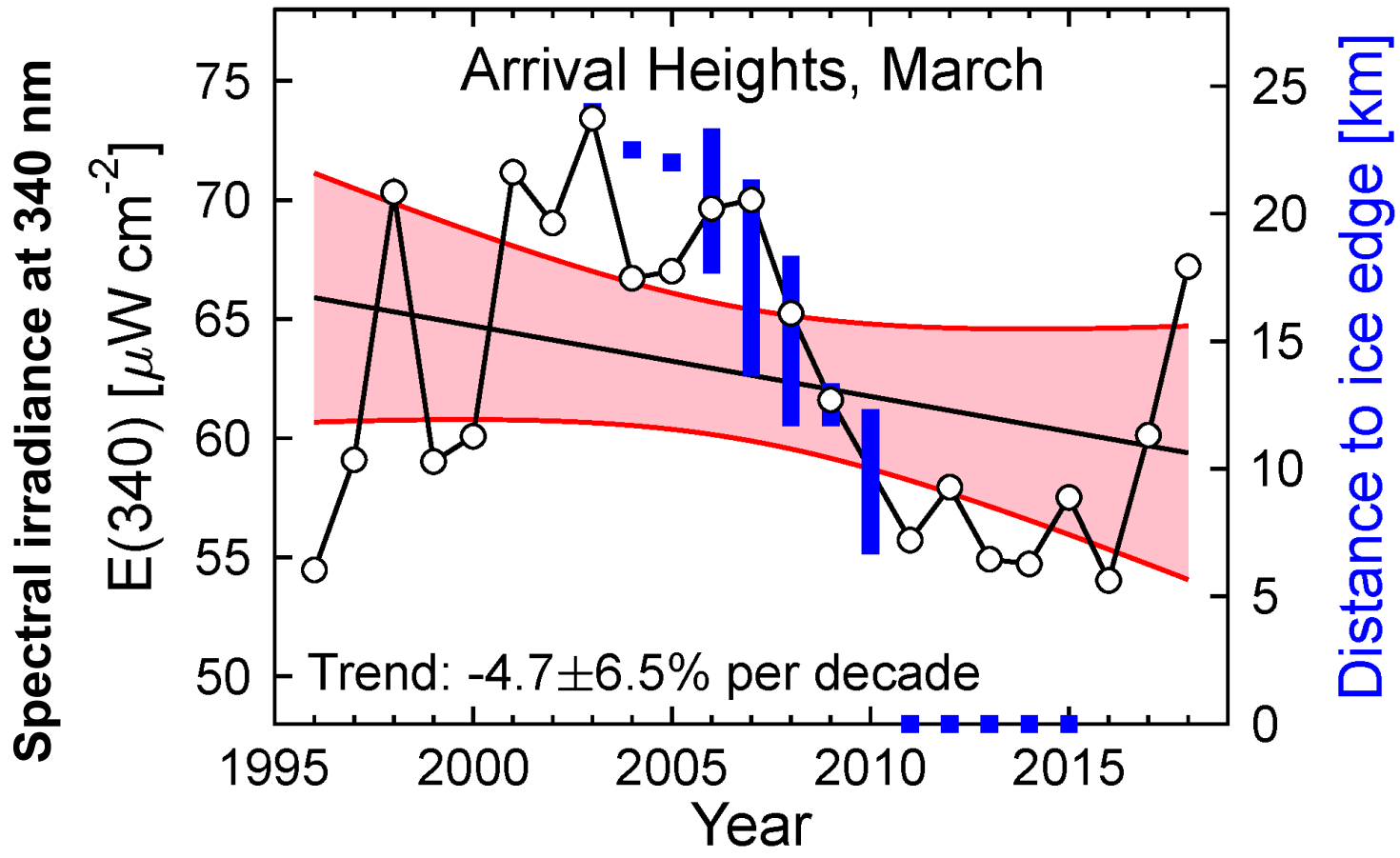
- Ozone, SUV-Dobson:
  Trend in total ozone measured by Dobson at South Pole
- E(340), corrected:
  Trend in spectral irradiance at 340 nm, corrected for drift in calibration scale

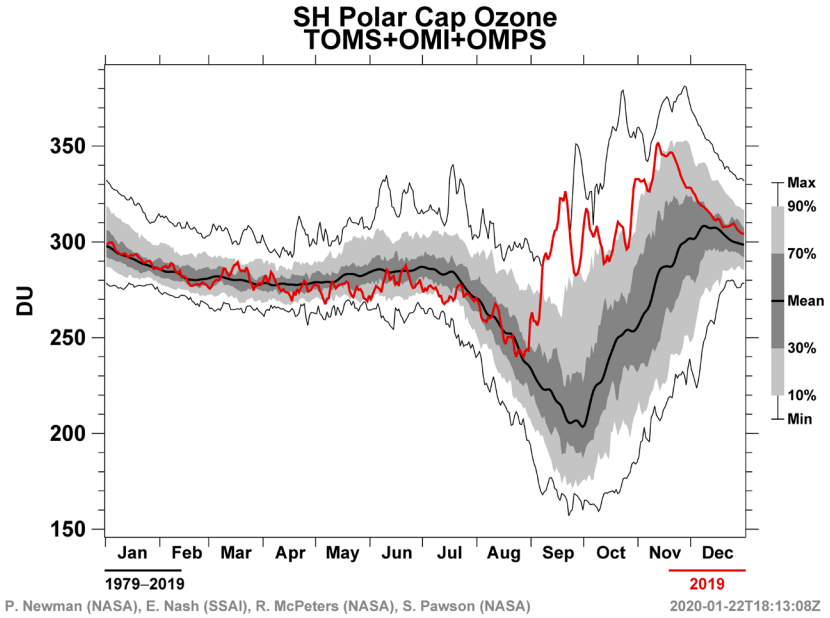
Effect of Fast Sea Ice on UV Irradiance at Arrival Heights



Distance to ice edge was inferred from Figure 3 of Kim, S., B. Saenz, J. Scanniello, K. Daly, D. and Ainley (2018). Local climatology of fast ice in McMurdo Sound, Antarctica. *Antarctic Science*, *30*(2), pp.125-142, doi: 10.1017/S0954102017000578.

Effect of Small Ozone Hole in Spring 2019 on Trends

https://research.noaa.gov/article/ArtMID/587/ArticleID/2566/2019-ozone-hole-smallest-on-record



https://ozonewatch.gsfc.nasa.gov

Decadal Trends, corrected for drift in calibration scale

	Season	Decadal Trend for period discussed by *McKenzie et al.* (2019)	Decadal Trend for 1996 – 2019/2020
South Pole	Spring	–7.8% ± 15.1%	–10.4% ± 14.4%
	Summer	–3.1% ± 4.7%	–3.5% ± 4.1%
Arrival Heights	Spring	–6.2% ± 13.6%	–7.8% ± 12.1%
	Summer	–4.5% ± 3.7%	–3.9% ± 2.8%

Conclusions

- Results confirmed the study by *McKenzie et al*. (2019) that UV Indices at the three Antarctic sites have been decreasing between 1996 and 2018, but trends for most months are not yet statistically significant.

- Decadal UV Index trends calculated from data corrected for drifts in calibrations are 0.7% – 1.7% smaller than those reported by *McKenzie et al*. (2019).

- For spring (September – November), statistically significant reductions in the UV Index have not yet been detected at any site because the ozone hole leads to large UV Index variability.
  It will likely take many more years until ozone recovery can be detected in UV data for spring.

- Trends in the UV Index are generally most significant for January and February.

  - At South Pole, significant decadal trends of –4.1% and –3.2% exist for January and February. These negative trends may be partly explained by positive trends in total ozone.
  - At Arrival Heights, a significant decadal trend of –4.5% is observed for summer. It can be explained with a significant upward trend in total ozone of 1.7% per decade for January plus the effect of changes in fast ice covering McMurdo Sound.

- Trends in the UV Index at Palmer station were generally not significant.