

# Volcanic forcing in the C20C+ D&A and HAPPI projects

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**This document examines the extent of volcanic forcing present in simulations submitted to the International CLIVAR Climate of the 20th Century Plus (C20C+) Detection and Attribution (D&A) project (Stone et al. In preparation) and/or the Half a degree Additional Warming, Prognosis and Projected Impacts (HAPPI) project (Mitchell et al. 2017). It is found that a number of submissions have errors in the volcanic forcing.**

## 1 Claimed volcanic forcing

The All-Hist and Nat-Hist experiment families in C20C+ D&A (and HAPPI for All-Hist) are intended to include the effects of changing historical natural forcings, including the effects of volcanic aerosols. Prompted by unexpected results in analyses by other researchers, this document intends to check that volcanic forcing has been included as claimed in the various submissions to both projects.

According to the table in (Stone et al. In preparation) and information on the web page detailing submissions to both projects (<http://portal.neresc.gov/c20c/data.html>) the following All-Hist/est1 submissions should include volcanic forcing.

- ARCCSS/ACCESS1-3/All-Hist/est1/v1-0
- CCCma/CanAM4/All-Hist/est1/v1-0
- ETH/CAM4-2degree/All-Hist/est1/v1-0
- LBNL/CAM5.1-0.25degree/All-Hist/est1/v1-0
- LBNL/CAM5.1-1degree/All-Hist/est1/v2-0
- LBNL/CAM5.1-2degree/All-Hist/est1/v1-1
- LBNL/CAM5.1.2-0.25degree/All-Hist/est1/v1-0
- LBNL/CAM5.1.2-0.25degree/All-Hist/est1/v1-0-aero
- MIROC/MIROC5/All-Hist/est1/v2-0
- MOHC/HadGEM3-A-N216/All-Hist/est1/v1-0
- MPI-M/ECHAM6-3-LR/All-Hist/est1/v1-1
- NOAA-ESRLandCIRES/CAM4/All-Hist/est1/v1-0
- NOAA-ESRLandCIRES/CAM5.1.1/All-Hist/est1/v1-0

The following submissions claim not to include volcanic forcing.

- NCC/NorESM1-HAPPI/All-Hist/est1/v1-0
- NOAA-ESRLandCIRES/ECHAM5.4All-Hist/est1/v1-0
- UCT-CSAG/HadAM3P-N96/All-Hist/est1/v2

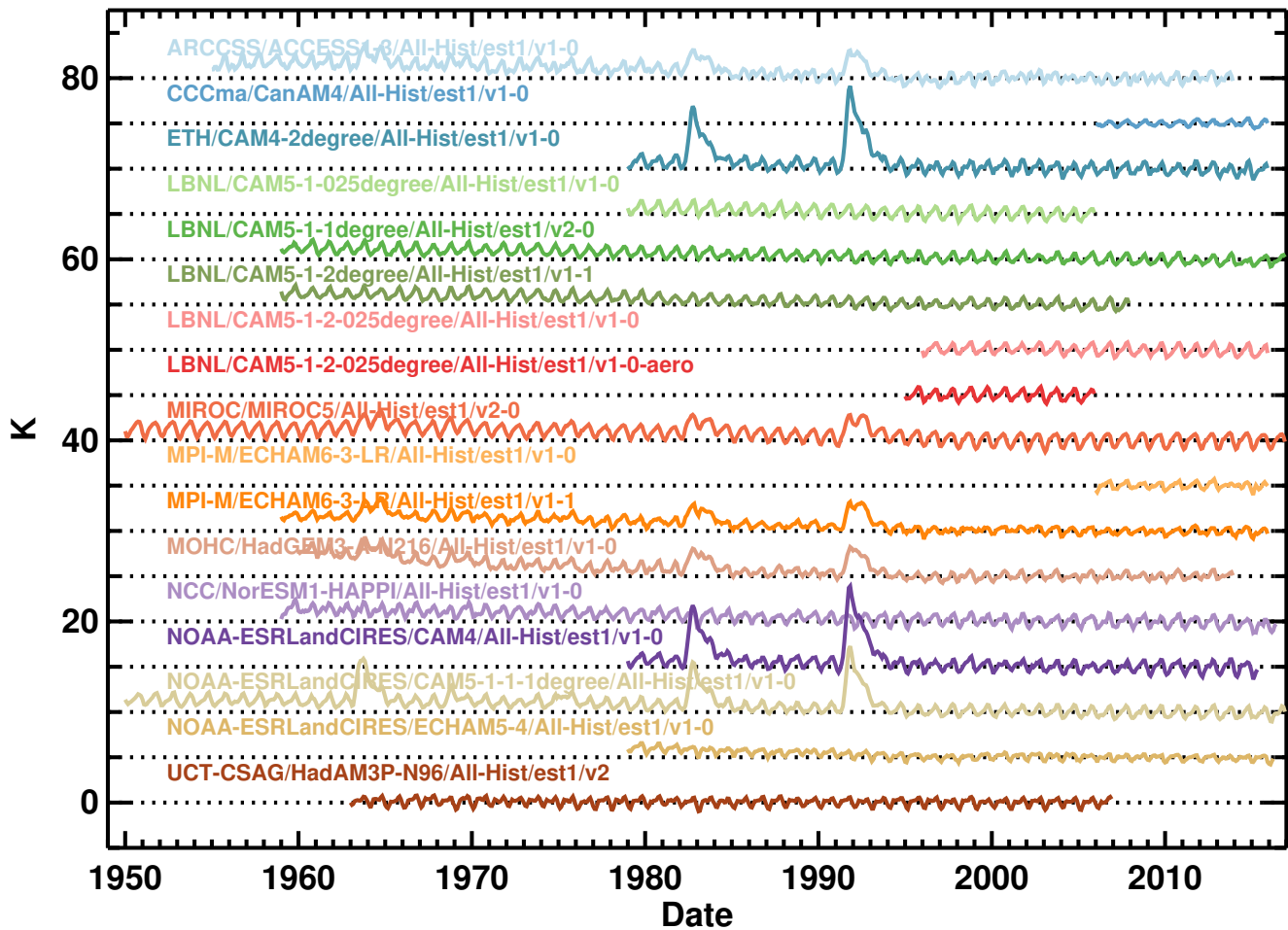


Figure 1: Globally averaged monthly mean temperature at 50 hPa from one simulation each from all All-Hist/est1 submissions to the C20C+ D&A and HAPPI projects. Data are from the longest available simulation. Values are anomalies from the annual mean, offset by multiples of 5 K for visibility.

## 2 Testing existence of volcanic forcing

Figure 1 shows the globally averaged monthly mean air temperature at 50 hPa from one (the longest) simulation from all of the submissions listed above. This level is in the lower stratosphere and would be expected to warm when volcanic aerosol concentrations increase in the stratosphere. Figure 2 shows the globally averaged outgoing shortwave radiation at the top of the atmosphere from submissions which include this output; it would also be expected to increase when volcanic aerosols increase.

Based on these figures, it appears that the following submissions do indeed include volcanic forcing, albeit the magnitude of the response to the forcing (and perhaps the forcing itself) varies considerably.

- ARCCSS/ACCESS1-3/All-Hist/est1/v1-0
- ETH/CAM4-2degree/All-Hist/est1/v1-0
- MIROC/MIROC5/All-Hist/est1/v2-0
- MOHC/HadGEM3-A-N216/All-Hist/est1/v1-0

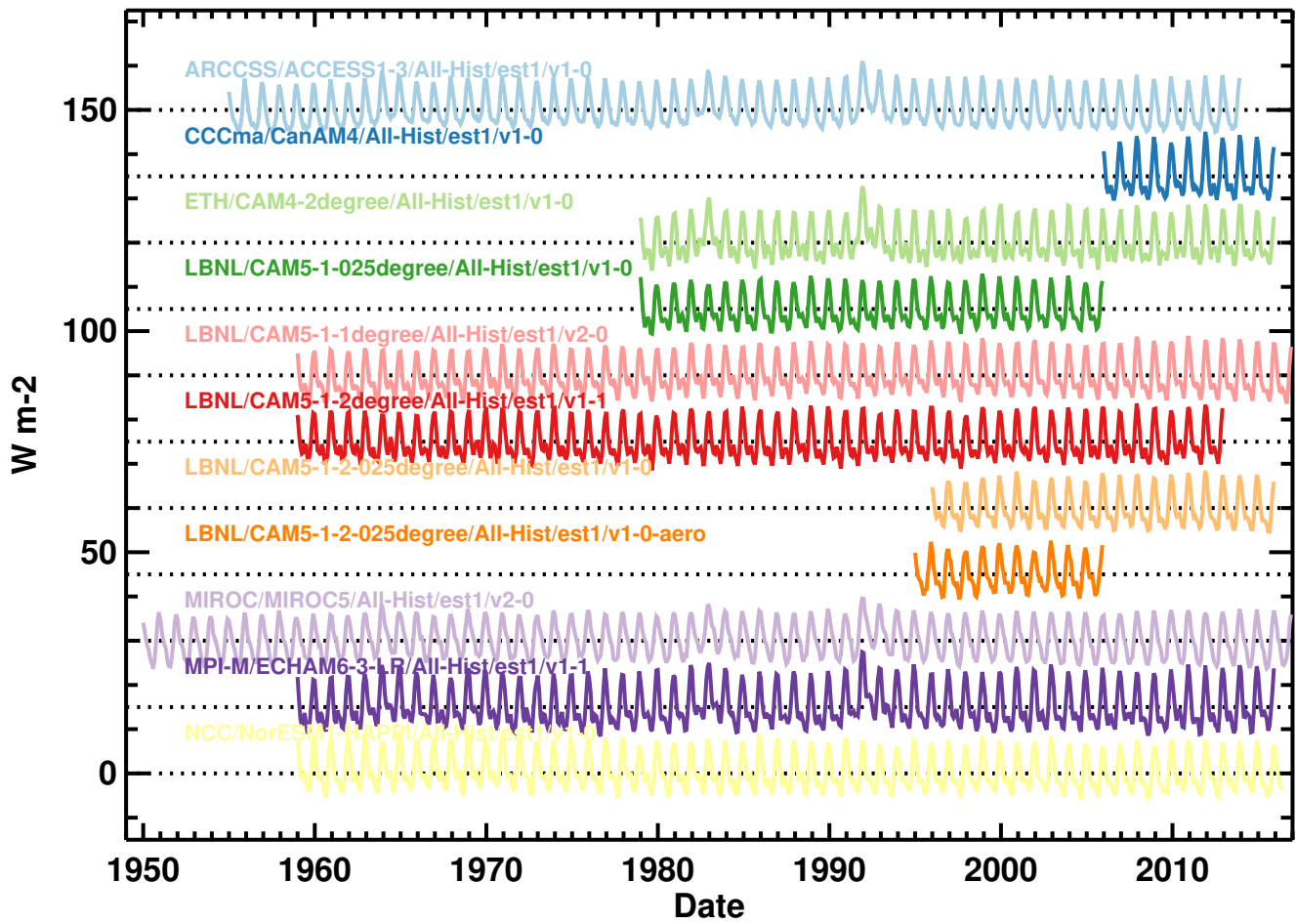


Figure 2: Globally averaged monthly mean outgoing shortwave radiation at the top of the atmosphere from one simulation each from most All-Hist/est1 submissions to the C20C+ D&A and HAPPI projects. This output is not available from some submissions. Data are from the longest available simulation (the same simulation used in Figure 1). Values are anomalies from the annual mean, offset by multiples of  $15 \text{ W}\cdot\text{m}^{-2}$  for visibility.

- MPI-M/ECHAM6-3-LR/All-Hist/est1/v1-1
- NOAA-ESRLandCIRES/CAM4/All-Hist/est1/v1-0
- NOAA-ESRLandCIRES/CAM5.1.1/All-Hist/est1/v1-0

However, the following submissions do not include volcanic forcing. Note that the absence is inferred for LBNL/CAM5.1.2-0.25degree/All-Hist/est1/v1-0, even though it does not include a simulation overlapping a period of major volcanic activity, because it was based on the same setup files as other submissions in this list.

- LBNL/CAM5.1-0.25degree/All-Hist/est1/v1-0
- LBNL/CAM5.1-1degree/All-Hist/est1/v2-0
- LBNL/CAM5.1-2degree/All-Hist/est1/v1-1
- LBNL/CAM5.1.2-0.25degree/All-Hist/est1/v1-0
- NCC/NorESM1-HAPPI/All-Hist/est1/v1-0
- NOAA-ESRLandCIRES/ECHAM5.4All-Hist/est1/v1-0
- UCT-CSAG/HadAM3P-N96/All-Hist/est1/v2

The inclusion of volcanic forcing cannot be verified for the following submissions because of a lack of output data available at the time of major eruptions. Thus they can in effect be considered to have volcanic forcing.

- CCCma/CanAM4/All-Hist/est1/v1-0
- LBNL/CAM5.1.2-0.25degree/All-Hist/est1/v1-0-aero

Figure 3 shows the 50 hPa time series from the HAPPI Plus15-Future/CMIP5-MMM-est1 submissions. There are no major eruptions during the period imitated by these simulations, and indeed none appear to have occurred in any of the submissions.

### 3 A volcanic forcing bug in CESM1

The five LBNL and NCC submissions lacking volcanic responses are all based on the Community Earth System Model 1 (CESM1). Figure 4 shows the globally averaged monthly mean mass mixing ratio of volcanic aerosol output from the same simulation of LBNL/CAM5.1-1degree/All-Hist/est1/v2-0 used in the generation of the other figures. There appears to be a bug in CESM1 such that it reads and outputs volcanic aerosol data, but neglects to show that data to the radiation scheme.

The LBNL/CAM5.1.2-0.25degree/All-Hist/est1/v1-0-aero contribution was run with prescribed aerosol emissions, instead of the prescribed concentrations used for the other CESM1-based submissions. It may be that the prognostic aerosol concentrations are shown to the radiation scheme, as the setup is more similar to the NOAA-ESRLandCIRES/CAM5.1.1-1degree/All-Hist/est1/v1-0 configuration; however, the simulations do not overlap periods of major volcanic activity, so it is not possible to confirm it at the moment.

## References

Mitchell, D., K. AchutaRao, M. Allen, I. Bethke, U. Beyerle, A. Ciavarella, P. M. Forster, J. Fuglestedt, N. Gillett, K. Haustein, W. Ingram, T. Iversen, S. Khari, N. Klingaman, N. Massey, E. Fischer, C.-F. Schleussner, J. Scinocca, O. Seland, H. Shiogama, E. Shuckburgh, S. Sparrow, D. Stone, P. Uhe, D. Wallom, M. Wehner, and R. Zaaboul, 2017: Half a degree additional warming, prognosis and projected impacts (HAPPI): background and experimental design. *Geosci. Model Dev.*, **10**, 571–583.

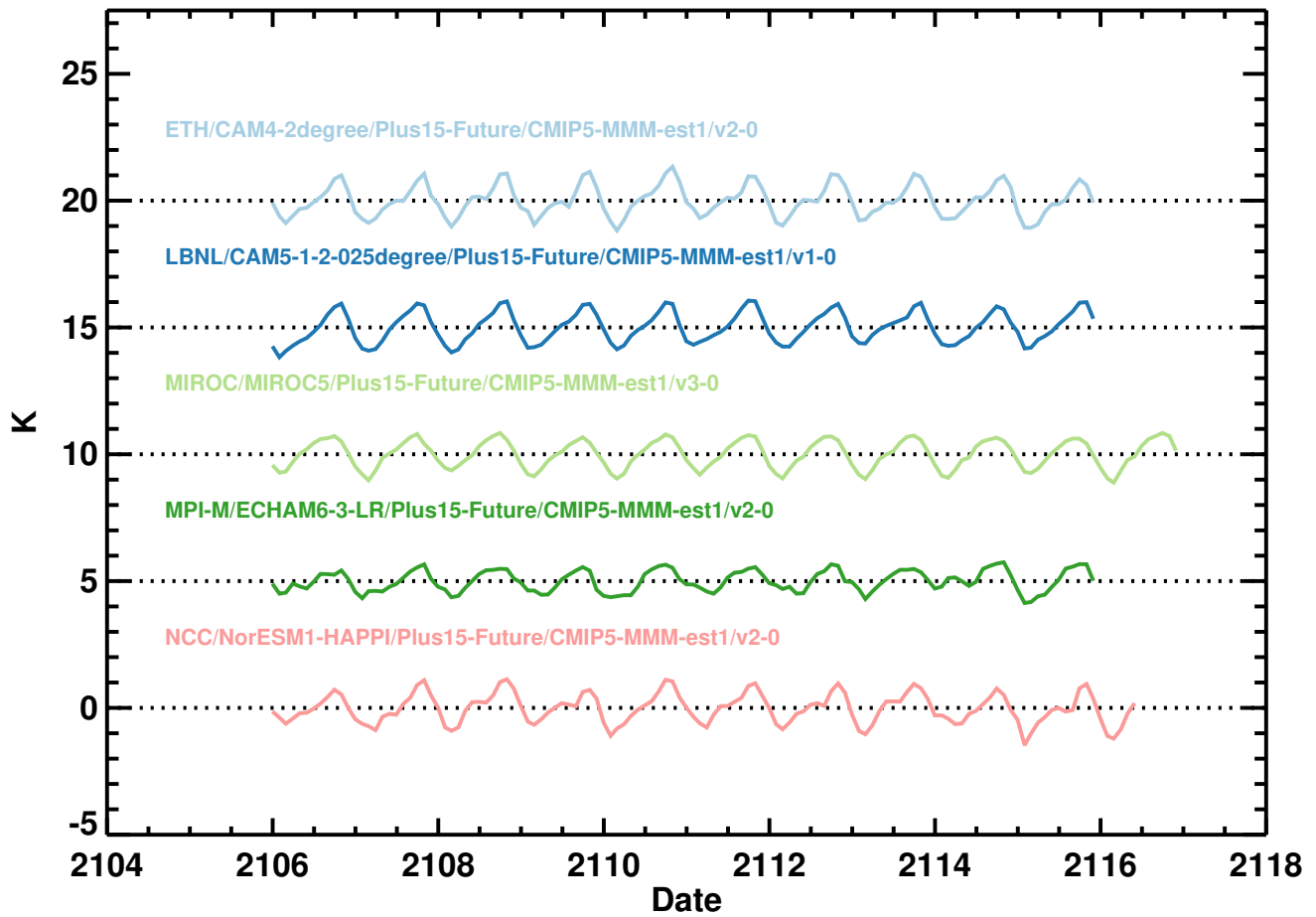


Figure 3: Globally averaged monthly mean temperature at 50 hPa from one simulation each from all Plus15-Future/CMIP5-MMM-est1 submissions to the HAPPI project. Values are anomalies from the annual mean, offset by multiples of 5 K for visibility.

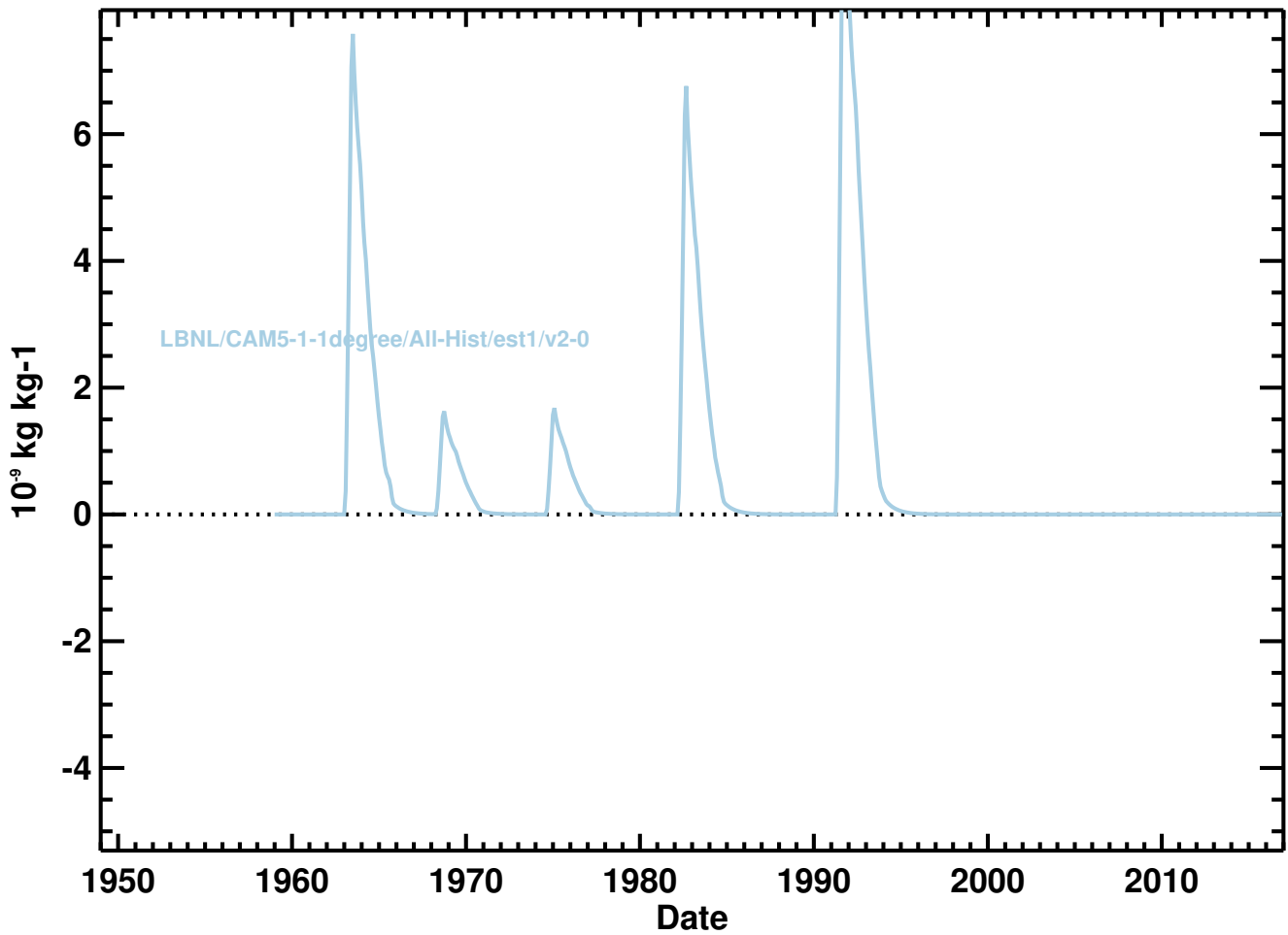


Figure 4: Globally averaged monthly mean mass mixing ratio of volcanic aerosol, output from a simulation of LBNL/CAM5.1-1degree/All-Hist/est1/v2-0. Data are from the same simulation used in the other figures.

Stone, D. A., N. Christidis, C. Folland, S. Perkins-Kirkpatrick, J. Perlwitz, H. Shiogama, M. F. Wehner, P. Wolski, S. Cholia, H. Krishnan, D. Murray, O. Angéilil, U. Beyerle, A. Ciavarella, A. Dittus, and X.-W. Quan, In preparation: Experiment design of the international clivar c20c+ detection and attribution project. *Weather and Climate Extremes*.