ABERRATIONS FROM BACKGROUND CLIMATE: CAUSES AND TIMESCALES

Aspen Global Change Institute: Future of Past Climate
Dr. Sierra Petersen – University of Michigan
ABERRATION: a definition

A departure from what is normal, usual, or expected.....typically one that is unwelcome

An irregularity, rarity, anomaly, deviation
What is background climate?
What is background climate? What counts as an aberration?
What is background climate?
What counts as an aberration?

TIMESCALES, TIMESCALES, TIMESCALES...
What is background climate? What counts as an aberration?

TIMESCALES, TIMESCALES, TIMESCALES...

(and rates of change)
Is anthropogenic warming an aberration?
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0.5°C over ~100 years vs. 0.2°C over ~1000 years

PAGES2k
Mann et al. 2008
HadCRUT4 instrumental data
Zooming out...
2,000 years

Marcott et al., 2013
Holocene Climate
10,000 years

Slow change on order 1°C over 1000’s of years

Marcott et al., 2013
Glacial \rightarrow \text{Interglacial} \\
20,000 \text{ years}

Larger temperature change, still relatively “slow”
Glacial Climate
~100,000 years

NGRIP $\delta^{18}O_{ice}$ (% SMOW)

Dansgaard-Oeschger cycles

Heinrich Events

Age (kya)
Dansgaard-Oeschger Cycles
~1500 yrs/cycle

- 8-16°C atmospheric warming in years to decades (over Greenland)
- Rapid warming likely due to abrupt changes in sea ice cover in Nordic Seas
- Some involvement of AMOC
Dansgaard-Oeschger Cycles ~1500 yrs/cycle

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...but is this unusual behavior?
Plio-Pleistocene Ice Age Cycles

Lisiecki & Raymo, 2004
Dansgaard-Oeschger Cycles
In previous ice ages?

d(ANT_d18Oice)/dt \propto 1/GRN_d18Oice

Although abrupt, maybe not that unusual...
Heinrich Events

[Image of a map showing the distribution of Heinrich Events across North America, with arrows indicating ice sheet retreat and deposition layers.

A diagram illustrating the sea level changes and ice sheet dynamics over different time periods (10,500 BP, 14,000 BP, 21,000 BP, 28,000 BP, 40,000 BP, 51,000 BP, 63,000 BP), labeled H-0 through H-6.]
Heinrich Events

Bond et al., 1992
Heinrich Events

Bond et al., 1992

Seierstad et al., 2014
Heinrich Events

Bassis, Petersen, & Cathles, 2017
No special physics required to make a Heinrich Event
Heinrich Events

Bond et al., 1992

Hodell et al., 2008
Again, occurring over multiple glacial cycles
Classes of aberrations

- Temperature changes
  - e.g. D-O’s, PETM
- Ice Sheet changes
  - e.g. HE’s, EOT
- Ocean Anoxic Events
- Mass Extinctions
- Global Shifts
  - e.g. Rise of pO$_2$, Evolution
MASS Extinction throughout Earth History

- All genera
- "Well-defined" genera
- Trend line
- "Big Five" mass extinctions
- Other mass extinctions

Rodhe & Muller, 2005 via Andersen at INESAD
Extinction throughout Earth History

“Short-lived” genera
(living < 45 Myr)

“Long-lived” genera
(living > 45 Myr)
Impacts, Volcanism & Mass Extinction

Caldiera & Rampino, 2017
Cretaceous-Paleogene Mass Extinction

Caldiera & Rampino, 2017
Cretaceous-Paleogene Boundary

Seymour Island, Antarctica

Petersen et al., 2016
Cretaceous-Paleogene Boundary

Temperature (°C)

Age (Ma)

Meyer, Petersen, et al., in review

Petersen et al., 2016

?? 67.4+/-0.3 ??

Main Phase Deccan Extinction Events

[29N 30N 31N 30R 29R 29N]

69.0 68.5 68.0 67.5 67.0 66.5 66.0 65.5
Non-Deccan

Meyer, Petersen, et al., in review

Cretaceous-Paleogene Boundary

Late Maastrichtian with multiple age constraints
Maastrichtian (biostratigraphy)
Late Campanian to Early Maastrichtian
Modern Mollusks
Pleistocene MIS 5e

Seymour Island (Antarctica)
Pee Dee River (South Carolina)
Neuquén Basin (Argentina)
Kharga Oasis (Egypt)
Fezzan (Libya)
Mt. Katmai (Alaska)
North Slope (Alaska)
Merced County (California)
Scania (Sweden)
San Juan Islands (Washington)
Cauvery Basin (India)
Providence (Rhode Island)
South River (Virginia)
Lake Tahoe (California)
Spectacle Island (Massachusetts)
Rocky Bay (Bermuda)

Proposed modern anthropogenic [Hg] background
Proposed pre-industrial [Hg] background

15.9 km downstream
7.8 km downstream
1.1 km downstream

[<Hg> (ng g\(^{-1}\); ppb)]
Cretaceous-Paleogene Boundary

Non-Deccan

Modern

Late Campanian to Early Maastrichtian

Pleistocene MIS 5e

Proposed pre-industrial [Hg] background

Modern Mollusks

Proposed modern anthropogenic [Hg] background

[Hg] (ng g$^{-1}$; ppb)

- Moscow Landing (Alabama)
- Seymour Island (Antarctica)
- Pee Dee River (South Carolina)
- Neuquén Basin (Argentina)
- Kharga Oasis (Egypt)
- Fezzan (Libya)
- Mt. Katmai (Alaska)
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Late Maastrichtian with multiple age constraints

Maastrichtian (biostratigraphy)

Maastrichtian (altered?)

Late Campanian to Early Maastrichtian

Modern Mollusks

Pleistocene

MIS 5e

Proposed modern anthropogenic [Hg] background

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Non-Deccan

Modern

Meyer, Petersen, et al., in review
Non-Deccan  Modern  Deccan-aged

Meyer, Petersen, et al., in review

Cretaceous-Paleogene Boundary

Late Campanian to Early Maastrichtian  Pleistocene

Modern Mollusks

Maastrichtian (biostratigraphy)  Maastrichtian (altered?)

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Moscow Landing (Alabama)  Seymour Island (Antarctica)  Merced County (California)  North Slope (Alaska)
Hg levels on par with modern polluted site, lasting Myr.
Aberrations from background climate...

Shocking in the moment, but possibly not that unusual over geologic time

- PETM
- K-Pg extinction
- ....