Eolian Deposition Patterns in the Eastern Equatorial Pacific Ocean and the Paleo-climate of the Late Cenozoic

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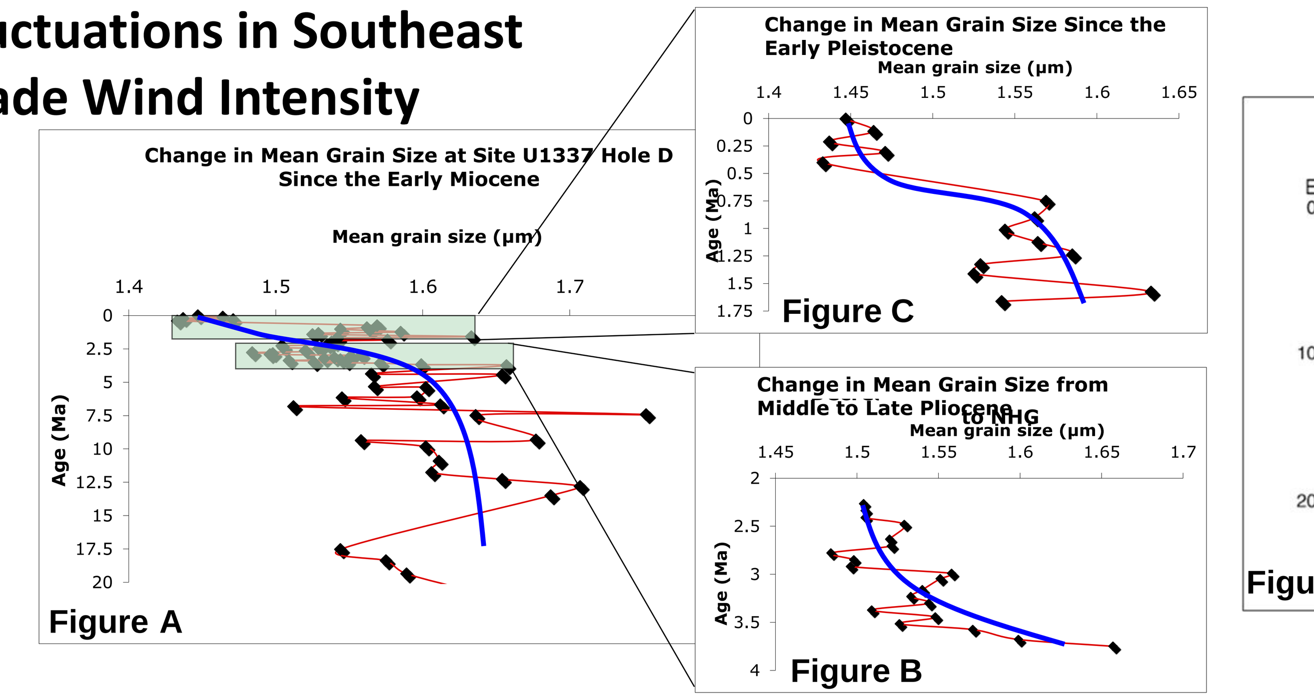
Abstract

Dust records from deep sea sediments help us understand ancient wind patterns during important climate transitions throughout the Cenozoic. We have isolated and analyzed the eolian fraction of bulk sediments recovered during Integrated Ocean Drilling Program (IODP) Expedition 320/321 in the eastern equatorial Pacific Ocean (EEP). Temporal and spatial patterns of grain size were examined to reveal changes in atmospheric circulation over the past 20 Ma. During the late Miocene to early Pliocene, the Earth's climate transitioned from a single-pole style glaciation (only Antarctica) to bi-polar glacial conditions (both Antarctica and glacial cycles in the Northern Hemisphere). The dust records transported by the ancient Southeast Trade Winds have been used to identify their intensity in relation to the paleo-locations of the intertropical convergence zone (ITCZ). The ITCZ is where the Trade Winds meet and is characterized by a reduction in the size of eolian dust. Past studies suggest a more northerly latitudinal position of the ITCZ during the middle to late Miocene, and a southerly shift as the Northern Trade Winds grew increasingly when northern hemisphere ice ages began in the late Cenozoic (Hovan, 1995). In our study, we have expanded the temporal resolution of these earlier studies to enable a better comparison between climate proxies such as past changes in wind intensity, global ice volume, equatorial upwelling, and biological productivity.

Fluctuations in Southeast Trade Wind Intensity



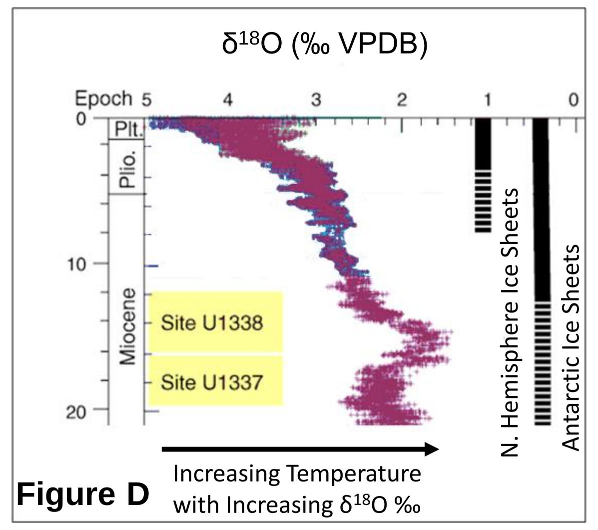
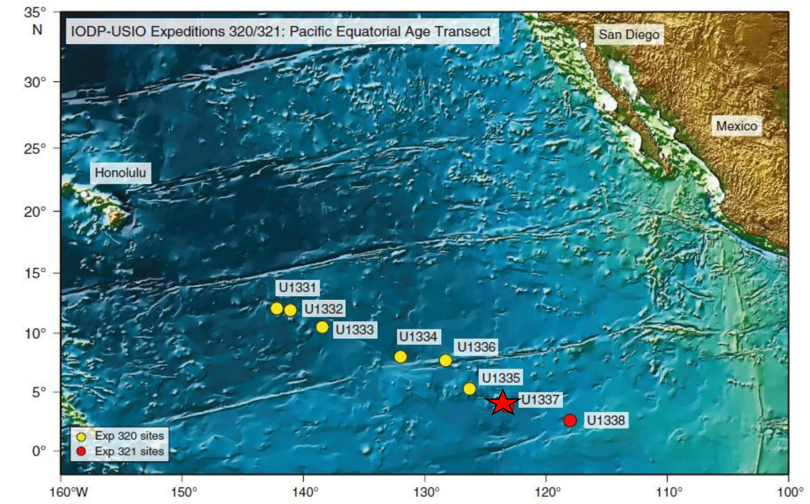


Figure D

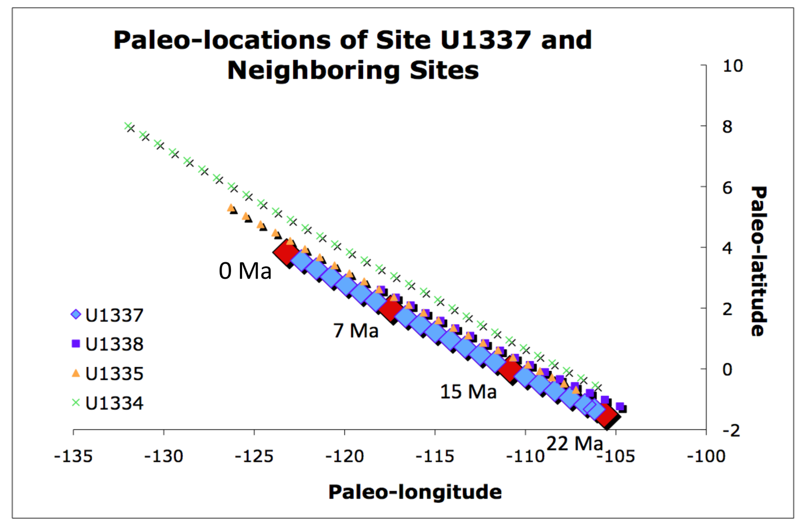
An overall trend of decreasing dust size is observed since the early Miocene (Figure A). A fining interval from 4-2.2 Ma (Figure B) indicates a weakening of the SE Trade Winds. This change in intensity occurred nearly simultaneously to the Northern Hemisphere Glaciation (NHG) (Figure D). Another strong decrease in grain size from 1.7-0 Ma (Figure C) indicates a weakening of the SE Trades over this interval.

Why Correlate Past Wind Intensities with Paleo-locations of Sites in the Eastern Equatorial Pacific Ocean?



Expedition 320/321 site map showing the present day location of each site.

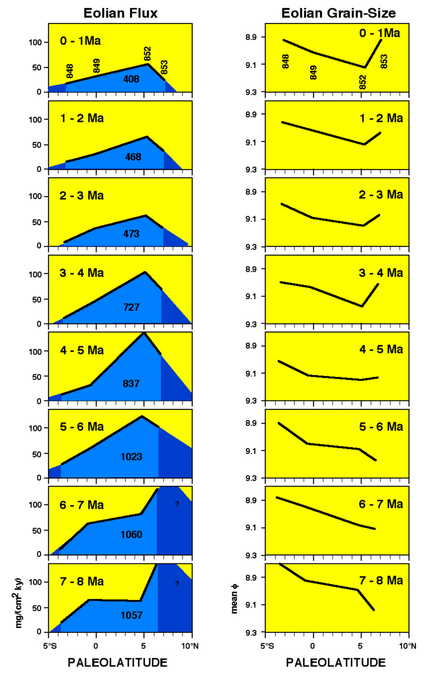
With an understanding of relative dust grain size, accumulation rates, and past motions of the Pacific Plate, the backtracked locations of sites from Expedition 320/321 are revealed.



Backtracked locations of Site U1337 and neighboring sites.

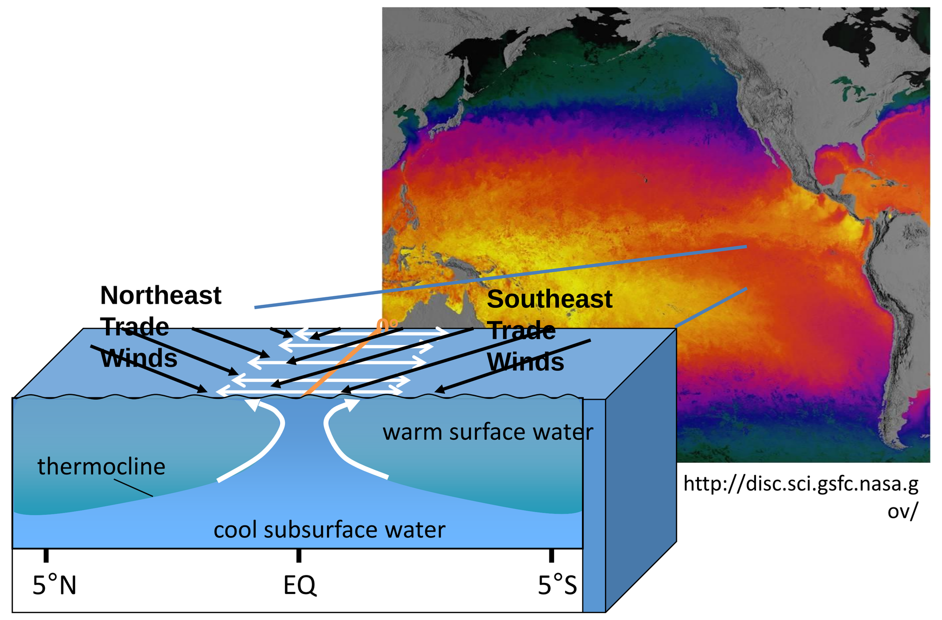
Grain size fluctuations and mass accumulation rates reveal past Trade Wind characteristics.

The ITCZ is marked by the finest grains and highest accumulation of dust in response to the lowest wind speeds as the Trade Winds converge. The ITCZ was farther north in the Miocene.



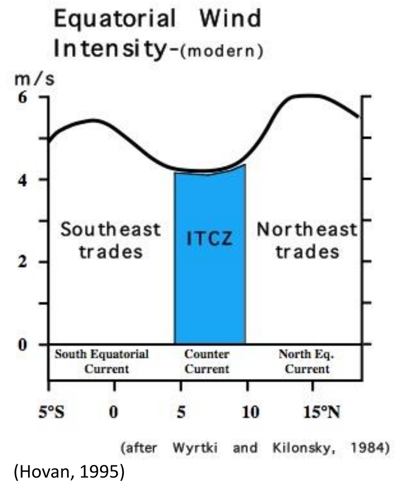
(Hovan, 1995)

Study site U1337D acts as an indicator of the Southeast Trades, providing insight to past wind speeds over and near the equator.



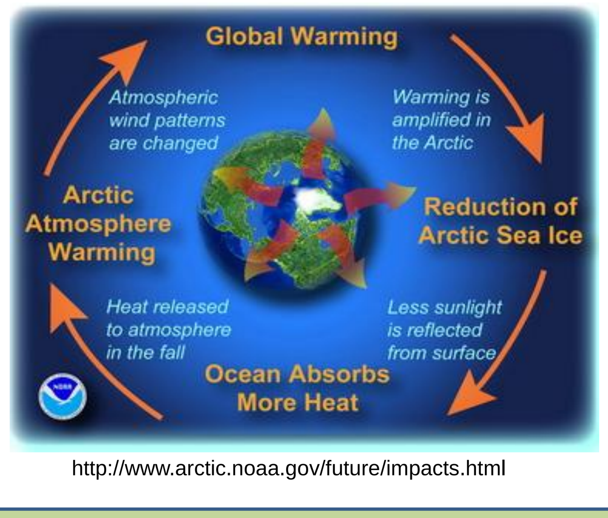
The relationship between the surface ocean and atmospheric circulation determine the level of upwelling at the equator. Upwelling increases as the SE Trades intensify.

Present day Trade Wind intensities suggest that the polar-equatorial gradient of the southern hemisphere is steeper than that of the northern, placing the ITCZ north of the equator.



(Hovan, 1995)

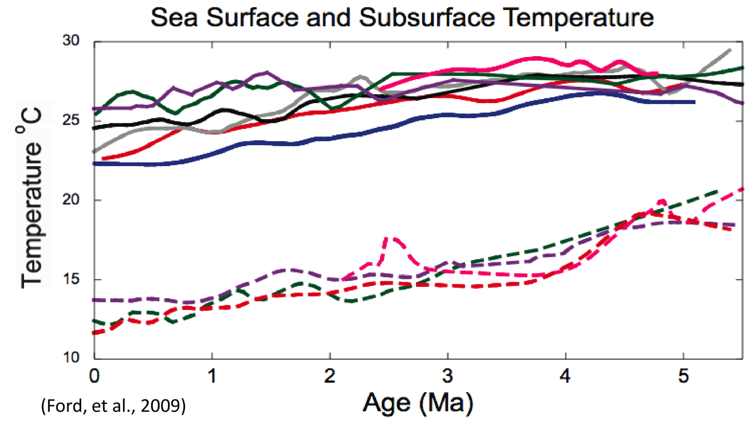
The polar-equatorial thermal gradient is believed to regulate equatorial wind intensities.



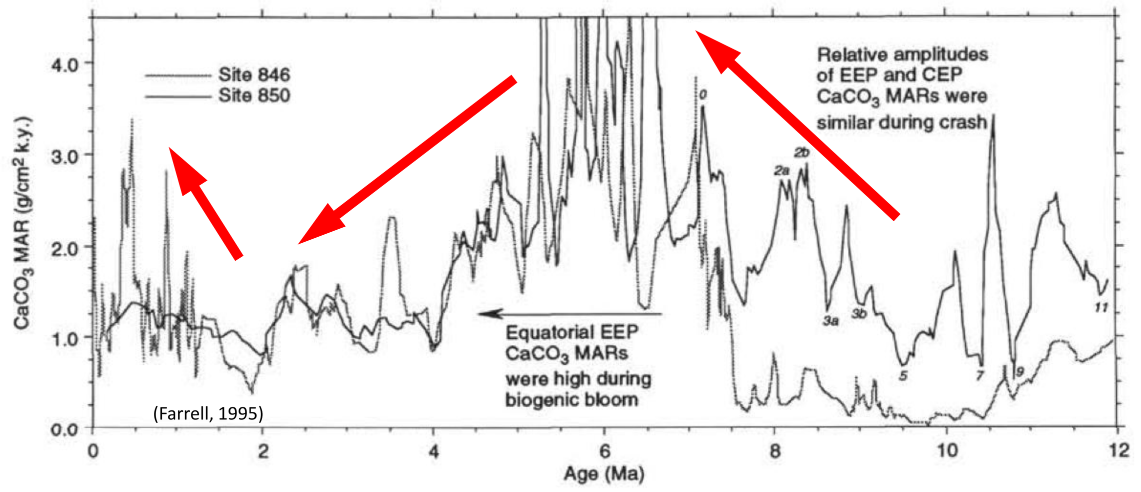
http://www.arctic.noaa.gov/future/impacts.html

By understanding these relationships that regulate global climate, predictions for future climatic and atmospheric scenarios can be made.

Comparing Grain Size to Other Climate Proxies: Upwelling and Biological Productivity



Sea surface and subsurface temperatures have cooled in the EEP since the early Pliocene. The thermocline shoaled within this period, suggesting that the modern upwelling system had developed.



$CaCO_3$ mass accumulation rates were used as indicators of productivity levels in the EEP. Biogenic blooms occurred from mid-Miocene to early Pliocene and late Pliocene to late Pleistocene, with a decrease from early to late Pliocene.

The Problems That Remain: Modifying the Chemical Extraction Technique

Figure A. U1337D-29H-5, 283.40-284.13 CCSF-A

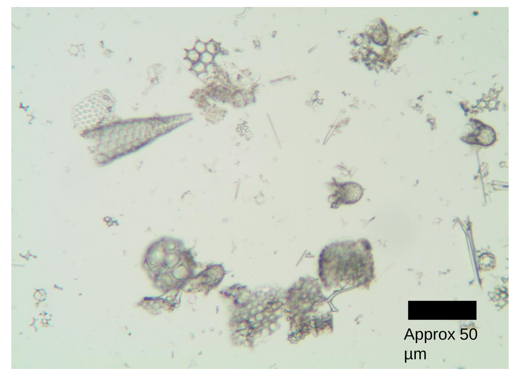


Figure B. 28H-3 sample sieved at 63µm, then sent through a sodium hydroxide rinse.

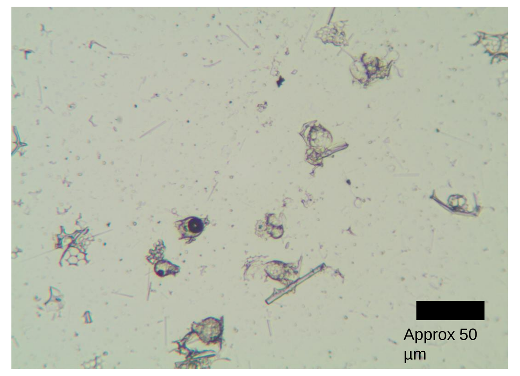


Figure C. 28H-3 extracted sample sieved at 38µm.

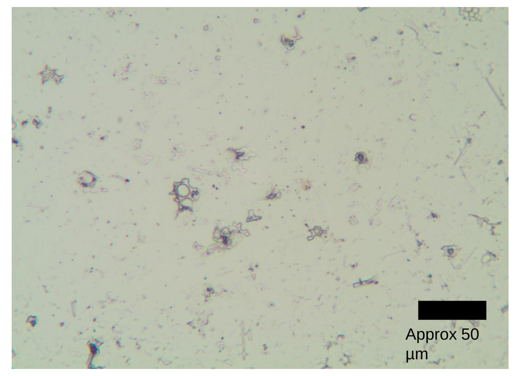


Figure D. 28H-3 extracted sample sieved at 20µm.

Dark brown segments in pre-Pleistocene cores yield high biogenic silica content (Figure A) that may not completely dissolve in a 2.0 hour, 1.0 molar sodium hydroxide rinse at 175 rpm and 80ºC (Figure B). In select bulk samples that maintained such contamination, the finer-grained dust component was isolated from the larger biogenic silica using sequential sieving (Figures C and D). An "electronic filter" was then applied to the grain size distribution using the Beckman-Coulter Multisizer software. Mean sizes reported here are based only on the 1-5µm fraction of these data.

Results/Discussion

A fining in dust grain size since the early Miocene suggests an overall weakening of the SE Trade Winds over this interval. The decrease at 4 Ma is consistent with a southerly shift of the ITCZ and northerly shift of the site beneath relatively weaker winds near the ITCZ (Hovan, 1995). Another fining in grain size from 1.7-0 Ma also suggests a period of weakened intensity. Further studies of the Northeast Trades are needed to confirm or disprove whether this indicates an unknown shift of the ITCZ. Because of a shallower thermocline, the sea surface and subsurface have cooled in the EEP since the early Pliocene, suggesting an increase in upwelling (Ford, 2009). In contrast, grain size shows a weakening of the SE Trades within this interval, but at 4 Ma, U1337D was getting relatively close to the southerly moving ITCZ. Equatorial wind intensity may influence productivity levels, but is not the only contributing factor. A weakening of the SE Trades and a drop in $CaCO_3$ content from early to late Pliocene each indicate a decrease in productivity. A $CaCO_3$ increase since the late Pliocene indicates a productivity increase, while the SE Trades weakened. To further enhance our understanding of past productivity levels, future studies of geochemical and sedimentological indicators will be made. Periods of high biogenic silica content contain fractions that may surpass the sodium hydroxide rinse. Future modifications to the chemical extraction procedure will be made in order to better dissolve the biogenic silica, while leaving the dust fraction undisturbed.

Acknowledgements and References

Many thanks to Dr. Steve Hovan for providing me with this research opportunity, advising me throughout, and supplying both figures characterizing the ITCZ. This study was made possible thanks to the IUP Geoscience Department. Funding is provided by the National Science Foundation (NSF). The cores used in this study, along with the Exp. 320/321 Site Map and $\delta^{18}O$ figure, were provided by the Integrated Ocean Drilling Program. The global warming "cycle" image was provided by the National Oceanic and Atmospheric Administration (NOAA). The sea surface temperature gradient image was provided by the National Aeronautics and Space Administration (NASA).

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