

Report on the QUEST DUST Workshop, Exeter, November 2007

Workshop Motivation: Dust is important not only as a diagnostic of climate and vegetation changes, but as an active climate component in possibly controlling radiative properties of the atmosphere and (through iron fertilisation) on ocean and atmospheric CO₂. Dust-cycle models still employ a relatively simple representation of dust properties and these simplifications could have severe impacts on the realism of the simulations of the impact of changes in dust loading on radiative forcing and biogeochemical cycling. Furthermore, state-of-the-art models still have major problems in simulating (a) dust source regions correctly, (b) the pulsed nature of dust emissions, and (c) realistic levels of dust deposition over the continents. The dust cycle will be simulated explicitly in QUEST-Deglaciation, and will also be simulated interactively by several of the models used in QUEST-DESIRE, including QESM and IPSL-ESM. Changes in dust loading will be of particular interest for the fully coupled simulations of the LGM, for radiative properties for the different interglacials, and as a factor in CO₂ at different stages of the last glacial. In addition to model improvements, it is vital to be able to evaluate the realism of the planned QUEST simulations. The DIRTMAP Database (Kohfeld and Harrison, 2001; Kohfeld and Tegen, 2007) contains dust-deposition records from ice and marine cores, and a more limited amount of data from terrestrial (loess) sites. The version of the database showcased in Kohfeld and Tegen (2007) contains terrestrial records assembled by the DIRTMAP consortium and published in the 2001 special issue of Quaternary Science Reviews. However, there has been much new work since then, resulting in new records of dust deposition, better spatial coverage of sites, improved chronologies for new and existing records, and new methods for extracting dust deposition rates and mineralogies (especially iron oxides, of key potential significance both for radiative and biogeochemical effects).

Workshop Achievements:

- (1) The 2-day workshop brought together 17 scientists (Appendix A), including representatives of the palaeodata community from key geographic regions and from terrestrial, marine and ice-core records of dust, dust-cycle modelers, and specialists in the modern biogeochemical aspects of dust. Initial presentations (Appendix B) provided an overview of the state-of-the-art across the whole domain of dust-related studies. Two additional presentations were provided by proxy (Kohfeld, N America and Sun, China).
- (2) Evaluation of the current DIRTMAP database indicates that there is a considerable amount of new data that needs to be incorporated to improve our ability to evaluate dust-cycle models. There are new, additional records from e.g. South America, Eurasia and the Middle East, and from the Southern Hemisphere in the marine realm. The current version of the DIRTMAP database includes very few terrestrial records extending beyond the last glacial maximum (ca 21,000 yr B.P.), although such records exist for most regions of the world. There has been a focus on records with high temporal resolution in recent years and there are records which e.g. show Dansgaard-Oeschger oscillations; these records are not in the existing version of the database. DIRTMAP was not designed to include data on provenancing or source-area characteristics; the quantity of such information on a site-specific basis is limited but its incorporation would greatly enhance the usefulness of the DIRTMAP database for modeling purposes. There are more data available on stratigraphic changes in size characteristics, and again incorporation of these data would provide a significant resource for modeling purposes.

- (3) The DIRTMAP database has been widely used for model evaluation but there are issues about how the data are ‘screened’ or ‘filtered’ before making such comparisons. In large part, the use of subjective screening of the sites is a function of the paucity of information that could be used to make objective quality-control estimates on site records and age models. Protocols need to be developed to allow such quality-control evaluation to be made and the metadata required to make these estimates need to be incorporated in the database. One issue here is that much of the required metadata is not included in publications; it will therefore be necessary to solicit inputs from the original authors to enhance the database.
- (4) There is a clear need for new field studies to derive much of the information that is required for the development of improved dust-cycle models, and contribute to the new questions now asked regarding dust-climate interactions, both radiative and biogeochemical. Additional field studies will also be required to fill crucial spatial gaps. Additional studies of known sites, including the use of improved dating techniques, will be required in order to produce records with the necessary high temporal resolution. Measurements of key parameters (particle size, bulk density, mineralogy) are also required. One future task for the QUEST dust working group is to frame a prioritization of future studies around key science questions and hypothesis testing.
- (5) State-of-the-art dust-cycle models generally incorporate preferential dust sources, such as palaeolake basins and low-lying areas. Remotely-sensed data from the Sahara suggesting that these areas are not major contributors of dust (Schepanski et al., 2007) are not consistent with geomorphic estimates of source areas (e.g. Koren et al., 2006). Geomorphic studies indicate that the approach to defining preferential dust-source areas as currently used by the models is both very simplistic and incomplete. Furthermore, these studies imply that there is considerable small-scale variability (e.g. across a single lake basin) and temporal variability in emissions from specific sources. It would be possible to parameterize this variability in a modeling context but this would require significantly improved characterization of potential source areas globally.
- (6) State-of-the-art dust-cycle models need to incorporate better characterization of dust properties (size distribution, mineralogy – especially with regard to iron oxides, and particle shape). The global dataset to be developed within DESIRE will facilitate this, but will require considerable assistance from internationally-distributed regional experts. This is an area where the QUEST dust working group can make a large contribution.
- (7) There is currently no standard for ‘benchmarking’ of dust-cycle models, but it is necessary to develop standards for both modern and palaeo-simulations. This involves defining protocols for the datasets used, significant enhancement (spatial and temporal) of the datasets, and also defining protocols for comparison methods and for dealing with uncertainties both in the observations and in the models.
- (8) Many palaeo-questions will require new types of dust-cycle model simulations. There is clearly a need to design transient simulations with fully-coupled climate-dust models to answer the questions posed by the DESIRE project. There may be a particular need for meso-scale modeling, for example, in order to simulate patterns of dust transport and deposition over the continents.
- (9) A major achievement of the workshop was the development of concrete plans to address current issues important to our understanding of the dust cycle on palaeo-timeframes. These concrete plans are outlined below.

Future Plans

- (1) The QUEST dust working group agreed that future meetings would be important in order to facilitate the provision of concrete products for QUEST and the international science community. These meetings would provide a motivation and timeframe for continued data synthesis, the development of protocols (e.g. for dating, for methodologies associated with measurement of particle size), analysis of the importance of dust properties for both radiative forcing and biogeochemical cycling, and targeted model experiments. We would hope that QUEST will continue to support these workshops (e.g. 1 per year for 3 years).
- (2) The QUEST dust working group will submit a proposal for recognition and workshop-funding support to the Palaeoclimate Commission (PALCOMM) of the International Quaternary Association (INQUA) before the end of 2007. The intention is to link planned palaeodust synthesis and analysis activities within IGBP-PAGES and PALCOMM, and to provide a broader international framework for the QUEST working group efforts.
- (3) The QUEST dust working group will produce an updated version of the DIRTMAP database, incorporating (a) new records and age models that have become available since ca 2001, (b) longer records, and particularly high-resolution records, that will target time windows identified by the DESIRE project (e.g. DO8/9, MIS5), (c) metadata to allow quality-control issues to be dealt with objectively, (d) information on mineralogy and isotopes relevant to provenancing, radiative forcing and bio-fertilisation, and (e) enhanced characterisation of the aeolian component of existing records. This update will be coordinated with work (led by *Karen Kohfeld*) to expand the DIRTMAP database to incorporate information on marine productivity and improved sedimentation rate estimation techniques.
- (4) Although we can exploit some existing resources to promote updating of DIRTMAP (e.g. in the US, *Art Bettis*), additional funding will be required to support personnel to work on the DIRTMAP database. The QUEST dust working group will develop independent proposals to the UK and French funding agencies (led by *Barbara Maher* and *Denis-Didier Rousseau*, respectively). The QUEST dust working group will encourage the development of further grant proposals to other national funding sources which could be used to support part of the database work (e.g. regional syntheses)
- (5) There are several ongoing efforts to map the geomorphic characteristics of dust sources areas on a regional scale. There is also an attempt to produce a global map of sand seas under the banner of INQUA. The QUEST dust working group (specifically *Jo Bullard* and *Grant McTainsh*) will liaise with individuals working on characterisation of the land surface, and make an assessment of the feasibility of producing a global map of source-area characteristics which could be used as a basis for devising a new model parameterisation of preferential sources.
- (6) There are plans to address the important issue of iron bioavailability and iron fertilisation of high nutrient, low chlorophyll ocean regions through a EUROCEAN workshop early in 2008. This is also an issue that is being addressed within SOLAS and iLEAPS. The QUEST dust working group (specifically *Peter Croot*) will liaise with these various groups and ensure that we exploit potential synergies with these groups.
- (7) The QUEST dust working group is planning two review-type articles to summarise our understanding of (a) the impact of dust properties on radiative forcing (led by *Adam Durant*), and (b) the role of dust in biogeochemical cycles on glacial-interglacial timescales (led by *Barbara Maher*). These papers will be produced and submitted over the next 6 months.

- (8) To focus attention and solicit data from the dust and modelling communities, the QUEST dust working group also plans to contribute reports on the workshop to PAGES (led by *Art Bettis*) and PAGES CLIVAR (led by *Adam Durant*).
- (9) Some members of the working group will attend the PMIP meeting planned for autumn 2008, and will contribute to two of the foci sessions there: (a) benchmarking (to demonstrate the potential usefulness of dust data for model validation) and (b) earth system model developments (to demonstrate how we are seeking to improve simulations of the dust cycle).
- (10) We plan to hold the next working group meeting in November 2008 in France. This workshop will likely focus on (a) development of protocols for database fields, in order to design best strategy for prioritisation of data input to database, (b) high-resolution records of dust deposition during D-O events, (c) relationships between geomorphic classification of land-surface and dust emissions.

Barbara Maher
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Appendix A: Workshop Participants

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Appendix B: Agenda, QUEST workshop on Dust Records on Glacial-Interglacial Timescales

Thursday 15th November: Background

- 14.00-14.30: Barbara Maher: Introduction, dust and climate: which dust, where and how?
- 14.30-15.00: Sandy Harrison: Dust in the DESIRE project: modelling and data-model comparisons
- 15.00-15.30: Yves Balkanski: Dust-modelling, key questions and uncertainties
- 15.30-16.00 Adam Durant: Dust Radiative Forcing
- 16.00-16.30 Coffee break
- 16.30-17.00 Peter Croot: Dust effects on the ocean and identification and quantification of recent dust deposition to the ocean
- 17.00-17.30 Sandy Harrison: Model evaluation using Palaeodata
- 17.30-18.00 Denis Didier Rousseau: International dust initiatives within IGBP

Friday 16th November: Show-and-tell

- 9.00-9.20: Jo Bullard: Geomorphological variability of dust-emitting sources
- 9.20-9.40: Art Bettis: Loess records in the USA
- 9.40-10.00: James Beget: Alaskan loess proxy records of four million years of high latitude climate history
- 10.00-10.20: Sun Youbin (by proxy): Dust deposition on the Chinese Loess Plateau
- 10.20-10.40: Denis Didier Rousseau: Eurasian dust records
- 10.40-11.00: Hezi Gildor: Glacial/interglacial dust changes
- 11.00-11.30: Coffee break
- 11.30-11.50: Paul Hesse: Marine records of dust
- 11.50-12.10: Doug Mackie: Sparse data for the Southern Ocean, implications for data collection, modeling, interpretation
- 12.10-12.30: Helen Roberts: The role of chronology in deciphering dust records
- 12.30-14.00 Lunch break
- 14.00-14.30: Hubertus Fischer: Ice core estimates of paleoclimatic changes in mineral dust transport
- 14.30-15.00: Jean-Robert Petit: A semi-empirical model for reproducing glacial/interglacial changes of dust and sea salt in central East Antarctica. Possible implications for simulations.
- 15.00-18.00: Moderated discussion: gaps, uncertainties and opportunities in palaeo-dust research

Morning, Day 3, Saturday 17th November

- 9.00-9.30: Karen Kohfeld (by proxy): DIRTMAP
- 9.30-10.30: Development of proposal to PALCOMM to support continued international network activities on the palaeo-dust cycle
- 11.00-13.00: Development of concrete strategy for updating the DIRTMAP database.