Report on the session 1 :
"Measurements and modeling of dust emission and deposition"

This report summarizes the mains issued identified from the contributions of the different speakers and from the final discussion.

Based on this report, a list of key recommendations has been established:

Key Recommendations:

1. Development of new dust emission and deposition schemes
2. Establish homogenised and complete experimental data sets, both field and laboratory for calibration and validation of the schemes
3. International effort for establishing a GIS dataset of surface properties relevant for dust emissions for regional and global dust model
4. Encourage field measurements of dust size distribution close to or in source regions based on a clear and standard definition of dust particle size
5. Inter-comparison of regional and global dust models with a specific focus on the differences due to the parameterization, the input data set, the dust size range.
6. Enhanced share of measurements and data sets
7. Concrete and effective international collaboration

The international efforts on these issues are extremely weak and the funding level on such activities is extremely low. Many well-know and critical problems cannot be solved, simply due to the lack of funding.

Dust emission and deposition processes

Model: Theoretical developments made during the 90's have lead to operational schemes for the parameterization of dust emission, including wind-erosion threshold velocity and saltation flux. Such schemes have been used quite widely in regional and global models for modelling dust storms and global mineral dust cycle. We can group the existing schemes roughly into five schemes, which can be summarized as follows:

Scheme-I: The dust-emission rate is parameterised in terms of the power of wind speed or friction velocity, and an empirical particle-size distribution is imposed on F to obtain dust emission rates for different particle-size bins. There is an empirical coefficient which lumps together various wind-erosion factors. The scheme is first proposed by Gillette and Passi (1988). It is popular due to its simple formulation. However, it is not simple to estimate its parameters. The scheme also requires the specification of airborne particle size distribution.

Scheme-II: These schemes have the common feature in that they are constructed upon the basis of simplified microscopic wind-erosion physics, supplemented with dust climate data derived from observations (e.g. Zender et al. 2003). A positive aspect of the scheme is that observed data are used to constrain the scheme behaviour. However, the constrained data also have problems.

Scheme-III: According to Marticorena and Bergametti (1995), the ratio between dust emission rate and saltation flux can be expressed as function of clay percentage of clay. There are three empirical coefficients which can be estimated by fitting the scheme to data. Despite of its simplicity, Scheme-III has captured two important aspects of the dust emission process: (1) dust emission is proportional to sand drift intensity and (2) this proportionality is dependent on clay content. The scheme is empirical and is not spectral and thus requires the specification of airborne particle size distribution..

Scheme-IV: A binding-energy based scheme has been proposed by Shao et al. (1993b, 1996) and Alfaro and Gomes (2001). The problem is that these models rely on a small set of idealized wind-tunnel experiments.

Scheme-V: Taking into consideration the three dust emission mechanisms (aerodynamic entrainment, saltation bombardment and aggregates disintegration), Shao (2001, 2004) suggested a spectral model. In Scheme-V, the micro-physics of dust emission has been taken into consideration. The input parameters required by Scheme-V have physical interpretations. However, the applications of Scheme-V are humped by the lack of soil and land-surface data that are not yet readily available, in particular the soil plastic pressure and the minimally- and fully-disturbed parent soil particle-size distributions.

There is no significant progress in the last 5 years on the description of the physical processes leading to the release of dust particles (talk by Shao). Further developments are thus required both from a theoretical and experimental point of view to better understand the cohesive forces of the soil and of the aggregates. Determining the soil binding energy appears as a big and critical challenge. Another limitation in the capability of available models to reproduce the measured mass flux is the quantitative prediction of the saltation flux and its size distribution. The most urgent problem is to have a coherent and self consistent experimental data set for model validation.

Field Experiment: Significant progress has been made in the experimental strategy and techniques on field dust measurements. Recent intensive field experiments have been conducted (ADEC, Taklamakan desert; JADE, Australia; AMMA, Niger) in order to measure not only the total mass fluxes but to measure the vertical dust flux as a function of size (see talk by Rajot et al.). In these field experiments, measurement of size-resolved saltation fluxes, erosion thresholds, other related quantities and soil size-distribution (undisturbed and disturbed) have been observed. These data sets are valuable for development and test of new physical dust emission and dust deposition (dry) parameterisations. To optimize further developments on the modelling of dust emission processes, efforts are needed to make these data sets available to modellers. Case studies during emission and deposition conditions and for which most of the model input parameters have been experimentally determined, and could be defined and used to test dust emission and deposition schemes. Additional experiments are still required to investigate new issues on the comparison between dust emission models with field measurements and in particular the hypothesis made to experimentally determine the vertical dust flux (i.e., constant flux with altitude; combination of emission and deposition during measurements, …).

However, such experimental set up cannot be replicated in many locations and thus can only concern a limited number of surface parameters and in particular of soil types. As a result laboratory experiments are required to further explore the binding energy of the soil and the link between the soil size distribution and the aerosol size distribution. This is also the most relevant approach to understand the change in elementary and mineralogical composition from the soil to the mineral dust.

It was noted that very few progress concerning the dust emissions due to anthropogenic activities have been made during the last 5 years. Some process studies have been performed combining wind tunnel and field measurements to quantify the erosion thresholds and fluxes over cultivated surfaces (South Tunisia, Niger) but no regional or global application of these works has been developed. These studies highlight the role of the change in agricultural practices, whose effect on dust emissions may be as important as the changes in land-use. However, the comparison between long-term data on the change in grazing pressure and aerosol indexes tends to suggest that these emissions may play a role in the long-term variability of the dust atmospheric content in transport areas (see talk by Ginoux). More activity on this subject appears as fundamental to better understand the inter-annual variability of the dust emissions.

It is clear however, that if such field or laboratory measurements are essential to develop and test theoretical models of dust emission they cannot really be used to constrain the dust emissions predicted by regional and global models. As a result, other approach and strategy must be developed to constrain the mass budget of mineral dust. A reasonable alternative should be to constrain the deposition instead of the emissions. From the intercomparison of the dust global models performed in the framework of AEROCOM (http.// etc ..), it appears that, despite large differences on dust emissions and deposition, most of the models reproduce quite correctly the dust load. In fact the modelled life-times vary by a factor of about 4 between the different models. This clearly suggests that the dust cycle remains under constrained in terms of mass budget.
The uncertainties in dust deposition are probably as high as dust emission estimates (see talk by Bergametti and Dulac). No proper evaluation of the available parameterizations of dry and wet deposition has been made using in situ experimental data sets. Most of the estimates of dust deposition derived from measurements at the global scale are based on data from marine sediments, i.e. only on oceanic surface. From these estimations, 25% of the total emitted dust appears to be deposited to the ocean. However, there is no quantitative information concerning the deposition of the remaining 75% of emitted dust. How to quantify dust deposition, in particular dust deposition for different types of land surfaces, is a critical issue, because it represents the only way to better constrain the mass budget of mineral dust, if we keep in mind the fact that we cannot have rapidly quantitative information on the dust emissions over arid regions.

Satellite data provides qualitative inputs in terms of source location and investigation of the spatial and temporal pattern of dust emission and transport close to the source areas (see talk by Shepanski). But satellite retrievals do not yet provide quantitative estimates of dust emission. The contribution of satellite observations to the estimation of “sink region” or to quantitative assessment of deposition fluxes should be further investigated. To use satellite observation to establish a database on the most frequent or intense source locations is desirable.

A pragmatic approach to some of the most critical problems is to establish a network of wet and dry deposition far and close to the source regions. Such network already exists in the far-source regions (EMEP, in Europe, IDAF in Africa; Japanese network et ..) but should be improved in the near-source region and along the main dust-transport pathways. The experimental determination of dry deposition remains challenging due to the poor efficiency of the collectors, and careful calibrations are needed. Standards collection procedures should be defined to make the different measurements comparable, at least in terms of deposition patterns. Concerning wet deposition, further theoretical developments are required to better understand the interactions between dust and cloud. Additional data on the dust solubility close and far from the sources are required (see session 5).

In addition to deposition data sets, a critical point is to have detailed size distribution of emitted dust. Dust models use quite different initial size distributions and the differences are accentuated by the different approaches used to treat the aerosol size distribution (spectral schemes; bins schemes with different numbers of bins etc.). A better estimate of psd of emitted dust, with observational data support, is key to reducing the discrepancies among the models. Special attention must be paid to the sampling of the coarse fraction of dust, since it contributes most to the mass discrepancies among different experimental data sets and different models. Discussions on the different types of size distribution measurements and of their consistency are made in Session 2.

Regional and global modelling

During the last five years, numerous regional and global models have been developed, which include dust emission and deposition schemes. A critical review of the different parameterizations used by these models has been presented (by Darmenova and Tanaka). As a general trend (with some exceptions), regional models tend to use physically-based dust emission schemes, while global models tend to use simpler schemes with certain additional constraints. Most of the global models use empirical parameterizations of the dust emission that include a tuning factor allowing to adjust the total dust emissions to provide a reasonable AOD distribution. In fact, the degree of simplification of dust emission into a model strongly depends on the objective of the simulations. Typically, forecasting regional models use simplified but operational parameterizations since their focus is only on the prediction of the timing and of the location of dust plumes.

From this review, it appears that the major limitation in the improvement of these models is the lack of relevant data set of input surface parameters. The most limiting input parameters are the undisturbed soil size distributions, the aeolian surface roughness (roughness length or roughness density) and the soil moisture. Some models, in particular regional meteorological models, includes surface modules to compute the soil moisture consistently with the model water budget, however they not represent properly the soil moisture in the thin top layer that must be considered for aeolian erosion purposes. Dynamic maps of vegetation would also help in reproducing the seasonal pattern of dust emissions in semi-arid regions. Here again, an international joint effort should be made to establish a cohesive dataset for dust models, by sharing available data sets and by developing additional ones.

The AEROCOM program provided a framework for global modellers to compare the performance of the different models and to investigate the uncertainties due to the different processes. As mentioned above, the results from this intercomparison experiment clearly underlines the necessity to further constrain the mass dust budget. However, depending on the objective of the simulations, either a mass or an optical closure can be performed that does not require the same type of “size distribution” or the same precision over the whole dust size range.

The possibility of performing a similar exercise for regional models has emerged from the discussion. The organisation of a joint workshop of regional modellers is encouraged in order to clearly identify the main targets and to define a rigorous comparison plan. Some kind of "benchmark tests" could be defined for case studies for which exhaustive data set from intensive field campaigns such as the SAMUM experiment could provide a good level of constrains.

Another issue that was recently raised from modelling studies is the sensitivity of the simulated emissions to the "precision" of the model surface wind fields. In global models, the simulated dust emissions strongly depend on the meteorological fields used as forcing. Similarly, global models tends to produce lower emissions than when they run in a climatic mode than when they are driven by external (re)analysed meteorological fields. It is clear that the influence of sub-scale meteorological systems or surface heterogeneity (i.e., complex topography like in the Bodélé Depression) features require the use of highly resolved meteorological models. However, even for such situations, differences in the surface wind fields computed from different regional models remain still important. In addition, the capacity of these models to reproduce some meteorological systems suspected to be extremely efficient for dust mobilization (moist-convection; low level jets etc.) is poor and thus their impact on the dust emission and deposition is not well assessed. The same problem should be raised on the precipitation fields when quantitative constrain on wet deposition will be available. It thus appears that a special attention must be paid to the fact the way the models, whatever their scales, reproduce the surface wind velocity responsible for the dust emission and the precipitation fields responsible for wet deposition. Another open issue is the way such local to sub-grid phenomenon's can be accounted for in global model. The continuous decrease in the spatial resolution at which analysed meteorological fields are available may help progressing on this aspect. However, the lack of meteorological observations in arid regions and more specifically close to the main dust sources has been underlined as a major limitation in the improvement of the meteorological fields in dust emission regions.

Note : as a first step toward the constitution of data base on dust emissions, it was agree to give the links to several internet web sites where data from field experiments or network or surface input data base can be downloaded.

Surface data for dust emission modelling :
http://www.lisa.univ-paris12.fr/mod/data/

Data on deposition: