Regional Modeling of Saharan Dust Transport towards the Tropical Atlantic

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Overview

- Motivation for regional dust modeling
- Dust modeling at the IfT Leipzig
- Application for field studies
- Outlook
Global Dust Model Intercomparison

Huneeus et al., 2011 (ACP)

Global Dust Models: AEROCOM

Median DOT ca. 15 models

http://dataipsl.ipsl.jussieu.fr/AEROCOM/aerocomhome.html M. Schulz, U. Norway

Barbados 59.62W ; 0m

15 Models

Observation

Global dust models:
- Climatological dust distributions
  - Study of dust-climate interactions

Discrepancies between global dust models and observations: Are dust processes adequately resolved?
Why use a Regional Dust Model?

- Recent field experiments investigated mineral dust properties and processes (e.g., AMMA, DABEX, SAMUM, ...):
  - Considerable progress in regional dust modeling!
- Regional-scale models (10-50 km grid resolution) expected to resolve meteorology better than global models (1-5 deg grid resolution); make better use of high-resolved surface data sets
- Usually only simulate individual events
Example for Dust/Smoke Regional Model Scheme

Model scheme: COSMO-MUSCAT

- **GME (Global Model)**
  - Radiation
    - δ-2-stream scheme
    - 3 solar/5 thermal spectral intervals
    - Modified aerosol composite
  - Surface properties
  - Satellite active fire observations

- **COSMO (Local Model)**
  - Wind fields

- **MUSCAT (Multiscale Chemistry Transport Model)**
  - 3D dust & smoke distribution
  - DES (Dust emission scheme)
  - LandFire (Smoke emission scheme)

- **On-line aerosol radiative feedback**

Figure: Heinold
Dust Emission Modelling

_Emission depending on_
- Surface wind speed
- Surface roughness
- Vegetation cover and type
- Soil particle size
- Soil moisture, (snow cover)
- Topographic depressions (lake sediments?) as preferential sources
Dust Source Activation Frequency
2006/03 – 2009/02

[Schepanski et al., JGR 2009]

# of DSA /season
Regional model COSMO-MUSCAT (domain: Sahara, 28 km grid)
Excluding areas where no dust emission is observed
Comparing modeled and measured aerosol optical depth
More than 60% of Saharan dust source activations are observed between 6:00 and 9:00 UTC: nocturnal LLJ
Break-down of the nocturnal low-level jet is an important mechanism for dust mobilisation. However, it is not clear if it is effective for dust transport.
Moist Convection Parameterization

03/06/06 18:00 UTC
Grid resolution: 14 km

Tiedke Parameterization

Kain-Fritsch Parameterization

Reinfried et al., 2009

No Convection Parameterization

Reinfried et al., 2009
Some Key Points

- Global-scale dust models perform well for optical thickness over ocean regions and seasonality. Other aspects (initial size distribution, atmospheric lifetimes) show strong deviations for different models.
- New remote sensing products are improving understanding of dust fluxes and processes in models.
- Regional-scale models as used for dust forecasting are used to clarify small-scale dust processes, however their performance for dust events connected to wet convection is limited.
Application in Field Studies
at the Leibniz Institute for Tropospheric Research

- SOPRAN: Ocean-Atmosphere exchange in the tropical Atlantic:
  - *Modeling dust deposition fluxes into the ocean*

- SAMUM: SAharan Mineral DUST experiment
  - *Reduce uncertainties in radiative properties of Saharan dust*
Dust Deposition in the Tropical Atlantic

Results from the SOPRAN project
Zonal Dust Flux Towards the Atlantic

January

20° W

July

Bodele

Mg/m²/month

Schepanski et al., 2009 (ACP)
SAMUM 2004-2011

- Surface and airborne optical, microphysical and mineralogical characterization of Saharan dust
- Characterization of the dust-filled atmospheric column with lidars, aircraft, and satellites
- Radiative effects + feedbacks of Saharan dust, regional transport modeling

Ansmann et al., Tellus 2011
SAMUM1 vs. SAMUM-2
(Ansmann et al., TELLUS special issue, 2011)

Lidar measurements: Near-source dust is evenly mixed within the boundary layer, above the Atlantic transported dust develops more complex layer structures.
SAMUM-1 Model Results
May 31-June 4 Episode

(a) OMI Al Satellite data
(b) Model aerosol optical thickness

Heinold et al., 2009

Grid resolution 28 km
202x159 / 40 layers
Some SAMUM-2 Results
(TELLUS special issue, 2011)
Model Results (January-February 2008)

Heinold et al., 2011
COSMO-MUSCAT: Dust & smoke

30/31 Jan ´08
Dust and Smoke Distribution
With and without considering radiative aerosol effect

AOT

31 January 2011

With Radiative Feedback

Dust + Smoke

No Feedback

Extinction profile

Heinold et al., 2011
Summary Regional Modelling

- The SAMUM campaign offered a unique opportunity to study dust properties and reduce uncertainty in direct dust radiative forcing, near-source and transported (TELLUS 2009 and 2011).
- A regional-scale dust models was developed within the SAMUM project, which is suited for comparison with field data, limitations in reproducing small-scale meteorology may cause problems.
- Radiative forcing by dust and smoke in the Sahel region can cause changes in transport pathways.
Addition and Outlook

German Projects in Barbados

- Barbados Cloud Observatory, MPI Hamburg
  http://barbados.zmaw.de/
Addition and Outlook

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- CARRIBA (2010-2011), IfT
  http://barbados2010-actos.blogspot.com/

  some figures from Heike Wex ....
CARRIBA
(Clouds, Aerosol, Radiation, and turbulence in the Trade Wind regime over Barbados)

ground based measurements at Ragged Point and

airborne measurements with ACTOS

measurements in November 2010 (CARRIBA 2010): 23 days of ground-based data and 17 research flights and April 2011 (CARRIBA 2011): 21 days of ground-based data and 16 research flights
comparing $N_{\text{total}}$ with airmasses and $N_{<80\text{nm}}$

grey background – trajectory came from Africa
datapoints coloured red or blue when $N_{\text{total}} > 250 \text{ cc}^{-1}$
datapoints coloured green: particle number concentration for sizes $<80\text{nm}$ ($N_{<80\text{nm}}$)

CARRIBA 2010

Trajectory analysis reveals:

- airmasses from Africa: high $N_{\text{total}}$, coarse-mode
- airmasses that passed through low pressure systems over the Atlantic
  -> low $N$ for particles $>100\text{nm}$ (large particles outwashed by rain)
  -> many "freshly" (age approx. 1-2 days)
  nucleated particles, i.e. high $N_{\text{total}}$

"regular“: Hoppel-minimum clearly visible (deviding small, non-activated particles from those that have been activated) and generally low $N_{\text{total}}$
Addition and Outlook

German Projects in Barbados

- Barbados Cloud Observatory, MPI Hamburg
  [http://barbados.zmaw.de/](http://barbados.zmaw.de/)

- CARRIBA (2010-2011), IfT

- SALTRACE: project in planning (coordinated by IfT)
  some figures from Albert Ansmann ....
Characterization of aerosol and aerosol-cloud interactions downwind of the SAMUM regions
Barbados
MPI HH
Raman lidar
(Serikov, Linne)

Polarization lidar, 1 July 2010

1064nm attenuated backscatter near range

Saharan dust
Cloud layer
MBL
Separating dust and smoke aerosol is important for assessing their
- Direct radiative effect
- Ice nucleation ability
Some Questions for Future Research

- Are large scale models sufficient to characterize the transport of dust across the tropical Atlantic and, in particular, to Barbados? Are convective mixing processes important?

- What are the main source areas for dust transported to the Americas? Are ‘anthropogenic’ dust sources important?

- Meteorological and climate controls on dust emissions and transport: What information would be required for projections of future changes?

- Does radiative forcing by dust (and smoke) have a noticeable impact on atmospheric dynamics and thus on transport patterns themselves?

- What are the impacts of far transported dust on cloud properties (warm or mixed phase clouds); are those different from ‘fresh’ unprocessed dust?