Atmosphere-Land-Ocean Interaction at the Southwestern Edge of the Saharan heat low

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Outline

1. West African monsoon
2. GERBILS field campaign
3. COSMO validation
4. The Atlantic Inflow at the Mauritanian Coast
5. Future and current work
1. The West African Monsoon System – Main features

- northeastern tradewinds: **Harmattan**
- Southeastern tradewinds become Southwesterlies when crossing equator: **monsoon flow**
- Zone of convergence: Intertropical Front **ITF/ITD**, Inter Tropical Convergence zone → moist convection

- Saharan Heat Low **SHL**: Dry convection
- African Easterly Jet **AEJ**: N-S temperature gradient, thermal wind balance
- Wave fluctuations within **AEJ**: African Easterly Waves **AEW**
- **Seasonal** phenomena (June-August)
1. The West African Monsoon System – Main features

- Moist convection: monsoon layer / ITD
- Dry convection at daytime: SHL region
  growing convective BL within residual BL

- Conv. Boundary Layer **CBL**
  + Saharan Residual boundary layer **SRL**
  = Saharan Planetary boundary layer **SPBL**
- Elevated and transported SPBL
  = Saharan Air Layer **SAL**

(Messager, 2007)
2. The GERBILS campaign

GERBILS – GERB Intercomparision of Longwave and Shortwave radiation

- *Discrepancy in clear-sky top of atmosphere outgoing longwave radiation (OLRc)* over Sahara between model (UM) and satellite

- Three 2-leg flights with **FAAM BAe146** 2nd half of June 2007
- dOLRc maximum in June/July
- western base Nouakchott, eastern base Niamey
- Flight track along 18°N over maximum dOLRc

*Figure 1. An example of the OLR anomaly when comparing the UM against a) the GERB instrument on Meteosat 8 (Haywood, 2007)*
2. GERBILS field campaign

Operational COSMO GERBILS V3.19 forecasts at IMK

- HP XC6000 Steinbuch Centre for Computing, KIT
- External data from DWD
- Initial / boundary data (3hourly) from IFS
- Initialised twice daily 00UTC, 12UTC
- Horizontal grid 305 x 161 gridpoints, 17°W - 2°E, 13°N - 23°N, 0.0625°
- 35 vertical levels
- 18 June - 30 June 2007

After GERBILS

- Domain shifted
- Budget calculations
3. The COSMO model – Model validation

- Flight B299 24/06/2007: aircraft profile
  (profile 4&5, 2.7-4.6°W, 18°N, 1114-1202UTC)
3. The COSMO model – Model evaluation

- Flight B299 24/06/2007: cross section of potential temperature at 18N
3. The COSMO model – Model validation

Example: total cloud cover

COSMO 23/06/2007 00UTC+33h forecast for 9 UTC 24/06/2007

Meteosat IR10.8 μm 9 UTC 24/06/2007
Atlantic Inflow:

- sea breeze/density current
- see breeze front
- frontal circulation
- gravity wave
- baroclinic zone
- diurnal cycle
- synoptic variability
Conditions in western Mauritania:

- land – sea temperature gradient:
  - cold canary current, upwelling deep waters
  - hot desert environment inland

- SHL
  - dry convection
  - turbulent mixing

- coastal plain south of 20°N

- Tagant mountains 400km inland

\[ T_{SST} \approx 22^\circ C \quad T_{2m} \approx 27^\circ C \]
\[ T_{sfc} > 45^\circ C \quad T_{2m} > 42^\circ C \]
Atlantic Inflow front: (in lower troposphere)

- Separates maritime, cool and stably-stratified air in the West from dry and hot continental air
- Stationary coastal front at daytime
- Nocturnal propagation
- Coldpool in coastal plain next morning.
4. Atlantic Inflow – horizontal extent
4. Atlantic Inflow – at a specific location

14°W, 18°N

- passage of coastal front at around 22UTC
- strong cooling and increasing of zonal wind component
- moist advection depending on synoptic conditions
4. frontal circulation and gravity wave

- Low-level density current lifts isentropes in stably-stratified mid-levels
- Crest-valley-crest wave combined with triplet of ascent-descent-ascent
- 10 m/s phase speed
- decouples from low-level front at Tagant
4. Heat and moisture budget

**COSMO Code adaptions:**

- Output of individual contributions to tendency equations for temperature and humidity

\[
\frac{\partial \theta}{\partial t} = -\mathbf{v}_h \cdot \nabla_{h,p} \theta - \omega \frac{\partial \theta}{\partial p} + Q_{\theta}
\]

\[
Q_{\theta} = M_{\theta}^{TD} + M_{\theta}^{RAD} + M_{\theta}^{Sq} + M_{\theta}^{MC} + M_{\theta}^{comp}
\]

- Tendency equation for potential temperature:

\[
\frac{\partial q^\nu}{\partial t} = -\mathbf{v}_h \cdot \nabla_{h,p} q^\nu - \omega \frac{\partial q^\nu}{\partial p} + Q_{q^\nu}
\]

\[
Q_{q^\nu} = M_{q^\nu}^{TD} + M_{q^\nu}^{Sq} + M_{q^\nu}^{MC} + M_{q^\nu}^{comp}
\]

Contributions to the local tendency (RES) are from: horizontal (HADV) and vertical advection (VADV), turbulent diffusion (MTD), radiation (RAD, only \(\Theta\)), sub-grid scale moist convection (SQ), grid scale moist convection (MMC), computational effects (COMP).
Interplay of horizontal advection and turbulent diffusion governs inland penetration of coastal front

- Turbulence at daytime hinders inland penetration
- As soon as turbulence decays in the afternoon front starts propagating inland
4. Impact on heat and moisture budgets

- Tendency terms areal averaged over box in Atlantic Inflow region
- Temporal average 0-48h: balance of horizontal advection and turbulence in heat budget, drying due to horizontal advection
- Temporal average for passage of the AI-front (18-22UTC): cooling and moistening due to horizontal advection!
5. Summary

Summary:
• SABL well represented in COSMO model
• Atlantic Inflow described as a mesoscale feature at the West African coast.
• Atlantic Inflow affects heat and moisture budget at the western flank of the Saharan heat low
• Frontal circulation could affect dust uplift

Future work:
• Simulations including dust: COSMO-ART
• More detailed look at heat and moisture budgets

The Atlantic Inflow to the Saharan heat low: observations and modelling. Grams et al. (2009), accepted with minor revisions, QJRMS Special Issue AMMA WP 2.1.
5. Current work

Extratropical transition of Tropical Cyclones in COSMO

- **Operational COSMO forecasts in support of T-PARC 2008**
  - Computed at HP XC4000 Steinbuch Centre for Computing, KIT
  - 0.025° and 0.0625° horizontal resolution, 51 vertical levels
  - GME and IFS as driving global models, 2 domains, 00Z, 12Z initial time
  - 16 forecasts per day, >700 forecasts from 1.8.2008-20.10.2008

- **PV-diagnostics for COSMO model output**
  - Calculation of balanced flow using PV-Inversion
  - Piecewise PV-Inversion

- **Investigation of ET scenarios**
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Homepage

http://www.imk.uni-karlsruhe.de/english/3841.php

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Thank you for your attention!
References


Marsham, J.H. et al., 2007, Observations of mesoscale and boundary-layer circulations affecting dust uplift and transport in the Saharan boundary layer. Submitted to ACP.

Marsham, J.H. et al., 2008, Uplift of Saharan dust at the ITD. Submitted to JGR.


