Water vapour budget associated to overshoots in the tropical stratosphere: mesoscale modeling study of August 5, 2006 during SCOUT-AMMA

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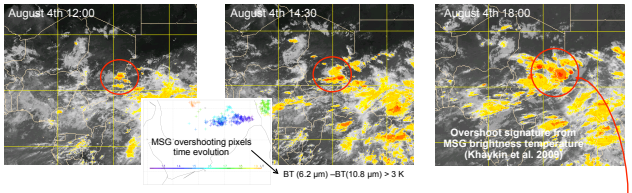
Abstract During the periods of August 04-05, large MCSs (Mesoscale Convective Systems) were observed in the region of Aïr (central Niger) which later moved toward Niamey. Another large MCS developed and overshooted the *tropopause* over Chad, upwind of the micro-SDLA and FLASH-B water vapor measurements which show an hydrated layer above the tropopause. In order to study the impact of such a strong convective activity on the amount of water entering the stratosphere, we present results of two high resolution mesoscale simulations (3 nested grids) of these cases with the BRAMS model. Thanks to ECMWF reanalyses including AMMA observations, the model simulates reasonably well the Aïr MCS, its extend, its propagation speed and its lifetime although this latter is shorter than the observed system. The model simulates an overshooting cell reaching 18.3 km. The water budget associated with this overshoot is comparable with the result of previous overshoots modeling studies (several tons/s). Another water budget associated with the overshooting MCS over Chad on August 4 is also given. This convective system is fairly well reproduced (position and propagation direction) by BRAMS, even though the modelled system triggers 4 hours later than the observations. The 3 nested grids simulation allows the convection to reach and cross the tropopause level.

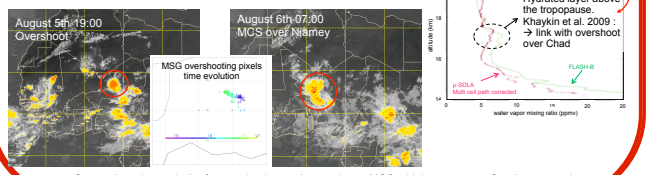
Meteorological situation

METEOSAT IR brightness temperature and MIT Radar at Niamey

Case of August 4th over Chad



Case of August 5th over Aïr (Central Niger)



Convection triggers in Aïr from a cloud area. It turns into a MSC which propagates South-westward.

The BRAMS model : description & simulation setup

BRAMS = Brazilian version of the RAMS mesoscale model. Dedicated to the tropics (http://www.cptec.inpe.br/brams)

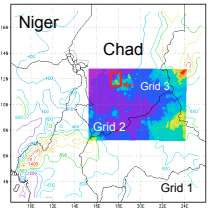
- Nested grids possible
- Subgrid scale parameterisation of convection : Grell scheme for Grid 1 & 2
- 4Dvar Nudging (e.g. ECMWF, radiosounding, etc…)

Setup :

- Initial conditions from ECMWF reanalyses including AMMA observations + soil moisture deduced from TRMM + surface data.
- Simulation from August 03st 12:00 UT → August 05th 12:00 UT
- Simulation from August 05st 00:00 UT → August 07th 00:00 UT
- 3 grid : 20 km / 4km / 1 km horizontal resolution.
- 68 vertical levels up to 30 km. 300 m resolution in the UTLS
- Microphysical Scheme : double moment. Setup from G. Pénide (LaMP)

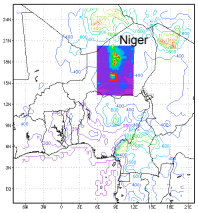
topography

Model grids used for the simulation. (4th August)

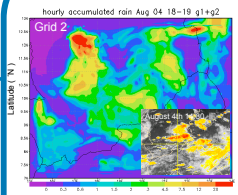


topography

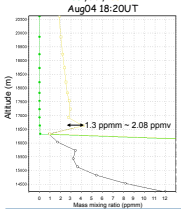
Model grids used for the simulation. (5th August)

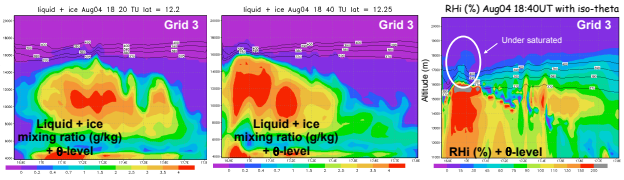


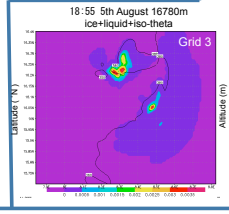
Main simulation results (4th August)

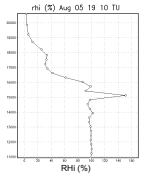


- Convection starts in the model 4 hours later than the observation in the Chad region.
- This convective system is fairly well reproduced by BRAMS.
- The 3 nested grids simulation allows the convection to reach the tropopause level and overshoot into the stratosphere (above the 400K θ-level) in the convective system mentioned in Khaykin et al. (2009) .
- The RHi profile at the position of overshoot shows that the ice evaporates rapidly once transported into the LS. Sedimentation of ice particles from the LS → UT may play a negligible role in the cross - tropopause water budget.

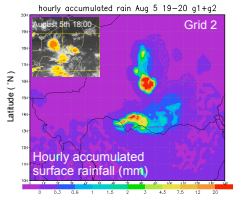


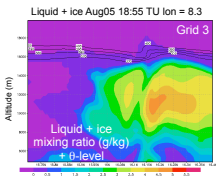






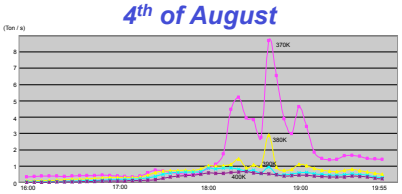
Main simulation results (5th August)





- Convection starts 1 hours later than the observation in the Aïr region. Its propagation direction and speed is correctly reproduced.
- According to our BTD calculation, the modeled overshoot appears later than the observations, although the overshooting convection is reproduced by the model. The overshoot reaches 18.3km at the maximum
- RHi profiles shows under-saturated conditions in the LS → rapid sublimation of ice.

4th of August



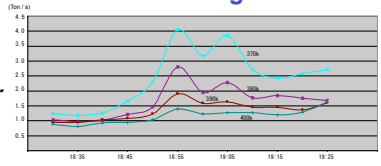
Theta (K)	Water mass flux during 4 hours (tons)	(tons/h/km²)
360K	116090	5.37
365K	45545	2.11
370K	24098	1.12
375K	14093	0.65
380K	9553	0.44
385K	7454	0.35
390K	6044	0.28
395K	5121	0.24
400K	4215	0.20

Water Budget

- Computed with a 5 minute time step on isentropic surfaces. The vertical wind speed used in the calculation is the relative speed of air with respect to the θ-level displacement.
- Figures : times series of upward total water flux through isentropic surface at 370K, 380K (~ tropopause), 390K and 400K over the third grid domain of the model during the overshoots period. Order of magnitute compatible with previous studies (Grosvenor et al. 2007, Chaboureau et al., 2007).
- Tables : total mass of total water crossing the θ-levels during the whole overshoot event. Comparable flux par unit of time and surface.

- The total amount of water crossing the tropopause is higher for August 4 than for August 5 because of a longer event.

5th of August



Theta (K)	Water mass flux during 1 hours (tons)	(tons/h/km²)
360	144263	23.29
365	27399	4.42
370	6911	1.12
375	3503	0.57
380	2377	0.39
385	1946	0.32
390	1666	0.27
395	1400	0.23
400	1222	0.20

Concluding remarks

1. **A fine resolution (3 grids → 1 km) is used to simulate 2 cases of overshoot and reproduce the propagation direction and speed of the MCSs.**
2. **Each overshoot induces water fluxes of several tons/s.**
3. **The overshoot over Chad (August 4) highlighted by Khaykin et al., (2009) to be responsible of the hydrated layer sampled by FLASH and micro-SDLA balloon flights on August 5 from Niamey is reproduced by our simulation.**
4. **Due to the very dry conditions in the LS, the ice particles injected by the overshoots sublimate rapidly. The enhancement of water vapor mixing ratio after the modelled overshoot is comparable with the one measured by FLASH and µ-SDLA.**

Acknowledgements

- AMMA database, DT-INSU SDLA team during the campaign. S. Khaykin for the FLASH-B data.

References

- Khaykin et al., *Atmos. Chem. Phys* , 9, 2275–2287, 2009
- *Chaboureau et al., Atmos. Chem. Phys., 7, 1731–1740, 2007*
- Grosvenor et al., *Atmos. Chem. Phys., 7, 4977–5002, 2007*