Study of aerosols effect on a marine stratocumulus diurnal cycle using Large Eddy Simulations

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1. Introduction
2. LES Model
3. Simulations
4. Discussion
5. Conclusions

Marine stratocumulus clouds

☞ **an important negative forcing on the Earth radiative budget**

To estimate this forcing:

- **Complex interaction between dynamics, radiation and microphysics**
- **Diurnal cycle**
- ? **Presence of aerosols (potentially able to alter cloud optical properties and life cycle, i.e. aerosol indirect effects)**

☞ **previous LES studies examined aerosols impacts for quasi-stationary conditions (nighttime)**

☞ **this study uses LES to explore the coupling between aerosols effects and the cloud diurnal cycle**

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The LES model

☞ **Meso-NH (Lafore et al. 1998) used in LES configuration with state-of-the-art parameterizations of turbulence, radiation, microphysics**

- **Turbulence: 3D scheme (Cuxart et al. 2000) with 1½ closure**
- **Advection: a positively defined second order centered scheme**
- **Microphysics: Khairoutdinov and Kogan (2000) scheme, typically designed for marine stratocumulus**
- **Radiation: ECMWF scheme**
  - **Savijarvi (1998) parameterization for LW optical properties**
  - **Fouquart (1987) for optical thickness and asymmetry factor**
  - **Sandu (2005) parameterization for cloud droplet single scattering albedo**

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Simulations

☞ **Typical summer situation over NE Pacific (similar to FIRE-I case)**

☞ **Large scale forcing, chosen to have a periodic diurnal cycle**
(no large scale advection and large scale divergence of $6X10^{-6}$ s^{-1})

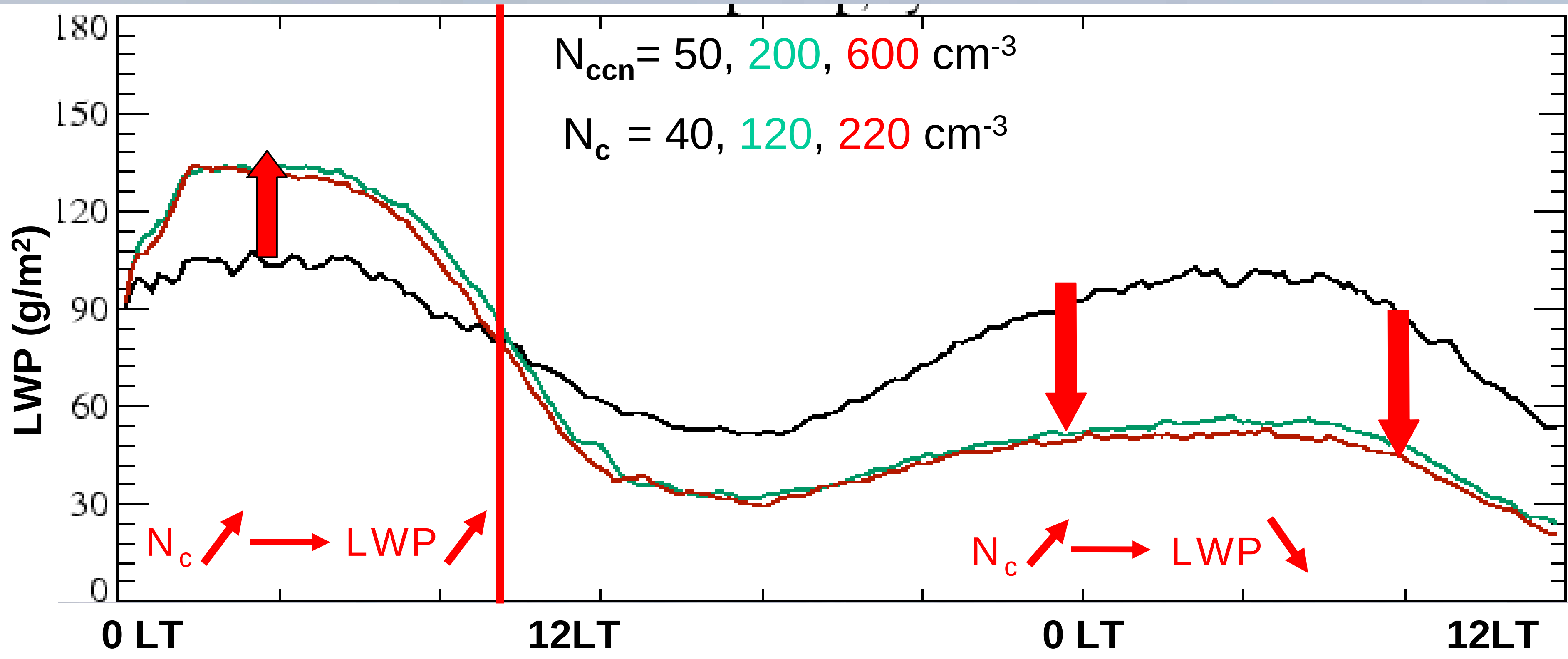
☞ **Simulations of a complete diurnal cycle (36 hours)**

- **different CCN concentrations : 50, 200, 600 cm^{-3}**
- **cloud droplet number concentration : 40-50 , 130-140, 220-240 cm^{-3}**

pristine ⟶ polluted case

☞ **Analysis of the response of the cloud diurnal cycle to the increase in CDNC**

Time evolution of the LWP(g/m²)



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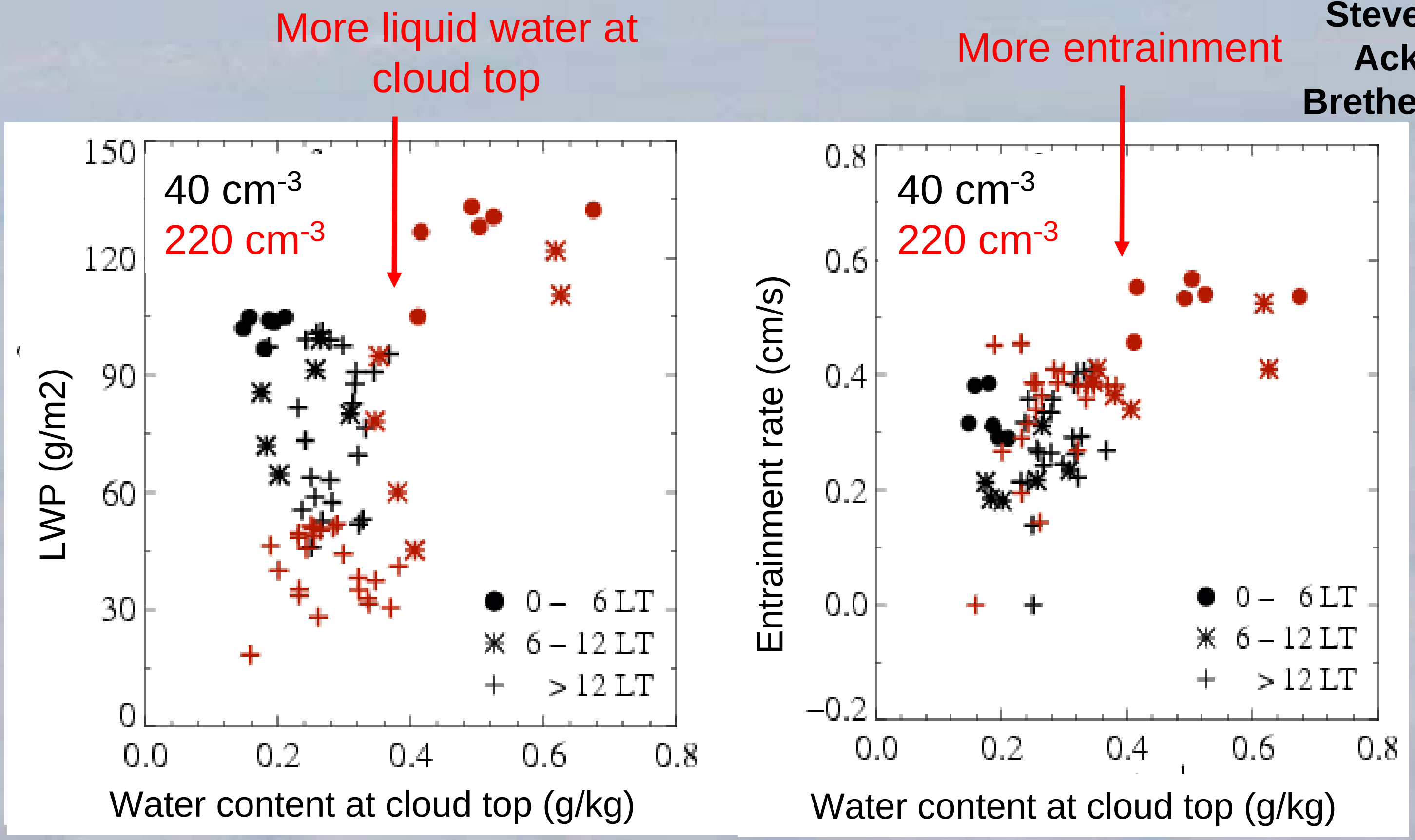
Precipitation, cloud droplet sedimentation, entrainment

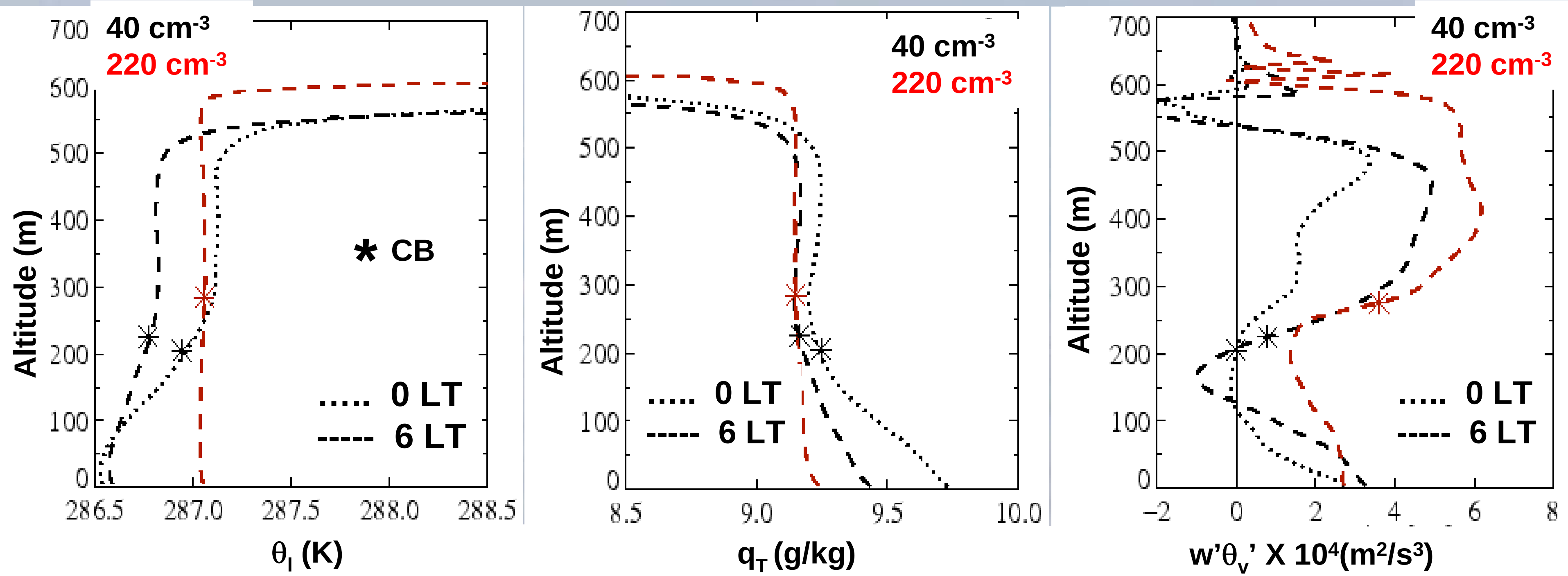
☞ **Pristine cloud (40 cm^{-3}) = precipitating, cloud droplet sedimentation**
Polluted clouds (120, 220 cm^{-3}) = non-precipitating

Stevens et al. 1998
Ackerman 2004
Bretherton et al. 2006



The coupling with the diurnal cycle (I)

☞ **The first nighttime period: 0 – 6 LT**



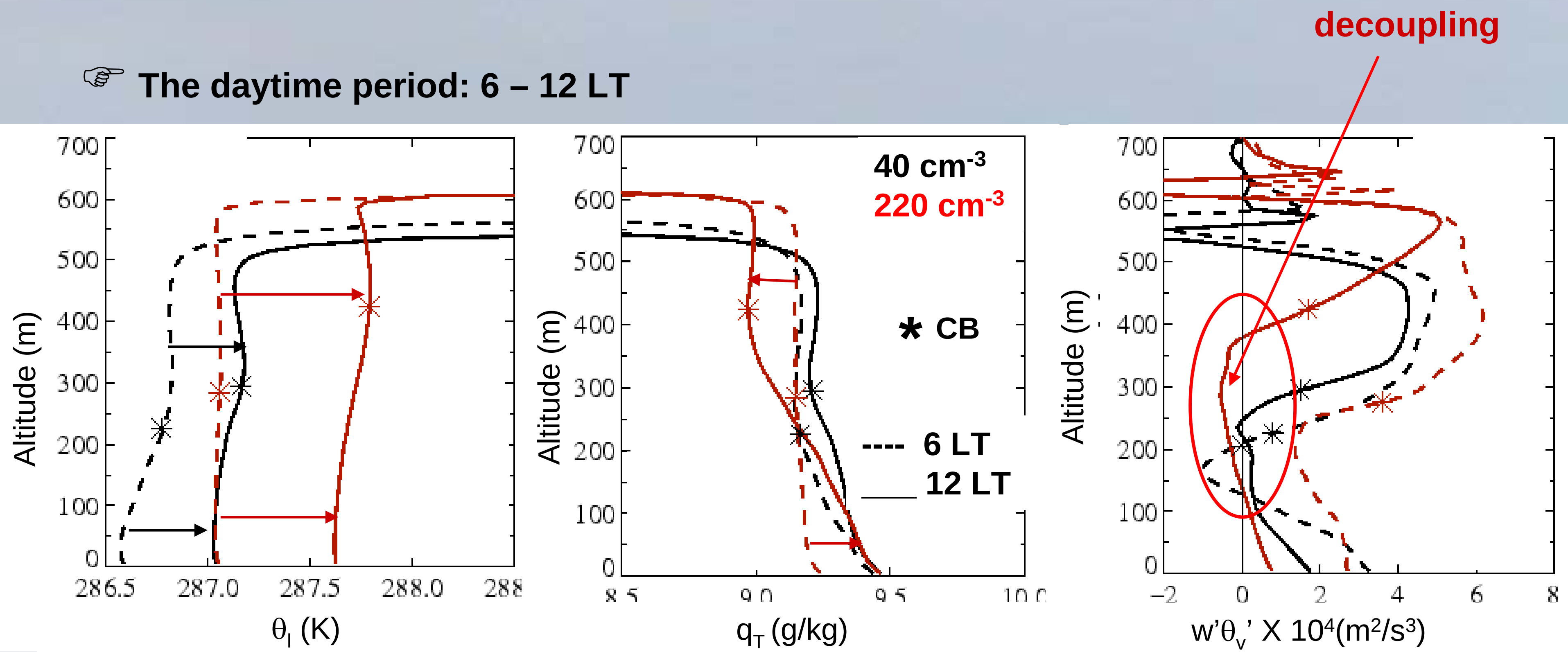
☞ **At 0 LT – stable state**

☞ **At 6 LT – pristine BL : the stability is reduced, but not perfectly coupled**

– polluted BL : strongly mixed

The coupling with the diurnal cycle (II)

☞ **The daytime period: 6 – 12 LT**

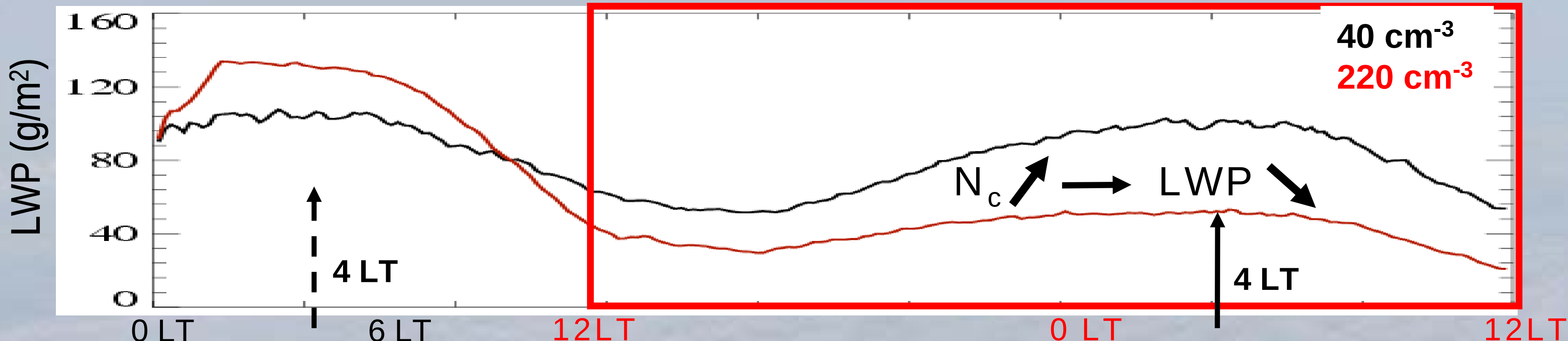


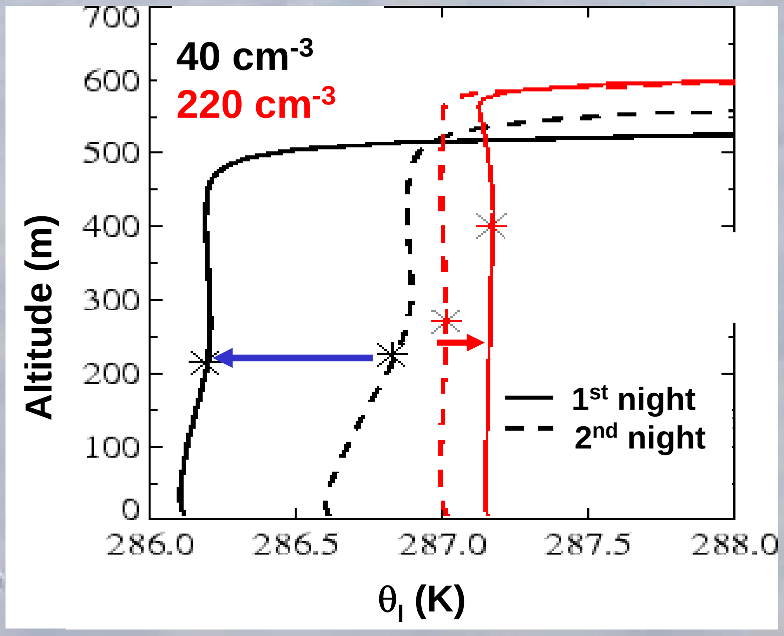
☞ **At 6 LT – pristine BL cooler and moister than the polluted one, but less coupled**

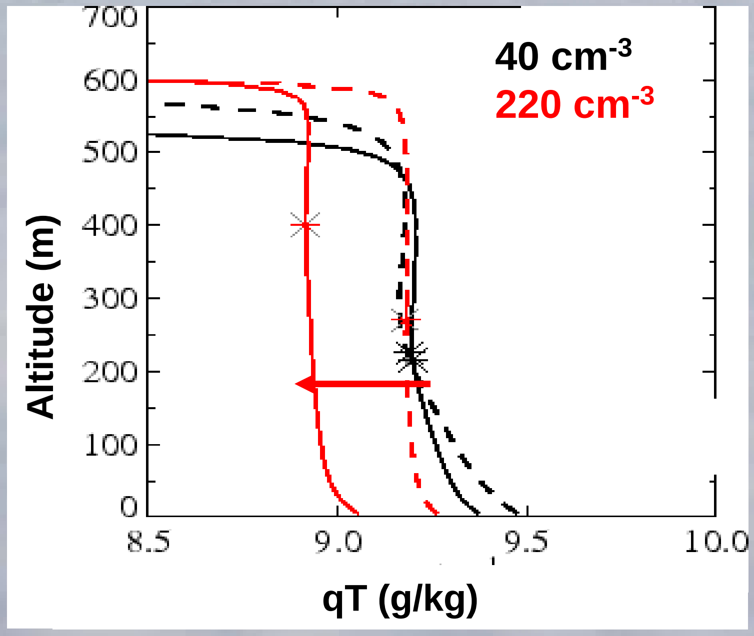
☞ **At 12 LT – pristine BL : more coupled than at 6LT**
– polluted BL : decoupled

The coupling with the diurnal cycle (III)

☞ **The last 24 hours of simulation**

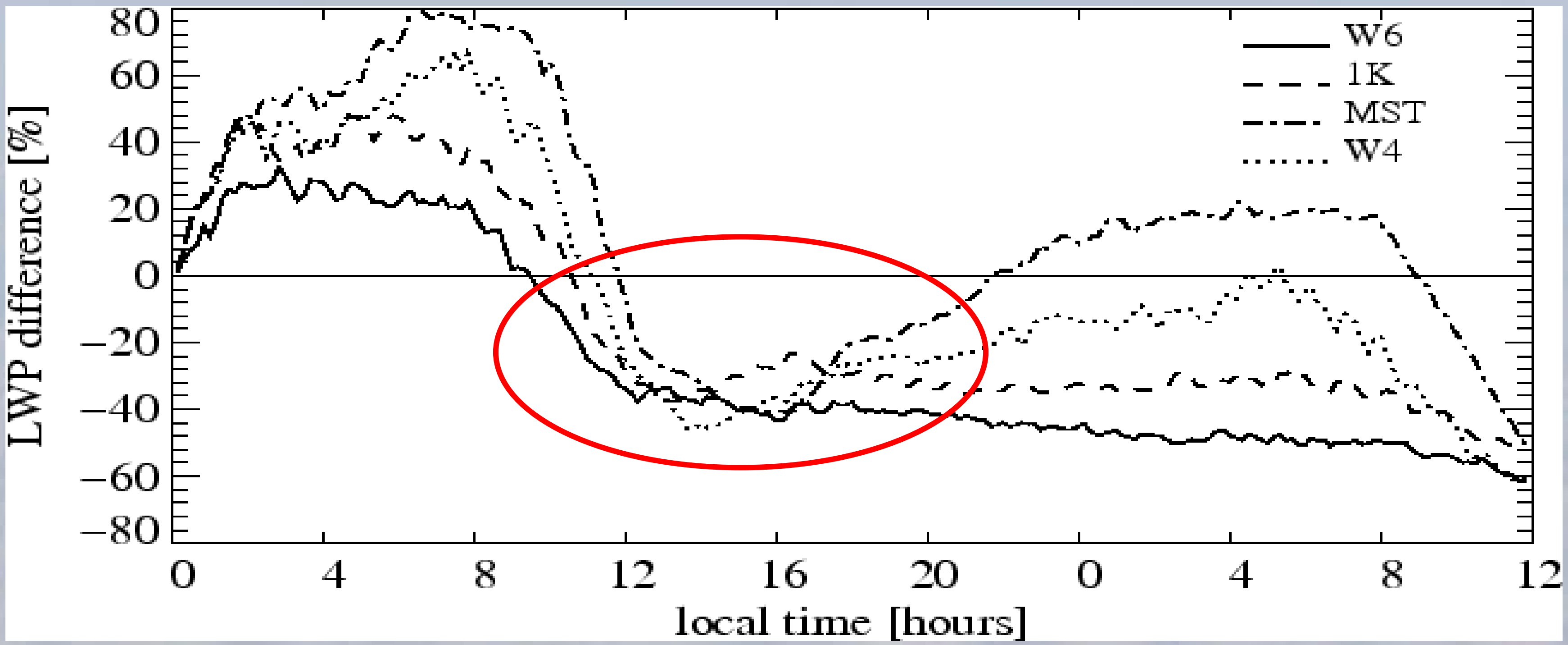






Sensitivity to large scale conditions

☞ **Relative difference in LWP between polluted and pristine case**



☞ **1K : horizontal advection of a colder air mass (-1k/day)**

☞ **MST : moister inversion (-1g/kg instead of -3g/kg)**

☞ **W4 : weaker subsidence (divergence of 4X10^{-6} s^{-1})**

Conclusions

- **For large scale conditions leading to a periodic diurnal cycle for pristine conditions, the increase in CDNC drives the boundary layer to a non reversible evolution and to the dissipation of the cloud layer**

- **During daytime, the LWP of polluted clouds is smaller than the one of pristine ones, irrespective of large scale conditions**

- **A positive feedback between enhanced entrainment, the surface fluxes and the impact of SW absorption and on the stability of the boundary layer**

- **The impact on cloud albedo might be even stronger, and less sensitive to large scale forcing, than previously indicated**

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