Effects of Representations of Autoconversion Threshold on Cloud-Resolving Model

Huan Guo (hguo@bnl.gov) and Yangang Liu (lyg@bnl.gov)
Brookhaven National Laboratory, Upton, NY 11973

BROOKHAVEN NATIONAL LABORATORY

ARM ATMOSPHERIC RADIATION MEASUREMENT PROGRAM

1. Introduction

➢**Motivation:**

The threshold behavior of autoconversion process has been largely described by ad hoc functions, which need further examinations.

➢**Method:**

ATHAM (Active Tracer High-resolution Atmospheric Model) is used to explore the effect of threshold functions on the contrasting clean and polluted cases.

2. Threshold Representation

➢**Generic expression:**

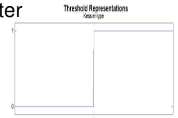
$$P = P_0 \, T$$

autoconversion rate (P); conversion of cloud to rain water (P_0); threshold behavior (T)

➢**Kessler-type:**

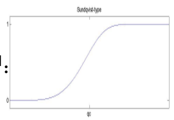
$$T_K = \mathcal{H}(q - q_c)$$

Heaviside function



➢**Generalized Sundqvist-type**[1]**:**

$$T_S = 1 - \exp[-(q/q_c)^p]$$



Note: as $p \rightarrow \infty$, $T_S \rightarrow T_K$

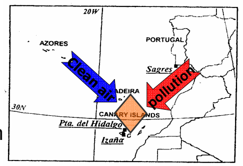
3. Model and Case Descriptions

ATHAM: 3D, non-hydrostatic, fully compressible[2]

ACE-2: over sub-tropical northeast Atlantica during 1997

clean case: on 26 June
pristine marine air

polluted case: on 9 July
anthropogenic pollution



4. Simulation Set-up and Results

We implement the generalized Sundqvist-type autoconversion scheme in contrasting clean and polluted cases, but using different threshold functions ($T_S = 1-\exp[-(q/q_c)^p]$) as shown in the following Table.

Test	'P$_0$'	'Sun2'	'Sun4'	'Sun100'
Threshold function	T_s =1	*P=2*	*P=4*	*P=100*

ATHAM was initialized and driven by the ECMWF reanalysis data. The first 6-h simulation was a spin-up and our analysis was performed for the last 24-h. Fig. 1 presents the temporal evolutions of cloud fraction and in-cloud liquid water path. For clarity, the results from the tests of 'Sun2' and 'Sun4' are omitted.

clean case (26 June)

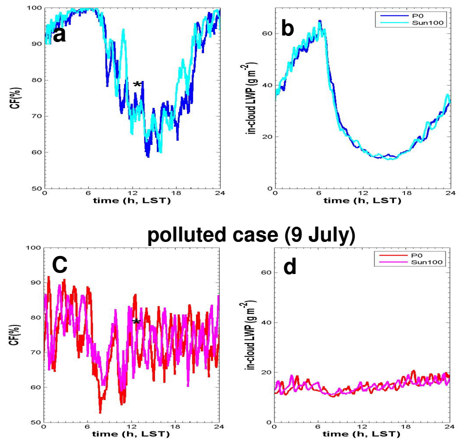


Fig. 1. Time series of cloud fraction (CF) and in-cloud liquid water path (LWP) in the clean (a and b) and polluted case (c and d) during the ACE-2.

As shown in Fig. 1, the differences of average CF and LWP in both the clean and polluted cases are insignificant, although two (extreme) threshold functions are adopted. [Note: 'P0' is continuous, and 'Sun100' is highly discontinuous and close to the Heaviside step function].

5.a. Discussion: Mass Ratio (x_s)

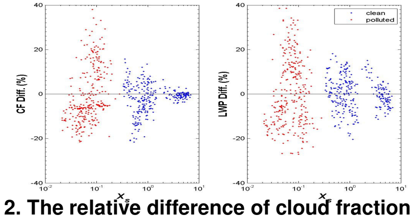


Fig. 2. The relative difference of cloud fraction (CF) & liquid water path (LWP) vs. the mass ration ($x_s = q/q_c$).

Threshold function depends on the mass ratio (x_s) of cloud water content (q) to critical content (q_c) ($x_s = q/q_c$). In Fig. 2, X_s varies from 0.01 to 10.0; and CF & LWP can vary up to 40% for small X_s.

5.b. Discussion: Autoconversion

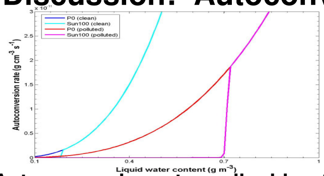


Fig. 3. Autoconversion rate vs. liquid water content.

For the clean case, the **small** magnitude difference of autoconversion rates with different threshold functions is because precipitation occurs at low liquid water content; for the polluted case, it is due to the low liquid water content and high droplet concentration such as the clouds of continental-origin.

6. Conclusions

1: Cloud macro-physical properties (e.g., cloud fraction and liquid water path) are insensitive to representations of the threshold function in autoconversion schemes.

2: Different representations of the threshold function could affect local and temporal variations of clouds.

Selected references:

1. Liu, Y., P. H. Daum, and R. McGraw, Parameterization of the autoconversion process. PART II: generalization of Sundqvist-type parameterizations, *J. Atmos. Sci.,* 63, 1103-1109 2006.
2. Guo, H., J. E. Penner, M. Herzog, and H. Pawlowska, Examination of the aerosol indirect effect under contrasting environments during the ACE-2 experiment, *Atmos. Chem. Phys.,* 7, 535–548, 2007.