# Microphysical and optical characteristics of frontal mixed modeled clouds

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**The paper is devoted to the study of the interconnection of cloudy microphysical characteristics with optical characteristics including the satellite signal (cloud reflectance) in visible and near-infrared part of spectrum. We have realized the next numerical models:**

**1. The time-dependent realistic model of stratiform mixed clouds with detailed microphysics (including the dimension distributions for water drops and 3 forms of ice crystals: needles, plates, columns).**
**2. Models of computations of scattering characteristics for drops are based on the Mie theory and crystals – on the geometric optic approximation methods. Computations were realized for the next wavelengths: 0.55; 0.78; 1.6; 3.6 mkm.**

**3. The Discrete Ordinate Method (DOM) for simulation of solar radiative transfer in not uniform cloud.**

**The simulation shows that the cloud optical thickness (COT) in mixed clouds changes with the cloud liquid water path. The ratio of the COT for λ = 1.6 mkm to the COT for λ = 0.55 mkm strong correlates with the cloud particle phase.**
**So, effective radius of cloud particles and ratio τ (1.6) / τ (0.55) which are retrieved from satellite signal data gives the best possibility to distinguish a cloudiness regions with thick liquid water layers and regions of highly crystallization.**

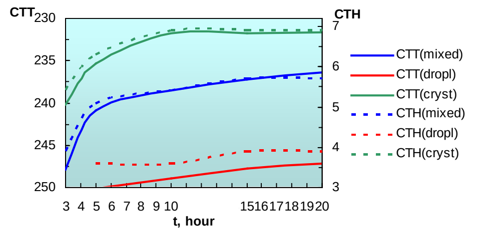


**Fig. 1. Dependence the cloud top temperature (CTT in °K) and cloud top height (CTH in km) from time of evolution of the mixed, mainly water (droplet) and ice (crystal) modelling clouds (A11, A22, B11 accord.)**

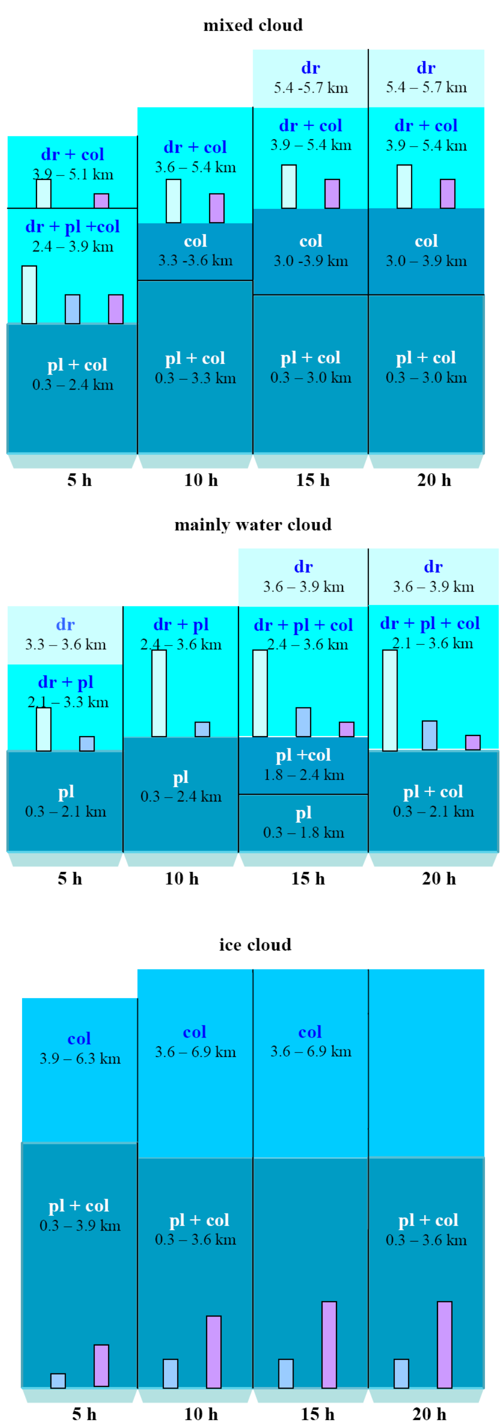


**Fig. 2. The cloud particle phase (layer wise) in the mixed, mainly water and ice modeling clouds (A11, A22, B11 accord.) depending on time of evolution of a clouds;**

☐ **- liquid water content;** ☐ ☐ **- ice water content (both values for comparison: "greater – smaller")**

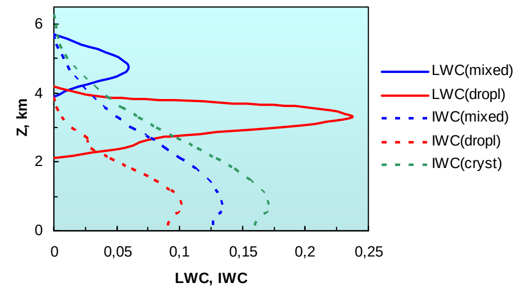


**Fig. 3. The vertical profiles of liquid water content (LWC) and ice water content (IWC, both in g/kg) in the mixed, mainly water (droplet) and ice (crystal) modelling clouds (A11, A22, B11 accord.) in 20 hours of cloudy evolution; (LWC = 0 in the ice cloud)**

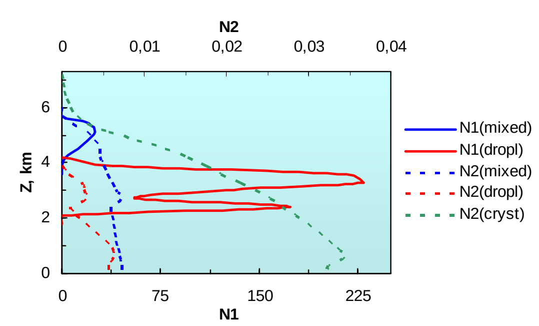


**Fig. 4. The vertical profiles of cloud particles concentrations in the mixed, mainly water (droplet) and ice (crystal) modelling clouds (A11, A22, B11 accord.) in 20 hours of cloudy evolution. Liquid droplets (N1) and ice crystals (N2) concentrations - in 1/cm³; (N1 = 0 in the ice cloud)**

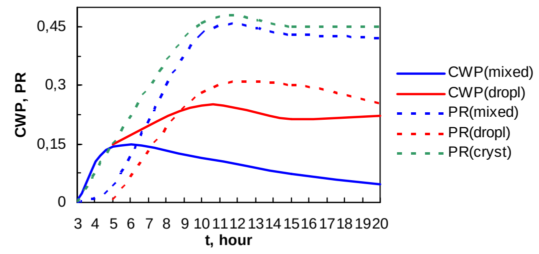


**Fig. 5. Dependence the cloud liquid water path (CWP in mm) and precipitation rate (PR in mm/h) from time of evolution of the mixed, mainly water (droplet) and ice (crystal) modeling clouds (A11, A22, B11 accord.); (CWP = 0 in the ice cloud)**

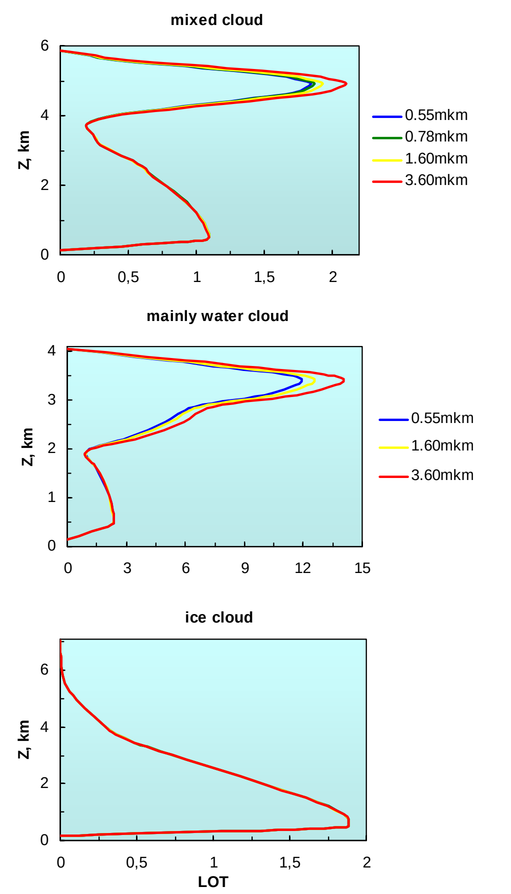


**Fig. 6. The vertical sections of local optical thickness (LOT) in different channels for the mixed, mainly water and ice modelling clouds (A11, A22, B11 accord.) in 20 hours of cloudy evolution. Values LOT for the ice cloud are identical to four channels**

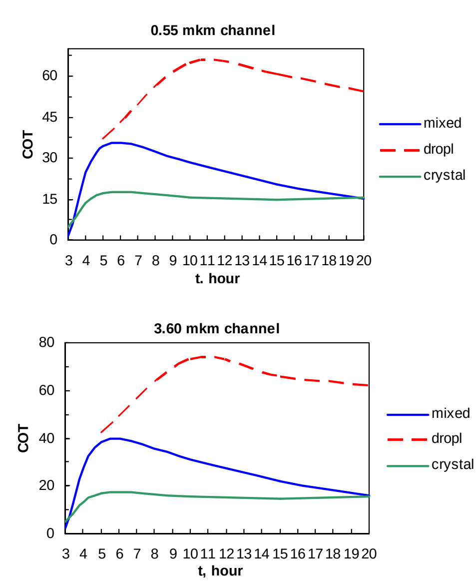


**Fig. 7. Dependence the cloud optical thickness (COT) from time of evolution of the mixed, mainly water (droplet) and ice (crystal) modelling clouds (A11, A22, B11 accord.)**

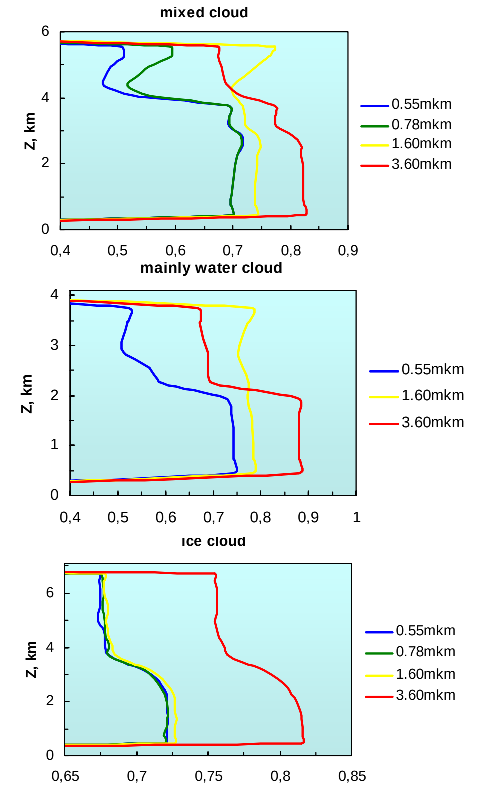


**Fig. 8. The vertical sections of asymmetry factors (G) in different channels for the mixed, mainly water and ice modelling clouds (A11, A22, B11 accord.) in 20 hours of cloudy evolution**

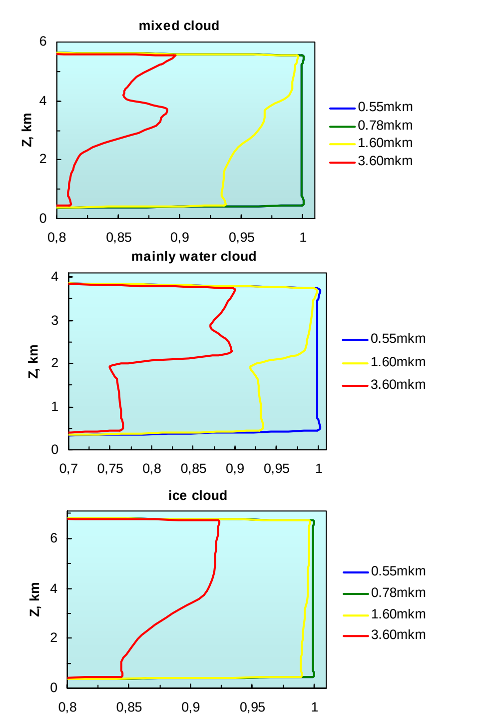
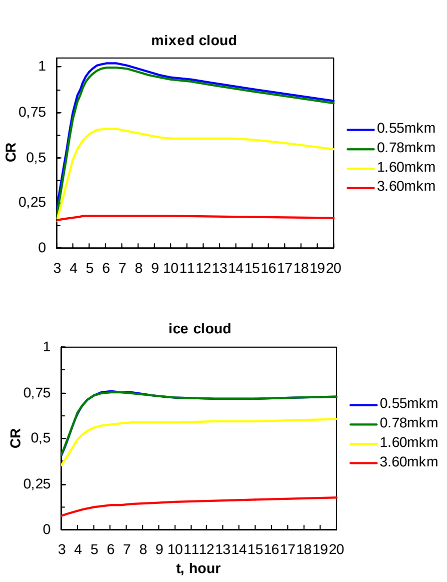


**Fig. 9. The vertical sections of single scattering albedo (W) in different channels for the mixed, mainly water and ice modelling clouds (A11, A22, B11 accord.) in 20 hours of cloudy evolution**



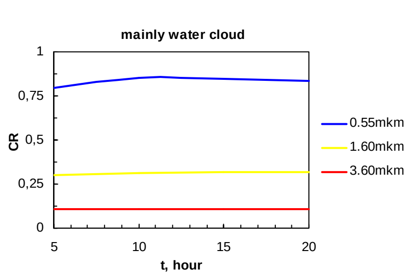


**Fig. 10. The simulated satellite signals (cloud reflectance, CR) in different channels during evolution of the mixed, mainly water and ice modelling clouds (A11, A22, B11 accord.)**

## CONCLUSIONS

If the nucleation rate (or concentration of active nuclei) increases, a cloud may crystallize in the case of the lower cloud top height (cloud top temperature T<-25 grad C).

Plates prevail in these clouds and the COT can rise to values of 40 - 45.

The crystal concentration in ice clouds is more than 10 per liter, the modal radius of plates is equal 300 - 400 mkm, the modal dimension of columns 100 - 200 mkm.

The particular feature of optical properties of ice clouds is as follows: COT does not depend on the radiation wavelength.

So this property and high values of effective radius of cloud particles form the informative criteria for distinguishing cloudiness regions with highly developed crystallization and precipitation formation.