

## THE GCOM-C/SGLI SATELLITE MISSION AND THE STUDY OF LONG-TERM CLOUD TYPES VARIATIONS

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### ABSTRACT:

The Global Change Observation Mission-Climate (GCOM-C) satellite with its high resolution sensor, the Second generation Global Imager (SGLI), are expected to provide new insights in the study of smaller scale clouds than actually detected, as well as refined measurements of the impact of clouds in the climate. To examine long-term trends of climate variations, the observations from this satellite should be combined to analyses of the present state of the climate. Using data from the National Oceanic and Atmospheric Administration-Advanced Very-High-Resolution Radiometer (NOAA-AVHRR) satellites' series, the present study analyzes this climate state and its connectivity to future observations as those from the GCOM-C satellite. 25 years of cloud data are examined and variations in the cloud types distribution and amounts are discussed. To correct for the orbit drift (due to late equatorial time crossing) of the various NOAA satellites used in this study, the cloud properties estimated are adjusted, taking into account the relationship between the drift and the solar zenith angle. Results show that the corrections made give reliable long-term cloud amounts trends and allow for a reasonable transition to the GCOM-C satellite.

### 1. INTRODUCTION

High degree of accuracy in satellite observations is necessary for a reliable assessment of long-term study of cloud variability. Integrating high resolution satellite imagery to actual satellite data is useful for the improvement of climate predictions. This is one the objectives of the future high-performance and fine spatial resolution GCOM-C polar orbiter. The advent of this new satellite will be a valuable tool for the detection of small scale cloud variability in time and space. In this study the present state of the cloud change is analyzed. The data used are 25 years (1982 to 2006) daytime cloud observations from the NOAA-AVHRR satellite. Cloud types' distribution and long-term cloud amount trends are extracted from these data then, a discussion on possibilities to reliably connect these data to the future GCOM-C satellite observations, is conducted. The cloud properties, necessary for the cloud types' distribution and amount estimation are the cloud optical depth, the cloud top pressure and the cloud fraction. The initial cloud properties were processed by the Pathfinder Atmospheres Extended (PATMOS-x) project using the following satellites NOAA-7, -9, -11, -14 -16 and -18. Though NOAA datasets have been corrected for residual sensor degradation, sensor inter-calibration differences, and viewing angle effects, the orbital drift experienced by many of the NOAA satellites needs to be removed. This drift is due to the satellite later equatorial time crossing. The correction method used in this study relies on the solar zenith angle (SZA) change related to the drift. This method is a linearization procedure that considers the correlation between the cloud type amount and the SZA change.

### 2. THE GCOM-C SATELLITE CHARACTERISTICS AND DATA PROCESSING

#### 2.1 Characteristics of the GCOM-C satellite

The prediction of the future of atmospheric movements has always been the main motivation of climate studies (Daley, 1991). The GCOM-C satellite is a climate observation polar orbiter whose data are expected to refine climate models predictions. Its descending local equatorial time will be AM  $10:30 \pm 15$  min. The sensor carried by this satellite, the Second-Generation Global Imager (SGLI), is the successor of the Global Imager (GLI) aboard ADEOS-II. SGLI is an optical sensor with multiple channels (19) ranging from the near-UV to the thermal infrared wavelengths (380nm to 12 $\mu$ m). It consists of two radiometer components, the Visible and Near Infrared Radiometer (SGLI-VNR) and the Infrared Scanner (SGLI-IRS). The SGLI-VNR is capable of observing polarized and non-polarized radiances: the non-polarization channels (11) have a nadir view spatial resolution of 250m and swath of 1150km; the polarization/along-track channels (2) have a slant view, a spatial resolution of 1km and a swath 1150km. The SGLI-IRS has 4 Shortwave infrared (SWI) channels with a spatial resolution of 250m/1km and a swath of 1400km, then 2 thermal infrared (TIR) channels with a spatial resolution of 500m and a swath 1400km.

#### 2.2 Processing of observation data

Using PATMOS-x global daytime cloud dataset processed from NOAA-AVHRR satellite afternoon orbit (2 PM) observations, the recent state of the climate is evaluated in terms of cloud types' distribution and amounts. The grid spatial resolution of the data used is 0.5\*0.5°. The ISCCP classification algorithm (Rossow et al, 1993, Rossow and Schiffer, 1999) is employed to distinguish 9 cloud types based on the cloud top pressure and

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the cloud optical depth. In this classification, clouds are first divided into 3 cloud layers (high, mid and low), and each cloud layer comprises 3 cloud types: the high clouds are cirrus (Ci), cirrostratus (Cs) and deep convection (Dc); the middle clouds are altocumulus (Ac), altostratus (As) and nimbostratus (Ns); and the low clouds are cumulus (Cu), stratocumulus (Sc) and stratus (St). Following this classification, the distribution and long-term (25 years) variations of clouds amounts at the global and regional scales are analyzed. The variations are either expressed in raw quantities or as anomalies relative to the average of the period of study. For long term trend analyses, the data used need to be calibrated. In the past, various calibrations have been applied on NOAA-AVHRR's data (Kidwell, 1995; Rao and Chen, 1995 and 1999; Cao et al, 2004). Though these calibrations have been successful in correcting most of the artifacts of lower levels satellite data, further corrections are needed as orbital drift effects have been noticed on various NOAA satellites (Price, 1991; Jin and Treadon, 2003). This drift results to the late equatorial time crossing of the satellites. The solar zenith angle (SZA) being proportional to this equatorial time crossing, can be used to correct the cloud quantities results. A linearization procedure relating the cloud types' amounts to the SZA is used to remove the drift effect. The results of these corrections show that there is an attenuation of the largest fluctuations in the cloud amount (CA) at various areas and more specifically at the inter-satellites' transition areas (between NOAA-7 and -9 then NOAA-9 and -11). The global cloud amounts corrected (i.e. after removal of the orbital drift effect) leads to a CA increase of 1% compared to the initial (64%). Also, there is a very slight change in the long-term cloud variation (from the initially no-specific trend to a slightly decreasing trend). Following these corrections, the cloud amounts estimated could be used to study long-term cloud types' trends.

### 3. EXTRACTION OF CLOUD TYPES TRENDS

Figure 1 shows the trends extracted from cloud amounts anomalies, from the major regions to the global scale. The cloud trends are presented for all clouds and at every cloud layer. The global cloud series slightly decreases. This nearly steady trend is driven by the near equilibrium between the strong increase in high clouds and the combined decrease of low and middle clouds. The high cloud increase noticed here is essentially due to the strong increase in cirrus clouds while the low cloud decrease is mostly the effect of stratocumulus clouds' strong decrease. The ocean cloud trend, contrary the global cloud trend, slightly increases (0.046%/year). This increase is due to the high contribution of high clouds (Compared to the global clouds, there is as much Ci positive contribution, a higher positive contribution from Cs and a lesser negative contribution from Dc). The land clouds present a completely different behaviour from that of the ocean clouds with a strongly decreasing trend (-0.213%CA/year). This trend is driven by the strong negative contribution of low clouds (Sc mainly: 30% of the trend). All regions combined, the land clouds show the second largest trend variation (decrease). The slight increase of ocean clouds is countered by the strong decrease of land clouds. The land clouds are therefore the driving force of the slightly negative global cloud trend. At the tropical area (30S-30N), there is a medium decrease of the overall cloud trend. This is driven by the combined negative action of all the three middle cloud types (~30% contribution) overwhelming the still strong increase in Ci clouds. The subtropical areas show a weak to strong negative trend in the south and north respectively. The south region trend is the

result of a particularly good balance between the contributions of every cloud layer with however a slightly dominant negative effect of the Sc. For the northern area, the strong decreasing trend is the result of the combined negative contribution of low clouds (mainly Sc) and middle clouds (mainly Ns). At the polar areas, the southern pole has a slightly increasing trend and the northern pole a strongly negative trend, undoubtedly the strongest of all the regions (-0.333 % CA/year). This behaviour is mostly the result of the equilibrium between opposite contributions of As (positive) and Ns (negative). In the northern pole all the cloud types decrease or some may show a lack of trend. The highest negative contributions are St (22%) and Ns (25%).

### 4. CONNECTIVITY TO THE GCOM-C SATELLITE

The goal of the GCOM-C mission is to develop long-term climate observations. To do this the satellite will rely not only on its proper capacities but also on the past and actual satellite data. In this regard one of the longest series of satellites observations is the NOAA satellites. The NOAA satellites from which the cloud properties were extracted for this study are launched at a local standard time (LST) of PM 2:00±30 min while the GCOM-C launch time will be AM 10:30±15. Connecting those two series of data would necessitate some adjustments as the clouds viewing times are different. One way to do this connection is to use a relationship linking cloud amounts at specified moments of the daily cloud cycle as retrieved from other satellites (e.g. geostationary satellites or other concomitant NOAA satellites). However, the daily cloud cycle varies according to the cloud type and the altitude. Another way is to compare the cloud amounts drawn from two well calibrated sensors aboard satellites flying at nearly similar times to the GCOM-C and the NOAA pm series. Terra MODIS (LST is as that of the GCOM-C i.e. AM 10:30) and Aqua MODIS (LST is PM 1:30 and, this is near to NOAA PM satellites) can respectively play this role. This Terra-Aqua combination is chosen in this study to conduct the connection between the NOAA analyses and the GCOM-C.

### 5. CONCLUSION

To examine the long-term climate changes, the present state of the climate should be evaluated. One of the most variable components of this climate state is the cloud type. Using long-term daytime cloud properties data of the NOAA-AVHRR processed by PATMOS-x, we examine the characteristics of the cloud types' variability in terms of their distribution and amount, for 25 years. To correct for the drifting observed with the NOAA satellites series, the cloud amounts extracted from this study are adjusted with the change of the solar zenith angle related to the drift. The corrected quantities and the trends derived are analyzed. Then the driving components of these trends are discussed. The global cloud series showed a slightly decreasing trend. This state is driven by the equilibrium between the highly positive contribution of high clouds and the combined negative action of low and middle clouds. Compared to the global clouds, the ocean cloud trend slightly increases; this is due to a higher contribution of high clouds (strong cirrus and cirrostratus increase). As the ocean trend is slightly positive, it can be said that the negative trend of the global cloud is mostly driven by the land clouds. These land clouds show a strongly negative trend driven by the negative contribution of low clouds (stratocumulus mainly). At the tropical area (30S-30N), there is a medium decrease of the overall cloud trend.

The subtropical areas show a weak to strong negative trend at the south and north respectively. At the polar areas, the southern pole has a slight increasing trend and the northern pole the strongest negative trend among all the regions. In the northern pole all the cloud types decrease or have an exceptionally steady trend.

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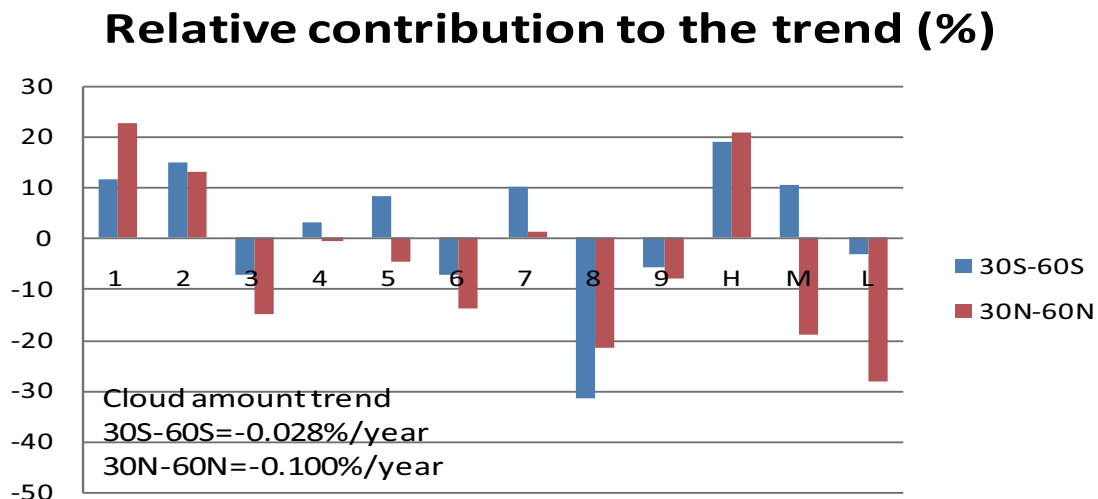
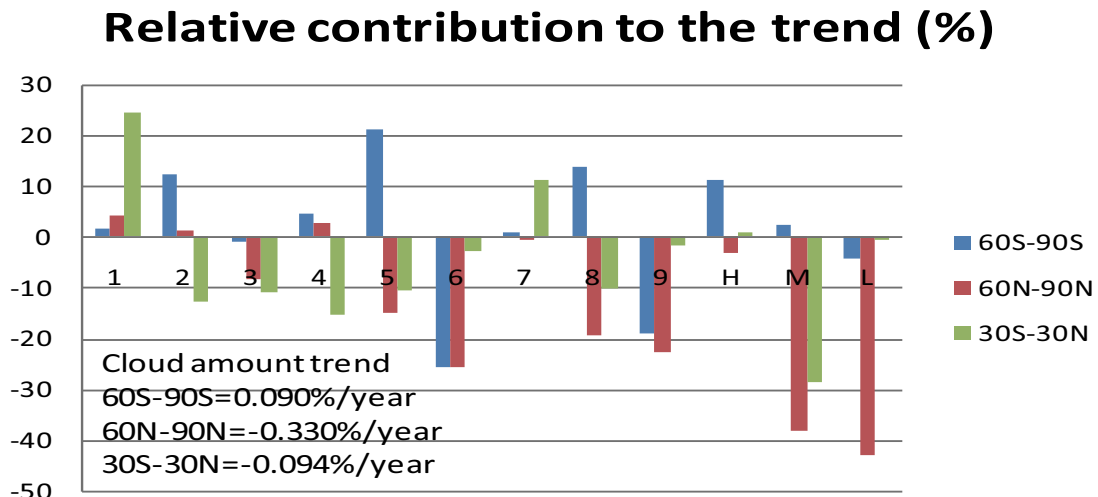
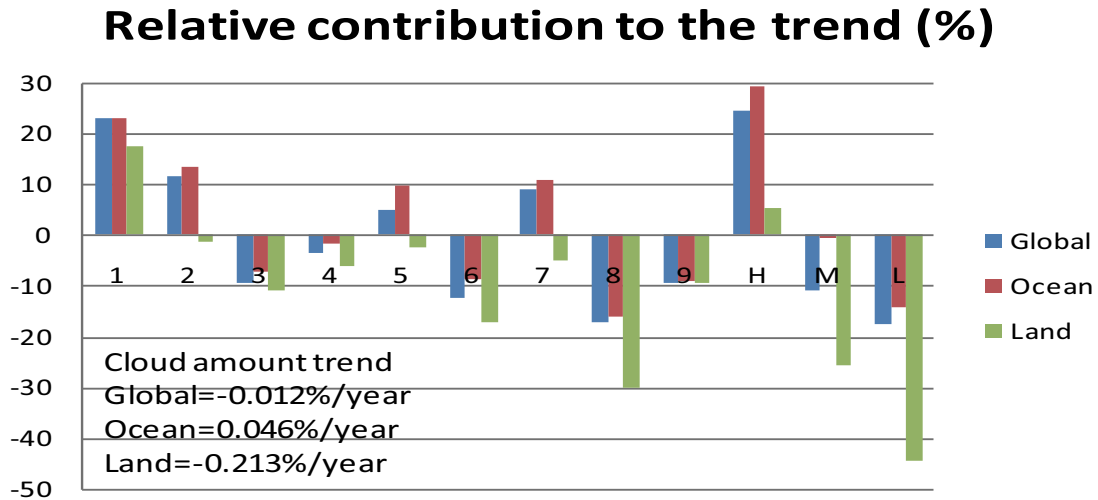


Figure 4. Individual cloud types contribution to the total cloud amount trend in each region. 1-Cirrus, 2-Cirrostratus, 3-Dense convection, 4-Alto cumulus, 5-Altostratus, 6-Nimbostratus, 7-Cumulus, 8-Stratocumulus, 9-Stratus, All- total of all clouds, H-high clouds, M-middle clouds, L-low clouds.