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Comparison of Spatial and Temporal Cloud Coverage Derived from CloudSat, CERES, ISCCP and Their Relationship with Precipitation Over Africa

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Abstract: The spatial and temporal cloud coverage derived by CloudSat, CERES, ISCCP satellite observations and their relationship with GPCP and TRMM precipitation in West, East and South of Africa were analyzed in this study. CloudSat, CERES and ISCCP show that the high spatial cloud coverage is more frequent in equatorial regions mainly due to more strong convection than other regions. CloudSat shows a low temporal cloud coverage than CERES and ISCCP which are close. Only ISCCP was used to investigate seasonal and temporal variability of different cloud types. The stratocumulus, altostratus, and cirrus clouds are the low, middle and high cloud types with high cloud coverage during JJA, JJA, MAM in West of Africa, during SON, JJA, MAM in East of Africa, and during SON, DJF, DJF in South of Africa respectively . The correlation between cloud coverage and precipitation dataset generally shows a low positive correlation in East of Africa probably due to GPCP and TRMM observations biases whereas a high positive correlation in West and South of Africa. Only middle clouds level in East of Africa, both low and middle in West of Africa show negative correlation with precipitation, whereas all cloud types level in South of Africa show a positive correlation with precipitation.

Keywords: CloudSat, CERES, ISCCP, Cloud Coverage, Precipitation, Africa

1. Introduction

Clouds are one the components which contribute to the Earth's weather and climate. The study of cloud microphysics help to understand the impacts of clouds on the formation of precipitation. Clouds are one of the major factors that influence the general circulation of the atmosphere, the hydrological cycle and the Earth radiation budget [1]. They are the fundamental stage of water cycle processes in the atmosphere, while by condensation of water vapor they form precipitation and the use various instruments as the millimeter-wave CloudSat radar systems help to a broader understanding of the radar reflection properties of various cloud types [2]. The CloudSat Cloud Profiling Radar (CPR) is able to measure the return power backscattered by clouds as function of distance from the radar [3]. The CERES cloud detection algorithm uses four wavelengths whereas ISCCP uses two in order to decide if it the pixel is clear or cloudy [4]. [5] explained that for thin high clouds above low clouds, the detection of multiyear clouds is difficult for ISCCP and CERES to accurately retrieve cloud tops because they are based on single layer clouds. ISCCP showed a peak of high cloud at night or in the earlier morning, around 20:00 local time away from the equator and later around 24:00 local time near the equator, and middle clouds were found to be the most significant cloud type for the tropics with the maximum at sunrise in Africa, while low clouds were found to reach the diurnal peak over land near noon and a diurnal peak over the ocean in the early morning [6]. Previous studies have been done by passive satellite sensors using algorithms based on different cloud spectral and physical features [7, 8]. The cloud microphysics is very sensitive to the cloud drop size distribution and shows that when the liquid water droplets are small, it is difficult for raindrops to grow until the sufficient size and reach the highest velocity in order to overcome the updrafts, and then the clouds fall out and reach the surface without evaporating [9]. The mechanism of cloud dynamical microphysics of several clouds types is different and they are characterized by different microphysical properties which results in different cloud radiative forcing [10]. High clouds are more distributed over the Intertropical convergence zone which is correlated to deep convective clouds [11]. [12]

showed that the CloudSat Cloud Profiling Radar is not able to detect liquid content in altocumulus clouds due to the small droplet size and low sensitivity of the radar. Clouds can be classified in thin, moderate and thick cloud depending on cloud optical depth. The cloud frequency averaged between 60^0S and 60^0N showed that thin clouds are cumulus (low level cloud), altocumulus (middle level cloud), cirrus (high level cloud), while the moderate clouds are stratocumulus (low level cloud), altostratus (middle level cloud), cirrostratus (high level cloud), and the thick clouds are stratus (low level cloud), nimbostratus (middle level cloud) and deep convective cloud (high level cloud) [5]. In the previous study GPCP succeed reasonable estimation in JJA in the place where there was much rainfall, and TRMM 3B42 and GPCP were highly correlated except in light rain area, where TRMM 3B42 has more rainfall in almost all land area [13] and another study showed a small difference between over land than ocean [14]. In Amazonian basin ISCCP high-level clouds were found mostly in the rain season and decrease considerably in the dry season, and the annual cycle showed that the middle clouds were similar to high level clouds whereas low level clouds were comparatively small, while large amounts of low level clouds during dry season, and there is a positive relationship between cloud and precipitation [15]. The increase of aerosol concentrations tends to decrease the size of cloud droplets and makes the precipitation formation less efficient and then increase cloud lifetime [16], while satellite data showed a reduction of rainfall because of small cloud particles that are influenced by air pollution [17]. The clouds types are good indicators of the dynamic and thermodynamics state of the atmosphere [18,19]. [20] studied the cloud coverage variability during summer over tropical Africa and found that the middle level clouds have the highest cloud coverage with the maximun between 18:00 local time and midnight, while the minimum between 09:00 local time and noon over land. [6] found that the the global average high cloud coverage occurs around 13:30 local time over land. The previous study showed the increase of precipitation with the increase of stratocumulus [21]. In the tropics and subtropics the precipitation amount is high which corresponds to intense convection [22,23]. The cumulus, stratocumulus and cumulonimbus exists more frequently in subtropics over land [24]. It is difficult for ISCCP to identify thin cirrus clouds in morning hours clouds probably due to the presence of low cloud levels below cirrus clouds [25].

2. Data and Methodology

Remote sensing data from various satellites which detect cloud coverage and precipitation amount at large scale have been used to compare spatial variability of cloud over three regions of Africa, namely west, east and south of Africa and to investigate the relationship between cloud coverage and precipitation distribution. Monthly cloud coverage data used in this study are derived from CloudSat (Cloud Satellite), CERES (Clouds and the Earth's Radiant Energy System) and ISCCP (International Satellite for Cloud Climatology) with temporal range of 2006 to 2010, 2000 to 2013 and 1995 to 2009 respectively. Monthly precipitation data are from GPCP (Global Precipitation Climatology Project) and TRMM 3B42 (Tropical Rainfall Measuring Mission) from 1979 to 2013 and 2006 to 2013 periods respectively. CloudSat was developed as a collaboration between NASA, the Canadian Space Agency (CSA), and the U.S. Air Force [26]. The TRMM satellite is a joint U.S.- Japan to monitor tropical and subtropical precipitation and also to estimate its associated latent heating. Its rainfall measuring instruments include the Precipitation Radar (PR), TRMM Microwave Image (TMI) and a Visible and Infrared Scanner (VIRS). CloudSat use a Cloud Profiling Radar (CPR) which is a 94 Hz near-nadir-looking radar that can provide profiles of cloud condensate and precipitation with a nominal vertical resolution of 500 m, and it aims to evaluate quantitatively the representation of clouds and cloud processes in global atmospheric circulation models, and the relationship between vertical profiles of cloud liquid and ice water content, cloud radiative properties, including the radiative heating by clouds [2]. The CPR has the ability to detect most but not all, tropospheric clouds [10]. The TRMM PR is the first active satellite microwave instrument to measure three dimensional structures of rainfall over the tropics and subtropics [27]. Clouds and the Earth's Radiant Energy System (CERES) is able to simultaneously observe relatively low resolution broadband radiances and high resolution imager narrowband radiances [4]. It uses 1km MODIS pixels sampled to a 4 km resolution for cloud observations [5]. The International Satellite Cloud Climatology Project (ISCCP) has been approved as the first project of the World Climate Research Programme (WCRP) with the main objective to collect and analyze satellite radiance data from the global distribution of cloud radiative properties in order to improve the modeling of cloud effects on climate [11]. The ISCCP combines infrared and visible radiances from geostationary satellites with the TIROS Operational Vertical Sounder (TOVS) atmospheric temperature and humidity and correlative surface ice/snow data in order to obtain cloud information of nine cloud types according to cloud top pressures: high (below 440 mb), middle (between 440 to 680) mb, and low (above 680 mb) [5]. ISCCP provides several cloud properties datasets at 30 km or 280 km spatial and 3 hourly to monthly temporal resolutions [15]. Even though CloudSat provides cloud types datasets, we have used only ISCCP to investigate them for long period. It is one of the best and most widely used datasets to study cloud properties[1]. GPCP data are combined from microwave-based estimates from SSM/I, IR rainfall estimates from geostationary and polar orbiting satellites, estimates from Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) and Atmospheric Infrared Sounder (AIRS), and surface rain gauges , whereby they were developed to improve the understanding of the spatial and temporal patterns of global precipitation, to provide a long time period of monthly and finer time precipitation analyses on global scale with a monthly analysis of 2.5^0 latitude × 2.5^0 longitude grid from 1979 to present [28].

GPCP has become very spatial and useful in unveiling the temporal and special distribution of tropical precipitation [14]. All data used in this study are archived and distributed by NASA and can be accessed at: http://mynasadata.larc.nasa.gov/.

3. Results and Analysis

In this study we have studied the monthly cloud coverage variability of low level clouds (cumulus (cu), stratocumulus (Sc), stratus (St)), middle level clouds (altocumulus (ac), altostratus (As), nimbostratus (Ns)), and high level clouds (cirrus (Ci), cirrostratus (Cs), deep convective (dc)). The relationship between cloud coverage and precipitation is also discussed. Many researches have been done on cloud variability in Africa, but there are no studies focused on relationship between cloud types and precipitation for temporal and spatial variabilities for specific regions. Due to low amount of ice in low level cloud, we only considered low level cloud with liquid where for middle and high level clouds we considered both liquid and ice contents. Clouds are weak scatterers of microwave radiation, in contrast to the much stronger reflection from the underlying surface of the earth. [6] explained that the net effect of diurnal variations of cloud types over land and cool the surface during the day for low cloud and warm the surface at night for both middle and high level clouds. In the previous study CloudSat and ISSCP were in agreement to cloud types distribution except cumulus (Cu) clouds [12]. CloudSat and CERES show the total monthly cloud coverage with the highest amount in equatorial regions (Fig. 1). The ITCZ portion is evident in both hemisphere with land maxima in Africa and South America [27]. High clouds coverage are related to the ITCZ which crosses equatorial regions two times per year. There is a good agreement in spatial cloud coverage distribution between CloudSat, CERES and ISCCP (Fig. 1). They show that during DJF (Fig. 1a, Fig. 1e), JJA (Fig. 1c, Fig. 1g), the high cloud coverage are more frequent between central of Africa and south of Africa, while during MAM (Fig. 1b, Fig. 1f) and SON (Fig. 1d, Fig. 1h) it is more dominated in central of Africa and east of Africa. The rainfall season in west, east and south of Africa occurs during JJA, both MAM and SON, DJF respectively. This shows that high cloud coverage occur during rain season. [3] showed that CloudSat may not be able to detect low-level clouds due to its coarse vertical resolution of about 500 m with a low sensitivity near the surface. The high and low total cloud coverage is remarquable in equatorial regions and in north of Africa respectively. The spatial distributions of cloud coverage derived from CERES and ISCCP are close and show remarquable difference with CloudSat especially in Atlantic ocean near the equatorial region during SON, JJA and DJF. CERES and ISCCP show high cloud coverage in that region whereas CloudSat shows low cloud coverage. During SON, ISCCP and CloudSat show high amount of cloud coverage whereas CERES shows low cloud coverage in regions located in south of Africa. ISCCP shows high amount of clouds than CERES and CloudSat.

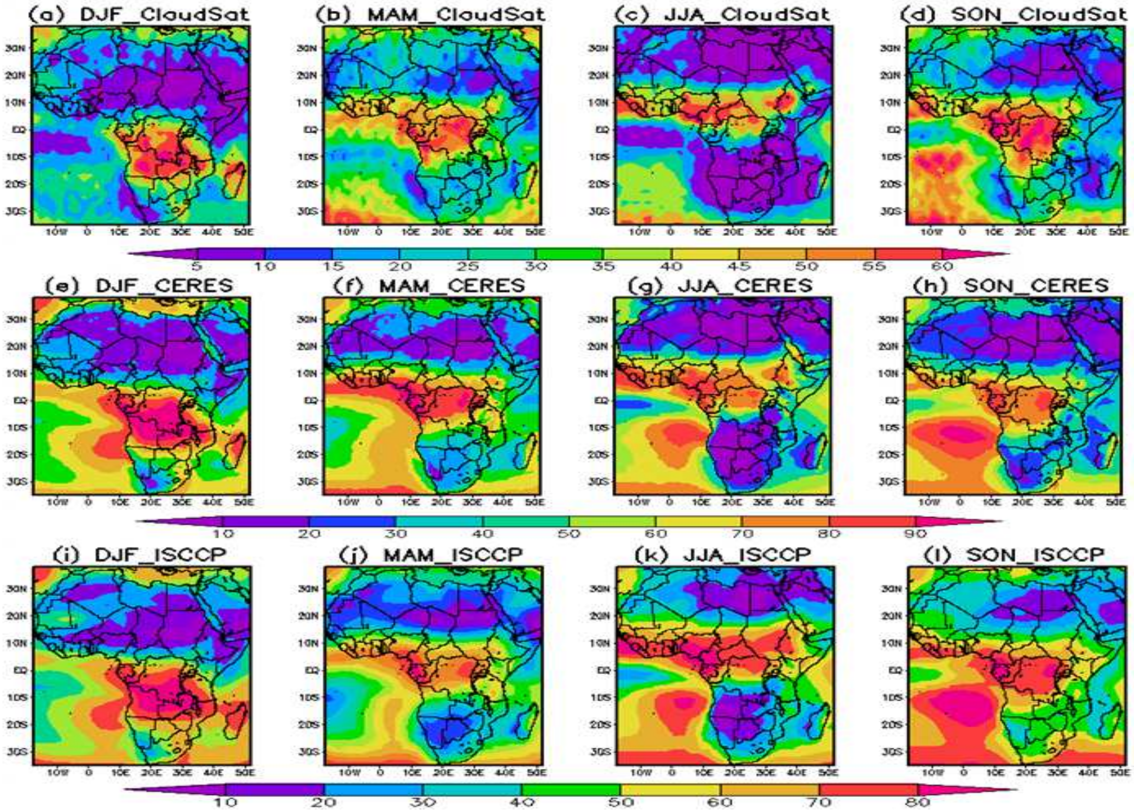

Figure 1. *Seasonal spatial cloud coverage (%) distribution based on ((a), (b), (c), (d) CloudSat, ((e), (f), (g), (h) CERES, and ((i), (j), (k), (l)) ISCCP over Africa.*

[10] showed that low clouds appear to be predominantly over ocean, and most abundant in the subtropical eastern oceans, where the sea surface temperature is comparatively low and the mean air motion is downward. Low level clouds investigated are cumulus (Cu) (Fig. 2a, Fig. 2b, Fig. 2c, Fig. 2d), stratocumulus (Sc) (Fig. 2e, Fig. 2f, Fig. 2g, Fig. 2h), stratus (St) (Fig. 2.i, Fig. 2j, Fig. 2k, Fig. 2l) with liquid contents. The ice contents in low level clouds are too low, in this study we didn't analyze them. Low clouds are associated with rain, although the rain intensity varies, stratus and stratocumulus are usually associated with drizzle, light rain or no rain at all and stratocumulus clouds are sometimes formed by the rain that falls from a layer of altostratus, and nimbostratus which middle level clouds always associated with rain [29]. Stratus clouds are predominatly developed in regions of intense tropical convection and cover approximately 22% of the Earth's surface and distributed diffusely over the convective regions of the Earth [10]. The Figure 2 shows that the coverage of low level clouds stratocumulus (Sc) and stratus (St) is small in Africa, whereas cumulus (Cu) is more frequent in north of Africa. Low clouds have the ability to produce drizzle but not heavy rain [15]. The results in Figure 2 show that low clouds in Africa are almost non-precipitating clouds as they are too low in rain season. [7] explained that the net effect of low clouds is to cool the surface during the day over land.

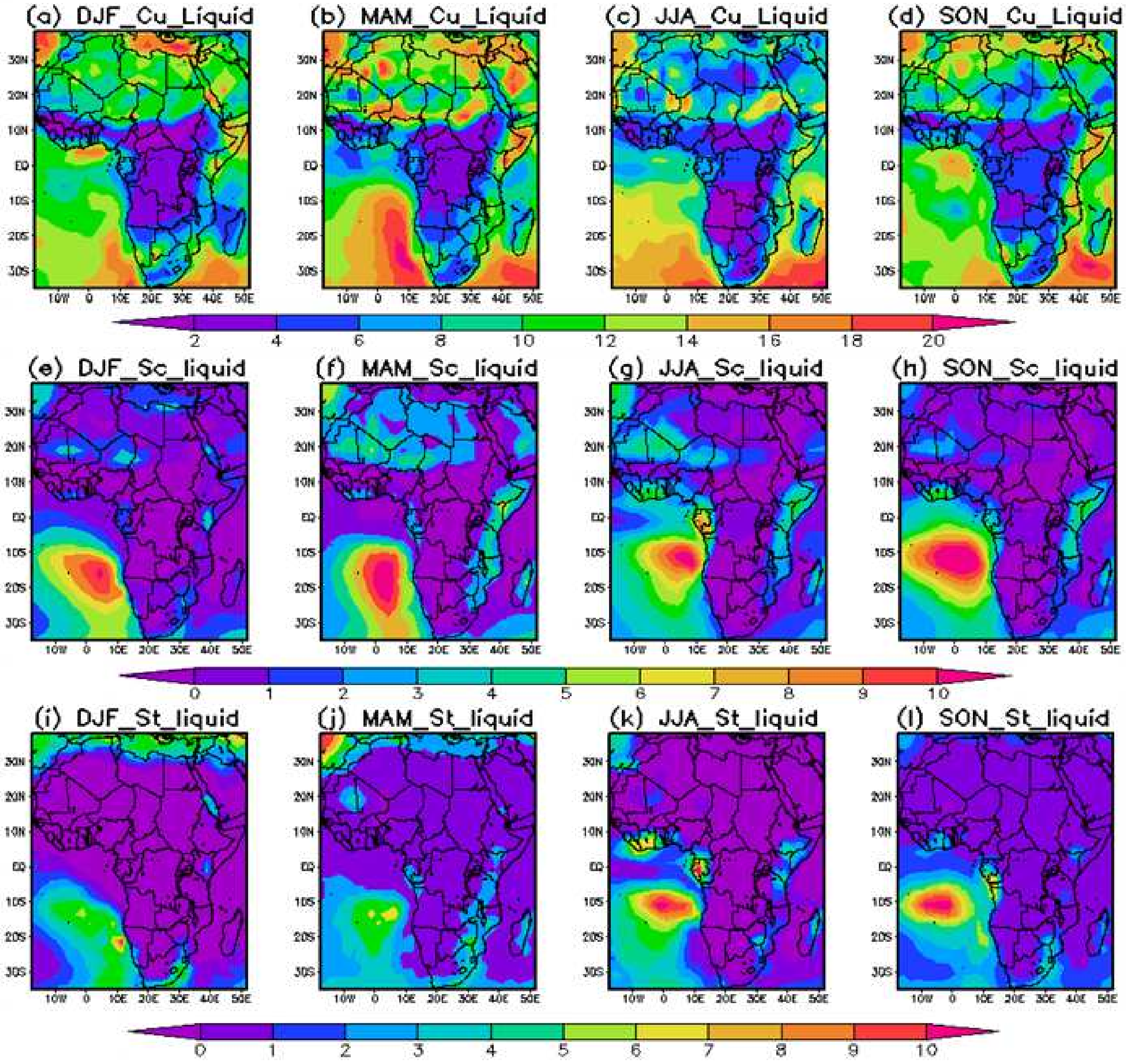

Figure 2. *Seasonal spatial ISCCP cloud coverage (%) distribution of low level cloud: ((a), (b), (c), (d)) cumulus (Cu), ((e), (f), (g), (h)) stratocumulus (Sc), ((i), (j), (k), (l)) stratus (St) with liquid contents.*

[12] explained that Stratocumulus (Sc) clouds occur most frequently over oceans, where between 30^0S and 30^0N they are mainly occur over West Africa, west coasts of north-central America and South America, while nimbostratus (Ns) clouds are often occur to the midlatitude and polar storm tracks, whereas deep convective (Dc) clouds are predominantly occur in the tropics. This confirms our results which shows that stratocumulus (Sc) is frequent over the Atlantic ocean , but with low amount over the Indian ocean (Fig. 2e, Fig. 2f, Fig. 2g, Fig. 2h). The stratocumulus and stratus low level clouds are too low over the African continent. ISCCP showed to take account of low level clouds which are not obscured by high level clouds [29]. The The Figure 3 shows the seasonal spatial distribution of middle level cloud coverage over Africa. Altostratus (As) also is more frequently over Atlantic but with a low amount over the Indian ocean (Fig. 3i, Fig. 3j, Fig. 3k, Fig. 3l). The middle level clouds with ice contents are extremely low (Fig. 3e, Fig. 3f, Fig. 3g Fig. 3h, Fig. 3m, Fig. 3n, Fig. 3o, Fig. 3p, Fig. 3u, Fig. 3v, Fig. 3w, Fig. 3x). The altostratus (As) are the middle cloud levels with high amount that occur in Africa, especially in equatorial regions (Fig. 3i, Fig. 3j, Fig. 3k, Fig. 3l). They occur with high amount during rain seasons which may explain their relationship with rainfall. The altocumulus (Ac) is more frequent over Indian ocean near equatorial regions but with less amount (Fig. 3a, Fig. 3b, Fig. 3c, Fig. 3d). It occurs during rainfall season but with less amount especially in west of Africa (Fig. 3c). The Ns clouds with liquid clouds occur mostly in the rainfall season. They occur especially in rain season but with less amount (Fig. 3q, Fig. 3r, Fig. 3s, Fig. 3t). [5] showed that between 60^0 S and 60^0 N, the general circulation models are significantly underestimate low and middle level clouds probably due to the cloud biases in the models.

The cirrus (Ci) high level cloud is the most dominant cloud with high amount in Africa. They are high enough during rainfall seasons (Fig. 4a, Fig. 4b, Fig. 4c, Fig. 4d). They are too low in north of Africa in all seasons. This shows that the Sahara desert may have impacts on Cirrus reduction or probably the ISCCP satellite is not able to detect them in desert areas. We have also realized that the Cirrus amount is too low in Namib desert located in South of Africa in rainfall season . The Kalahari desert located not far from Namib desert shows some part with less cirrus clout amount during rainfall season. The cirrostratus (Cs) clouds are concentrated in equatorial regions in all seasons (Fig. 4e, Fig. 4f, Fog. 4g, Fig. 4h). It is the only cloud which occur with high amount in equatorial regions, whereas other regions with too less amount in all seasons. The The deep convective cloud (dc) or cumulonimbus (Cb) was found generally cover small areas over land [25]. The deep convective (dc) clouds are mostly occur around the equator in all seasons in Africa (Fig. 4i, Fig. 4j, Fig. 4k, Fig. 4l). The results show that all high level clouds occur with high amount over land whereas over ocean they are too low, except in DJF where they are significantly high over Indian ocean (Fig. 4a, Fig. 4e, Fig. 4i). The Cirrus clouds appear to be high also over Indian ocean during MAM and SON rainfall seasons in East of Africa (Fig. 4b, Fig. 4d). [12] used CloudSat and CALIPSO in their previous study and showed that large mixed phase Ac vertical depths are located in South of Africa, Northern South and Est Asia regions. [24] showed that the absorption of infrared radiation by high clouds is dominated in low latitudes which results to an infrared heating by clouds at low altitudes, while the emission of infrared radiation from low clouds at higher altitudes results to an enhancement of cooling. [10] showed that high clouds types occur preferentially where convection occurs in the tropics and in midlatitude storm tracks, where high thick clouds occur in a smaller fraction of the globe than thin clouds, and in the regions with the most active convection. [25] found that the cirrus has a negative trend in North Africa during MAM. Our results show extremely low coverage of cirrus clouds in North of Africa probably due to the Sahara desert. [6] explained that due to the African Easterly Jet (AEJ) in East of Africa, there is no significant high clouds during JJA. Our results confirm their results for only cirrostratus (Cs) and deep convective clouds (dc) in all seasons whereas there is significant high cloud coverage of cirrus (Ci) especially in SON and MAM in East of Africa.

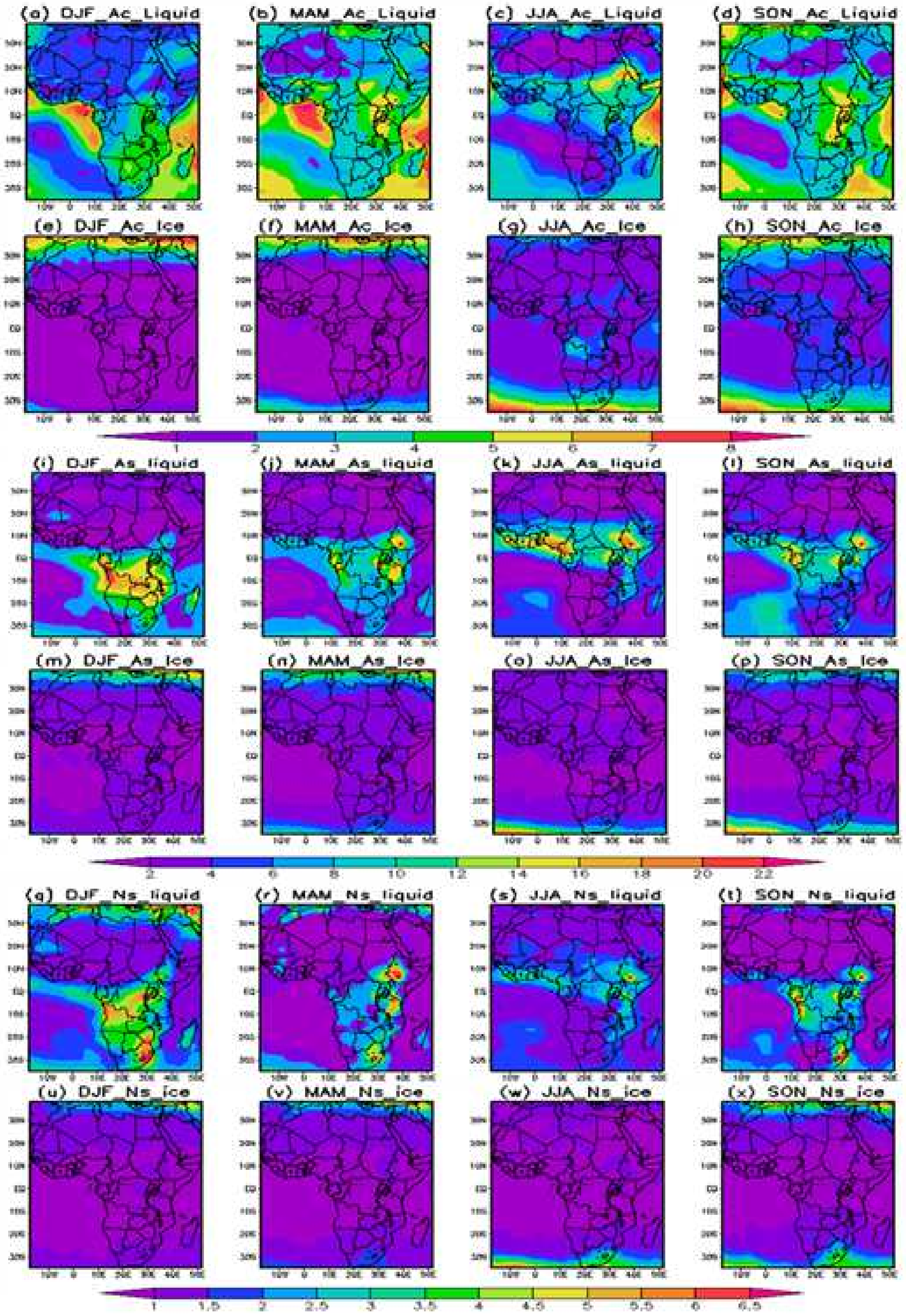

Figure 3. *Seasonal spatial ISCCP cloud coverage (%) distribution of middle level clouds : ((a), (b), (c), (d)) altocumulus (Ac) with ice, ((e), (f), (g), (h)) altocumulus (Ac) with liquid, ((i), (j), (k), (l)) altostratus (As) with ice and ((m), (n), (0), (p)) altostratus (As) with liquid, ((q), (r), (s), (t) nimbostratus (Ns) with ice and ((u), (v), (w), (x) nimbostratus (Ns) with ice clouds.*

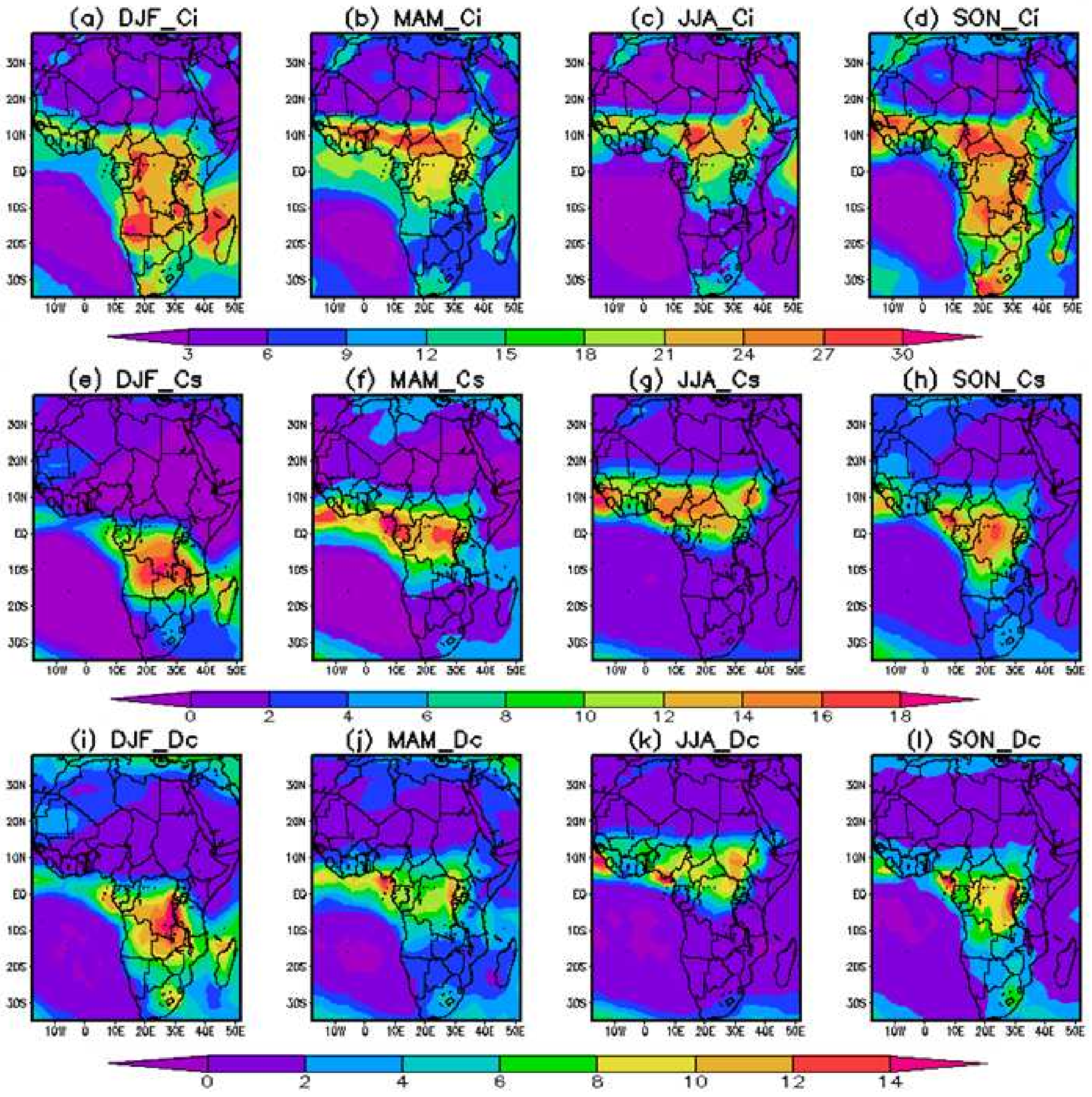

Figure 4. *Seasonal spatial ISCCP cloud coverage (%) distribution of high level clouds: ((a), (b), (c), (d)) cirrus, ((e), (f), (g), (h)) cirrostratus clouds and ((i), (j), (k), (l) deep convective clouds.*

[7] explained that the net effect of middle and high clouds is to warm the surface at night over land. [19] showed that it is difficult to detect the amount and the presence of middle and high clouds in overcast sky condition. [2] explained that satellite informations are valuable over land for discerning patterns and magnitudes in areas where gauges are sparsely distributed or with questionable quality. The temporal total cloud coverage patterns of CloudSat, ISCCP and CERES vary depending on season by region in Africa (Fig. 5). In the previous study at global scale they have considered latitudinal patterns and found that high clouds show a different pattern with low and middle cloud types [13]. For our study we only considered temporal patterns of total cloud coverage. In West Africa (Fig. 5a, Fig. 5b), East of Africa (Fig. 5 c, Fig. 5d) and South of Africa (Fig. 5e, Fig. 5f) the total cloud coverage temporal are correlated with rainfall season. The precipitation amounts increase (decrease) as cloud coverage increase (decrease) respectively (Fig. 5) wich indicates relationship between cloud and precipitation. The rainfall season is during JJA in west of Africa (Fig. 5b), in MAM and SON in east of Africa (Fig. 5d) , and DJF in south of Africa (Fig. 5f) which are seasons with high cloud coverage. [15] showed also that there is relationship between cloud and precipitation. The cloud cover by CloudSat is lower than ISCCP and CERES which are close in West (Figure 5.a), East (Fig.5c) and South (Fig. 5e) of Africa. [4] also found that the pattern of CERES and ISCCP are similar with a zonal mean of 56.3% and 63.6% respectively.

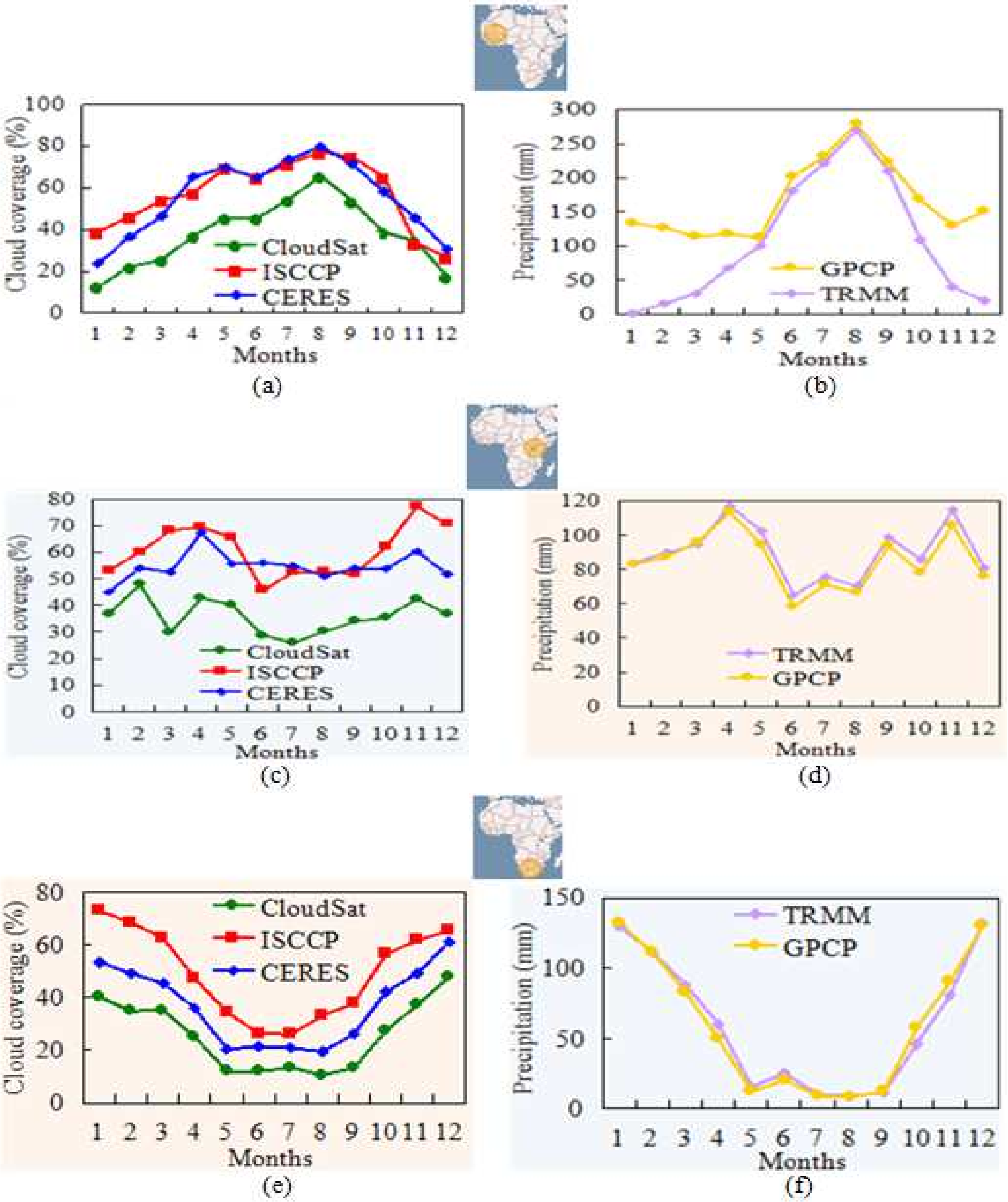

Figure 5. *Temporal of total cloud coverage (%) and monthly mean precipitation (mm) variabilities in ((a), (b) West of Africa, ((c), (d) East of Africa and ((e), (f)) South of Africa.*

There is a remarkable increase of cloud coverage in rainy seasons whereas a decrease in dry seasons. In East and South of Africa the GPCP and TRMM are too close across the year while in west of Africa they are close only during rain season (JJA). The temporal distribution allowed us to know the cloud type amount for a specific small region. The spatial distribution of low level cloud shows that it is cumulus cloud which cover large region in north of Africa, but with less amount in west of Africa (Fig. 2a, Fig. 2b, Fig. 2c, Fig. 2d). The low, middle and high cloud types with high cloud coverage are stratocumulus with liquid (Sc_liq) in July (17.19%), altostratus with liquid (As_liq) in August (11.63%) and cirrus (Ci) in April (23.47%) in west of Africa respectively (Fig. 6). In east of Africa the low, middle and high cloud types with high cloud coverage are stratocumulus with liquid (Sc_liq) in August (14.06%), altostratus with liquid (As_liq) in November (11.47%) and cirrus (Ci) in April (27.44%) respectively (Fig. 7). In south of Africa the low, middle and high cloud types with high cloud coverage are stratocumulus with liquid (Sc_liq) in October (8.10%), altostratus with liquid (As_liq) in January (9.55%) and cirrus (Ci) in January (25.65%) respectively (Fig. 8).

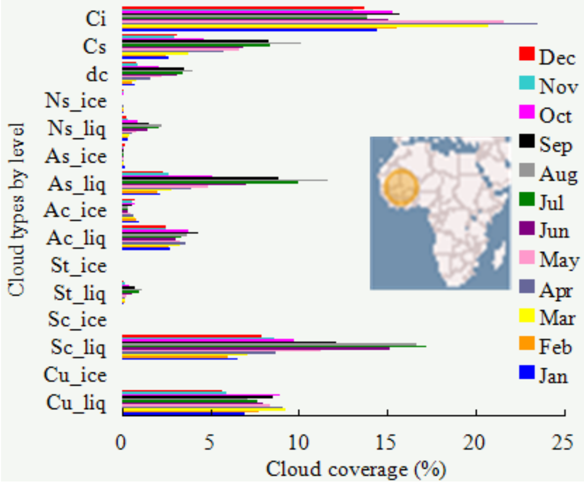

Figure 6. *Annual temporal variability of cloud type coverage in west of Africa.*

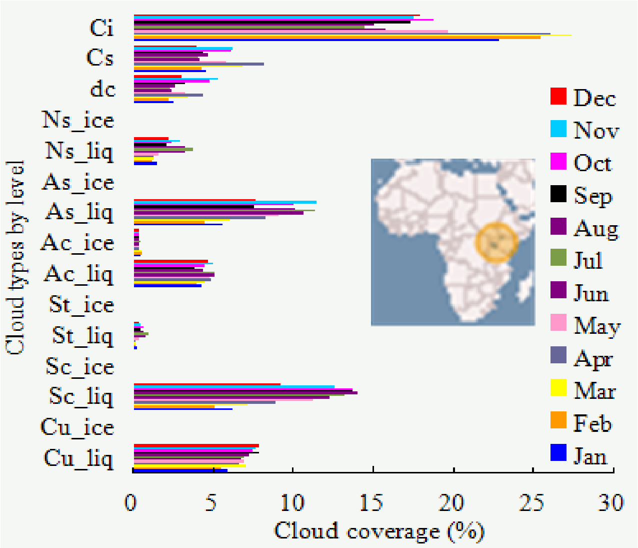

Figure 7. *Annual temporal variability of cloud type coverage in east of Africa.*

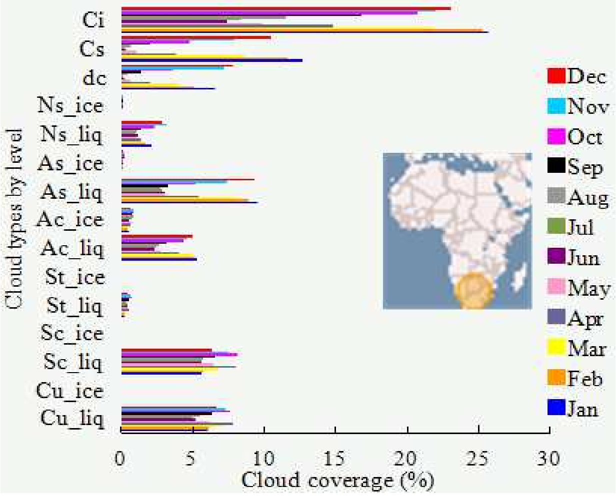

Figure 8. *Annual temporal variability of cloud type coverage in south of Africa.*

The correlation between cloud coverage and precipitation is generally low in east of Africa whereas is high in west and south of Africa (Fig. 9). In west of Africa the cumulus (Cu) with liquid and the cirrus (Ci) show negative correlation whereas stratocumulus (Sc), stratus (St), nimbostratus (Ns), altocumulus (Ac), altostratus (As) and cirrostratus (Cs) show a positive correlation. In East of Africa there are only middle clouds stratus (St) and nimbostratus (Ns) with liquid which show negative correlation whereas cumulus (Cu), stratocumulus (Sc), altocumulus (Ac), altostratus (As), cirrostratus (Cs) and cirrus (Ci) show a positive correlation. The only region in which all cloud types analyzed in this study show positive correlation is south of Africa. CloudSat and ISCCP show less and almost high amount respectively across the year in west, east and south of Africa. The results show that dominant high, middle and low clouds per year are the same in west, east and south of Africa but in different seasons. Those high, middle and low clouds are cirrus, altostratus with liquid and stratocumulus with liquid respectively. In west of Africa the rain season occur in JJA and the high cloud cirrus, middle altostratus with liquid and stratocumulus with liquid occur with significant amount during April, August and July (Fig. 6). During the JJA season in west of Africa there is a strong convection accompanied by the west african monsoon [6].

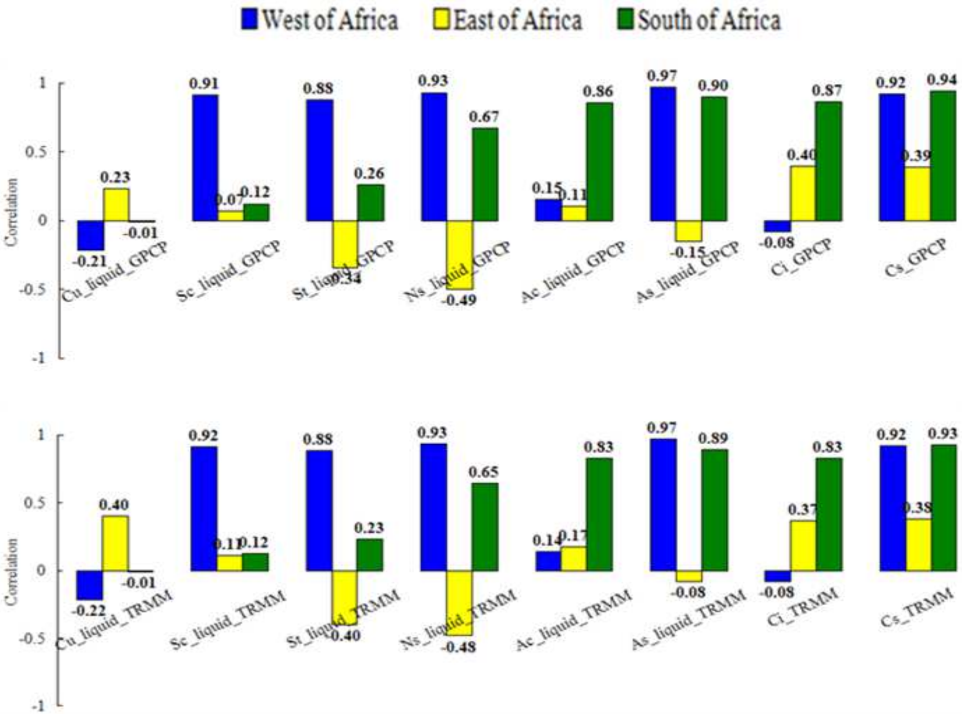

Figure 9. *Correlation between ISCCP cloud types with GPCP and TRMM precipitation in (blue color) West of Africa, (yellow color) East of Africa and (green color) South of Africa.*

[28] explained that over land the percentage of GPCP variation is about 10% in most areas significant rain but is higher up to approximately 20% in East of Africa along the equator. [27] compared satellite estimates of rain with rain gauge data and found a large discrepancy in the rainy area of equatorial Africa, where satellite estimates were nearly twice as large as the gauge estimates. [31] showed that TRMM tends to overestimate rain gauges in regions with high rainfall amount over Africa. This could explain the low correlation between cloud and precipitation in East of Africa which is region located near the equator and where the ITCZ crosses two times per year. In general the results show the positive correlation between cloud and precipitation in Africa.

4. Conclusion

Many previous studies have been done at global scale which doesn't allow us to know in details cloud and precipitation distribution at small scale. [5] showed that seasonal variation high cloud coverage is related to the movement of the ITCZ. [30] used surface observations data and found that the global average shows a decrease of stratus, altostratus, nimbostratus and high clouds as the major contributor to the decrease of total cover, while there is an increase of stratocumulus, cumulus, cumulonimbus, altostratus. This study is focused on seasonal spatial variability of cloud coverage and their relationship with precipitation in specific regions of Africa. In this study we used CloudSat, CERES, ISCCP to analyze the spatial and temporal total cloud coverage while only ISCCP was used to investigate the relationship between different cloud types coverage and rainfall in west, east and south of Africa. The new findings are: CloudSat shows low amount of cloud coverage while CERES and ISCCP are high and close.

CloudSat and CERES show that large spatial cloud coverage is located in regions close to the equator.The correlation between cloud types and precipitation vary differently by region in Africa. In west and south of Africa there exist a high positive correlation while there is low correlation in east of Africa. cumulus and cirrus which are low and middle cloud levels show a negative correlation in west of Africa, whereas in east of Africa there are only middle cloud Stratus (St) and nimbostratus. South of Africa is the only region which shows a positive correlation between all cloud types and precipitation. The high seasonal spatial and temporal cloud coverage are stratocumulus, altostratus and Cirrus. They occur with high amount during JJA, JJA, MAM in West of Africa, in SON, JJA, MAM in East of Africa, and during SON, DJF, DJF in south of Africa respectively. Stratocumulus middle clouds are more and less frequent over Atlantic ocean and Indian whereas altocumulus middle clouds are less and more over Atlantic ocean and Indian ocean near equatorial regions respectively. Only middle clouds level in east of Africa, both low and middle in west of Africa show negative correlation with precipitation whereas all cloud types level in south of Africa show a positive correlation with precipitation. The cirrus high level clouds show a low amount in North of Africa in al seasons, probably due the Sahara desert. We have also analyzed that the Namib desert have less amount of cirrus clouds in all seasons. Cirrostratus clouds are only clouds which show high amount in equatorial regions and less amount in other regions in Africa in all seasons. The high level clouds occur with high (low) amount over land (ocean) except a significant high amount during DJF over Indian ocean. Our results show that the impact of cloud types on rainfall in west, east and south of Africa is different. The deep understanding of the relationship between cloud and rainfall will help to validate models and satellite sensors.

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