3.1.5 ATSK16 001

A. Algorithm Outline

（１） Algotrithm Code: ATSK16

（２） Product Code: CLFR

（３） PI names: Tamio Takamura

（４） Overview of algorithm

Abstract

The algorithm described in the ATSK16 can classify clouds into several types using data from ATSK3_r, based on the ISCCP categories. The characteristics of this algorithm have an index of cloud shape and an additional classification of cirrus. The cloud shape can be determined by sum of spatial differences between each pixel in an area of 0.25° x 0.25° in Lat. and Lon., so a high difference means cumulus-type and a low one stratus-type. The split window technique can separate a cirrus cloud from other clouds.

The cloud information by the ATSK16 algorithm can be used for estimation of surface radiation budget as a research product

Background

Clouds can adjust climate variability due to reflection of solar radiation and emission of themselves. Therefore, the Earth radiation budget at the surface and TOA is controlled by global distributions of cloud characteristics, such as amount(or cloud fraction), cloud top height and optical thickness. As well known, a major part of clouds basically play a role of parasol because of their relatively thick in optical depth. In some cases, however, clouds with thin optical thickness and higher altitude such as cirrus can make the Earth surface warm, in other words greenhouse effect, due to weak reflection of direct solar radiation and relatively high emmisivity for terrestrial radiation. So the global distribution of cloud type and its characteristics is decisive information for the energy budget and hydorological pattern of the Earth.

Cloud response for climate change will be expected to stabilize the Earth-atmosphere system due to increase in cloud fraction with the global warming as a negative feedback. And also cloud pattern of its appearance in the regional area will be changed according to locally-thermal unbalance induced by the global warming. This has possibilities to affect the local weather and modify the local climate pattern. It is one of reasons to know the cloud statistics in the global and regional scale.

The radiation budget and the water budget at the surface are dependent on the complex motion of cloud and precipitation in the atmosphere, where cloud appears in the combined motion of the global and local circulation. So, it is important to know the yearly and spatial variation, resulting on understanding the change of circulation systems. 001

In addition to the cloud response to the global warming, climate effects of the polluted atmosphere including suspended particles from human activities are worried due to the cloud increase in amount and optical characteristics. This indirect effect has been estimated insufficiently, as pointed out by ISCCP, and is another important issue for human activity effect. Therefore, statistical difference in cloud characteristics between inside and outside of a polluted atmosphere may give an index of its climatic effect.

The ISCCP program has been running under importance of global energy balance affected by cloud. The ISCCP can categorize clouds into 9 types according to their optical thickness and cloud top height (or cloud top temperature). Our algorithm is basically accordance with the ISCCP algorithm which has separation boundaries of 440 and 680hPa in cloud height, and 3.6 and 23 in cloud optical thickness. The cloud top temperature can be derived from the infrared window channel, and the optical thickness from the visible reflectance.

In our algorithm, cirrus cloud can be detected using a split window technique before the cloud classification routine by the ISCCP algorithm, because of its detection difficulty of very thin and high cloud. This technique uses a small difference in transmittance of 10um window region for ice and has an advantage of no dependence of surface conditions.

Moreover, cloud inhomogenity routine has been added in our algorithm, which can produce cloud type of stratus- or cumulus-type. This means a cloud multi-layerness or overlapping index.
Cloud overlapping information is useful for estimation of surface radiation because satellite passive sensor cannot give any information of multi-layer cloud.

B. Theoretical Description

(1) Methodology and logic flow

In this algorithm, cloud pixels are classified by the cloud top pressure and by the cloud optical thickness into 9 water cloud types. Before the classification, the ice cloud is separated by the split window method. The index of cloud imhomogeneity is also derived. The values of the cloud optical thickness in each class for same cloud top pressure are averaged.

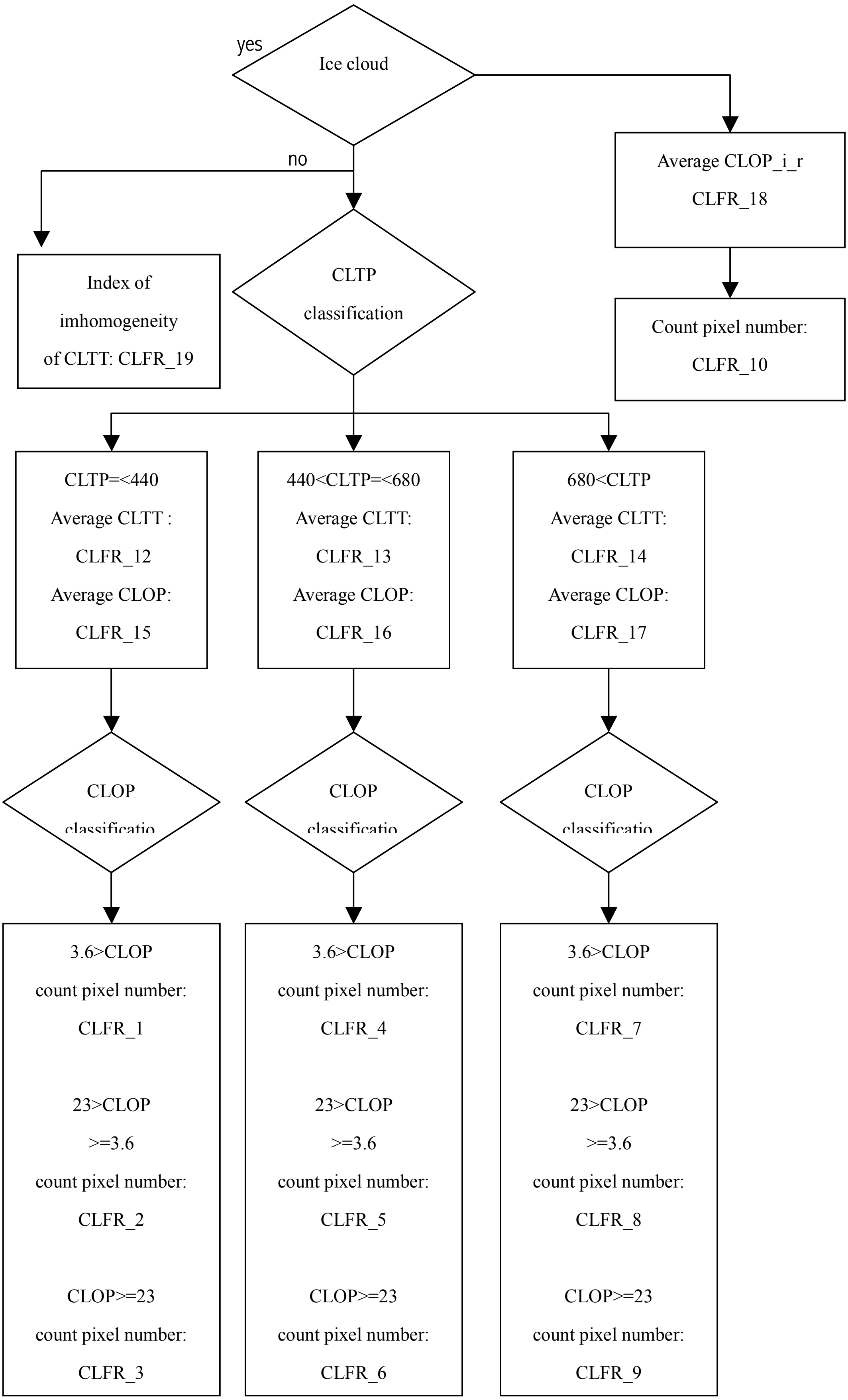
The border values of cloud top temperature are 440 hPa and 680hPa, and that of the cloud optical thickness are 3.6 and 23.0. These values are originated in Rossow and Garder (1996).

The sum of spatial differences of the cloud top temperature is calculated for the index of imhomogeneity. The index is derived from the sum of the absolute value of temperature difference in latitudinal direction and in longitudinal direction. The index shows that the cloud in a segment tends to be stratus or cumulus, and is referred in the cloud over-lapping model in the radiation transfer calculation. 001

CLTP_w_r, CLTT_w_r, CLOP_w_r, CLFLG(result of split window) and CLOP_i_r are provided from storage unit ‘ work_wr’.

The logic flow is following:

1. Separation of ice cloud by the split window (in ATSK3_r).
2. Classification of cloud pixel by the cloud top pressure (CLTP_w_r) into 3 categories.
3. Averaging the cloud top temperature (CLTT_w_r) and the cloud optical thickness (CLOP_w_r) in the each category.
4. Classification of 3 cloud top pressure categories by the cloud optical thickness (CLOP_w_r) into 9 categories and counting number of pixel in each category
5. Calculating the index of imhomogeneity from all the cloud top temperature


Ice cloud
yes
no
Average CLOP_i_r
CLFR_18
Count pixel number:
CLFR_10
Index of
imhomogeneity
of CLTT: CLFR_19
CLTP
classification
CLTP=<440
Average CLTT :
CLFR_12
Average CLOP:
CLFR_15
440<CLTP=<680
Average CLTT:
CLFR_13
Average CLOP:
CLFR_16
680<CLTP
Average CLTT:
CLFR_14
Average CLOP:
CLFR_17
CLOP
classificatio
CLOP
classificatio
CLOP
classificatio
3.6>CLOP
count pixel number:
CLFR_1
23>CLOP
>=3.6
count pixel number:
CLFR_2
CLOP>=23
count pixel number:
CLFR_3
3.6>CLOP
count pixel number:
CLFR_4
23>CLOP
>=3.6
count pixel number:
CLFR_5
CLOP>=23
count pixel number:
CLFR_6
3.6>CLOP
count pixel number:
CLFR_7
23>CLOP
>=3.6
count pixel number:
CLFR_8
CLOP>=23
count pixel number:
CLFR_9

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Those results in 4days are averaged or the latest result in 4days is stored. The algorithm has a parameter for selection of those two method.

This algorithm also works as the post process of ATSK3_r and ATSK3_e. CLER_w_r, CLHT_w_r, CLTT_w_r, CLOP_w_r, CLWP_w_r and CLOP_i_r from ATSK3_r are averaged in a segment and also averaged in 4 days. CLER_i_e,CLOP_i_e and CLTT_i_e from ATSK3_e are averaged in 4 days.

(2) Physical and Mathematical aspects of the algorithm

Classifying cloud pixel by the cloud top temperature and by the cloud optical thickness is useful to estimate the effect on global radiation budget from cloud, although the methodologies of classification and averaging are simple in this algorithm. The borders of the classification is based on ISCCP (International Satellite Cloud Climate Project), hence the product is available to compare with the data in ISCCP.

The product is designed to be useful data to calculate the radiation transfer. The cloud is classified into three vertical layers in which cloud is generated by different reason and the optical thickness is compiled in the layer, because of the limit of computer resource, although it is the best method that all the cloud optical thickness in a segment are calculated.

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C. Practical Considerations

(1) Programming, Procedural, Running Considerations

Program Requirements: The following table shows information about the expected software generated from this algorithm.

Program Memory	300 MBytes
Program Size	Bytes
Required Channels	
Necessary/Ancillary Data	
Expected Disk Volume	
Special Programs or Subroutines	

(2) Calibration and validation

(a) Approach

Atmospheric validation data are obtained by continuous measurements at several validation sites, intensive field experiments performed several times after launch, and data that already exist.

Basic approach of the validation with those data sets is based on physical simulation of radiation fields. For this purpose a good radiative transfer model has to be used with input of optical parameters retrieved from validation efforts.

This plan will include a validation not only for cloud but also for aerosol, because both of them can affect the radiation field in the atmosphere, independently and/or cooperatively.

(b) Measured Quantities

The following quantities are useful to be measured by GLI-ATMOS.

(a) Spectral direct and sky radiances: Sky radiance measurements will be performed for retrieving column aerosol size distribution, optical thickness, and phase function. This is also effective for vicarious calibration under clear sky condition.

(b) Shortwave and longwave radiant fluxes at ground surface: Surface radiative radiant energy fluxes are important to assess the validity of retrieved atmospheric products, which should suitably reproduce the surface energy fluxes.

(c) Spectral radiances at surface and several heights of atmosphere: Surface and airborne spectrometers are useful for measurements to provide spectral radiances for studying GLI algorithms and validation.

(d) Aerosol microphysical parameters: Aerosol samplers and instruments for measuring total scattering cross section, absorption cross sections and upward scattering fraction are useful for providing geophysical parameters to synthesize atmospheric path radiances. Lidar is also important for measuring aerosol stratification and backscattering cross section.

(e) Cloud microphysical parameters: Microwave radiometers and airborne particle probes are important for validation of cloud optical thickness and effective particle radius retrievals. Lidar is also useful for measuring cloud stratification of thin clouds and bottom height of thick clouds.

These are important for simulating surface radiant energy fluxes. Cloud amount validation is also an issue to be conducted.

(f) Water vapor: GLI can derive high spatial-resolution data of water vapor distribution. Water vapor and temperature fields should be provided by validation effort. Sonde data will be used. FTIR type spectrometer is useful for evaluating the water vapor effects on the radiation field.

(g) Precipitation: GLI can provide warm precipitation over land. Rain validation data from radar and rain-gauge should be collected.

Quantities for validation/vicarious calibration are shown in Table 1.

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Table 1: Quantities for validation/vicarious calibration. S, R and V in level-column mean standard product, research product, and validation/vicarious product, respectively. Other satellite sensors are also listed for comparison.

Quantity	Level	Accuracy	Methods Note
CLFR	S	5%	Surface obs., Lidar, CPR,GIO, AVHRR
CLOP	S	10%	Aircraft, SWAR, POLDER, MODIS, AVHRR
CLWT	S	20%	Aircraft, MCWR, AMSR,SSM/I
CLRE	S	20%	Aircraft, MODIS, AVHRR
CLTP	S	0.5K	Sonde, Lidar
CLHT	S	1km	Sonde, Lidar
CLBH	R	1km	Sonde, Lidar
WTVA	R	0.2g/cm2	Sonde, GPS, Sun photometer AMSR, SSM/I
AROP	S	10%	Sky radiometer/Sun photometer, POLDER,MODIS, AVHRR
FSSRF	R	5W/m2	BSRN, GLI-ATMOS
FSTOA	R	5W/m2	CERES instantaneous
FLTOA	R	5W/m2	CERES instantaneous
PRCP	R	Factor 2	Radar, CPR

#1: Sensor names: GEO (Geostationary satellites), CPR (Cloud Profiling Radar), SWSR (ShortWave Spectral Radiometer), MCWR (MiCroWave Radiometer)

#2: Product name: CLFR (Cloud fraction); CLOP (Cloud optical thickness); CLWT (Cloud water path); CLRE (Effective cloud particle radius); CLHT (Cloud top height); CLBH (Cloud bottom height); WTVA (Column water vapor amount); AROP (Aerosol optical thickness); FSSRF (Shortwave surface radiative flux); FSTOA (Shortwave TOA radiative flux); FLTOA (Longwave TOA radiative flux); PRCP (Precipitation).

(c) Sites

Validation sites have to be selected in order to cover various atmospheric/surface conditions and various scientific interests. Candidates of validation sites that should be invested by GLI-ATMOS are listed in Table 2. Chinese and South-East Asian sites are important for obtaining data for anthropogenic air pollution and aerosol loading effects in the Asian region. Ocean measurements by vessels are needed for obtaining data in clean airmass and studying maritime aerosol and cloud fields.

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Table 2: Validation site candidates for GLI-ATMOS and main program names for operating the site. OP OL, and TS in the third column mean operating, planned, and testing stage, respectively.

Code	Name	Status	Programs
L1	Sri Samrong	OP	GAME, GLI-ATMOS, SKYNET
L2	Shou-Xian	OP	GAME, GLI-ATMOS, SKYNET
L3	Yinchuan	OP	SKYNET
L4	Mandalgovi	OP	SKYNET
L5	Fukue-jima	TS	GLI-ATMOS
L6	Miyako-jima	PL	GLI-ATMOS
L7	Bukittinggi	OP	GAW
S1	Ship-Mirai	TS	Frontier
S2	Line Australia	TS	GLI -ATMOS
S3	Line Persia	TS	GLI -ATMOS

#1: Program name: GAME (GEWEX Asian Monsoon Experiment); SKYNET (SKY radiometer NETwork); GAW (Global Atmospheric Watch program); Frontier (Frontier Program)

(d) Instrumentation

Instruments listed in Table 3 should be deployed at the sites in Table 2 for performing the GLI validation. The packages have to be designed meeting with requirements for network development. Shipborne system design is also important. Since the operating sites have some of these instruments already as listed in Table 2, it should be carefully investigated what instruments should be added to each site.

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Table 3: Instruments important for GLI-ATMOS

Instrument	Quantities for validation (see Table 1)
Sky radiometer	Sky radiance, AROP
SW, LW fluxmeter	FSSRF, Longwave surface radiation
Pyrheliometer	FSSRF, AROP, WTVA
SW spectral radiometer (SWSR)	FSSRF, CLRE, CLOP, CLWT
FTIR	IR surface radiation budget
Microwave radiometer (MCWR)	CLWT, WTVA
GPS	WTVA, support for radiative transfer calculation
Aerosol sampler	aerosol chemical characterization, support for aerosol retrievals
Aethalometer	aerosol single scattering albedo, support for aerosol retrievals
Total nephelomer	aerosol extinction coefficient, support for aerosol retrievals

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Sky radiometer is important for obtaining column values of aerosol size distribution and scattering phase function. The result is useful for retrieving GLI-received radiances for vicarious calibration. Aerosol samplers, aethalometer and total nephelometer are important for obtaing single scattering albedo of aerosols, that are needed for radiative transfer calculation of GLI-received radiances and the radiation budget at surface and top of atmosphere (TOA). Microwave radiometer is important for obtaining column water vapor amount and cloud liquid water path. GPS is useful to obtain the water vapor amount at the site. This should be regarded as supplementary data sets, rather than validation of water vapor amount, for radiative transfer calcuation. SW spectral radiometer is a radiometer to measure nadir radiances at several wavelengths from 0.3 to 2.2 microns for obtaining cloud optical thickness, effective particle radius and liquid water path combining with the microwave radiometer data. Satellite products of clouds, aerosols and water vapor should be checked whether they can produce surface radiation budget measured by fluxmeters, pyrheliometer and FTIR.

(e) **Intensive Field Experiments**

Intensive field experiments are important to integrate validation efforts in atmosphere, ocean, land and cryosphere groups. GLI-ATMOS is interested in performing field experiments with other groups, since the atmosphere interacts with ocean, land and snow/ice surfaces. Aircraft measurements of upwelling radiances are important for vicarious calibration. Table 4 lists airborne facilities useful for GLI-ATMOS. GLI-ATMOS should invest in airborne instrumentation such as AMSS, AMR and PMS-probes. Also it should be implemented with international collaboration.

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Table 4: Airborne measurement facilities useful for GLI-ATMOS

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GLI-ATMOS	AMSS, AMR, (PMS)
Thailand	PMS, CCN, King Air x 2, G21
MODIS	MAS, HIS
LaMP	PMS, PVM, Nephelometer
Nagoya & Hokkaido Univ, Meteor. Res. Inst.	PMS

6 months, 12 months, 18 months, and 24 months after launch are suitable candidates for timing of the experiments. 12 and 24 month timing should be an intensive field observation campaign with other GLI groups to cover atmosphere and earth's surface.

(3) Quality Control and Diagnostic Information

(4) Exception Handling

(5) Constraints, Limitations, Assumptions

(6) Publications and Papers

D. References

Rossow, W. B. and A. W. Walker, D. E. Beuschel and M. D. Roiter, 1996: International satellite cloud climatology project (ISCCP), documentation of new cloud datasets. World Meteorological Organization. 115 pp.