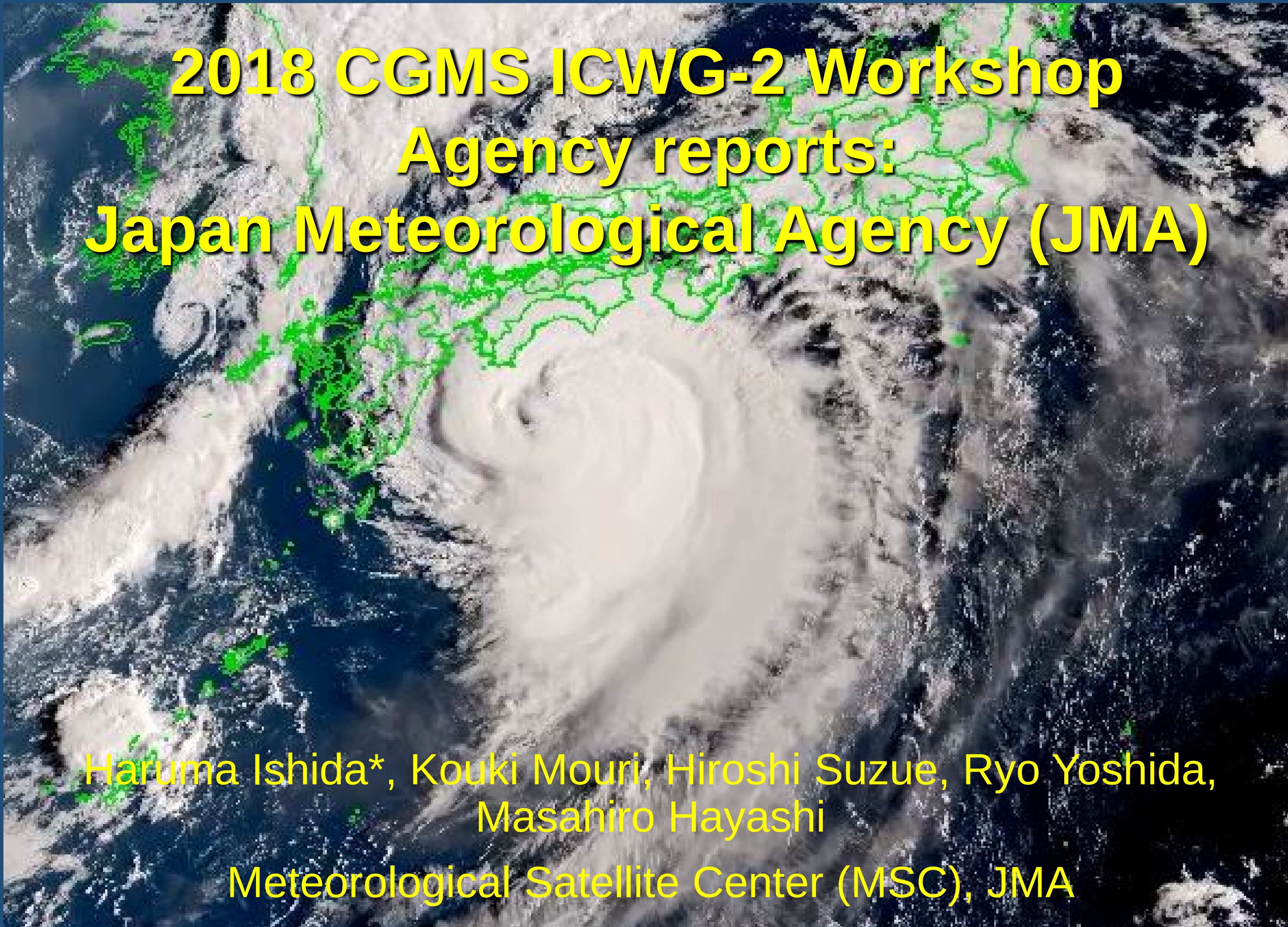


2018 CGMS ICWG-2 Workshop
Agency reports:
Japan Meteorological Agency (JMA)

Haruma Ishida*, Kouki Mouri, Hiroshi Suzue, Ryo Yoshida, Masahiro Hayashi

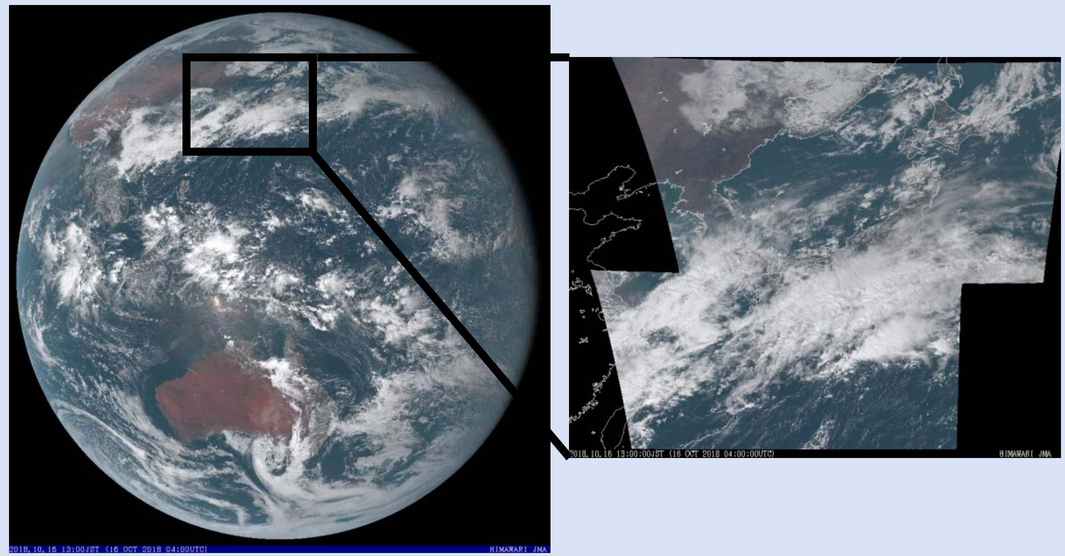
Meteorological Satellite Center (MSC), JMA

1. Spec. of Himawari-8 Advanced Himawari Imager

No.	Wavelength(μm)	Resolution
1	0.47	1 km
2	0.51	
3	0.64	0.5 km
4	0.86	1 km
5	1.6	2 km
6	2.3	
7	3.9	
8	6.2	
9	6.9	
10	7.3	
11	8.6	
12	9.6	
13	10.4	
14	11.2	
15	12.4	
16	13.3	

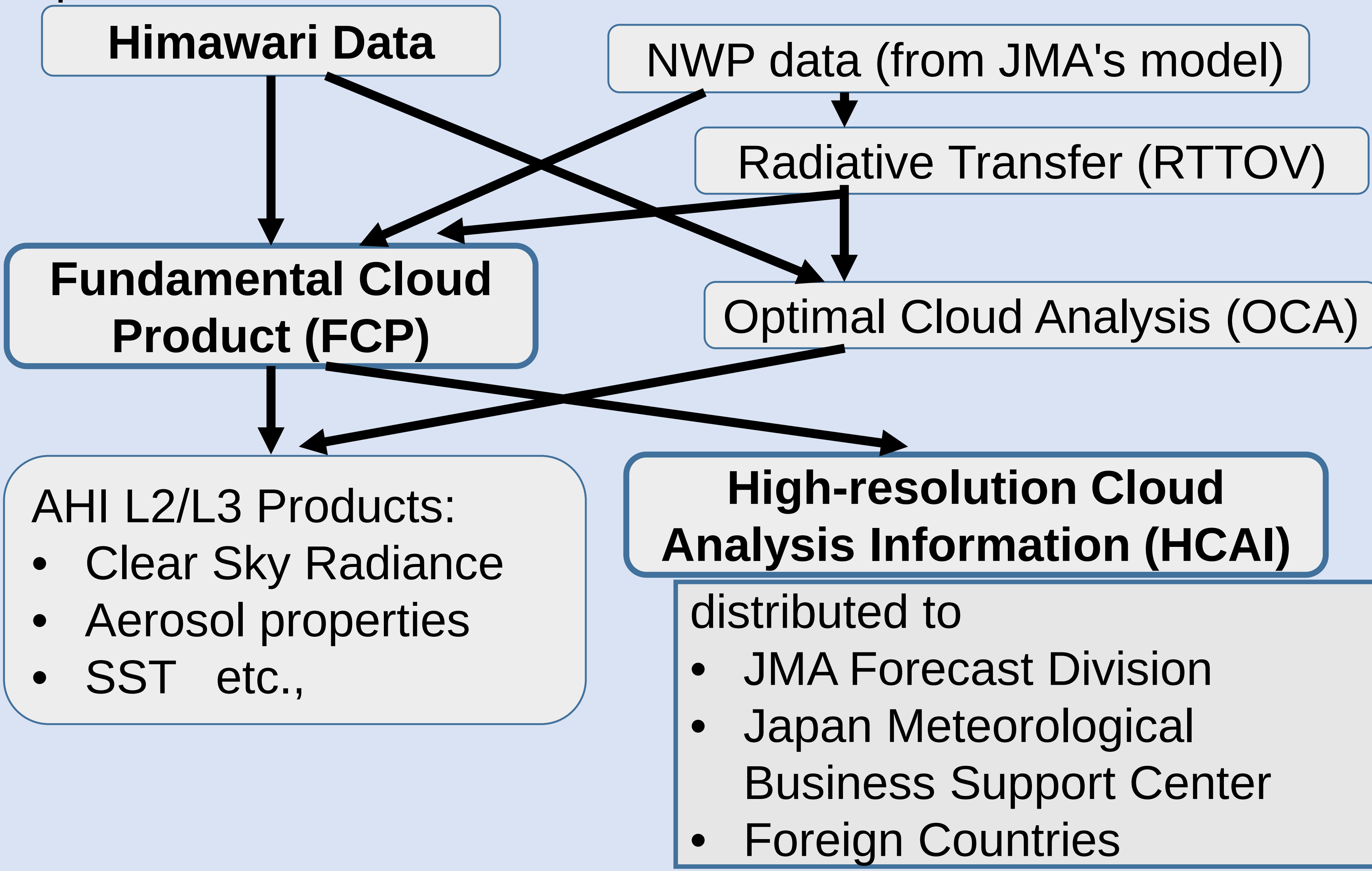
Temporal resolution:

- Full disk: 10 min.
- Japan and mobile obs.: 2.5 min.



2. Himawari Cloud Products

Operation flow:

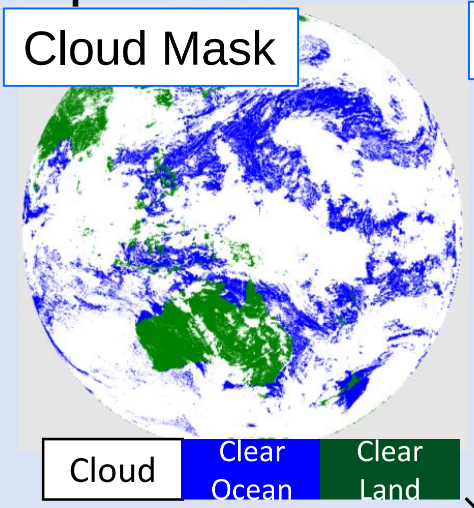


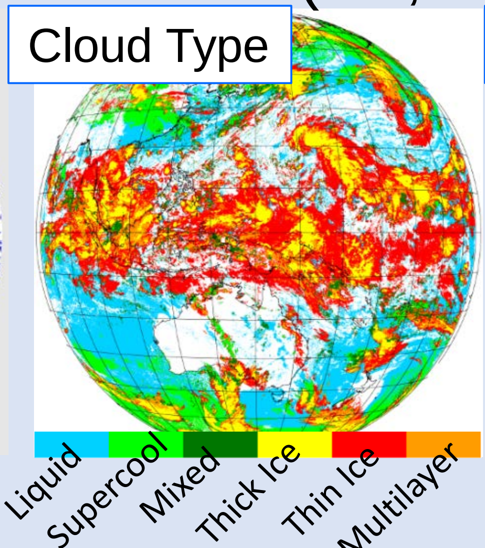
For forecast, disaster mitigation, monitoring, business…

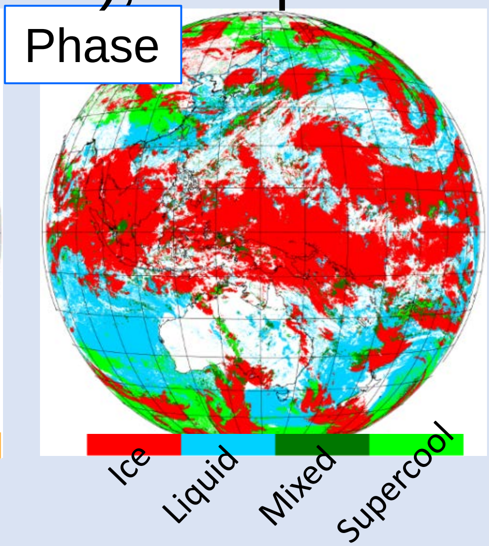
2. Himawari Cloud Products

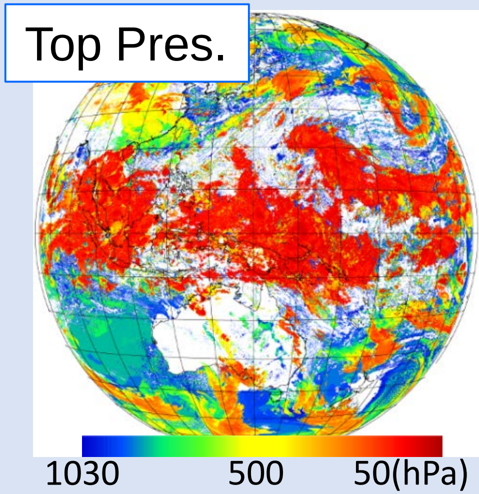
Fundamental Cloud Product (FCP)

Spatial: same as IR band (i.e., 2 km), Temporal: 1 hour





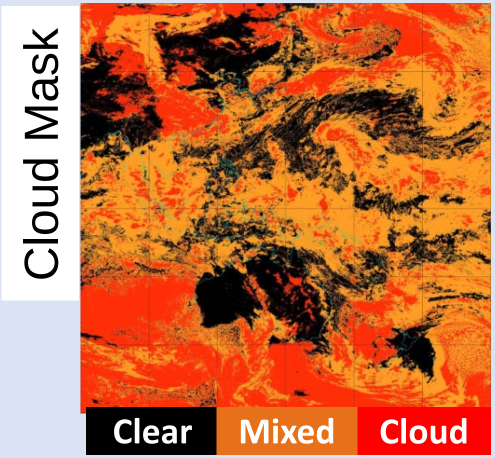


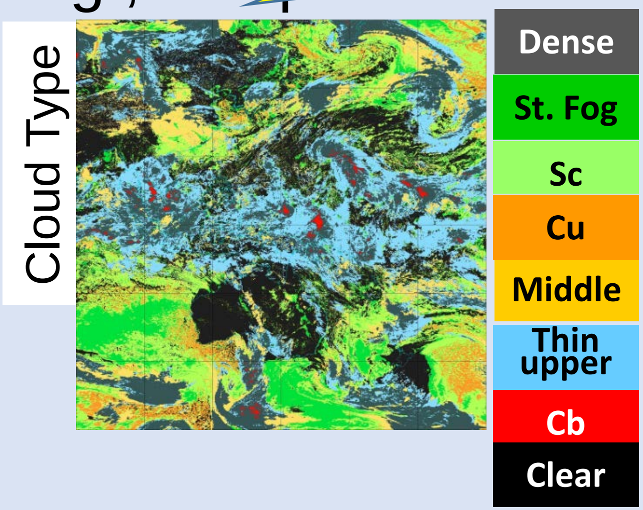


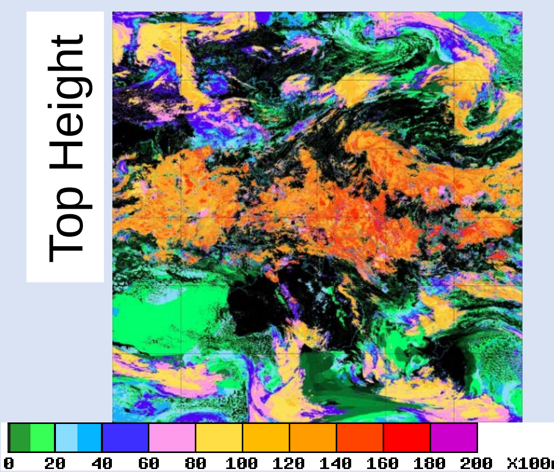
High-resolution Cloud Analysis Information (HCAI)

Spatial: 0.02 X 0.02 deg., Temporal: 1 hour

More detailed



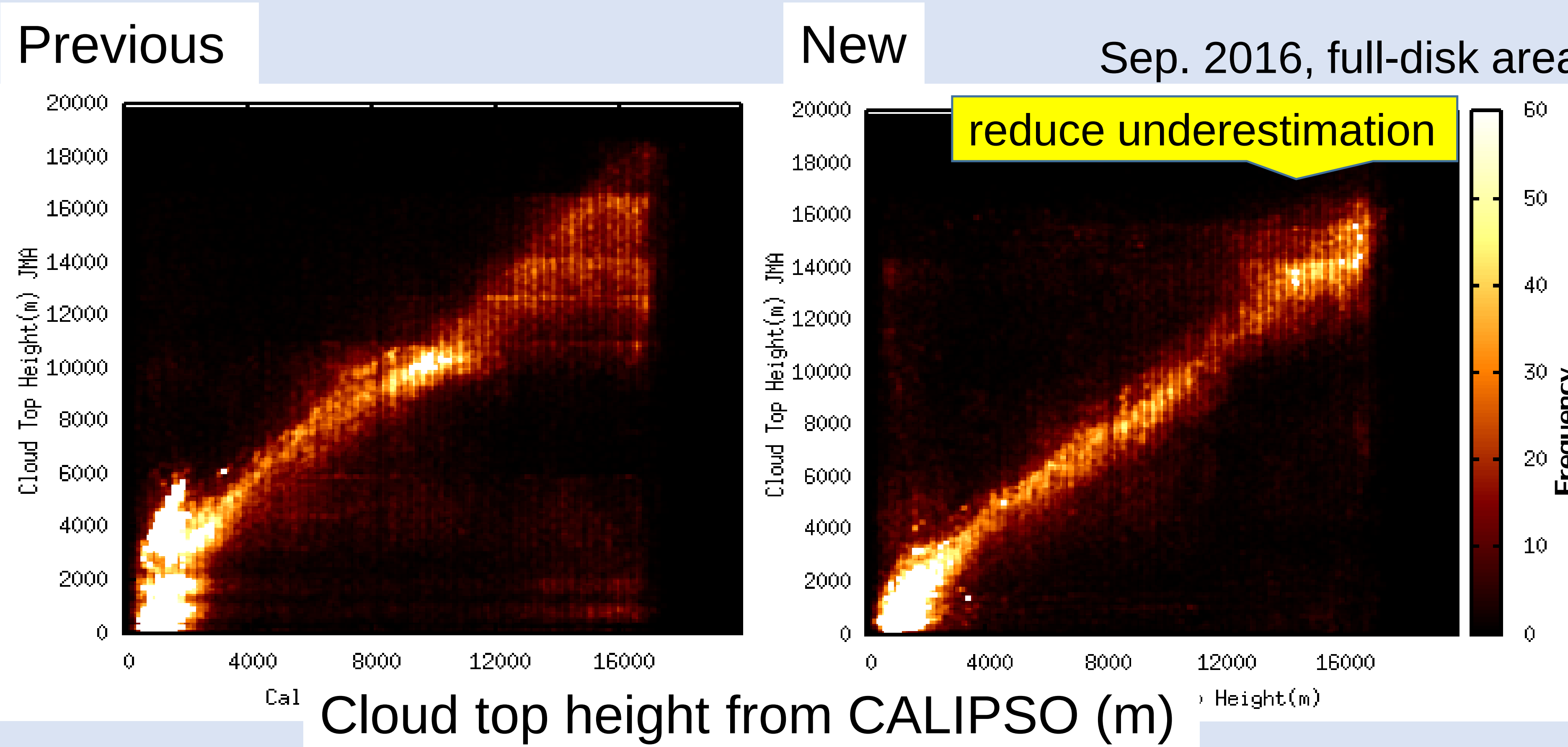




3. Recent improvements

Update Cloud Top Height algorithm

- since 0200 UTC on 21 March 2017
- To correct top height underestimation for optically thin clouds

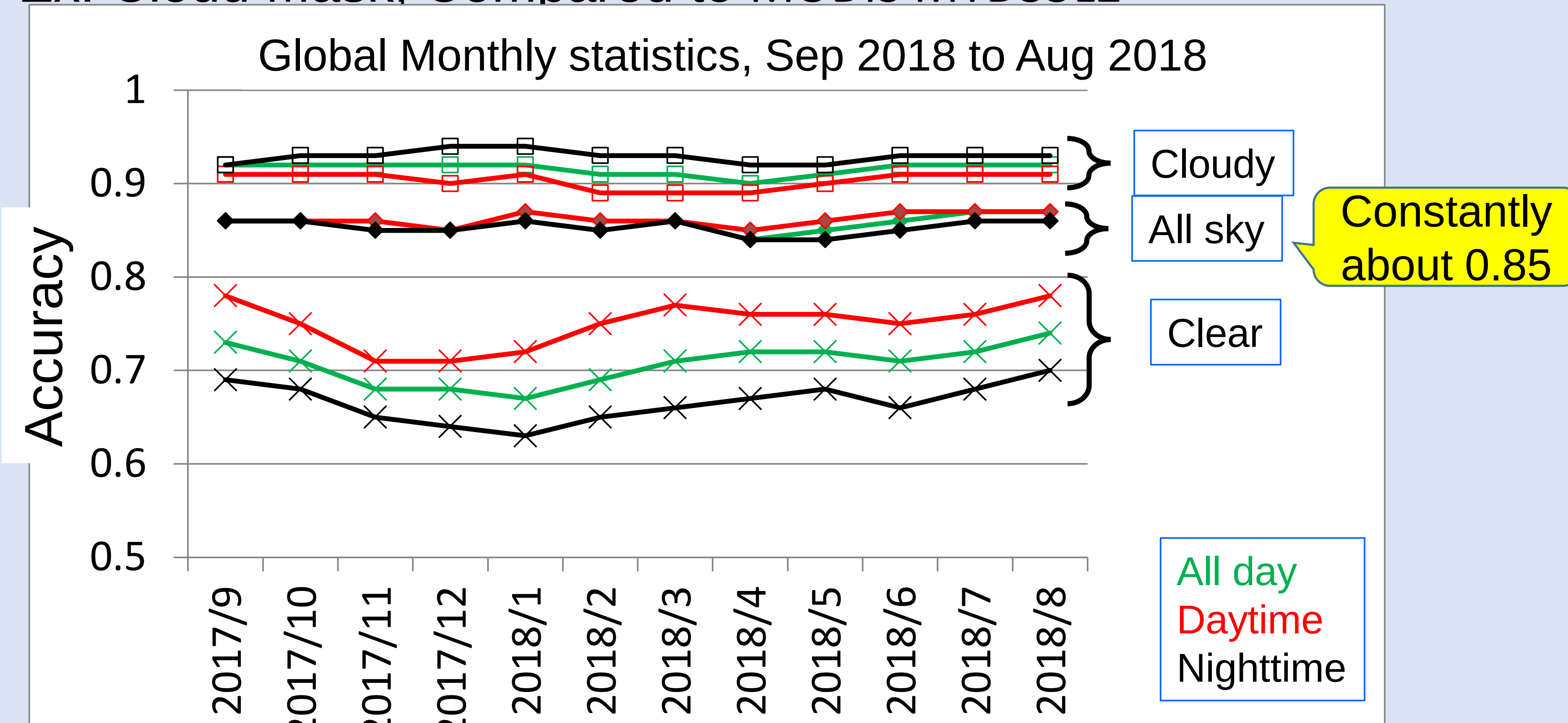


Explanation: tomorrow presentation

4. Validation works

Products are routinely validated.

Ex. Cloud Mask; Compared to MODIS MYD35L2



	MODIS Clear	MODIS Cloud
JMA Clear	A	B

$$\text{All sky accuracy} = \frac{A + D}{A + B + C + D}$$

A

C

Checking the accuracy and its fluctuation

5. Future Plan

Improvement of current cloud products:

- 10-minite interval production
    - ✓ To speed up the running

Himawari-8 new products under construction:

- Fog monitoring (land and ocean, day and night)
- Snow/Ice surface detection
- Surface solar radiation
- Sunshine duration

Improvement of operational cloud products by Meteorological Satellite Center of Japan Meteorological Agency

Haruma Ishida*, Kouki Mouri, Hiroshi Suzue, Ryo Yoshida, Masahiro Hayashi

Meteorological Satellite Center (MSC), Japan Meteorological Agency (JMA)

2018 Oct.

1. Introduction

Two topics:

1. Improvement of cloud top height in operational cloud products of Advanced Himawari Imager (AHI) by JMA/MSC
   - ✓Point of algorithm change
   - ✓Validation

2. Investigation of the applicability and utility of machine-learning techniques for cloud product algorithm
   - ✓especially cloud mask and type discrimination
   - ✓A preliminary study for future operation

2. Improvement of Cloud top height

2-1. New Algorithm

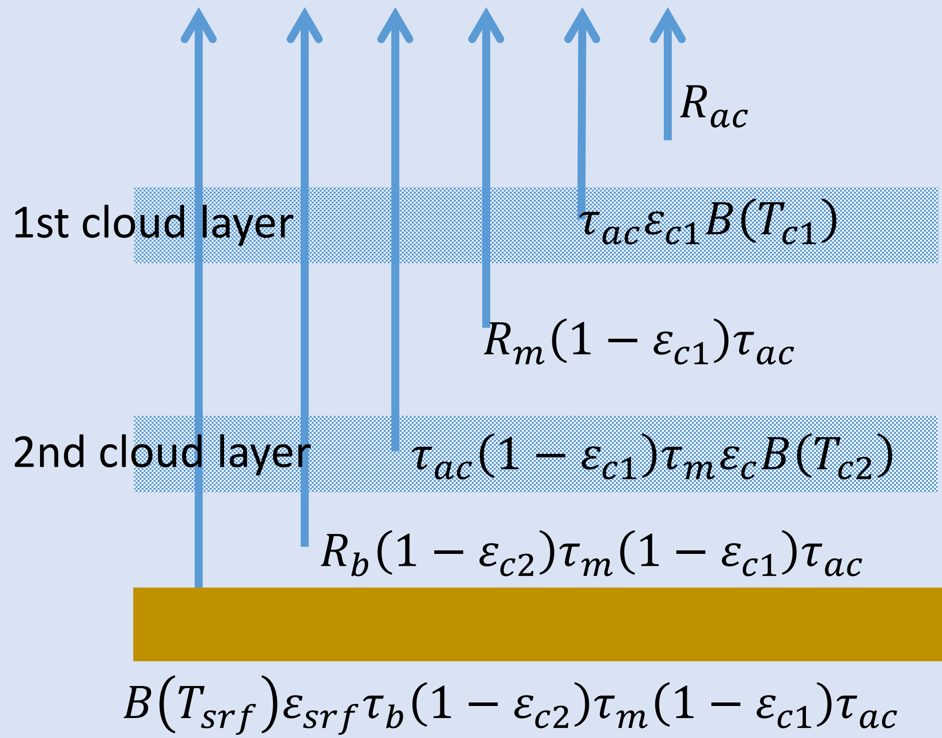
<u>Change from single cloud layer model to double layer</u>

In the optimal estimation method:

$$\begin{pmatrix} Tc1 \\ \varepsilon c1(11.2\mu m) \\ \beta c1(12.4, 11.2) \\ Tc2 \\ \varepsilon c2(11.2\mu m) \\ \beta c2(12.4, 11.2) \end{pmatrix} \qquad \begin{pmatrix} BT(11.2\mu m) \\ BT(11.2) - BT(12.4) \\ BT(11.2) - BT(13.3) \\ BT(11.2) - BT(8.6) \\ BT(6.2\mu m) \\ BT(7.3\mu m) \end{pmatrix}$$

State vector | Dependent vector

Tc; cloud temp.[K]
ε_c; cloud emissivity [-]
β_c; ratio of cloud trans.



Radiative transfer equation for Jacobian calculation:

$$\begin{aligned} Robs &= R_{\mathrm{ac}} + \tau_{\mathrm{ac}}\varepsilon_{\mathrm{c1}}B(T_{\mathrm{c1}}) + \tau_{\mathrm{ac}}(1-\varepsilon_{\mathrm{c1}})R_{\mathrm{m}} + \tau_{\mathrm{ac}}(1-\varepsilon_{\mathrm{c1}})\tau_{\mathrm{m}}\varepsilon_{\mathrm{c2}}B(T_{\mathrm{c2}}) \\ &+ \tau_{\mathrm{ac}}(1-\varepsilon_{\mathrm{c1}})\tau_{\mathrm{m}}(1-\varepsilon_{\mathrm{c2}})R_{\mathrm{b}} + \tau_{\mathrm{ac}}(1-\varepsilon_{\mathrm{c1}})\tau_{\mathrm{m}}(1-\varepsilon_{\mathrm{c2}})\tau_{\mathrm{b}}\varepsilon_{\mathrm{srf}}B(T_{\mathrm{srf}}) \end{aligned}$$

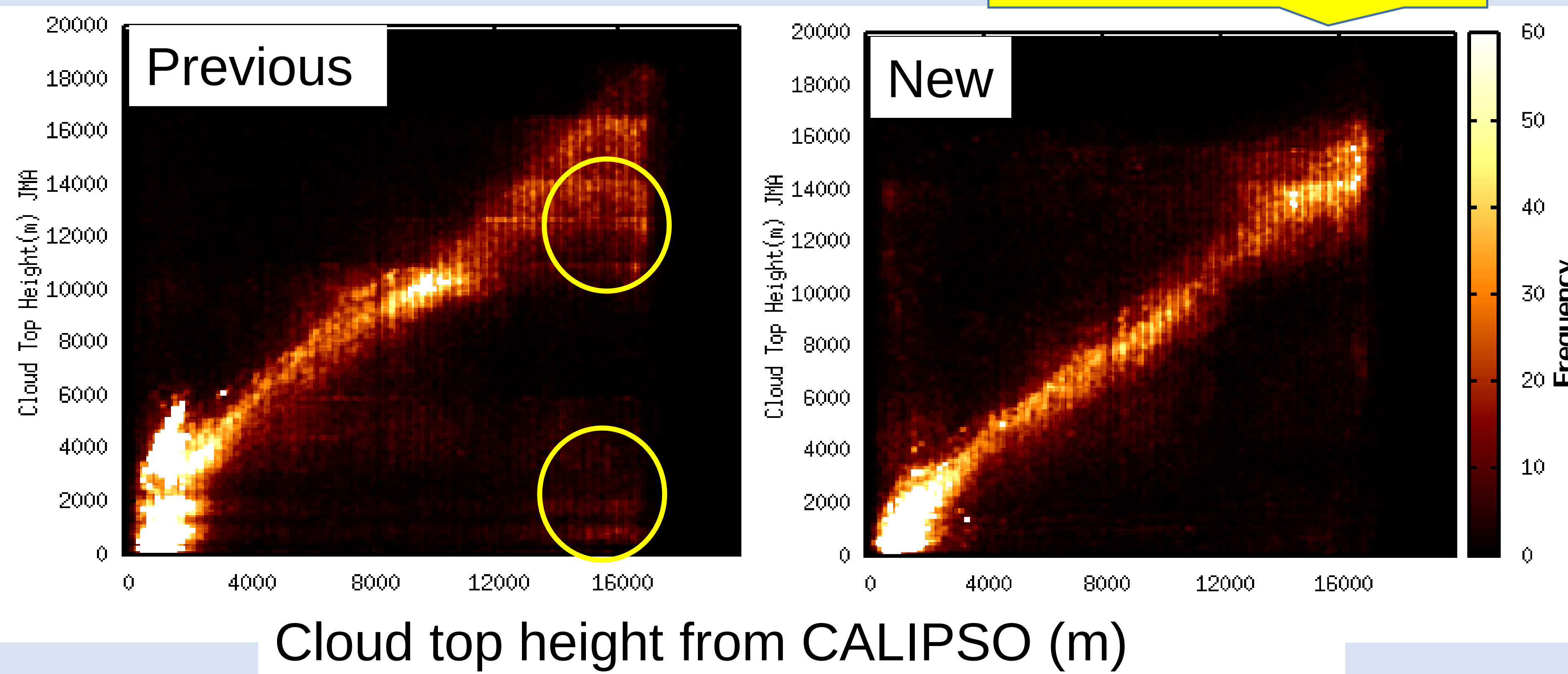
Cloud top height and pressure derived from temperature

2. Improvement of Cloud top height
2-2. Results

Comparison to CALIPSO:

Sep. 2016, full-disk area

reduce underestimation

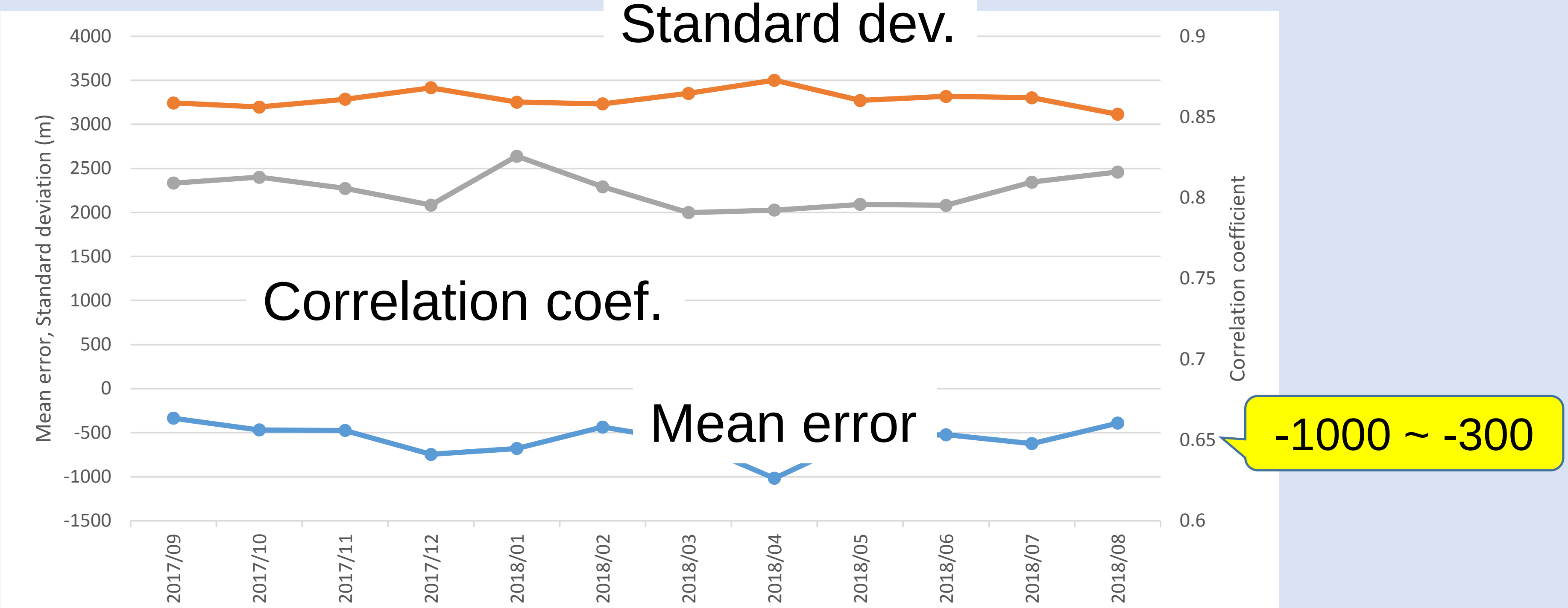


Underestimation reduced

2. Improvement of Cloud top height

2-3. Validation

Global monthly statistics:



yearly	Mean Error [m] Himawari8-CALIPSO	Std. Dev. [m]	Correlation Coef.
Old	-1001.4	3703.8	0.75
New	-490.6	3148.9	0.82

Improved, but the difference from CALIPSO still remains

3. Applicability of machine-learning

3-1. Difficulties of cloud (type) discrimination

Cloud (type) discrimination involves own inherent difficulties:

- “subjectivity” of cloud (type)
  - ◆Cloud properties continuously varies
    - ◆the boundary among them (e.g., clear/cloudy) intrinsically vague
  - ➢The cloud (type) definition (i.e., the criteria of “correct”): determined subjectively depending on purposes
    - ➢No absolutely correct criteria of cloud (type)
- Incorrect discrimination: unavoidable
  - ◆A variety of conditions: difficult to consider all situations in advance of constructing a classifier (e.g., rare or local cases)
  - ➢A classifier adjustment --- new incorrect results under other conditions!
    - ➢Trial and error --- a haphazard way

A difference from other general classification problems

3. Applicability of machine-learning

3-2. Requirements for cloud discrimination methods

Clarify requirements to overcome the difficulties:

1. Procedure of appropriate training dataset preparation
   - ◆ No objectively labeled data
     - ➢ To avoid a circular argument
2. To determine a reasonable classifier for each purpose
   - ◆ No absolutely correct criteria, i.e., subjectivity
3. To quantitatively estimate likelihood of cloud type
   - ◆ To treat the vagueness
4. To construct a practical adjustment procedure
   - ◆ to avoid the haphazard way

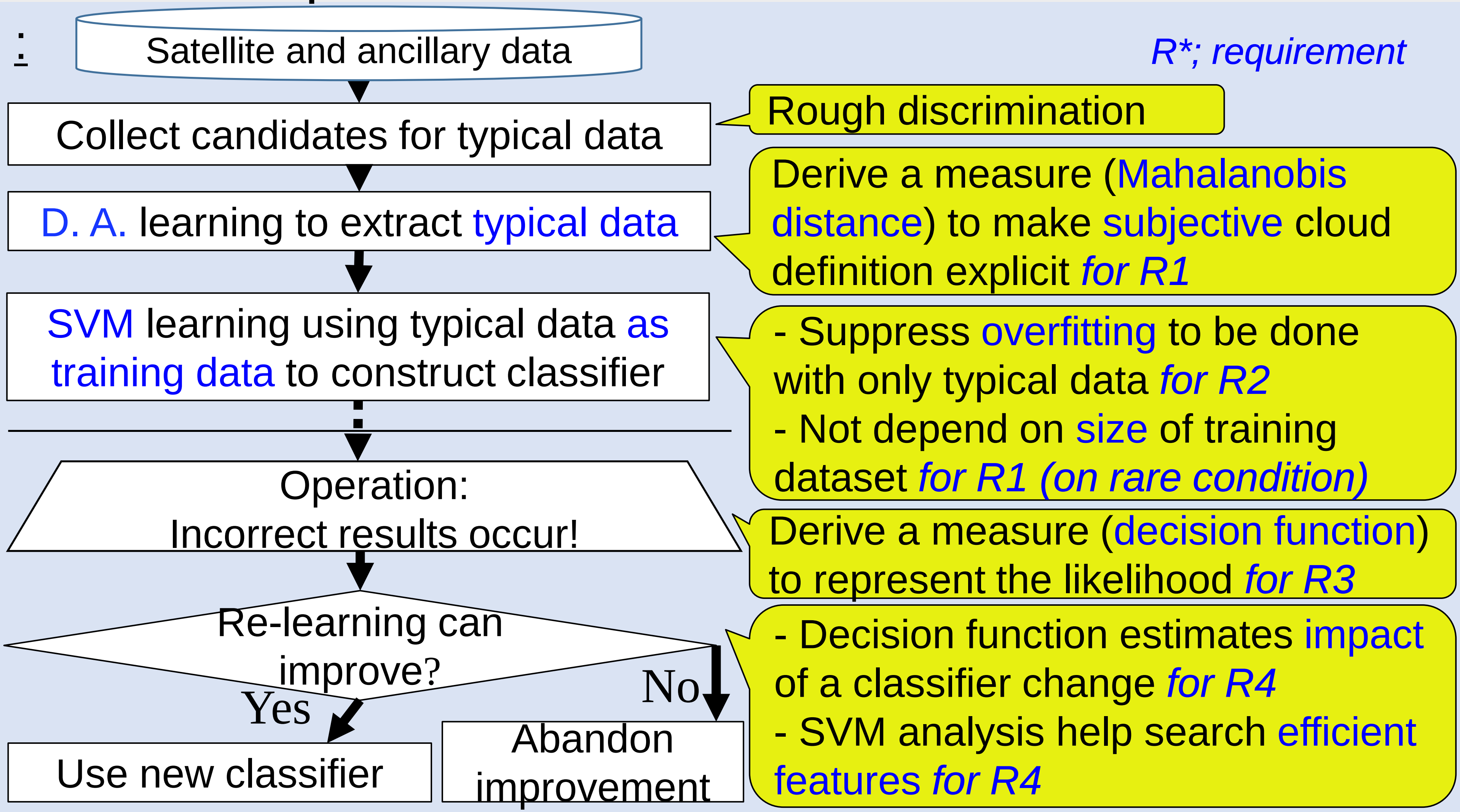
Besides,

- Save computer resource
- The generality to be applicable to various sensors/targets

Machine-learning incorporation: satisfying these requirements

3. Applicability of machine-learning

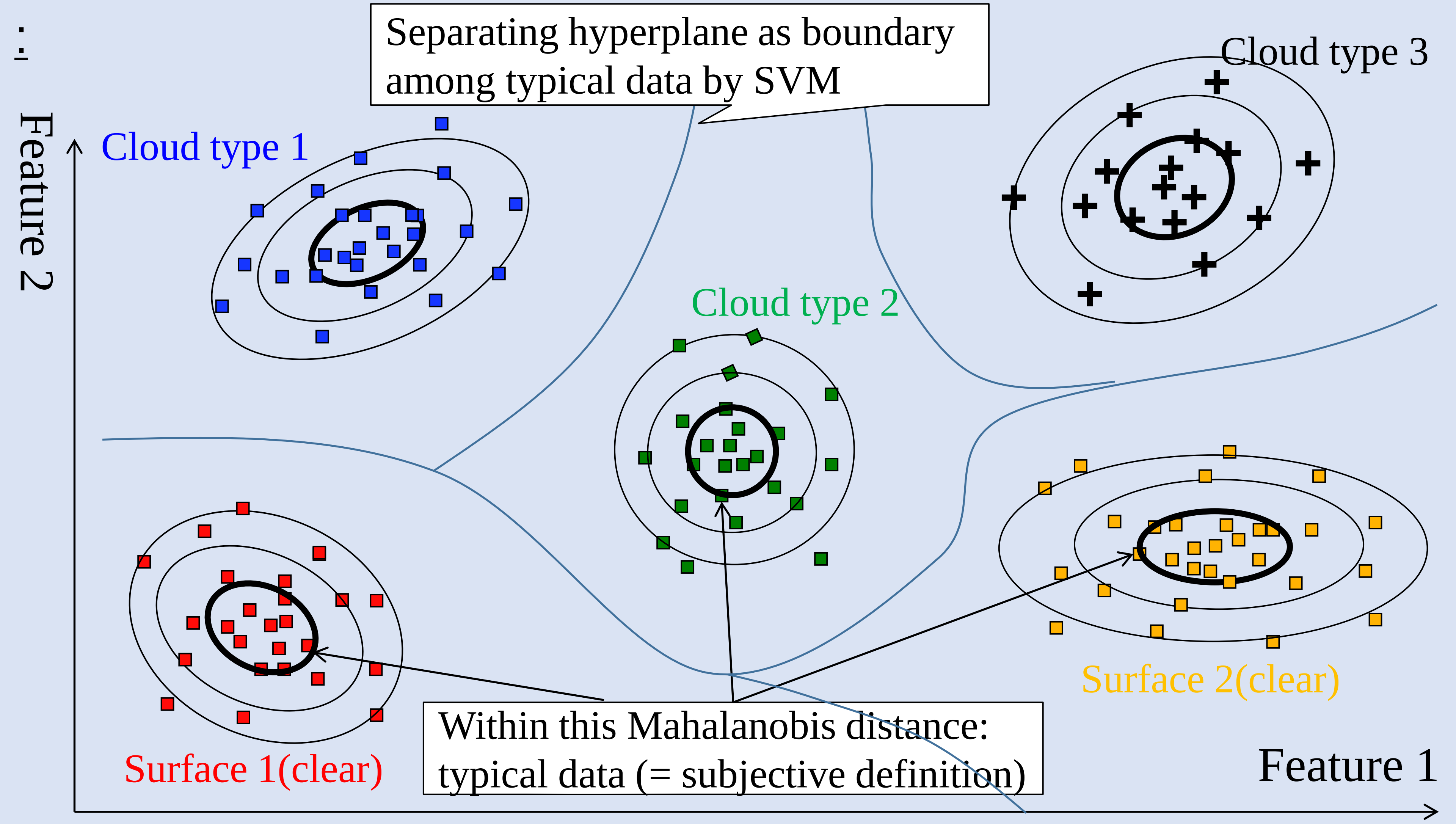
3-3. Development: Flow of method



Ishida et al., 2018, Development of a support vector machine based cloud detection method for MODIS with the adjustability to various conditions. *Rem. Sens. Environ.*, 205, 390–407.

3. Applicability of machine-learning

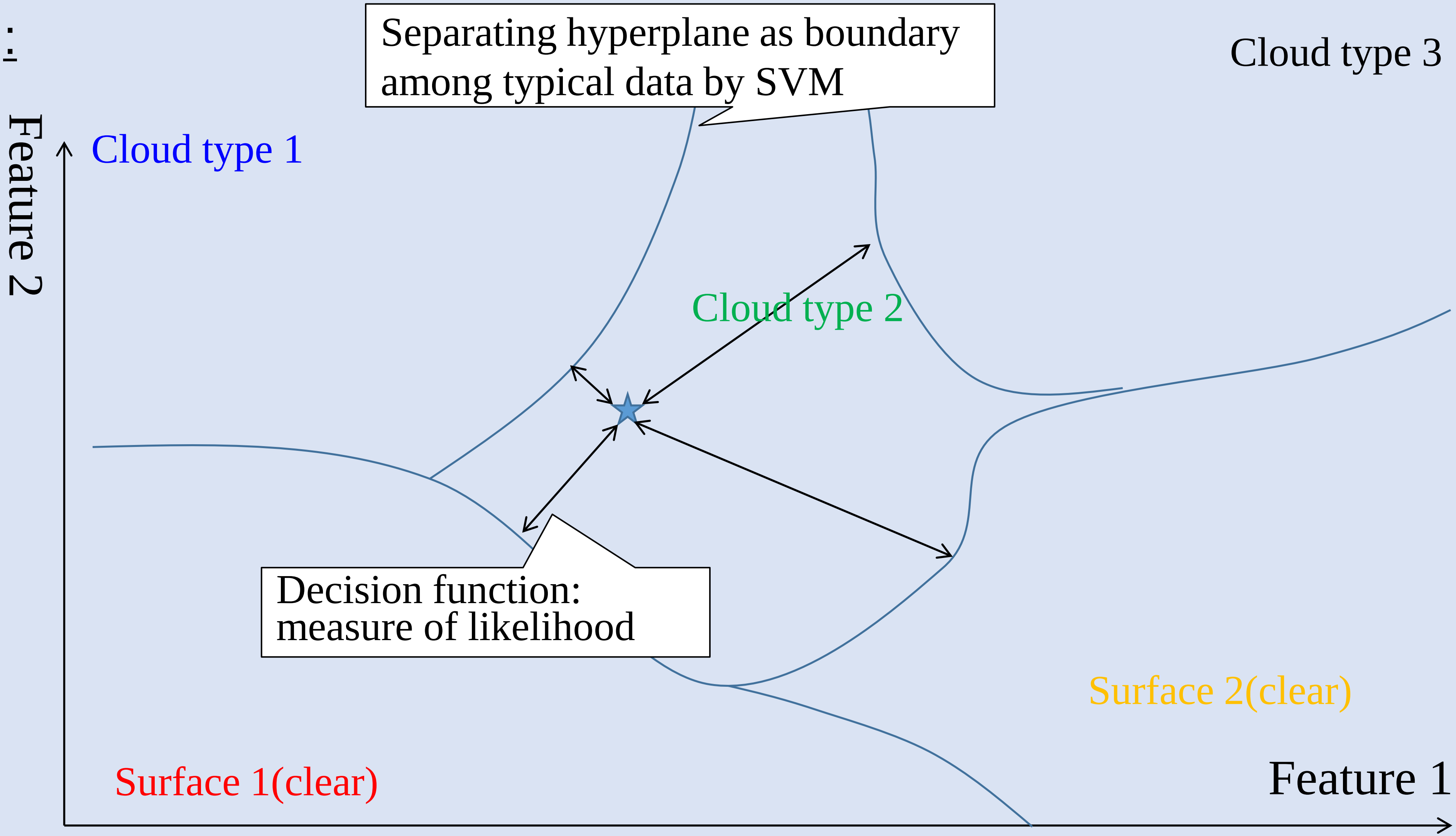
3-4. Development: Conceptual schematic



SVM learning with only typical data; reasonable classifier

3. Applicability of machine-learning

3-4. Development: Conceptual schematic

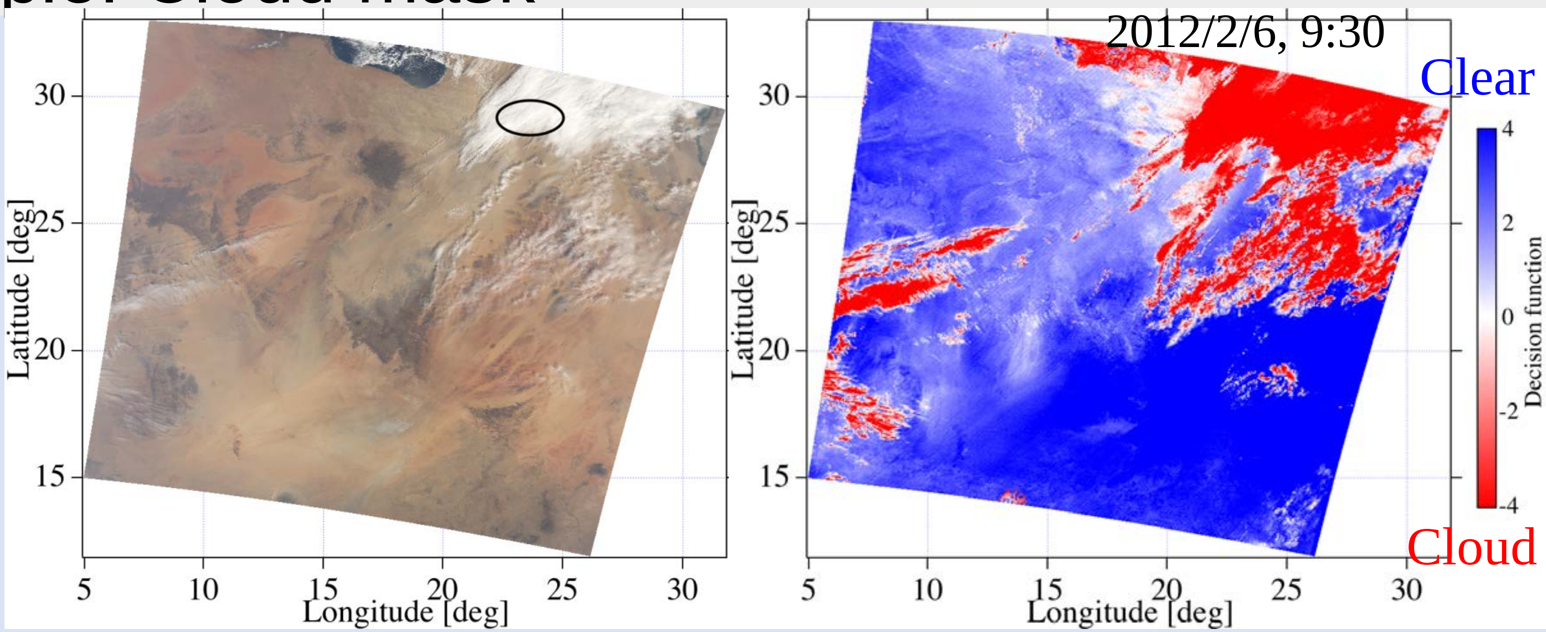


SVM learning with only typical data; reasonable classifier

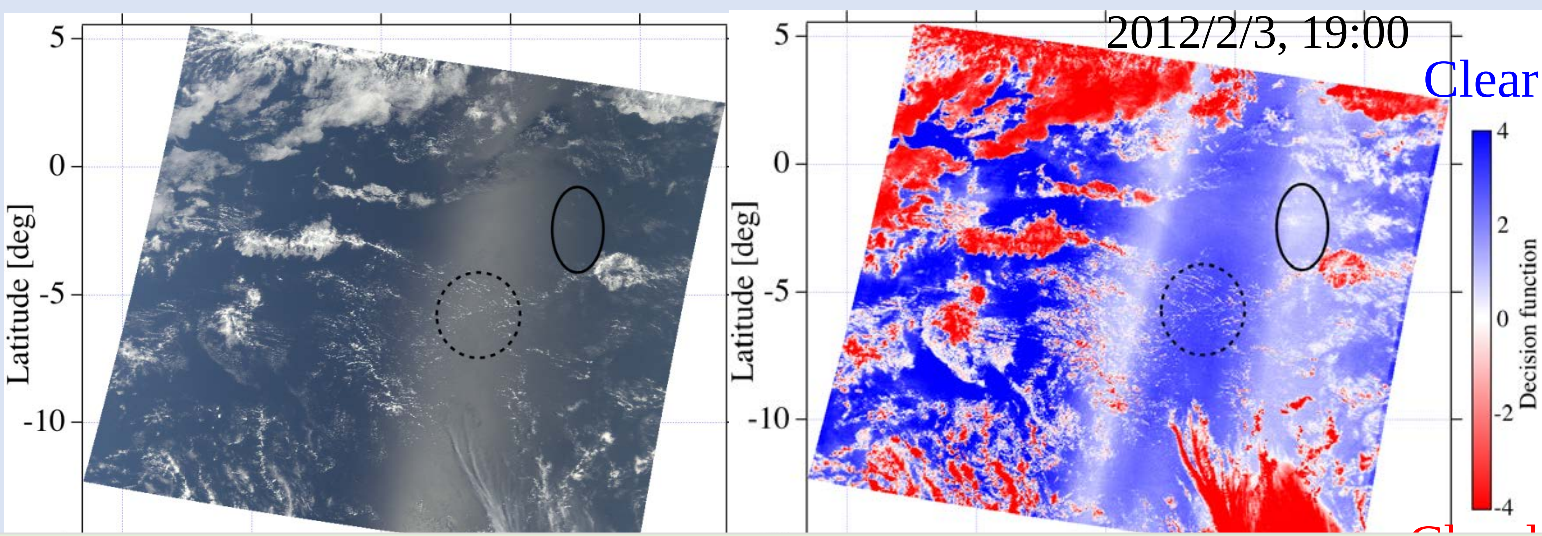
3. Applicability of machine-learning

3-5. Example: Cloud mask

Desert
by MODIS



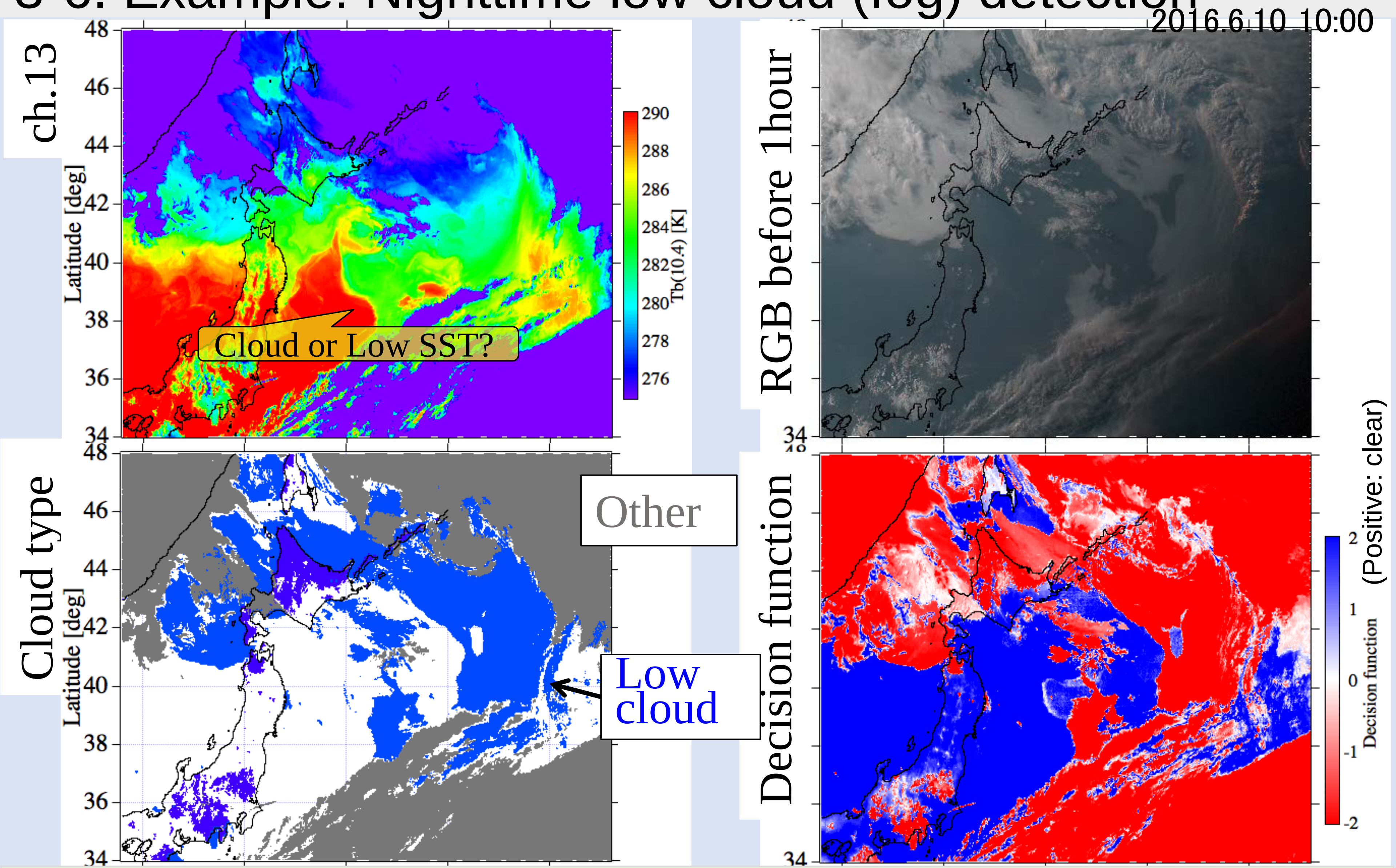
Ocean
by MODIS



The decision function: appropriate for a measure of likelihood

3. Applicability of machine-learning

3-6. Example: Nighttime low cloud (fog) detection



SVM using all IR bands of AHI: reasonable discrimination

4. Conclusions

- AHI cloud product: the algorithm for cloud top height retrieval has been improved.
  - ➢ Reduce under estimation in the previous version

- A way of incorporating machine-learning techniques into cloud (type) discrimination
  - ➢ To overcome the own difficulties
  - ➢ SVM: suitable and applicable
  - ✓ How about other techniques (e.g., Neural Networks)?

appendix

Fundamental Cloud Product: Cloud Mask

- ✓ Threshold tests for observed reflectance and brightness temperature(TBB)
- ✓ Referring to the NWC-SAF and GOES-R/ABI ATBDs
- ✓ Each threshold depends on the clear-sky reflectance/TBB

  Reflectance:
  - (Land) MODIS BRDF / Albedo product (MOD43)
  - (Sea) Cox and Munk, 1954
  - (Ice) Aoki et al., 1999, 2000(JGR)

  TBB:
  - RTTOV calculation on the cloud free condition

Tests	Primary parameters
Snow/sea ice detection	R1.6
Top temperature tests	T10.4
Top reflectance tests	R0.64, T3.9-T10.4
Top emissivity tests	T10.4-T8.6, T10.4-T3.9, T12.4-T3.9
Cloud absorption tests	T10.4-T12.4, T8.6-T10.4, T3.9-T10.4
Atmospheric absorption tests	T7.3-T10.4, T12.4-T10.4

- ✓ In addition, spatial/temporal uniformity tests are applied

For further information:
Imai, T., and R. Yoshida, 2016: Algorithm theoretical basis for Himawari-8 Cloud Mask Product. Meteorological Satellite Center Technical Note, 61

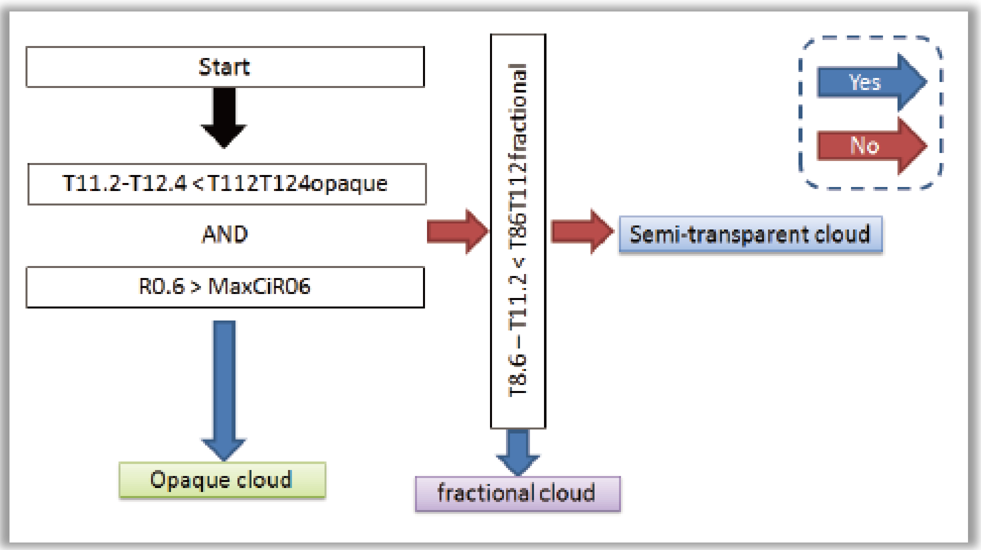
Fundamental Cloud Product: Cloud Type/Phase

✓ Cloud Type

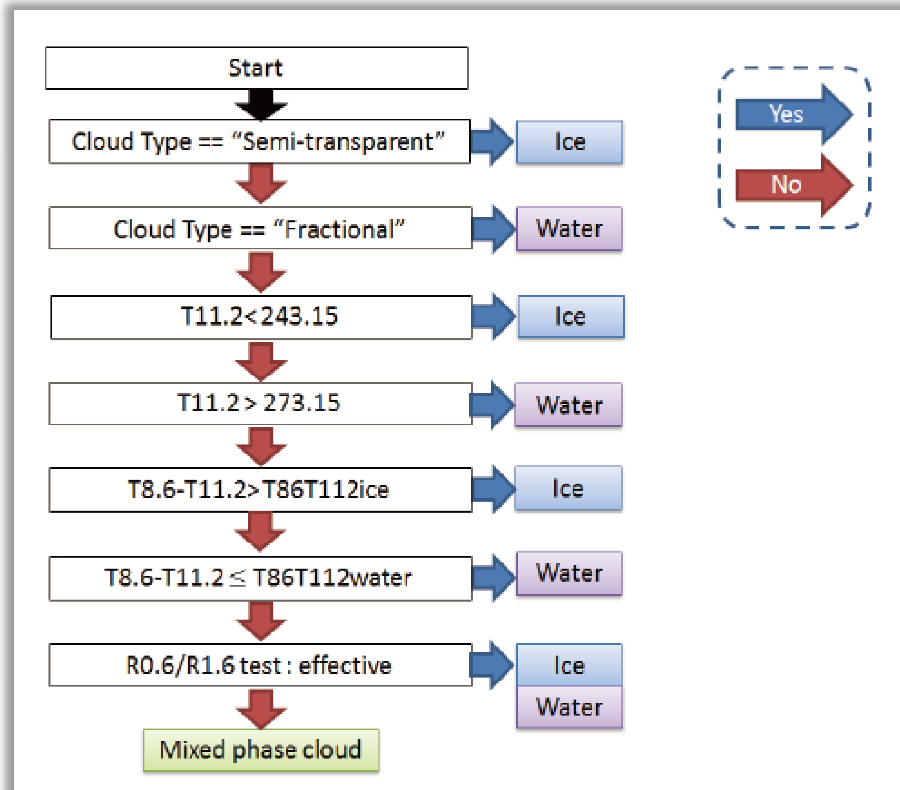
A cloudy pixel is categorized into “opaque ”, “semi-transparent” or “fractional”

✓ Cloud Phase

Cloud top phase (Water/Ice/Mixed) is determined based on observed TBB, reflectance and the Cloud Type



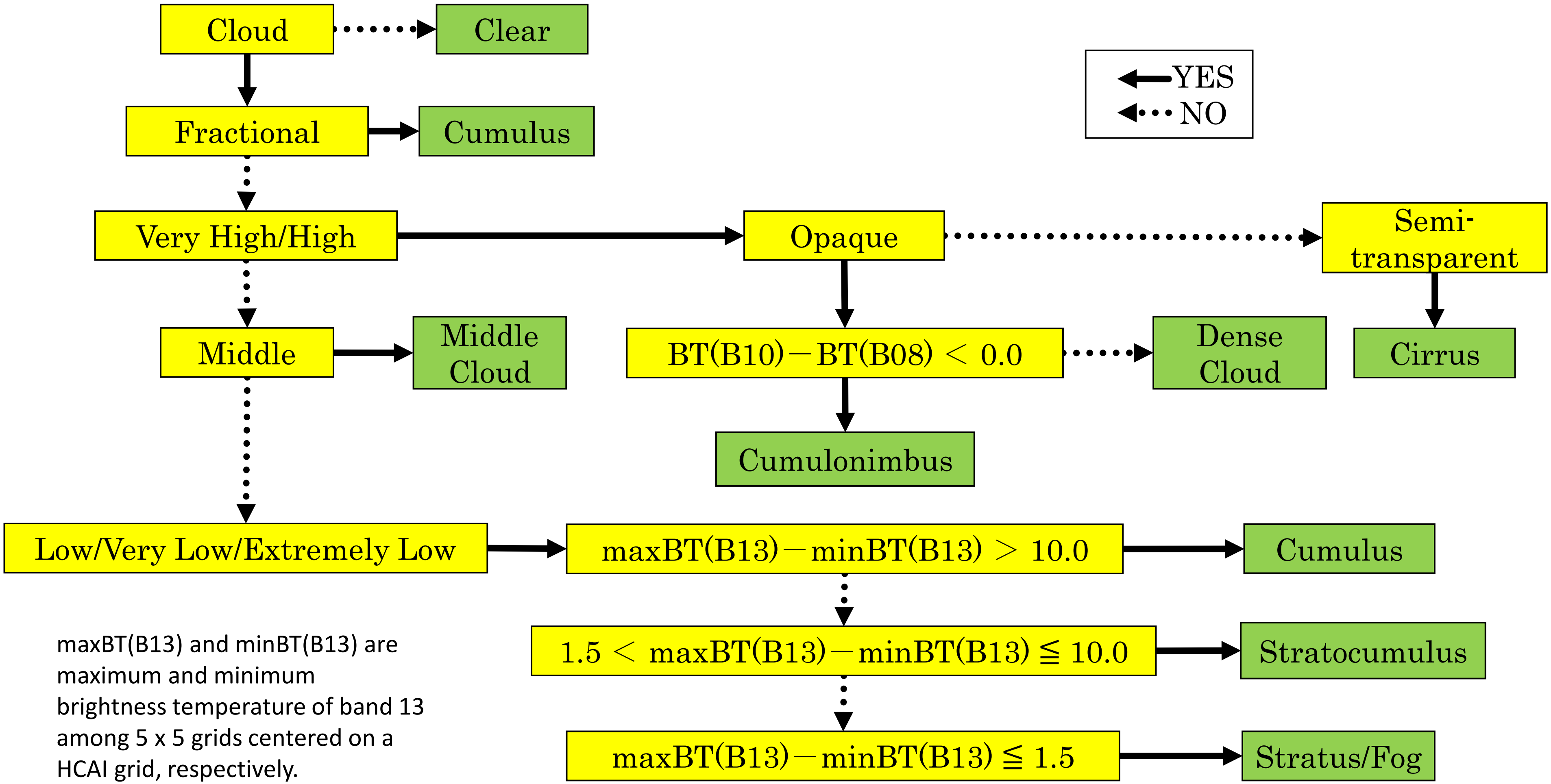
Cloud Type determination scheme (daytime)



Cloud Phase discrimination scheme (daytime)

For further information:
Mouri et al., 2016:Algorithm Theoretical Basis Document of Cloud Type/Phase Product. Meteorological Satellite Center Technical Note, 61

HCAI Cloud Type determination

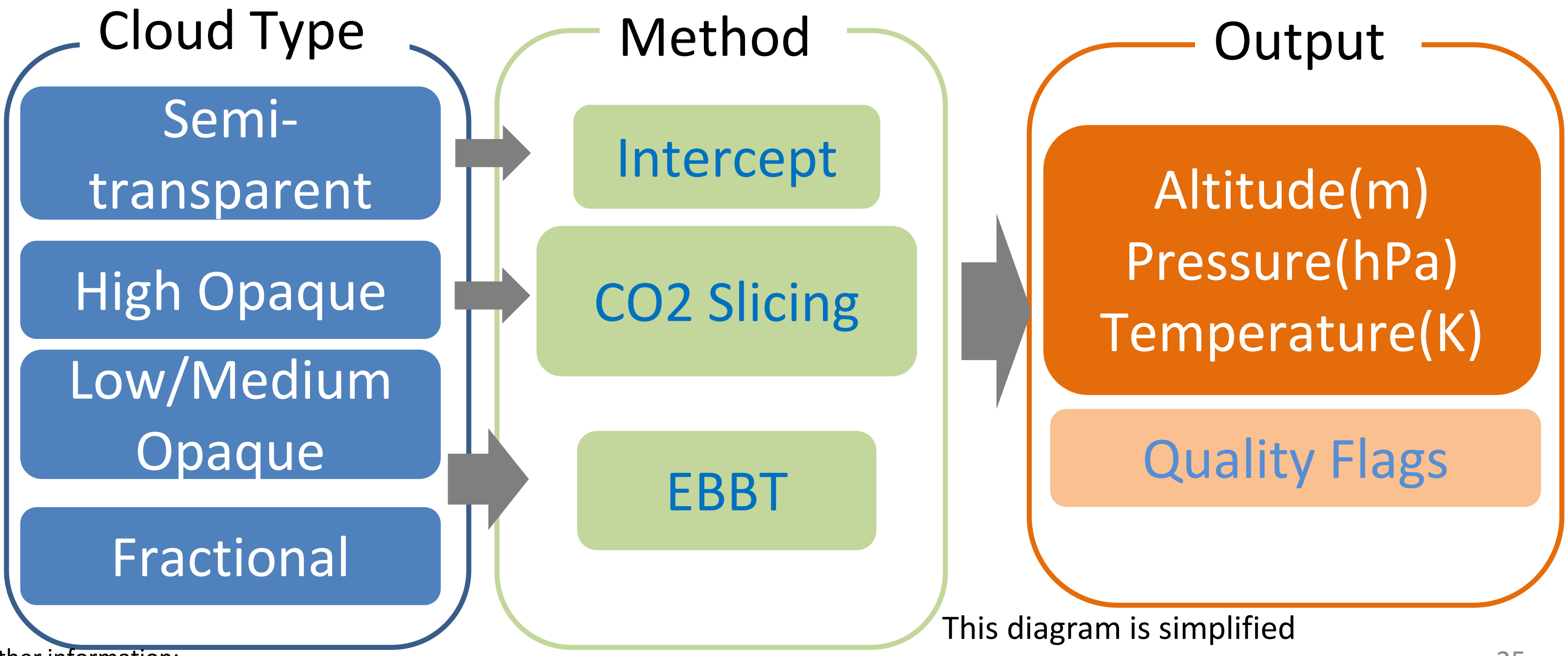


maxBT(B13) and minBT(B13) are maximum and minimum brightness temperature of band 13 among 5 x 5 grids centered on a HCAI grid, respectively.

For further information:
Suzue et al., 2016:High-resolution Cloud Analysis Information derived from Himawari-8 data. Meteorological Satellite Center Technical Note, 61

Fundamental Cloud Product: Cloud Top Height

- ✓ Combining three conventional methods
  - CO_2 Slicing method (Menzel et al., 1982)
  - IRW/H_2O Intercept Method (Schmetz et al., 1993)
  - Equivalent Black Body Temperature (EBBT) Method
- ✓ One method selected based on the cloud type



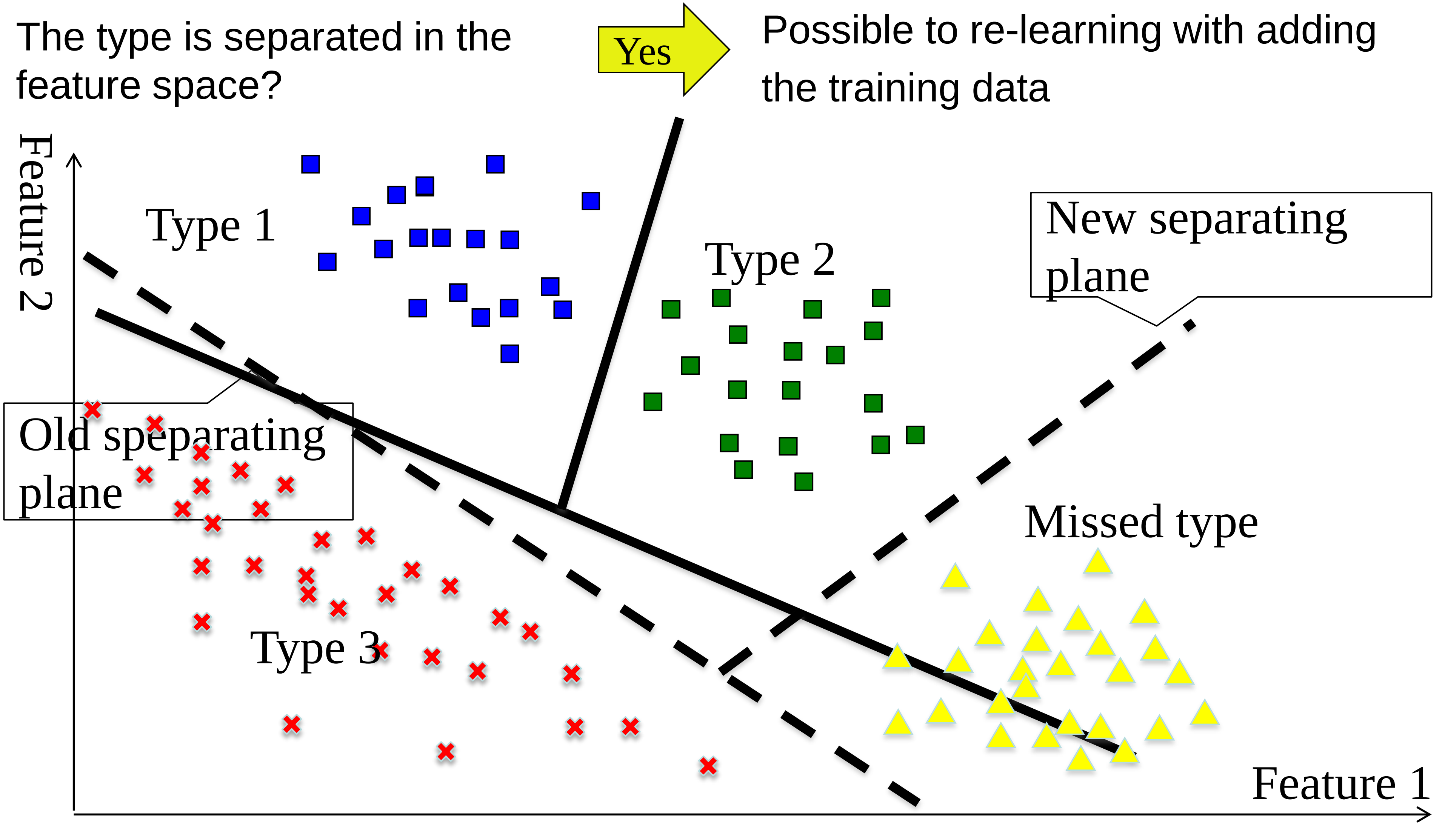
This diagram is simplified

For further information:
Mouri et al., 2016:Algorithm Theoretical Basis Document of Cloud Top Height Product. Meteorological Satellite Center Technical Note, 61

2. Adjustment by adding training dataset

If a type of surface or cloud is usually incorrectly discriminated…

The type is separated in the feature space?



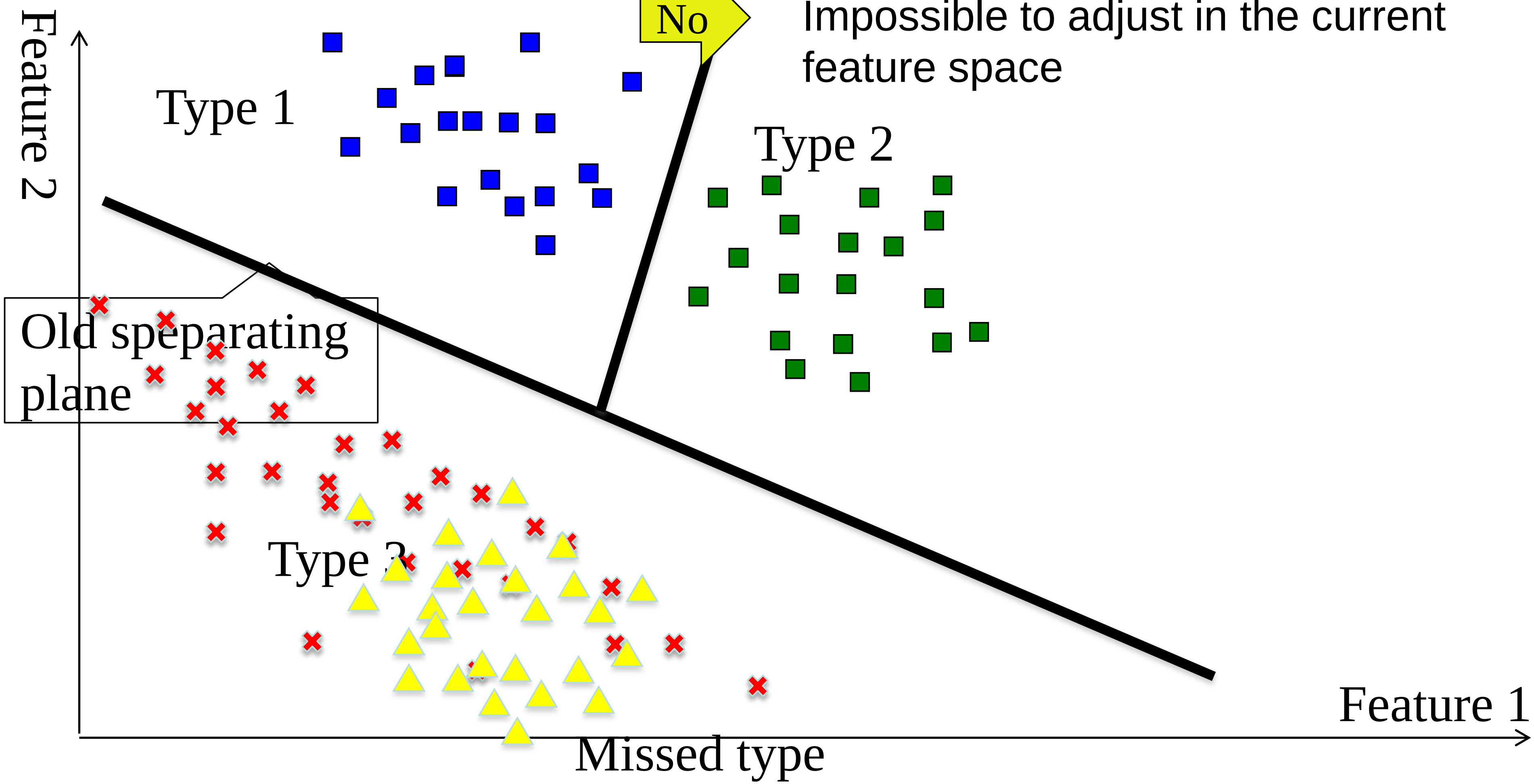
2. Adjustment by adding training dataset

If a type of surface or cloud is usually incorrectly discriminated…

The type is separated in the feature space?

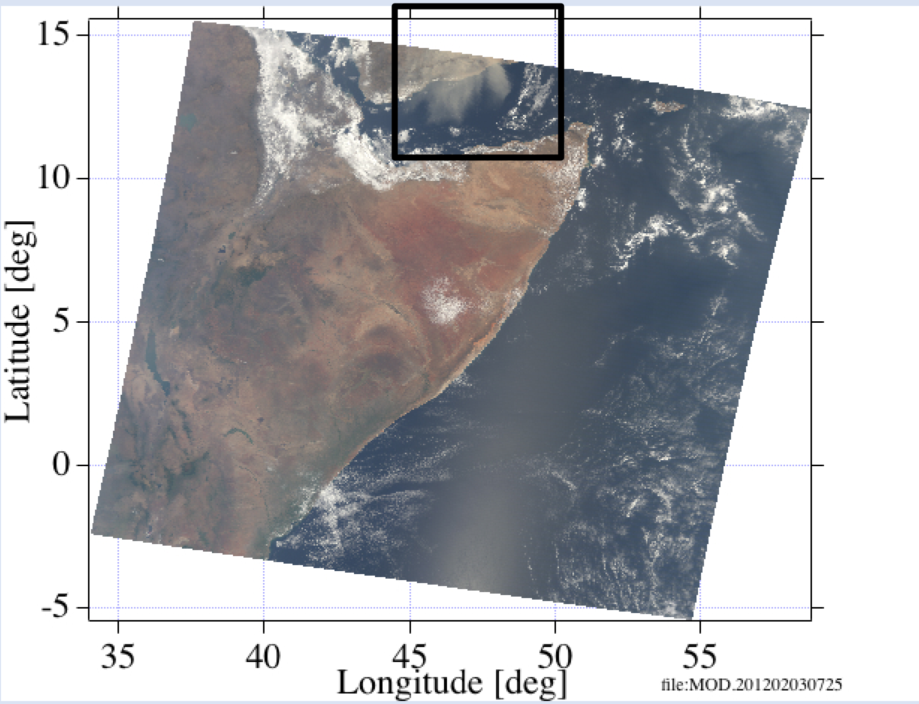
Yes → Possible to re-learning with adding the training data

No → Impossible to adjust in the current feature space

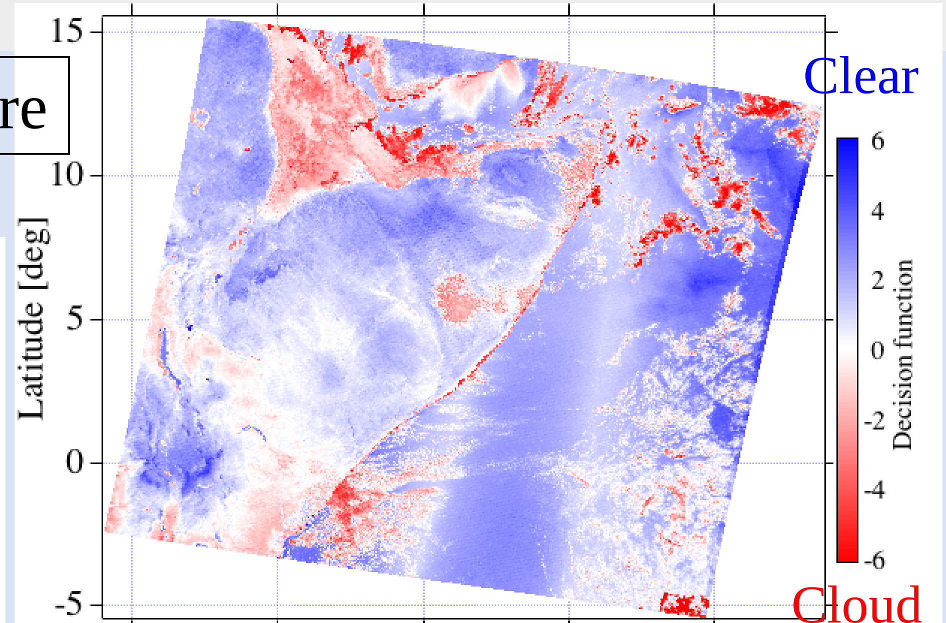


3. Adjustment by adding training dataset

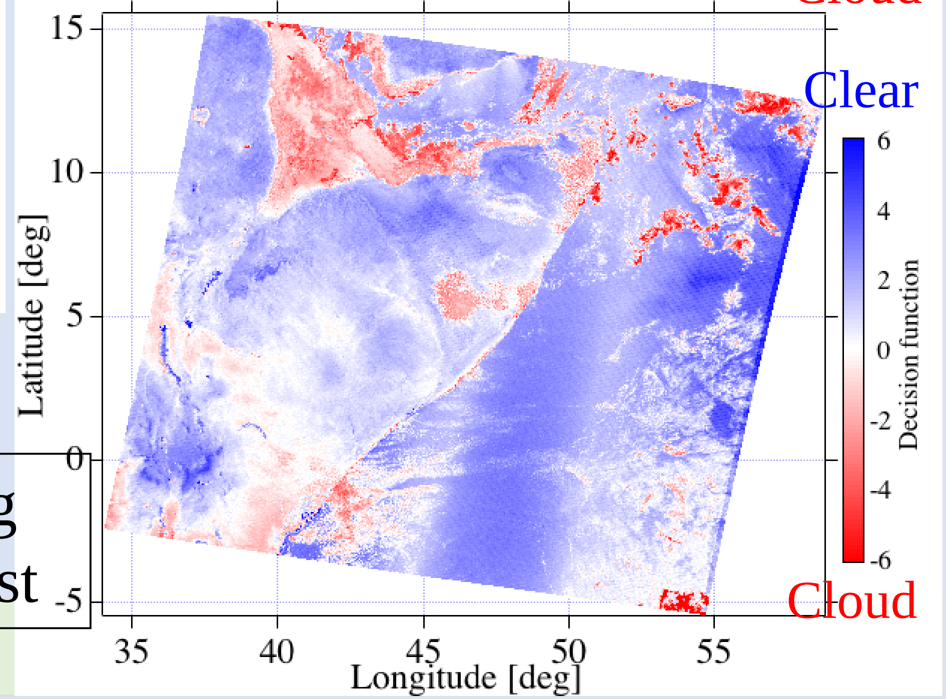
MODIS, dust



Before

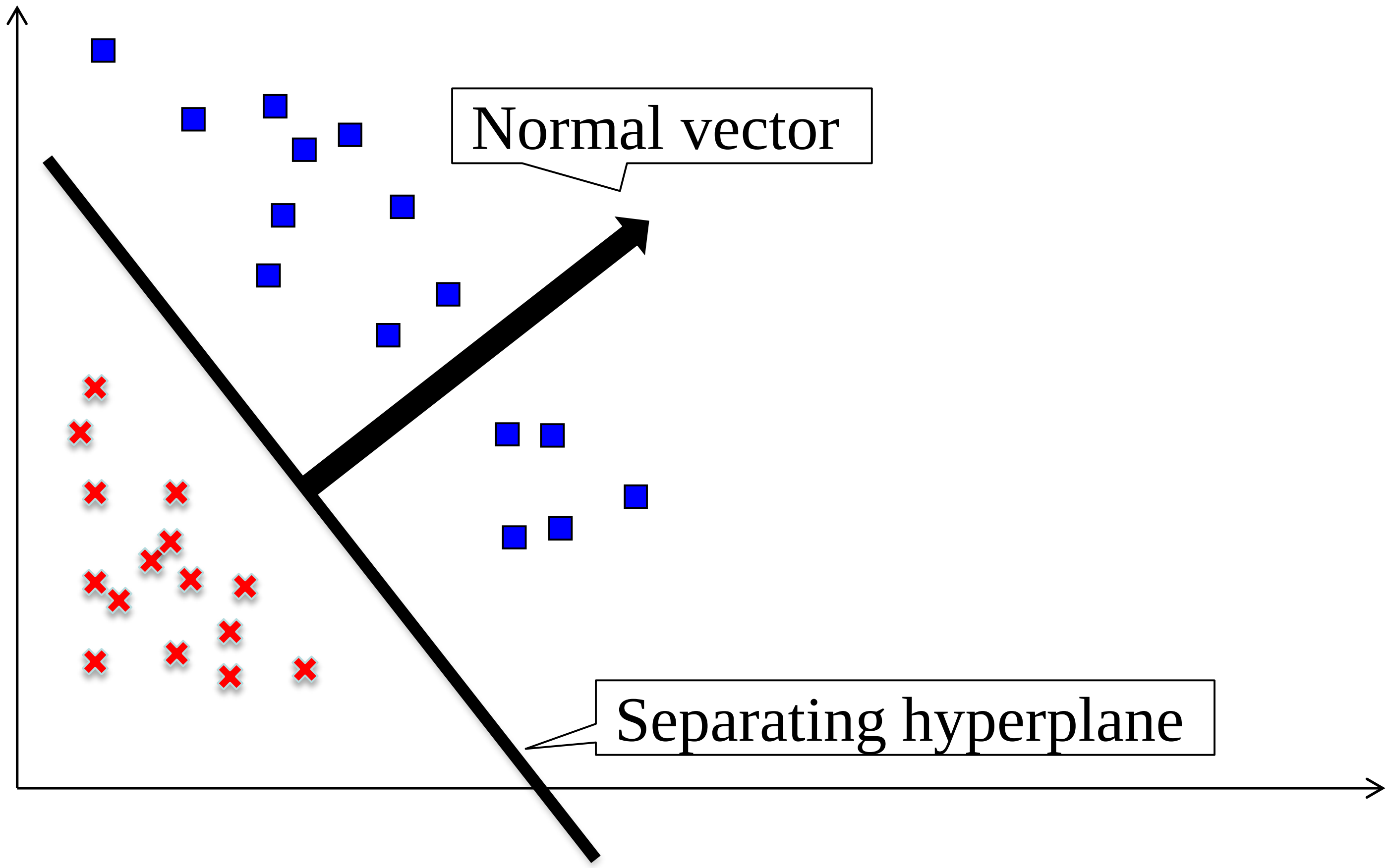


Re-learning adding training data of dust



5. Effectivity of features

5-1. index; length of the projection of the normal vector



The length of the projection of the normal vector means the contribution of the feature to the classification

5. Effectivity of features

5-1. Feature selection

Over water, MODIS