Development of a microwave land surface emissivity algorithm for precipitation retrieval

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Microwave land surface emissivity

- Microwave rainfall retrieval over land
  - Remains challenging because the microwave surface emissivity is poorly constrained over land.
    - ε is highly variable over space and time, and depends on many factors including soil moisture, vegetation, snow cover, etc.
  - Relies on scattering signals from ice particles above rain.
    - Warm rain accompanied by little ice above is largely missed.
    - Dry, light snowfall is often left undetected.
- Efforts to evaluate microwave land surface emissivity
  - Model-based: Develop a land surface model and assign synthetic emissivity for each surface type etc.
  - Observation-based: Retrieve emissivity from observed microwave Tb from scene to scene.

Land sfc emissivity algorithm for GPM

- JAXA (domestic) GPM land emissivity algorithm
  - Team
    - H. Masunaga, F. A. Furuzawa, and H. Minda (Nagoya U).
  - Estimates ε from observed T_bs (Prigent et al., 2006).
  - Utilizes radar observations for identifying rain-free scenes.
    - A reliable measure to minimize rain contamination.
  - An “EOF estimator” to derive high-frequency emissivities.
    - To avoid noise from cloud emissions at high frequency Tbs.
  - A prototype algorithm is being experimented with
    - 1) TRMM TMI and PR for frequencies of 85 GHz and lower.
    - 2) AMSU collocated with PR for WV sounding channels (not shown today.)
  - Aimed at future implementation in the GSMaP algorithm.
    - ↔ NASA PMM ε algorithms for GPM radiometer/combined retrievals.

Retrieval methodology

Clear-sky emissivity algorithm (Prigent et al. 2006)

$$\tau(z_0, z_1) = \int_{z_0}^{z_1} \alpha(z) dz$$

$$T_{\text{atm}}^{\downarrow} = \int_H^0 T(z)[\alpha(z)/\mu] e^{-\tau(z,0)/\mu} dz + T_{\text{cosm}} e^{-\tau(0,H)/\mu}$$

$$T_{\text{atm}}^{\uparrow} = \int_0^H T(z)[\alpha(z)/\mu] e^{-\tau(z,H)/\mu} dz.$$

$$\varepsilon_p = \frac{\text{Tb}_p - T_{\text{atm}}^{\uparrow} - T_{\text{atm}}^{\downarrow} e^{-\tau(0,H)/\mu}}{e^{-\tau(0,H)/\mu} (T_{\text{surf}} - T_{\text{atm}}^{\downarrow})}$$

Atmospheric parameters (T, q_v, q_c) are estimated from JRA/JCDAS.

Emissivity is first estimated for rain-free scenes where TRMM PR sees no rain..

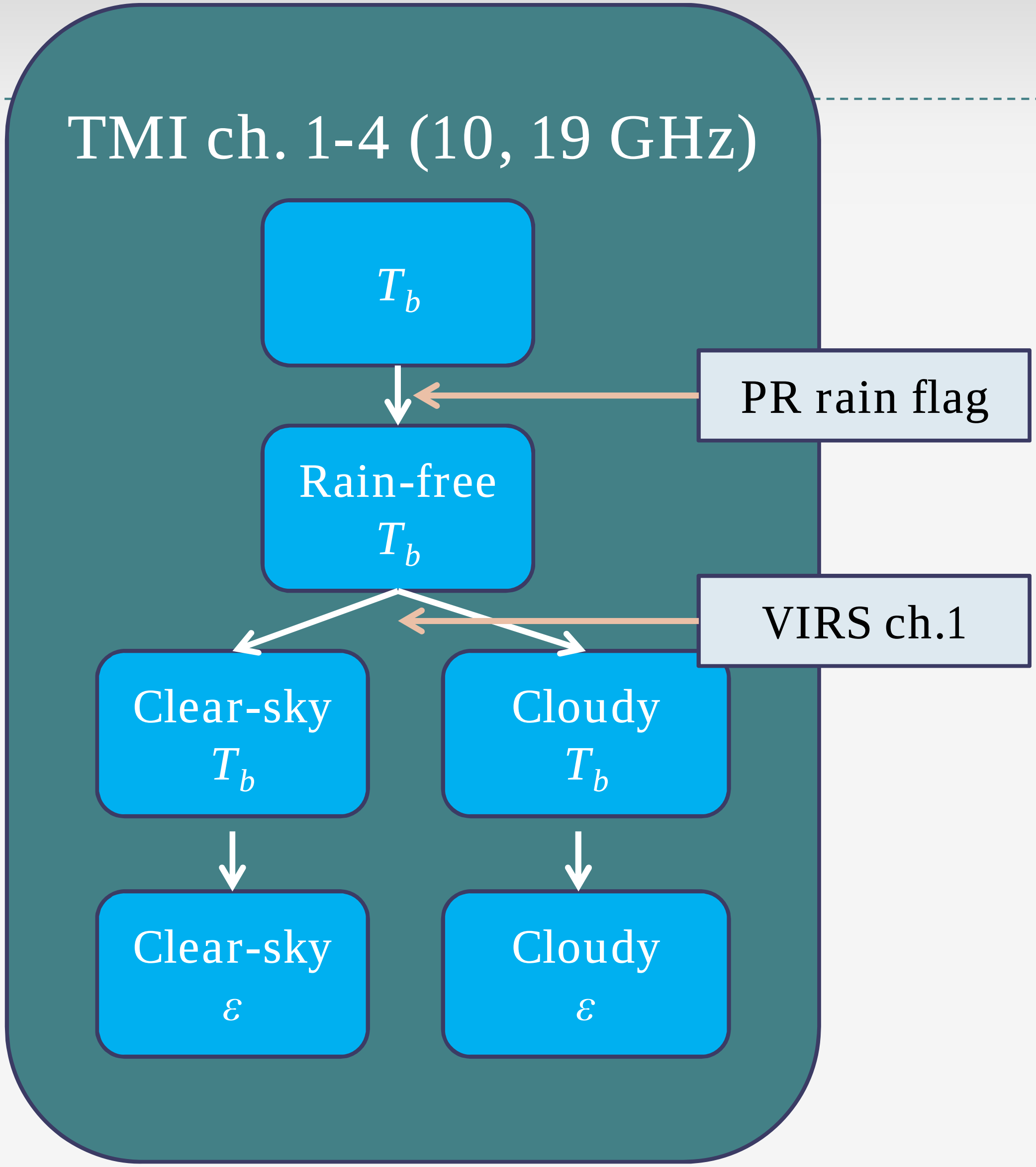
Emissivity for raining scenes

- Interpolate the clear-sky emissivity across raining scenes
  - Spatial averaging with Gaussian weights

$$\varepsilon_i = \frac{\sum_j \varepsilon_j \exp(-d_{ij}^2 / \sigma^2)}{\sum_j \exp(-d_{ij}^2 / \sigma^2)}$$

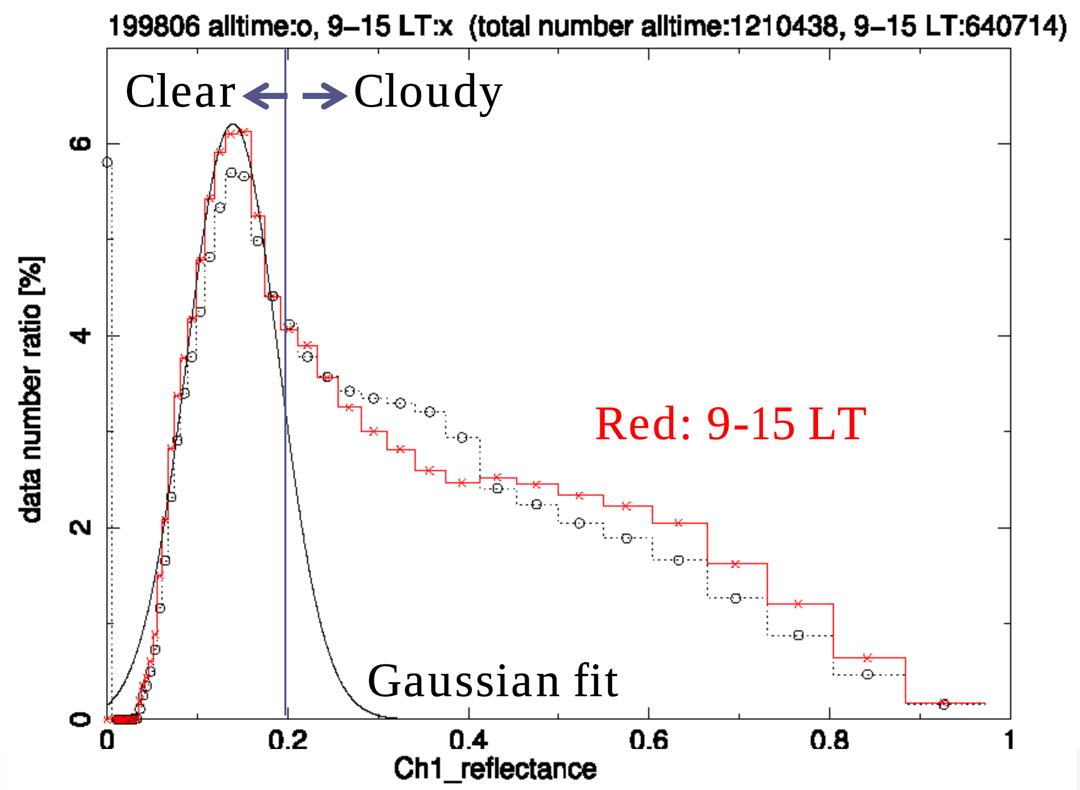
d_{ij} : distance between FOV_i and FOV_j

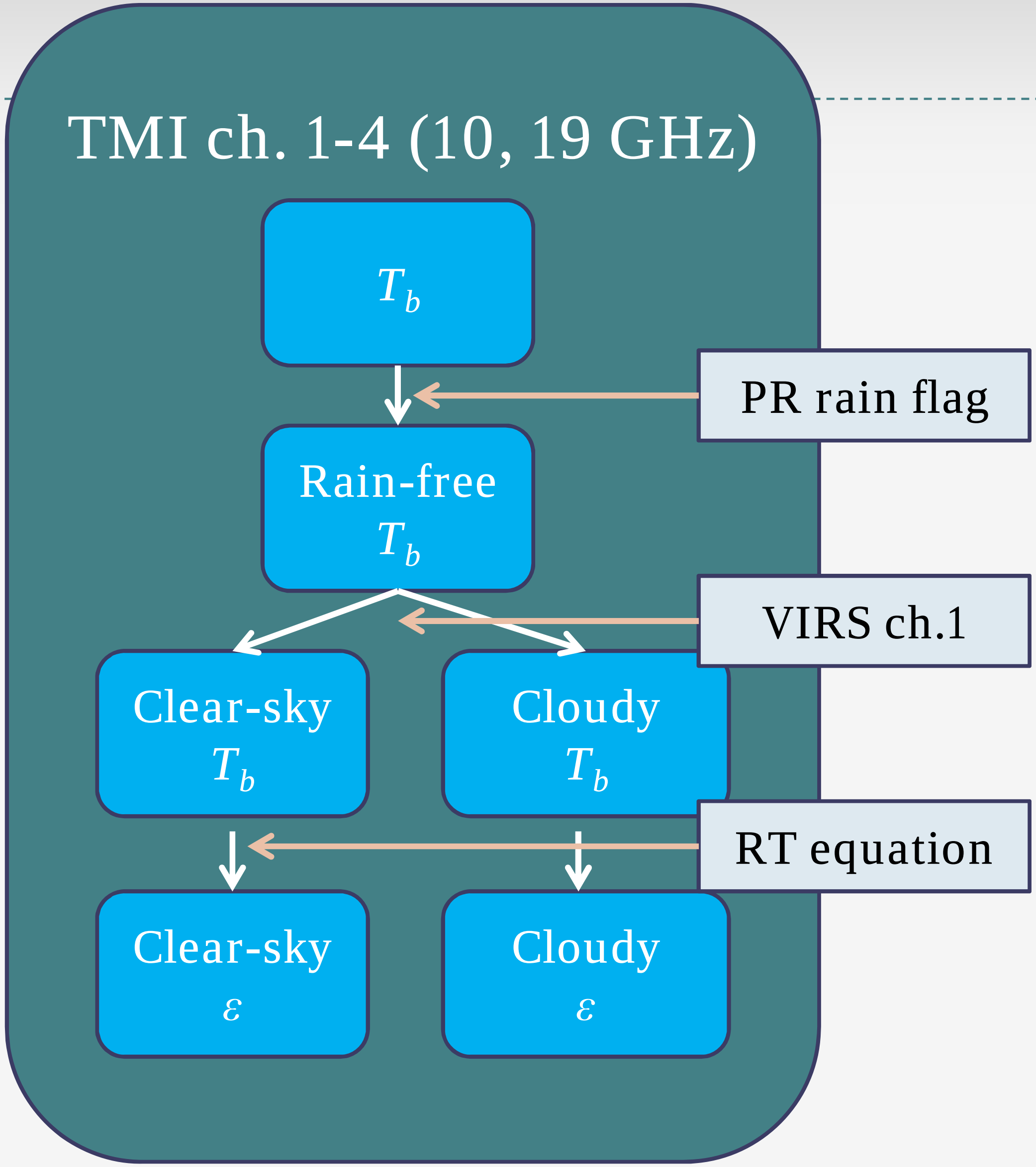
σ : correlation length ($= 0.1\,\mathrm{deg}$)

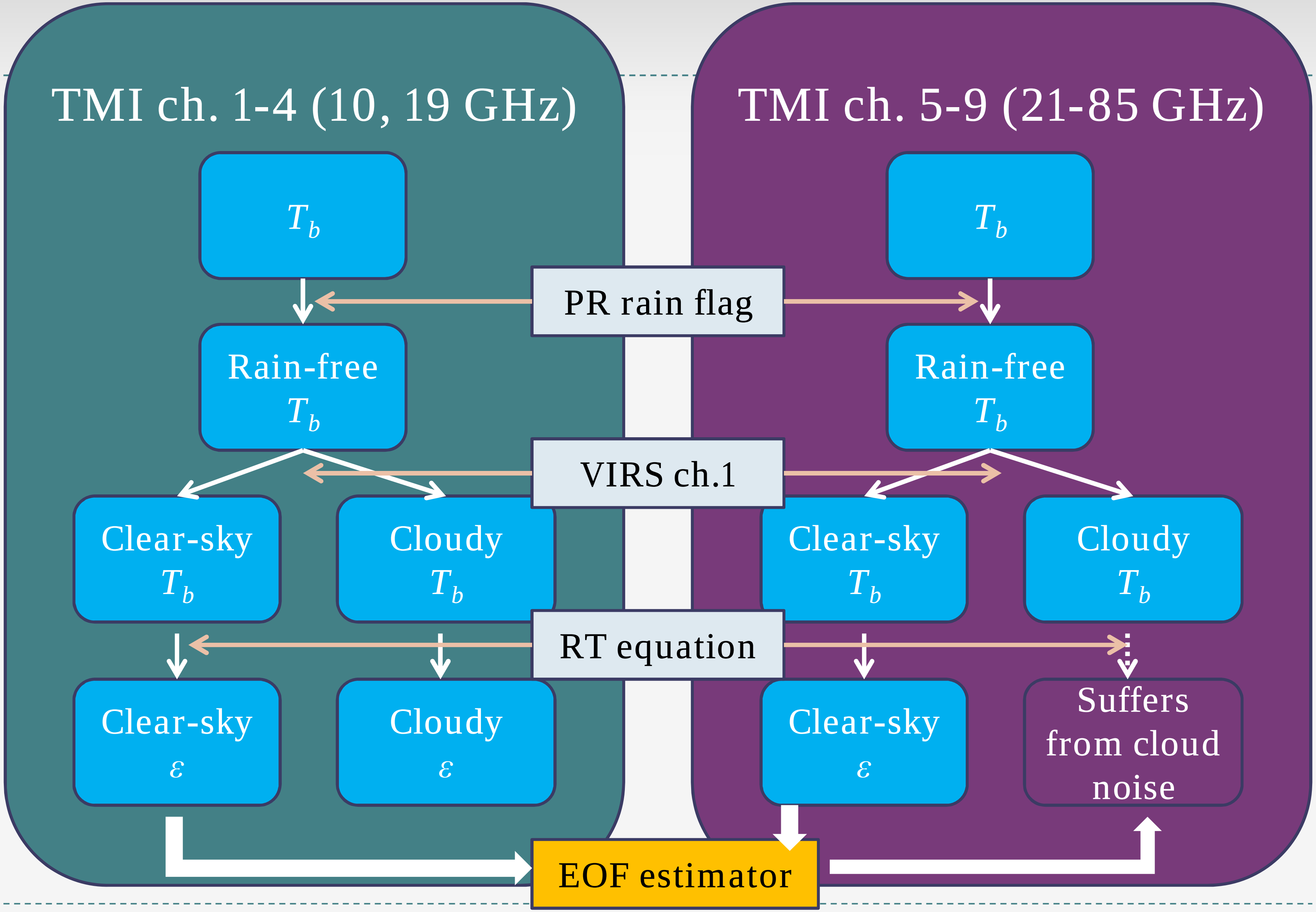

TMI ch. 1-4 (10, 19 GHz)
T_b
PR rain flag
Rain-free
T_b
VIRS ch.1
Clear-sky
T_b
Cloudy
T_b
Clear-sky
ε
Cloudy
ε

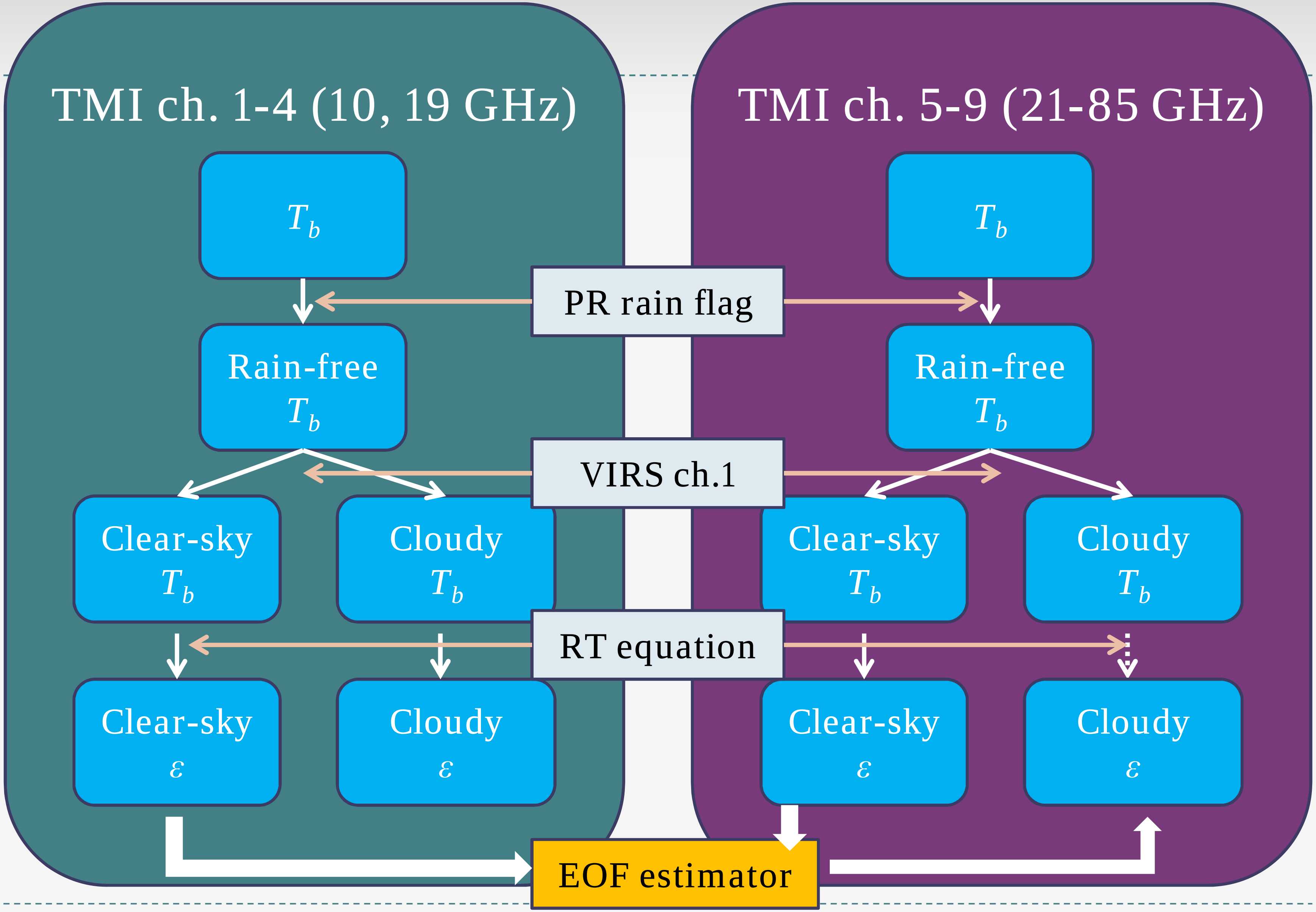
Cloud screening

- VIRS-based cloud screening
  - Cloud fraction < 0.22 within a 0.2° × 0.2° box: clear sky
    - Visible (ch.1) reflectance < 0.2 is defined as a cloud-free pixel.




TMI ch. 1-4 (10, 19 GHz)
T_b
PR rain flag
Rain-free T_b
VIRS ch.1
Clear-sky T_b
Cloudy T_b
RT equation
Clear-sky ε
Cloudy ε


TMI ch. 1-4 (10, 19 GHz)
TMI ch. 5-9 (21-85 GHz)
T_b
T_b
PR rain flag
Rain-free T_b
Rain-free T_b
VIRS ch.1
Clear-sky T_b
Cloudy T_b
Clear-sky T_b
Cloudy T_b
RT equation
Clear-sky ε
Cloudy ε
Clear-sky ε
Suffers from cloud noise
EOF estimator


TMI ch. 1-4 (10, 19 GHz)
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T_b
T_b
PR rain flag
Rain-free T_b
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VIRS ch.1
Clear-sky T_b
Cloudy T_b
Clear-sky T_b
Cloudy T_b
RT equation
Clear-sky ε
Cloudy ε
Clear-sky ε
Cloudy ε
EOF estimator

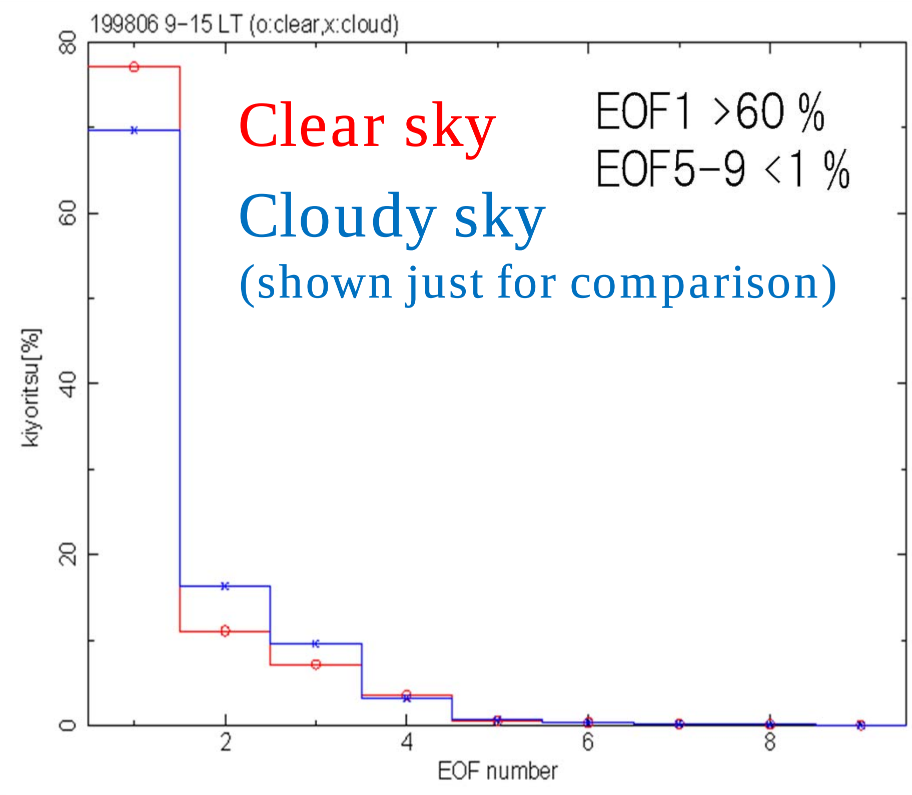
Recent algorithm updates

- Implementation of EOF-based estimator
  - ε at high frequencies (> 85 GHz) suffers from the water vapor and cloud water uncertainties.
  - This problem may be avoided by an "EOF estimator":
    - 1) Retrieve ε at each frequency for cloud-free scenes.
    - 2) Compute EOF s of the clear-sky ε across all 9 TMI frequencies.
      - These EOFs represent the inter-frequency covariance of ε.
    - 3) All-sky (clear- and cloudy-sky w/o rain) retrieval is run with the 4 low-frequency channels (10 GHz V/H and 19 GHz V/H).
      - These low frequencies are likely insensitive to non-raining clouds.
    - 4) ε at higher frequencies (21, 37, and 85 GHz) are obtained by extrapolating the lower 4 channels exploiting the first 4 EOFs.
      - The first 4 EOFs are assumed to explain most of the variability in ε.

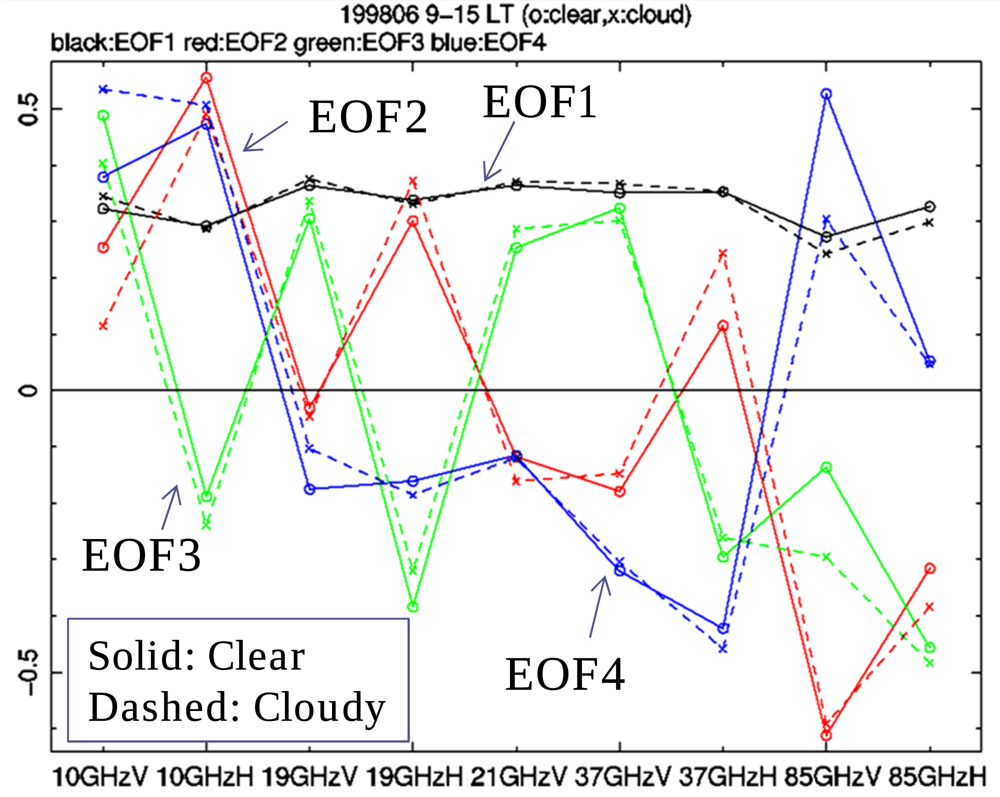
EOF properties

1998 (Jun) 9-15LT

Contribution to total variability

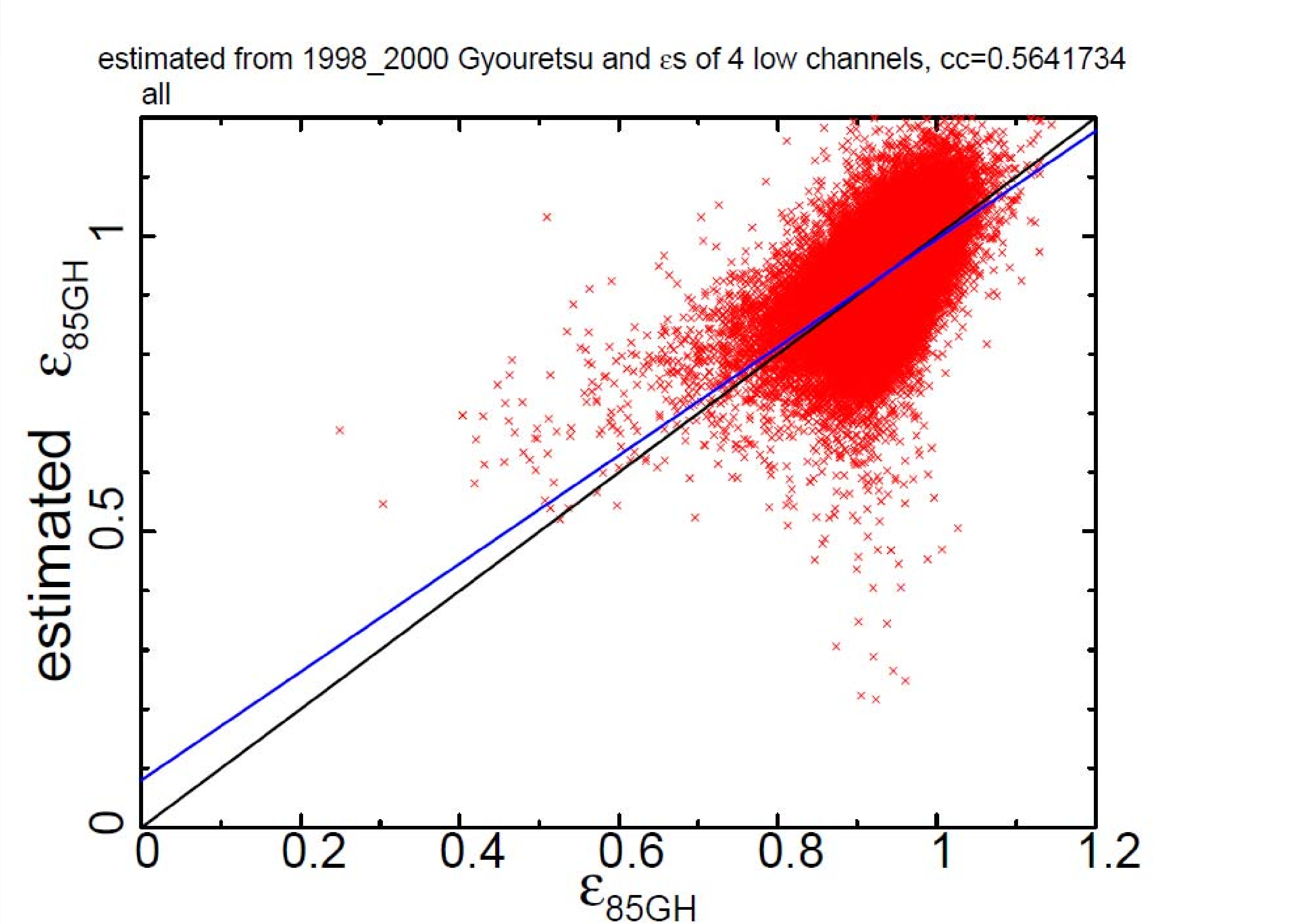


EOF components

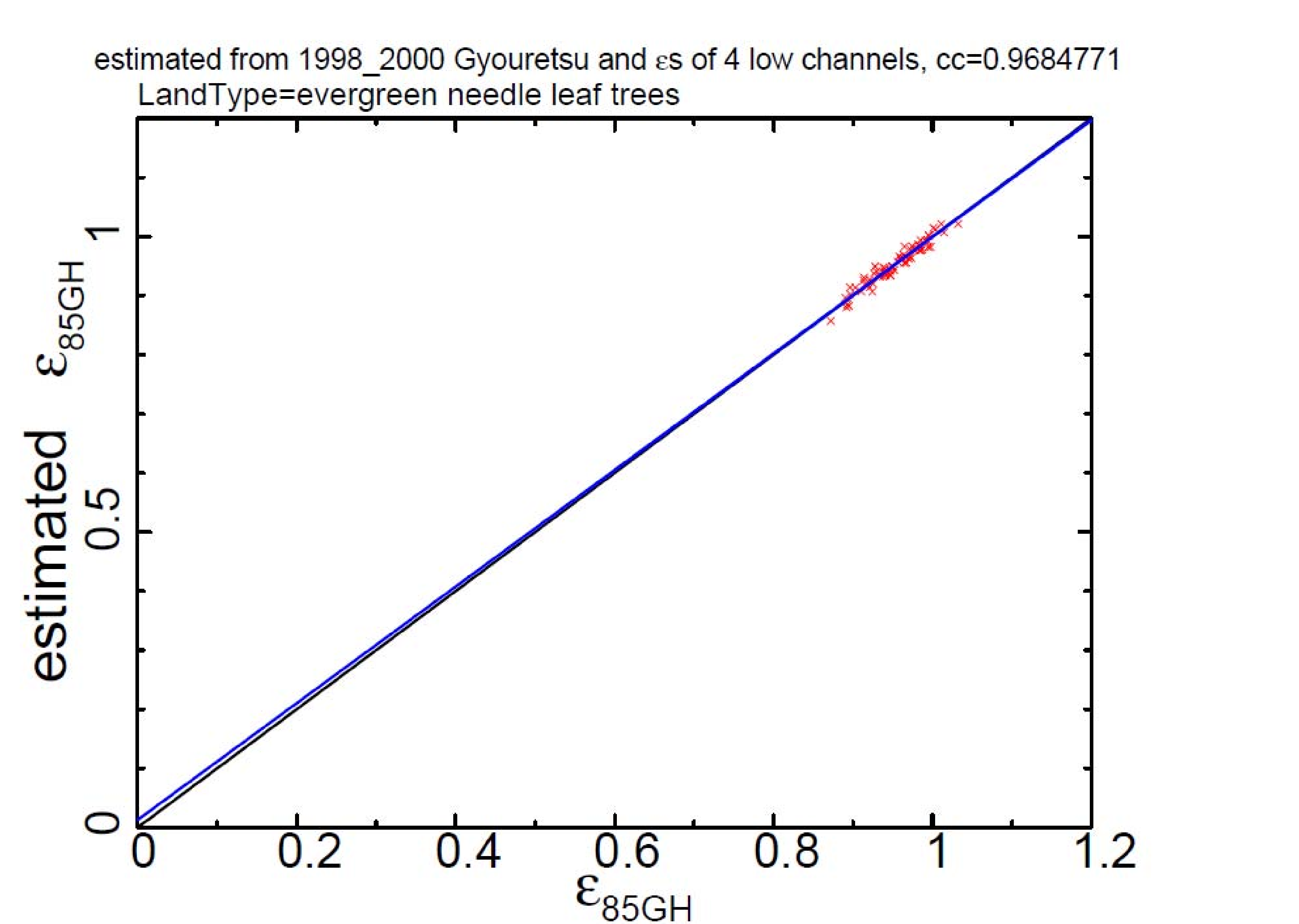


TMI channels

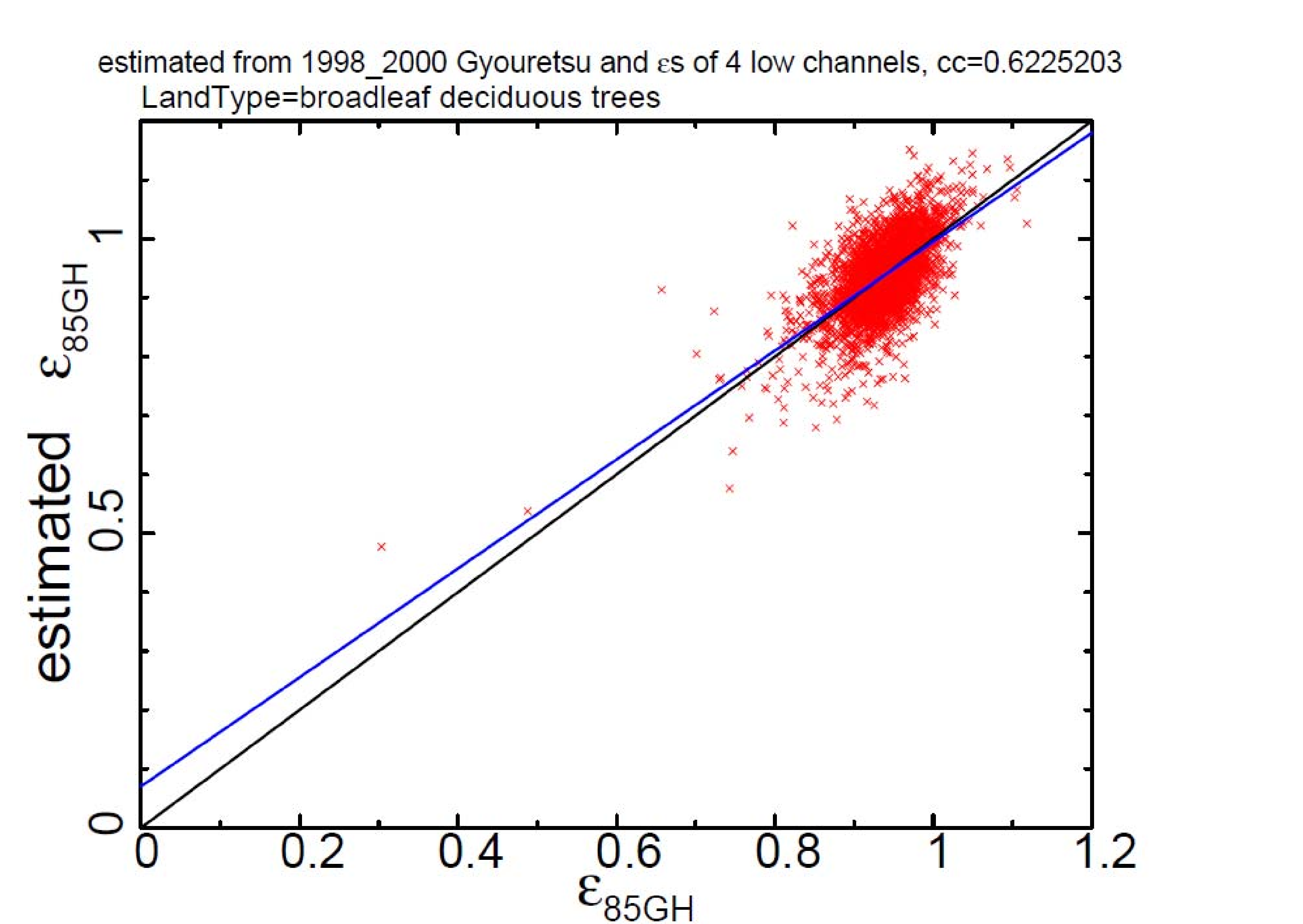
Clear-sky 85 GHz ε w or w/o EOF estimator



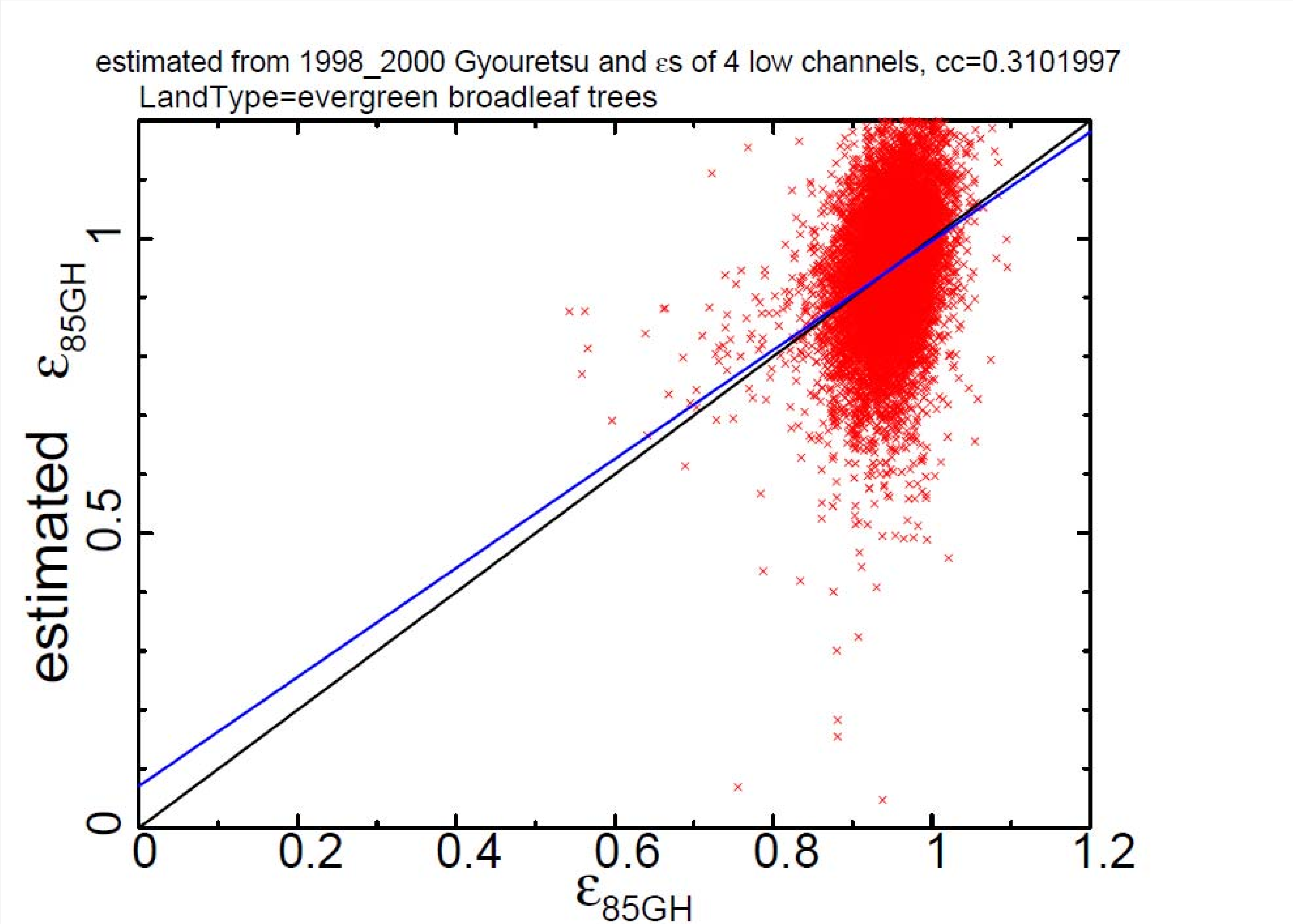
Land-type breakdown -1: evergreen needle leaf



Land-type breakdown -2: broadleaf deciduous

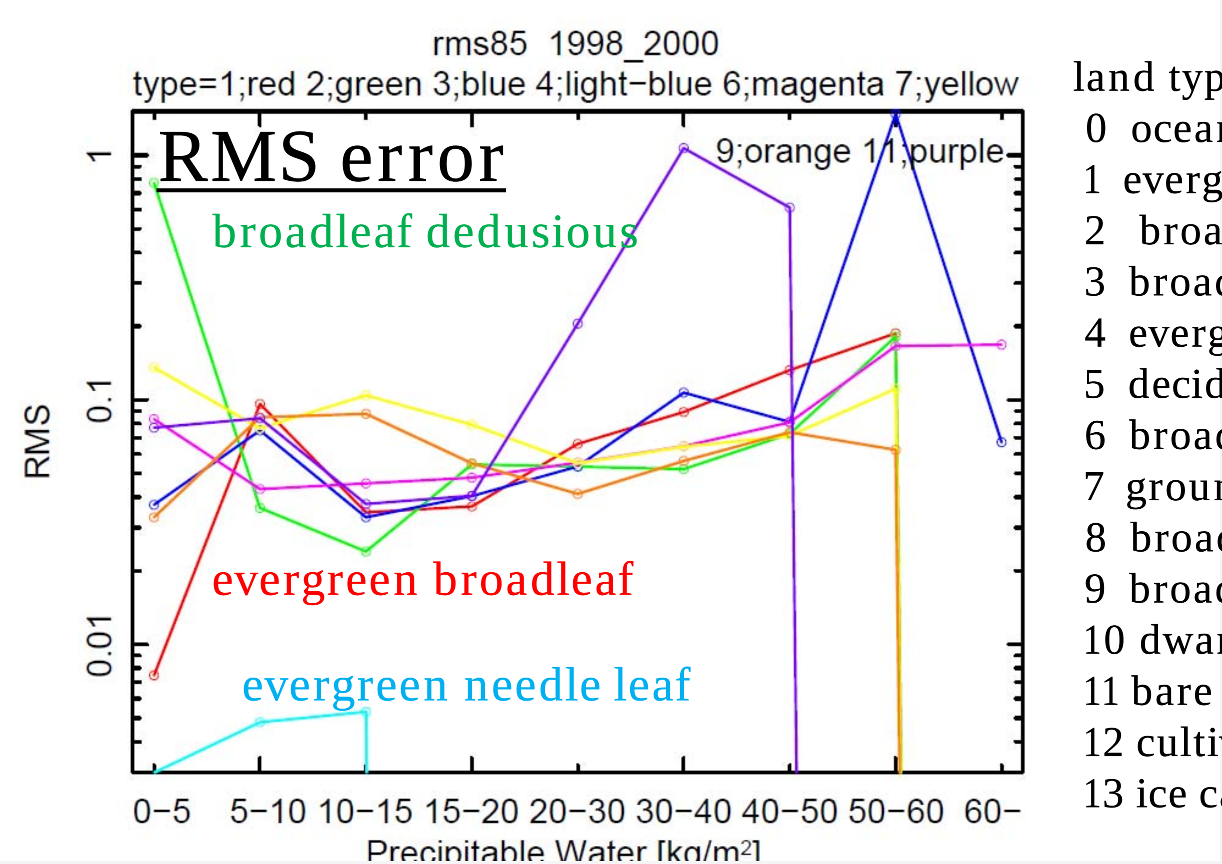


Land-type breakdown -3: evergreen broadleaf



What degrades the EOF performance?

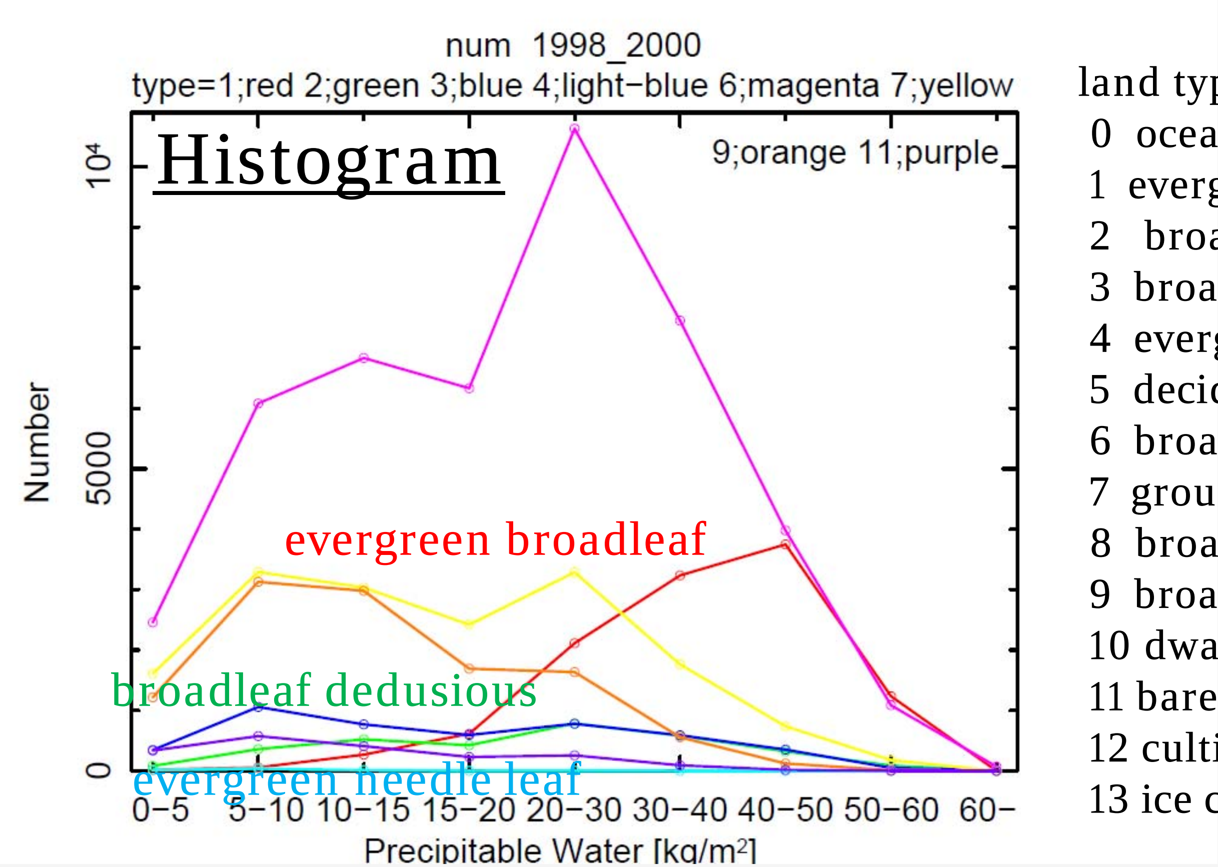
- Possible causes for the poor performance
  - Water vapor uncertainty?



land types
0 ocean
1 evergreen broadleaf trees
2 broadleaf deciduous trees
3 broadleaf and needle leaf trees
4 evergreen needle leaf trees
5 deciduous needle leaf trees
6 broadleaf trees with groundcover
7 groundcover
8 broadleaf shrubs with groundcover
9 broadleaf shrubs with bare soil
10 dwarf trees and shrubs
11 bare soil
12 cultivated land
13 ice cap and glacier

What degrades the EOF performance?

- Possible causes for the poor performance
  - Water vapor uncertainty, combined with sampling error?



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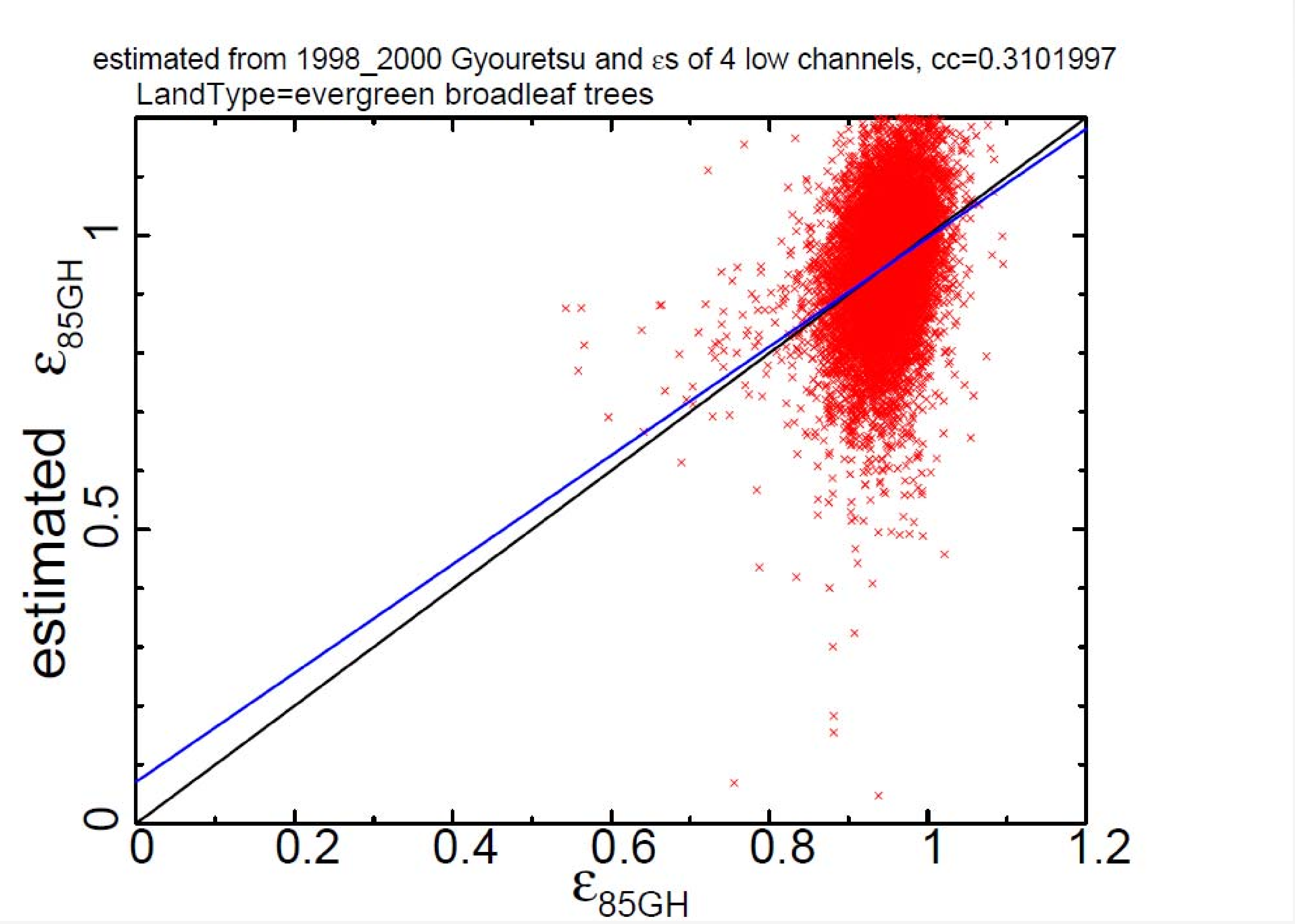
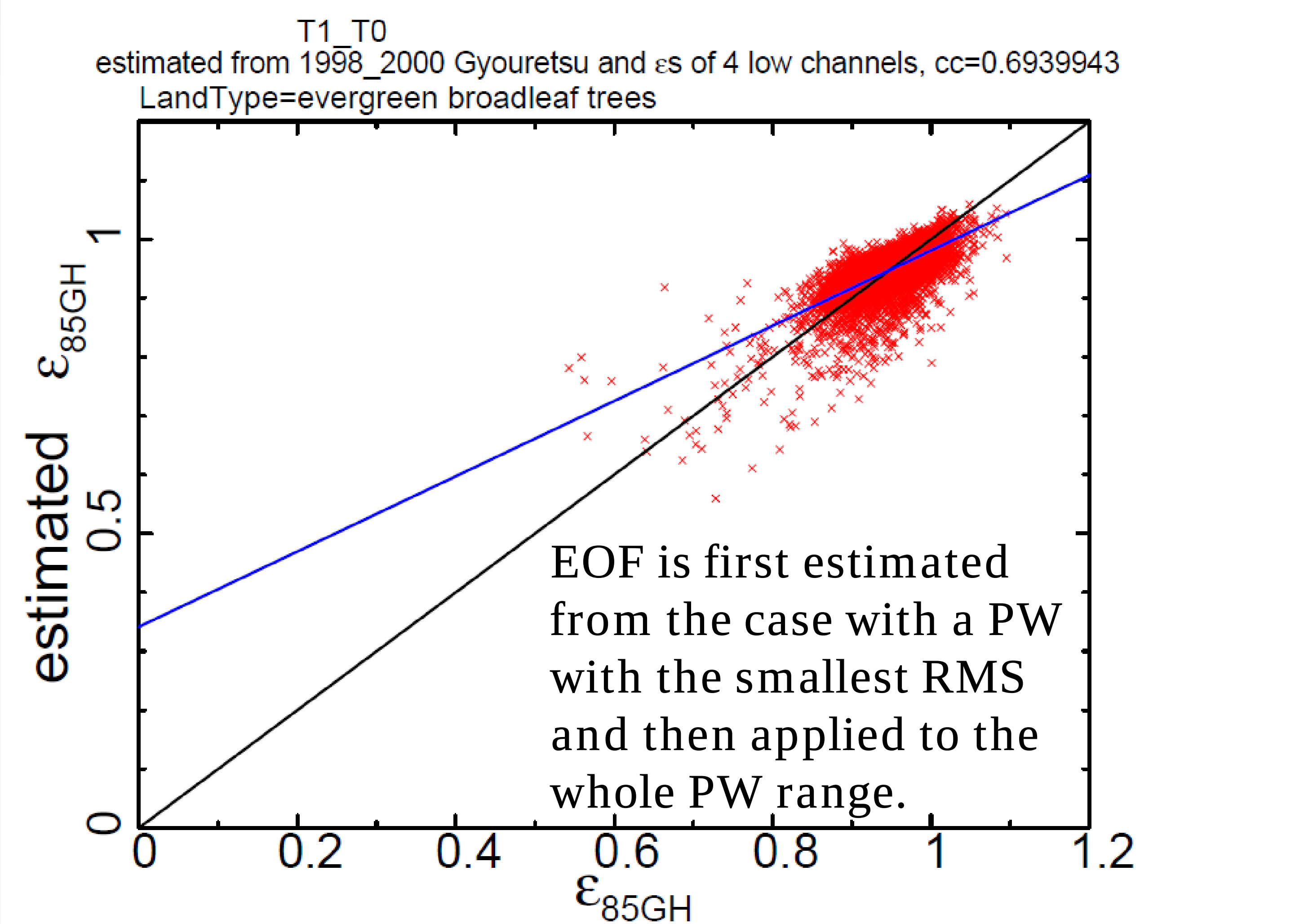
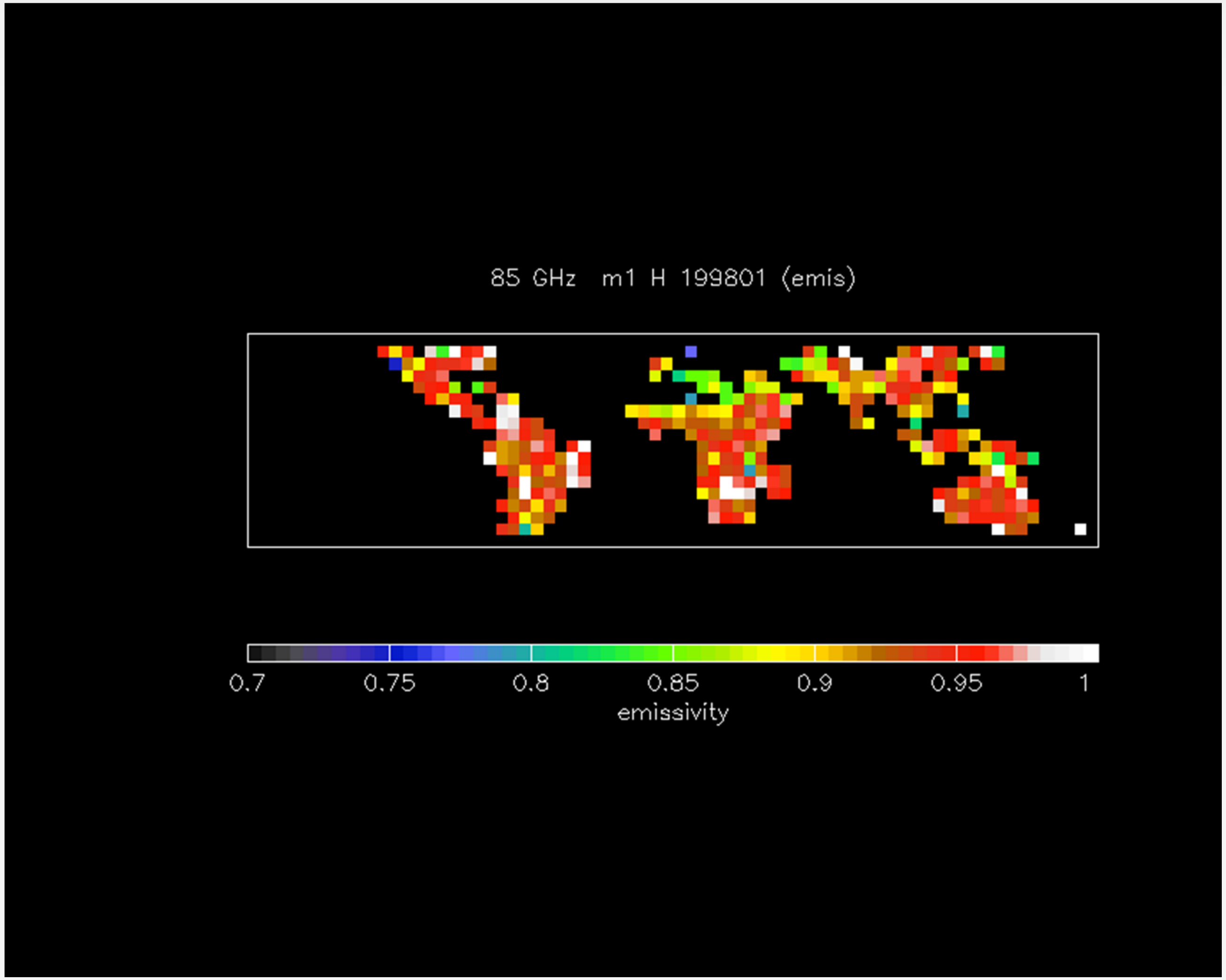


Using the EOF from the best case scenario



Global map: monthly 85 GHz H emissivity



Summary and future tasks

- Land surface emissivity algorithm
  - A before-launch algorithm is being tested with TRMM.
  - Simultaneous radar obs. provides a reliable rain screening.
  - Cloud contamination is mitigated by an EOF estimator.
    - Performance is generally improved when the EOF estimator is applied to different land surface types individually (with exceptions).
    - Will continue to work for the further refinement of the algorithm.
- Collaboration plans
  - Will retain the close collaboration with the GSMaP team.
  - Also will continue to participate in the emissivity inter-comparison project by NASA LSWG.
    - Ferraro et al. (IEEE TGRS, 2012), Tian et al. (IEEE TGRS, 2014), Norouzi et al., (AGU fall meeting, 2013), etc.