*A giant ash cloud (EPA)

Insights into Volcanic Ash Plume From Space-borne Passive Microwave Imagery

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Motivation

- **Volcanic Impact:** Volcanoes are important contributors to altering Earth's climate, affecting the radiative budget
- **Limited Current Capabilities:** Current volcano observations mostly limited to low depth sensors
- **Relatively Unstudied:** Passive microwave sensors can potentially be an additional source of data for analysis

Mt. Pinatubo 1991 (USGS)

Adapted from Eliasson et al. 2011

Background: Scattering vs Emission

- Mie Scattering typical of ice particles in atmosphere
- Absorption/emission from liquid water as it absorbs shortwave radiation from the sun and re-emits as longwave radiation

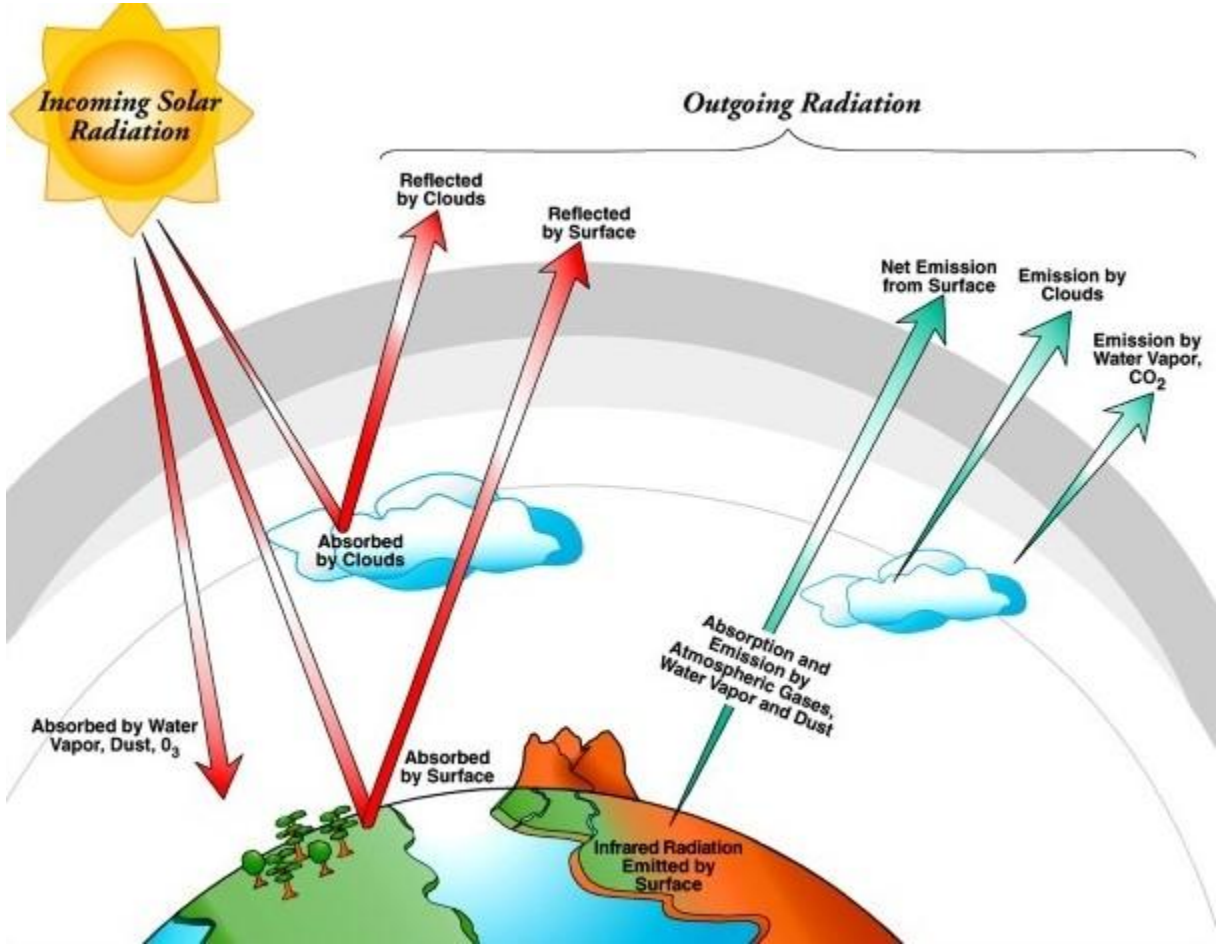
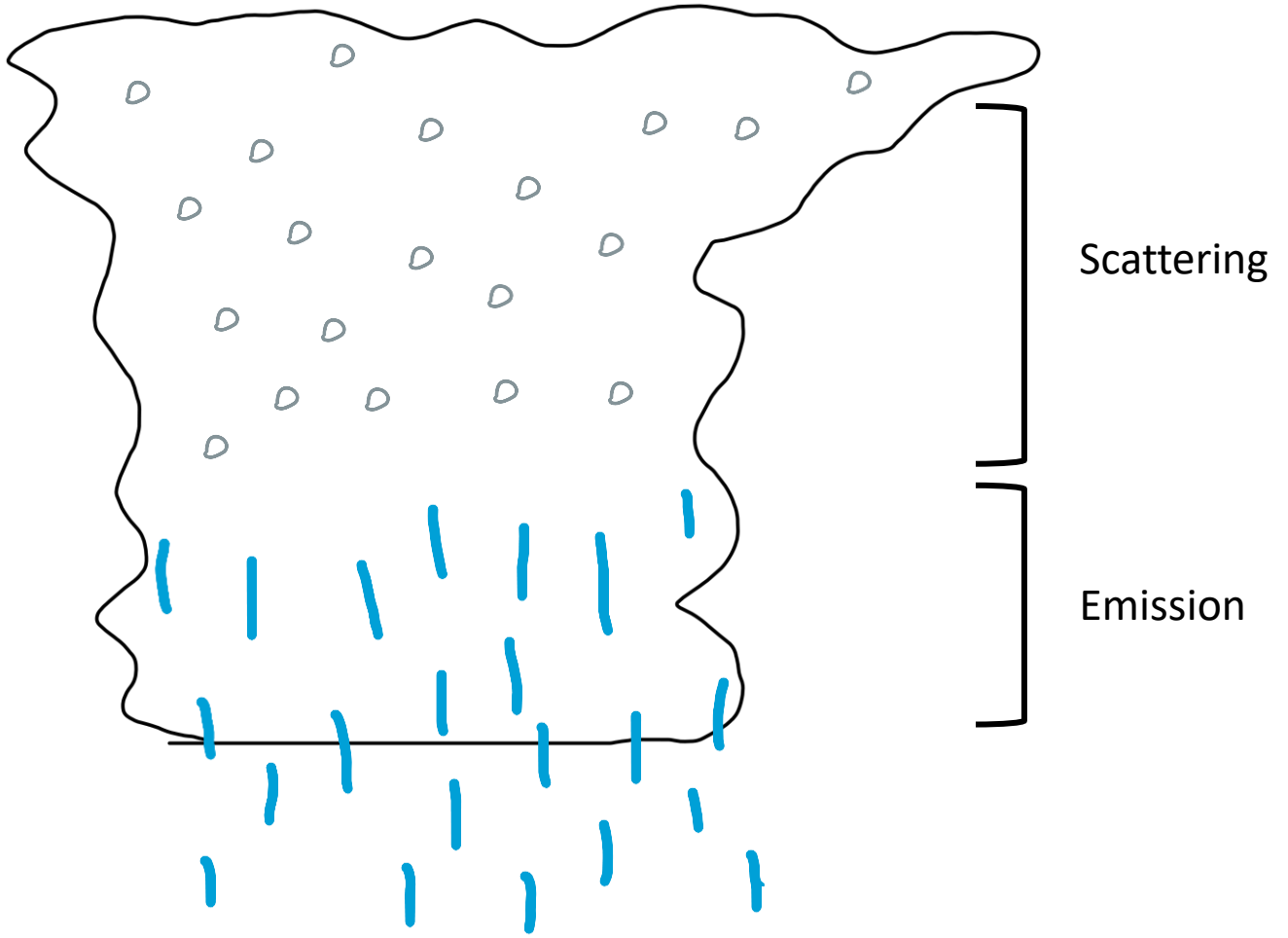


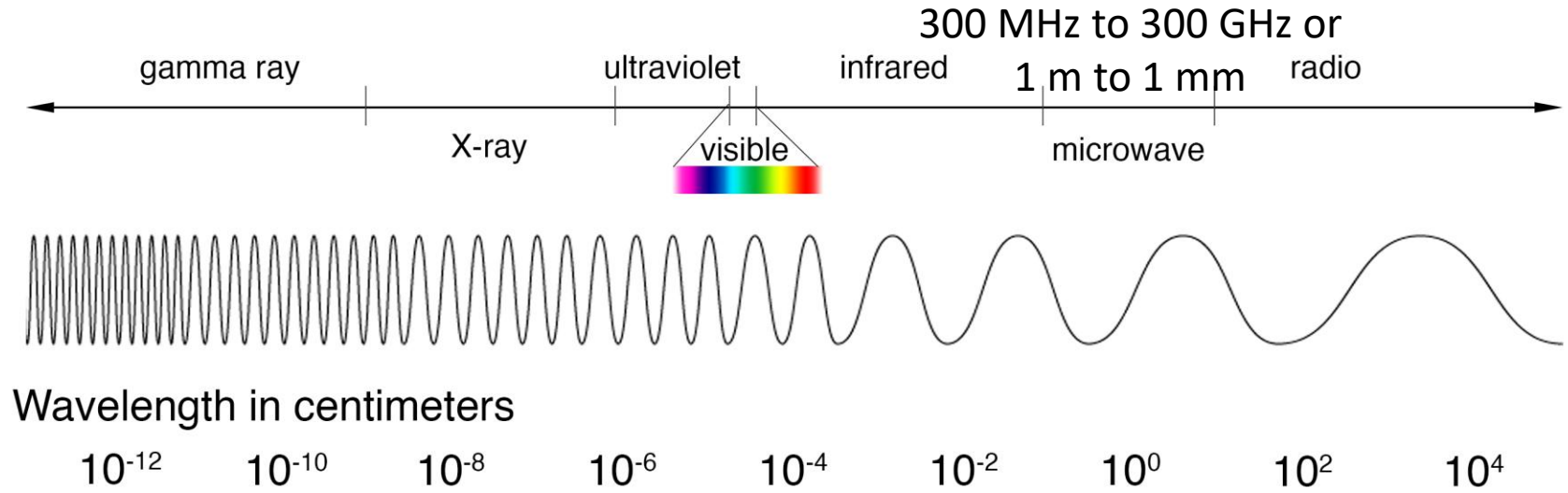
Image via energy.gov

Relevance in Meteorology

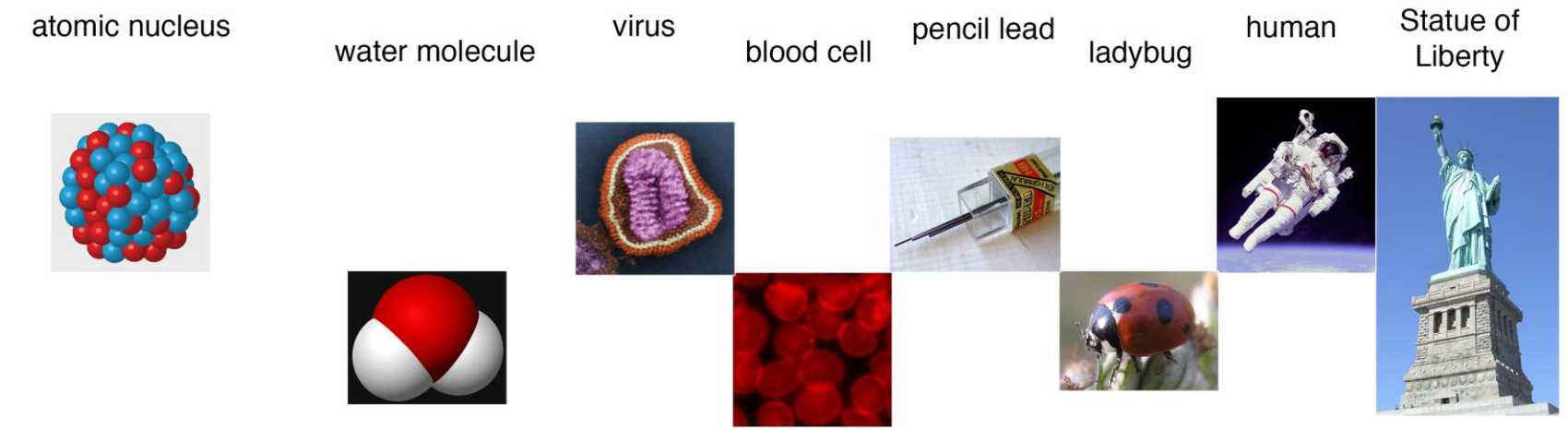
- Deep convective clouds have both scattering and emission, each from different parts of the cloud structure
- Only relevant for microwave radiation



Background: Passive Microwave Satellites

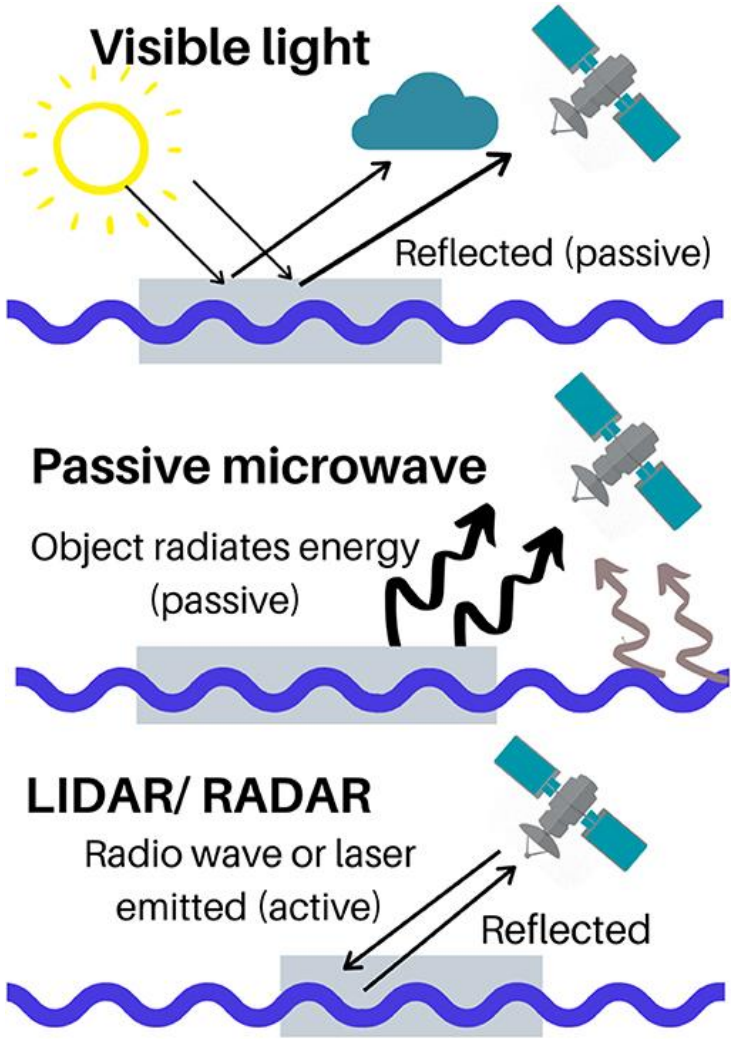


Similar in size to...



Background: Passive Microwave Satellites

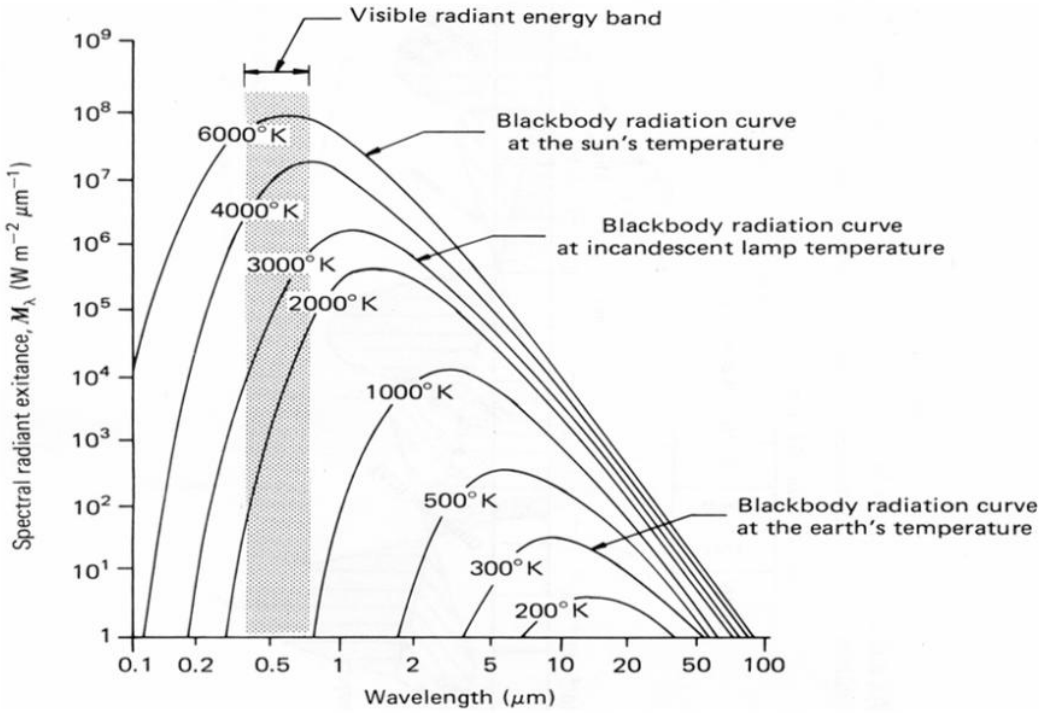
- Active vs. Passive
  - Active satellites emit some signal, then measures the received power of the signal
  - Passive satellites retrieve the radiation emitted from the particles themselves
- Satellites used in this study are passive



What is a brightness temperature?

- $B_\lambda(T) = \dfrac{2hc^2}{\lambda^5\left(e^{\frac{hc}{k_B\lambda T}}-1\right)}$ = total intensity of emitted radiation
- TB = $B_\lambda^{-1}(I_\lambda)$

Given an intensity of radiation emitted by a blackbody, we can find its temperature

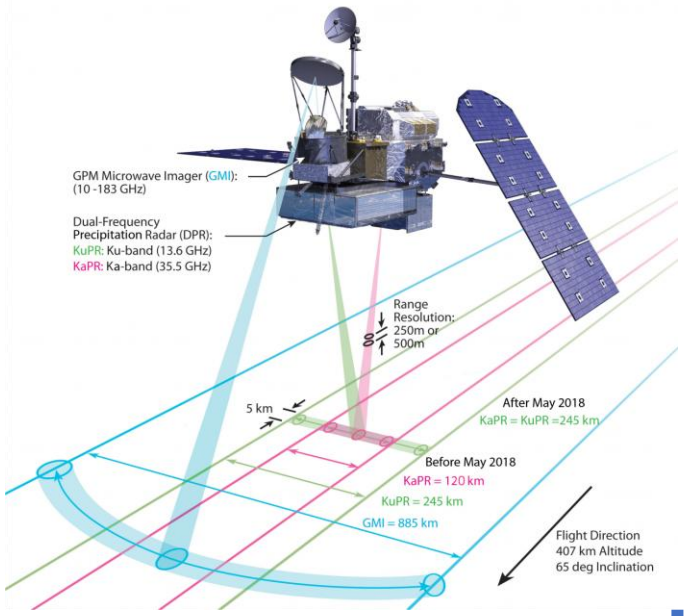


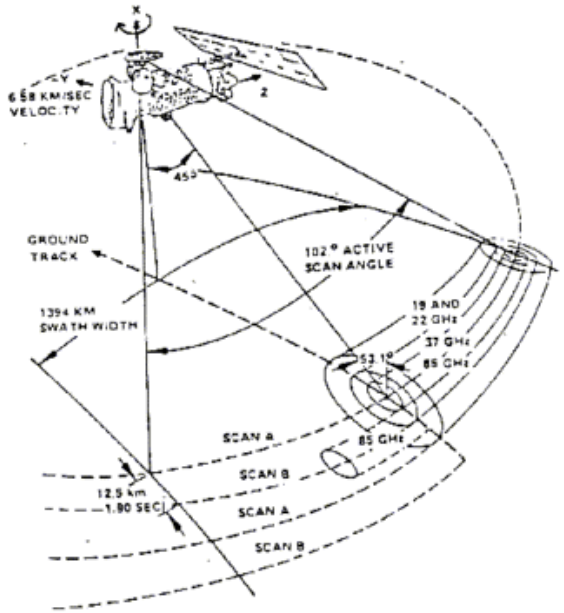
Scattering Induced TB Depression

$$\Delta TB = TB_{obs} - TB_{sim}$$

- Brightness temperatures (TB) can simply be described as a combination of emission/scattering of different hydrometeors in the atmosphere
- TB_{sim} is cloud free simulation
- ΔTB can help isolate the signal of hydrometeors
- Low microwave frequencies are better for emission, while high frequencies are better for scattering

TB Observed



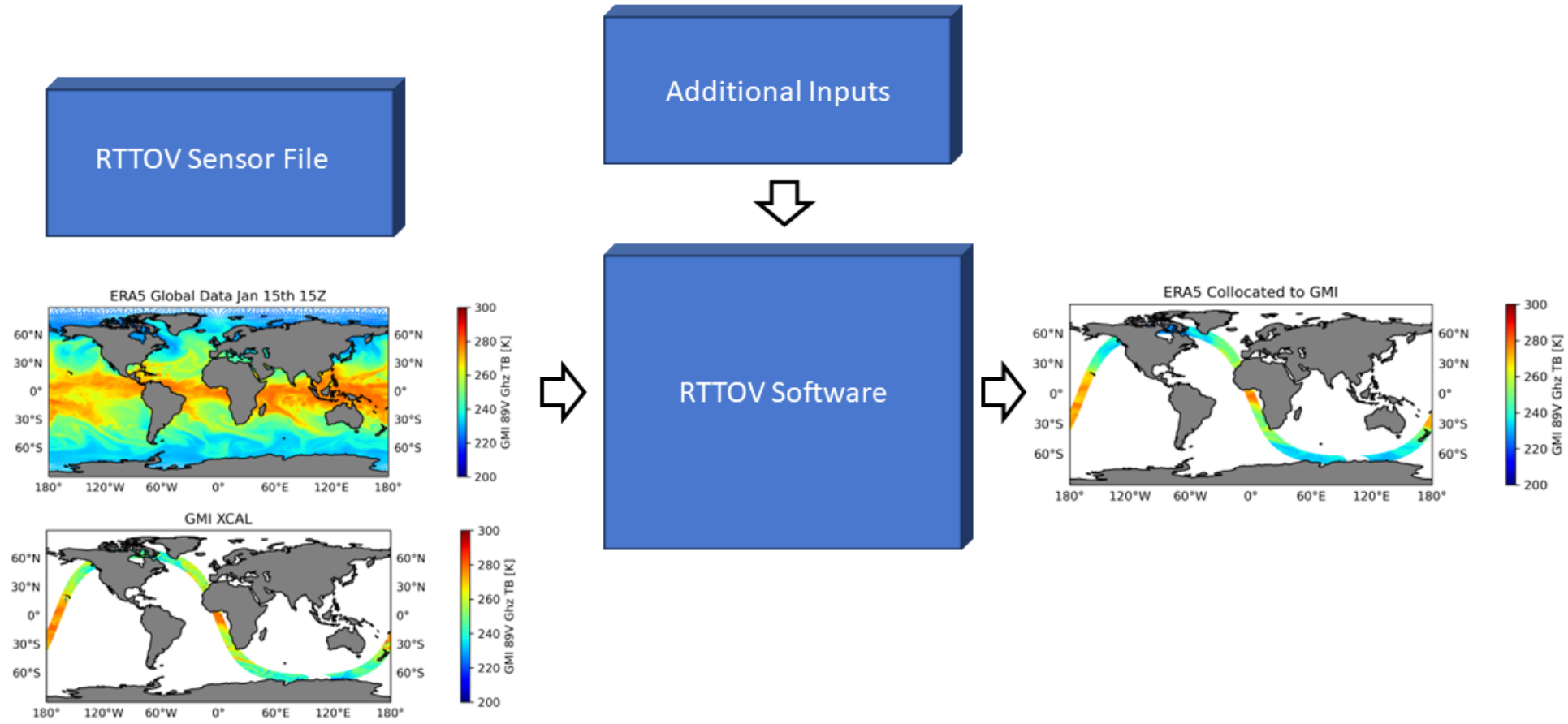


Collocate Eruption

Satellite	Channel	Frequency (GHz)	Polarization	Swath
SSMIS	8	150	H	S3
	9	183±1	H	S3
	10	183±3	H	S3
	11	183±7	H	S3
	12	19	H	S1
	13	19	V	S1
	14	22	V	S1
	15	37	H	S2
	16	37	V	S2
	17	91	V	S4
	18	91	H	S4
GMI	1	10.6	V	S1
	2	10.6	H	S1
	3	18.7	V	S1
	4	18.7	H	S1
	5	23	V	S1
	6	37	V	S1
	7	37	H	S1
	8	89	V	S1
	9	89	H	S1
	10	166	V	S2
	11	166	H	S2
	12	183±3	V	S2
	13	183±7	V	S2

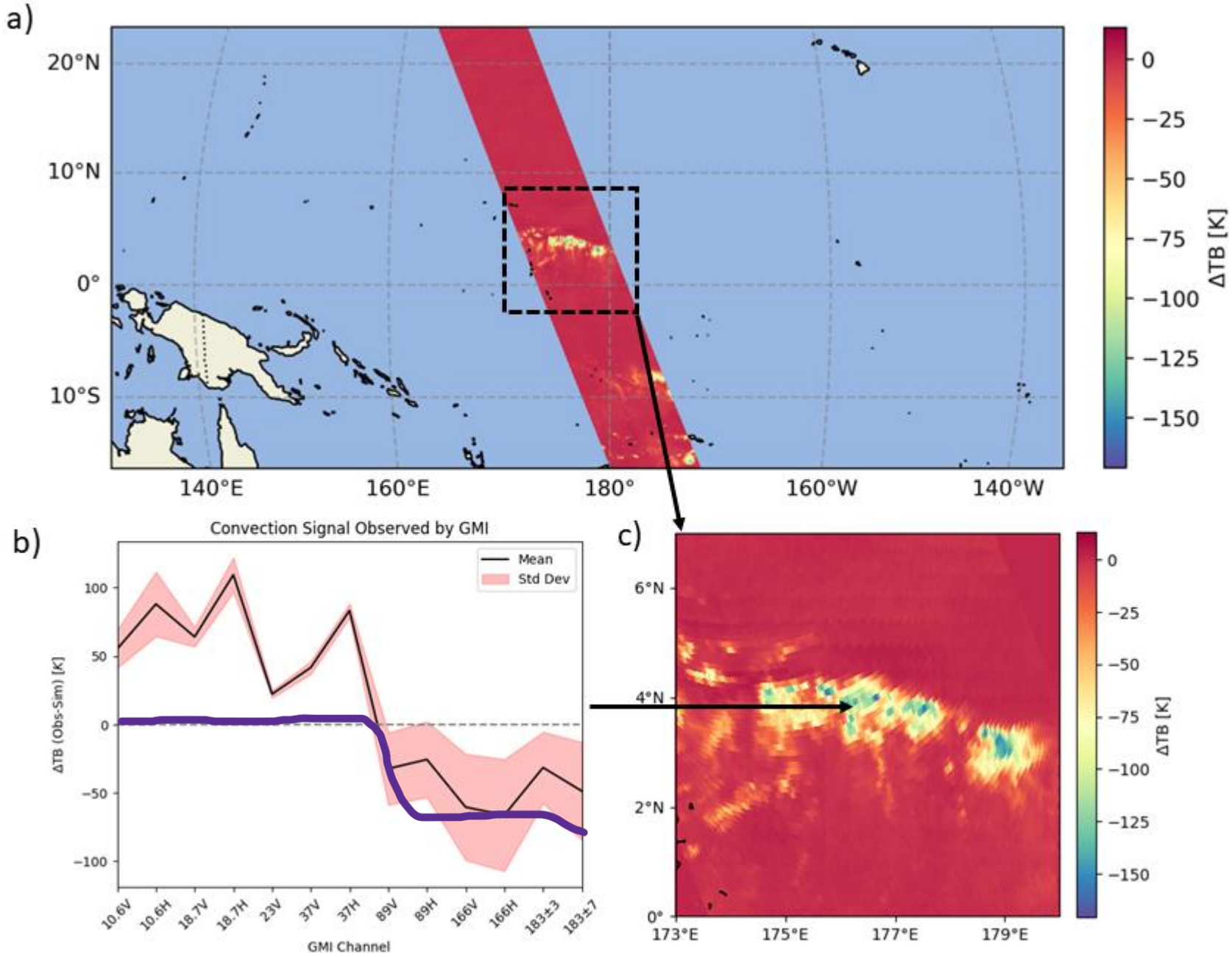
*Infrared & Visible data from Data Integration and Analysis System (DIAS) by Japan Agency for Marine-Earth Science and Technology (JAMSTEC) Himawari-8

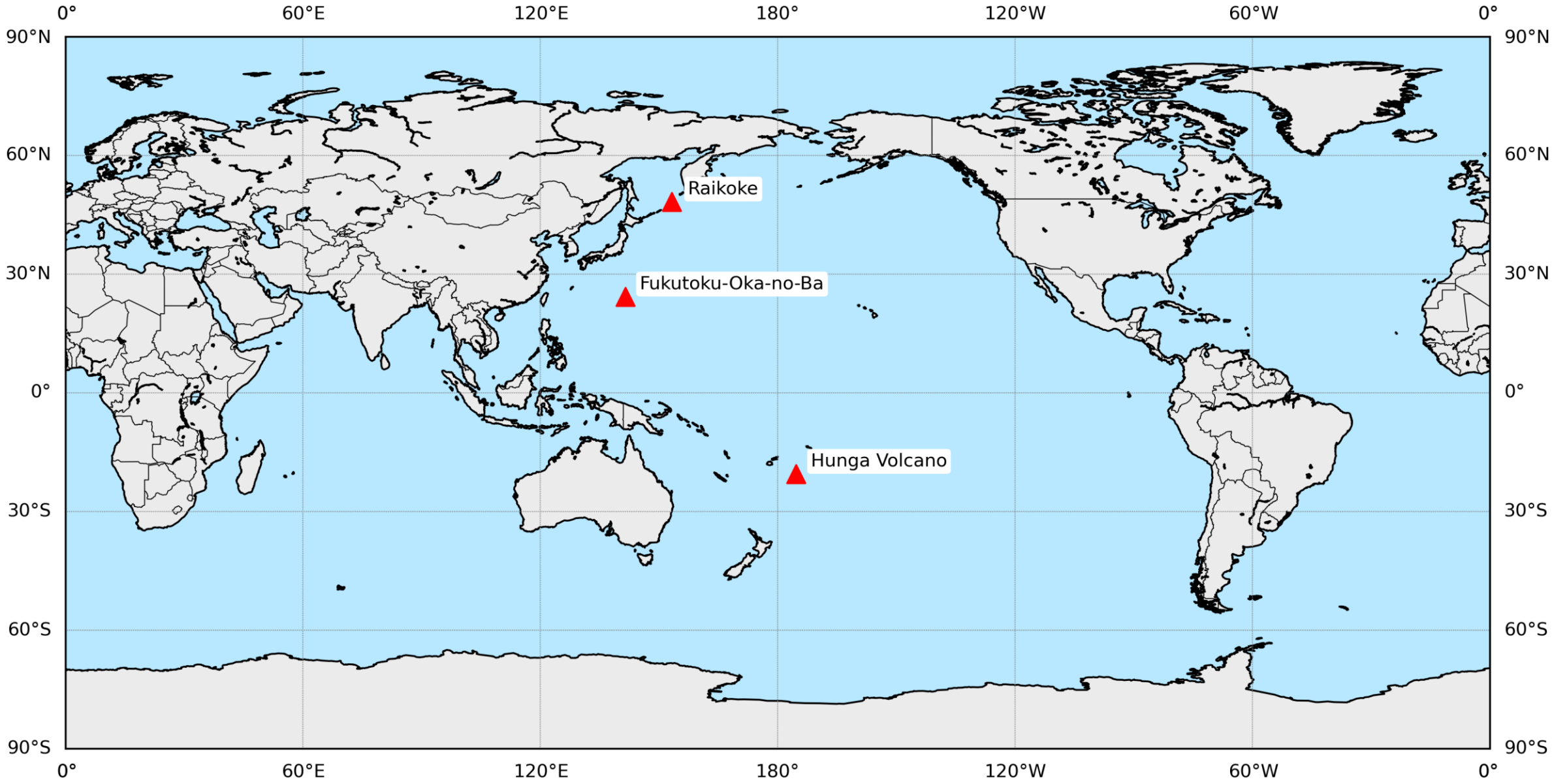
TB Simulated Process



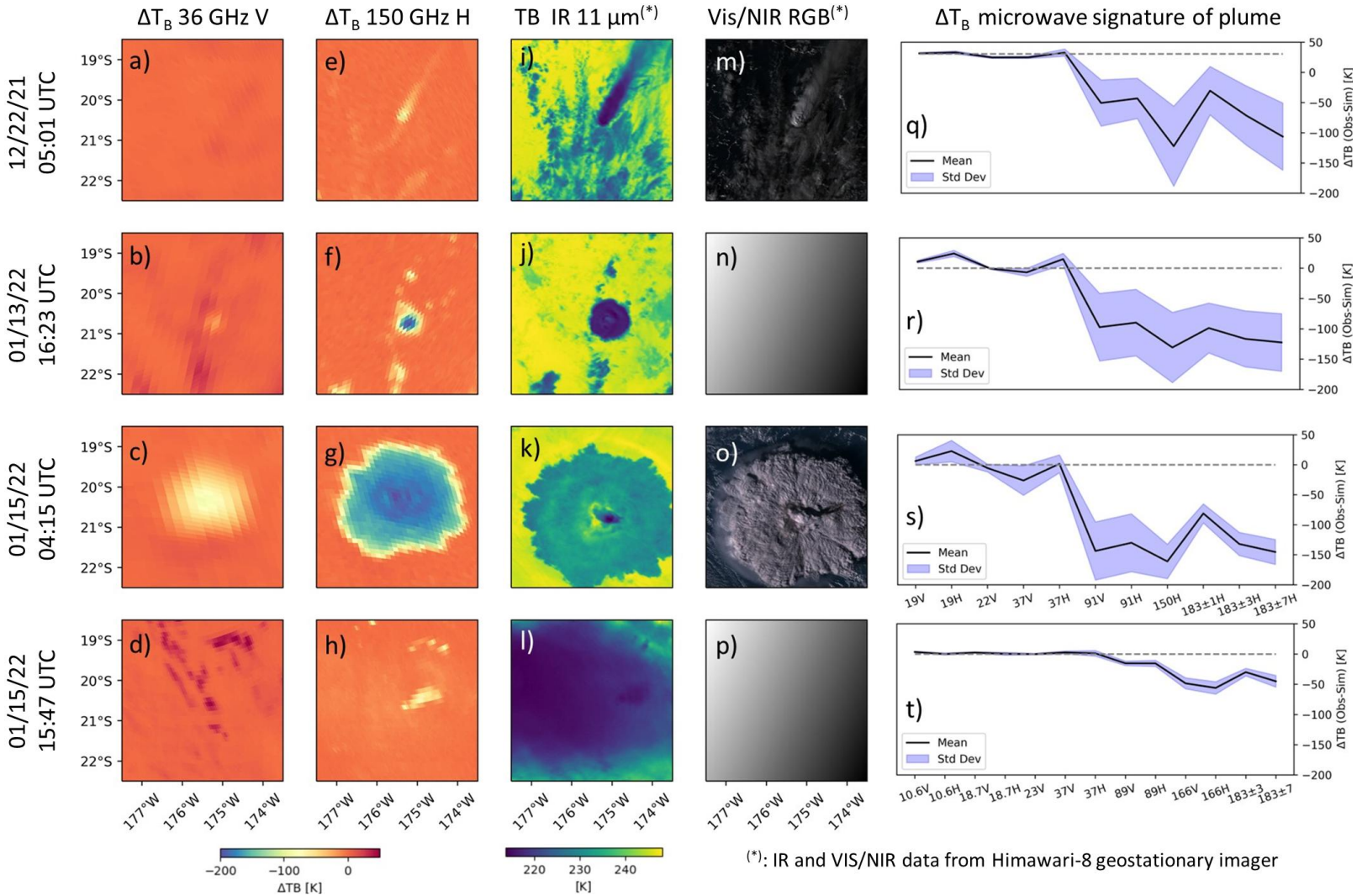
Convective Example

What would a volcanic signal look like?



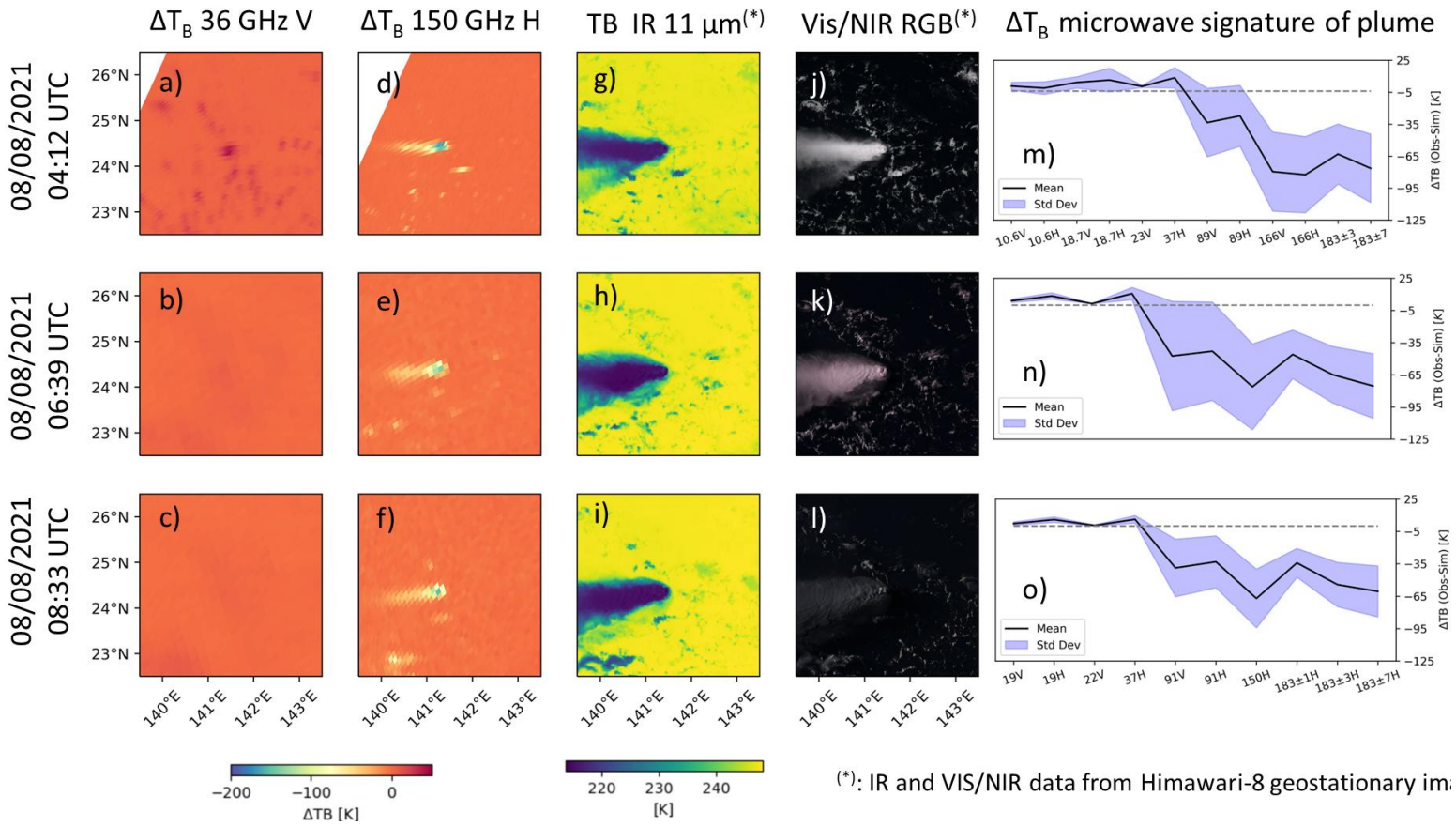

0°
60°E
120°E
180°
120°W
60°W
0°
90°N
60°N
30°N
0°
30°S
60°S
90°S
Raikoke
Fukutoku-Oka-no-Ba
Hunga Volcano

Hunga Volcano



(*): IR and VIS/NIR data from Himawari-8 geostationary imager

Fukutoku



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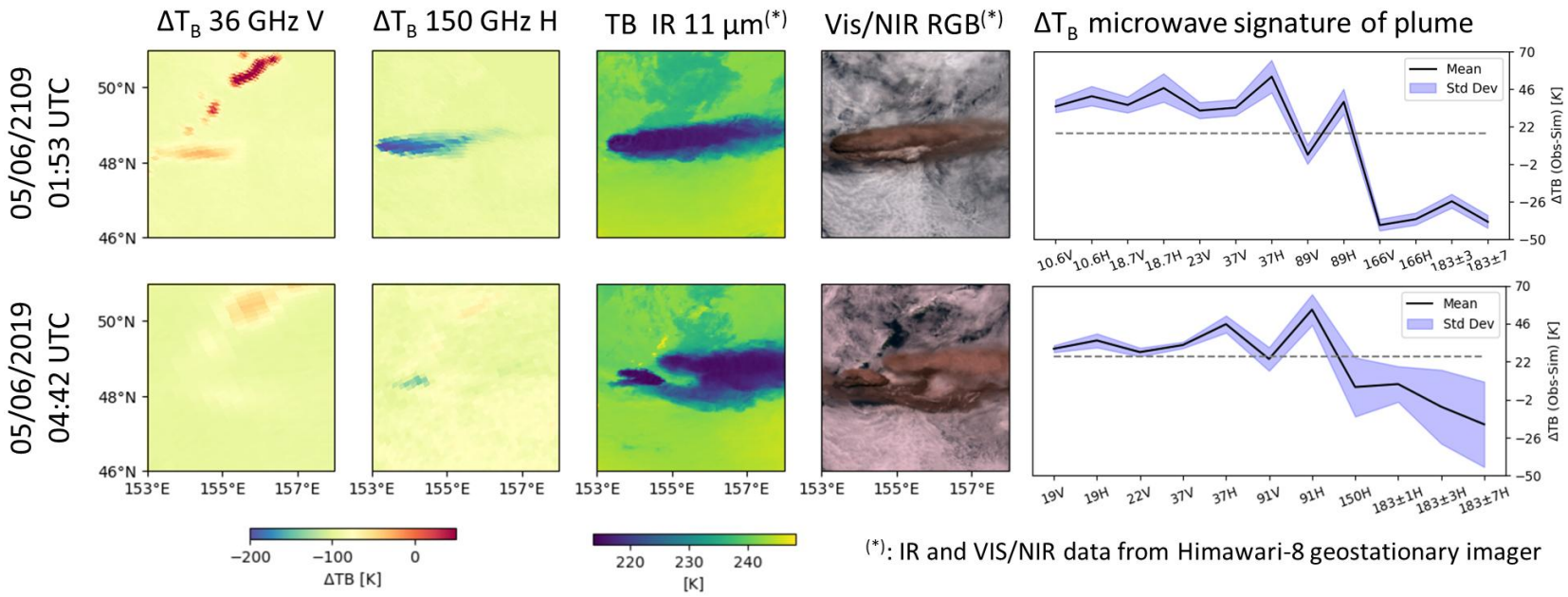
Raikoke



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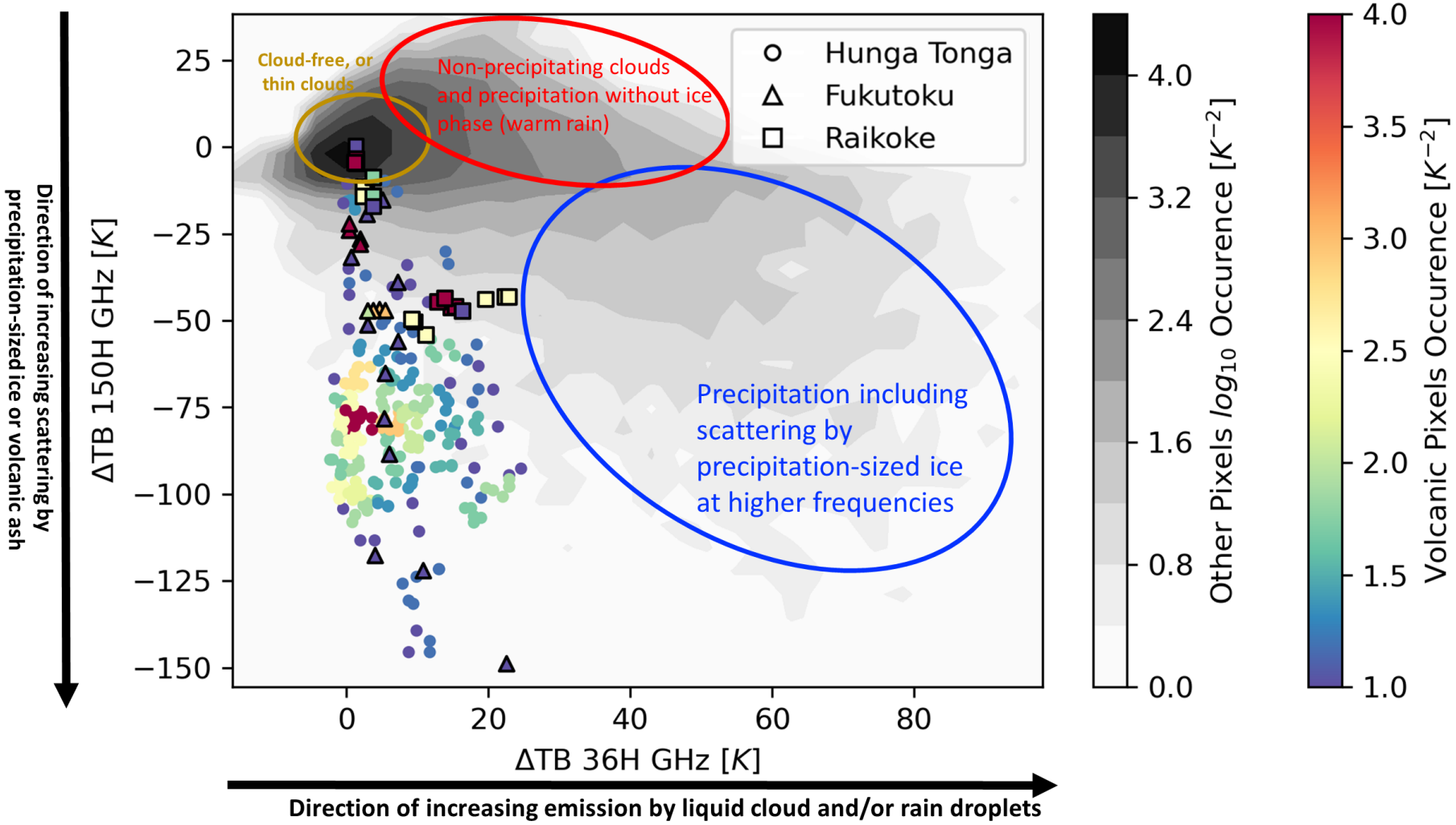
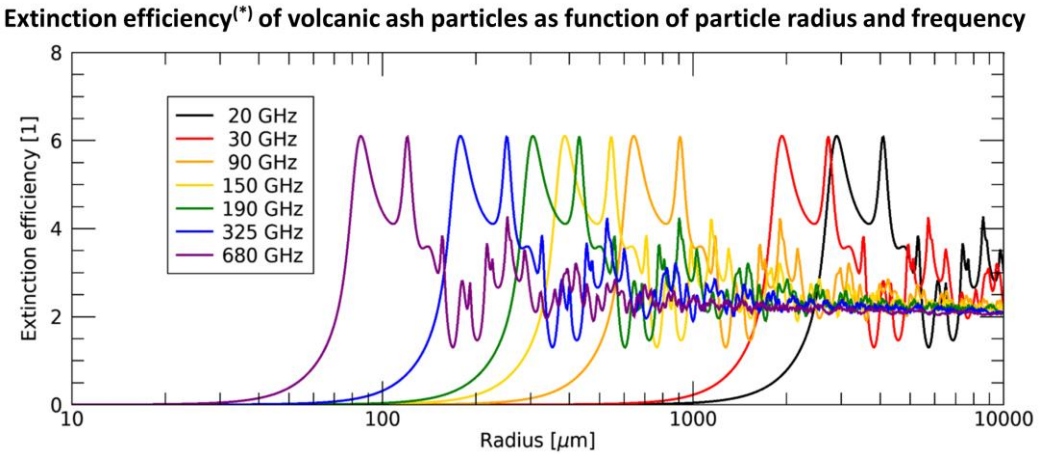
Volcanic Pixel Distributions



So Why Passive Microwaves?

1. Can provide full lifetime snapshots of eruptions anywhere on the globe
2. Able to differentiate between pixels of volcanic plumes and pixels of other hydrometeors in the atmosphere
3. Deeper insights into volcanic plume compared to shallow-retrieving sensors
4. Future mission applications
5. Difficulty: resolution of ~20km, small features might go undetected



Future Work

- **Physical Understanding**
  - Set up retrieval algorithms for ash occurrence based on the observed signals.
  - Set up generalizable algorithmic approach
- **Statistical Applications**
  - Bayesian/AI approach
- **Modeling Limits**
  - Are There cases where this methodology will fail?

Questions?