Thermal footprints preceding volcanic eruptions

2014 Ontake phreatic eruption
>60 fatalities
[credit: BBC news]

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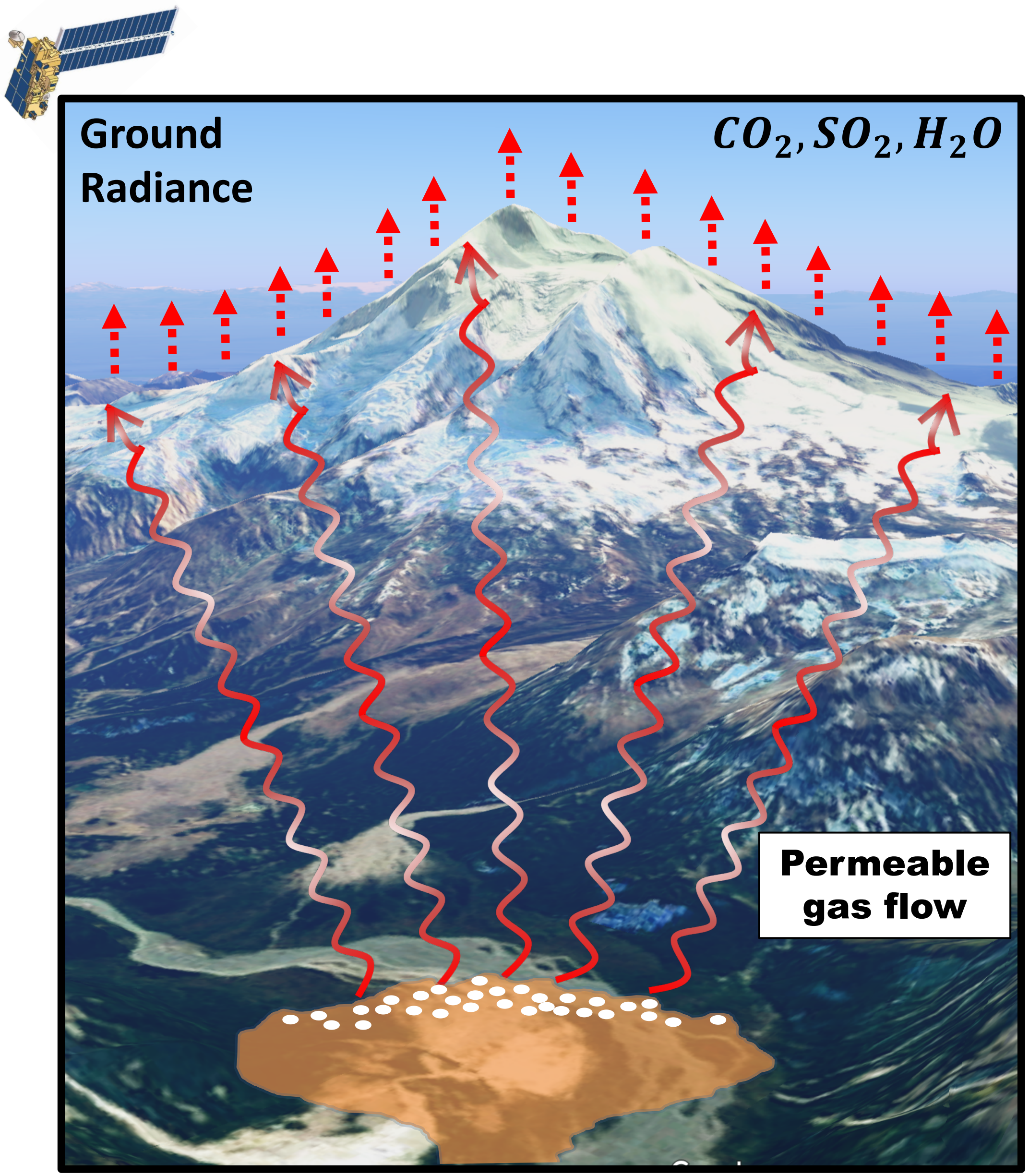
HYPOTHESIS: radiance of volcanic edifices reflects subsurface processes



[credit: Google Earth, NASA]

- **Degassing magma reservoir**
  [e.g., Stix and de Moor, 2018]
- **Diffuse outgassing**
- **Subsurface changes probably affect diffuse outgassing**
- **How to monitor diffuse outgassing?**

Difficult from the ground …
[e.g., Chiodini et al., 1998; Hernández et al., 2001; Schwandner et al., 2004]

… even more difficult from space

⇩

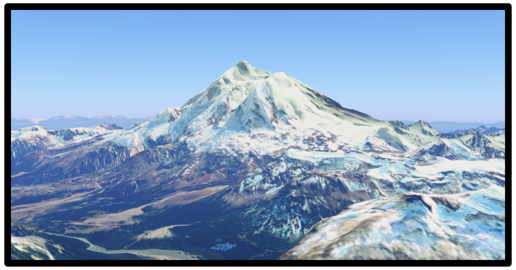
Diffuse heat output
[e.g., Epiard et al., 2017; Melián et al., 2010]

RESEARCH QUESTION

1. Do diffuse heat emissions vary significantly before eruptions? If yes, why?
2. Can we forecast eruptions from space?

- Method
- Results
- Discussion

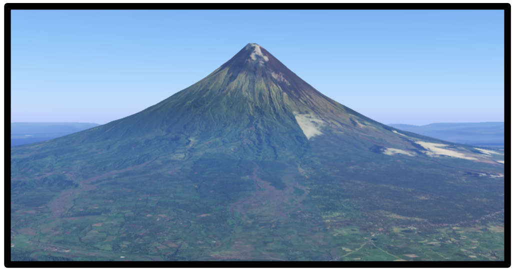
Redoubt (USA) / 2009



Ontake (Japan) / 2007, 2014

Ruapehu (New Zealand)
2006, 2007

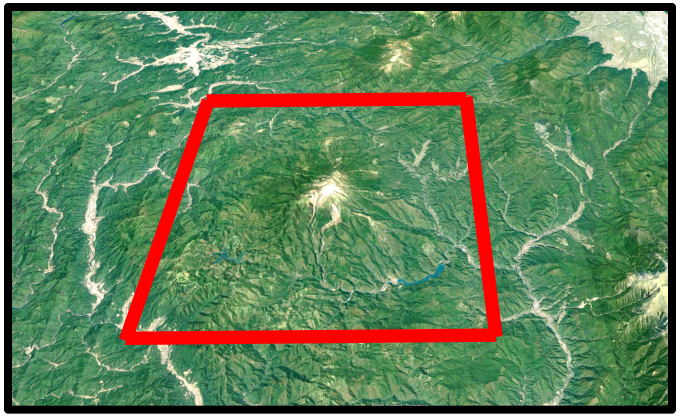
Mayon (Philippines)
2003, 2004, 2005, 2006,
2008, 2009, 2013, 2014, 2018



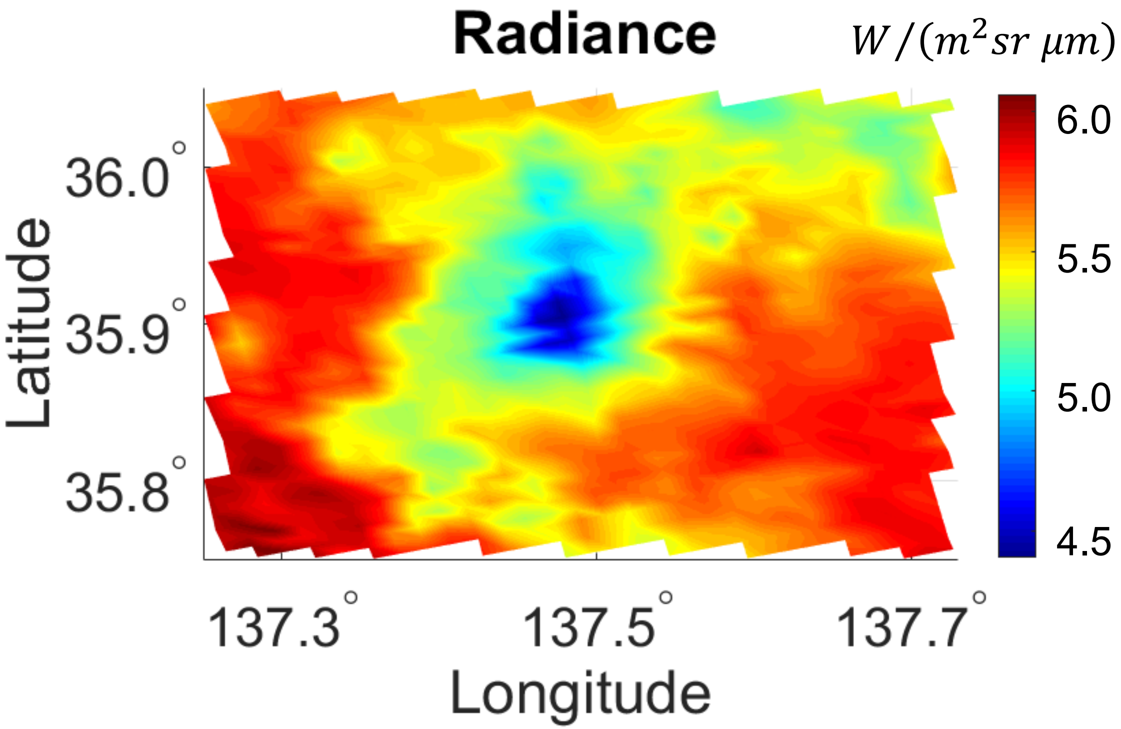
Median-of-median algorithm

1. Radiance data (Level 1B MODIS Terra/Aqua; Band 31: 10.780-11.280 μm; ~1x1 km).

2. MEDIAN radiance of the "coldest" pixels (L_c^*)



$\sim 1,000\ \mathrm{km}^2$



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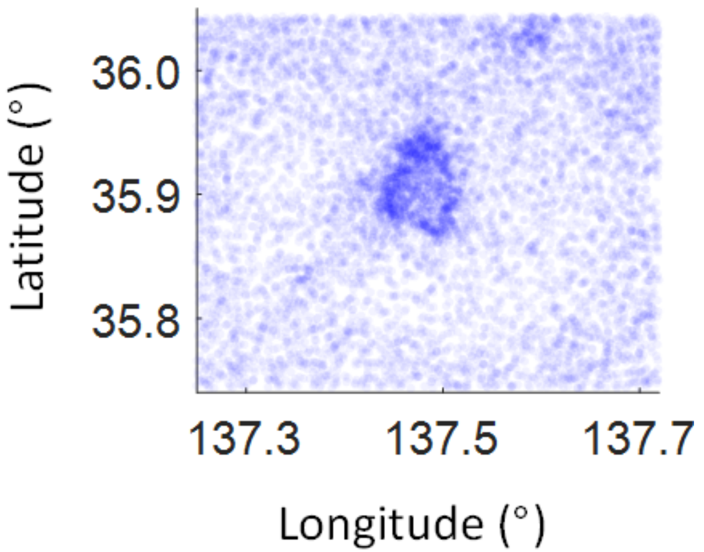

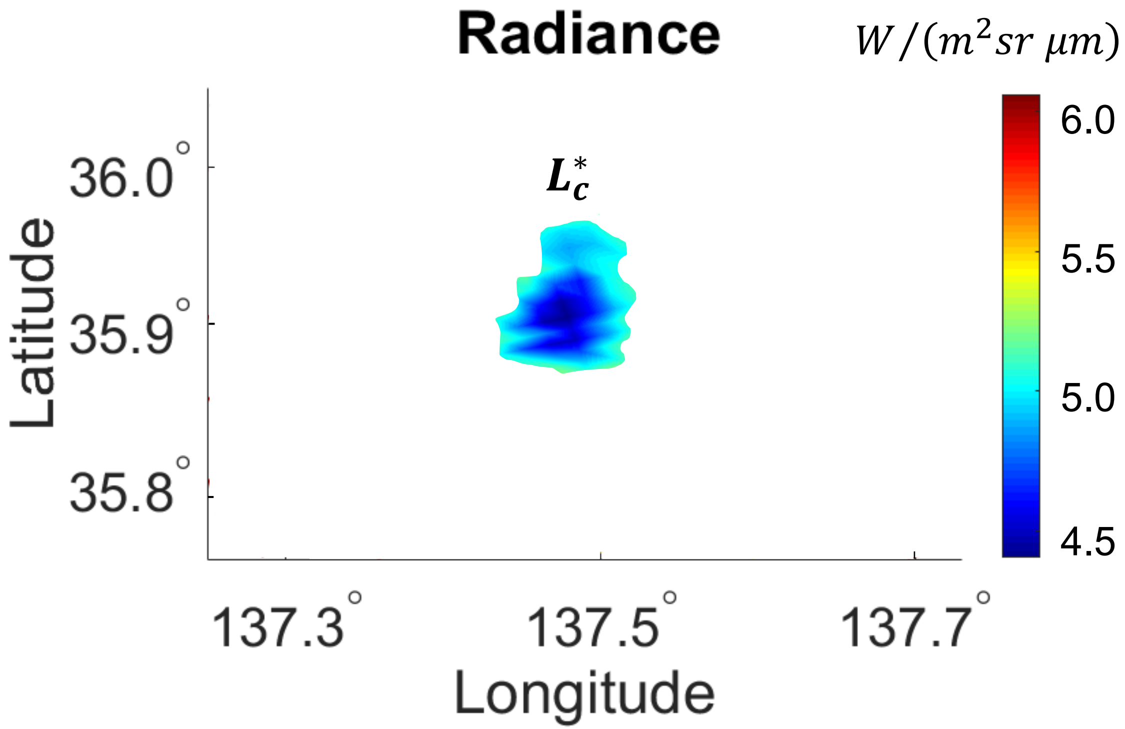

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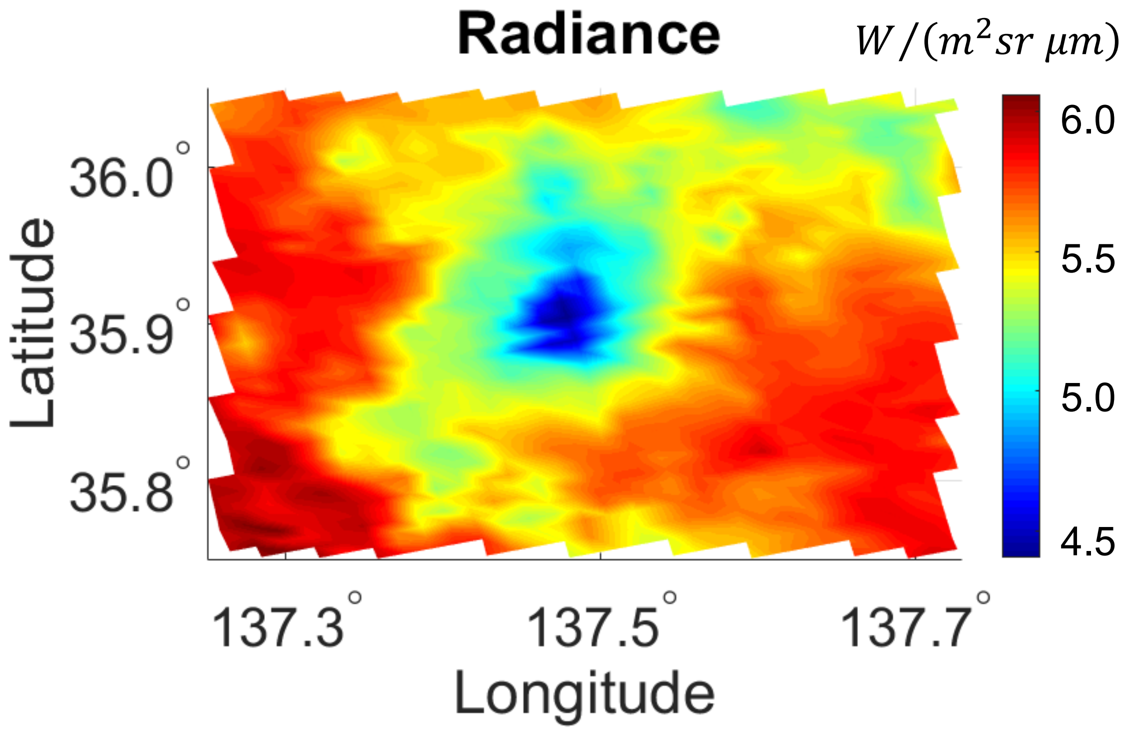
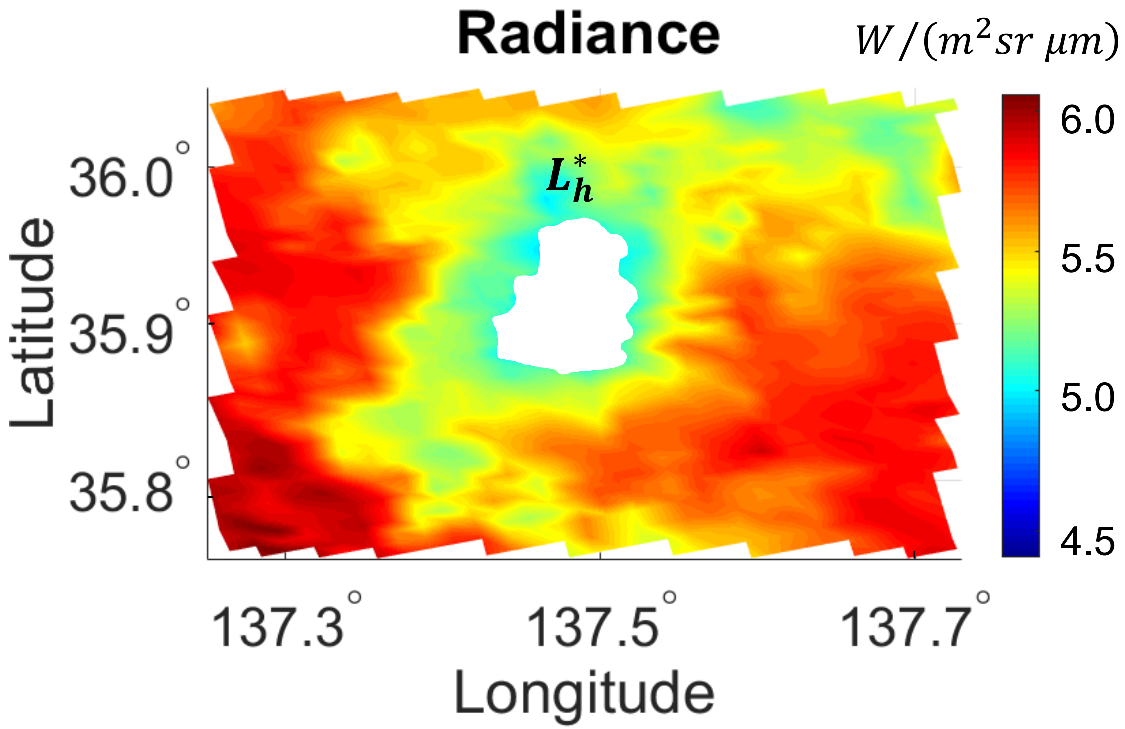


METHOD RESULTS DISCUSSION

Median-of-median algorithm

1. Radiance data (Level 1B MODIS Terra/Aqua; Band 31: 10.780-11.280 μm; ~1x1 km).

2. MEDIAN radiance of the "coldest" pixels (L_c^*) and "hottest" pixels (L_h^*).



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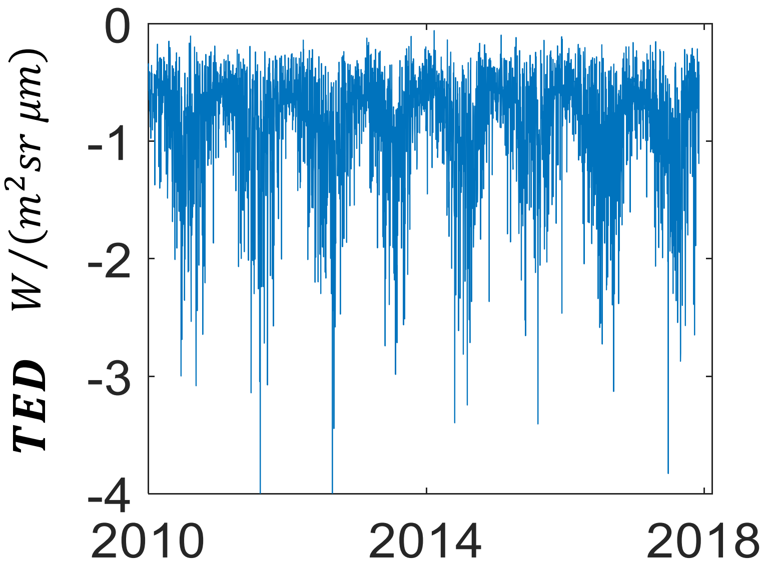
3. DIFFERENCE between median radiance of the "coldest" and "hottest" pixels ($L_c^* - L_h^*$).
4. DAILY MEDIAN of the difference [Thermal Emission Difference: TED].



$$L_{c,1}^*, \ldots L_{c,n}^* \qquad L_{h,1}^*, \ldots L_{h,n}^*$$

$$L_{c,1}^* - L_{h,1}^*$$
$$\vdots$$
$$L_{c,n}^* - L_{h,n}^*$$

$$TED = L_c - L_h$$

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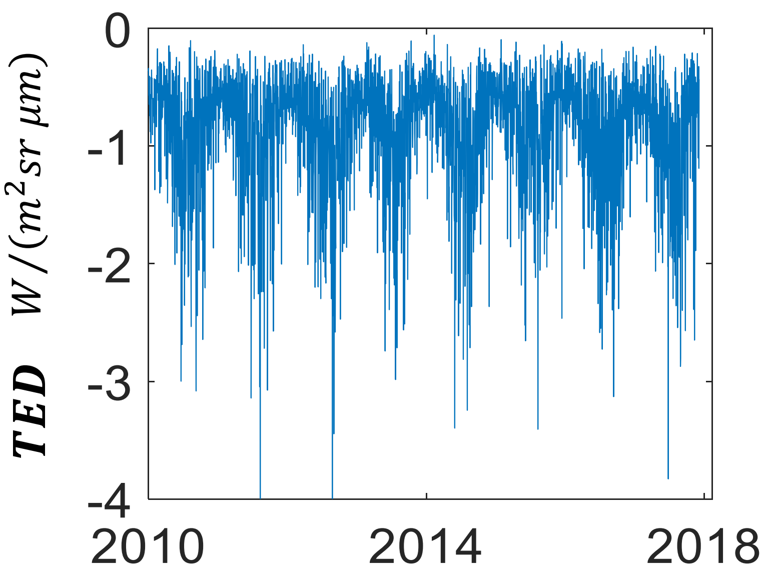
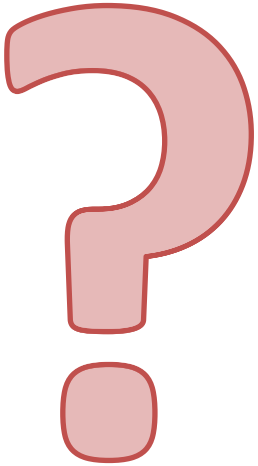


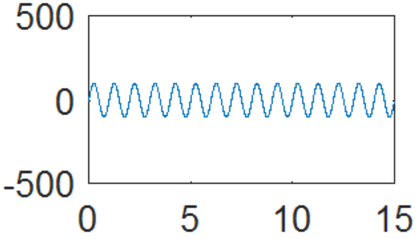


Montecarlo experiments

1. **Synthetic TED time series.**

2. **Test denoising techniques (moving mean, moving median, wavelet, Savitzky-Golay).**

Seasonal component



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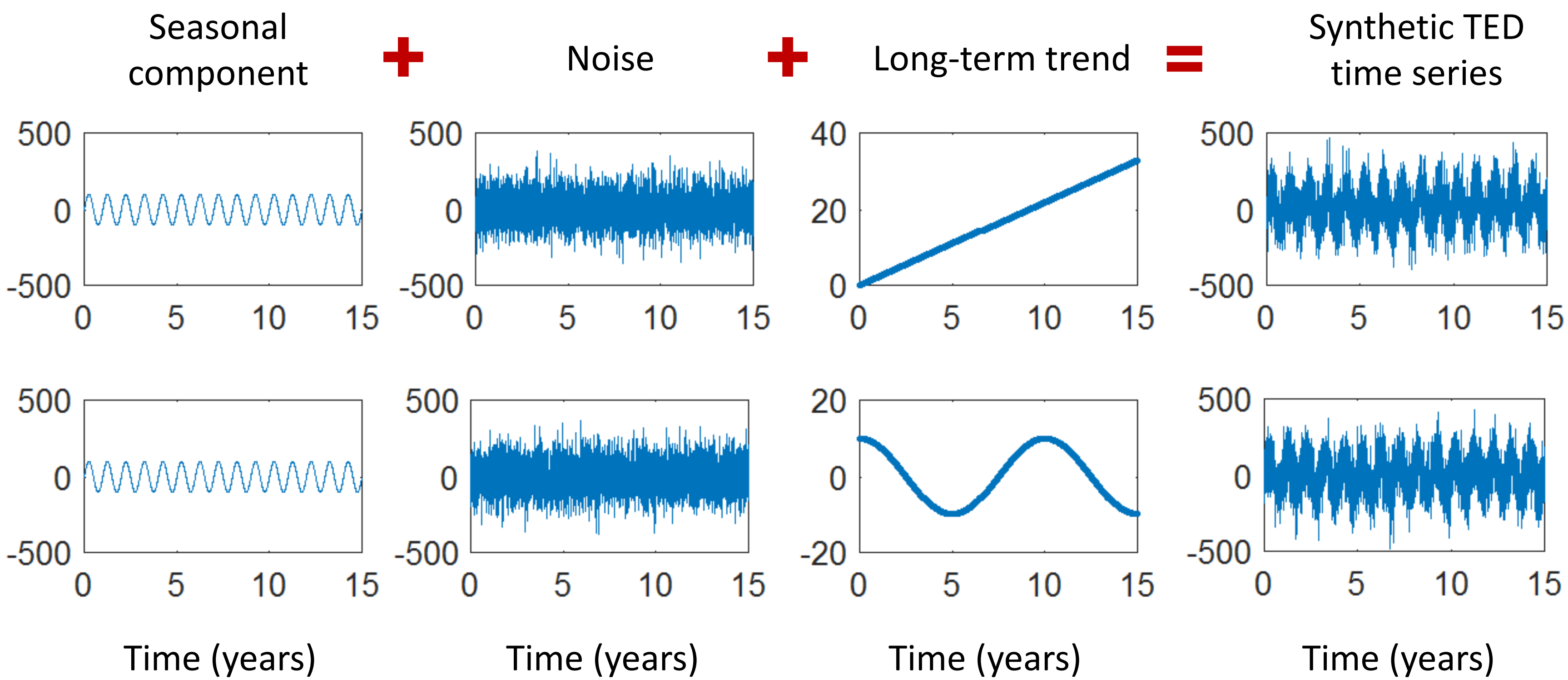

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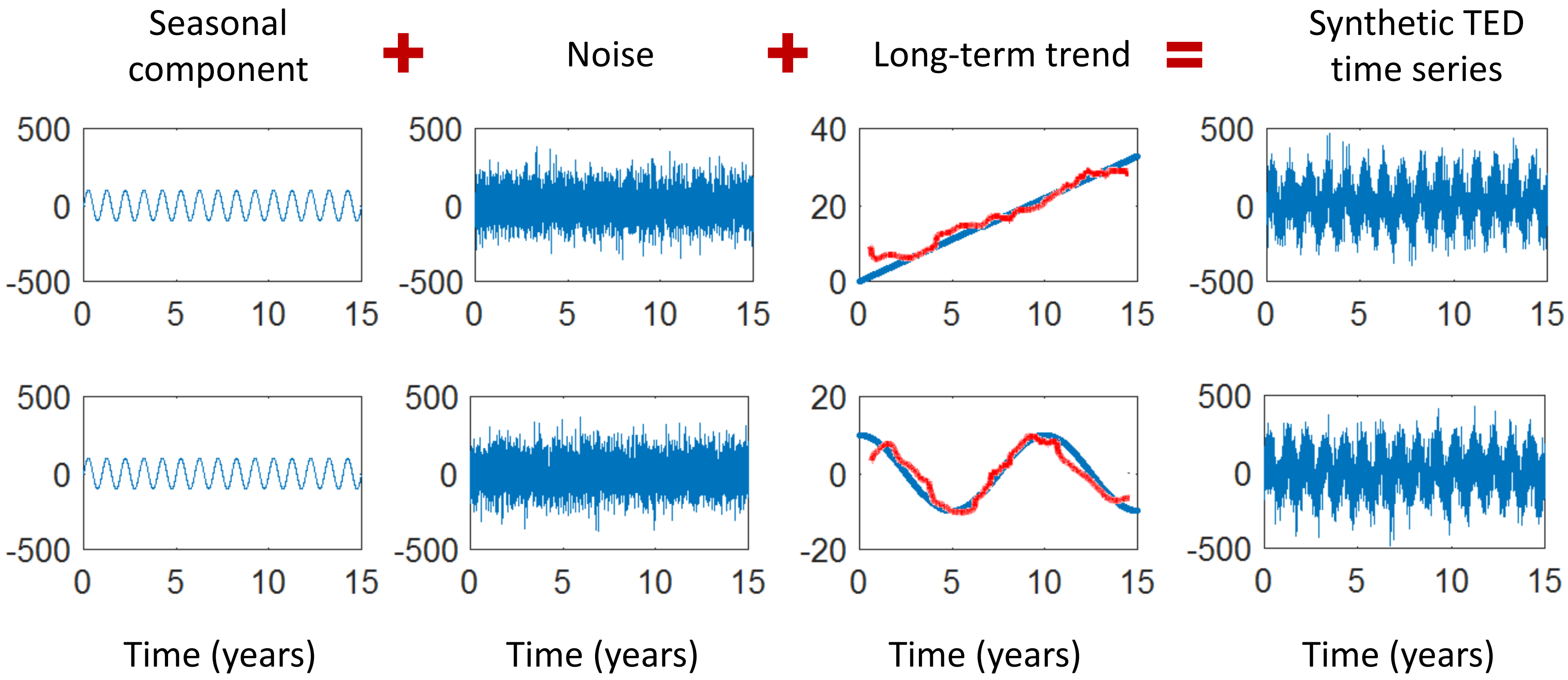
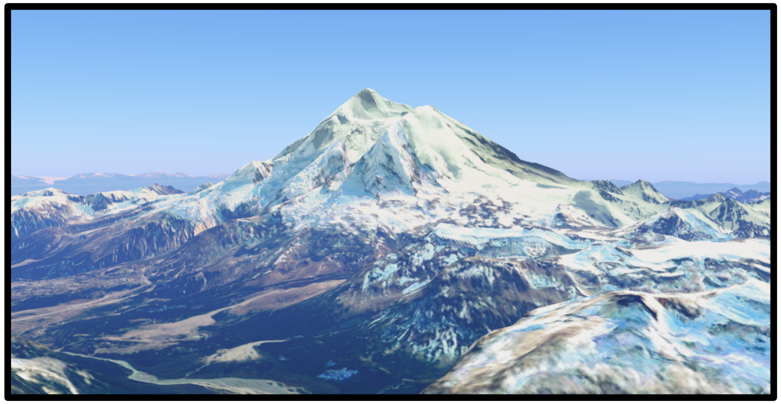


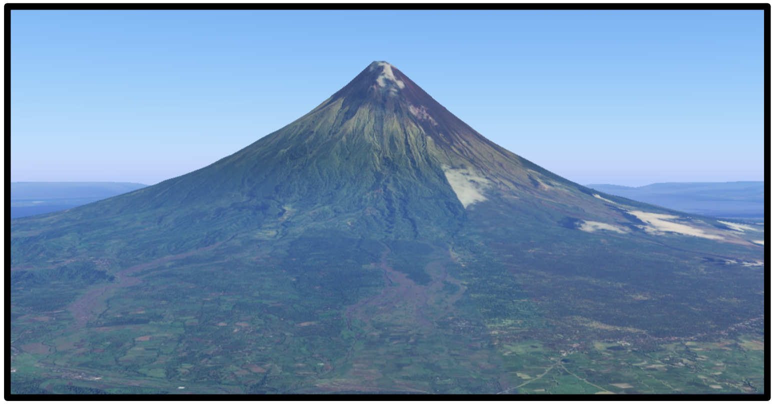
Redoubt (USA)



Ontake (Japan)

Ruapehu (New Zealand)

Mayon (Philippines)



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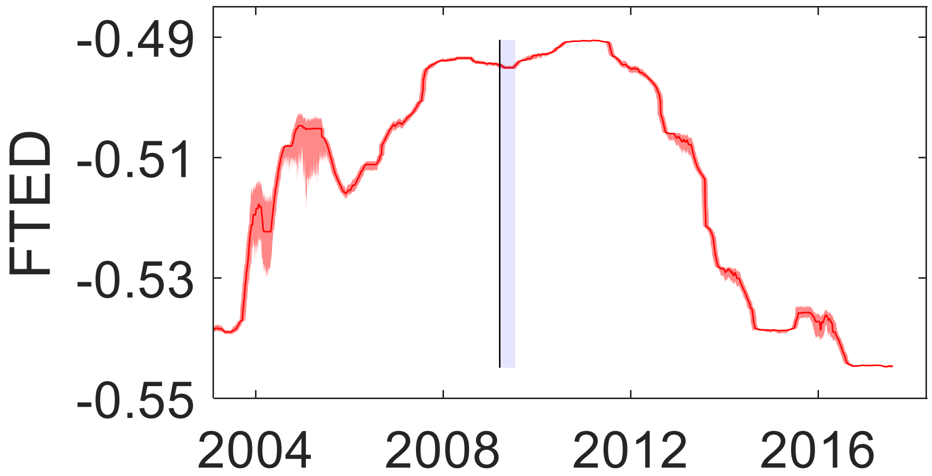

Ontake (Japan)

FTED units:
$W/(m^2 sr\ \mu m)$

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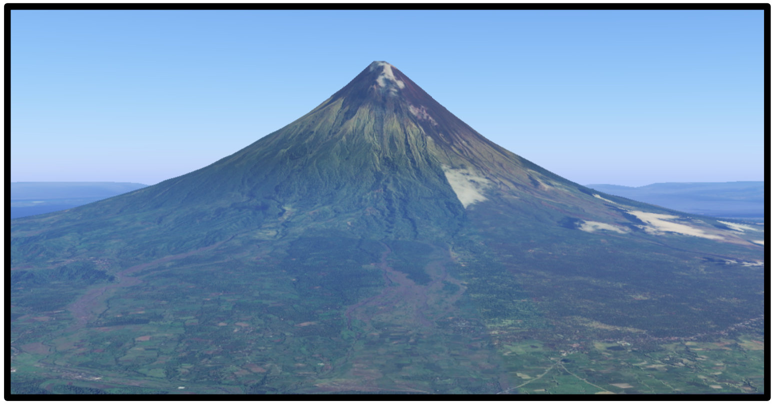

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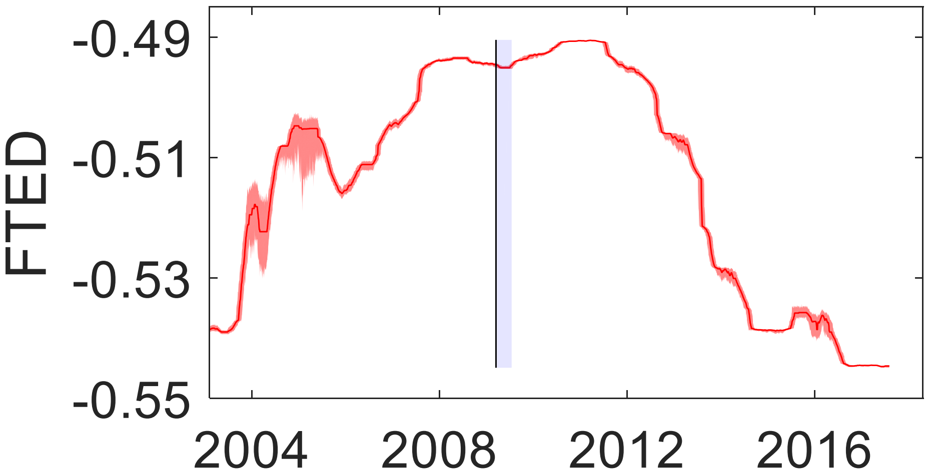

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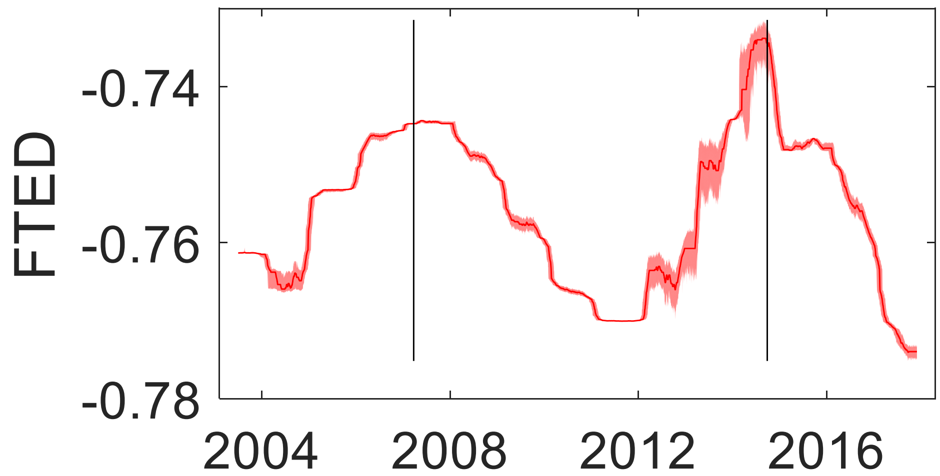

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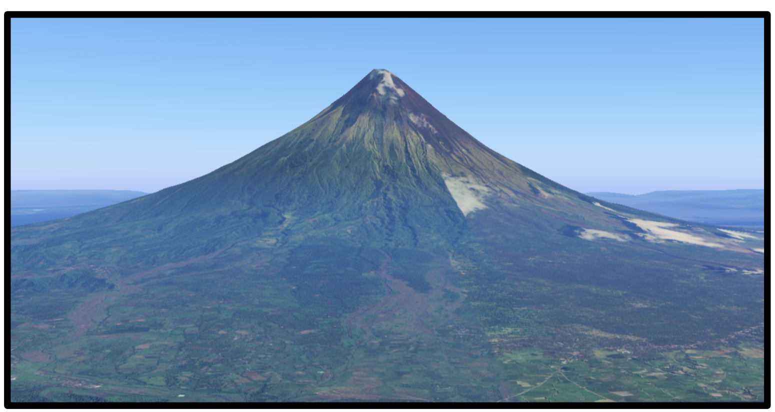
Mayon (Philippines)



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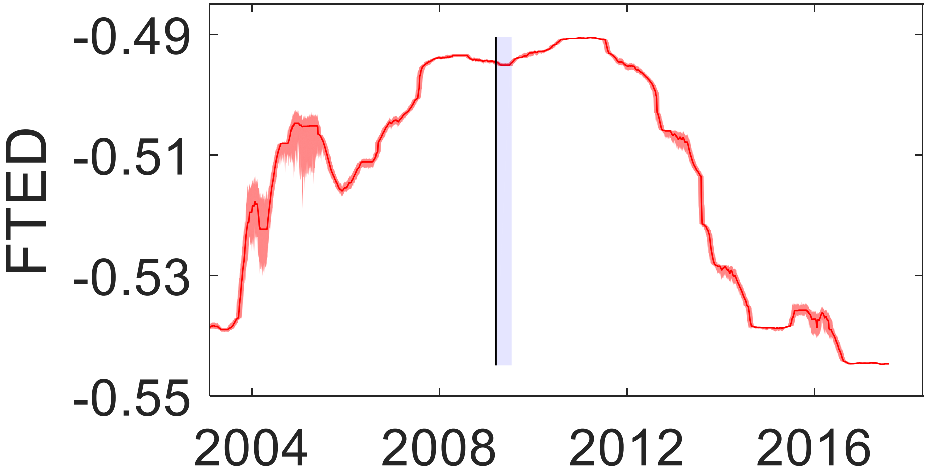

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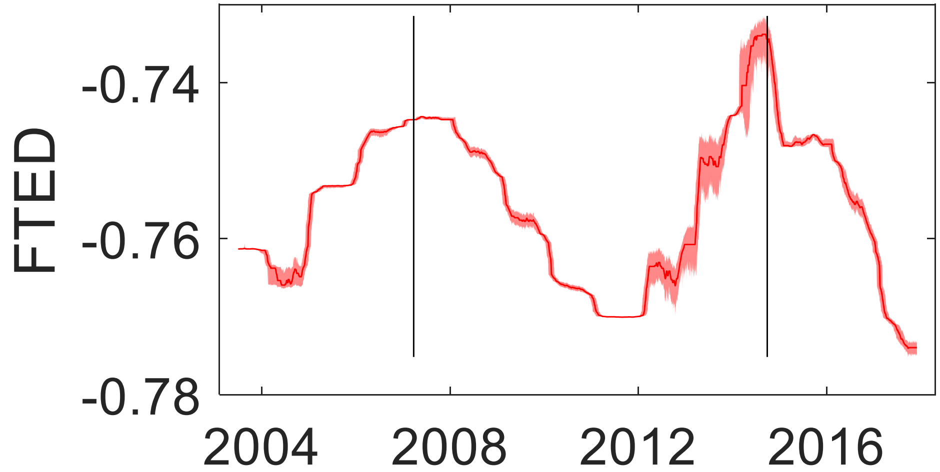

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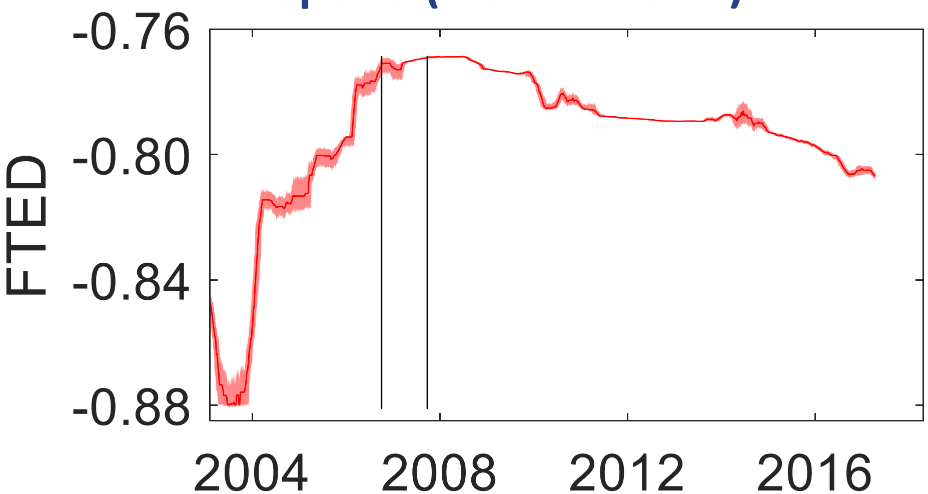
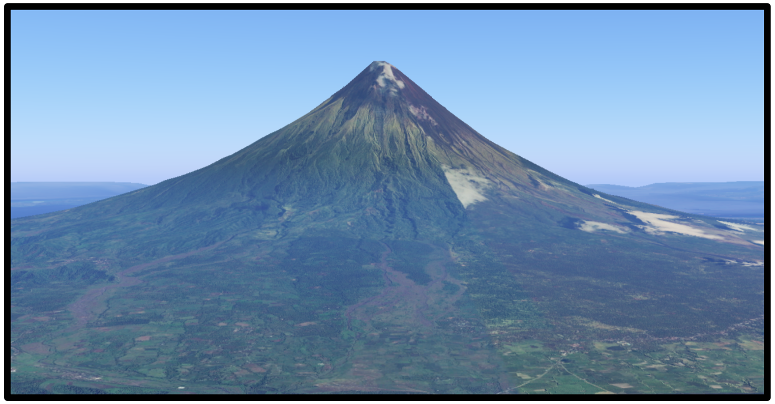
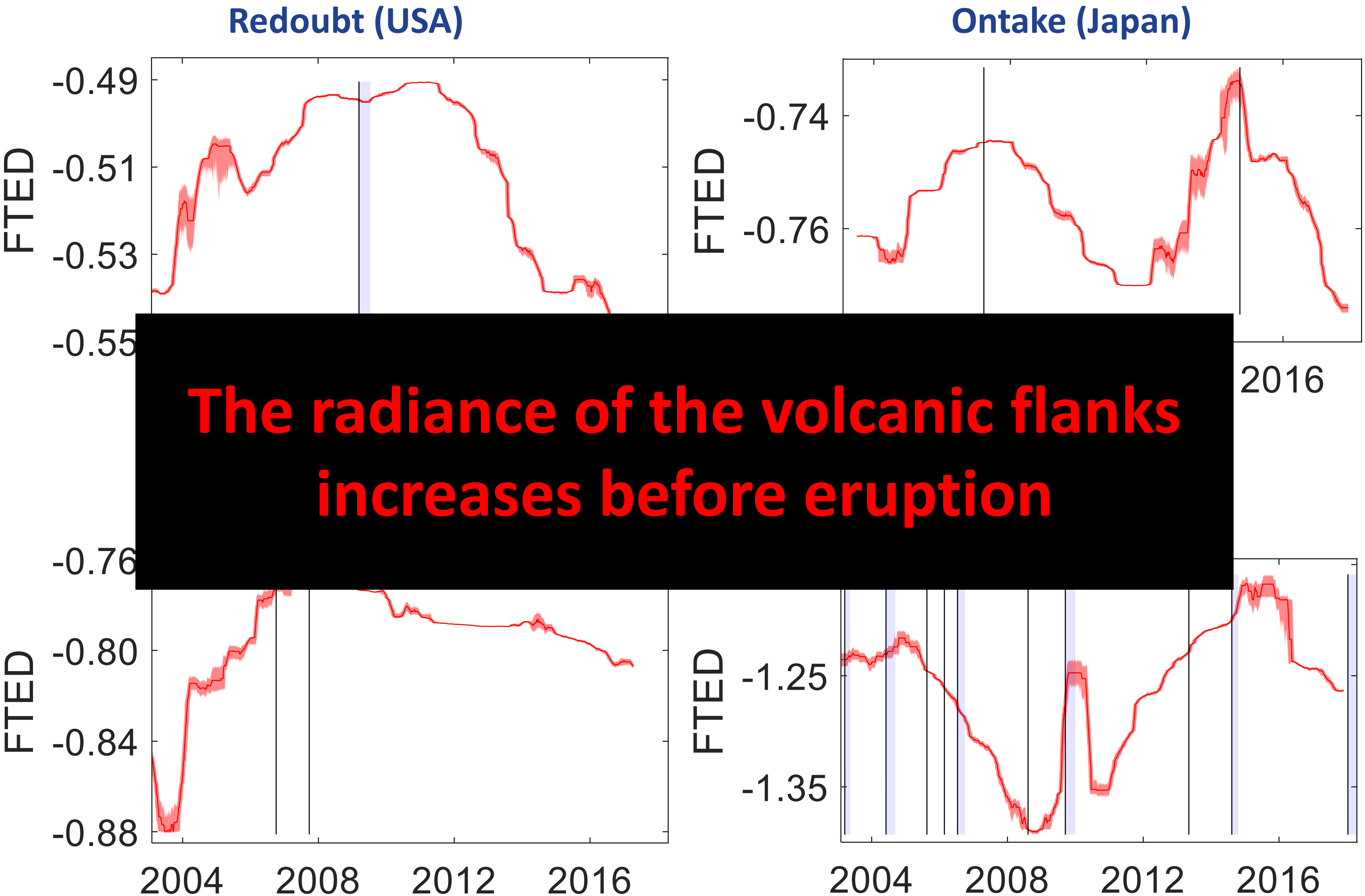


Mayon (Philippines)



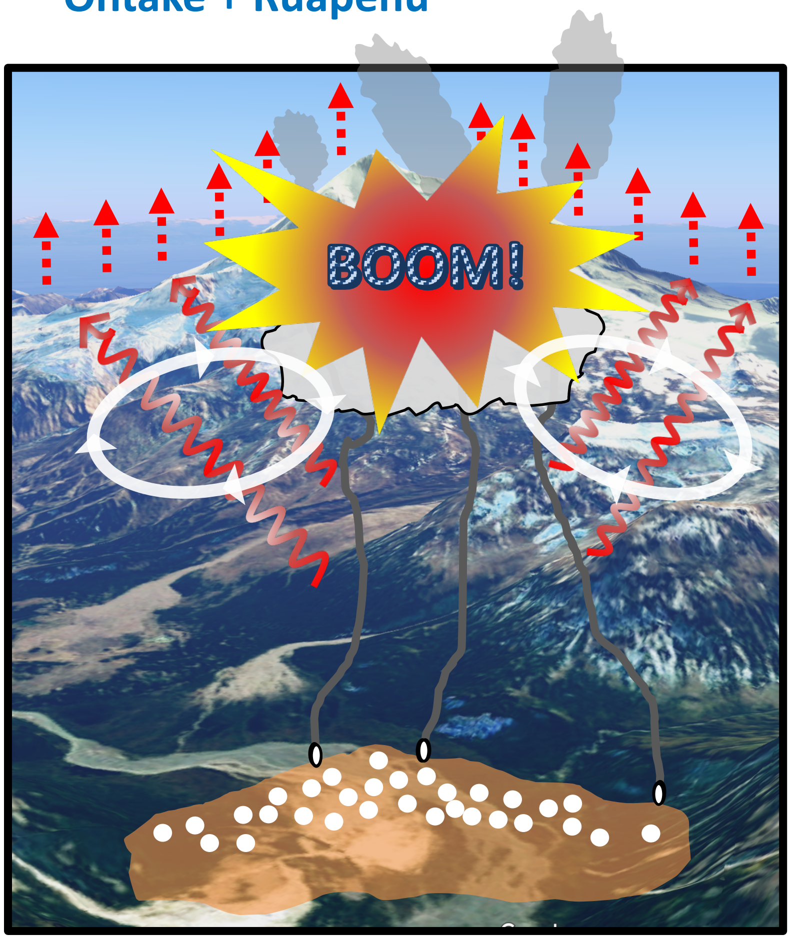


The radiance of the volcanic flanks increases before eruption

Why did the long-wavelenght radiance increase prior to eruptions?

1 **Channelized VS diffuse outgassing**
[e.g., Notsu et al., 2006; Girona et al., 2018]

Ontake + Ruapehu



[credit: Google Earth]

2

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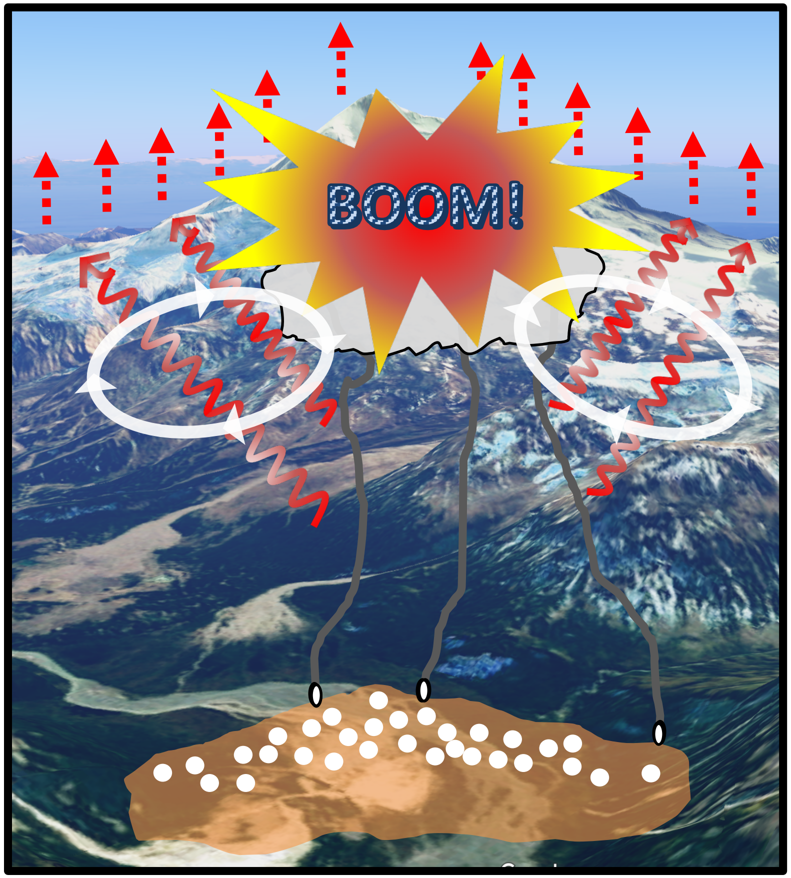
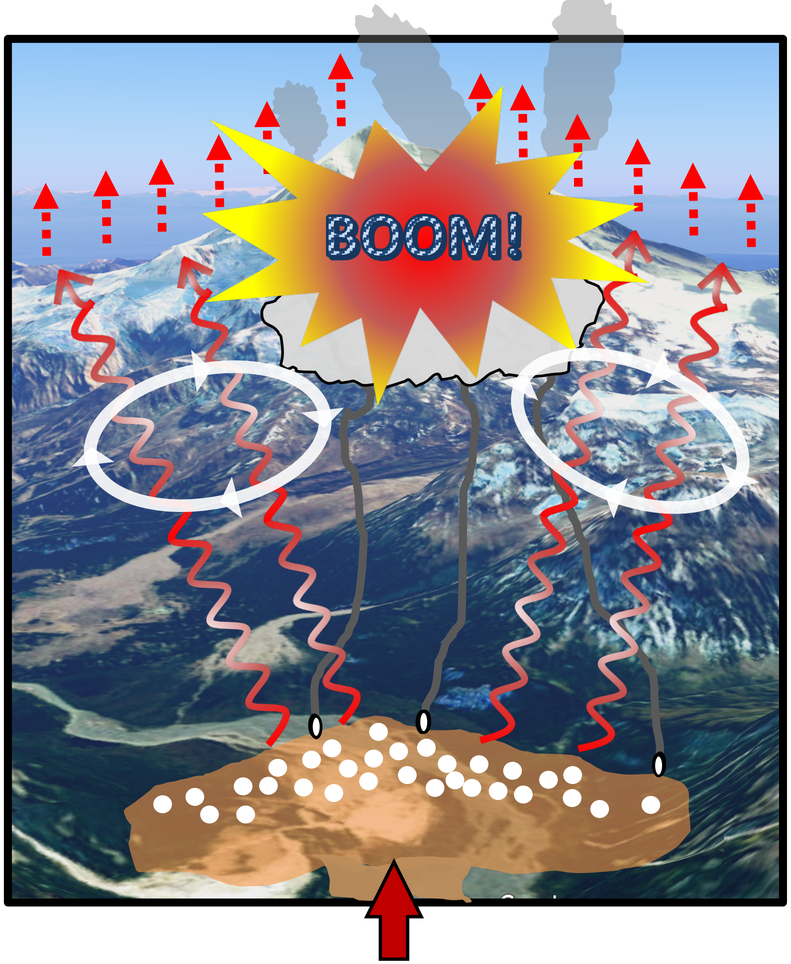


[credit: Google Earth]

2 **Magma ascent**

Redoubt + Mayon (2009-2010)



RESEARCH QUESTIONS

1 Do diffuse heat emissions vary significantly before eruptions? If yes, why?

- **R1**: YES. The overall radiance of the volcanic flanks increased prior to recent eruptions of Redoubt, Ontake, Ruapehu, and Mayon volcanoes.

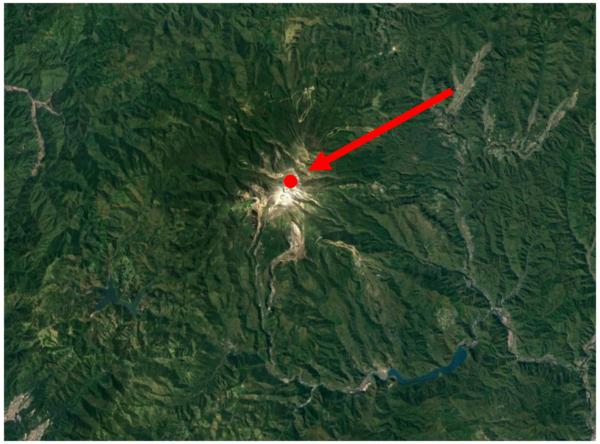
  The radiance of the volcanic flanks may increase with diffuse outgassing → by the ascent of magma to the surface or channel changes.

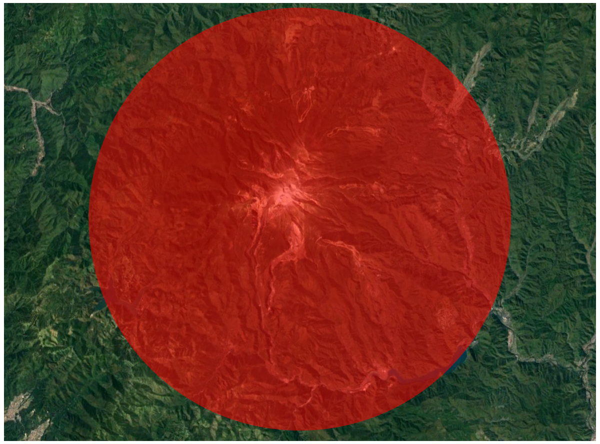
2 Can we forecast eruptions from space?

- **R2**: Results are promising for long-term forecasting. Boundary effects related to filtering must be taken into account for real-time monitoring.

Hotspot **vs** **Overall view**

[e.g., Pieri and Abrams, 2005;
Reath et al., 2016]





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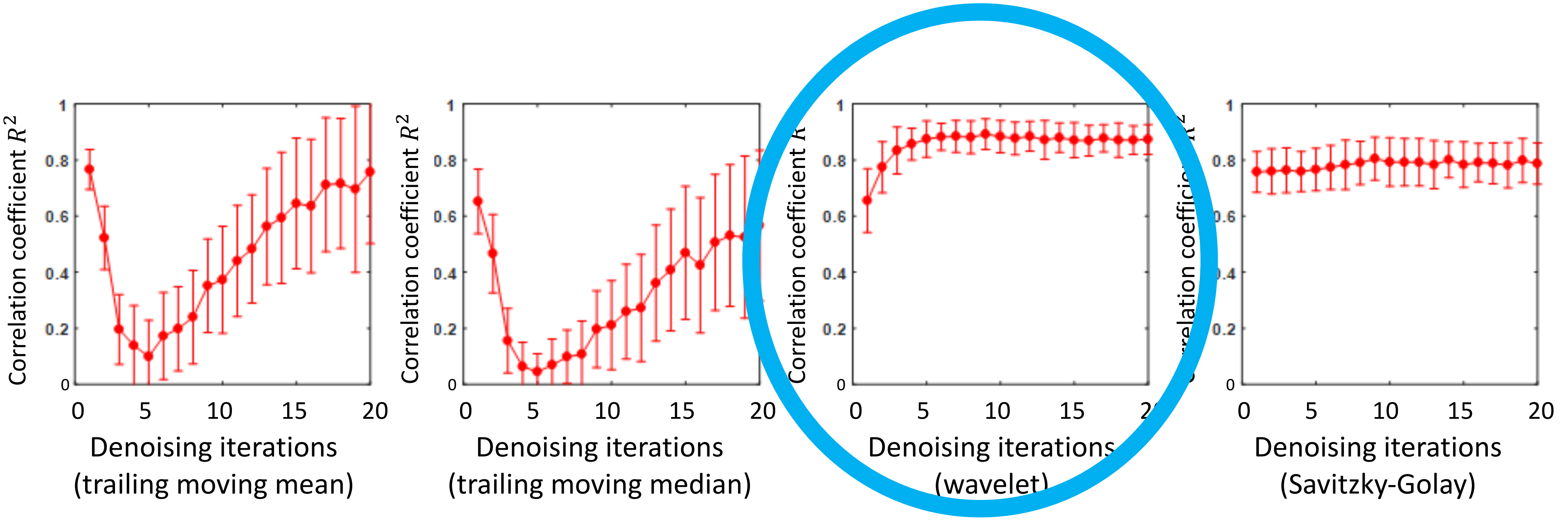

A combination of WAVELET and MEDIAN filters is suitable to detect long-term trends