

Satellite-based thermal precursors of volcanic eruptions



2014 Ontake phreatic eruption
>60 fatalities

[credit: BBC news]



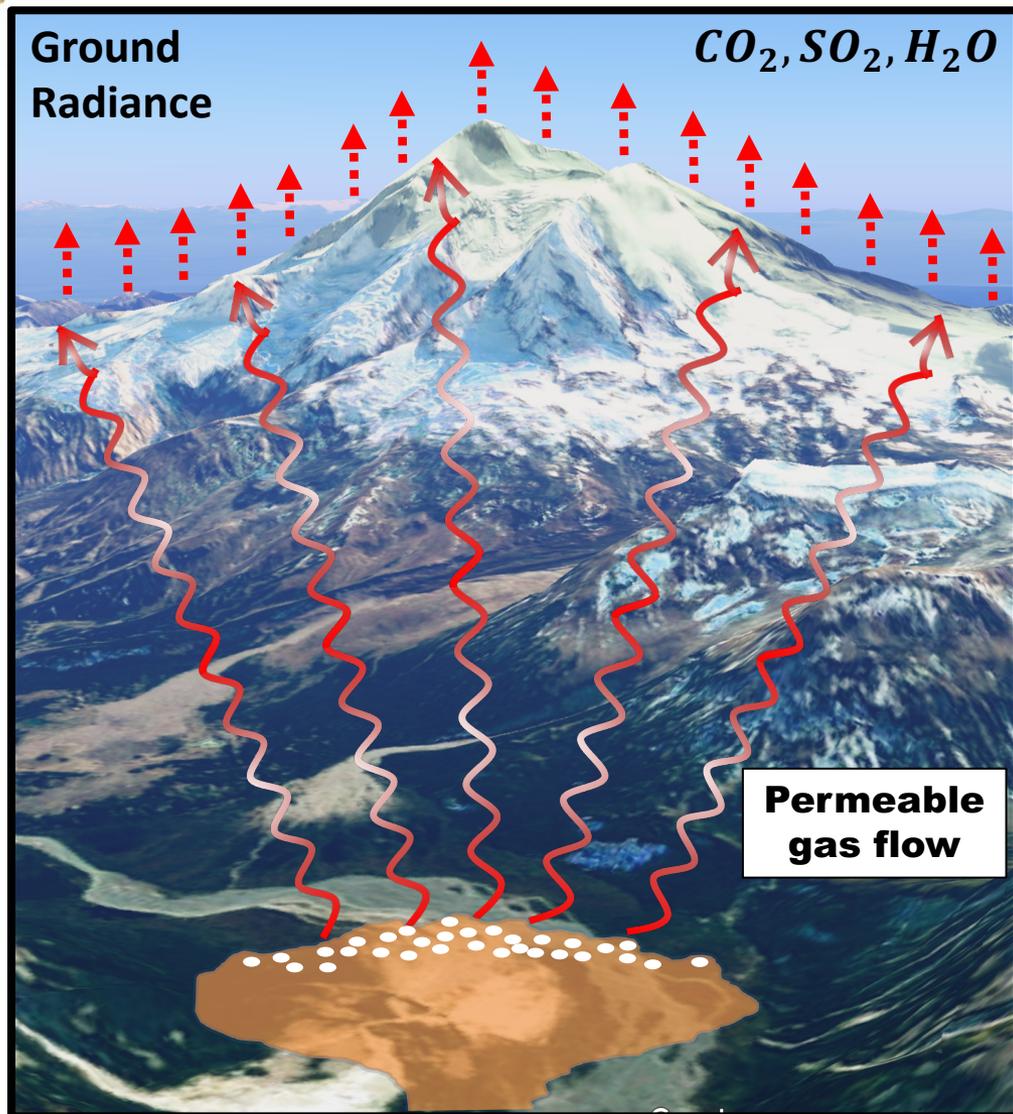
Cities on Volcanoes 10
6 September 2018

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Vincent Realmuto



Jet Propulsion Laboratory
California Institute of Technology

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

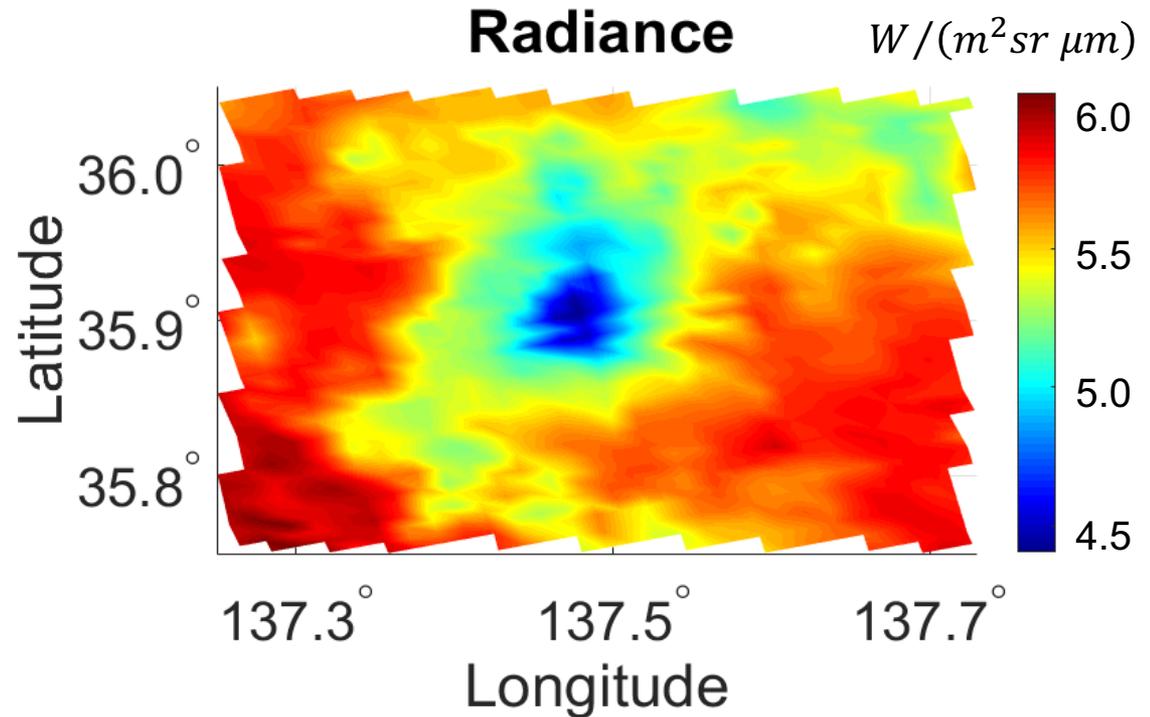


Median-of-median algorithm

- 1 Radiance data (Level 1B MODIS Terra/Aqua; Band 31: 10.780-11.280 μm ; $\sim 1 \times 1 \text{ km}$).
- 2 MEDIAN radiance of the “coldest” pixels (L_c^*)



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



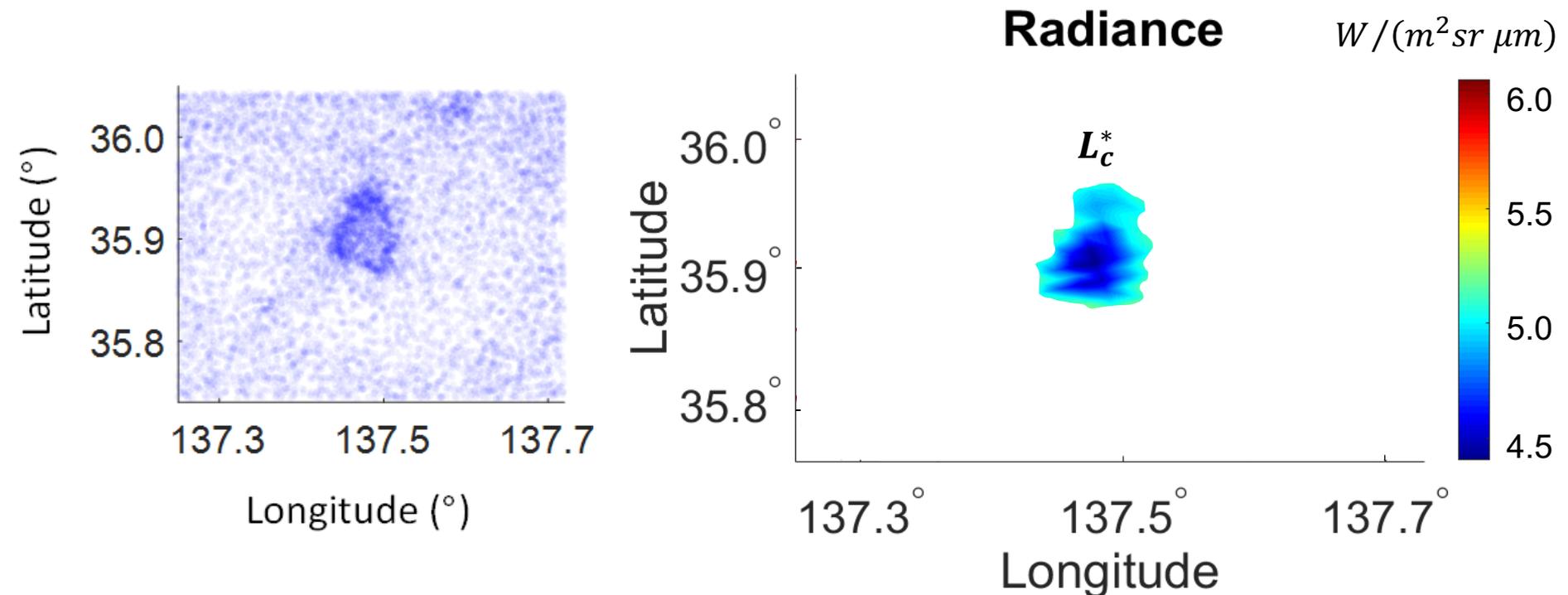
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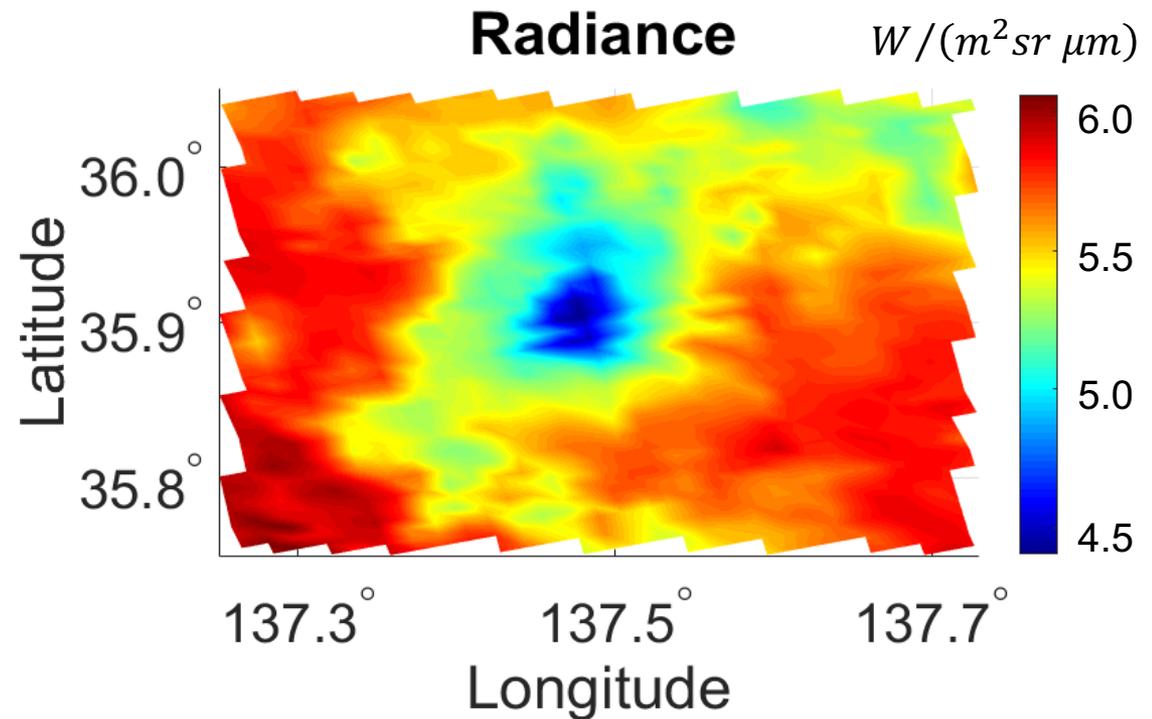
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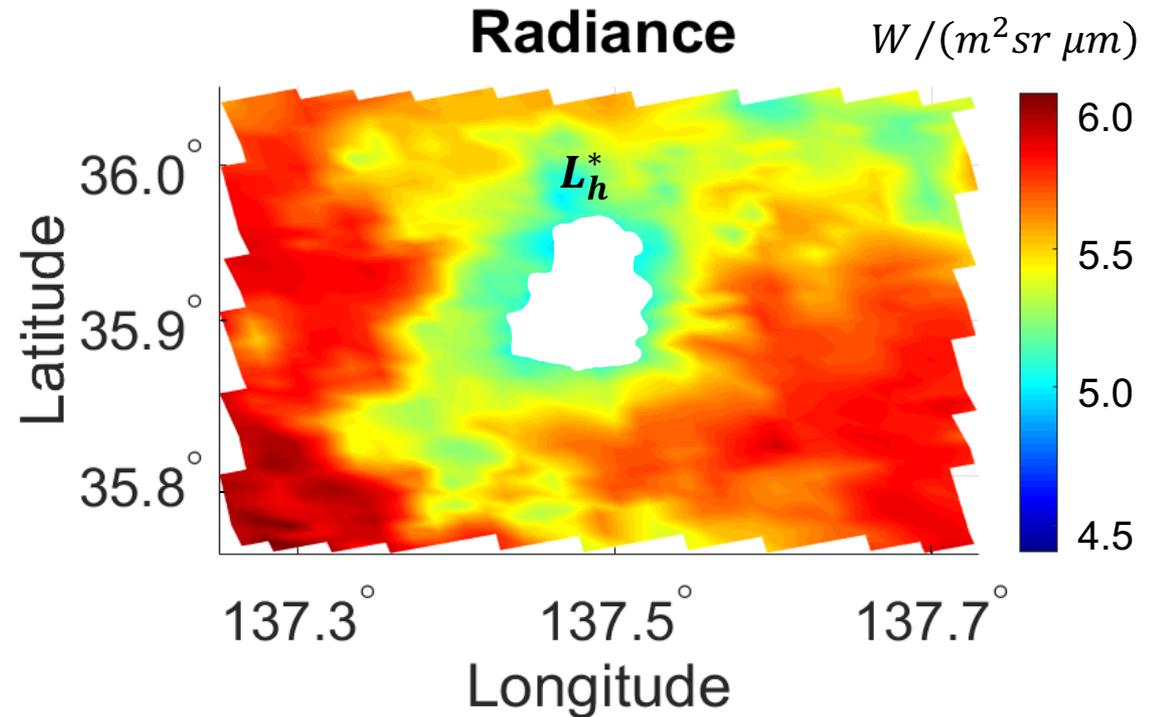
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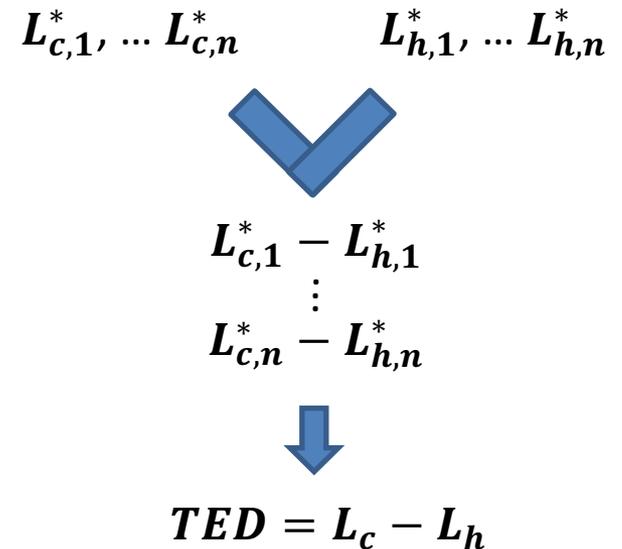
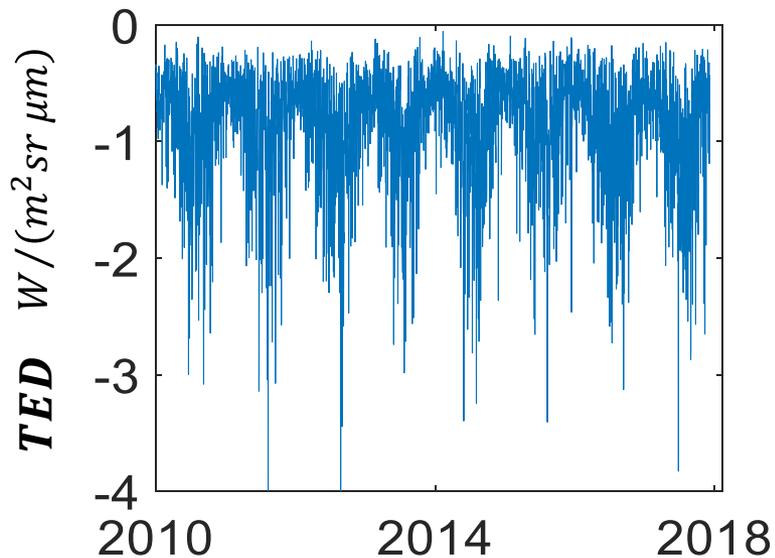
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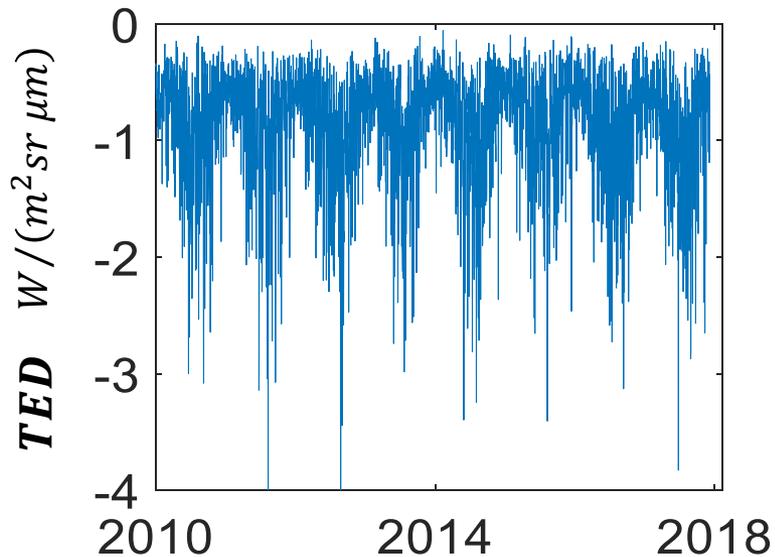
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- 4 DAILY MEDIAN of the difference [Thermal Emission Difference: TED].



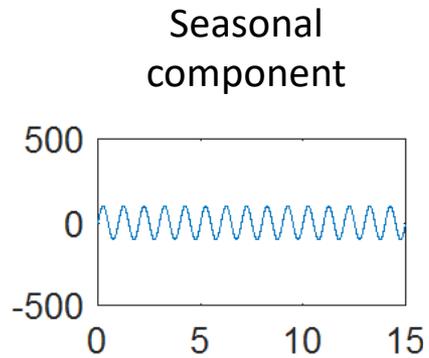
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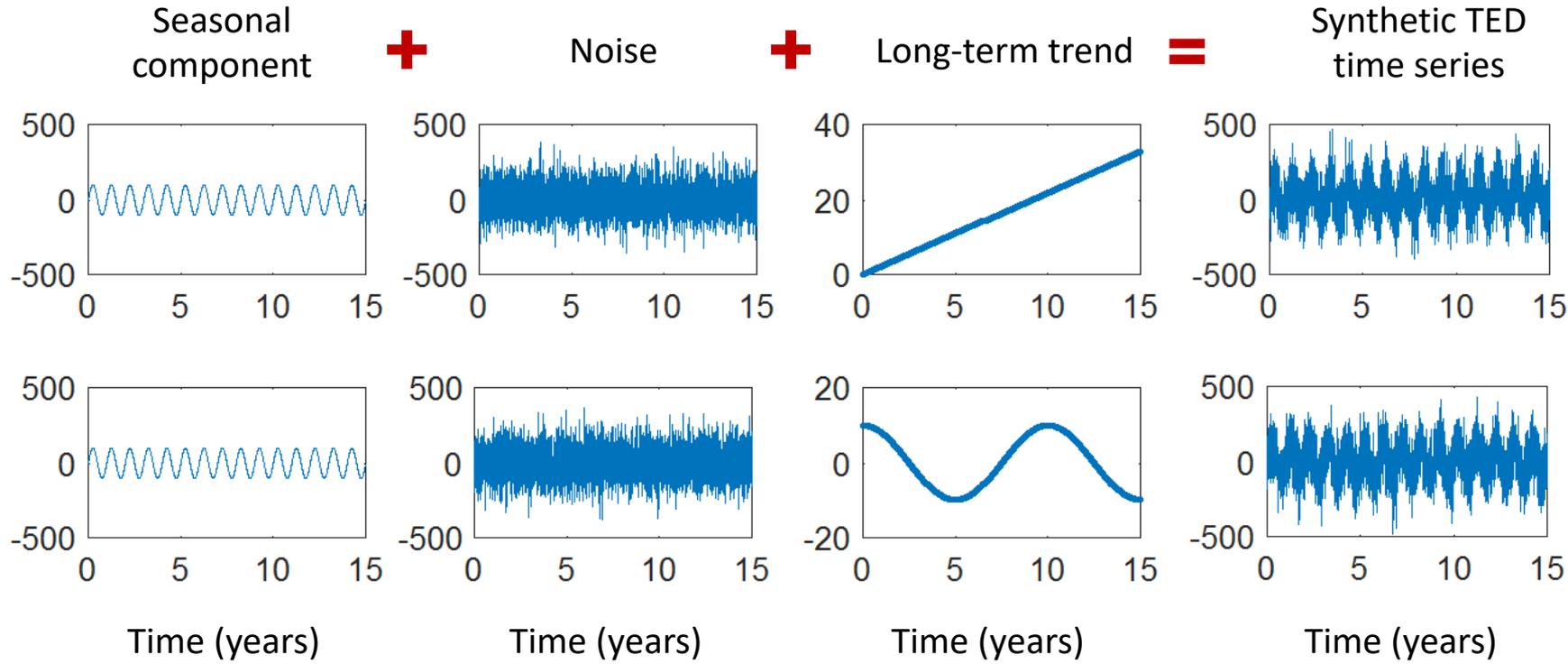
Montecarlo experiments

- 1 Synthetic TED time series.
- 2 Test denoising techniques (moving mean, moving median, wavelet, Savitzky-Golay).



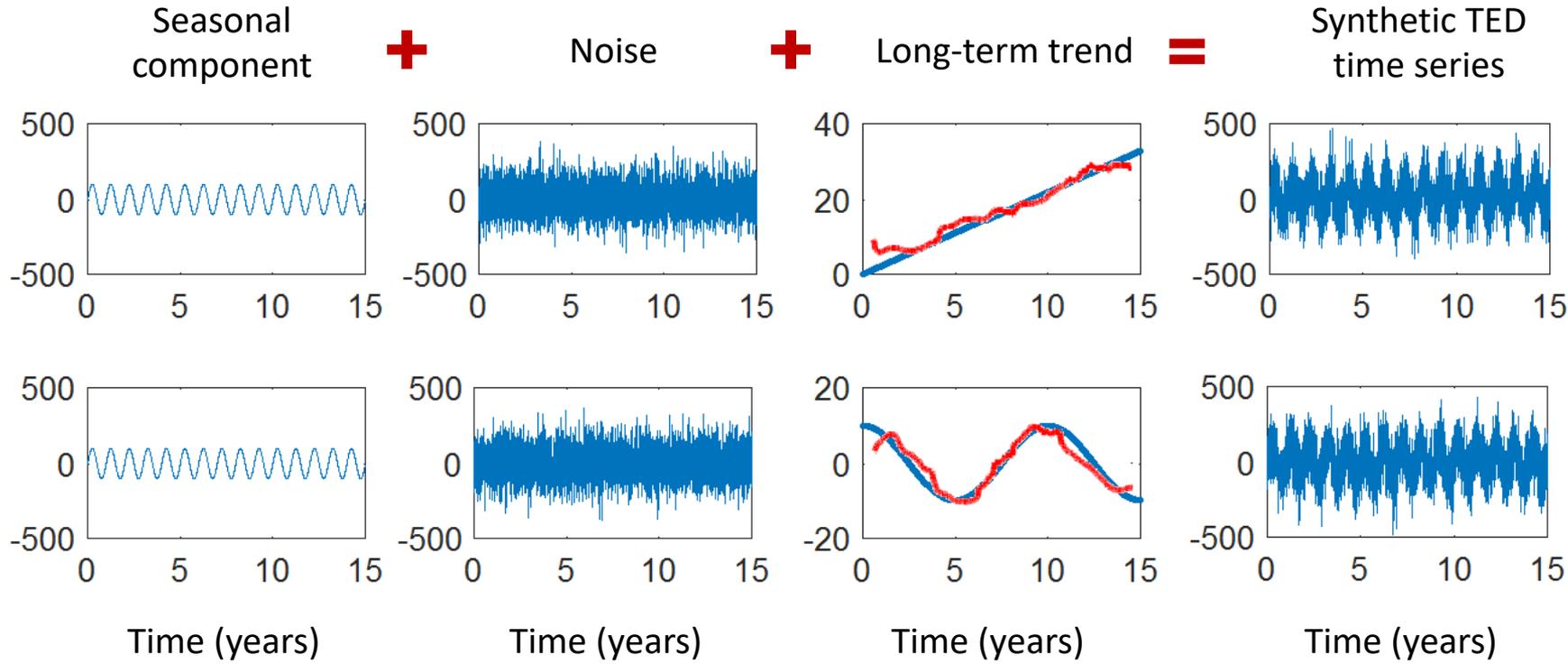
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Redoubt (USA)



Ontake (Japan)



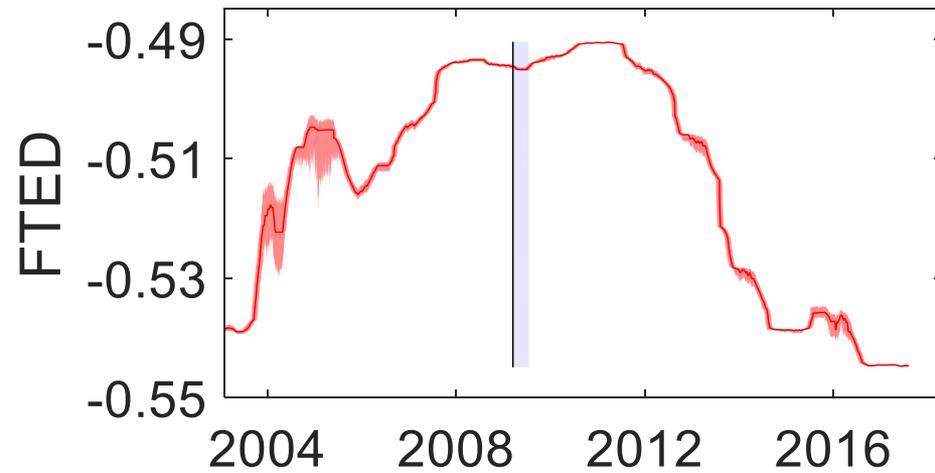
Ruapehu (New Zealand)



Mayon (Philippines)



Redoubt (USA)



Ontake (Japan)



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

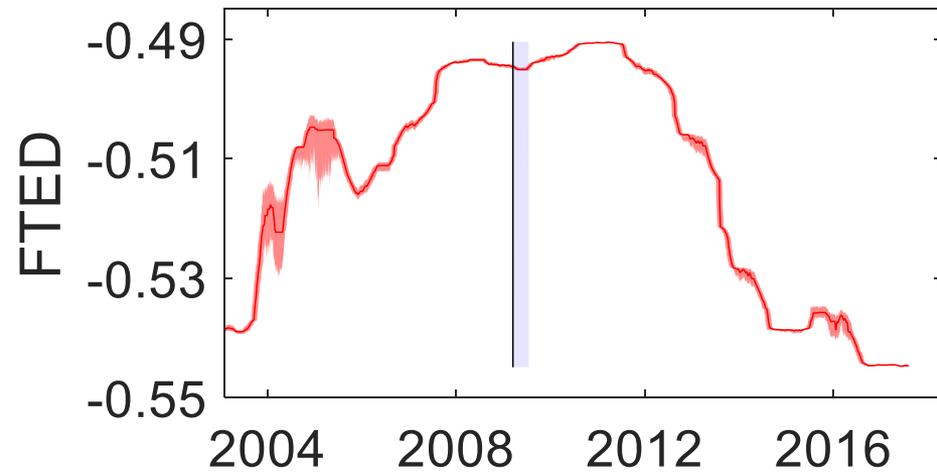
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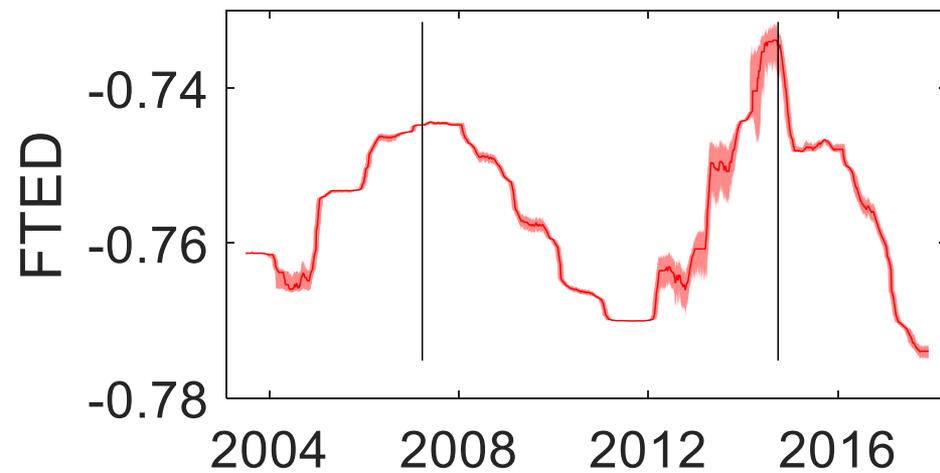
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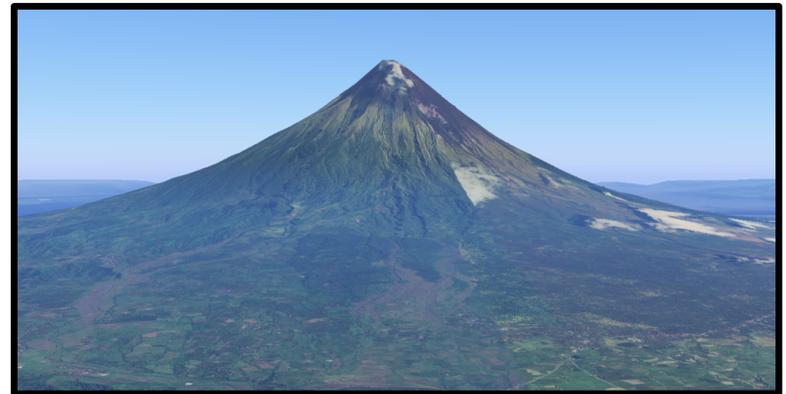


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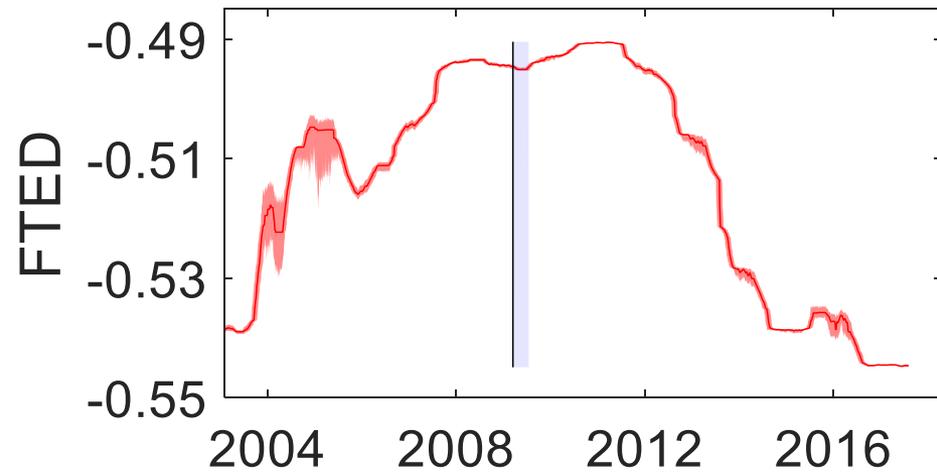


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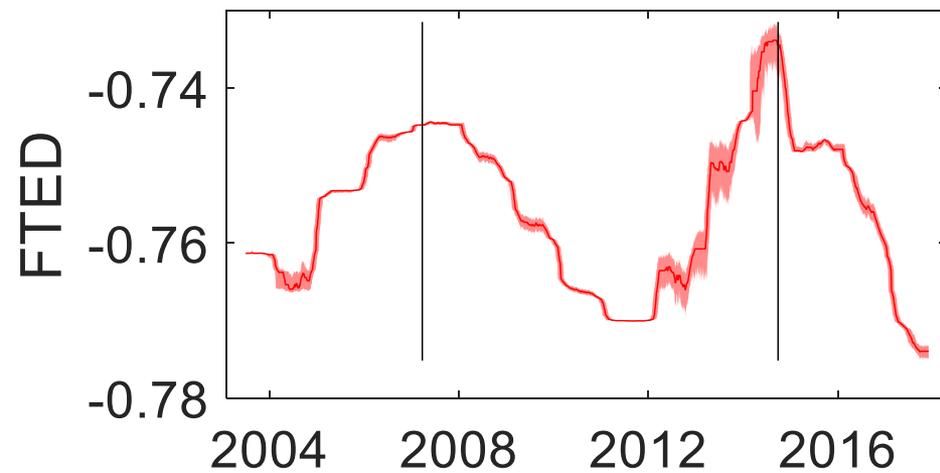
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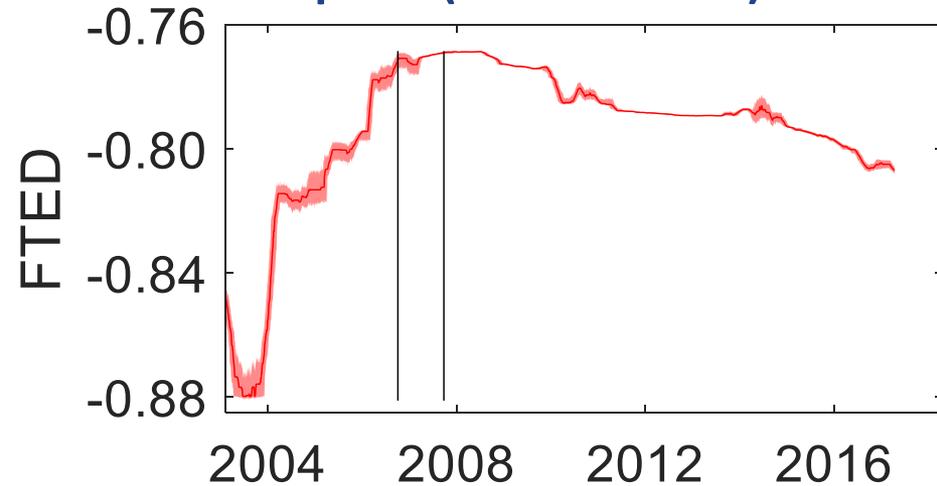


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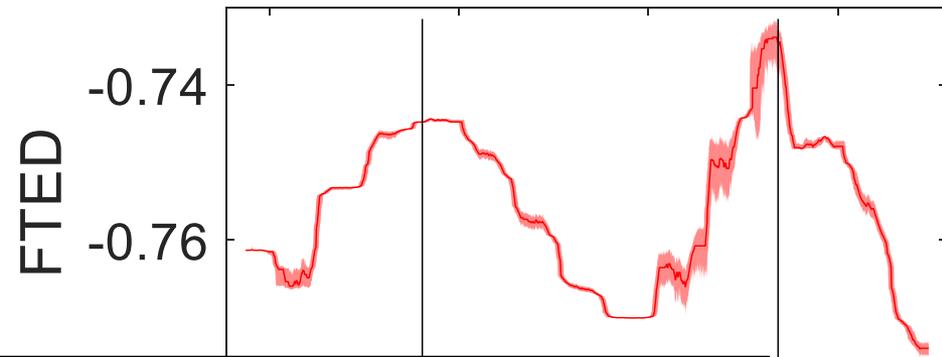
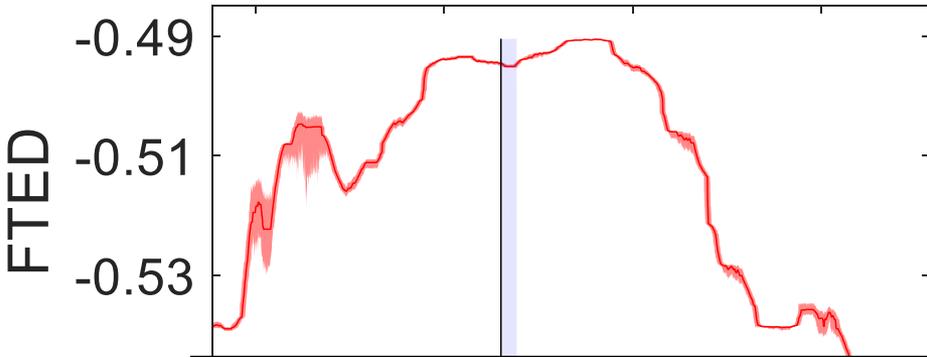


Mayon (Philippines)

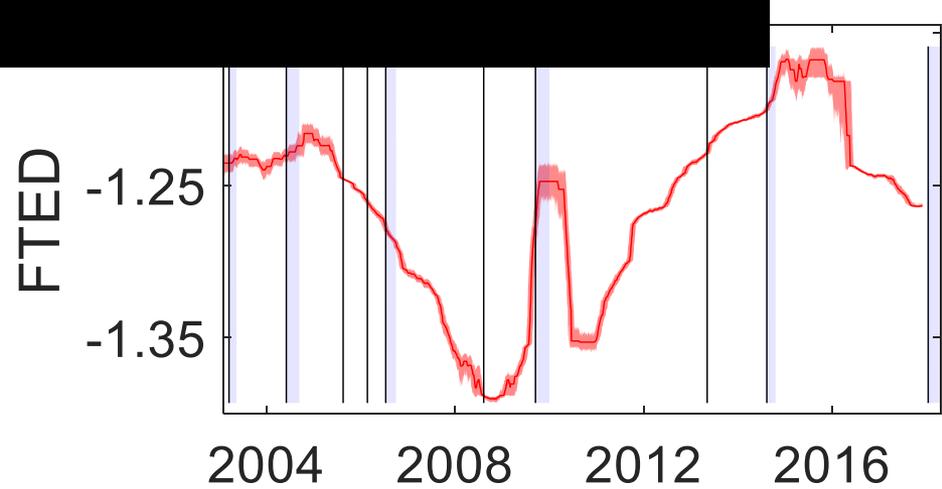
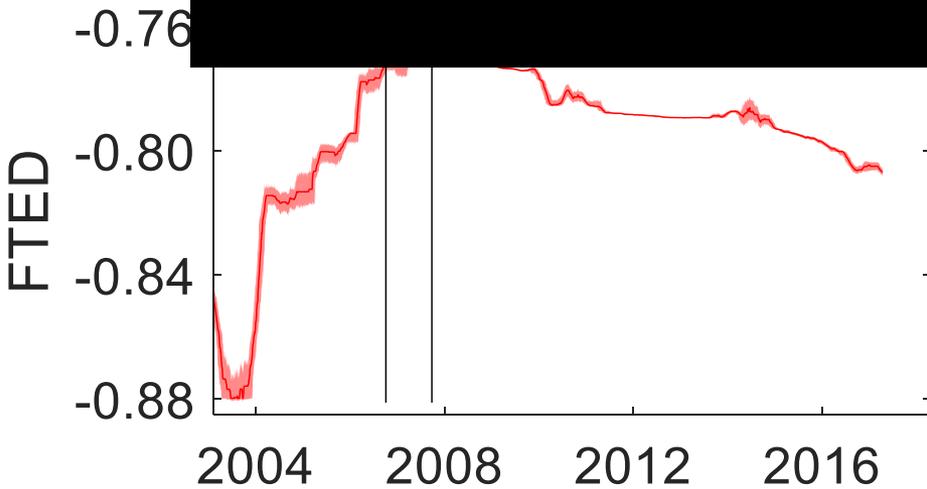


Redoubt (USA)

Ontake (Japan)



The radiance of the volcanic flanks increases before eruption

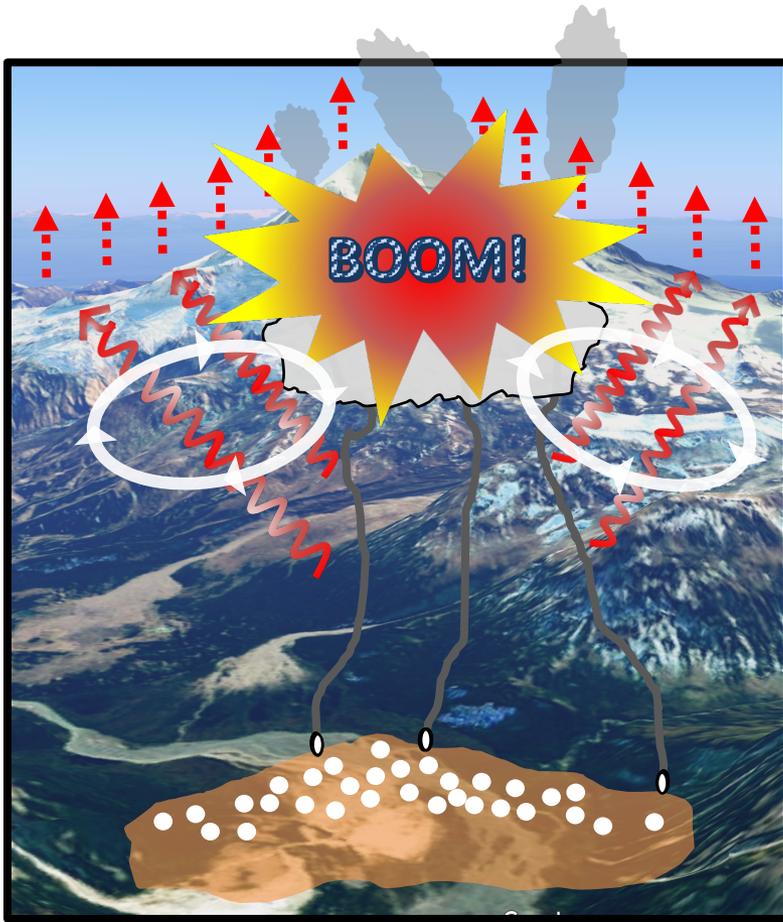


Why did the long-wavelength radiance increase prior to eruptions?

1 Channelized VS diffuse outgassing

[e.g., Notsu et al., 2006; Girona et al., 2018]

2



[credit: Google Earth]

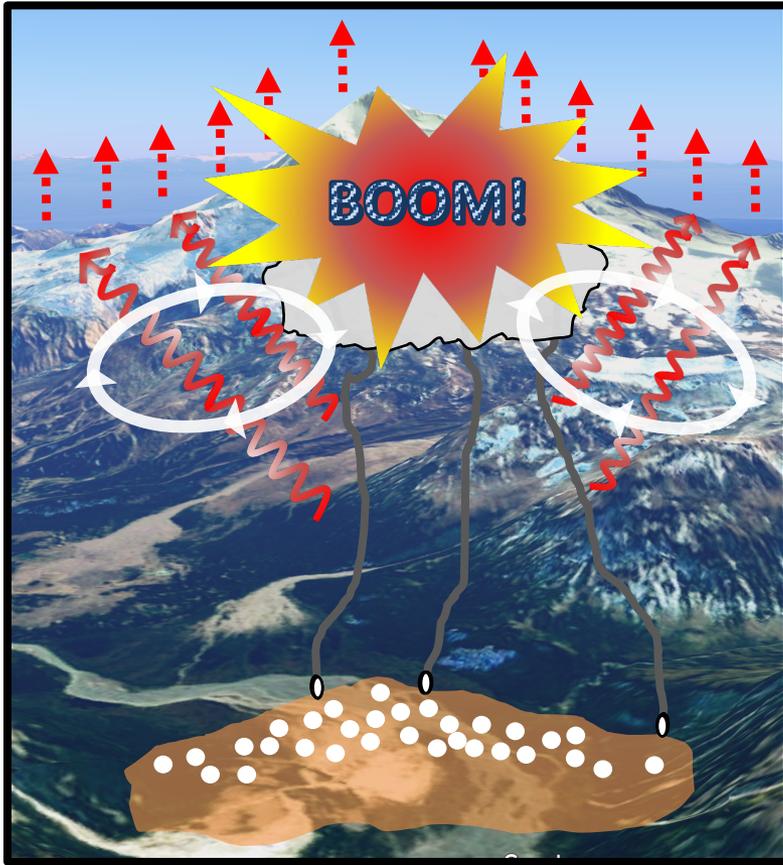
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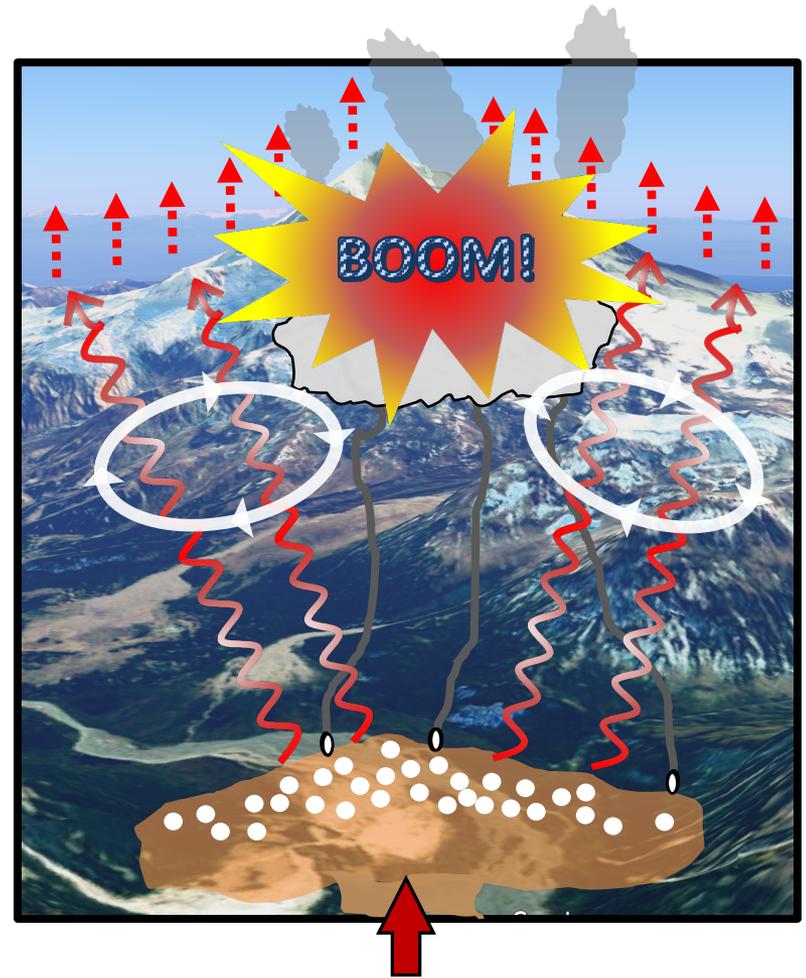
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- 1** Channelized VS diffuse outgassing
[e.g., Notsu et al., 2006; Girona et al., 2018]



[credit: Google Earth]

- 2** Magma ascent



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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.

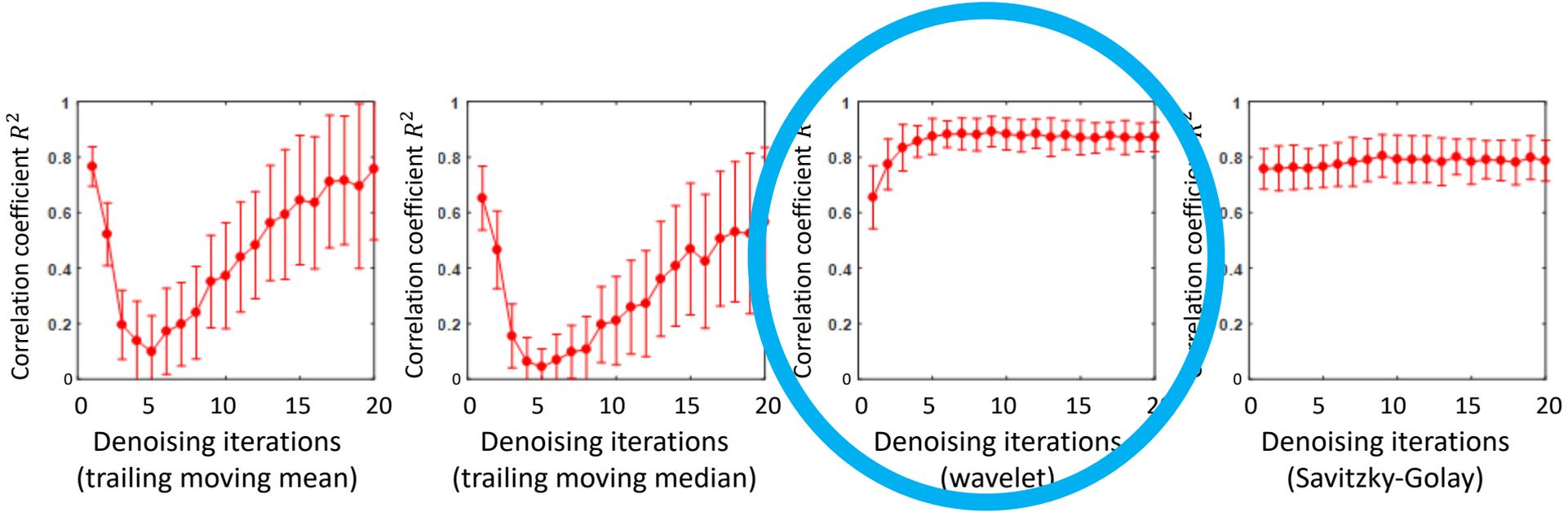
2 Can we forecast eruptions from space?

• R2:

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

Montecarlo experiments

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



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

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