



STREVA Project: Analysis of volcanic ash and impacts



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An aerial photograph of a volcanic landscape. In the center, there is a large, dark, circular crater with a prominent rim. The surrounding terrain consists of numerous ridges and valleys, some of which are covered in green vegetation. The background shows a coastline with a blue sea under a clear sky. The text is overlaid on the image in white, bold font.

Why are we interested in volcanic ash?

During our research you told us it was an important issue in 1979; we found it to be very important in 1902

- **For our other study areas (ongoing eruptions in Montserrat and Tungurahua, Ecuador) also true**



Volcanic ash: messy, destructive and an irritant



- Disrupts international air traffic
- Destroys individual livelihoods
- Damages crops and livestock
- Damages infrastructure
- Impacts human health

1979 eruption of Soufriere St. Vincent

How do we 'predict' the future?

- Map out ash dispersal from past eruptions
- Map out past impacts
- Model future eruptions that represent a range of realistic eruption and weather scenarios
- Look at close analogues to St. Vincent and understand their impacts



Tephra damaged breadfruit leaf from March 1903 eruption, British Geological Survey Archive

Scenario Exercise St Vincent, STREVA Forensic Workshop January 2014



Scenario Exercise St Vincent, Caribbean Ash Hazards and Impacts (CaASHI) Workshop March 2015

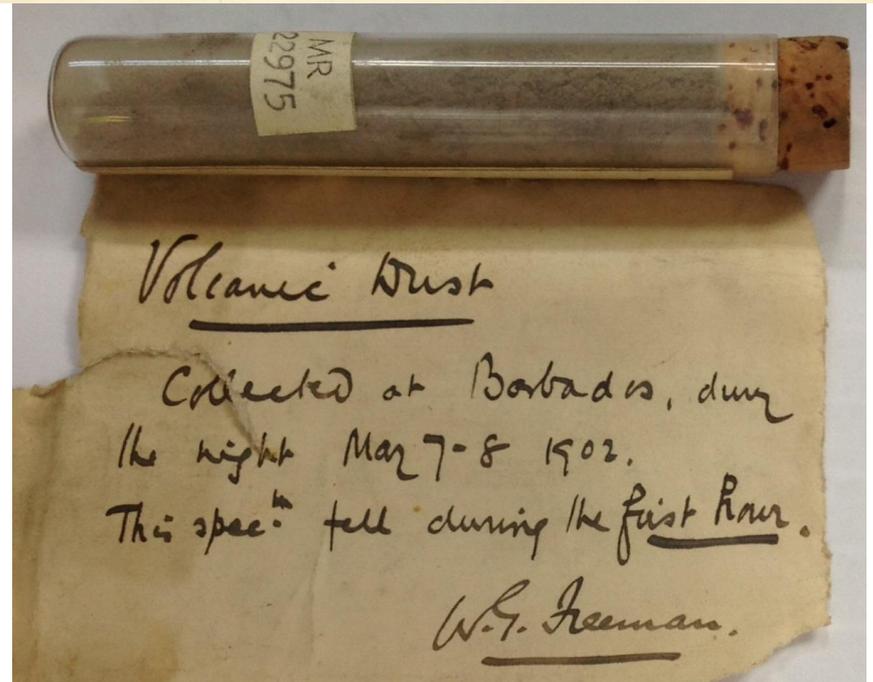
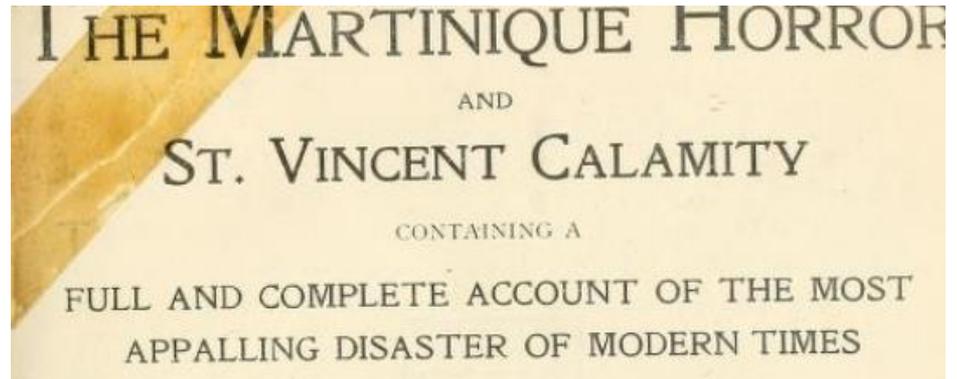


**Inter and
intra-
setting
learning**



Past ashfall: Databases we used

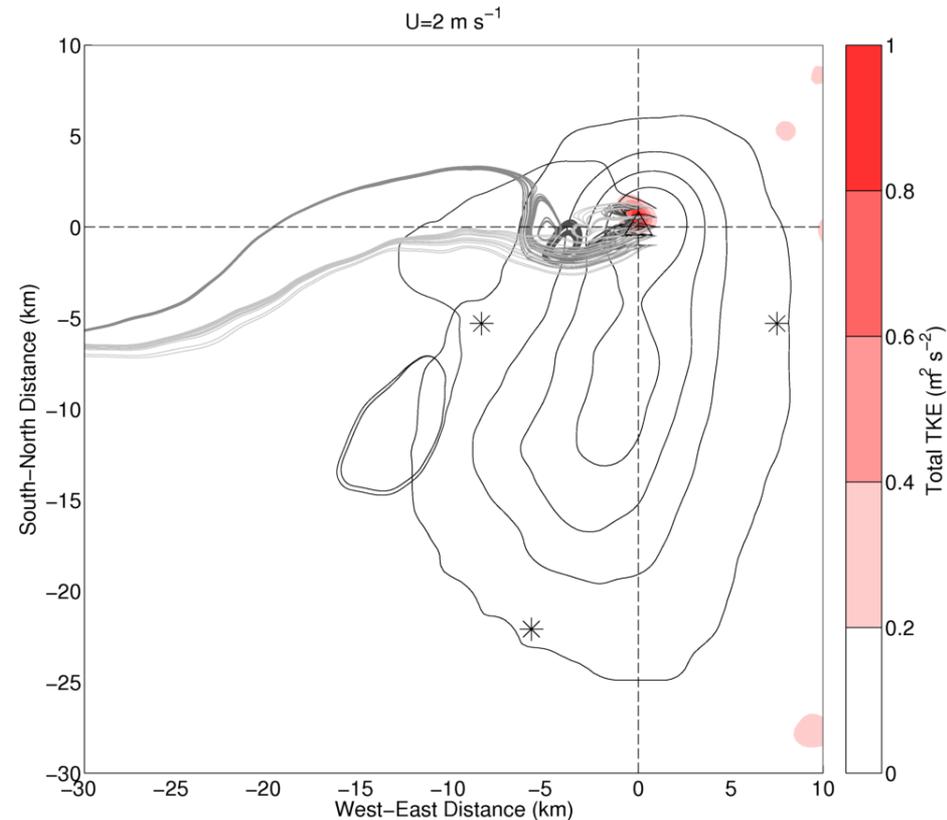
- Official contemporary accounts (largely police, military and governmental)
- Colonial archive: correspondence and observations
- Anecdotal contemporary accounts and media reporting
- Scientific analysis (contemporary and recent)
- ('new')



David Pyle, British Geological Survey Archive

New data gathering and modelling

- More detailed ash dispersal modelling
- Used several different types of model



1902 – 1903 Eruptions

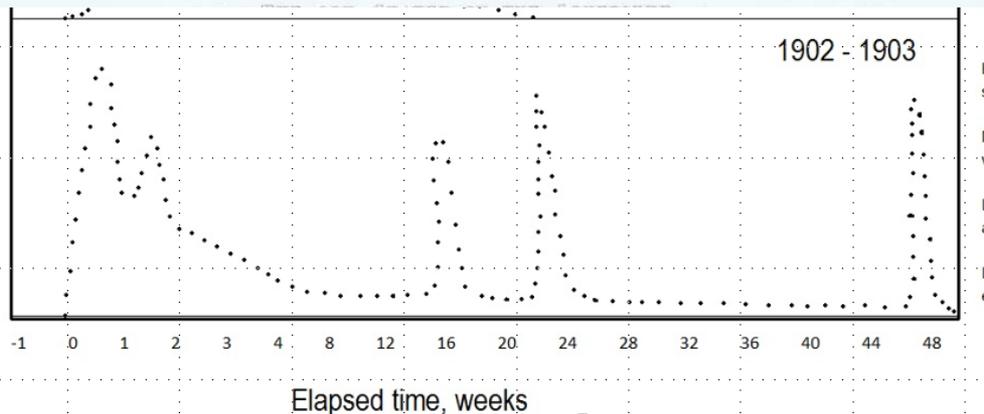


Drawn by Simon Caddy, Ray Artill

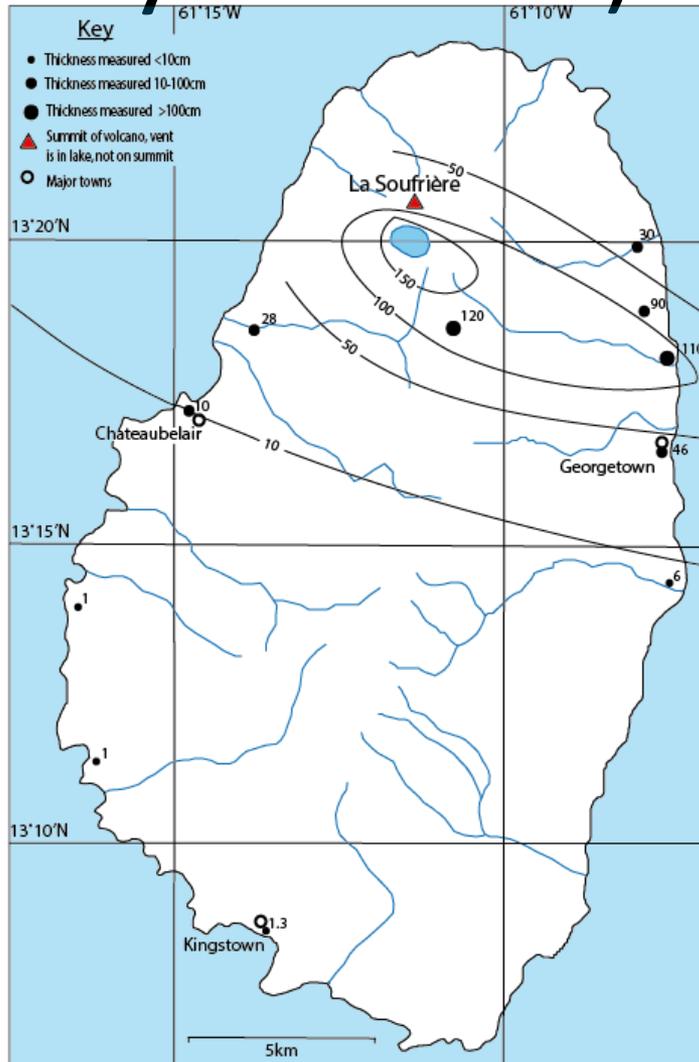
Engineered by W. Weston, A.S.A.

7th and 21st May,
3rd-4th September,
15th-16th October
22nd March (1903)

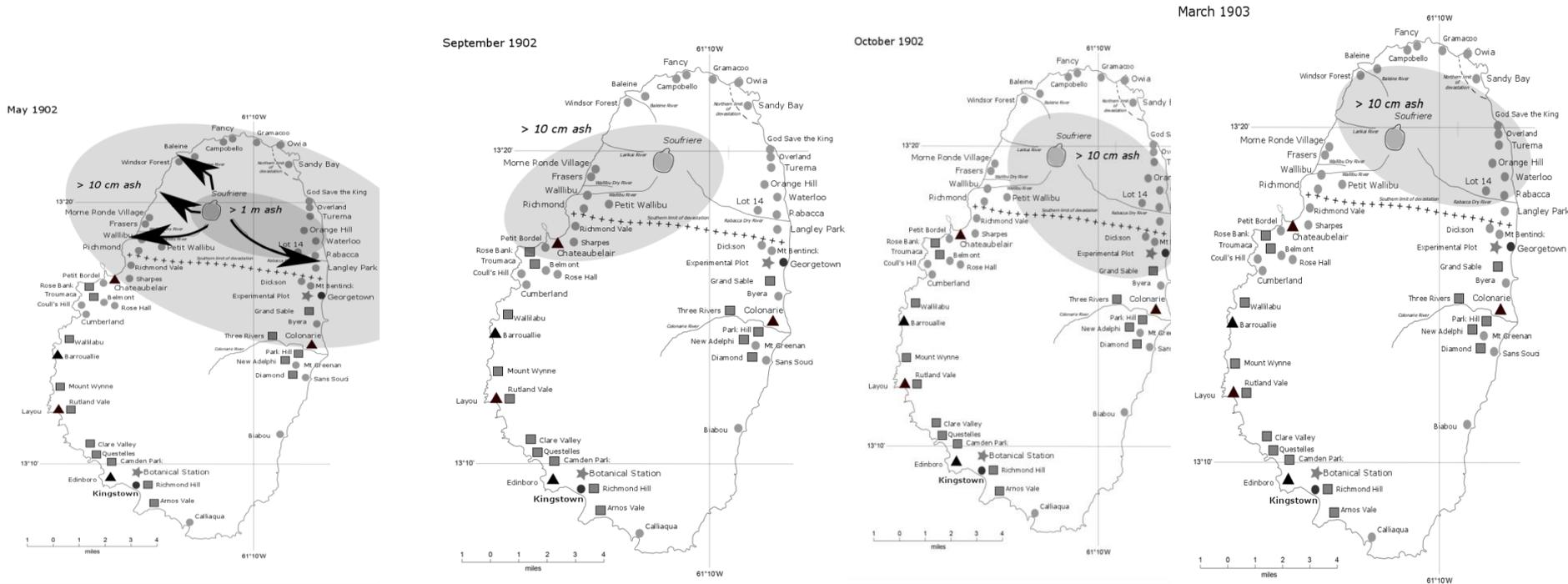
Larger than any of
the explosions in
1979



Reconstruction of where ash fell (May 7th 1902)



10 cm ash 'contour' illustration of variability from differing prevailing conditions and eruption size



On St. Vincent (May 7th)

- Official accounts
- Small amounts of ash falling nr Georgetown by midday
- Ash detected on Leeward side of island evening before
- 'Lamps lit' in Kingstown at 4pm

Ashfall remembered

'My grandfather was born in the 1800s and he told us for days that they were going to the mountains and seeing this white thing on the plants and so on....'

From Barbados

- If sounds taken as height of eruption
 - + 2 hours becoming gloomy
 - +2.75 hours first fall
 - +4.5 hours 'quite heavy'
- 4 kg per m⁻² over **12 hours**



David Pyle, Natural History Museum Archive, London
170 km but still received cms of ash!

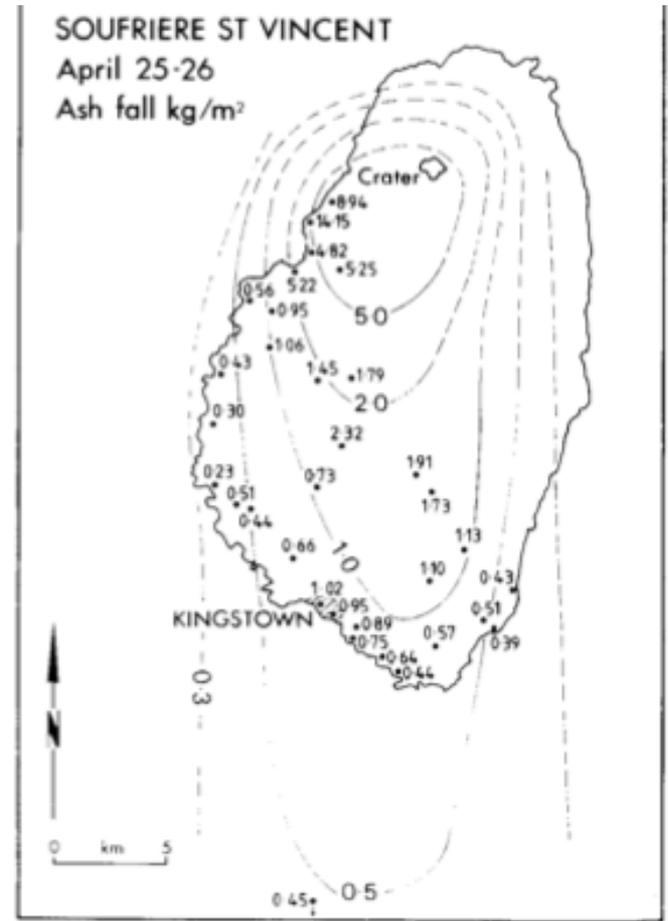
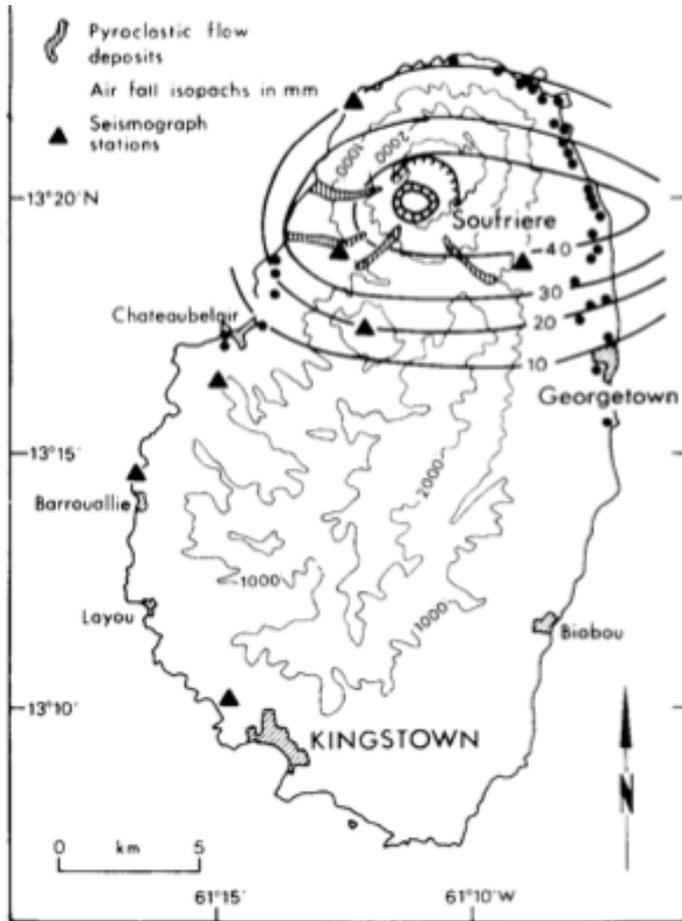
1979 eruptions



Smaller eruptions over a few weeks

13th, 17th and 22nd and 26th of April

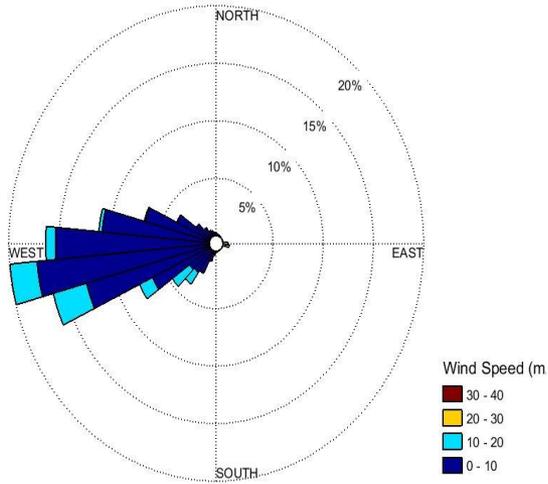
Observations in 1979



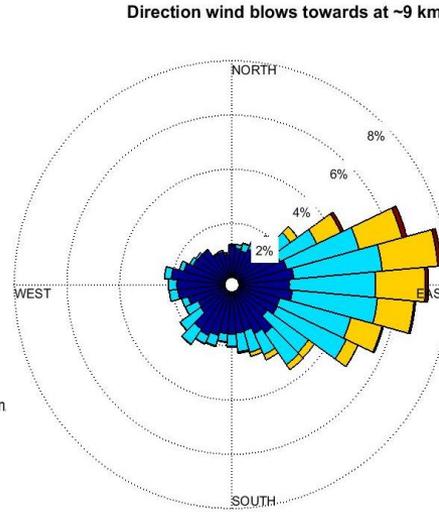
Modelling of ash dispersal

- *Tephra 2D and ASHFALL (outputs as kgm^{-2})*
- *WRF-CHEM (3D, outputs as kgm^{-2} and concentration over time)*

Winds at ~300 m

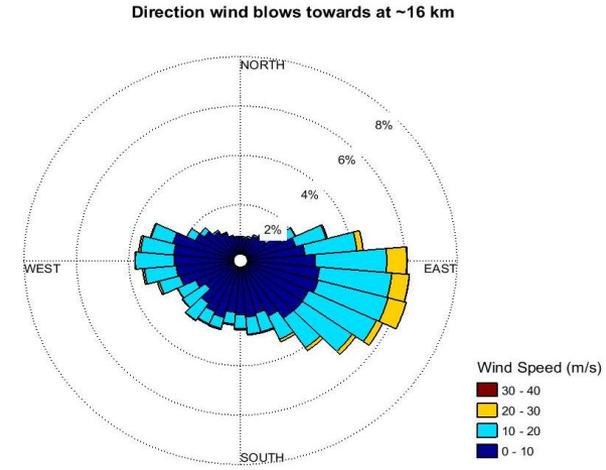


Winds at 9 km



Windrose code written by Susanna Jenkins

Winds at ~16 km

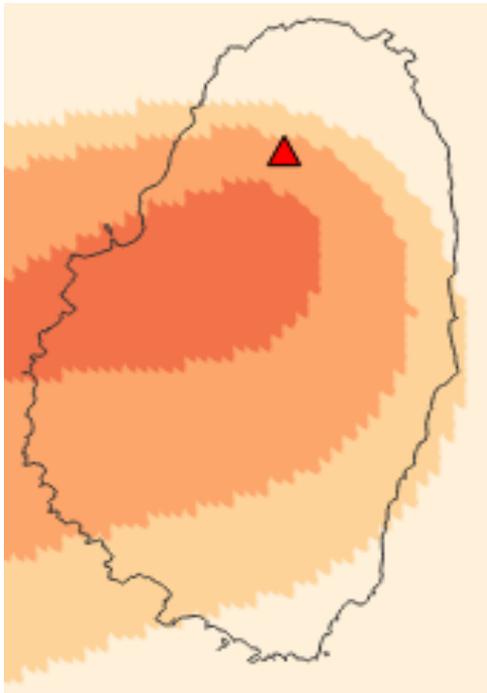


Windrose code written by Susanna Jenkins

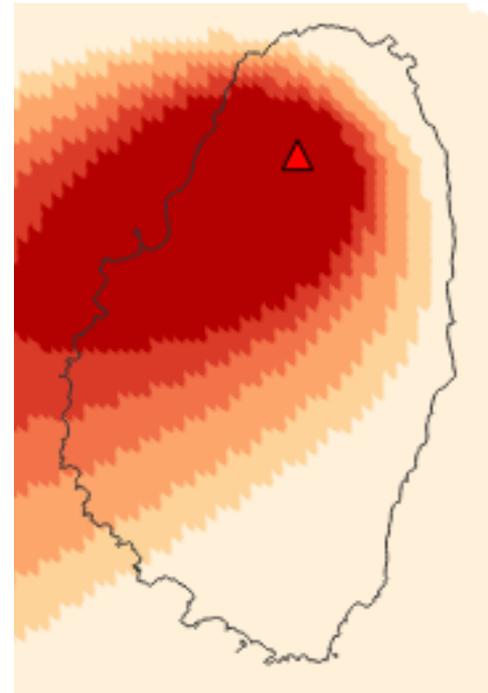
Using NCEP-DOE Reanalysis 2 data (1990-2011).

Show direction winds blow *towards*

Tephra 2D

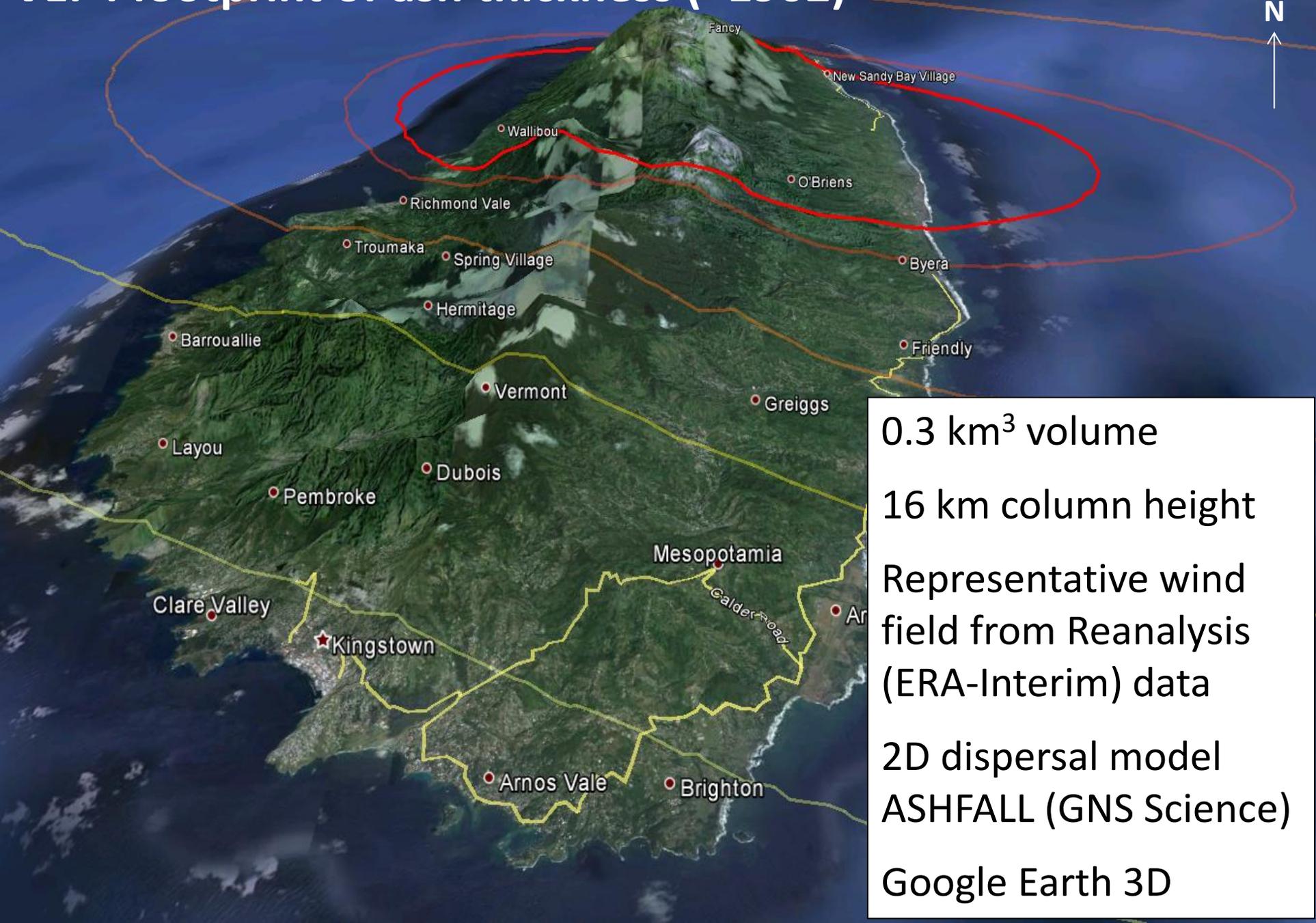


1979



1902

VEI 4 footprint of ash thickness (~1902)



0.3 km³ volume

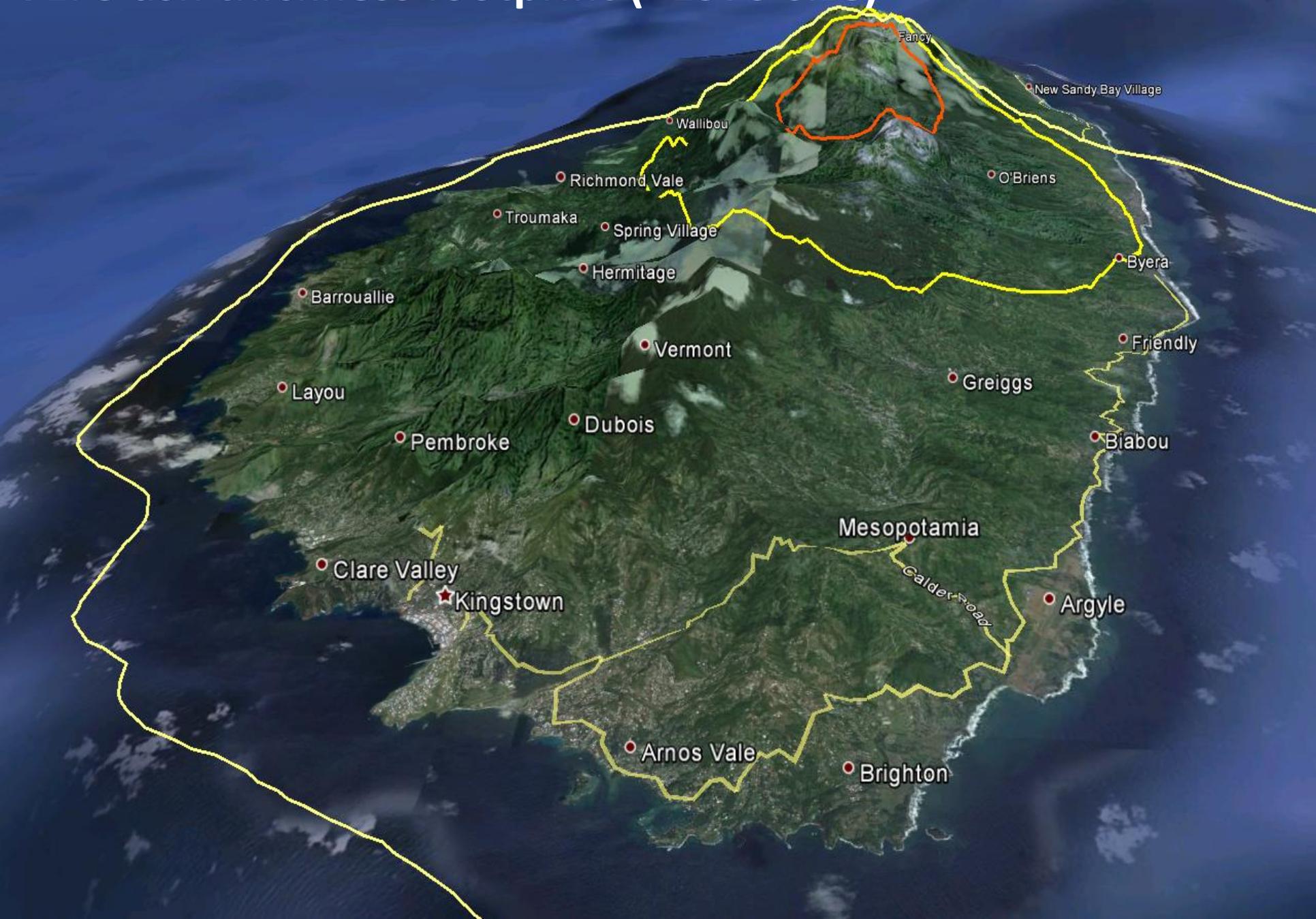
16 km column height

Representative wind field from Reanalysis (ERA-Interim) data

2D dispersal model ASHFALL (GNS Science)

Google Earth 3D

VEI 3 ash thickness footprint (~1979 size)



Detailed modelling of ash dispersal

- Ash dispersal prediction is typically carried out at ~10km resolution operationally and with ash modelling offline
- This leads to parameterising or neglecting of lower resolution processes and details
 - *Cloud formation*
 - *Local circulation*
 - *Terrain*
 - *Rainfall*
- Mesoscale models can be used with grid resolutions down to 30-100m
- How important are these extra details?

High resolution numerical modelling

Resolves
general
atmospheric
circulation

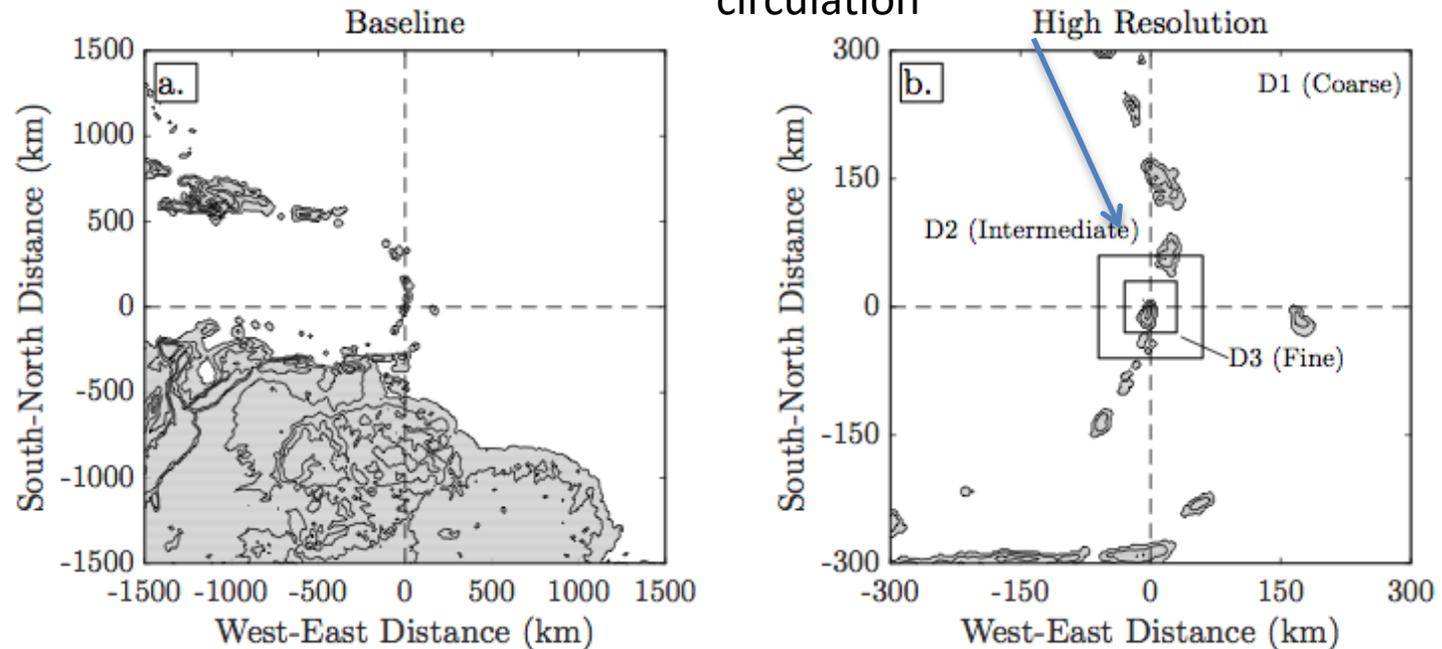


Figure 2: Model domains used in the simulations. (a) Baseline simulations ($\delta x = 10$ km). (b) High resolution simulations (δx starts at 2.7 km for the coarse domain, and the lowers to 0.9 and 0.3 km for the intermediate and fine domains respectively). Gray shading indicates land. Contours at 1, 100, 500, and 1000 m.

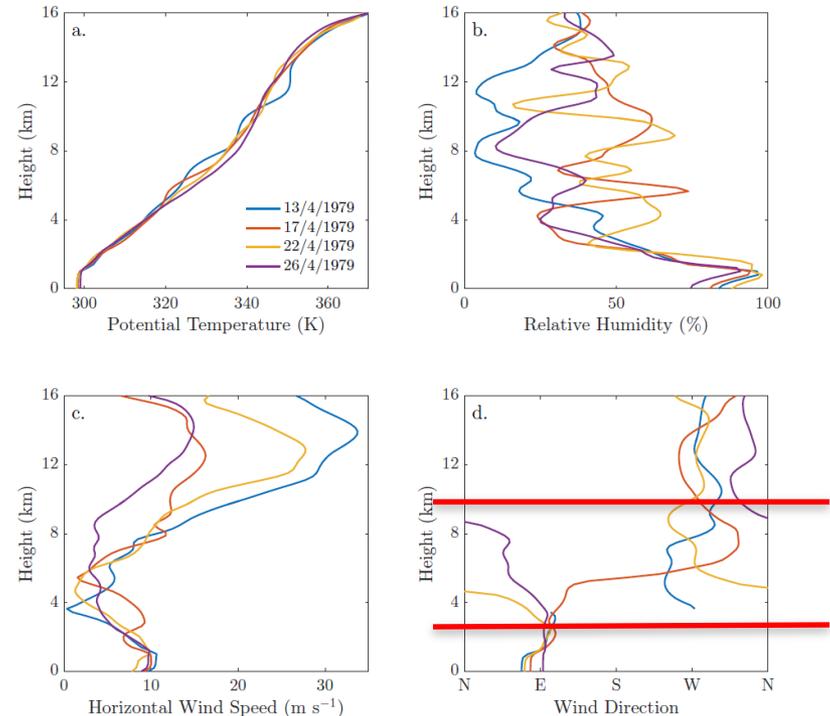
High resolution numerical modelling of ash

VOLCANIC DUST SHOT UPWARD.

On the occasion just referred to there was another phenomenon which has again been witnessed during the outbreak of the St. Vincent Soufriere. An enormous volume of volcanic dust was shot high into the air—it attained a height, it has been estimated, of fully 16,000 feet—where it was taken up by the counter currents, and wafted across more than a hundred miles of water, in a direction directly contrary to that of the prevailing trade winds, and then deposited, in the shape of an impalpable powder, as dark and fine as lampblack, on the Island of Barbados and the surrounding sea. The same phenomenon was noted during the late explosions, when a great shower of volcanic dust made its way eastward from the crater of the Soufriere to the island standing isolated far out at sea, although the trade winds were blowing steadily all the while towards the southwest.

For two years the scientific corps of the Weather Bureau at Washington has been engaged in studying the direction and force of these upper air currents, and the phenomena connected with the eruptions of Mt. Pelée and the St. Vincent Soufriere will

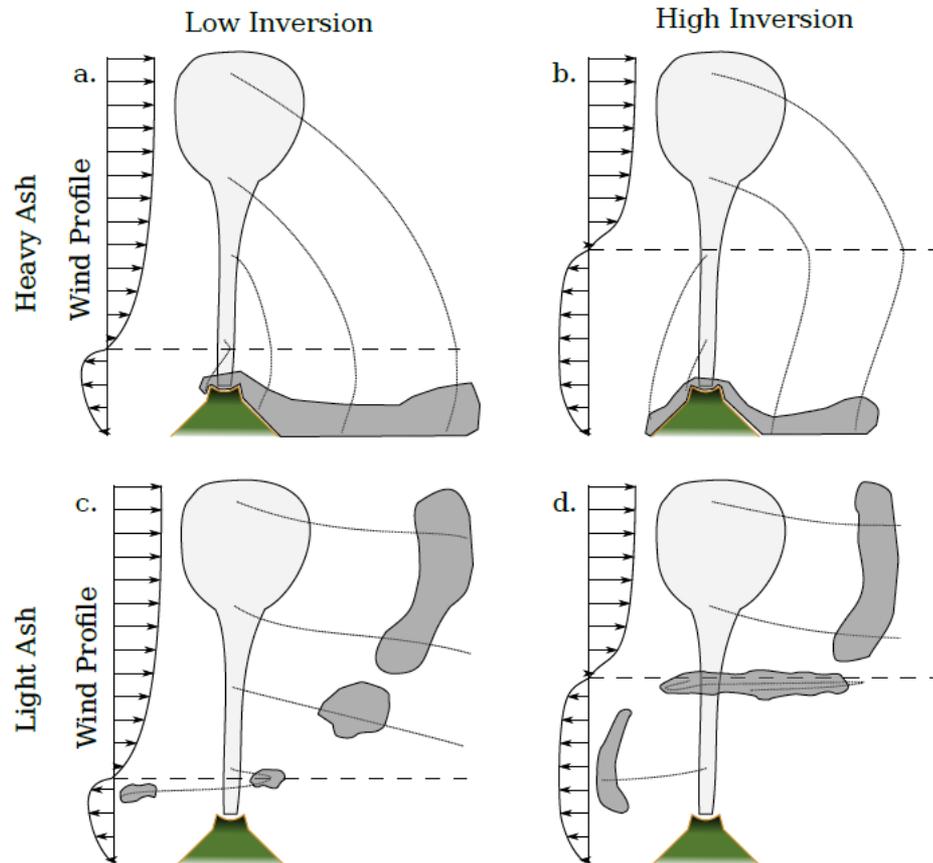
J. Miller (1902)



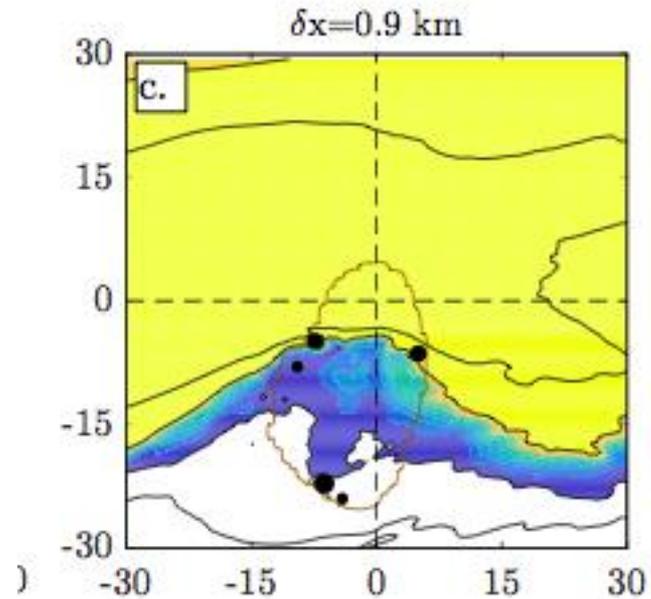
Strong shear in layer 4-8 km, needs good vertical resolution, varies with windspeed

Poulidis et al., 2015 report and in prep.

Secondary maxima and enhanced dispersal times



More anomalies: 1902 Ash Fall on Barbados



Distal ashfall

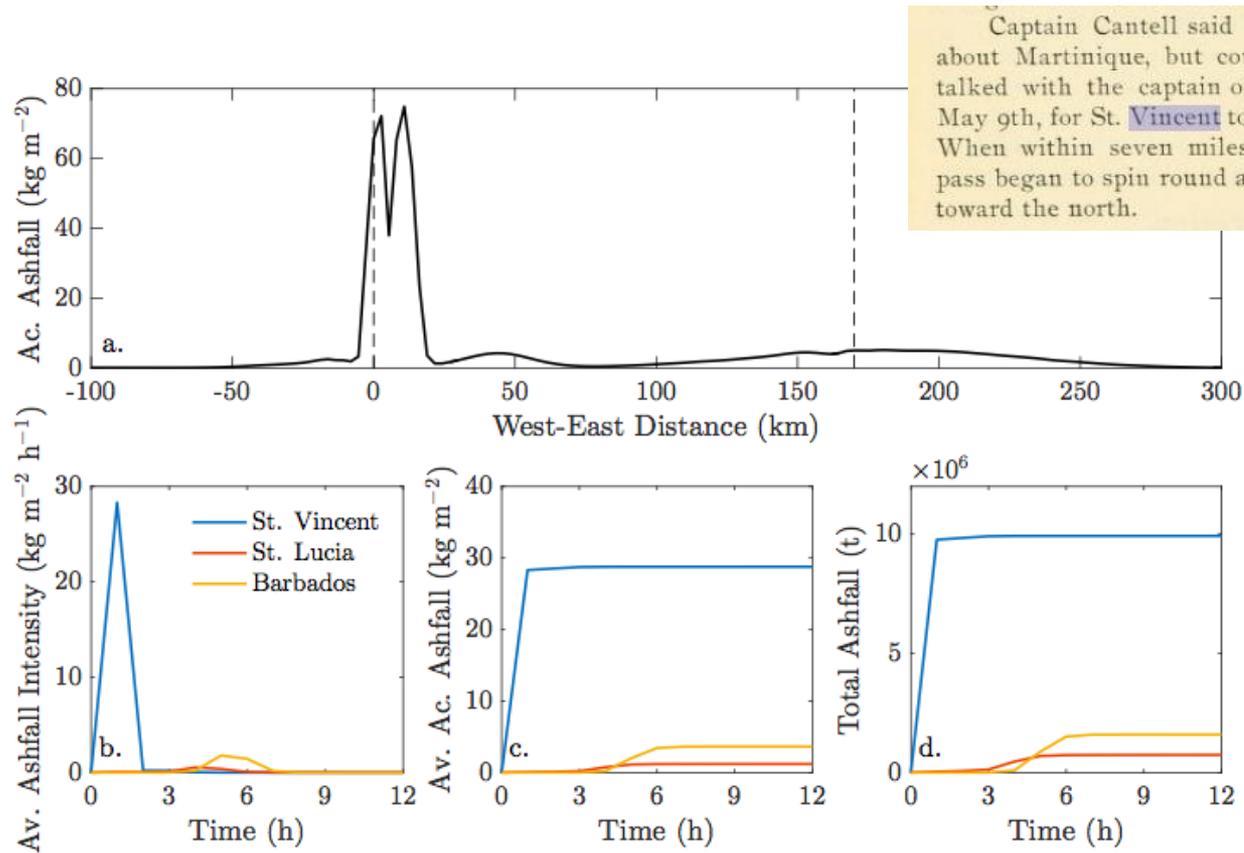


Figure 13: Controlled eruption, $H_p = 16$ km, $\delta x = 2.7$ km. (a) Total ashfall distribution at 24 h after the eruption across the West–East direction at the middle of the domain (over La Soufrière). (b) Ashfall intensity, (c) average ashfall, and (d) total ashfall over the islands of St. Vincent, St. Lucia, and Barbados against time.

Key Research Findings

- We understand a lot more about how ash was be distributed in 1902 and 1979 (and their impacts)
- We have models that do ‘a good job’ of reproducing that
- We can ‘forecast’ ash dispersal and arrivals but know each eruption will be different
- We can present this data in lots of different ways and would like your opinion about what is most important and the best way to do it for your needs

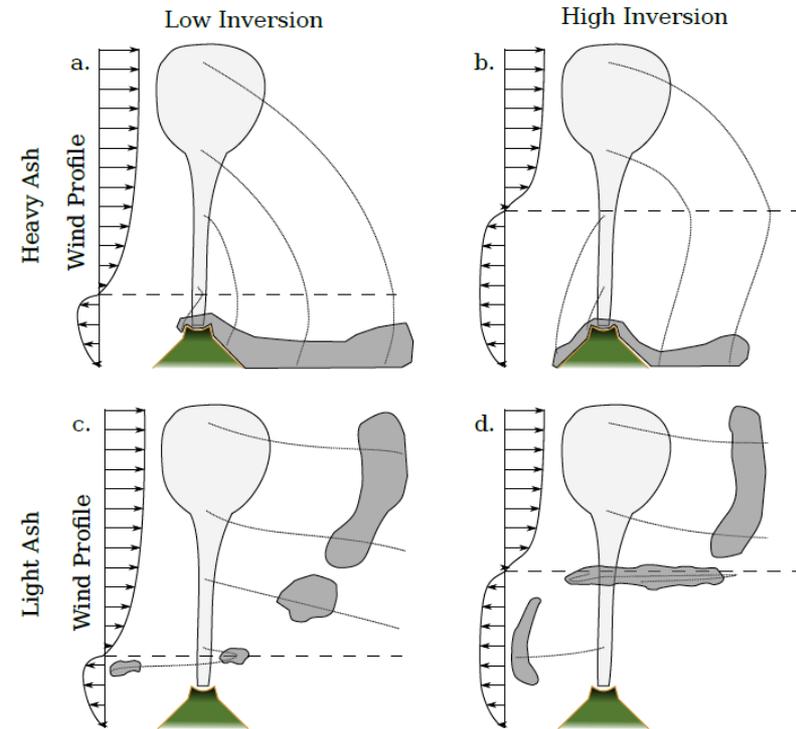
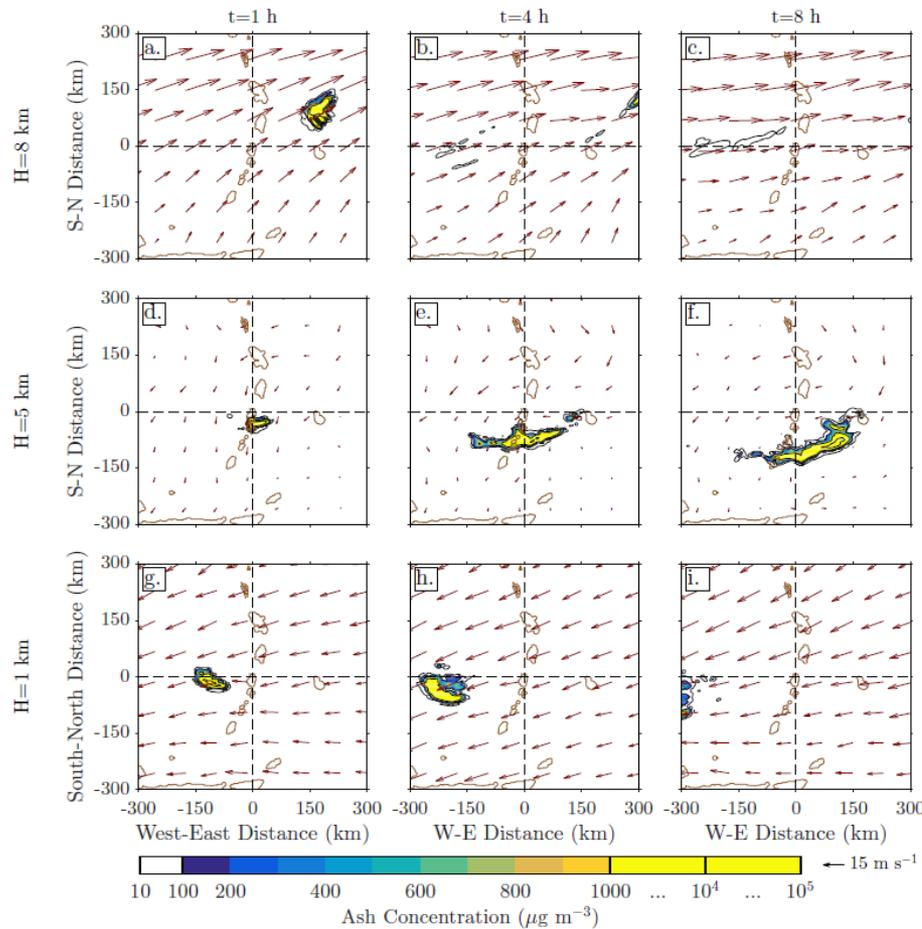
How do we apply these lessons?

Conclusions

‘Forensic analysis’ has not only extended our understanding of the drivers of volcanic risk; but has broadened our perspectives on the physical hazards and sign-posted the way for greater leaps in our understanding of the most important processes during an eruption.’



Secondary maxima and enhanced dispersal times



Other Significant Hazard	Historical Event	Eruption	Geological Advance
		1718	
	1719 Caribs invited French to settle		
	1763 handed to UK, surveyed and land sold – fighting with Caribs (1779 French rule)		
	1783 Treaty of Versailles (UK colony)	1784 recognition of 2 small lakes	1785 Hutton's 'Theory of the Earth'

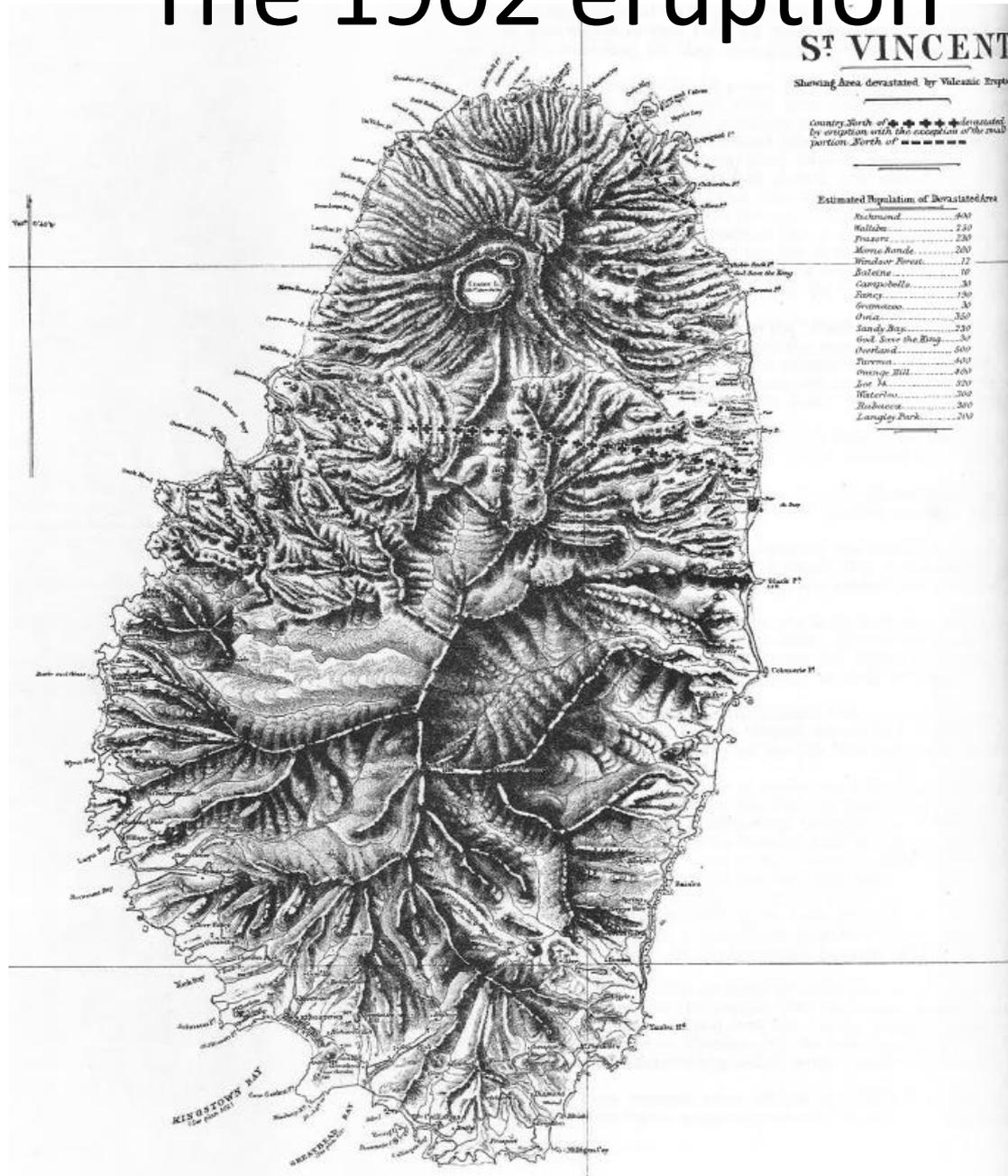
Past eruptions



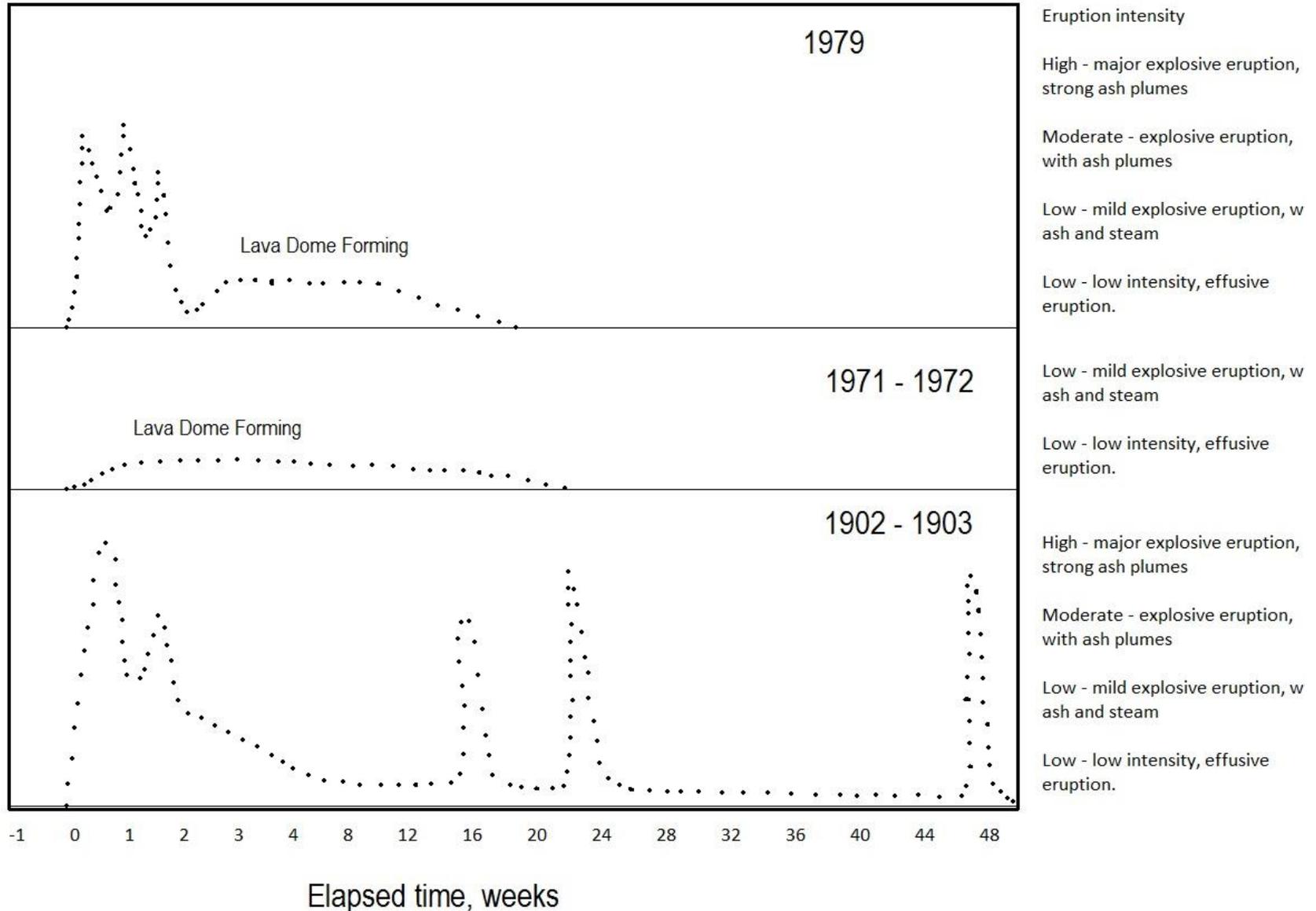
St Vincent Botanical Station, 1850's

- March 26, 1718, explosive
- April 27, 1812, explosive
- May 7, 1902 – March 1903, explosive
- October, 1971, effusive
- April 13-26, 1979, explosive, followed by 6 months of lava dome emplacement

The 1902 eruption



The 'eruption cycle' on St Vincent



1902

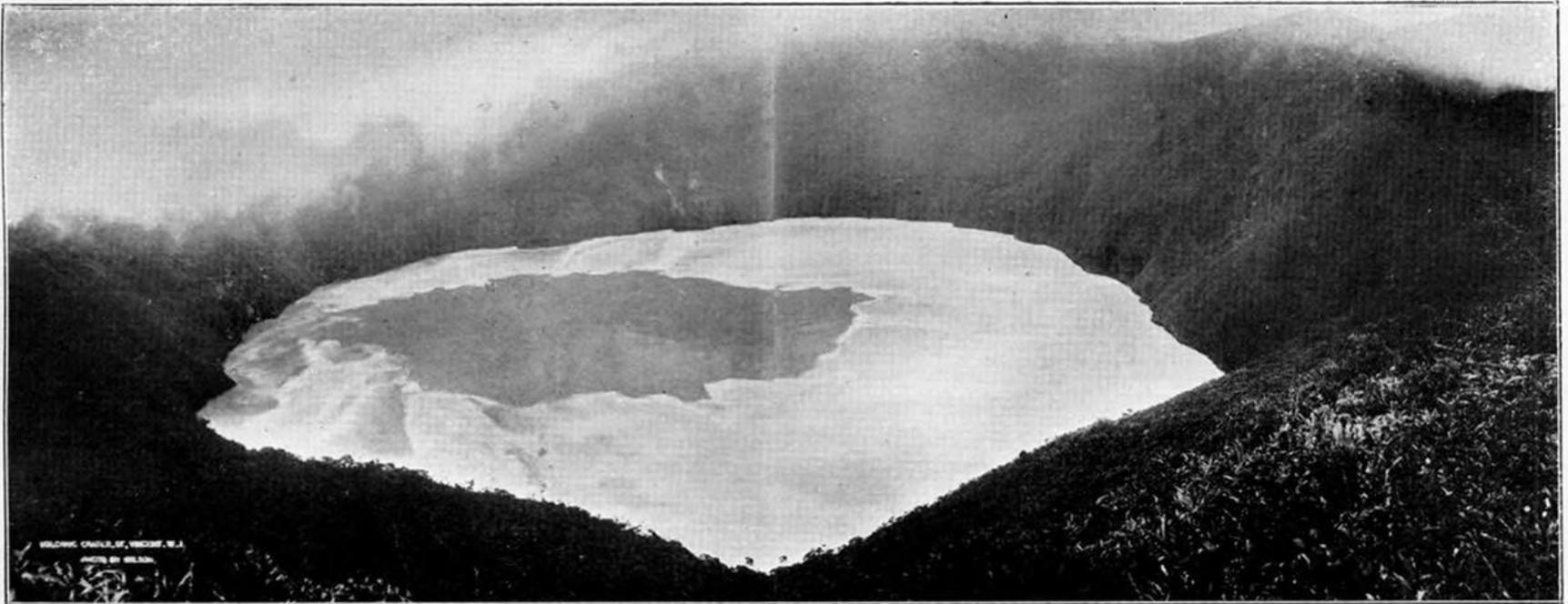


Fig. 2.—Soufrière crater lake before eruption.

(Photo. by J. C. Wilson, Kingstown.)

Magistrate's report, May 8, 1902

28

POLICE MAGISTRATE, 2nd District, to ADMINISTRATOR.

His Honour

THE ADMINISTRATOR,

ABOUT half an hour after I spoke with you by telephone there were several outbursts of flames of fire from the top of the mountain, followed by stones the size of a man's fist, and larger, showering down in large quantities.

At 2.30 p.m. the whole country was in entire darkness, fire all the time being emitted from the mountain top; the darkness never cleared up, and there was no telling whether it was night or day except by reference to the clock. The scene was more than I can express, and the terrified condition of the people can better be imagined than described—the whole place is covered with lava and sand 12 to 14 inches in depth.

Over 300 people are in Georgetown at the school house, and other places, and you may be assured that I shall be up and doing all I can to relieve them.

Several houses in the vicinities of Dicksons, Rabacca and Byera are destroyed, and several deaths have taken place; at present I have heard of about 30.

The arrowroot works at Rabacca partly destroyed and the Bay Store completely destroyed. It is quite impossible for me at this time (2.15 a.m., of 8th May) to give anything like a full account of damage done, not being in a position to do so, but I shall, as soon as I am able to ascertain, write you fully.

H. B. I.

May 8, 1902.

P.S.—I shall be glad to have whatever food supplies Your Honour can send me.

H. B. I.

THE NATION'S SYMPATHY.

Mr. McRae, of Georgia, said he was glad to believe that the people of the United States were willing that Congress should not only express their sympathy with suffering, but that they were willing that Congress should extend the proposed relief. He hoped that the bill would be passed unanimously, but if that could not be done, that it should be passed speedily. [Applause.]

Mr. Livingston, of Georgia, said that it had been the practice of the United States ever since the Republic was established, to extend aid to the suffering, even to the uttermost parts of the earth, and he did not believe that the policy would now be reversed. [Applause.]

The bill was passed—196 to 9. The negative votes were cast by Messrs. Clayton of Alabama, Burgess and Lanham of Texas, Gains, Moon and Snodgrass of Tennessee, Tate of Georgia, Underwood of Alabama, and Williams of Mississippi.

International
competition over
provision of 'relief'

CONTRIBUTIONS IN LONDON.

Mr. Chamberlain contributed \$250 to the Mansion House West Indian relief fund. Much satisfaction was expressed at the opening of the Mansion House West Indian relief fund, while the tardiness of the action taken by the authorities was adversely commented on. Thus, the Westminster Gazette said.

"Once again, in the cause of charity, our kinsmen across the Atlantic have gained a substantial start, and have set the Old Country an example of swift and magnificent generosity, from which we might well benefit."

Capitalists were somewhat slow in subscribing to the Mansion House fund. Only \$25,000 had been received, of which amount the Bank of England contributed \$5,000 and the Corporation of London \$2,500.

St. Paul's Cathedral and other churches arranged for special collections on Sunday in aid of the fund.

The 1902 eruption of the Soufriere, St Vincent



Impact of the pyroclastic density currents, from Flett and Anderson (1902)

Aftermath - 1902 recorded by Tempest Anderson



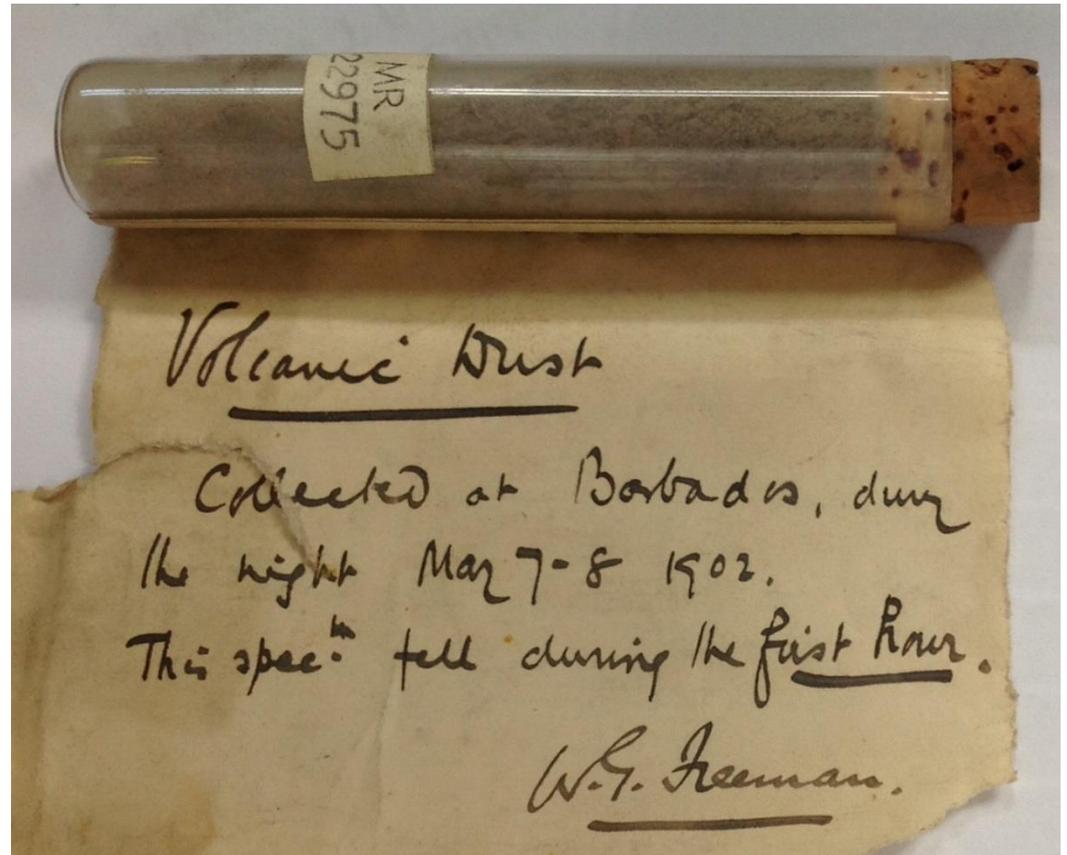
May 1902 Ash fall

[Barbados, 10 May 1902]

I.. forward .. herewith an extract from the "Agricultural News" .. respecting the fall of ash that occurred on this island between 4 pm on the 7th until 5 am on the morning of the 8th..

There is little doubt that this ash was brought by an upper current of wind from .. St Vincent..90 miles to the West of Barbados. ..

With the view of obtaining the fullest information .. ash samples are being communicated to Professor Judd .. of the Royal College of Science, South Kensington



British Geological Survey Archive

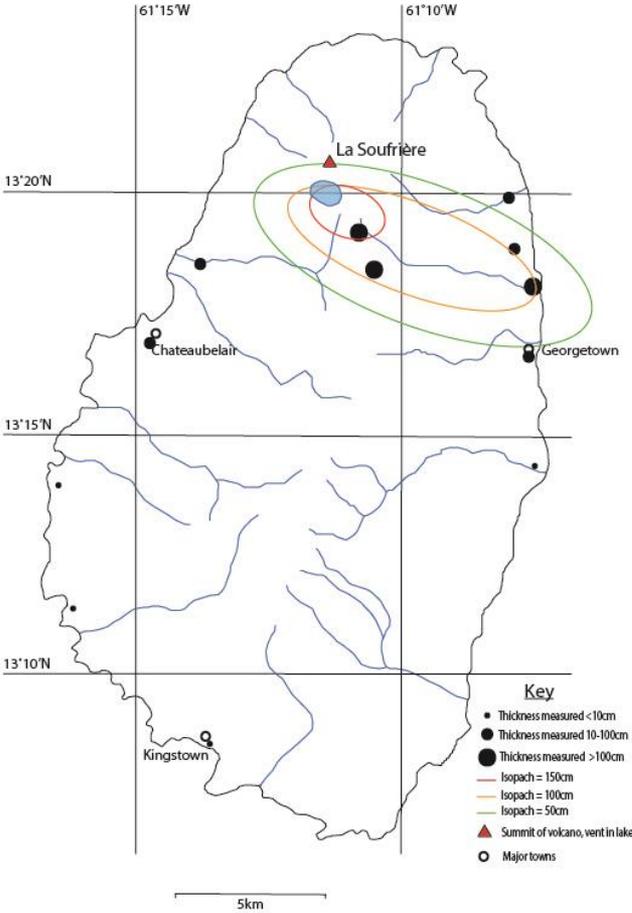
19th Century Eruptions

- 1812 Eruption (VEI 4)
- 1834 Slavery abolished
- (Portuguese and East Indian immigration)
- ?1880 Eruption



William Turner

May 7 1902 Ashfallout



Note that template map sourced from: <http://www.sogival.com/en/destination/58>

1718 – ‘that the island of St Vincent .. is turn’d in to a Vulcano or burning mountain’ [Daniel Defoe]

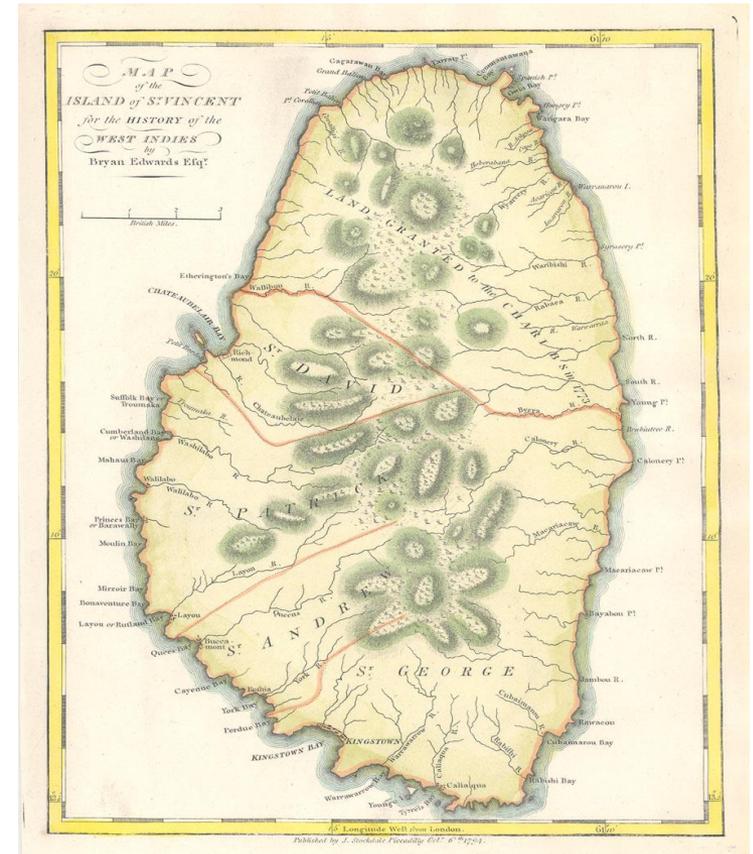


THE DESTRUCTION OF THE ISLE OF ST VINCENT

(From “Mist’s Journal,” July 5, 1718.)

WE have a piece of public news this time of such consequence, and so necessary for all our readers to be fully acquainted with, that our friends who have written several letters to us, which otherwise deserve publishing, must excuse us for this week.

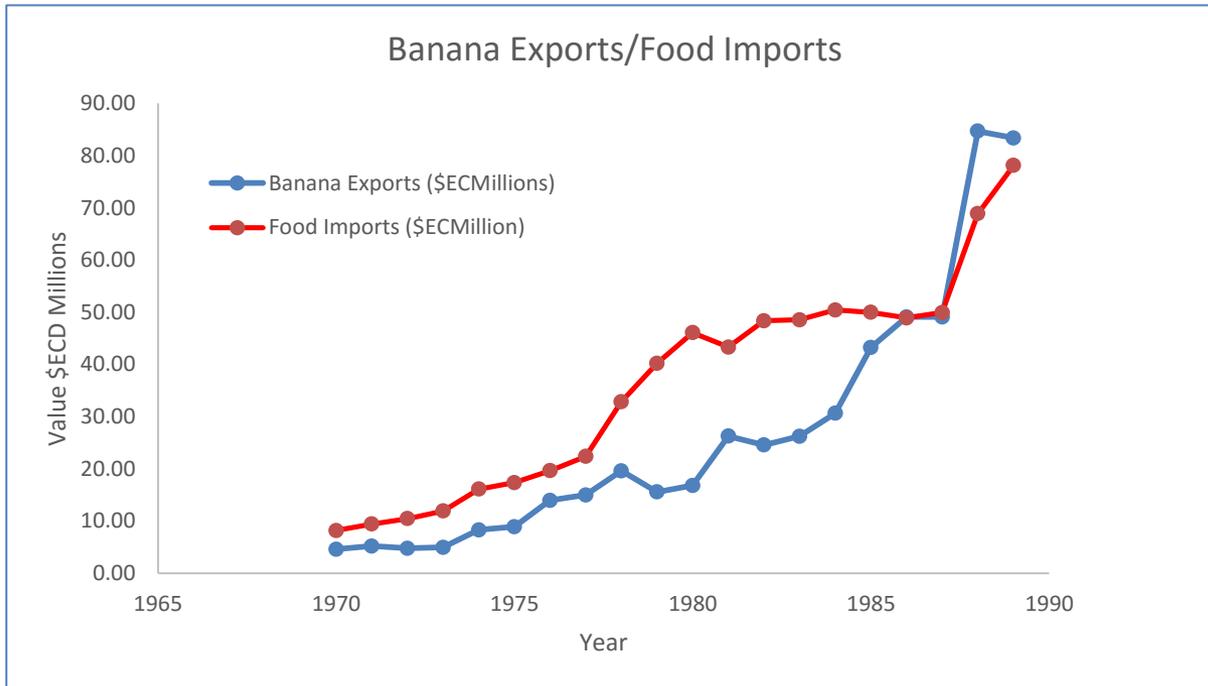
This relates to the entire desolation of the island of St Vincent, in the West Indies, by the immediate hand of Nature, directed by Providence, and in a manner astonishing to all the world, the like of which never happened since the Creation, or, at least, since the destruction of the earth by water in the general Deluge.



Map of St Vincent, 1794.

University of Illinois Rare Books Library.

1718 eruption, described by Daniel Defoe.



(Grossman, 1993)

The 1812 eruption of St Vincent

Diary of Hugh Perry Keane.

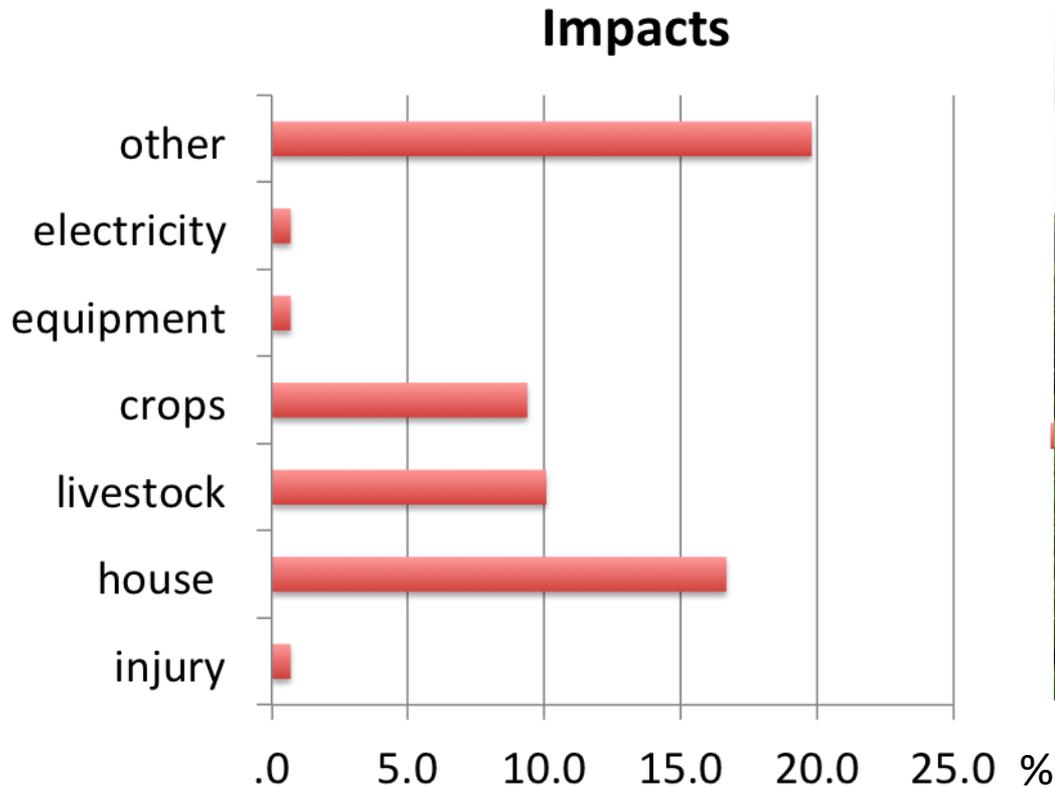
St Vincent, Thursday April 30th,
1812.

In the afternoon the rousing of the Mountain increased and at 7 o'clock the flames burst forth and the dreadful eruption began. All night watching it between 2 & 5 o'clock in the morning showers of stones & earthquakes threatened our immediate destruction.



Painting of the 1812 eruption by JMW Turner, based on a sketch by Hugh Perry Keane

1979 – Impacts – Ash was important



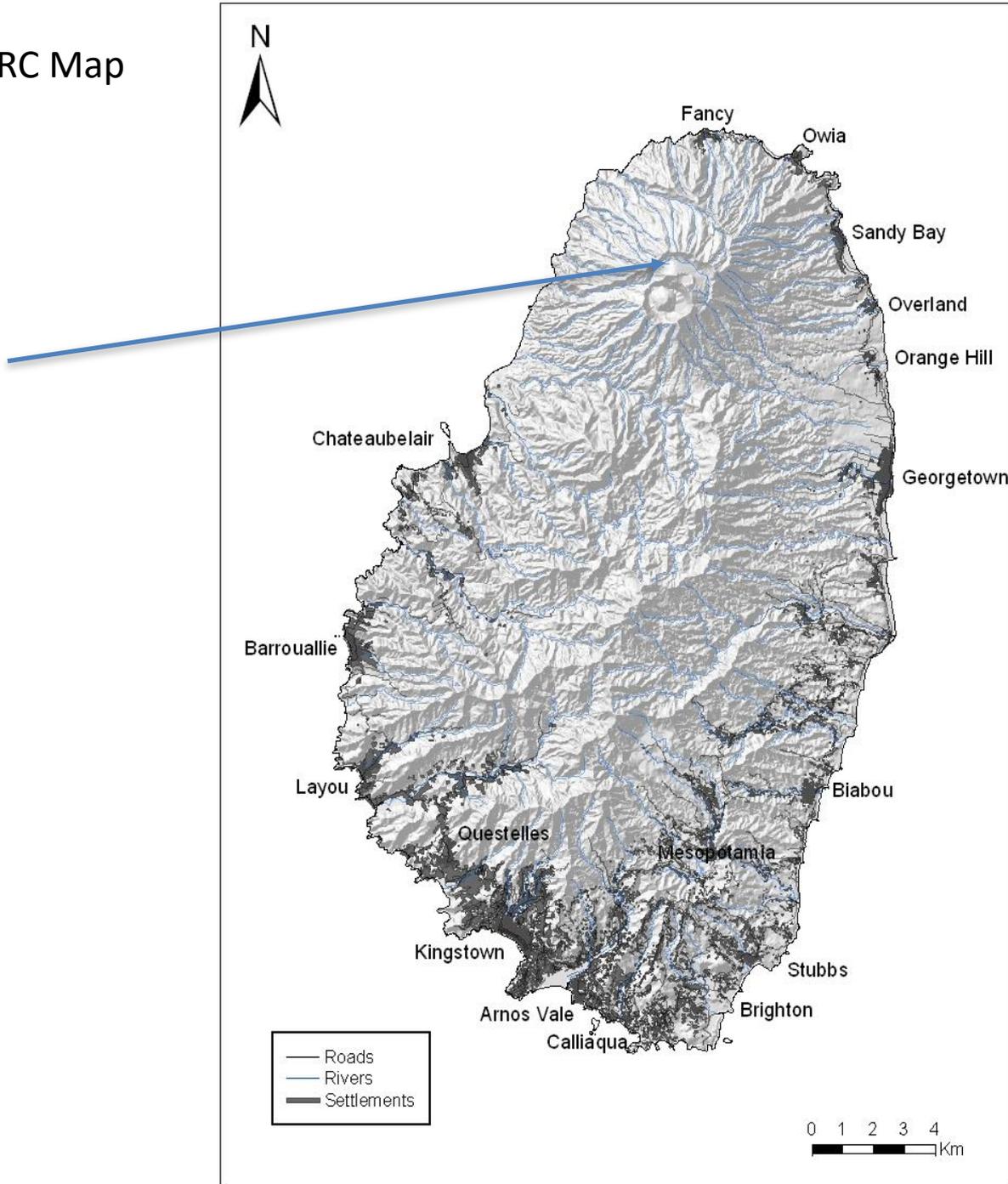
Teresa Armijos

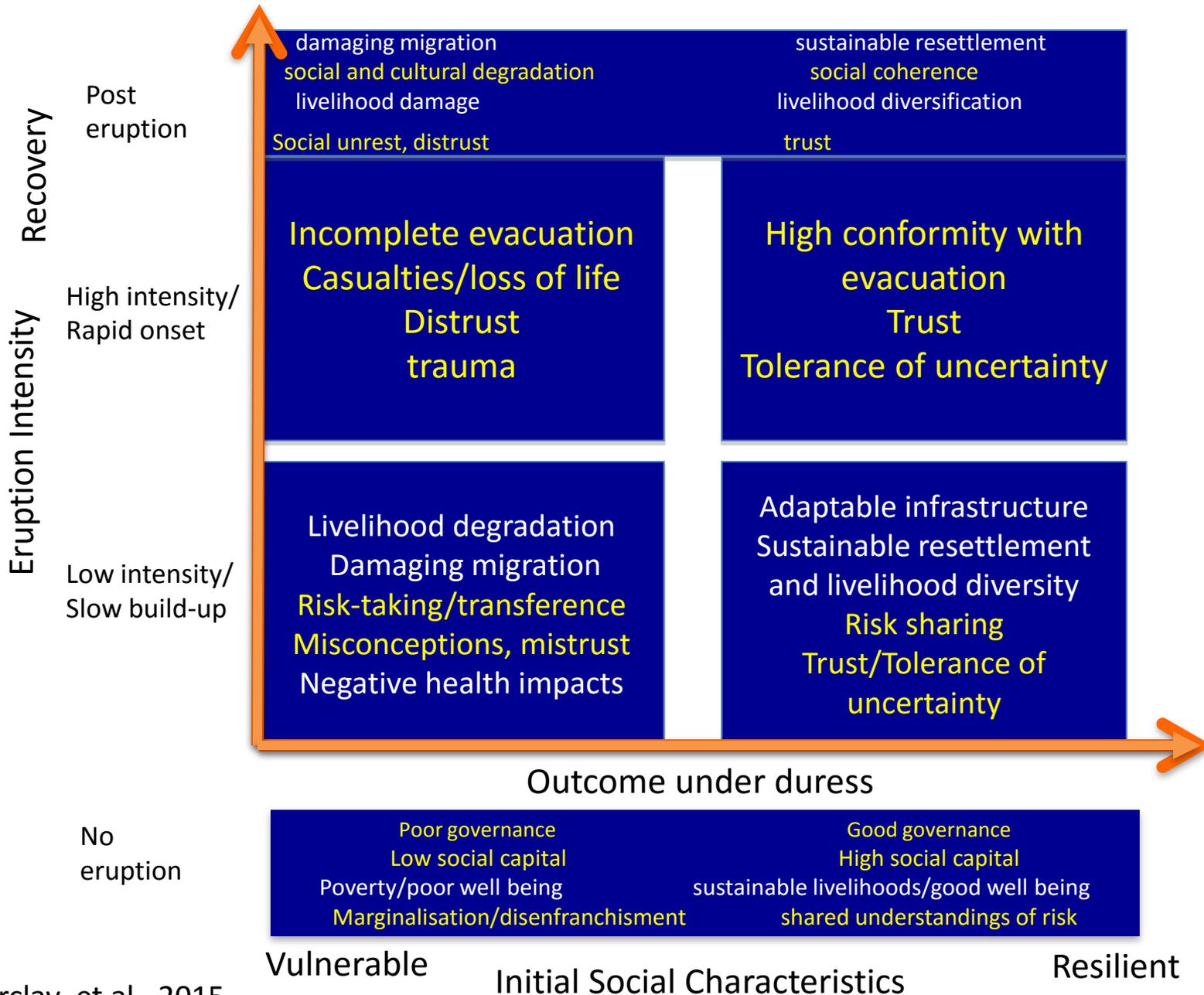
Compare: self-reported house impacts of 20% in 2013 floods and 39% Hurricane Tomas

Larger scale infrastructure damage esp. shelters

2015, SRC Map

New crater

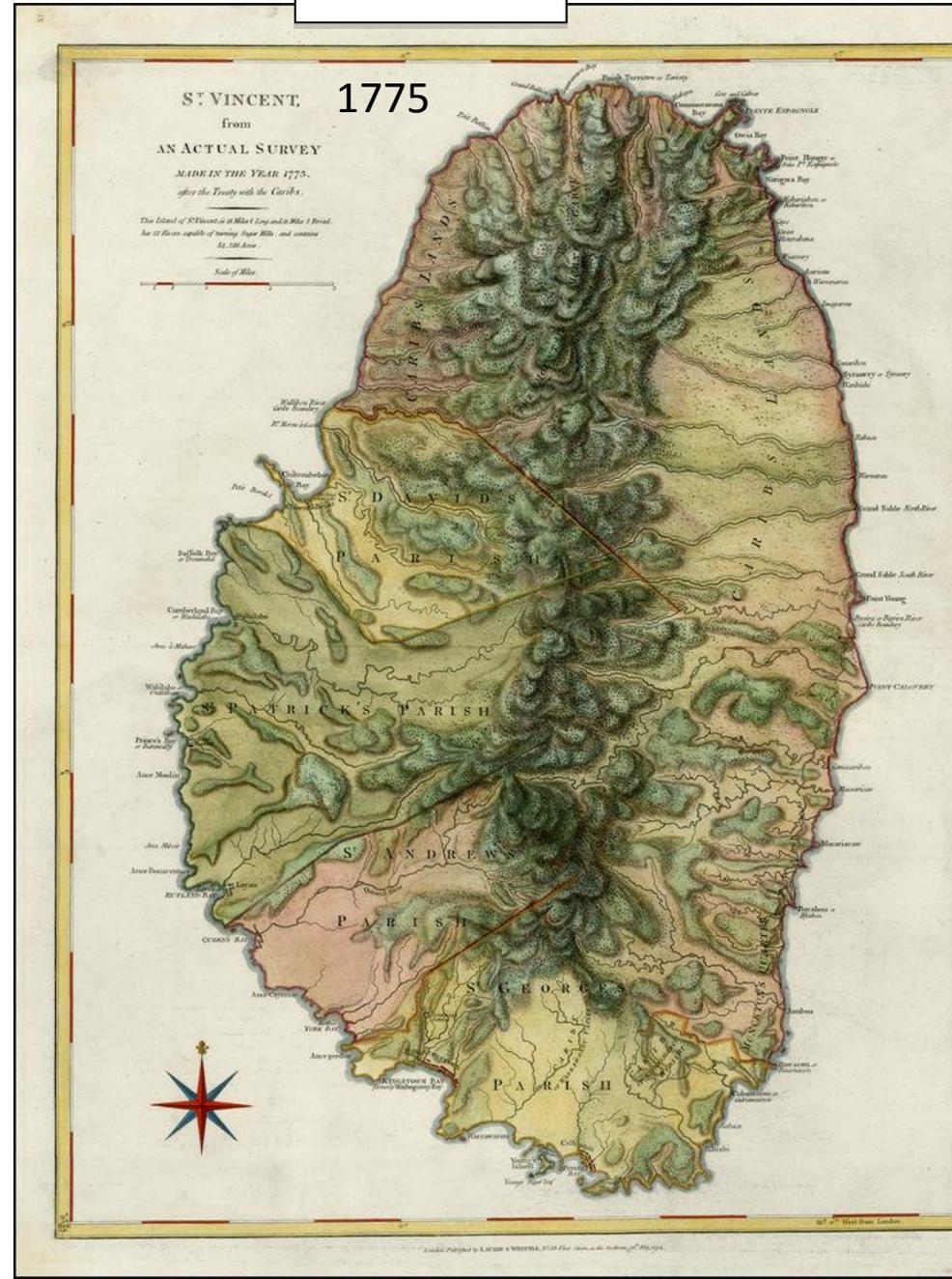




2015, SRC Map

NOW

THEN





Few and Hicks, 2015. J. App. Volc.