

# Adapting to changes in volcanic behaviour: formal and informal interactions for enhanced risk management at Tungurahua Volcano, Ecuador

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*Building Resilience to Geohazards in the Face of  
Uncertainty*

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# Adapting to extreme forms of environmental change

- How can communities adapt to extreme forms of environmental change and uncertainty over the longer term?
- Analyse the interactions between scientists, communities and risk managers in Tungurahua volcano – active since 1999
- Combine methodologies from different disciplines
- Examine the interpretation and communication of uncertain scientific information during a long-lived volcanic eruption
- Our study shows that a ‘shadow network’ has developed in interaction with the formal risk management institutions in Ecuador, improving decision-making in response to heightened volcanic activity

# Methods and Analysis

## Combining different disciplines



OBSERVATORIO DEL VOLCÁN TUNGURAHUA  
INSTITUTO GEOFÍSICO  
ESCUELA POLITÉCNICA NACIONAL



no supera los 100 m.

22h08 V. de Cusúa informa que observa una columna de emisión desde el sector.  
V. de Runtún informa que observa columna de emisión sostenida.

**Sábado 1 de Febrero 2014 (día 032)**

01h01 Ronda de vigías.

V. Manzano indica que en la tarde ocurrió 1 explosión con rodamiento de bloques.

V. Choglontus, indica que en la madrugada y noche se produjo la caída de ceniza. Se reporta un cañonazo en horas de la tarde. Después de ese evento, se produce la caída de ceniza **con tamaño de grano como el del azúcar**.

V. Bilbao indica que se escuchó un cañonazo en la tarde y se observa una columna de emisión pero no existe caída de ceniza en el sector.

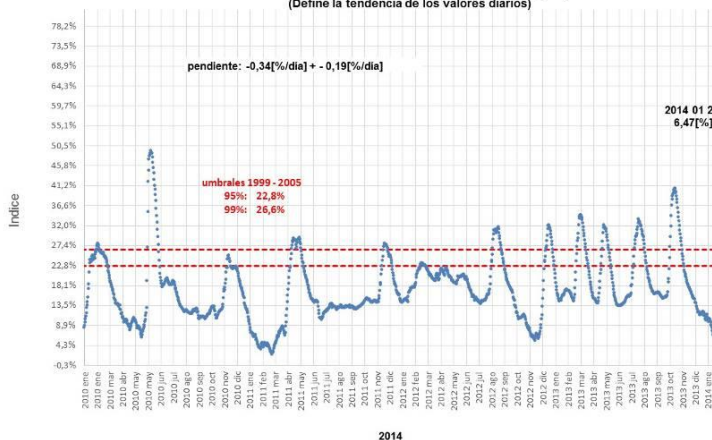
V. de Juive Chico, indica que se generó un hongo tras la explosión de alrededor de las 17h00 (TL) y la caída de ceniza al SE.

V. de Pondoá observó desde el sector la explosión de las 17h00 (TL) generándose una columna de vapor y ceniza que se dirigió al SE y SW. No hubo caída de ceniza en el sector.

V. de Pondoá indica relativa tranquilidad en el sector. Explosión a las 17h00 (TL) con carga moderada de ceniza.

- Interviews, survey and grey literature analysis
- Examine monitoring network evolution
- Instituto Geofísico reports
- Risk management and governance systems
- Analysis of communication and evacuation processes during crises
- Scientific papers on volcanic activity

TUNGURAHUA - INDICE DE ACTIVIDAD SÍSMICA (IAS)  
(Define la tendencia de los valores diarios)



IAS - Nivel de Actividad Sísmica

>= 8	Muy Alta	
7	Alta	
6	Moderada - Alta	
5	Moderada	
4	Moderada Baja	
3	Baja	
2	Muy Baja	
1	Muy Baja	

# Repeated shocks: changes in volcanic behaviour since 1999 and the need to adapt

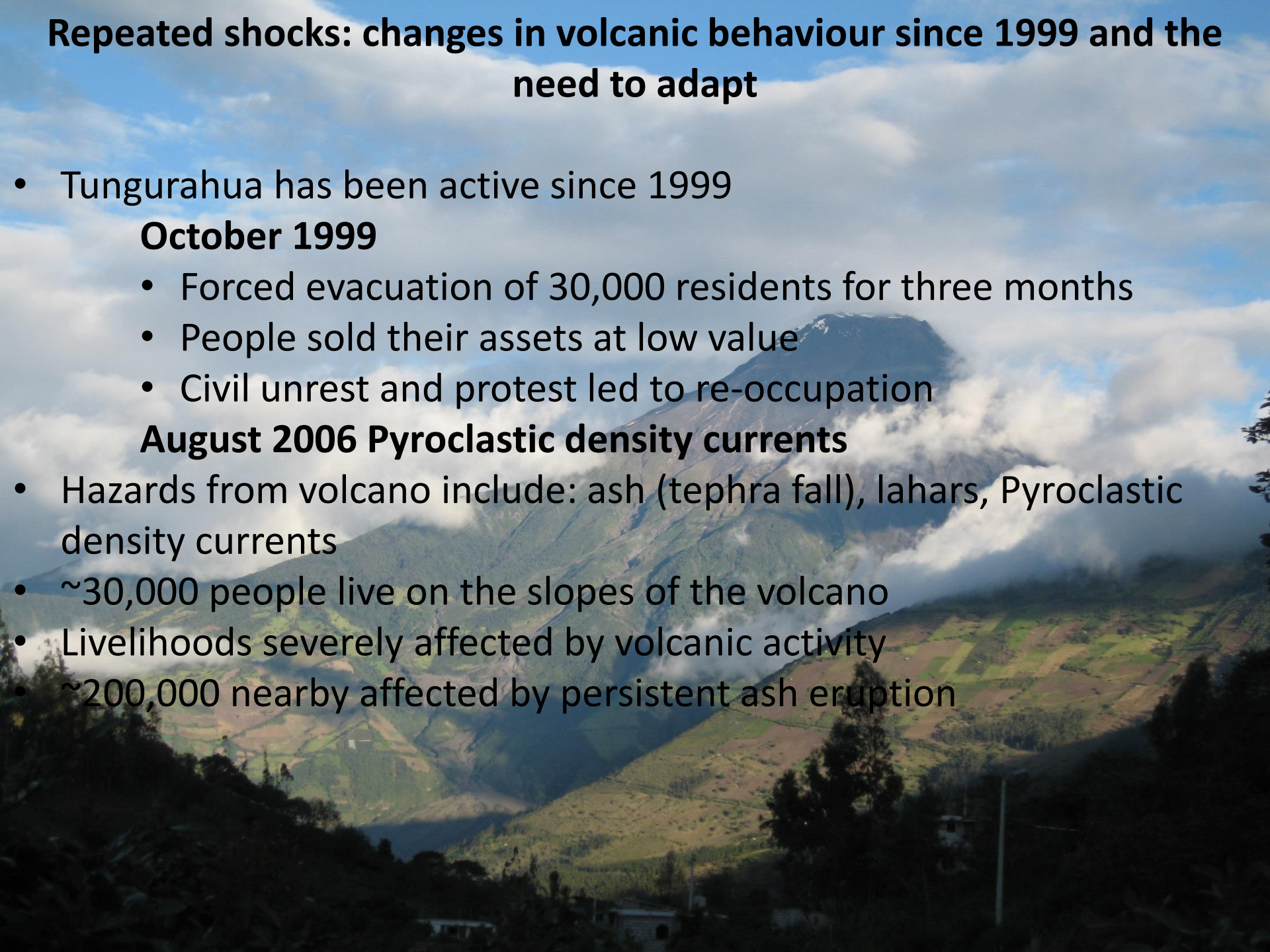
- Tungurahua has been active since 1999

## **October 1999**

- Forced evacuation of 30,000 residents for three months
- People sold their assets at low value
- Civil unrest and protest led to re-occupation

## **August 2006 Pyroclastic density currents**

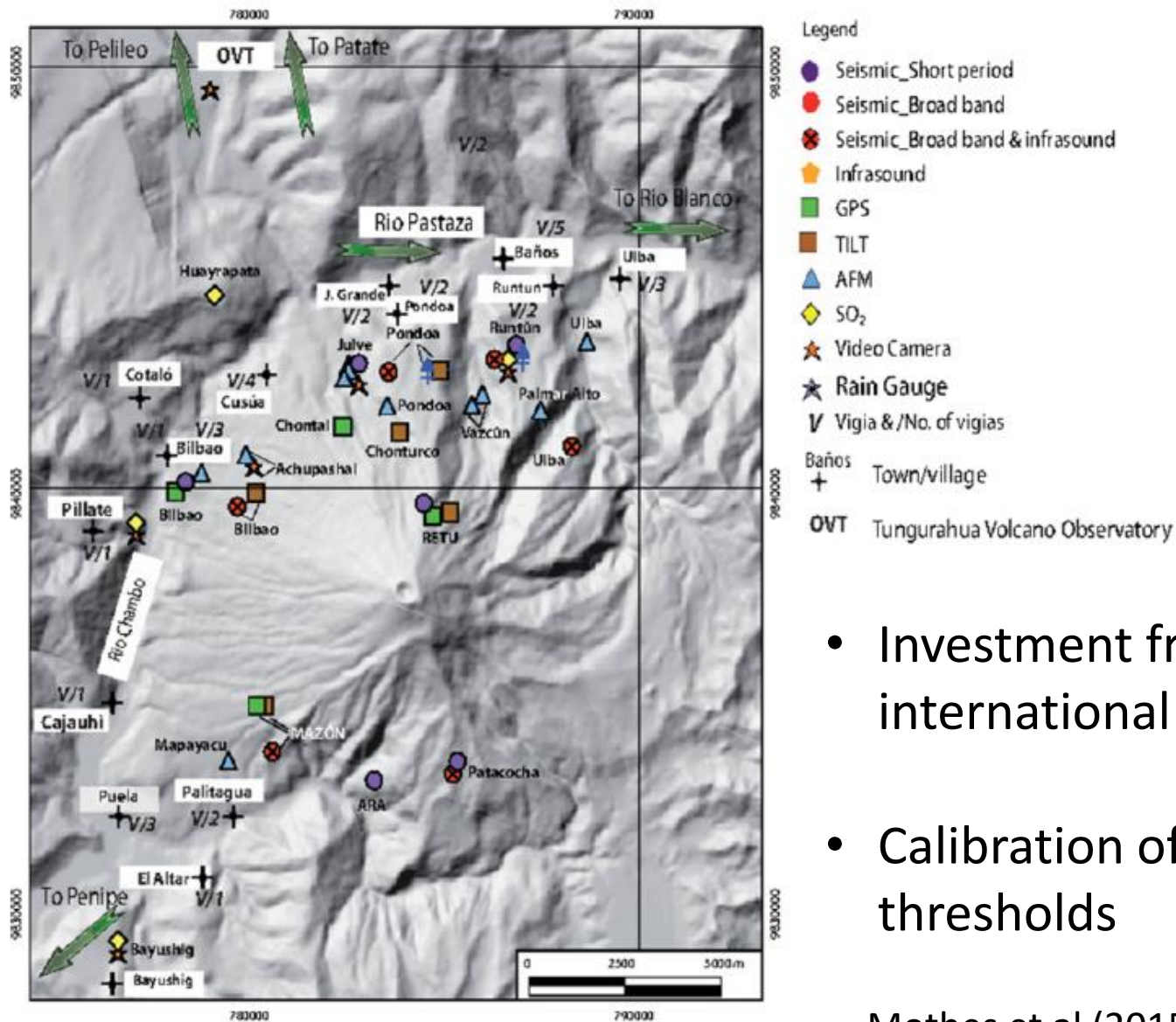
- Hazards from volcano include: ash (tephra fall), lahars, Pyroclastic density currents
- ~30,000 people live on the slopes of the volcano
- Livelihoods severely affected by volcanic activity
- ~200,000 nearby affected by persistent ash eruption



# Formal Risk Management – Creation of Observatorio del Volcán Tungurahua (1999)



# Formal Risk Management – Monitoring network developments (2002 – 2006)

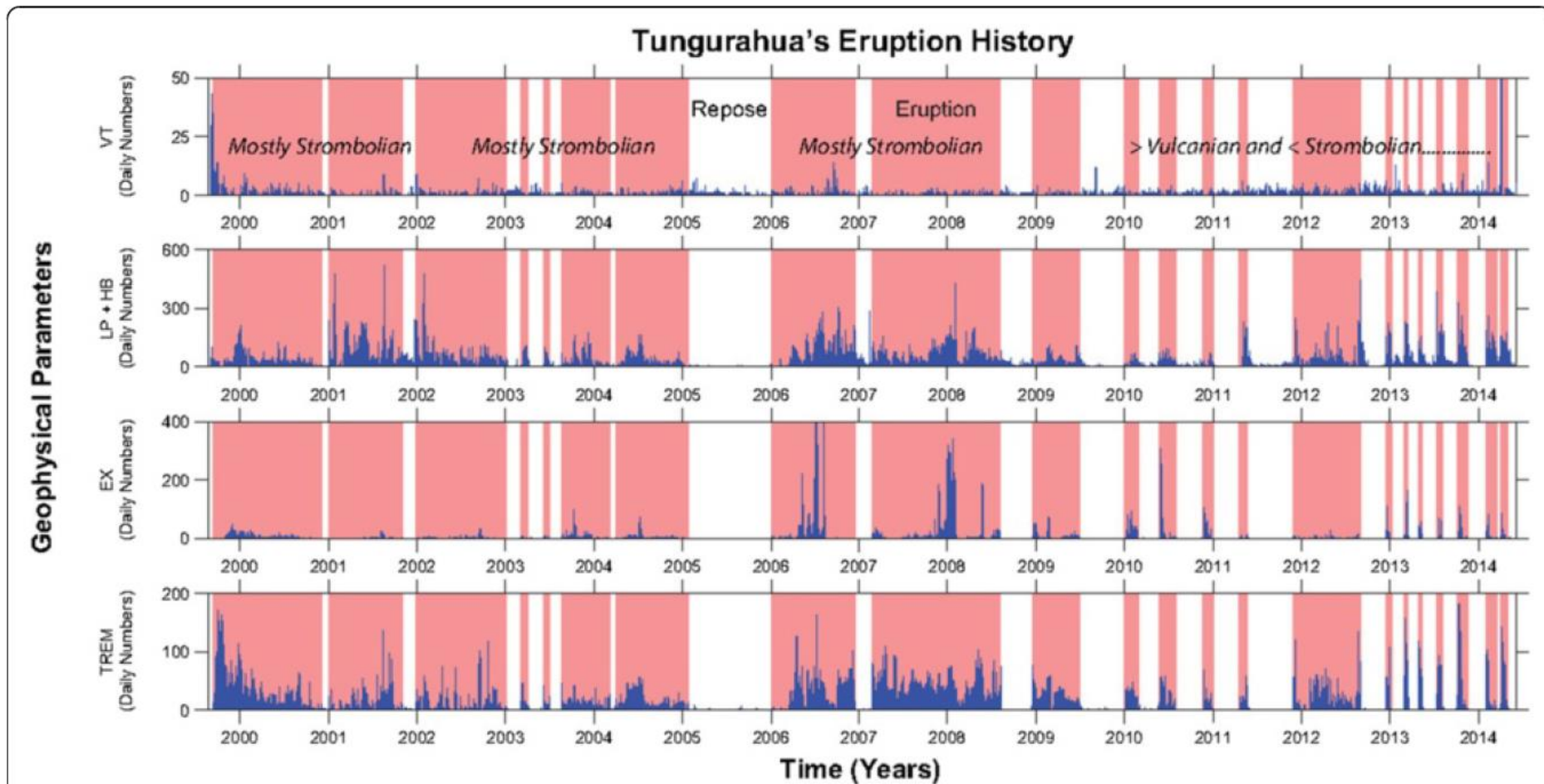


- Investment from international projects
- Calibration of instrumental thresholds

Mothes et al (2015)

# Formal Risk Management – Physical Volcanology

Mothes et al (2015)



**Figure 5** A timeline of Tungurahua's eruptive activity 1999–2014. Shown on the left margins are the daily numbers of seismic events: VT = volcano-tectonic; LP + HB = long period and hybrids; EX = explosions and TREM = volcanic tremor. Eruptive activity is represented by light pink color, while repose is represented by white. The activity was predominantly Strombolian-style through 2010. Vulcanian style was more predominant between 2010 to present.

# Informal Risk Management Vigía Network (2000)



- Vigías – community based volunteers supporting monitoring activities
- Early warning system
- Facilitate scientists-community communications
- Roles have developed with time
- Aid evacuation during crisis

Stone et al (2014), Mothes et al (2015)





# Informal system – shared language (2006)

Observations	Associated Surface Activity	Interpretation	Usage (from OVT reports)
'Bramidos' (roaring)	Smaller explosions	Repeated minor failures in shallow conduit (Strombolian jetting) <sup>1</sup>	July 2006 (largely by scientists) August 2006, February 2014
'Canonazos' (cannon fire)	Larger explosions	'Associated with high energy seismic outbursts' <u>Vulcanian</u> explosion from failure in shallow conduit <sup>2</sup>	July 2006 (largely by scientists; observers = ' <u>detonaciones</u> ':) August 2006, February 2014
'Movimiento de suelo' (ground movement)	Felt ground motion	Increasing intensity of seismic activity <sup>1</sup>	July 2006 August 2006
'La vibración de ventanales' (window rattling)	Explosions	Increased intensity of Strombolian jetting <sup>1</sup>	July 2006 August 2006
'Caída de ceniza negra y fina' (fine black ash fall)	Ash fall	Possibly new magmatic activity	February 2014
'Caída de ceniza con tamaño de grano como el del azúcar' (Ashfall with grains like sugar)	Ash fall	Increasing intensity of explosions	February 2014
'Caída de ceniza fina'	Ash fall	Fine ash	August 2006, February 2014

- Communicating thresholds of activity using informal language that has local meaning
- Some terms were used often by scientists, having been learned from the vigías or communities

# Formal system – national risk management

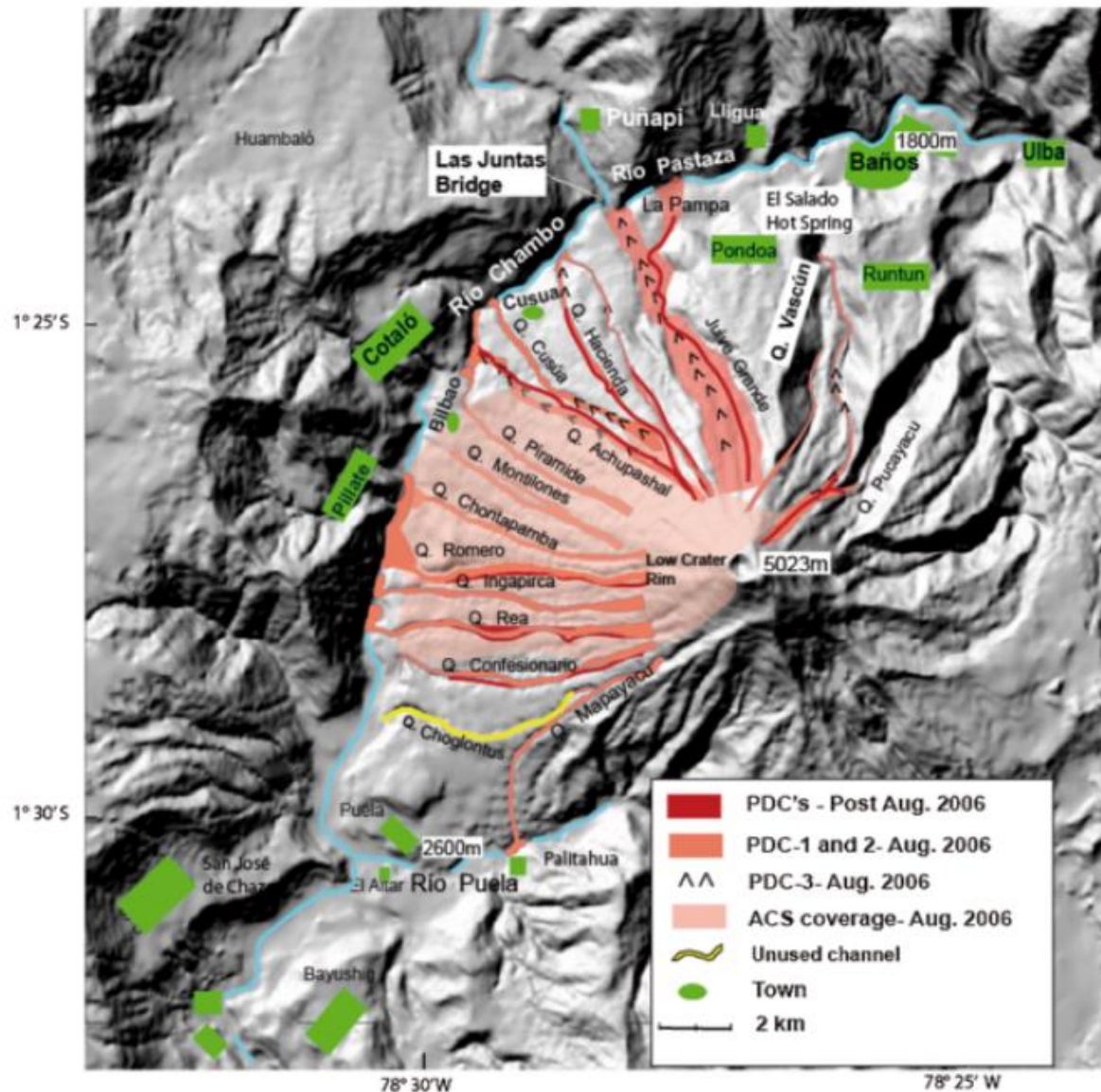
- Civil Defense (response)
- Between 1999 and 2006: training and improved shelter availability and evacuation routes
- 2008 Secretaría de Gestion de Riesgos - DRM
- Local and national risk management – decentralisation process
- Alert level system at local level
- Unique system in Tungurahua - support daily evacuation, funds to support livelihoods

# Formal and Informal System Pyroclastic density currents – July and August 2006

a

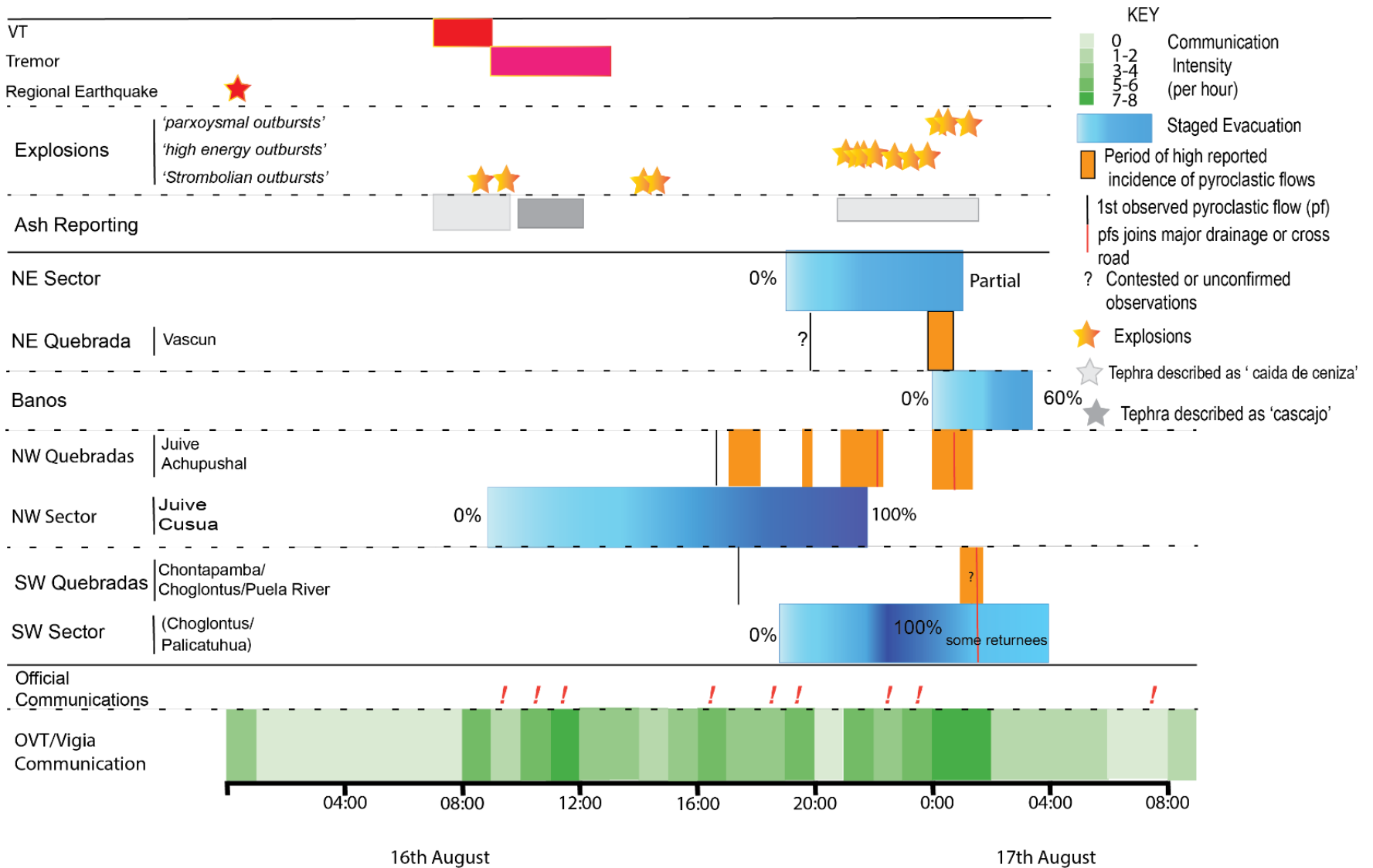


b



Mothes et al (2015)

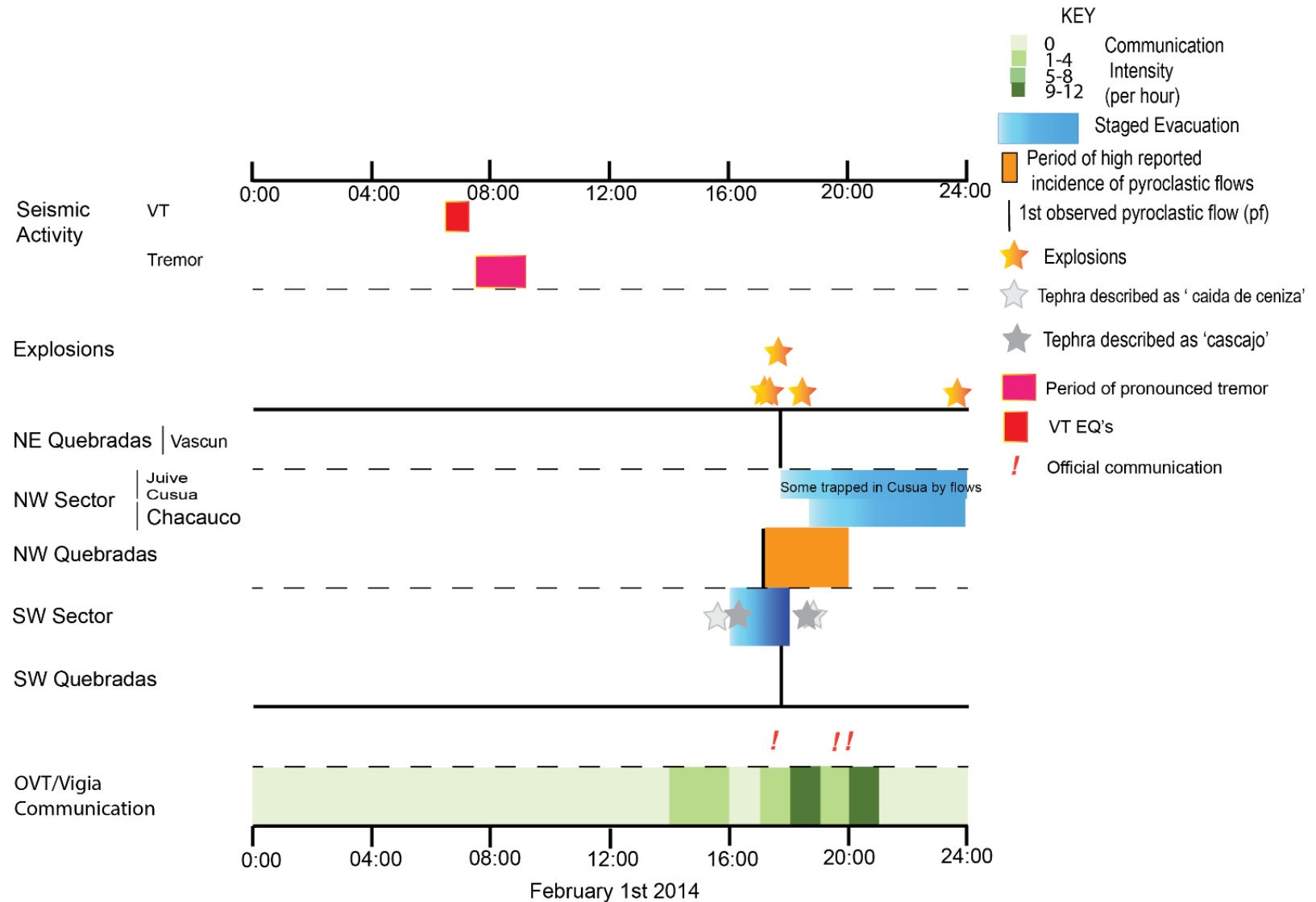
# Response to August 2006 eruption



# 1<sup>st</sup> February 2014 eruption



# Response to February 2014 eruption





# Summary

- Formal and informal risk management interactions have facilitated important **adaptations in the scientific advisory response during eruptions** (near-real-time interpretation of the volcanic hazards), **in hazard communication, and in the evacuation processes**
- Improved communications have created an effective voluntary evacuation system
- Understanding how shadow networks act to minimise the negative consequences of volcanic activity provides valuable insights for increasing societal resilience to other types of hazards

**Armijos, M.T.**, Phillips, J.C. Wilkinson, E., Barclay, J., Palacios, P., Hicks, A., Mothes, P., Stone, J. (2017). 'Adapting to changes in volcanic behavior: formal and informal interactions for disaster risk management at Tungurahua Volcano, Ecuador'. *Global Environmental Change*, 45:217-226