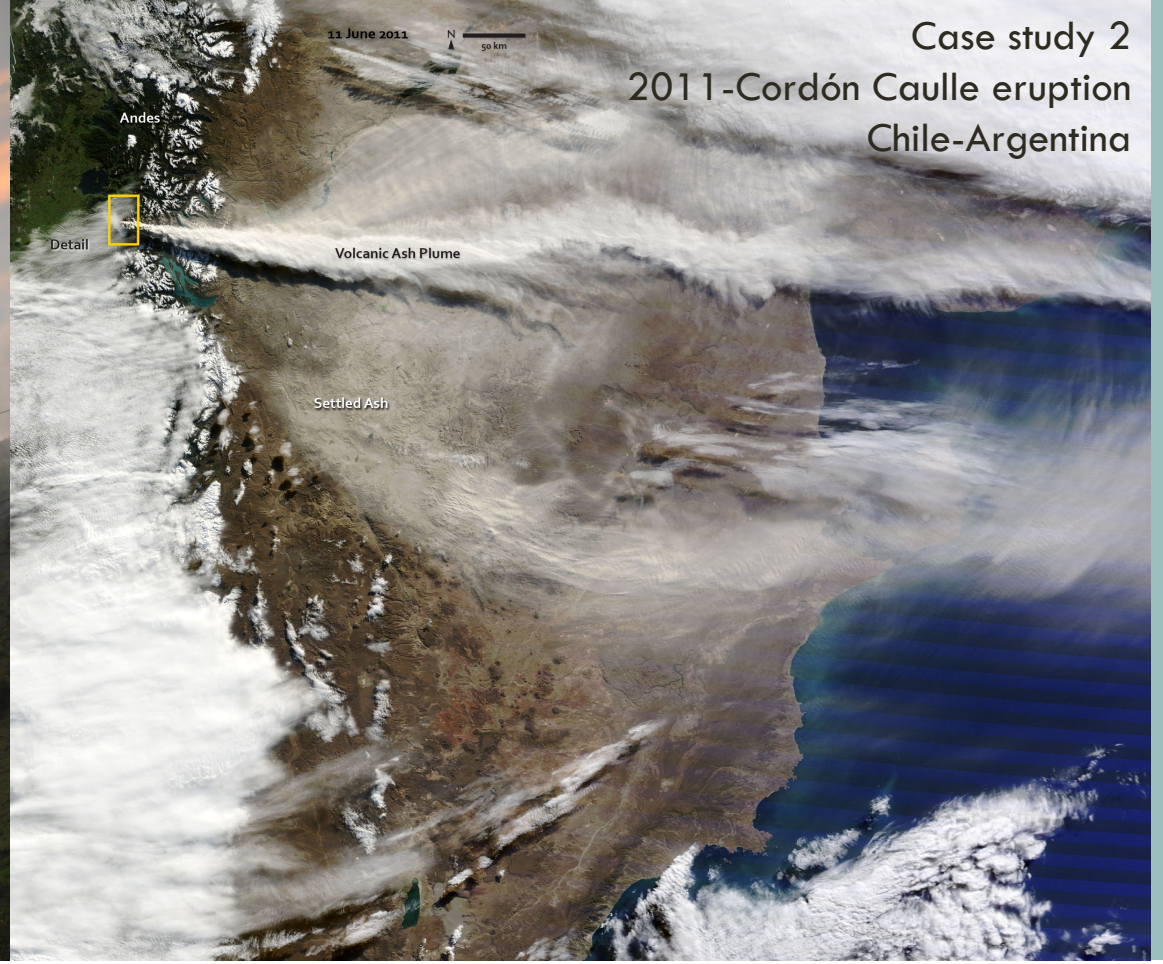
Case study 1
Tungurahua
Ecuador



Case study 2
2011-Cordón Caulle eruption
Chile-Argentina

FORENSIC ANALYSIS OF IMPACT

PILLAR 1: DISASTER RISK KNOWLEDGE

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Advancing Volcanic Hazards in Early Warning for All

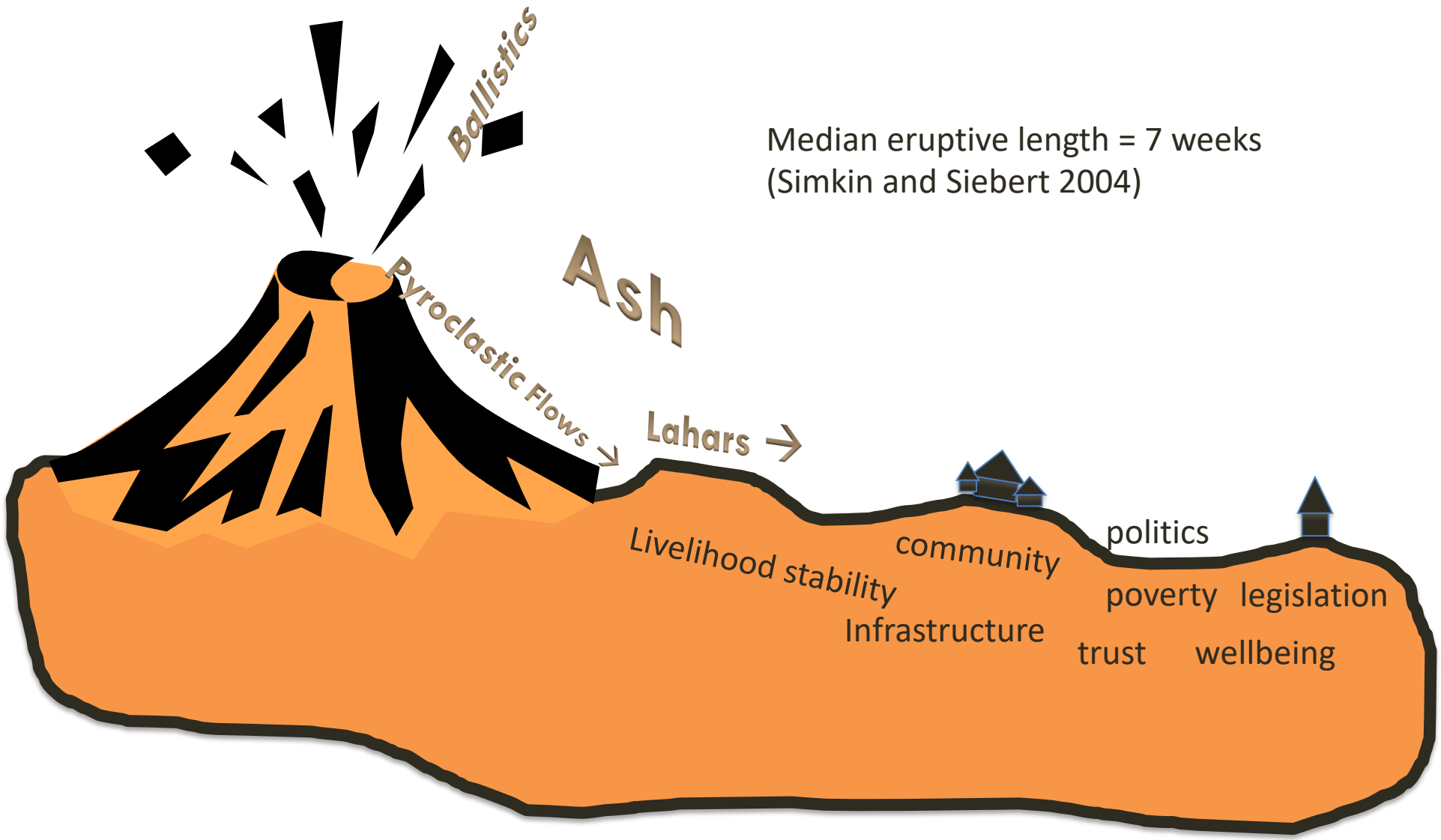
CHALLENGES FROM DYNAMIC VOLCANIC BEHAVIOUR

- Median eruption duration is 7 weeks (Simkin and Siebert, 2004)
- Behaviour can vary strongly: high and low intensity activity
- The eruptive episode two minutes ago will change the hazard for the eruptive episode in two days time

Photo: Jon Stone, UEA

Barclay et al 2019

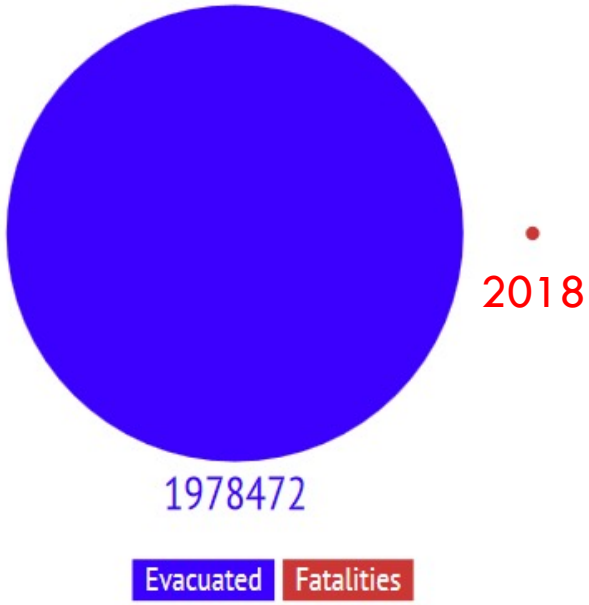
DYNAMIC VOLCANIC RISK: CHALLENGES FROM SOCIAL BEHAVIOUR

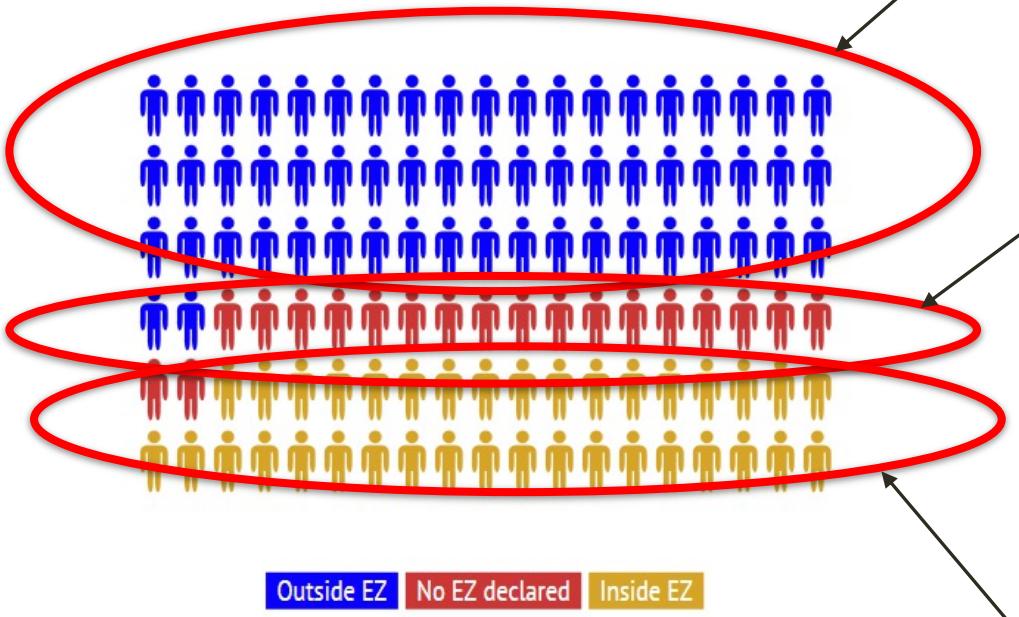


Median eruptive length = 7 weeks
(Simkin and Siebert 2004)

Barclay et al (2019)

GLOBAL ANALYSIS OF VOLCANIC DEATHS 1985-2014





Location of those killed

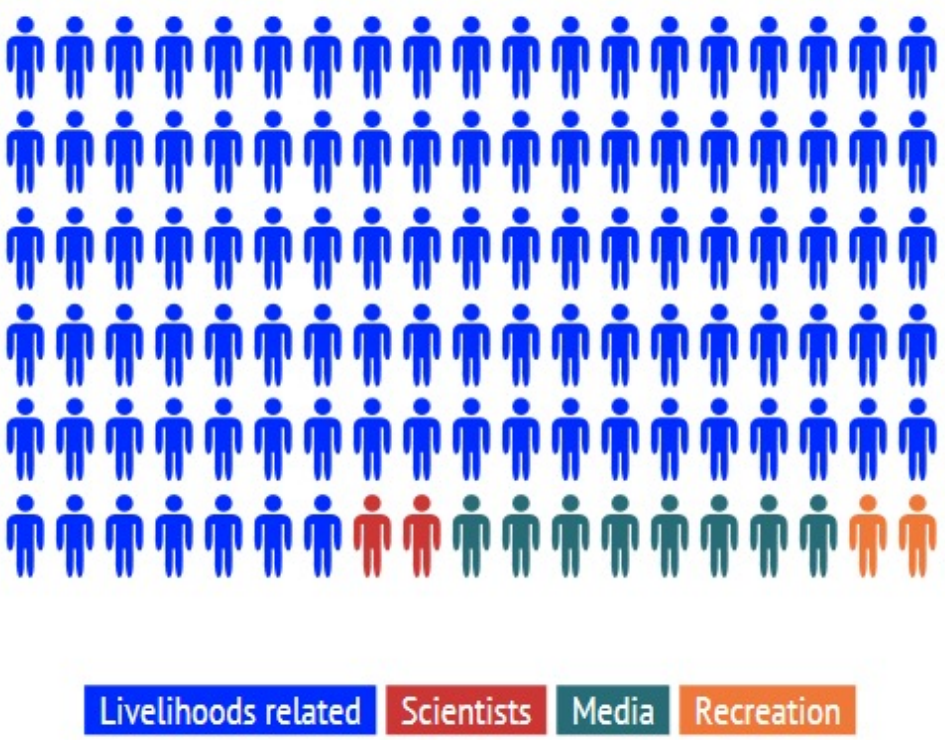
Incomplete understanding of volcanic impact

Inadequate Volcanic forecasting (or risk management)

Poorly anticipated Social processes

Barclay et al (2019)

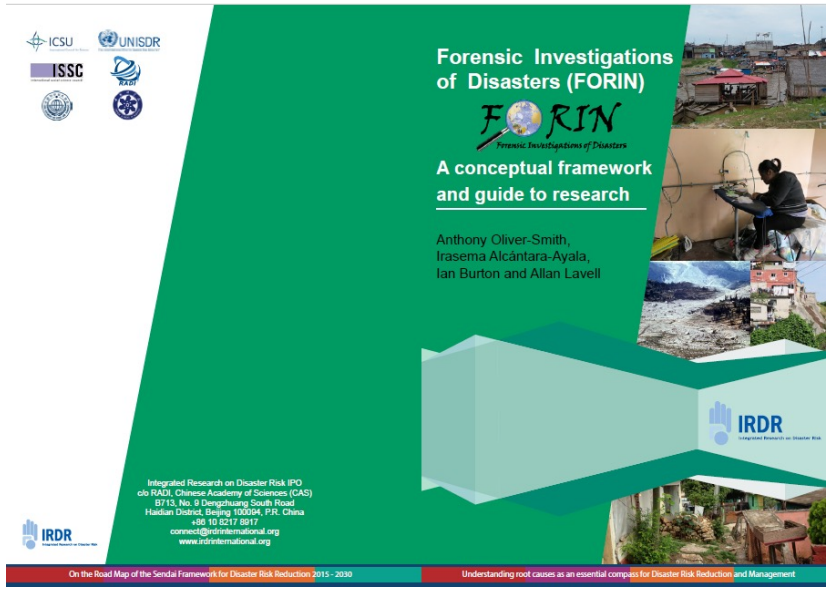
‘ACTIVITY’ OF THOSE KILLED WITHIN EXCLUDED ZONES 1985-2014



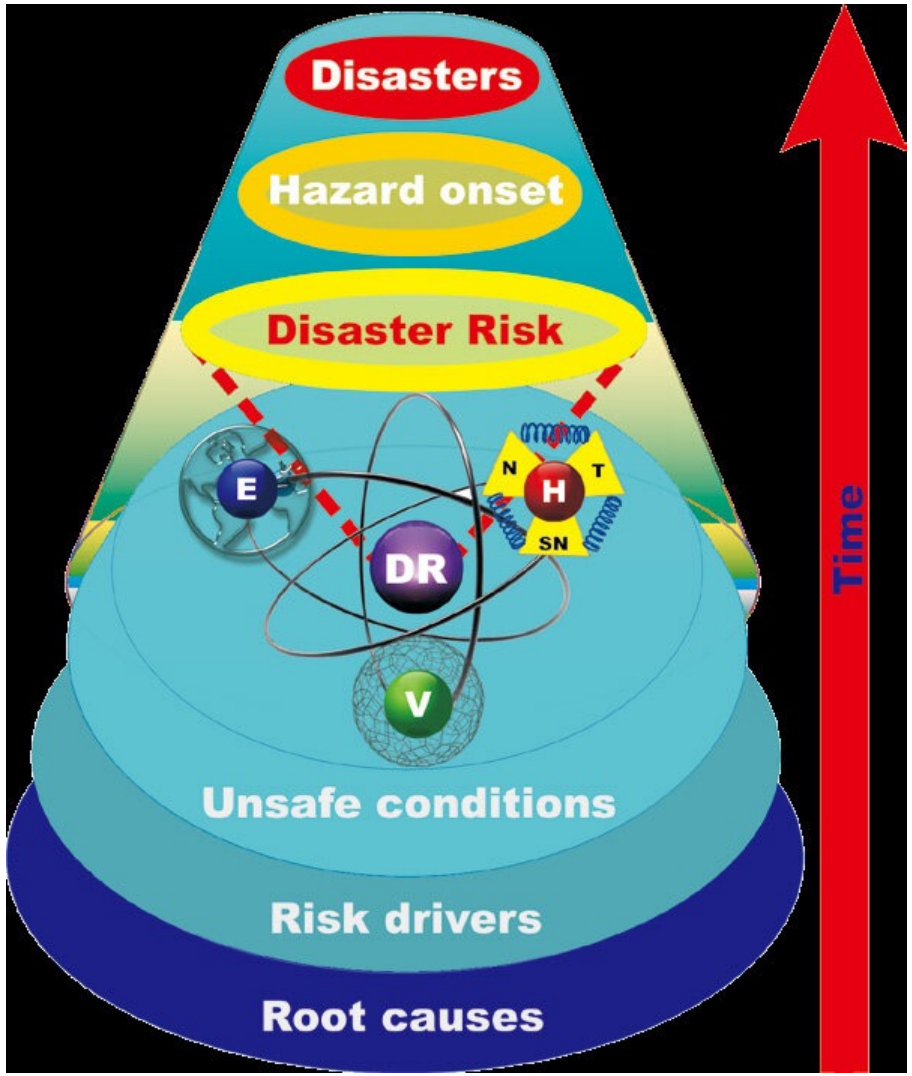
Risk, lives and livelihoods are inter-related

Barclay et al (2019)

FORENSIC INVESTIGATION OF DISASTERS (FORIN*)



- Retrospective longitudinal analysis
- Scenario building
- Comparative case analysis
- Meta-analysis



*Integrated Research on Disaster Risk (IRDR) launched by the International Council for Science (ICSU), the International Social Science Council (ISSC) and the UNISDR

CASE STUDY 1: VOLCAN TUNGURAHUA, ECUADOR

- Eruption from 1999 – 2016
- Retrospective analysis of volcanic risk management – formal and informal components

Armijos et al (2017)

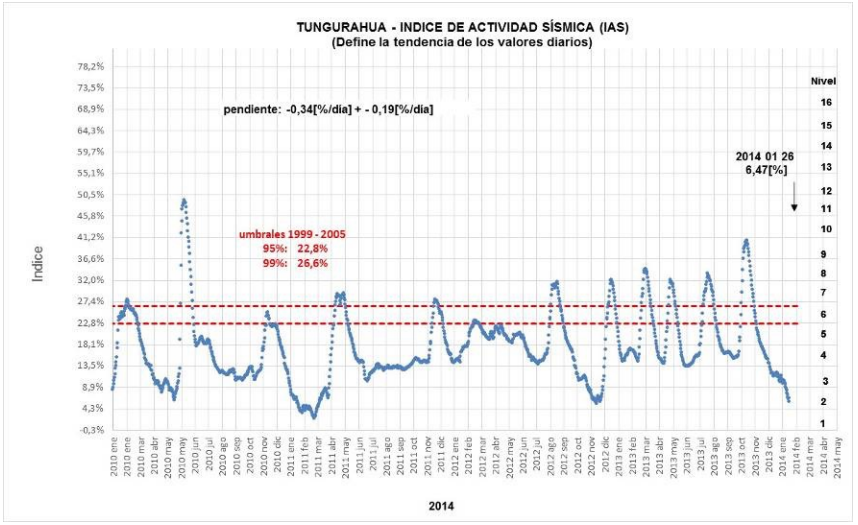
APPROACH AND METHODS

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 secot.
V. de Runtún informa que observa columna de emisión sostenida.

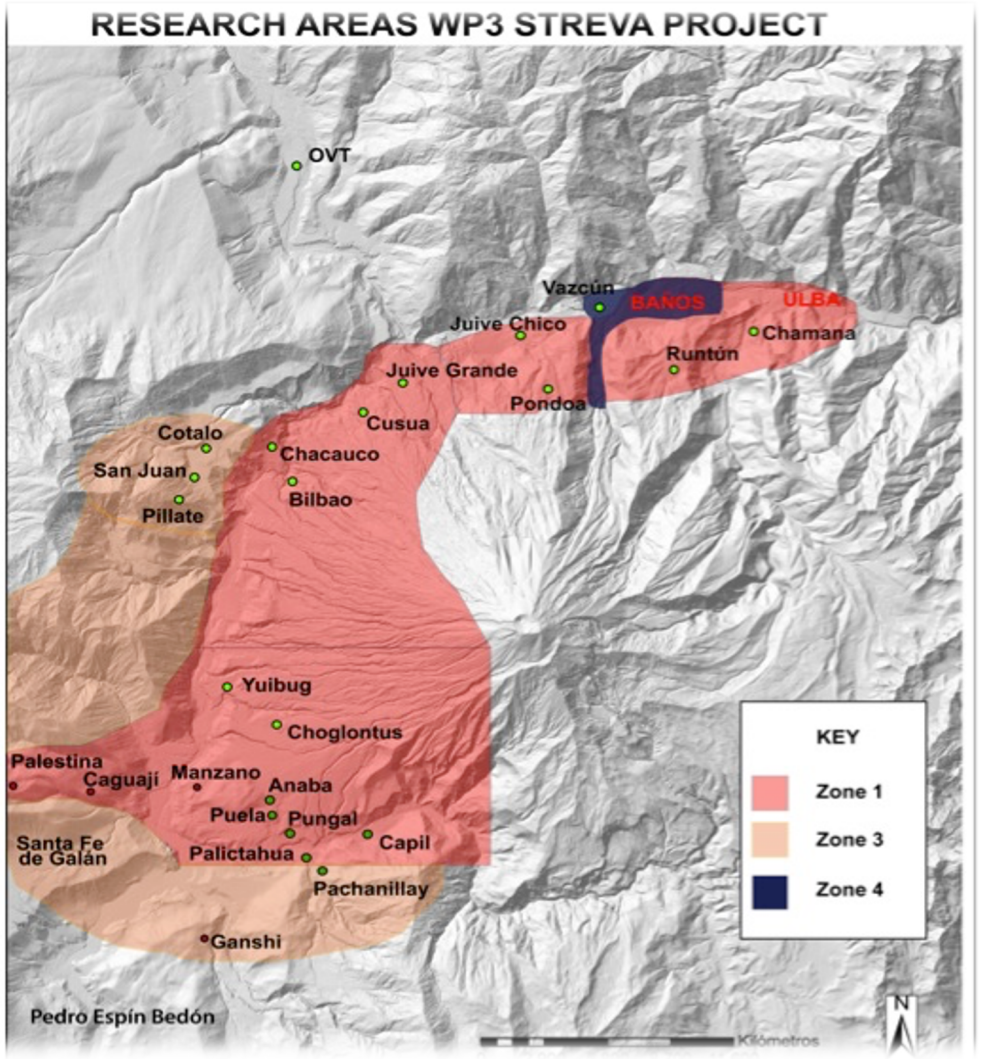
Sábado 1 de Febrero 2014 (día 032)

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



- Instituto Geofisico (IG-EPN) reports
- Scientific papers on volcanic activity
- Analysis of monitoring network evolution
- Analysis of communication around crises

APPROACH AND METHODS



- Qualitative research
- Risk management and governance
- 4 month fieldwork
- 50 semi-structured interviews
- Workshops

  410 household survey
- Sampling based on 4 zones

1999

- Unrest started April 1999
- On October 15 IG-EPN (responsible scientific agency) recommended raising the alert level
- Forced evacuation of 30,000 residents for three months
- People selling assets at low value
- Civil unrest and protest led to re-occupation

ECUADOR: TOWN OF BANOS EVACUATED BECAUSE OF TUNGURAHUA VOLCANIC ACTIVITY

CREATION OF OBSERVATORIO VOLCAN TUNGURAHUA (1999)

CREATION OF VIGIA NETWORK (2000)

- Vigias are influential community members
- Part of OVT radio network
- 8 pm daily ‘ronda’

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

Physical Volcanology

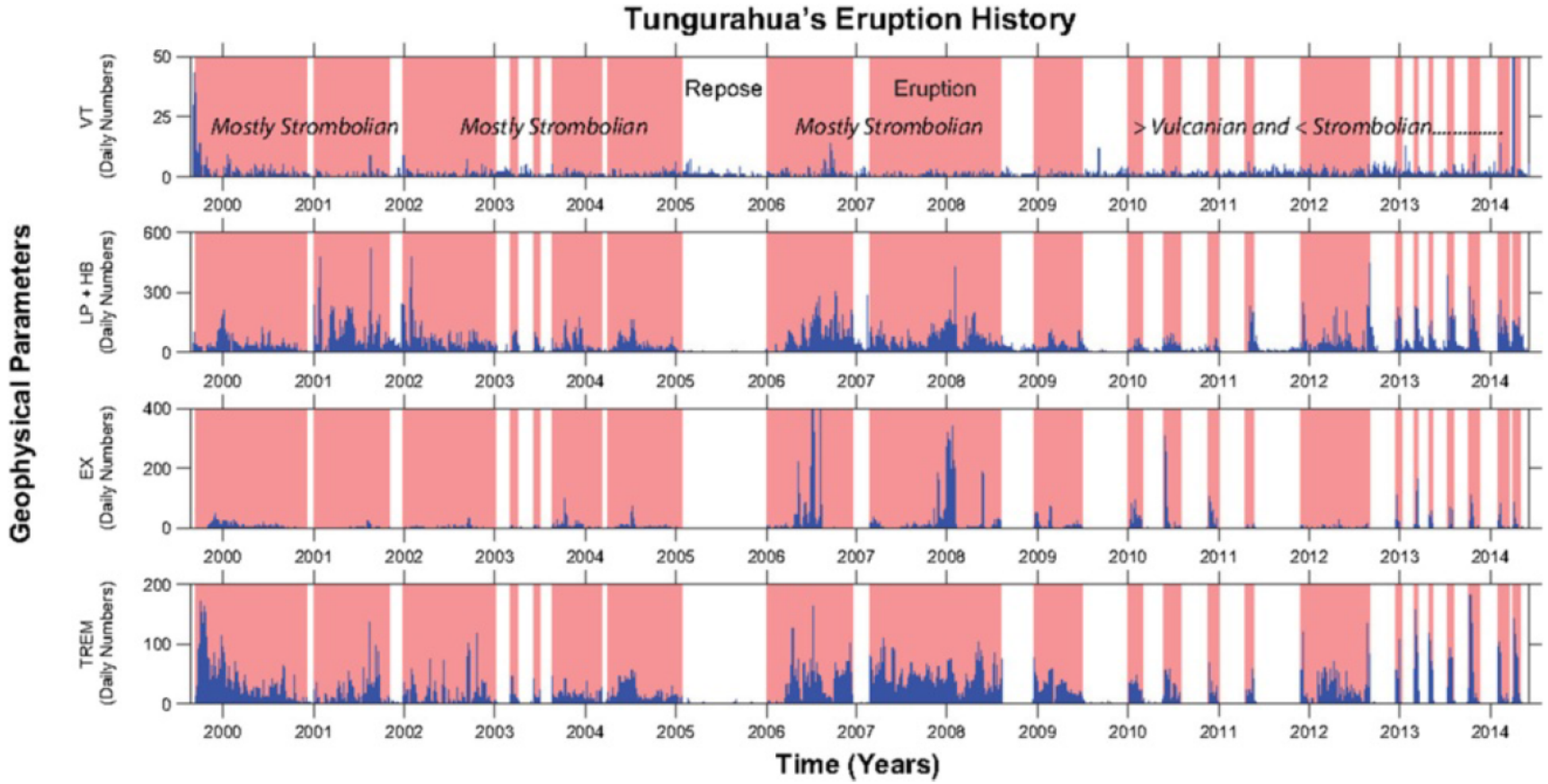
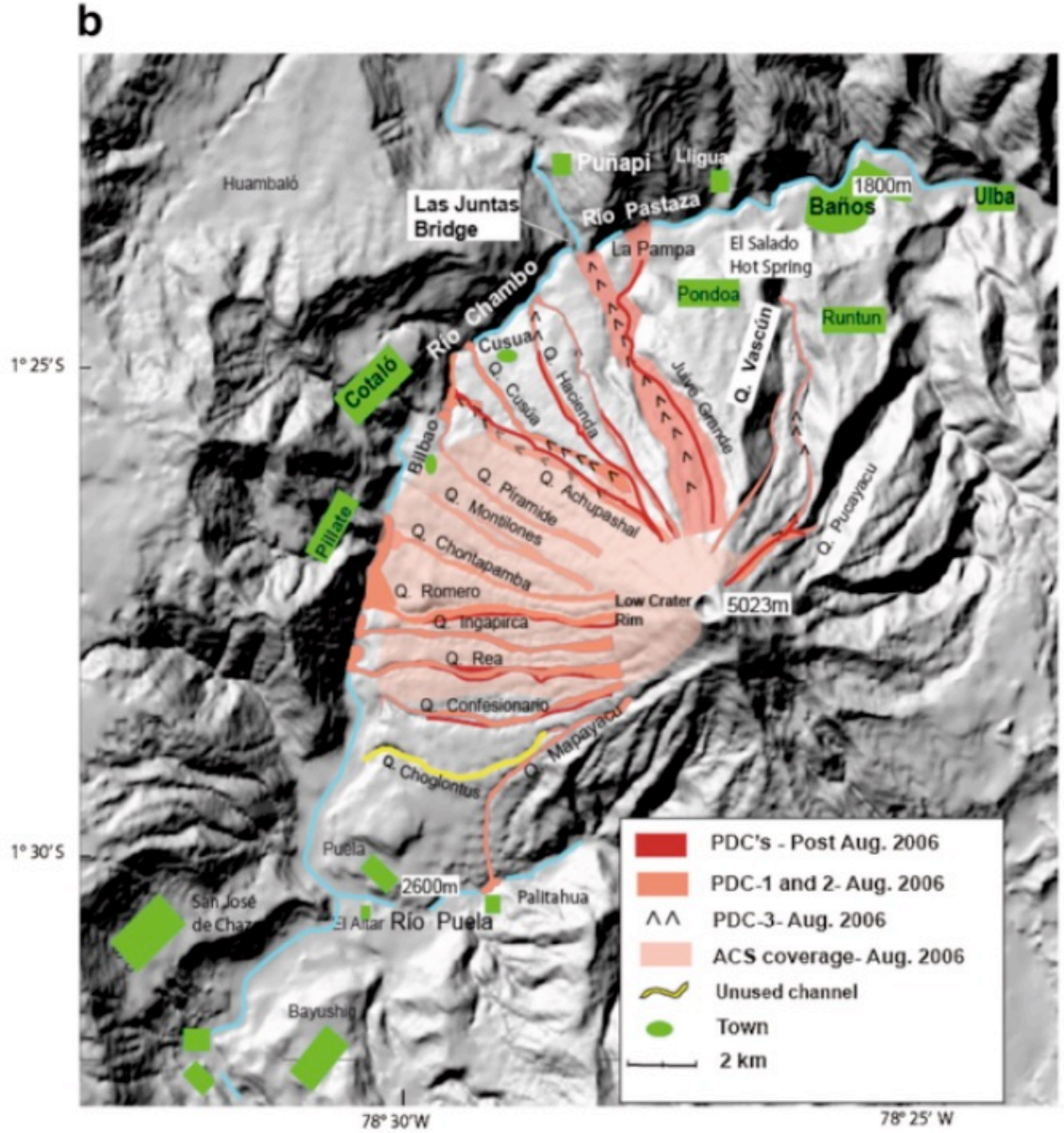


Figure 5 A timeline of Tungurahua´s eruptive activity 1999–2014. Shown on the left margins are the daily numbers of seismic events: VT = volcano-tectonic; LP + HB = long period and hybrids; EX = explosions and TREM = volcanic tremor. Eruptive activity is represented by light pink color, while repose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

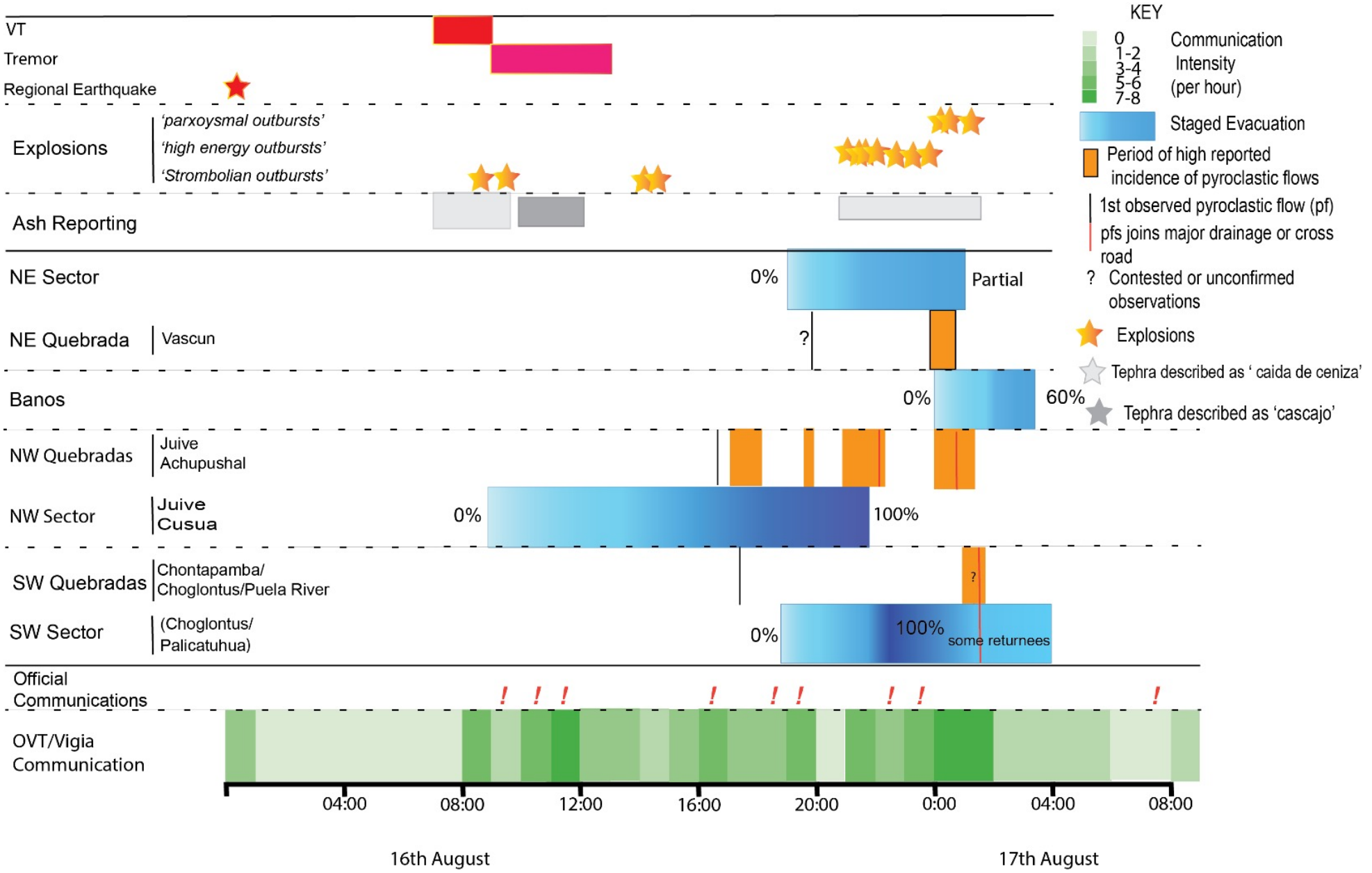
Mothes et al (2015)

2006 PYROCLASTIC DENSITY CURRENTS - AUGUST



Mothes et al (2015)

RESPONSE TO AUGUST 2006 ERUPTION

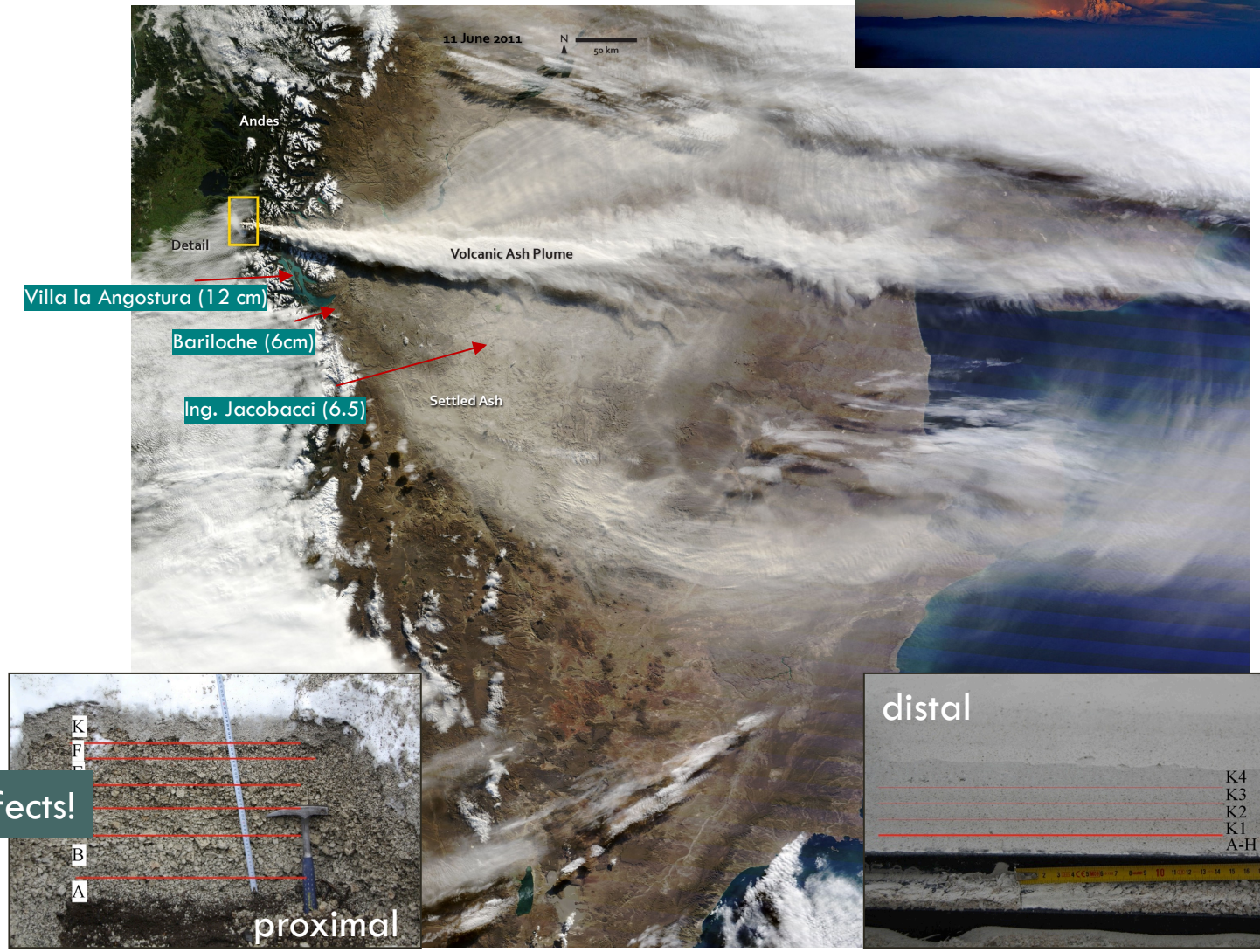


CASE STUDY 2: 2011-CORDÓN CAULLE, CHILE-ARGENTINA

VARIABILITY OF PROCESSES AND PRODUCTS AT VARIOUS SPACE/TIME SCALES

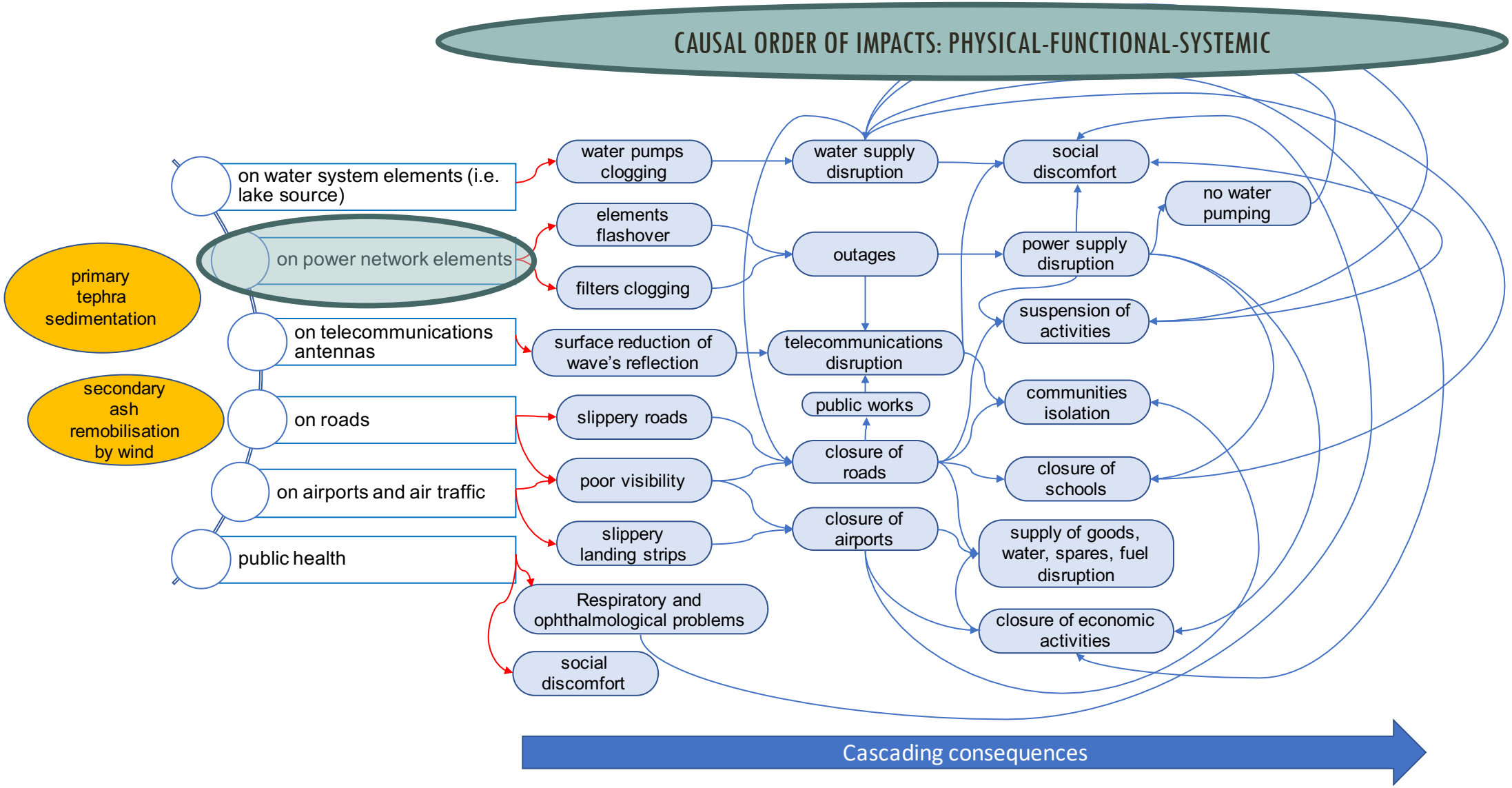
- Subplinian (plume height ~8-14 km a.s.l)
- Rhyolitic magma
- VEI 4-5, ~1km^3 tephra volume
- Complex temporal scales
  - → 24 hours climactic phase
  - → ~1 year of ash emissions
  - →>20 years of aeolian remobilisation
- Large variability of grainsize/thickness

→ long-lasting and complex chains of cascading effects!



APPROACH AND METHODS

APPROACH AND METHODS



Dominguez et al., 2021, Frontiers

APPROACH AND METHODS

To answer the
what, who, when, how and why

Classical post-event Impact Assessment

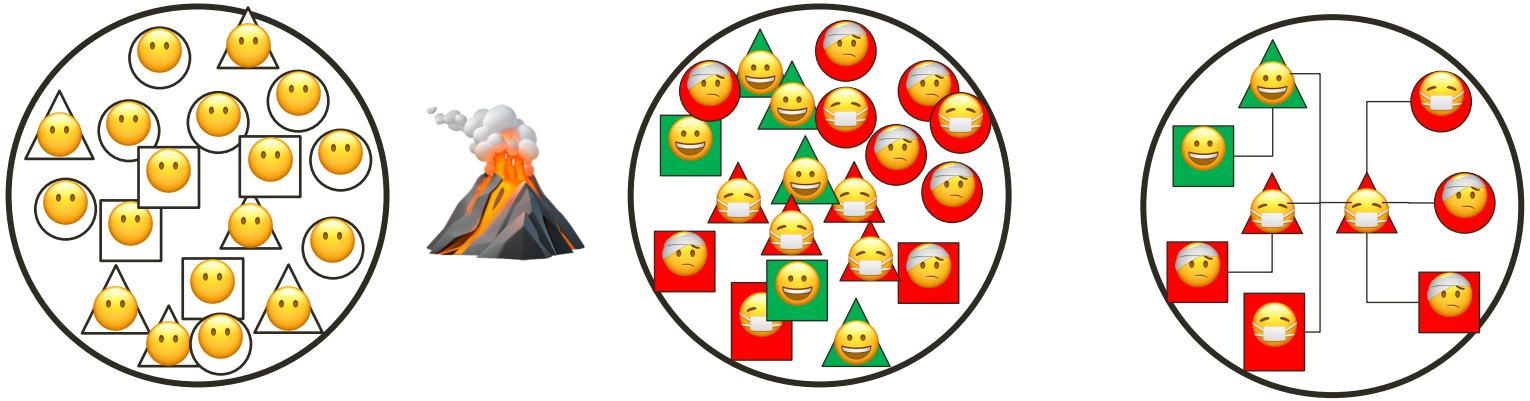
Vulnerability conditions
Exposed element
Hazard intensity

Forensic Analysis

FORIN* / STREVA

Root Cause/Consequence Analysis

Reliability/Incident Analysis



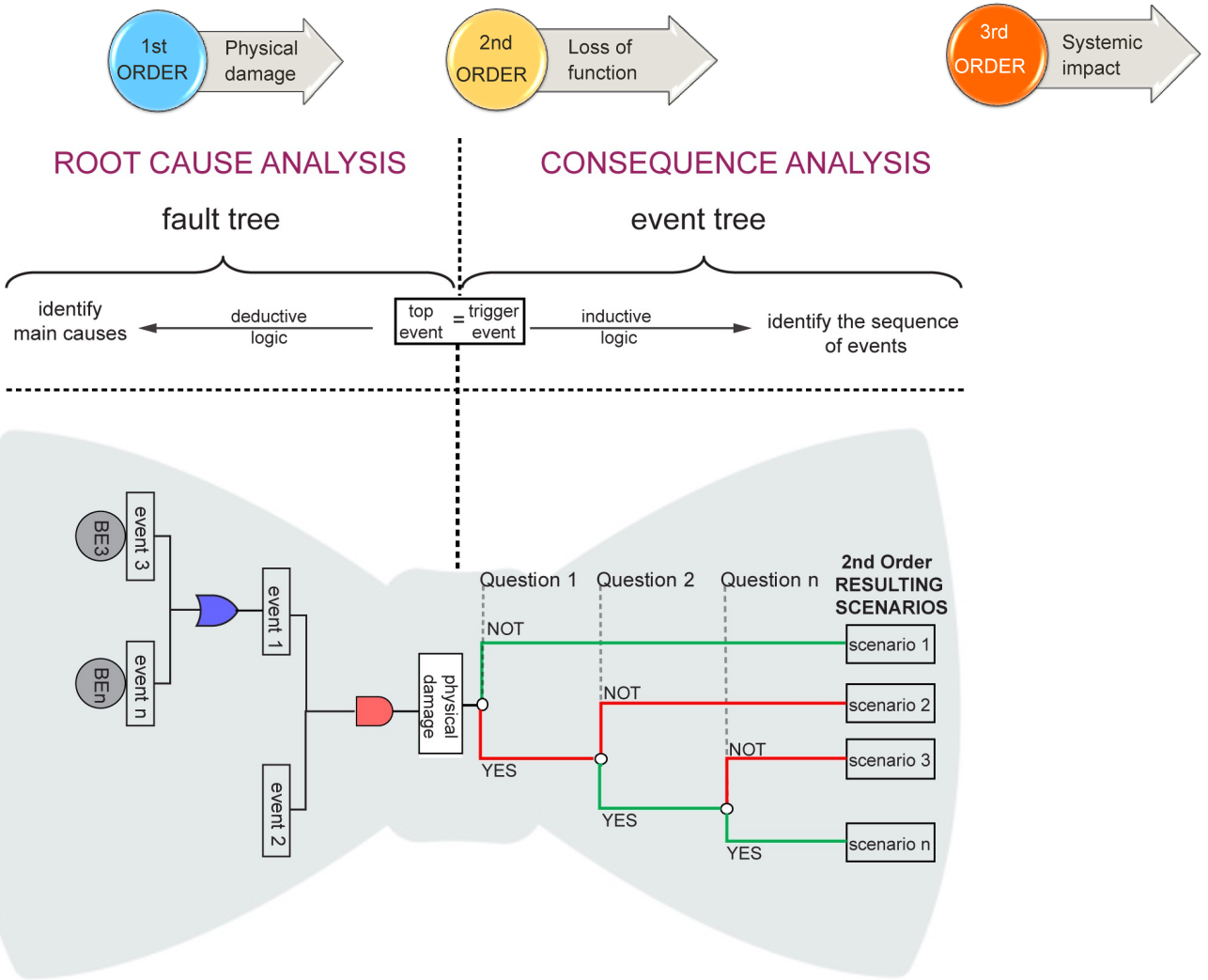
- ✓ Identify the role of each risk component (hazard, exposure, vulnerability and response)
- ✓ Depict and prioritize critical areas of intervention
- ✓ Improve impact data collection for future catalogues

FORIN: https://www.preventionweb.net/publications/view/48809

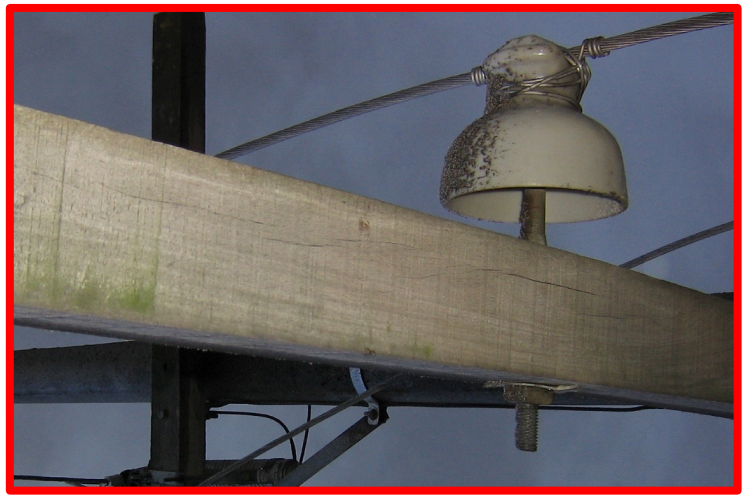
STREVA: https://research-portal.uea.ac.uk/en/projects/streva-strengthening-resilience-to-volcanic-areas

*Integrated Research on Disaster Risk (IRDR) launched by the International Council for Science (ICSU), the International Social Science Council (ISSC) and the UNISDR

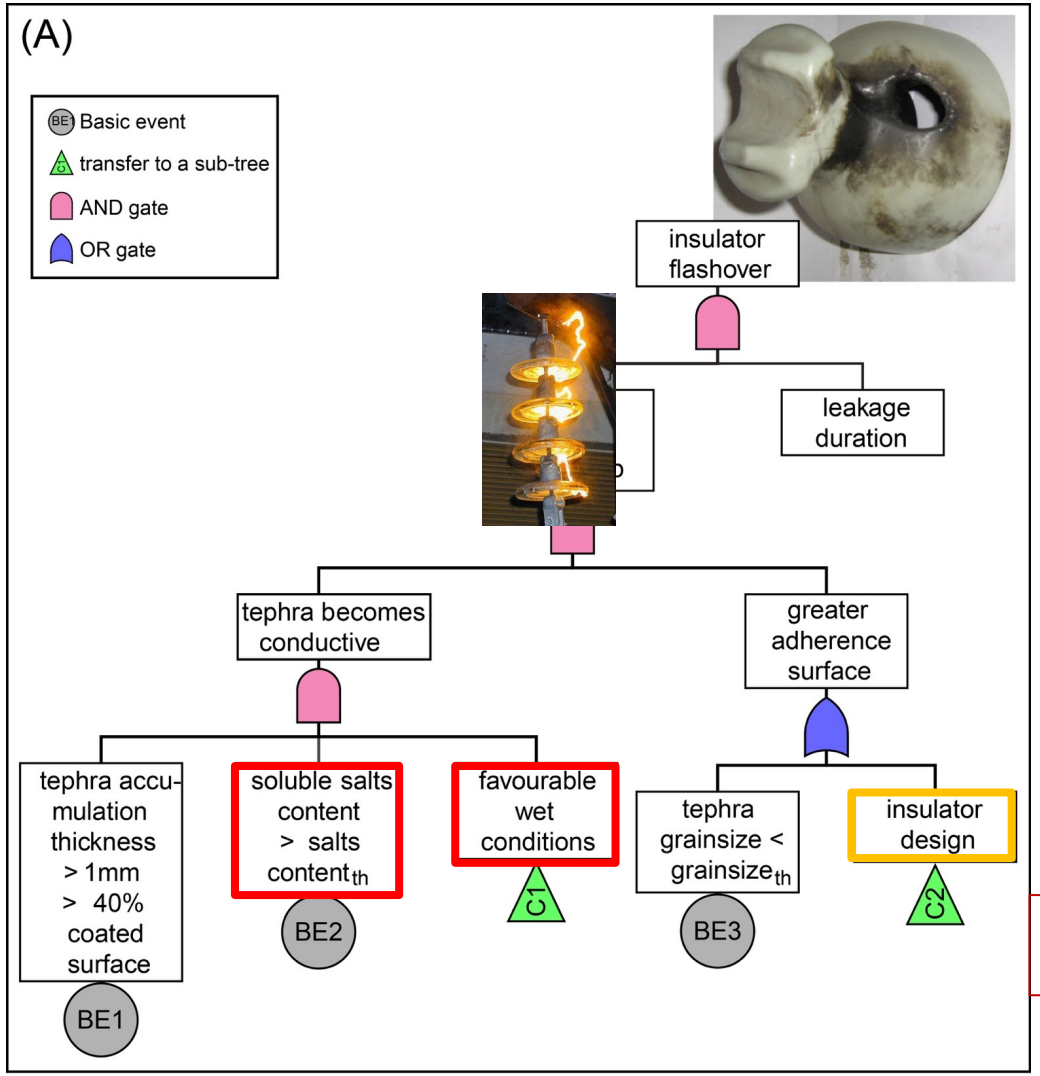
LOGICAL TOOLS TO DESCRIBE AND CONNECT IMPACTS : THE BOW-TIE APPROACH



FAULT TREE OF INSULATORS FAILURE



Previous studies:
Wardman et al. 2012
Lopez et al. 2016
Lopez Chachalo 2017



P_{damage}

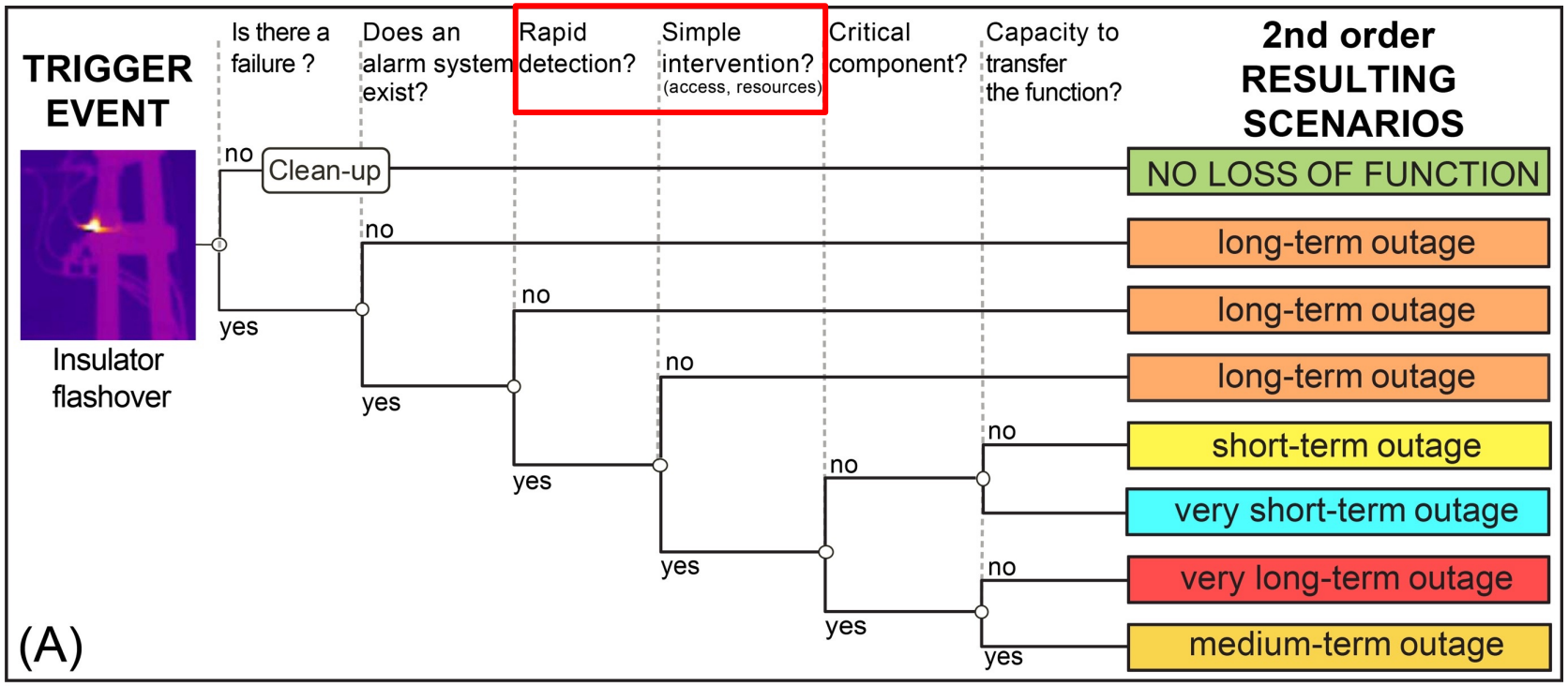
top event

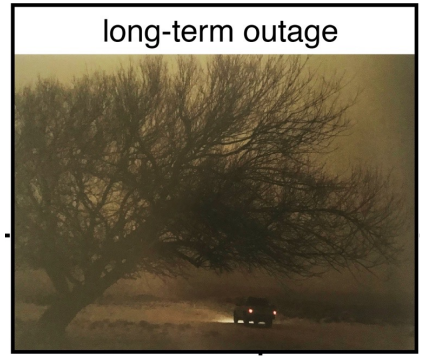
Deductive logic

Identify causes
(backward thinking)

EVENT TREE OF FUNCTIONALITY SCENARIOS

Severity of impact = *f*(duration, area affected)





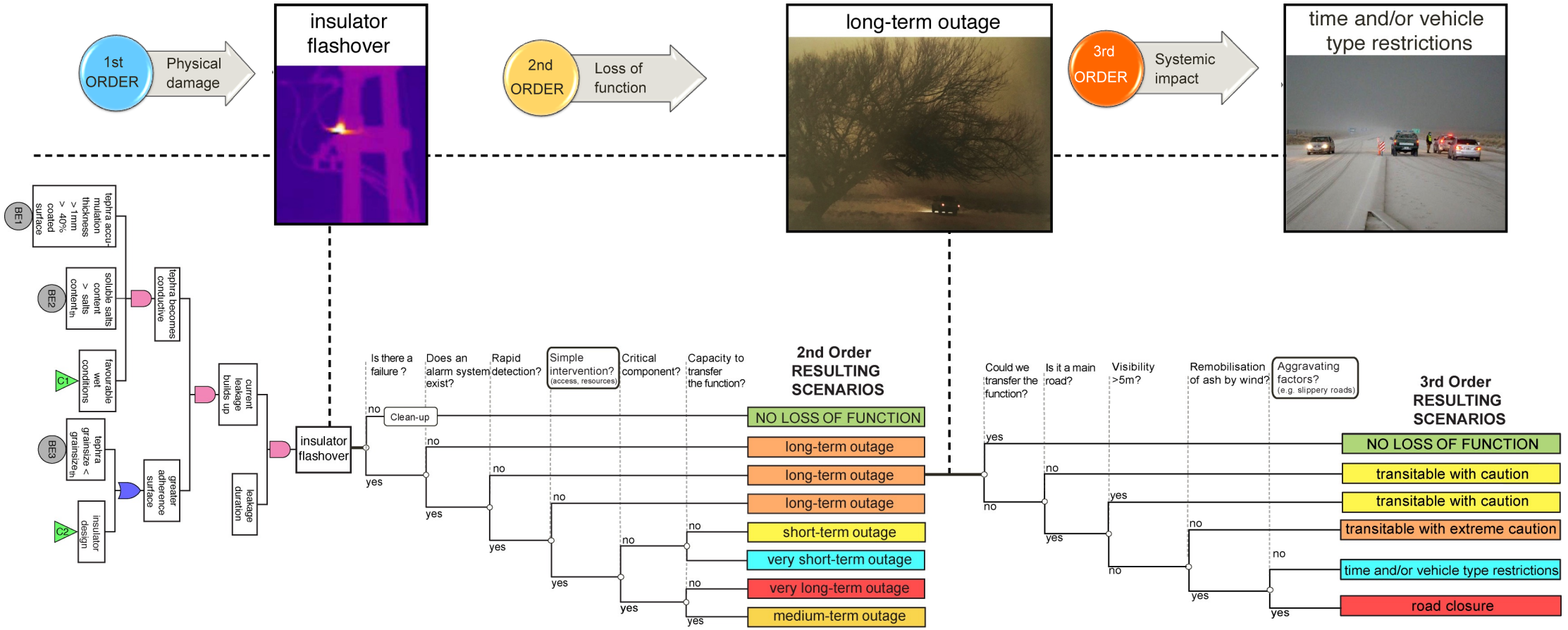
trigger event → Identify sequence of events (forward thinking) → scenarios

Inductive logic

$P_{dysfunction \mid damage}$

Dominguez et al., 2021

CASCADING EFFECTS ON THE POWER SUPPLY SYSTEM (1 PATH)



Dominguez et al., 2021

INDENTIFYING CRITICAL POINTS

1st ORDER

- ✓ **Protect the insulators**
- ✓ **Clean-up as soon as possible**

DESIGN

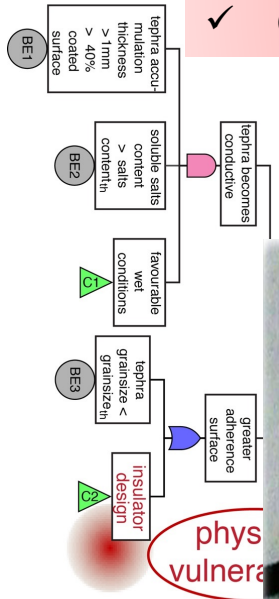
- ✓ Increase the number of insulators in each chain
- ✓ Develop more resistant materials

→ need of experimental/empirical data to develop fragility curves!

ACTION PROTOCOLS

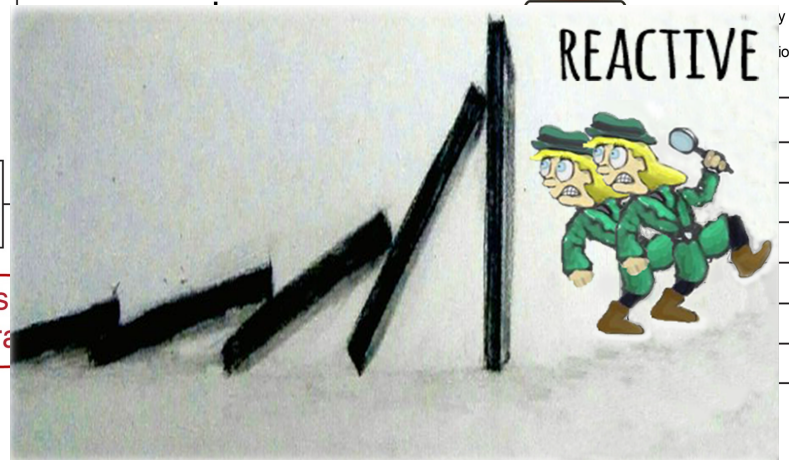
- ✓ Coordinate public works + civil protection + CIS

→ need of data to perform cost-benefit analysis and invest in better preparedness



systemic vulnerability

response

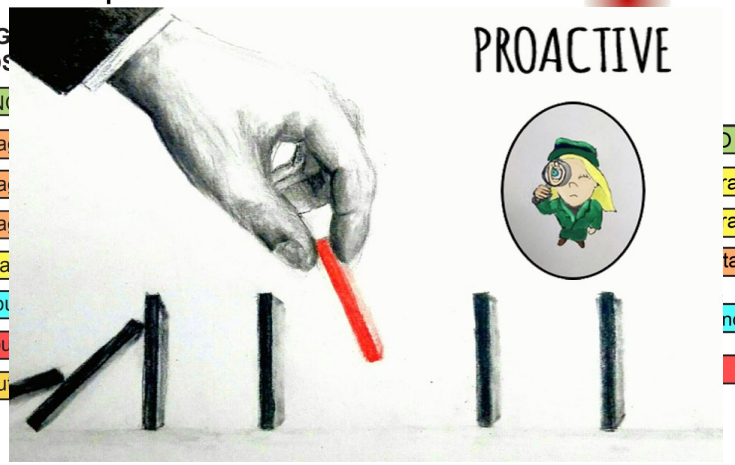


2nd Order RESULTING SCENARIOS

- NO LOSS OF FUN
- long-term outa
- long-term outa
- long-term outa
- short-term outa
- very short-term ou
- very long-term ou
- medium-term ou

hazard

systemic vulnerability



3rd Order RESULTING SCENARIOS

- LOSS OF FUNCTION
- ansitable with caution
- ansitable with caution
- table with extreme caution
- nd/or vehicle type restrictions
- road closure

FORENSIC ANALYSIS RELEVANCE IN EARLY WARNING SYSTEMS

Classical post-event Impact Assessment

Hazard intensity

Vulnerability conditions

Exposed element

Forensic Analysis

FORIN* / STREVA

Root Cause/Consequence Analysis

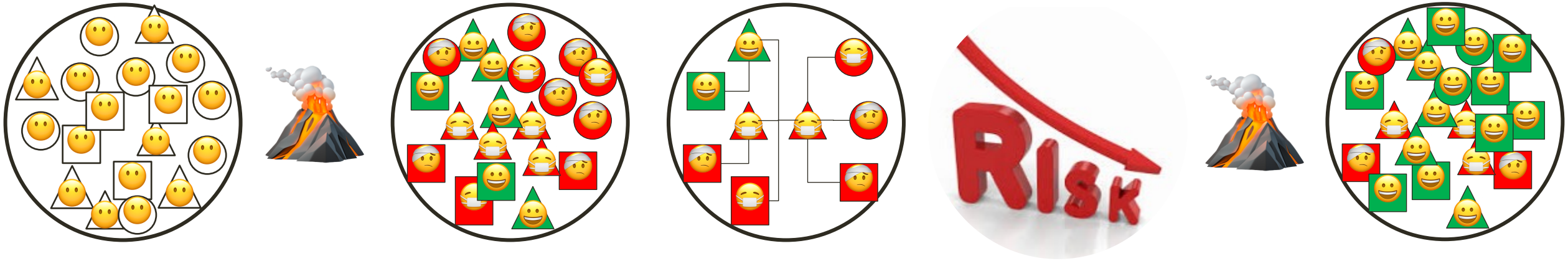
Reliability/Incident Analysis

Pre-event Impact Assessment

Key impact drivers
Intervention priorities
Impact data for catalogues

Early Warning Systems

Validation, upgrading and improvement of EWS and impact catalogues



Event

Impact

DRR strategies

Future event

Reduced impact!

CONCLUSIONS AND REMARKS

- ✓ Two case studies : complementing perspectives
  - → Tungurahua **retrospective** analysis and its significance on **preparedness** and decisions
  - → Cordón Caulle **root cause/consequence analysis** on complex cascading impacts of CI

- ✓ Forensic Investigation is fundamental to disentangle the **drivers of impact** from deep socio-political contexts to structured engineering perspectives

- ✓ Understanding impact drivers is key to establish mitigation measures
  → **inform Early Warning Systems** from real experiences and lessons of past events.

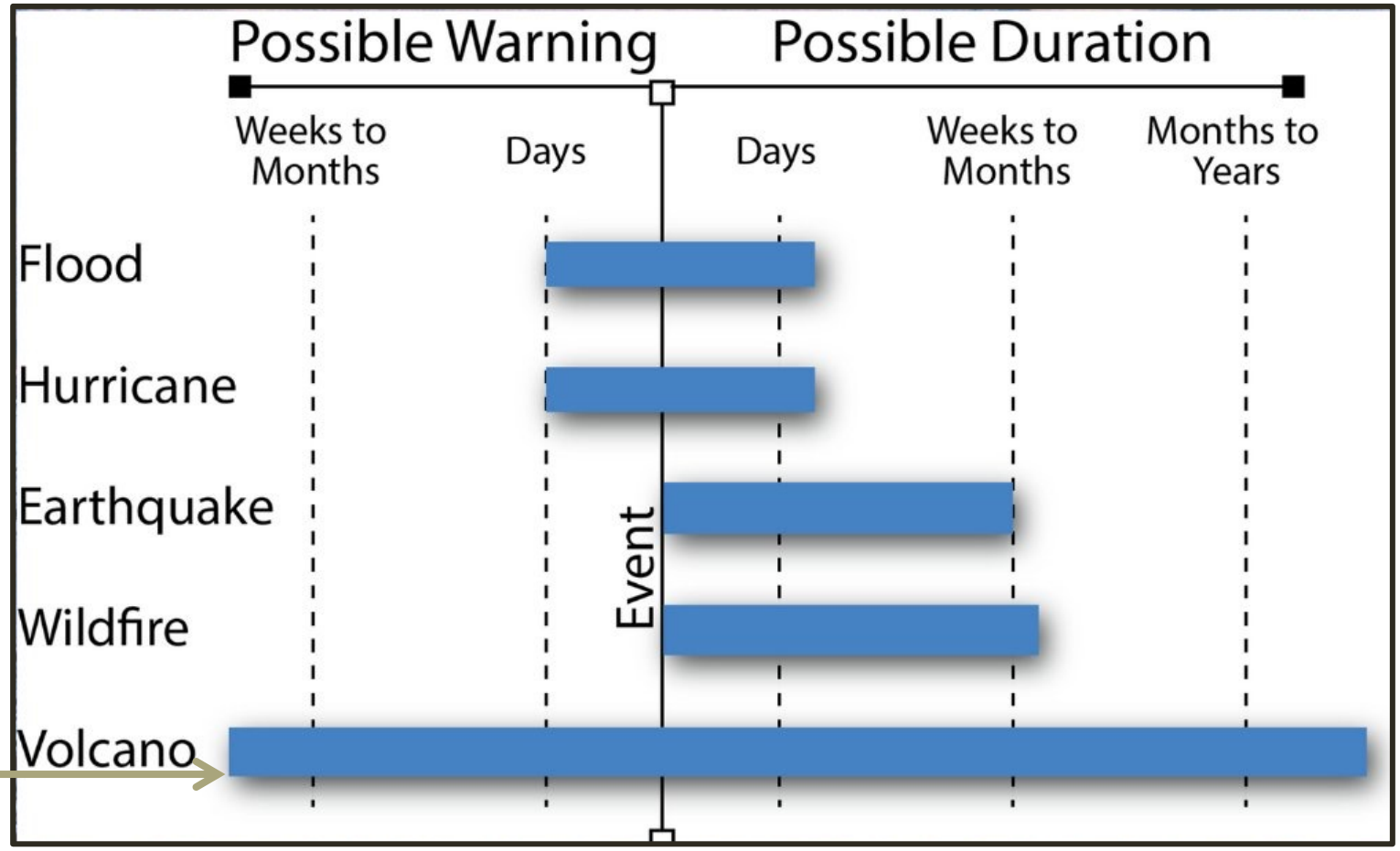
- ✓ Volcanic Risk is a multiple dimension problem that needs **trans-disciplinary** solutions
  → forensic approaches promote **synergies** among all stakeholders (community, institutions, scientists)

✓ What's next? How can we efficiently apply these lessons to EWS?

"Early warnings and actions save lives" - António Guterres-UN -

Geological and historical record

Lessons learnt from past events



Modified from USGS

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USGS https://www.usgs.gov/media/images/volcanic-eruptions-have-a-much-longer-warning-phase-onse