The Abdus Salam
International Centre for Theoretical Physics

United Nations
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Cultural Organization

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2142-23

Advanced Conference on Seismic Risk Mitigation and Sustainable Development

10 - 14 May 2010

Building a sustainable earthquake risk reduction program: Lessons from Haiti (and other events)

Arthur Lerner-Lam

Lamont-Doherty Earth Observatory
Columbia University, New York, USA

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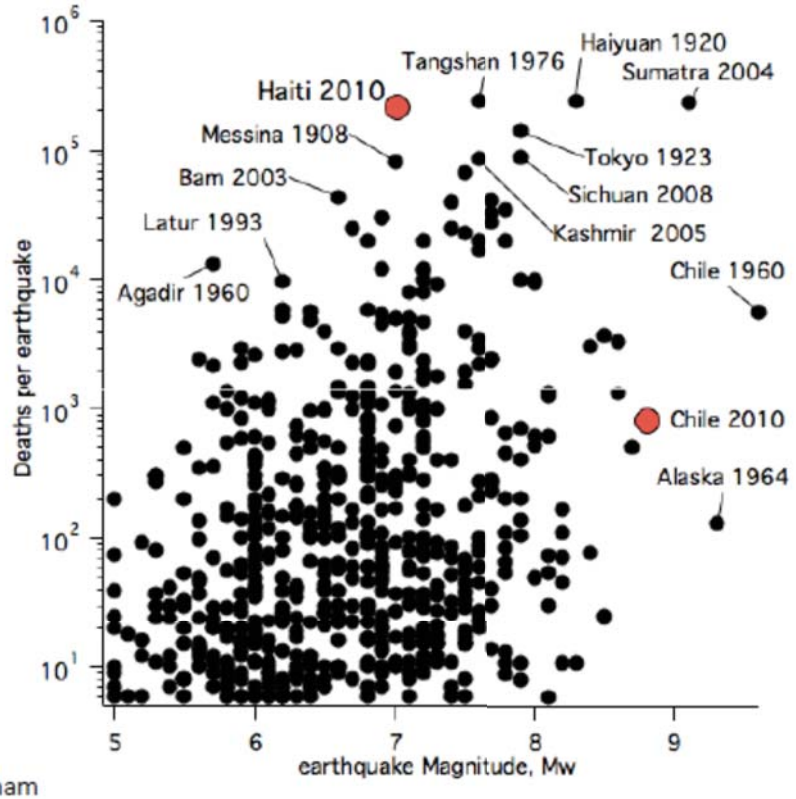
ICTP Advanced Conference on Seismic Risk Mitigation and Sustainable Development

10-14 May, 2010



Graph R. Bilham

Abbreviated Haiti Timeline

- 12 January 2010 event
- First 2 days:
  - Event source characterization
  - Aftershocks
  - UN request for event summaries
- First two weeks
  - Preparation of science and engineering surveys
  - Aftershock and triggered earthquake probabilities
  - Ad hoc seismic working group meets

Abbreviated timeline

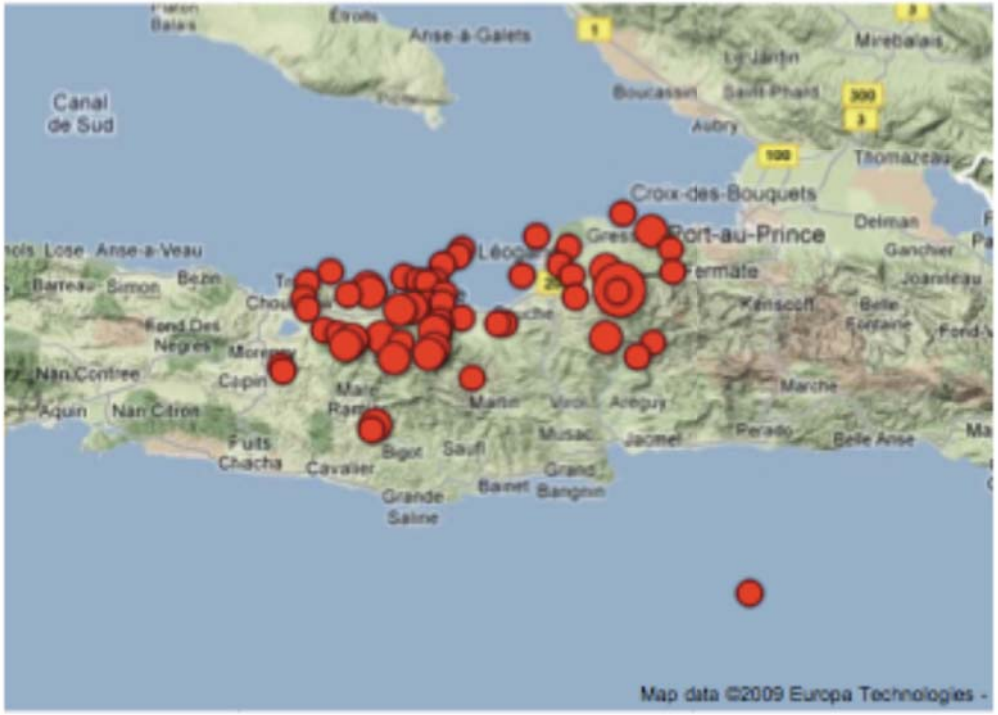
- 21 Jan: USGS releases aftershock statement
- 29 Jan: As Hoc UN briefing, NY
- 30 Jan: USGS releases triggered earthquake study
- 2-3 Feb: UNEP (w/ Calais) briefs GoH
- 23 Feb: USGS seismicity update
- February-March
  - WB and UN needs assessments
  - WB/UN multihazard analysis
  - Geophysical surveys and analysis
- Late March: science workshop and UN Donor Conference
- April: proposal for Haiti NEHRP

USGS
science for a changing world

Earthquake Hazards Program

M7.0 Haiti Earthquake and Aftershocks

Last Updated: 25 January 2010, 20:57:38 UTC



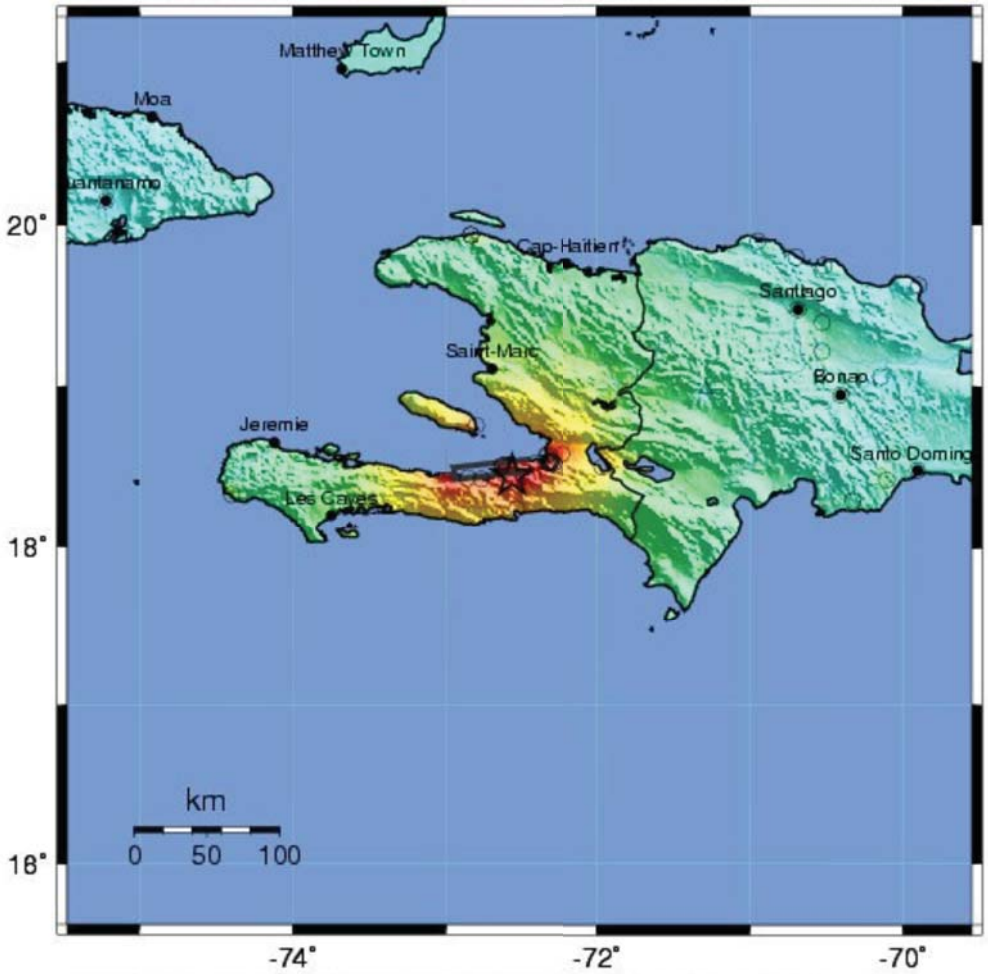
Legend

M1 M2 M3 M4 M5 M6 M7 M8

This aftershock map was manually generated for M7.0 January 12, 2010 Haiti Earthquake. It includes the mainshock and aftershocks at the time of the last update (top of page), but some information may be out of date.

USGS ShakeMap : HAITI REGION

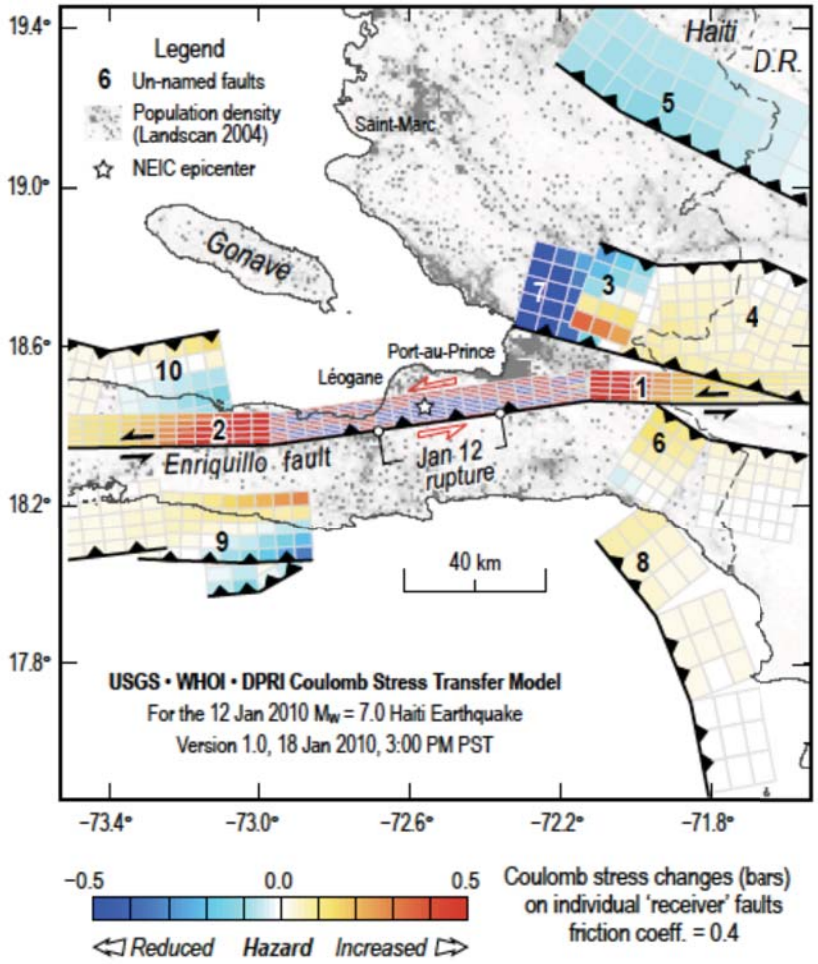
Tue Jan 12, 2010 21:53:10 GMT M 7.0 N18.45 W72.57 Depth: 13.0km ID:2010rja6



Map Version 8 Processed Thu Feb 25, 2010 11:56:09 AM MST -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Lin et al., Version 1.0, 18 January, 2010, 15:30 PST



USGS Issues Assessment of Aftershock Hazards in Haiti

Released: 1/21/2010 5:49:20 PM

- **Aftershocks: The aftershock sequence of a magnitude-7 earthquake will continue for months if not years in the affected area. The frequency of events will diminish with time, but damaging earthquakes will remain possible in the coming months. There is also a small chance of subsequent earthquakes larger than the initial shock. The sequence from the Port-au-Prince earthquake continues to be very strong and active. Based on this activity and the statistics of aftershock sequences, our estimate for aftershock activity during a 30-day period beginning January 21, 2010, is as follows:**
- **The probability of one or more earthquakes of magnitude 7 or greater is less that 3 percent.**
- **The probability of one or more earthquakes of magnitude 6 or greater is 25 percent.**
- **The probability of one or more earthquakes of magnitude 5 or greater is about 90 percent. Approximately 2 to 3 aftershocks of magnitude 5 or greater are expected within this time period.**
- **These estimates will be updated as new information becomes available.**

Source: D. Applegate, USGS

USGS Updates Assessment of Earthquake Hazard and Safety in Haiti and the Caribbean

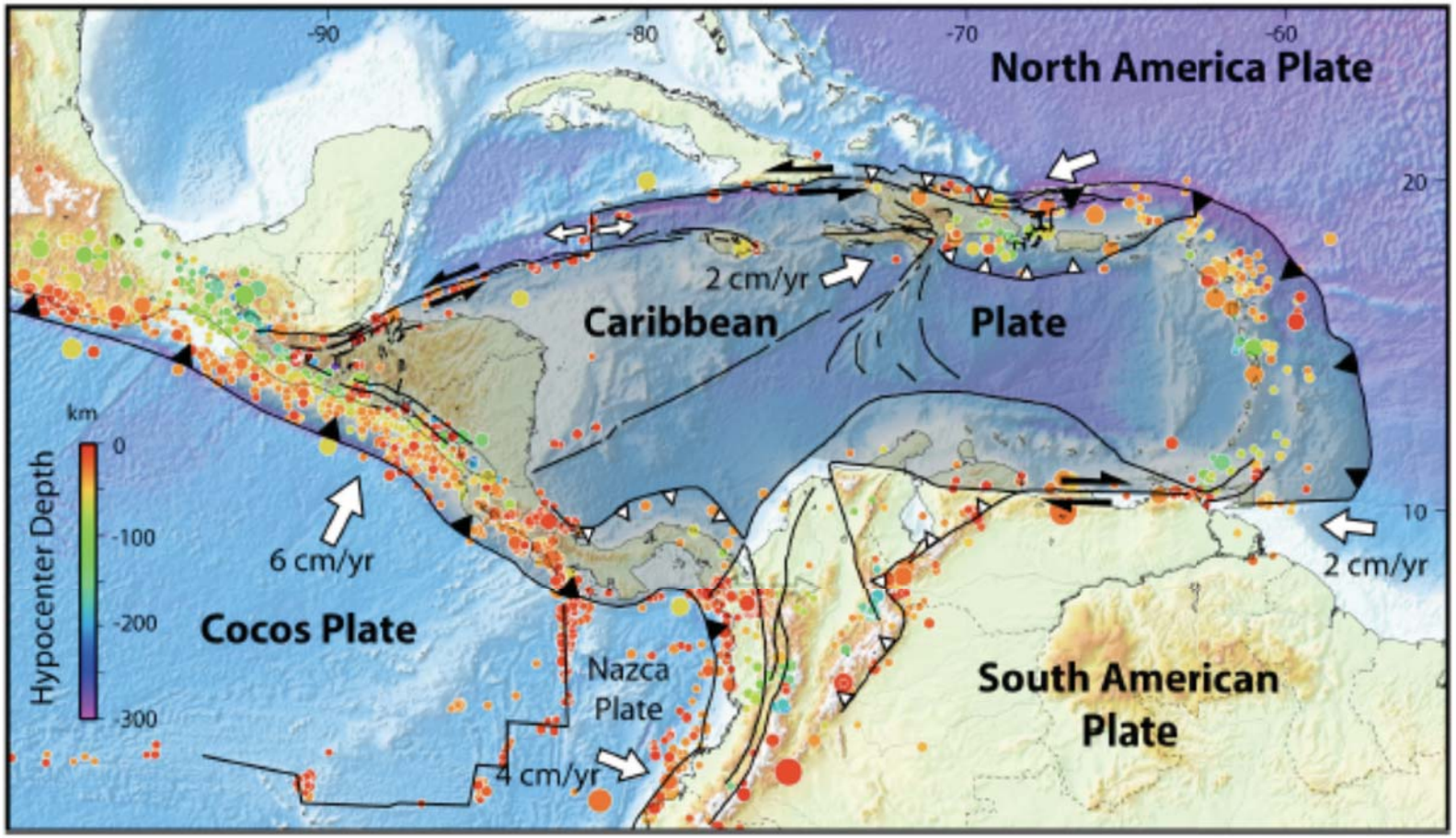
Released: 2/23/2010 2:33:18 PM

Aftershock magnitude (M)	30-day period	90-day period	1-year period
M 5 or greater	55%	80%	95%
M 6 or greater	7%	15%	25%
M 7 or greater	1 %	2 %	3 %

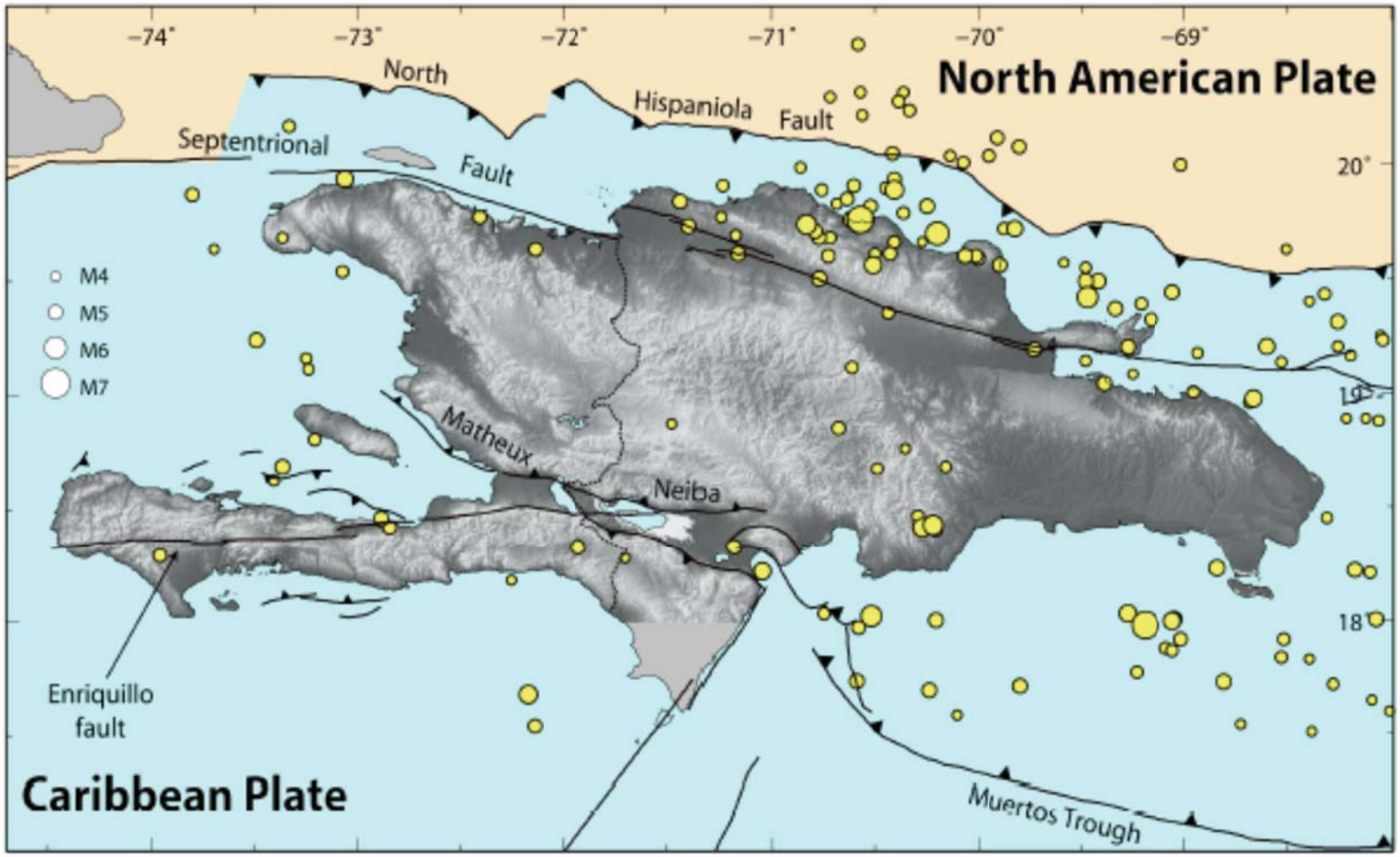
Source: USGS, David Applegate

Issues

- Resource heterogeneity
  - Loose federation of seismic resources
  - UNOSAT, data sharing agreements, US and European agency input
  - Academic input
- Pressure from aid agencies
- Pressure from press
- Pressure from Internet
- Local expertise incapacitated
- External command and control
  - (US SouthCom)



Slide credit: Eric Calais



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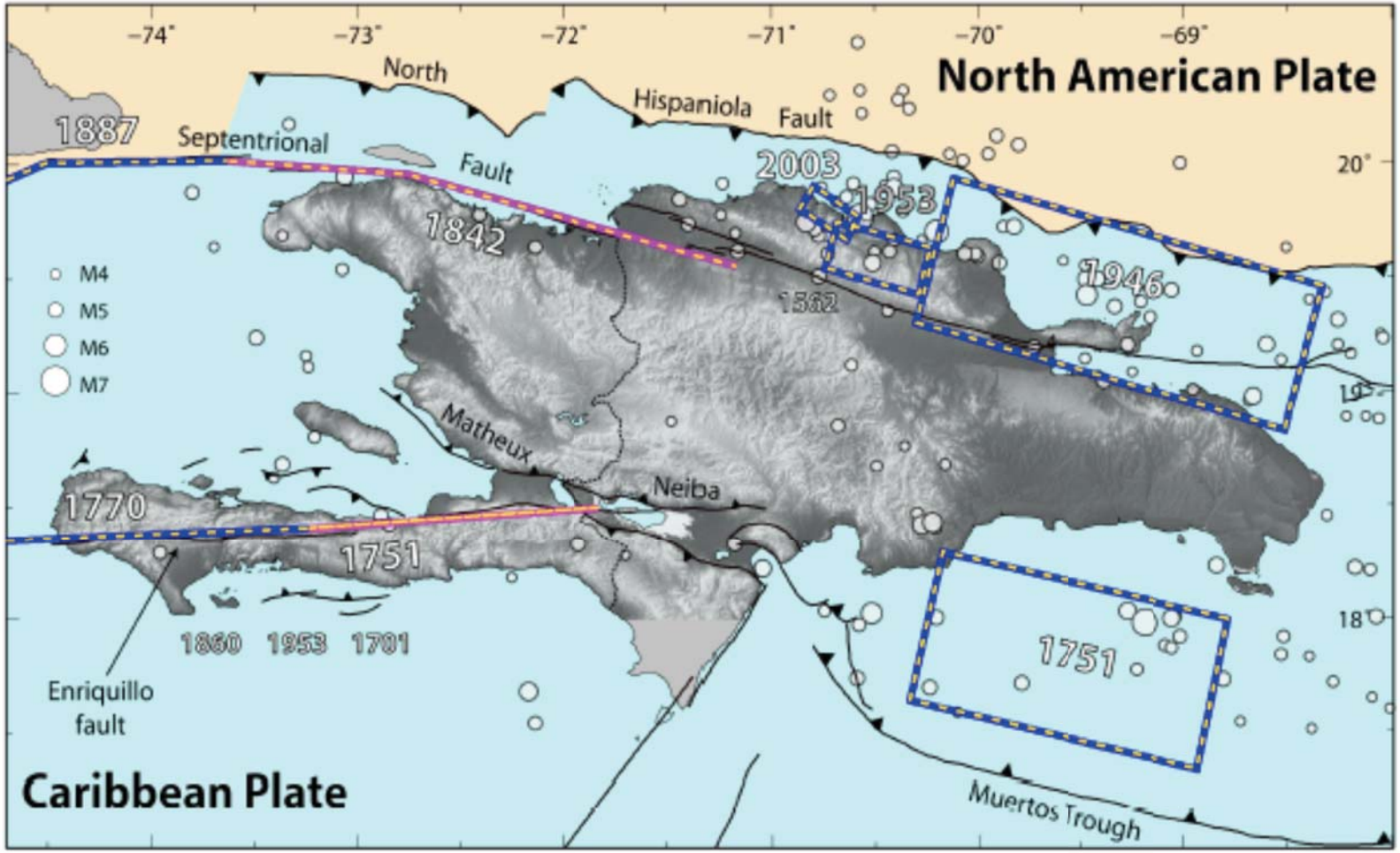
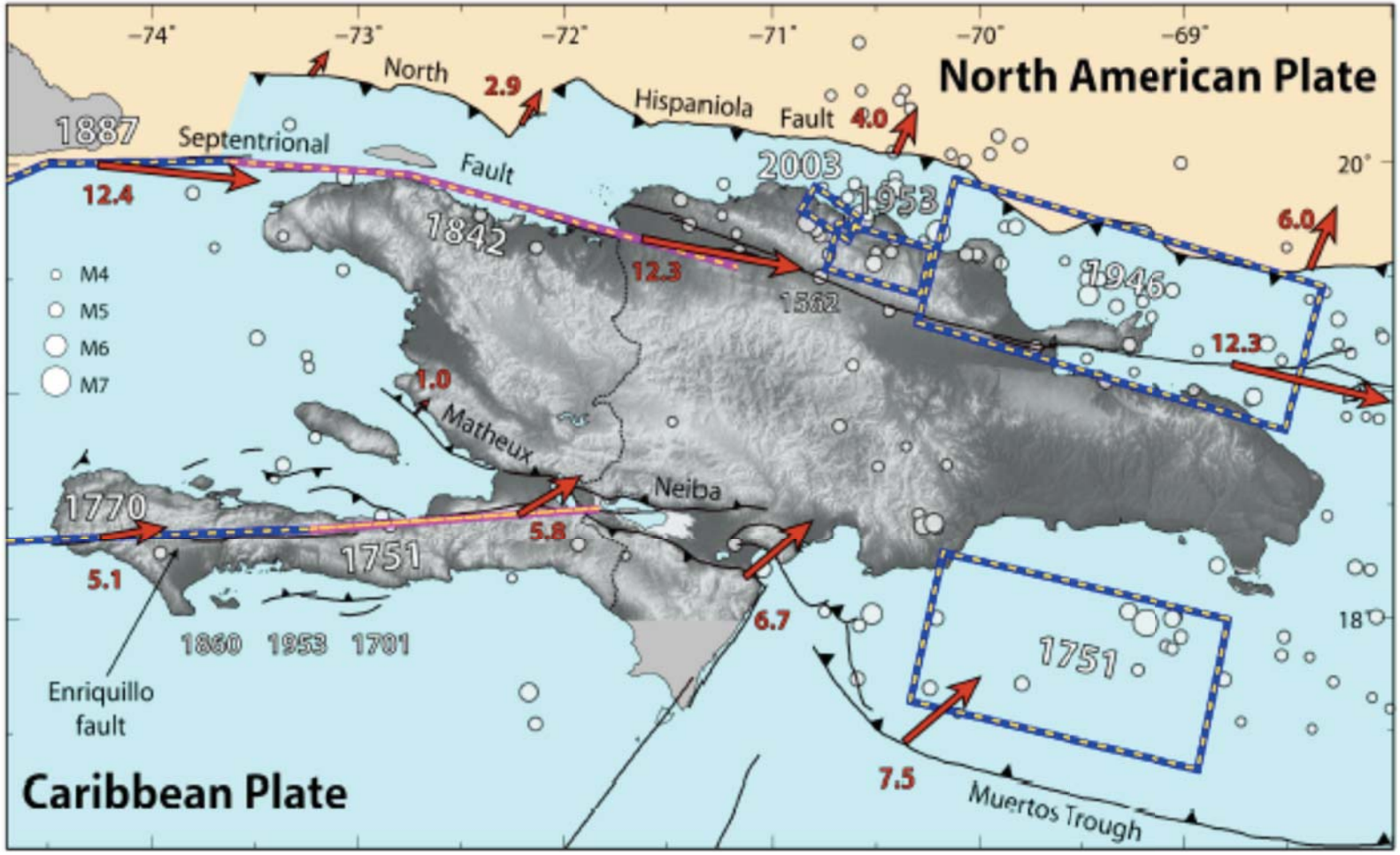
Slide credit: Eric Calais

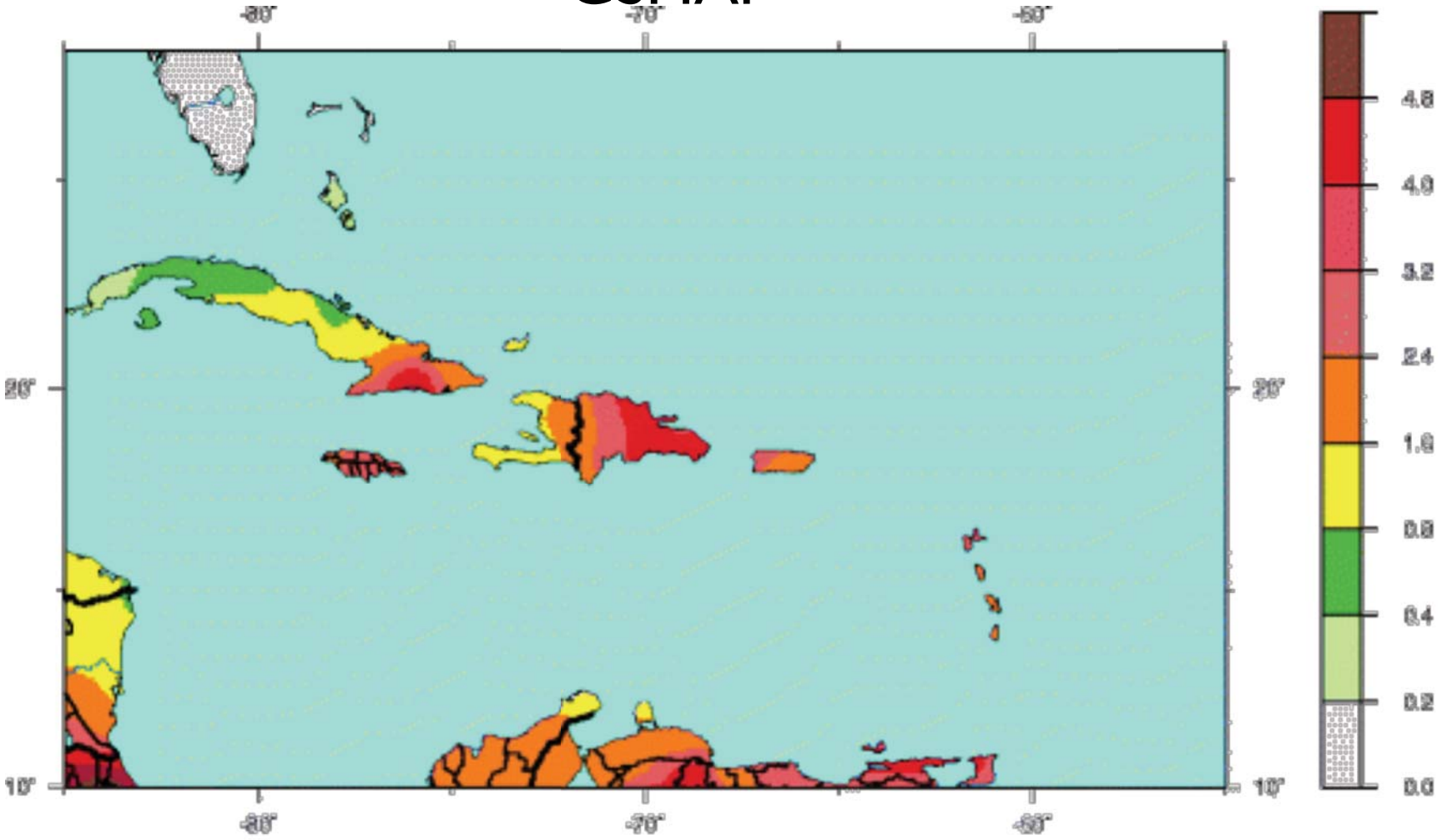


Slide credit: Eric Calais



Slide credit: Eric Calais

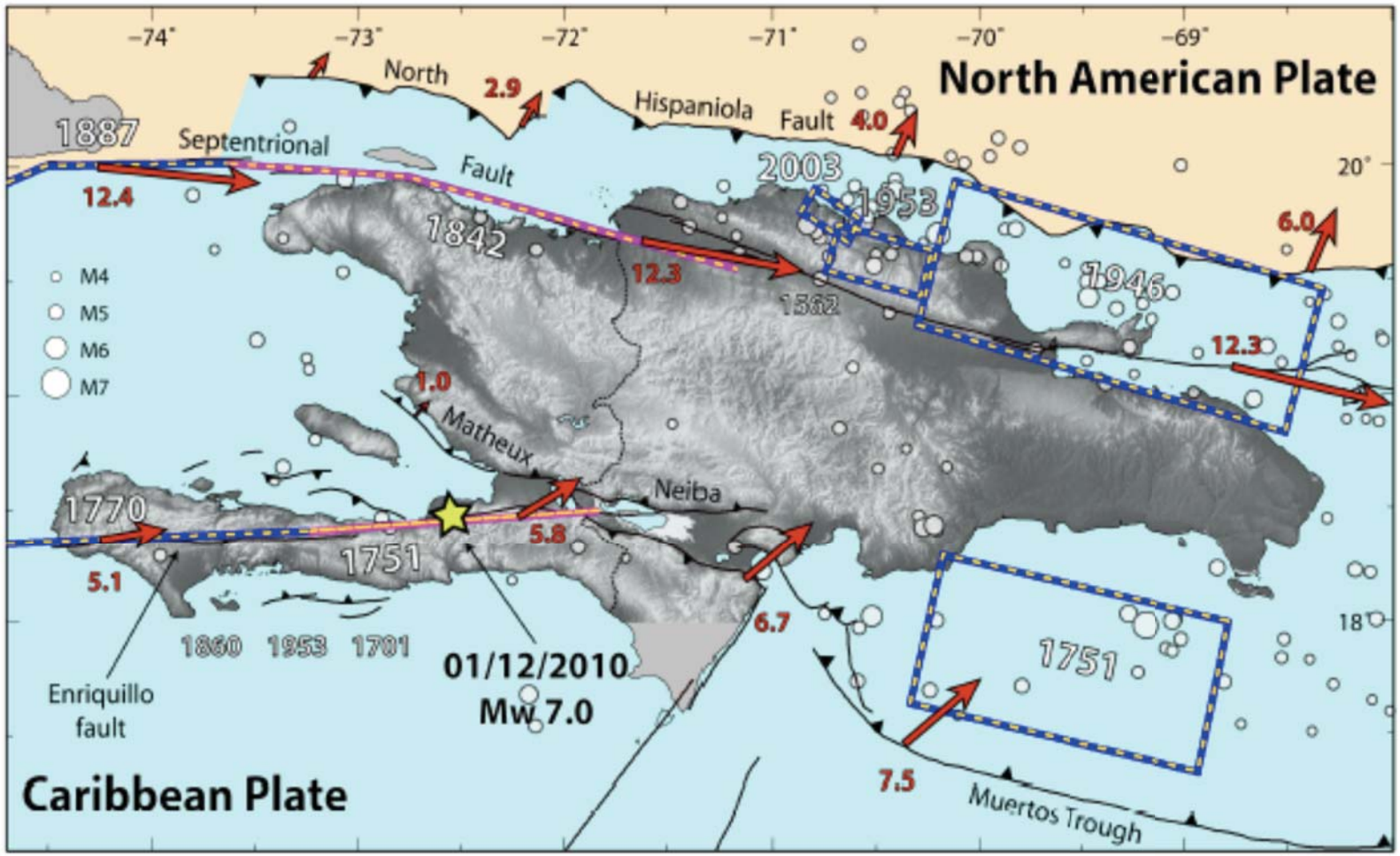
GSHAP



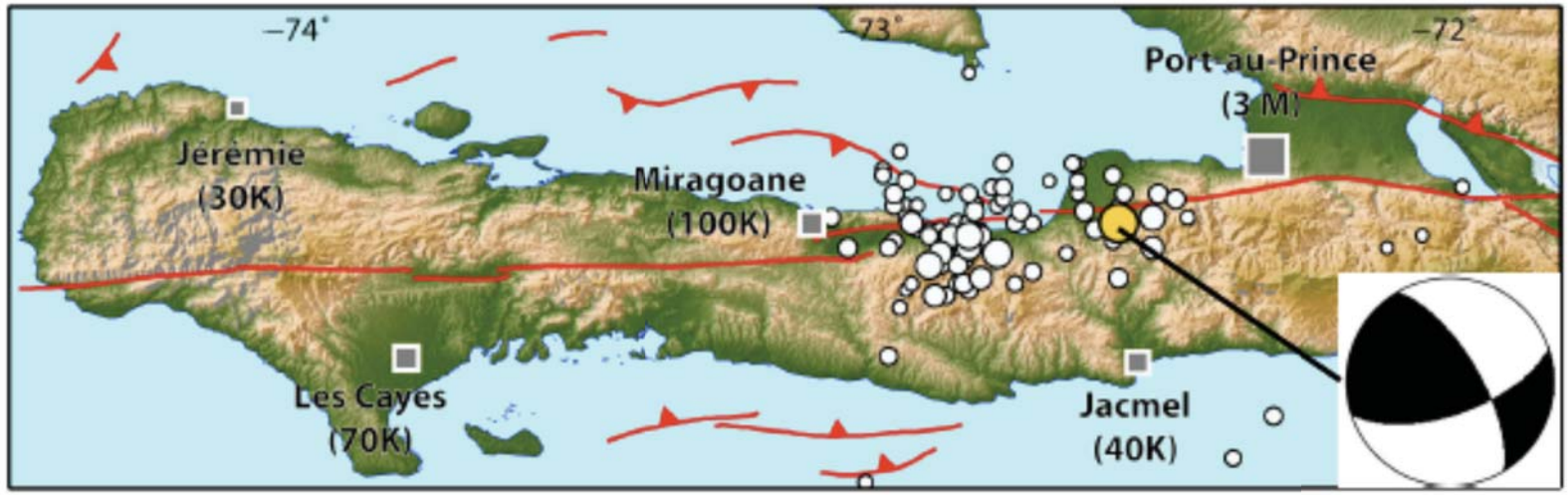
Peak Ground Acceleration (m/s^2) with 10% Probability of Exceedance in 50 Years

Previous Large Earthquakes on the Enriquillo Fault (EF)

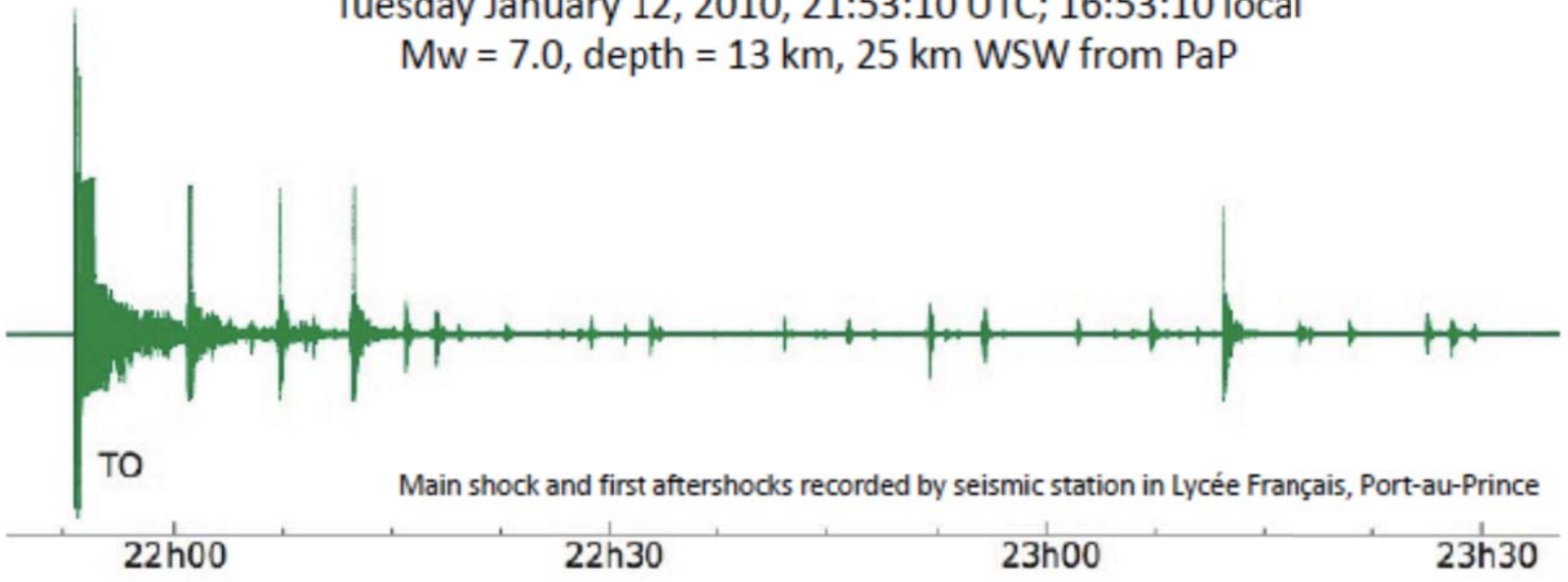
- October 18, 1751
- November 21, 1751
- June 3, 1770
- Sources:
  - Mann and others, 1998; Ali and others, 2008
- The EF must accommodate 7±2 mm/yr of relative plate motion inferred from GPS measurements (Manaker and others, 2008)
- Suggests a portion of EF longer than the part that ruptured has accumulated 1.7 m of tectonic load since the last earthquakes
- Used by Manaker et al. (2008) to estimate potential for large earthquake. Not a prediction.



Slide credit: Eric Calais



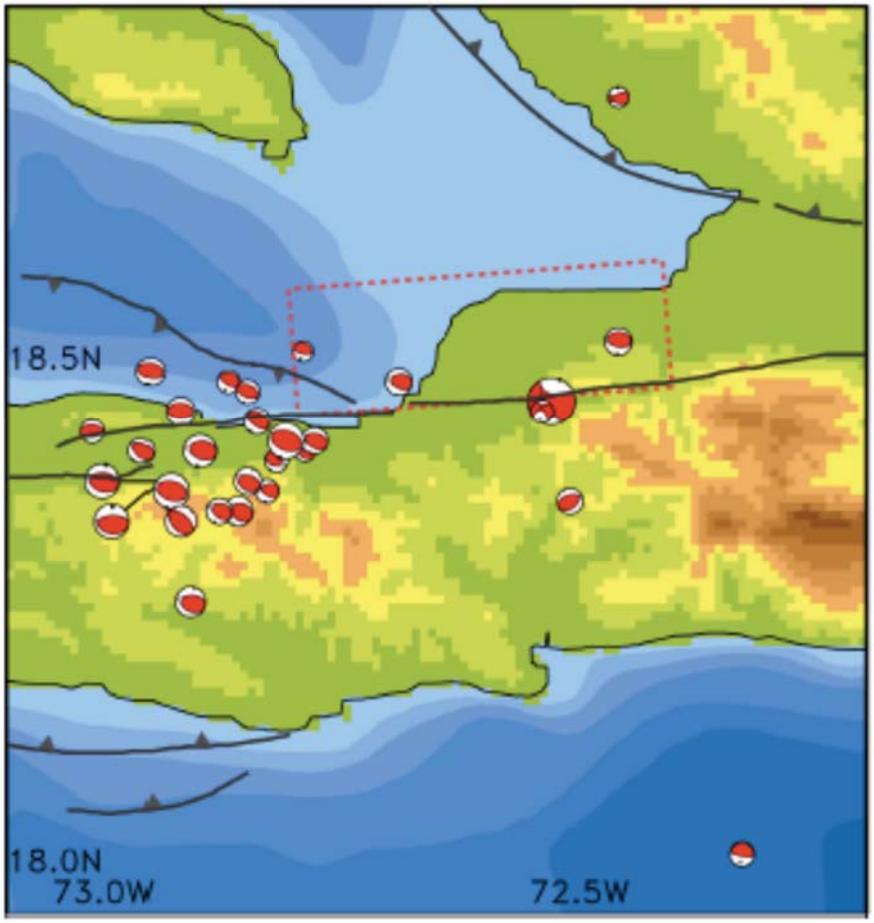
Tuesday January 12, 2010, 21:53:10 UTC; 16:53:10 local
Mw = 7.0, depth = 13 km, 25 km WSW from PaP



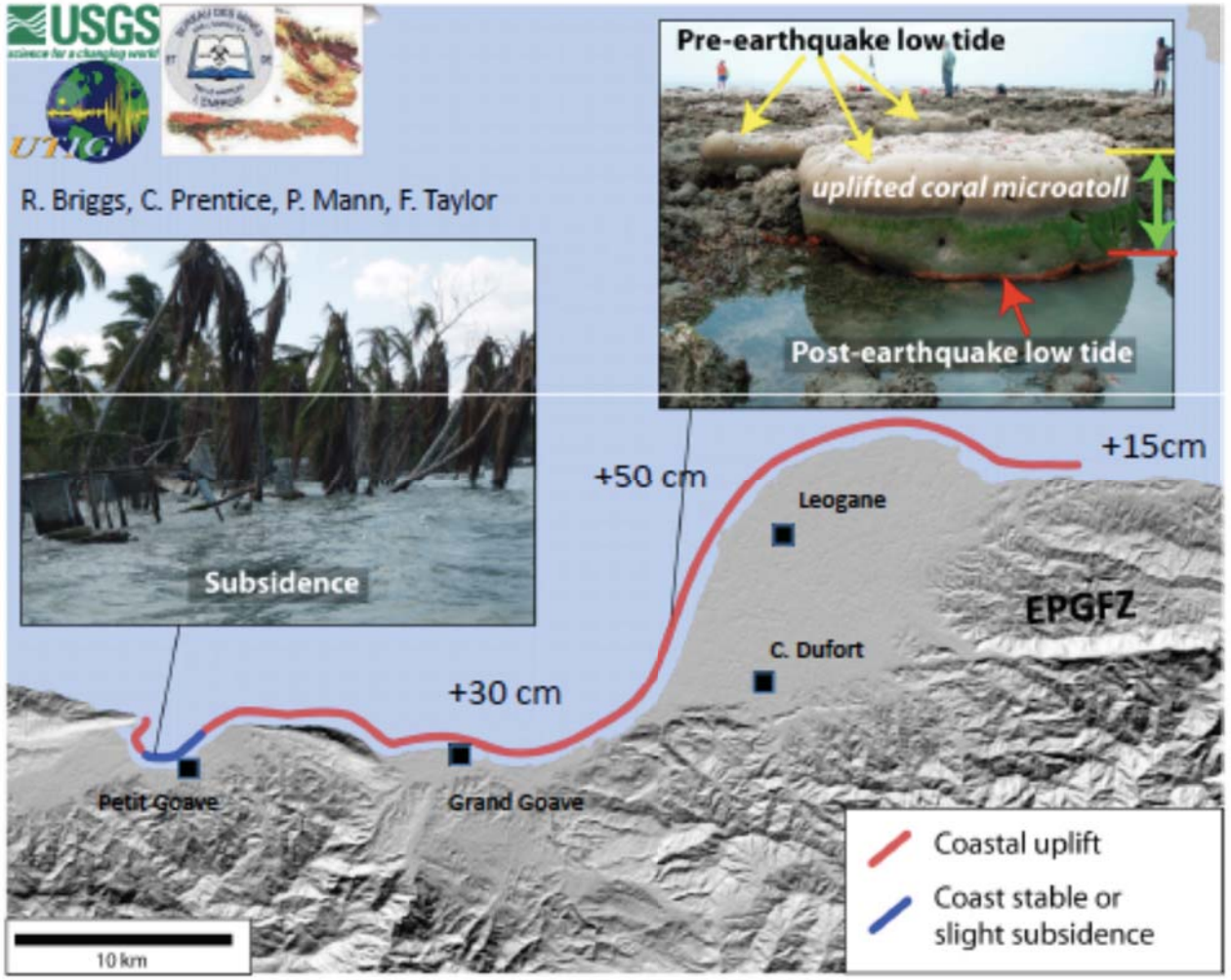
Slide credit: Eric Calais

CMT solutions for main shock and aftershocks (M>4, 3/9/2010)

M. Nettles and
V. Hjorleifsdottir, 2010, LDEO

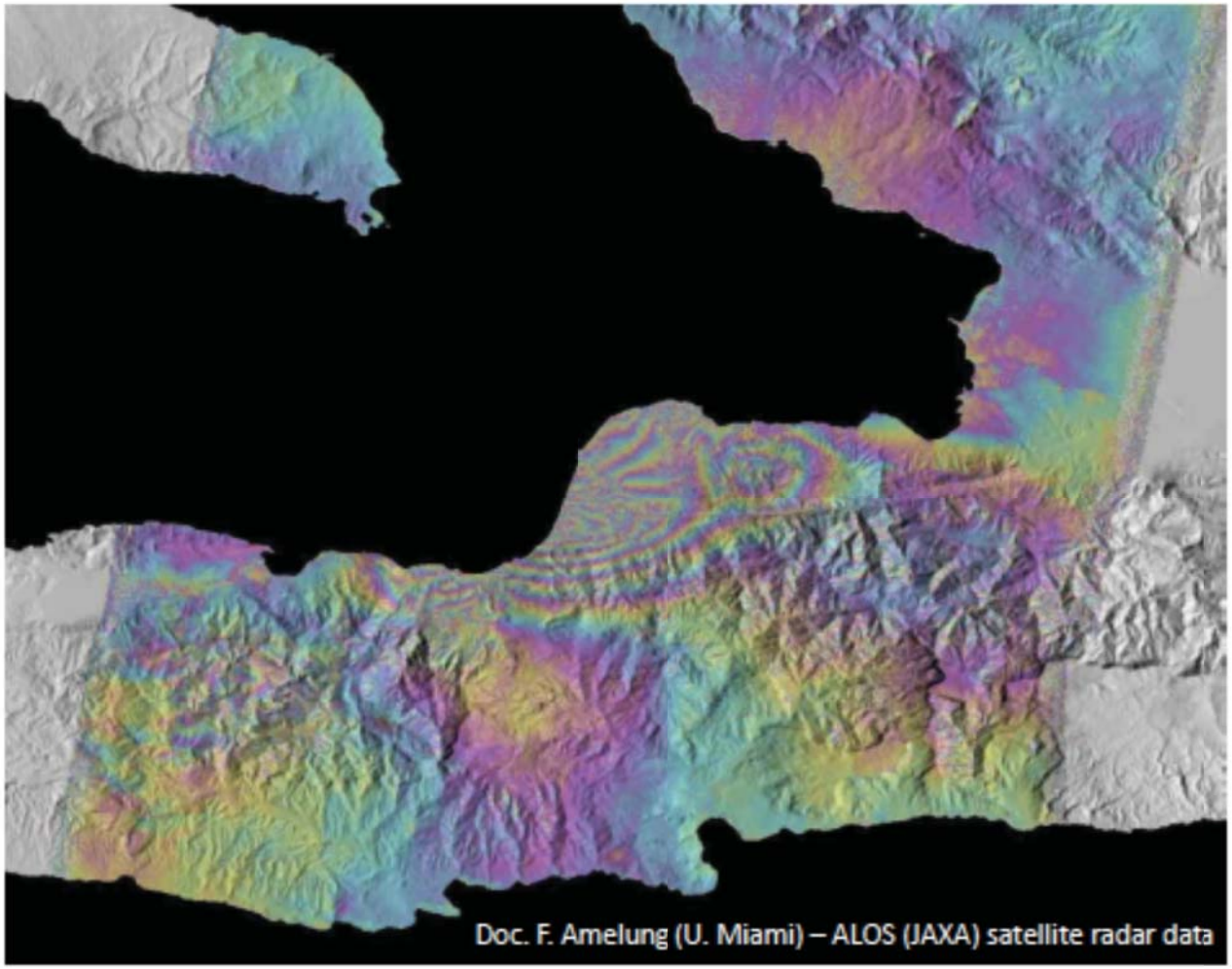


Coastal observations

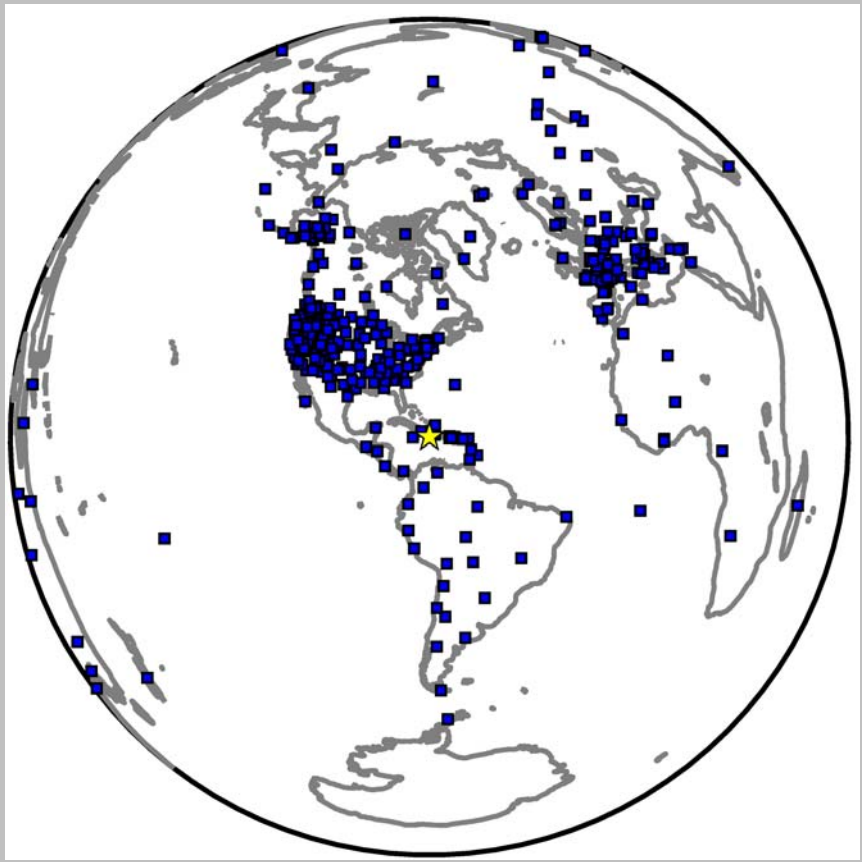


Slide credit: Eric Calais

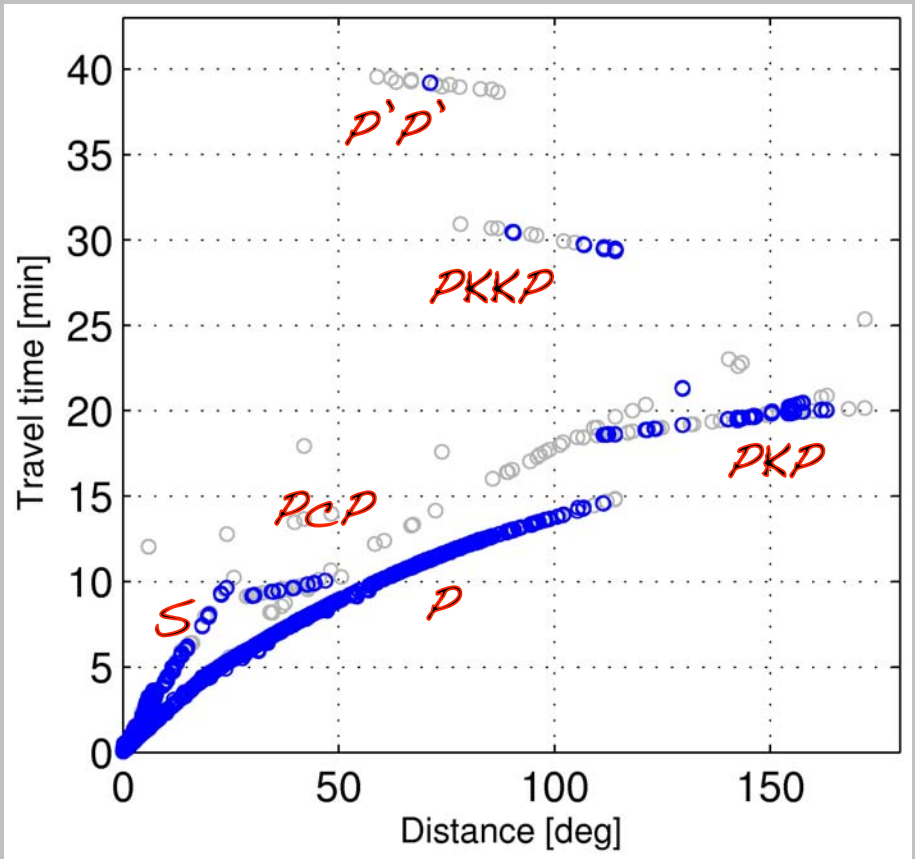
Coseismic displacements from InSAR

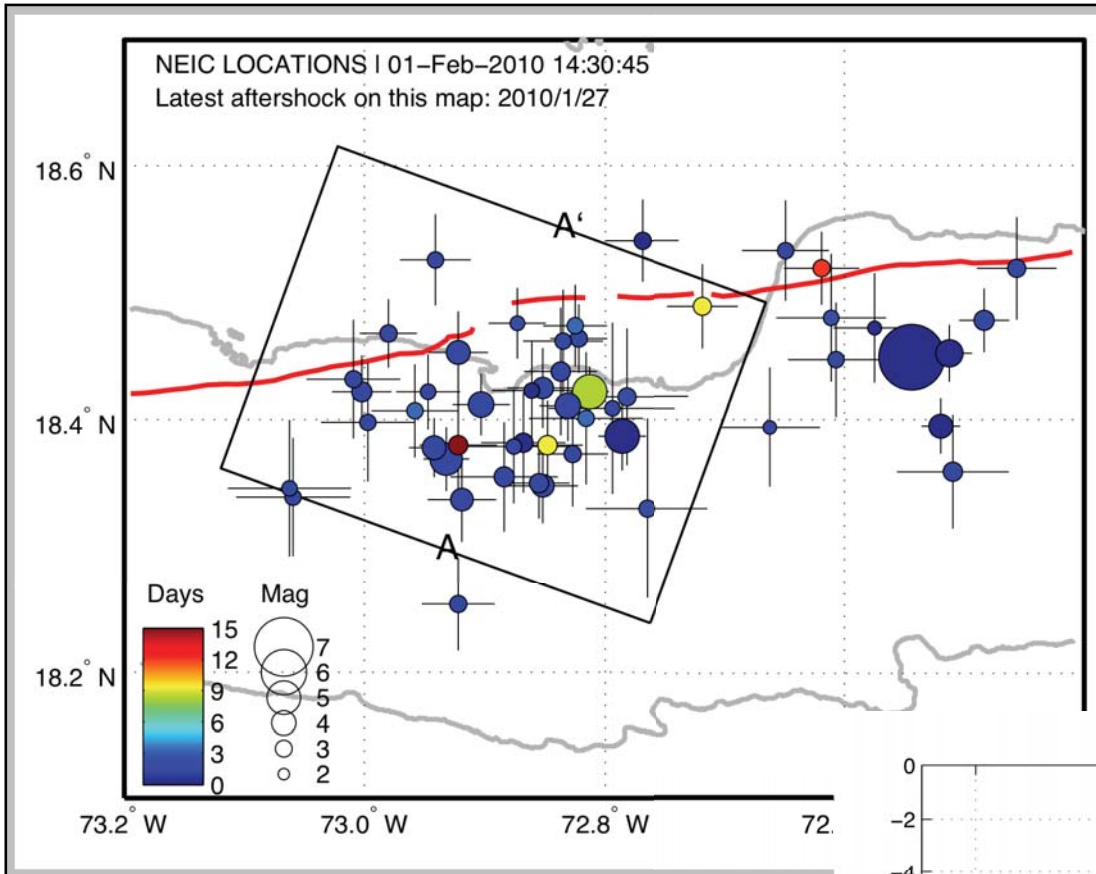


Global station distribution

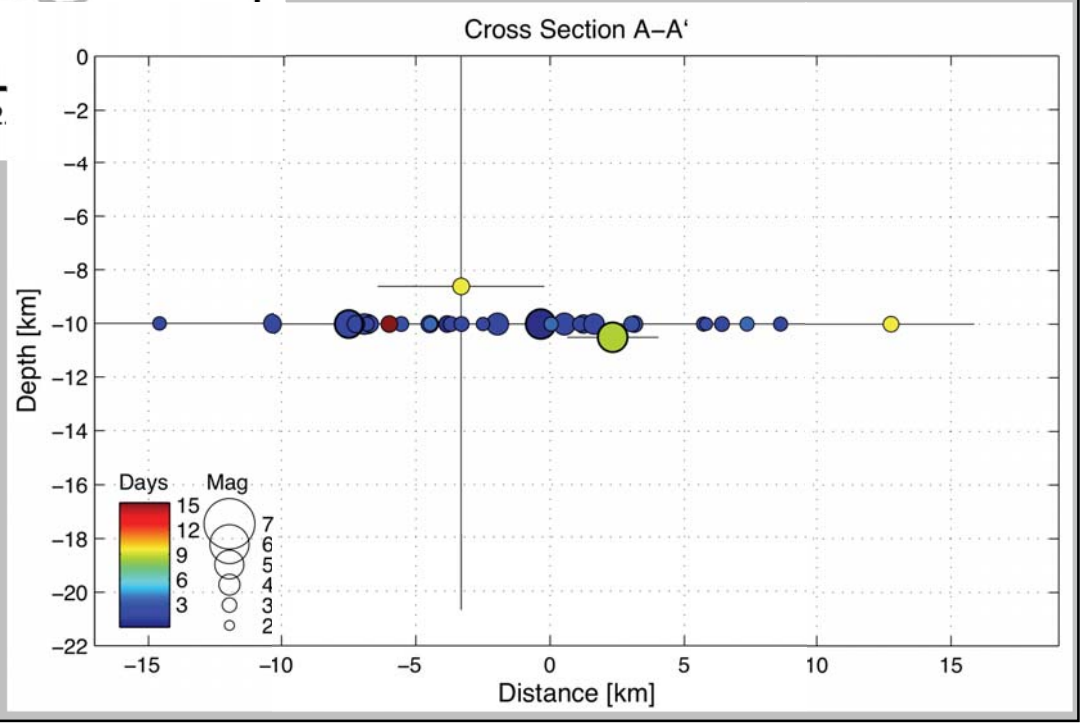


NEIC phase arrival time readings

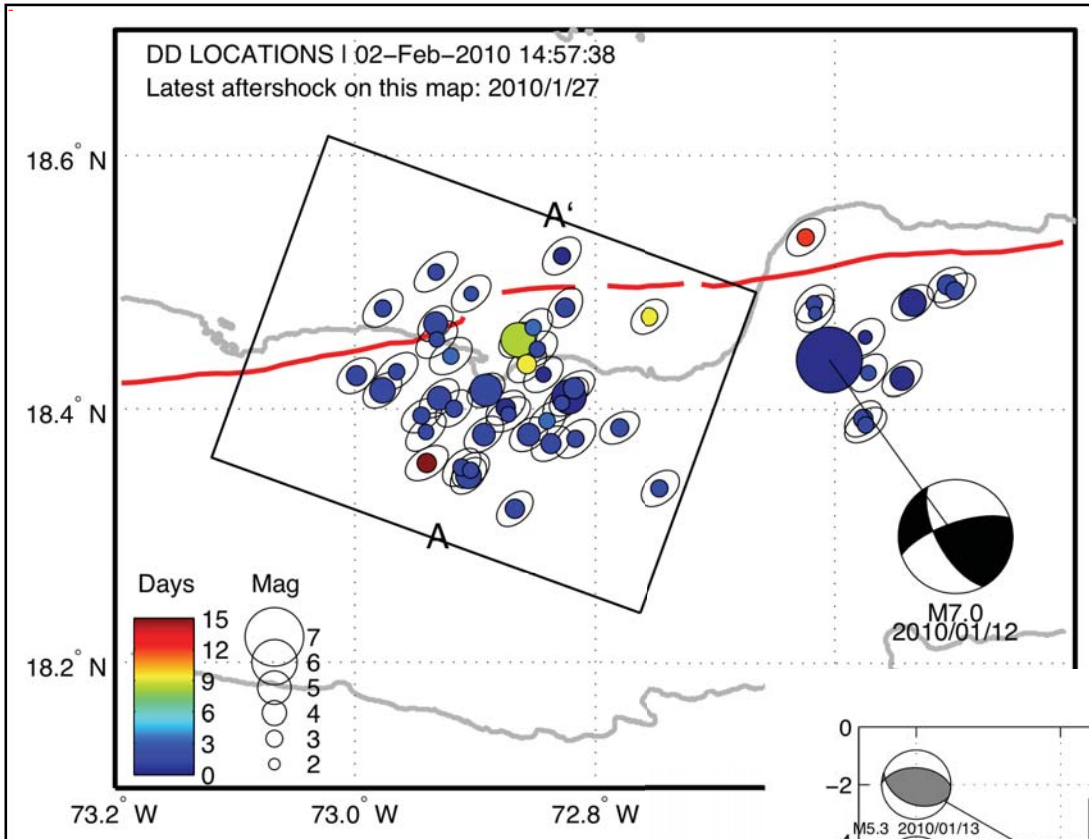




Routine locations by the USGS/NEIC

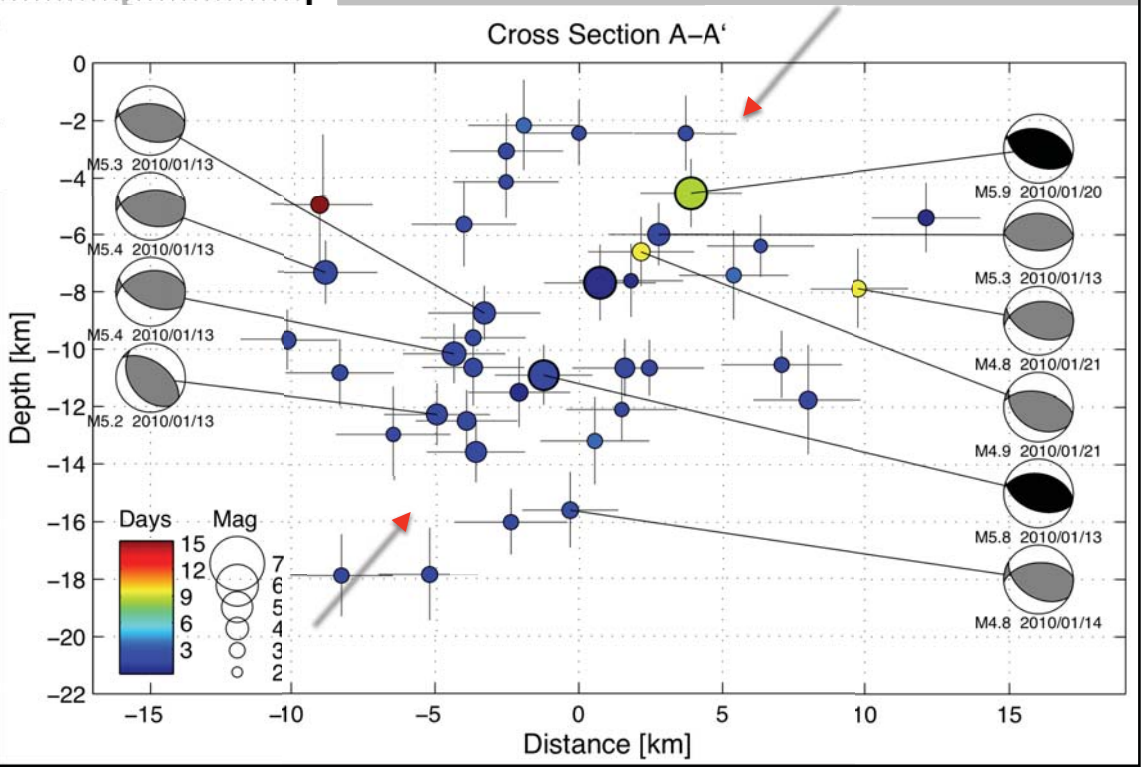


NEIC fixes unresolved depths @ 10 km



Preliminary double-difference relocations using pick delay times

Largest aftershocks on SSW dipping thrust fault



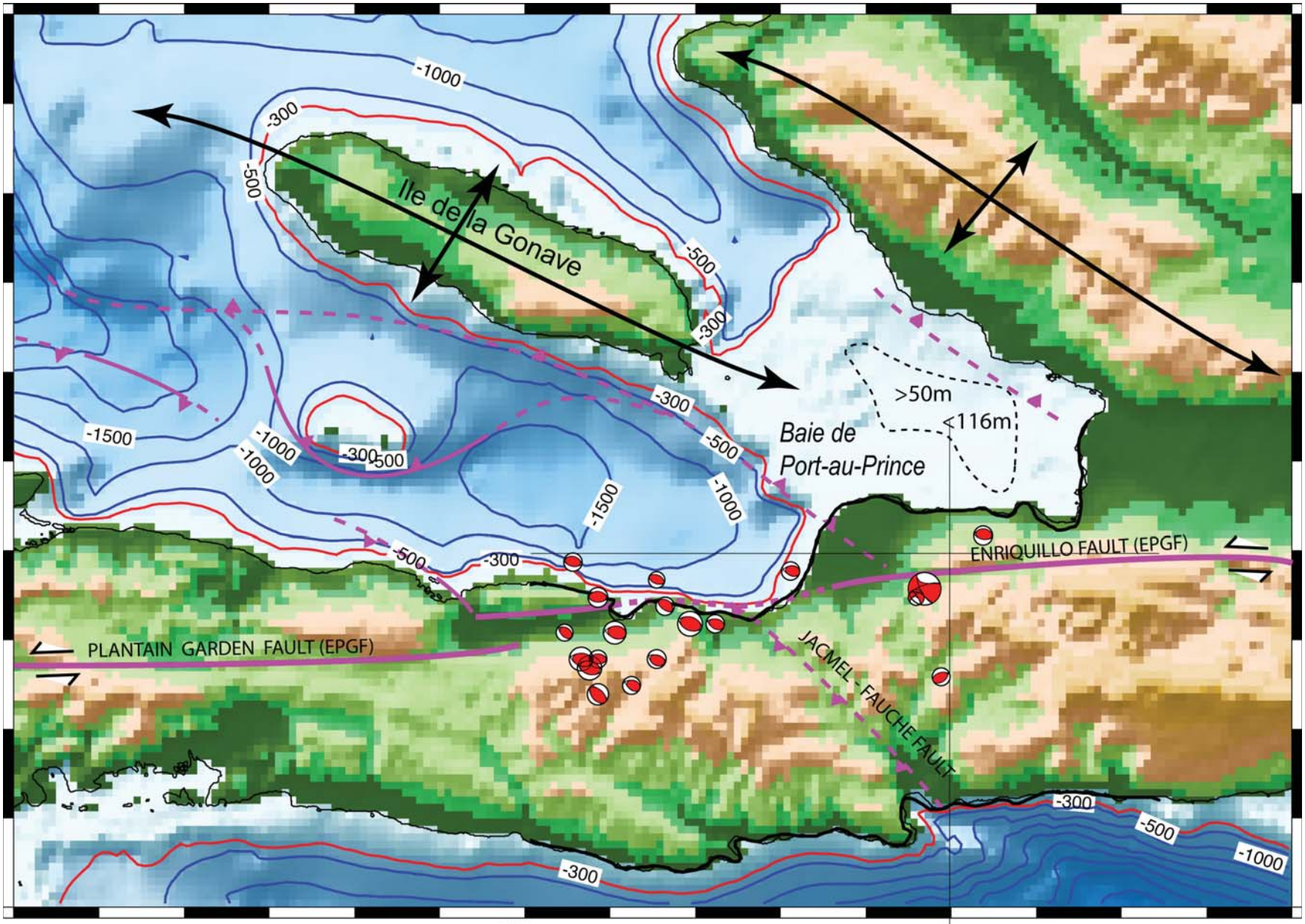
NEIC-DD epicenter location differences:

Mean = 5 km

Max = 16 km

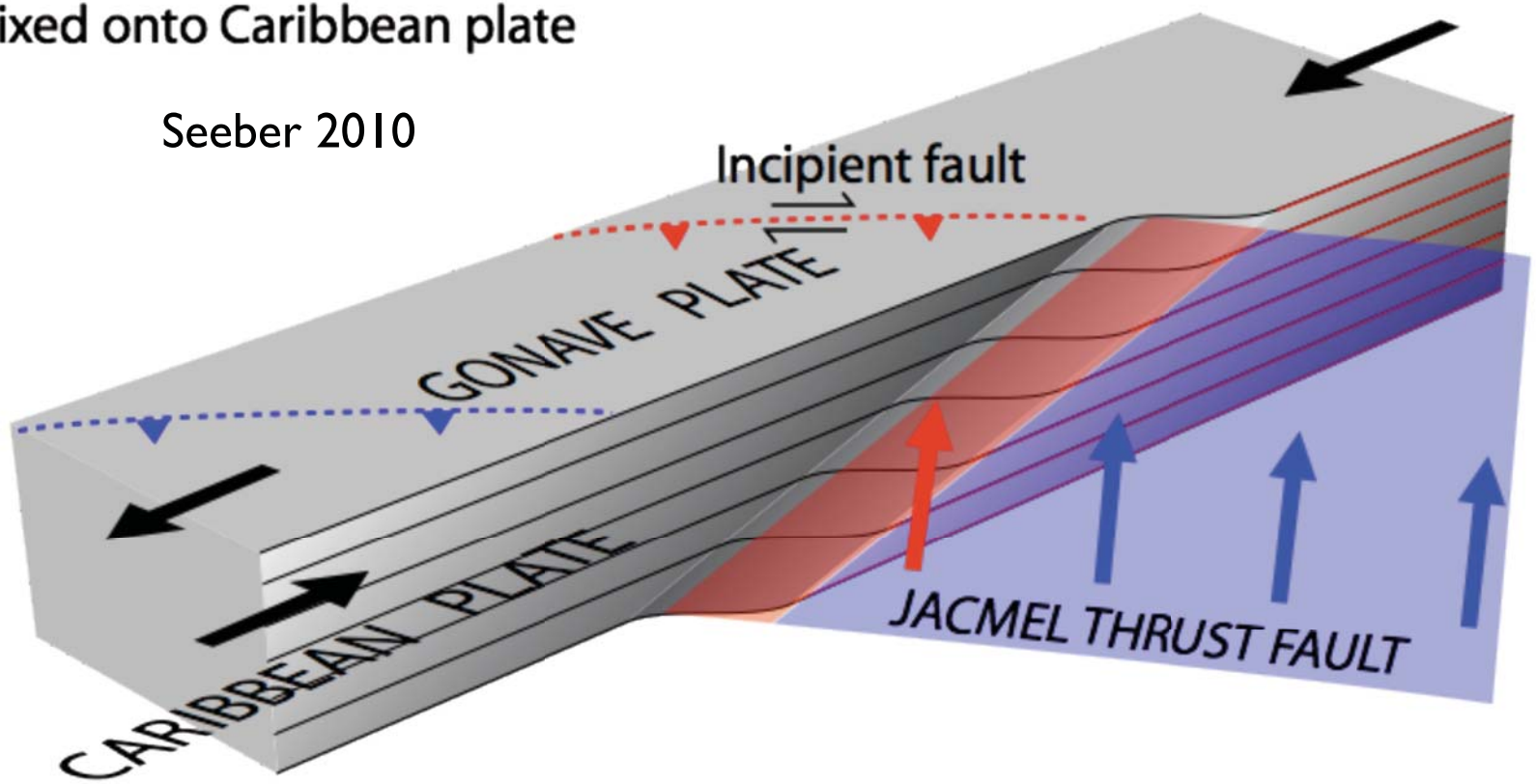
Min = 0.6 km

gCMTs from Nettles & Hjorleifsdottir


-1000
-300
-500
Ile de la Gonave
-500
-300
-300
-1500
-1000
-1000
-300
-500
-300
-500
-1000
-1500
>50m
<116m
Baie de
Port-au-Prince
-500
-300
ENRIQUILLO FAULT (EPGF)
PLANTAIN GARDEN FAULT (EPGF)
JACMEL - FAUCHE FAULT
-300
-500
-1000
-300
10km

Constricting double bend is caused by Jacmel fault and is fixed onto Caribbean plate

Seeber 2010



Caribbean plate shortens along strike of the NA-C boundary because approces ENE-directed subduction

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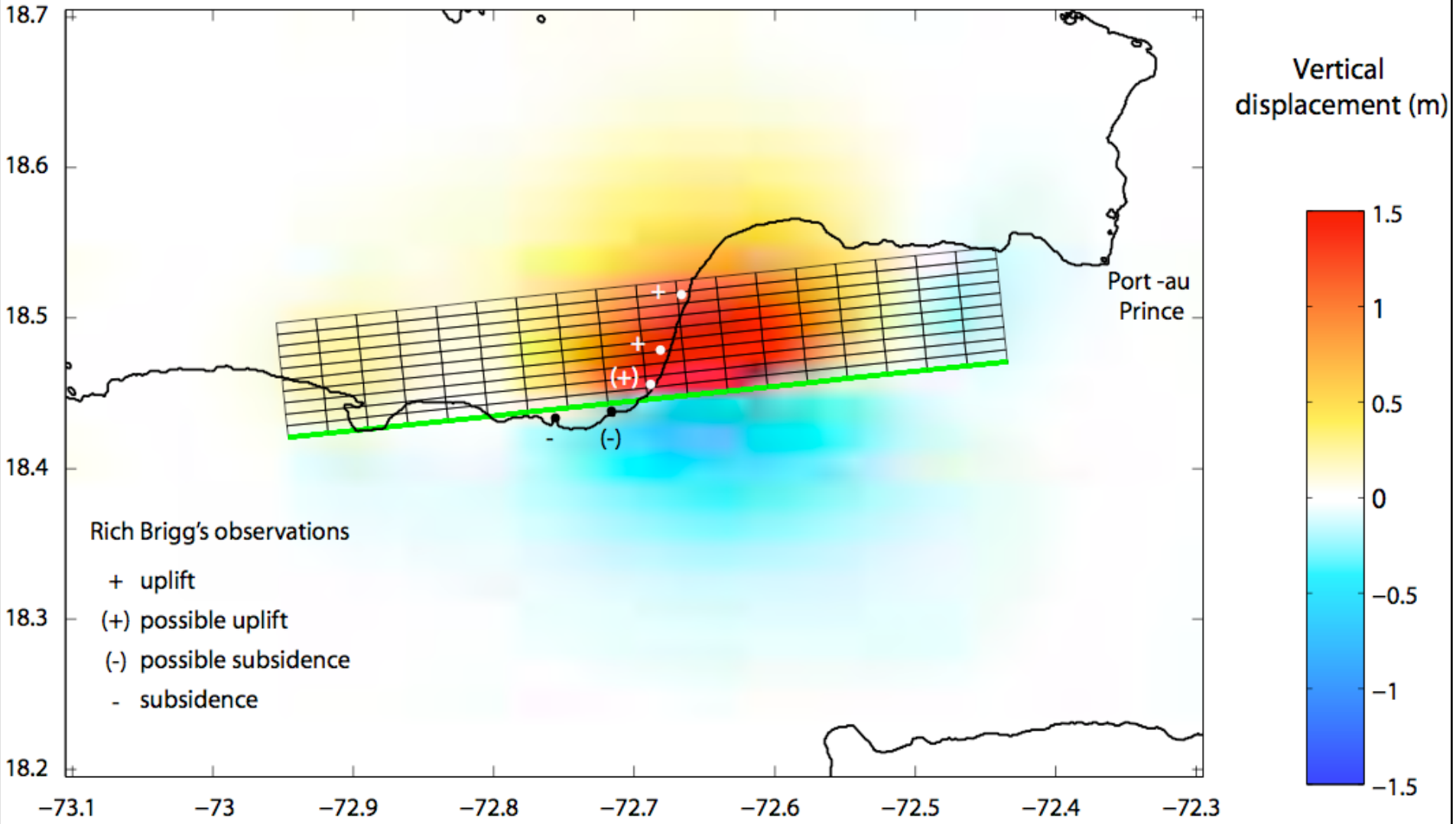
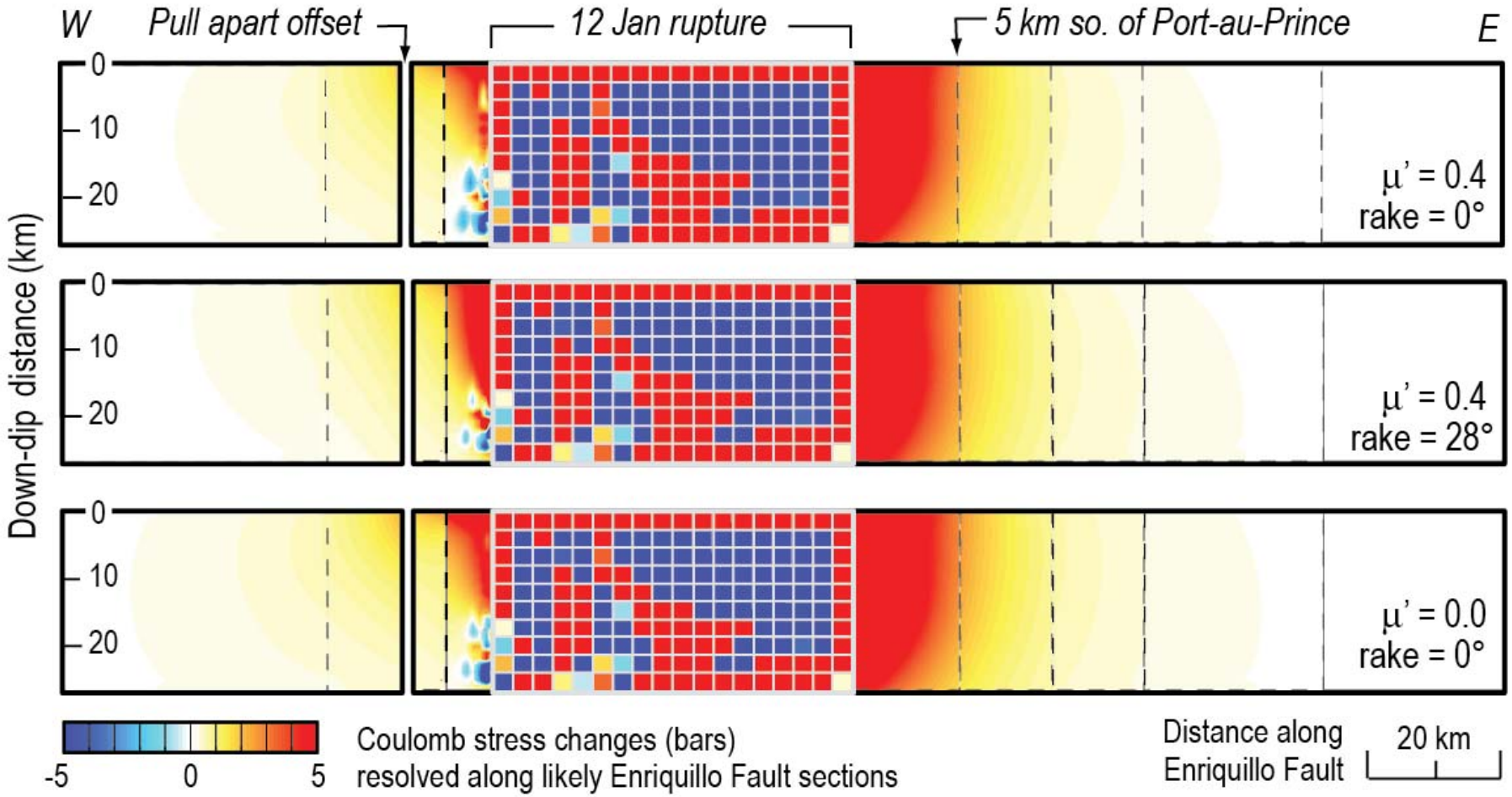
Gavin Hayes' revised source model matches coastal deformation

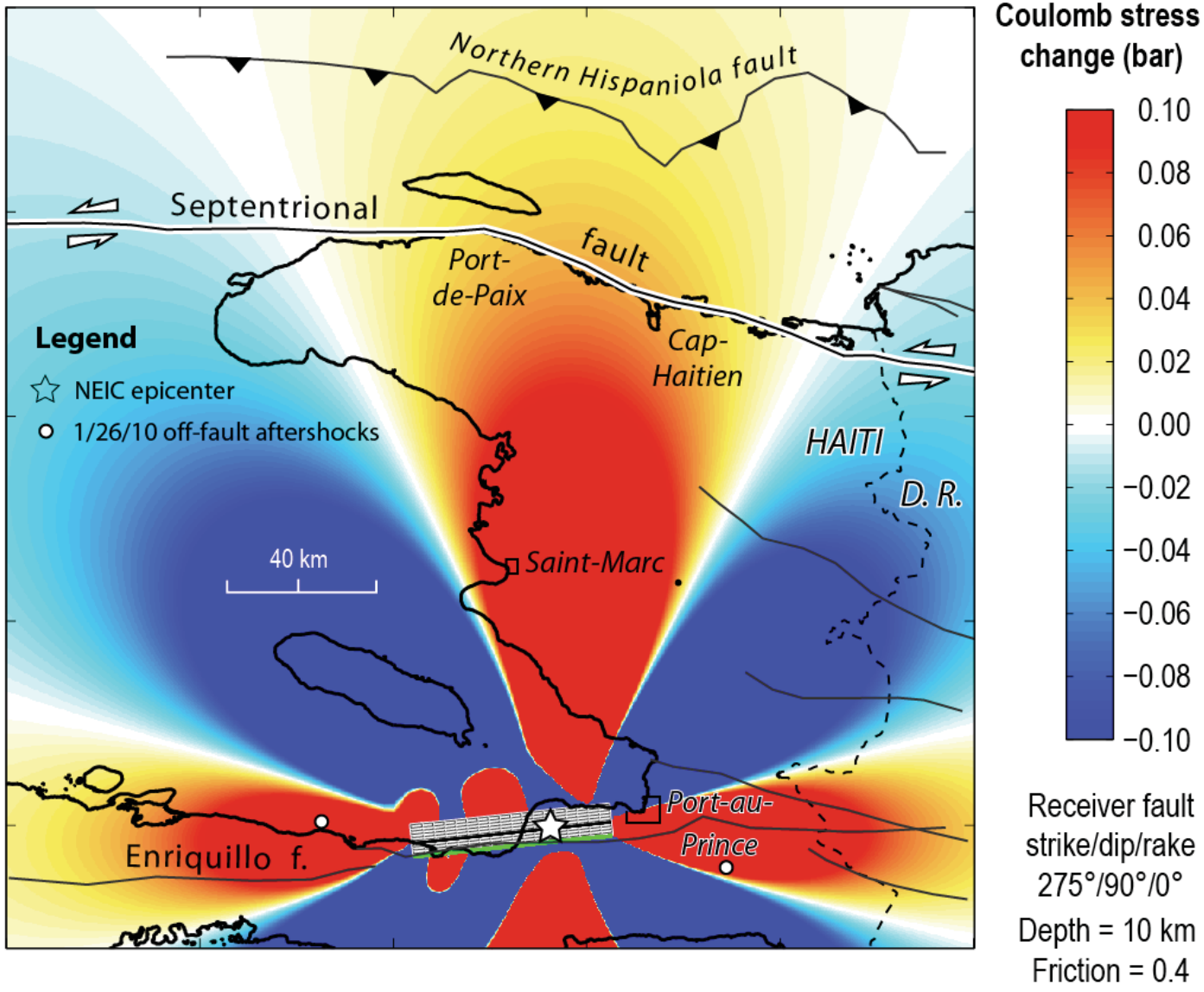


Enriquillo fault: Greater stress is transferred to the Port-au-Prince section



USGS Open-File Rep. 2010-1019 by Lin, Stein, Sevilgen & Toda

Septentrional fault: A very small—but positive—stress transfer



USGS Open-File Rep. 2010-1019 by Lin, Stein, Sevilgen & Toda

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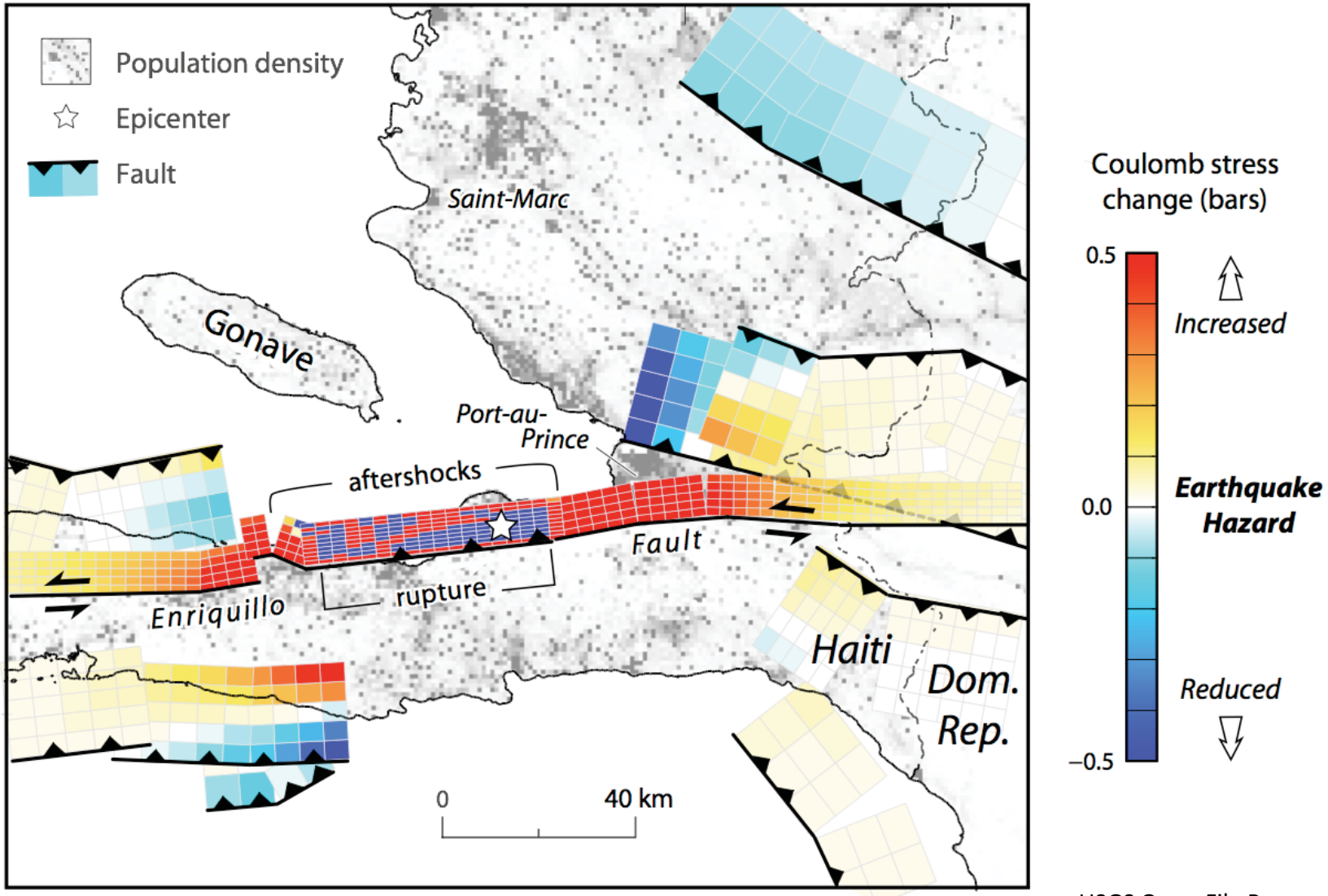
Enriquillo fault sustains much higher stress increase than surrounding thrust faults



USGS Open-File Rep. 2010-1019 by Lin, Stein, Sevilgen & Toda

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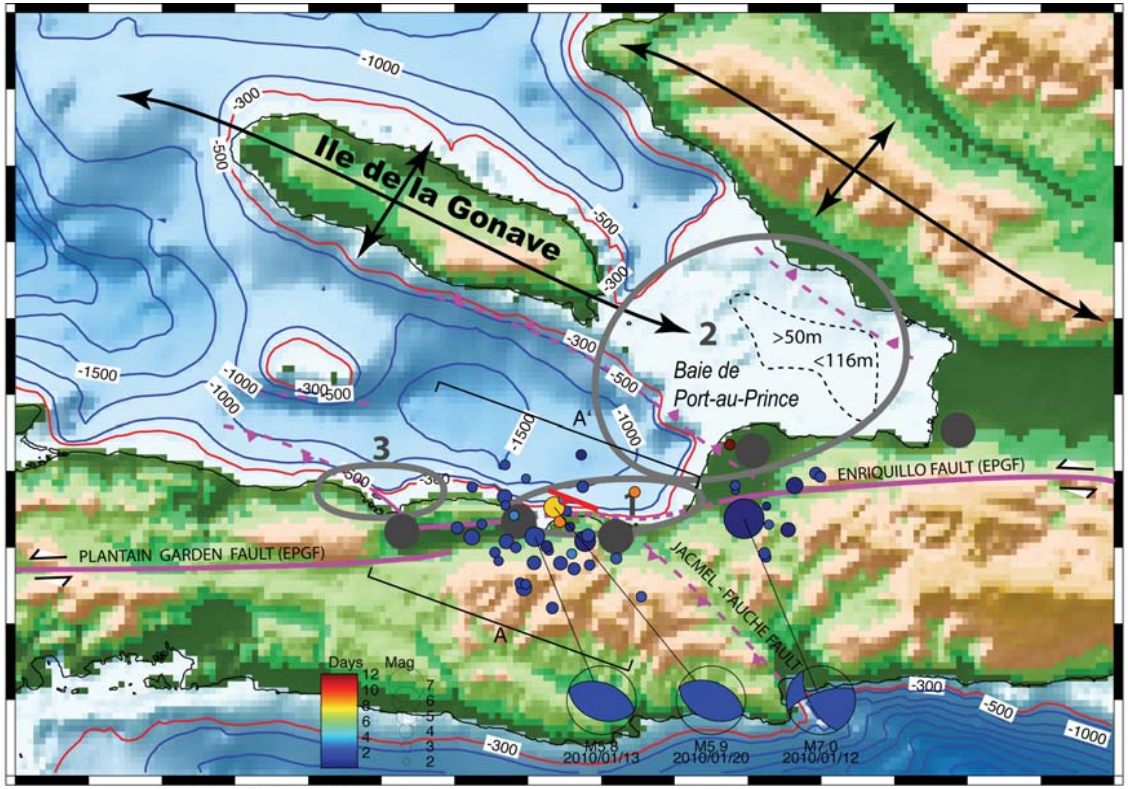
Source: Lin et al., USGS OFR 2010-1019

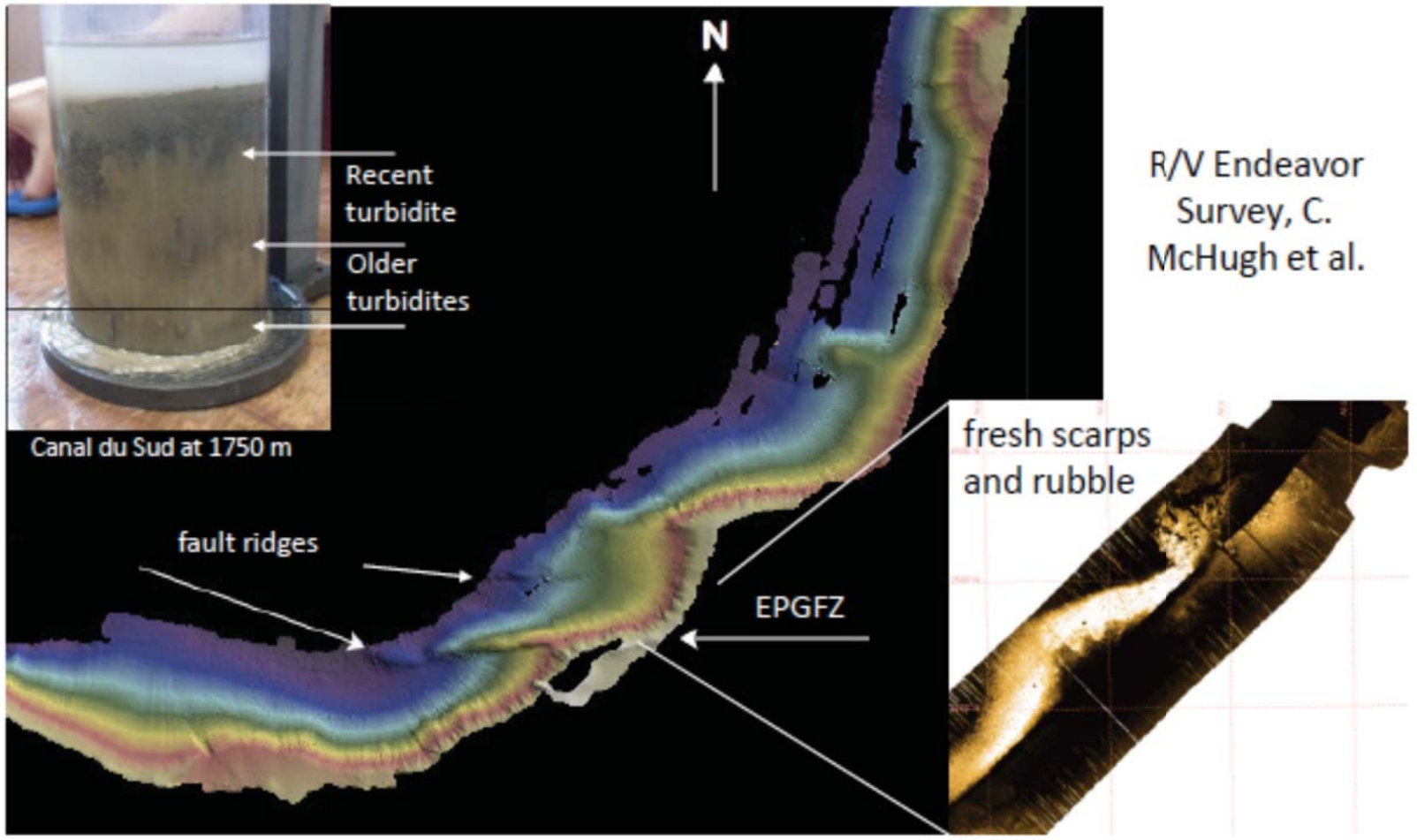
Lamont/UTIG Survey



GEBCO, GMT, USGS

Fig. 1. Proposed survey areas 1, 2, 3 (in order of priority) are within the gray ellipses. The survey will extend to ~ 300 m contour. 1 contains the submarine portion of the EPFG where coseismic rupture could have reached the sea floor. 2 is a large shallow area of the Gonave Gulf that contains an isolated basin, which is likely to be maintained by subsidence and active structure(s) given the abundant sediment supply. 3 is the intersection of a NW-striking thrust (?) fault and the EPGF. The star and small red circles are the mainshock and aftershock epicenters (USGS).

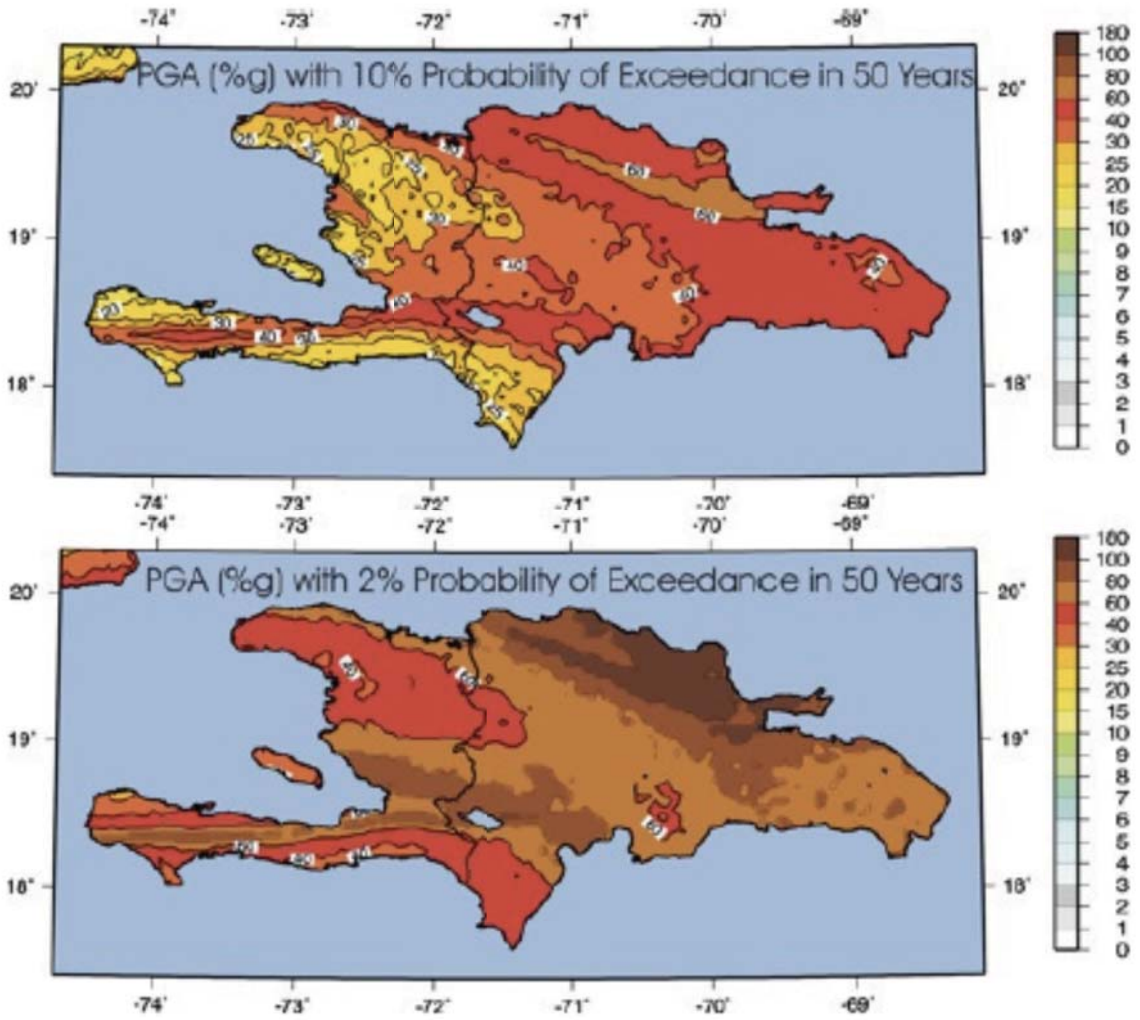
Offshore REPONS observations



R/V Endeavor Survey, C. McHugh et al.

Slide credit: Eric Calais

First seismic hazard maps (PSHA)



Frankel, A.et al., Documentation for Initial Seismic Hazard Maps for Haiti, USGS Open-File Report 2010.

A National Earthquake Risk Reduction Program for Haiti (UNEP proposal)

- A National Earthquake Risk Reduction Program in Haiti
  - Basic science
  - Hazards and engineering
  - Education, communication, outreach
  - Advisory and policy development
  - Capacity building
- Framework for:
  - Engaging Haitian technicians, authorities, population
  - Coordinating monitoring, data collection, modeling (sci + eng)
  - Ensuring effective data/technology transfer to Haiti
  - Developing institutional and human capacity
  - Ensuring effective, sustainable, impact on vulnerability reduction (mitigation)

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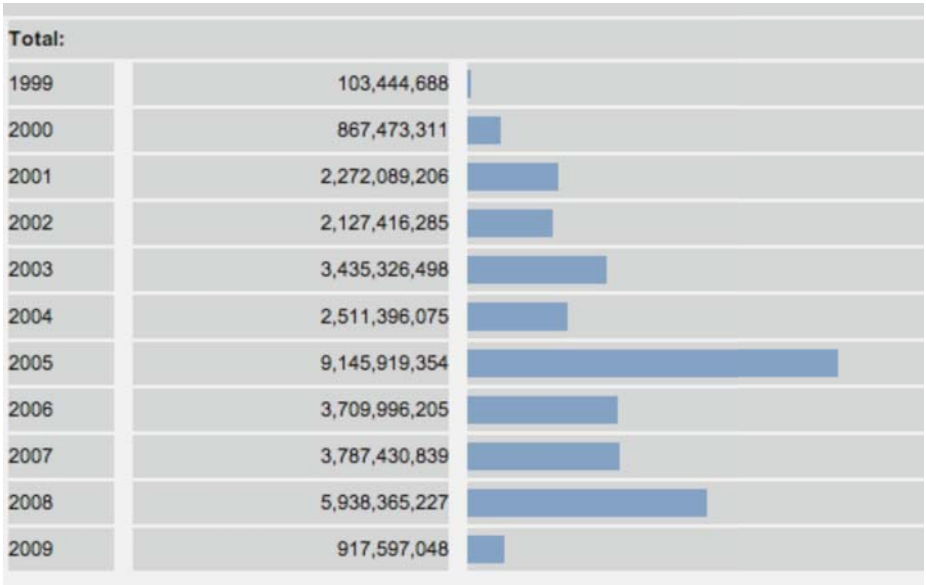
Slide credit: Eric Calais

ReliefWeb Financial Tracking Service

Natural Disaster Donor Contributions, USD
All reported international humanitarian aid

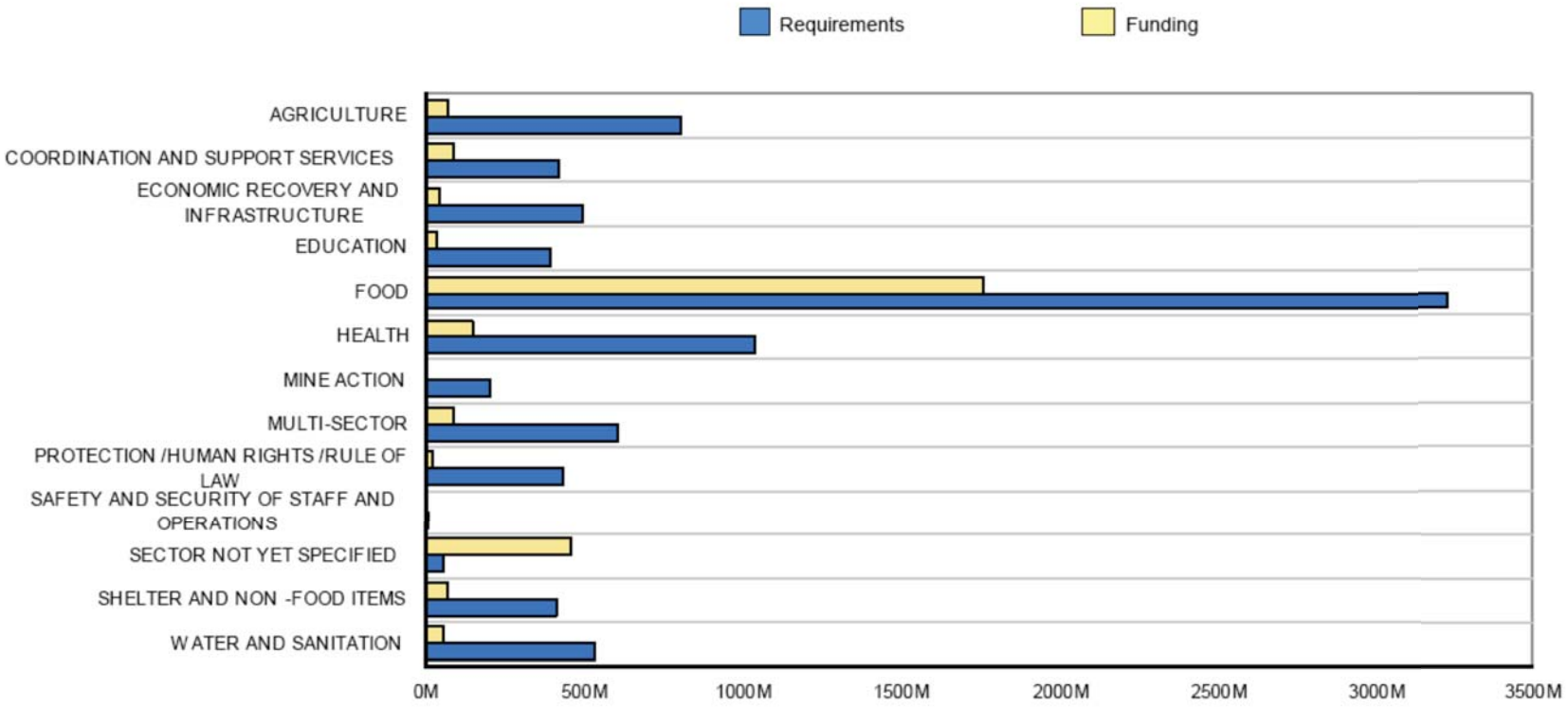


Total:	
1999	103,444,688
2000	867,473,311
2001	2,272,089,206
2002	2,127,416,285
2003	3,435,326,498
2004	2,511,396,075
2005	9,145,919,354
2006	3,709,996,205
2007	3,787,430,839
2008	5,938,365,227
2009	917,597,048

Total: $34.8B, 1999-2009(partial)

Consolidated and Flash Appeals by Sector

2008



NOTE: "Funding" means Contributions + Commitments

Source: http://ocha.unog.ch/fts/reports/daily/ocha_R30_y2009___0904220935.pdf

Earthquake Risk Reduction

Connection to Sustainable Development

Sustained ERR Program

One of Bilham's False ASSUMPTIONS

World Bank Performance

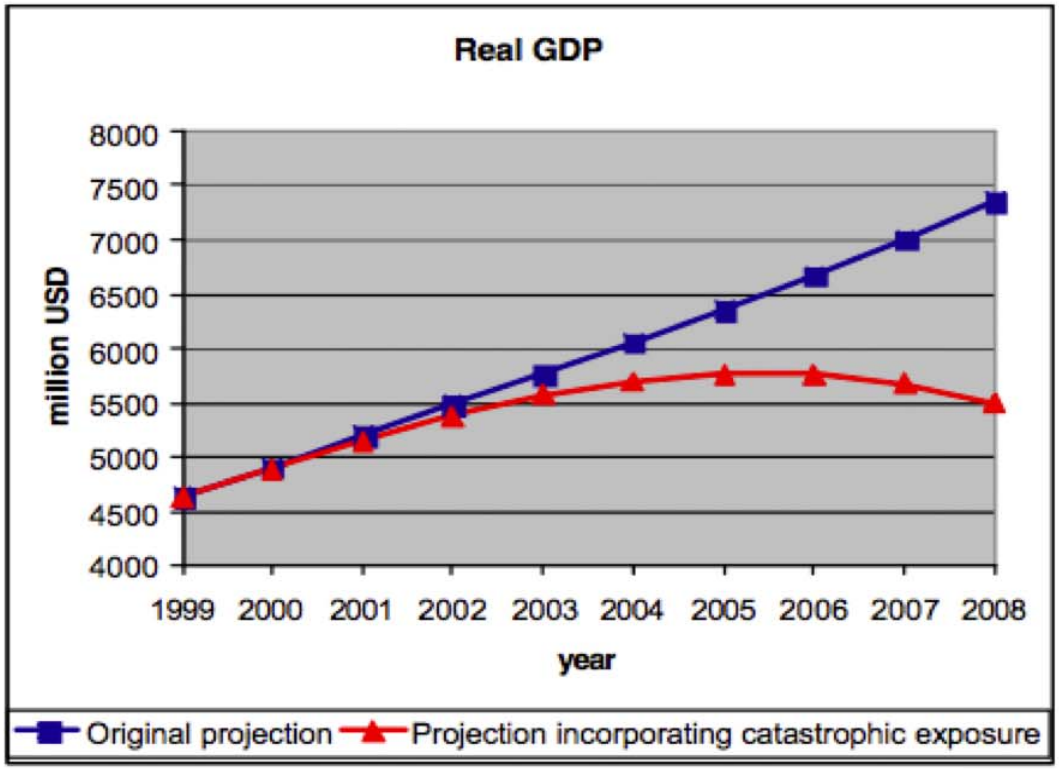
- World Bank disaster response projects perform better than Bank's total portfolio;
- Bank is better at reconstruction of damaged infrastructure and housing than it is at reducing vulnerabilities and their root causes;
- In half of the countries requiring disaster reconstruction, disaster prevention played no role in overall development strategy.

source: IEG 2006

Link to Sustainability "Recovery Trap" hypotheses

- Recovery and reconstruction costs are macro-shocks and perturb normal growth
- Additional debt burden for reconstruction and recovery is cumulative
- Persistent occurrence of disasters imparts a "permanent" gap between unperturbed projection and actual growth.
- Gap is independent of growth rate.
- Post-disaster recovery spending is not sustainable

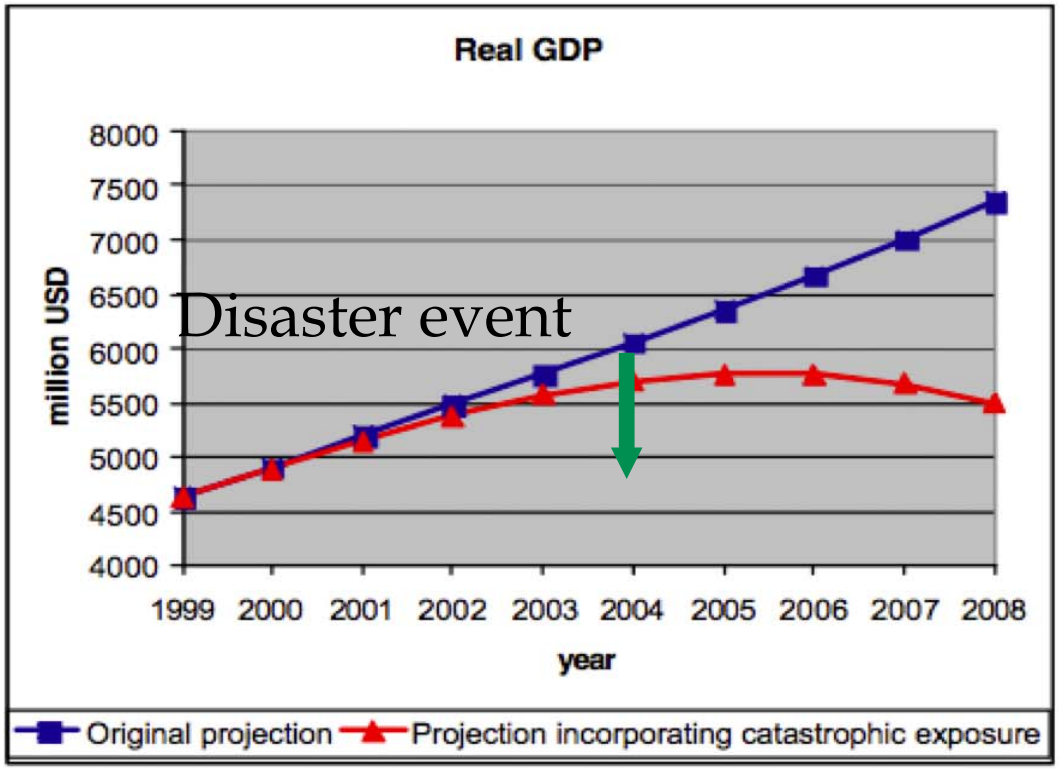
Disasters drive lower growth -
meager savings lost to recovery efforts



Freeman, Estimating chronic risk from natural disasters in developing countries: A case study on Honduras, 2000

Calculation by Paul Freeman; Slide courtesy of J. Mutter

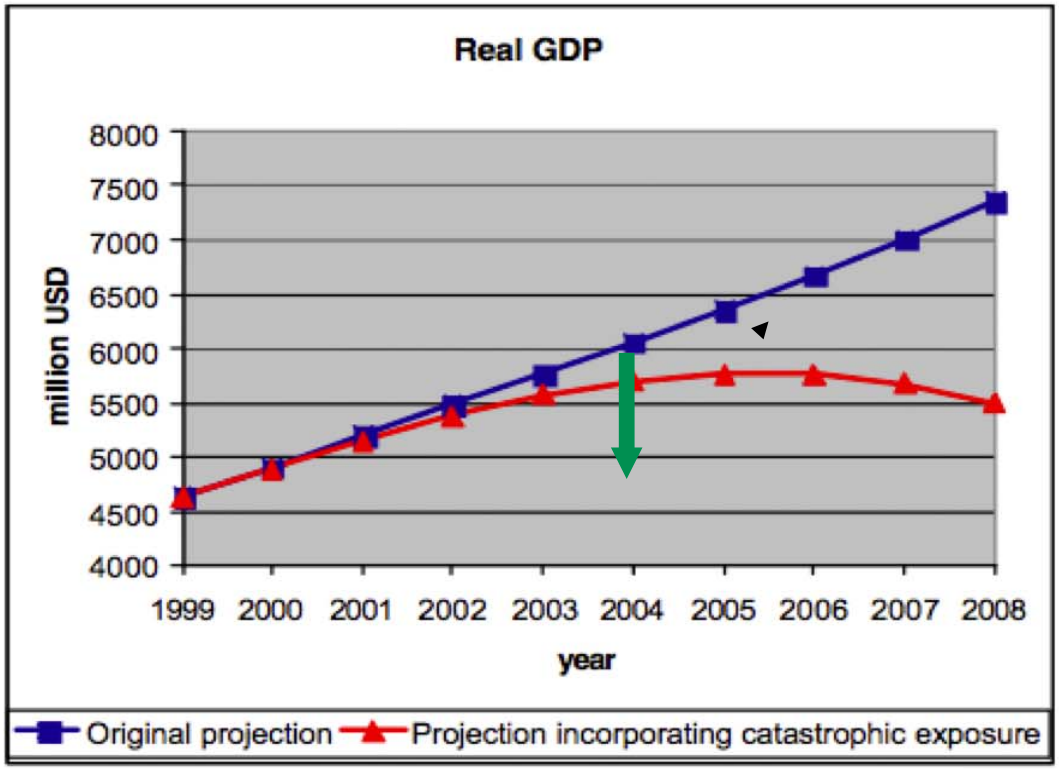
Composed of a set of individual events that are macro-economic shocks that remove productive capital



Freeman, Estimating chronic risk from natural disasters in developing countries: A case study on Honduras, 2000

Slide courtesy of J. Mutter

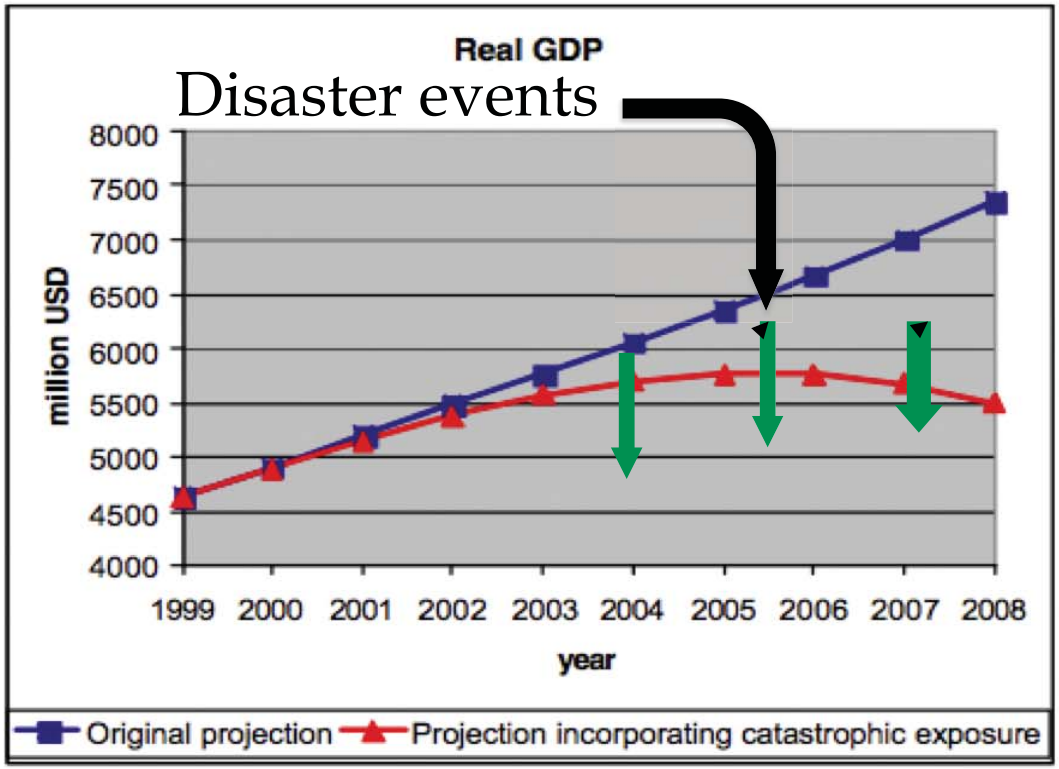
To get back to the blue curve recovery has to be at a greater rate than the pre-disaster growth



Freeman, Estimating chronic risk from natural disasters in developing countries: A case study on Honduras, 2000

Slide courtesy of J. Mutter

More likely to result from erratic growth and set backs creating a "recovery gap"

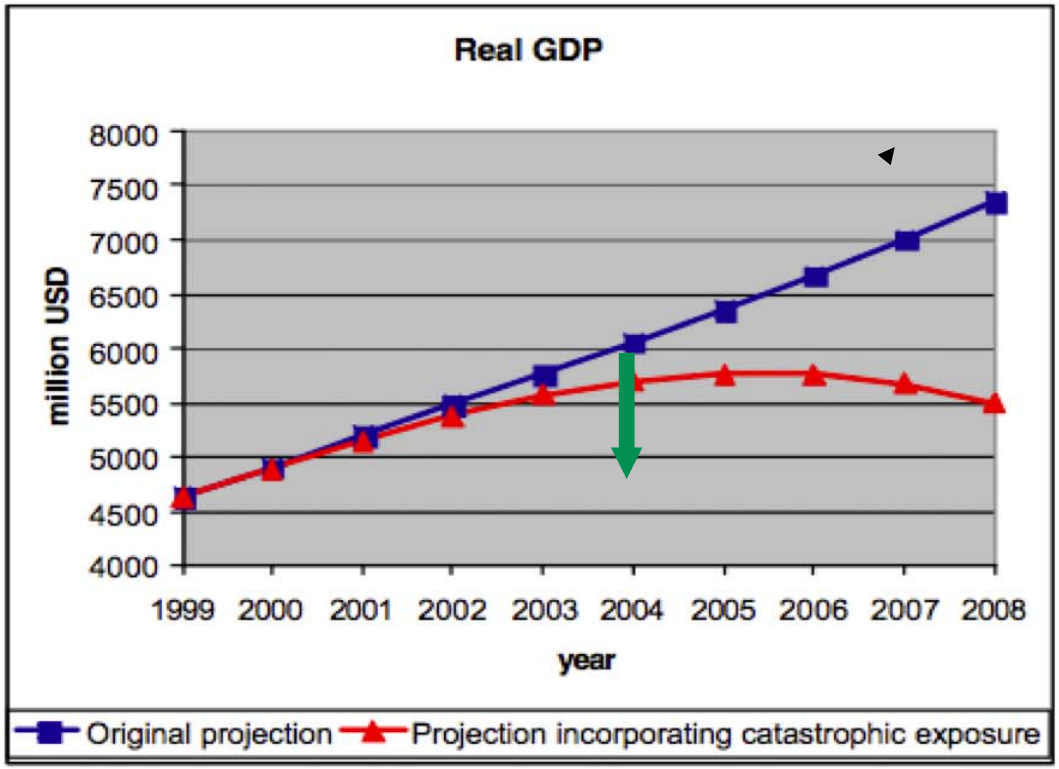


?

Freeman, Estimating chronic risk from natural disasters in developing countries: A case study on Honduras, 2000

Slide courtesy of J. Mutter

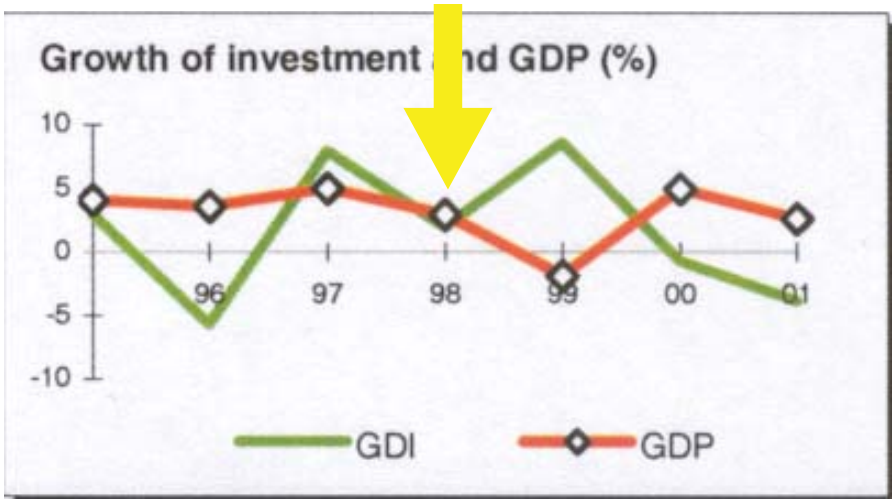
Higher growth rates post-disaster Sustainable?



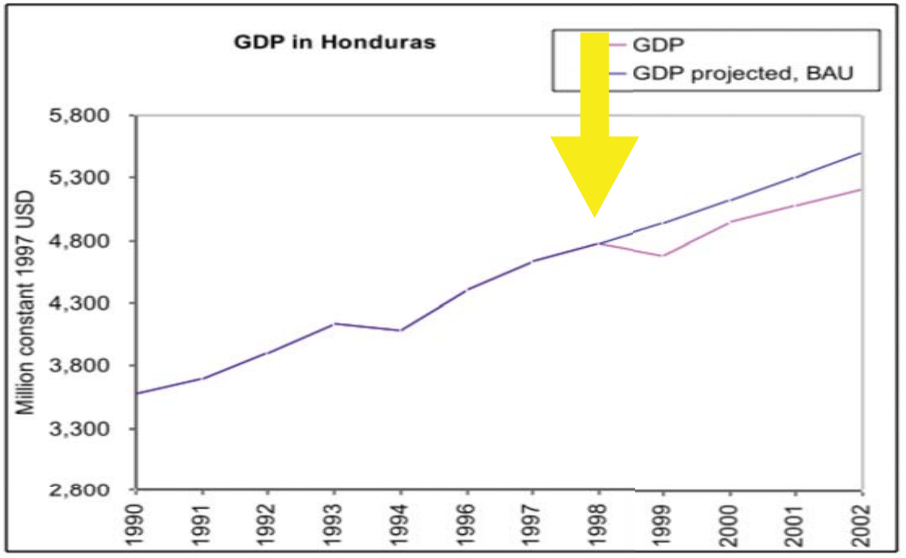
Freeman, Estimating chronic risk from natural disasters in developing countries: A case study on Honduras, 2000

Slide courtesy of J. Mutter

Honduras after Hurricane Mitch 1998



Melcher and Hochrainer 2004



Source: World Bank 2002, 2003

IIASA

International Institute for Applied Systems Analysis
"Science for Global Insight"

Hazard mitigation in a sustainable development context: assertions

- Risk reduction contributes to sustainable development
  - Future loss prevention is measured against future economic growth
  - Long-term policies and planning are emphasized
  - Risk resiliency affects the ability to adapt to environmental stressors
  - Risk reduction forces a discussion of present cost vs. discounted future benefit

Hazard mitigation in a sustainable development context

- But is Risk Reduction itself sustainable?
  - Near-term priorities
  - Focus on collective threats
  - Match between national strategies and community needs
  - Adaptation to new threats
  - Shared political will
  - Budgets
  - Importance of research and the translation to applications and operations

Four Phases of National Program (A seismologist's view)

I. Pre-seismic or Inter-seismic

II. Co-seismic

III. Post-seismic

IV. Transition to Reconstruction and Recovery – the Transient Phase

In each phase, there is a knowledge (data) gap between science and policy

National Risk Reduction Program
"Pre-seismic" phase: standard elements

- Risk identification and assessment
- Design and implementation of risk management strategies
- Preparation for next disaster
- Maintaining interest in risk reduction activities and research
- PSHA? DSHA? Neo-DSHA? PPSHA?
  - Balance Extreme events (HILP) vs. persistent threat – combined strategy

Risk Assessment: Exposure Mapping

- Population census
  - urban, rural
  - day, night
  - commuting network, parameters
- Building and infrastructure inventory
- Critical facilities prioritization
- Network, lifeline vulnerabilities
- Location and access to open areas, parks
- Fragility assessment, indigenous structures

Social Exposure

- Social networks
  - family
  - religious
  - occupational
- Economic indicators
  - sector performance
  - diversity
  - quality of life
  - livelihood
  - Geographic and sector distribution of GDP
- Buffering and Absorptive capacity

Risk indicators

- Define risk metric
  - Loss of life
  - Loss of livelihood
  - Loss of economic function
  - Political impact
  - Acceptable Residual Risk
- Direct damage
  - Residential
  - Infrastructure
  - Networks (lifelines)
- Data problem

National Risk Reduction Program
"Co-seismic" phase

- Rapid characterization of source
- Rapid characterization of ground motion
- Aftershock and triggered event forecasting
- Damage assessments
- Technical support of humanitarian assistance
- Planning for rapid response scientific and engineering surveys

“Co-seismic”

- Near-real-time earthquake source characterization
  - < 1 minute response time and distribution
- Near-real-time ground motion analysis
  - Shakecast
  - Shakemap
- Damage assessment
  - PAGER (USGS)
  - Technical surveys
- Information Distribution Mechanisms

National Risk Reduction Program
"Post-seismic" phase

- Aftershock probabilities
- Triggered earthquake probabilities
- Needs Assessments
- Logistic support
  - Humanitarian relief and aid agencies
  - Science
  - Engineering
- Relief infrastructure planning
- Beginning of Recovery Planning

Transition to Reconstruction and Recovery

- System Performance Assessment
- Needs List
- Enhancement/restructuring of in-country scientific and technical assets
  - Agency structure and resources
  - Human and technical capital
  - Plans and proposals

Transition to Reconstruction and Recovery

- Scientific and technical collaborations
  - government, academic and NGO partners
  - prioritization
  - goals (local) and attention to local/national needs
- Community vs. national imperatives
  - National-local conflicts
  - Relocation of settlements
  - Defining acceptable risk
    - Community is more “precautionary”

Transition and Recovery Partnerships

- Interactions with UN, Banks, National Development Organizations, NGOs, Private sector, Academic sector
- Planning documents and Technical proposals produced by potential partners
- Community involvement, organized and ad hoc
- Relocation/settlement discussions
- transitioning capital investments to sustainable budgeted activity and national ownership
  - E.g. sustainable monitoring networks

Assertions

- Focus on loss estimation does little to quantify absorptive and buffering capacities (especially social vulnerabilities)
- poverty, development <=> vulnerability framework needs research
- Resilience to "acceptable level of risk" needs definition – who decides?
- Older concepts of "mitigation, response and recovery" are morphing into newer conceptualizations of "adaptation" in response to climate change debate

Policy Framework:
Disasters <=> Development

- International Decade for Natural Disaster Reduction 1990-1999
- International Strategy for Disaster Reduction 2000 -
- Hyogo Framework 2005
  - Indian Ocean Tsunami, 2004
- World Bank, UN and Inter-American Development Bank reports and evaluations, through 2009
- GFDRR at WB
- Copenhagen 2009, Climate Risk Management, and Adaptation

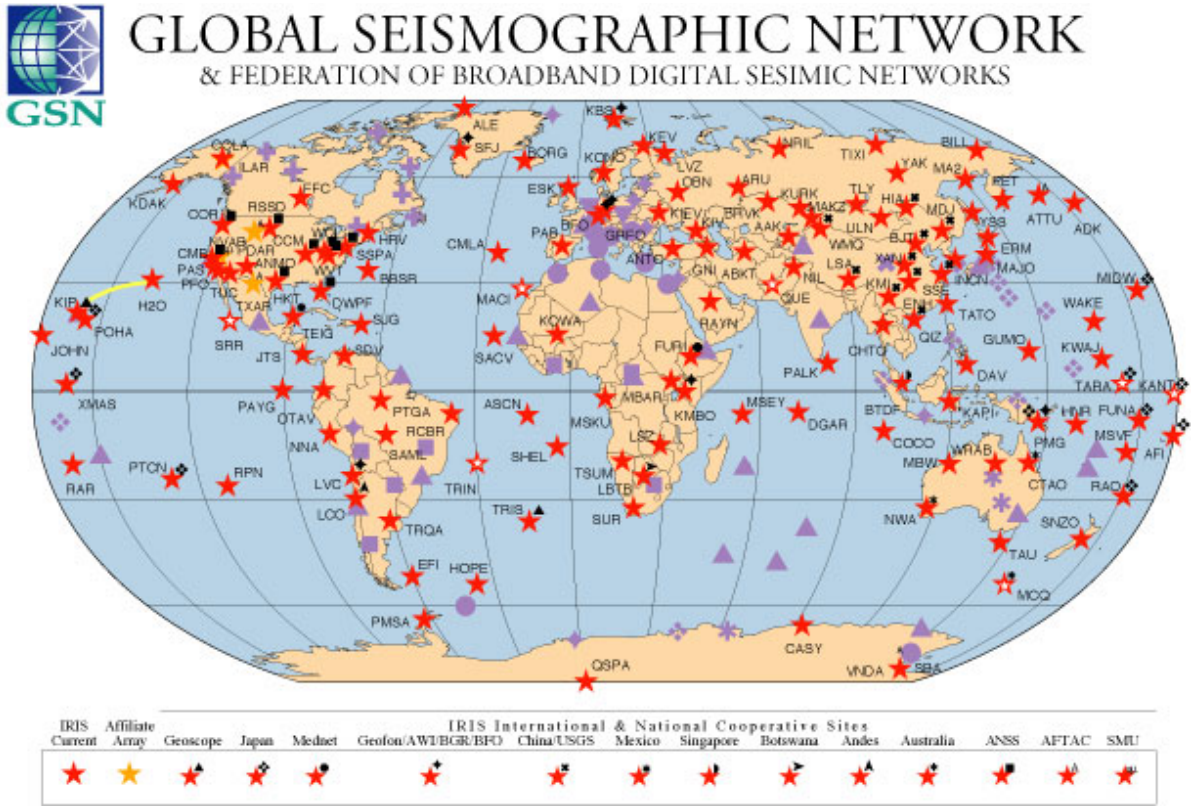
Global and National Scales Mix Science and Policy

- Global => monitoring, infrastructure, research
- Policy framework => research collaboration, capacity building, science for sustainability
- National/Regional => New/improved monitoring networks
- Maturity and sophistication of environmental monitoring networks, *and the provision of data products informed by research*, provide basis for partnerships with international organizations for improving human well-being (hazards, resources, other)

“Globalized” S&T Capacity

- **Developing regional capacities** for hazard reduction, resource exploration, and treaty verification; research links to implementation at national and sub-national scales
- **Leveraging global infrastructure** for tech transfer to national networks - link to knowledge management for risk assessment
- **Linking curiosity-driven science and human well-being:** universities will develop scholarship for rational, environmentally-conscious and risk-aware economic and social development
- **Quantifying relationship between disasters and development**
- **Improved partnerships:** government/university, public/private, enterprise links to international development organizations

Global Monitoring Infrastructure Backbone is International



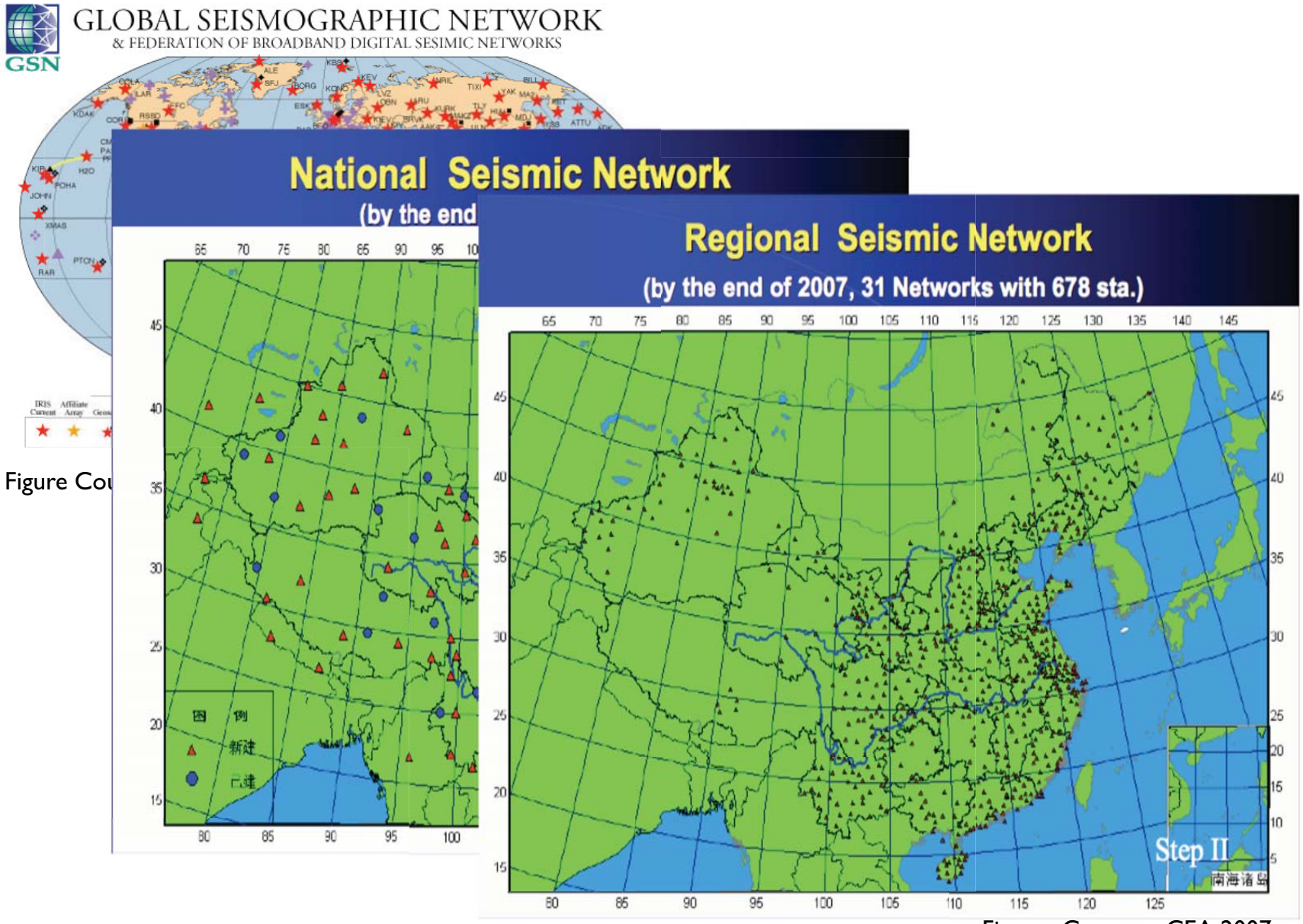


Figure Cou

Figures Courtesy CEA 2007

Figure courtesy Andrew Nyblade, PSU

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- Degree Programme
- Student Biographies
- Technical Training
- Scientific Observatories [Seismic Stations]
- AfricaArray Science
- Participants
- How to Become Involved
- AfricaArray Support
- Geophysics Field Course
- News & Announcements
- Publications
- Resources & Links

Home > About *AfricaArray*

About AfricaArray

Overview, Rationale a

Introduction
Focus
Founding Organizatic
Implementation Tim
Outcomes

Statement of Problem

Introduction
Need for Scientists i

Organizational and Op

Founding Partners
Administration

AfricaArray Science

Geophysics Theme

Funding

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History

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Co-Directors

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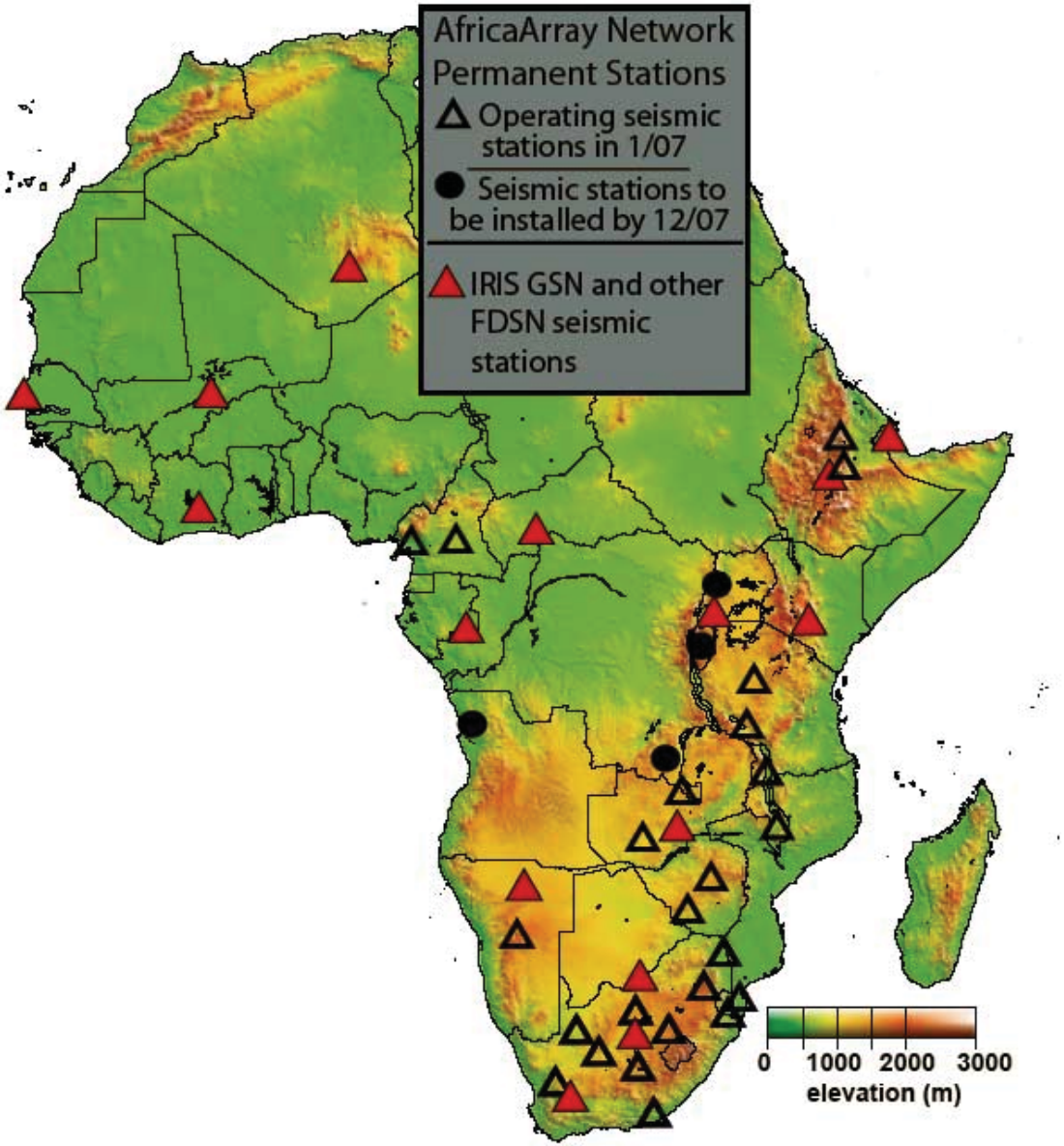

Linking Global and National Monitoring

- globally consistent data with regional resolution
- high-standard, peer-reviewed analysis - best science enabled by open data
- coordinated performance assessments and reviews
- regionally appropriate data products
- technical, training, research exchanges and collaboration

Conditions

- Eliminate technical barriers to data integration
- Develop multiple approaches to data sharing
  - real-time, parameter
  - data-sharing pathways
  - GEO, UN, CTBTO efforts, “dual use”
- Coordinate international research, education and training initiatives
- Establish dedicated funding lines

Missing Links

- “First-step” inertia
- Transition from capitalization and deployment of new or upgraded national/ regional networks to sustained operations and maintenance
- Link to economic and social development strategies?
- Needed: a disaster-development dialog that includes monitoring explicitly (ISDR, IDB and WB dedicated funds, GEO).

Global/National Integration

Where are we now?

- Strong FDSN - need an intergovernmental voice (and international multi-use framework; GEOSS)
- Multi-scale integration of national networks using global infrastructure
  - technical, training, collaborative science
- Exploit regional field programs
  - EarthScope, Deep Lightning, AfricaArray
- Open data exchange in real time

Thank You