The SZ4D Initiative and the Modeling Collaboratory for Subduction

Thorsten W. Becker

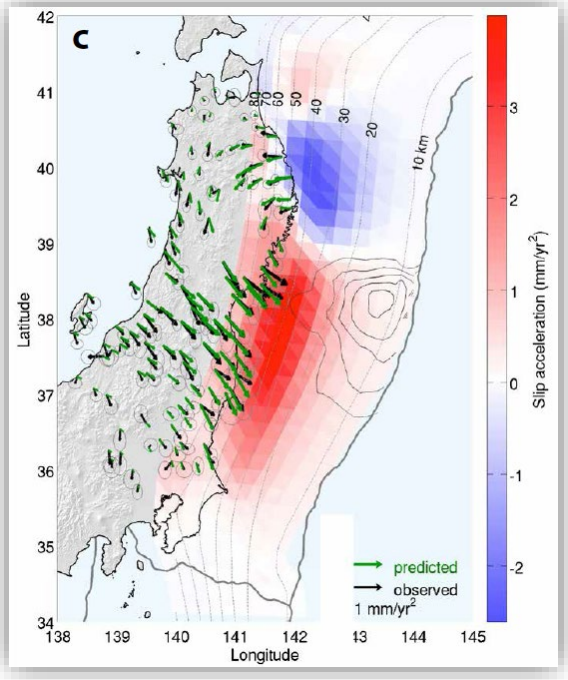
The MCS RCN team : Kyle Anderson, Mark Behn, Magali Billen, Chuck Connor, Allison Duvall, Eric Dunham, Helge Gonnermann, Kaj Johnson, Gabriel Lotto, Amanda Thomas, and Ikuko Wada

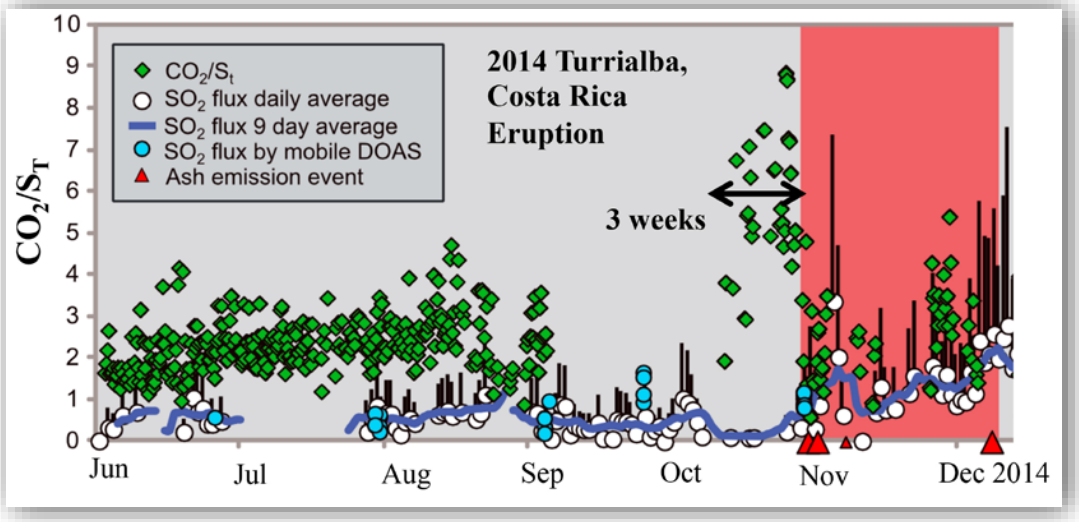
The SZ4D team, including : Terry Plank, Harold Tobin, and Tobias Fischer

Modeling earthquake source processes: From tectonics to dynamic rupture

Caltech, Pasadena CA
October 10, 2018

Goal: Decadal scale, physics-based hazard assessment for megathrust and arc volcano systems in tectonic context

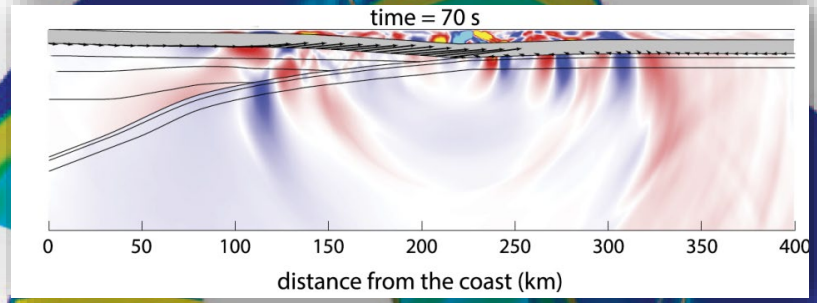


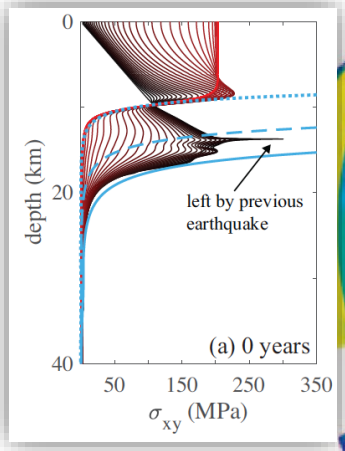


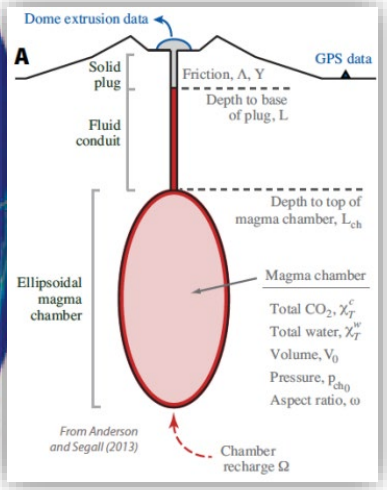
- link transients to physics and probabilities

Mavrommatis et al. (2014); de Moor et al. (2016)

Multi-scale, multi-physics problem

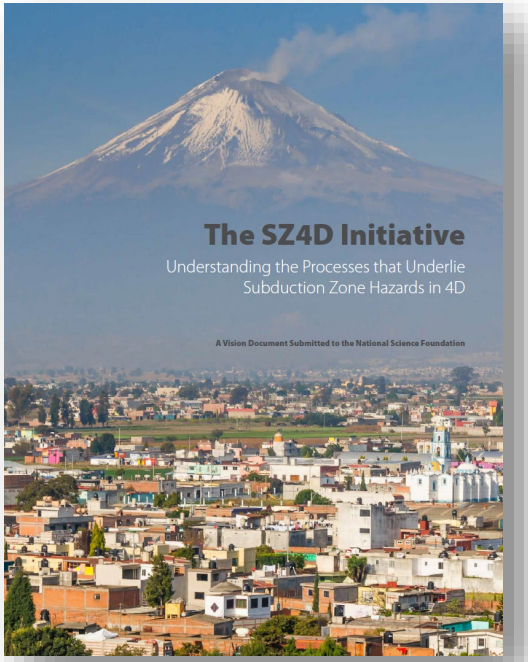




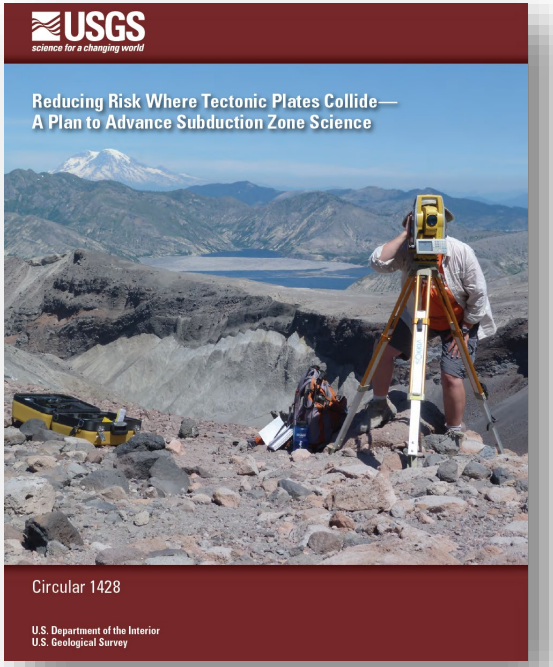


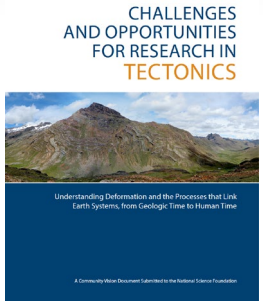
with incomplete data, incomplete physics

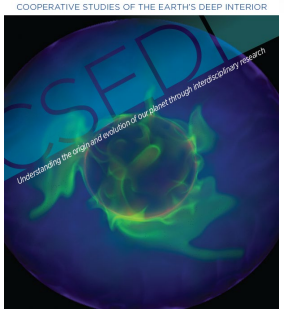
Mavrommatis et al. (2014); deMoor et al. (2016); Allison & Dunham (2017); Kozdon & Dunham (2014); Wilson et al. (2014); Stadler et al. (2010)

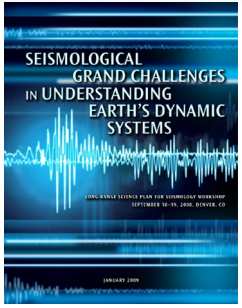

The SZ4D Initiative
Understanding the Processes that Underlie Subduction Zone Hazards in 4D
A Vision Document Submitted to the National Science Foundation


The National Academies of
SCIENCES • ENGINEERING • MEDICINE
REPORT
Volcanic
Eruptions and their
Repose,
Unrest,
Precursors, and
Timing


USGS
science for a changing world
Reducing Risk Where Tectonic Plates Collide—
A Plan to Advance Subduction Zone Science
Circular 1428
U.S. Department of the Interior
U.S. Geological Survey

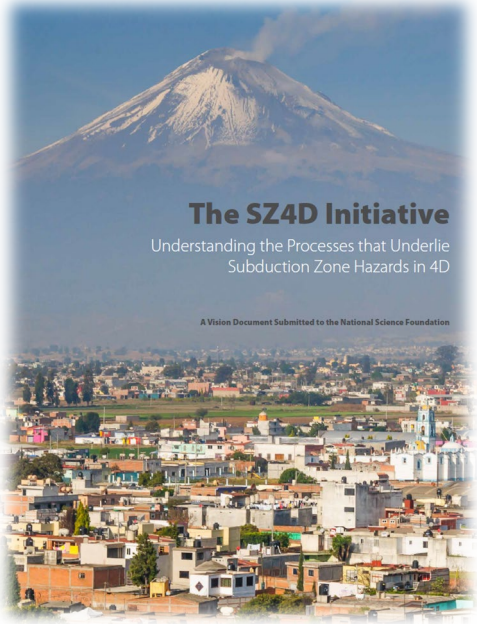

CHALLENGES
AND OPPORTUNITIES
FOR RESEARCH IN
TECTONICS
Understanding Deformation and the Processes that Link Earth Systems, from Geologic Time to Human Time
A Community Vision Document Submitted to the National Science Foundation

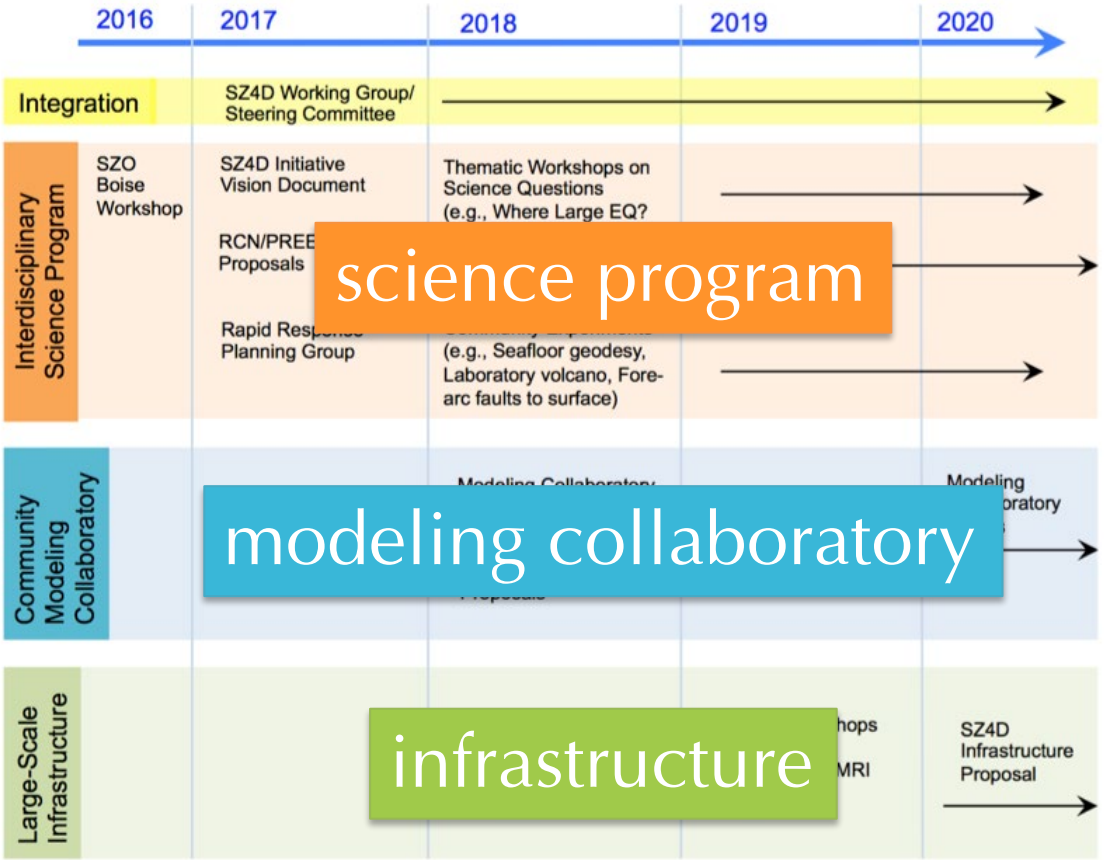

COOPERATIVE STUDIES OF THE EARTH'S DEEP INTERIOR
CSEDI
Understanding the origin and evolution of our planet through interdisciplinary research


SEISMOLOGICAL
GRAND CHALLENGES
IN UNDERSTANDING
EARTH'S DYNAMIC
SYSTEMS
LONG-RANGE SCIENCE PLAN FOR SEISMOLOGY WORKSHOP
SEPTEMBER 30–35, 2006, DENVER, CO
JANUARY 2009


Report from the NASA Earth Surface and Interior (ESI) Focus Area Workshop, November 2–3, 2015, Arlington, Virginia
CHALLENGES
AND
OPPORTUNITIES
FOR RESEARCH
IN ESI (CORE)

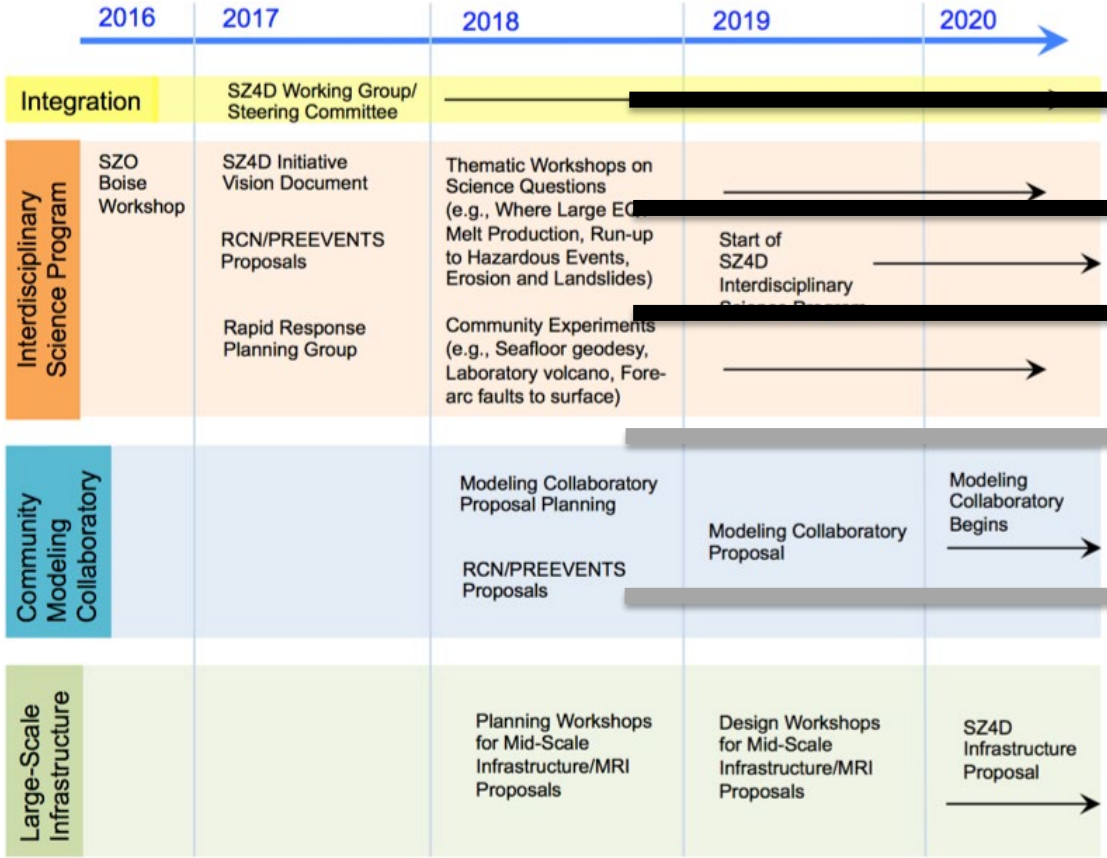
SZ4D implementation recommendations





McGuire, J., Plank, T., et al. (2017)

Examples of SZ4D activities, including Research Collaboration Networks (RCNs)



SZ4D Umbrella RCN

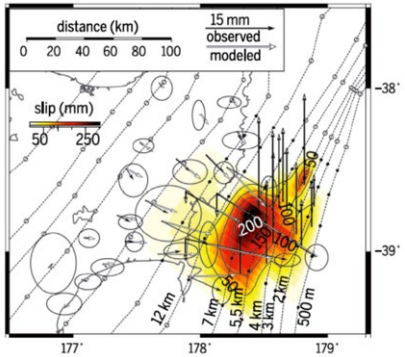
CONVERSE RCN

MCS RCN

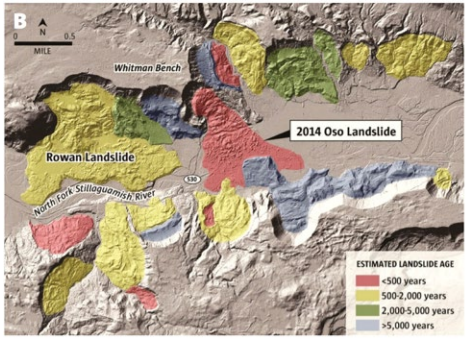
Community Volcano Experiment Workshop

Experimental Community Workshop

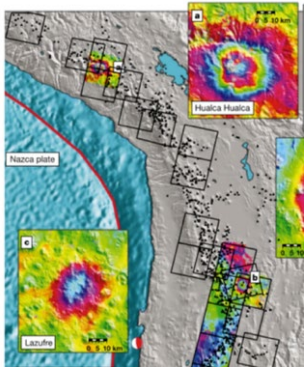
SZ4D Umbrella RCN Working Groups



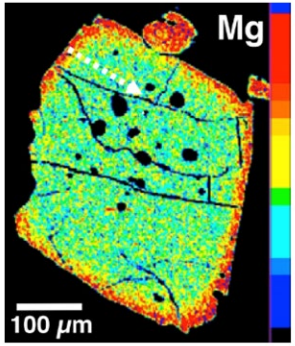
What controls the mode and timing of slip along the megathrust?



Linking landslides to forearc deformation



Responding to emergent megathrust and volcanic events internationally

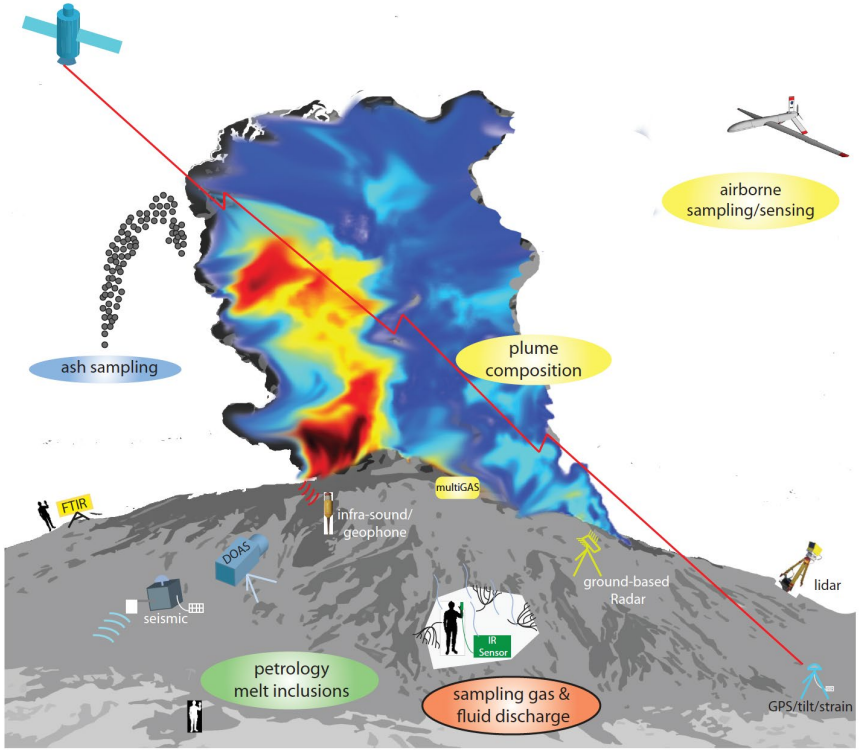


Magmatic drivers of eruption

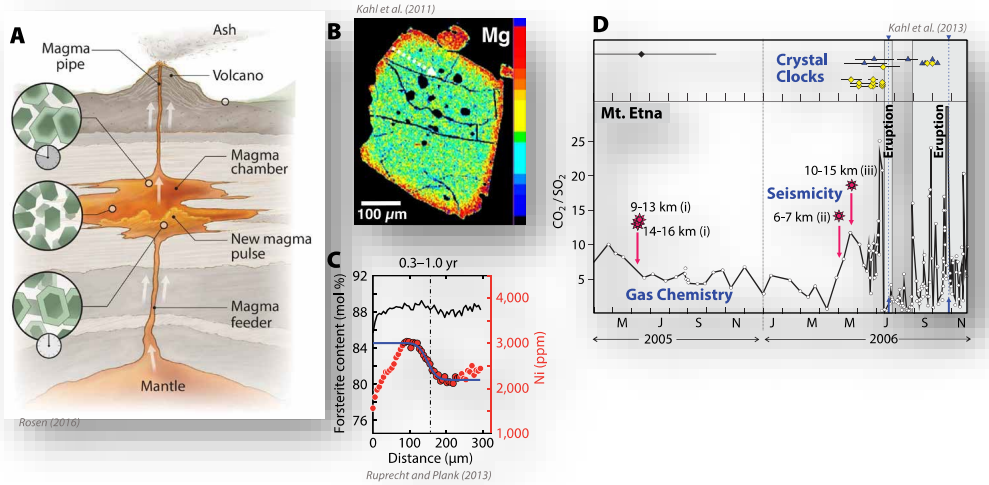
SZ4D Umbrella RCN

- Steering committee: Diego Arcas, Emily Brodsky, David Chadwell, Allison Duvall, Melodie French, Matt Haney, Diego Melgar, George Hilley, Sarah Penniston-Dorland, Terry Plank, Diana Roman, Donna Shillington, Christy Till, Harold Tobin (PI), Doug Wiens
- Activities:
  - Communication (web, news, etc.)
  - In Reach (research community)
  - Out Reach (broader science community, agencies, stakeholders, and public)
  - Sponsor and facilitate Working Groups to develop SZ4D program
- Outcomes:
  - A dialog
  - A community
  - **A plan (for implementation across scales)**

Community Network for Volcanic Eruption Response (CONVERSE) RCN



- Multi-disciplinary, near-real time observations and samples analysis for physico-chemical volcano system models



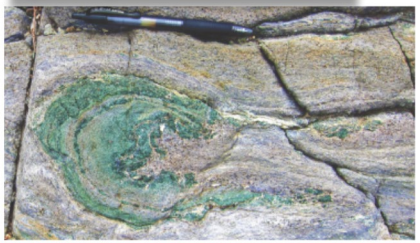
Community Network for Volcanic Eruption Response (CONVERSE) RCN

- Steering committee: Tobias Fischer (PI), Diana Roman, Ronni Grapenthin, David Fee, Kari Cooper, Paul Wallace, Christy Till, Simon Carn, Karen Johannesson, Einat Lev, Bruce Houghton, Peter LaFemina, Leslie Hale, Liz Cottrell
- Activities:
  - 10 disciplinary workshops, including USGS – academia coordination
  - Interdisciplinary Eruption Response Workshop
- Outcomes:
  - formulate a collaboration strategy between USGS and academic institutions
  - establish a framework protocol and infrastructure for data collection and integration
  - strengthen volcano science and the ability to collect critical data at an eruption in order to maximize scientific return and overcome observational bias

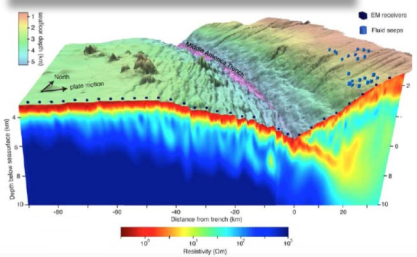
Modeling Collaboratory for Subduction (MCS)

- modeling framework for multidisciplinary data integration
- physics-based hazard assessment
- collaborative, open, reproducible, modular approach

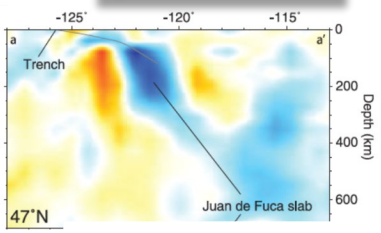
geological constraints

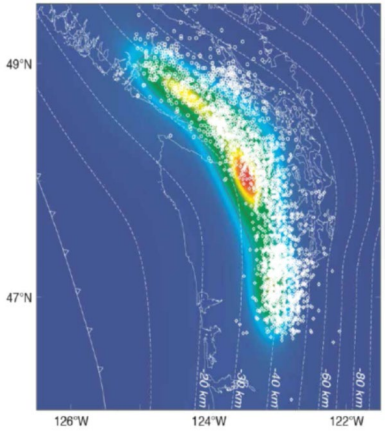


active source and MT

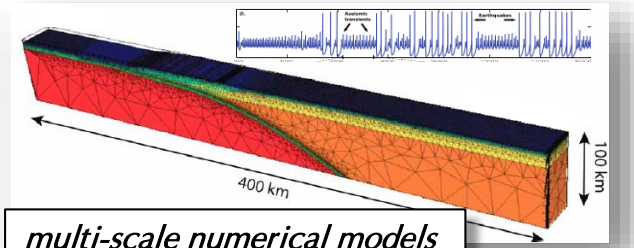


passive source

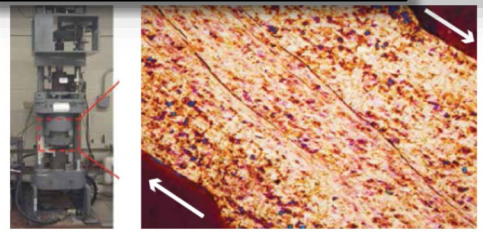




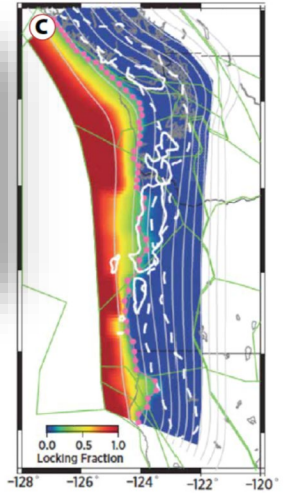
earthquake source seismology



multi-scale numerical models



rock mechanics experiments



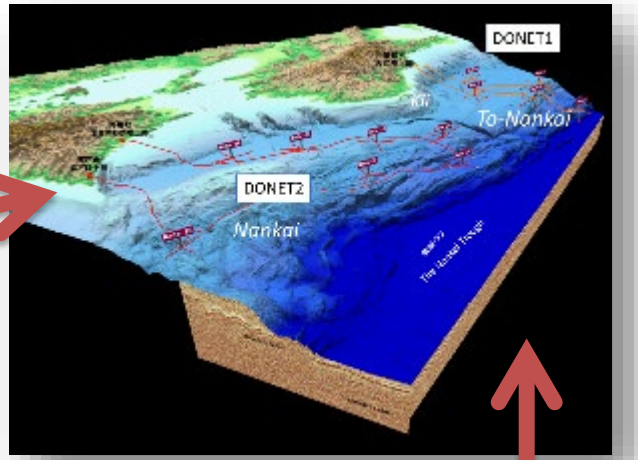
on and offshore geodesy

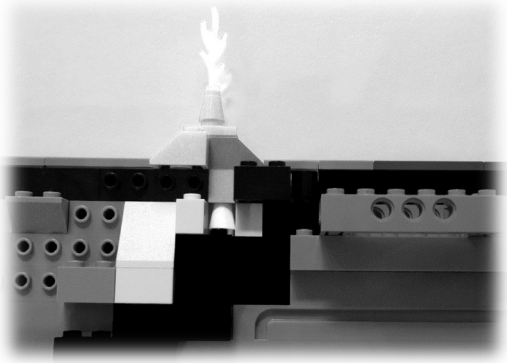
Gomberg et al. (2010); Naif et al. (2015); Chadwell et al. (2015); Schmalzle et al. (2014); Hawley et al. (2016); Tong & Lavier (2017); Proctor & Hirth (2015); W. Behr (pers. comm.)

MCS: Modular Community Systems Science

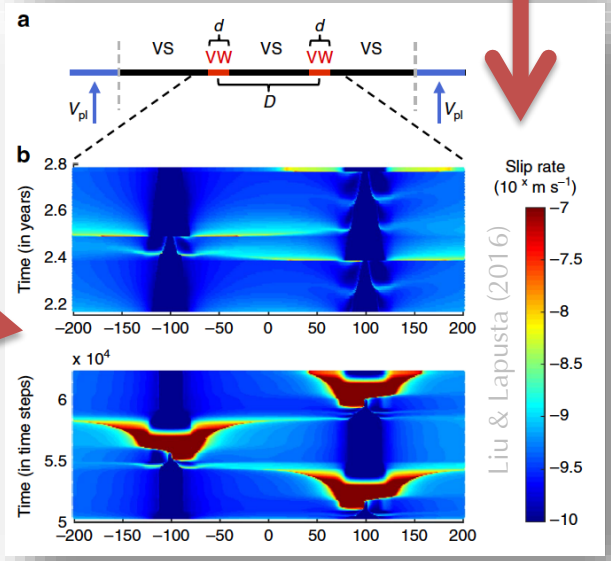
MCS implementation and partnerships

regional sensor networks





ab initio physics models



CIG COMPUTATIONAL INFRASTRUCTURE for GEODYNAMICS

SCEC

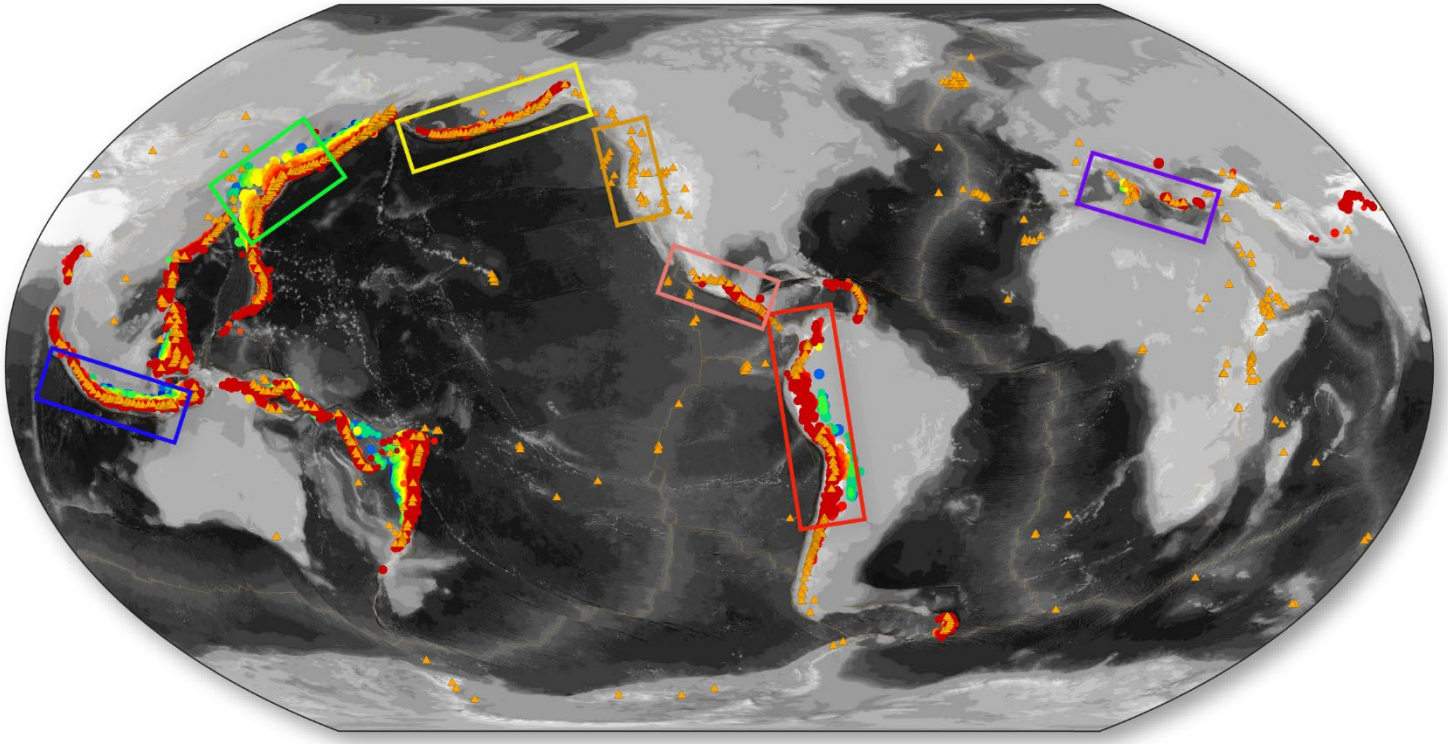
EPOS EUROPEANPLATEOBSERVINGSYSTEM

JAMSTEC

CIDER
Cooperative Institute for Dynamic Earth Research

MCS: Global observatory integration

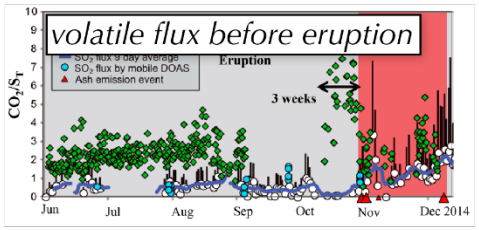
- applying and testing modeling framework across different
  - tectonic settings
  - stages of seismic & volcanic cycle
- support a network of global observatories
- **an integrative community for open science – research and training**

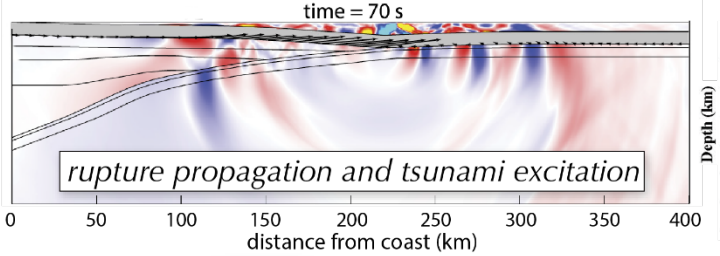


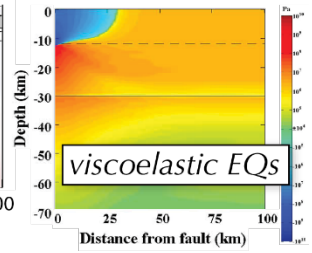
(*example* observatories, completed to various degrees)

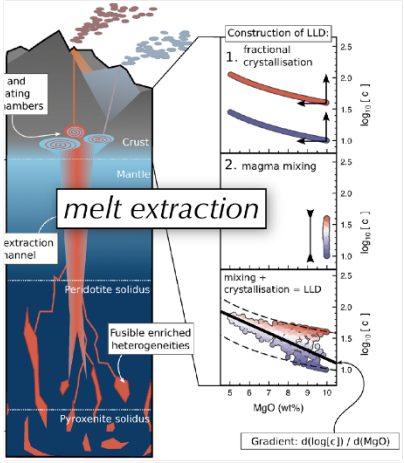
MCS Planning RCN

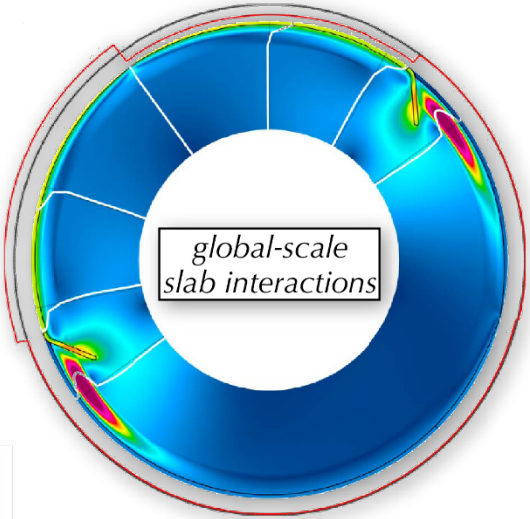
- knowledge and implementation gaps
- study micro-physics upscaling and cross-scale interactions
- empower high performance computing
- evaluate megathrust and volcano model state of the art

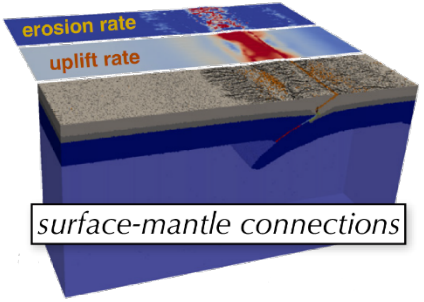


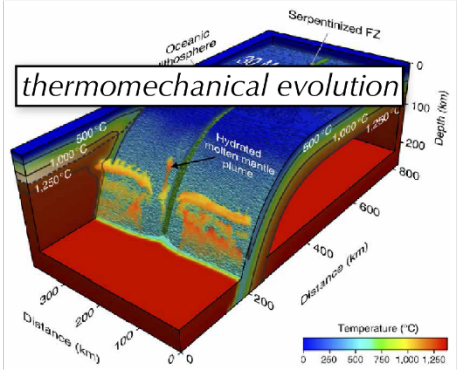


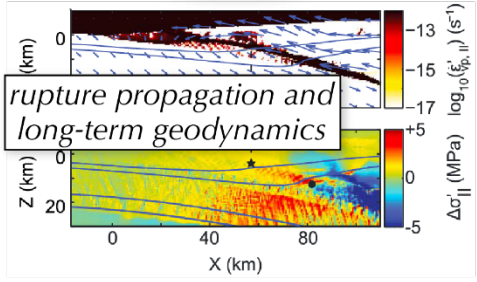


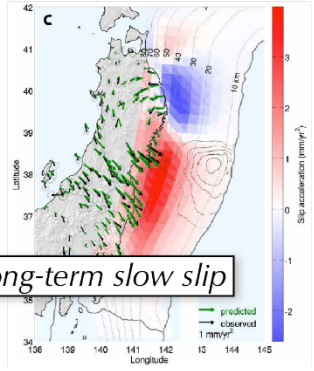








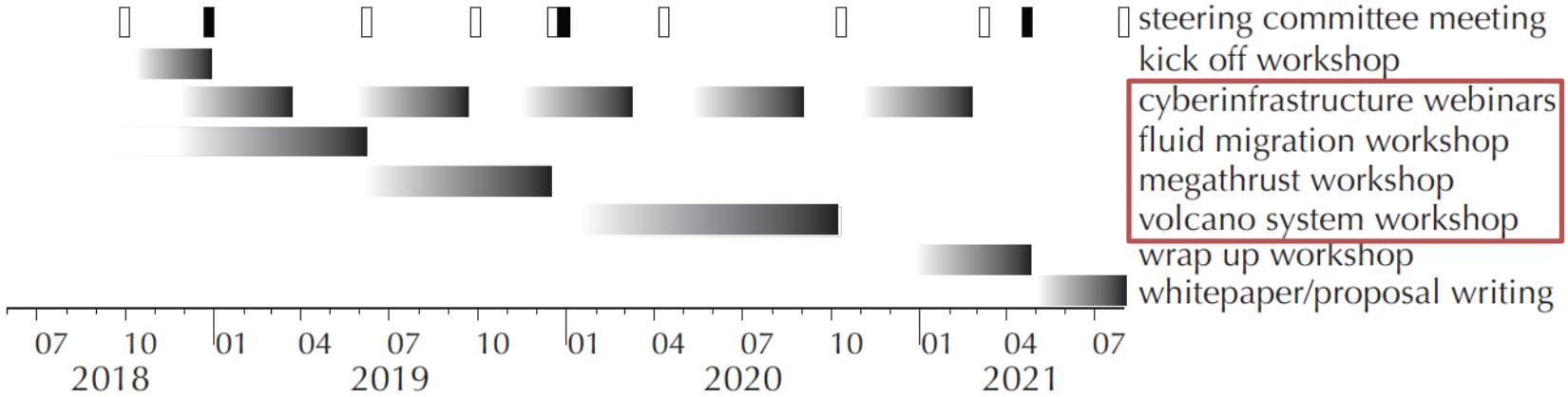




Mavrommatis et al. (2014); deMoor et al. (2016); Ueda et al. (2015)van Dinther et al. (2014); Allison & Dunham (2017); McCormack & Hesse (2017); Kozdon & Dunham (2014); Manea et al. (2014) Wilson et al. (2014); Gerault et al. (2012)

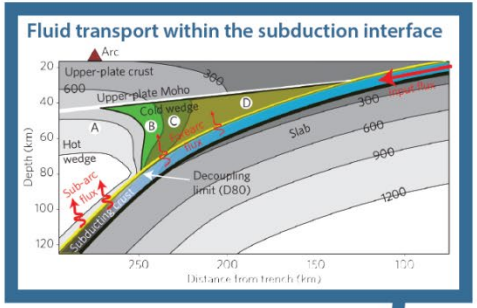
MCS RCN

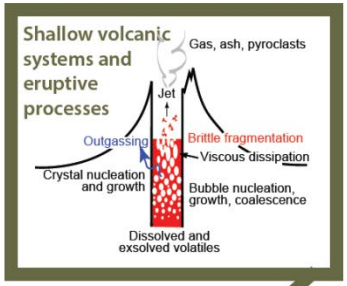
sz4dmcs.org

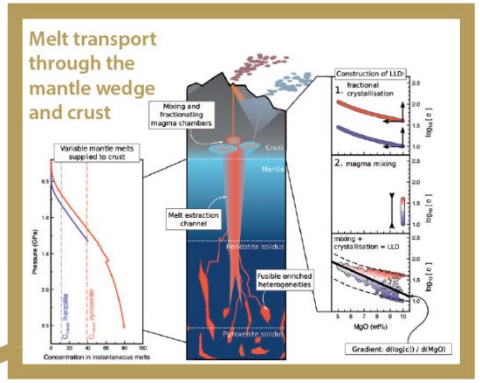


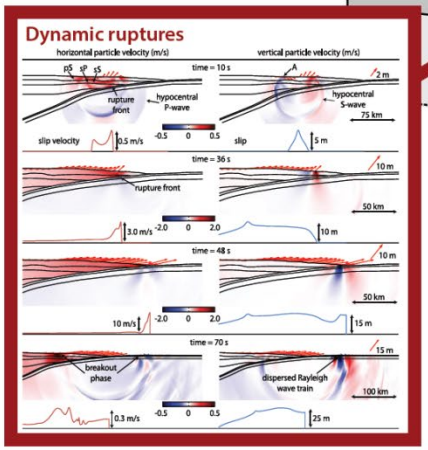
Workshop focus on interactions

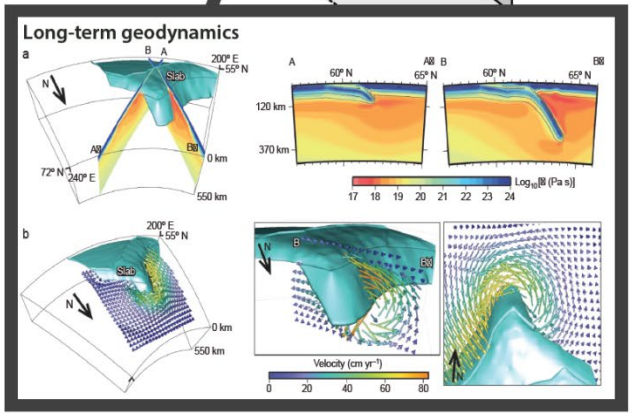
- Stress transfer
- Fluid and melt flux
- …

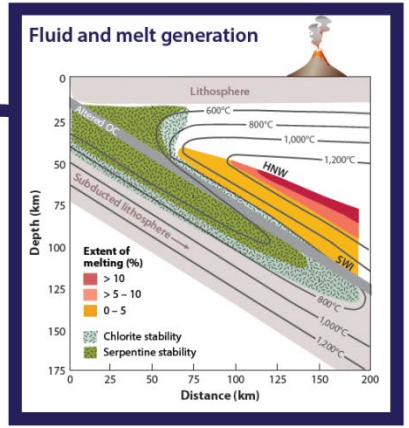












Hyndman & Wang (2003); Kozdon &Dunham (2013); Jadamec & Billen (2010); Grove et al. (2012) Shorttle et al (2015); Gonnermann & Manga (2005); Abers et al. (2017)

MCS RCN **Model Building** workshops

- **Fluid and melt migration microphysics upscaling: a common mode of interaction for all systems**
  - How are fracture formation and fluid migration coupled in the magma plumbing system?
  - What is the role of fluid transport in explaining interseismic deformation phenomena, such as slow slip?
  - How to best incorporate the micro-physics and up-scale?

- **Megathrust modeling (system I): Physics and interactions (with tectonics, convection and volcanoes)**
  - How are subduction zone faults loaded, and what is the best way to incorporate the insights from long-term and short-term models for seismic cycle models?
  - Can integrated models be used to forecast the spatial distribution of earthquakes? Do we know the material and structural parameters at the appropriate conditions?

- **Volcano modeling (system II): Physics and interactions (with earthquakes, tectonics, convection)**
  - How do numerical simulations on an arc-scale constrain the location, timing, and magnitudes of volcanic eruptions?
  - On the scale of volcanic systems, how does the lithosphere (e.g. material & stress state) influence the magma transport?

- **Cyber infrastructure needs**
  - Do we have the software tools available or under development to address the right multiscale, multi-physics problems?
  - What are the best practices to empower a diverse community of scientists to use cutting edge hardware?
  - What are the database needs, and how to merge the modeling with database frameworks?

Additional slides

The MCS planning RCN

- In person workshop series (20-30 people, possibly with EPOS)
- Webinar series on cyberinfrastructure
- Online collaboration support (e.g. Slack)
- Three year, $400k program – funded in Fall of 2018
- Steering committee
  - defines milestones and refines RCN
  - in charge of coordination and inclusiveness of efforts
  - workshop organization – SC plus external chairs
  - community engagement (online collaboration)
  - works with part-time admin on outreach and open documentation of workshop results and reports

Workshop series

- Setting the stage for the MCS and the RCN
- Hands-on, problem oriented
  1. Building an megathrust model
  2. Handling fluid and melt migration
  3. Building a subduction zone volcano model
  4. Cyber infrastructure and modeling needs
- MCS implementation and white paper

SC RCN Coordination Strategy

- Links with other SZ4D RCNs (e.g. volcano by Fischer & Co.)
- Links with CIG, NASA, EarthCUBE, SCEC, NGEO
- International collaboration: Form strong links with EU (e.g. EPOS), Japan (e.g. JAMSTEC, U Tokyo & Tohoku), and SE Asia
  - Japan's post K effort (Hori and Ichimura)
  - EU EPOS (volcano supersites (WP11), multi-scale observatories (WP16)): Elisa Calignano (Utrecht), Massimo Cocco (INGV)
  - planned EU Cost action: Francesca Funiciello (Rome)