Modeling Collaboratory for Subduction Zone Science

Thorsten Becker, Kyle Anderson, Mark Behn, Magali Billen, Chuck Connor, Eric Dunham, Alison Duvall, Alice Gabriel, Helge Gonnermann, Kaj Johnson, Leif Karlstrom, Gabriel Lotto, Amanda Thomas, Ikuko Wada

MCS-RCN Townhall

May 13, 2021 - 2 pm Central

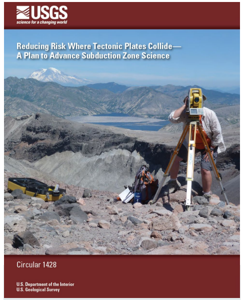
@sz4d_mcs contact@sz4dmcs.org

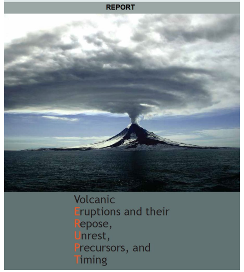
NSF

MCS RCN

Modeling Collaboratory for Subduction (MCS): Science Goals

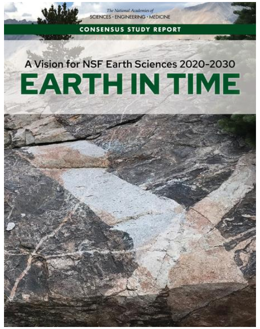
Understanding the physics of subduction zone systems

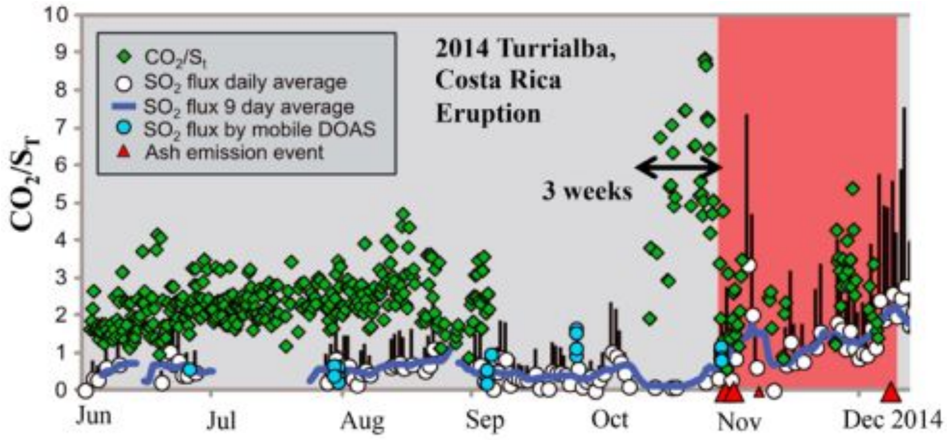




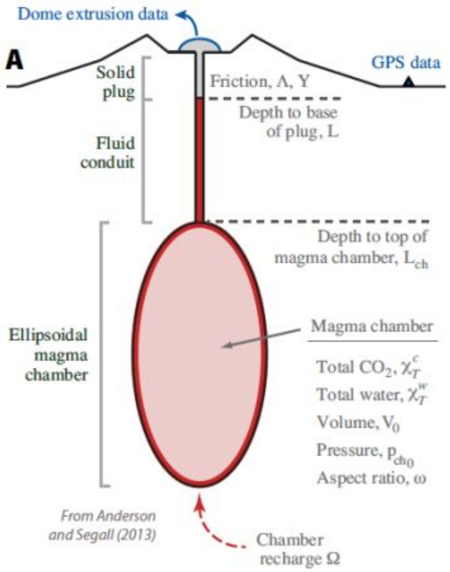
Key science issues:

- **Nature of asperities** (stationary vs. dynamic), with implications for earthquake and tsunami hazard assessment
- Links between **geodetically determined plate boundary coupling and future earthquake ruptures**
- Linking crustal magma transport and storage, thermo-mechanical structure, and volcanic activity: **Melt production to eruption**
- Capture **long term evolution** of arcs (e.g plutons) and **short term hazards and monitoring** (active volcanoes)
- Feedbacks between **magmatic and surface processes** in controlling subduction margin tectonics and **megathrust cycle**





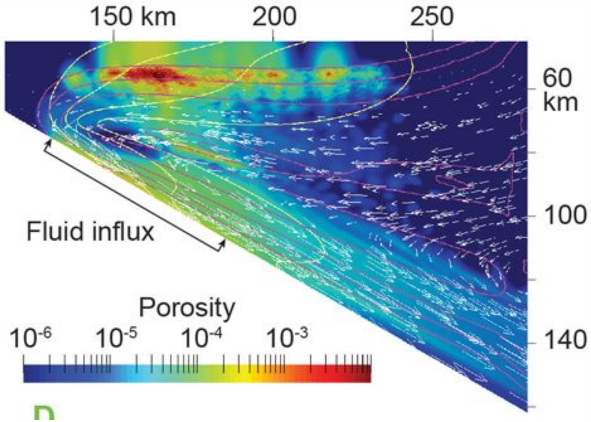
deMoor et al. (2016)



Segall

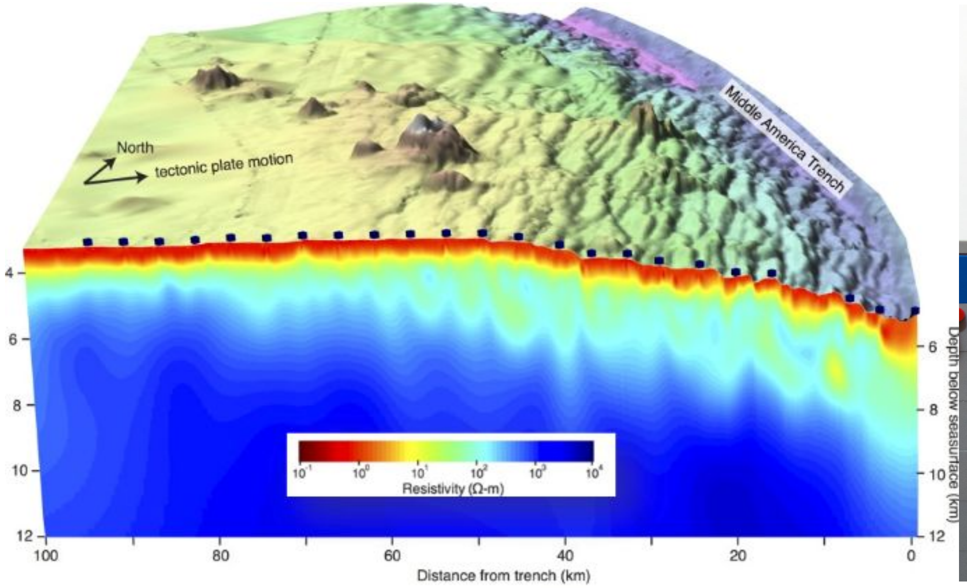
Volcano forecasting example

- How to link volcanic system state and long-term subduction margin evolution to event probabilities?
- How to quantify uncertainties and unknowns in diverse multiscale data, e.g., crystal clocks, seismicity, gas emissions?
- **How to build physics-based, predictive volcano systems models?**



Cerpa et al. (2017)

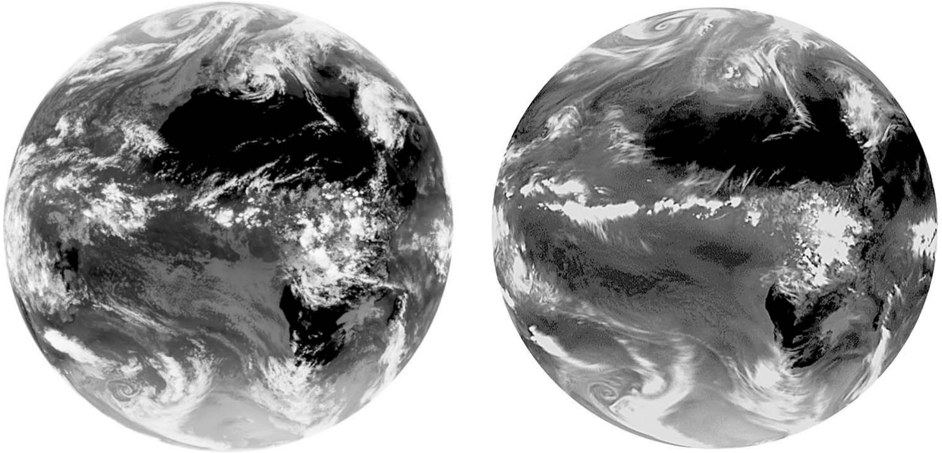
MCS: A digital subduction zone for SZ4D

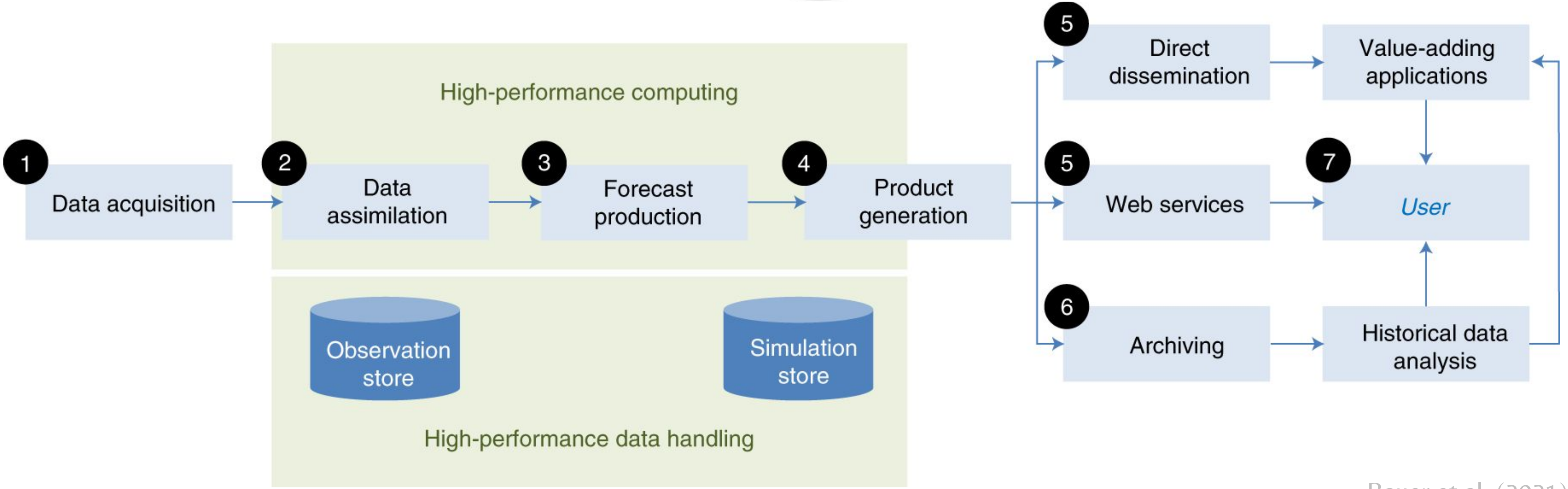


- ❖ Science-driven and enabling computational infrastructure and large-scale community effort is needed to advance systems levels understanding

Naif et al. (2015)

Digital twins in climate science



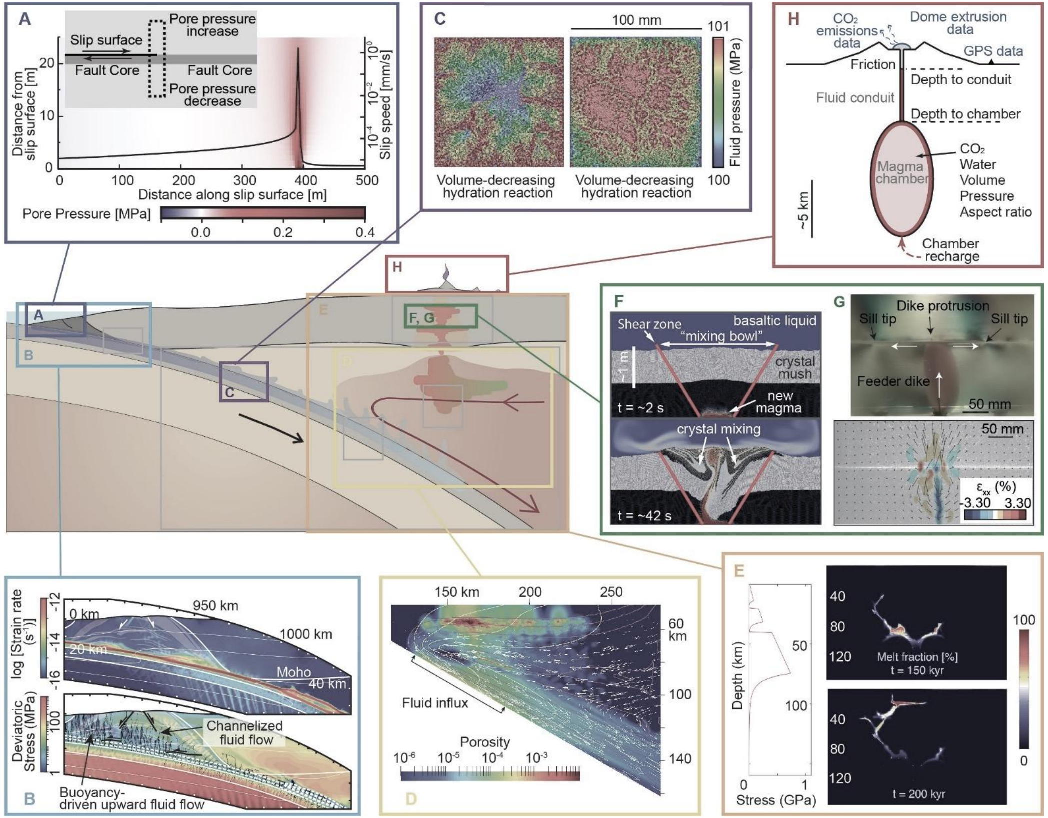


Bauer et al. (2021)

Uncertainty about subduction physics requires validation of fundamental models

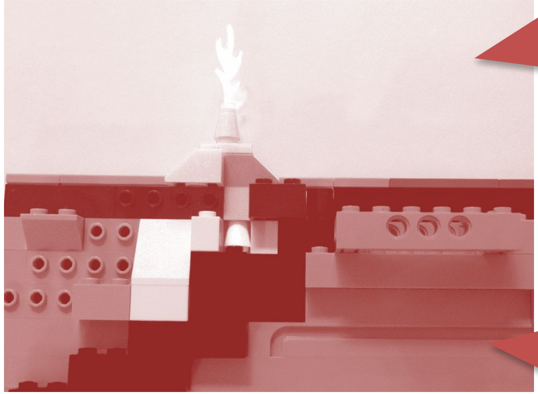
Solid Earth systems dynamics is not climate science

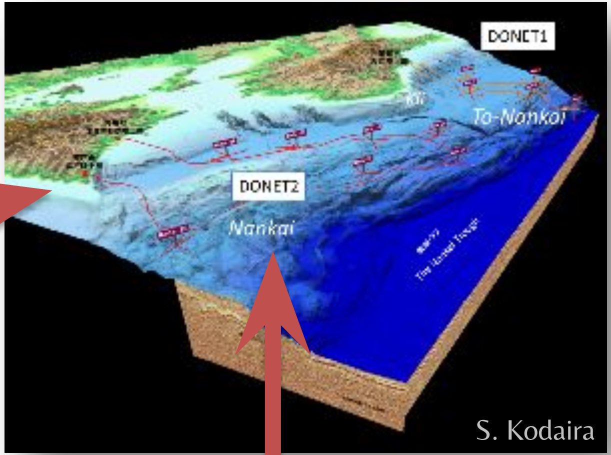
- ➢ major remaining questions regarding physics
- ➢ adjoints and data assimilation incompletely explored
- ➢ important role for modeling-based exploration of emergent dynamics



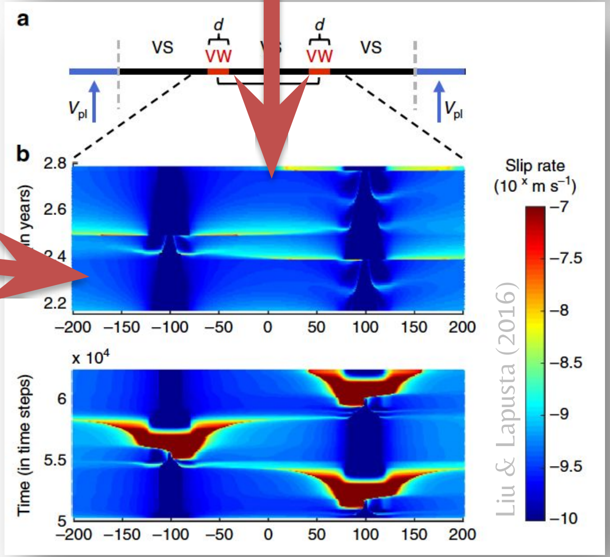
Wada and Karlstrom (2020)

MCS: Connections for science and communities





Regional data assimilation



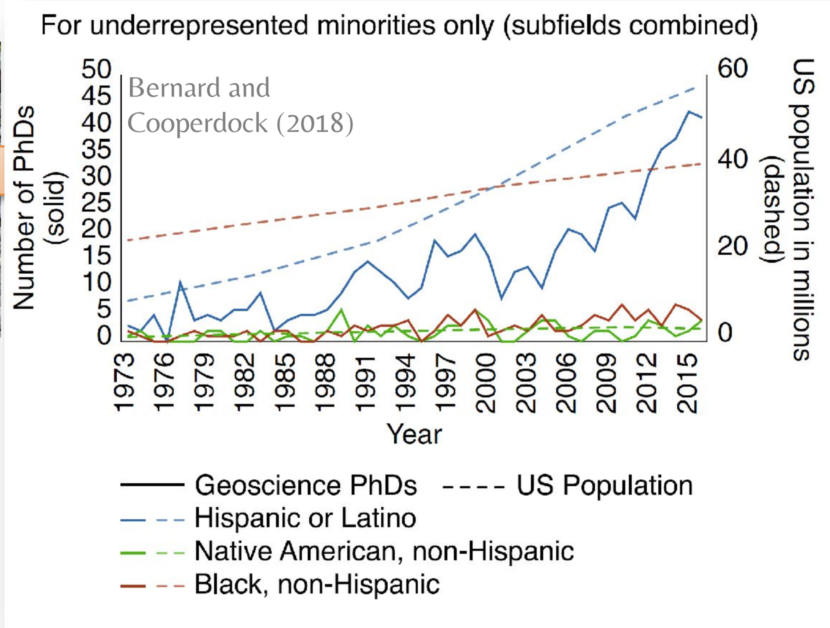
Fundamental physics

MCS: Modular Community Systems Science

- Inclusive and equitable community building, observationalists and modelers
- International collaboration
- Science focused, distributed, open, FAIR, and sustainable model and code-development
- Data integration using verified building blocks
- Regional laboratories for validation
- Capacity building and access to leading-edge computing

Computational geoscience training as a complementary pathway for enhancing diversity in the geosciences

AAPG Explorer

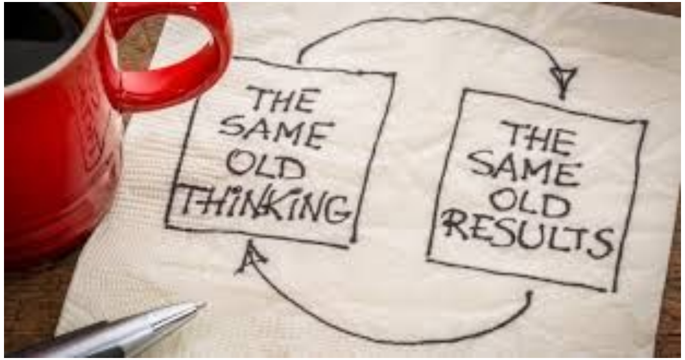


SCEC USEIt (2016), USC

- Inclusive, scalable entry point for K12 science education underserved communities
- More students play computer games than go camping?

Building Equity and Capacity in Geoscience (BECG)
Other integrative efforts within SZ4D

- **Charge to BECG:** Identify the correct set of activities that are strategically useful and maximize the specific assets of SZ4D
- **Intrinsic Goal:** Transform the mindset of our community to embrace education, outreach, capacity building, diversity, equity, inclusion, and social justice as critical for successful science



- Connects to the MCS ideas about modular community systems science

Building Equity and Capacity in Geoscience Research Targets

- Leverage international efforts into sustainable capacity building partnerships that avoid colonial attitude

- Use SZ geohazards to inform and address social justice and equity issues
- Educational efforts that are more inclusive with measurable student learning outcomes

- A more distributed model of outreach through science communication training for the SZ4D community
- Identify and develop evidenced-based best practices for interdisciplinary collaboration

Modeling Collaboratory for Subduction RCN

MCS
RCN

NSF

sz4dmcs.org, Fall 2018 – Fall 2021

MCS RCN Activities

Workshop 1: Fluid and Melt Transport

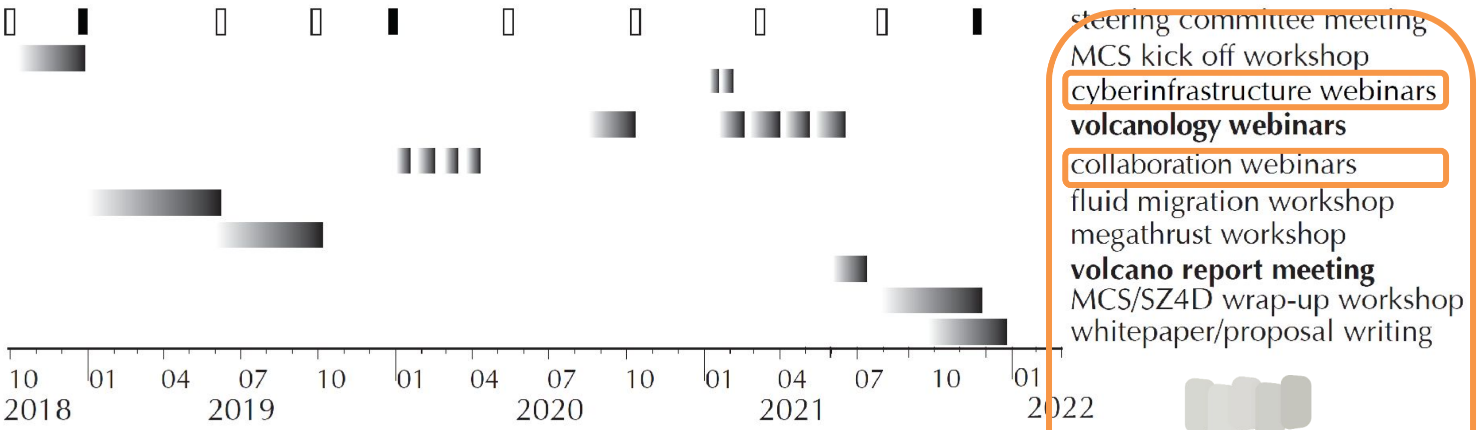
- Fluid migration & fracture formation in magma systems
- Lithosphere-scale magma transport
- Microscopic and short-time-scale processes

Workshop 2: Megathrust Modeling

- Sequences of earthquakes & aseismic slip
- Dynamic rupture and tsunamis
- Geodynamics and surface processes

Workshop 3: Volcano Modeling

- Location, timing, and magnitudes of volcanic eruptions on an arc scale
- How does the lithosphere influence magma transport?



Community Network for Volcanic Eruption Response (CONVERSE)

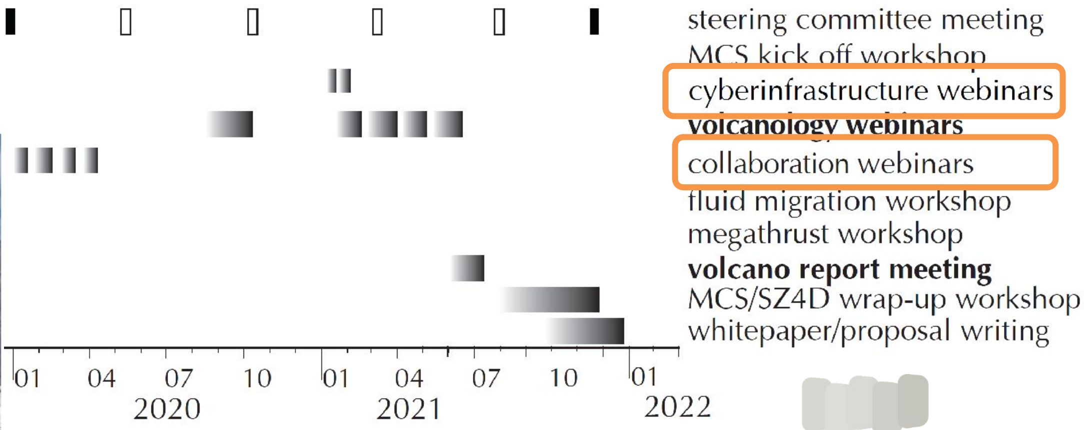
MCS RCN and Surface Processes

- Landscape evolution plays a key role in fault loading and magmatic systems
- Insights into mass wasting processes to link dynamic wave propagation with landslide hazard estimate
- Joint workshop with Landscape and Seascapes group @ SZ4D postponed to Fall 2021, integrative links with earthquake and volcano activities of SZ4D as well.

Whitepaper Reporting Outcomes from NSF-Sponsored Workshop:

CTSP: Coupling of Tectonic and Surface Processes

April 25–27, 2018; Boulder CO



CSDMS community surface dynamics modeling system

CIG COMPUTATIONAL INFRASTRUCTURE for GEODYNAMICS

MCS RCN

Fluid transport in subduction zones:
Role of the MCS

- ➢ Need better understanding of processes that control fluid migration at huge range of scales - a grand challenge
- ➢ Community modeling resources should include approaches for model validation
- ➢ Cross-disciplinary training and knowledge exchange
- ➢ Fluid transport is a unifying framework for subduction systems, including all groups within SZ4D. Perhaps a common research framework, e.g., controls on magnitude and frequency of eruption and earthquake hazards

Modeling Collaboratory for Subduction RCN
Fluid Migration Workshop Report

May 29 – June 1, 2019
University of Minnesota – Twin Cities

Workshop Writing Committee:

Ikuko Wada and Leif Karlstrom
Diane Arcay
Luca Caricchi
Patrick Fulton
Taras Gerya
Kayla Iacovino
Tobias Keller
Rachel Lauer
Gabriel Lotto
Laurent Montesi
Tianhaozhe Sun
Hans Vrijmoed
Jessica Warren

Published online November 2019 – https://www.sz4dmcs.org/fluids-workshop

Fluids Workshop Report (download here)

SZ4D

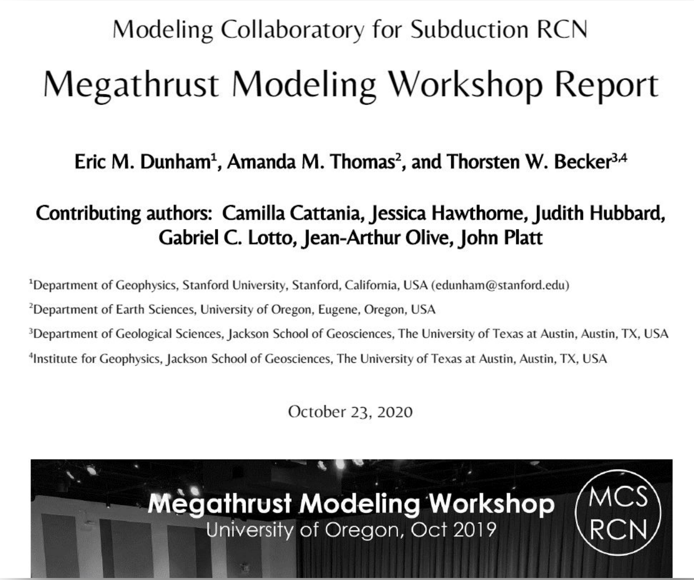
MCS RCN

Understanding the physics of megathrust systems:
Role of the MCS

Megathrust Report (download here)

Vision for MCS as ***community-building organization***:

- ➢ International and open collaboration, engaging with partner organizations in US (e.g., USGS) and abroad
- ➢ Focus groups, organized along multiple axes:
  - ○ Regional laboratories and case histories
  - ○ Processes
  - ○ Links with SZ4D through community model building, and data interpretation efforts
- ➢ Integration of modeling efforts with observations and lab experiments for hypothesis testing



Modeling Collaboratory for Subduction RCN

Megathrust Modeling Workshop Report

Eric M. Dunham[1], Amanda M. Thomas[2], and Thorsten W. Becker[3,4]

Contributing authors: Camilla Cattania, Jessica Hawthorne, Judith Hubbard, Gabriel C. Lotto, Jean-Arthur Olive, John Platt

[1]Department of Geophysics, Stanford University, Stanford, California, USA (edunham@stanford.edu)
[2]Department of Earth Sciences, University of Oregon, Eugene, Oregon, USA
[3]Department of Geological Sciences, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA
[4]Institute for Geophysics, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA

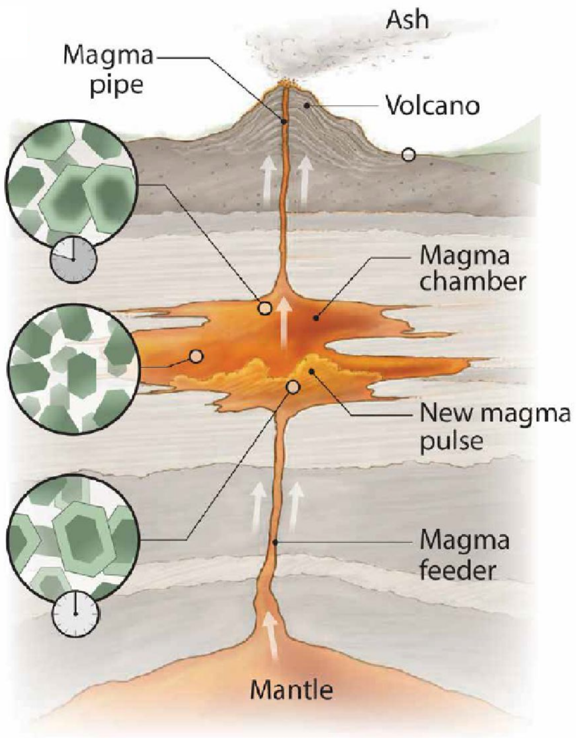
October 23, 2020

Dunham, Thomas, et al. (*EarthArXiv*, doi:10.31223/X5730M, 2020)

MCS RCN

Understanding the physics of volcanic systems:
Role of the MCS

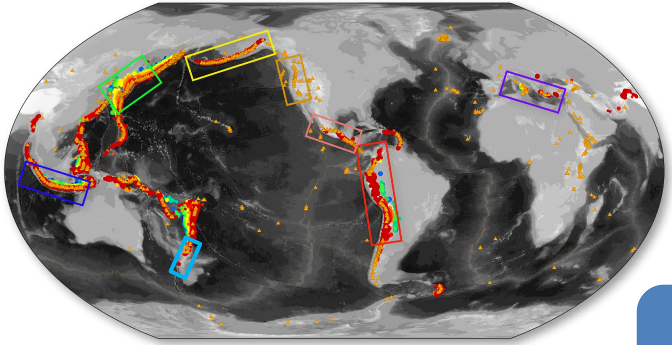
- ➢ Grants for model development and collaboration
- ➢ Modeling Collaboratory Network
  - ○ Workshops, summer schools
  - ○ Interdisciplinary collaboration
- ➢ Development of open-source, well-documented, interoperable models
  - ○ Supporting/enable the development of reusable model building blocks
  - ○ Supporting/enabling model verification, validation, and benchmarking
  - ○ Computational support infrastructure

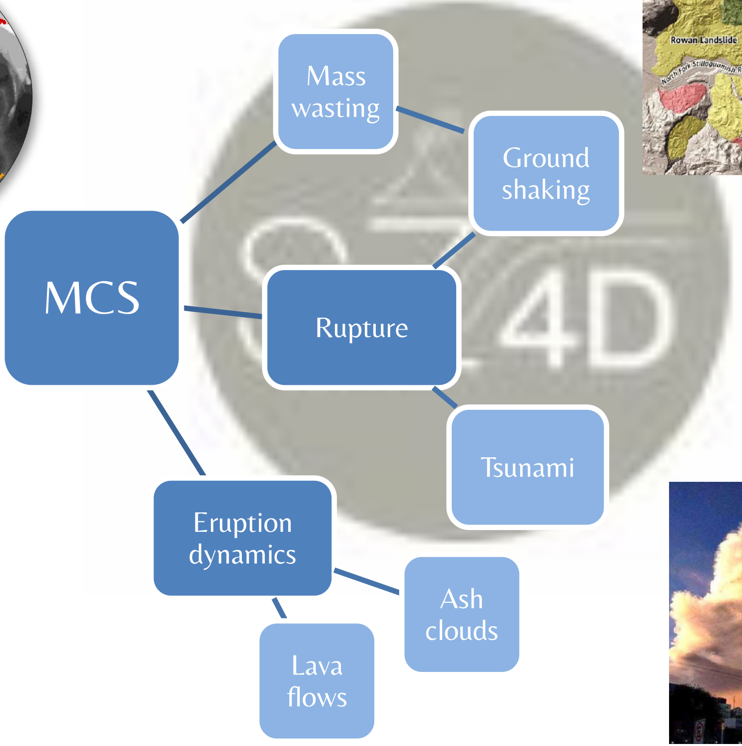


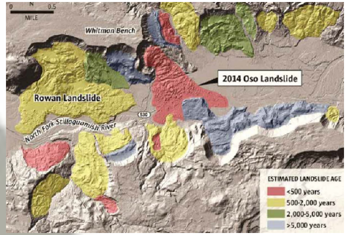
Rosen (2016)

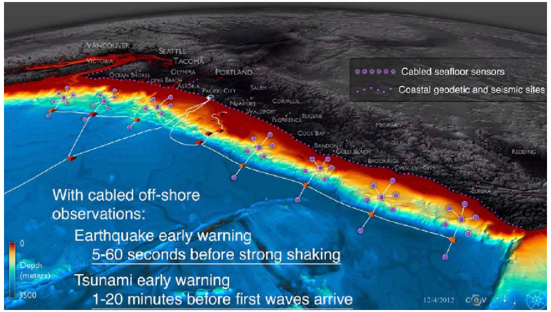
MCS RCN

MCS: Physical models to understand hazard









Credits: AP, Global Volcanism Program, University of Washington, Wilcock et al. (2016)

MCS RCN

MCS Design Objectives

Sustained Computational Geoscience Community Support and Model Development

Natural laboratory focus groups

Subduction zone science integration

Process focus groups

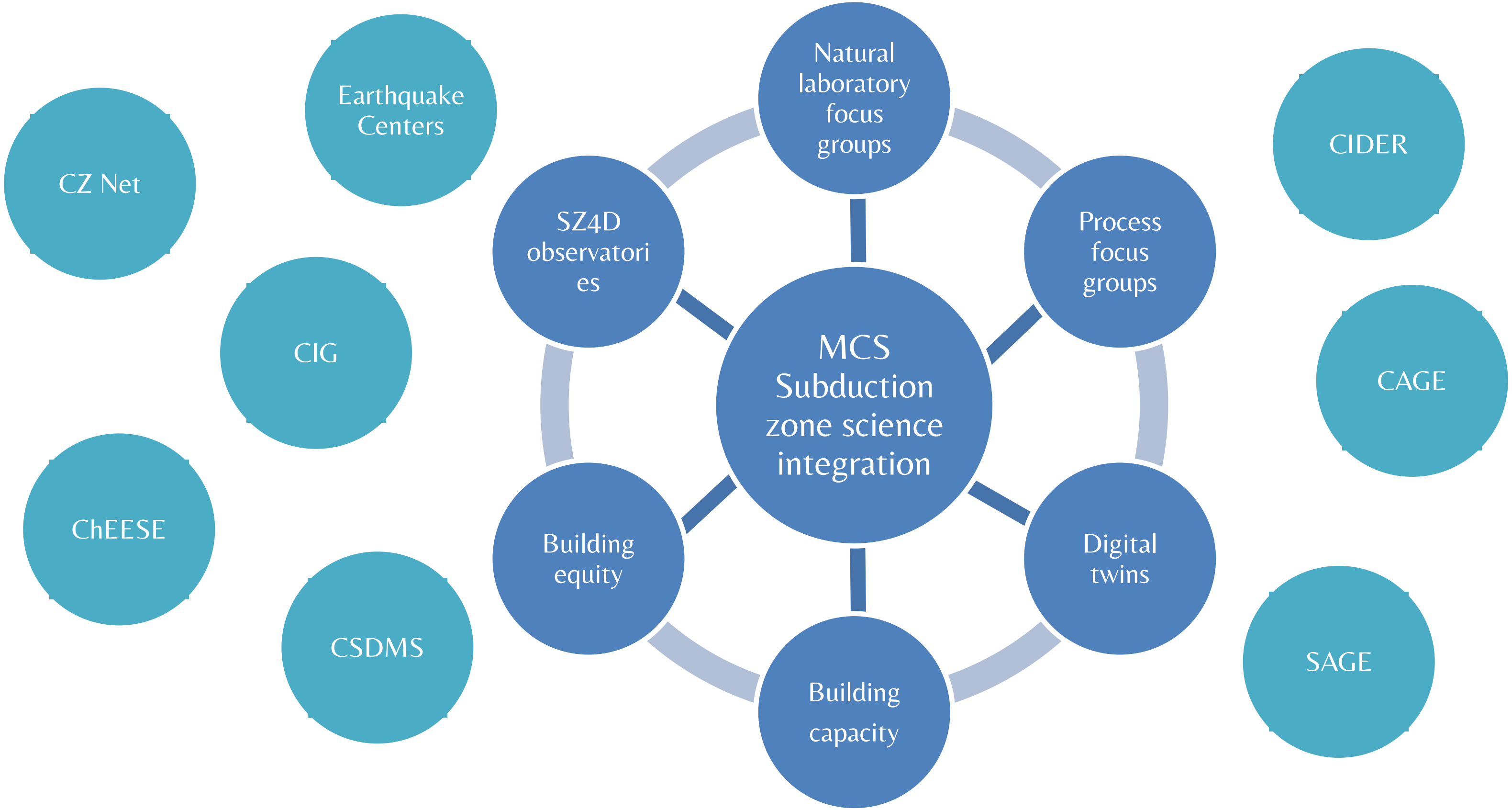
Training and Outreach

Code and Cookbook development

Workflows and Access to Computing

MCS RCN

MCS as a **subduction zone science hub** for SZ4D



MCS Design Objectives

Verification

Are we building the system right?

Validation

Are we building the right system?

Uncertainty Quantification

Optimal Experimental Design

MCS Structure and Programs

Coordination & communication	Database and workflow support	Applied math support	Statistics and data science support
Documentation and cookbook support	Hardware support (parallelization, GPU, architecture)	Workshops and hackathon support	Post-doc and grad student program
Code development grants	Outreach activities	HPCC allocations	Cloud compute allocations

MCS RCN

Example MCS Code Lego Kits driven by community input

- Thermo-petrological magma dynamics (host rock + dike)
- Visco-elastic earthquake cycle with fluid transport
- Global, 3-D, thermal convection with two phase flow
- New framework for multi-physics, multi-scale (Julia, FEniCS)
- Complex physico-chemical fluid framework
- Coupled tectonics-surface processes
- Python/Jupyter notebook cookbooks and teaching modules

MCS RCN

MCS Implementation Straw-Man

Must have:

- Workshops and collaboration between observationalists and modelers
- Structural and code database
- Program manager/coordinator
- Community driven science committee

High priority:

- Programmers at center and on loan to community
- Subawards for code development outside SZ4D program
- Compute allocations
- Post-doc program

MCS RCN

Community impact of MCS

- New, large-scale, science-driven and science-enabling computational infrastructure needed to advance systems levels problems
- Integrative science to complement and optimize new observational and laboratory efforts
- Computational geoscience for physics based hazard assessment
- Training and enhancing diversity in the geosciences
- Generating new opportunities for interdisciplinary research
- Leveraging and democratization of computational science advances

MCS RCN

Questions for the community and breakouts

1. Which suggested MCS **activities** are the highest priority?
2. Is the suggested MCS **structure** well aligned with those priorities?
3. Which MCS **tools, codes, and repositories** would the most useful?
4. Is the MCS well aligned to to ensure observations, including from SZ4D, are best **integrated** into models?

[Slides for breakout discussions here]

MCS RCN