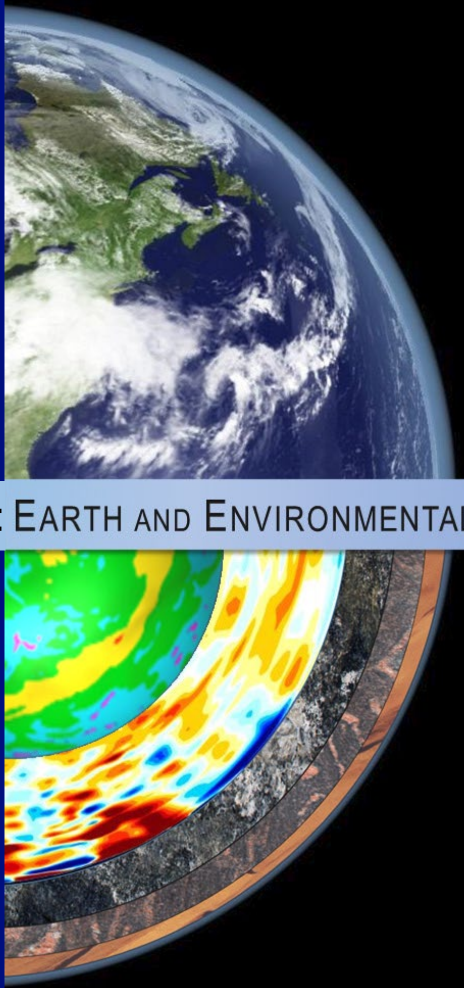
UCI-LANL miniWorkshop

Theme 1:
Climate and Environmental Systems Modeling

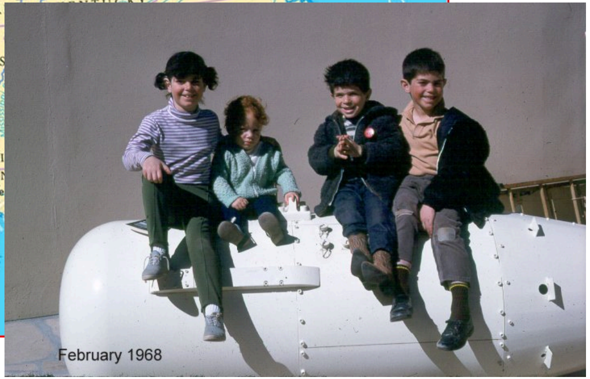
ANDREW WOLFSBERG **DIVISION LEADER:** EARTH AND ENVIRONMENTAL SCIENCES DIVISION



University of California, Irvine
December 3, 2021

By way of introduction…

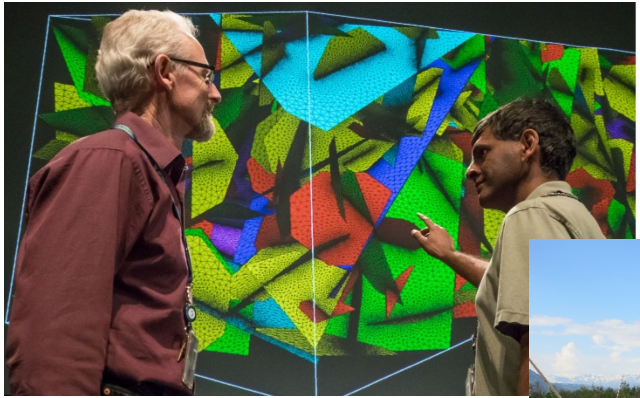
- UC Irvine was the first UC I knew, too (Uncle Max was a professor here)
- Born, raised, returned to Los Alamos



February 1968

Earth and Environmental Sciences Division

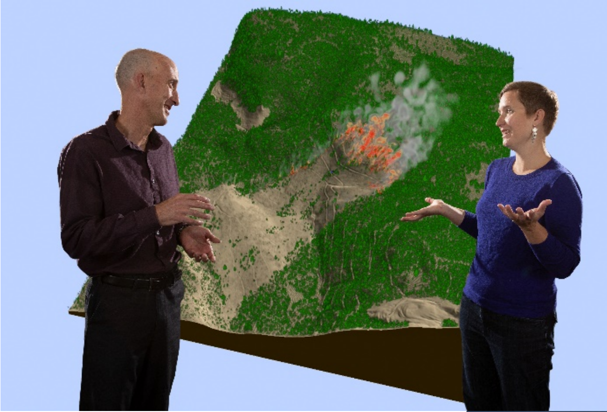
- Home of Earth, atmosphere, hydrology, and ecology disciplines at the Laboratory. *
- Fundamental *discovery* science and *mission-focused* applications unravel poorly understood processes and support decisions of national importance.
- Our researchers investigate carbon-neutral *energy*, detection of nuclear *threats*, and ecological, hydrological, climate, and atmospheric impacts.



* But certainly not the only division where these topics are considered

Earth and Environmental Sciences Division

- **Earth System Observations**
  - Atmosphere, Climate, and Ecosystem Science Team
  - Geochemistry and Geomaterials Research Team
  - Field Instrument Deployments and Operations
  - Geology and Geospatial Analysis Team
  - Radioactive-Geochemistry Team
- **Computational Earth Science**
  - Applied Terrestrial, Energy, and Atmospheric Modeling Team
  - Subsurface Flow and Transport Team
- **Geophysics**
  - Modeling and Simulation Team
  - Seismo-acoustics Team
  - Sensors and Signatures Team

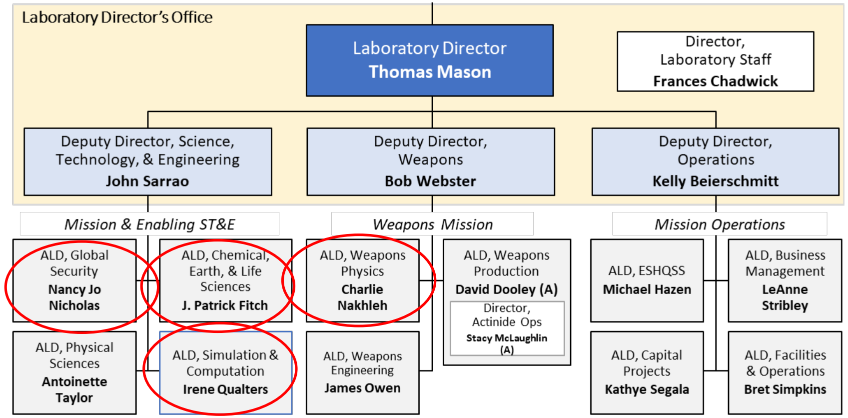


- 17 Undergrads
- 51 Grad Students
- 26 Postdocs

- Home of GUIDE: Geoscientists United for Inclusion, Diversity, and Equity

We provide multidisciplinary solutions to complex problems in climate and environmental change; sustainable energy; and nuclear and global security.

Climate and Environmental Systems Modeling Spans Multiple Divisions at LANL



Los Alamos NATIONAL LABORATORY

LANL's research portfolio encompasses

theory, experiment, measurements and modeling across all climate components

With particular expertise in

Polar science

Oceans

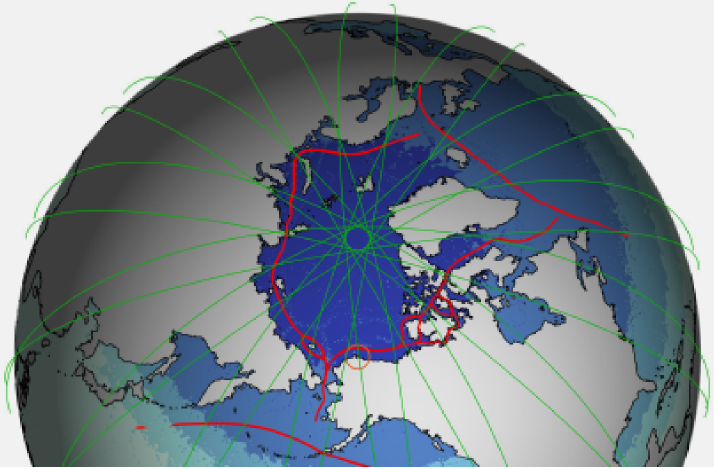
Watershed science and coastal ecogeomorphology

Fire, aerosols and ecosystems

Next-gen ESM development

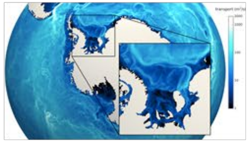
Computational performance

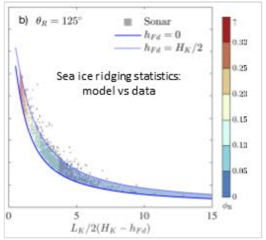
Climate and Environmental Security

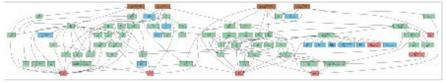


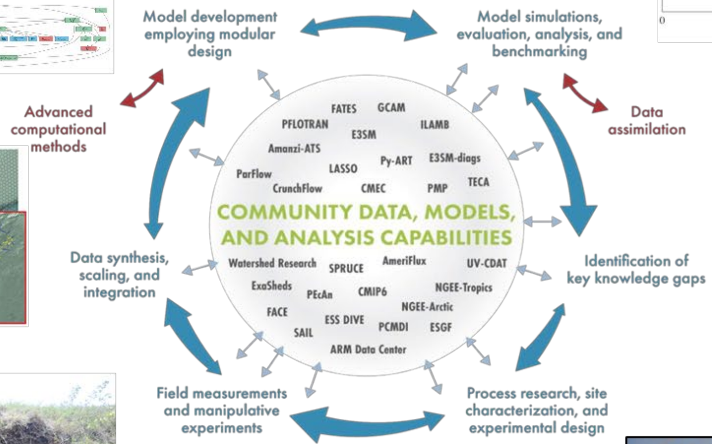
Some (of the many) R&D Topics at LANL in Climate and Environmental Systems Modeling

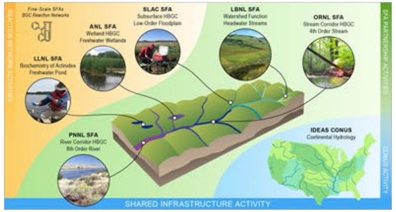
MODEX: Intentional, iterative modeling and experimental cycle







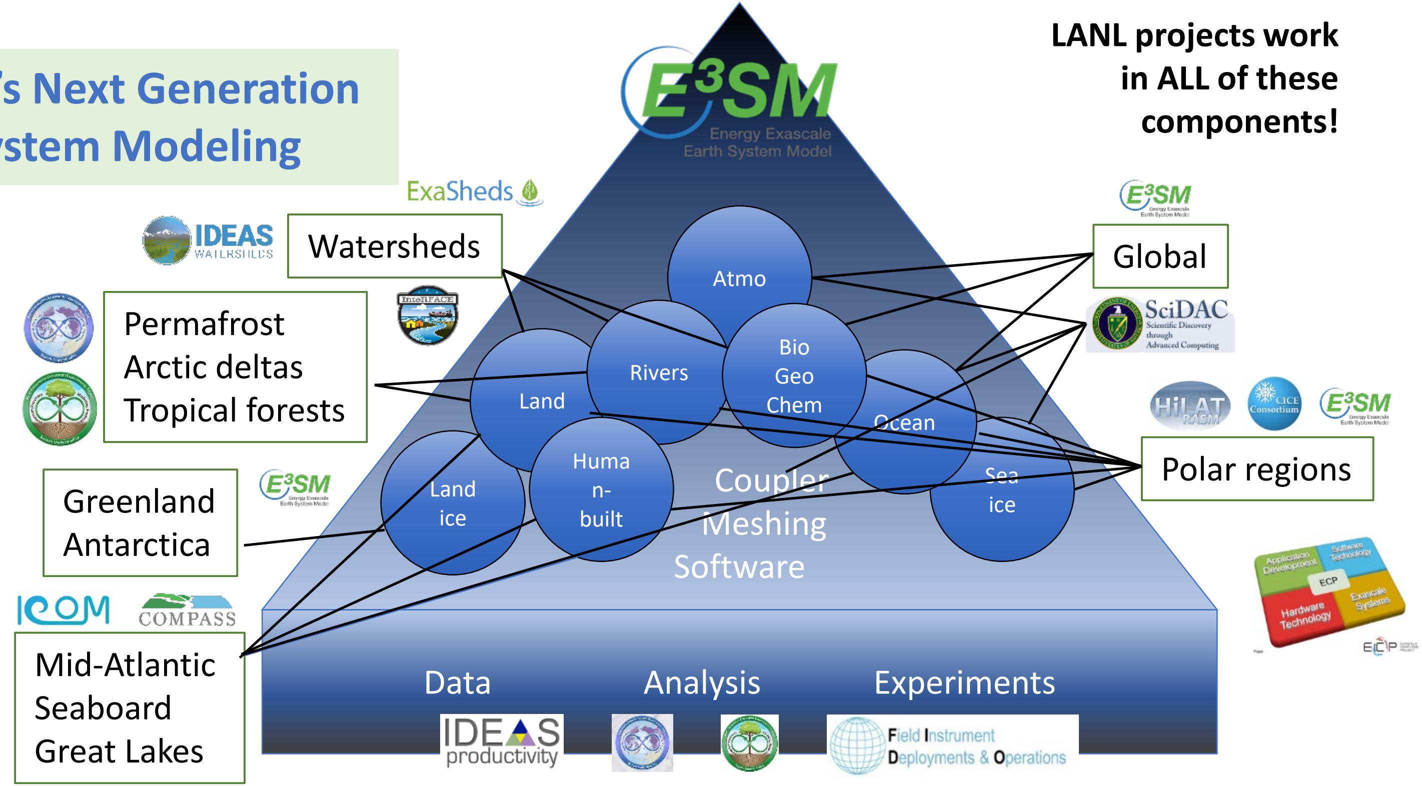




Some (of the many) R&D Topics at LANL in Climate and Environmental Systems Modeling

DOE-SC's Next Generation Earth System Modeling

LANL projects work in ALL of these components!



Fire Modeling: Next Generation Science for Risk Management, Smoke Assessments, and Decision Support

A proactive approach to wildland fire

Accelerating the safe use of prescriptive fires through science-based fuels management optimization

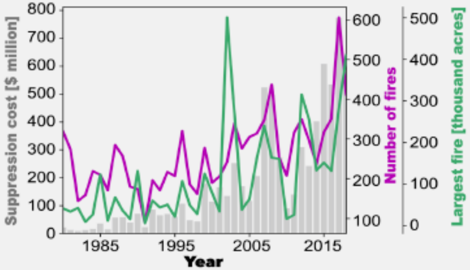
- Unique multi-fidelity coupled fire/atmosphere modeling tools
  - **FIRETEC**: HPC-based high-fidelity CFD wildfire model
  - **QUIC-Fire**: New fast-running tool for ensemble calculations
- Address critical science questions for evaluating land management option trade-offs
  - Wildfire risk management
  - Watershed security
  - Ecosystem sustainability
  - Smoke generation and atmosphere injection
  - Carbon storage
  - Infrastructure impacts
- Vital partnerships for maximizing national-scale impact and successful transition from research to application

PI: R. Linn

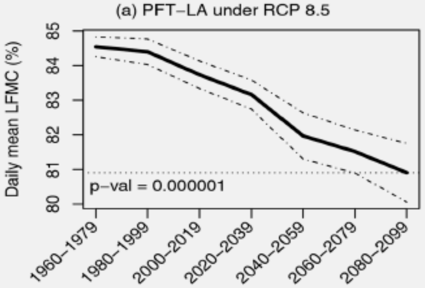
Quantifying the impact of climate change on California fire

Modeling impacts of climate change on forest mortality and fire risk

- Understand complex interactions within California wildlands, while developing a modeling framework that can be applied to other regions
- Collaborative effort between several UC Universities, LBNL, and LANL
- ***LANL Roles:***
  - FATES development
  - Live fuel moisture study
  - Attribution of observed fire trends to climate, fuel management, and ignition source distribution



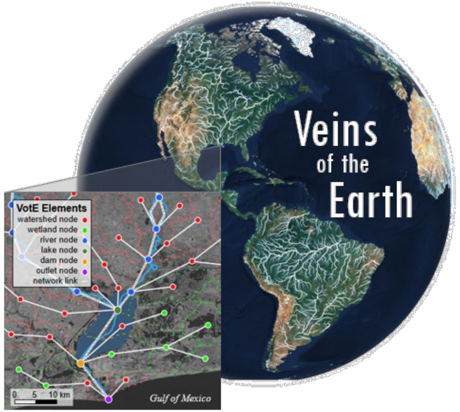
CA fire frequency and size, as well as suppression costs, have increased significantly since 1980. Data source: fire.ca.gov



Live fuel moisture content, a driver of fire risk in CA chaparral, is projected to continue decreasing with climate change.

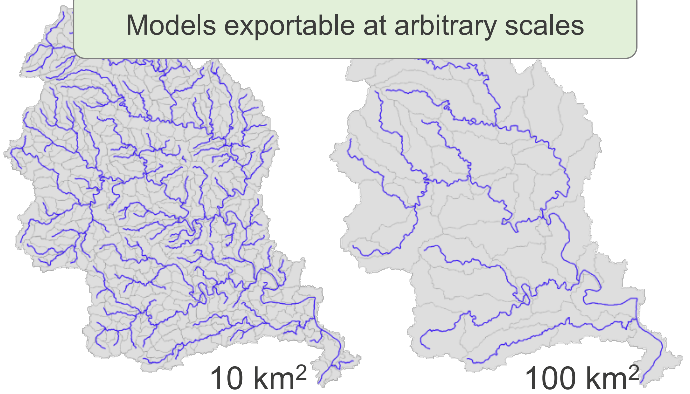
A Global, High-Resolution River Network Model for Improved Flood Risk Prediction

VotE: a platform for river-centric data science and model building



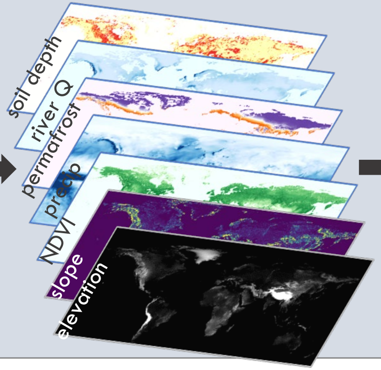
- global coverage
- vectorized representations of river network components including
  - river reaches + associated watersheds
  - reach properties (length, slope, width, sinuosity, etc.)
  - streamflow gages (~35,000 gages via GSIM)
  - lakes/reservoirs (via HydroLakes and ReaLSAT)
  - dams (aggregated from five dam datasets)
- model building
  - any “resolution” (finest is 1km^2 watershed area)
  - lumped or distributed approaches

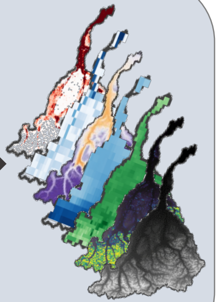
Models exportable at arbitrary scales

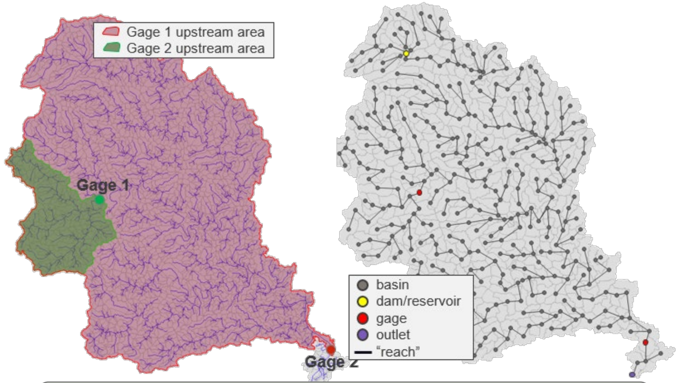


rabpro

Provides forcing data and watershed parameters







Both lumped and distributed models supported

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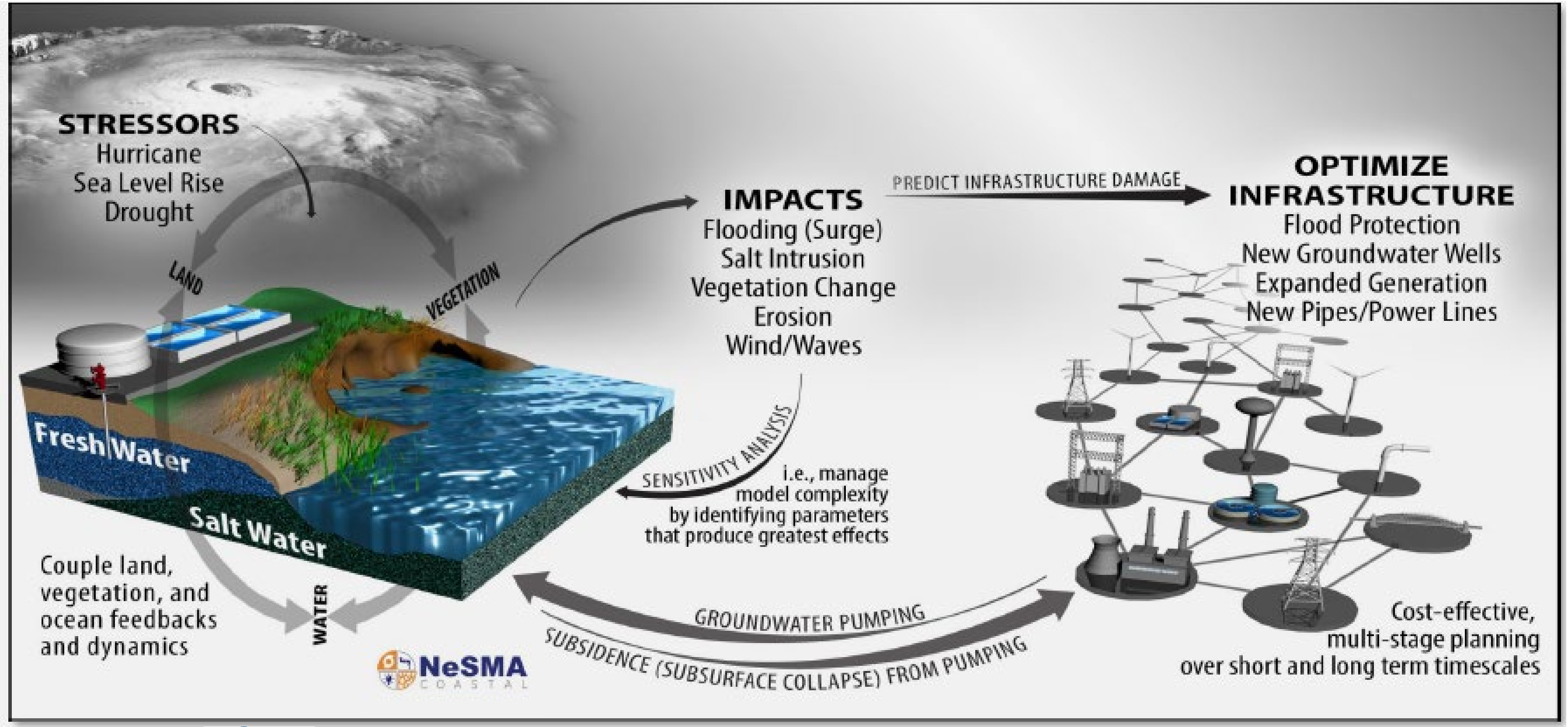
PIs: Jon Schwenk and Katrina Bennet

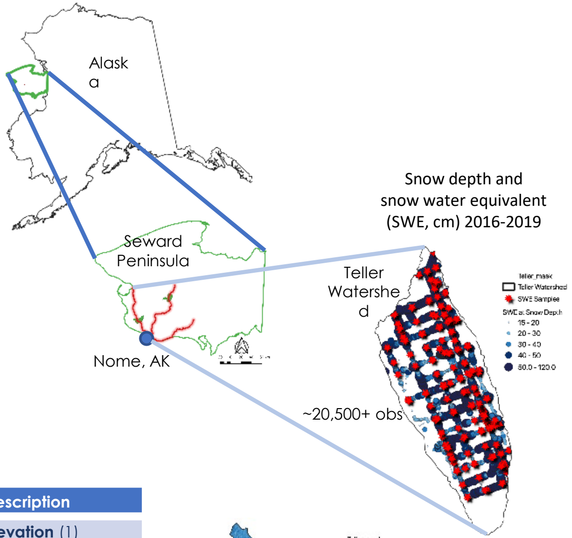
LDRD investment informs coastal process projects:



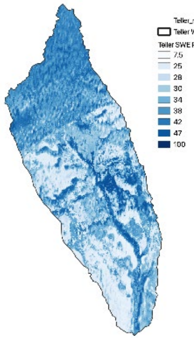
Artificial Intelligence
Machine Learning
Examples

- ❖ Data–model fusion / analysis
- ❖ Feature detection and characterization
- ❖ Emulation / improving models
- ❖ Prediction

Discovering drivers of snow redistribution



Description
Elevation (1)
Slope (1)
Curvature (1)
Exposure/Wind (6)
Vegetation Type (5)
Microtopography (5)
NDVI (1)



randomForest model of SWE incorporates environmental drivers (left)

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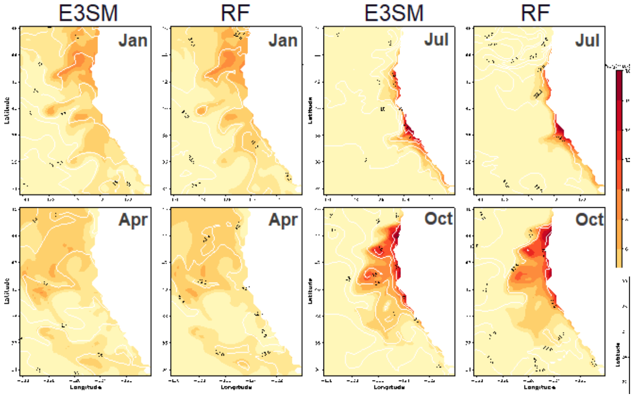
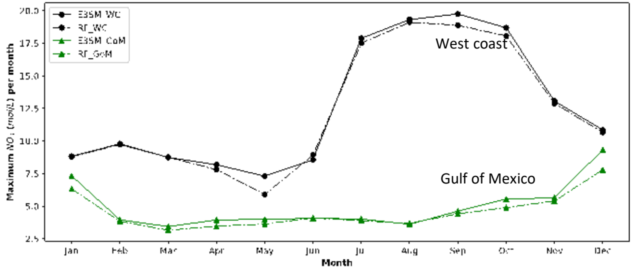
Ecosystem emulation



California coast

ML extracts biogeochemical nutrient relationship to ocean state variables



PI: M. Maltrud

Experimental Links

- Aerosol Size, Composition, Optical Properties, Hygroscopicity, simulated Photochemistry
- Greenhouse gases including isotopes, NOx, HCHO, N_2O
- Solar Fourier Transform Spectrometry: GHG column
- Laboratory and Ambient by Ground, Aircraft, UAV & Satellite
- Data Driven Models: Process, Parameterization, Flux inversions, Machine Learning
- Climate Impacts, Treaty Verification & Weapons Effect

- IRMS – Isotopic signatures and markers – Seeking to acquire MAT253 Ultra to enable clumped isotope analysis: CO_2, CO, CH_4; but also SO_x and NO_x

UCI Collaborations with CAFÉ

- Jim Randerson (UCOP, BERAC, AI4ESP)
  - Fire, Ecology, Climate Feedbacks, V&V
- Claudia Czimczik (student Cindy Yanez, UCOP)
  - ^{14}C to quantify decarbonization, carbon cycle-NGEE
- Jim Smith, Anne Marie Carleton & Manabu Shirawa
  - Aerosols, Atmospheric chemistry (ASR, TRACER, UCOP)
- Eric Saltzman (paleo, NSF), Mike Prather (Atm Chem models) & Alex Guenther (forest gas emissions)

Extra Slides

Long-term ST&E stewardship is based on Capability Pillars

- Our capability pillars define six key areas of science, technology, and engineering in which we must lead

Engineering

MATERIALS FOR THE FUTURE	Defects and Interfaces Extreme Environments Emergent Phenomena
NUCLEAR AND PARTICLE FUTURES	Applied Nuclear Science & Engineering Nuclear & Particle Physics, Astrophysics & Cosmology Accelerator Science & Technology High Energy Density Physics & Fluid Dynamics
INTEGRATING INFORMATION, SCIENCE, AND TECHNOLOGY FOR PREDICTION	Computing Platforms Computational Methods Data Science
SCIENCE OF SIGNATURES	Nuclear Detonation Nuclear Processing, Movement, Weaponization Natural and Anthropogenic Phenomena
COMPLEX NATURAL AND ENGINEERED SYSTEMS	Human–Natural System Interactions: Nuclear Engineered Systems Human–Natural System Interactions: Non-Nuclear
WEAPONS SYSTEMS	Design Manufacturing Analysis

CNES is Organized into Three Strategic Challenges

- **Challenge #1** - Explain the complex interactions and resulting impacts between natural environments and human actions from nuclear threats.
  - **10-year goal:** Understand and predict the effects of nuclear events on natural environments (Earth's core to space).
- **Challenge #2** - Design, build, protect, predict and control engineered systems.
  - **10-year goal:** Develop sufficient predictive ability to enable improved resilience in design of engineered systems or, where applicable, to develop the means to maintain positive control even outside of design lifetime or specification.
- **Challenge #3** - Explain the complex interactions and resulting impacts between natural environments and human actions involving non-nuclear threats.
  - **10-year goal:** Establish science-based models and systems of human-environment interactions representing natural threats and anthropogenic non-nuclear threats that inform national policy and decision makers.

Interactions between natural environments and human actions

#1 For nuclear threats

#2 Design, build, protect, predict, and control engineered systems

#3 For non-nuclear threats

LANL is strongly invested in improved understanding and prediction of Earth system dynamics and change

Los Alamos leads DOE's cryosphere modeling, and more

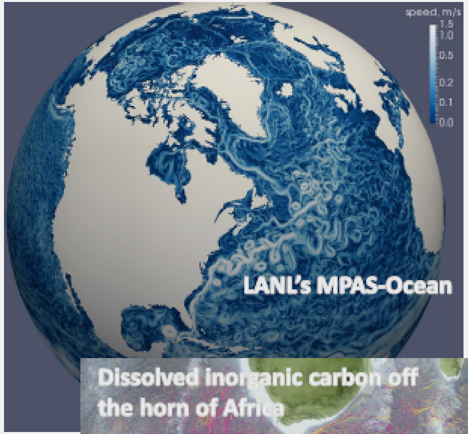
DOE BER Earth and Environmental Systems Sciences flagship projects

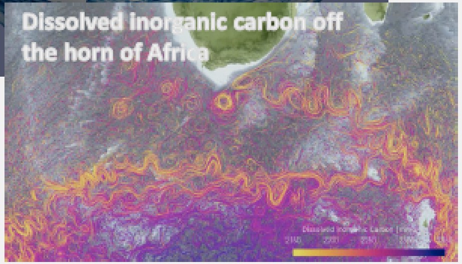
- **E3SM**: Energy Exascale Earth System Model
  - **MPAS-ocean, sea ice, ice sheets**
  - **Cryosphere, Water cycle, Biogeochemistry science thrusts**
  - **CICE Consortium**
- **InteRFACE**: Interdisciplinary Research for Arctic Coastal Environments
- **ICoM**: Integrated Coastal Modeling
- **COMPASS**: Coastal Observations, Mechanisms, and Predictions Across Systems and Scales
- **NGEE-Arctic and Tropics**: Next Generation Ecosystem Experiments
- **HiLAT-RASM**: High Latitude Analysis and Testing – Regional Arctic System Model
- **FIDO**: Field Instrument Deployments & Operations
- **Carbonaceous Aerosols**
- **IDEAS-Watersheds**: Interoperable Design of Extreme-scale Application Software
- **ExaSheds**

DOE BER/ASCR SciDAC projects

- **ProSPecT**: Probabilistic Sea level Projections from ice sheet and Earth system models
- **DEMSI**: Discrete Element Sea-Ice Model
- **CANGA**: Coupling Approaches for Next-Generation Architectures

Numerous university collaborations





Office of Science Projects

- Creating a Sea-Level-Enabled E3SM
- Arctic environmental change and its impacts
- Linking ocean to land to human systems in complex watersheds
- Interdisciplinary Research for Arctic Coastal Environments
- Diagnosing near-future changes in Arctic sea ice and ocean conditions
- Coastal Observations, Mechanisms, Predictions Across Systems and Scales (COMPASS)
- Interoperable Design of Extreme-scale Application Software (IDEAS)
- Observations and models at hillslope and watershed scale
- E3SM mesh refinement with a global focus
- Discrete Element Model for Sea Ice

Artificial Intelligence
Machine Learning
Examples

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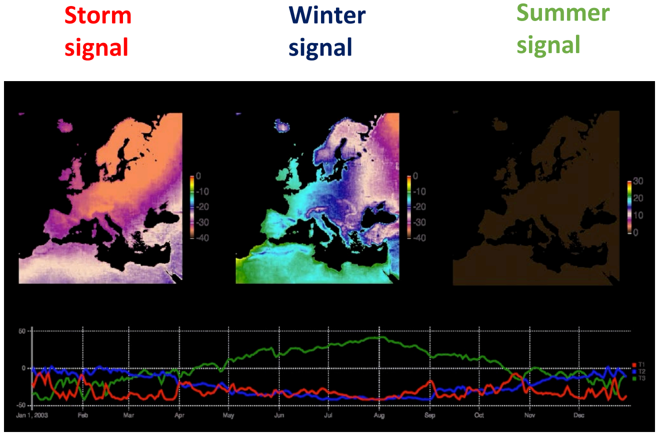
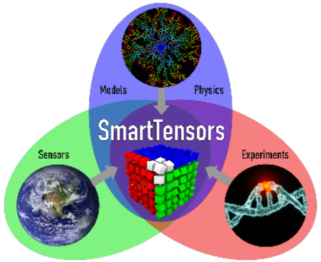
PI: B. Alexandrov

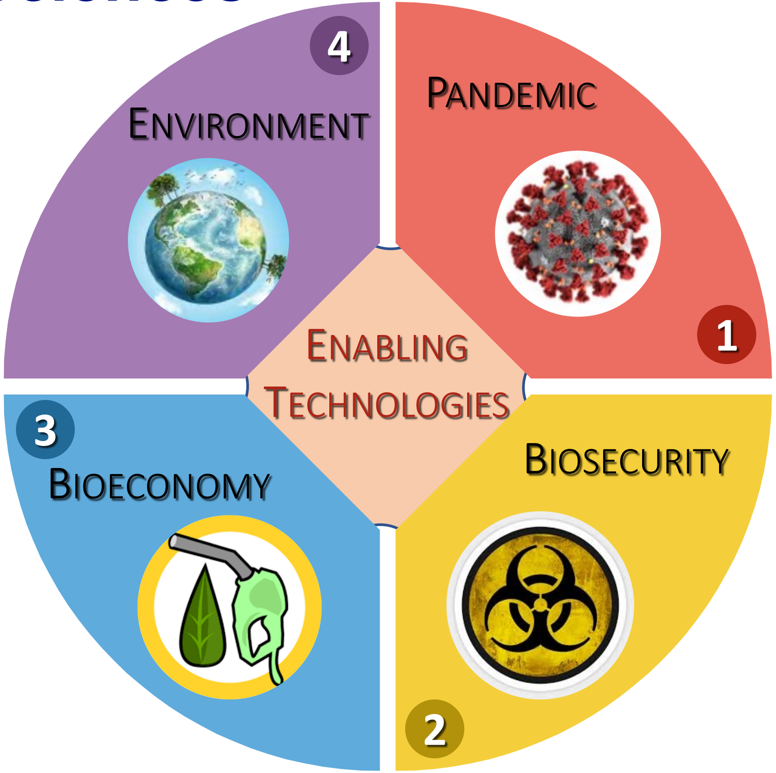
Characterization of heat waves in Europe



Unsupervised ML (nonnegative matrix or tensor factorization) finds common signatures in climate model outputs



The four Grand Challenges in National Security Life Sciences



1 Preparing for the Next Pandemic
- Epidemiological Modeling
- Global Biosurveillance
- Data Integration and Risk Communication

2 Building our Biosecurity Future
- Biothreat Impact to Humans
- Diagnostics and countermeasures
- Classified Analyses

3 Growing a Robust Bioeconomy
- Renewable Bioenergy and Biofuels
- Biomanufacturing
- Algal Biotechnology

4 Climate Change, Environment and Human Health
- Climate Impacts and National Security
- Ecological Health Security
- Food Security