Advanced Forest Fire Planning introducing Quantitative Climate Intuition (QCI)

Presented to the Tactical Fire Remote Sensing Advisory Committee (TFRSAC) Meeting

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NASA Grant 80NSSC22K1817 - Advanced Forest Fire Planning introducing Quantitative Climate Intuition (QCI) (Formerly called Complexity Management (QCM)/Artificial Intuition)

Goal: Through QCI, identify locations/areas of forest system sensitivity and stress that often leads to wildfires or wildland fires.

Project Details:

- Duration: Nov 2022 – Dec 2024
- Initial work to build out wildfire case studies to determine areas of forest system stress (ignition zones)
- Investigate incorporating NASA remote sensing data sets in conjunction with other data sets
- Demonstrate technique in operational setting to key stakeholders (i.e. California Department of Forestry and Fire Protection (CAL FIRE))

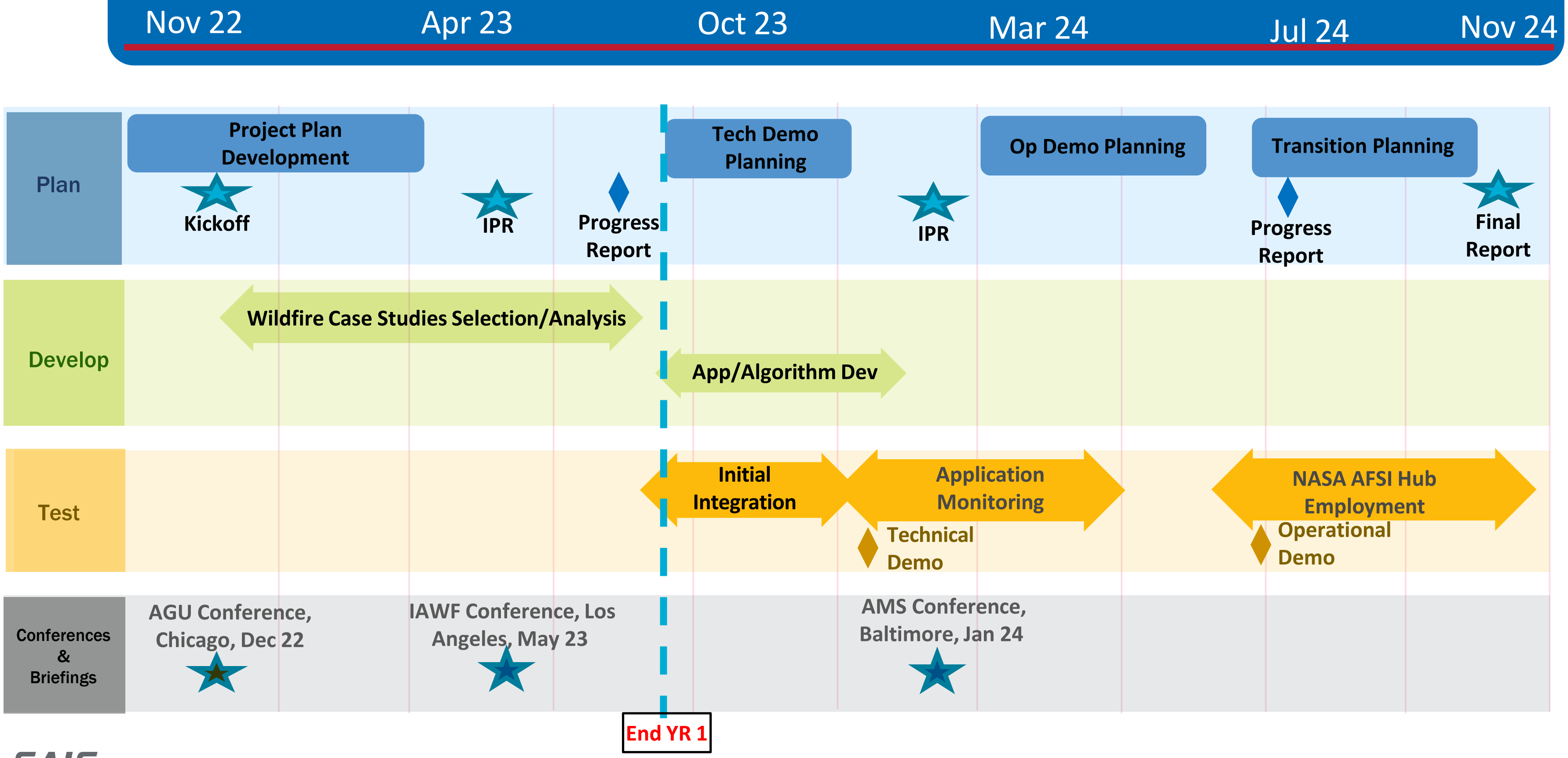
Project Team:

- Steve Ambrose – Co-PI, SAIC Chief Climate Scientist
- Sean Nolan, Co-PI/PM
- Dr. John Timler – Solution Architect
- Dr. David Morrison – Modeling and Analytics
- Daniel (Dane) Davidson – Project Controller

-NASA Program Manager: Dr. David Green, Wildland FireSense Management Team

-NASA Project Manager: Dr. Jessica McCarty, Miami University (Ohio)

NASA Project QCM/Artificial Intuition Timeline

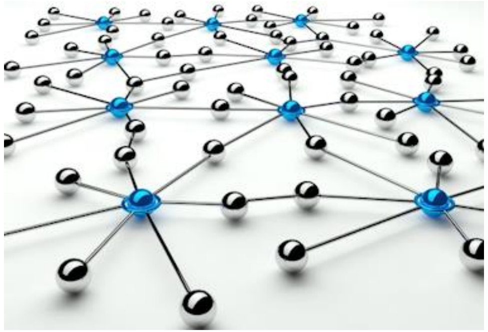


What is Complexity?

- Complexity is a fundamental property of all systems, just like energy. It is a scalar function of structure and uncertainty. It quantifies the amount of structured information within a system.
- Complexity is measured in cbits (complexity bits).

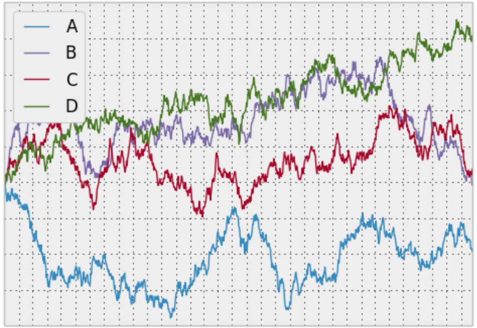
Structure

(Interdependency of players)



Uncertainty

(Noise content in information)



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Quantitative Complexity Management (QCM): Model-free Analysis of Data

The brain processes a scatter plot not as data, but as an image created in the cortex; it then identifies instantaneously a series of features, even if the image is blurred. This is done without any calculations, building equations, or model fitting. Adapted by nature, the brain can perform this task without resorting to mathematics and has done so long before the discovery of mathematics. The data analysis technology delivered by SAIC/Ontonix mimics the brain. No statistics, no regressions or cluster analysis, no model fitting, no fuzzy logic: just brand new, disruptive technology in its purest form.

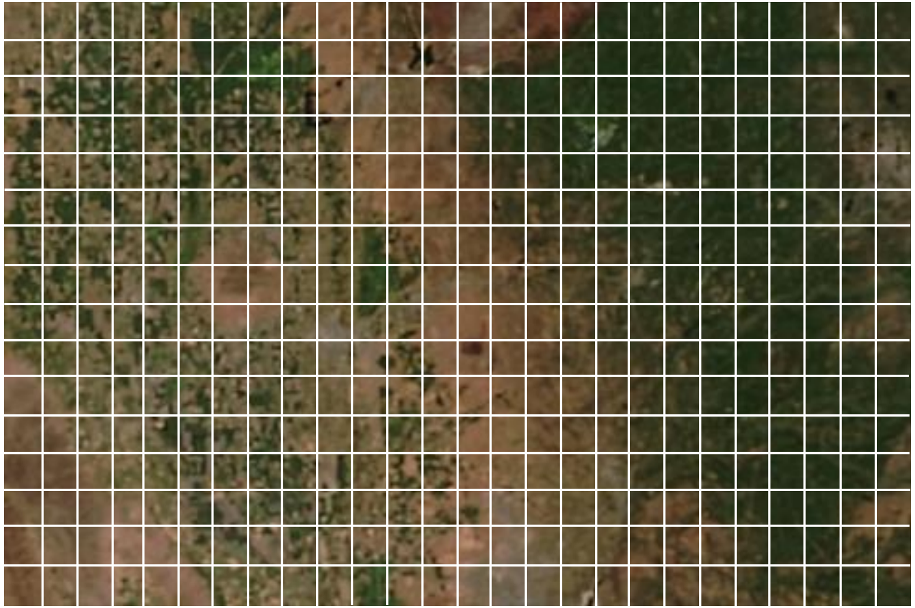
Preliminary Exploration of Forestry Use Cases

1. Evaluation of Forest Ecosystem Robustness and Fragility from Satellite Optical Imagery

2. Correlations between complexity of drought maps and fire activity

3. Near term plans include incorporating additional data sets such as air quality and temperature maps.

Quantitative Complexity Management (QCM) for Forest Criticality



16

26

Divide Satellite Image into Grid and Apply QCM to Each Element

- QCM is a model free approach that quantifies the entropy and correlation of system interdependencies to identify system anomalies
- QCM 'Artificial Intuition' can be used in a Stand Alone Capacity or in Conjunction with ML/AI
- Changes in Grid Elements can be Tracked Overtime
- Size of Grid and Size of Elements can be Scaled for Regional Comparisons
- Temperature, Rainfall, Wind Speed and other Environmental Data Sets can be Integrated into Multi-Layered QCM Image Analysis

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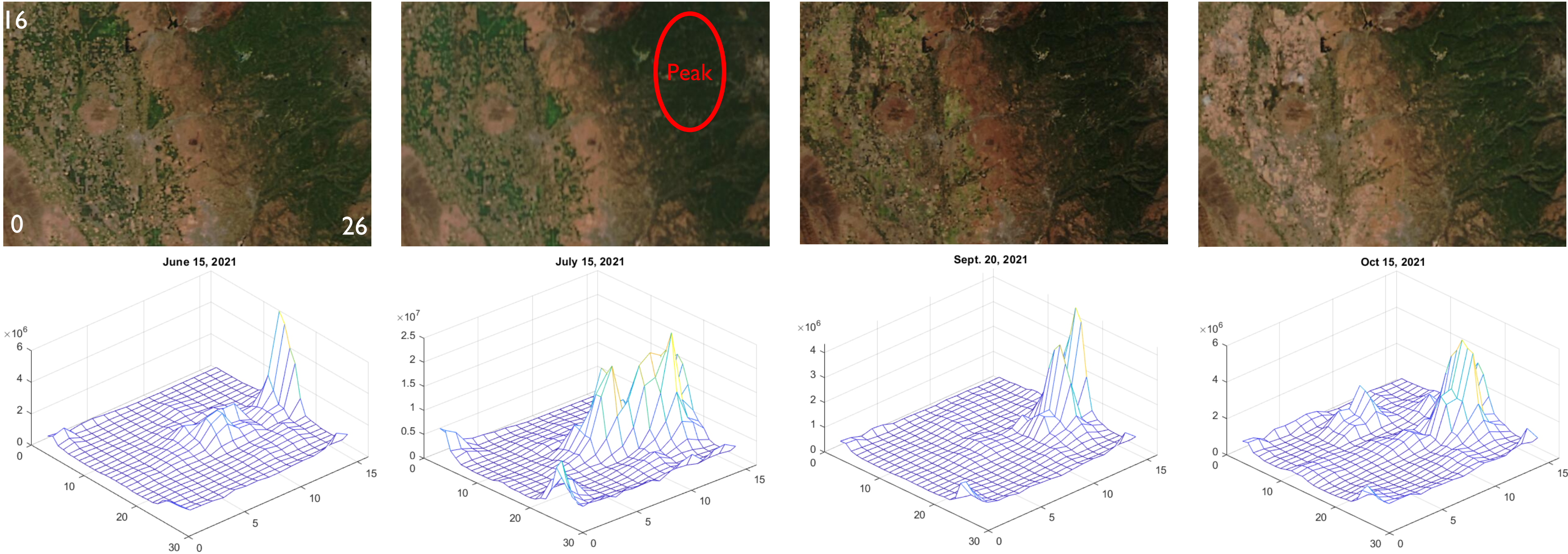
Complexity Analysis of Foliage in Southern California



Peak Complexity = 6.0×10^6

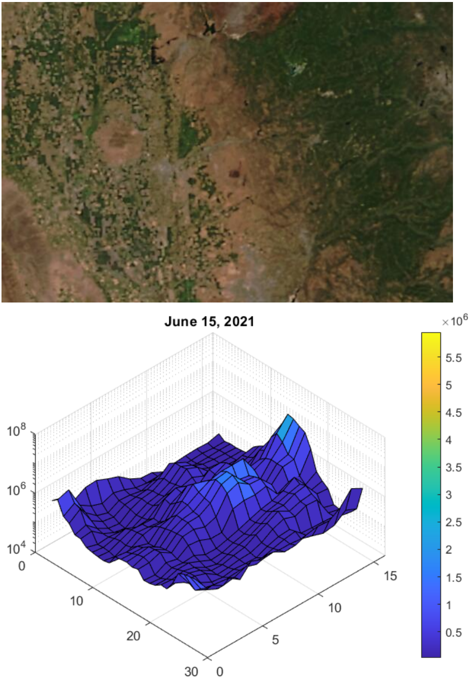
Peak Complexity = 2.3×10^7
Factor of 4 increase

Peak Complexity = 4.3×10^6
Factor of 5 decrease

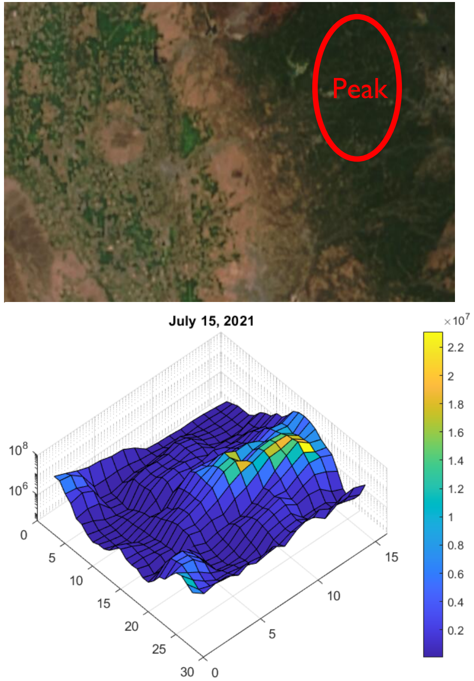
Peak Complexity = 5.0×10^6

Local Complexity Increases and Diminishes in Conjunction with Growth Season.
Densest Region of Foliage has Highest Complexity.

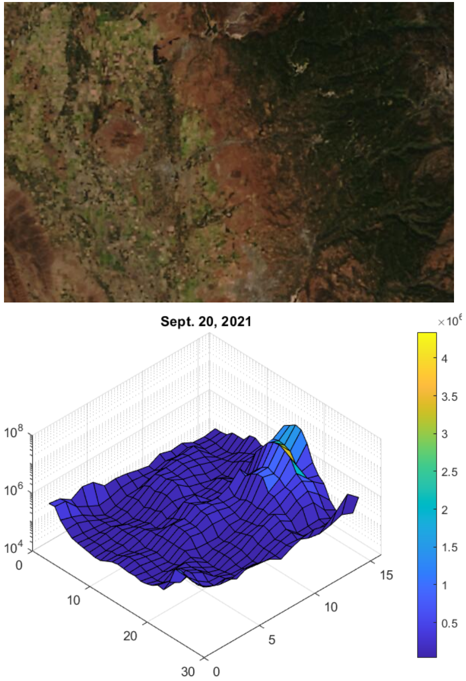
Complexity Analysis of Foliage in Southern California (semi log Z axis)



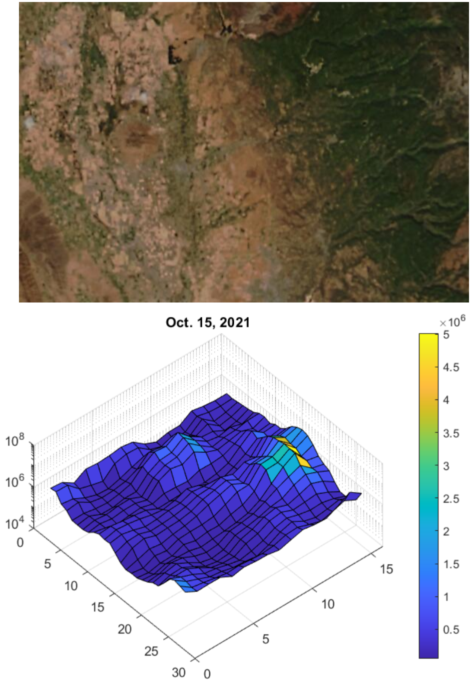
Peak Complexity = 6.0×10^6



Peak Complexity = 2.3×10^7
Factor of 4 increase



Peak Complexity = 4.3×10^6
Factor of 5 decrease



Peak Complexity = 5.0×10^6

Logarithmic Scale Shows Complexity Topology Narrative for a Growth Season
(August Satellite Imagery Obscured by Forest Fires)

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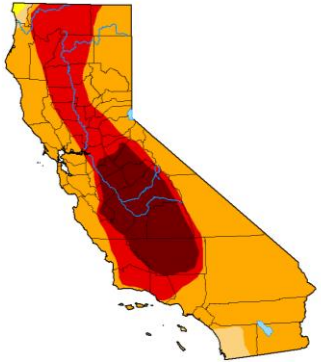
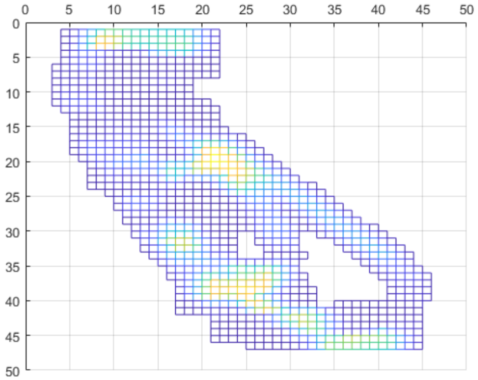
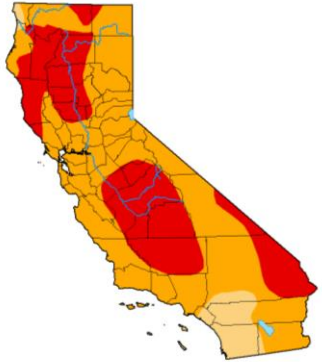
Drought Maps Converted to Complexity Maps with Artificial Intuition



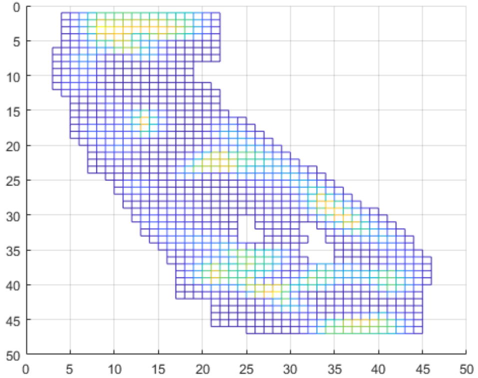
Drought Map
9/13/2022



Complexity Map
9/12/2022



Drought Map
3/15/2022

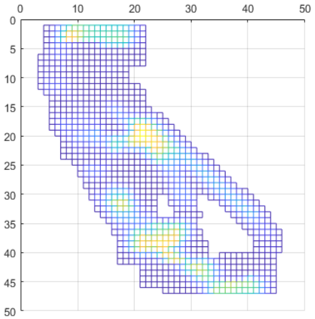


Complexity Map
3/15/2022

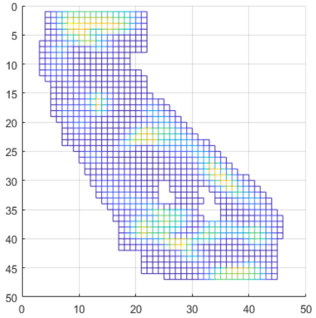
https://droughtmonitor.unl.edu/Maps/MapArchive.aspx

Correlation of Drought Dynamics to Potential Fire Activity

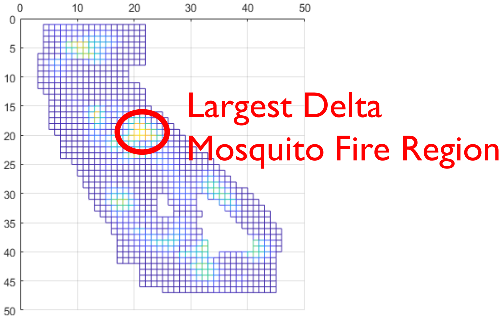
Complexity 9/12/2022



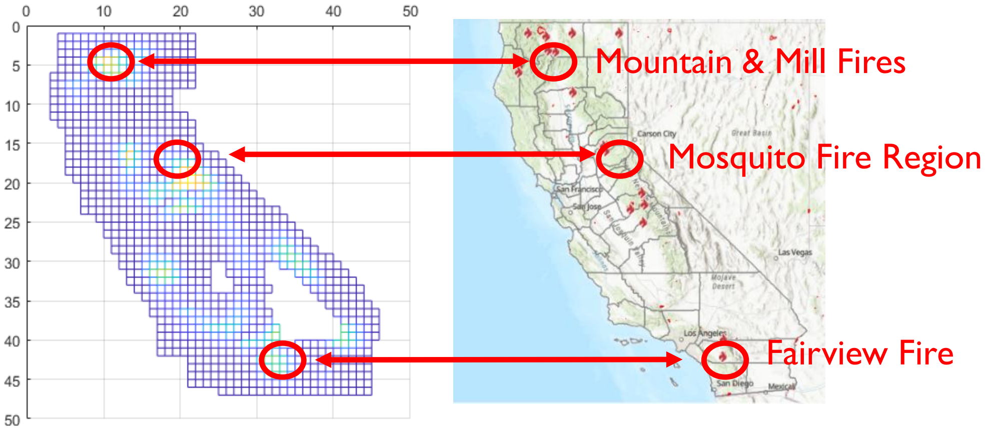
Complexity 3/15/2022



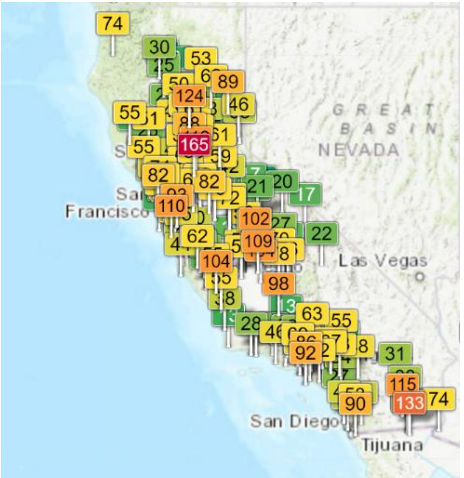
Complexity Delta



Not conclusive, but definitely interesting to see the relationship Current major fires correspond to complexity delta regions from drought maps.

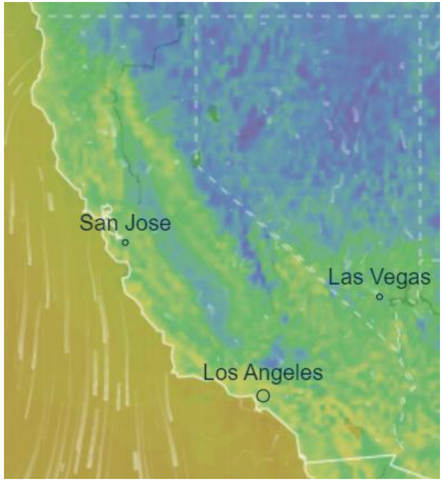


Path towards integrating diverse data sets



Air Quality

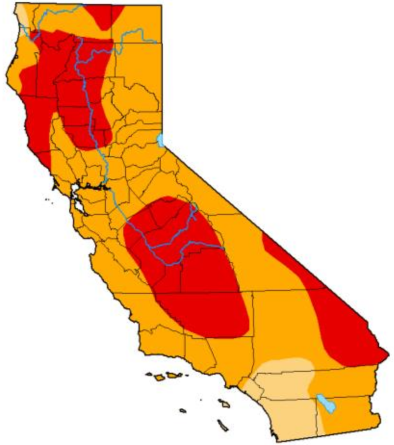
https://aqicn.org/map/california/



Temperature Models

https://www.ventusky.com/?p=36.7;-124.1;4&l=temperature-2m

Each data stream (air quality, temperature, drought level) becomes a column with individual rows being distinct points in time for the entire system.



Drought Maps

https://droughtmonitor.unl.edu/Maps/MapArchive.aspx

Examples of Forestry Criticality Analysis Enabled by QCI

- Forest Historical State of Health Monitoring and Prognostics
- Detection and Evaluation of Insect Infestation Events
- Short and Long Term Impact of Drought
- Logging Impact Assessment and Modeling
- Quantitative Ranking of Forests Overall Resiliency
- Real Time Prediction of Trends, Inflection Points and Catalyst Nexuses for Forest Fires
- Individually or Collectively Assess Impact of Diverse Data Sets (Urban Growth, Terrain, Water Supply…) on Forest Resiliency

Collaboration Opportunities & Next Steps

- Collaboration Opportunities:
  - Data Archive Access
  - Data Preprocessing (diverse formats => numerical tables)
  - Results Visualization
- Next Steps
  - Integrate More Diverse Data Sets
  - Show Historical Correlation Between Complexity and Forest Health
  - Ultimate Goal is Employ QCI in a Predictive Capacity for Forest Protection

Stakeholder Outreach

- California Department of Forestry and Fire Protection (CAL FIRE):
  - Ongoing Discussions with R&D and Innovation Team to test QCI on historical and emerging fire events
  - Proposed Use Cases:
    - Provide analysis of wildfire risk to community infrastructure to analyze long term accumulation of vegetation around infrastructure.
    - Using historical case studies, determine of deployment of operational assets, such as fire suppressant, fire crews, and other equipment makes the best use of resources and effectiveness in fighting the fires.
    - Analyze drought conditions as a potential key indicator for fire risk on a statewide scale
    - Investigate enhanced forecasts for seasonal/monthly planning that integrate climate-weather and fuels are necessary, while balancing Air Quality (AQ)
- Seeking outreach to any state and local contacts to see if they are interested in participating in our projects and studies.

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SAIC's Climate Enterprise

Contact Information and Link to Climate Enterprise Website

Steve Ambrose, Chief Climate Scientist – stephen.d.ambrose@saic.com
Sean Nolan, PM – sean.m.nolan@saic.com
Dr. John Timler, Lead Project Scientist – john.p.timler@saic.com

Climate Enterprise Website – https://www.saic.com/what-we-do/mission-support/climate-enterprise

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Thank you!

Backup Slides

QCI Computation Parameters

16 vCore	32 vCore	200 vCore	300 vCore	640 vCore	Memory used	Number Elements
2.08 sec	1.48 sec	0.54 sec	0.48 sec	0.41 sec	40 MB	300,000
16.41 sec	13.3 sec	2.12 sec	1.83 sec	1.25 sec	436 MB	580,000
0:02:34	0:01:44	20.72 sec	16.39 sec	8.84 sec	3.7 GB	1,740,000
0:58:43	0:21:20	0:04:22	0:02:56	0:01:25	41.98 GB	5,800,000
N/A	N/A	0:28:05	0:18:42	0:08:49	260 GB	14,500,000
N/A	N/A	N/A	0:50:08	0:25:09	760 GB	24,192,786

Approximately Linear Reduction in Computation Time with Additional Cores
Both Cloud and Dedicated Server Implementations Available