JPL Machine Learning For Earth Science

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Context

Data Science Life Cycle

Formulation | Acquisition | Transport | Operations | Calibration | Curation | QC | Analysis | Knowledge | Archiving

- Quick Analysis
  - Quick Calibration
  - Quick QC
  - Quick Analysis
  - Quick Knowledge
- Annotate
- Advise / React
- Repeat

Quick-Look products enable earlier reaction

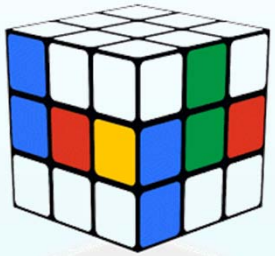
Advisory systems direct focus

What is Machine Learning?

Algorithms that inductively self-assemble from examples.

Expert Examples
(e.g. Estimates 1-10 of attractiveness of picture)

Training Data
(Encompasses domain of responsibility)



Functional System
- Interpretable as required
- Fixed code (V&V ready)
- Not ever-learning (mostly)
- **EASILY UPDATED**

Strength:
Don't specify rules
Don't explain "how"

Machine Learning simplifies & systematizes the building and updating of Autonomy / Advisory systems

Higher Level Questions / Actions

“Where should I start looking?”

“Show me more like this.”

“What is likely to happen next?”

“(Re)optimize my system.”

”How many kinds are there?”

“Show me the most interesting first.”

“What inputs are most informative?”

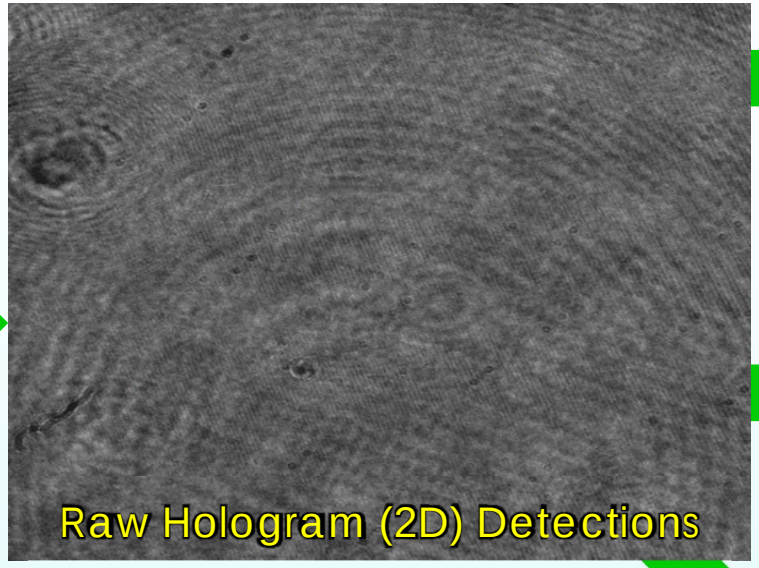
“Show me new things.”

JPL DS / ML Applications

1. **Science-driven use cases**
2. **Explanability**
3. **“Let Me Help”**

Holographic Life Detection

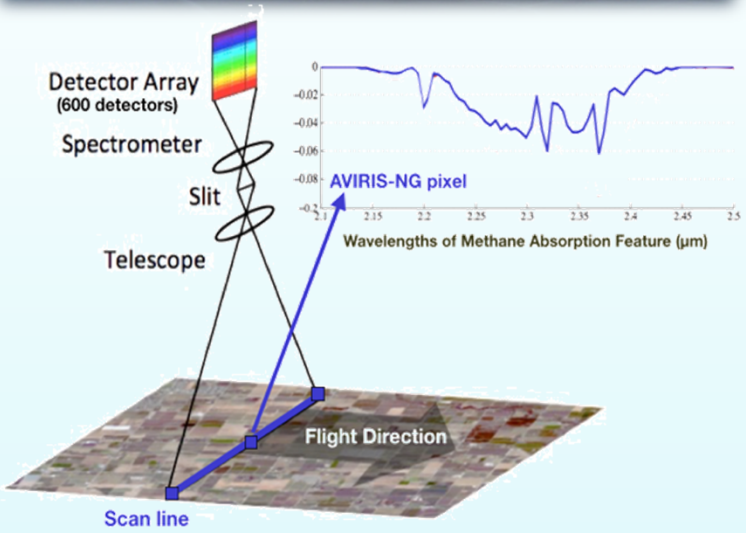
Drs. Lukas Mandrake, Gary Doran, Brian Bue



- Digital Holographic Microscopes
  - Big data (4D, ~GB/s), rare findings
- Motility ~ Life (composition agnostic!)
- HELM ML system detects, tracks, and classifies in messy, raw 2D holograms

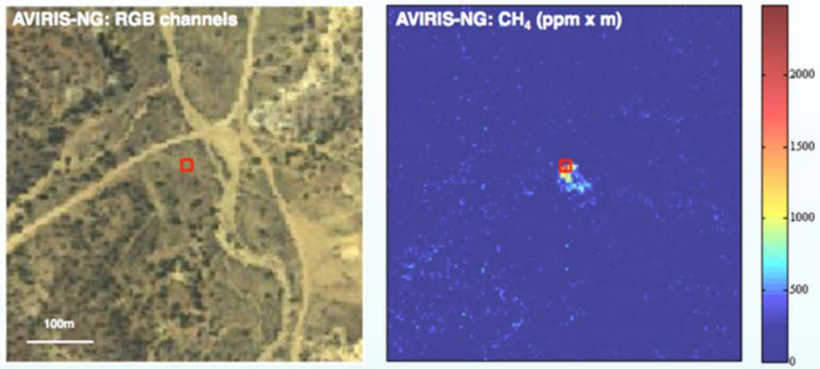
AVIRIS-NG Hyperspectral

Dr. David Thompson, Dr. Brian Bue, et al



Airborne Imaging Spectrometer

CH4 detection in four corners



Enabled ground team to find underground pipe leaks

Multiple gas pipelines shut down / repaired
Machine Learning "That Matters"

Quality/Uncertainty Estimation

Dr. Lukas Mandrake

Don't Pre-Filter Data:
No Data Quality Flags

instead

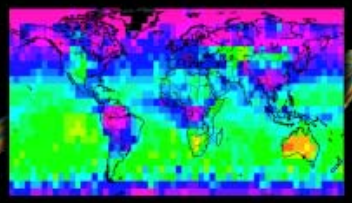
Order by Trust
Learn from Experts

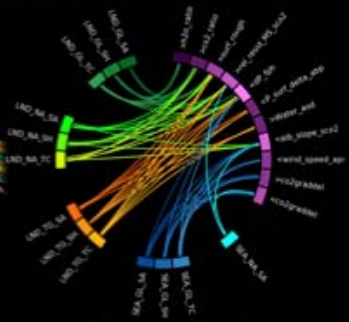
New Approach: Ordering by Trust

No ground truth? No problem!

What must be true to Trust Dataset?

Genetically discovers best, simple recipes to predict Trust.





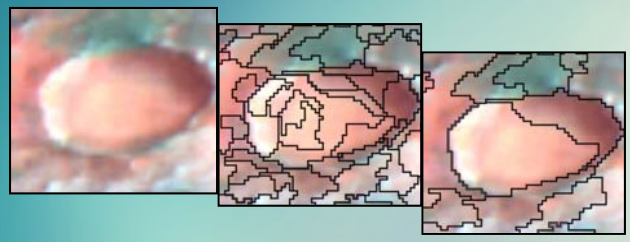
Make Trust maps, Learn vars that predict Trust

Users take Trusted data first.
Custom filtration & dataset size

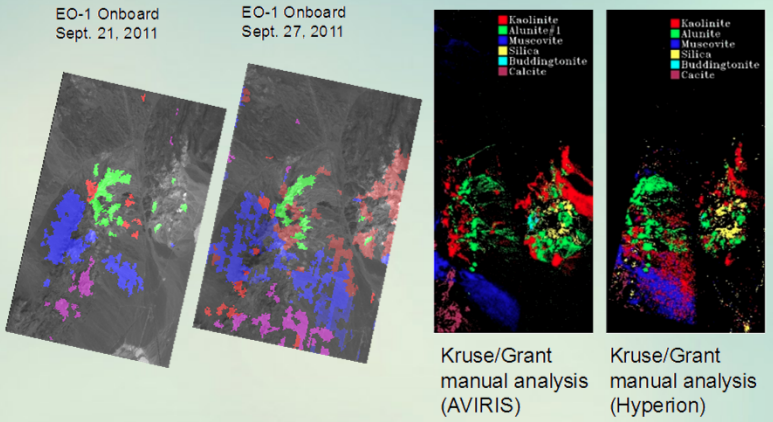
Current OCO-2 Quality Estimation Product / NASA Software of the Year runner-up

Orbital Spectral Analysis

Superpixel segmentation



SMACC Endmembers

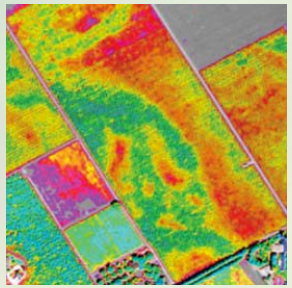


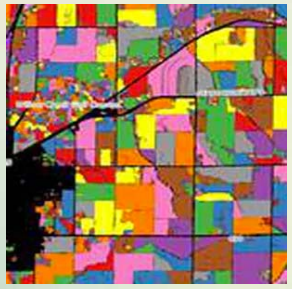
Kruse/Grant manual analysis (AVIRIS)

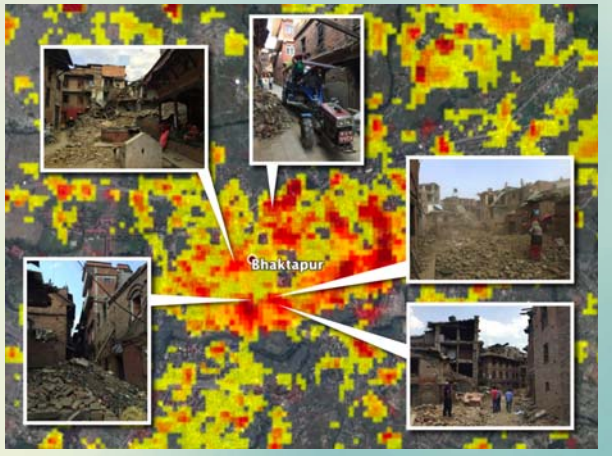
Kruse/Grant manual analysis (Hyperion)

Similar orbital tech used for

- Minerology maps
- Identifying crop-types
- Recognizing diseased citrus
- Estimating hurricane damage



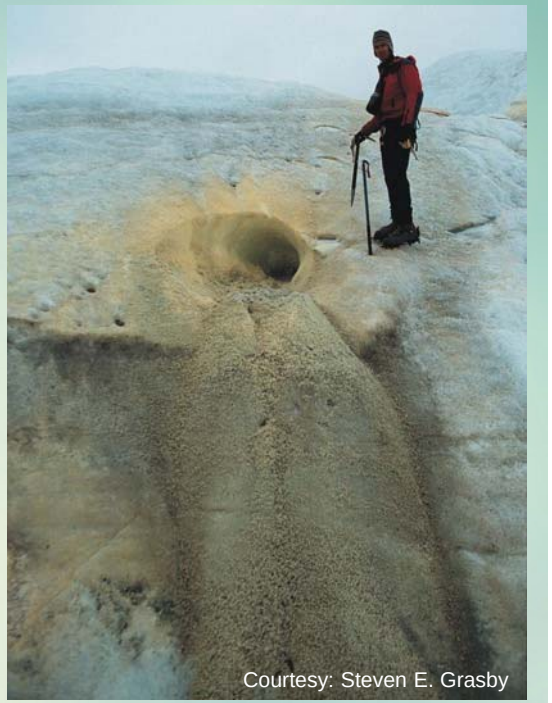




D. Thompson et al., 2012. *TGARS*.

Spectral Minority Targets

- Borup Fiord sulfur springs
- Biosignature analog site for Europa
- Detect and track from orbit (EO-1)
  - Support vector machine (SVM) classifier
  - 26 detections as of May 31, 2016



EO-1 image
(Hyperion)

Sulfur detection (yellow)

D. Gleeson et al., 2010. *Remote Sensing of Environment.*
L. Mandrake et al., 2012. *ACM TIST.*

How to Supercharge NASA Data Science

The Growth of DS Concepts

- $30-$50k
- Proof of Principle
- Single Problem

- $150k-$300k
- Extensive Validation
- Single User Focus

- $400k-$1M
- Mission Funding
- Flight Readiness

- $1M - $5M
- Multiple Mission
- Becomes Heritage

- JPL has this under control
- R&TD system
- Engineering Improvement
- Data Science Working Group

- Major bottleneck
- Can try for AMMOS Tech
- Needed for approaching missions
- Try to navigate science-based R&TD process

- Missions ~receptive
- Require extensive validation for entry
- Need to translate to “onboard” reqs

- Each mission different “captain” of own ship
- Often afraid NASA won’t like Data Science / ML
- Fear becomes main challenge

Shared Repositories for past DS / ML datasets & labels

Pot of Money to validate DS / ML systems to mission ready status

Mission AO specifically requesting new DS / ML techniques

Thank You!