Terrestrial Ecosystems Information Data Product Conception, Formulation, Production and Applications – a Determinant of Mission Motivation and Impact

SMAP Launch 2015

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Outline

- Background: “selling” a mission concept
- Data Product Life Cycle
  - Information Product Identification
  - Algorithm Development & Physical Measurement: Calibration and Validation
  - Applications: Decision Support *AND* Research
- Conclusions

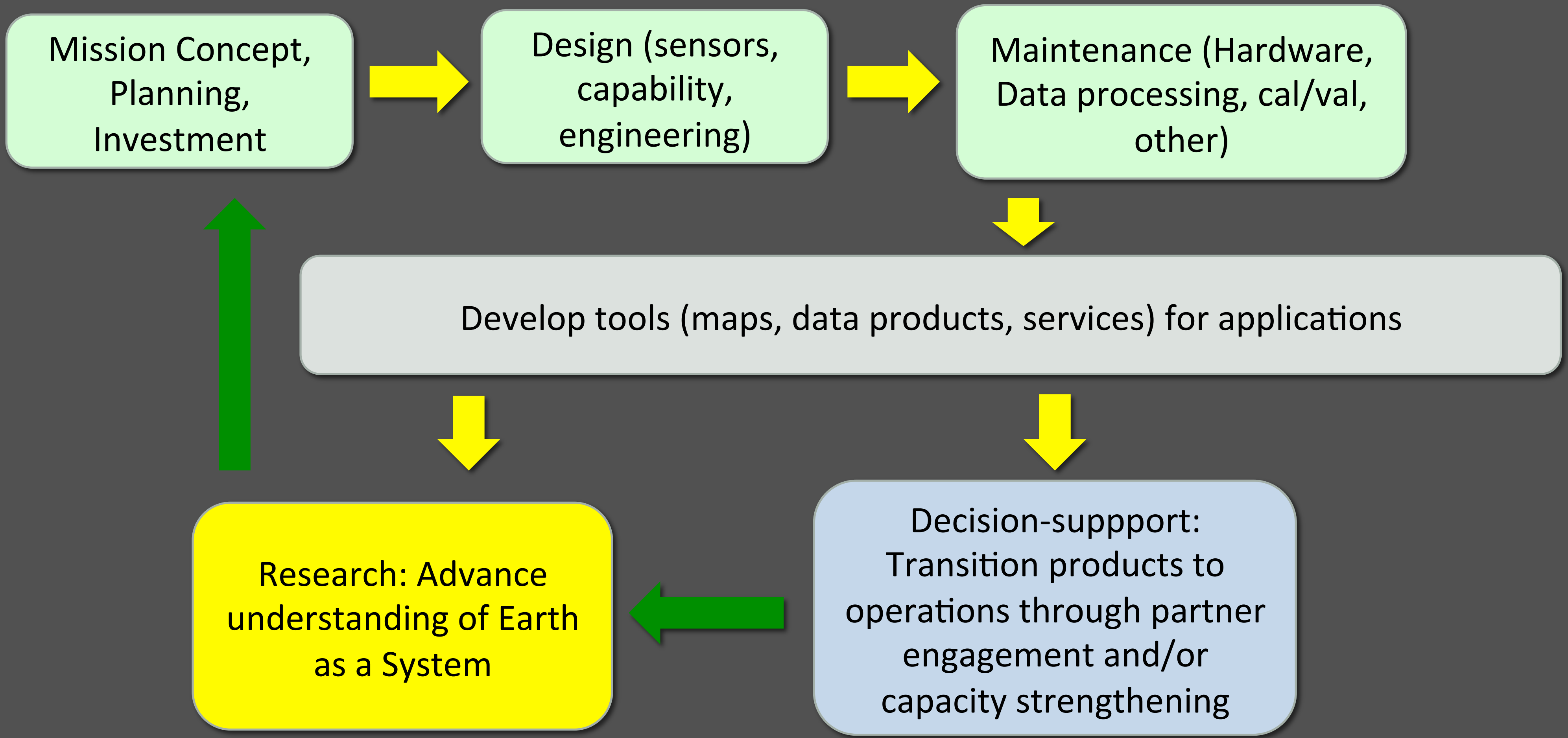
Defining mission "success"

- Commonly defined as meeting Level 1 and Level 2 science and engineering requirements
- BUT, this assumes you have a mission to meet the Level 1 and Level 2 science and engineering requirements
- How do you get a mission to the point of even being evaluated on the ability to meet these requirements?
- THIS is what I am defining as "mission success" - the success of getting a mission funded and seeing it through to the end, inclusive of meeting requirements, but more specifically, setting requirements.

How are missions selected?

- Decadal Survey – a document released every 10 years that draws on global community contributed white papers specifying the state of knowledge for their discipline within Earth Science (or planetary) and what is needed to advance Earth System Science in the next 10 years
  - Recommended missions to both NOAA and NASA
  - NASA does "new"
  - Recommendations not prescriptions
  - They are still competed (either in concept or in implementation) - a science narrative addressing a broad community (i.e., Earth system science) is key
    - How do we select the "sellable" science?

Think of the Mission Life Cycle and ask yourself: what dataset is absolutely most needed to advance understanding of the Earth System



Proposal Process and Mission Development

- Two types of missions: Directed (OCO-3, NISAR, SWOT, etc.) AND Competed
- Phase A -- proposal
  - All missions: ”short” proposals based on science merit (STM), science implementation, and mission implementation
  - Competed ONLY: detailed proposal of science and mission implementation
- Phase B - commissioning review
- Phase C - “cut metal”
- Phase D - assembly, test, launch, operations (ATLO)
- Phase E - after launch and checkout period

Science Traceability Matrix (STM) is the foundation, success rests on this, yet its in the first step and *cannot* be revised without starting the process over!

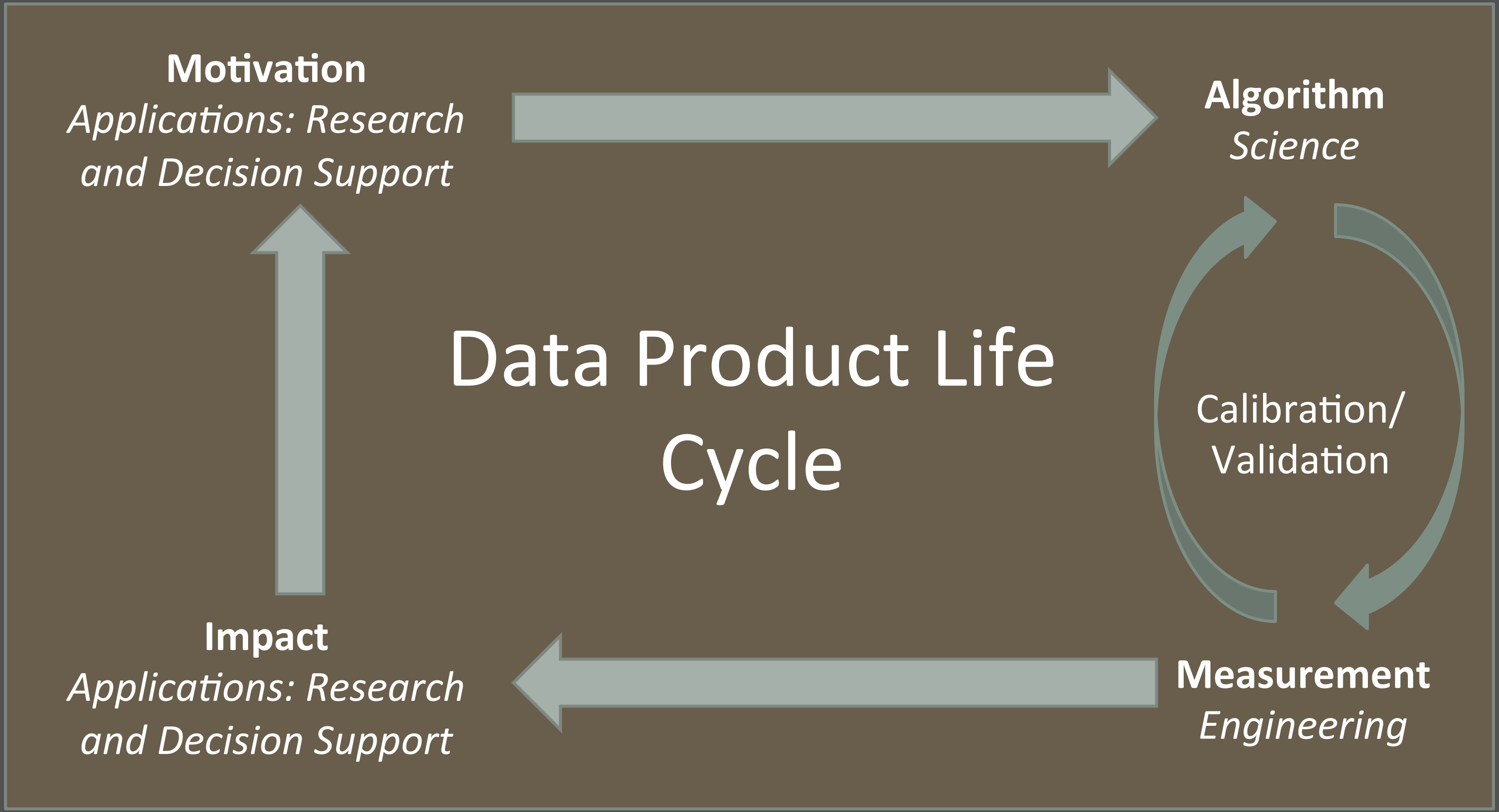
Science Goals	Science Objectives	Physical Parameter Measurement Requirement	Observables Measurement Requirement	Instrument Functional Requirements	Project Performance	Mission Functional Requirements
Direct Quote from NASA Decadal Survey or Science Plan	To *Determine* (if hypotheses are true – from Level 4 Data)	*Property of Object* (predicted to differ due to hypotheses) – Level 2 & 3 Data	*Property of Signal* (predicted to differ due to hypotheses) – Level 1 Data	*Property of Signal* (predicted to differ due to hypotheses) – Level 1 Data	*Signal* Radiometric, Spectral, Spatial, Temporal and/or Polarimetric Range and Resolution – Level 0 Data Sensitivities	Observation Location, Observation Time, Observation Direction & Change

STM relies on data products, generally defined as:

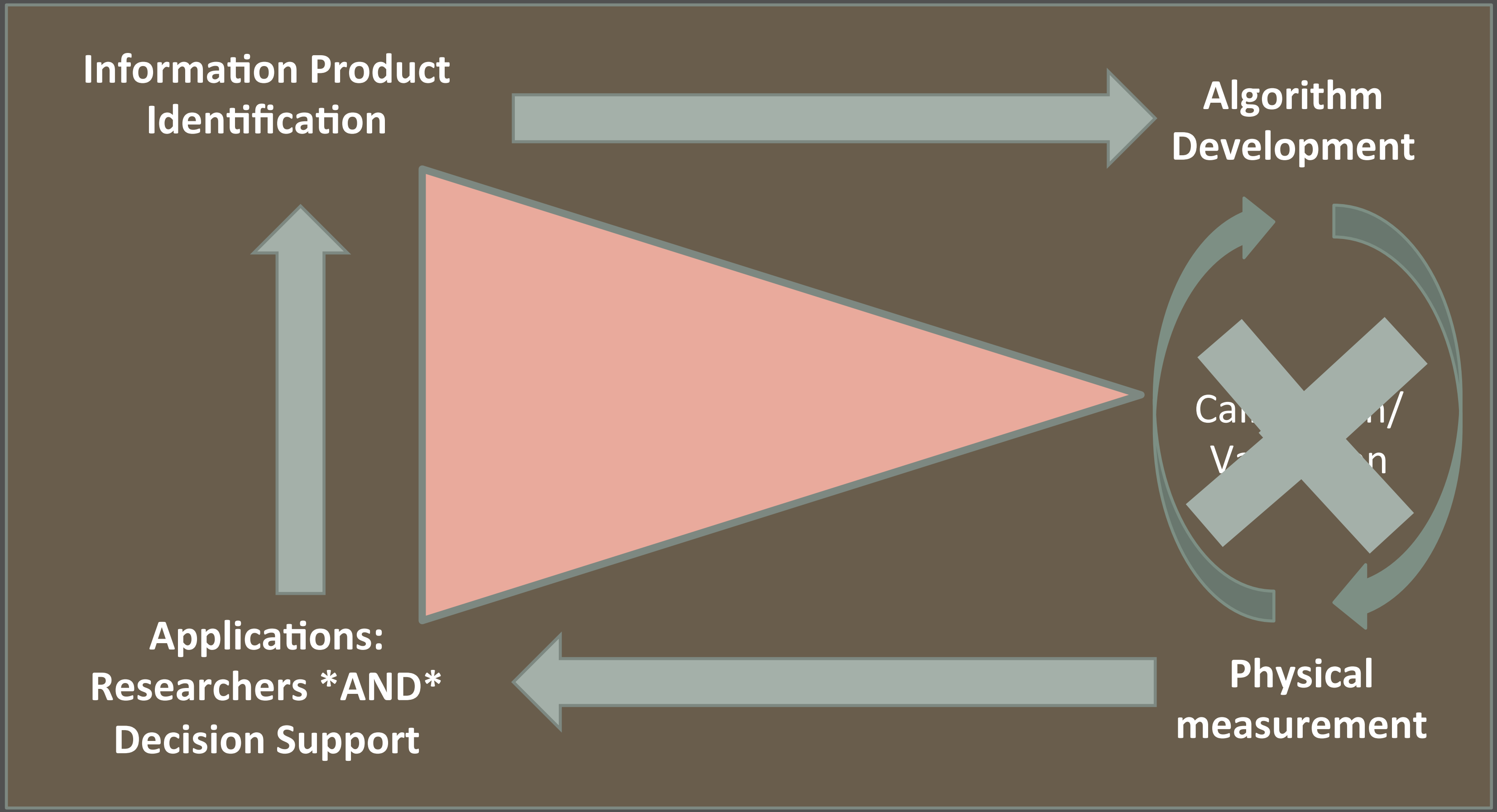
Level	Description
L0	Instrument science packets (e.g., raw voltage, counts, etc.)
L1A	Geolocated in space and may have been transformed (calibrated/ rearranged) in a reversible manner
L1B	Irreversibly transformed (resamples/remapped/calibrated)
L1C	L1A and L1B resampled and mapped onto uniform space-time grids
L2	Geophysical parameter
L3	Geophysical parameters mapped onto uniform space time grids
L4	Model-enhanced geophysical parameter

- Data products are so essential to STMs that A Team recently had a study to develop an internal Data Science Traceability Matrix (DSTM)
- TROMBONE Case study result using DSTM could have avoided two weaknesses

Data product life cycle starts and ends with the motivation and the impact of a mission



Data product life cycle



Information Product Identification

- Working with a partner agency directly, BUT they often don't know what to ask for OR what they ask for is either not feasible or not really what they want
- Workshops
  - Flight Project Applications Workshops (NISAR, SWOT, ASO, HyspIRI etc.)
  - Other (KISS, AGU Townhalls, etc.)
- JPL A Team Study for concept formulation

A Team Study for Product Needs: Fire Ecology

- Sometimes we have no precedence for what ”end users” want because it’s for a new technology and the end users haven’t even become aware of what they can ask for
- Carve a unique niche for JPL in wildfire science from other NASA centers: fire ecology focus, but what products?
- Study invited forest and fire managers and a fire behavior modeler who developed the algorithm for a recently adopted operational fire behavior model for Colorado State to talk about airborne technologies that we have and possible products

Remote Sensing for Wildfire Applications
Customers: US Forest Service, US Department of Interior

Operational Phase	Category	Data product	observeable(s)	Mission: airborne	Mission: Spaceborne***	End-user priority	Readiness**: Product	Readiness**: Algorithm	JPL capability
Pre-Fire	Vegetation	Canopy water content	L-band radar backscatter	UAVSAR	SMAP	LOW	M	E	X
			radiance	AVIRIS	None	MOD		E	X
		fuels structure	LiDAR	LiDAR	None	LOW	E	E	X
			L- and P-band radar tomography	UAVSAR & Airmoss	TanDEM-X		M	E	
		vegetation species map	radiance	AVIRIS	None	HIGH	N	M	X
	soils	total soil moisture	P-band radar backscatter	Airmoss	SMAP, SMOS	LOW	E	M	X
	Management	successional stage/ "site index" = potential growing capacity	See rest of table: soil type map (external source), vegetation species map, fuel structure			LOW	M	M	
Active	Atmosphere/ Weather/ Cimate	plume tracking/ air quality monitoring (trace gases)	radiances	HyTES	OCO-2, OMI, TROPOMI, GOME(2), IASI, MOPITT, MISR, AIRS, CRIS	MOD	E	M	X
			in situ mass spec	Whole Air Sampler	None		E	M	
	detection	early detection	thermal infrared	None	Firesat	MOD	E	M	X
	fire behavior	Fire Radiative Power	thermal infrared	MASTER	MODIS, VIIRS	LOW	M	M	X
		fire extent/ perimeter maps	thermal infrared	NIROPS/MASTER	MODIS, VIIRS	MOD	N	M	X
Post-Fire	Atmosphere/ Weather/ Cimate	meterological data: wind, temperature, rain, relative humidity	radar backscatter & radiometer birghtness temperature	None	Constellation: AIRS, MODIS, CALIPSO, PMM, Cloudsat	LOW	M	E	
	soils	soil characterization: type & surface chemistry	soil type	external source		LOW	E	E	X
			radiance	AVIRIS-ng	None		N	M	
	Vegetation	vegetation species map	radiance	AVIRIS	None	HIGH	N	M	X
		mortality index	radiance	AVIRIS	None	LOW	N	M	X
		fire severity	radiance	chance AVIRIS	Landsat	HIGH	M	M	X
	surface	topographic map (30m resolution)	LiDAR	LiDAR	None	LOW	E	E	X
			Radar interferometer	UAVSAR & Airmoss	SRTM		M	M	
	Management	management suitability index	See Above: topography, meteorological data, soil type, mortality, species			HIGH	N	N	

**N = New; M = Exisiting needs modifications; E = existing, fine as is

High priority | Low priority | Requires Low priority data product

*** NOTE: Most of the products requested were either new, or managers need better accuracy or high spatial/temporal resolution than what is currently provided by spaceborne platforms

Jet Propulsion Laboratory A Team Study on Wildfire Applications

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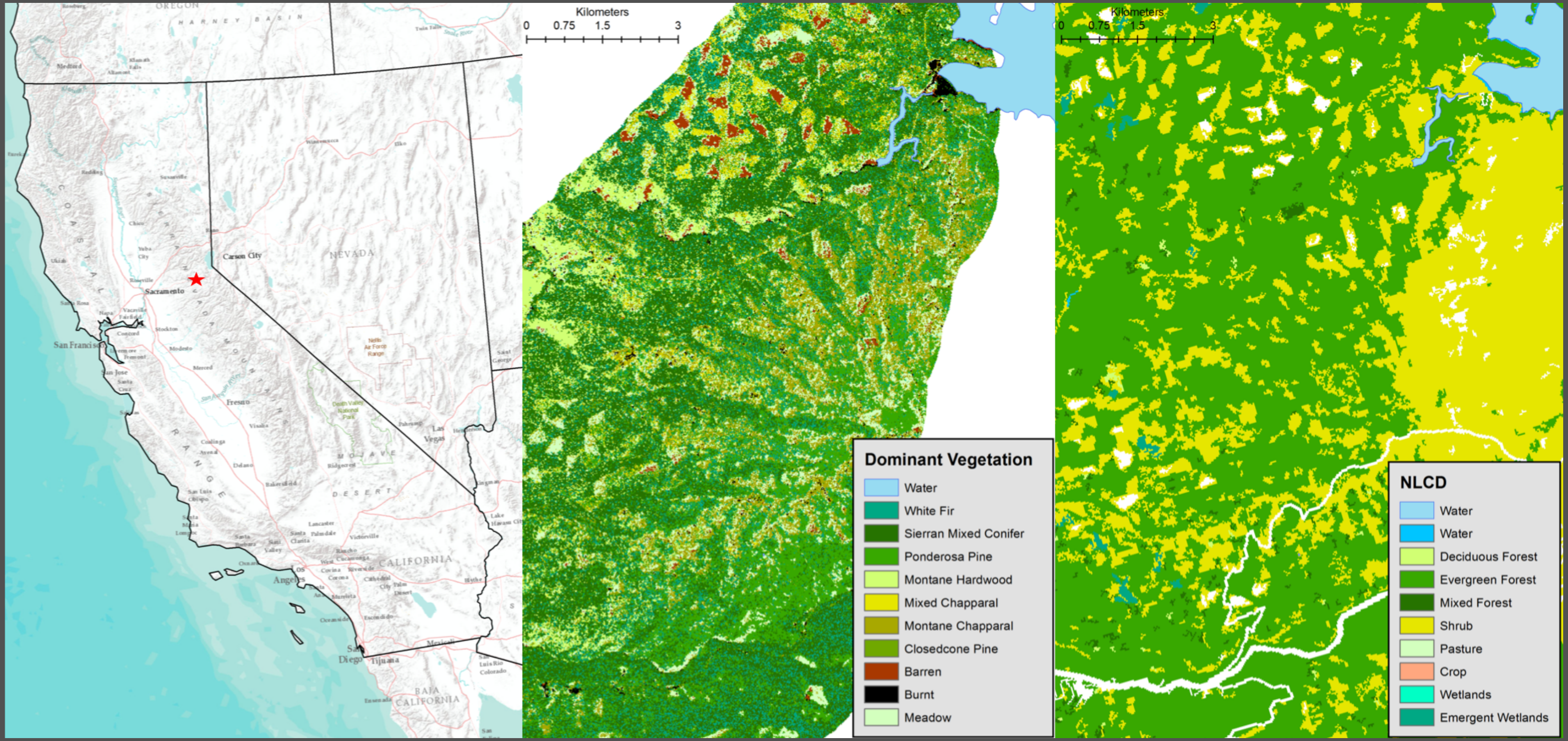
Resulted in two internal JPL investments to develop information products

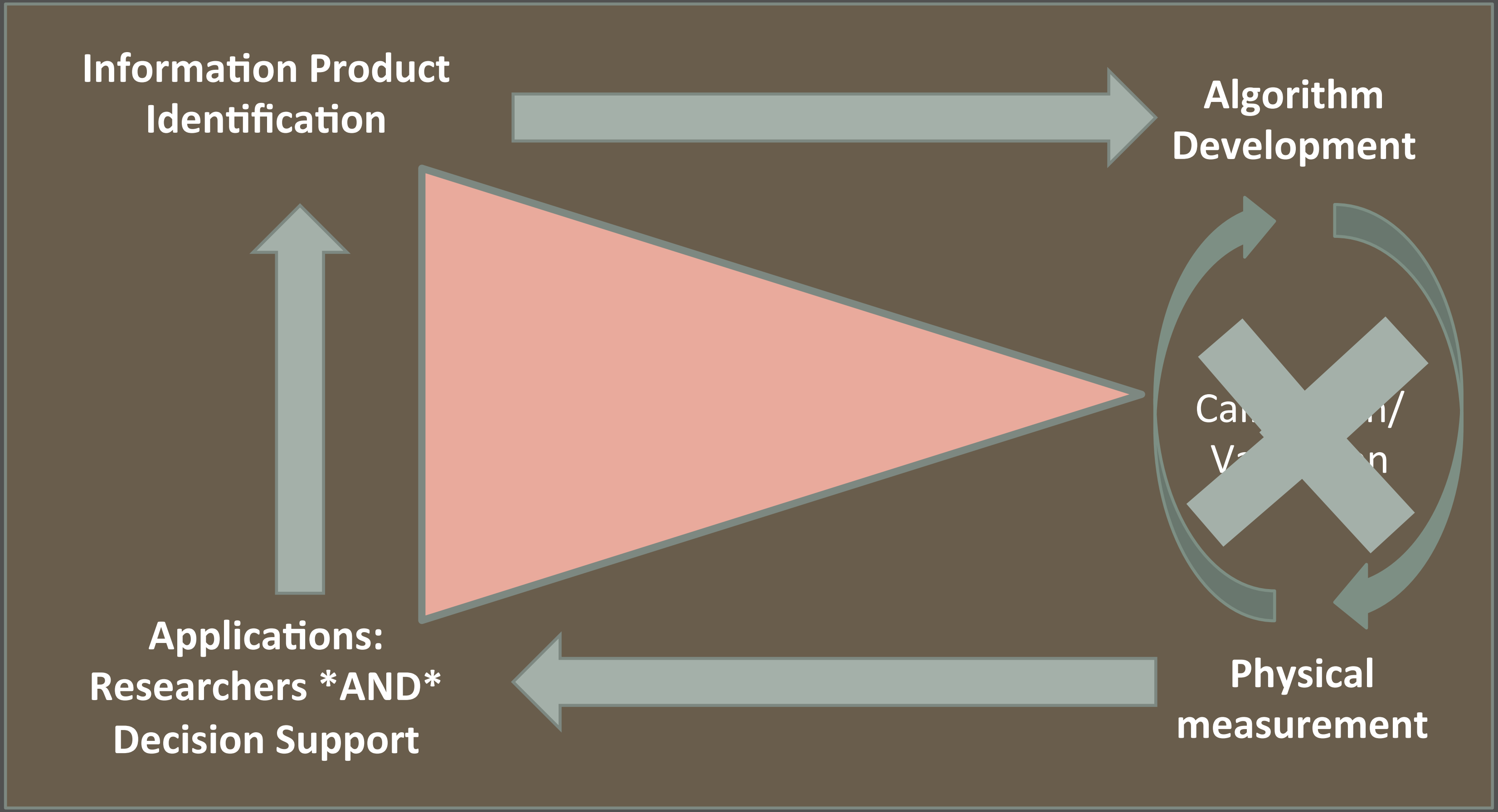
Vegetation species mapping over pre-HyspIRI airborne campaign

Motivation: implications for biodiversity and habitat mapping that affects how terrestrial ecosystems are managed

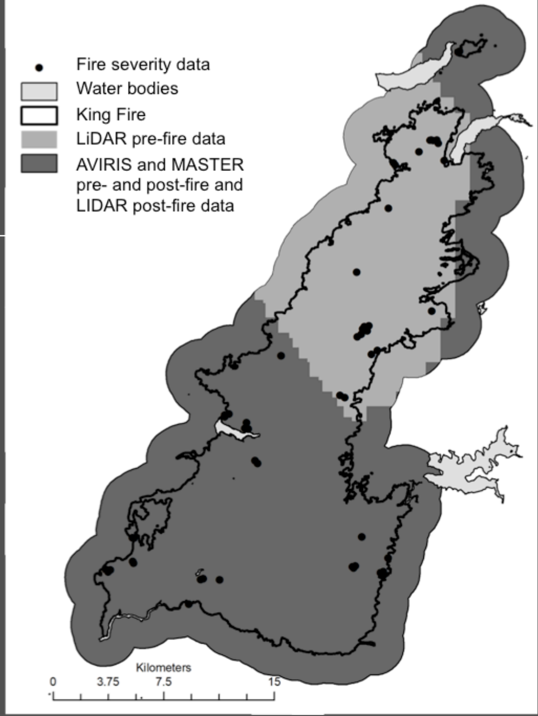


Project Manager & Science Lead: E. Natasha Stavros

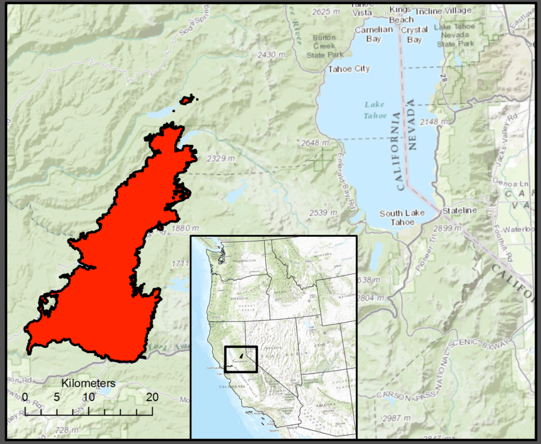
Data product life cycle



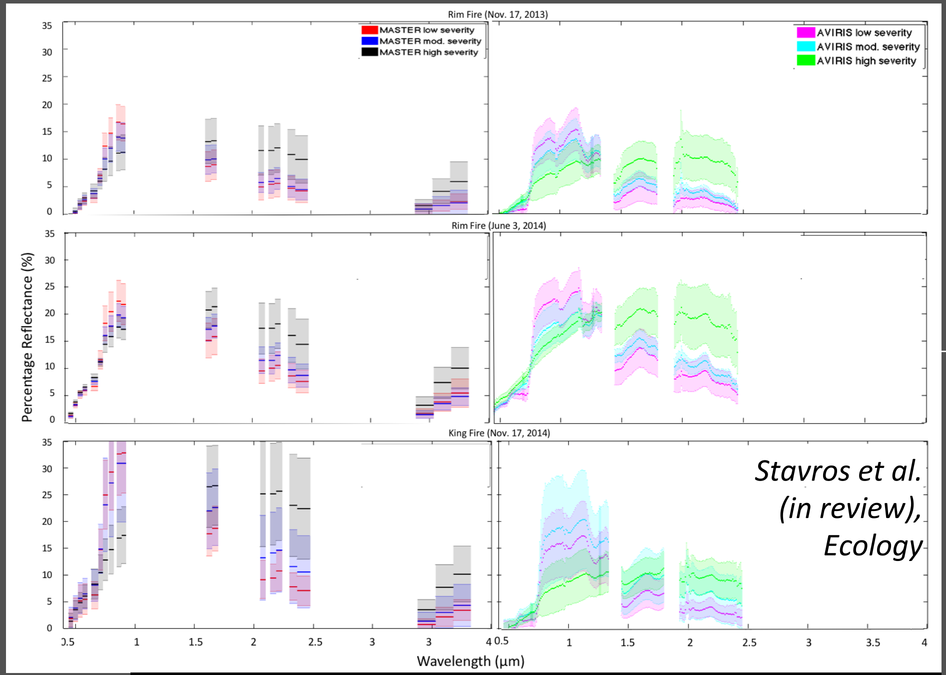
Applications for decision support *and* research: King Fire Rapid Response Example

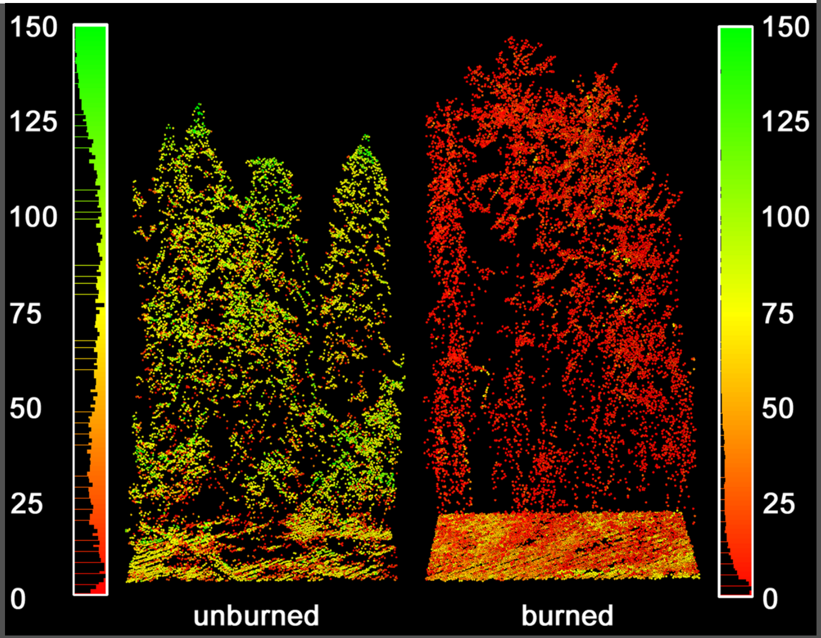


- Data offered an unprecedented opportunity, so we determined what information we could derive to serve:
  - Science:
    - Fuel attributes that influence fire behavior across a landscape
    - Megafires climate vs. century of fire exclusion?
  - Decision support:
    - How sensitive is input into operational fire behavior model used for active fire management?
    - Vegetation succession post-disturbance



- And worked to increase usability, discoverability and access to data from these flight projects that can be used by a non-technical RS community and to demonstrate utility



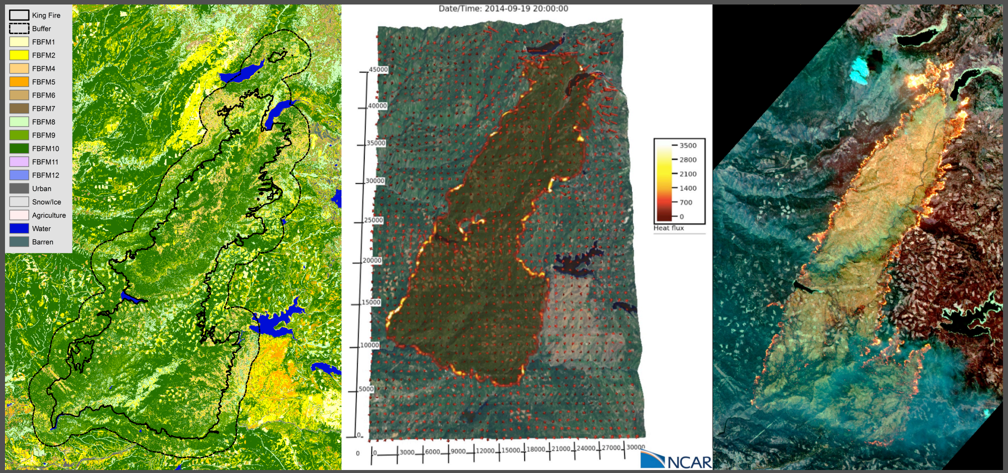


Data for Decision Support

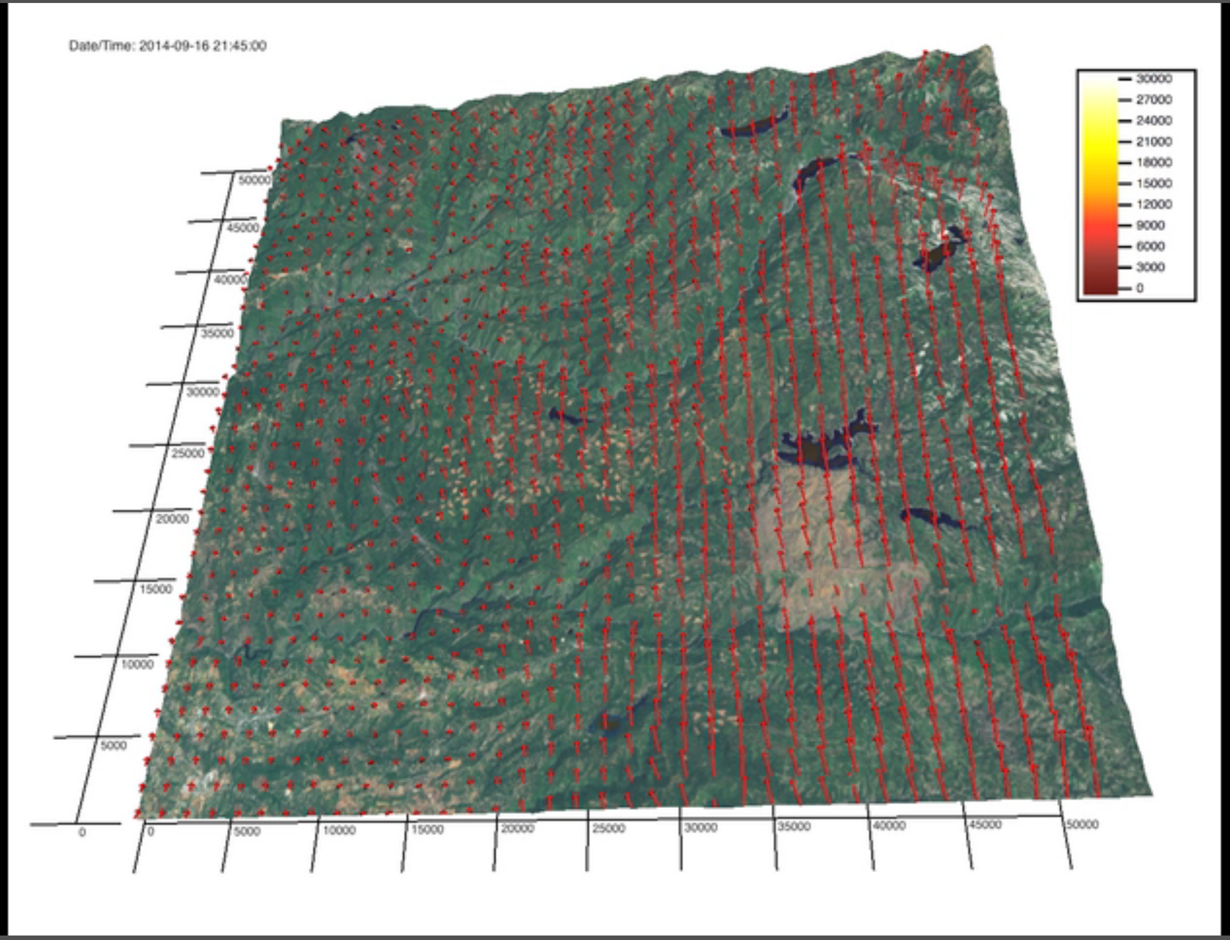
- Data Collection
  - Commissioned post-fire LiDAR using ASO
  - Pre-HyspIRI airborne campaign of AVIRIS and MASTER
- Data processing
  - AVIRIS Level 2 orthorectified surface reflectance
  - MASTER Level 2 LST and emissivity
  - AVIRIS & MASTER Level 3 spectral indices (e.g., NDVI)
  - LiDAR Level 2 vegetation structural metrics
- Described (Stavros et. al, 2016 *Ecology*) and archived at ORNL DAAC & http://wildfire.jpl.nasa.gov/

Analysis

- Data products of dominant species and vegetation structure were used to develop fuel model map
- Sensitivity analyses of 375 m pixel x 1 minute fire behavior simulations using CAWFE model

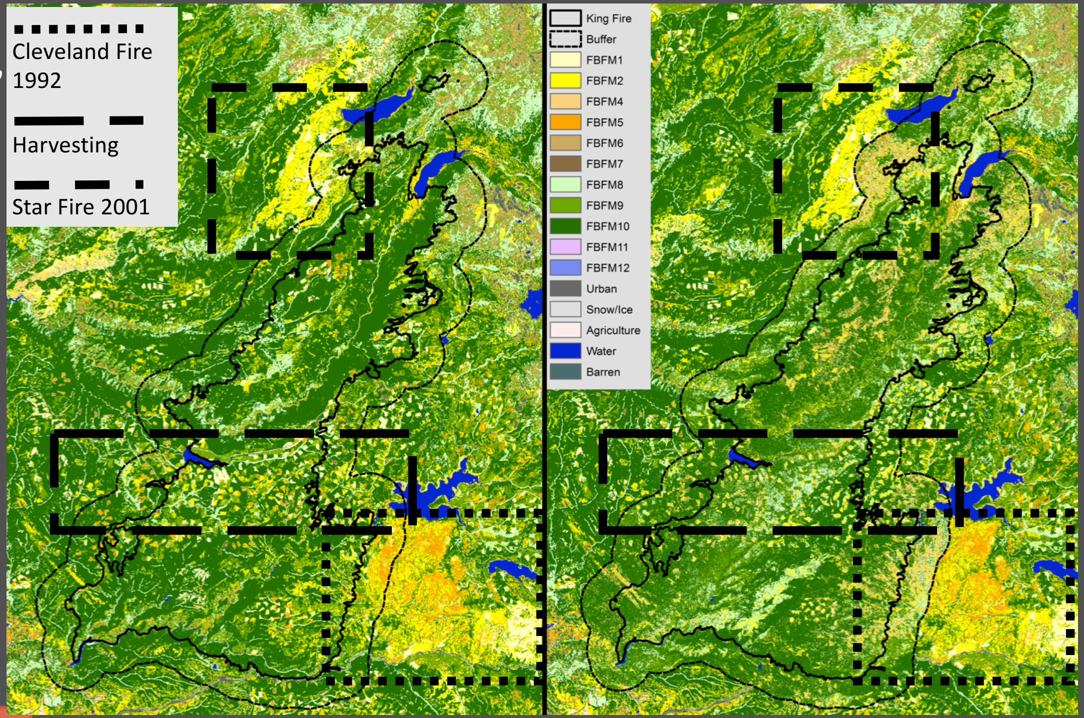


Fuel model map → CAWFE Fire Simulation → MASTER Thermal IR Data



Research Findings

- Contrary to previous thought about extreme fires, neither fuels nor mesoscale weather are completely responsible for fire behavior and effects. The King Fire is proof that it's BOTH -- the intrinsic feedback between fire and local weather is a key player *Coen et al. (in review), Science Advances*
- Fuels matter differently based on different aspects of fire behavior:



Fire Behavior	Important Fuel Attribute
Spread rate	Horizontal connectivity and fuel condition
Fire extent	Fuel type and vertical structure *Stavros et al. (in prep.), GCB*

Concluding Thoughts

- Missions are not selected without thinking of the end-to-end information product life cycle
- The STM is the foundation of any mission and it is strengthened by a DSTM
- The engineering is there - we're ready for launch – but now, we should put some serious thought into the the information needed to "sell" the mission, and by which the mission success depends
  - Presenting a robust and focused science narrative
    - Josh – ET
    - Rob – Dust
    - Greg – biodiversity
    - Michelle – coral
  - Setting ourselves up for success by refining the processes for distilling information products at regional and global scales so that we can have clear and traceable science and engineering requirements
    - David – uncertainty
    - Dennison – GV:NPV:substrate
    - Asner/Stavros – species
    - Andrew- methane)