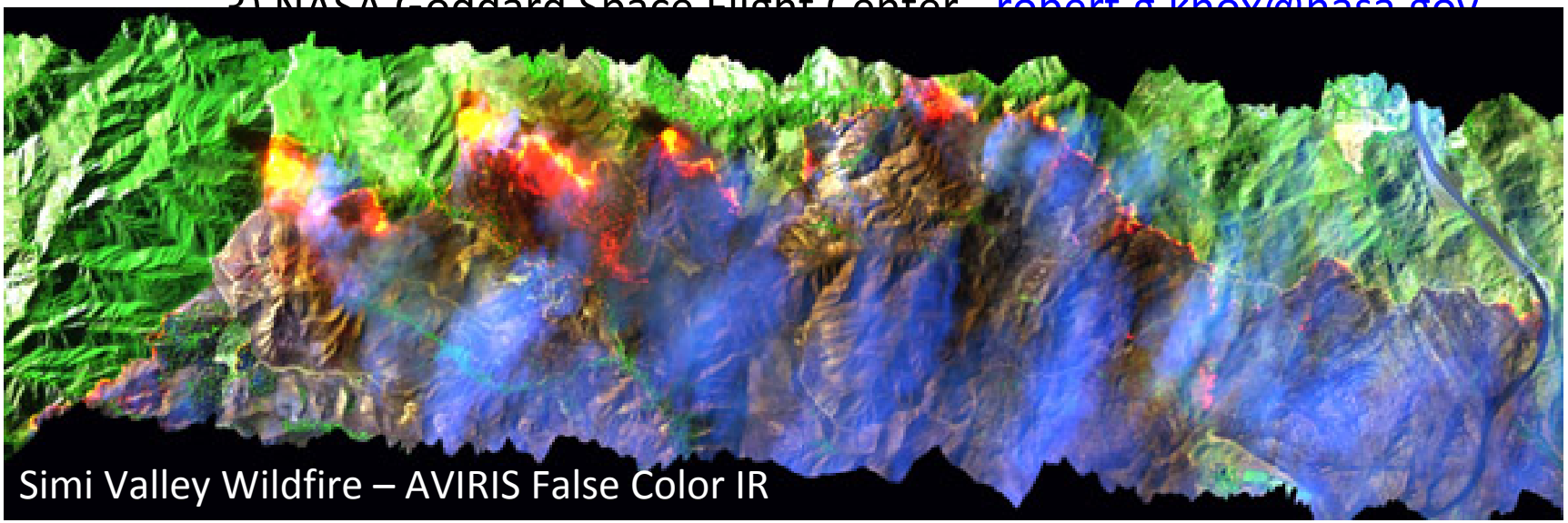
VQ4 – Ecosystem Response to Disturbance

John Gamon[1], Greg Asner[2], Bob Knox[3],
with contributions from the HyspIRI Science team

1) Univ. of Alberta, Earth & Atmospheric Sciences - jgamon@gmail.com
2) Carnegie Institution, Dept. of Global Ecology - gpa@stanford.edu
3) NASA Goddard Space Flight Center - robert.g.knox@nasa.gov



Simi Valley Wildfire – AVIRIS False Color IR

VQ4. Overarching Question

- **How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?**

Core Science Issues - Disturbance

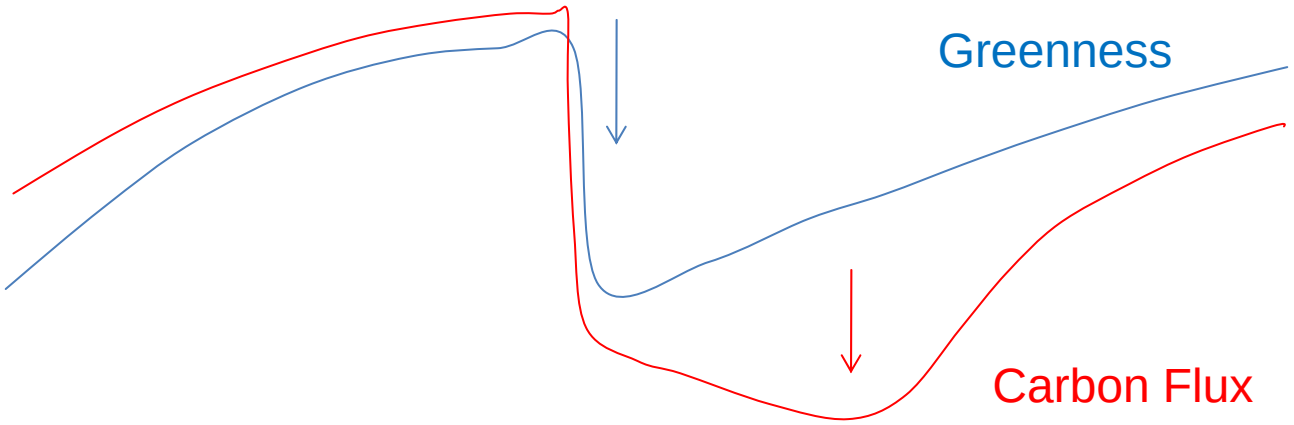
- The norm (not the exception)
- Multiple, non-linear, interacting factors
- Key to understanding “phase shifts” (state changes)

Hypothesis:

- Biophysical and chemical attributes of ecosystems change with and respond to disturbance, thus large-scale measurements of key parameters such as fractional material cover, biochemicals, nutrients and water properties can reveal changing disturbance patterns over time.

Challenge:

- Multiple interactive (often non-linear) processes operating at multiple time scales (not necessarily matching HyspIRI acquisitions).



Needs:

- Models (including *process* models)
- Ecological framework
- Interdisciplinary informatics framework

Sub-questions

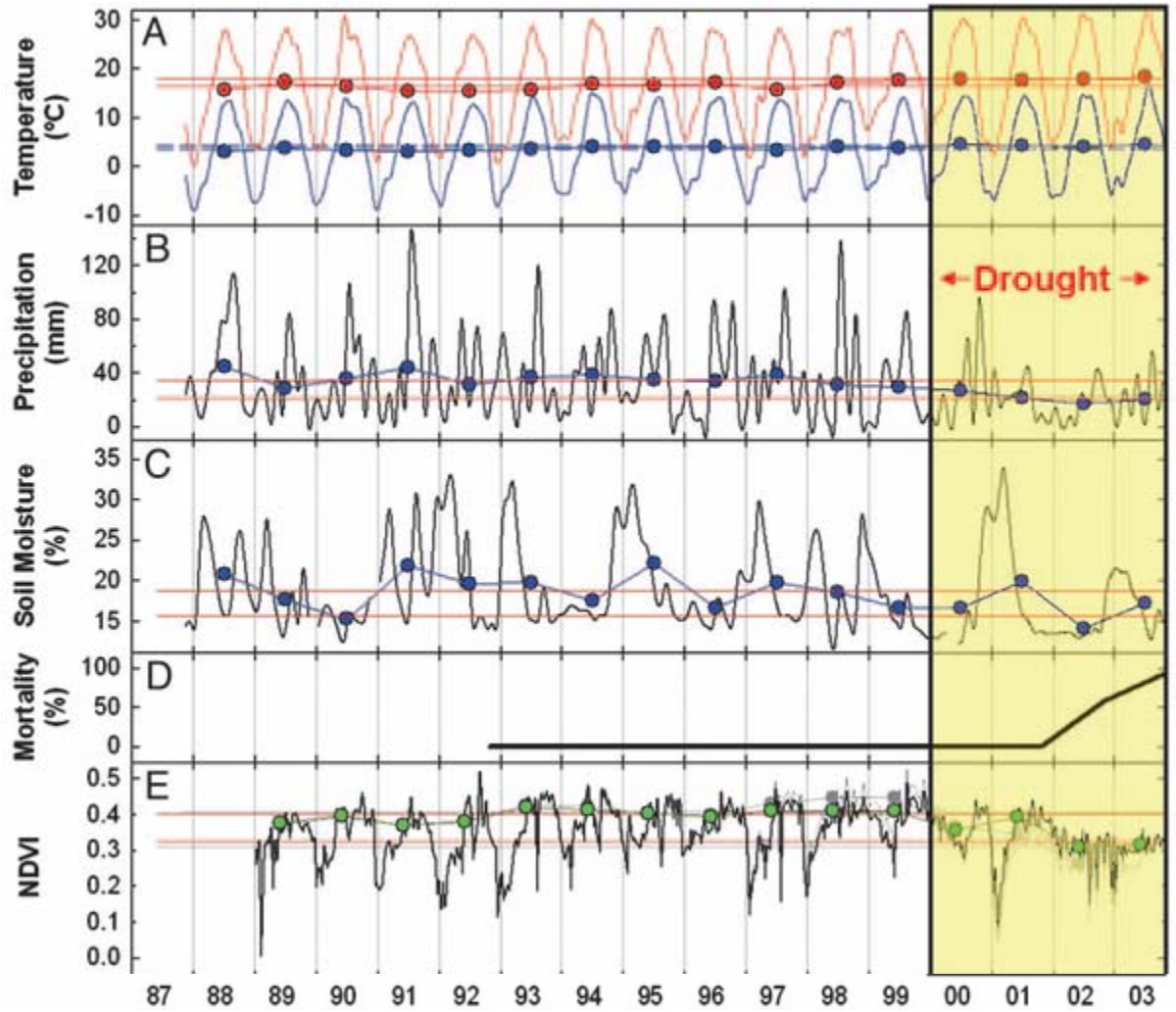
1) How do patterns of abrupt (pulse) disturbance vary and change over time within and across ecosystems? [DS 196]
2) How do climate changes affect disturbance such as fire and insect damage?
3) What are the interactions between invasive species and other types of disturbance?
4) How are human-caused and natural disturbances changing the biodiversity and composition of ecosystems (e.g. through changes in the distribution and abundance of organisms, communities and ecosystems)?
5) How do climate change, pollution and disturbance augment the vulnerability of ecosystems to invasive species? [DS 114, 196]
6) What are the effects of disturbances on productivity, water resources, and other ecosystem functions and services? [DS 196]
7) How do changes in human uses of ecosystems alter their vulnerability to disturbance and extreme events? [DS 196]

Q ID	Science Objectives		Data Products		Requirements
	Science Question	Scientific (Measurement) Objective	Data Product Requirement	Mission Functional Requirement	Scientific Measurement Requirement
DS Statement	**Changes in Disturbance Activity : How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?**				
VQ4-1	How do patterns of abrupt (pulse) disturbance vary and change over time within and across ecosystems?	Measure changes (<10%) in fractional cover (from clearing, logging, wetland drainage, fire, weather related, etc.) at the seasonal and multiyear time scales, to characterize disturbance regimes in global ecosystems (e.g., conditional frequencies and/or return intervals for VQ1 ecosystem classes). Measure the seasonal and multi year change in abundance and fractions of biotic and abiotic components of the aquatic environment.	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 900with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; ~200mbs downlink, >8X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; accurate enough to simulate historical satellite data through band synthesis.; Atmospheric Correction; AC validation; Geolocation: 10 m (1 sigma); Ground processing; Seasonal latency: 30m (3σ) Pointing knowledge ;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380 900@10nm) of biotic and abiotic components of the aquatic environment with high precision and accuracy. Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-2	How do climate changes affect disturbances such as fire and insect damage? [DS 196]	Measure changes in vegetation canopy cover, pigments, and water content in ecosystems globally at the seasonal and multiyear time scale. Make measurements in such a way that they are backward compatible with pre existing estimates and algorithms (e.g., band synthesis for historical vegetation indexes), as well as allowing more advanced algorithmic approaches. (Measure PV, NPV and Soil (+/ 5%) using full VSWIR and SWIR algorithms.) (Measure characteristic changes or differences in plant pigments (10% changes in total chlorophyll, carotenoids, anthocyanins) and water	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 900with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >5X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; Seasonal latency; 30m (3σ) Pointing knowledge;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380 900@10nm) of biotic and abiotic components of the aquatic environment with high precision and accuracy (i.e. coral bleaching, storm damage). Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-3	What are the interactions between invasive species and other types of disturbance?	Measure the distribution and cover of key invasive species that introduce novel life histories or functional types, in concert with disturbance measurements. Measure (disturbance related) changes in vegetation canopy cover, pigments, and water content in ecosystems globally at the seasonal and multiyear time scale. (Measure PV, NPV and Soil using full VSWIR and SWIR algorithms.)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 900with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >5X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; Seasonal latency; 30m (3σ) Pointing knowledge;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380 900@10nm) of biotic and abiotic components of the aquatic environment with high precision and accuracy (i.e. coral bleaching, storm damage). Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-4	How are human-caused and natural disturbances changing the biodiversity composition of ecosystems, e.g.: through changes in the distribution and abundance of organisms, communities, and ecosystems?	Measure the composition of ecosystems and ecological diversity indicators globally and at the seasonal and multiyear time scale. (Measure PV, NPV and Soil using full VSWIR and SWIR algorithms.)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 900with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >5X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; Seasonal latency; 30m (3σ) Pointing knowledge;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380 900@10nm) of biotic and abiotic components of the aquatic environment with high precision and accuracy (i.e. coral bleaching, storm damage). Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-5	How do climate change, pollution and disturbance augment the vulnerability of ecosystems to invasive species? [DS 114,196]	Measure disturbances and ecosystem status. Measure invasive trends. Measure at the seasonal to multiyear time scale. (Measure PV, NPV and Soil using full VSWIR and SWIR algorithms.)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask). L2 water leaving radiance spectrum between 380 900with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >5X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; Seasonal latency; 30m (3σ) Pointing knowledge;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure diagnostic spectral signature (380 900@10nm) of biotic and abiotic components of the aquatic environment with high precision and accuracy (i.e. coral bleaching, storm damage). Selected wavelengths in the short wavelength infrared (1250, 1650, 2250) to enable atmospheric correction for aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-6	What are the effects of disturbances on productivity, water resources, and other ecosystem functions and services? [DS 196]	Measure disturbances and productivity indicators including ecosystem function and services on the seasonal to multiyear time scale. (Measure PV, NPV and Soil using full VSWIR and SWIR algorithms.)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask)	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >5X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; Seasonal latency; 30m (3σ) Pointing knowledge;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-7	How do changes in human uses of ecosystems affect their vulnerability to disturbance and extreme events? [DS 196]	Measure status of ecosystems globally and in relation to disturbances and major events at the seasonal to multiyear time scale. (Measure PV, NPV and Soil using full VSWIR and SWIR algorithms.)	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20; Rigorous cal/val program; Monthly lunar cals; Daily solar cals; 6 per year vcals; >5X zeroloss compression; ~11 am sun sync LEO orbit; Radiometric calibration; Atmospheric Correction; AC validation; Geolocation; Pointing strategy to minimize sun glint; Avoid terrestrial hot spot; Ground processing; Seasonal latency; 30m (3σ) Pointing knowledge;	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.
VQ4-8	How do active and post-fire disturbances impact ecosystem processes and related human decisions.	Measure the fuel and intensity properties of actively burning fires and post fire recovery.	L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).	Surface reflectance in the solar reflected spectrum for elevation angles >20: Rigorous cal/val program: Monthly lunar cals: Daily solar cals: 6 per year vcals: ~200mbs downlink: >5X zeroloss compression: ~11 am sun sync LEO orbit: Radiometric calibration: Atmospheric Correction	Measure surface reflectance in the VSWIR region (400 2500@10nm) at high precision and accuracy (for spectral mixture algorithms to give insight to subpixel events). Selected wavelengths (760+/ 20 oxygen for surface pressure and atm aerosols; 940 +/ 50 and 1150+/ 50 for water vapor; 1380 +/ 20 for cirus clouds) to allow for atmospheric correction for terrestrial and aquatic observations. Measure globally at spatial resolution patch scale relevant for ecosystem 10^4 to 10^6 m^2. Measure seasonally (90 day revisit) through several (3) years to observe the seasonal regional occurrence and trends. Measure with a revisit time of at most 20 days.

1) How do patterns of abrupt (pulse) disturbance vary and change over time within and across ecosystems? [DS 196]

- Precipitation (e.g. ENSO)
- Extreme temperature (e.g. ENSO)
- Insect outbreaks
- Fire
- Nutrient pulses
- Storms, etc.

Recent Drought in Western US



Breshears et al. 2005

VQ4-1 Science Traceability Matrix:

Science Question: How do patterns of abrupt (pulse) disturbance vary and change over time within and across ecosystems? [DS 196]

Measurement Objective: Measure the composition of ecosystems and ecological diversity indicators globally and at the seasonal and multi-year time scale. (Measure PV, NPV and Soil using full VSWIR and SWIR algorithms.)

Data Products:

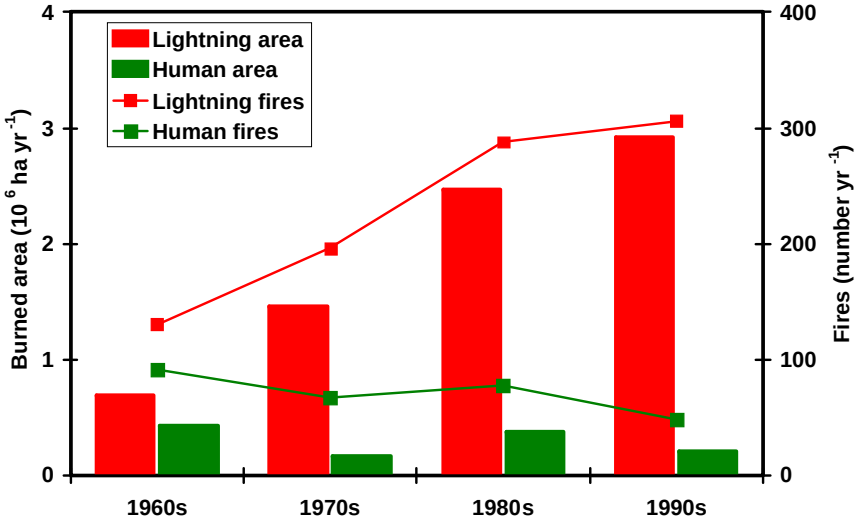
L2 atmospherically corrected spectral reflectance with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).

L2 water leaving radiance spectrum between 380 - 900 with Geolocation and observation and illumination geometry (with appropriate cloud, cloud shadows, atmospheric aerosol mask).

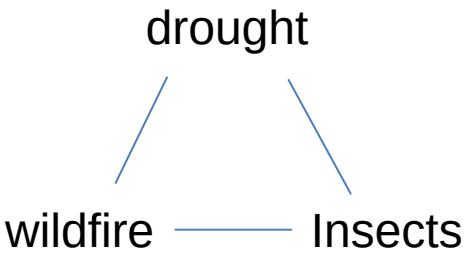
Technical Requirements…

2) How do climate changes affect disturbance such as fire and insect damage?

Wildfire area - Alaska



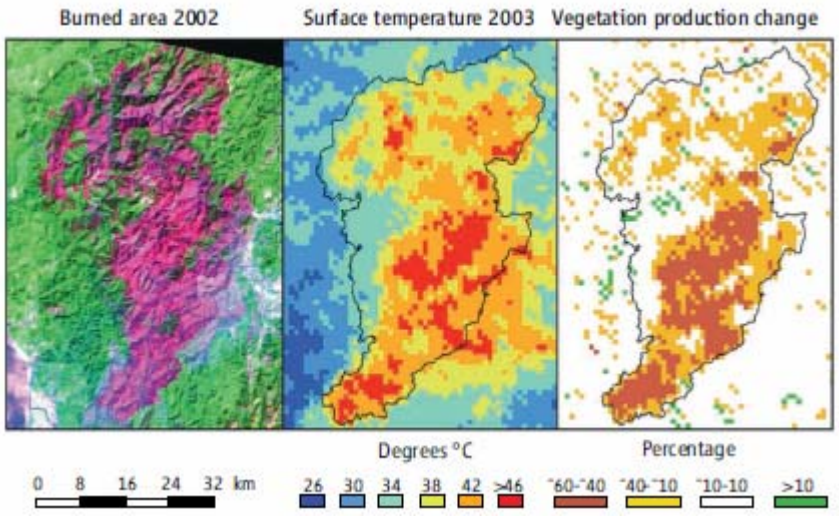
E. Kasischke



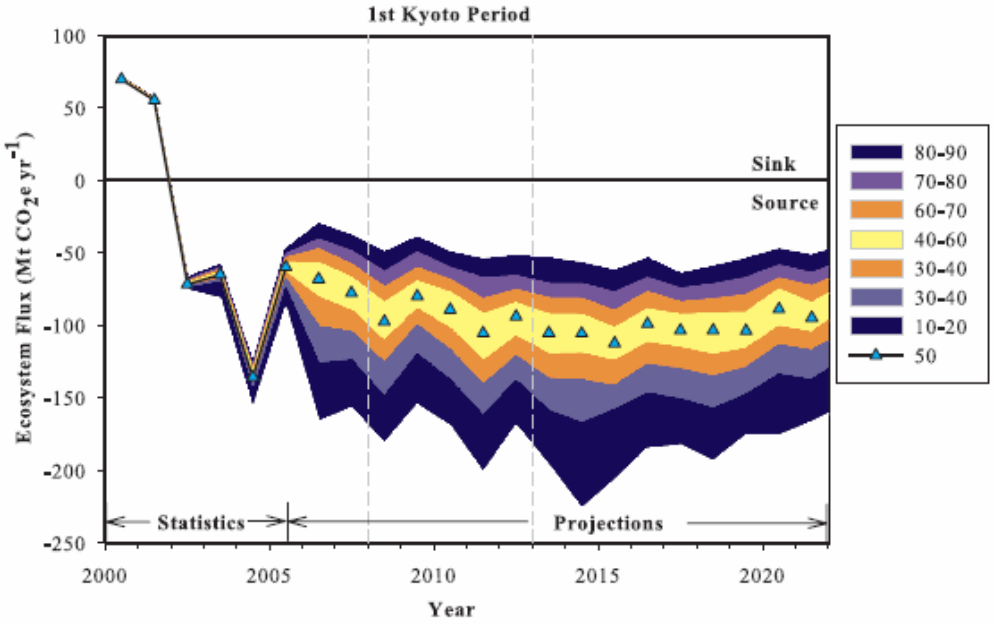
Bark Beetle Damage

http://climateprogress.org/wp-content/uploads/2008/11/pinebeetlenyt.jpg

2) How do climate changes affect disturbance such as fire and insect damage? (continued)



Running et al. 2008



Kurz et al. 2007

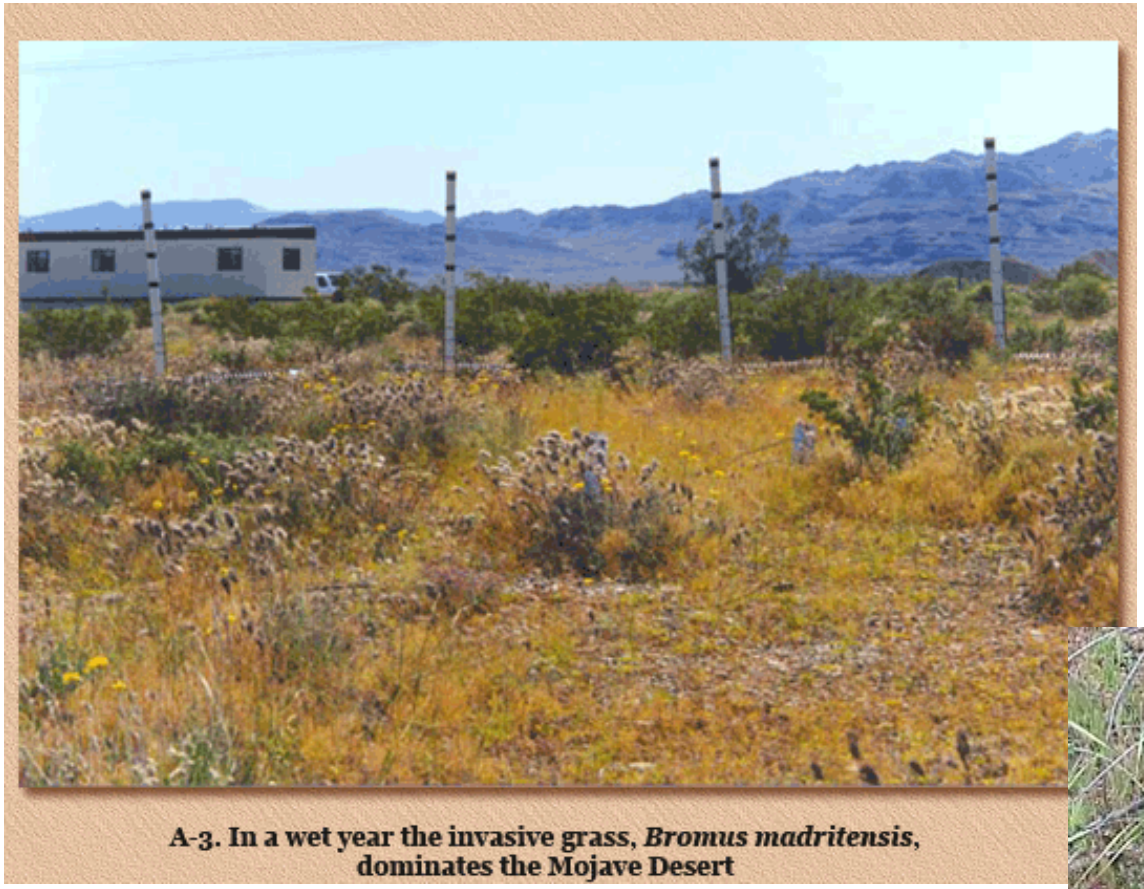
3) What are the interactions between invasive species and other types of disturbance?

Bromus sp.

Wildfire
Nitrogen deposition
Elevated CO_2

http://www.ext.colostate.edu/PUBS/NATRES/06310.html

Red brome invasion in the Mojave Desert is enhanced by disturbance

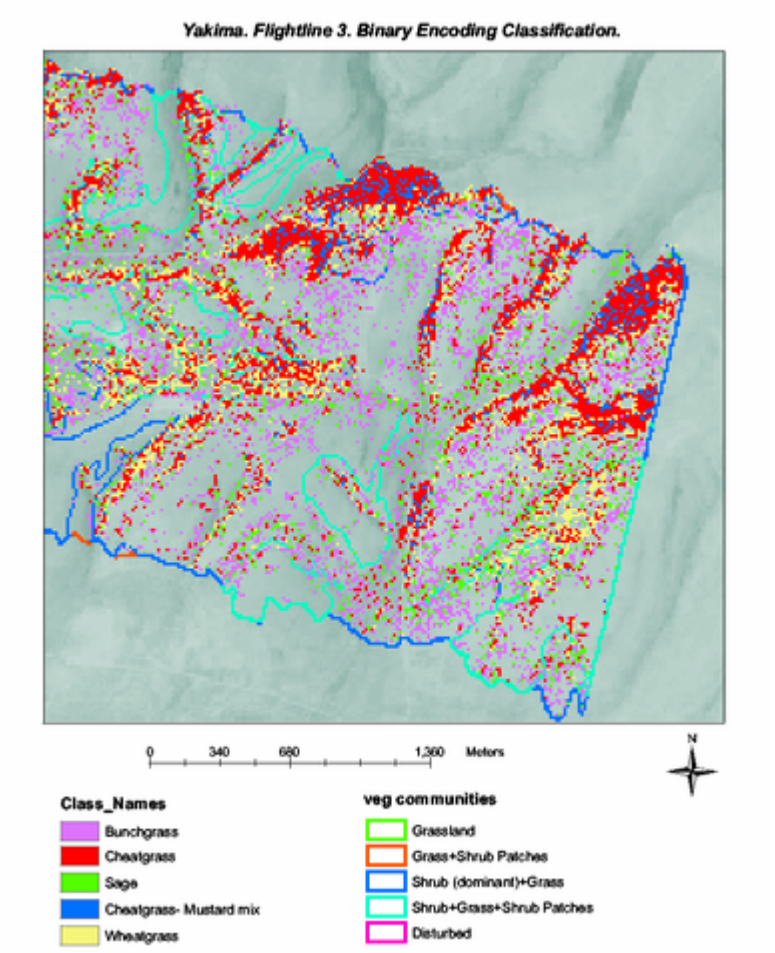


A-3. In a wet year the invasive grass, *Bromus madritensis*, dominates the Mojave Desert

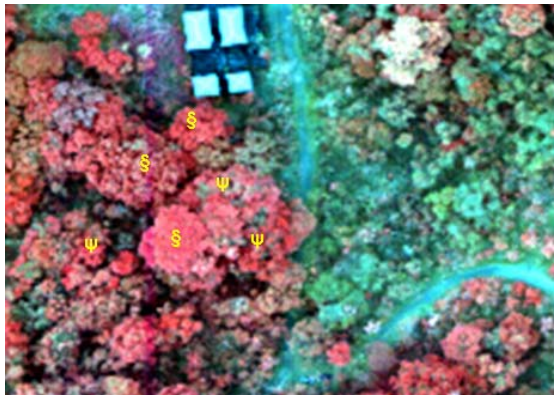
Nevada Desert Face Facility

http://www.intranet.csupomona.edu/~jcclark/flora/plants/poaceae/bromus_madritensis.html

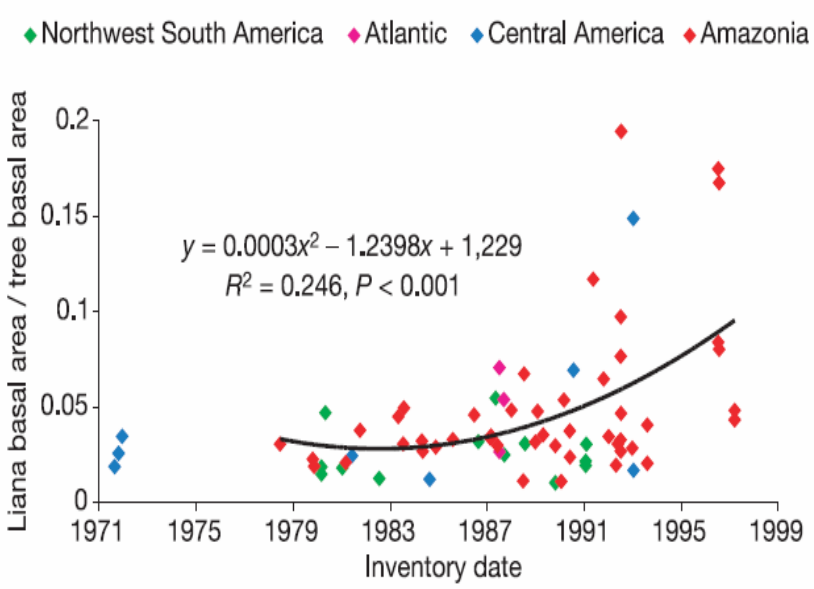
4) How are human-caused and natural disturbances changing the biodiversity and composition of ecosystems?



Bromus tectorum invasion in western Washington (S. Ustin)

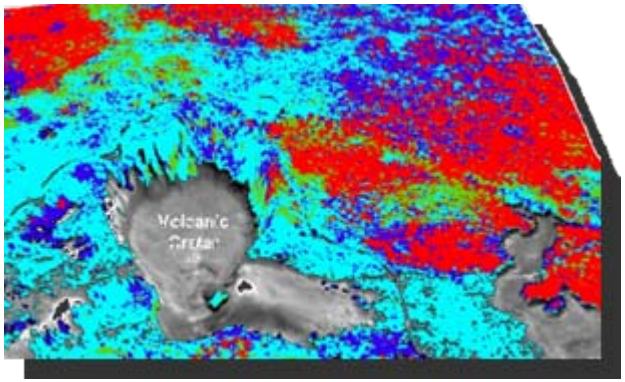


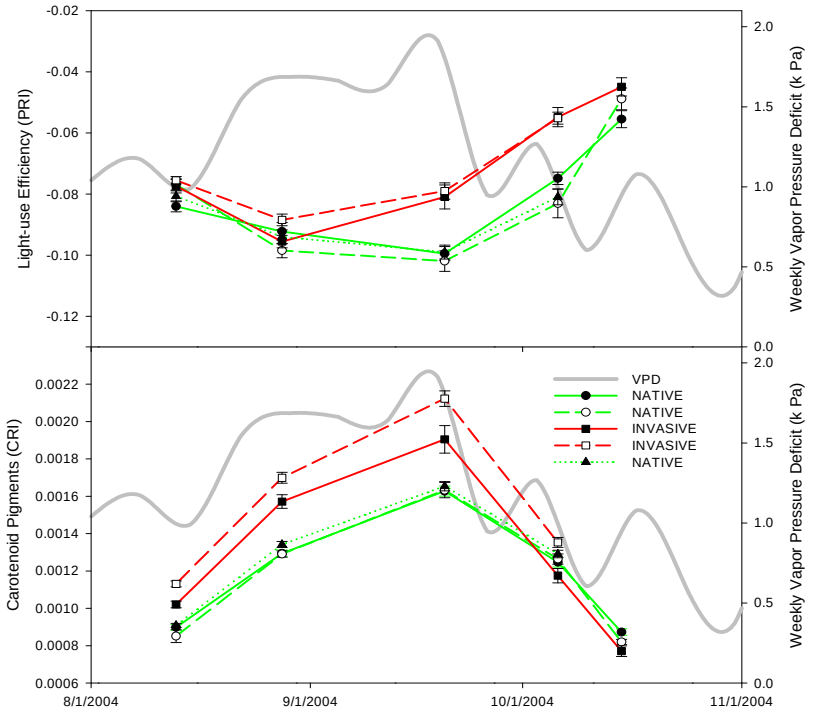
HYDICE (Kalacska et al. 2007)



Relative dominance of lianas in tropical forests as function of their inventory date (Phillips et al. 2002, Nature).

5) How do climate change, pollution and disturbance augment the vulnerability of ecosystems to invasive species? [DS 114, 196]

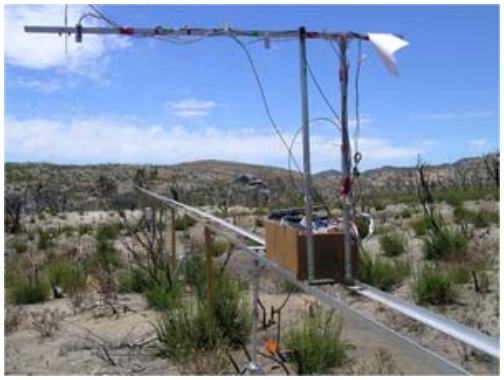


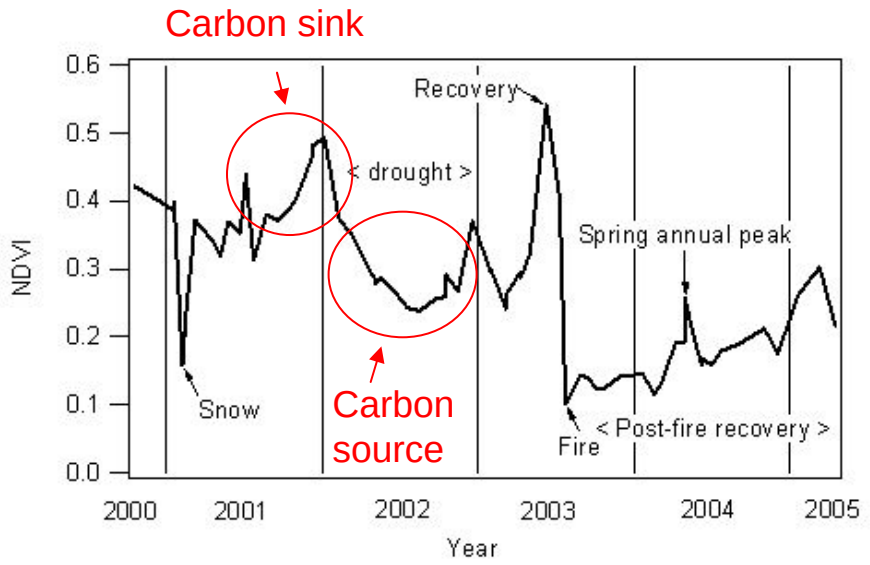


Combining NASA AVIRIS (top) and multi-temporal Hyperion (graphs) revealed that invasive trees (red lines) out-grow native trees (green lines) during periods of climate stress (gray line)

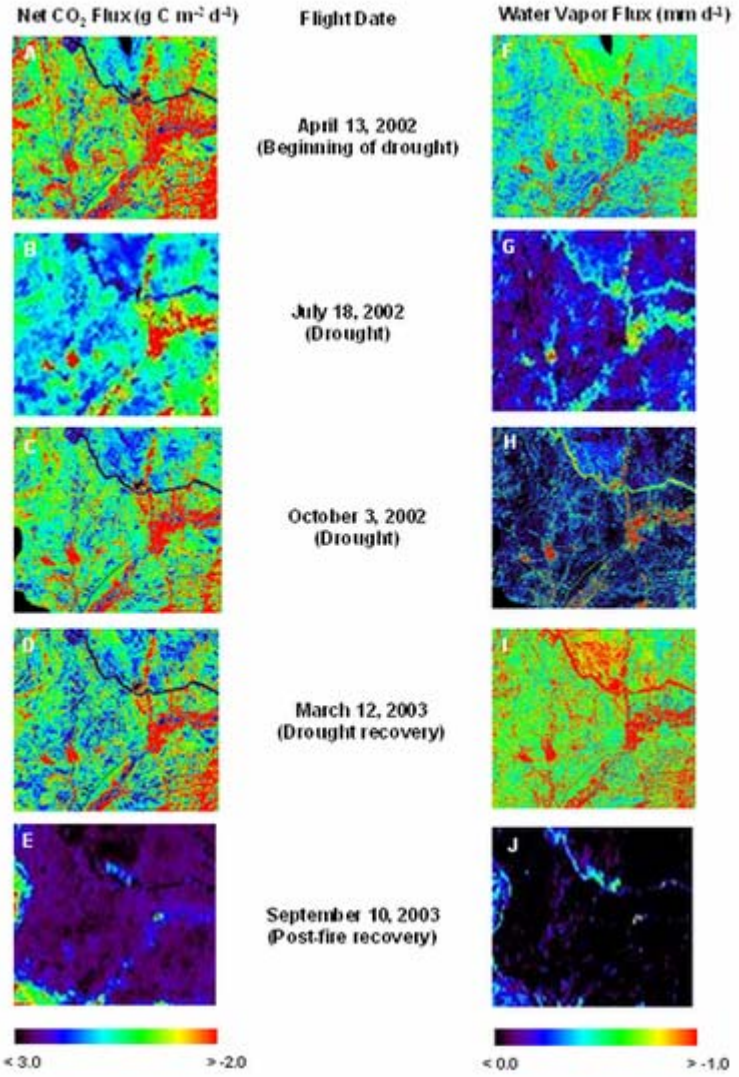
Greg Asner

6) What are the effects of disturbances on productivity, water resources, and other ecosystem functions and services? [DS 196]

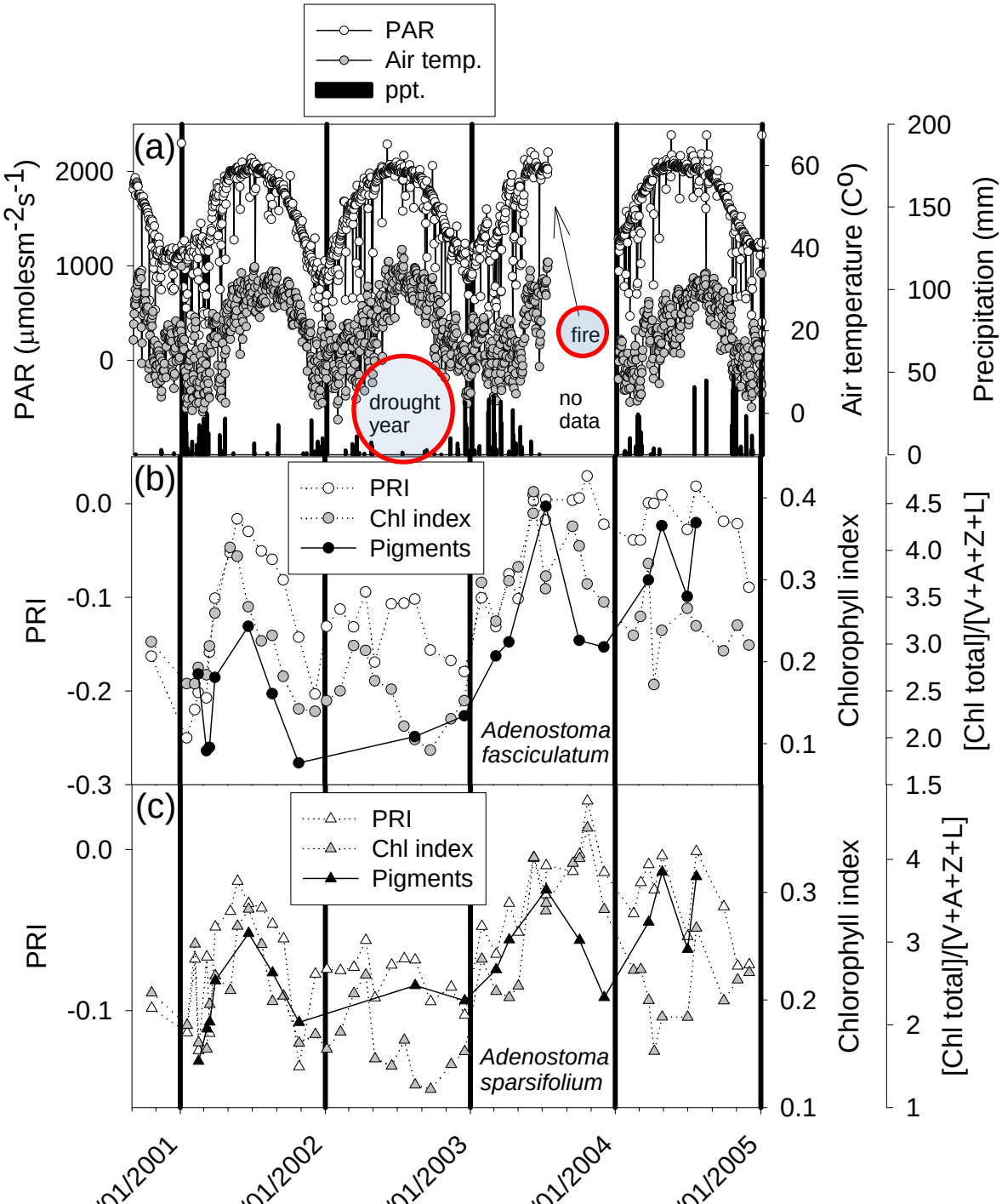


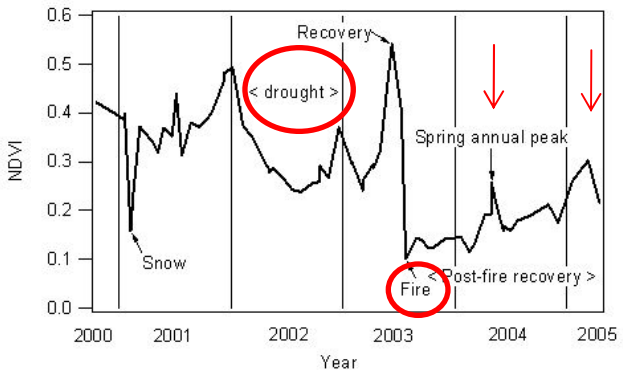


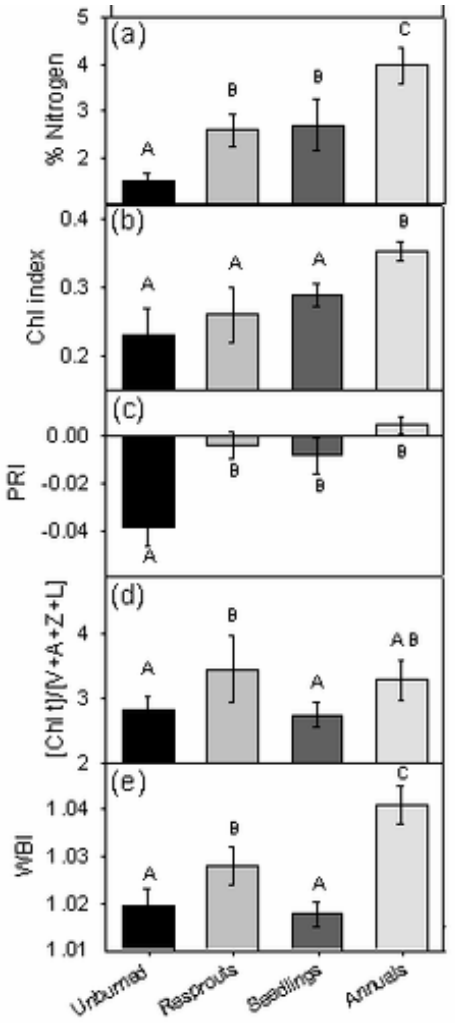
Gamon et al. 2006



Fuentes et al. 2006

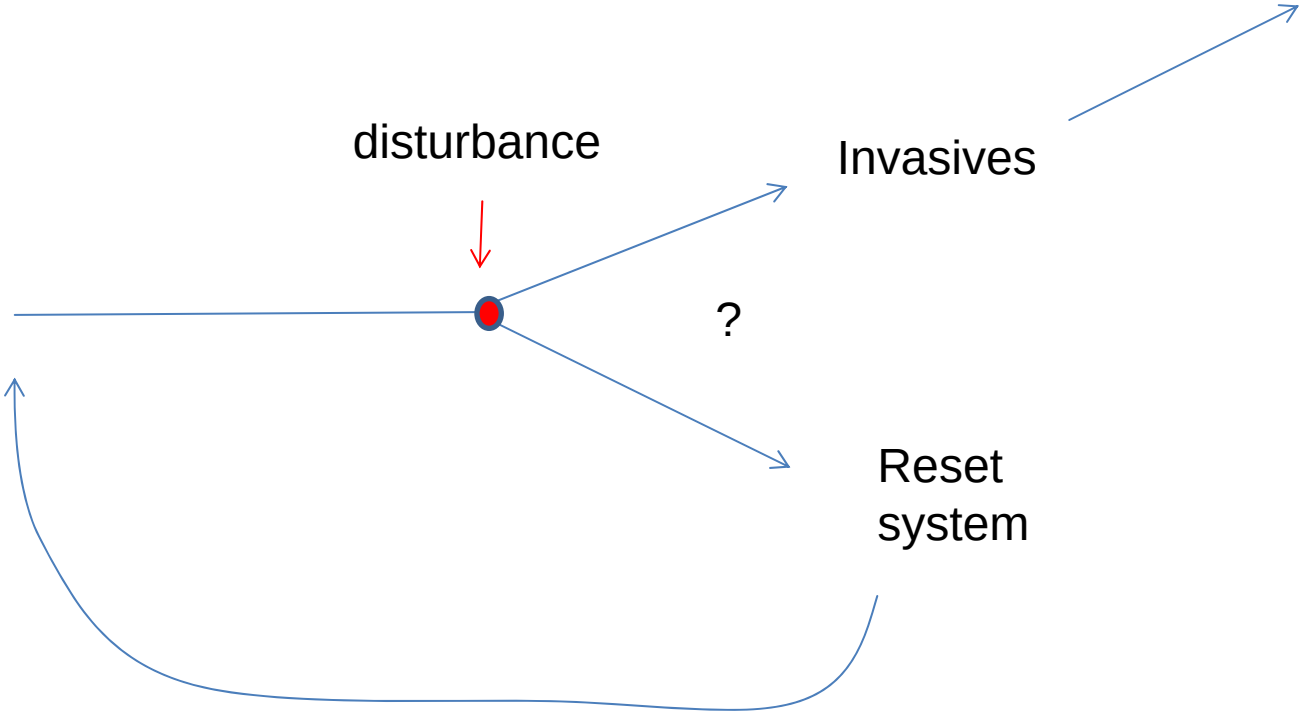

PAR
Air temp.
ppt.
(a)
PAR (µmolesm-2s-1)
Air temperature (C°)
Precipitation (mm)
drought year
fire
no data
(b)
PRI
Chl index
Pigments
Chlorophyll index
[Chl total]/[V+A+Z+L]
Adenostoma fasciculatum
(c)
Adenostoma sparsifolium
01/2001
01/2002
01/2003
01/2004
01/2005


NDVI
Year
Recovery
< drought >
Spring annual peak
Snow
Fire
< Post-fire recovery >

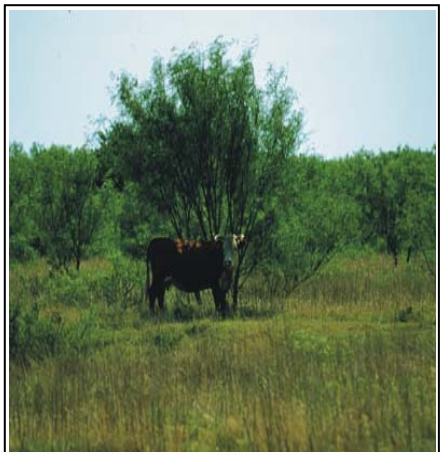

(a)
% Nitrogen
(b)
Chl index
(c)
PRI
(d)
[Chl t]/[V+A+Z+L]
(e)
WBI
Unburned
Resprouts
Seedlings
Annuals

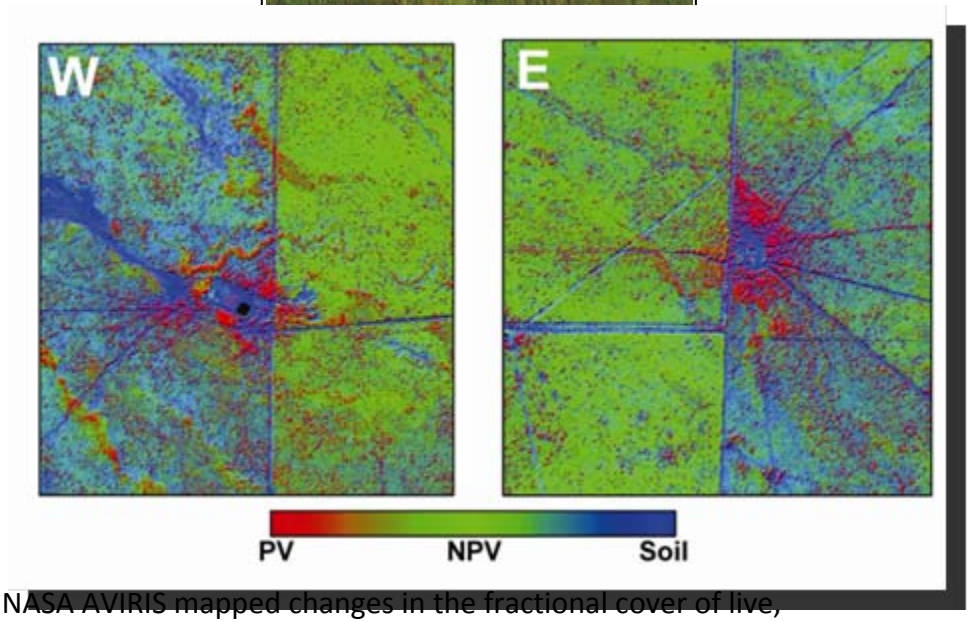
Silva & Gamon

Alternative Scenarios:



7) How do changes in human uses of ecosystems alter their vulnerability to disturbance and extreme events? [DS 196]





NASA AVIRIS mapped changes in the fractional cover of live, photosynthetic vegetation (PV), dead non-photosynthetic vegetation (NPV) and bare soil following construction of a fence to exclude cattle grazing from ecological sensitive desert ecosystems in Argentina.

Greg Asner

Level 3 Products:

- Standard Indices (NDVI, EVI, Water indices, PRI, percent cover (water, soil, PV, NPV…)
- Functional vegetation types (“optical types” – linked to structure, biochemistry, and phenology)
- Other?

Validation & Research

- Multidisciplinary (with heavy dose of ecology)
- Multi-scale – understand mechanism and address scale mis-match
- Incorporating Experimental methods
- Heavy emphasis on informatics/cyberinfrastructure
- Make use of existing validation networks