Science Rationale

STM Ecosystem Function and Diversity

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission Requirements
Ecosystem Function and Diversity				
Changes in regional and global extent of plant and plankton functional types (PFT)	Dominant PFT fractions (terrestrial): e.g. tree, shrub, herbaceous, cryptogam; thick/thin leaves; broad/needle leaves; deciduous/evergreen; nitrogen-fixer/non-fixer; C3/C4 physiology	PFT fraction uncertainty: ±10%	Imaging spectrometer: SNR: 600 VNIR, 300 SWIR (ZA=23.5°, 25% reflectance)	Surface reflectance for solar zenith angles ≤70°
		Annual products of ≤ monthly observations	>95% abs. radiometric cal., >98% on-orbit rel. reflectance	Monthly lunar cal. maneuvers; design for daily solar cal.
		Sampling 10^5 m^2 patches	≤60 m pixels	~840 Mbps raw data rate
		Regionally important PFT		Regional algorithm development
	(a) Dominant functional types (aquatic): e.g. phytoplankton (diatoms, dinoflagellates, coccolithophores, N-fixers), kelp, seagrass, mangroves, *Spartina*, etc. (b) Aquatic biogeochemical constituent: (phytoplankton, sediment, CDOM, benthos)	380-2500 nm reflectance, high dynamic range (dark aquatic targets near bright surfaces)	SNR—violet/blue/green: 400:1, yellow/orange/red: 300:1, wavelength >900 nm: ≥100:1; 14 bit digitization	Terra-like sun-synchronous, repeat-track, low Earth orbit; local equatorial crossing time:10:30 to 11:30 am
		Global coverage: full resolution for shallow water < 50 m deep and coarse resolution (~1 km) data for deeper water	> 99.5% radiometric calibration relative stability	Reversible high resolution data calibration
			Rapid (<2 pixel) bright target recovery (no significant ringing)	High-throughput on-board processing for spatial aggregation of open ocean data
Changes in spatial extent of certain diagnostic species	Diagnostic species/taxa: e.g., (terrestrial) pine, juniper, larch, *Cecropia*; (aquatic) sea grass, live coral, *Trichodesmium*, diatoms, dinoflagellates	Regional coverage with annual products	>95% cross-track uniformity & spectral uniformity	Data corrected for atmosphere & observing geometry
Changes in global extent of ecosystems	Refined ecosystem types (terrestrial): e.g. grasslands, shrublands, broadleaf evergreen forests, needleleaf evergreen woodlands, etc.	Classification accuracy ≥90%	High-fidelity imaging spectrometer: 0.4 - 2.5 µm; ≤10 nm resolution; >99% linearity (2 to 98% saturation)	Landsat-like sun-synchronous, repeat-track orbit; local equatorial crossing time 10-11 am
	Refined ecosystem types: (a) shallow/clear water: tropical coral reef, macroalgal beds, sediments; (b) shallow/turbid: estuaries, river plume, harmful and benign blooms; (c) lakes	Annual products of ≤ monthly observations	High-fidelity imaging spectrometer: 0.38 - 2.5 µm; polarization sensitivity <2%	Rigorous cal/val program
			No significant cross-talk between bands, stray light, or ghosting (<0.2% ocean TOA)	Pointing strategy to avoid sunglint pattern and hot spot

Science Rationale

STM Biogeochemical Cycles

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission Requirements
Biogeochemical Cycles				
Environmental change effects on productivity, carbon storage and biogeochemical cycles of ecosystems;	Refined ecosystem types	≥90% complete for ice-free land and coastal/marine waters shallower than 50 m deep	Average duty cycle 12-15% at full resolution	Weekly science processing: 9-10 Tbytes of spectrometer data
	Leaf and canopy water content (terrestrial)	Quantify liquid water and water vapor absorption	Spectral resolution ≤10 nm for 800-1300 nm range	Compatible data over full seasonal cycles
	Phytoplankton type and benthic type (aquatic)	Quantify phytoplankton cell sizes, N-fixers; substrate living, non-living, seagrass, coral	Spectral resolution ≤10 nm for 380-2500 nm range	Linked automated observations using in situ observatories to assess water clarity and other parameters in real-time
	Leaf and canopy pigment and nutrient content (terrestrial)	Spectral feature analysis of the 400-2500 nm range	High data quality 400-750 nm, including UV-blue transition	Data corrected for atmosphere & observing geometry
How these effects feed back to other components of the Earth system	Community pigment and nutrient content (aquatic)	Spectral feature analysis of the 380-2500 nm range	Spectral range: 0.38 to 2.5 μm	Normalized water-leaving radiance
	Canopy light-use efficiency and gross/net primary production (terrestrial)	Pigment analyses, nitrogen analyses, canopy water data	Swath width: 145 km (baseline)	Revisit interval: Goal 3-5 days; Baseline 19 days
		Canopy cover phenology data at weekly time scales	*Option:* 2nd spectrometer with ≥600 km swath	Modeling community engaged in product definition and evaluation.
	Community light-use efficiency and gross/net primary production (aquatic)	Pigment analyses, nitrogen analyses, fluorescence line height, CDOM, suspended sediment distribution	High SNR near solar-stimulated chlorophyll fluorescence peak (683 nm)	Access to ancillary data: Wind Speed, Mixed-Layer-Depth, Sea Surface Temperature

Science Rationale

Ecosystem Response to Disturbance

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission Requirements
Ecosystem Response to Disturbance				
Disturbance effects on the distribution of ecosystems	Fractional cover of photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV), soil, ice/snow (terrestrial)	Cover uncertainty: ±5%; dynamic range: 5-95%	Spectral quality sufficient to control for variable soil reflectance in cover estimates	Mission life: 3 years; 6-year goal
		Measured at 2 X 10^3 m^2, changes at 10^4 m^2 grain, sampling 10^5 m^2 patches	Re-sampled effective ground resolution ≤ 120 m; pixel resolution ≤ 60 m	Time-tagging, pointing & position knowledge provide for ≤30 m mapping uncertainty (3 σ)
	Size and distribution of aquatic plant blooms and patches (including plankton and benthic species), colored dissolved organic carbon (DOC) and suspended sediment distrib.	Separate absorption effects due to pigments and CDOM; separate water column effects when assessing benthic cover	Spectral quality and resolution sufficient to control for CDOM and water column effects	Robust cross-discipline program (terrestrial and aquatic linked ecosystem studies, to examine ridges-to-reefs types of ecosystem linkages)
	Refined ecosystem types	Global coverage	Stable response (>99.5 %) over orbit segments ≥ 40 min.	3-axis pointing control; with real-time position knowledge; robust cross-discipline program
Disturbance effects on the biodiversity of ecosystems	Fractional cover (terrestrial); Bloom/patch abundance	Detect and quantify fractional cover and phytoplankton abundance changes: ≥ 10%	Long-term: >95% absolute radiometric calibration, >98% on-orbit relative reflectance	Seasonally matched, stable, high-quality level 3 data
	(a) Dominant functional types; (b) Biogeochemical constituents (aquatic)	≥ 80% complete per seasonal (≤ 96-day) re-observation	Average duty cycle 12-15% at full resolution	Operations optimized for seasonal repeat coverage
	Diagnostic species/taxa	Annual products of ≤ monthly observations	same as above	Consistent distribution data for diagnostic species (level 3)
Disturbance effects on the functioning of ecosystems	Fractional cover (terrestrial); Bloom/patch abundance	Full global coverage	Average duty cycle 12-15%; maximum: 2 orbits at 40%	Storage & downlink of ~1.9 Tbits in 2 orbits (2:1 data reduction)
	Leaf and canopy water (land); Phytoplankton type and benthic type (aquatic)	≤ monthly observations and data products	same as above	Seasonally matched high-quality canopy water data (level 3)
	Pigment and nutrient content	Quantify changes in pigments/nutrients	same as above	Seasonally matched pigment & nutrient content data (level 3)
	Canopy/community light-use efficiency and gross/net primary production	Estimate the global amount and intensity of disturbance in modeling grid cells ½° × ½°	Aggregate duty cycle 40%, with coarse resolution data	Sufficient sampling to estimate disturbance distribution functions at ≤ 3000 km^2 scales

Science Rationale

STM Ecosystems and Human Well-Being

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission Requirements
Ecosystems and Human Well-Being				
Ecosystem change effects on human health, resource use, and resource management	(a) Dominant functional types; (b) Biogeochemical constituents (aquatic)	Annual products from ≤ monthly observations	>95% abs. radiometric cal., >98% on-orbit rel. reflectance	Watershed-based data retrieval for ridge to reef assessments
	Diagnostic species/taxa	Regional coverage	same as above	Simple off-track imaging requests
	Refined ecosystem types	Global coverage	Stable response (>99.5 %) over orbit segments (≥ 40 min.)	Decision support system development that includes ecosystem-based models
	Fractional cover (terrestrial); Bloom/patch abundance	≤ monthly observations (more frequent for targeted events)	Swath width: 145-150 km	Revisit interval (tropics): 3-30 days (with cross-track pointing)
	Leaf and canopy water (land); Phytoplankton type and benthic type (aquatic)	≤ monthly observations and products	Spectral resolution ≤10 nm	Comparable coincident data over full seasonal cycles
	Pigment and nutrient content	Spectral feature analysis of the 380-2500 nm range	Spectral range: 0.38 - 2.5 μm	Spectra corrected to apparent reflectance/normalized water-leaving radiance
	Canopy/community light-use efficiency and gross/net primary production	Pigments, nitrogen, canopy water content, phytoplankton type and benthic type	High SNR, particularly around solar-stimulated chlorophyll fluorescence peak	Global biosphere carbon-based production estimates

Science Rationale
STM Volcanoes

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
Volcanoes: What are the changes in the behavior of active volcanoes? Can we quantify the amount of material released into the atmosphere by volcanoes and estimate its impact on Earth's climate? How can we help predict and mitigate volcanic hazards?				
Do volcanoes signal impending eruptions through changes in surface temperature or gas emission rates and are such changes unique to specific types of eruptions?	Detect, quantify and monitor subtle variations in: 1) surface temperatures 2) sulfur dioxide emissions at low, non-eruptive flux levels. Compilation of long-term baseline data sets.	Temperature measurements in the range -20 to 100 ˚C. TIR radiance measurements at ~8 µm; 5 other TIR bands for use in SO2 retrieval algorithm; 7 day repeat.	7 TIR channels, 7-12 µm Pixel size ≤60 m NEΔT ~0.2 K. >95% abs. radiometric calibration	Nighttime data acquisitions.
What do changes in the rate of lava effusion tell us about the maximum lengths that lava flows can attain, the likely duration of lava flow-forming eruptions, and the sizes of magma chambers?	Area covered by active lava flows; Lava flow surface temperatures; Radiant flux from lava flow surfaces.	Temperature measurements in the range 0 to 1200 ˚C (active lava), and 0-50 ˚C (ambient background). 5 day repeat.	1 low gain channel at ~4 µm (NEΔT ~ 1-2 K) 2 nominal gain channels at 10-12 µm Pixel size ≤90 m Rapid bright target recovery at 4 µm (<2 pixels), bands saturate at 1200C	Nighttime data acquisitions. NIR/SWIR hyperspectral data is beneficial. Rapid response off nadir pointing capability. Rapid re-tasking for acquisition of targets of opportunity.
What are the impacts of volcanic gas emissions on local and regional atmospheric conditions, and the contributions to the global budget of sulfate aerosols?	Quantifying SO2 emission rates; Quantify rate at which SO2 is converted to sulfate aerosol.	Four spectral channels at 8.5, 10, 11, and 12 µm; NEΔT of 0.2 K, 7 day repeat	7 channels, 8-12 µm. Pixel size ≤90 m >95% abs. radiometric calibration	NIR/SWIR hyperspectral data desireable to assist in recognition of meteorological clouds and estimation of plume height. Night-time data acquisitions.
What are the characteristic dispersal patterns and residence times for volcanic ash clouds and how long do they remain a threat to aviation?	Discrimination of volcanic ash clouds from meteorological clouds (both water and ice), in both wet and dry air masses.	Four spectral channels at 8.5, 10, 11, and 12 µm; Nedt of 0.2 K, Max. repeat cycle of 5 days.	4 channels, 8-14 µm. Pixel size ≤90 m >95% abs. radiometric calibration	NIR/SWIR hyperspectral data valuable to assist in recognition of meteorological clouds and estimation of plume height. Night time data acquisitions to increase the frequency of observation.
What is the distribution of hydrothermally altered rocks and other structural features on volcanic edifices for prediction of debris flow hazards?	Surface emissivity; Sub-pixel abundance of alteration minerals.	Ability to discern variation in silica content of +/- 5% based on 8-12 µm band minimum position; ability to discern diagnostic non-silicate spectral features.	7 channels, 8-14 µm. Pixel size ≤50 m. >95% abs. radiometric calibration	NIR/SWIR hyperspectral data.

Science Rationale
STM Wildfires

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
Wildfires: How are global fire regimes changing in response to changing climate and land use practices? Are regions becoming more fire prone? What is the role of fire in global biogeochemical cycling, particularly atmospheric composition? Are there regional feedbacks between fire and climate change?				
How are global fire regimes (fire location, type, frequency, and intensity) changing in response to changing climate and land use practices?	Fire detection, fire intensity	Detect flaming and smoldering fires as small as ~10 sq. m in size, fire radiative power, 4-10 day repeat cycle	Low and normal gain channels at 4 and 11 µm. Low-gain saturation at 1400 K, 1100 K, respectively, with 2-3 K NEdT; normal-gain NEdT < 0.2 K. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration. Opportunistic use of additional bands in 8-14 µm region.	Daytime and nighttime data acquisition, sun synchronous orbit
Are regions becoming more fire prone?	Fire detection	Detect flaming and smoldering fires as small as ~10 sq. m in size, 4-10 day repeat cycle	4 and 11 µm channels having 390 K saturation, < 0.2K NEdT. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration.	Daytime and nighttime data acquisition, sun synchronous orbit
What is the role of fire in global biogeochemical cycling, particularly atmospheric composition?	Fire detection, fire intensity, burn severity, delineate burned area	Detect flaming and smoldering fires as small as ~10 sq. m in size, fire radiative power, 4-10 day repeat cycle	Low and normal gain channels at 4 and 11 µm. Low-gain saturation at 1400 K, 1100 K, respectively, with 2-3 K NEdT; normal-gain NEdT < 0.2 K. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration.	Daytime and nighttime data acquisition, sun synchronous orbit, vegetation cover for fuel potential
Are there regional feedbacks between fire and climate change?	Fire detection, fire intensity	Detect flaming and smoldering fires as small as ~10 sq. m in size, fire radiative power, 4-10 day repeat cycle	Low and normal gain channels at 4 and 11 microns. Low-gain saturation at 1400 K, 1100 K, respectively, with 2-3 K NEdT; normal-gain NEdT < 0.2 K. Stable behavior in the event of saturation. 50-100 m spatial resolution. Accurate inter-band coregistration.	Daytime and nighttime data acquisition, sun synchronous orbit

Science Rationale

STM Water Use and Availability

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
Water Use and Availability: As global freshwater supplies become increasingly limited, how can we better characterize trends in local and regional water use and moisture availability to help conserve this critical resource?				
How can we improve spatial information about evapotranspiration (water loss to the atmosphere) to facilitate better management of our Earth's freshwater	Evapotranspiration at scales resolving the typical lengthscales of landsurface moisture heterogeneity	Global coverage; ~weekly repeat; resolving e.g., field, riparian patches, reservoirs, water rights polygons; LST accurate to <1K; ~10:30AM overpass	$\leq$50m resolution; 2 bands in 10-12µm and at least 1 emissivity-sensitive band (e.g. 8.5-9.5µm); Min/Max T 270/360 K	Maps of vegetation index; landuse; insolation data; Landsat like mid-morning sun-synchronous overpass
How can we obtain better information about vegetation water stress conditions at spatiotemporal scales that are beneficial for global drought early detection, mitigation, and impact assessment efforts?	Stress index at field scales	Global coverage; ~weekly repeat; resolving field-scale (1 ha) patches; LST accurate to <1K; ~10:30AM overpass	$\leq$100m resolution; 3+ bands as above; Min/Max T 270/360 K	As above; some methods require potential evapotranspiration
What is the current global irrigated acreage, how is it changing with time, and are these changes in a sustainable balance with regional water availability?	Robust detection of pixels receiving seasonal water inputs in excess of rainfall	Global coverage; ~monthly repeat; resolving irrigation patches; ~10:30 AM overpass	$\leq$100m resolution; 3+ bands as above; Min/Max T 270/360 K	Agriculture/non-agric. classification; vegetation index
Can remote sensing-based technologies improve irrigation efficiency in water-scarce agricultural regions?	Accurate evapotranspiration at sub-field scales	< weekly repeat, irrigation patches well resolved; LST accurate to 0.5K; ~10:30AM overpass	$\leq$50m resolution; 3+ bands as above; Min/Max T 270/360 K	Vegetation index; accurate local meteorological forcing conditions

Science Rationale
STM Urbanization

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
Urbanization: How does urbanization affect the local, regional, and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare				
How do changes in land cover and land use affect surface energy balance and the sustainability and production of natural and human ecosystems?	Surface temperature Surface energy balance Surface energy fluxes Surface emissivity Global coverage	Low and high temp. targets NEΔT 0.2-0.3 3-6 bands from 8-12μm High spatial resolution (~45m)	Multiple spectral bands for surface temp. discrimination of urban surfaces Min T/Max T 273/370 (K)	High temporal resolution (weekly) Accuracy of 1 deg.K/NEΔT 0.2-0.3
What are the dynamics, magnitude, and spatial form of the urban heat island effect (UHI), how does it change from city to city, what are its temporal, diurnal, and nocturnal characteristics, and what are regional impacts of the UHI on biophysical, climatic, and environmental processes?	Measurement of urban surface temperature spatial extent Day/night thermal surface measurements Seasonal observations Global coverage	Multispectral thermal measurements for target discrimination (3-6) bands High spatial resolution (~45m) Day/night observations	Multiple spectral bands (3-6 bands) from 8-12μm for day/night surface temp. measurements High spatial resolution (~45m) Min T/Max T 273/370 K for diurnal observations	High temporal resolution (weekly) Accuracy of 1 deg.K/NEΔT 0.2-0.3
How can the characteristics associated with environmentally related health effects, such as factors influencing heat stress on humans and surface temperatures that affect vector-borne aqnd animal-borne diseases, be better resolved and measured?	Surface temperature Surface water/wetness Global coverage	Detection of wet/dry surfaces Daytime/nighttime observations Vegetated/non-vegetated surfaces	Multispectral thermal bands for surface temperature measurements (3-6 bands) Diurnal and nocturnal observations Low temperature and high temperature targets (NEΔT 0.2-0.3 K)	High temporal resolution (weekly) High spatial resolution (~45m) Accuracy of 1 deg.K/NEΔT 0.2-0.3

Science Rationale

STM Surface Composition and Change

Summary STM

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?				
What is the spectrally observable mineralogy of the Earth's surface?	Surface emissivity variations associated with mineralogy and rock type in exposed terranes	Variation in silica content and non-silicate spectral features based on 8-12 um band shape	7 bands in 8-12 um range with NEΔT < 0.2 K; spatial resolution < 50 m; temporal repeat quarterly	Band to band calibration must be validated, preferably in-flight
How has the Earth's surface been affected by human exploitation of non-renewable resources (oil & gas, mining)?	Surface emissivity variations associated with the mineralogy of mine waste dumps and pits	Variation in mineral content based on 8-12 um band shape including detection of sulfate spectral features.	7 bands in 8-12 um range with NEΔT < 0.2 K; spatial resolution < 50 m; temporal repeat monthly	Band to band calibration must be validated, preferably in-flight
Can we detect transient thermal anomalies associated with faulting and earthquake activity?	Surface temperature across fault zones corrected for emissivity variations	Discern temporal variations in temperature with high precision	3+ bands in 8-12 um range with NEΔT < 0.2 K; Spatial res. < 100 m; temporal repeat 1-4 days	Nightime data necessary to minimize radiant interference due to solar heating
How is thermal-atmospheric coupling during earthquakes related to active faulting?	Surface temperature corrected for emissivity variations	Discern temporal variations in temperature with high precision	3+ bands in 8-12 um range with NEΔT < 0.2 K; Spatial resolution < 100 m; temporal repeat 1-4 days	Use of 7.5 um band to characterize atmospheric water vapor
How can we better identify and delineate the geothermal resources of the world?	Surface temperature corrected for emissivity variations	Discern variations in temperature with high precision and spatial resolution	3+ bands in 8-12 um range with NEΔT < 0.2 K; Spatial resolution < 50 m; temporal repeat quarterly	Daytime/nightime image pairs needed to account for thermal inertia
How do surface temperature anomalies (hot spots) relate to deeper thermal sources, such as lava tubes and underground fires?	Surface temperature corrected for emissivity variations	Discern variations in temperature with high precision and spatial resolution	3+ bands in 8-12 um range with NEΔT < 0.2 K; Spatial resolution < 50 m; temporal repeat weekly	Nightime data necessary to minimize radiant interference due to solar heating
What is the spatial distribution and dynamic behavior of surface temperatures and emissivities of various land surfaces?	Surface emissivity variations and temperatures of all surficial cover materials	Complex surface emissivity properties based on 8-12 um band shape	7 bands in 8-12 um range with NEΔT < 0.2 K; spatial resolution < 50 m; temporal repeat weekly	Accurate methods of temperature emissivity separation applicable to wide range of materials needed.