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Susan Stitt, John Dwyer, Dennis Dye, Edward Josberger, 2011
Terrestrial Essential Climate Variables (ECVs) at a Glance

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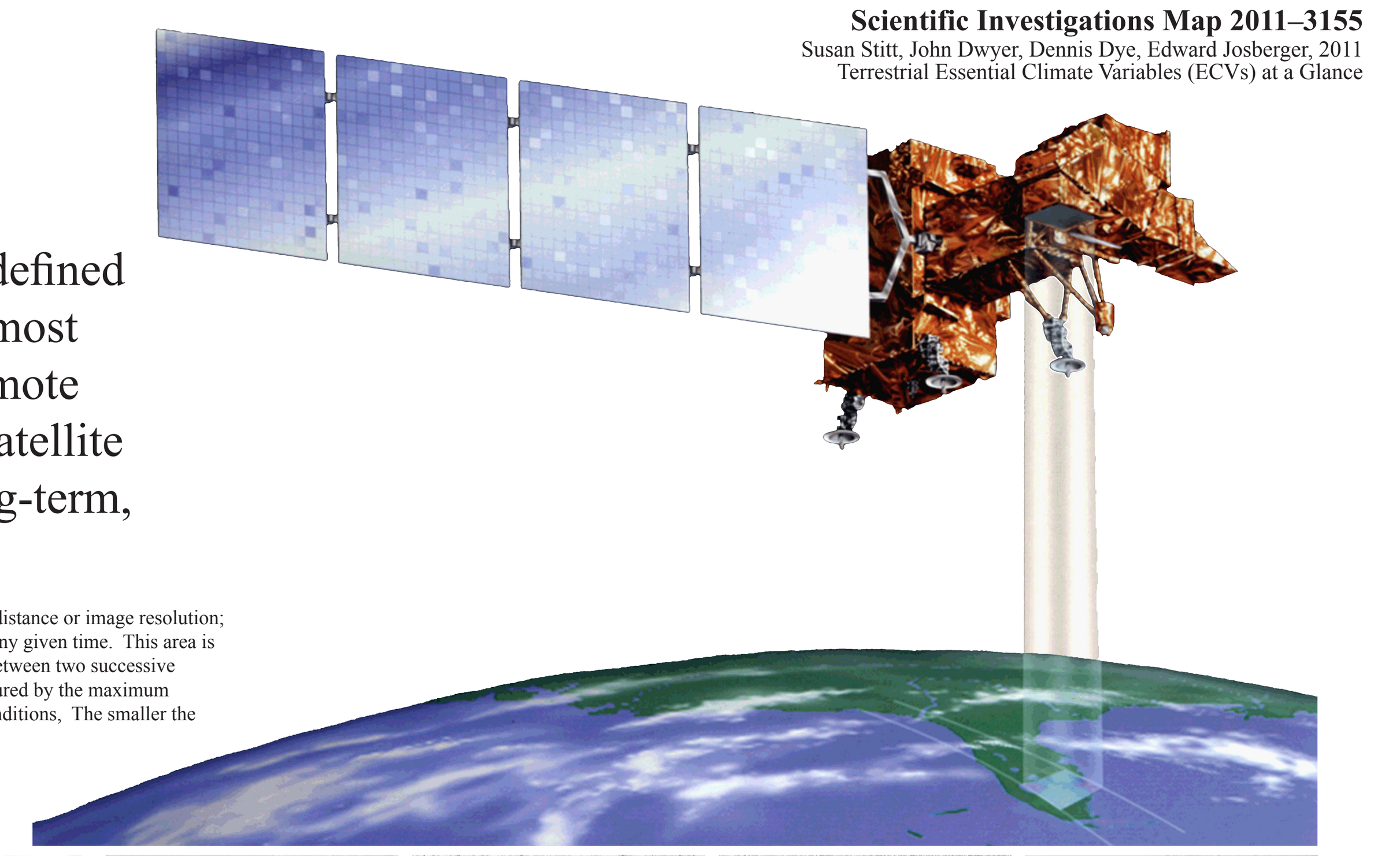

The Global Terrestrial Observing System (GTOS), Global Climate Observing System (GCOS), World Meteorological Organization (WMO), and Committee on Earth Observation Satellites (CEOS) all support consistent global land observations and measurements. To accomplish this goal, GCOS defined Essential Climate Variables (ECVs) as measurements of atmosphere, oceans, and land that are technically and economically feasible for systematic observation and that are needed to meet the United Nations Framework Convention on Climate Change and requirements of the Intergovernmental Panel on Climate Change. The following are the climate variables defined by GCOS that relate to terrestrial measurements. Several of them are currently measured most appropriately by in-place observations, whereas others are suitable for measurement by remote sensing technologies. The U.S. Geological Survey is the steward of the Landsat archive, satellite imagery collected from 1972 to the present, that provides a potential basis for deriving long-term, global-scale, accurate, timely and consistent measurements of many of these ECVs.

[**Units of measure:** °C, degrees Celsius; µm, micrometers; cm, centimeters; g/m^2, grams per square meter; km^2, square kilometers; L, liters; m, meters; mm, millimeters; m/s, meters per second; m^3/s, cms, or cumec, cubic meters per second
Measured features: DHR, directional hemispherical reflectance; ECV, essential climate variable; fAPAR, fraction of absorbed photosynthetically active radiation; FRP, fire radiated power; LAI, leaf area index
Organizations: ESA, European Space Agency; EUMETSAT, European Organization for the Exploitation of Meteorological Satellites; FAO, United Nations food and Agricultural Organization; GCOS, global Climate Observing System; GTOS, Global Terrestrial Observing System; ICSU, International Council for Science; IOC, Intergovernmental Oceanographic Commission; IPCC, Intergovernmental Panel on Climate Change; NASA, National Aeronautics and Space Administration; NOAA, National Oceanic and Atmospheric Administration; POSTEL, Pôle d' Observation des Surfaces Continentals par Telédétection; UNEP, Cultural United Nations Environmental Programme; UNESCO, United Nations Educational, Scientific and Cultural Organization; UNFCCC, United Nations Framework Convention on Climate Change; WMO, World Meteorological Organization
Databases: WFABBA, Wildfire Automated Biomass Burning Algorithm
Remote-sensing methods or devices: AMSR, advanced microwave scanning radiometer; ATSR, along-track scanning radiometer; AVHRR, advanced very high resolution radiometer; BRDF, bidirectional reflectance distribution function; GRACE, Gravity Recovery and Climate Experiment; MERIS, medium resolution imaging spectrometer; MODIS, moderate resolution imaging spectroradiometer; PARASOL, polarization and anisotropy of reflectances for atmospheric sciences couple with observations from a LiDAR (laser detection and ranging); POLDER, polarization and directionality of the earth's reflectances; SeaWiFS, sea-viewing wide field-of-view sensor; SEVIRI, spinning-enhanced visible and infrared imager; SMAP, soil moisture active and passive; SMOS, soil moisture and ocean salinity; VGT, SPOT (Satellites Pour l'Observation de la Terre vegetation sensor
Definitions: accuracy, the difference between the measured value of a variable and the truth; horizontal resolution, sampling distance or image resolution; IFOV, instantaneous field of view, or the area on the ground that is viewed by a single detector from a given altitude at any given time. This area is often provided as a linear measure of the side of a square encompassing the area viewed; observing cycle, the interval between two successive observations; stability, the extent to which accuracy remains constant over time and between systems. Stability is measured by the maximum departure (of the short-term average as compared with the long term average) of a variable measured under identical conditions, The smaller the maximum departure, the greater the stability of the dataset]


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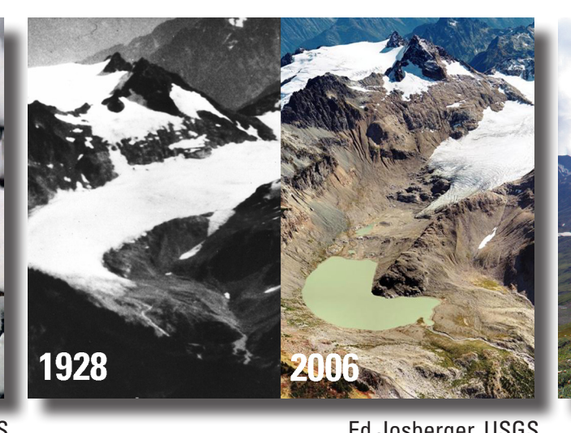

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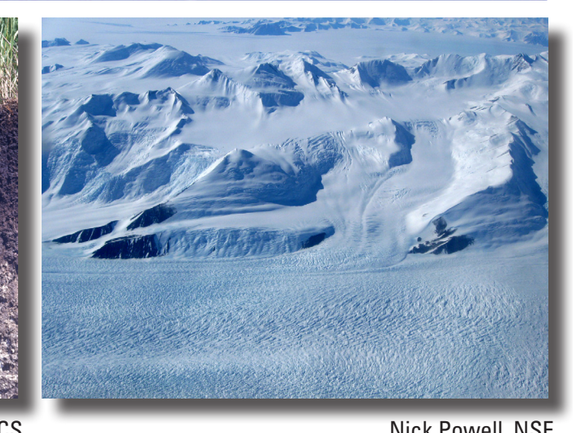
Nick Powell, NSF

ECVs	River discharge	Water use	Groundwater	Lakes
Definition	The rate at which water flows through a cross-section as volume per unit time, usually cubic meters per second. Data not primarily derived from satellites; however research into laser and radar altimetry for determining river levels and flow rates would be valuable.	Under development Agricultural water Irrigated land Industrial and domestic water Environmental maintenance water.	Groundwater level (m) is the elevation of the water table expressed as a height above a datum, such as sea level, or as a depth below the surface. Groundwater recharge (m/s) is a natural process whereby permeable soil or rock allows water to readily seep into the aquifer. Groundwater recharge (m/s) is a process whereby groundwater leaves the aquifer as seepage into wetlands, lakes and streams. Water quality is the composition of dissolved or contained constituents within water. Data not derived primarily from satellites.	Lake storage is the volume of water accumulated in a surface water feature at a specific water level. Lake level is the elevation of the water surface relative to a datum. Lake surface area may vary as a function of lake level and is often related to the volume of stored water. Data on lake surface area and surface temperature are derived primarily from satellites. Data on lake levels and volumes require a combination of in-place and satellite measurements.
Why of interest?	Freshwater discharge from rivers influences oceanic circulation at interannual to decadal time scales. A strong human-caused influence on water resources is difficult to distinguish from the climate-change signal. Because of this relation, records of discharge from pristine river basins are useful in detecting climate change.	Because climate is closely linked with the hydrological cycle, climate variability substantially affects water resources.It is estimated that 2,000 to 5,000 L of water are required to produce one person's daily food. The U.N. Food and Agricultural Organization (FAO) estimated that by 2030 the effective irrigated area in developing countries will need to be a third higher than year 2000 usage and that 14 percent more water will need to be available for agricultural purposes.	Groundwater replenishes streams, rivers, and wetlands and helps to support wildlife habitat; it is used as the primary source of drinking water and also in agricultural and industrial activities. Around the world, groundwater resources are under increasing pressure from human activities and climate change. Satellite observations are increasingly used to assess global groundwater resources and changes in groundwater storage.	Changes in lake volume, level, and area may be indicators of changes in climate. Analysis of temporal and spatial variability of lake levels and lake surface areas is important to global climate research and the planning and management of regional resources. Lake temperature affects freeze-up and break-up dates, which are markers used in regional climate monitoring.
Variables measured	Monthly discharge data for seasonal and inter-annual changes; instantaneous or event-based data for changes of extremes. Climate change investigations should use discharge from catchments with minimal or accountable anthropogenic effects.	*Under development* Agricultural water Irrigated land Industrial and domestic water use Environmental maintenance-water needs	Groundwater level, groundwater recharge, groundwater discharge, well groundwater level, and groundwater quality	Lake level, lake area, and lake surface temperature. GCOS target requirements refer to measurement of the approximately 150 priority lakes in the Global Terrestrial Network—Lakes.
GCOS target requirements	±15–20% of the true value. **Tier 1:** 15 minutes to 1 hour. **Tier 2:** hourly to mean daily. **Tier 3:** mean daily to monthly. At specific sites, at least one per biome type; in the long term, one for every 2º by 2º grid.	*Under development*	*Under development*	**Maps of lakes** **Accuracy:** 5% maximum error of omission and commission location accuracy better than 1/3 instantaneous field-of-view (IFOV) with 250 m target IFOV **Resolution:** 250 m horizontal resolution; monthly observing cycle **Stability:** 5% maximum error of omission and commission; location accuracy better than 1/3 of IFOV with 250 m target IFOV **Lake level** **Accuracy:** 10 cm with respect to reference geoid **Resolution:** <4 km horizontal resolution, monthly observing cycle **Stability:** 10 cm with respect to reference geoid **Surface temperature** **Accuracy:** ±0.2°C **Resolution:** 1 km horizontal resolution, daily observing cycle **Stability:** ±0.1°C
Existing products, players, and links	Currently, in-place methods are the most cost-effective and reliable way to measure river discharge. Remote sensing observations of river discharge are being developed and have potential, but they cannot yet replace in-place monitoring, especially in terms of accuracy. **Global Runoff Data Centre Database** http://www.bafg.de/nn_267060/GRDC/EN/Home/ **Global Terrestrial Network— River Discharge** http://www.bafg.de/nn_298726/GRDC/EN/02__Services/05__Special__DBs/GTNR/gtnr__node.html?__nnn=true **The Global River Discharge Database version 1.1** http://www.rivdis.sr.unh.edu/ **US Geological Survey Surface Water Methods and Modeling** http://water.usgs.gov/osw/methods.html	**FAO–AQUASTAT** http://www.fao.org/nr/water/aquastat/main/index.stm **UN Water** www.unwater.org/flashindex.html **World Water Assessment Program** www.unesco.org/water/wwap **WHO-UNICEF Joint Monitoring Programme for water supply and sanitation** http://www.wssinfo.org/ **Global Resource Information Database of UNEP** www.grid.unep.ch/data/index.php **International Water Management Institute (IWMI)** http://www.iwmi.cgiar.org **World Bank - Water Resources Management** www.worldbank.org/water **Challenge Program on Water and Food** www.waterandfood.org **US Geological Survey Water Use in the United States** http://water.usgs.gov/watuse/	**WMO Hydrology and Water Resources Programme** http://www.wmo.int/pages/prog/hwrp/index_en.html **WMO Hydrological Information Referral Service** http://www.wmo.int/pages/prog/hwrp/INFOHYDRO/infohydro_index.html **Global Terrestrial Network - Hydrology** http://www.gtn-h.net/ **Group on Earth Observations Global Groundwater Monitoring System** http://www.earthobservations.org/wa_igwco_th_gw.shtml **International Groundwater Resources Assessment Centre** http://www.igrac.net/ **Global Groundwater Information System** http://www.igrac.net/publications/104 **US Geological Survey Groundwater** http://water.usgs.gov/ogw/	**European Space Agency (ESA) River & Lake** http://tethys.eaprs.cse.dmu.ac.uk/RiverLake/shared/main/ **International Data Centre on Hydrology of Lakes and Reservoirs** http://www.hydrolare.ru/ **International Lake Environment Committee Index of World Lakes** http://wldb.ilec.or.jp/ **MSSL-WCMC-UNEP Lake and Catchment Area Conservation Database** https://s10.lite.msu.edu/res/msu/botonl/b_online/library/wcmc/index-15.html **Water Systems Analysis Group** http://www.wsag.unh.edu/data.html **World Lakes Network** http://www.worldlakes.org/ **US EPA STORET** http://www.epa.gov/storet/about.html **Africa Lakes Database** http://www.wwap-dss.sr.unh.edu/
Data gaps	In-place discharge measurements are well established and standardized. Free and unrestricted access to the discharge data and the provision of discharge data to international data centers needs urgent attention. Additional research is needed in altimetry and other sensing techniques to derive more information about river discharge from existing and planned satellite systems.	Gridded global datasets of irrigated area using satellite data are needed. Regular information on the timing and frequency of irrigation is also needed. In-place information that complements remote sensing data is generally not available.	Currently, in-place measurements dominate global groundwater assessments. However, in many countries systematic monitoring of groundwater quantity or quality is minimal or nonexistent. Satellite observations are increasingly important, but only at lower spatial and temporal resolutions. GRACE and interferometric synthetic-aperture radar are key satellite systems. The ability to archive, document, and distribute global data is needed.	No global data archive is currently established. Current data are often fragmented or not accessible. The accuracy of surface temperature measurements is limited by stability and accuracy of infrared sensors. Currently visible and near infrared, radar, altimetry, and high-resolution infrared imagery are used for lake measurements. Additional variables (date of freeze-up & date of ice break-up) would be valuable and should be measured.

ECVs	Snow cover	Glaciers and ice caps	Permafrost and seasonally frozen ground	Albedo
Definition	Snow cover (usually km^2) is the accumulation of snow on the ground. Extent of snow cover (usually km^2) is the total land area covered by some amount of snow. Depth of snow cover (usually cm) is the combined total depth of old and new snow on the ground. Snow water equivalent (usually mm) is the water content obtained from melting snow. Snow cover duration is expressed as the number of days of continuous, uninterrupted snow cover (sometimes as the total days that snow was on the ground, continuous or not). Data on extent and duration of snow cover are primarily derived from satellites. Data on depth of snow cover and snow water equivalent require a combination of in-place and satellite measurements.	A glacier forms where snow accumulation exceeds ablation (melting and sublimation). Gravity compacts the snow into ice and causes the ice to flow downhill, typically constrained by the surrounding topography. An ice cap is a dome-shaped ice mass covering an underlying highland area. A change in the mass balance (difference between accumulation and ablation) is an indication of annual atmospheric conditions. Advances or retreats of glaciers during many years are indirect reactions to long-term climatic changes. Data on area is primarily derived from satellite observations. Mass balance is derived from in-place observations.	Permafrost is the subsurface material that remains continuously at or below 0°C for two or more consecutive years. Ground temperature (°C) is measured at specified depths. Active layer is the surface layer of ground subject to annual thawing and freezing; it is measured in thickness (cm) and temperature (°C). Seasonally frozen ground refers to soils without permafrost that freeze and thaw seasonally, measured in depth (cm) and temperature (°C). Not derived primarily from satellites.	Albedo is the ratio of radiant flux reflected from the Earth's surface to incoming irradiance. Albedo varies as a function of surface properties and illumination. Because albedo depends on the intrinsic composition and structure of the surface cover and because of atmospheric conditions, remote sensing offers the only practical method of measuring and monitoring global albedo. Data derived primarily from satellites.
Why of interest?	Snow cover is the land-surface characteristic responsible for the largest intraannual and interannual differences in albedo. Surface temperature strongly depends on the presence or absence of snow cover. Long time series of snow-cover trends serves as an indicator of climate change. Snow cover markedly influences the land-surface water budget. If climate warms, earlier snowmelt may lead to reduced stream flow during summer, when water demand is highest.	Changes in glaciers provide some of the clearest evidence of climate change, are early-detection observations, and have the potential to substantially change sea level, the terrestrial water cycle, and society.	Decadal changes in permafrost temperatures and depth of freeze and thaw are indicators of changes in climate. Seasonally frozen ground influences surface and subsurface hydrology.	Albedo is an important parameter for modeling land surface radiation balance and for the monitoring and detection of land-surface change. Albedo varies in space and time on the basis of changes in solar position, snowfall, vegetation growth, and human activities.
Variables measured	Snow cover albedo, snow cover extent, snow cover depth, and snow cover duration; snow grain size, snow water equivalent, and the presence of liquid water.	Specific mass balance, in water equivalent (m), front variation (m), and area (km^2). Data for satellite-derived variables include maps of the areas covered by glaciers, and elevation changes used in mass balance determinations.	Permafrost—Thermal state of permafrost ground temperatures (°C) measured at specified depths. The active layer is defined by thickness measured in centimeters and by temperature (°C). Seasonal frozen ground measured as depth (cm) and temperature (°C).	Black-sky albedo (or directional hemispherical reflectance (DHR)) in the absence of a diffuse irradiance component (no atmospheric scattering). Since DHR is a function of the solar zenith angle, it is usually computed for a specific time (such as local solar noon).
GCOS target requirements	**Accuracy:** 5% maximum error of omission and commission in snow area. Location better than 1/3 IFOV with target IFOV of 100 m in complex terrain, 1 km elsewhere. **Resolution:** 100 m horizontal resolution for areas of complex terrain, 1 km elsewhere, with a daily observing cycle. **Stability:** 5% maximum error of omission and commission in snow area. Location accuracy better than 1/3 IFOV	**Maps of areas covered by glaciers** **Accuracy:** 5% maximum error of omission and commission in glacier area maps. Location accuracy better than 1/3 IFOV of sensor with target IFOV 30 m. **Resolution:** 30 m horizontal resolution. 1 year observing cycle. **Stability:** 5% maximum error of omission and commission. Location better than 1/3 IFOV of sensor with target IFOV of 30 m.	*Under development*	**Accuracy:** 5% **Resolution:** 1 km horizontal resolution and a daily observing cycle. **Stability:** 1%
Existing products, players, and links	**National Snow & Ice Data Center (NSIDC)** http://nsidc.org/data/snow.html **NASA MODIS snow products** http://modis-snow-ice.gsfc.nasa.gov/ **World Data Center for Remote Sensing of the Atmosphere (SEVIRI snow cover)** http://wdc.dlr.de/data_products/SURFACE/ **NOAA National Operational Hydrologic Remote Sensing Center** http://www.nohrsc.noaa.gov/nh_snowcover/ **NOAA National Climatic Data Center** http://www.ncdc.noaa.gov/oa/ncdc.html **NOAA NWS COOP Snow Depth & Snowfall** http://www.cpc.ncep.noaa.gov/products/season_update/snow_map/ **Carbon Dioxide Information Analysis Center** http://cdiac.ornl.gov/climate/snow/snow_table.html **US Department of Agriculture Natural Resources Conservation Service SNOTEL sites** http://www.wcc.nrcs.usda.gov/snow/	**Global Land Ice Measurements from Space** http://www.glims.org/ **The World Glacier Monitoring Service Global Terrestrial Network—Glaciers within the Global Climate/Terrestrial Observing System** *(has established a multi-tiered process for studying glaciers and ice caps)* http://www.wgms.ch/ **National Snow and Ice Data Center World Glacier Inventory** http://nsidc.org/data/glacier_inventory/index.html **National Snow and Ice Data Center Glacier Mass Balance and Regime Measurements and Analysis, 1945–2003** *(National Snow and Ice Data Center also hosts other glacier data sets)* http://nsidc.org/data/g10002.html **ESA—GlobGlacier** http://www.globglacier.ch/ **U.S. Geological Survey Glacier studies** http://ak.water.usgs.gov/glaciology http://wa.water.usgs.gov/projects/glacier	**Global Terrestrial Network—Permafrost** http://www.gtnp.org/ **Circumpolar Active Layer Monitoring** http://www.udel.edu/Geography/calm/ **International Permafrost Association (IPA)** http://ipa.arcticportal.org/ **Research Council of Norway, Thermal State of Permafrost in Norway and Svalbard** http://www.tspnorway.com/ **National Snow and Ice Data Center** http://nsidc.org/data/frozen_ground.html **National Snow and Ice Data Center—Frozen Ground Data Center** http://nsidc.org/fgdc/ **Ninth International Conference on Permafrost** http://www.nicop.org/	**European Space Agency MERIS Albedo Level 3 Demo Products** http://earth.esa.int/object/index.cfm?fobjectid=3809 **NOAA Surface Radiation Network** http://www.srrb.noaa.gov/surfrad/ **NASA MODIS Albedo/BRDF** https://lpdaac.usgs.gov/lpdaac/products/modis_products_table **NASA MISR Level 3 Albedo/Cloud Product** http://public-asdc.larc.nasa.gov/cgi-bin/daacxt/LarcECSColL3Albedo.cgi **NASA Clouds and Earth's Radiant Energy System/ Atmospheric Radiation Measurement Validation Experiment** http://www-cave.larc.nasa.gov/cave/fsw-sfcalb/ **POSTEL Land Surface Albedo** http://postel.mediasfrance.org/en/BIO-GEOPHYSICAL-PRODUCTS/Land-Surface-Albedo/ **ESA EUMETSAT Meteosat second generation SEVIRI Surface Albedo** http://navigator.eumetsat.int/discovery/Start/Explore/DirectExtended.do?EOResourceIdentifier=EO:EUM:DAT:MSG:AL-SEVIRI
Data gaps	Data from many sources need to be blended to obtain globally applicable data. Standard methods are needed to validate and quantify the accuracy of satellite-based passive microwave retrieval algorithms. Snow-cloud discrimination needs to be improved while avoiding sensor saturation. Errors associated with not detecting snow cover under forest canopy need to be quantified and techniques developed to adjust for these errors.	A detailed global inventory of glaciers and ice caps is incomplete, and detailed inventories are not usually repeated. Some glaciers are not adequately measured by current satellite data. Specific mass balance is generally measured with in-place methods. Changes in gravity, as measured by the GRACE satellite system, offer the potential to determine large-scale variations in glacier mass.	Standards and protocols for permafrost thermal-state measurements are missing. Regional gaps exist in the network. Continuity of borehole networks and measurements is important. Operational mapping of seasonal soil freeze and thaw needs to be implemented.	Reprocessing of historical data is needed to incorporate more recent knowledge and data, as well as to compare data from various systems. Because of insufficient angular sampling with Landsat, ancillary data sources are required for BRDF specification. One promising solution is a sensor fusion approach using MODIS.

ECVs	Land Cover	fAPAR	Leaf area index	Above-ground biomass
Definition	Observed physical (natural or planned) cover and human constructions that cover the earth's surface. Data derived primarily from satellites.	Fraction of absorbed photosynthetically active radiation (fAPAR) is a measure of incident visible light (0.4–0.7 µm) that is absorbed by a vegetation canopy. Data derived primarily from satellites.	Leaf area index (LAI) is the vertically projected horizontal leaf area per unit horizontal ground area. Data derived primarily from satellites. LAI is also commonly measured using direct harvesting or indirect radiation methods. Standardization and cross-validation between methodologies is needed.	Biomass in this context is defined as above-ground mass per unit area of living plant material (g/m^2). Additional biomass pools such as on-the-ground (litter), below-ground biomass, and dead biomass are not monitored by this ECV. Data derived primarily from satellites.
Why of interest?	Changes in land cover alter the exchange of energy between the land and atmosphere and affect atmospheric concentrations of greenhouse gases, which can lead to climate variability and change. Changes in land cover can also directly alter habitat, interfere with migration of some species, and provide a pathway for invasive species and disease vectors.	fAPAR is used to drive models of carbon uptake, net primary productivity, transpiration, water cycling interactions, and climate. It is also used to improve crop management by providing information on vegetation yields and stress and on soil quality.	Leaf area index is a useful surrogate for leaf structure and therefore photosynthesis, respiration, interception of solar energy and, on a larger scale, vegetation's link to climate and hydrology. It is a measure of productivity for agricultural production and ecosystem health. In models it is used to represent vegetation amount or structure or to estimate fAPAR.	Photosynthesis withdraws CO_2 from the atmosphere and stores it as biomass (within forests, approximately 50% of biomass is carbon). The quantity of biomass consumed by fire affects emissions of CO_2 and other trace gases and aerosols. Change in biomass is used to estimate biological carbon sequestration or loss.
Variables measured	Moderate- and high-resolution land-cover variables (for instance, tree, shrub, herb, water, and barren density) and types; land cover change products. Global land-cover-change variable maps at 10–30 m resolution produced annually and land-cover-change type maps at 5-year intervals.	Distribution of fAPAR, a measure of canopy light interception (flux) related directly to photosynthesis and vegetation carbon exchange.	Maps of LAI.	Above-ground vegetation biomass and biomass change.
GCOS target requirements	**Moderate resolution** **Accuracy:** 15% maximum error of omission and commission in mapping individual classes. Location accuracy better than 1/3 IFOV with target IFOV of 250 m. **Resolution:** 250 m to 1 km horizontal resolution, 1-year observing cycle. **Stability:** 15% maximum error of omission and commission in mapping individual classes. **High resolution** **Accuracy:** 5% maximum error of omission and commission in mapping individual classes. Location accuracy better than 1/3 IFOV with target IFOV 10–30 m **Resolution:** 10–30 m horizontal resolution, 5-year observing cycle. **Stability:** 5% maximum error of omission & commission. Location accuracy better than 1/3 IFOV.	**Accuracy:** 0.05 between measurements of the same target from different sensors **Resolution:** 250 m horizontal resolution, and a daily observing cycle. Summarized over various time periods. **Stability:** 0.05 over the lifetime of each satellite	**Accuracy:** 0.5 average as per IFOV **Resolution:** 250 m horizontal resolution, daily observing cycle. Summarize at various time periods. **Stability:** 0.5 average as per IFOV	**Accuracy:** 5% Above-ground biomass can be measured with an accuracy of 10% to 20% using in-place methods, comparable accuracy from satellite estimates is desired. **Resolution:** 10-30 m horizontal resolution, 1-year observing cycle. **Stability:** 5%
Existing products, players, and links	**Global Observation of Forest and Land Cover Dynamics land cover datasets** http://www.gofc-gold.uni-jena.de/sites/data/gofc.htm **U.S. Geological Survey Global Land Cover Characterization** http://edc2.usgs.gov/glcc/glcc.php **FAO Global Land Cover Network** http://www.glcn.org/dat_0_en.jsp **World Data Center for Remote Sensing of the Atmosphere (MERIS Land Cover)** http://wdc.dlr.de/data_products/SURFACE/ **MODIS Land Cover Products** https://lpdaac.usgs.gov/lpdaac/products/modis_products_table **University of Maryland Global Land Cover Facility** http://glcf.umd.edu/data/landcover/	**GLOBCARBON fAPAR** http://geofront.vgt.vito.be/geosuccess/relay.do?dispatch=FAPAR_info **SeaWIFS 1.5 km daily, 10-day, & monthly; Sept 97 to June 2006** http://fapar.jrc.ec.europa.eu/ **NASA MODIS** https://lpdaac.usgs.gov/lpdaac/products/modis_products_table *(both LAI & fPAR are found in the same product)* **NASA MISR 1.1 km daily, monthly, seasonal and yearly products** http://eosweb.larc.nasa.gov/PRODOCS/misr/level3/product.html#land	**NASA MODIS** https://lpdaac.usgs.gov/lpdaac/products/modis_products_table *(both fPAR & LAI are found in the same products)* **NASA MISR** http://eosweb.larc.nasa.gov/PRODOCS/misr/level3/product.html#land **POSTEL Leaf Area Index** http://postel.mediasfrance.org/en/BIOGEOPHYSICAL-PRODUCTS/Leaf-Area-Index---LAI/ **GLOBCARBON** http://geofront.vgt.vito.be/geosuccess/relay.do?dispatch=LAI_info **EUMETSAT/LSA SAF** http://landsaf.meteo.pt/algorithms.jsp;jsessionid=F3E0110262B58CDD1D8CFC9C1A1F6322?seltab=9&starttab=9 **Global LAI from Field Measurements, 1932-2000** http://daac.ornl.gov/VEGETATION/lai_des.html	**ESA—BIOMASS** http://www.esa.int/esaLP/SEMI9NBDNRF_LPfuturemis_0.html **Global IPCC Tier-1 Global Biomass Carbon Map for 2000** http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html **Global Forest Growing Stock, Biomass and Carbon Map Based on FAO Statistics** http://www.iiasa.ac.at/Research/FOR/download.html?sb=15 **U.S. Forest Service Forest Biomass across lower 48 states & Alaska** http://webmap.ornl.gov/biomass/biomass.html **National Biomass and Carbon Dataset 2000, Woods Hole Research Center** http://www.whrc.org/mapping/nbcd/index.html **U.S. Forest Inventory and Analysis program** http://199.128.173.17/fiadb4-downloads/datamart.html
Data gaps	Land cover product specifications are evolving, but the FAO Land Cover Classification System is the accepted standard for land-cover type maps. Issues concern access to high-resolution remotely sensed data, global data coverage and availability, methods, consistency, and availability of products with time.	Currently multispectral imagery (visible and near infrared), especially with multi-angular viewing capability (MODIS, MERIS, POLDER, VGT, PARASOL, ATSR, SeaWiFS, and SEVIRI) are used for measuring fAPAR. Large differences in data gathered from 1997 onward need to be resolved.	The accuracy of LAI measurements falls when canopy cover is sparse. The accuracy of LAI estimates and separation of LAI from fAPAR improves with multi-angular measurements. LAI estimates from various sensors and algorithms have large differences, which should be resolved.	Interferometric polarimetric synthetic-aperture radar (ALOS L-band) and LIDAR can effectively estimate above-ground biomass, alone or in combination with optical imagers (such as Landsat and MODIS). However, the lack of systematic coverage precludes consistent and operational approaches. Few products look at change. Many models are statistical and require local calibration.

ECVs	Fire disturbance	Soil moisture	Soil carbon	Ice sheets
Definition	Fire disturbance is defined by the three variables below. Burned area is the area affected by a human-made or natural fire. Active fire is the area covered by vegetation that is currently being burned by a human-made or natural fire. Fire radiated power (FRP) is the rate at which radiative energy is emitted by an active fire. Data derived primarily from satellites.	*Under development* Data can be derived from active and passive microwave satellite imagery.	*Under development* Data not derived primarily from satellites.	Earth's two continental ice sheets are in Greenland and in Antarctica. These ice sheets actively influence global climate and react to climate change during millennial time scales, whereas glaciers and ice caps react to climate typically during time scales of a few decades Data derived primarily from satellites.
Why of interest?	Fire can be both beneficial and detrimental; fire disturbs some ecosystems, but it is useful in others that depend on it. It can be a valuable tool for land managers, but it produces abundant atmospheric emissions. Fire-disturbance measurements are used in global-change research, estimating atmospheric emissions, developing periodic global and regional assessments, managing fires, and developing policy. FRP strongly correlates with the rate of combustion, allowing CO_2 emissions to be estimated. FRP observations through time can provide an estimate of total CO_2 emitted during a fire.	Soil moisture is a key parameter in land surface processes. It controls the movement of rainfall into runoff, the prediction of precipitation, and biogeochemical processes, and it influences the land-surface energy balance.	Soils represent the largest terrestrial carbon pool, which is roughly two or three times that of atmospheric CO_2. Although soil carbon in forests is substantial, surprisingly, the largest soil carbon stocks are primarily in wetlands and peat lands, a majority of which are located in permafrost and in the tropics. Currently, soil carbon is rarely considered in land-management decisions but, with additional knowledge about soil carbon, it could become an important management topic.	Changes in ice sheets have the potential to markedly change sea level, the terrestrial water cycle, and society. Ice sheet albedo can be a strong indicator of the ice sheet's amount of ablation (melting and sublimation).
Variables measured	Burned area (km2); active fires (presence or absence); fire radiated power (watts or joules per second).	*Under development*	*Under development*	Specific mass balance in water equivalent (m), front variation (m), and area (km). Satellite-derived variables include (1) maps of the areas covered by ice sheets; (2) ice sheet elevation changes for mass balance determinations, and (3) ice sheet albedo
GCOS target requirements	**Burned Area** **Accuracy:** 5% maximum error of omission and commission **Resolution:** 250 m horizontal and daily observing cycle **Stability:** 5% **Active Fires** **Accuracy:** 5% maximum error of omission and commission **Resolution:** 250 m horizontal resolution; daily observing cycle **Stability:** n/a in the context of a supplementary variable **Fire Radiated Power** **Accuracy:** 5 % **Resolution:** 1 km horizontal resolution, daily observing cycle **Stability:** n/a in the context of a supplementary variable	*Under development*	*Under development*	**Ice-sheet elevation changes** **Accuracy:** 0.1 m **Resolution:** 100 m horizontal and 1-year observing cycle **Stability:** 0.1 m
Existing products, players, and links	**Global Fire Monitoring Center** http://www.fire.uni-freiburg.de/ **Global Observation of Forest and Land Cover Dynamics fire** http://gofc-fire.umd.edu/ **ATSR World Fire Atlas** http://wfaa-dat.esrin.esa.int/ **GlobScar** http://gcmd.nasa.gov/records/GCMD_GLOBSCAR.html **MODIS Active Fire & Burned Area Products** http://modis-fire.umd.edu/index.html **EUMETSAT** http://www.eumetsat.int/Home/Main/DataProducts/Land/index.htm?l=en **WFABBA** http://cimss.ssec.wisc.edu/goes/burn/wfabba.html **Global Fire Emissions Database version 2** http://ess1.ess.uci.edu/~jranders/data/GFED2/readme.pdf **University of Maryland / NASA Fire Information for Resource Management System** http://maps.geog.umd.edu/firms/ **NOAA/National Environmental Satellite, Data, and Information Service Hazards Mapping System** http://www.osdpd.noaa.gov/ml/land/hms.html	**ESA—Soil Moisture and Ocean Salinity (SMOS)** www.esa.int/smos **NASA JPL Soil Moisture Active & Passive (SMAP)** http://smap.jpl.nasa.gov/ **International Soil Moisture Network** http://www.ipf.tuwien.ac.at/insitu **The International Satellite Land Surface Climatology Project II** http://daac.ornl.gov/ISLSCP_II/islscpii.shtml **Global Soil Wetness Project 2** http://grads.iges.org/gswp/ **Daily Soil Moisture of Europe** http://edo.jrc.ec.europa.eu/php/index.php?action=view&id=19 **U.S. Natural Resources Conservation Service Soil Climate Analysis Network** http://www.wcc.nrcs.usda.gov/scan/ **NOAA ESRL CPC Soil Moisture** http://www.esrl.noaa.gov/psd/data/gridded/data.cpcsoil.html	**FLUXNET** http://daac.ornl.gov/FLUXNET/fluxnet.shtml **International Long Term Ecological Research** http://www.ilternet.edu/ **Global Terrestrial Observing Network** http://www.fao.org/gtos/gt-net.html **Harmonized World Soil Database** http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html **World Soil Information** http://www.isric.org/ **The Global Change and Terrestrial Ecosystems Soil Organic Matter Network (Global Change and Terrestrial Ecosystems Soil Organic Matter Network)** http://www.rothamsted.ac.uk/aen/somnet/	**Global Land Ice Measurements from Space** http://nsidc.org/glims/ **Global Terrestrial Network—Glaciers** http://gosic.org/gtos/GTNet-G-data-access.htm **National Snow and Ice Data Center** http://nsidc.org/ **Mosaic of Antarctica** http://nsidc.org/data/nsidc-0280.html
Data gaps	The AVHRR archive held by NOAA (and NASA) needs to be reprocessed, so that known deficiencies in sensor calibration and directional and atmospheric problems can be corrected. FRP requires unsaturated radiance measurements from high-resolution sensors that are being included in research and future satellite plans.	Active and passive microwave remote sensing (AMSR, SMOS, SMAP) can provide spatially averaged soil moisture. No designated baseline network exists. Continuity is needed after research missions end.	No designated global network or data center exists, and the data contain major geographical gaps. Soil carbon is extremely variable and difficult to measure. The total amount and distribution of carbon stored in soils is uncertain. Estimates of carbon stored at various depths are needed.	Strengthen the current monitoring network with additional observation series around the two ice sheets. Large uncertainty in ice loss from ice sheets, ice velocity, isostatic rebound, and thermal expansion.

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