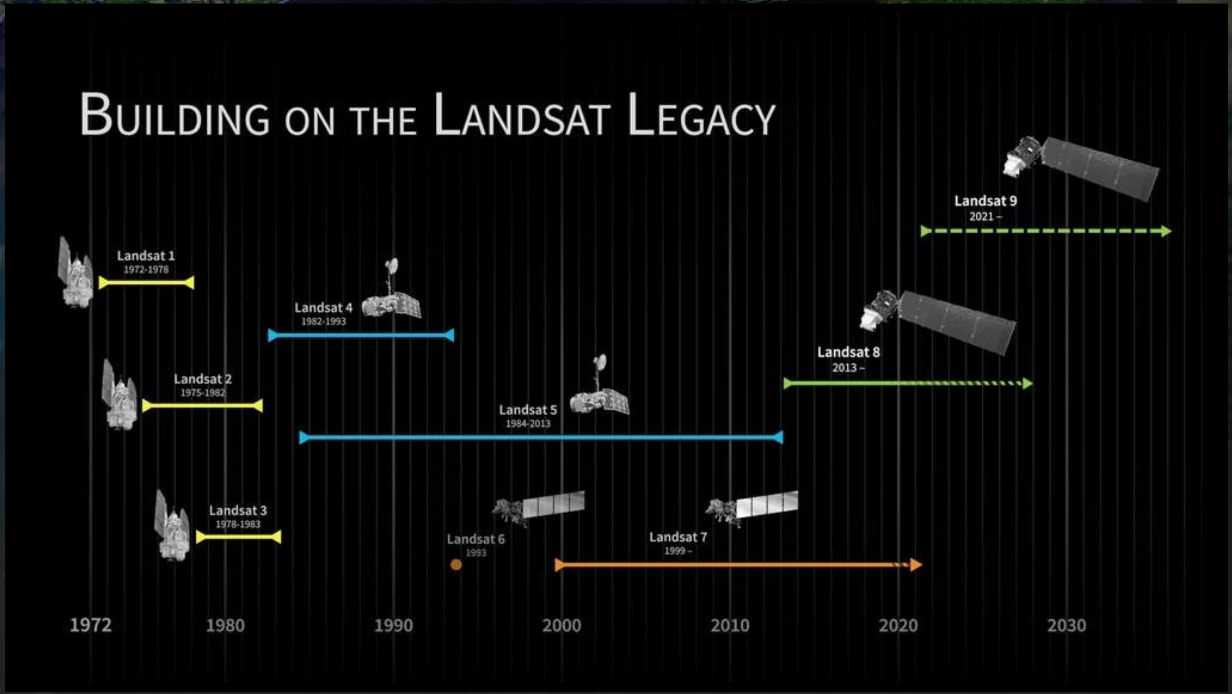
Sustainable Land Imaging (SLI) Landsat Next: Improvements for Science

May 2022

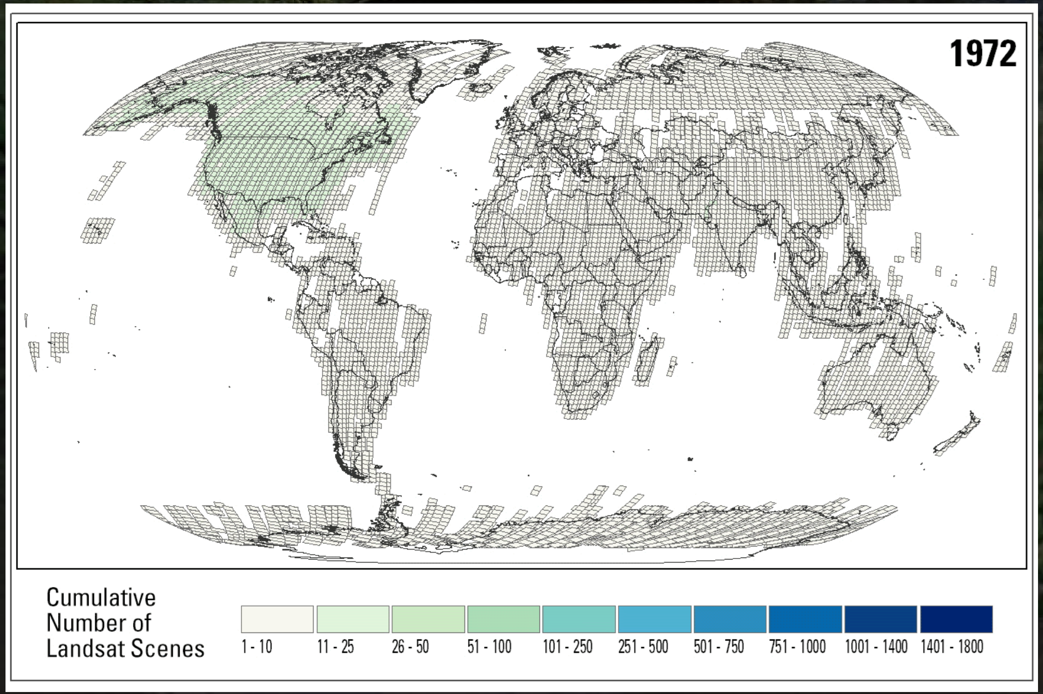
Sustainable Land Imaging (SLI)

A partnership between DOI/USGS and NASA to ensure sustained access to high-quality, global, land-imaging measurements compatible with the existing 50-year Landsat record for research and operational users

- NASA responsible for developing the space segment, launch and on-orbit check-out
- DOI/USGS responsible for developing the ground segment, flight and ground system operations



- Nearly five-decade record of land cover, land use, and vegetation condition
- Large area coverage for global, continental and regional land cover studies



- Archive contains 300 billion km^2
- Adds 40 million km^2 per day

Landsat Next

- **Landsat Next**: Under the SLI agreement, the U.S. intends to implement a robust spaceborne, land imaging system to ensure continued collection of data for processing into useful and efficient information products for use by the wide range of interested science communities.
- **Mission Concept:** Collection of “superspectral” land observations featuring both richer spectral information and higher spatial resolution than Landsat 8 and 9 with improved temporal frequency.
- **Requirements:** Reflect the needs of users for:
  - **Improved temporal revisit** for monitoring dynamic land and water surfaces such as vegetation crop phenology, burn severity, water use and quality, coastal and wetland change, glacier and ice sheet dynamics.
  - **Improved spatial resolution** for agricultural monitoring, ecological monitoring, urban studies, water resources management and other applications.
  - **Synergy with European Sentinel-2** bands allowing easier merging of information products.
  - **Improved spectral resolution** to support new and evolving applications, including surface water quality, cryospheric science, geology, and agricultural applications including crop water consumption.
  - **Preservation of heritage performance**: spatial, geometric, radiometric, and Signal-to-Noise Ratio (SNR).

Origin of Mission Science Requirements

Landsat Next Requirements reflect user priorities for land monitoring, as reflected in key documents

- USGS User Needs Survey of Federal Agencies (Wu et al., 2019)
- Landsat Advisory Group (LAG) "Recommendations for Possible Future US Global Land Data Collection Missions Beyond Landsat 9" (2018)
- National Research Council "Landsat and Beyond" (2013)
- Recommendations from the NASA/USGS Landsat Science Team
- Feedback from Landsat Next Request for Information (Fall 2020)

Both the Landsat Science Team and an ad-hoc Federal Agencies Expert Panel provided written endorsement for the mission science requirements

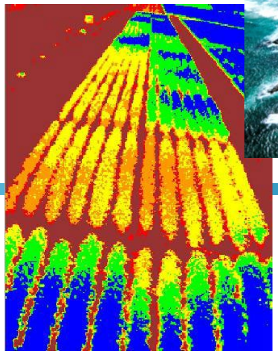
USGS SLI User Needs Findings

US Federal agency land imaging users identified the need to maintain **Landsat data continuity** and improves in **temporal, spatial and spectral** resolution from Landsat Next

Improve **temporal** coverage to at least weekly observation for agriculture, forestry, disasters, water quantity and quality

Improve **spatial** resolution to 10/20m (Sentinel-2 example) for VSWIR and 30/60m for TIR for agriculture, land use/cover, glacier/ice sheet, urban and coastal applications

Specific targeted **spectral** bands to support emerging applications and improving atmospheric correction and surface temperature retrieval



LNext

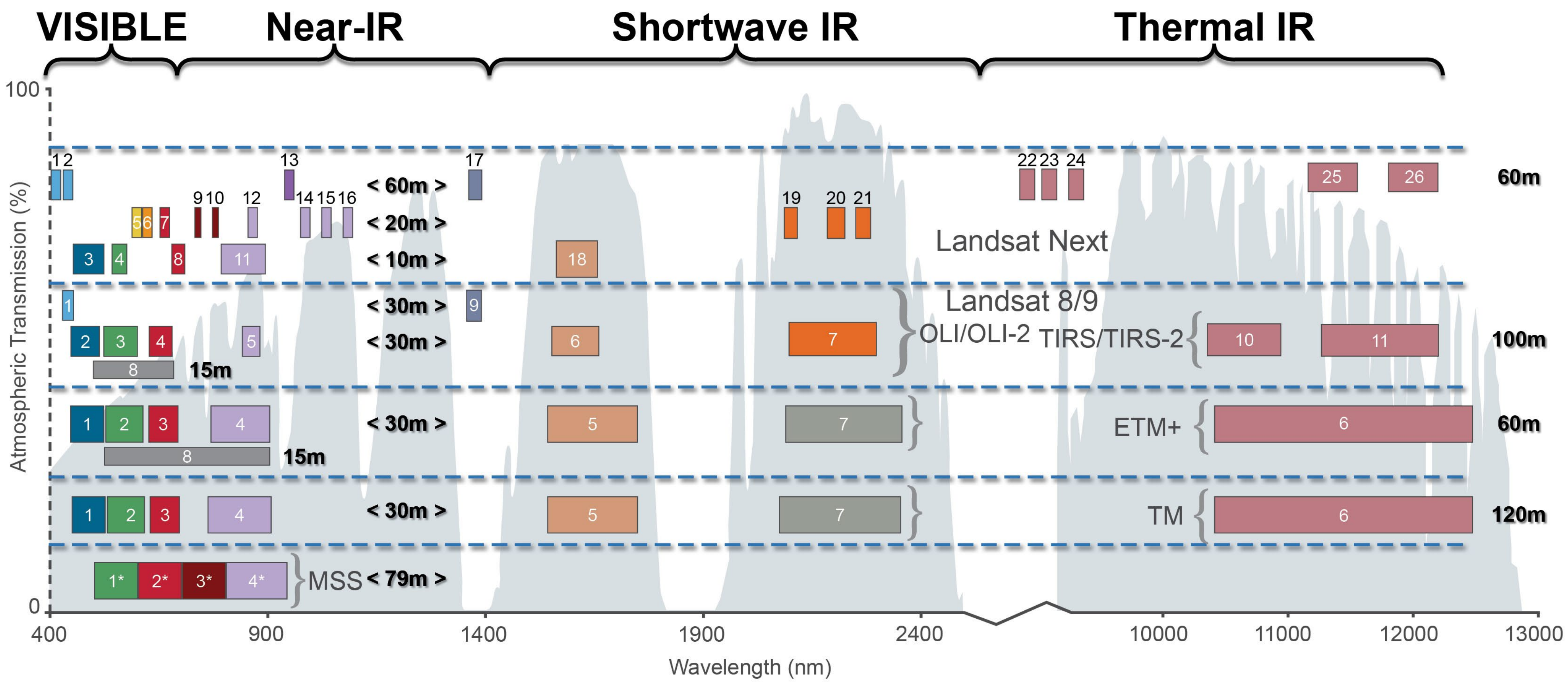
Landsat Next

Spectral Coverage

Landsat Continuity | Synergy with Sentinel-2 | Emerging Applications

	Band Name	Ground Sample Distance (m)	Center wavelength (nm)	Band width (nm)	Rationale
1	Violet	60	412	20	Improved aerosol retrieval; CDOM from inland/coastal water
2	Coastal Aerosol	20	443	20	Landsat
3	Blue	10	490	65	Landsat
4	Green	10	560	35	Landsat
5	Yellow	20	600	30	Leaf chlorosis, vegetation stress and mapping
6	Orange	20	620	20	Phycocyanin detection for Harmful Algal Blooms
7	Red 1	20	650	20	Phycocyanin, chlorophyll
8	Red 2	10	665	30	Landsat
9	Red Edge 1	20	705	15	LAI, Chlorophyll, plant stress (Sentinel-2)
10	Red Edge 2	20	740	15	LAI, Chlorophyll, plant stress(Sentinel-2)
11	NIR_Broad	10	842	115	10m NDVI (Sentinel-2)
12	NIR1	20	865	20	Landsat continuity (note-S2 narrower than L8)
13	Water vapor	60	945	20	Improved atmospheric correction for LST, SR (Sentinel-2)
14	Liquid Water	20	985	20	Liquid water, water surface state
15	Snow/Ice 1	20	1035	20	Snow grain size for water resources
16	Snow/Ice 2	20	1090	20	Ice absorption, snow grain size
17	Cirrus	60	1375	30	Landsat
18	SWIR 1	10	1610	90	Landsat
19	SWIR 2a	20	2130	30	Subdivided for cellulose/crop residue measurement (Landsat)
20	SWIR 2b	20	2220	40	Subdivided for cellulose/crop residue measurement (Landsat)
21	SWIR 2c	20	2260	40	Subdivided for cellulose/crop residue measurement (Landsat)
22	TIR 1	60	8300	250	Temperature/emissivity separation, mineral and surface composition mapping
23	TIR 2	60	8600	350	Temperature/emissivity separation, mineral mapping, volcanic emissions (SO_2)
24	TIR 3	60	9100	350	Temperature/emissivity separation, mineral and surface composition mapping
25	TIR 4	60	11300	550	Temperature/emissivity separation, cloud detection, carbonates (Landsat)
26	TIR 5	60	12000	550	Temperature/emissivity separation, cloud detection, snow grain size (Landsat)

Spectral Band Comparisons Among Landsat Missions

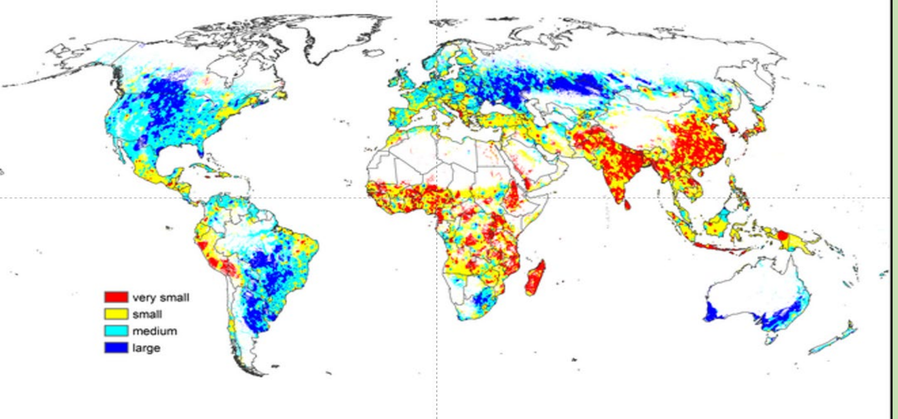


* MSS bands 1–4 were known as bands 4–7, respectively, on Landsats 1–3

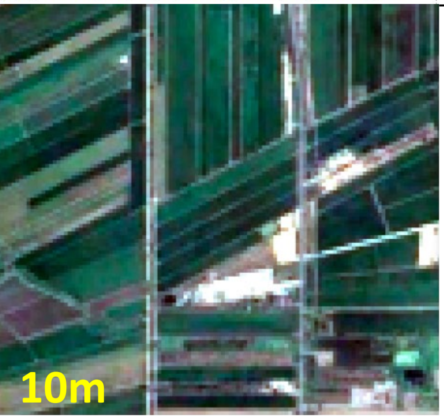
Primary Benefit Areas for Landsat Next Enhancements

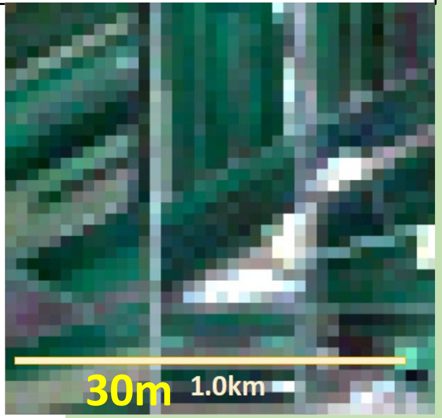
Benefit Areas		Spatial (10/60m)	Temporal (9-day)	Spectral (SS)
Agriculture	Mapping Cropland	✓		
	Crop Tillage and Soil Conservation		✓	✓
	Crop Growth and Health	✓	✓	✓
	Water Consumption	✓	✓	
Forest Monitoring	Deforestation	✓	✓	
	Forest Fires	✓	✓	
	Forest Health	✓	✓	✓
	Forest Inventory	✓	✓	✓
Water	Water Quality		✓	✓
Climate	Ice Dynamics	✓	✓	
	Urban Environments	✓	✓	
	Snow Hydrology		✓	✓
Minerals	Mineral Mapping	✓		✓

Global Cropland and Field Size



(1km) based on interpolation of field size data collected via a crowdsourced campaign using Geo-Wiki
Global Change Biology
Volume 21, Issue 5, pages 1980-1992, 16 JAN 2015 DOI: 10.1111/gcb.12838
http://onlinelibrary.wiley.com/doi/10.1111/gcb.12838/full#gcb12838-fig-0004





Monitoring Global Croplands

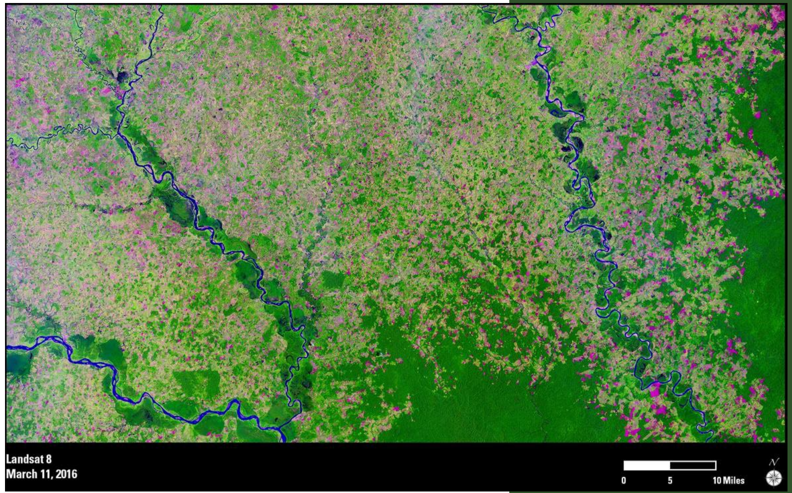
FAO estimates the gross value of global agricultural production at over <u>$5 trillion</u>.

The world population experiencing food insecurity ranges from <u>0.76 to 1 billion people</u>.

Global impacts of improved spatial resolution arise from smaller field sizes in many regions

- Food insecurity occurs in countries where smaller farmland areas are hard to monitor and delay international humanitarian assistance.
- **Landsat Next at 10m will capture most of the 40% of global croplands currently missed by Landsat (*Lesiv et al. 2018*), and 20-25% more US croplands**

Forest Monitoring – Deforestation & Carbon



During 2020, Landsat was used to measure a net change of 12 million ha in global tree cover (i.e., deforestation without regeneration or planting).

- Deforestation of primary tropical forest was equal in area to the Netherlands, and carbon emissions were equal to 570 million cars (double the number of cars on the road in the US).
- Worldwide operational alert systems based on Landsat data have allowed countries in Africa to reduce losses by 18% in five years.

Landsat Next will improve monitoring of global deforestation & net loss:

- Shortening the revisit time from 16 to 8 d will help obtain unobstructed views in persistently cloudy tropical regions.
- Forest degradation -- a reduction in tree density, diversity and health due to selective harvest, fire, urbanization, and shifting agriculture -- will be detected with Landsat Next's finer spatial resolution and enhanced spectral capability.

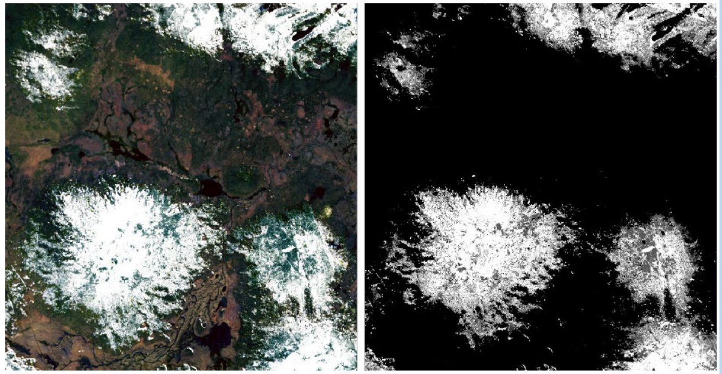
Water Quality

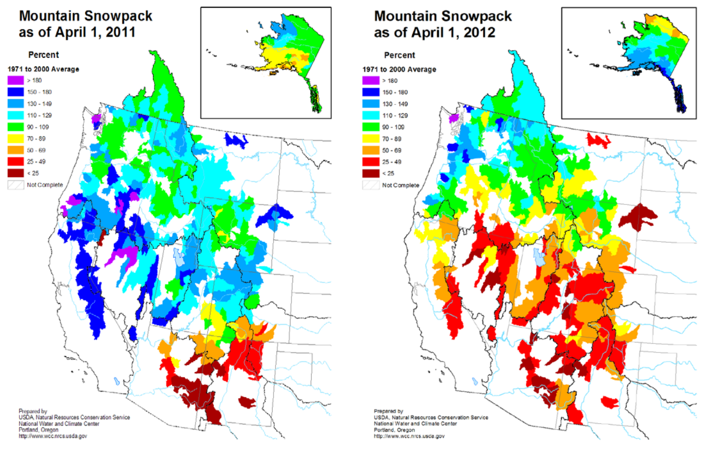
In the US alone up to 48 million Americans drink from sources susceptible to Harmful algal blooms (HABs). HABs occur with increasing frequency and impact human health, the fishing industry, coastal and lakeside property, and tourism

- For Lake Erie, a summer-long algal bloom could result in 3600 fewer fishing licenses issued and $2.25 million to $5.58 million in lost economic activity.
- One of the largest green tides ever took place in China and emergency costs estimated at $232 million and $100 million in aquaculture losses

New spectral capabilities are needed to better detect the specific organisms that cause harmful blooms at **higher frequency to allow early detection and timely mitigation**

- Narrow visible bands are needed for cyanobacteria tracking.
- A recent study indicates that Landsat Next spectral bands will improve the accuracy of HAB mapping by **up to 50%** compared to Landsat 8/9 (Zolfaghari et al., 2021)





Snow Hydrology

Systematic observations of seasonal snow are required to map and quantify snow-covered area and extent, snow cover duration and melt timing, surface albedo and light absorbing impurities.

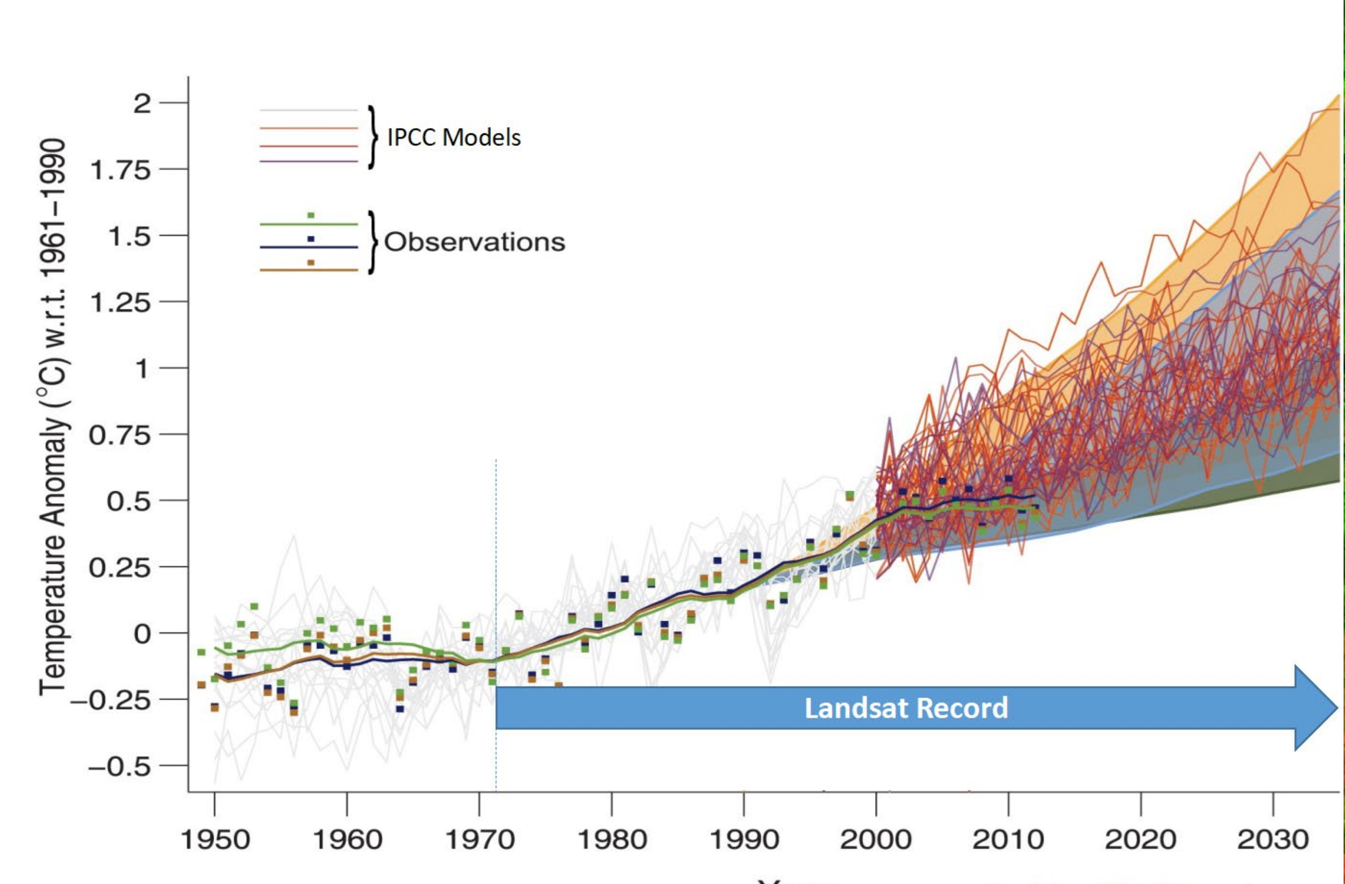
- Long term trends in decreasing Northern Hemisphere spring snow cover show significant correlations with warming temperatures
- Western US seasonal snowpack contributes between 50 to 70% of available annual water quantity in storage reservoirs
- Light absorbing impurities on snow trigger earlier melt in dust prone regions

Increased temporal frequency and new spectral measurement capabilities are needed for snow hydrology to:

- Reduce cloud cover contamination while increasing detection of rapidly evolving snow processes and melt timing
- Measure the presence of liquid water content and snow grain size for melt state determination

Landsat & Climate Change

"The US Global Change Research Program identified Landsat as a critical observatory for climate and environmental change research due to the unbroken length of the Landsat record and its ability to monitor remote regions with surface features such as glaciers, rainforests, permafrost, and coral reefs."
-CRS Report on L9 and the Future of the Sustainable Land Imaging Program

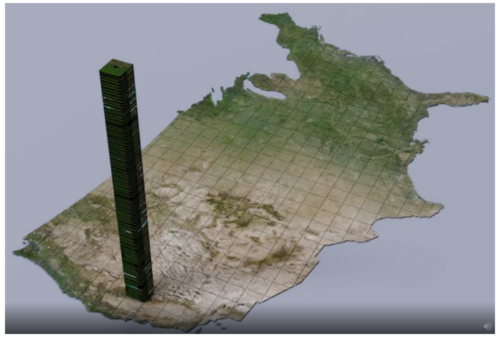


Graph from IPCC AR5 report

- Deforestation, Reforestation, and global carbon sources/sinks
- Long-term ecologic responses to climate change (eg. high latitude greening; forest die back; coral bleaching)
- Glacier and ice sheet velocity and mass balance
- Short-term impacts of droughts on crop productivity and natural vegetation
- Urban heat islands

LNext Science Data Products

- **LNext science mission products will include the following in either scene or tiled formats for VSWIR and TIR measurements:**
  - Level-1 Top of Atmosphere (TOA) calibrated digital counts, view angles, and metadata
  - Level-2 Surface Reflectance, Aquatic Reflectance, Surface Temperature, and Surface Emissivity geophysical quantities, view angles, and metadata
- **LNext science algorithms (i.e., atmospheric correction) for product generation will require evolution and advances:**
  - Leverage new atmospheric and surface spectral measures on-board (e.g., aerosol, water vapor, emissivity)
  - Will include BRDF correction to nadir reflectance
  - TIR algorithms will combine temperature-emissivity separation (TES) and generalized dual channel techniques
- **LNext science mission products will be processed into the existing Landsat Collection at time of operations**



Source: USGS

Summary

- Landsat Next draft requirements reflect **documented priorities** from the user community for improved temporal revisit, higher spatial resolution, and additional spectral coverage.

- Landsat Next provides **a quantum leap in measurement capabilities** in order to meet emerging challenges in land and climate science.

- Landsat Next continues the long-term calibration, stability and **science quality** Landsat data, while promotes synergy with international missions such as the Sentinel-2.