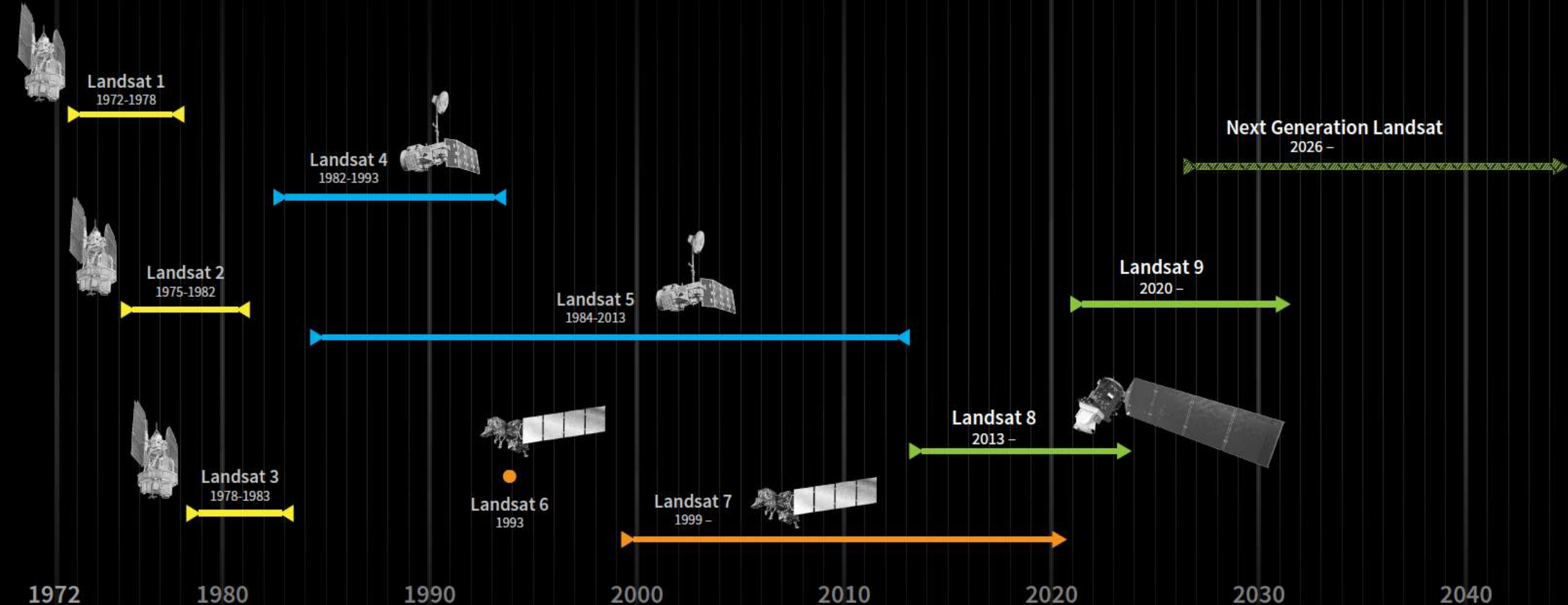


# Update on Landsat 9 and Sustainable Land Imaging

Jeff Masek, NASA Landsat Project Scientist / GSFC  
September 24, 2019

# BUILDING ON THE LANDSAT LEGACY

Landsat is a USGS/NASA Partnership





# Landsat Science: 1600 peer-reviewed papers per year

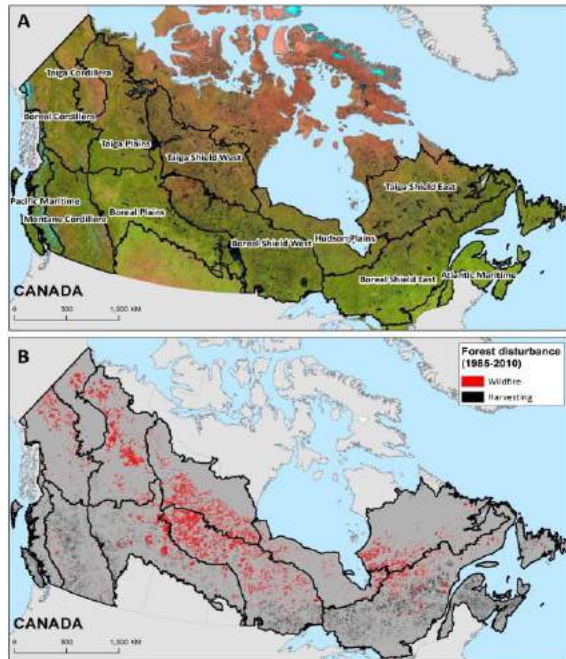
- Global mapping of patterns and trends in land cover & land use
- Climate impacts on ecosystems
- Physical climatology, hydrology, cryosphere processes



A nationwide annual characterization of 25 years of forest disturbance and recovery for Canada using Landsat time series

Joanne C. White<sup>1,\*</sup>, Michael A. Wulder<sup>4</sup>, Txomin Hermosilla<sup>13</sup>, Nicholas C. Coops<sup>13</sup>, Geordie W. Hobart<sup>4</sup>

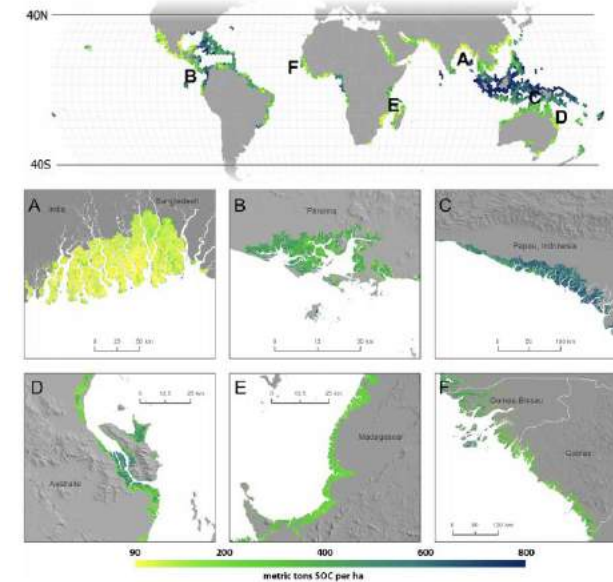
<sup>1</sup> Canadian Forest Service, Pacific Forestry Centre, Natural Resources Canada, 3000 Hwy 100, Victoria BC V8T 4M2, Canada  
<sup>4</sup> Department of Forest Biology Management, Forest Science Center, 2603 Wood-Mill University of British Columbia, Vancouver, BC V6T 1Z4, Canada



## Environmental Research Letters

### A global map of mangrove forest soil carbon at 30 m spatial resolution

Jonathan Sanderman<sup>1,2,3</sup>, Tomislav Hengl<sup>2</sup>, Greg Fiske<sup>4</sup>, Kylan Solvik<sup>1</sup>, Maria Fernanda Adame<sup>5</sup>, Lisa Benson<sup>6,7</sup>, Jacob J. Bukoski<sup>8</sup>, Paul Carnell<sup>9</sup>, Miguel Cifuentes-Jara<sup>8</sup>, Daniel Donato<sup>10</sup>, Clare Duncan<sup>6,8</sup>, Ebrahim M. Eid<sup>11,12</sup>, Philine zu Ermgassen<sup>13,14</sup>, Carolyn J. Ewers Lewis<sup>8</sup>, Peter I. Macreadie<sup>8</sup>, Leah Glass<sup>8</sup>, Selena Gress<sup>15</sup>, Sunny L. Jardine<sup>12</sup>, Trevor G. Jones<sup>13</sup>, Eugene Ndemem Nsoombo<sup>16</sup>, Md. Mizanur Rahman<sup>15</sup>, Christian J. Sanders<sup>10</sup>, Mark Spalding<sup>17</sup> and Emily Landis<sup>17</sup>

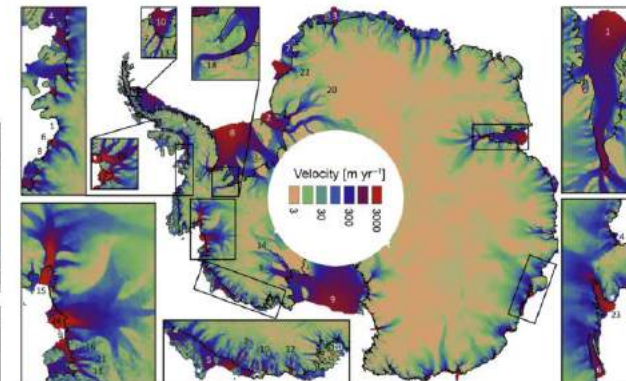


The Cryosphere, 12, 521–547, 2018  
https://doi.org/10.5194/tc-12-521-2018  
© Author(s) 2018. This work is distributed under the Creative Commons Attribution 3.0 License.



### Increased West Antarctic and unchanged East Antarctic ice discharge over the last 7 years

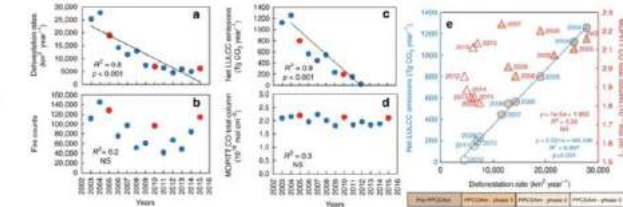
Alex S. Gardner<sup>1</sup>, Geir Moholdt<sup>2</sup>, Ted Scambos<sup>3</sup>, Mark Fahnestock<sup>4</sup>, Stefan Ligtenberg<sup>5</sup>, Michiel van den Broeke<sup>5</sup>, and Johan Nilsson<sup>1</sup>



Article | Open Access | Published: 13 February 2018

### 21st Century drought-related fires counteract the decline of Amazon deforestation carbon emissions

Luiz E. O. C. Aragão<sup>1</sup>, Liana O. Anderson, Marisa G. Fonseca, Thais M. Rosan, Laura B. Vedovato, Fabien H. Wagner, Camila V. J. Silva, Celso H. L. Silva Junior, Egidio Arai, Ana P. Aguiar, Jos Barlow, Erika Berenguer, Merritt N. Deeter, Lucas G. Domingues, Luciana Gatti, Manuel Gloor, Yadvinder Malhi, Jose A. Marengo, John B. Miller, Oliver L. Phillips & Sassan Saatchi

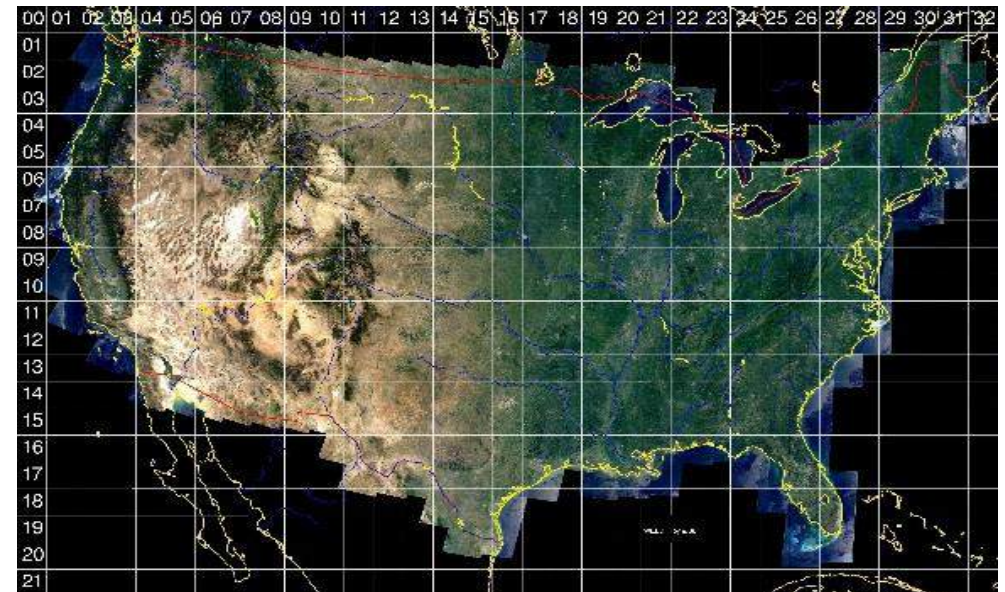


Annual trends in deforestation and forest fire-associated carbon emissions in the Brazilian Amazon. Linear trends (2003–2015) of annual **a** deforestation rates, **b** active fires counts, **c** reported Brazilian net land use and land cover change-related CO<sub>2</sub> emission estimates<sup>1</sup> (Net LULCC emissions) and **d** Measurements of Pollution in the Troposphere (MOPITT) CO total

# Landsat Products: USGS

- USGS releasing “Collection 2” data products early 2020
  - Improved geolocation via Sentinel-2 Global Reference
  - Routine Level 2 (Surface Reflectance, Surface Temperature) products from L5-8
- US Analysis Ready Data surface reflectance available on tiled UTM grid
- Level-3 Products available for US
  - Dynamic surface water extent
  - Burned area
  - Snow-covered area

<https://www.usgs.gov/land-resources/nli/landsat>





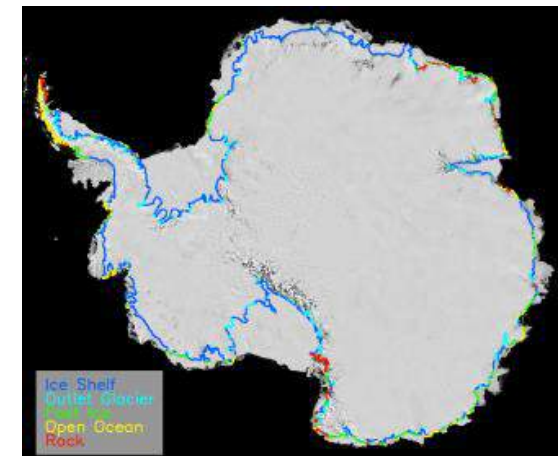
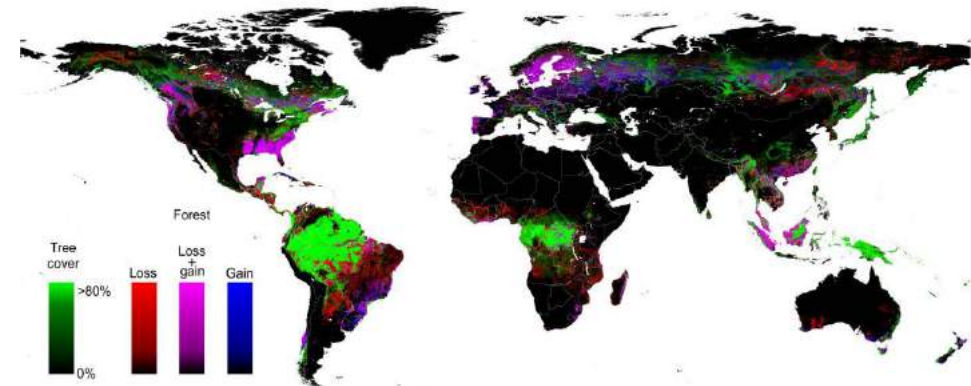
# Landsat Products: Community

## Global land cover / land use

- Global forest change (Hansen/UMD)
- Global agricultural extent (Thenkabail/USGS)
- Dynamic surface water (Pekel/JRC)
- GoLIVE Land Ice Velocity (Scambos/NSIDC)
- Urbanized Area (DeCoulston/GSFC)

## US National Applications

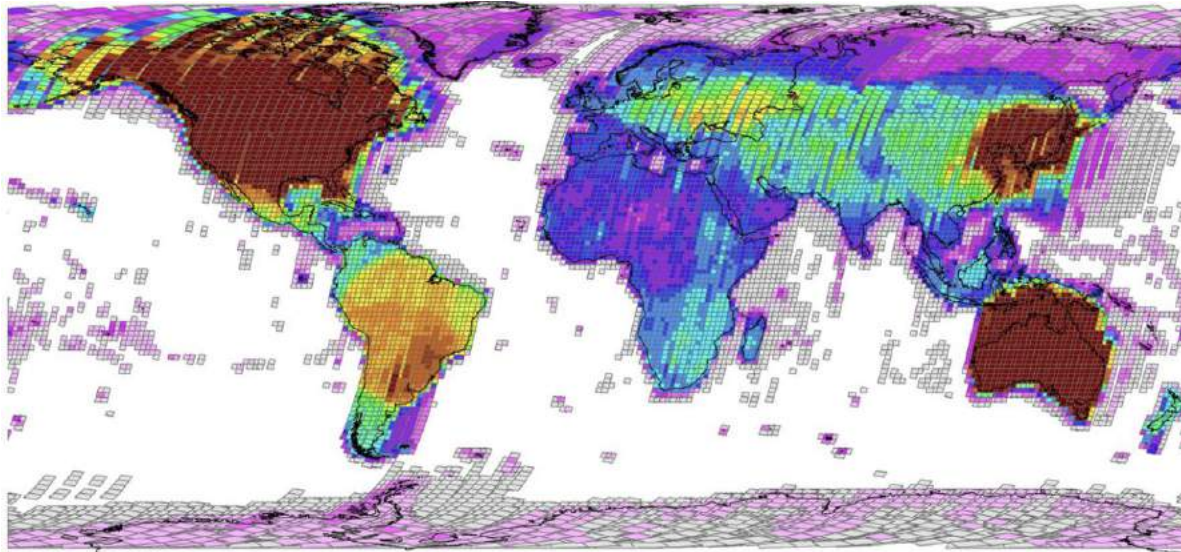
- USDA Cropland Data Layer
- USFS/USGS Landfire & MTBS
- USGS National Land Cover (NLDC, LC-MAP)



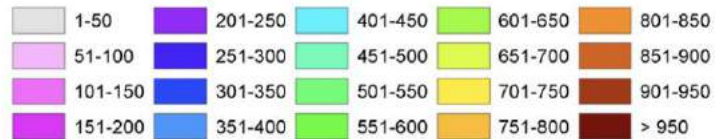
# Landsat Archive Status

- USGS Archive includes ~7M scenes
- ~1200 new images added each day (Landsat 7, 8)

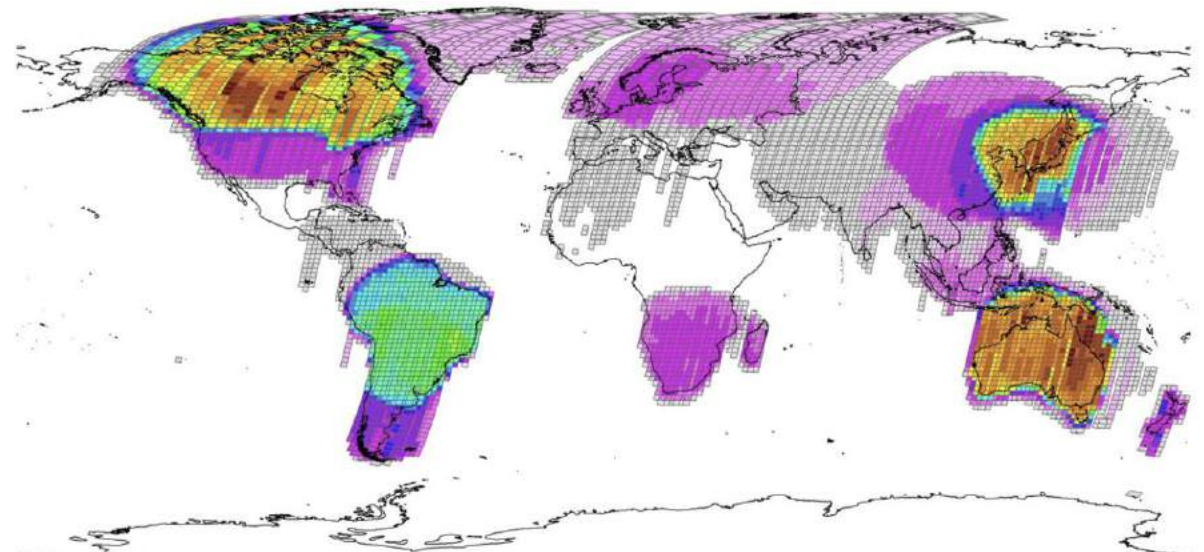
2015 USGS Archive Density



Number of images



Global Archive Consolidation (LGAC) Contribution



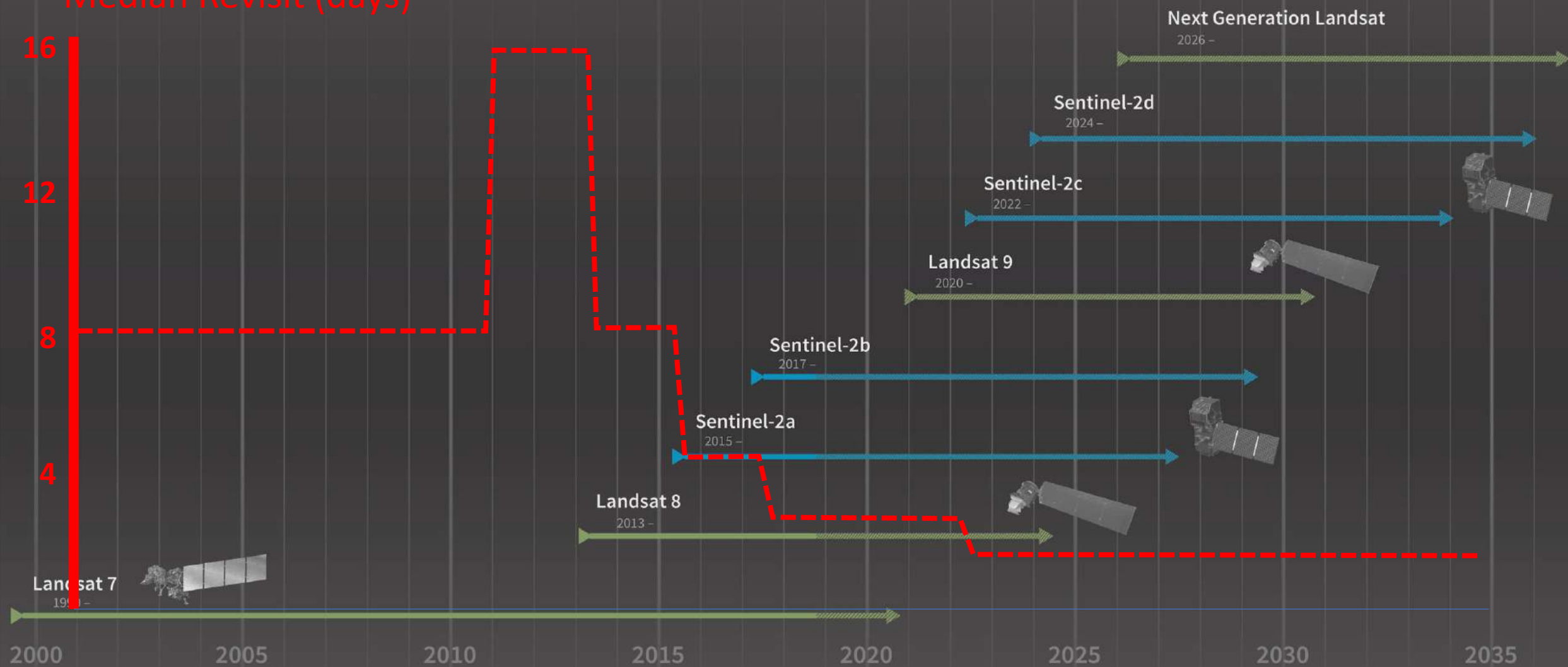
Number of images





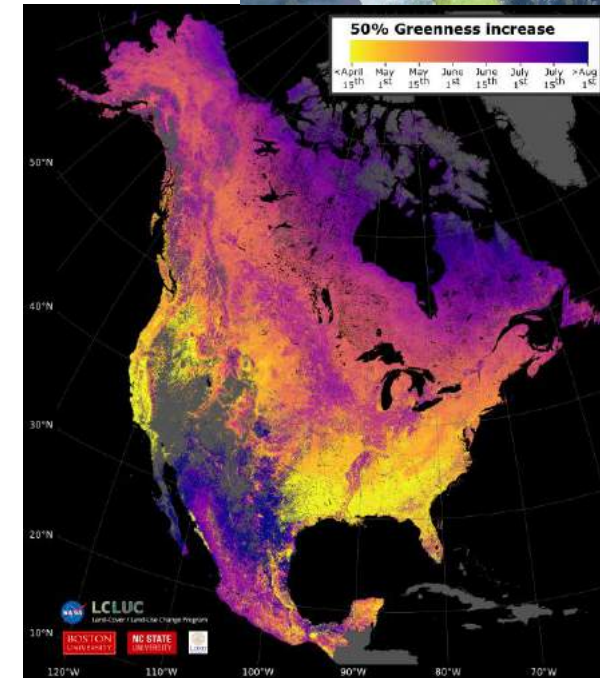
# The Landsat + Sentinel-2 Constellation

Median Revisit (days)



# Landsat / Sentinel Synergy

- More data are better!
- Combining Landsat & Sentinel-2 allows global land revisit every 2-3 days
- Landsat & Sentinel-2 teams collaborate on instrument characterization & cross-calibration
- New research products
  - Harmonized Landsat/Sentinel-2 (HLS)
  - LCLUC Multi-Sensor Land Imaging (MuSLI)



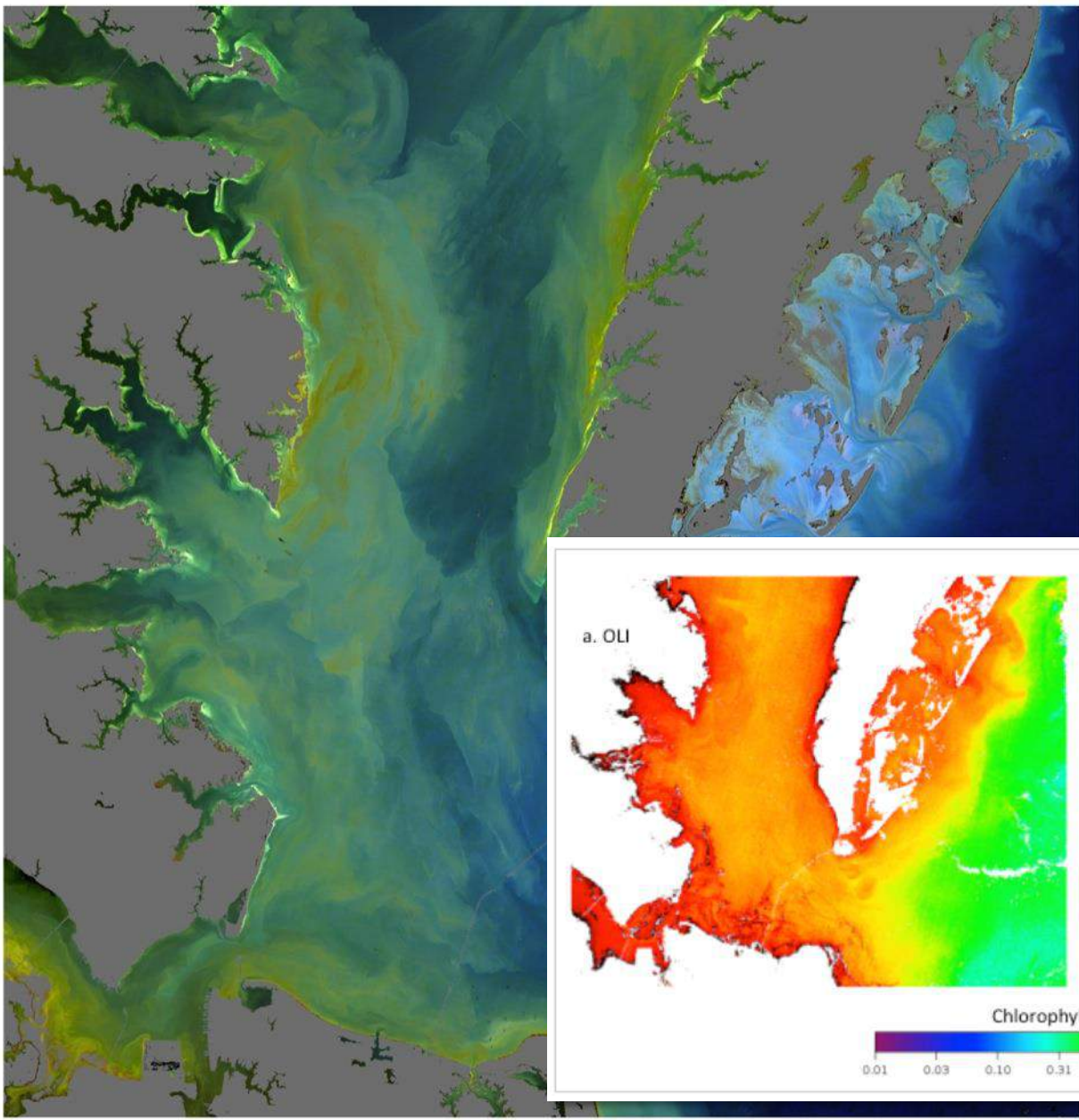
*Courtesy M. Friedl, BU*



# Landsat 9 Status

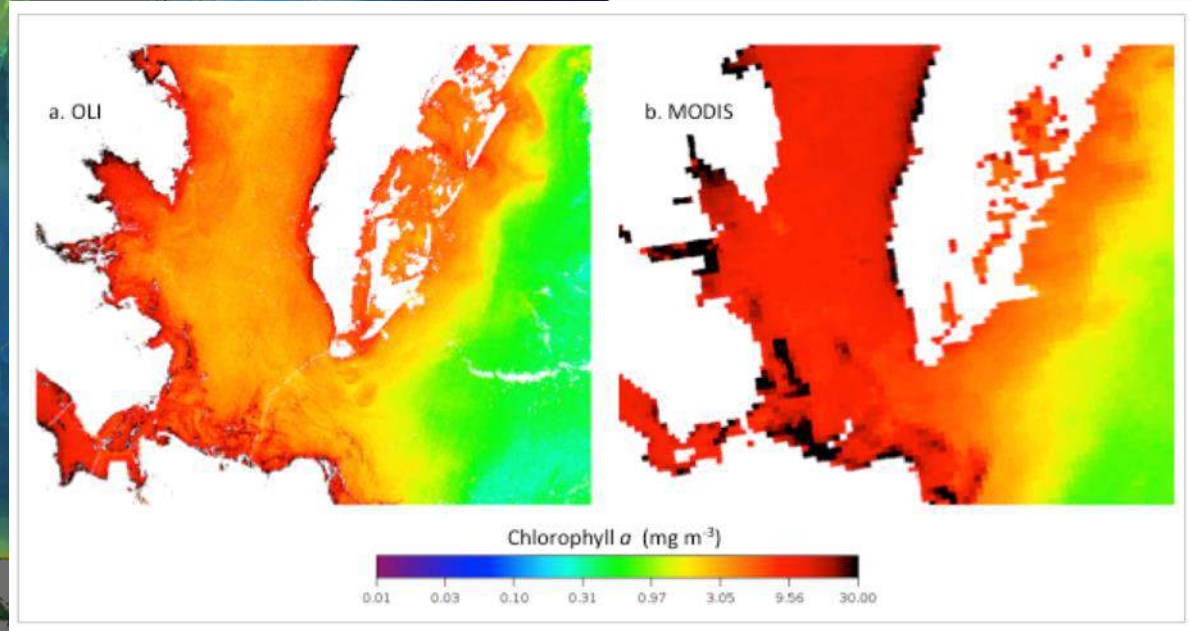
- Landsat 9 is a “near clone” of Landsat 8
  - Partnership between NASA (space segment) and USGS (ground segment and operations)
  - 30m VSWIR imagery from Operational Land Imager 2 (OLI-2)
  - 100m TIR imagery from Thermal Infrared Sensor 2 (TIRS-2)
- Instruments are complete and have shipped to Northrup-Grumman for integration on the spacecraft
  - Instrument performance appears to be excellent
  - Stray light on TIRS-2 reduced by ~10x compared to Landsat 8 TIRS
- Landsat 9 still slated for December 2020 launch
  - Spacecraft integration is slightly delayed, and the schedule is challenging





## Landsat-8 OLI Coastal Ocean Color

*Improved OLI SNR & 443 nm band  
permit Landsat-based retrieval of  
Chlorophyll A for the first time*



**Figure 4:** *Three-band water-leaving reflectance,  $R_{rs}(\lambda)$ , composite image over the mouth of Chesapeake Bay showing detailed distribution patterns of sediments and colored organic matter that can be retrieved from OLI using standard NASA ocean color processing in SeaDAS. The composite was generated using the red, green, and blue reflectances at 655, 561, and 443nm, respectively.*

*Franz et al., 2014*



# Sustainable Land Imaging - Overview

**While recognizing the scientific need for continuity with the 47-year Landsat record, we are seeing new trends & opportunities in land remote sensing**

- *Evolving user needs for...*
  - *Improved temporal revisit*
  - *Additional spectral coverage & resolution*
  - *Higher spatial resolution*
  - *Integration with other modalities (lidar, radar)*
- *Increasing use of “small sat” platforms and distributed architectures*
- *Increasing number of commercial imaging systems*
- *Potential synergy with international systems (e.g. Sentinel-2)*
- *High-performance computing and increased emphasis on information rather than images*

**The challenge is to advance the measurement capability, while preserving continuity and constraining program costs**

# Sustainable Land Imaging – Architecture Study

USGS and NASA are currently collaborating on an architecture study for future US Land Imaging missions:

“Execute a feasibility study for the design and implementation approach of a [spaceborne system to provide global, continuous Landsat-quality multispectral and thermal infrared measurements](#) for approximately a fifteen-year period starting in 2026... Address commercial, international, and other US Government providers of Earth observation data”

Architecture Study Team (AST) considering non-traditional options for Landsat follow-on, including constellation approaches, multi/super/hyperspectral options, international partnerships, and incorporation of commercial data streams

Study input includes:

- User needs assessed by USGS survey approach
- New instrument options from industry via NASA Earth Science Technology Office (ESTO)



# Draft SLI Threshold Requirements

- Supports most minimum user needs
- Clear observation every ~14 days (8 day revisit)
- VSWIR bands at 30m, TIR/atmospheric bands at 60m
- Current Landsat spectral bands with minor additions
  - Water vapor (S2; atmospheric correction)
  - Red edge bands (S2; vegetation condition/health & water quality)
  - 8.6mm TIR band (ASTER/MODIS; emissivity/LST separation)

	Band name	GSD (m)	Center wavelength (nm)	Band width (nm)
1	Coastal Aerosol	60	443	20
2	Blue	30	490	65
3	Green	30	560	35
4	Red	30	665	30
5	Red Edge 1	30	705	15
6	Red Edge 2	30	740	15
7	Red Edge 3	30	783	20
8	NIR	30	865	20
9	Water vapor	60	945	20
10	Cirrus	60	1375	30
11	SWIR 1	30	1610	90
12	SWIR 2	30	2190	180
14	TIR 1	60	8650	350
15	TIR 2	60	10800	1000
16	TIR 3	60	12000	1000

# Draft SLI Goal Requirements

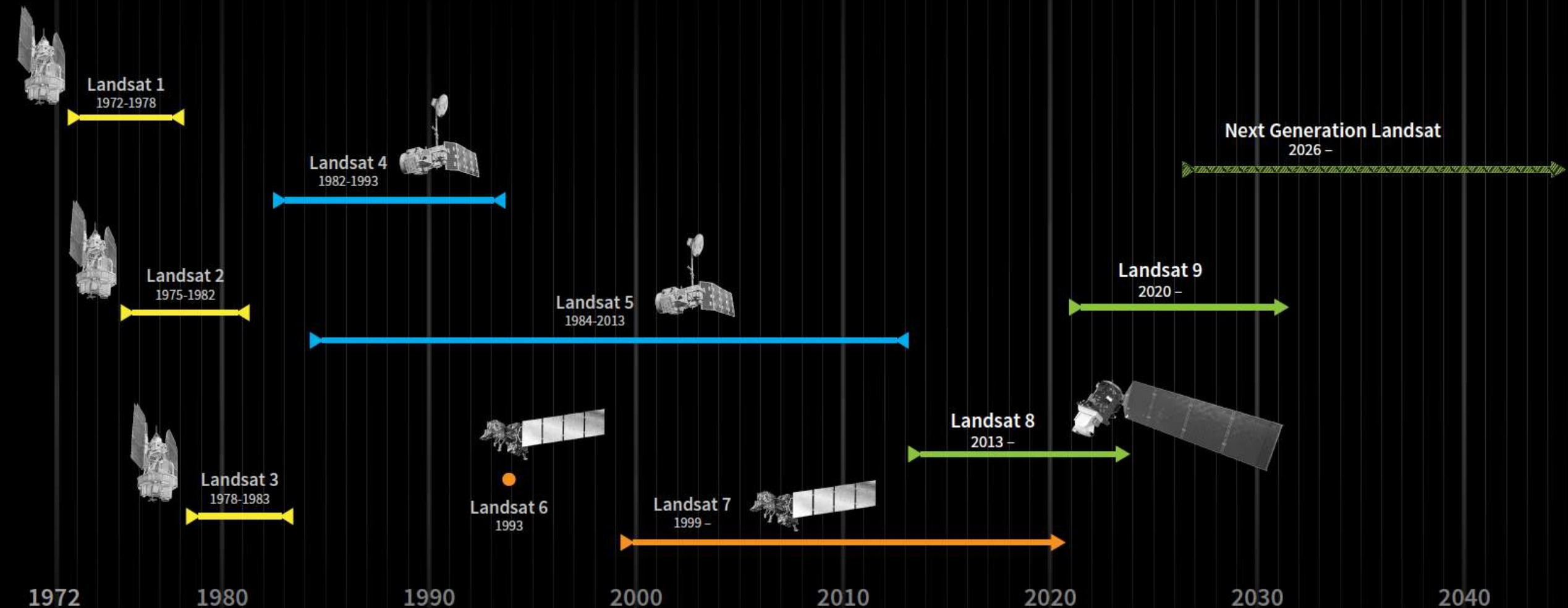
- Supports many breakthrough user needs
- Clear observation every ~5 days (3 day revisit)
- VNIR at 10m; narrow bands and SWIR at 20m; atmospheric/TIR at 60m
- Additional, high-priority narrow bands

	Band name	GSD (m)	Center wavelength (nm)	Band width (nm)	Rationale
1a	Violet	60	410	20	Improved aerosol retrieval; CDOM from inland/coastal water
1	CA	60	443	20	Landsat
2	Blue	10	490	65	Landsat
3	Green	10	560	35	Landsat
4a	Orange	20	620	20	Phycocyanin detection for Harmful Algal Blooms
4	Red	10	665	30	Landsat
5	Red Edge 1	20	705	15	LAI, Chlorophyll, plant stress (S2)
6	Red Edge 2	20	740	15	LAI, Chlorophyll, plant stress (S2)
7	Red Edge 3	20	783	20	Water quality (TBR) (S2)
8	NIR_Broad	10	842	115	10m NDVI (S2)
8a	NIR1	20	865	20	Continuity (note – S2 narrower than L8)
9	Water vapor	60	945	20	Improved atmospheric correction for LST, SR (S2)
8b	NIR2	20	1035	20	Snow grain size for water resources
10	Cirrus	60	1375	30	Landsat
11	SWIR 1	20	1610	90	Landsat
12a	SWIR 2a	20	2040	30	Subdivided for cellulose/crop residue measurement (Landsat)
12b	SWIR 2b	20	2100	40	Subdivided for cellulose/crop residue measurement (Landsat)
12c	SWIR 2c	20	2210	40	Subdivided for cellulose/crop residue measurement (Landsat)
13	MWIR*	60	3980	300	Active fire, volcanos, fire radiative power (MODIS)
14a	TIR 1a	60	8300	350	Mineral and surface composition mapping (ASTER)
14	TIR 1	60	8650	350	Emissivity separation, volcanos (SO2) (MODIS/ASTER)
14b	TIR 1b	60	9100	350	Mineral and surface composition mapping (ASTER)
15	TIR 2	60	10800	1000	Surface temperature (Landsat)
16	TIR 3	60	12000	1000	Surface temperature, snow grain size (Landsat)

\*MWIR currently being evaluated for value/feasibility

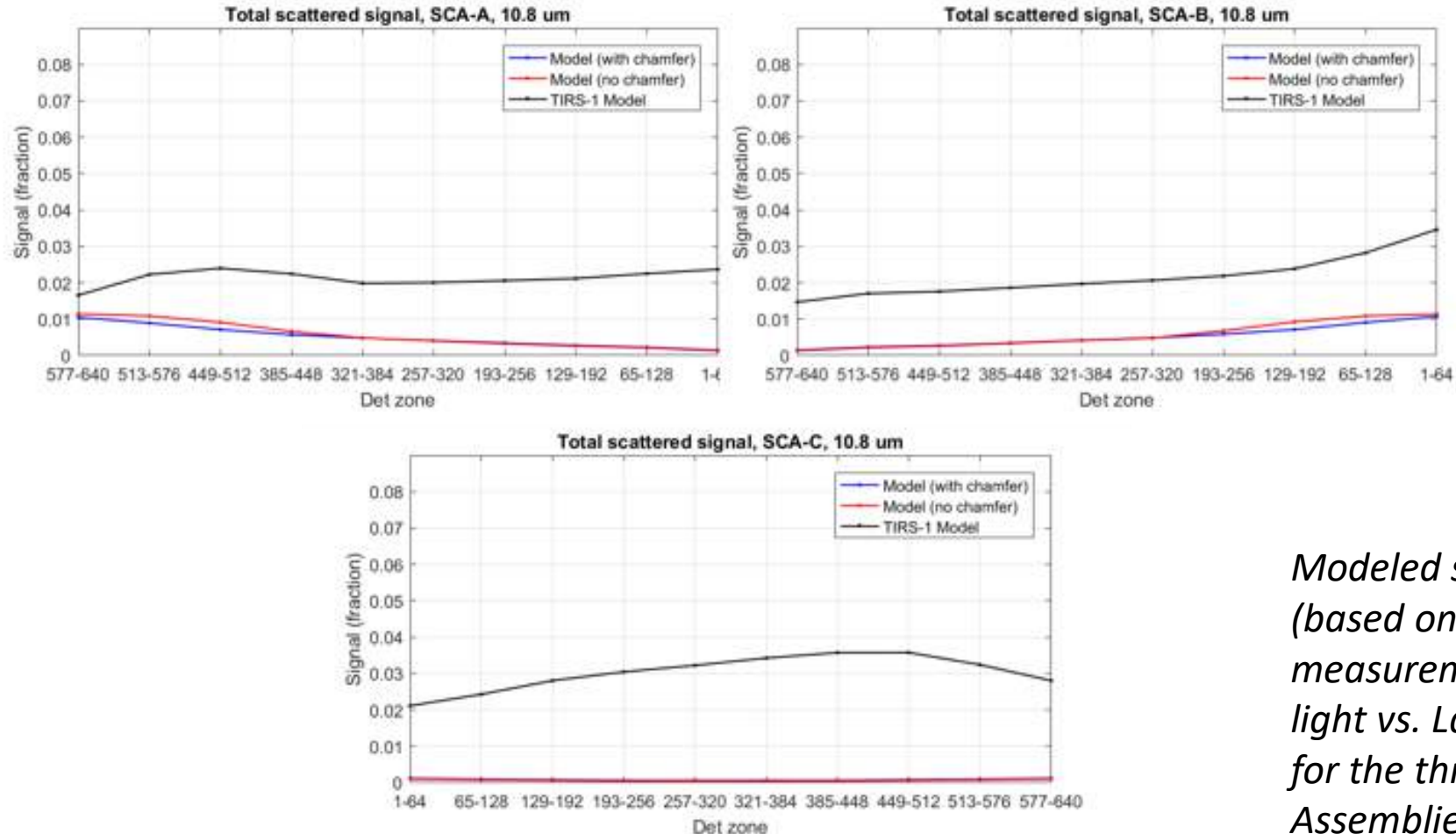


# BUILDING ON THE LANDSAT LEGACY



Backup

# TIRS-2 Stray Light – Reduced by 10x



*Modeled stray light performance (based on pre-launch measurements) of TIRS-2 stray light vs. Landsat 8 TIRS stray light, for the three TIRS Sensor Chip Assemblies*