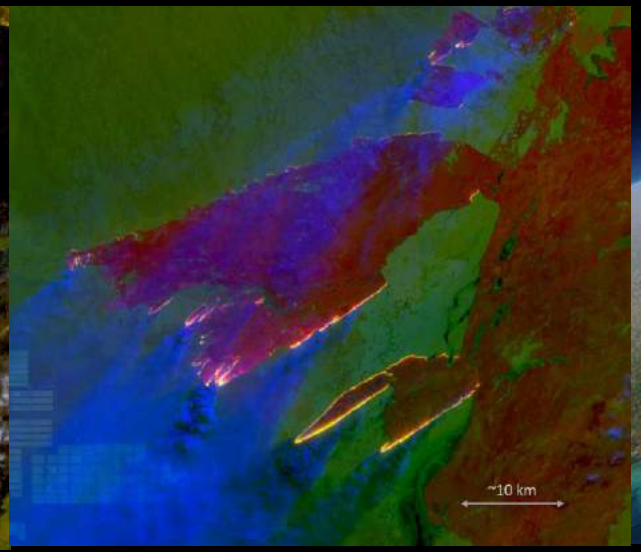


Update on Landsat 9 and Sustainable Land Imaging

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

Building on the Landsat Legacy

Landsat is a USGS/NASA Partnership

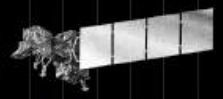
Landsat 1
1972-1978

Landsat 4
1982-1993

Landsat 2
1975-1982

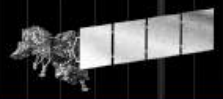
Landsat 5
1984-2013

Landsat 3
1978-1983



Landsat 6
1993

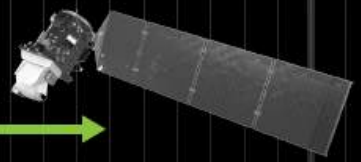
Landsat 7
1999 –



Next Generation Landsat
2026 –

Landsat 9
2020 –

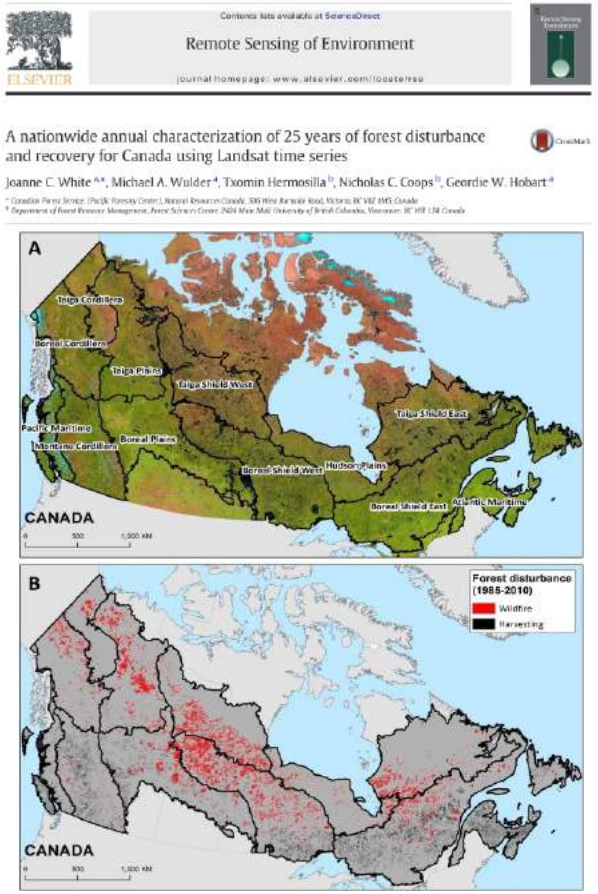
Landsat 8
2013 –

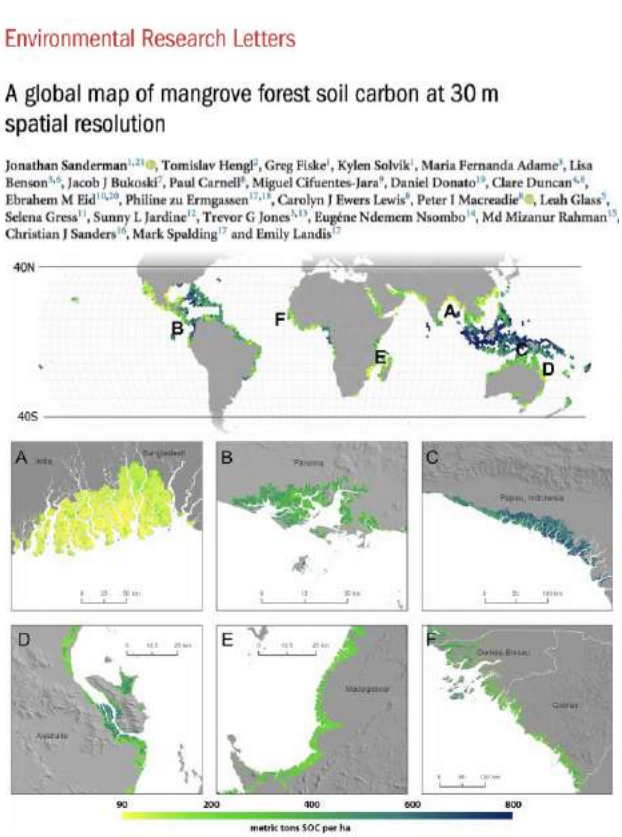


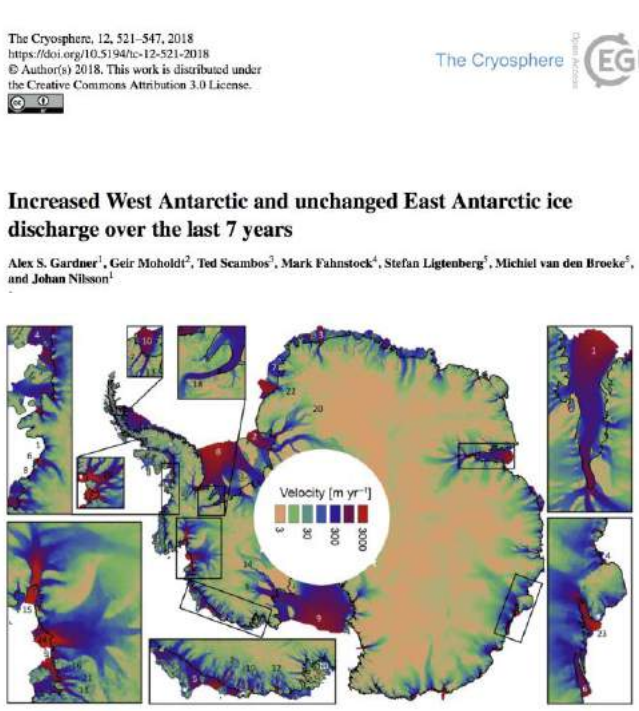
1972 1980 1990 2000 2010 2020 2030 2040

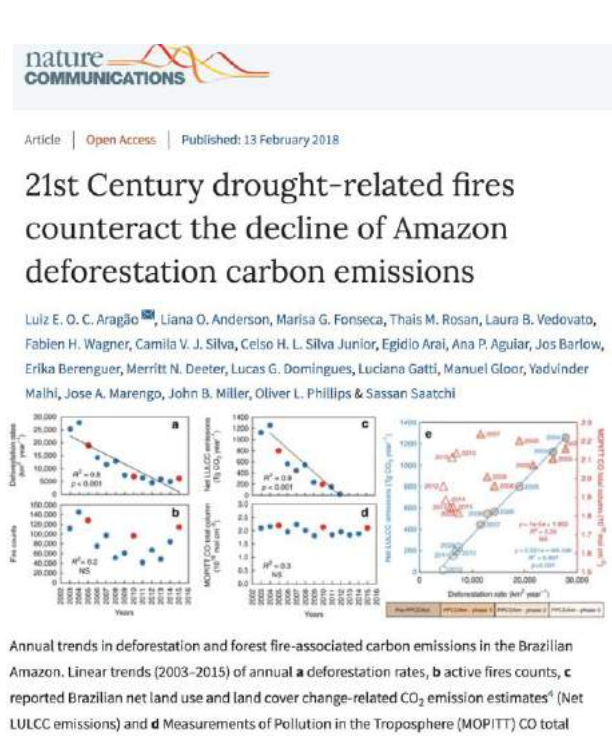
Landsat Science: 1600 peer-reviewed papers per year

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







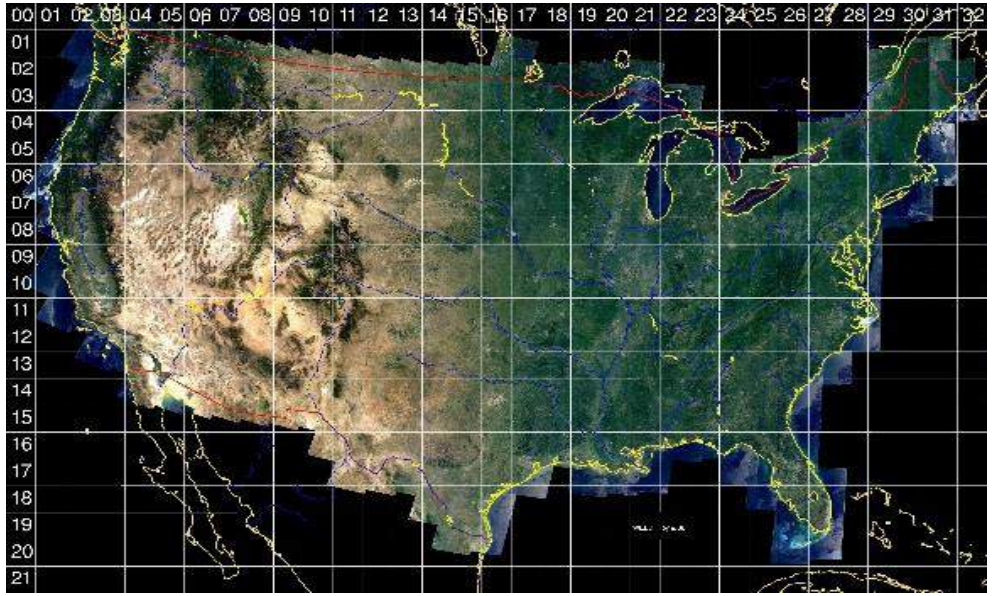


Landsat Products: USGS

- 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

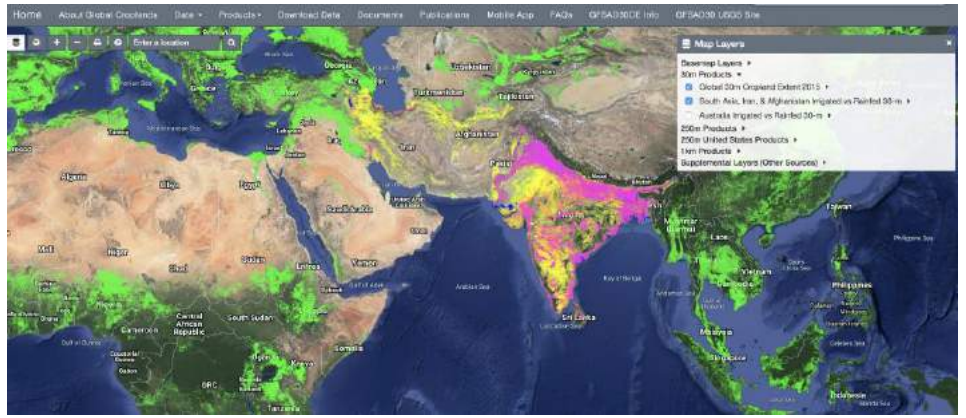
Landsat Products: Community

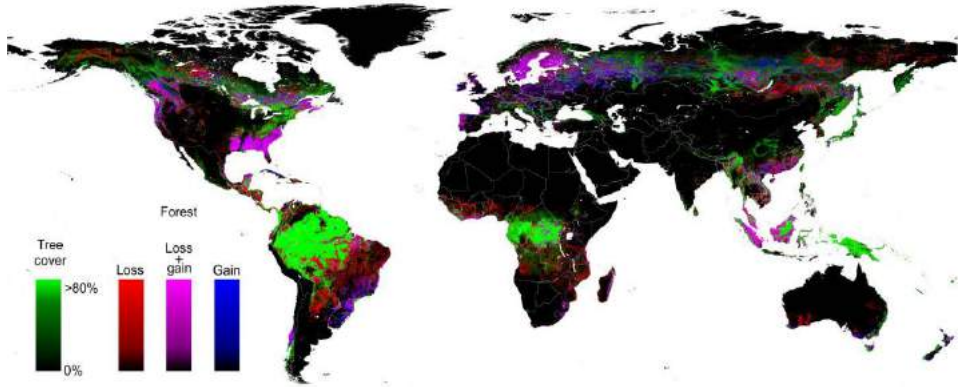
Global land cover / land use

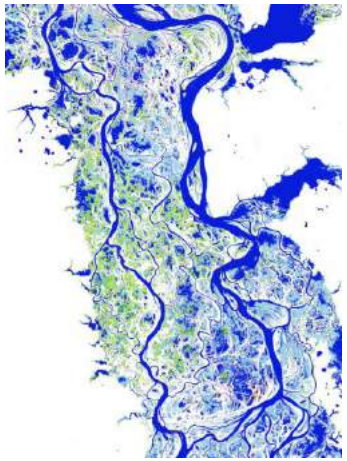
- Global forest change (Hansen/UMD)
- Global agricultural extent (Thenkabail/USGS)
- Dynamic surface water (Pekel/JRC)
- GoLIVE Land Ice Velocity (Scambos/NSIDC)
- Urbanized Area (DeCoulston/GSFC)

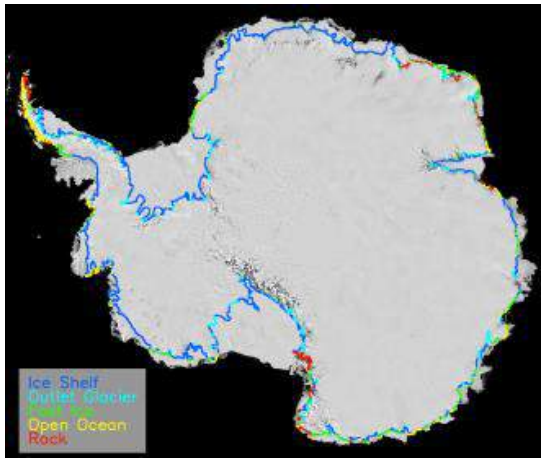
US National Applications

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





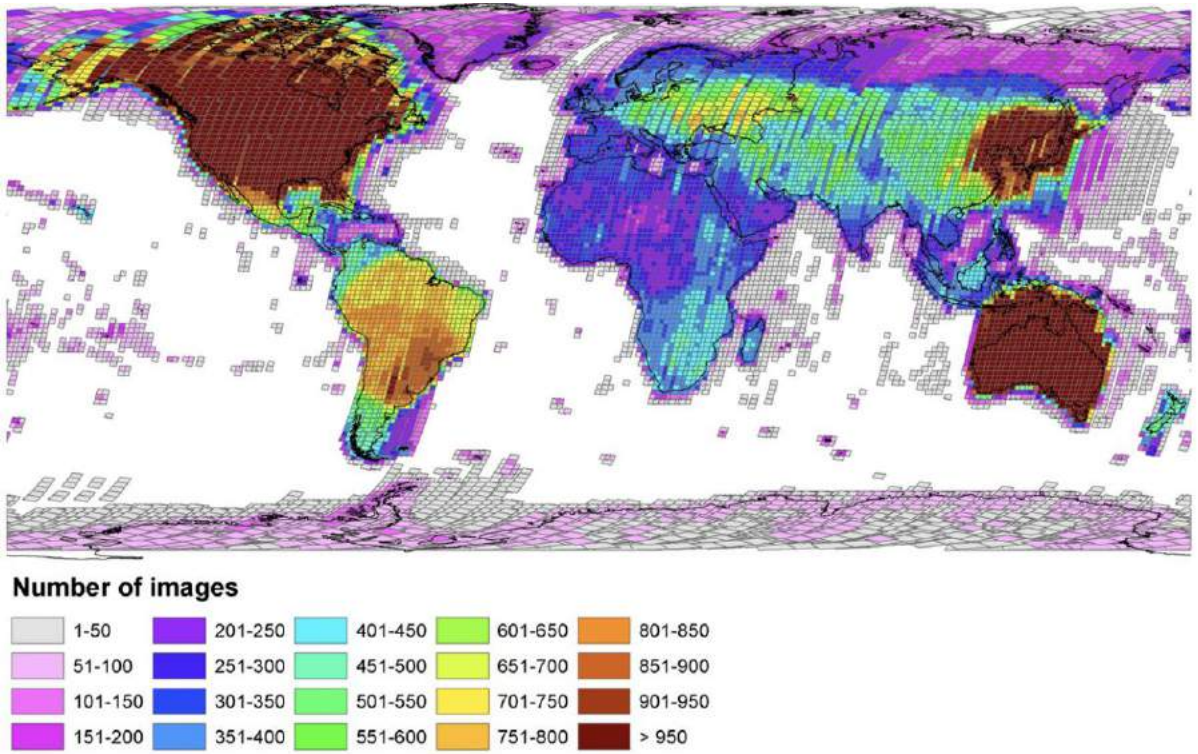




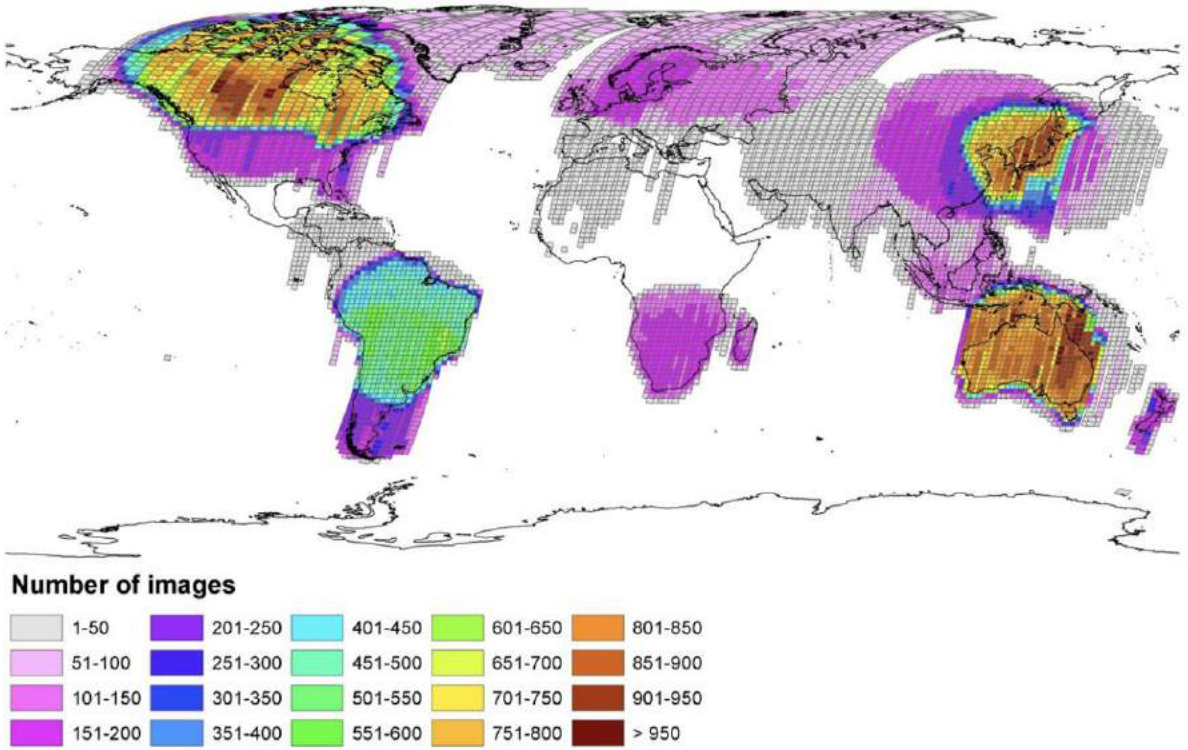
Landsat Archive Status

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

2015 USGS Archive Density

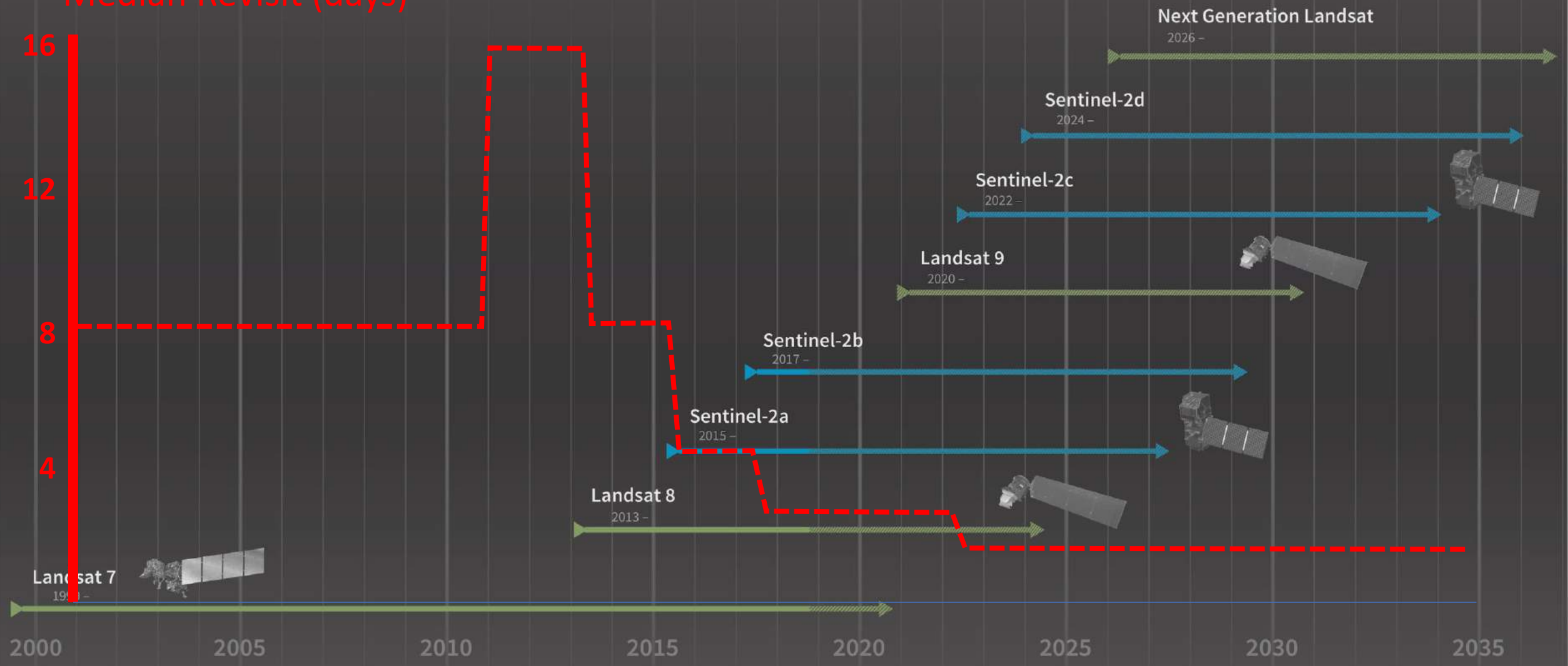


Global Archive Consolidation (LGAC) Contribution



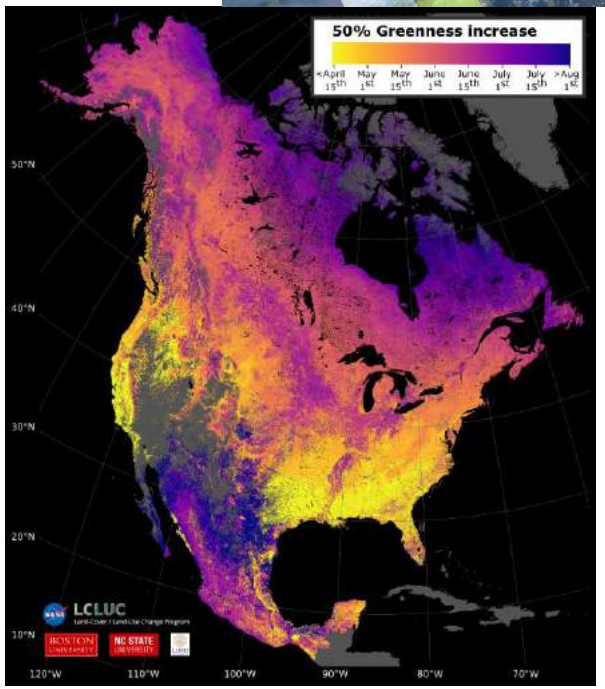
From Wulder et al., 2016, RSE

The Landsat + Sentinel-2 Constellation



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 delayede, 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

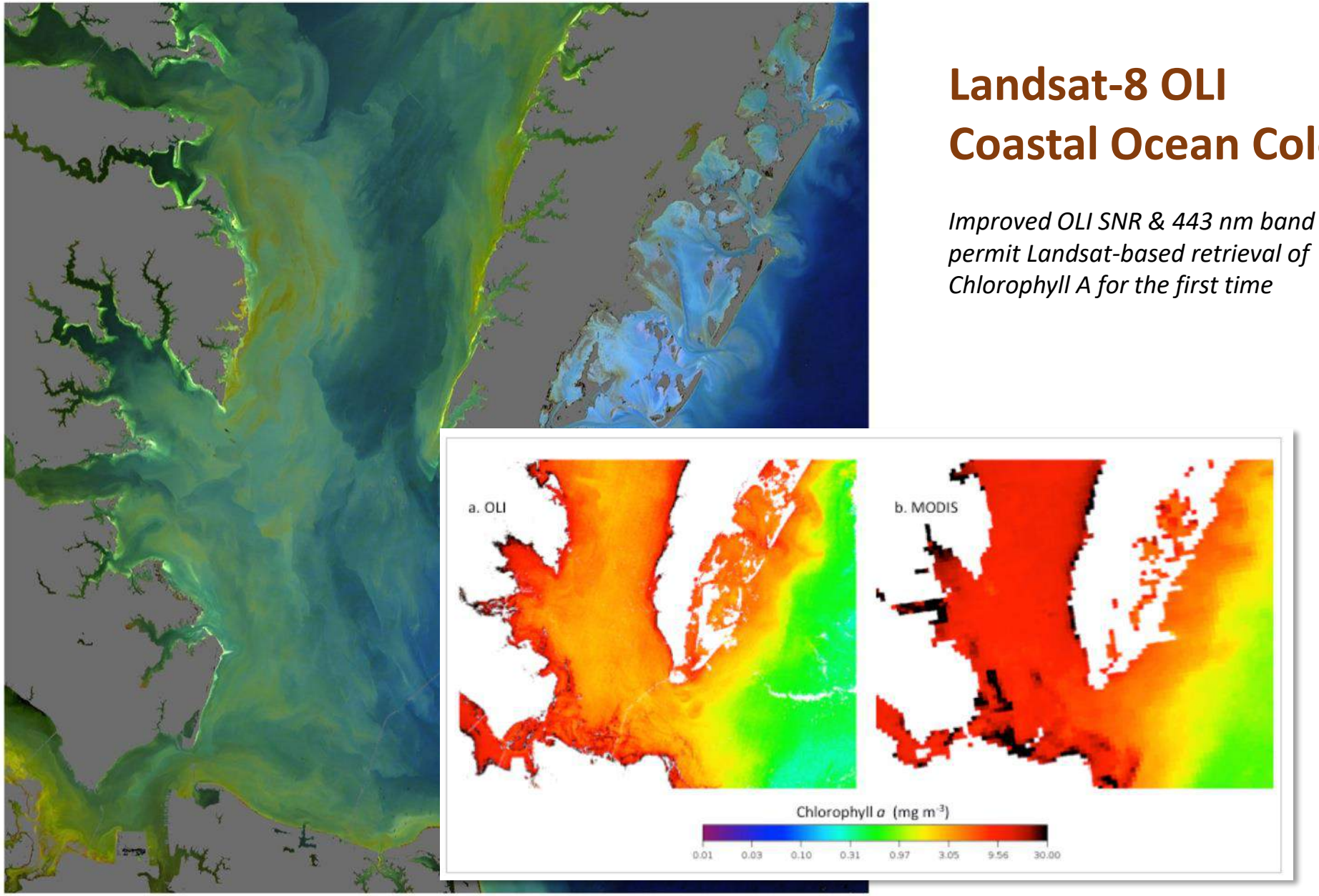


Figure 4: ***Three-band water-leaving reflectance, Rrs(λ), composite image over the mouth of Chesapeake Bay showing detailed distribution patterns of sediments and colored organic matter that can be retrieved from OLI using standard NASA ocean color processing in SeaDAS. The composite was generated using 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

https://www.fbo.gov/utils/view?id=25beed08973428c9c649250fa5c546f7

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

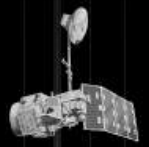
	Band name	GSD (m)	Center wavelength (nm)	Band width (nm)	Rationale
1a	Violet	60	410	20	Improved aerosol retrieval; CDOM from inland/coastal water
1	CA	60	443	20	Landsat
2	Blue	10	490	65	Landsat
3	Green	10	560	35	Landsat
4a	Orange	20	620	20	Phycocyanin detection for Harmful Algal Blooms
4	Red	10	665	30	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*

https://www.fbo.gov/utils/view?id=25beed08973428c9c649250fa5c546f7

Building on the Landsat Legacy

Landsat 1
1972-1978



Landsat 4
1982-1993

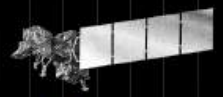
Next Generation Landsat
2026 –

Landsat 2
1975-1982

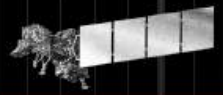
Landsat 5
1984-2013

Landsat 9
2020 –

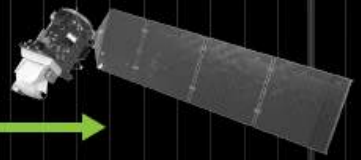
Landsat 3
1978-1983



Landsat 6
1993



Landsat 7
1999 –

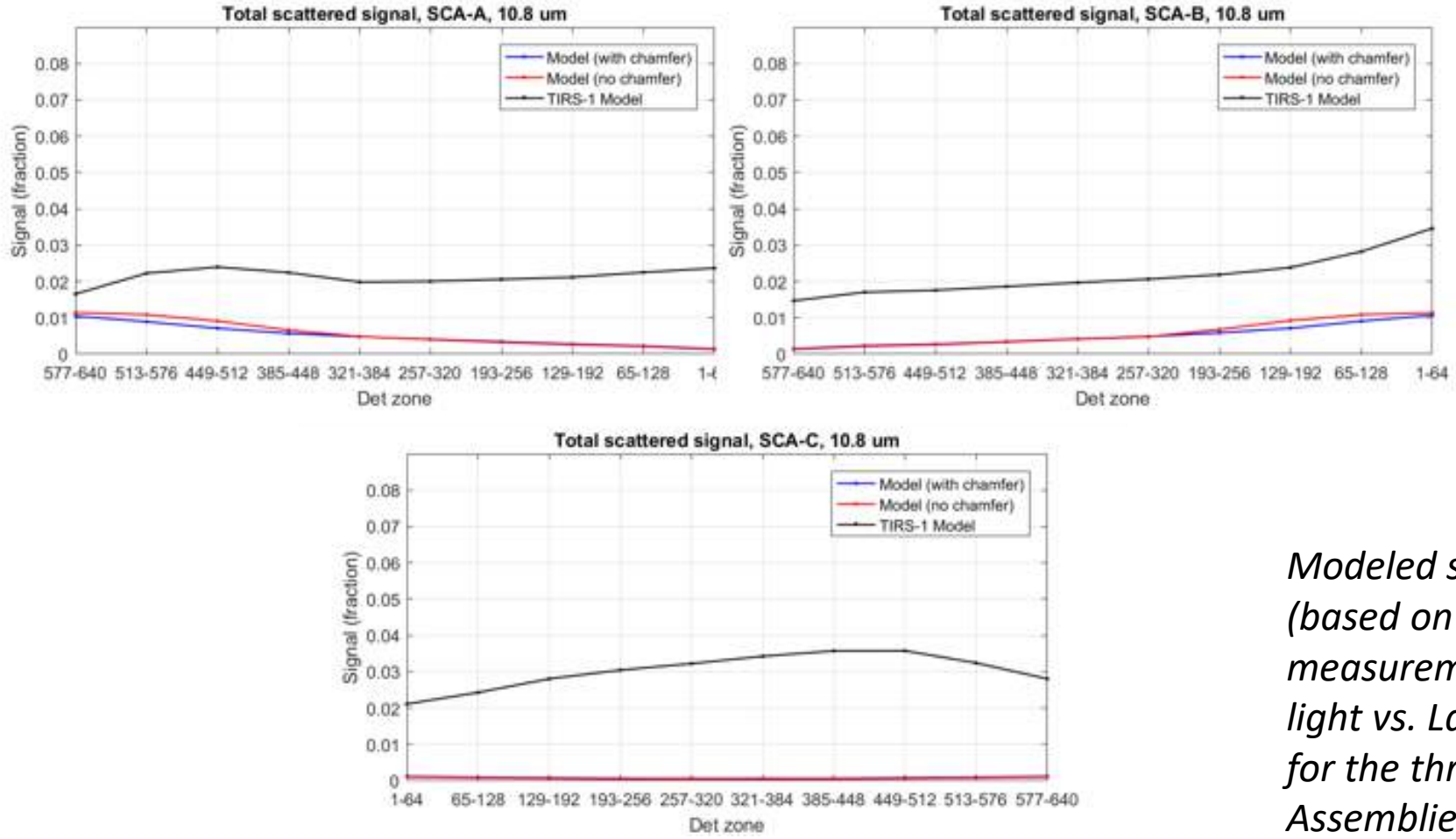


Landsat 8
2013 –

1972 1980 1990 2000 2010 2020 2030 2040

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