Limitations of Satellite Observations

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Requested Discussion Topics (Paraphrased)

- Highlight the benefits and limitations of the variety of satellite data/products used as the basis for fire emissions inventories.
- What are key uncertainties in the [satellite-based fire] products that are used to estimate fire emissions and how do these uncertainties influence emissions inventories?
- What are the largest gaps, uncertainties, constraints, limitations, and/or challenges facing the use of satellite data for fire emissions quantification, currently and in the future?
- What single measure would you support to bring us closer to estimating the reality of what is burned that would move us closer to identify approaches to reach net-zero GHG fire emissions?

Highlight the benefits and limitations of using the variety of satellite data and products that are used as the basis for fire emissions inventories... (1 of 3)

- Product/measurement scope
  - Active fire presence
  - Fire radiative power (FRP)
  - Burned area
  - Land cover maps (→ fuel type)
  - Other: fuel moisture, meteorology (precipitation, wind speed, cloud cover, etc.), land/water state, soil moisture, elevation, ...

Highlight the benefits and limitations of using the variety of satellite data and products that are used as the basis for fire emissions inventories... (2 of 3)

- Benefits
  - Only practical way to comprehensively observe fire activity over the terrestrial biosphere
  - Much/most of these data are freely available
  - Increasingly capable and useful
- Limitations
  - Satellite data record is extremely short compared to times scales of climate and human-history
  - Data that are acquired are often not up to (or not *quite* up to) the task for which they end up being employed
  - Quality and consistency of satellite data record varies over time and space

Highlight the benefits and limitations of using the variety of satellite data and products that are used as the basis for fire emissions inventories... (3 of 3)

- Specific case: FRP-based vs. inventory-based emissions estimation
  - FRP-based approaches avoid need for detailed information about what burned, but require high frequency temporal sampling
  - Inventory-based methods require detailed information to estimate what burned, but have much more relaxed temporal sampling requirements

What are key uncertainties in the measurements/products that are used to estimate fire emissions (e.g., burned areas, fire detection, FRP, ...) and how do these uncertainties influence emissions inventories? (1 of 3)

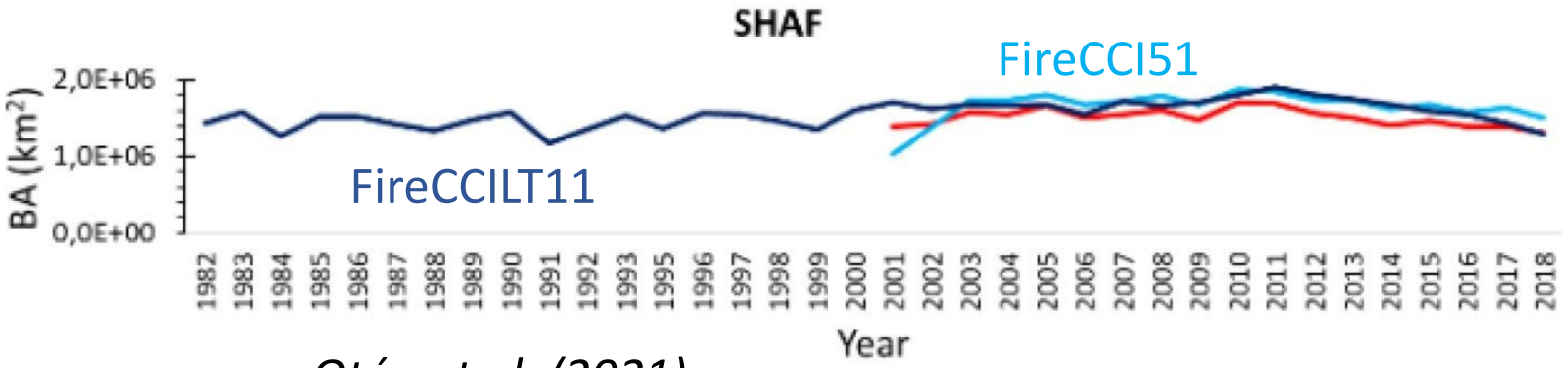
- Active fire, burned area
  - Omission errors
    - Missed fire (e.g, too small/cool), missed burn (e.g., burn is too small and/or fragmented)
  - Commission errors
    - False fire (e.g., sun glint), false burn (e.g., cloud shadow)
- FRP
  - Imperfect knowledge of atmospheric transmittance and fire emissivity
  - Slight error resulting from analytical approximation used in retrieval
- Land cover
  - Misclassification of land cover classes

What are key uncertainties in the measurements/products that are used to estimate fire emissions (e.g., burned areas, fire detection, FRP, …) and how do these uncertainties influence emissions inventories? (2 of 3)

- Influence on emissions inventories
  - Emissions may be overestimated or underestimated
  - Emissions may be systematically biased
  - Emissions may be assigned to the wrong time
  - Emissions may be assigned to the wrong place
  - Emissions may be incorrectly attributed to fire
  - Emissions may be attributed to the wrong species
- *Caveat*
  - Important to not overlook errors introduced by the models that make use of these data
    - Explicit and implicit assumptions

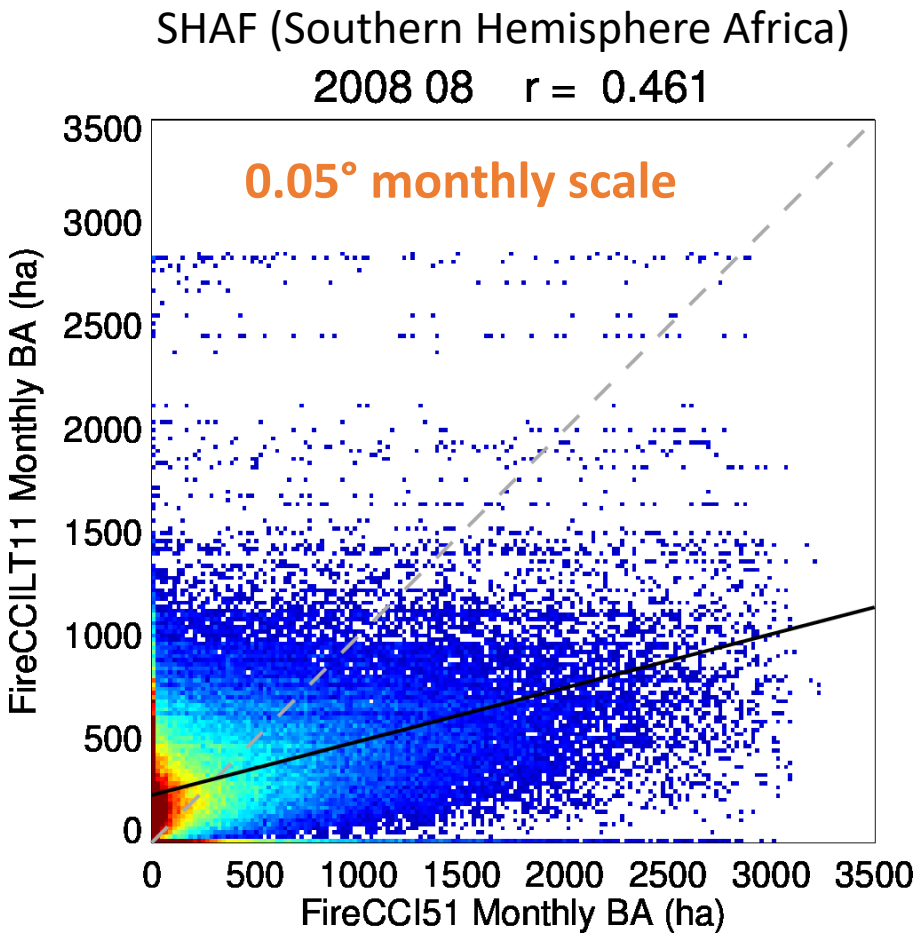
What are key uncertainties in the measurements/products that are used to estimate fire emissions (e.g., burned areas, fire detection, FRP, …) and how do these uncertainties influence emissions inventories? (3 of 3)

- Scale issue
  - Product accuracy/agreement is scale dependent (space + time)
  - Agreement at finer spatial/temporal scales may not be what you expect



Otón et al. (2021)

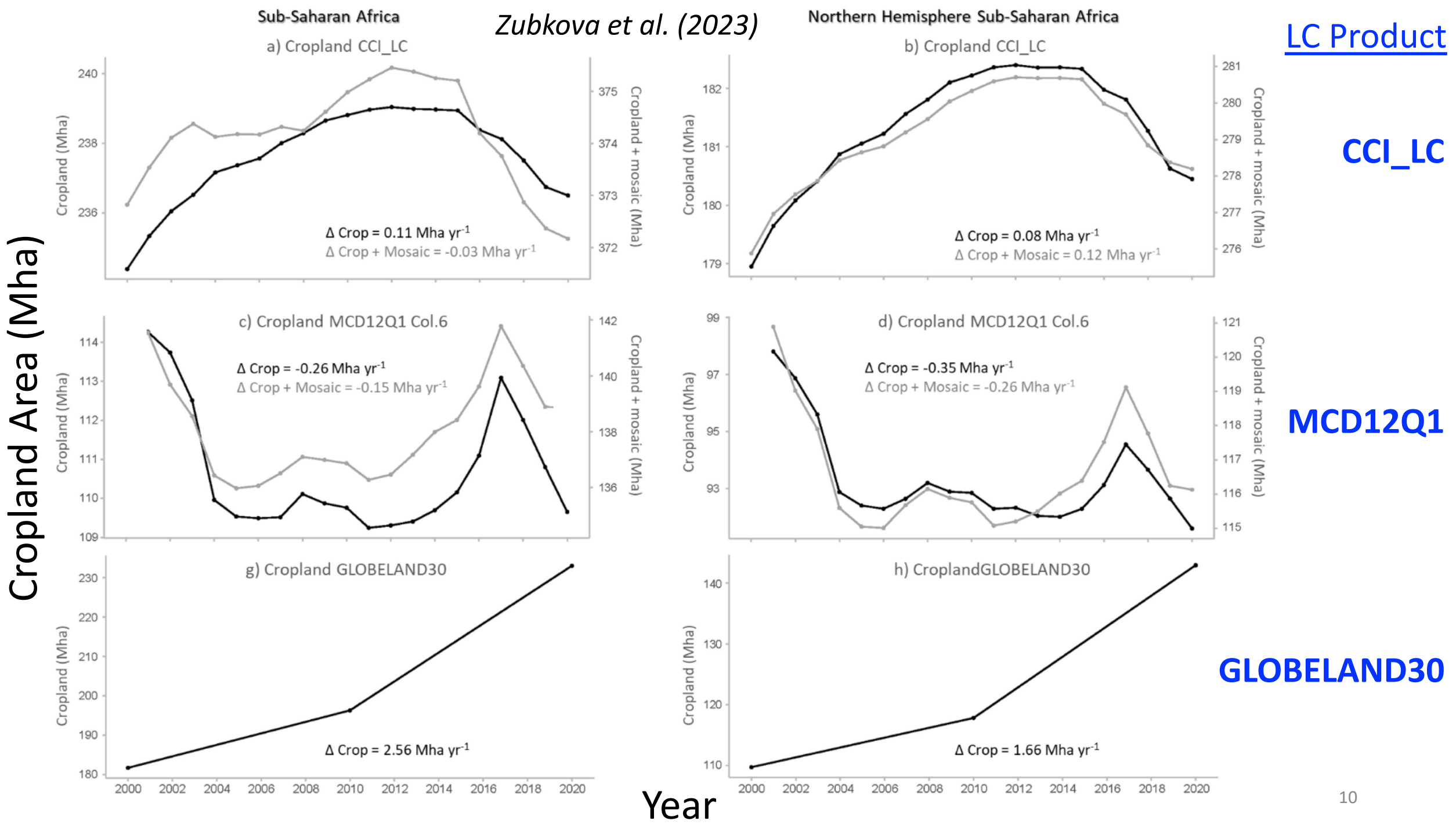
continental annual scale



What are the largest gaps, uncertainties, constraints, limitations, and/or challenges facing the use of satellite data for fire emissions quantification, currently and in the future? (1 of 2)

- Small burns
  - Large-scale (spatial + temporal) burned area maps necessarily rely on low resolution imagery
  - At these resolutions (e.g., MODIS), multitudes of small burns are missed completely
  - Is burned area declining in Africa, or are the burns merely becoming more fragmented/patchy and as a result more likely to be missed?
- Diurnal sampling
  - Polar orbiters provide limited temporal sample of diurnal fire cycle
  - Geostationary sensors offer excellent temporal sampling but have less sensitivity to smaller fires + systematically biased/distorted spatial sampling
- Discrepancies in land cover data sets

Zubkova et al. (2023)



LC Product

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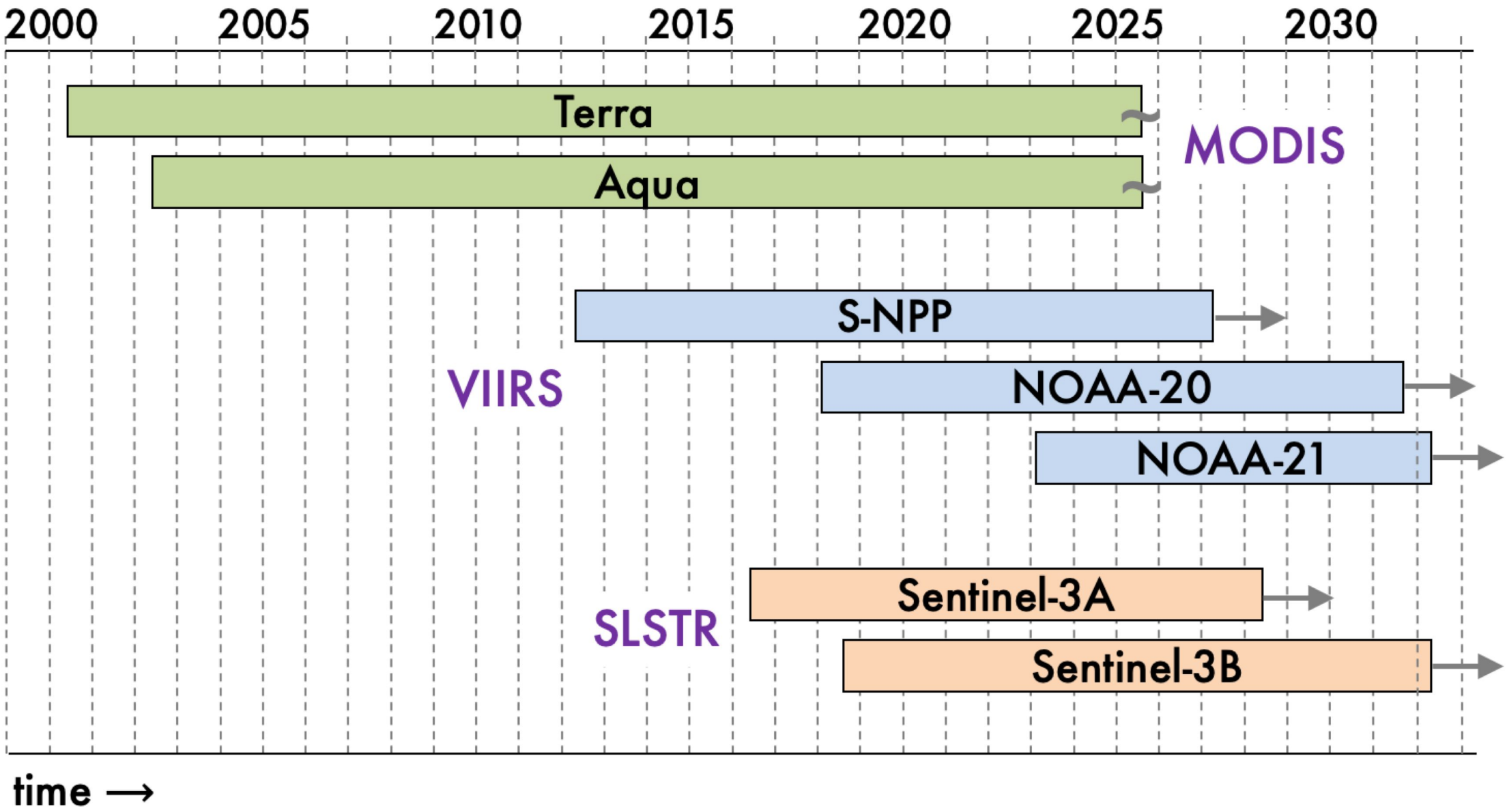
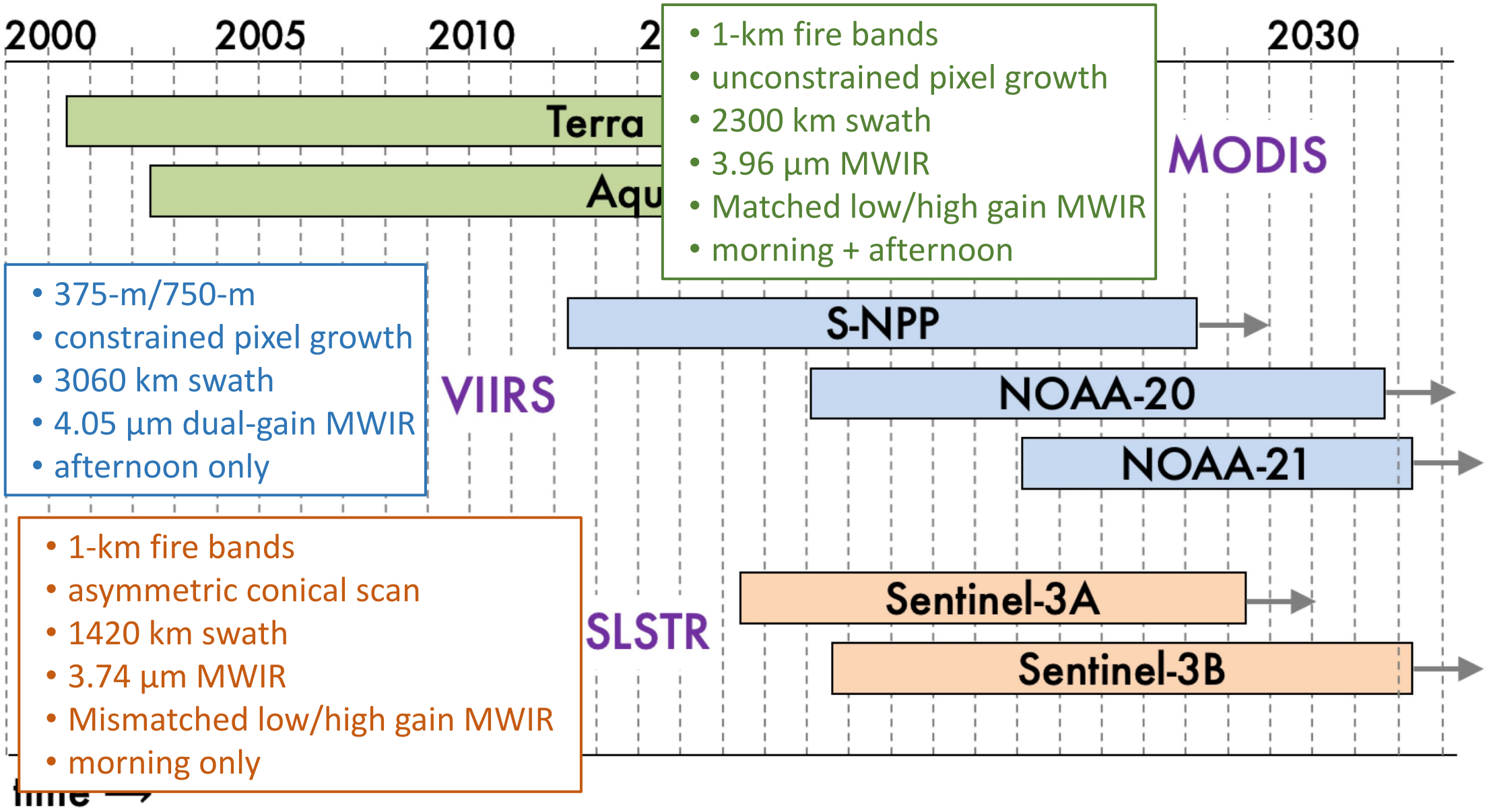
GLOBELAND30

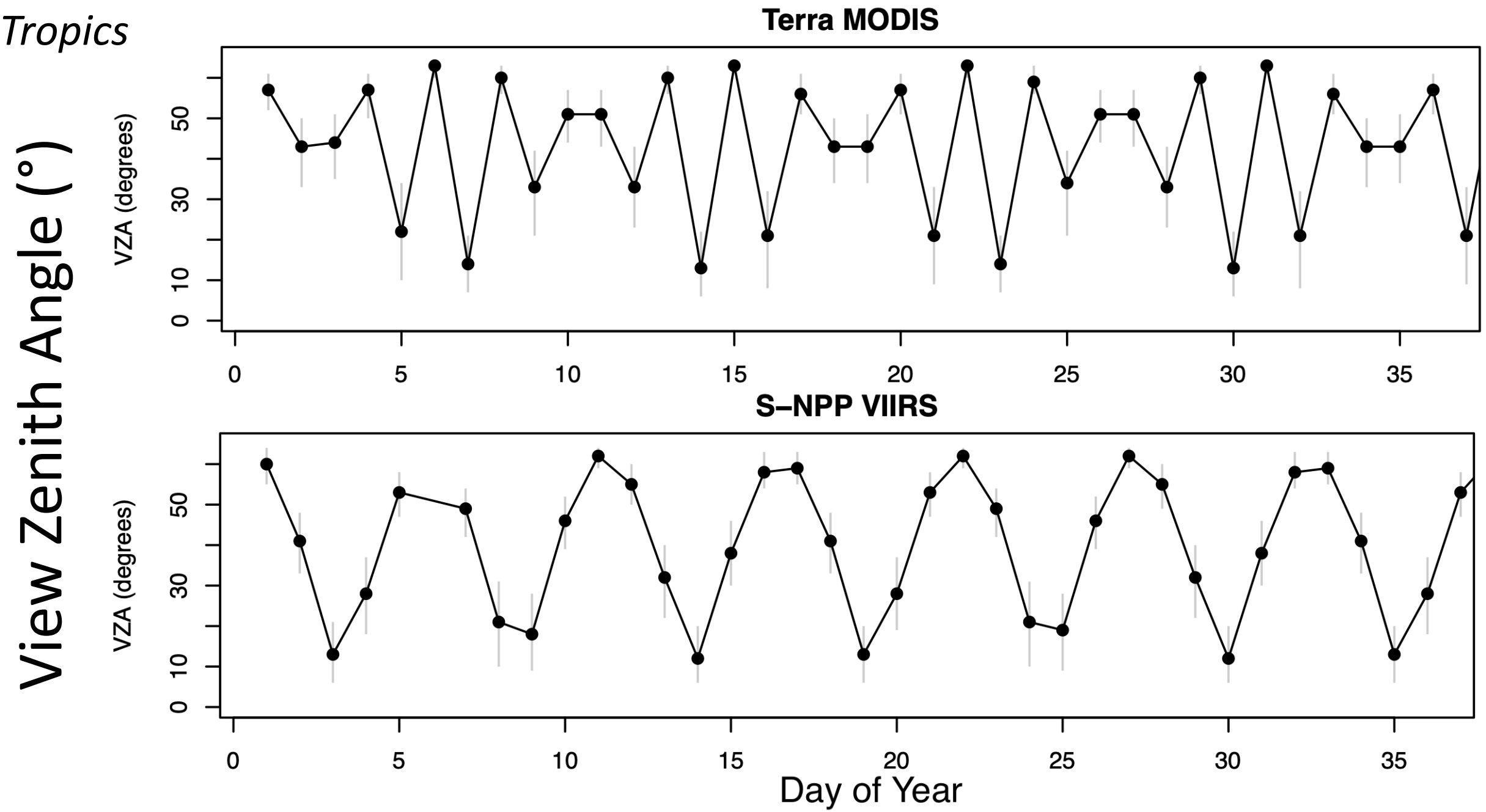
What are the largest gaps, uncertainties, constraints, limitations, and/or challenges facing the use of satellite data for fire emissions quantification, currently and in the future? (2 of 2)

- Long-term data continuity (historical and future)
  - Orbit + sensor differences impact observation record in both obvious and subtle ways
  - Less than stellar spectral, spatial, and temporal consistency across sensors and orbits
- Quality assurance
  - Increasingly easy to produce large-scale remote sensing data sets very rapidly
  - Quality assurance and validation are essential but are sometimes neglected


2000
2005
2010
2015
2020
2025
2030
Terra
Aqua
MODIS
S-NPP
NOAA-20
NOAA-21
VIIRS
Sentinel-3A
Sentinel-3B
SLSTR
time ⟶


2000
2005
2010
2030
Terra
Aqu
MODIS
• 1-km fire bands
• unconstrained pixel growth
• 2300 km swath
• 3.96 µm MWIR
• Matched low/high gain MWIR
• morning + afternoon
• 375-m/750-m
• constrained pixel growth
• 3060 km swath
• 4.05 µm dual-gain MWIR
• afternoon only
VIIRS
S-NPP
NOAA-20
NOAA-21
• 1-km fire bands
• asymmetric conical scan
• 1420 km swath
• 3.74 µm MWIR
• Mismatched low/high gain MWIR
• morning only
SLSTR
Sentinel-3A
Sentinel-3B
time

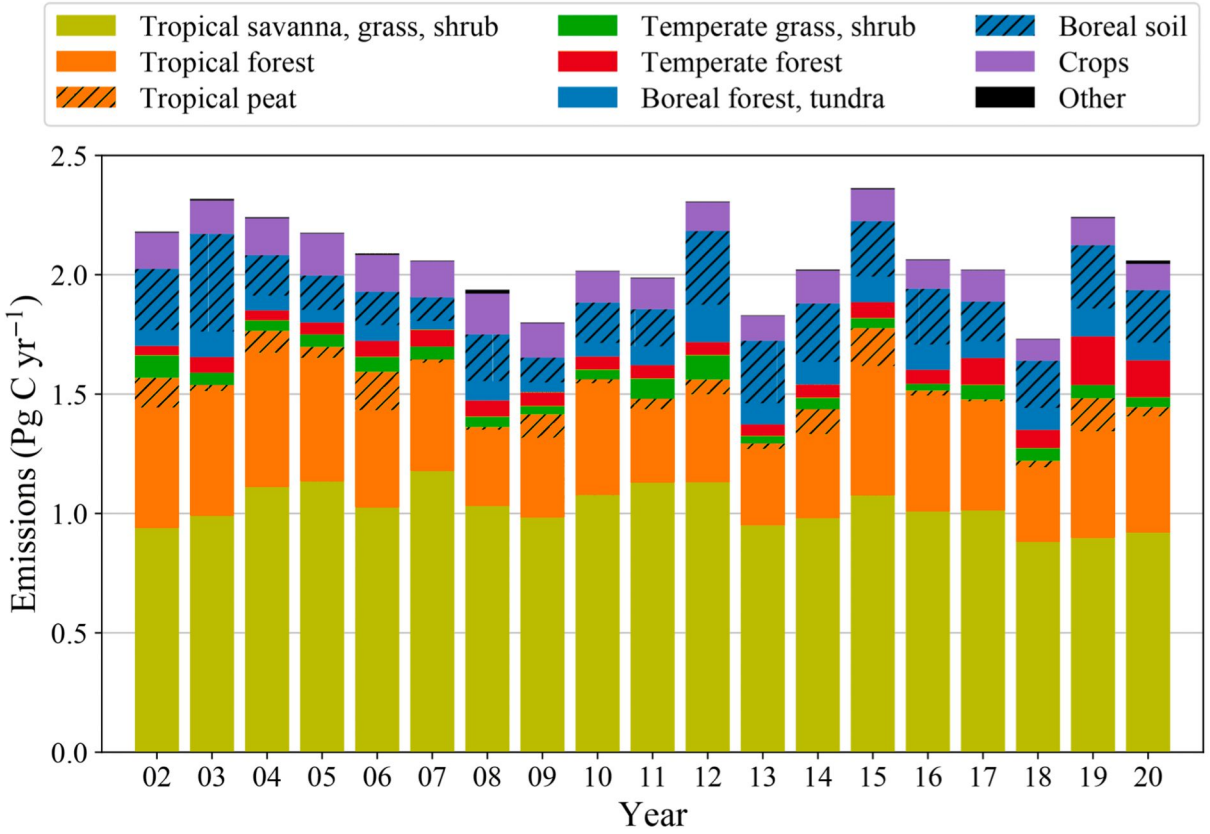
Tropics



Amplitude varies with latitude

What single measure would you support to bring us closer to estimating the reality of what is burned that would move us closer to identify approaches to reach ***net-zero*** *GHG* ~~***fire***~~ *emissions?*

- Caveats
  - Stipulation of single measure can confound response
  - This objective is a subset of the broader goal of quantifying fire emissions *in toto*
  - My response is driven heavily by focus on net-zero emissions
    - Target forest + peatland fire emissions
    - Savanna + agricultural fires become irrelevant



2002-2020 global annual fire emissions

van Wees et al., 2022, Geosci. Model Dev.

What single measure would you support to bring us closer to estimating the reality of what is burned that would move us closer to identify approaches to reach ***net-zero*** *GHG* ~~***fire***~~ *emissions?*

- FRP → FRE →combusted biomass → fire emissions for relevant regions
- Geostationary satellites supplemented with polar orbiters at high latitudes
- GOES ABI + Himawari AHI (existing)
  - 2-km fire channels, 1–15-min sampling
- Meteosat Third Generation Flexible Combined Imager (new)
  - 500-m/1-km/2-km channels (1-km fire), 2.5–10-min sampling
- GeoXO Imager (“early 2030s”)
  - 250-m/500-m/1-km channels (1-km fire), 1–10-min sampling
- Exploit sampling rate to improve spatial resolution