Climate Data Records from Space

Leveraging 3 Decades of Satellite Observations To Provide Trusted Climate Information

SpaceOps 2010

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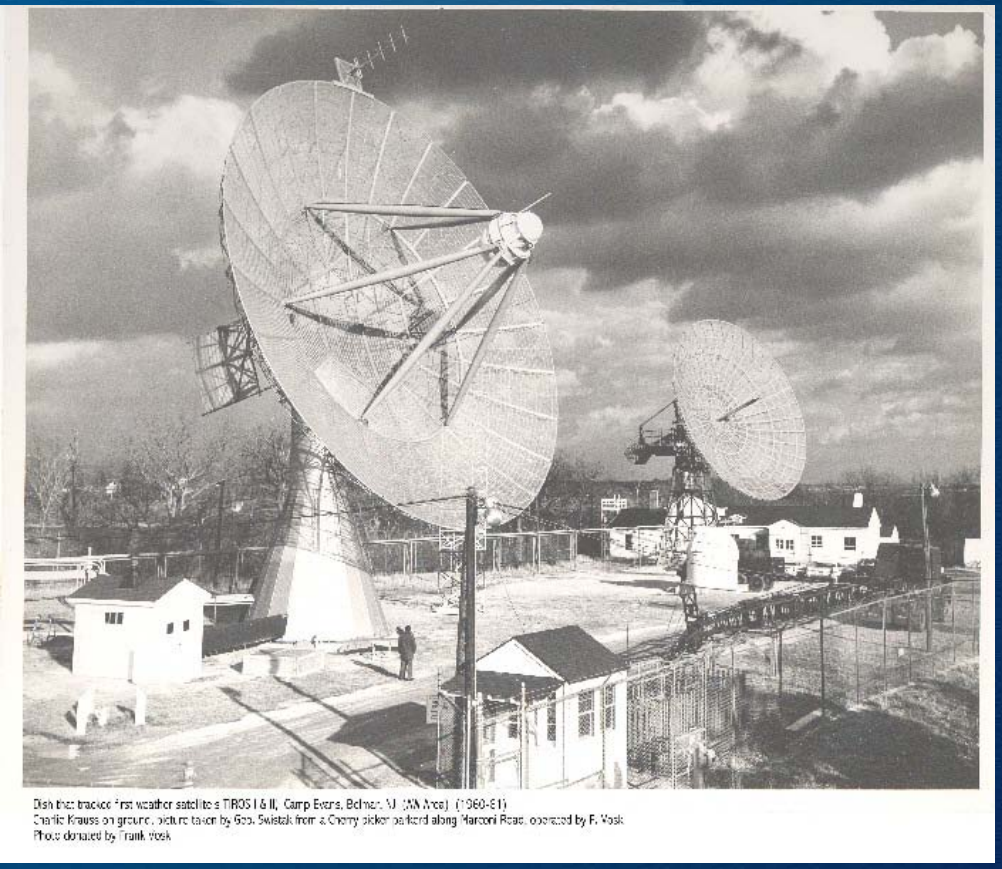
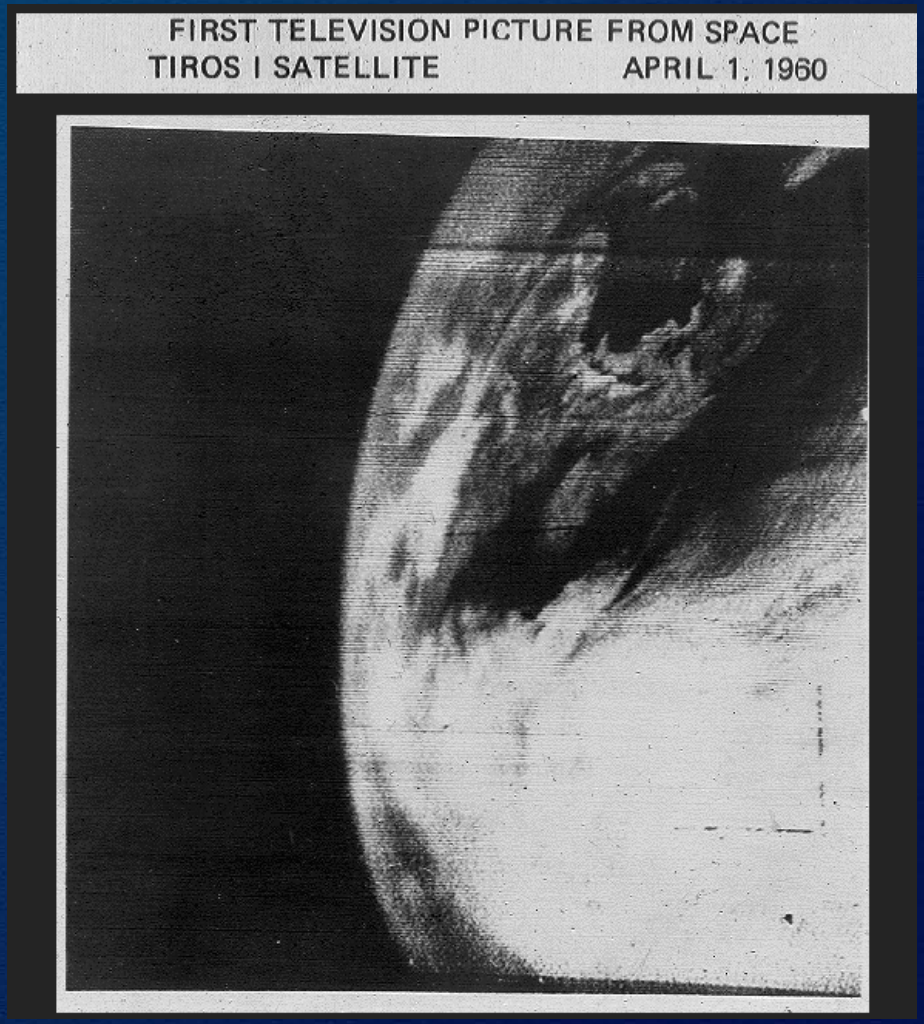
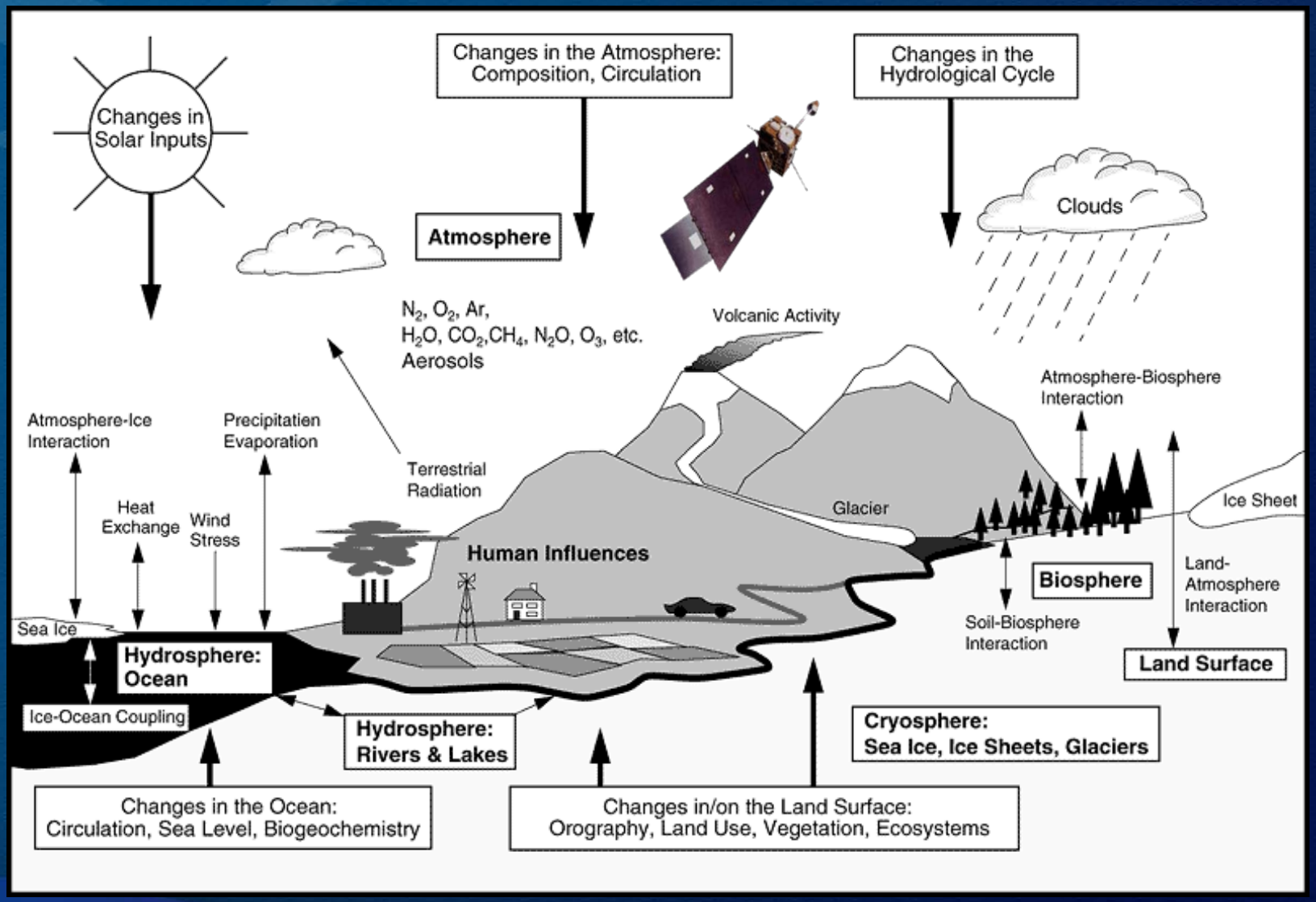
1960: Earth Observations From Space



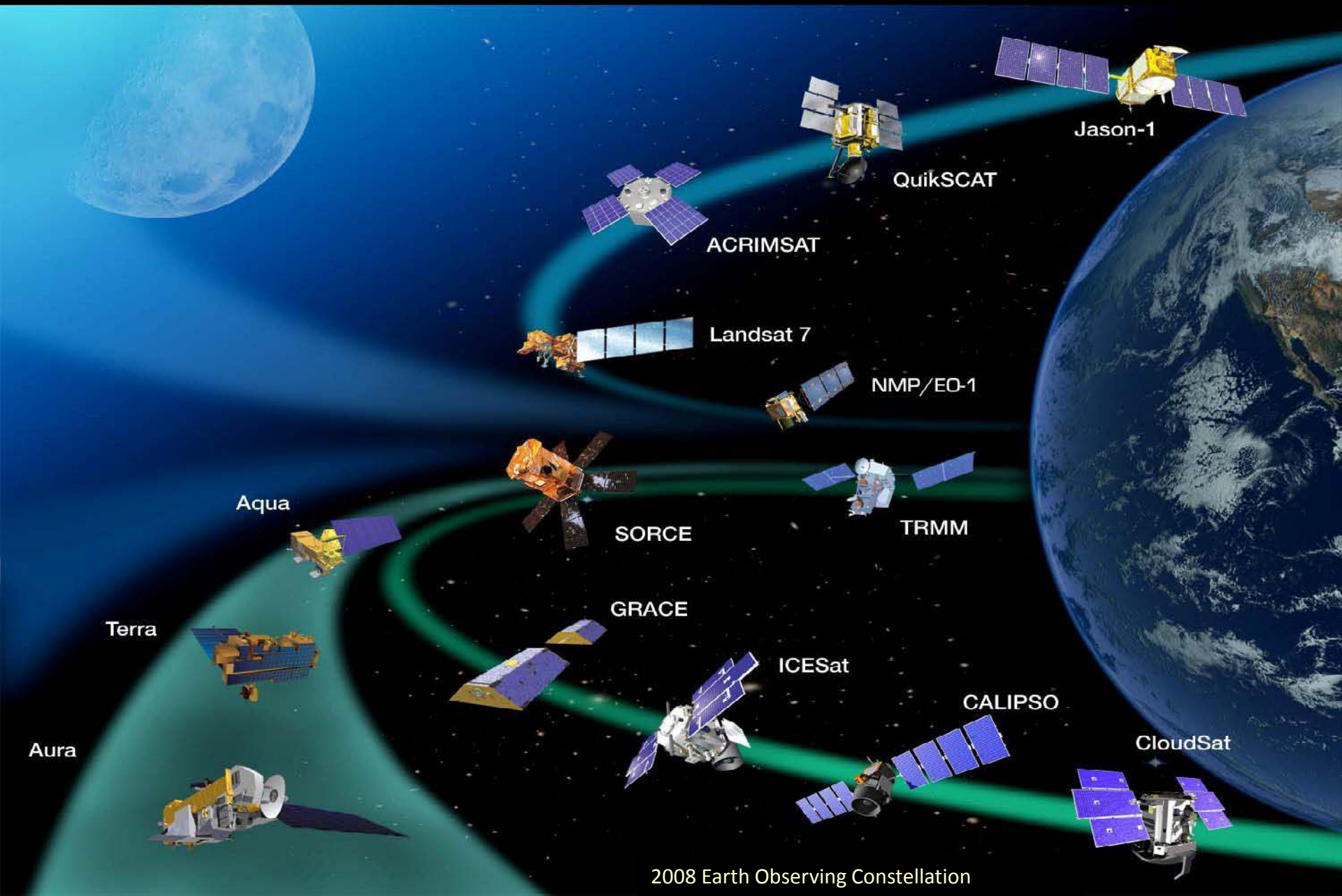


Despite massive infrastructure and crude cameras, “climate” begins to be recorded

The Global Climate System



Development of New Observing Technology

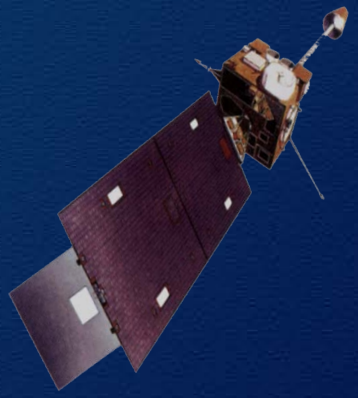


2008 Earth Observing Constellation

New Approach for Climate Science

Operational weather or hazard approach:

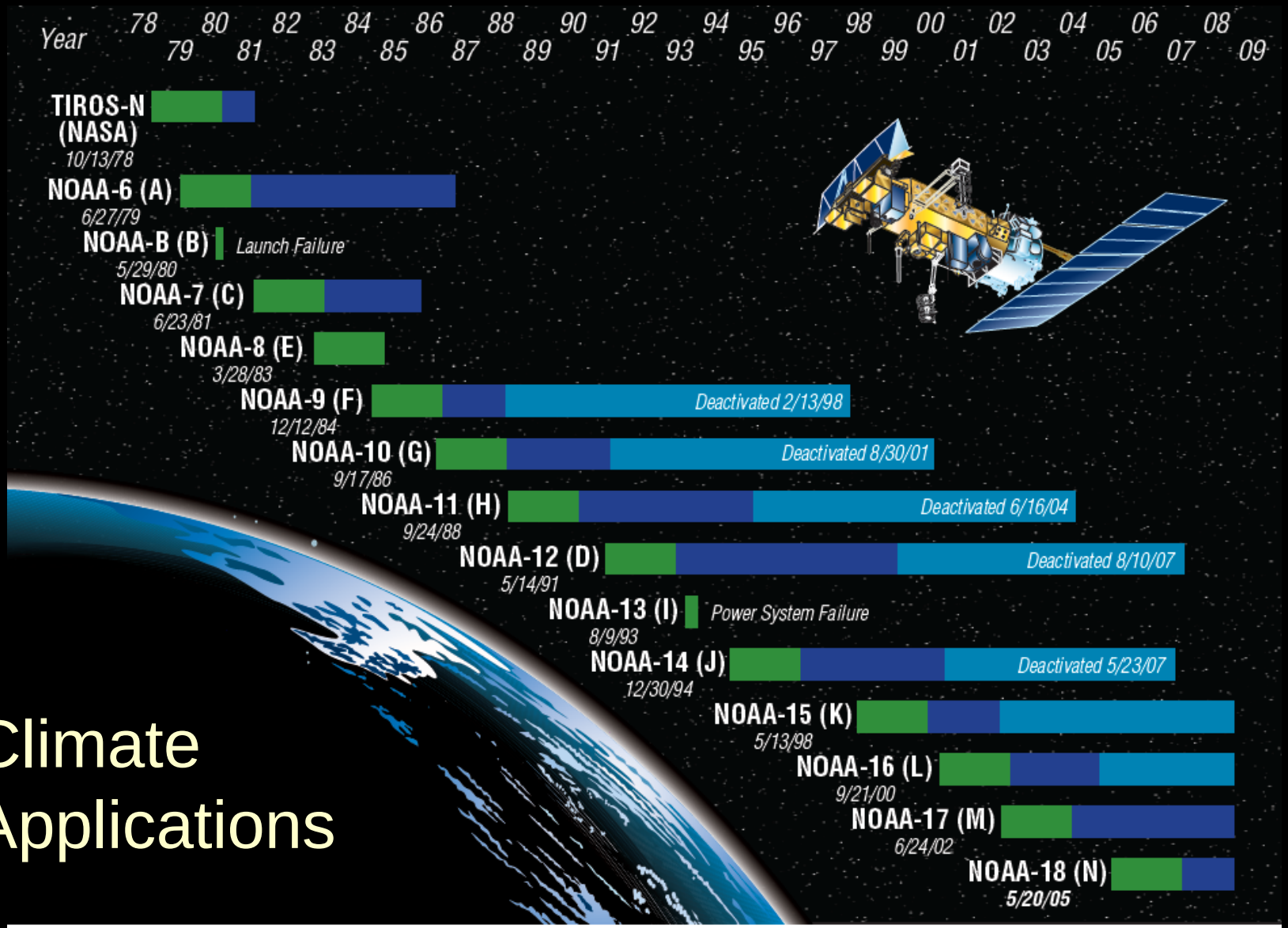
1. Identify needs for real-time products
2. Minimize latency and delivery speed
3. Ensure ability to ingest data into weather forecasts
4. Past data is of little relevance



Climate needs are different:

- New sensors in 1's or 2's not sufficient – need many in series
- Climate change signals tend to be smaller and require the highly advanced processing of decades-long, coherent records
  - Reasonable lags in processing are acceptable
- Changes or on-orbit degradation in observing systems impart unacceptable biases for more rigorous climate science requirements
  - e.g. combining JPSS with relevant heritage data sets

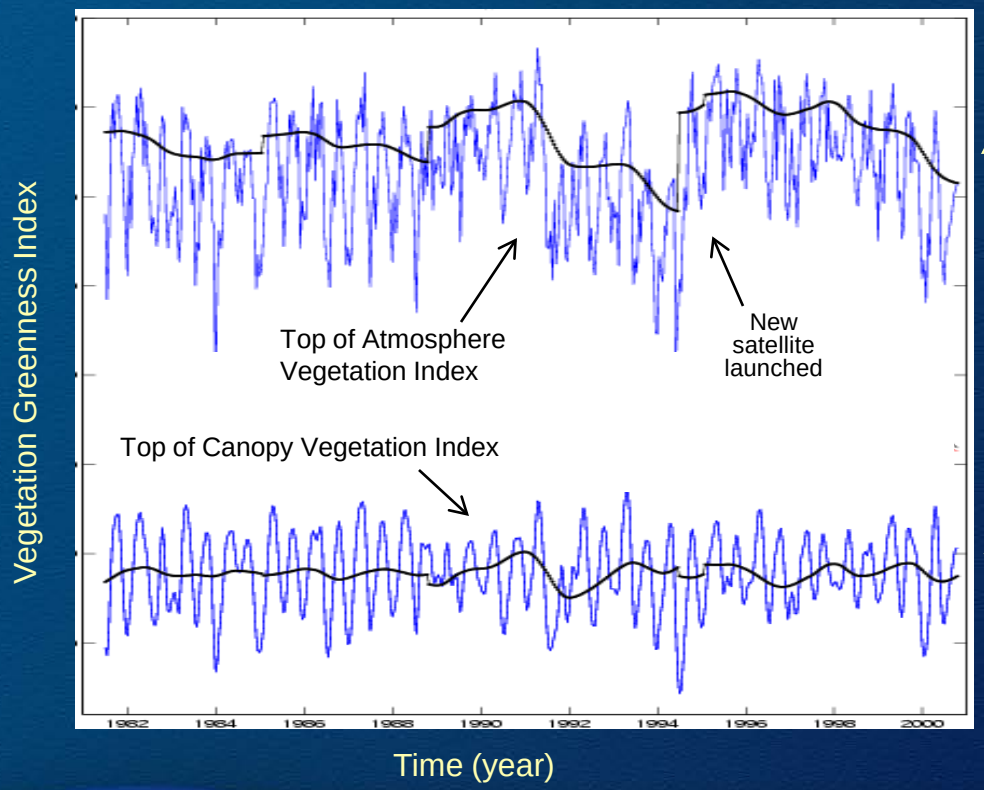
Multiple Decades of Data using Older Systems



Climate Applications

Climate Data Records development requires homogenization across different Data "Epochs"

Uncorrected Data Time Series Contain Both Environmental Information and Satellite-induced Artifacts



Operational weather/hazard products are produced *rapidly* to potentially save life and property

Climate Data Records provide long term product consistency through *retrospective* reprocessing with advanced algorithms, ancillary data and evolved instrument understanding.

Image courtesy C. Tucker

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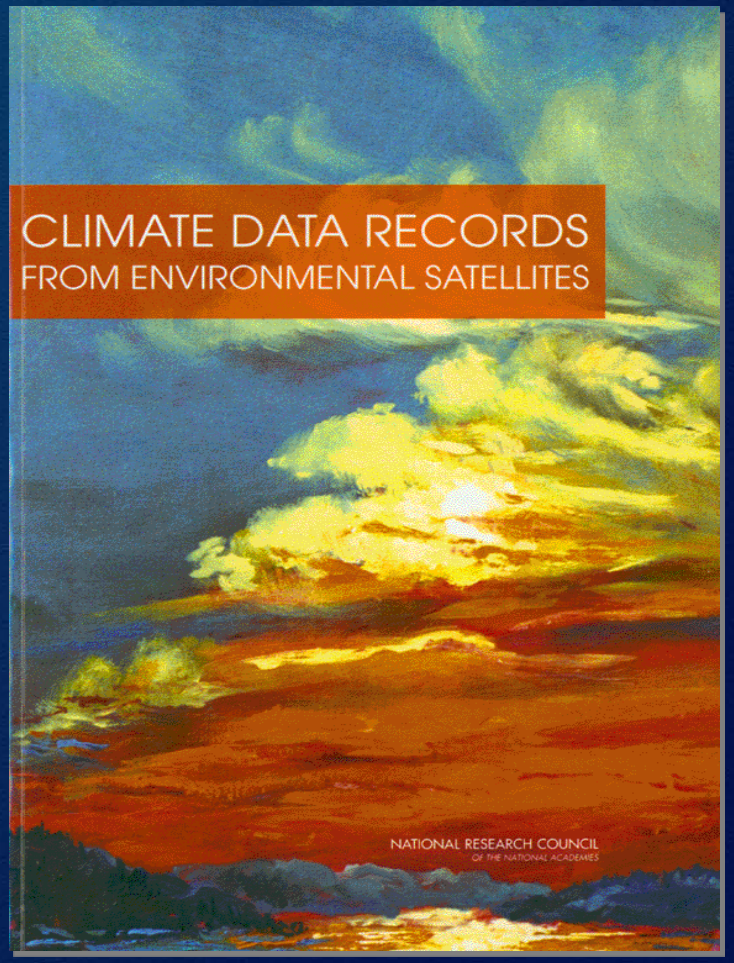
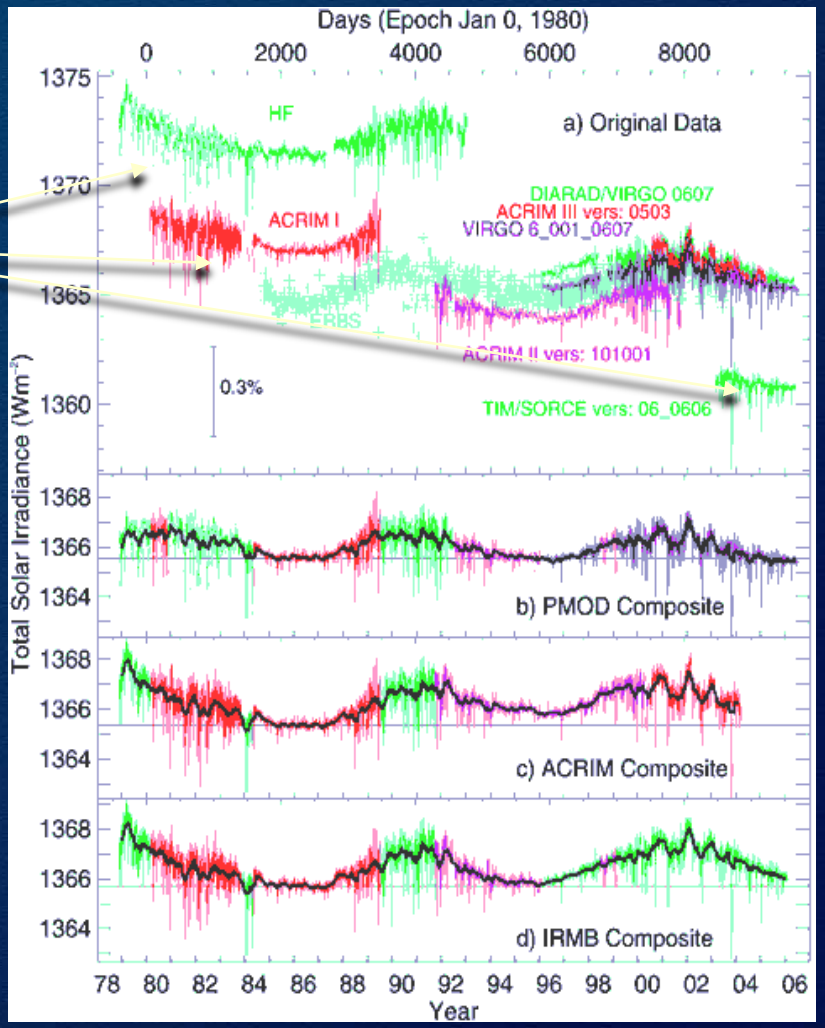
What is a climate data record?

- A <u>Climate Data Record (CDR)</u> is a time series of sufficient length, consistency, and continuity to determine climate variability and change
  - **FCDR**: Calibrated signals for a family of sensors together with the ancillary data used to calibrate them. (e.g. brightness temperatures, TOA radiances)
  - **TCDR**: Geophysical variables derived from FCDRs; May be generated by blending satellite observations, in-situ data, and model output (e.g., Aerosol Optical Depth, SST)
- A <u>Climate Information Record (CIR)</u> provides specific information about an environmental phenomena of importance to science and society (e.g., Hurricane tracks, Arctic Sea Ice Extent, Incidence of disease)



Solar Irradiance Record From Research Satellites

- Original data (EDRs) cover several decades
- Multiple data sources
- Work Needed for CDR:
  - Sensor models to explain differences
  - Development of homogeneous data set versions
  - Estimation of detectable variability and trends
- Ensemble approach?



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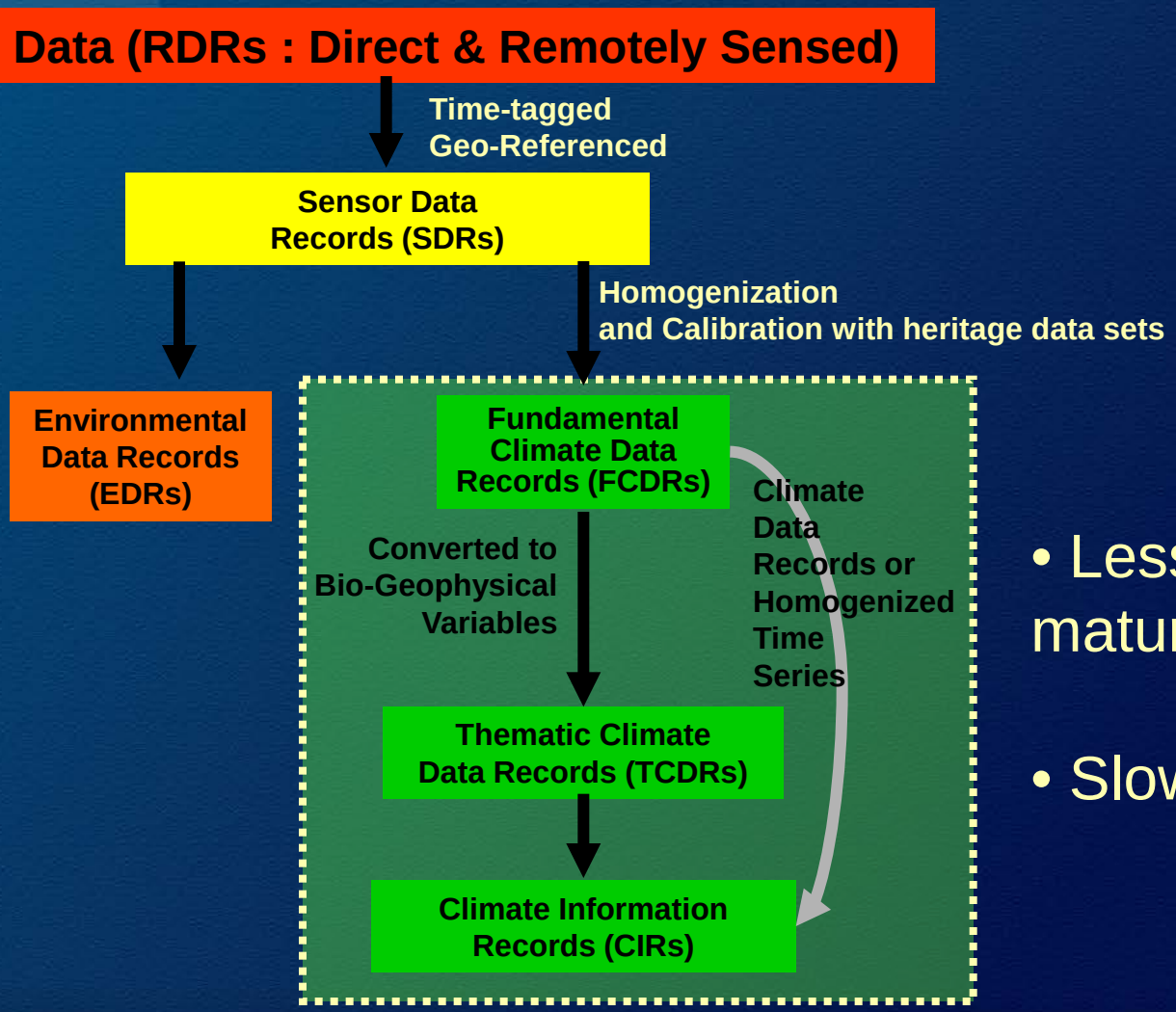
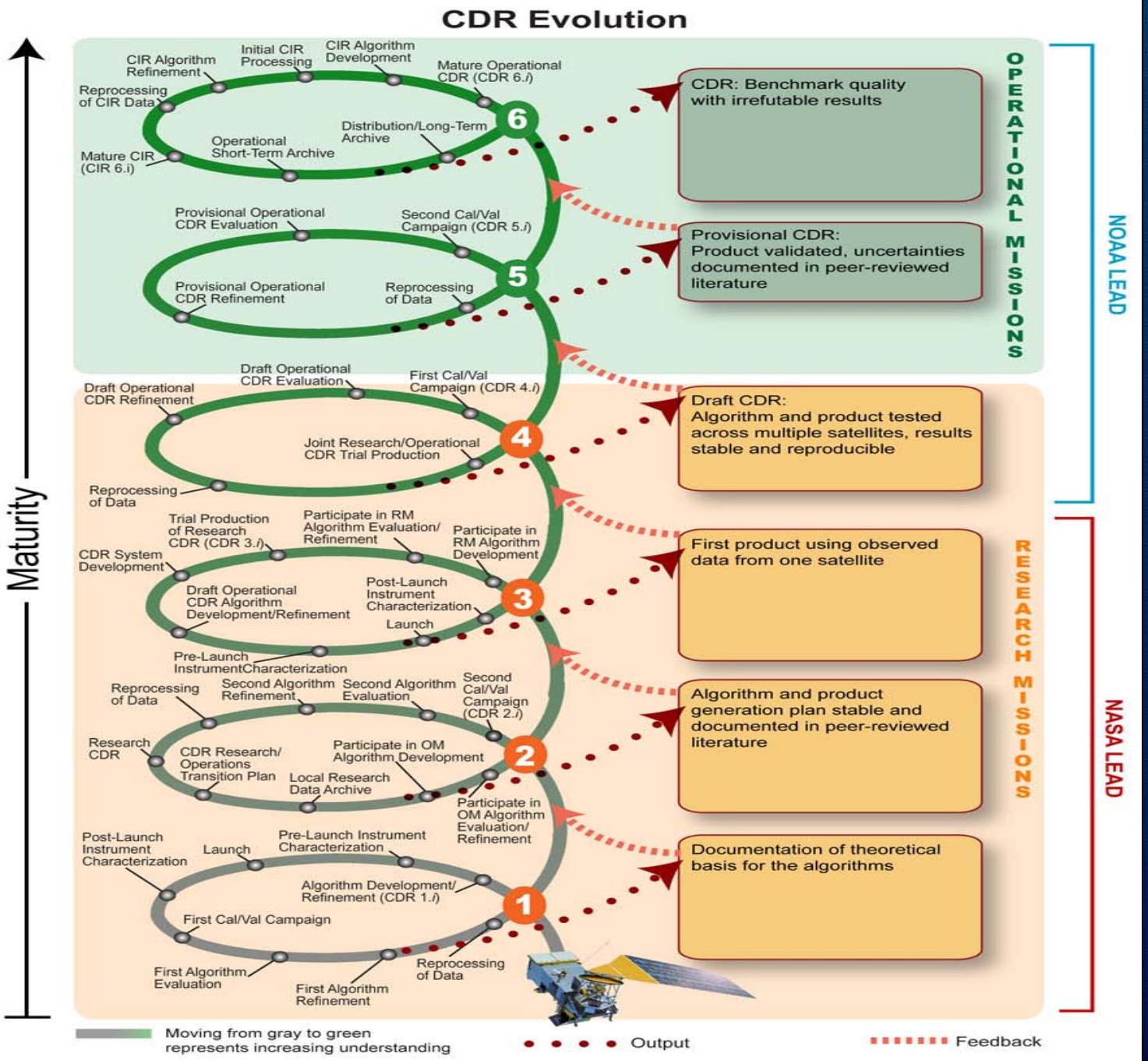
Weather vs. Climate Processing

- Well-defined
- Mature
- Rapid



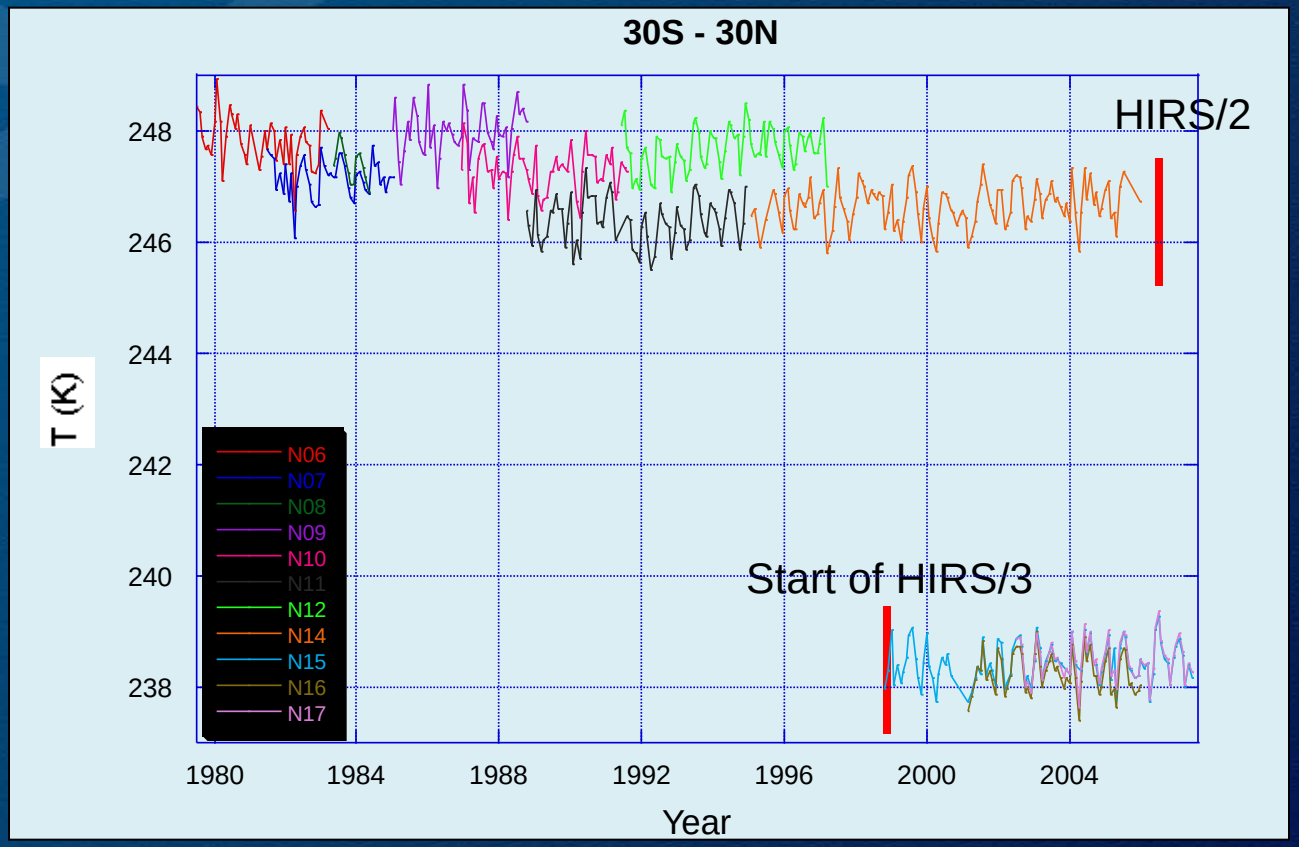
- Less mature
- Slow



CDR Evolution

Requires mature algorithms, good under-standing of systems

Upper Tropospheric Water Vapor EDRs from HIRS



- Due to the independence of individual HIRS instrument's calibration, biases exist from satellite to satellite.
- These intersatellite biases have become a common source of uncertainty faced by long-term studies.

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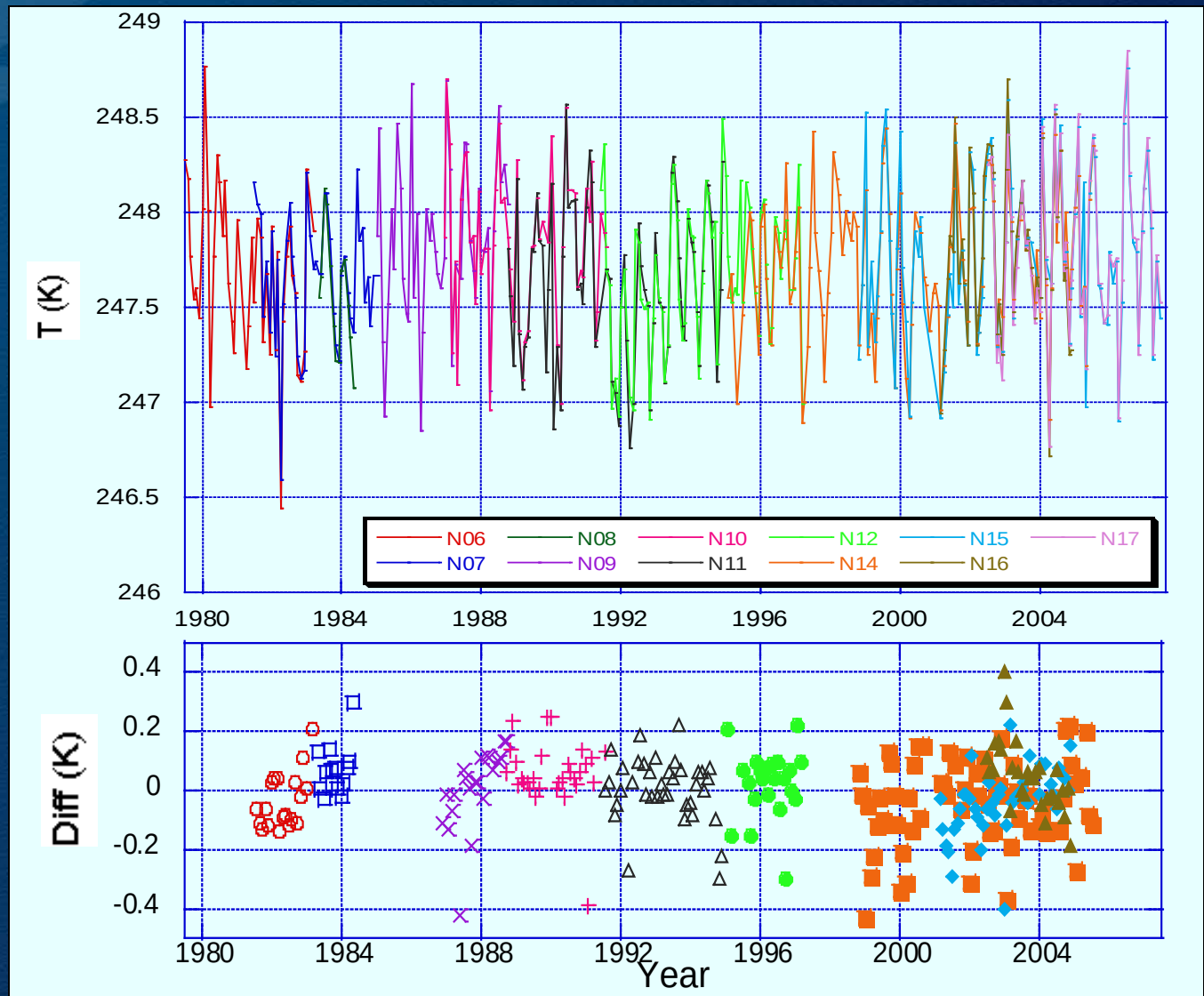
Intersatellite Calibration and Correction Provides FCDR

- Biases minimized.
- Temperature dependent biases accounted for.
- Similar overall variances between HIRS/2 and HIRS/3.
- Time series can be extended as variance preserved.



Pairs	N06-N07	N07-N08	N09-N10	N10-N11	N11-N12	N12-N14	N14-N15	N15-N16	N16-N17
Ave Diff	-0.065	0.073	0.008	0.059	0.006	0.048	-0.042	-0.035	0.048

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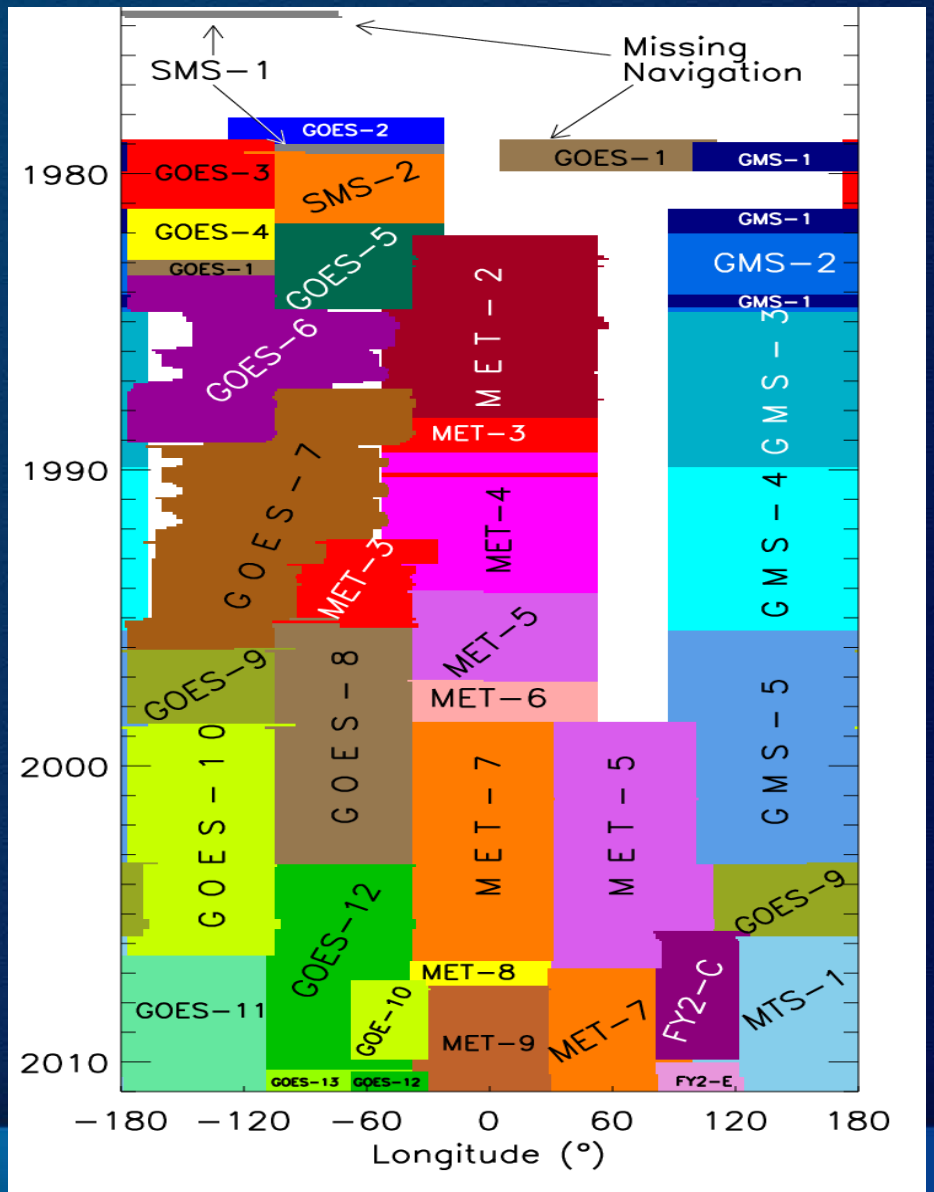
Example: Unifying the Patchwork of Historic Geostationary Satellite Observations of Clouds

Geostationary satellite cloud products were stored without stewardship for ~15 years.

Merged data from 29 satellites, stored in 9 data formats, 7 location reference systems, and multiple calibrations into a single commonly-formatted and accessible data record.



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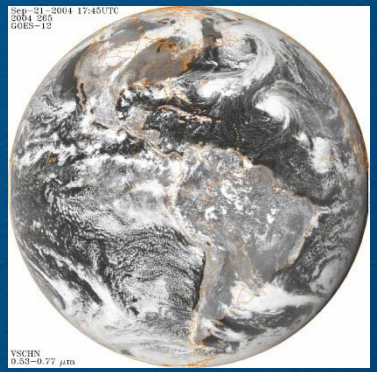
Revealing Climate Information Within Archived Data

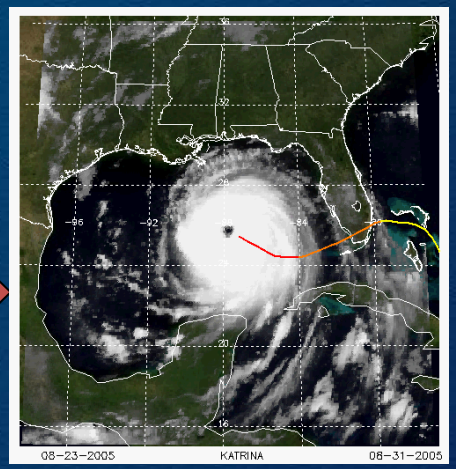
Raw Satellite Data



29 Geostationary Satellites
+ 8 Polar Satellites

Different designs, spectral bands, formats, navigation, resolutions, algorithms (Knapp et al., 2007)

30 Year Fundamental CDRs

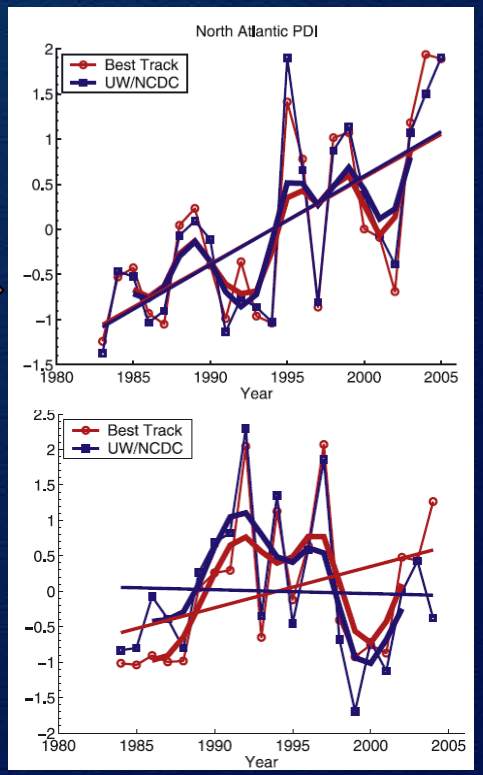


HURSAT-B1

- Geo-located
- Calibrated
- netCDF
- 8km, 3-hourly

(Knapp et al., 2007)

CIR: Global and Basin Objective Hurricane Intensity Trends



New intensity estimates (e.g., Kossin et al. 2007)

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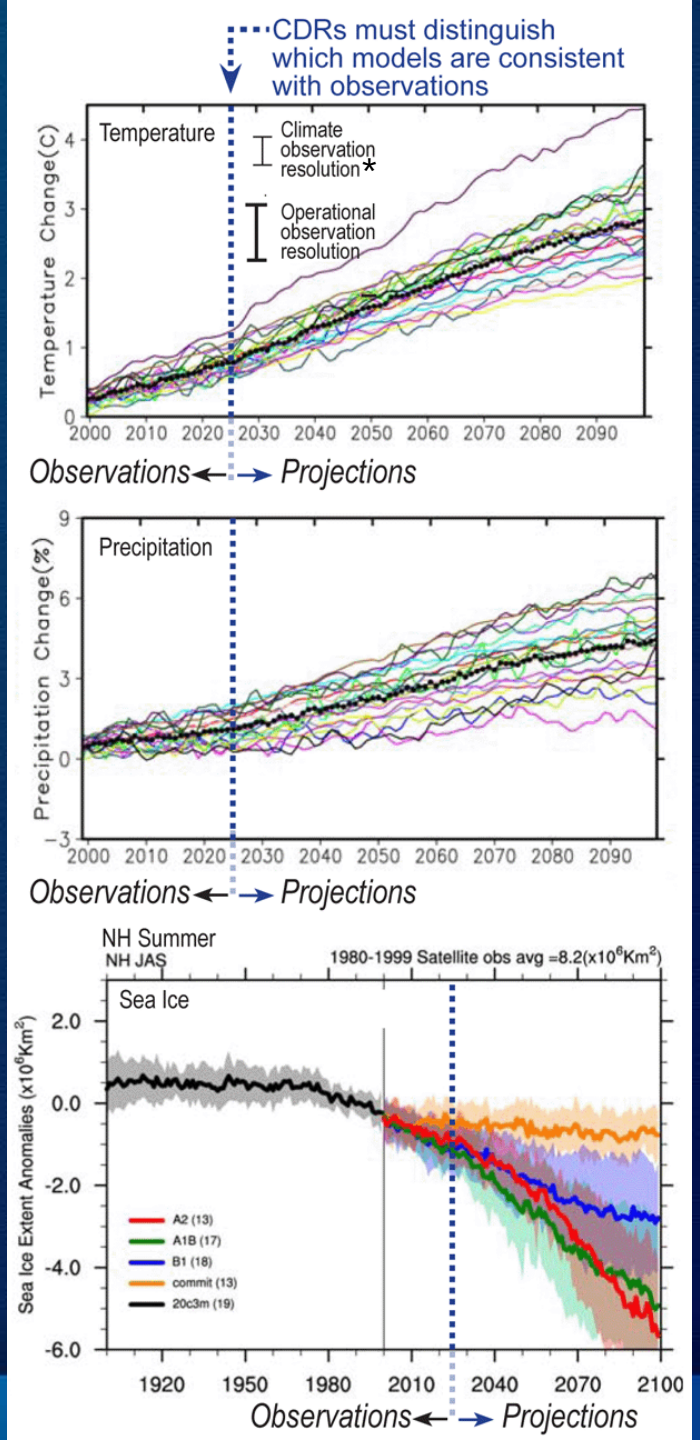
Use Scenario: CDRs Can Identify Most Accurate IPCC Model Projection

- IPCC model projections for most parameters vary greatly
- Mitigation and adaptation strategies depend on identifying which models are best
- Only high quality, sustained CDRs can validate climate model projections



*Resolution scale in Panel 1 is notional only.

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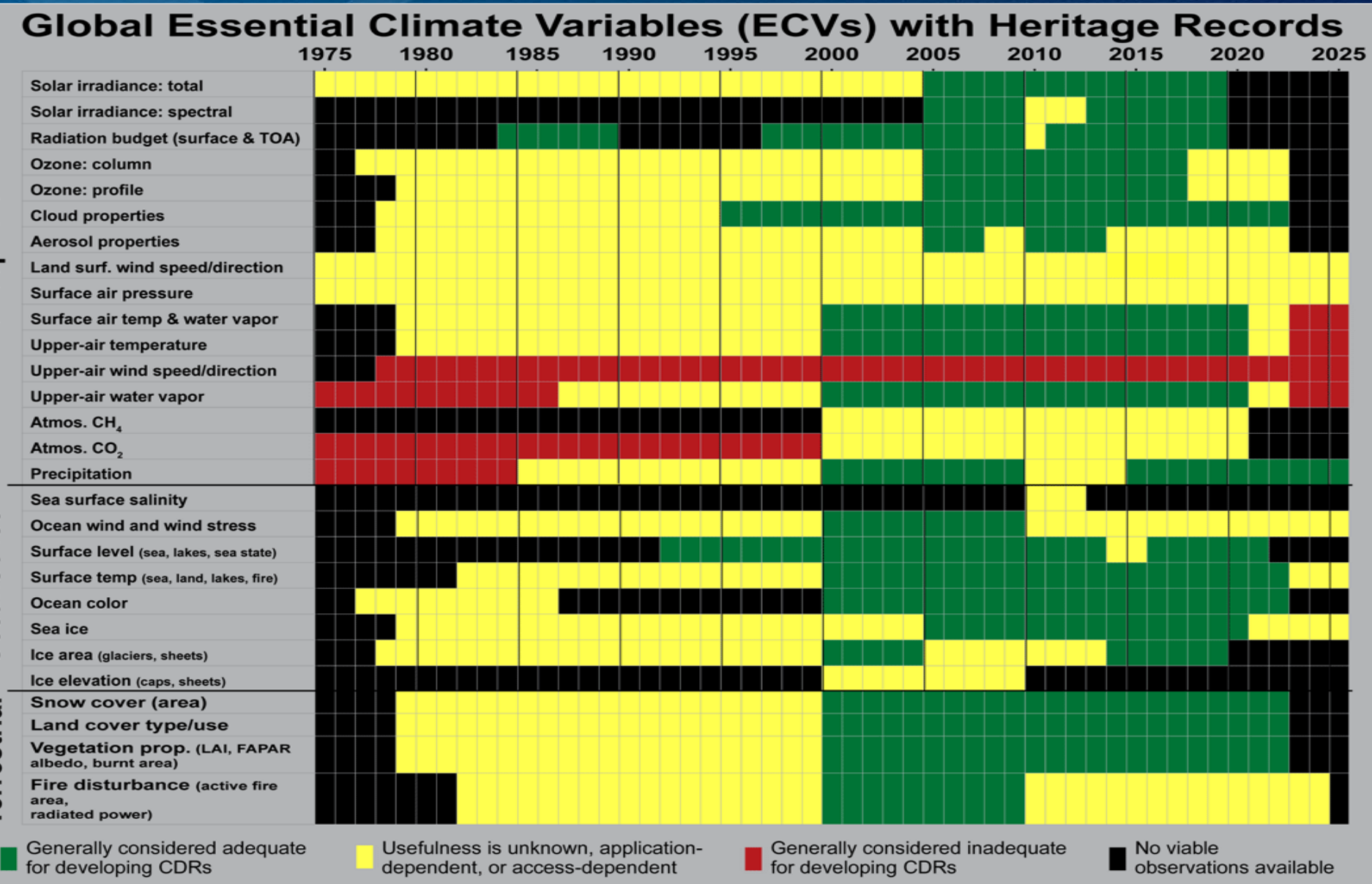
Challenges

- Can we fly sensors with sufficiently accurate on-board degradation/stability checks to enable easy (easier?) CDR production?
- Can we avoid gaps in key measurements (e.g. solar irradiance) in order to preserve the CDR time series?
- Can we archive climate data in a thoughtful manner, and with sufficient metadata, to best facilitate future research?
- Can avoid operational conflicts for missions with both climate and weather/hazard requirements ?

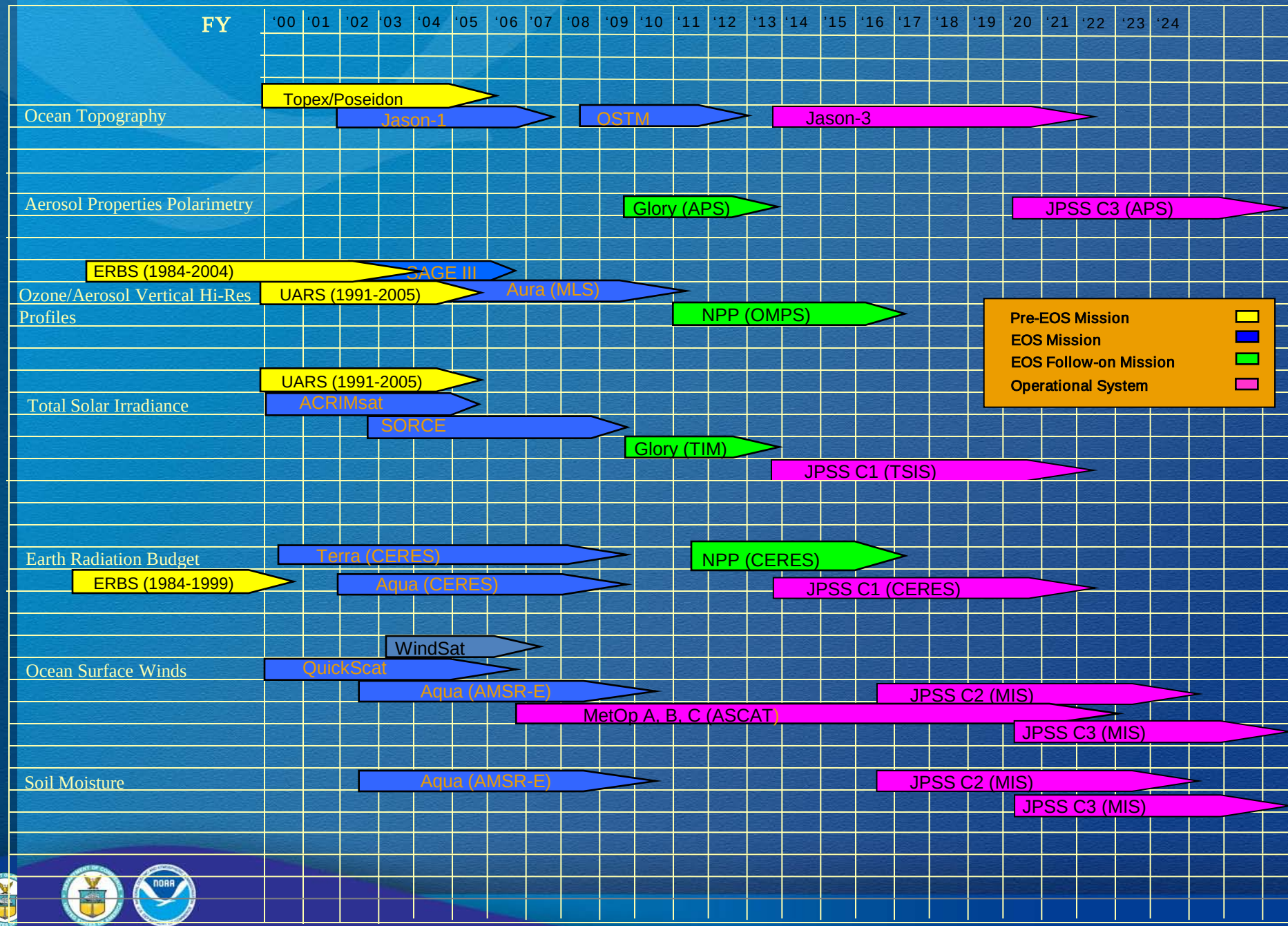
Questions?

Backups

Merging NASA/NOAA/USGS Data Will Provide Information at Climate Time Scales and Quality

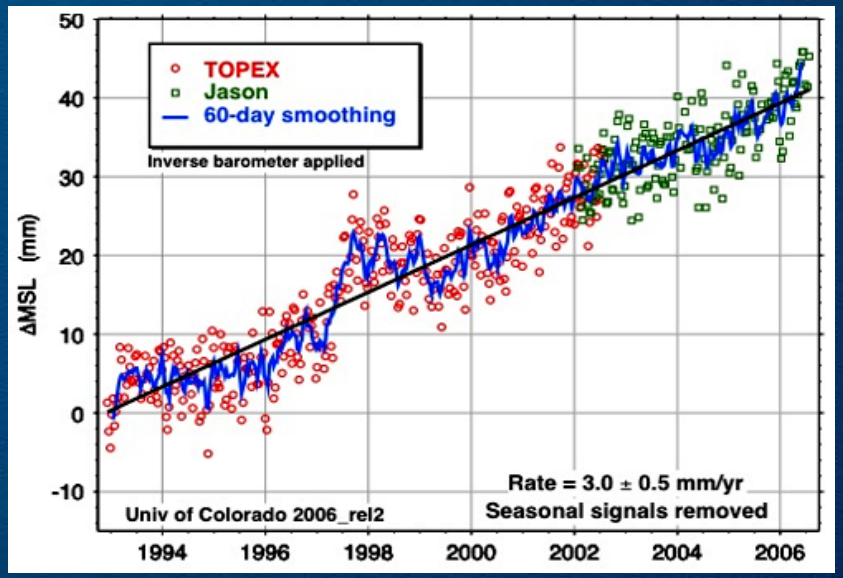


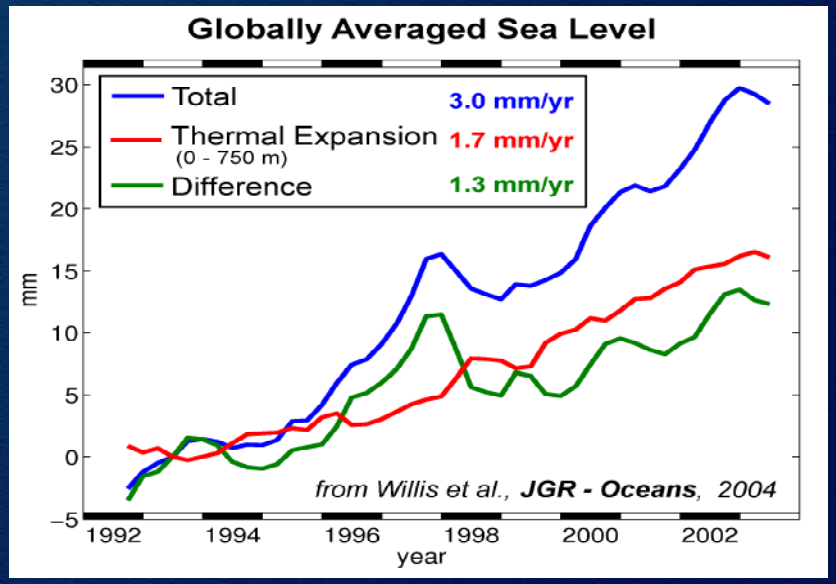
JPSS(NPOESS) Standalone Climate Sensor Recoveries (As Of February 2009)



Ocean Height CIR and Models Reveal Similar Rise From Melting and Expansion

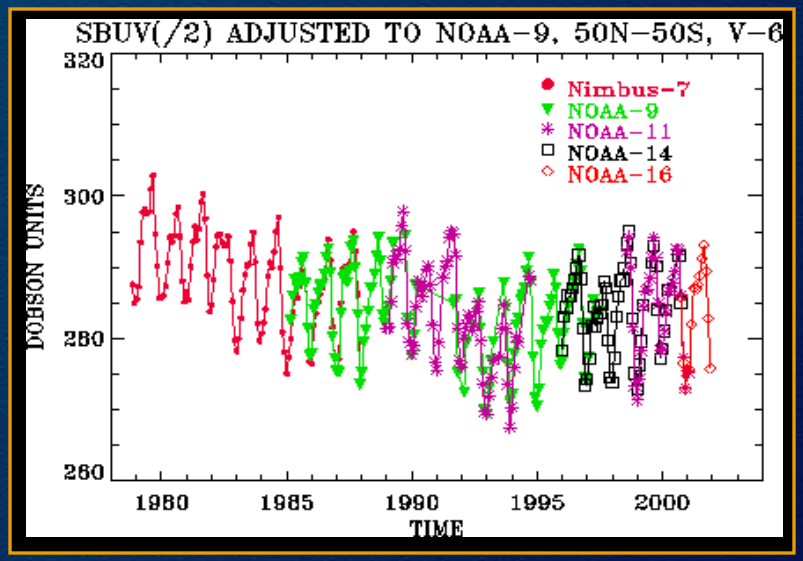
- Critical indicator of climate change and its potential impacts on coastlines
- Global record began in early 1990s
- The Ocean Surface Topography Mission (OSTM) or "Jason 2" launched in 2008 and will provide altimetric data through 2011 and possibly through 2013
- NOAA and partners currently studying a follow-on flight

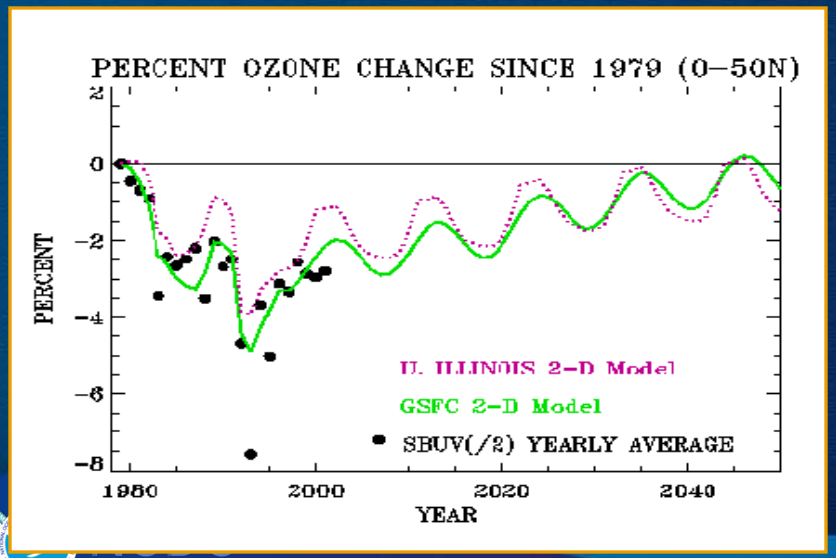


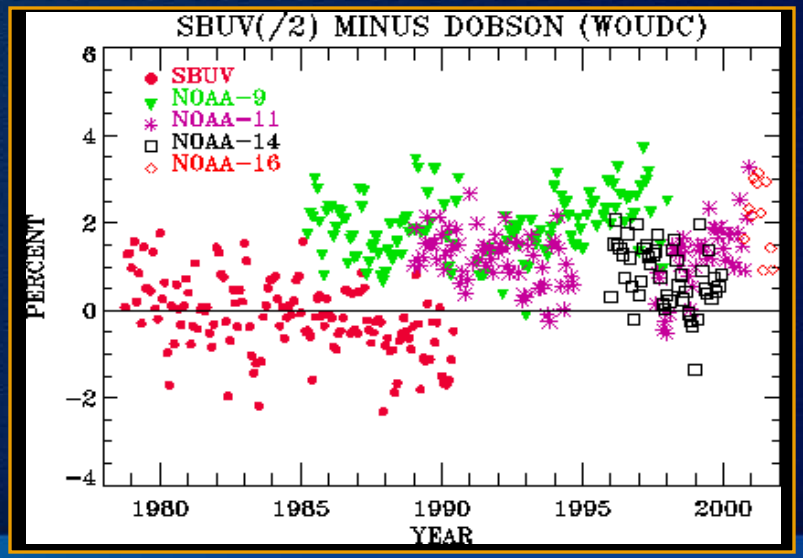


Ozone CIR Used To Validate Models and Verify International Treaties

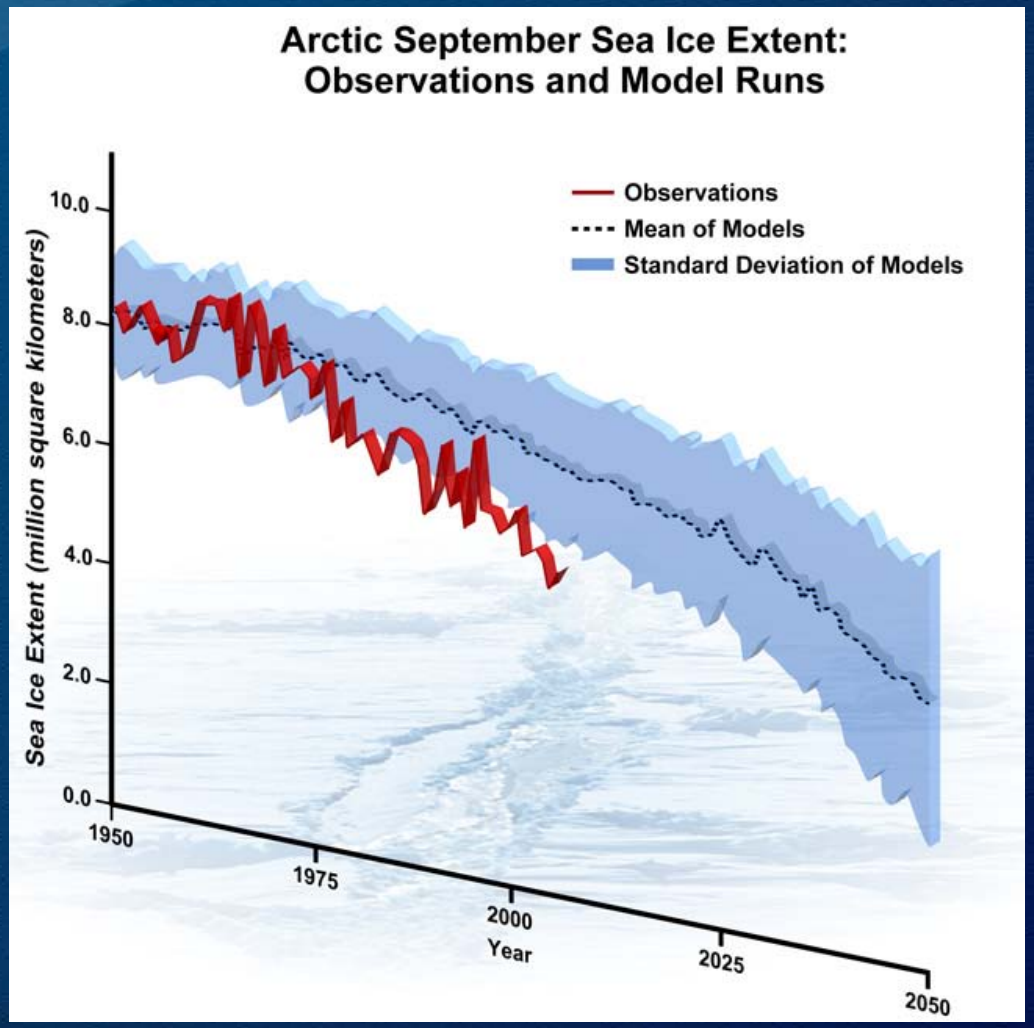
- Ozone is adjusted to NOAA-9
- Validated against Dobson Stations
- Reprocessed when new algorithms are developed by joint NOAA/NASA team
- Compared with models







Arctic Sea Ice Extent CIR: Thaw Rate Exceeds Predictions



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Maturity Matrix Identifies Milestones and Research-to-Operations Transition Points

Daily Optimum Interpolation Sea Surface Temperature

: Completed
: In Process

Maturity	Sensor Use	Algorithm Stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications
1	Research Mission	Significant changes likely	Incomplete	Draft ATBD	Minimal	Limited data availability to develop familiarity	Little or none
2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing
3	Research Missions	Minimal changes expected	Research grade (extensive); Meets international standards	Public ATBD; Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.
4	Operational Mission	Minimal changes expected	Stable, Allows provenance tracking and reproducibility; Meets international standards	Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.
5	All relevant research and operational missions; unified and coherent record demonstrated across different sensors	Stable and reproducible	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Multi-mission record is publicly available with associated uncertainty estimate	Used in various published applications and assessments by different investigators
6	All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following extensive scrutiny	Stable and reproducible; homogeneous and published error budget	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Product, algorithm, validation, processing and metadata described in peer-reviewed literature	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation	Multi-mission record is publicly available from Long-Term archive	Used in various published applications and assessments by different investigators

Candidate Climate Information Records (CIRs) from JPSS

Climate Information Record (CIR)

A Climate Information Product is a time series derived from CDRs and related long-term measurements to provide specific information about environmental phenomena of particular importance to science and society. CIRs are often designed to convey key aspects of complex environmental phenomena in a manner useful to a variety of user communities.

Discipline Area	CIRs (list names)	Primary Sensor Dependencies
Atmosphere	Climate Forecast System	VIIRS, CrIMMS, MIS
	Climate Data Assimilation System (CDAS) / Reanalysis	VIIRS, CrIMMS, MIS
	Ozone Hole Area	OMPS, CrIMMS
	Earth Radiation Budget	ERBS
	Stratospheric Warming	CrIMMS
	Extratropical Storm Tracks	CrIMMS
	Tropical Storm tracks	VIIRS, CrIMMS, MIS
	Teleconnection Indices	CrIMMS
	Multi-Decadal Signal	VIIRS, CrIMMS, MIS
	Tropical Atlantic Circulation Indices	VIIRS, CrIMMS, MIS
	Accumulated Cyclone Energy Index	VIIRS, CrIMMS, MIS
	North Atlantic Oscillation Index	CrIMMS
	Precipitation	MIS
	Ozone Hole Size	OMPS, CrIMMS
	Polarward Heat Flux	CrIMMS
	Polar Vortex Area	CrIMMS
	Polar Stratospheric Cloud Area	CrIMMS
	Cross Tropopause Mass Flux	OMPS, CrIMMS
	Stratosphere Temperature Monitoring	CrIMMS
	Total and Profile Ozone Monitoring	OMPS, CrIMMS
	SW/LW Radiation (evaporation)	CrIMMS
Ocean	ENSO Indices	VIIRS, CrIMMS, MIS
	Ocean Data Assimilation System	VIIRS, CrIMMS, MIS
	Surface Wind	MIS
	Surface Heat Flux	VIIRS, CrIMMS, MIS
	Salinity	MIS
	Sea Level Height	Altimetry
Terrestrial	Drought coverage/intensity	VIIRS, CrIMMS, MIS
	Flood monitoring	VIIRS, CrIMMS, MIS
	Snow Cover Area	VIIRS
	Soil Moisture	MIS

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