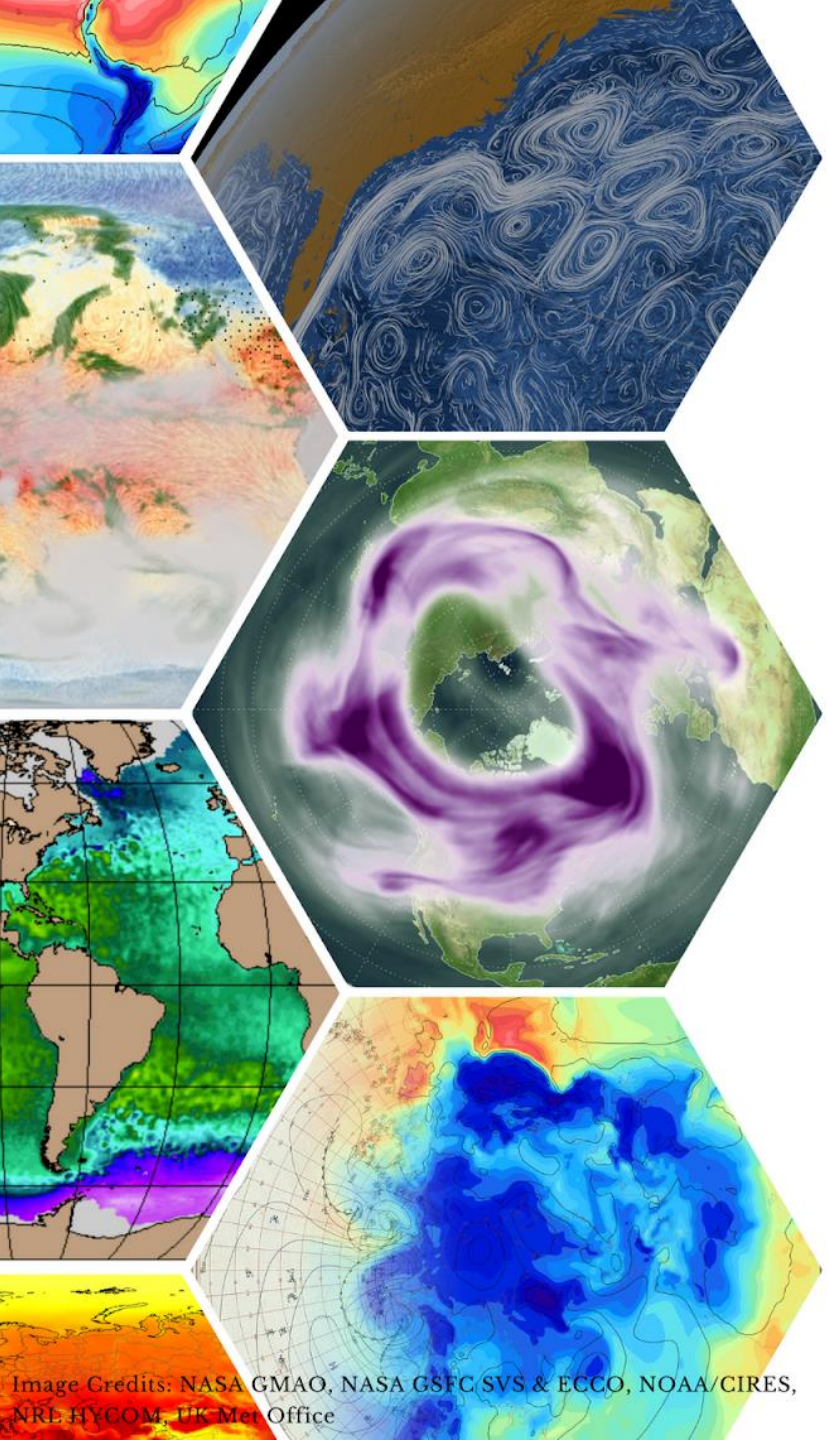


Image Credits: NASA GMAO, NASA GSFC SVS & ECCO, NOAA/CIRES, NRL HYCOM, UK Met Office

https://usclivar.org/meetings/reanalysis-2021

Workshop on Future US Earth System Reanalysis

MAY 16-18, 2022
BOULDER, CO & VIRTUAL

A workshop aimed at developing a shared scientific, technological, and application vision for the future of US reanalysis efforts.

Scientific Organizing Committee
Sergey Frolov, NOAA PSL (co-chair)
Cécile Rousseaux, NASA (co-chair)
Tom Auligne, JCSDA
Dick Dee, Planet A
Ron Gelaro, NASA GMAO
Patrick Heimbach, U. Texas
Isla Simpson, NCAR
Laura Slivinski, CIRES/NOAA PSL

Sponsored by

US CLIVAR NASA NOAA NSF

Objectives

1. Identify **scientific goals** for the next generation of reanalysis from the atmospheric, oceanographic, and cryosphere perspectives.

2. Identify opportunities for **exploiting technological advancements** in Earth system models, data assimilation systems, observations, and computational infrastructure.

3. Identify priorities and **opportunities for tighter collaboration** between the US institutions, the US and the international reanalysis communities, and between reanalysis and observational communities.

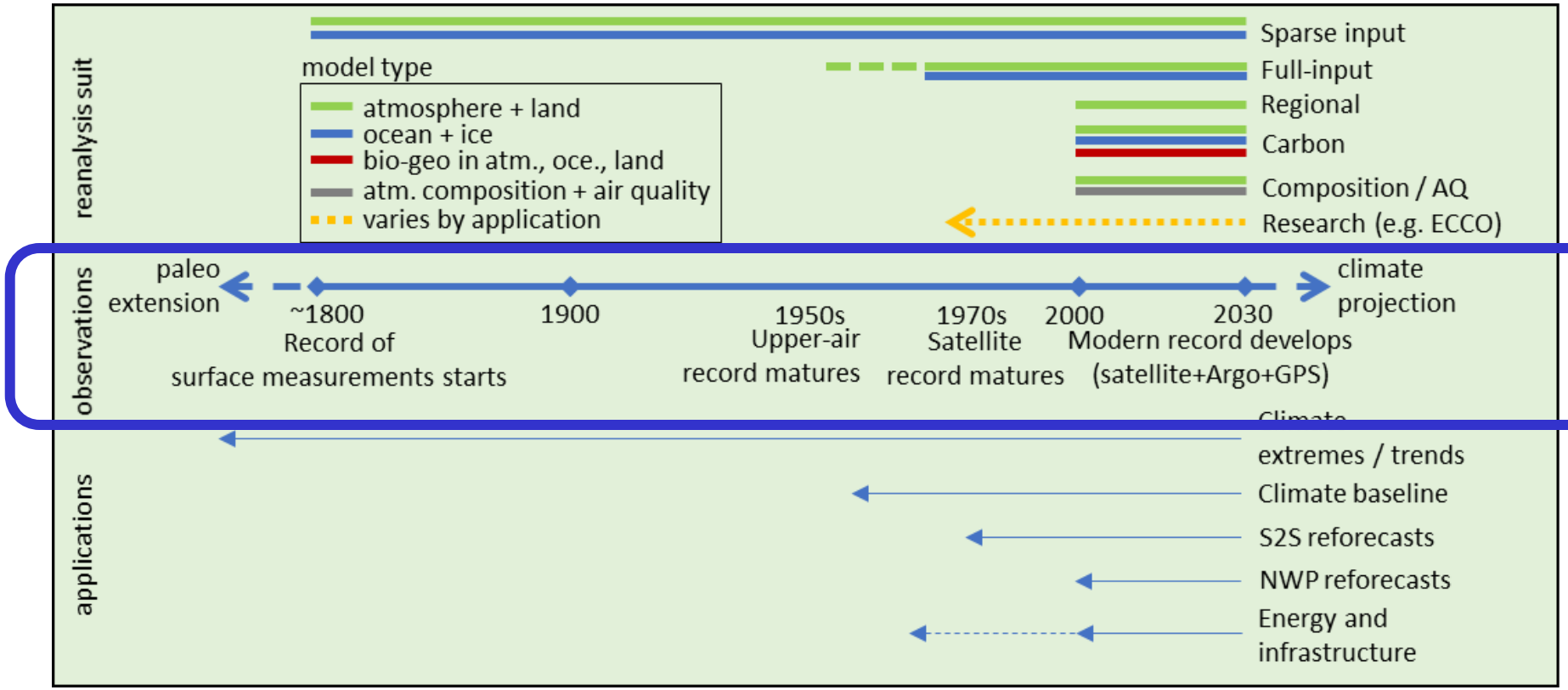
Cross cutting recommendation: 10-year vision of consistent reanalysis

- Consistent across multiple components of the Earth system:
  - Atmosphere, ocean, ice, land, carbon, air quality, hydrological cycle;
  - Fluxes across components; and
  - Start to close essential budgets of heat, water, and carbon.
- Consistent in representation of temporal trends:
  - Robust to changes in the observing system;
  - Estimates of uncertainty that reflect changes in the observing network.
- Colocation of compute and reanalysis product storage:
  - Consistent access across multiple reanalysis producers.
- Consistent/common error metrics and diagnostics that can guide development and evaluation of future products.

Do we need one reanalysis to rule them all?

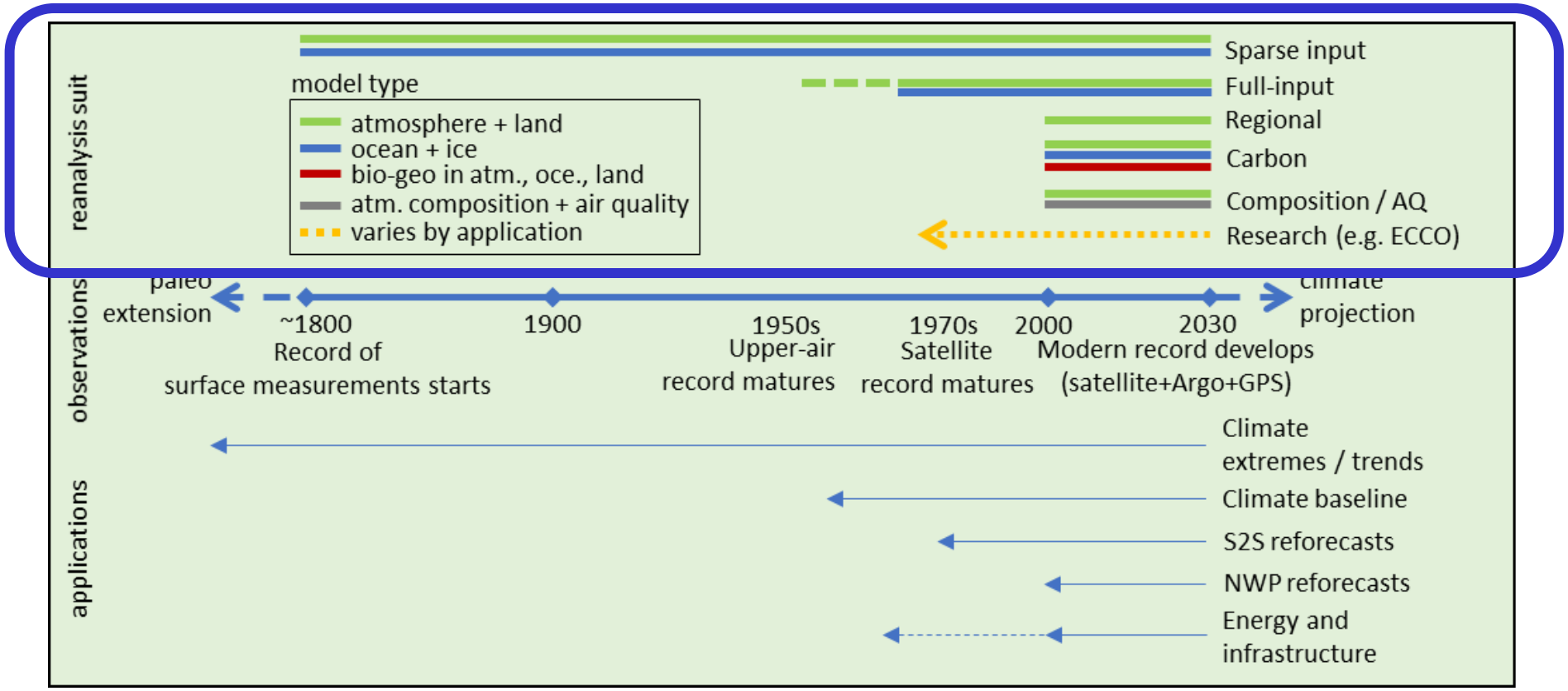
"A consensus was reached that striving for a single reanalysis product that integrates all components of the Earth system and satisfies the diverse user needs is infeasible and would likely degrade the accuracy of individual Earth System components."

Suite of reanalysis:
Strategy for development of consistent reanalysis products



Availability of historic data will dictate types of products that we can produce

Suite of reanalysis:
Strategy for development of consistent reanalysis products



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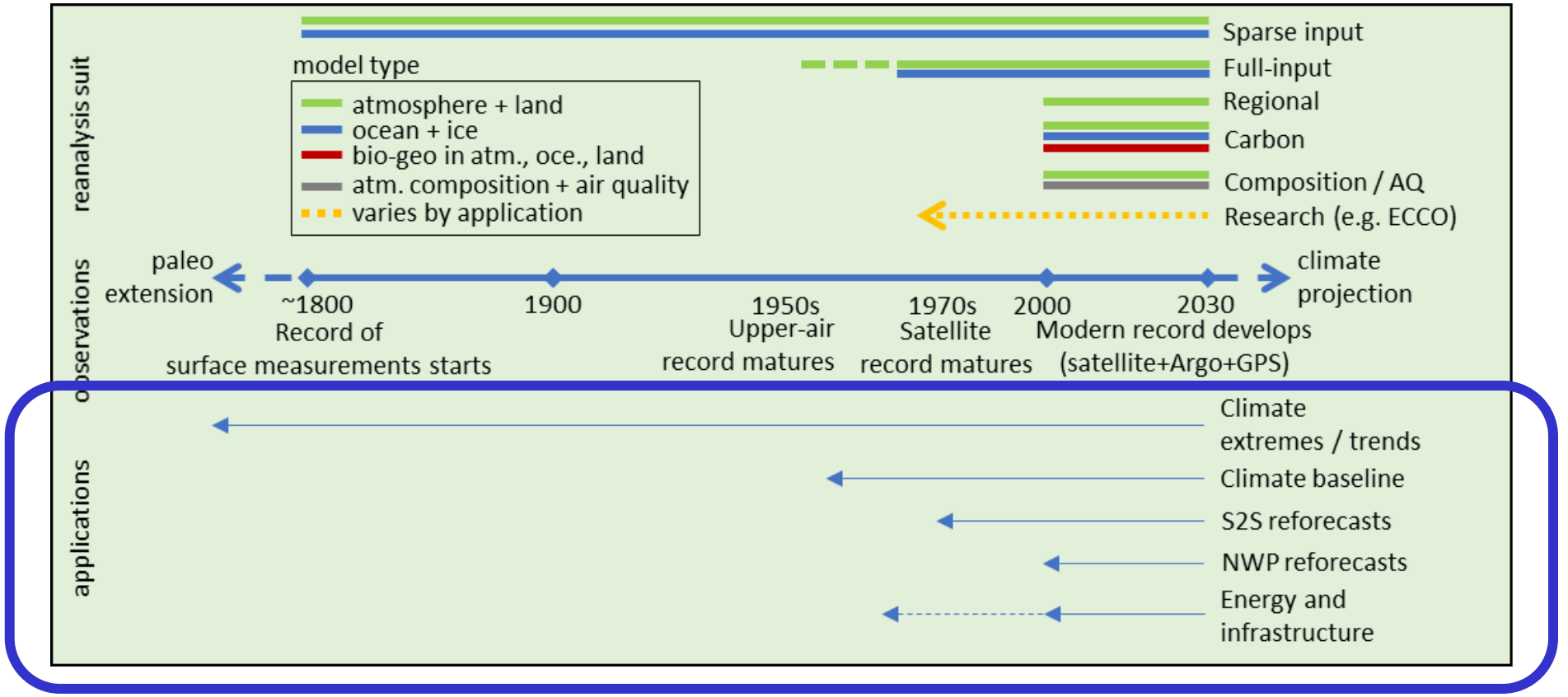
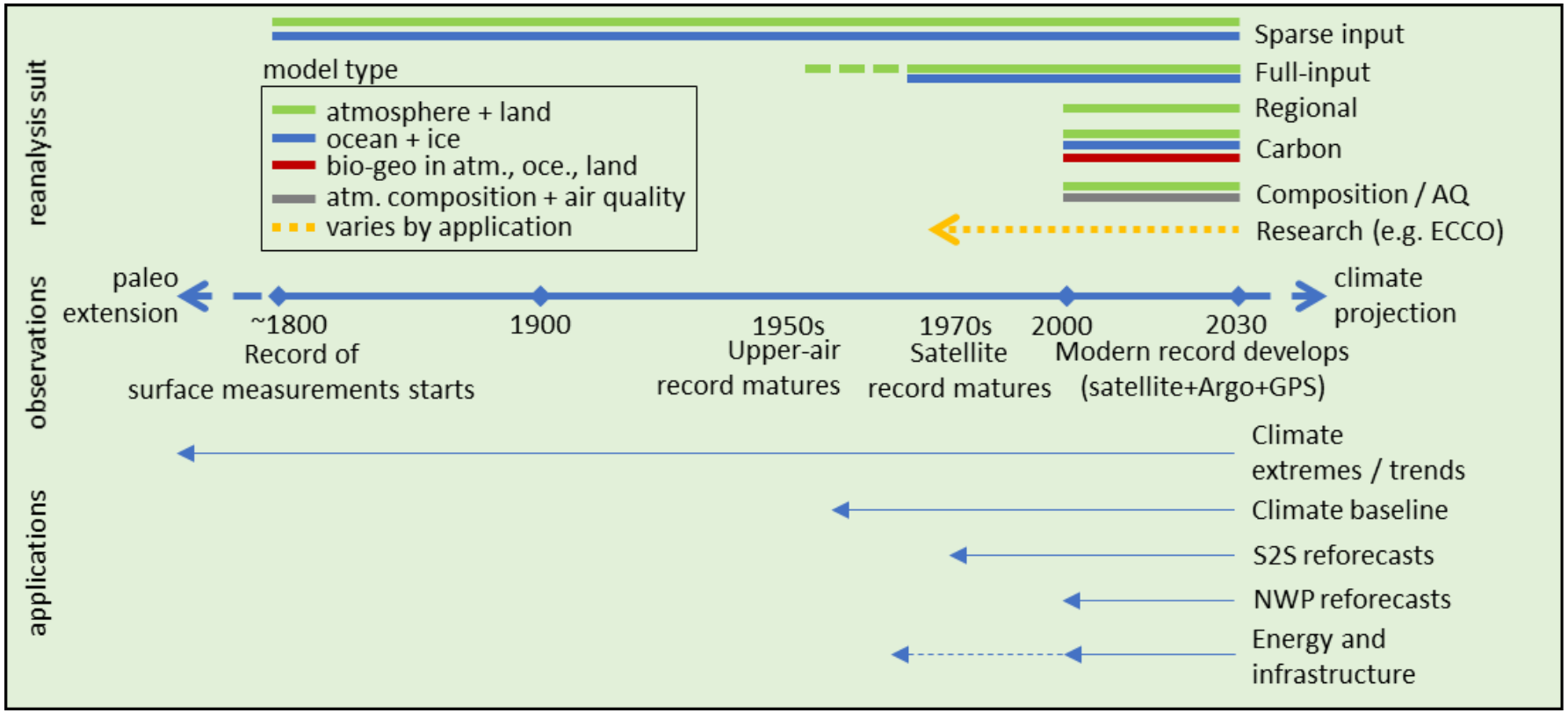


Proposed reanalysis suite projects on a wide range of applications and stakeholder needs.

Suite of reanalysis:
Strategy for development of consistent reanalysis products



- Backbone reanalysis includes:
  - Sparse-input centennial reanalysis (only assimilates surface observations with a long historic record) and
  - Full-input modern era reanalysis (all available data, including satellite record from late 1970s),
  - Each produced with state-of-the-art coupled atmosphere, ocean, ice, and land models.
- Backbone products will drive carbon stock, air quality, and hydrological reanalyses at global or regional scale.

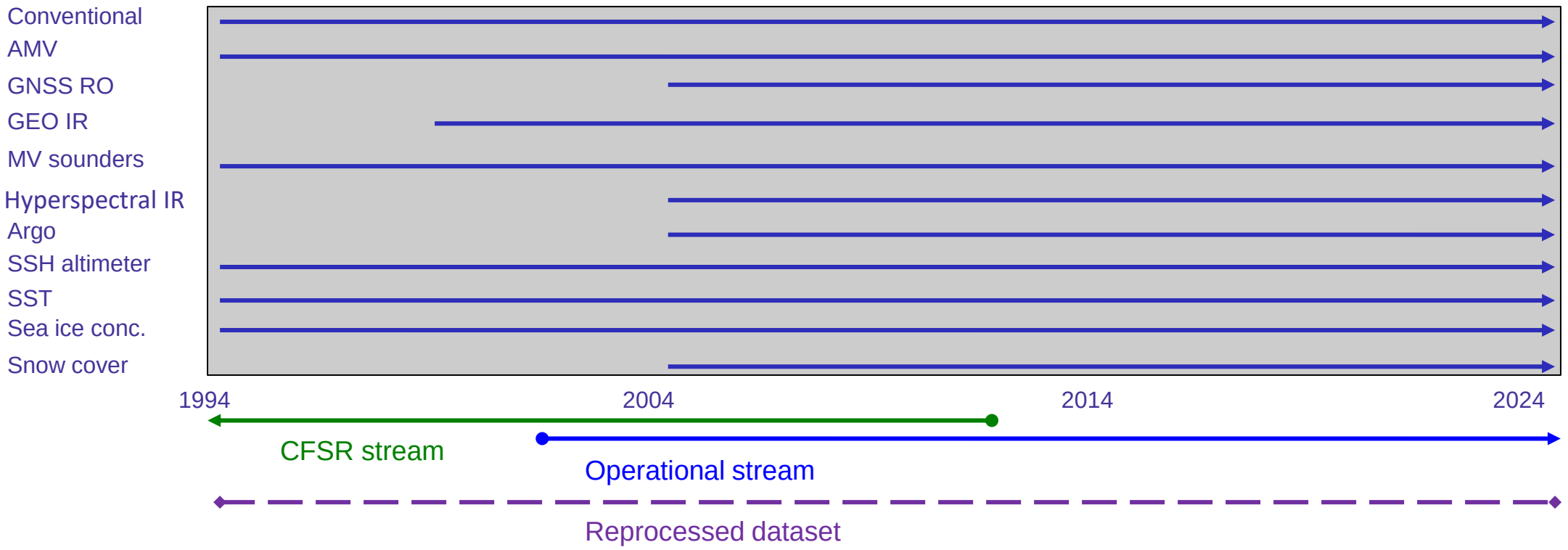
Key scientific challenges

- Reanalysis with coupled models:
  - Reducing biases and closed budgets.
- Accounting for storage and fluxes of carbon:
  - Land modeling is a leading challenge.
- Representation of droughts, precipitation, water movement and storage between Earth system components.
- More realistic representation of tropospheric ozone in support of air quality reanalysis.
- Reduction of systematic model errors.

Needs for shared infrastructure

- Shared modeling components:
  - FV3, MOM6, CICE, ESMF, CPPP, ….
- Shared data assimilation infrastructure:
  - Joint Effort for Data assimilation Integration–JEDI.
- Shared and open database of inputs:
  - Full suite of observations for a coupled reanalysis.
  - Forcing and boundary conditions: SST products, CO_2 forcing, land use databases, etc.
- Shared diagnostics and error metrics.
- Common access patterns for products:
  - Need to collocate computations with reanalysis and observational products from multiple producers.

Ongoing work on shared observational database



- Join project between NOAA EMC/PSL and NASA GMAO
- Assemble 30+ years of atmosphere/ocean/ice/land observations in reanalysis-ready formats.
- Curated dataset that includes multiple (including reprocessed) versions of data.
- Unified access enabled by cloud services.

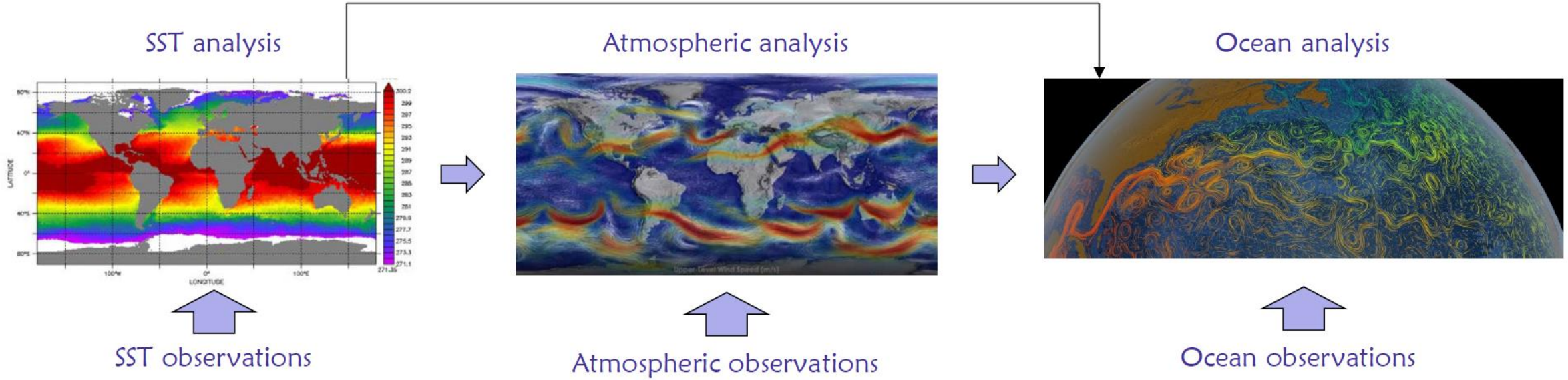
Summary

- A multi-agency sustained effort is needed to fulfill the 10-year vision for the consistent reanalysis.

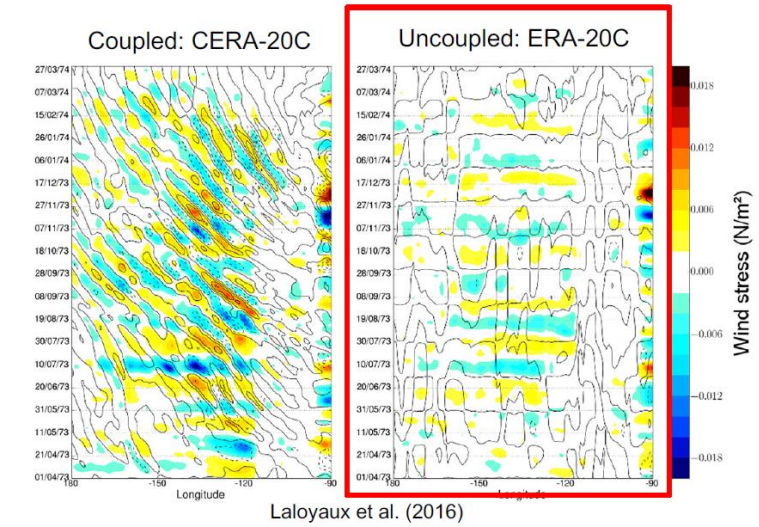
- New methods for inter-agency collaboration might be needed to share and focus limited resources (lessons learned from the EU Copernicus Climate Services).

End

Current approach to reanalysis production (e.g. ERA or MERRA series)



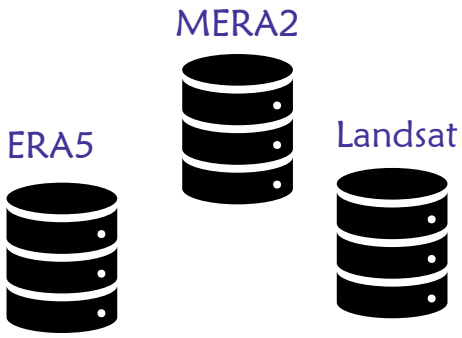
- (top) Most of the modern reanalysis (MERRA, ERA, GEFS, GLORYS) are produced sequentially (uncoupled).
- (right) Uncoupled reanalysis can be inconsistent across model interfaces, resulting in inconsistent fluxes and inability to close budgets.

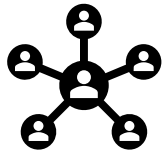


Laloyaux et al. (2016)

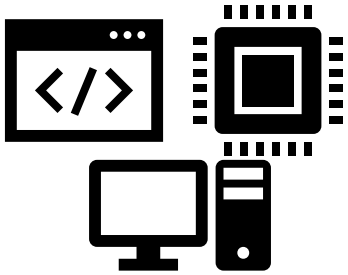
Cloud-based analysis workflows

On-prem paradigm



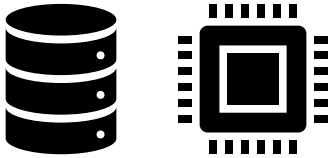


User downloads datasets over internet



User stores data and performs the analysis locally

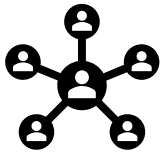
Emerging cloud paradigm



Datasets and compute are collocated

Standardized services for access to data

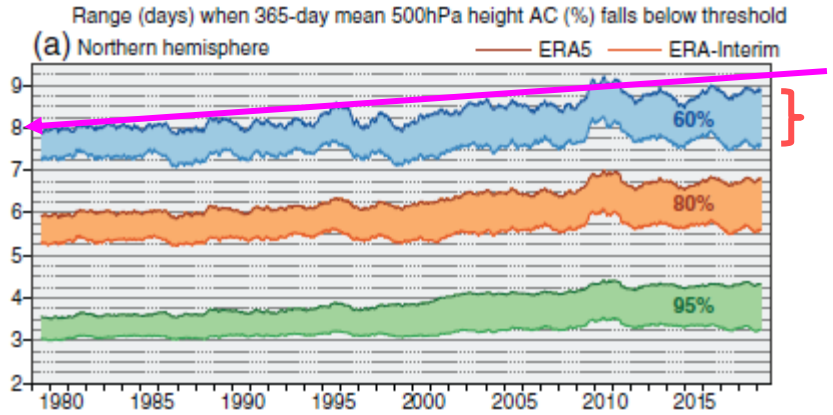
Code is written and executed on the cloud



A much smaller sub-set of results is downloaded over internet

Data analysis can be performed with lightweight end user hardware.

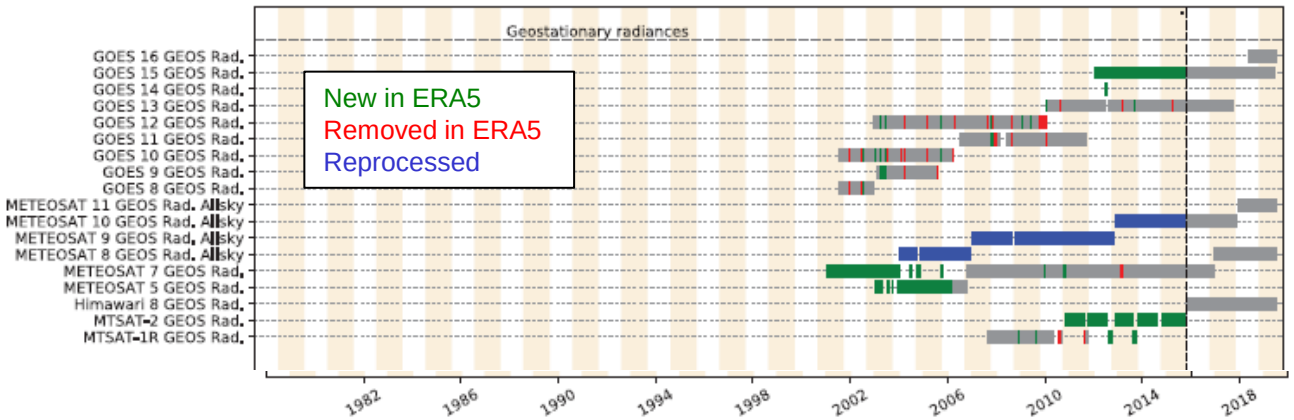
Reanalysis is an on-going activity



Reanalysis skill degrades as fewer observations are available

Reanalysis quality greatly improves with evolution of the forecast/DA system

Example of observations used in ERA5 compared to ERAI



- Quality of reanalysis continuously improves due to better models, more compute power and improved recovery of historical observations.

Hersbach et.al 2020 QJRMS