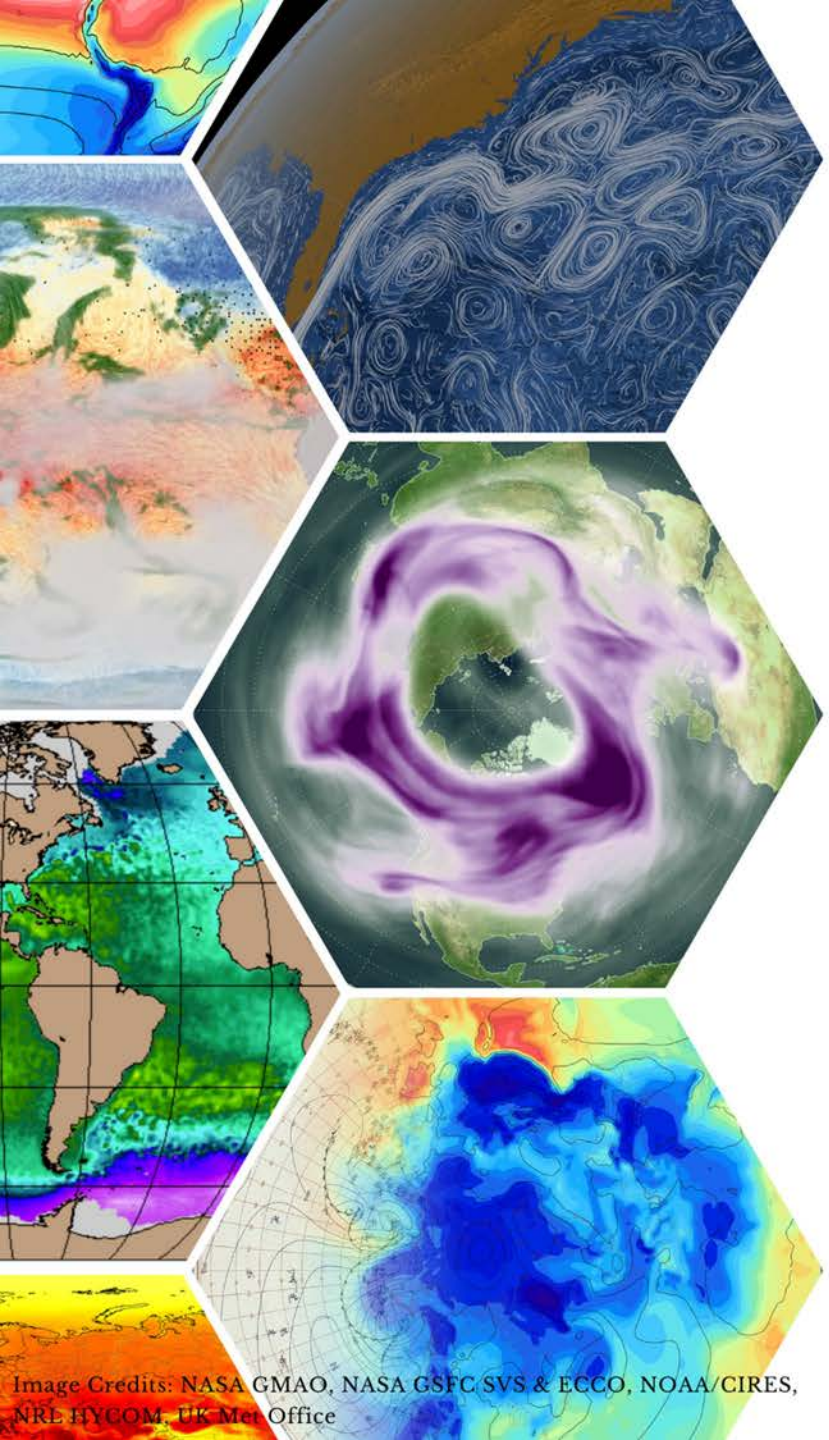

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https://usclivar.org/meetings/reanalysis-2021

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

Outcomes

The desired outcome is a *BAMS*-type article with a **10-year vision** for a reanalysis that is consistent across Earth system components, identifying:

- **scientific goals** for the next generation of reanalysis from the atmospheric, oceanographic, and cryospheric perspectives.

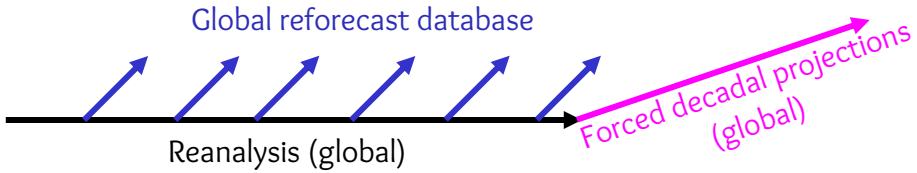
- opportunities for exploiting **technological advancements** in Earth system models, data assimilation systems, observations, and computational infrastructure.

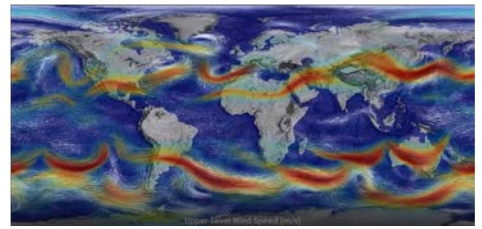
- priorities and opportunities for **tighter collaboration** between the US institutions, the US and the international reanalysis communities, and between reanalysis and observational communities.

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

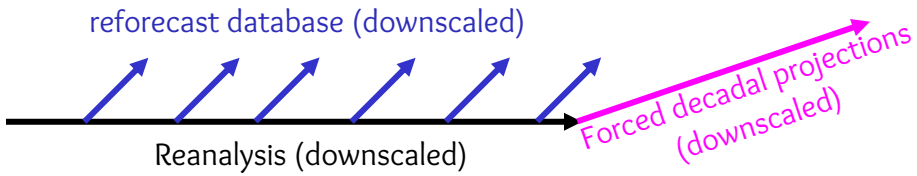
https://usclivar.org/meetings/reanalysis-2021-webinars

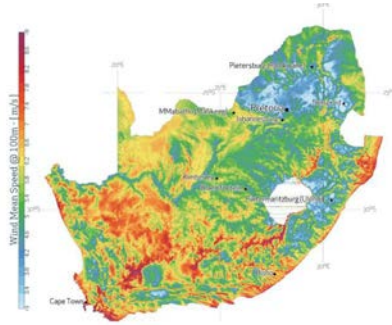
A case for digital twins



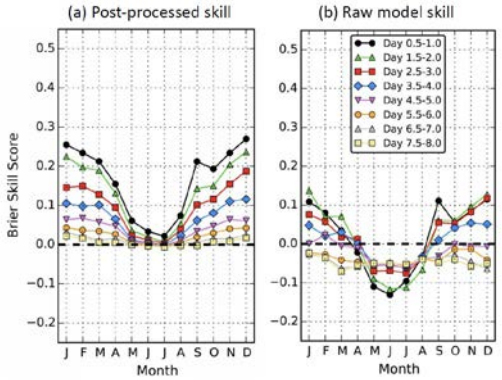


Regional downscaling (100km->1km)





NWP post-processing



Application value chain

Training of machine learning models

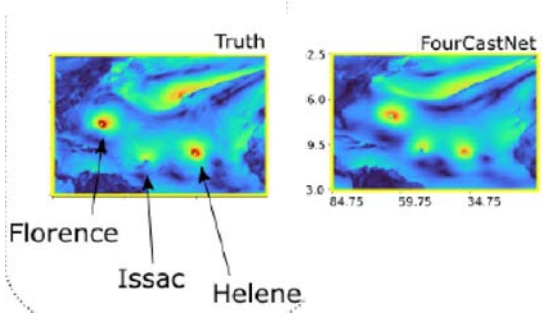
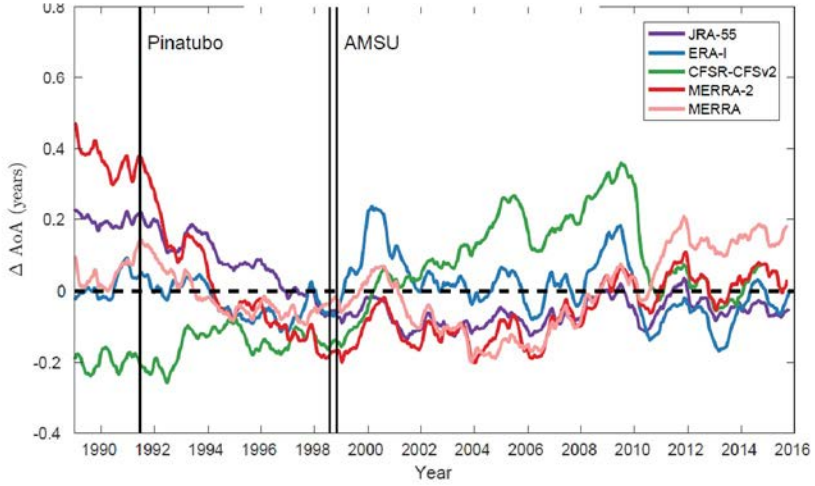


Image Credits: NASA GMAO, NASA GSFC SVS & ECCO, NOAA/CIRES, NRL HYCOM, UK Met Office

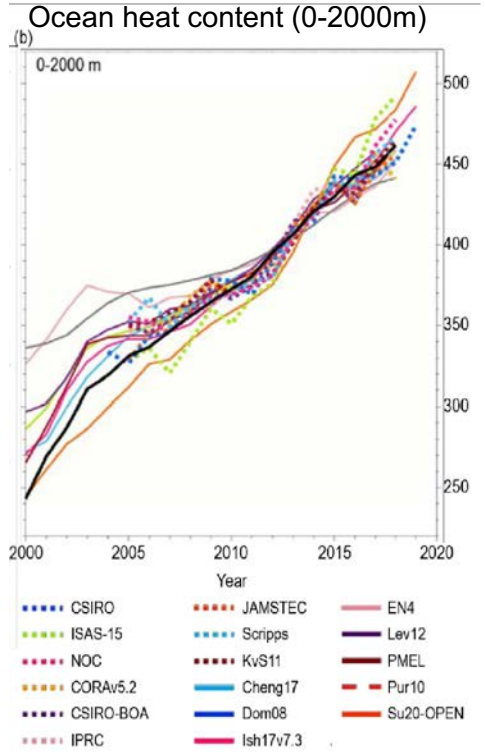
Advanced scientific users of reanalysis

Age of air anomalies (72S-72N and 16-28 km)



Adapted from Chabrillat et al. (2018)

Ocean heat content (0-2000m)



IPCC, AR6, Chapter 2 (Gulev et al., 2021)

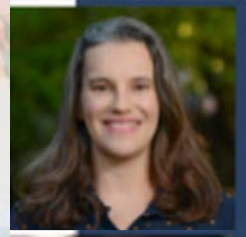
- Scientific community has many sophisticated use-cases for the reanalyses products, including IPCC assessments, reanalysis inter-comparisons, model development, climate intervention, flux and budget analyses, etc.
- Opportunities for closer collaboration between reanalysis producers and science end-users (common software, metrics etc.).

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

March 8, 2022 | 4pm ET

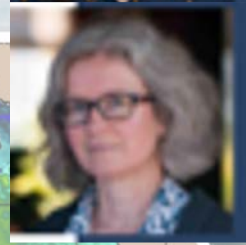
Arlindo da Silva
NASA Goddard

Planning for future observing systems focused on coupled processes



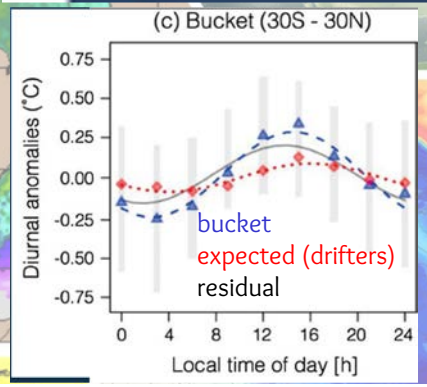
Linden Ashcroft
University of Melbourne

Sparse data rescue



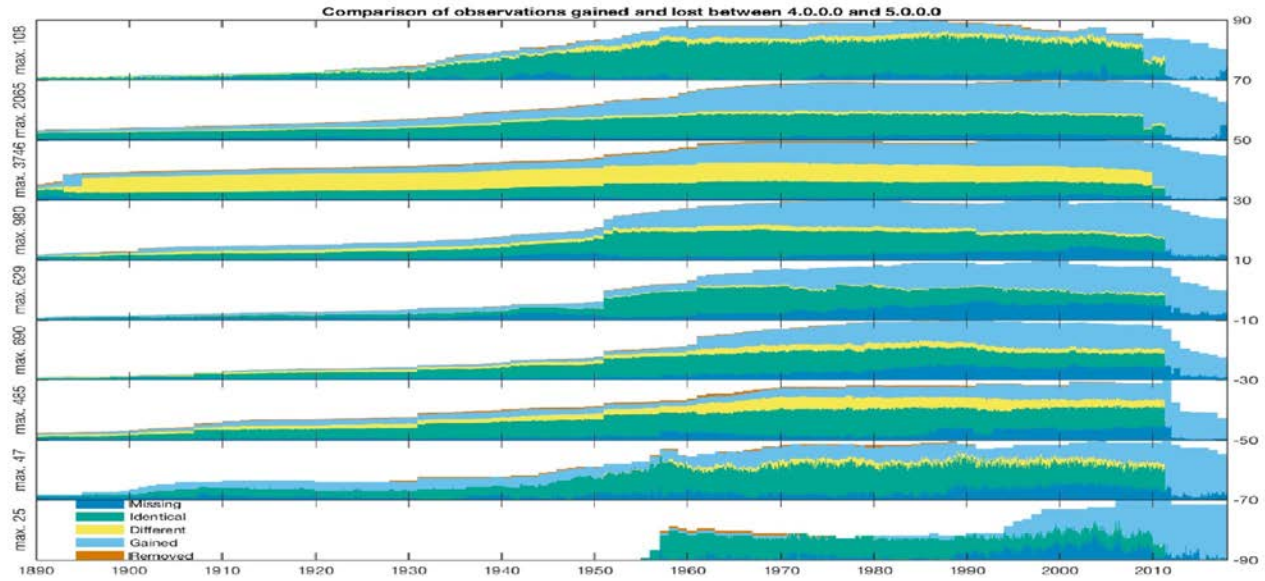
Elizabeth Kent
National Oceanography Centre

Role of SST forcing in reanalysis and ability to reconstruct climate records



Chan, D., & Huybers, P. (2021). Correcting Observational Biases in SST Observations Removes Anomalous Warmth during World War II, JClim.

Reprocessing of surface temp (CRUTEMP)



18??-1950
Sparse instrumented record

1950-1979
Conventional record

1979-1998
early satellite

1998-2020
Modern satellite record

2020+
Post-Modern satellite record
(precipitation, clouds, and aerosols)

Cloud as a game-changer

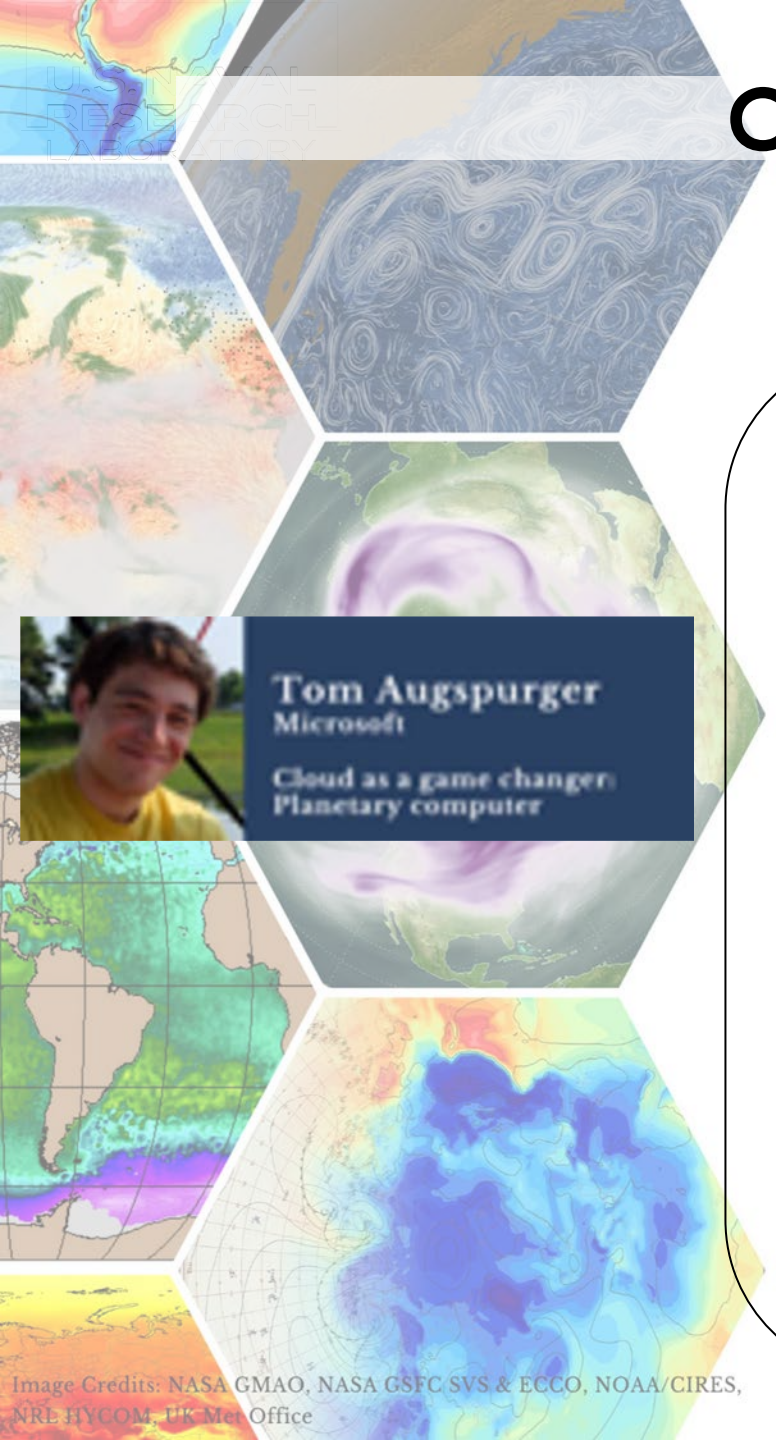


Image Credits: NASA GMAO, NASA GSFC SVS & ECCO, NOAA/CIRES, NRL HYCOM, UK Met Office

On-prem paradigm

MERA2

ERA5

Landsat

User downloads datasets over internet

User stores data and performs the analysis locally

Cloud-based paradigm

Datasets and compute are collocated

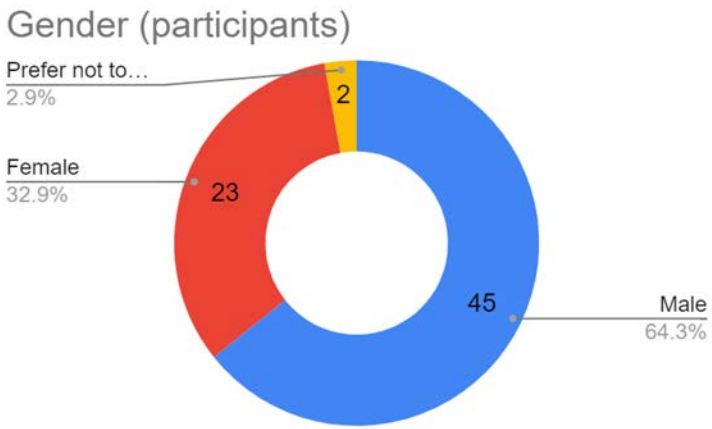
Standardized services for access to data

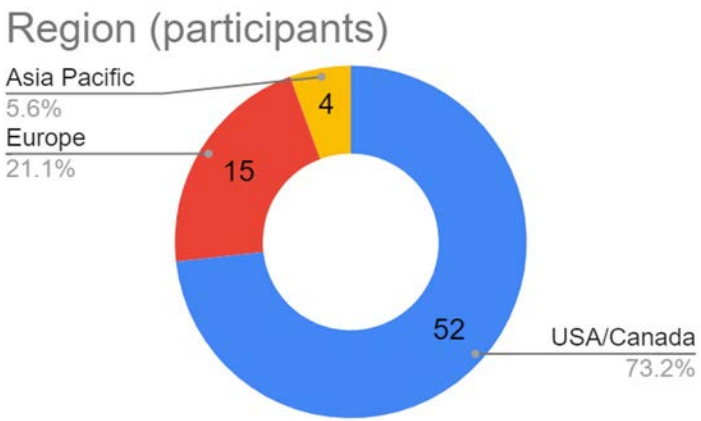
Code is written and executed on the cloud

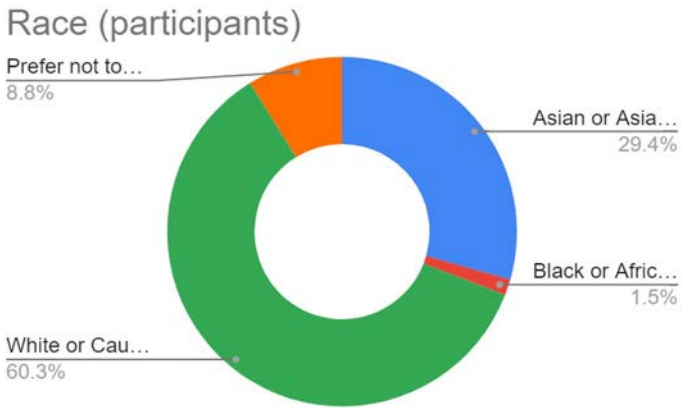
A much smaller sub-set of results is downloaded over internet

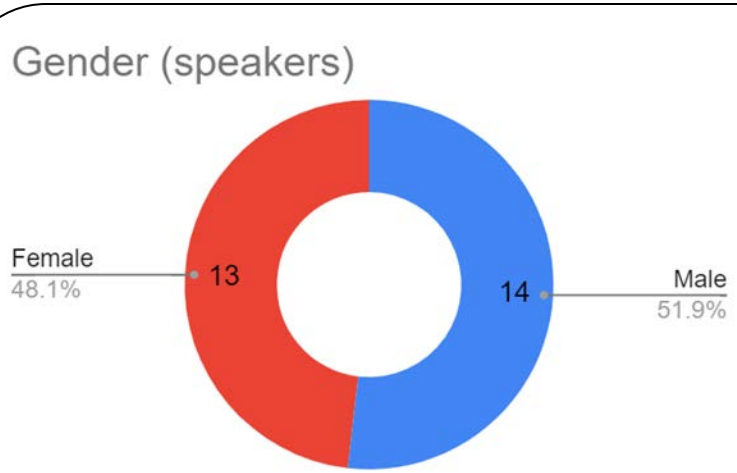
Data analysis can be performed with lightweight end user hardware.

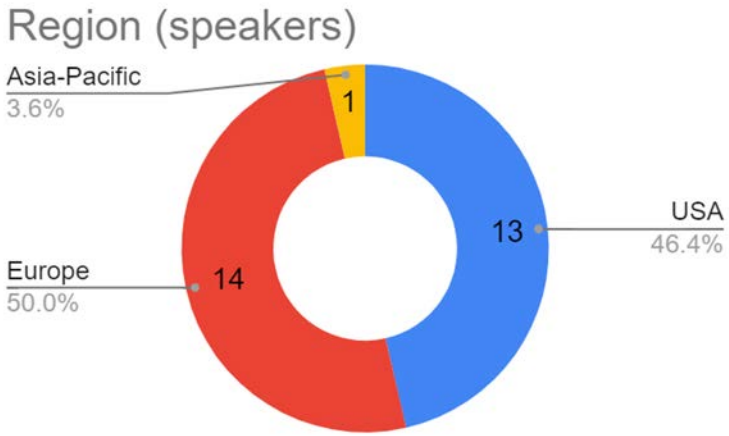
Diversity and inclusion

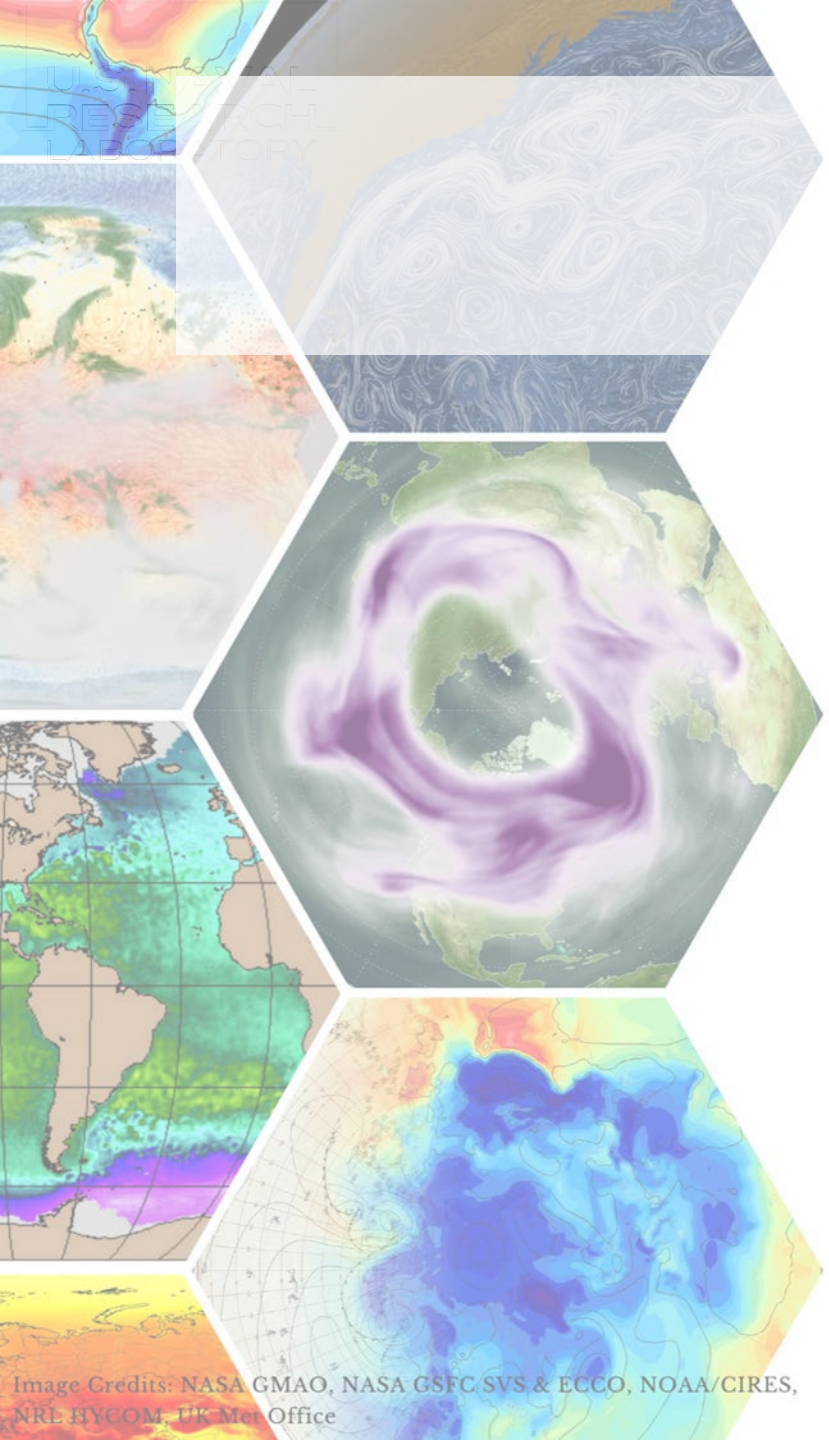






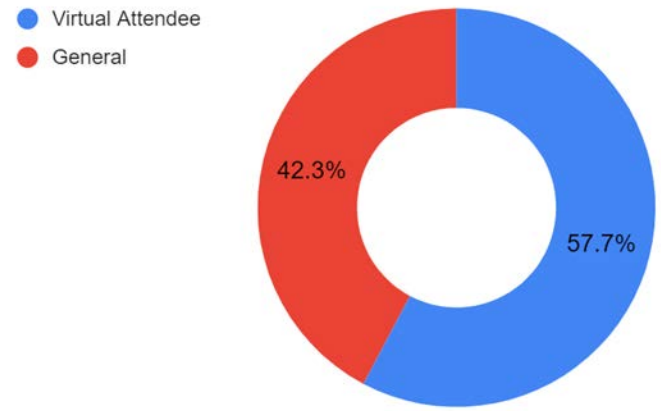






Logistics

- Wifi
- Bathrooms
- Reception
- Posters



Day 1 goals
10-year vision: Science of reanalysis

- Elucidate how science and applications (including numerical weather prediction) drive the need for consistent reanalysis.
- Identify model components and the level of coupling that is feasible to achieve in the next decade.
- Catalogue observational data available to support a consistent climate reanalysis, and identify needs for observational data rescue and future observing systems required.

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

Day 1 Breakout questions
10-year vision: Science of reanalysis

1. What do you see as the main user requirements within your field for a consistent/integrated Earth system reanalysis?
2. How would you define consistent reanalysis?
3. Emerging applications: what can reanalysis products currently be used for, and what would you like to use them for in the future?
4. What are some opportunities and unmet needs in the private sector regarding reanalysis? What are the opportunities for private-public partnership?
5. What are some opportunities and unmet needs for NWP regarding reanalysis (MRW, S2S, decadal prediction)?
6. How can we foster collaboration (synergy) between the climate modeling and reanalysis production communities? Are there examples of this collaboration currently working?

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

What do you see as the main user requirements within your field for a consistent/integrated Earth system reanalysis?

There is a tension between different kinds of users e.g., those who want to look at long term trends are looking for consistency in time, while those who want to use them for initialization or to examine processes on shorter timescales want the most realistic state possible. Different people will want different things

- People want to be able to look at trends. Requires consistency in time and minimization of artifacts due to observing system changes.
- To gain a process-level understanding we want reanalyses to get trends right for the right reasons i.e., the correct multivariate relationships and budget terms
- Consistent approach across systems/centers for characterizing budgets (e.g., diagnose and output individual terms). May be challenging given different approaches (MERRA vs ERA)
- There should also be a consistent quality across space (e.g., Africa vs Europe)
- Given the tension between desires of different users, maybe there needs to be a suite of reanalysis products to address different needs e.g., climate monitoring vs NWP reforcasting vs budget analysis.
- Consistency of data formats (or maybe API) and improved data accessibility.
- Use of a consistent set of metrics to track improvements and changes as new components and features are added from one version to the next and for intercomparison of products.
- Guidance on appropriate use of specific datasets.
- Uncertainties and error budgets as part of the standard products.
- Consistency in fields seen by different components of the model e.g., CO2 in the BGC aspects being consistent with CO2 seen by the radiation scheme.

Emerging applications: what can reanalysis products currently be used for, and what would you like to use them for in the future?

Future uses:

- Carbon fluxes and stocks including ocean, land and atmosphere. The land is where the major work is needed (probably more than 10 years worth - community is fragmented, need to work together to achieve this goal).
  - engage with the UNFCCC "Global Stocktake" of the the 2014 Paris Agreement
- More coupled reanalyses with dynamic ocean.
- More ocean biogeochemistry applications.
- More high frequency and fine spatial scale output
- More trustworthy representation of precipitation (again for process-level understanding using reanalyses)
- Tropospheric ozone across the coupled atmosphere-land-biosphere system
  - consistent treatment vis-a-vis air quality
- Enhanced use of analysis increments to understand underlying model issues.
- Enhanced feedback to observing system requirements.

What are some opportunities and unmet needs in the private sector regarding reanalysis? What are the opportunities for private-public partnership?

- Use of reanalysis data in conjunction with health data,
  - interaction with public health community, improved health data for better data
  - examples are spread of flu, vector-borne diseases, …
  - pollution exposure (multiple health stressors and compound impacts)
- Expanded use of reanalyses in guiding energy transition to renewables
  - wind energy as one example
- Use of reanalysis data as training data sets for ML applications by the private sector - reanalysis community can provide required domain knowledge
- Use for context by coastal planners in the context of regional sea level change and coastal flooding (relationship to large-scale coupled ocean-atmosphere processes)
- Uses in conjunction with the New Blue Economy
- Uses in conjunction with agriculture planning
- Improved training. What you can do with reanalyses and what you can't
- Improved documentation for cloud providers
  - example of GoogleEarth which has some of the reanalysis data, but poorly documented, no provenance, …
- Potential collaboration with Pangeo for tool chains.

What are some opportunities and unmet needs for NWP regarding reanalysis (MRW, S2S, decadal prediction)?

- Signal-to-noise paradox in S2S hindcasts is a major concern. Can reanalyses teach us something about its origins?
- Overcoming the time scale gap (NWP vs. climate models)
  - possibly via seamless prediction systems NWP -> S2S -> interannual -> decadal

How can we foster collaboration between the climate modeling and reanalysis production communities?

- Enhanced collaboration with Earth System Modelling communities. Both communities will gain - reanalyses will gain from process representation capabilities in ESM's, ESM's will gain from the understanding of underlying model issues revealed by e.g., analysis increments.
- Enhanced use of assimilation frameworks to diagnose morel errors.
- Extending the notion of data assimilation to support comprehensive, data-informed climate model calibration
  - enhance "grey-matter optimization by formal parameter estimation workflows
- Climate modeling community could leverage expertise of reanalysis community to
  - confront model with diverse, heterogeneous data streams
  - characterization of uncertainties in the reanalyses vs. climate models
  - shared analyses of multivariate response relationships in reanalyses vs. climate models

Examples: DART runs with CESM. Challenges = expensive to run

C3S model has been successful in creating a direct channel between produces, users and modellers

SPARC/S-RIP has been successful.

Title

- Text

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