2.3 Observations

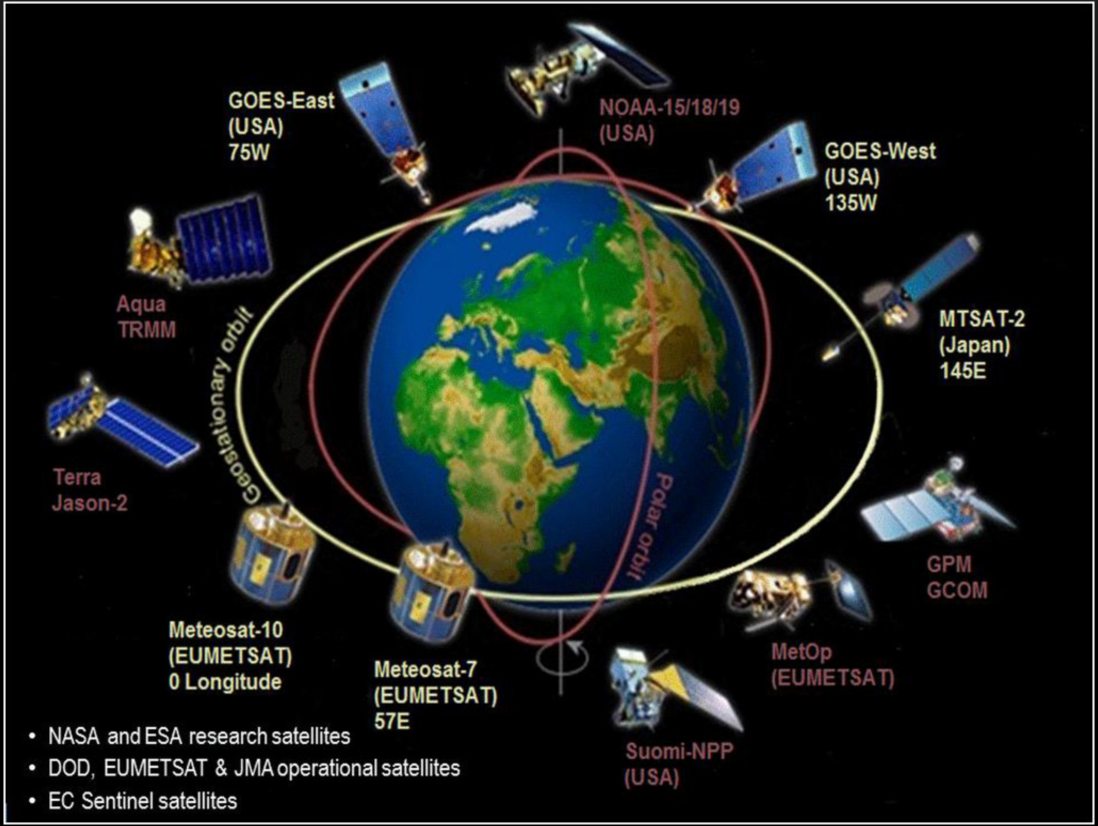
- Building blocks of climate prediction
  - Observations
  - Statistical/dynamical/hybrid models
  - Data assimilation
  - Validation and verification
- *Why do we need observations for climate prediction?*
  - Develop a statistical model
  - Initialize a climate model
  - Assess the model prediction skill
  - Identify biases and errors in numerical models
  - improve our process understanding, aid in the parameterization of unresolved processes, and identify new statistical predictors

Questions

- What atmospheric, ocean and land observations are relevant for climate variability and prediction on a certain time scale?
- What limitations and advantages do different observational sources have?

Atmosphere

- Conventional observations have increased substantially over years. For example, upper air observations (rawinsondes, pilot balloons, etc.) grew from less than 50 soundings in the 1920s to about 1,000 in the 1950s.
- Satellite data are an important observational data source owing to their good spatial and temporal coverage. Satellite products can provide information on atmospheric composition, hydrometeors, surface wind, and vertical profiles of T and humidity (National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*)



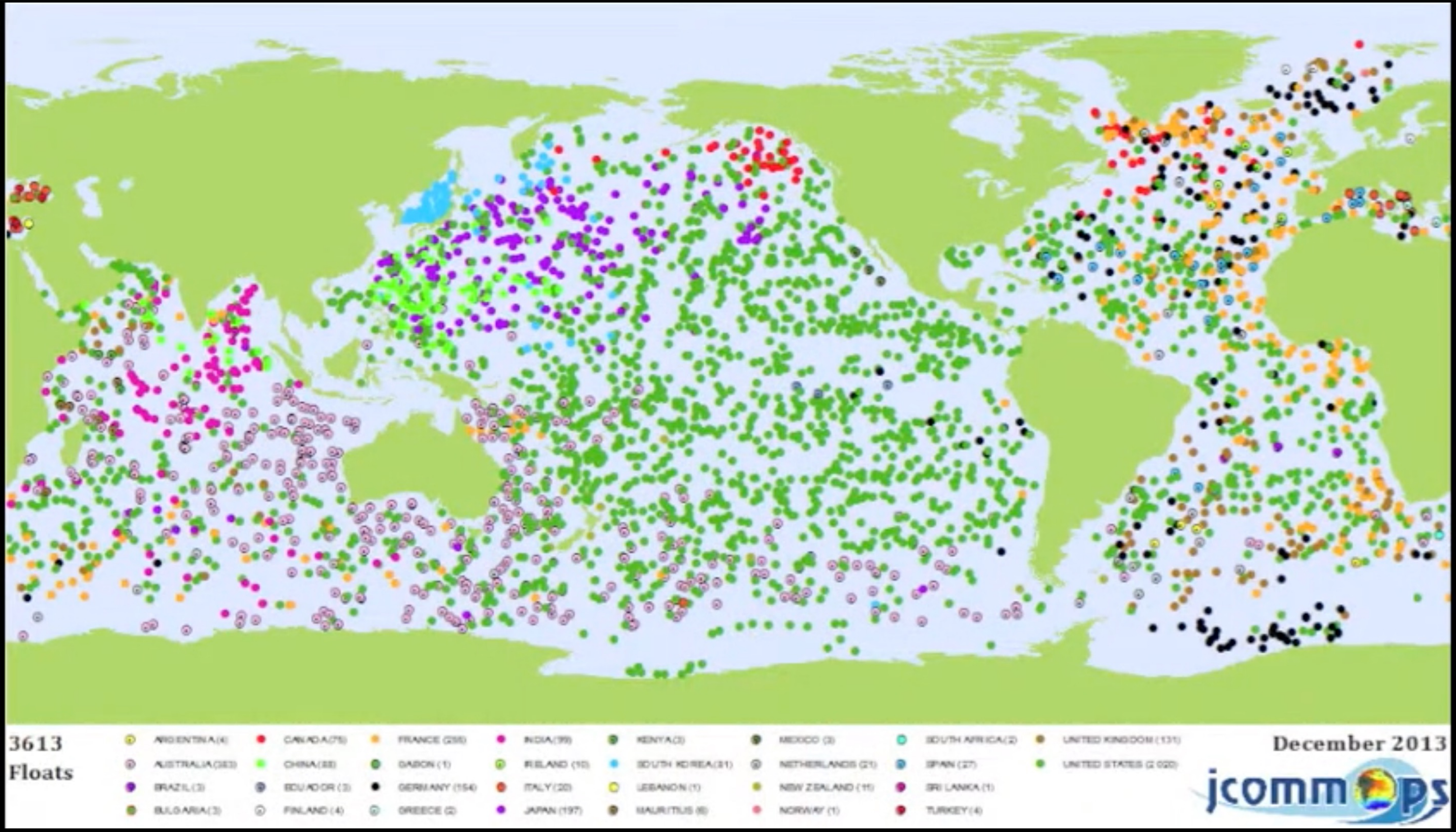
The satellite-based observing system. Polar-orbiting satellites (red) are distinct from those in geostationary orbits (white) and are defined by their equatorial crossing time (Lord et al. 2016, BAMS, © American Meteorological Society. Used with permission)

Ocean

- The states of the ocean surface and sub-surface, especially tropical sea surface temperature (SST), affect the atmosphere on intraseasonal to interannual timescales.
- Near-term climate prediction benefits from the initialization of surface and sub-surface ocean state.
- Global ocean observing systems
  - The Argo
  - Global drifter array
  - OceanSITES

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

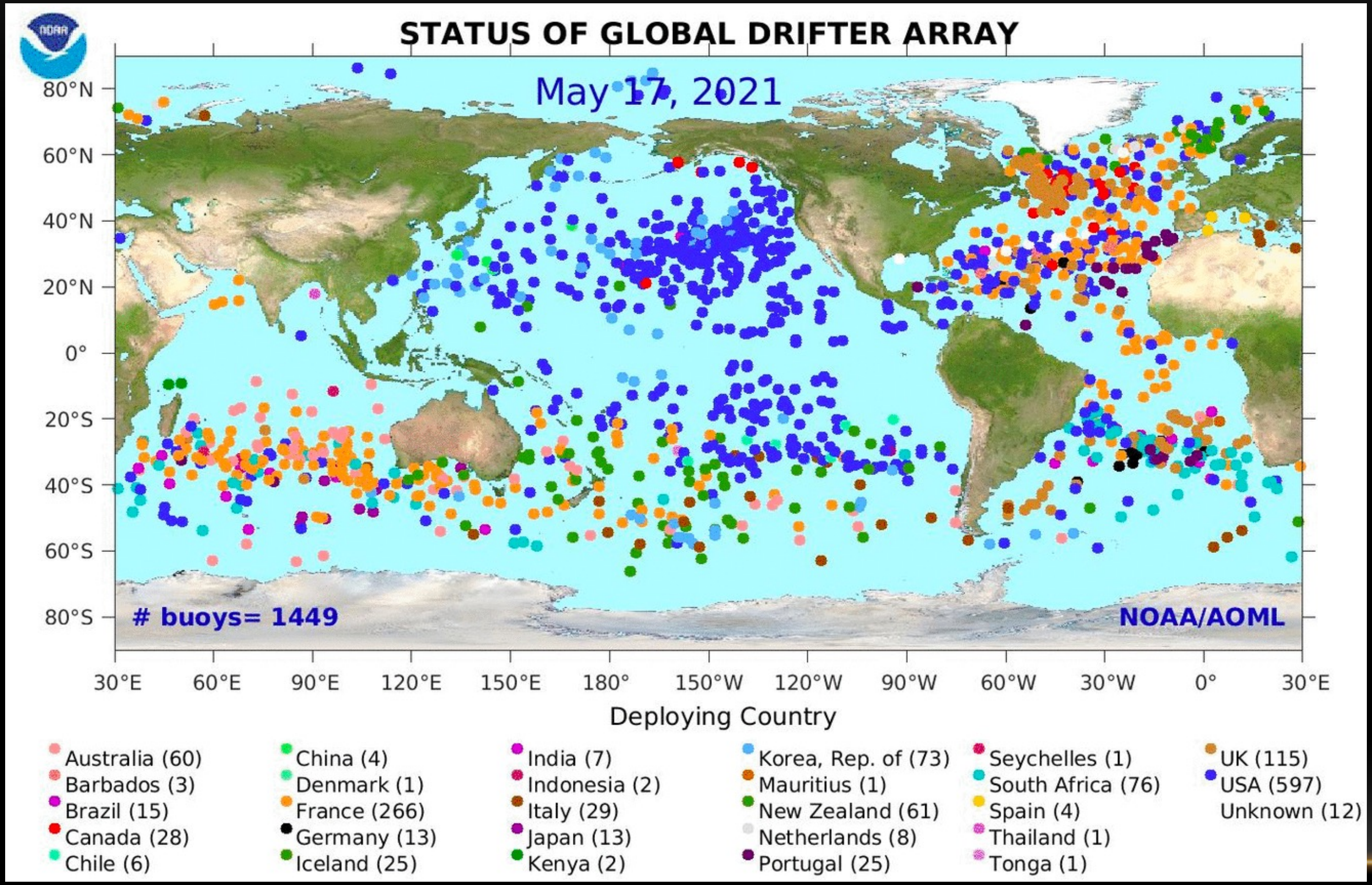
Argo



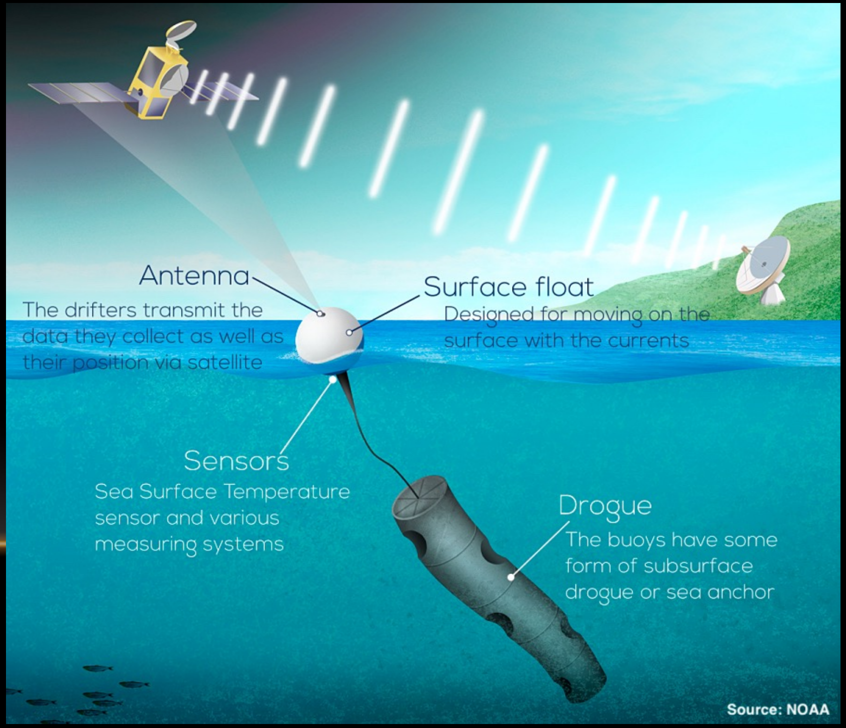
- Argo is the broad-scale global array of temperature/salinity profiling floats and a major component of the ocean observing system.
- The standard Argo float mission is as follows: The float descends to a target depth of 1000m to drift and then descends again to 2000m to start the temperature and salinity profile.
- The name Argo is chosen to emphasize the strong complementary relationship of the global float array with the Jason altimeter mission (In Greek mythology Jason sailed on his ship the Argo searching the golden fleece).

https://www.aoml.noaa.gov/phod/argo

Global Drifter Array

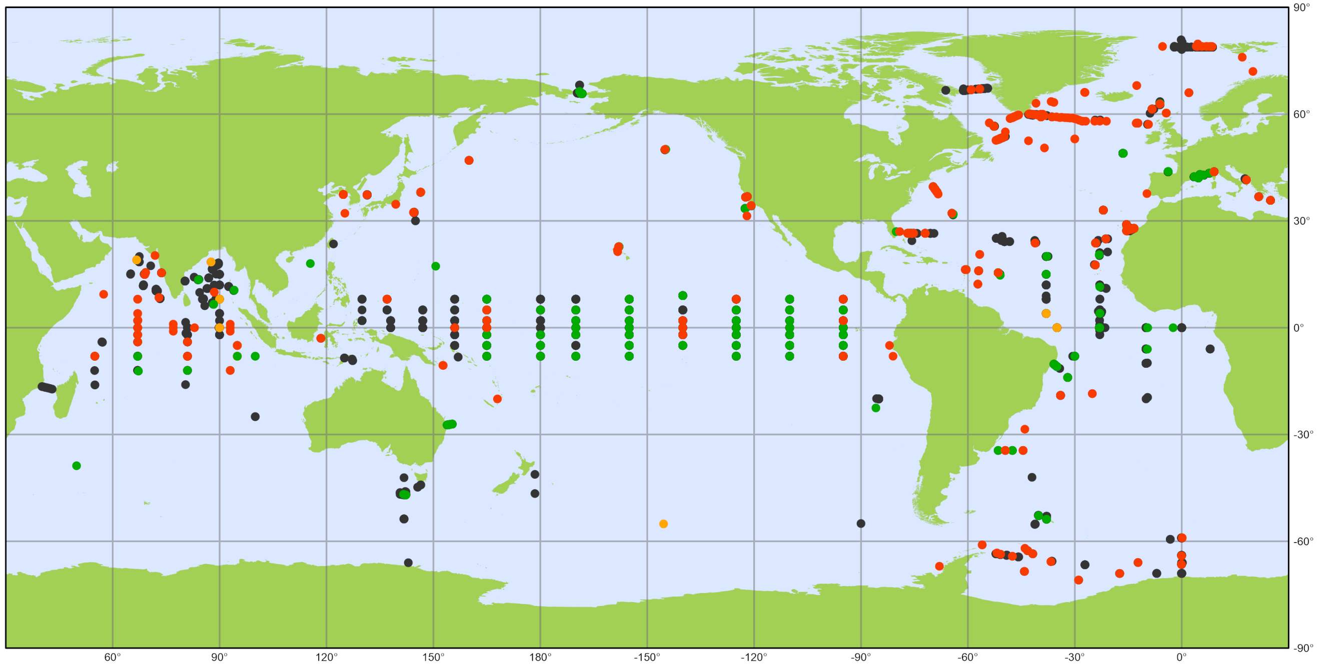


- a global array of satellite-tracked surface drifting buoys
- measures mixed layer currents, sea surface temperature, atmospheric pressure, winds and salinity.



https://www.aoml.noaa.gov/phod/gdp/

OceanSITES



OceanSITES

Platforms by status

January 2022

Information received from the platform operators

REGISTERED · OPERATIONAL · INACTIVE · CLOSED

OceanSITES

Total of 142 sites as of 06/14/2018

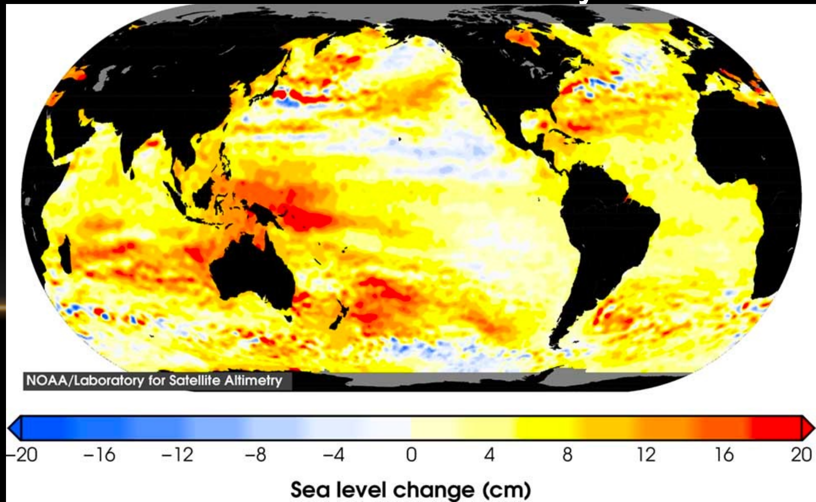
Generated by ocean-ops.org, 2022-02-02
Projection: Plate Carree (-150.0000)

http://www.oceansites.org/

- **OceanSITES** is an international system of long-term, open-ocean reference stations monitoring the full depth of the ocean from air-sea interactions down to the seafloor.
- Observations cover meteorology, physical oceanography, transport of water, biogeochemistry, and parameters relevant to the carbon cycle, ocean acidification, the ecosystem, and geophysics.
- Operational applications include the detection of events, initialization and validation of assimilation products, and reference data for forecasts.

Satellite observations of Ocean

- Sea Surface Temperatures: The most commonly used instrument to collect sea surface temperatures is the Visible Infrared Imaging Radiometer Suite (VIIRS)
- Sea Surface Coloring: color data helps researchers determine the impact of floods along the coast, detect river plumes, and locate blooms of harmful algae.
- Sea Level Change: One of the most significant potential impacts of climate change is sea level rise. Long-term observations of global mean sea level provides a way to test climate models' predictions of global warming.
- Sea Surface Salinity: Aquarius was NASA's first satellite-based instrument to detect sea surface salinity.



https://oceanservice.noaa.gov/facts/satellites-ocean.html

Land

- Land conditions, such as soil moisture, soil temperature and snow, affect the heat and moisture fluxes between the land and the atmosphere and are highly relevant for climate prediction.
- Changes in land conditions from human use or climate change can affect regional and global climate, such as the Amazon deforestation.
- Changes in land conditions modulate the likelihood, intensity and duration of many extreme events, including heatwaves.

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

Soil Moisture

- Limitations of in situ soil moisture measurements:
  - Highly localized and not representative of soil moisture considered by a climate model (which is the mean over a grid cell)
  - Limited spatial coverage
  - Limited temporal coverage
- Satellite observations:
  - good spatial coverage but relatively short record
  - Only capture the top few millimeters of the soil
- Land Data Assimilation System (LDAS)
  - model integrations to generate soil moisture (driven by atmospheric conditions, including precipitation)

Snow

- Real-time direct measurements of snow do not exist on the global scale, though some measurements are available on the regional scale.
- Satellite instruments (such as MODIS) provide global-scale, high-resolution estimates of snow cover, but satellite estimates of snow water equivalent (SWE) are difficult.
- LDAS can produce SWE data in addition to soil moisture.

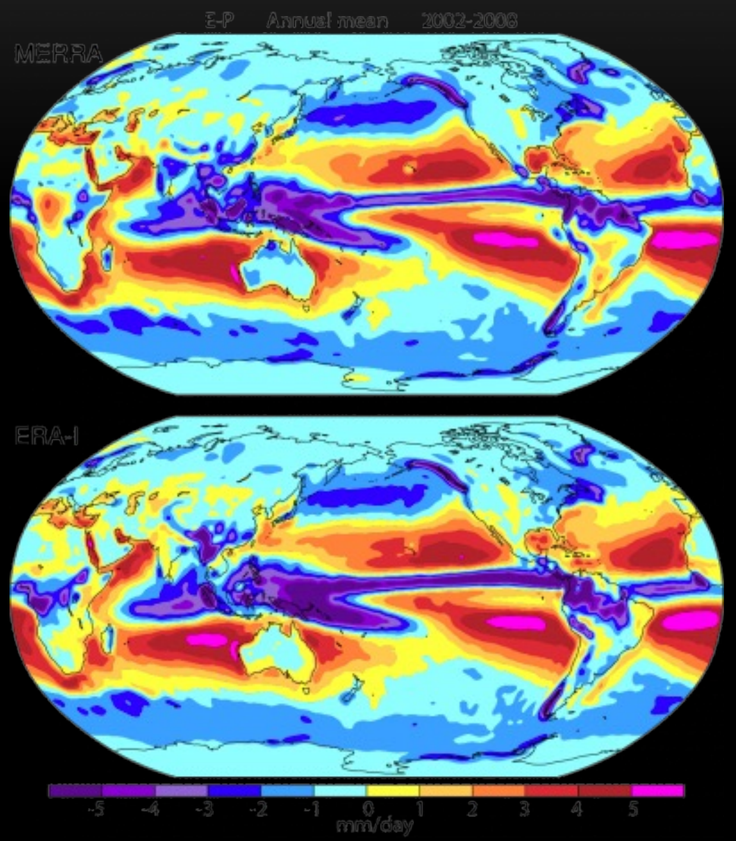
Reanalysis

- ***What is reanalysis?***
    - They are a blend of observations with past short-range weather forecasts through data assimilation. Reanalysis data provide the most complete picture currently possible of past weather and climate.
- ***Why is reanalysis important?***
    - To understand climate change and current weather extremes, it is important to have observations of the past over a long time period.
    - The quality and quantity of observations vary with time and from region to region. Even in the satellite era, observations alone cannot provide a complete and accurate picture of the state of the Earth system across the globe at a given point in time.
    - Reanalyses are consistent in time and have "complete" spatial coverage, and different variables are consistent dynamically and physically (the same modern data assimilation system and forecasting model throughout the reanalysis period).

from the ECMWF Fact sheet: Reanalysis (https://www.ecmwf.int/en/about/media-centre/focus/2020/fact-sheet-reanalysis)

Reanalysis (cont'd)

- Limitations: strictly speaking, reanalyses are not "observations".
  - Reanalysis reliability depends on available observations and can considerably vary with location, time period, and variable considered.
  - Diagnostic variables related to the hydrological cycle, such as precipitation and evaporation, need to be used with extreme caution.
  - Spurious variability and trends may exist in reanalyses due to the changing mix of observations, observation errors and model biases.
- Some commonly used reanalyses:
  - NCEP-NCAR R1, NCEP R2, NASA MERRA, ERA-Interim, ERA-5, JRA
  - See a Summary of Atmospheric Reanalysis products at https://climatedataguide.ucar.edu/climate-data/atmospheric-reanalysis-overview-comparison-tables



Evaporation minus Precipitation in MERRA (top) and ERA-Interim (bottom) based on Trenberth et al. (2011). (Contributed by J Fasullo)

from the ECMWF Fact sheet: Reanalysis (https://www.ecmwf.int/en/about/media-centre/focus/2020/fact-sheet-reanalysis)

References

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- Lord, S., Gayno, G., & Yang, F. (2016). Analysis of an Observing System Experiment for the Joint Polar Satellite System, Bulletin of the American Meteorological Society, 97(8), 1409-1425.
- NCAR Climate Data Guide, "ATMOSPHERIC REANALYSIS: OVERVIEW & COMPARISON TABLES": https://climatedataguide.ucar.edu/climate-data/atmospheric-reanalysis-overview-comparison-tables