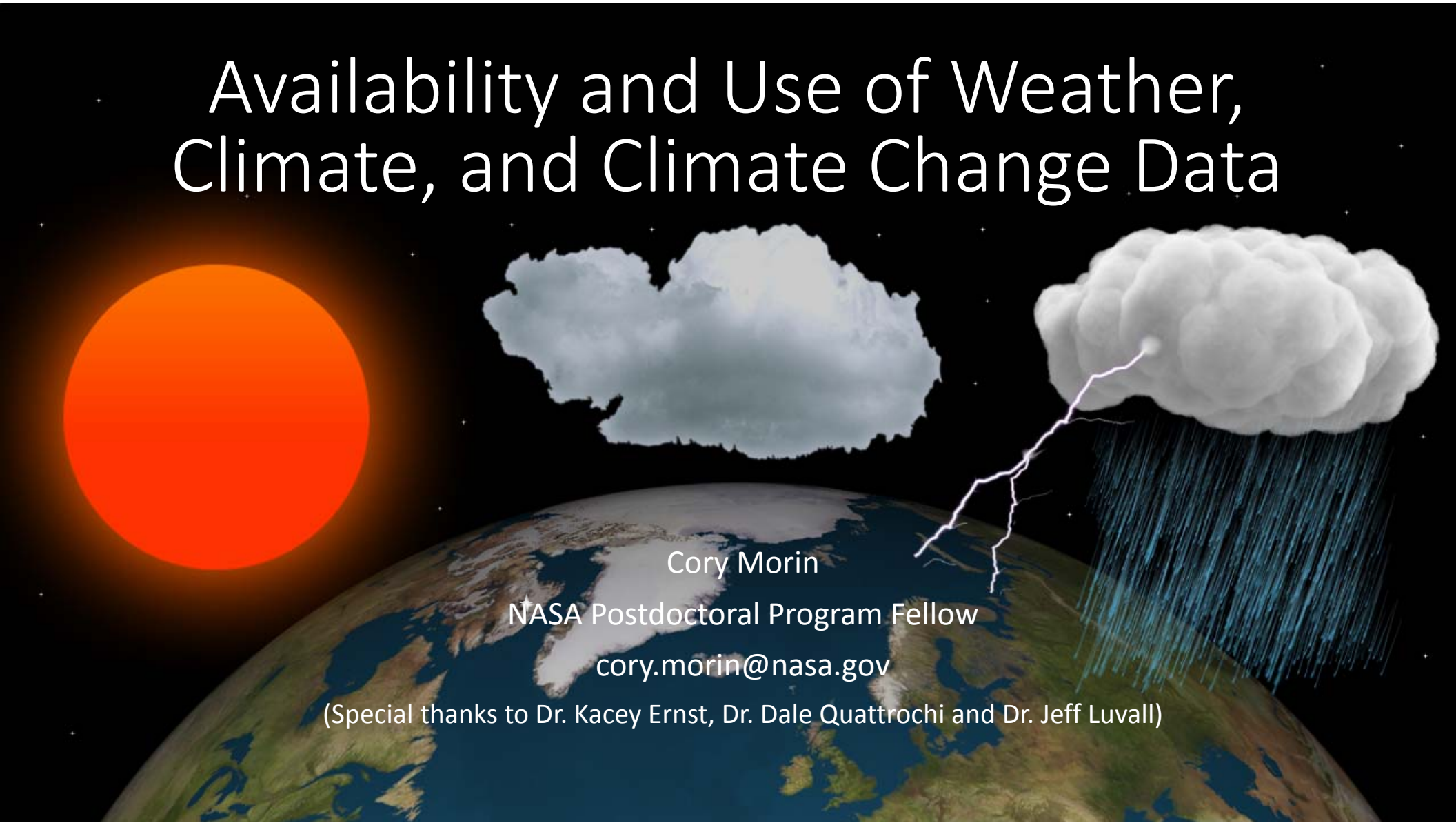
Availability and Use of Weather, Climate, and Climate Change Data



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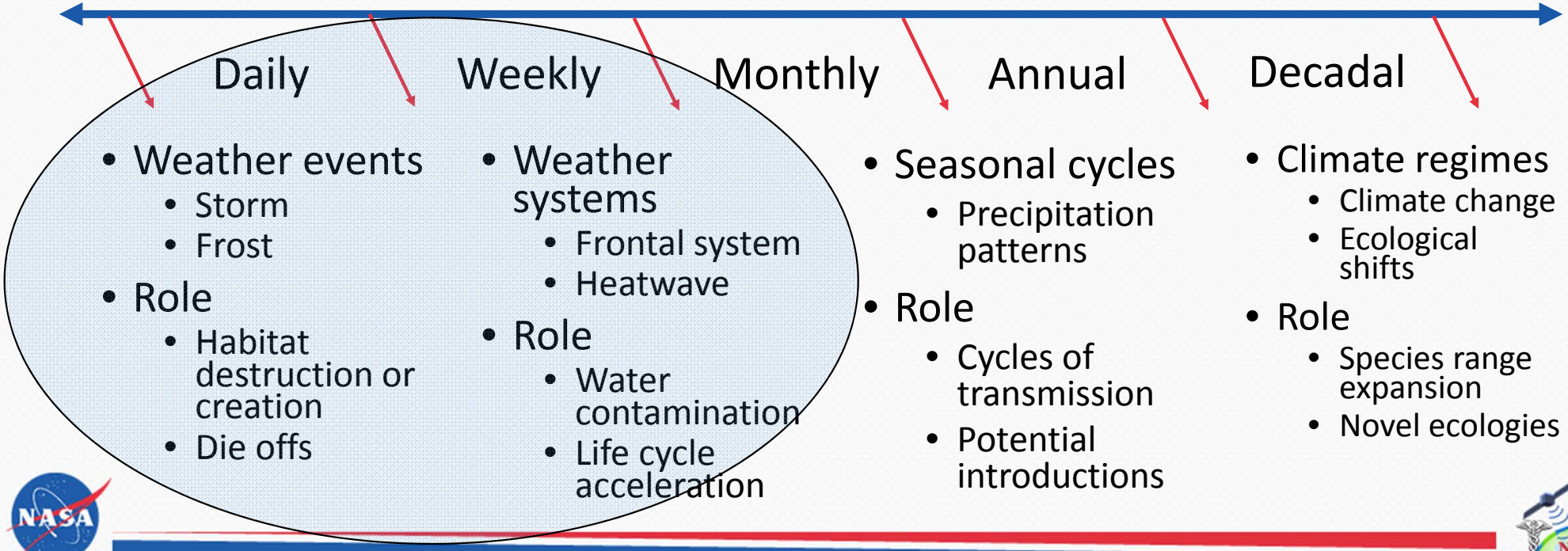
(Special thanks to Dr. Kacey Ernst, Dr. Dale Quattrochi and Dr. Jeff Luvall)

Weather

- Weather: The conditions of the atmosphere at a particular location and time period (i.e. its raining in Cape Town and the temperature is 20°C)



Climate

- Climate: The long-term average conditions of the atmosphere over a region (i.e. Tucson, Arizona has an arid climate with seasonal precipitation)

Daily

- Weather events
  - Storm
  - Frost
- Role
  - Habitat destruction or creation
  - Die offs

Weekly

- Weather systems
  - Frontal system
  - Heatwave
- Role
  - Water contamination
  - Life cycle acceleration

Monthly

Annual

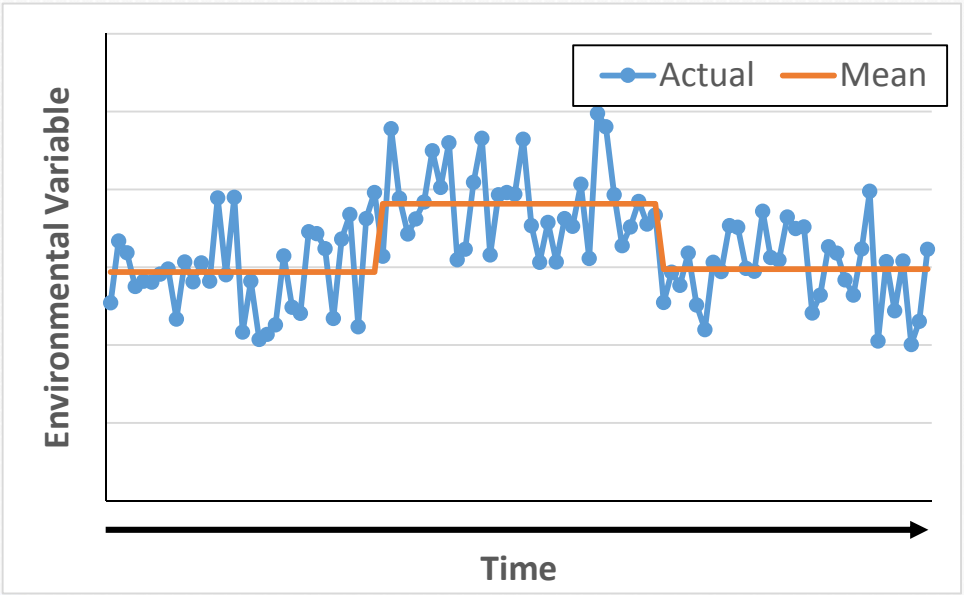
- Seasonal cycles
  - Precipitation patterns
- Role
  - Cycles of transmission
  - Potential introductions

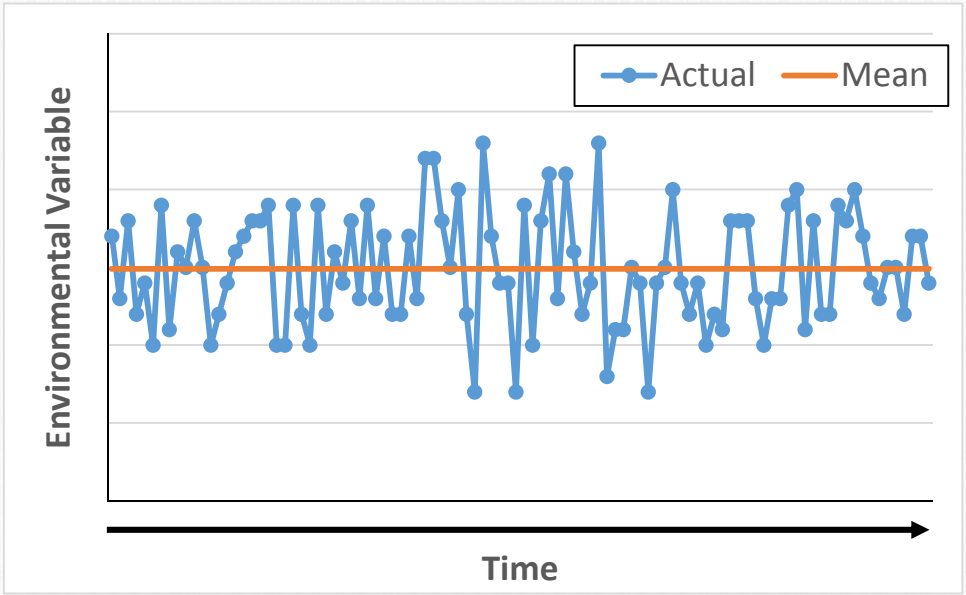
Decadal

- Climate regimes
  - Climate change
  - Ecological shifts
- Role
  - Species range expansion
  - Novel ecologies

Climate Variability

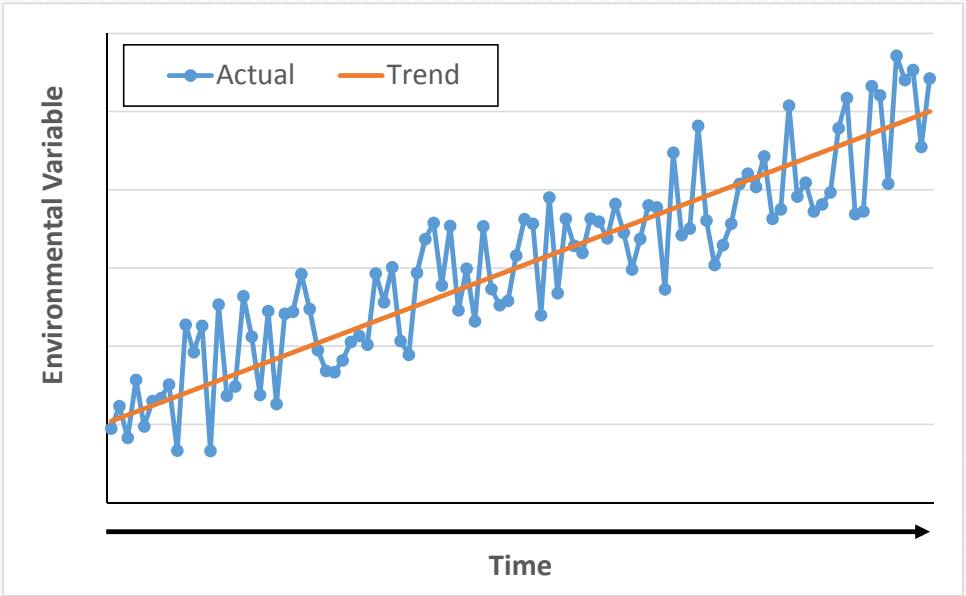
- Climate variability: The fluctuation in climate around its mean value
  - Can include phases and oscillations

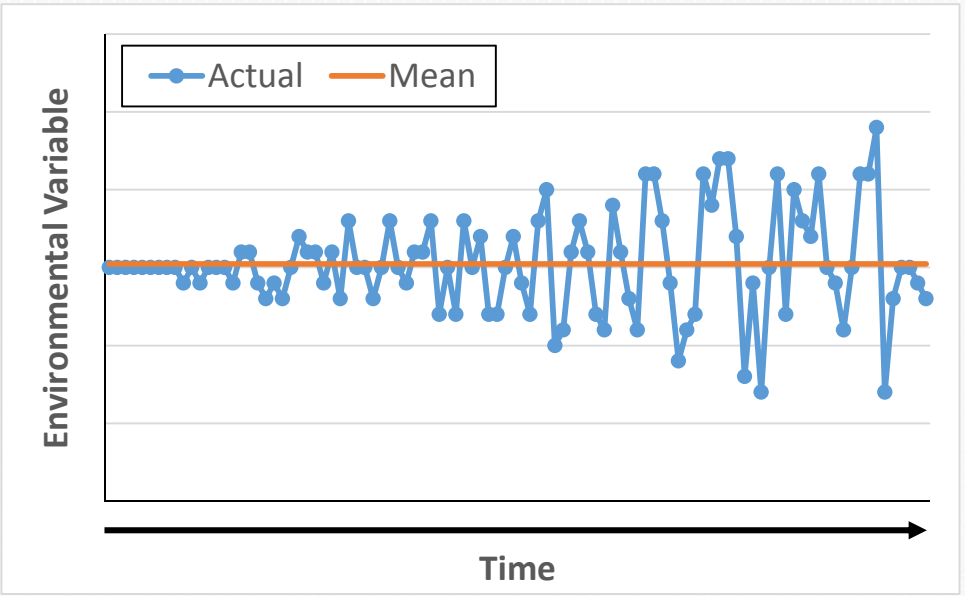




Climate Change

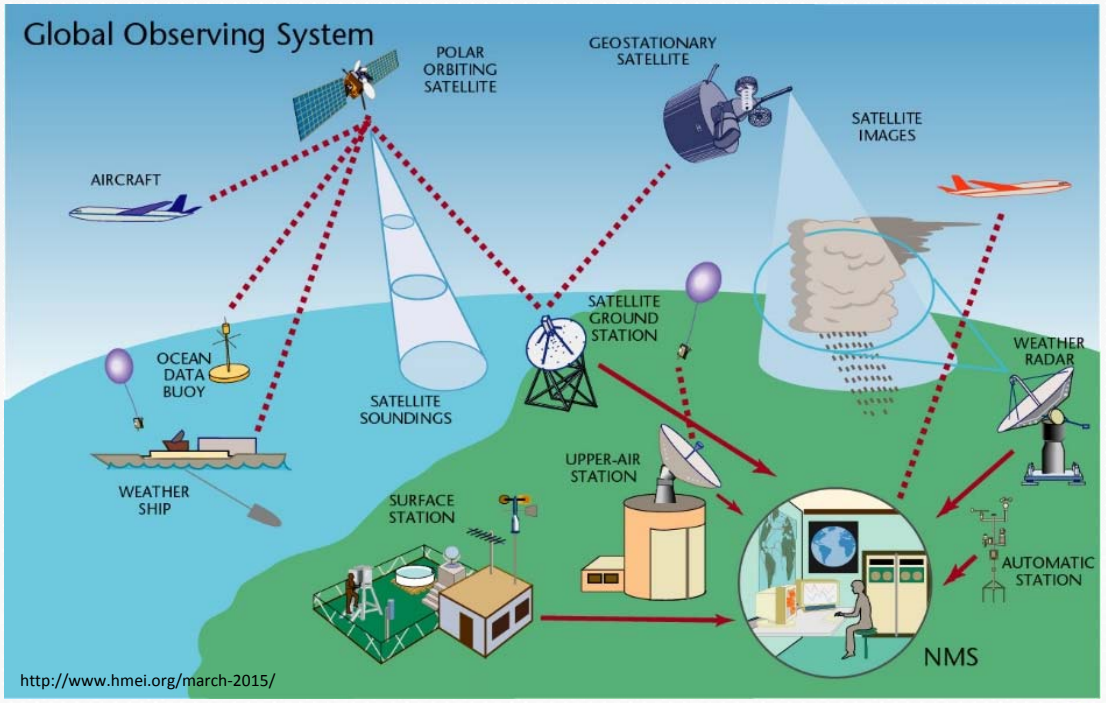
- Climate change: A long-term alteration in climate mean or variation
  - Associated with trends





Sources of Data

- Weather/Climate Data
  - Paleoclimate data
  - Stations and other recorders
  - Satellite and remotely sensed data
  - Reanalysis datasets
  - Forecasting
- Climate Change
  - Global climate models (GCMs)
  - Scenario building
  - Downscaling

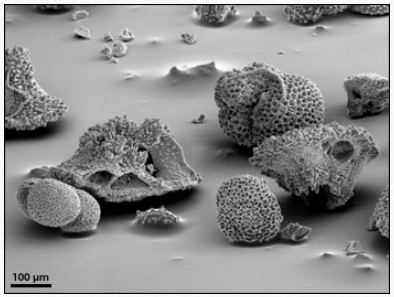


Paleoclimate Data

- Past climate data obtained through proxy records
- Many methods of obtainment
  - Ice cores
  - Tree rings (dendrochronology)
  - Sediments
  - Various organisms
- Rarely used in climate and disease research

http://sites.dartmouth.edu/jstroup/photo-gallery/

http://www.thenakedscientists.com/HTML/interviews/interview/643/

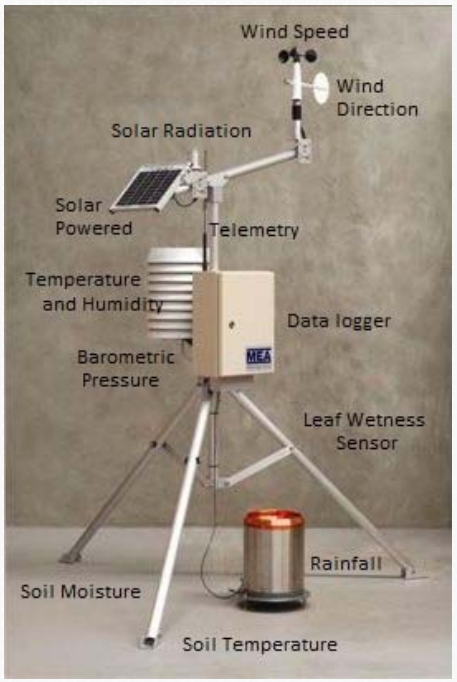


Earthobservatory.nasa.gov

http://www.visualisingdata.com/2015/02/dendrochronology-visualisation-literacy/

Weather Stations

- Can record a suite of variables depending on the instrumentation
  - Temperature, precipitation, humidity, wind speed, wind direction, incoming solar radiation
  - Records are usually daily
- Found at many airports, universities, and research centers
- Data is often available through local or national weather services



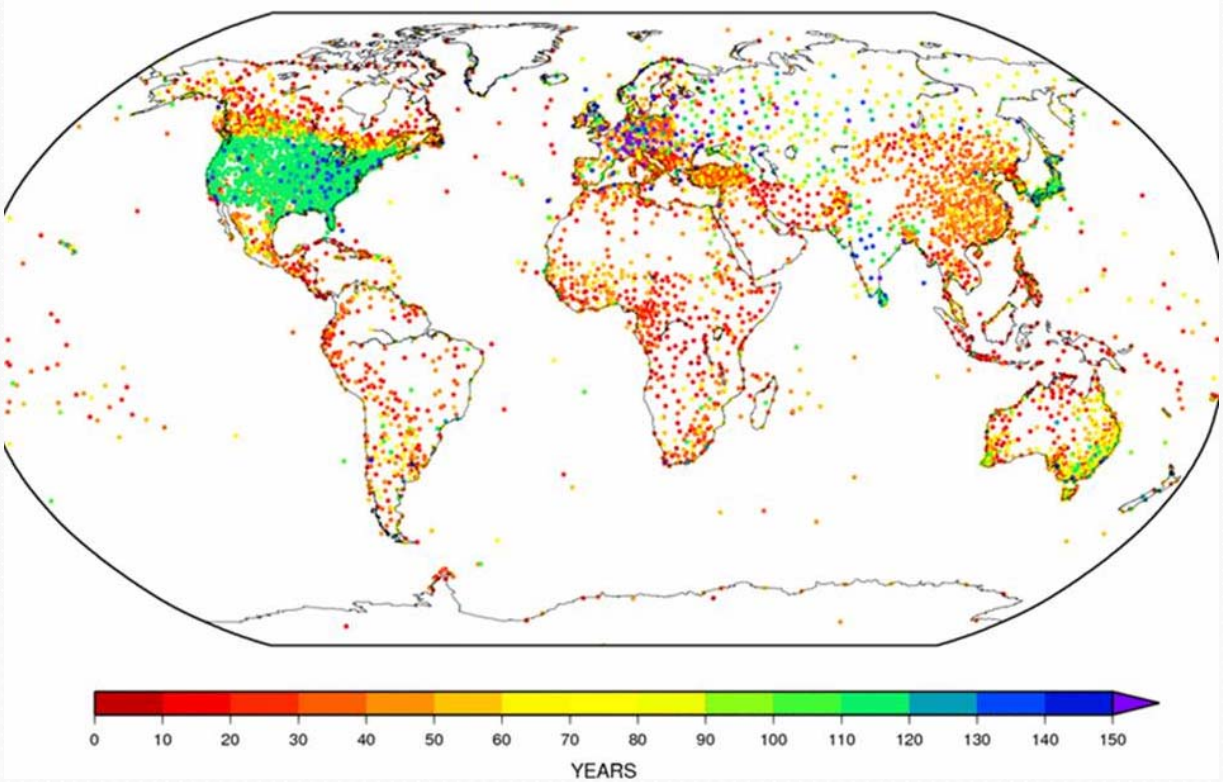
http://mea.com.au/upload/AWS_with_Labels.jpg

Weather Stations

- Strengths
  - Often record many variables
  - Daily resolution (sometimes hourly)
  - Most populated areas contain at least one
  - Long record history
- Weaknesses
  - Not uniformly distributed
  - Potential breaks in recording or location
  - Can be heavily influenced by local environment
  - Not representative of a large area
  - Data is sometimes unavailable or expensive

https://www.wunderground.com/weatherstation/installationguide.asp

Global Historical Climatology Network



https://catalog.data.gov/dataset/global-historical-climatology-network-monthly-ghcn-m-version-3

Mini Weather Data Loggers

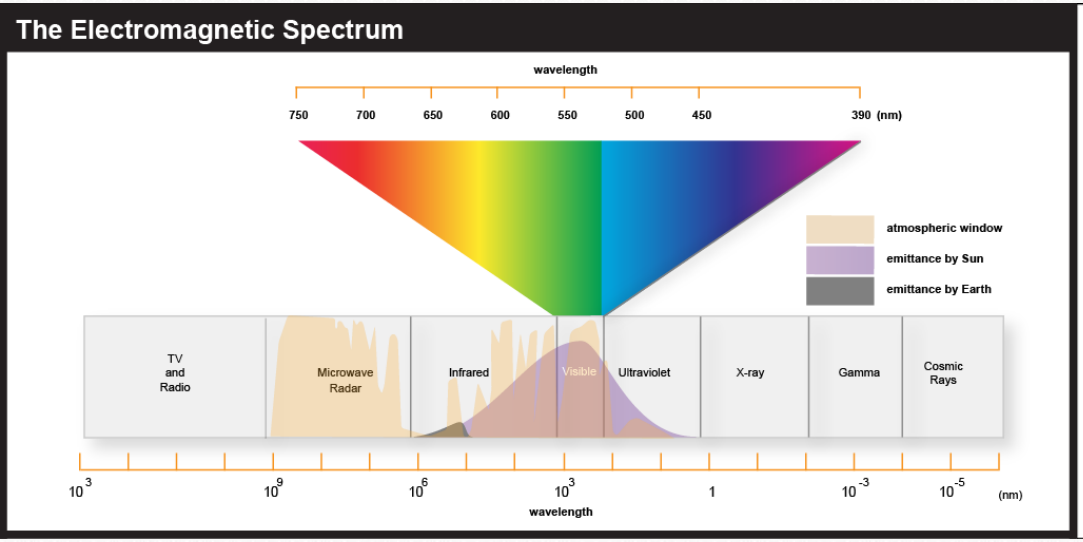
- Devices for collecting weather data
  - Generally record temperature and/or humidity
  - Data downloaded via connection to laptop or wifi
- Advantages
  - Small and inexpensive
  - Can record at various time intervals
  - Good for sampling microclimates
- Disadvantages
  - Usually self employed
  - Limited variables
  - Representative of very small areas

http://thermometer.co.uk/71-humidity-and-temperature-data-loggers

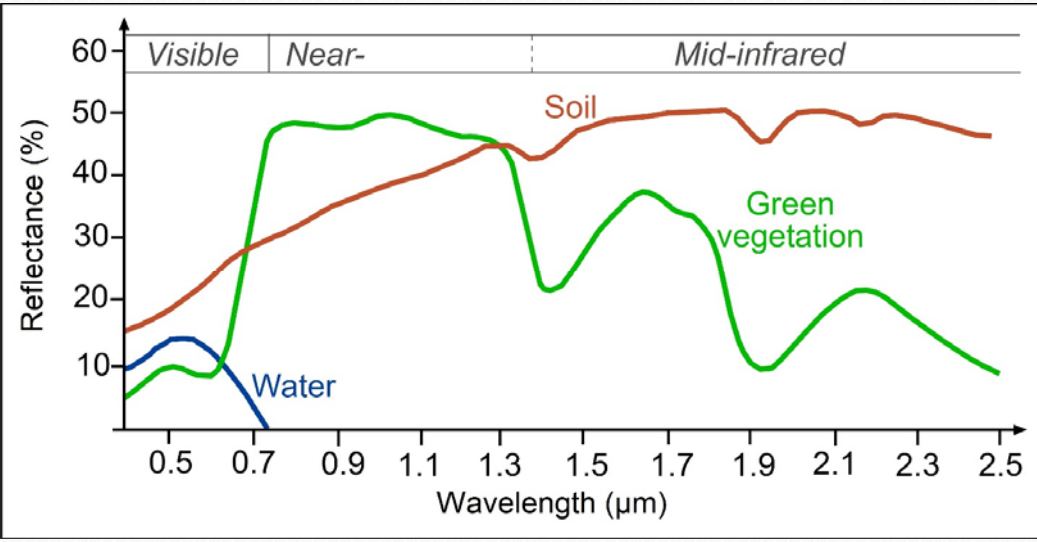
Remote Sensing: How it Works

- Technique that collects information through signals (i.e., electromagnetic radiation) using sensors with filters specific to certain wavelengths
  - Found on satellites, planes, towers, ect.
  - Features on Earth identified through their specific radiative frequencies

https://www.e-education.psu.edu/geog160/node/1958

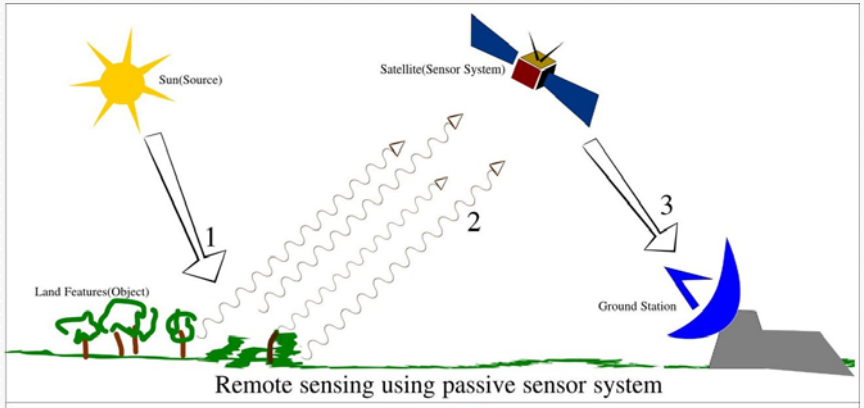


http://www.seos-project.eu/modules/classification/classification-c00-p05.html

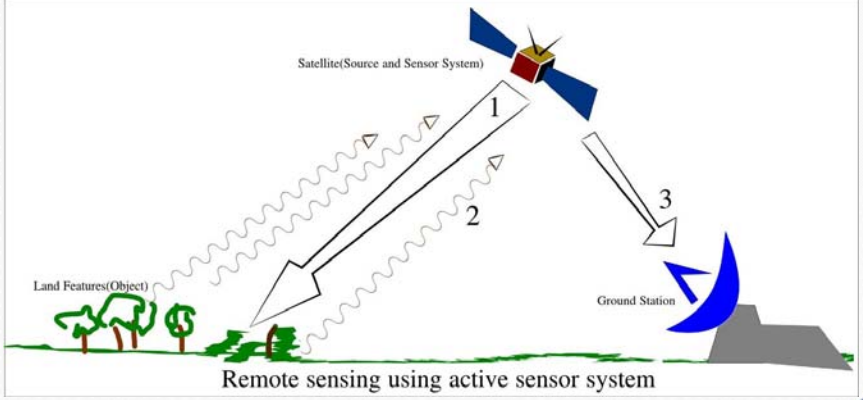


Remote Sensing Techniques

- Passive vs Active remote sensing
  - Passive only collects signal
  - Active emits a signal and then collects a return signal
- Levels of data
  - 0: Raw data
  - 1: Data calibrated, georeferenced, time-referenced, ect.
  - 2: Derived geophysical variables
  - 3: Data mapped on uniform grid
  - 4: Modeled variables from the lower level data (NDVI)



Remote sensing using passive sensor system



Remote sensing using active sensor system

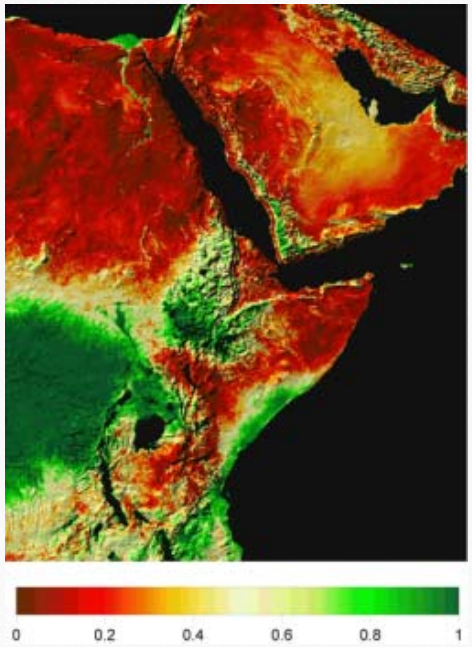
https://en.wikipedia.org/wiki/Remote_sensing

What Can Remote Sensing Measure?

- Temperature- ECOSTRESS (2017), HyspIRI (2020+), ASTER (1999), Landsat (5,7,8), MODIS
- Precipitation- GPM (2014)
- Soil Moisture- SMAP(2015)
- Hyperspectral- Hyperion (2000), HyspIRI (2020+)
- Structure - IceSat2 (2016)
- Flooding/water levels lakes streams, groundwater storage – GRACE (2002) SWOT (late 2020)
- Land Cover/Use- Landsat, MODIS, ASTER, Sentinel-2(2015)

Remote Sensing Strengths

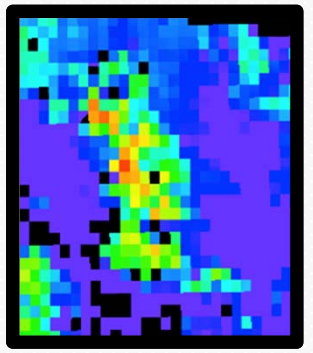
- Measures environmental state functions important to pathogen life cycles
  - Precipitation, soil moisture, temperature, vapor pressure deficits, wet/dry edges, solar radiation….
- But also the interfaces as process functions:
  - Land use/cover mapping; Ecological functions/structure, canopy cover, species, phenology, aquatic plant coverage…..
- And provides a Spatial Context
  - Spatial coverage & topography – local, regional & global…
- Lastly, but perhaps the greatest strength:
  - Provides a time series of measurements



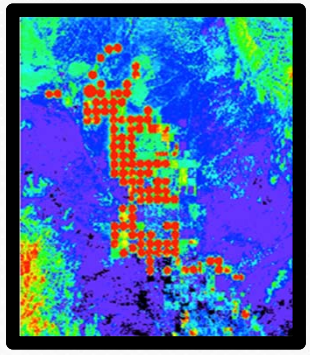
Remote Sensing Weaknesses

- Tradeoff between spatial and temporal resolution
  - Satellites may pass over multiple times per day or once every few weeks
  - Spatial resolution can by sub-meter to kilometers
- Atmospheric interference
  - Clouds can obscure views
  - Detrimental if the data has poor temporal resolution
- Accuracy and interpretation
  - Algorithms often required and will not be perfect
- Availability
  - Although NASA provides data free, other space agencies and private companies charge exorbitant prices for data

MODIS – 1 km

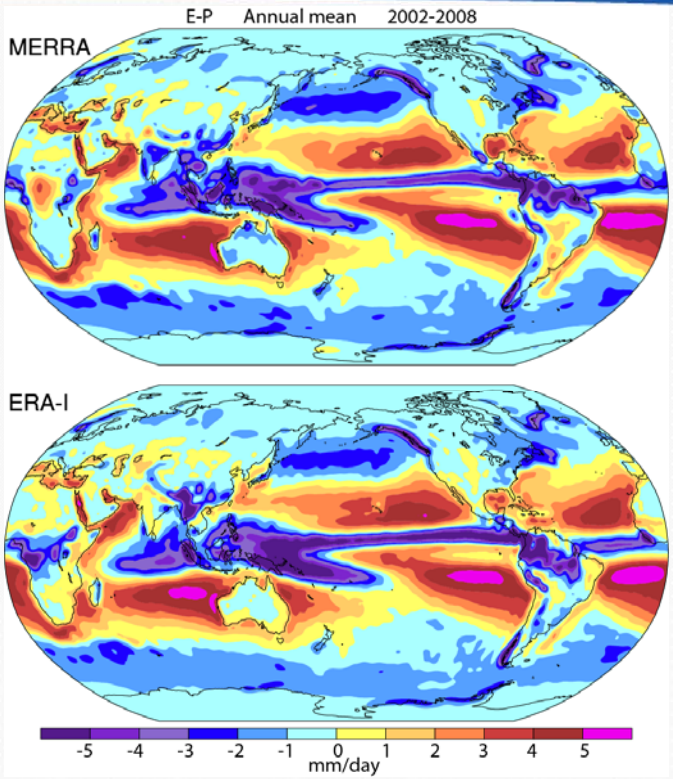


Landsat 7 – 60 m



Reanalysis Data

- Uses multiple sources of recorded climate data combined with data assimilation and modeling techniques to create a gridded environmental datasets
  - Observational data from weather stations, satellites, radiosondes, ect.
- Multiple sources
  - NASA Global Land Data Assimilation System
  - NCEP Reanalysis



https://climatedataguide.ucar.edu/climate-data/atmospheric-reanalysis-overview-comparison-tables

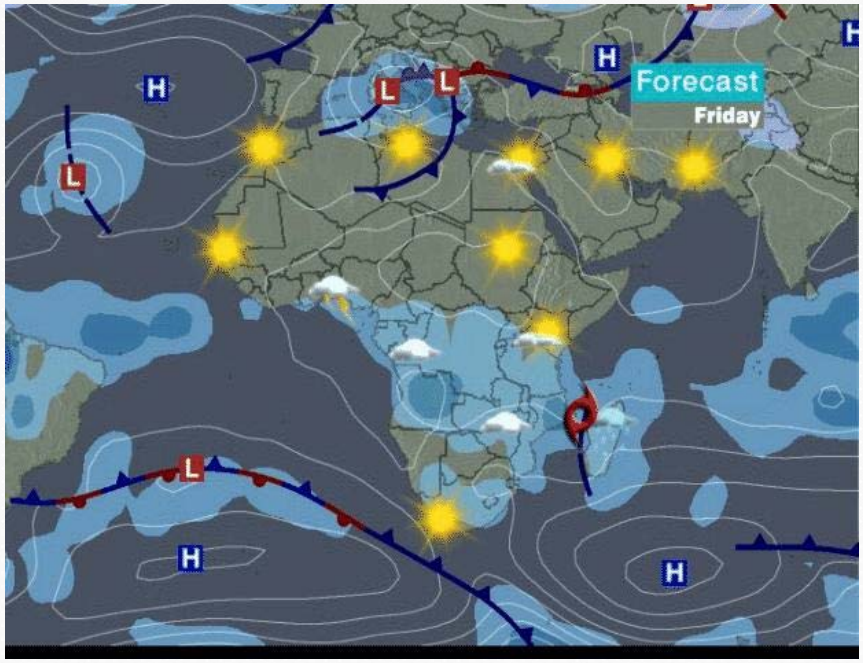
Reanalysis Data

- Advantages
  - Includes huge amount of variables
  - Global gridded data with consistent spatial and temporal resolution
  - Incorporates millions of observations
  - Free and relatively easy to use
- Disadvantages
  - Reliability depends on location, time period, and variable
  - The type and number of observations changes over time
  - Use of modeled data

http://cpo.noaa.gov/ClimatePrograms/ModelingAnalysisPredictionsandProjections/MAPPNewsEvents/TabId/506/ArtMID/1256/ArticleID/197/MAPP-kicks-off-Climate-Reanalysis-Task-Force-activities.aspx

Weather Forecasts

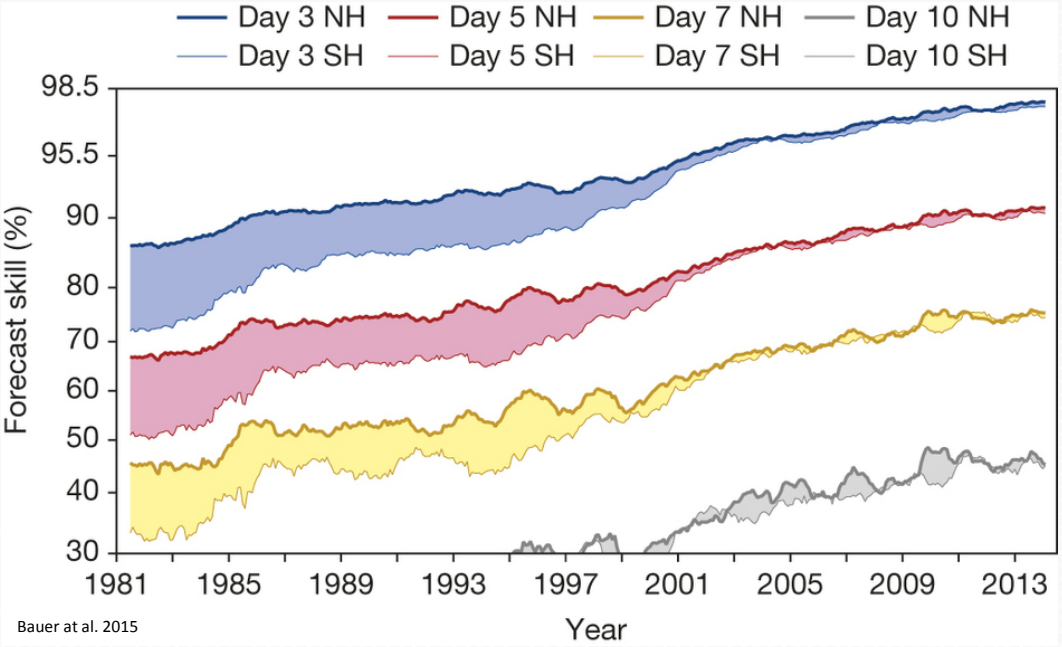
- Short-term predictions out to 2 weeks into the future
- Meteorologists use multiple methods to produce forecasts
  - Current observational data
    - Tracking weather systems and air masses
  - Weather forecasting models
    - Weather research and forecasting model WRF
  - Experience



http://www.cnn.com/WEATHER/Africa/frct.html

Weather Forecasts

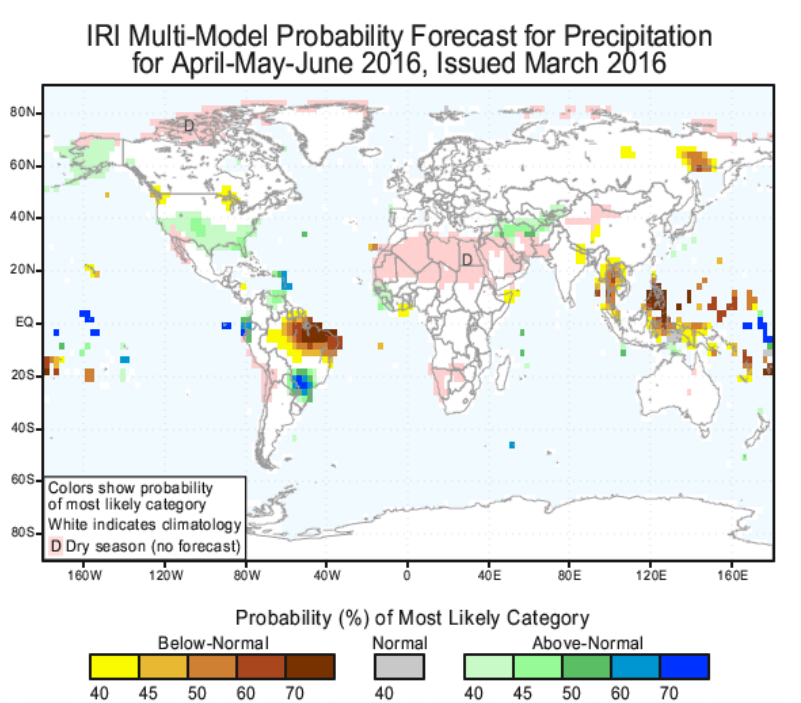
- Multiple sources
  - Local or national weather service
  - Private companies: TV or Websites
    - weatherunderground.com
- Considerations when using weather forecast data
  - Uncertainty
  - Forecasts degrade in quality as they extend out
  - Evaluation of forecasts are important



Bauer at al. 2015

Seasonal Forecasts

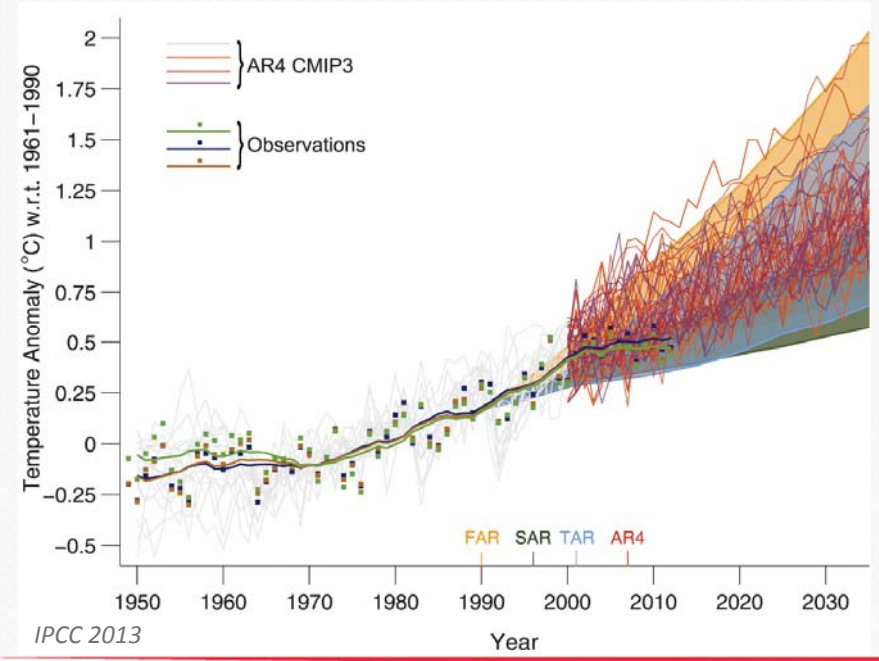
- 1-6 Month Forecasts
  - Based on long-term climate trends, sea surface temperatures, oscillations
  - From numerical weather prediction models and/or statistical models
- Example: North American Multi-Model Ensemble
  - Made up of multiple models
  - Gridded, monthly
    - Daily downscaled version available but are not specific daily predicitons



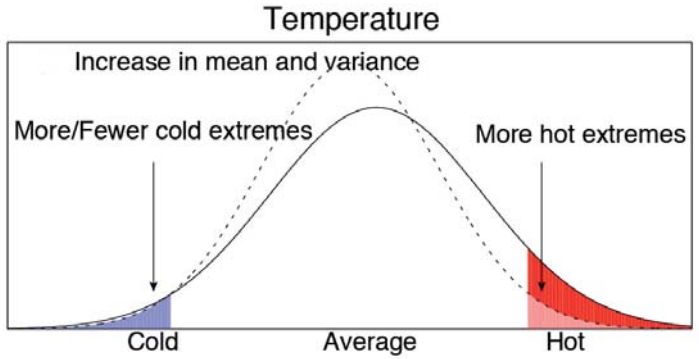
http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

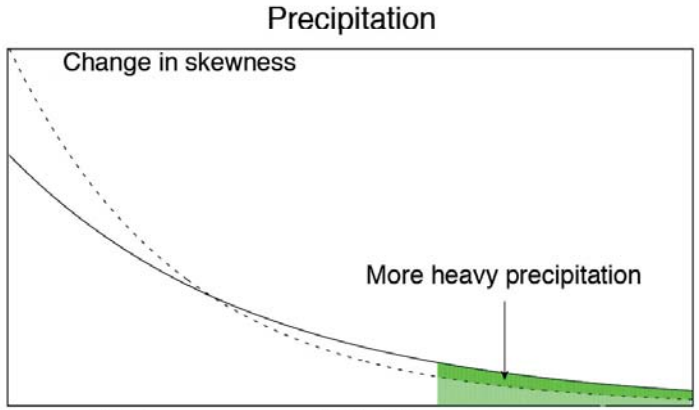
Climate Variability and Change

- Shift in mean and variance
- Increase in frequency of extreme conditions



IPCC 2013

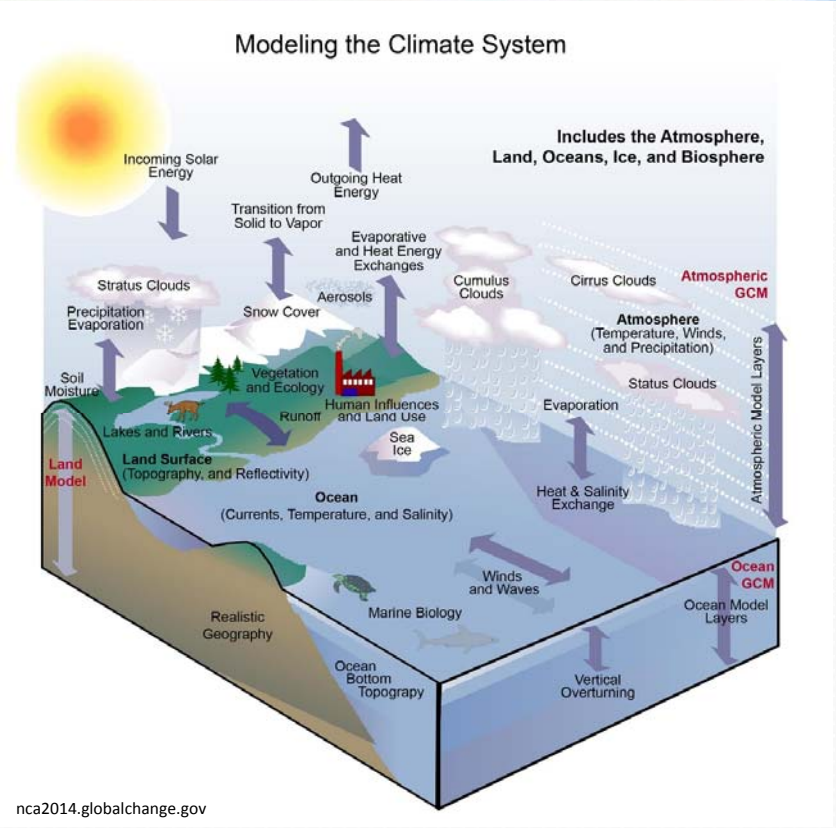




IPCC 2013

Global Climate Models

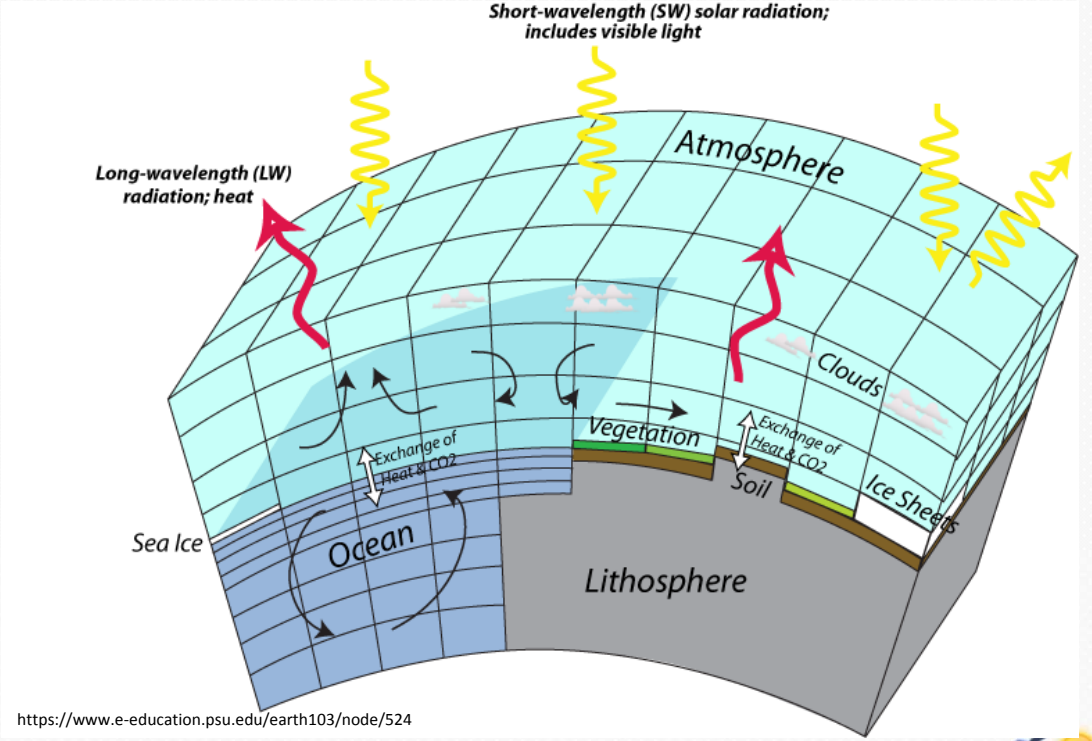
- Global climate models
  - Attempt to simulate the climate system through mathematically modeling the physical, chemical, and biological processes that occur within and between the atmosphere, hydrosphere, lithosphere, and biosphere
  - Many different models with different resolutions, assumptions, and regional accuracy



nca2014.globalchange.gov

Climate Change Models

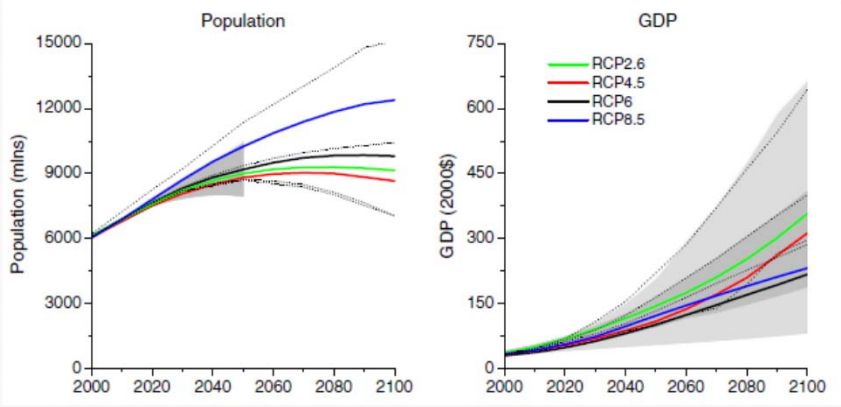
- Earth and atmosphere divided into a 3-d grid which interact
- Higher resolution is more accurate but requires increased computing power
- Can simulate the climate system under various conditions

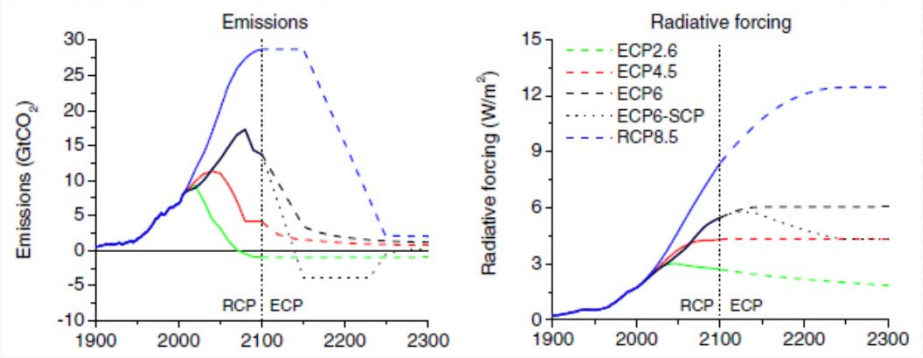


https://www.e-education.psu.edu/earth103/node/524

Climate Change Data

- GCM inputs
  - Greenhouse gas, aerosol, and pollutant concentrations
  - Land use/cover
- Representative concentration pathways
  - Scenarios created based on projected socioeconomic conditions
- Designed to deal with uncertainty

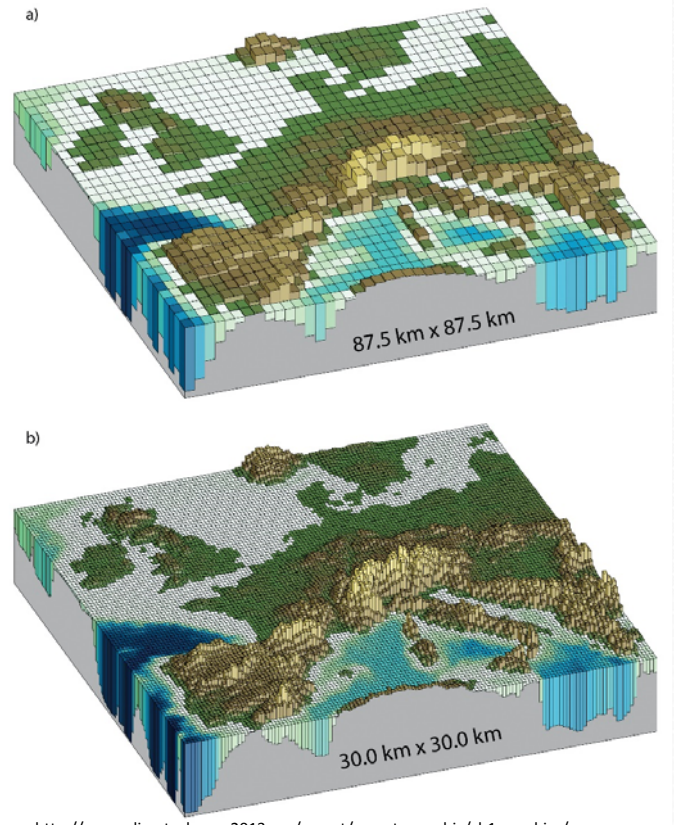




Van Vuuren et al. 2011

Downscaling Climate Change Data

- A method of estimating local scale climate/weather features from larger scale models
  - Important for local impact assessments
- Downscaling can refer to both spatial and/or temporal downscaling
- Two major methods of downscaling GCM climate data
  - Dynamic downscaling
  - Statistical downscaling

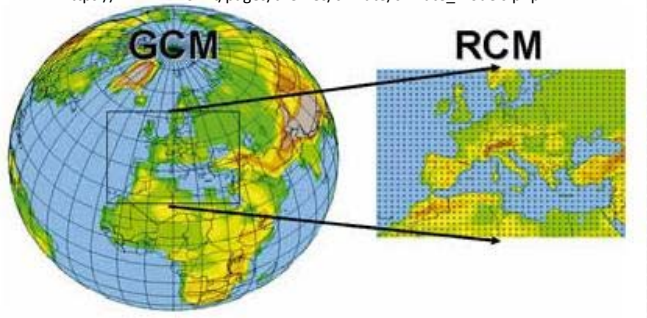


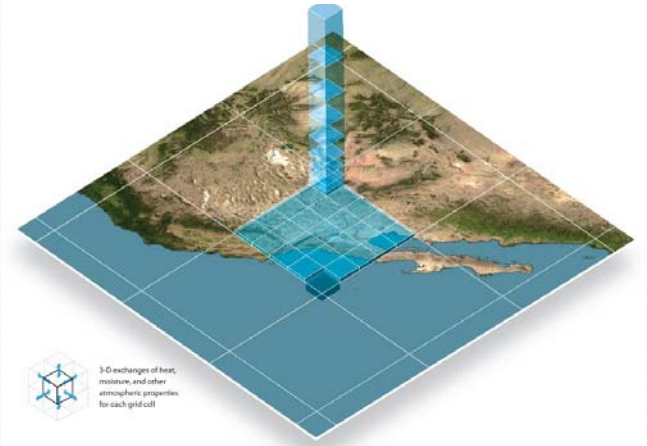
http://www.climatechange2013.org/report/reports-graphic/ch1-graphics/

Dynamic Downscaling

- Regional GCMS
  - GCM boundary conditions used to drive a finer scale numerical weather/climate model
- Advantages
  - Based on known atmospheric mechanics
  - Atmospheric processes resolved
  - Does not rely on historical records
- Disadvantages
  - High complexity and computing power
  - Small scale processes still difficult to simulate
  - Relies on accuracy of GCMs

https://www.wmo.int/pages/themes/climate/climate_models.php

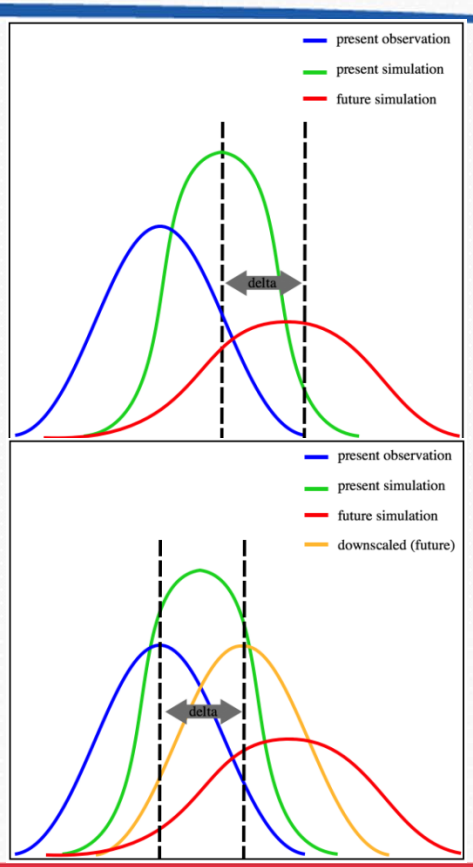




https://www2.ucar.edu/news/understanding-climate-change-multimedia-gallery

Statistical Downscaling

- Based on relationships between large-scale and local atmospheric conditions
  - Methods: linear regression, weather classification, weather generators
- Advantages
  - Simple with little required computer power
  - Can downscale to very fine resolution
  - Methods are flexible
- Disadvantages
  - Assumes stationary relationships over time
  - Accuracy and resolution are method dependent
  - Relies on accuracy of GCMs and historic data



https://rcmes.jpl.nasa.gov/content/statistical-downscaling

Data Considerations in Climate and Health Research

- What is the required resolution?
  - Spatial
  - Temporal
- What is the period of study?
  - Historic
  - Future
- How to deal with uncertainty?
  - Sources
  - Solutions

http://www.labreporter.com/the-impact-of-climate-change-on-human-health/

What is the required resolution?

Site/Point

- Microclimate
  - Pool of standing water
  - Protected area like sewer
- Data
  - Weather data logger
  - Weather station

Local

- Ecosystem
  - Wetlands area
  - Forrest
- Data
  - Weather station
  - Remote sensing/satellite
  - Reanalysis data

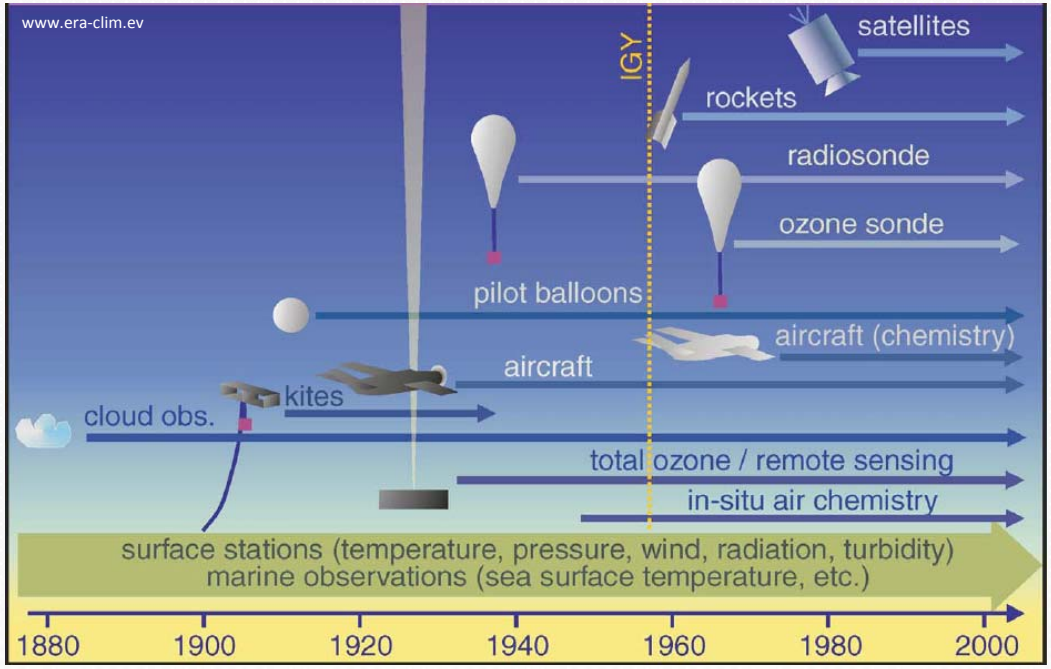
Regional

- Climate zone
  - Tropical, Arid, temperate
- Data
  - Remote sensing/satellite
  - Reanalysis data

*Remember that temporal resolution may also be an issue but only when trying to obtain a finer resolution

What is the Period of Study?

- Historic
  - Methods of collecting weather/climate data change over time
    - Certain variables are only available more recently
  - The number of collections also changes over time
- Future
  - Short-term: weather forecast
  - Mid-term: seasonal forecast
  - Long-term: climate change



Uncertainty increases as forecast increases while specificity decreases

How to Deal with Uncertainty?

- Uncertainty comes from multiple sources
  - Model parameterization
  - Model accuracy
  - Data accuracy
- Solutions
  - Select appropriate models and data
  - Use multiple models / parameters / datasets
  - Evaluate predictions when possible
  - Report ranges