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

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Weather

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

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

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

**Decadal**
Climate

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

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Decadal
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://www.thenakedscientists.com/HTML/interviews/interview/643/
http://www.visualisingdata.com/2015/02/dendrochronology-visualisation-literacy/
http://sites.dartmouth.edu/stroup/photo-gallery/
Earthobservatory.nasa.gov
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
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

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, etc.
  - 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, etc.
  • 2: Derived geophysical variables
  • 3: Data mapped on uniform grid
  • 4: Modeled variables from the lower level data (NDVI)
What Can Remote Sensing Measure?

- Temperature: ECOSTRESS (2017), HyspIRI (2020+), ASTER (1999), Landsat (5,7,8), MODIS
- Precipitation: GPM (2014)
- Structure: IceSat2 (2016)
- Flooding/water levels: lakes, streams, groundwater storage – GRACE (2002) SWOT (late 2020)
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 be 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
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, etc.
• Multiple sources
  • NASA Global Land Data Assimilation System
  • NCEP Reanalysis

[Links: 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/MAPPNewEvents/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

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 predictions

Climate Variability and Change

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

[Image: Downscaling examples showing different scales and spatial resolutions]
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
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

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

CMIP5 projected changes in global mean ANN temperature

Temperature change relative to 1961–1990 [K]

Year

http://flattish2.rssing.com/chan-1497342/all_p1116.html