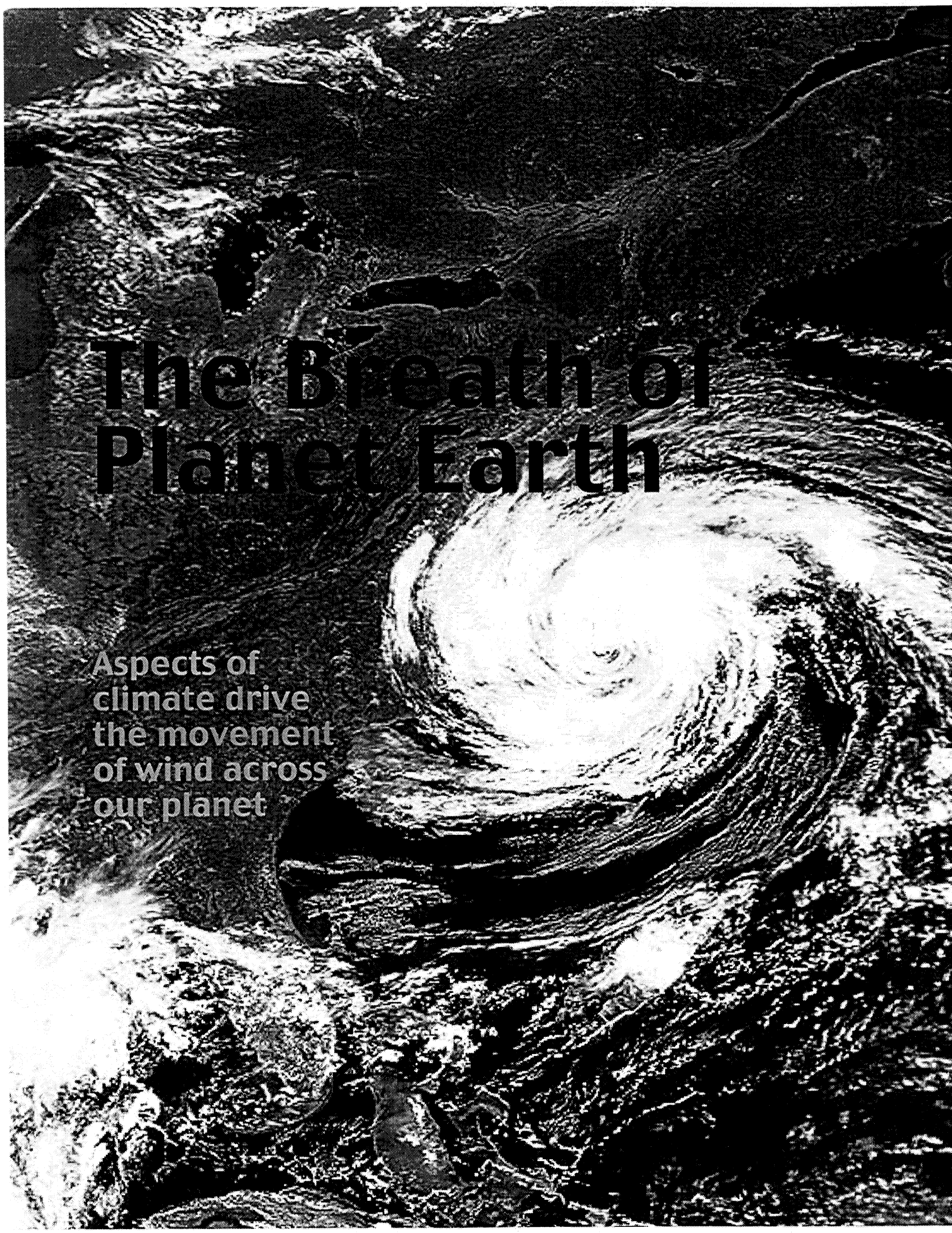
The Breath of Planet Earth

Aspects of climate drive the movement of wind across our planet



Atmospheric Circulation

Differences in air pressure are a major cause of atmospheric circulation. Because heat excites the movement of atoms, warm temperatures cause air molecules to expand. Because those molecules now occupy a larger space, the pressure that their weight exerts is decreased. Air from surrounding high-pressure areas is pushed toward the low-pressure areas, creating circulation.

This process causes a major pattern of global atmosphere movement known as *meridional circulation*. In this form of *convection*, or vertical air movement, heated equatorial air rises and travels through the upper atmosphere toward higher latitudes. Air just above the equator heads toward the North Pole, and air just below the equator moves southward. This air movement fills the gap created where increased air pressure pushes down cold air. The cold air moves along the surface back toward the equator, replacing the air masses that rise there.

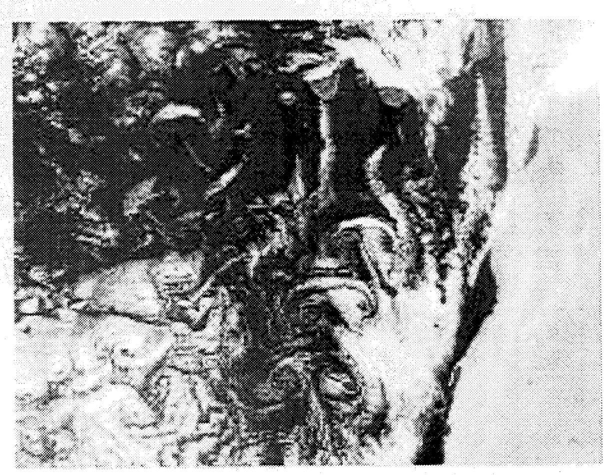
Another influence on atmospheric circulation is the Coriolis force. Because of the Earth's rotation, large-scale wind currents move in the direction of this axial spin around low-pressure areas. Wind rotates counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Just as the Earth's rotation affects airflow, so too does its surface. In the phenomenon of orographic lifting, elevated topographic features such as mountain ranges lift air as it moves up their surface.

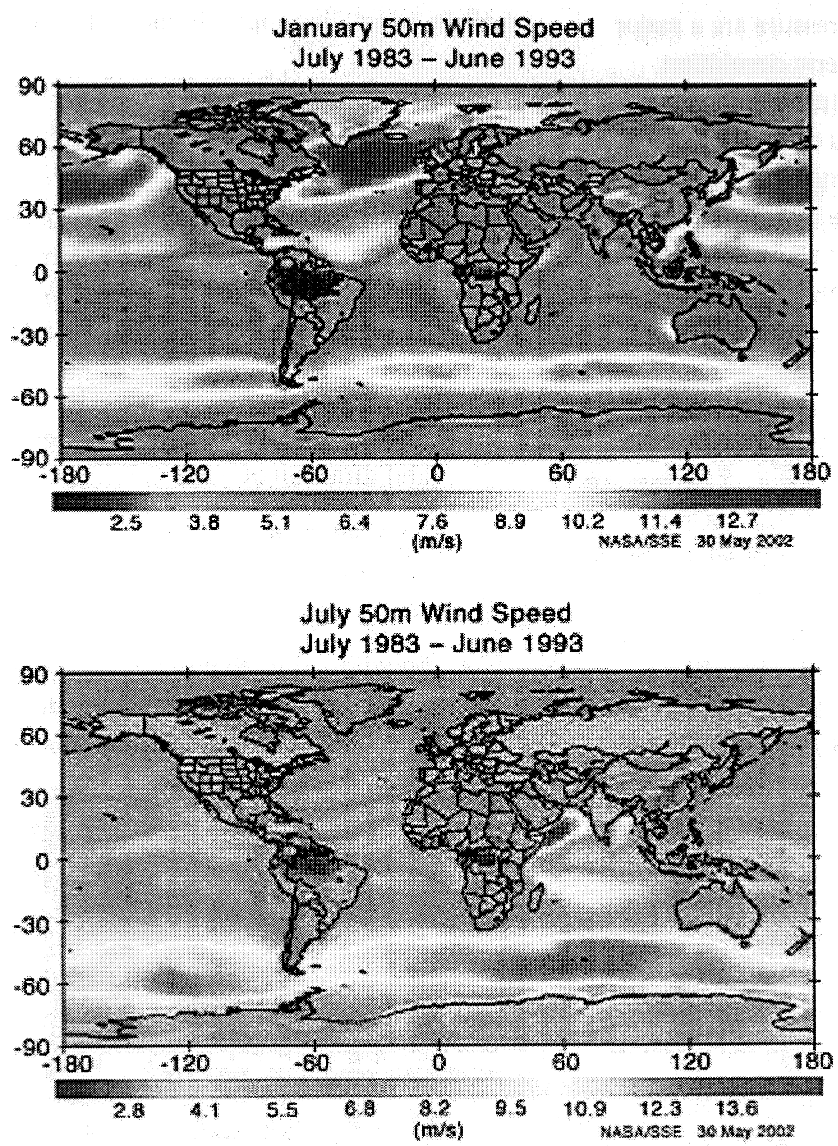
Atmospheric modeling

Scientists have developed numerical systems to quantify and predict the behavior of atmospheric winds. These systems are called *atmospheric general circulation models* (AGCMs). An AGCM has three major components:

- Equations that calculate the speed and direction of wind currents
- Parameterizations that estimate the values of other climate factors that can affect wind currents
- Boundary data that defines the physical grid points at which the model calculates atmospheric circulation

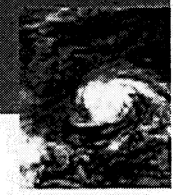


Clouds swirl around the high peaks of the Canary Islands. The influence of a land feature on atmospheric circulation is called an *orographic effect*. *Image credit: SeaWiFS Project, NASA Goddard Space Flight Center, and ORBIMAGE*



The measurements of satellite-borne sensors can be assimilated into records of monthly averaged wind speed. *Image credit: NASA Surface Meteorology and Solar Energy Project*

After calculating initial values for wind speed and direction at each grid point, an AGCM determines whether any condensation or clouds are present. The presence of water or cloud cover is important because these things influence atmospheric temperature. For example, clouds



reflect sunlight away from the Earth, and raindrops scatter solar energy that passes through them.

Next, the AGCM produces temperature values for the grid points. As noted earlier, temperature affects air pressure, and air pressure differences drive circulation.

Finally, the model accounts for factors that may reduce the kinetic energy of wind movement. One such factor is the orographic effect of land topography, which creates a drag on surface winds.

Atmospheric observation

For years, scientists relied on weather balloons to carry the instruments that recorded wind speed and direction. Today, observations from orbiting satellites help scientists keep a direct eye on atmospheric circulation.

For example, an altimeter bounces radar pulses off the ocean surface. By analyzing the signal that is reflected back, an altimeter can determine various physical properties. Among those properties are the speed and direction of the wind that moves over the ocean. Generally, a smaller signal feedback indicates that the radar pulse was scattered in multiple directions. This result hints at a choppy sea surface and, therefore, high winds over the ocean.

A radiometer can derive information on wind near the ocean surface by recording the microwave emission of sunlight reflecting off the oceans. This measurement indicates the ocean's brightness temperature, or *apparent temperature*. The temperature is merely apparent because different factors can actually alter a microwave reading. For example, sea foam, which is likely to be caused by high winds, can increase a brightness temperature measurement.

In this process, multiple recordings must be taken over the same area at different angles. Atmospheric interference and other geophysical factors that can affect an ocean surface microwave reading must be taken out. For example, rain interferes with microwave readings and makes an ocean appear warmer than it actually is.

References

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Wentz, F. J., "Measurement of oceanic wind vector using satellite microwave radiometers," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 30, 960-972, 1992

Research Profile: Assimilation of Surface Wind Observations

Investigators:
Robert Atlas, Stephen Bloom, and Joseph Otterman, NASA Goddard Space Flight Center, Data Assimilation Office

The Data Assimilation Office (DAO) developed and tested several methods of assimilating microwave observations from satellites into high-resolution global grids of ocean surface wind data. These data sets were released for public use, and several scientific articles have made use of them.

This project used measurements from the Special Sensor Microwave/Imager (SSM/I) instrument, a satellite-based radiometer that records the microwave emission of sunlight as it is reflected off the ocean surface. The SSM/I indicates the ocean's brightness temperature, or apparent temperature. Brightness temperature is merely apparent because the roughness of the ocean surface can alter a microwave reading. This is how surface wind speed can be derived from microwave readings.

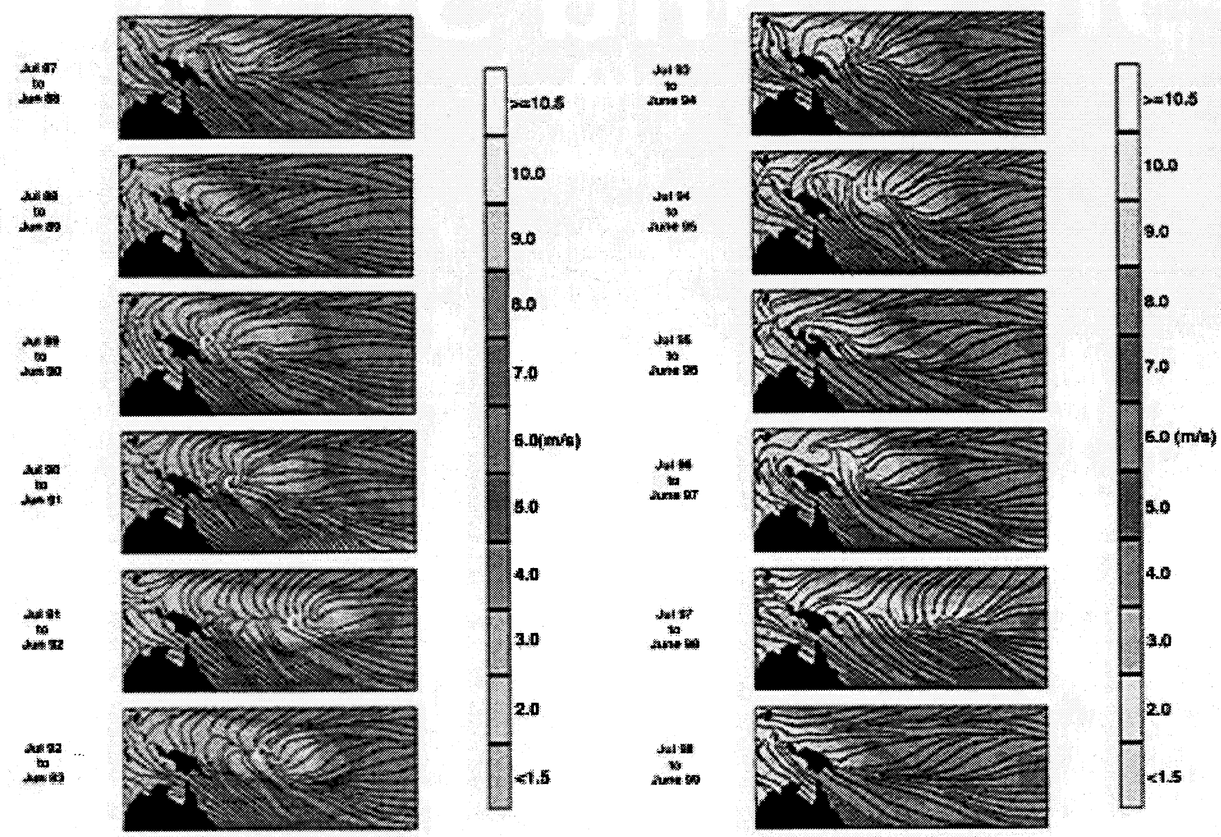
On their own, the SSM/I recordings indicate surface wind speed but not direction. To fill in the blanks, the DAO combined, or *assimilated*, the SSM/I data set with surface observations and analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF).

The DAO researchers devised six different methods to filter together these measurement sets and generate wind direction vectors. They tested the results for each method using in situ measurements, simulated surface winds, and the Seasat Scatterometer wind vector data set. Ultimately, the tests showed that a variational analysis method was the most accurate.

Once the DAO researchers had selected a filtering method, they applied it to process wind direction vectors for the SSM/I data set. For the period of July 1987 through December 1999, analyses were performed at 6-hour intervals. This amounted to more than 10,000 time steps for a 1-degree latitude by 1-degree longitude global grid. This data set is now available to the public through the Distributed Active Archive Center at the NASA Jet Propulsion Laboratory.

The DAO researchers then created more global grids of wind speed and direction by assimilating the SSM/I measurements with other data sets. One of these data sets was gdas1, in which the National Centers for Environmental Prediction (NCEP) merged climate recordings from numerous sources into a single set of meteorological fields. The final product of this effort was a global set of wind information that runs from July 1999 to the present. It is available via anonymous ftp to NASA investigators. Also in 2000, work began on the assimilation of wind speed data from the NCEP Reanalyses recordings into a climatological record for the years 1987-1999.

Atmospheric Circulation



The SSM/I data set is used to map out the annual average streamline patterns over the surface of the western tropical Pacific region. The depicted area is an *intertropical convergence zone,* where trade winds from the Northern and Southern Hemispheres meet. The "C" represents the convergent vortex. It moves eastward during the warm phase of the ENSO cycle and then back west as the warm phase decays. To produce the SSM/I data set, the Data Assimilation Office used surface wind information from the ECMWF.