The Data Assimilation Research Centre

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Data Assimilation

The objective of data assimilation (DA) is to determine the evolving state of the atmosphere or ocean. Two main sources of information are combined in DA:

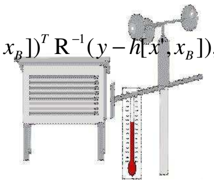
- **Observations** - there is an array of fixed meteorological and oceanographic observation sites making direct measurements (ground stations, radiosonde stations and buoys). Other information comes from moving platforms such as aircraft and ships. Many instruments, such as satellites, make remotely sensed (indirect) measurements of the Earth system.
- **Models** - The states of the atmosphere and ocean are estimated using forecast models. Such estimates are called background states.

The true state of each system can be better estimated by combining these two types of information in a mathematically rigorous, but subtle way. This is the procedure of variational DA. DA works by adjusting an estimate of the state until it agrees simultaneously with the background forecast and with the observations, within the specified background and observation errors. This is an iterative process of predicting the observations and correcting the state, and works by minimizing a cost function, J (below). This is a kind of inverse model.

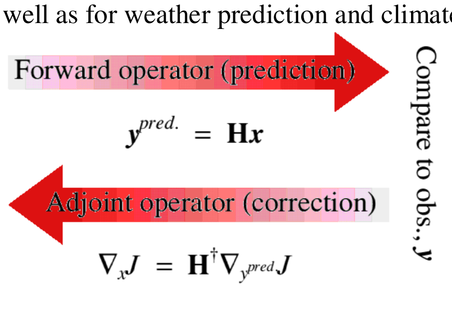
$$J[x'] = \frac{1}{2}(x'-x'_B)^T \mathrm{B}^{-1}(x'-x'_B) + \frac{1}{2}(y-h[x',x_B])^T \mathrm{R}^{-1}(y-h[x',x_B]),$$

$$\nabla_{x'} J = \mathrm{B}^{-1}(x'-x'_B) + \mathrm{H}^T \mathrm{R}^{-1}(y-h[x',x_B]),$$

where $\mathrm{H} = \frac{\partial h}{\partial x'}$ and $x = x_B + x'$.

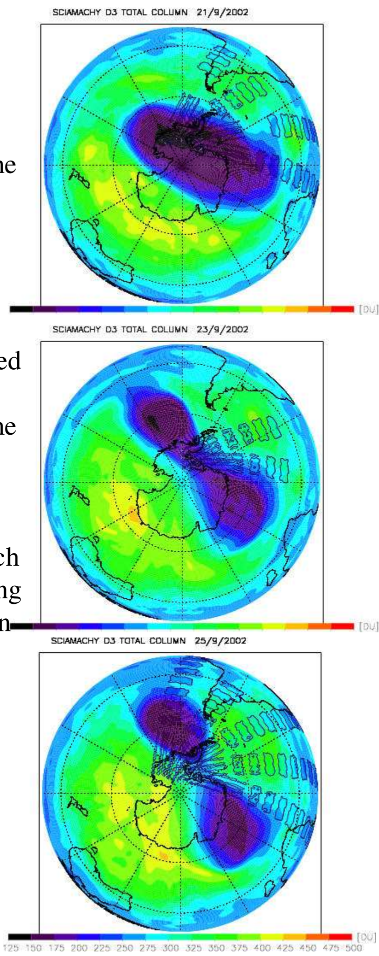


Inverse modelling is a powerful means of inferring information about a system by using imperfect, and incomplete observations, combined with models of the system's behaviour. A great benefit is that remotely sensed observations can be used. These are observations that are indirectly related to the model's fields. In meteorology, radiance measurements of the atmosphere are such examples. Inverse modelling is exploited in many science and engineering applications (astrophysics, medicine, geology, etc.) as well as for weather prediction and climate studies.



Climate applications of Data Assimilation

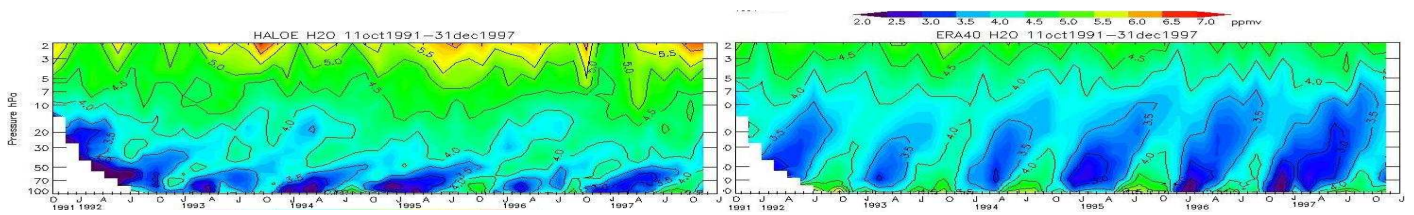
The Southern Polar Vortex Split



The three panels on the right are a view from space of total ozone amounts over the the South Pole. The deep blue colouring denotes the ozone hole, which forms during springtime over Antarctica as a result of chemical reactions involving man-made chlorofluoro-carbons. The sequence shows a dramatic and completely unexpected split in the ozone hole during Sept. 2002, during which air low in ozone was transported equatorward and mixed with air at middle latitudes.

The fields were derived at the Dutch Met. service, KNMI, by assimilating data from the GOME instrument on the European Space Agency's ERS satellite into a chemical-transport model. Superimposed are patches showing ozone amounts derived from ESA's Envisat satellite, launched in February 2002. Data assimilation allows different data sets to be combined in an optimal manner to provide global, self-consistent fields of meteorological and chemical quantities. By using time sequences of such fields, detailed studies can be made of ozone depletion in the stratosphere and of other processes relevant to climate change.

The "tape recorder" (TR) signal in the tropical stratosphere is formed by the upward advection of water vapour from the tropical tropopause, which has a seasonal cycle there. It has been observed by the orbiting HALOE instrument (below left). The ERA-40 'assimilation' of the TR (bottom right) relies entirely on the model background in the stratosphere since no stratospheric water vapour observations are assimilated. The transport model used by ERA-40 gives rise to a tape recorder that is too 'fast' - a problem common to most models. Better knowledge of stratospheric water vapour requires improved models in combination with stratospheric water vapour measurements.



Thanks to Ross Bannister, Alan O'Neill and Emmanouil Oikonomo.

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