Comparison of TOVS Pathfinder Data Sets for Arctic Applications

The NASA/NOAA Pathfinder Program was conceived in the early 1990s with the primary goal of making available to the scientific community products derived from existing multi-year satellite data sets. Prior to this program, it was prohibitively expensive for any investigator who was not directly affiliated with a satellite sensor to acquire a long data record. The Pathfinder Program made the valuable contribution of disseminating these radiance data sets to the investigators who had been selected to participate the program. Each investigator was charged with generating products for as long a record as possible and making them available to the community. Pathfinder data sets were created from the AVHRR (Advanced Very High Resolution Radiometer), TOVS (TIROS Operational Vertical Sounder), 3 generations of passive microwave instruments, GOES. and Landsat. See http://xtreme.gsfc.nasa.gov/pathfinder/path_sites.html for links to each Pathfinder data set.

The TOVS component of the program is unique in that several algorithms were used to process the data, resulting in 5 distinct TOVS Pathfinder data sets (Paths A, B, C1, C2, and P). Understandably, there is confusion in the community about why this was done and which data set one should use. The “why” is simple to explain, albeit unsatisfactory. No agreement could be reached by the TOVS community as to which algorithm produced the most accurate results -- and, in fact, it was (and still is) believed that each set of products is best for certain applications. This report briefly describes the differences among the data sets as well as the pros and cons in using them for Arctic applications that are relevant to SEARCH. Please note that some of the evaluations stated here are not unanimously agreed upon among the community.

Overall

All TOVS Pathfinder data sets share the following characteristics: 1) global coverage, except for Path-P, which is only for the Arctic region north of 60°N; 2) span most of the TOVS 20-year record; and 3) contain temperature and moisture profiles and cloud parameters (except Paths C1 and C2). The primary difference among the data sets is the philosophy behind the retrieval algorithms used to create them. Because TOVS was designed as a tool for operational weather forecasting and not a climate instrument, its radiances were not well calibrated. All Pathfinder data sets suffer to varying degrees from remaining calibration errors, which may arise from sensor degradation with time, orbital degradation, non-identical channels, and other inter-satellite differences. More information about each Pathfinder data set, including references, can be obtained through the Pathfinder WWW site given above.

Path-A -- GSFC

Spatial coverage: global

Temporal coverage: 22 years, 1979-2000

Horizontal resolution: 1° x 1°

Temporal resolution: daily, pentad, monthly

Path-A has the strengths of being higher resolution than the other TOVS Pathfinders, the list of products is extensive, the temporal coverage extends through 2000, and the algorithm is well documented.The distinguishing feature of the algorithm used to create the Path-A data set is that it requires a first-guess temperature profile, which it obtains from a non-frozen, 6-hour forecast from the Goddard Earth Observation System GCM. There is concern in the climate community that this procedure may introduce model-related biases, and consequently observed trends in the retrieved parameters may include effects that are not due to changing climate. Other concerns arise in areas where NWP models and GCMs perform poorly, i.e., data-sparse regions such as the Southern Ocean and the central Arctic, where the first guess may introduce an erroneous bias to the retrieval. The cloud detection and clearing method employed by Path-A is also a source of uncertainty, particularly in sea-ice covered areas and over non-uniform land. The technique relies on a comparison of adjacent pixels. The colder pixels are declared cloudy, which is often not the case when surface-based inversions and low clouds exist, and it may also miss-identify pixels in heterogeneous ice conditions. Comparisons of retrieved cloud fractions in the Arctic with AVHRR imagery shows clearly that the algorithm greatly under-detects clouds. To my knowledge, little validation of high-latitude Path-A products has been performed.

Path-B -- Laboiratoire de Meteorologie Dynamique

Spatial coverage: global Temporal coverage: 17 years, 1979-1995

Horizontal resolution: 100 x 100 km Temporal resolution: daily, pentad, monthly

Path-B is similar to Path-A in its extensive list of products, but Path-B's horizontal resolution is coarser. The primary difference between them is that the processing algorithm (Improved Initialization Algorithm or "3I") obtains its first guess from a fixed, comprehensive library of profiles distilled from several hundred thousand radiosondes from around the globe. It is thought that this technique eliminates spurious trends arising from the first guess. The 3I algorithm also has the advantage of having been modified specifically for Arctic conditions, especially with respect to cloud detection and surface temperature retrieval. Particularly important for polar regions is that the cloud detection, retrieval, and clearing techniques do not rely on comparing adjacent pixels, thereby eliminating effects of heterogeneous surface conditions. Clouds that are warmer than the surface are recognized and retrieved. A weakness of Path-B is that it does not perform retrievals over high elevation. Products have been used extensively over high-latitude open water to study polar lows and lower stratosphere processes. The Path-P algorithm is almost identical to this one.

Path-C1, C2 -- Stennis, NOAA

Spatial coverage: global Temporal coverage: unknown

Horizontal resolution: 2° x 2° Temporal resolution: daily, monthly

Both of the C paths offer only thick-layer mean temperatures based only on the microwave sensor in TOVS (MSU). The algorithm has the advantage that it does not require a first guess, and therefore avoids any possible biases resulting from the influence of the

first guess selection. The list of products is limited, as a result, and vertical resolution is coarse. Cloud and surface information are not provided, but a great deal of effort has gone into calibration. Recently a new calibration problem was identified, thus the possibility exists that additional unaccounted for calibration issues remain. No validation in polar regions has been performed, to my knowledge.

Path-P -- UW, Rutgers, LMD

Spatial coverage: north of 60°N Temporal coverage: 20 years, 1979-1998

Horizontal resolution: 100 x 100 km Temporal resolution: daily, monthly

Path-P was specifically designed for the Arctic region, excluding Greenland and other areas with elevation over 1000 m. Path-P uses the same processing algorithm as Path-B (3I) with several modifications to improve its performance over snow and ice-covered surfaces and to provide additional products of interest to polar researchers. While Path-B uses a neural network to retrieve a moisture profile, Path-P uses a physical-statistical approach (also developed by LMD) that proved more accurate in Arctic conditions. Surface temperature and cloud detection methods have also been improved. The Path-P data set includes several polar-specific products, such as surface type (ocean/land/sea ice), geostrophic drag coefficient, surface wind turning angle, and surface pressure from NCEP reanalysis. Extensive validation has been performed with data from the CEAREX, LeadEx, and SHEBA field experiments, as well as radiosondes from NP stations, COADS, and HARA. Recent improvements have been made to retrievals of surface skin temperature, precipitable water, and upper-level temperatures. A project to revamp the cloud retrieval algorithm has been recently funded by NASA.