

THE NETCDF OPERATORS (NCO): AUTOMATIC REMAPPING OF GRIDDED GEOSCIENCE DATA

In order to analyze Earth system models (ESMs) and evaluate their simulations relative to global, satellite-based observations, geoscientists must often remap data between different coordinate systems (or “grids”). To add to the complexity, these data are often provided in different formats. For instance, ESMs store data in the Network Common Data Form (netCDF) format, while NASA often stores satellite data in the Hierarchical Data Format (HDF).

The netCDF Operators (NCO) effort has developed the first software tool to automatically remap data expressed in diverse formats onto different grids. Previously, such remapping required familiarity with intricate mathematical operations and multiple tools. Now innovative NCO algorithms automatically identify the relevant grids, choose the appropriate mathematical options, and accurately remap the data with a single command. Figure 1 demonstrates satellite-observed data remapped from a single overflight swath onto the corresponding location and grid necessary to evaluate the accuracy of a global model simulation.

Today’s researchers now can readily perform what was formerly a time-consuming and error-prone remapping task. NCO significantly eases intercomparison of ESM simulations with those of other models, and with satellite-

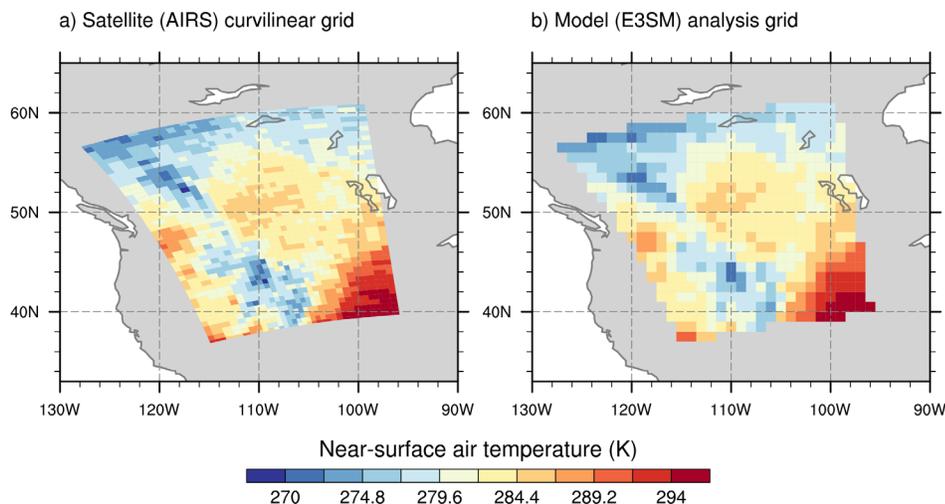


Figure 1. NCO remapping of HDF format, fine-scale temperature data derived from NASA satellite measurements (left), onto a coarser DOE E3SM model grid in netCDF format (right).

based measurements. It thus expedites deeper understanding of geophysical processes and accelerates their improved representation in ESMs.

LONGSTANDING CYBERINFRASTRUCTURE

Since 1997, NCO has been continually improved and released as open-source software. Thousands of international geophysical scientists use NCO on both personal and supercomputer platforms to manipulate and analyze data stored in netCDF and HDF formats. DOE’s support has made this longstanding cyberinfrastructure for geoscience easy to install in modern scientific computing environments, such as Python/Anaconda and Enterprise Linux.

Since current satellite and model data are usually distributed on different coordinate grids, intercomparison and analysis of swath, curvilinear, rectangular, and unstructured data (SCRUD) is increasingly important. Remapping SCRUD on different grids was previously difficult and error-prone because 1) non-rectangular grids are geometrically complex, 2) data sets often lack grid information, and 3) the requisite tools were intricate and inflexible. Now, NCO’s **ncremap** operator automatically remaps

Get NCO

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• <https://github.com/nco/nco>

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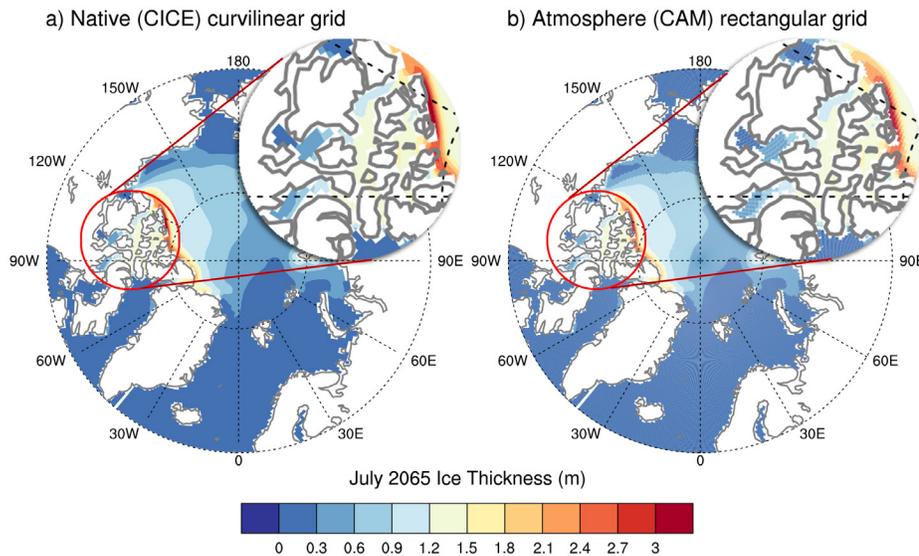


Figure 2. Remapping of CICE sea-ice model data (left) by the netCDF Operator **ncremap** (right).

SCRUD and requires little expertise to use.

The ability of **ncremap** to handle SCRUD is displayed in figure 2. The simulation by the DOE-supported CICE sea-ice model (left) produces idiosyncratic metadata that traditional remapping software cannot interpret; but **ncremap** identifies and adjusts for unconventional grid geometries and metadata, and accurately remaps the CICE data without requiring user intervention (right). The **ncremap** operator accepts a sliding threshold for the fractional area of sea ice presence in the source data (left) needed to create a valid (instead of blank) gridcell in the destination data (right).

In its most powerful analysis mode, **ncremap** interrogates data files and stores an internal mapping database of satellite and model grid information, thereby inferring

source and destination grids with unprecedented accuracy. This allows a user to work solely with the data files that are readily available, without having to manually locate or generate grid information—a time-consuming task.

User feedback also continually improves the mapping database. For instance, the **ncremap** operator can utilize pre-stored grid information supplied by more advanced users. For the rectangular grids most commonly used for analysis, **ncremap** can even generate this information itself.

To speed-up repetitive remapping between the same source and destination grids, **ncremap** generates the necessary pre-computed weights and stores these offline, employing the robust weight-generation algorithms of the Earth System Modeling Framework (ESMF) and TempestRemap

libraries. With offline weights available, supercomputer users can take advantage of the **ncremap** parallelized weight-application features to remap hundreds of files simultaneously. NCO code is written in the C language, with parallelization via the Open Multi-Processing (OpenMP) and Message Passing Interface (MPI) libraries providing the fastest possible regridding. Comparisons show that NCO performs regridding up to 100 times faster than other similar-purpose tools.

In addition to automatic remapping, DOE has supported development and delivery of numerous other NCO features. For example, NCO performs much of the workflow that converts raw ESM output into the statistical climatologies favored by researchers and organizations such as DOE, NASA, and the Intergovernmental Panel on Climate Change (IPCC). NCO also includes capabilities for high performance time-series extraction and optimal data compression techniques.

SUPPORT

*DOE Biological and Environmental Research, Earth System Modeling
 NASA Advancing Collaborative Connections for Earth System Science (ACCESS)*

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¹Zender, CS (2008). "Analysis of self-describing gridded geoscience data with netCDF operators (NCO)", *Environ. Modell. Softw.* 23(10): 1338-1342. DOI:10.1016/j.envsoft.2008.03.004

²2015 American Geophysical Union Poster Presentation, http://dust.ess.uci.edu/smn/pst_nco_agu_201512.pdf

³2017 ACME All Hands Meeting Presentation, http://dust.ess.uci.edu/smn/smn_nco_acme_201706.pdf