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**xarray***extras*Documentation  
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**xarray***extras*Developers

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This module offers several extensions to `xarray`, which could not be included into the main module because they fall into one or more of the following categories:

- They're too experimental
- They're too niche
- They introduce major new dependencies (e.g. `numba` or a C compiler)
- They would be better done by doing major rework on multiple packages, and then one would need to wait for said changes to reach a stable release of each package - *in the right order*.

The API of `xarray-extras` is unstable by definition, as features will be progressively migrated upwards towards `xarray`, `dask`, `numpy`, `pandas`, etc.



## FEATURES

*csv* Multi-threaded CSV writer, much faster than `pandas.DataFrame.to_csv()`, with full support for `dask` and `dask distributed`.

*cumulatives* Advanced cumulative sum/productory/mean functions

*interpolate* `dask`-optimized n-dimensional spline interpolation

*numba\_extras* Additions to `numba`

*sort* Advanced sort/take functions

*stack* Tools for stacking/unstacking dimensions





## 2.1 Installation

### 2.1.1 Required dependencies

- Python 3.8 or later
- `scipy`
- `xarray`
- `dask`
- `numba`
- C compiler (only if building from sources)

### 2.1.2 Deployment

- With `pip`: `pip install xarray-extras`
- With `anaconda`: `conda install -c conda-forge xarray-extras`

## 2.2 Development Guidelines

### 2.2.1 Install

1. Clone this repository with `git`:

```
git clone git@github.com:crusaderky/xarray-extras.git
cd xarray-extras
```

2. Install `anaconda` or `miniconda` (OS-dependent)

```
conda env create -n xarray_extras --file ci/requirements.yml
conda activate xarray_extras
```

4. Install C compilation stack:

**Linux**

```
conda install gcc_linux-64
```

### MacOSX

```
conda install clang_osx-64
```

**Windows** You need to manually install the Microsoft C compiler tools. Refer to CPython documentation.

To keep a fork in sync with the upstream source:

```
cd xarray_extras
git remote add upstream git@github.com:crusaderky/xarray_extras.git
git remote -v
git fetch -a upstream
git checkout main
git pull upstream main
git push origin main
```

## 2.2.2 Test

Test using `py.test`:

```
python setup.py build_ext --inplace
py.test xarray_extras
```

## 2.2.3 Code Formatting

`xarray_extras` uses several code linters (flake8, black, isort, pyupgrade, mypy), which are enforced by CI. Developers should run them locally before they submit a PR, through the single command

```
pre-commit run --all-files
```

This makes sure that linter versions and options are aligned for all developers.

Optionally, you may wish to setup the [pre-commit hooks](#) to run automatically when you make a git commit. This can be done by running:

```
pre-commit install
```

from the root of the `xarray_extras` repository. Now the code linters will be run each time you commit changes. You can skip these checks with `git commit --no-verify` or with the short version `git commit -n`.

## 2.3 What's New

### 2.3.1 v0.6.0 (Unreleased)

- Added explicit CI tests for Python 3.10 (v0.5.0 already supports it, although not formally).
- Dropped support for Python 3.7

### 2.3.2 v0.5.0 (2021-12-01)

- Bumped minimum version of all dependencies:

Dependency	v0.4.2	v0.5.0
python	3.5	3.7
dask	0.19	2021.4
numba	0.34	0.52
numpy	1.13	1.18
pandas	0.21	1.1
scipy	1.0	1.5
xarray	0.10.1	0.16

- Added support for Python 3.8 and 3.9
- Removed `xarray_extras.backports` module
- Migrated CI to github workflows
- Added code linters: `pyupgrade`, `isort`, `black`
- Run all code linters through pre-commit
- Use `setuptools-scm` for versioning
- Moved the whole contents of `setup.py` to `setup.cfg`

### 2.3.3 v0.4.2 (2019-06-03)

- Type annotations
- Mandatory `mypy` validation in CI
- CI unit tests for Windows now run on Python 3.7
- Compatibility with `dask`  $\geq 1.1$
- Suppress deprecation warnings with `pandas`  $\geq 0.24$
- `to_csv()` changes:
  - When invoked on a 1-dimensional `DataArray`, the default value for the `index` parameter has been changed from `False` to `True`, coherently to the default for `pandas.Series.to_csv` from `pandas 0.24`. This applies also to users who have `pandas < 0.24` installed.
  - support for `line_terminator` parameter (all `pandas` versions);
  - fix incorrect line terminator in Windows with `pandas`  $\geq 0.24$
  - support for `compression='infer'` (all `pandas` versions)
  - support for `compression` parameter with `pandas < 0.23`

### 2.3.4 v0.4.1 (2019-02-02)

- Fixed build regression in `readthedocs`

### 2.3.5 v0.4.0 (2019-02-02)

- Moved `recursive_diff`, `recursive_eq` and `ncdiff` to their own package `recursive_diff`
- Fixed bug in `proper_unstack()` where unstacking coords with `dtype=datetime64` would convert them to integer
- Mandatory flake8 in CI

### 2.3.6 v0.3.0 (2018-12-13)

- Changed license to Apache 2.0
- Increased minimum versions: `dask`  $\geq 0.19$ , `pandas`  $\geq 0.21$ , `xarray`  $\geq 0.10.1$ , `pytest`  $\geq 3.6$
- New function `proper_unstack()`
- New functions `recursive_diff` and `recursive_eq`
- New command-line tool `ncdiff`
- Blacklisted Python 3.7 conda-forge builds in CI tests

### 2.3.7 v0.2.2 (2018-07-24)

- Fixed segmentation faults in `to_csv()`
- Added conda-forge travis build
- Blacklisted `dask-0.18.2` because of regression in `argtopk(split_every=2)`

### 2.3.8 v0.2.1 (2018-07-22)

- Added parameter `nozil=True` to `to_csv()`, which will switch to a C-accelerated implementation instead of `pandas to_csv` (albeit with caveats). Fixed deadlock in `to_csv` as well as compatibility with `dask distributed`. `Pandas` code (when using `nozil=False`) is not wrapped by a subprocess anymore, which means it won't be able to use more than 1 CPU (but compression can run in pipeline). `to_csv` has lost the ability to write to a buffer - only file paths are supported now.
- AppVeyor integration

### 2.3.9 v0.2.0 (2018-07-15)

- New function `xarray_extras.csv.to_csv()`
- Speed up interpolation for `k=2` and `k=3`
- CI: Rigorous tracking of minimum dependency versions
- CI: Explicit support for Python 3.7

### 2.3.10 v0.1.0 (2018-05-19)

Initial release.

## 2.4 csv

Multi-threaded CSV writer, much faster than `pandas.DataFrame.to_csv()`, with full support for `dask` and `dask distributed`.

`xarray_extras.csv.to_csv(x: xarray.DataArray, path: str, *, nogil: bool = True, **kwargs)`

Print DataArray to CSV.

When `x` has numpy backend, this function is functionally equivalent to (but much) faster than):

```
x.to_pandas().to_csv(path_or_buf, **kwargs)
```

When `x` has dask backend, this function returns a dask delayed object which will write to the disk only when its `.compute()` method is invoked.

Formatting and optional compression are parallelised across all available CPUs, using one dask task per chunk on the first dimension. Chunks on other dimensions will be merged ahead of computation.

#### Parameters

- `x` – `DataArray` with one or two dimensions
- `path` (`str`) – Output file path
- `nogil` (`bool`) – If True, use accelerated C implementation. Several kwargs won't be processed correctly (see limitations below). If False, use `pandas.to_csv` method (slow, and does not release the GIL). `nogil=True` exclusively supports float and integer values dtypes (but the coords can be anything). In case of incompatible dtype, `nogil` is automatically switched to False.
- `kwargs` – Passed verbatim to `pandas.DataFrame.to_csv()` or `pandas.Series.to_csv()`

#### Limitations

- Fancy URIs are not (yet) supported.
- `compression='zip'` is not supported. All other compression methods (`gzip`, `bz2`, `xz`) are supported.
- When running with `nogil=True`, the following parameters are ignored: `columns`, `quoting`, `quotechar`, `doublequote`, `escapechar`, `chunksize`, `decimal`

#### Distributed computing

This function supports `dask distributed`, with the caveat that all workers must write to the same shared mountpoint and that the shared filesystem must strictly guarantee **close-open coherency**, meaning that one must be able to call `write()` and then `close()` on a file descriptor from one host and then immediately afterwards `open()` from another host and see the output from the first host. Note that, for performance reasons, most network filesystems do not enable this feature by default.

Alternatively, one may write to local mountpoints and then manually collect and concatenate the partial outputs.

## 2.5 cumulatives

Advanced cumulative sum/productory/mean functions

`xarray_extras.cumulatives.compound_mean`(*x*: `xarray_extras.cumulatives.T`, *c*: `xarray.DataArray`, *xdim*: `collections.abc.Hashable`, *cdim*: `collections.abc.Hashable`) → `xarray_extras.cumulatives.T`

Compound mean among arbitrary points of *x* along *dim* See `compound_sum()`.

`xarray_extras.cumulatives.compound_prod`(*x*: `xarray_extras.cumulatives.T`, *c*: `xarray.DataArray`, *xdim*: `collections.abc.Hashable`, *cdim*: `collections.abc.Hashable`) → `xarray_extras.cumulatives.T`

Compound product among arbitrary points of *x* along *dim* See `compound_sum()`.

`xarray_extras.cumulatives.compound_sum`(*x*: `xarray_extras.cumulatives.T`, *c*: `xarray.DataArray`, *xdim*: `collections.abc.Hashable`, *cdim*: `collections.abc.Hashable`) → `xarray_extras.cumulatives.T`

Compound sum on arbitrary points of *x* along *dim*.

### Parameters

- **x** – `DataArray` or `Dataset` containing the data to be compounded
- **c** (`xarray.DataArray`) – array where every row contains elements of `x.coords[xdim]` and is used to build a point of the output. The cells in the row are matched against `x.coords[dim]` and perform a sum. If different rows of *c* require different amounts of points from *x*, they must be padded on the right with `NaN`, `NaT`, or `''` (respectively for numbers, datetimes, and strings).
- **xdim** (`hashable`) – dimension of *x* to acquire data from. The coord associated to it must be monotonic ascending.
- **cdim** (`hashable`) – dimension of *c* that represent the vector of points to be compounded for every point of *dim*

**Returns** `xarray` object of the same type and dtype as *x*, with all dims from *x* and *c* except *xdim* and *cdim*.

example:

```
>>> x = xarray.DataArray(
>>>     [10, 20, 30],
>>>     dims=['x'], coords={'x': ['foo', 'bar', 'baz']})
>>> c = xarray.DataArray(
>>>     [['foo', 'baz', None],
>>>      ['bar', 'baz', 'baz']],
>>>     dims=['y', 'c'], coords={'y': ['new1', 'new2']})
>>> compound_sum(x, c, 'x', 'c')
<xarray.DataArray (y: 2)>
array([40, 80])
Coordinates:
  * y          (y) <U4 'new1' 'new2'
```

`xarray_extras.cumulatives.cummean`(*x*: *T*, *dim*: `Hashable`, *skipna*: `bool | None = None`) → *T*

$$y_i = \text{mean}(x_0, x_1, \dots, x_i)$$

### Parameters

- **x** – `DataArray` or `Dataset`
- **dim** (*hashable*) – dimension along which to calculate the mean
- **skipna** (*bool*) – If True, skip missing values (as marked by NaN). By default, only skips missing values for float dtypes; other dtypes either do not have a sentinel missing value (int) or skipna=True has not been implemented (object, datetime64 or timedelta64).

**Returns** xarray object of the same type, dtype, and shape as x

## 2.6 interpolate

xarray spline interpolation functions

`xarray_extras.interpolate.splev(x_new: xarray.DataArray, tck: xarray.Dataset, extrapolate: bool | str = True) → xarray.DataArray`

Evaluate the B-spline generated with `splrep()`.

### Parameters

- **x\_new** – Any `DataArray` with any number of dims, not necessarily the original interpolation dim. Alternatively, it can be any 1-dimensional array-like; it will be automatically converted to a `DataArray` on the interpolation dim.
- **tck** (`xarray.Dataset`) – As returned by `splrep()`. It can have been:
  - transposed (not recommended, as performance will drop if c is not C-contiguous)
  - sliced, reordered, or (re)chunked, on any dim except the interpolation dim
  - computed from dask to numpy backend
  - round-tripped to disk
- **extrapolate** –
  - True** Extrapolate the first and last polynomial pieces of b-spline functions active on the base interval
  - False** Return NaNs outside of the base interval
  - 'periodic'** Periodic extrapolation is used
  - 'clip'** Return `y[0]` and `y[-1]` outside of the base interval

**Returns** `DataArray` with all dims of the interpolated array, minus the interpolation dim, plus all dims of `x_new`

See `splrep()` for usage example.

`xarray_extras.interpolate.splrep(a: xarray.DataArray, dim: collections.abc.Hashable, k: int = 3) → xarray.Dataset`

Calculate the univariate B-spline for an N-dimensional array

### Parameters

- **a** (`xarray.DataArray`) – any `DataArray`
- **dim** – dimension of a to be interpolated. `a.coords[dim]` must be strictly monotonic ascending. All int, float (not complex), or datetime dtypes are supported.

- **k** (*int*) – B-spline order:

k	interpolation kind
0	nearest neighbour
1	linear
2	quadratic
3	cubic

**Returns** `Dataset` with `t`, `c`, `k` (knots, coefficients, order) variables, the same shape and coords as the input, that can be passed to `splev()`.

Example:

```
>>> x = np.arange(0, 120, 20)
>>> x = xarray.DataArray(x, dims=['x'], coords={'x': x})
>>> s = xarray.DataArray(np.linspace(1, 20, 5), dims=['s'])
>>> y = np.exp(-x / s)
>>> x_new = np.arange(0, 120, 1)
>>> tck = splrep(y, 'x')
>>> y_new = splev(x_new, tck)
```

### Features

- Interpolate a ND array on any arbitrary dimension
- dask supported on both on the interpolated array and `x_new`
- Supports ND `x_new` arrays
- The CPU-heavy interpolator generation (`splrep()`) is executed only once and then can be applied to multiple `x_new` (`splev()`)
- memory-efficient
- Can be pickled and used on dask distributed

### Limitations

- Chunks are not supported along dim on the interpolated dimension.

## 2.7 numba\_extras

Extensions to numba

`xarray_extras.numba_extras.guvectorize` (*signature: str, layout: str, \*\*kws*) → Callable[[Callable], Any]  
Convenience wrapper around `numba.guvectorize()`. Generate signature for all possible data types and set a few healthy defaults.

### Parameters

- **signature** (*str*) – numba signature, containing {T}
- **layout** (*str*) – as in `numba.guvectorize()`
- **kws** – passed verbatim to `numba.guvectorize()`. This function changes the default for cache from False to True.

example:



```
guvectorize("{T}[:, {T}[:, "(i)->(i)")
```

Is the same as:

```
numba.guvectorize([
    "float32[:, float32[:,
    "float64[:, float64[:,
    ...
], "(i)->(i)", cache=True)
```

**Note:** Discussing upstream fix; see <https://github.com/numba/numba/issues/2936>.

## 2.8 sort

Sorting functions

`xarray_extras.sort.argmaxtopk(a: TV, k: int, dim: Hashable, split_every: int | None = None) → TV`

Extract the indexes of the *k* largest elements from *a* on the given dimension, and return them sorted from largest to smallest. If *k* is negative, extract the *-k* smallest elements instead, and return them sorted from smallest to largest.

This assumes that *k* is small. All results will be returned in a single chunk along the given axis.

`xarray_extras.sort.take_along_dim(a: xarray_extras.sort.T, ind: xarray_extras.sort.T, dim: collections.abc.Hashable) → xarray_extras.sort.T`

Use the output of `argtopk()` to pick points from *a*.

### Parameters

- **a** – `xarray.DataArray` or `xarray.Dataset`
- **ind** – array of ints, as returned by `argtopk()`
- **dim** – dimension along which `argtopk` was executed

`xarray_extras.sort.topk(a: TV, k: int, dim: Hashable, split_every: int | None = None) → TV`

Extract the *k* largest elements from *a* on the given dimension, and return them sorted from largest to smallest. If *k* is negative, extract the *-k* smallest elements instead, and return them sorted from smallest to largest.

This assumes that *k* is small. All results will be returned in a single chunk along the given axis.

An example that uses all of the above functions is *source attribution*. Given a generic function  $y = f(x_0, x_1, \dots, x_i)$ , which is embarrassingly parallel along a given dimension, one wants to find:

- the top *k* elements of *y* along the dimension
- the elements of all *x*'s that generated the top *k* elements of *y*

```
>>> from xarray import DataArray
>>> from xarray_extras.sort import *
>>> x = DataArray([[5, 3, 2, 8, 1],
>>>                [0, 7, 1, 3, 2]], dims=['x', 's'])
>>> y = x.sum('x') # y = f(x), embarrassingly parallel among dimension 's'
>>> y
<xarray.DataArray (s: 5)>
```

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```

array([ 5, 10,  3, 11,  3])
Dimensions without coordinates: s
>>> top_y = topk(y, 3, 's')
>>> top_y
<xarray.DataArray (s: 3)>
array([11, 10,  5])
Dimensions without coordinates: s
>>> top_x = take_along_dim(x, argtopk(y, 3, 's'), 's')
>>> top_x
<xarray.DataArray (x: 2, s: 3)>
array([[8, 3, 5],
       [3, 7, 0]])
Dimensions without coordinates: x, s

```

## 2.9 stack

Utilities for stacking/unstacking dimensions

`xarray_extras.stack.proper_unstack`(*array: xarray\_extras.stack.T, dim: collections.abc.Hashable*) → `xarray_extras.stack.T`

Work around an issue in xarray that causes the data to be sorted alphabetically by label on `unstack()`:

<https://github.com/pydata/xarray/issues/906>

Also work around issue that causes string labels to be converted to objects:

<https://github.com/pydata/xarray/issues/907>

### Parameters

- **array** – `xarray.DataArray` or `xarray.Dataset` to unstack
- **dim** (*str*) – Name of existing dimension to unstack

**Returns** `xarray.DataArray` or `xarray.Dataset` with unstacked dimension

## CREDITS

- `proper_unstack()` was originally developed by Legal & General and released to the open source community in 2018.
- All boilerplate is from `python_project_template`, which in turn is from `xarray`.



**LICENSE**

xarray-extras is available under the open source [Apache License](#).



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