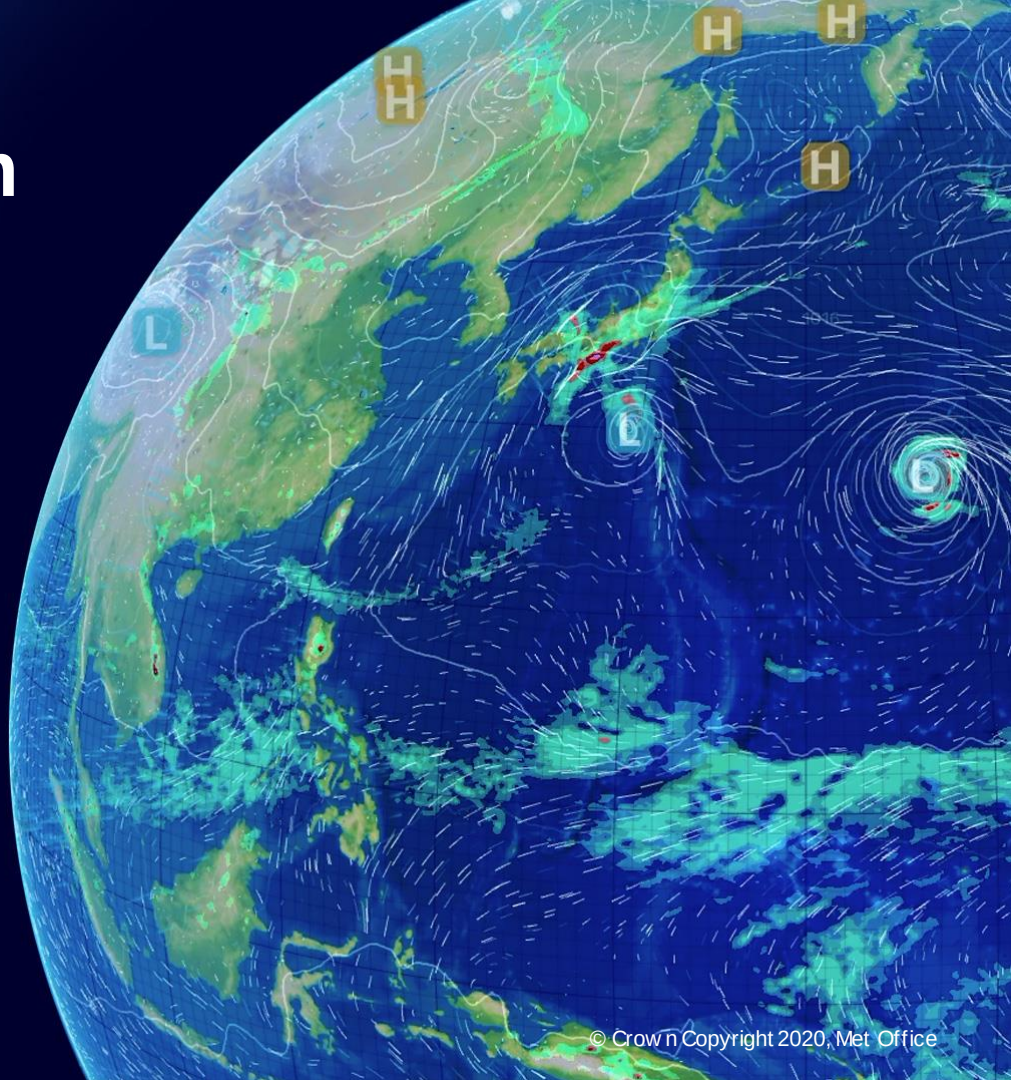
Observation Error from NetCDF

Carwyn Pelley

https://github.com/JCSDA-internal/ufo/issues/276



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Overview

1. Requirements.
2. Background.
3. Current situation (observation error from yaml).
4. Proposed new “filter”.
5. Proposed new generic observation error from NetCDF obsfunction.
6. Usecases.
7. Summary.

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Requirement

Develop an error assignment mechanism sufficiently flexible to cover a wide range of observation types.

- Provide observation error explicitly via the Yaml file.
  - As a constant.
  - List of values to be linearly interpolated.
  - Support assigning only error variances – no off-diagonal covariances.
- Provide observation error via a Netcdf file.
  - Support error variance or the full R matrix (only the diag(R) will need to be assigned at present).
  - Support uni-variant and multi-variant observation error.
  - Require linear and nearest neighbour interpolation methods.

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Background

DA combines model states (backgrounds) with observations, weighted by their respective errors (**B** and **R**), to provide a best estimate of the state (analysis).

R is then called the *observation error covariance matrix*. When the obserror is small, analysis is pulled towards the observation. When large, it is pulled towards the background.

This observation error consists of **measurement error** and **representation error**.

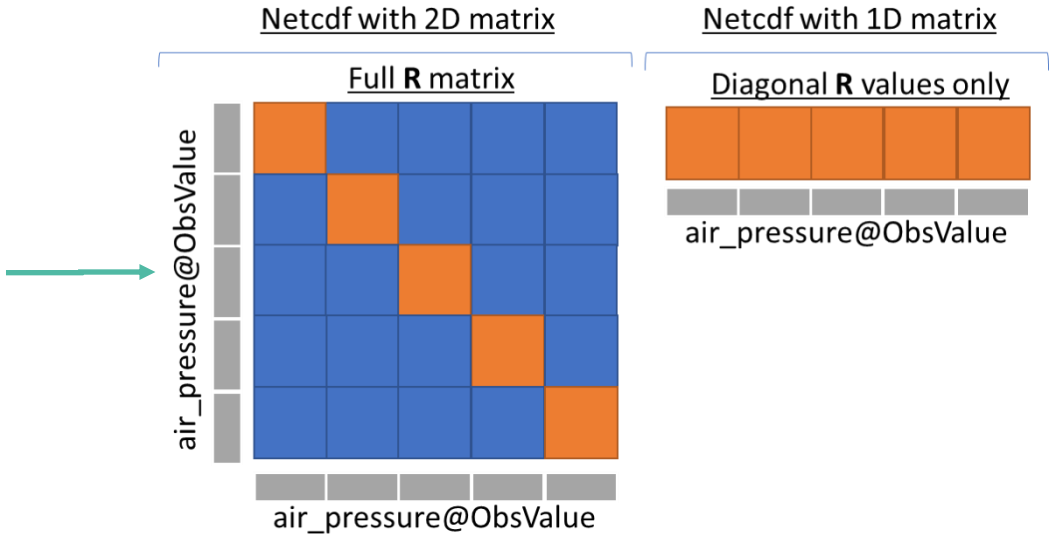
Background

- Measurement error is the combined accuracy and precision of an instrument or difference between the truth and reported value by the instrument.
- Representation error often dominates and corresponds to:
  - Observation pre-processing (preparation and selection of observations).
  - Unresolved scales/processes
  - Observation operator error (mapping the model fields to the observation).

Background

R is normally approximated as diagonal where Observation errors are uncorrelated. This is the what we will be supporting in the first instance.

To satisfy this approximation, observations are thinned and error variances are inflated.



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Assign error from yaml

Explicit setting, error variance:
(handled by #251 - Greg Thompson)

```
- filter: Blacklist
  filter variables:
  - name: air_temperature
  action:
    name: assign error
    error function:
      name: LinearInterp@ObsFunction
      options:
        xvar:
          name: air_pressure@ObsValue
        xvals: [x, x, x, x]
        errors: [x, x, x, x]
```

Explicit setting, error constant:
(already supported by UFO AssignError)

```
- filter: Blacklist
  filter variables:
  - name: air_temperature
  action:
    name: assign error
    error parameter: 1.5
```

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Proposal – New filter

- Deprecate the existing BlackList and DomainCheck filters in favour of a new "PerformAction" filter that performs both as well as making better sense for the "assigning error" action.

Equivalent behaviour to the existing BlackList (action: reject, default): (rejects all observations selected by the "where" statement and retains all others)

```
 - filter: PerformAction
   filter variables:
   - name: air_temperature
...
   action:
     name: reject
```

Equivalent behaviour to the existing DomainCheck (action: reject_inverse): (retains all observations selected by the "where" statement and rejects all others)

```
 - filter: PerformAction
   filter variables:
   - name: air_temperature
...
   action:
     name: accept
```

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Proposal – New generic obsfunction

- Define a new generic “ObsErrorModelFromNetCDF” obsfunction.
  - Handles the general case of handling observation errors from NetCDF.
    - Extract
    - Interpolation (nearest, linear).
  - Will uses functionality defined elsewhere for loading, representing, extracting, interpolating the observation error.
    - This will allow users to define their own custom observation error obsfunctions.

Usecase1: Uni-variant observation error

NetCDF structure:

Observation error	air_pressure
DIMENSION COORDS:	
air_pressure	x

Note: Dimension coordinates are those which are monatonically increasing

Corresponding yaml:

```
- filter: PerformAction
  filter variables:
  - name: air_temperature
  action:
    name: assign error
    error function:
      name: ObsErrorModelFromNetCDF@ObsFunction
      options:
        file: xxx.nc
        interpolation:
          linear:
            - air_pressure@MetaData
```

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Usecase2: Multi-variant observation error

NetCDF structure (full R matrix represented):

Observation error	channel_number	channel_number	index
DIMENSION COORDS:			
index			x
AUXILIARY COORDS:			
channel_number	x	x	
satellite_id			x
processing_center			x
latitude_band			x

NetCDF structure (error variance only represented):

Observation error	channel_number	index
DIMENSION COORDS:		
channel_number	x	
index		x
AUXILIARY COORDS:		
satellite_id		x
processing_center		x
latitude_band		x

Usecase2: Multi-variant observation error

```
- filter: PerformAction
  filter variables:
  - name: air_temperature
  action:
    name: assign error
    error function:
      name: ObsErrorModelFromNetCDF@ObsFunction
      options:
        file: xxx.nc
        interpolation:
          exact match:
            - channel_number@MetaData
            - satellite_id@MetaData
            - processing_center@MetaData
          linear:
            - latitude_band@MetaData
```

Variables specified are expected to be contained within the Observation error NetCDF as well as the observation space. Here, for each observation, extract the observation error from the NetCDF with the corresponding channel_number, satellite_id and processing_center (exact match). Then, linearly interpolate the observation error as a function of air pressure to the observation space air pressure to determine the observation error on the air_temperature.

Usecase3: User custom behaviour

```
- filter: PerformAction
  filter variables:
  - name: air_temperature
  action:
    name: assign error
    error function:
      name: <user-defined-obsfunction-#1@ObsFunction>
      options:
        file: xxx.nc
        interpolation:
          exact match:
            - <user-defined-obsfunction-#2@obsfunction>
            - channel_number@MetaData
            - satellite_id@MetaData
            - processing_center@MetaData
          linear:
            - air_pressure@MetaData
```

Custom observation error derivation. Access to the same functionality as our generic filter (extract, interpolation etc.).

Where the dimension coordinate name(s) are not part of the obsSpace, so the user must provide an obsFunction to do the mapping in this case.

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Summary

1. We would like to make use of ioda engines to fetch observation error from NetCDF.
2. We would propose to deprecate the “BlackList” and “DomainCheck” filters in favour of a new “PerformAction” filter.
    1. JEDI versioning and deprecations strategies in place?
3. New generic “ObsErrorModelFromNetCDF” obsfunction to handle our usecases while allowing the flexibility of custom user behaviour.

More information: https://github.com/JCSDA-internal/ufo/issues/276