Enhancing Data Sets for Accelerated Wind Energy Development

Advancing the state of the art in data set dissemination

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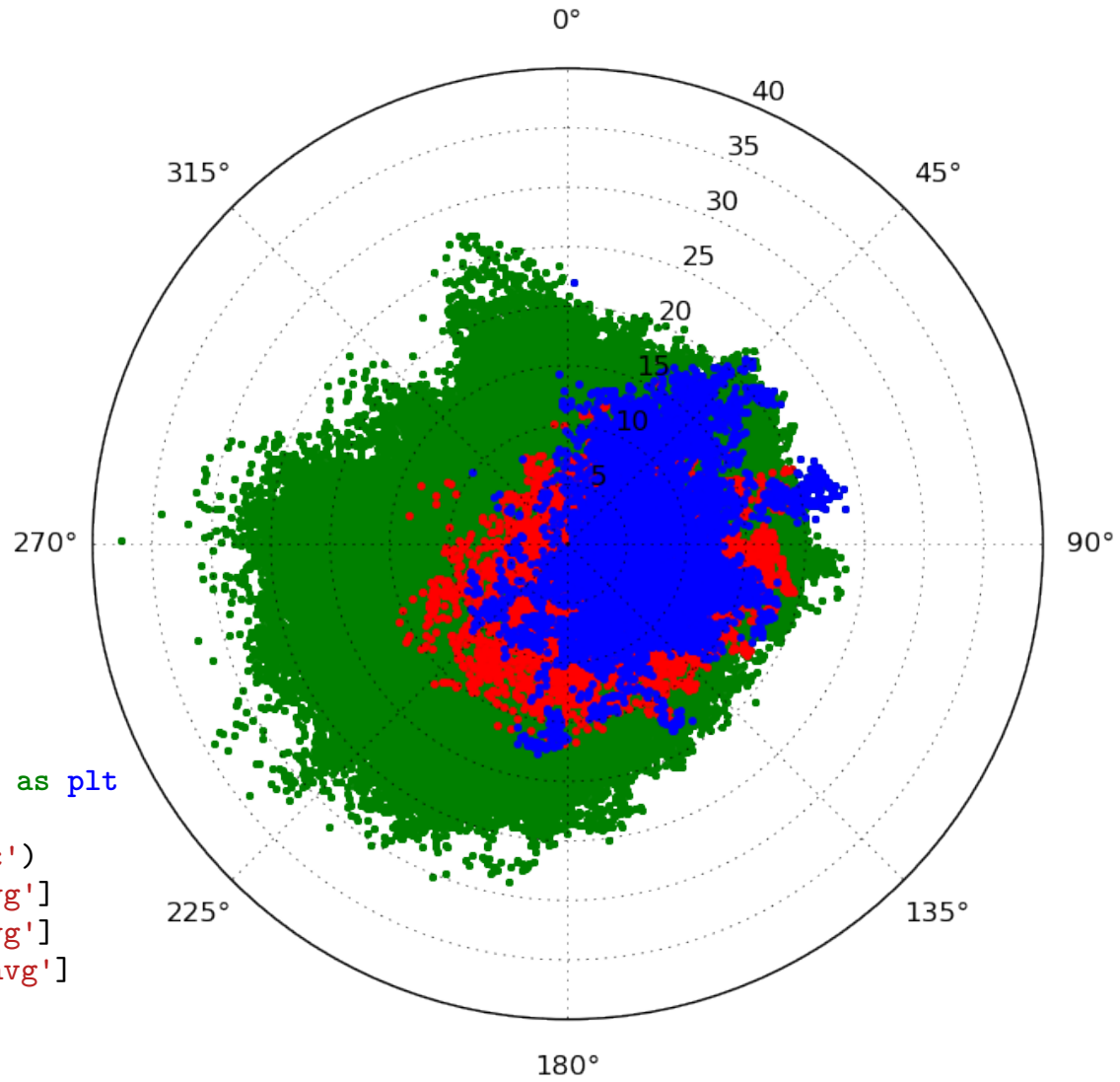
TU Delft




```
import netCDF4 as nc
import matplotlib.pyplot as plt

f = nc.Dataset('Fino1.nc')
d = f['WV/Wr'][:, 3]['avg']
v = f['CA/Wg'][:, 6]['avg']
T = f['HTT/Lt'][:, 4]['avg']
freezing = T <= 0
warm = T > 20

sp = plt.subplot(1, 1, 1, projection='polar')
sp.set_theta_direction(-1)
sp.set_theta_zero_location('N')
plt.plot(np.radians(d), v, '.g')
plt.plot(np.radians(d[warm]), v[warm], '.r')
plt.plot(np.radians(d[freezing]), v[freezing], '.b')
```

Basic Claims

Problem

Current data dissemination practice *hampers* research.

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Solution

We have the tools to instead *facilitate* research.

Problem: Issues *accessing* the data

- scarcity of open data sets

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- scarcity of open data sets
- very prevalent use of limited-functionality CSV format files

```
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```

Problem: Issues *accessing* the data

- scarcity of open data sets
- very prevalent use of limited-functionality CSV format files

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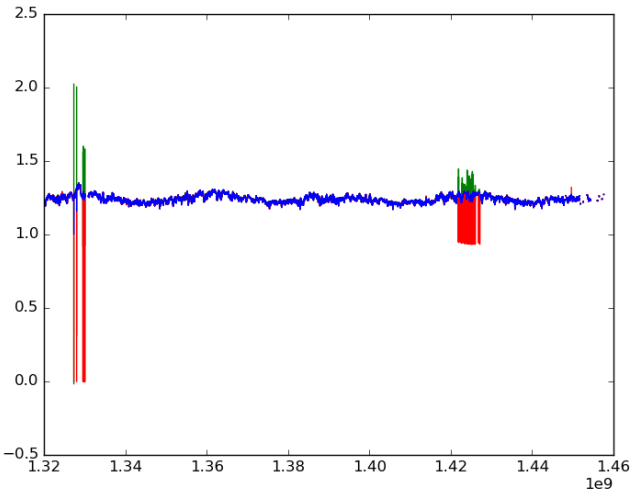
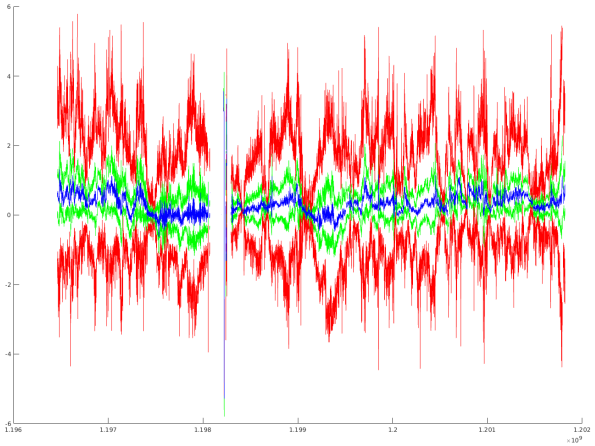
```

- documentation:
  - spread around
  - incomplete

Problem: Issues *with* the data

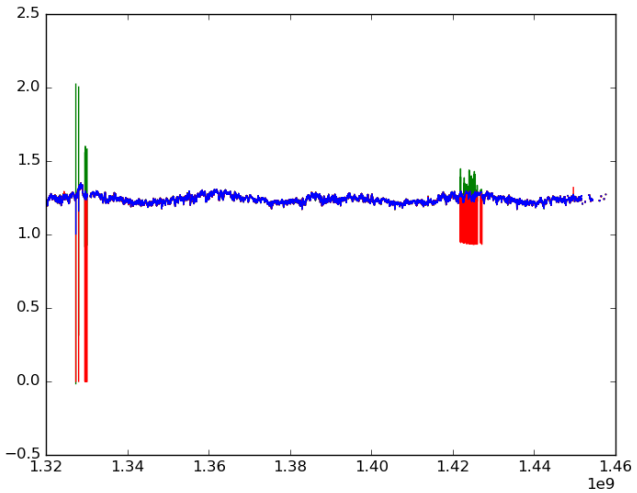
- still faulty data included despite best-effort tests

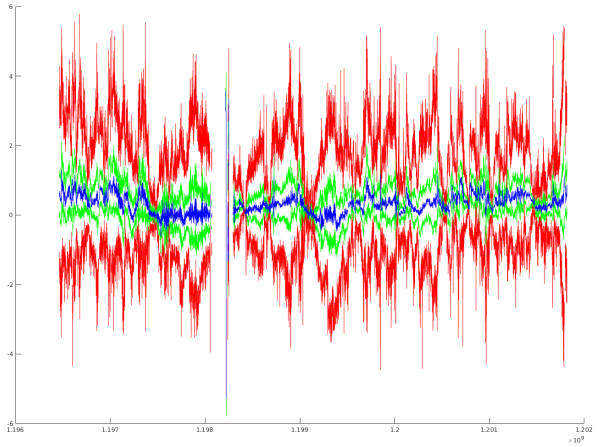




Problem: Issues *with* the data

- still faulty data included despite best-effort tests



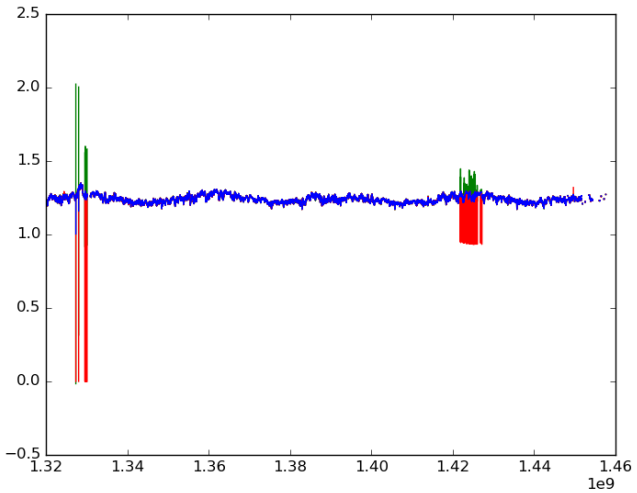


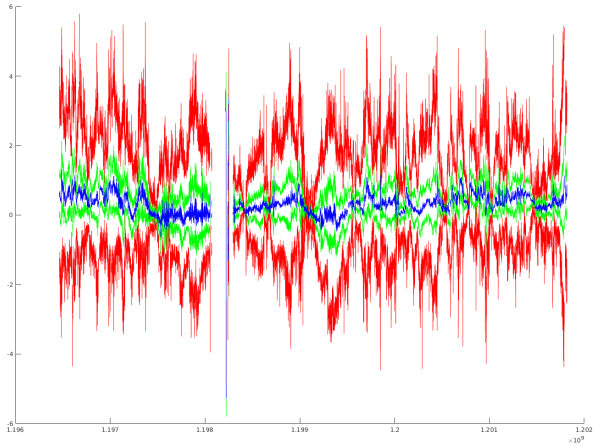
- no principled significance information

1.23456789 or 1.235 or 1.2?

Problem: Issues *with* the data

- still faulty data included despite best-effort tests





- no principled significance information

1.23456789 or 1.235 or 1.2?

- no information about missingness mechanisms
  - instrument defect? type?
  - eliminated during quality control?

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Metadata

```
<class 'netCDF4._netCDF4.Variable'>
compound Wr(time, level_UA)
    accuracy_abs: 1.0
    long_name: wind direction
    valid_range: [   0.  359.]
    standard_name: wind_from_direction
    units: °
    sampling_frequency: 50.0
    cell_methods: ['avg'] time: mean (interval: 10 minutes ...)
                  ['std'] time: standard_deviation (inter...)
    accuracy_propagated_avg: 0.0057735
    standard_error_avg: 0.0057735
    standard_error_std: 0.00408255
    accuracy_propagated_std: 0.0057736
compound data type: {'names':['avg','std','flag'], ...}
path = /UA
unlimited dimensions:
current shape = (683856, 3)
```

Solution: Binary formats for enhanced data access

- established binary data formats (HDF5, netCDF4)
- support in data analysis tools, network support (OPeNDAP)
- allows structured storage & various data types
- arbitrary key-value metadata (but use conventions!)
- integrated compression & check-summing

Solution: Ensuring quality with improved processes

- add to existing set of automated tests
  - leverage available metadata more fully
  - more statistical analyses
  - build a shared database of issues and tests
- automatically calculate and encode per-value error bounds

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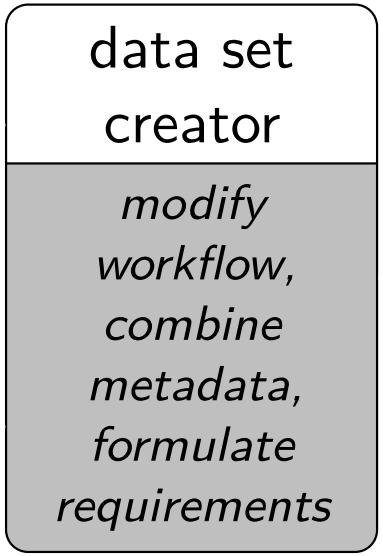
- add to existing set of automated tests
  - leverage available metadata more fully
  - more statistical analyses
  - build a shared database of issues and tests
- automatically calculate and encode per-value error bounds
- rigorous documentation of data set creation process
- versioning and unique identification of data sets

What must we do to make this vision come true?



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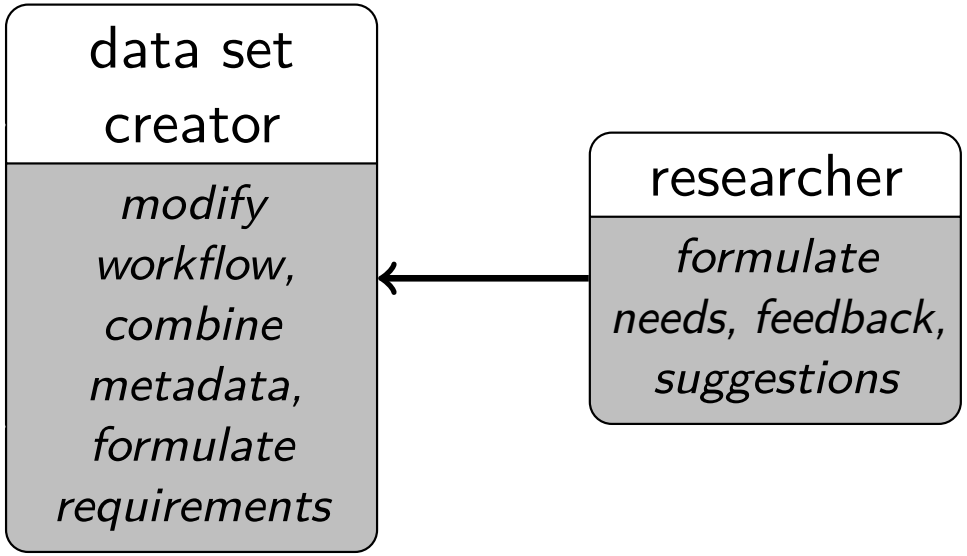

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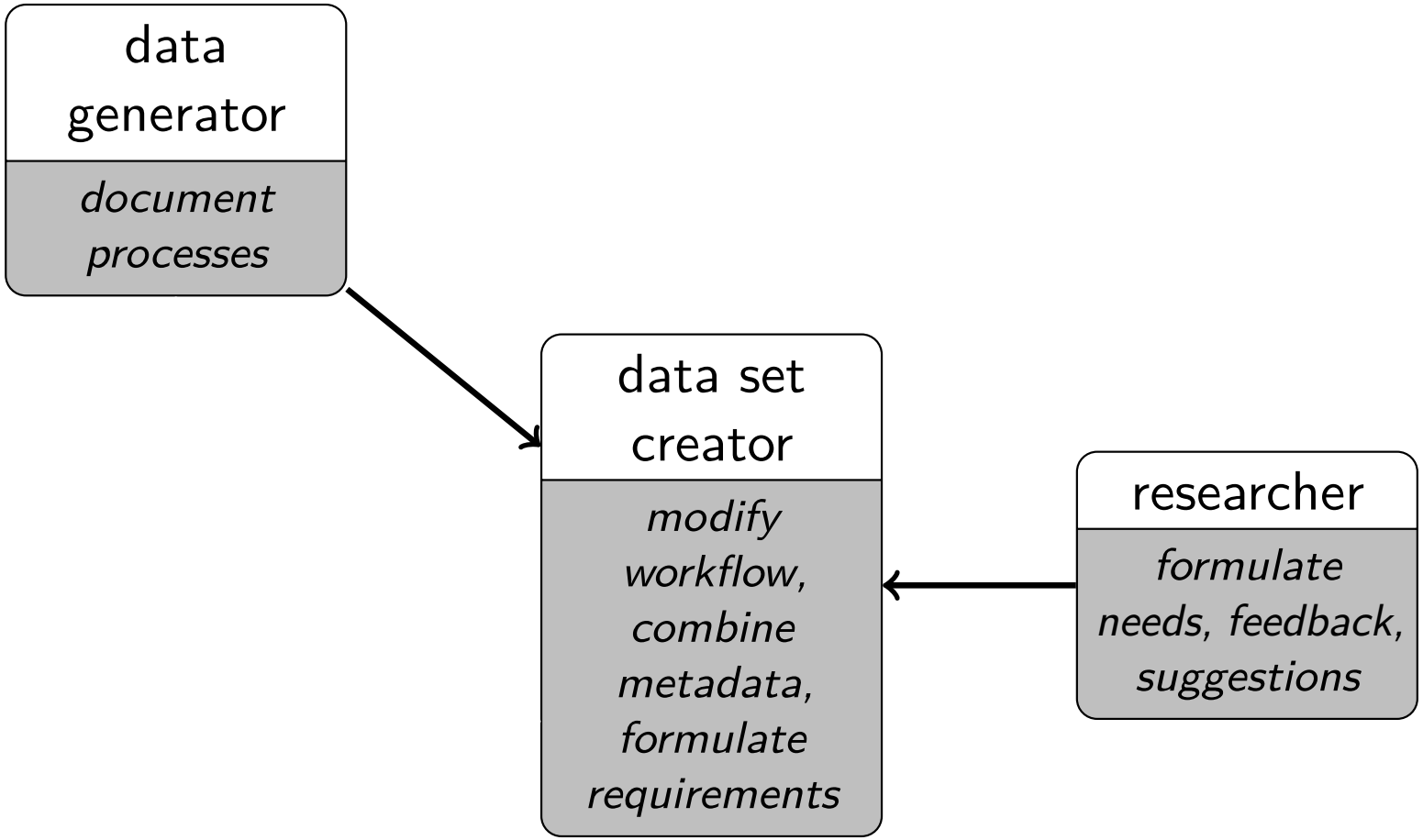
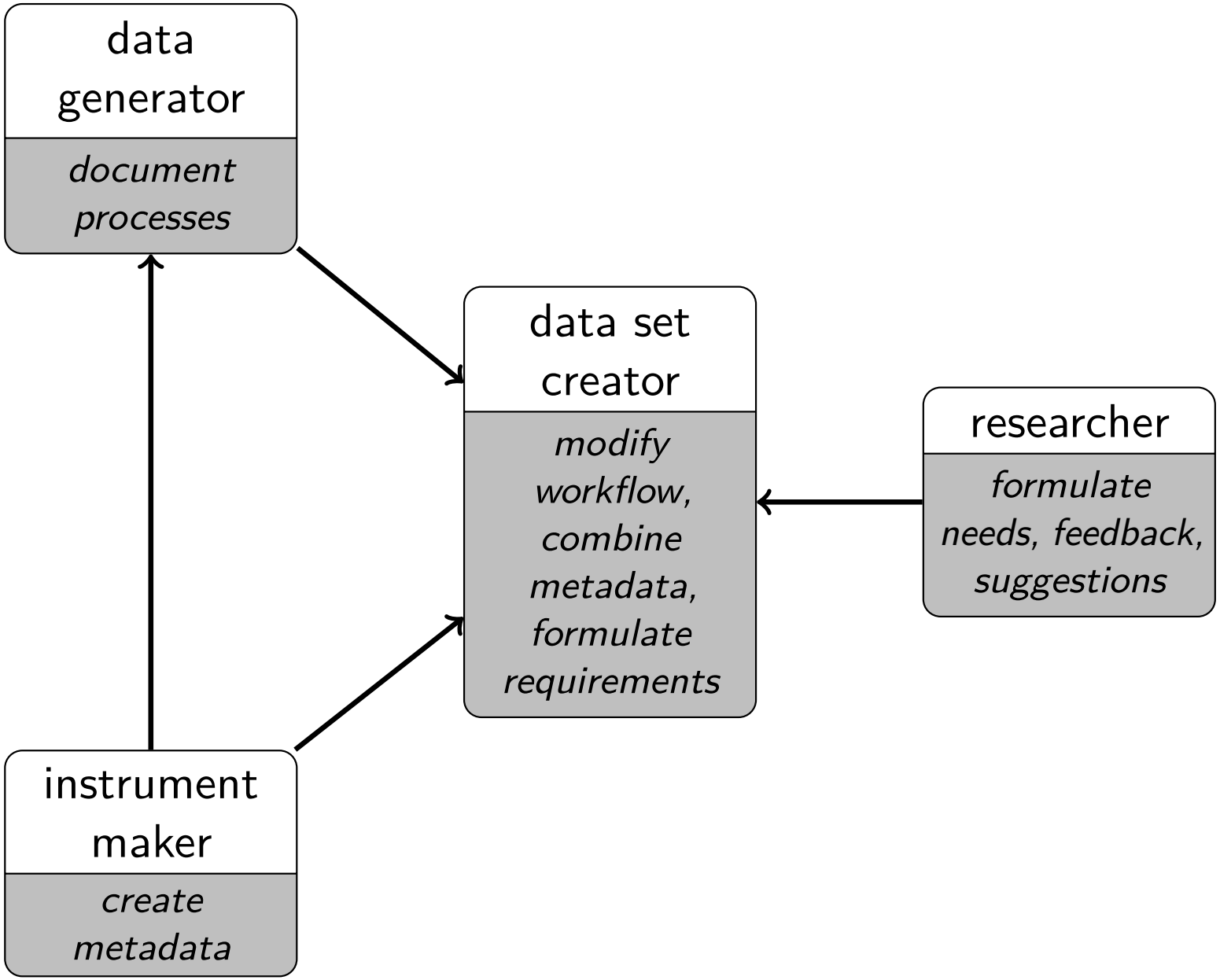


What must we do to make this vision come true?



Looking beyond

- role of data set (warehouse) managers?
- not offshore wind-specific
  - share experiences with other communities
  - join forces with them
- influence metadata conventions
- provide feedback to binary format designers

Basic Claims Revisited

Problem

Current dissemination practice *hampers* research.

- unnecessarily difficult to access data
- documentation detached from data sets
- still too much faulty data goes unnoticed

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Current dissemination practice *hampers* research.

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Solution

We have the tools to instead *facilitate* research.

- binary data formats such as HDF5 and netCDF4
- metadata attached to data sets
- improved processes (testing, encoding, documentation,. . .)

Thanks

- to the *people at ECN* for the help they provided
- to *Michiel Zaaijer* for focusing discussion
- and **to *you* for your attention**

TU Delft

Enhancing Data Sets for Accelerated Wind Energy Development

Advancing the state of the art in data set dissemination

Erik Quaeghebeur

Wind Energy Group – Delft University of Technology

OEEC 2017 – EUROS for wind energy
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