Karl Hendrik Tamkivi

Migrating White Storks (*Ciconia ciconia*) and Climate Change: a Neverending Summer?

Applied Machine Learning for Biological Problems

2023W 301169-1

17.01.2024

universität wien

Datasets

Migration Data

MPIAB Argos white stork tracking (1991-2017)

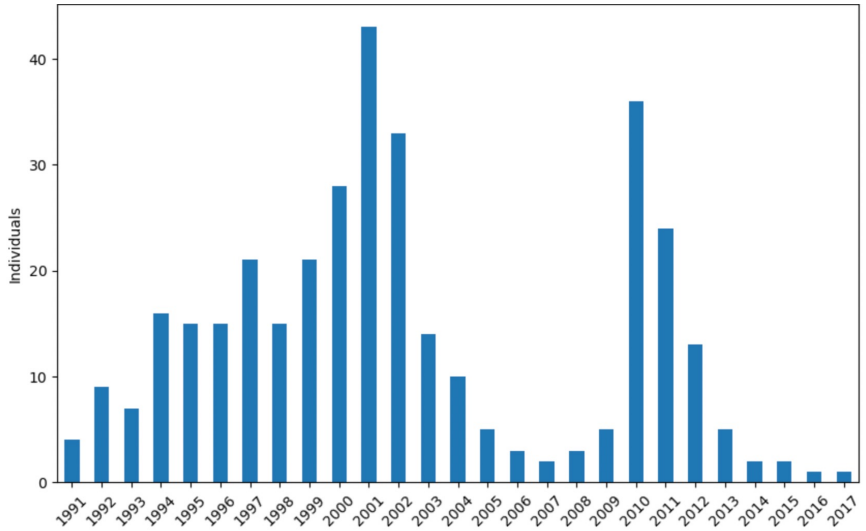
27 years of data

204 different birds

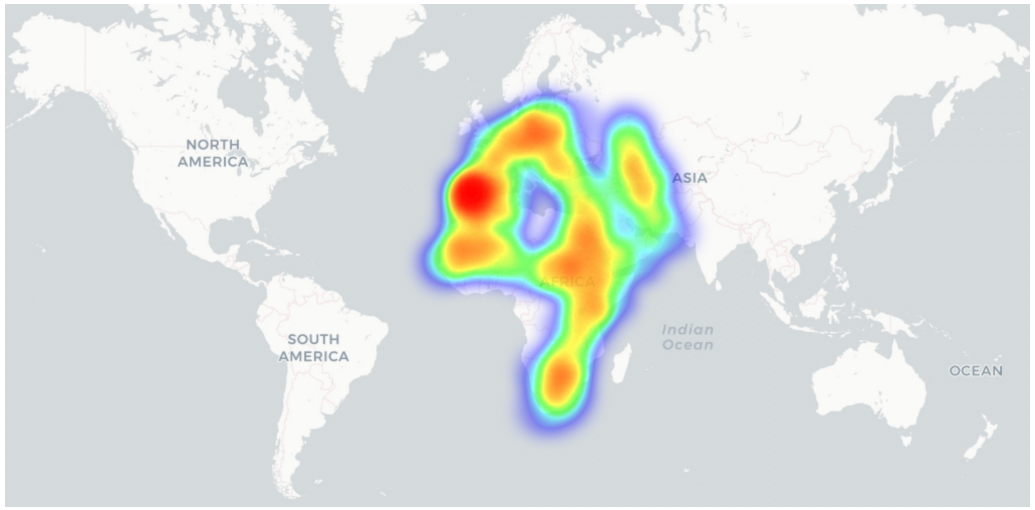
181 017 GPS locations

Including variables like: timestamp, longitude, latitude, altitude, identification number etc.

Tracked individuals per Year



GPS location density



Datasets

Temperature Data

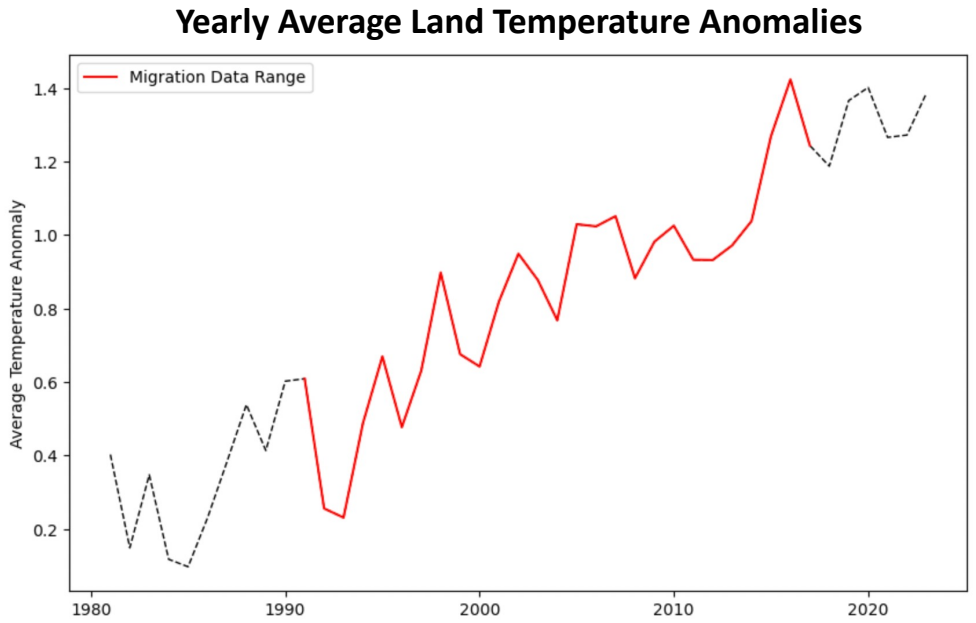
Estimated Global Land-Surface TAVG (1750-2023)

274 years of monthly data

Based on 50 691 time series with 21 339 392 data points

Anomalies compared to 1951-1980 average

Including variables like: year, month, monthly anomaly, annual anomaly etc.



Research question

Climate change leads to differential shifts in the timing of annual cycle stages in a migratory bird

Barbara M. Tomotani, Henk van der Jeugd, Phillip Gienapp, Iván de la Hera, Jos Pilzecker, Corry Teichmann, Marcel E. Visser

First published: 06 December 2017 | https://doi.org/10.1111/gcb.14006 | Citations: 58

"Global warming can lead to increased or decreased intervals between annual cycle stages in migratory birds. Therefore, climate change will also alter the time constraints across the annual cycle."

1 December 2002

Predicting Life-Cycle Adaptation of Migratory Birds to Global Climate Change

Timothy Coppack, Christiaan Both

"In different species annual breeding and migration cycles can also be controlled primarily by endogenous rhythms and photoperiodic cues which do not relate to temperature."

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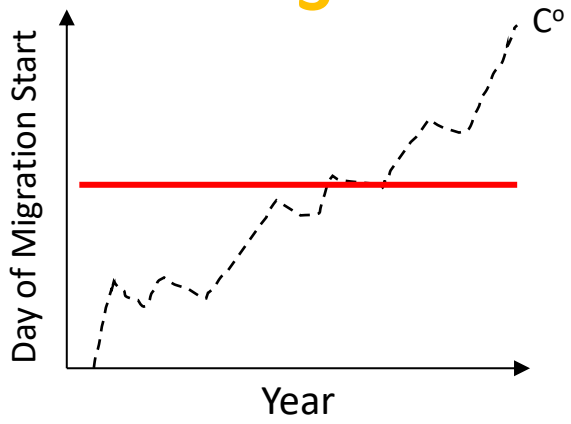
Research question:

Has the global average temperature increase caused a shift in the migration starting dates for the white storks?

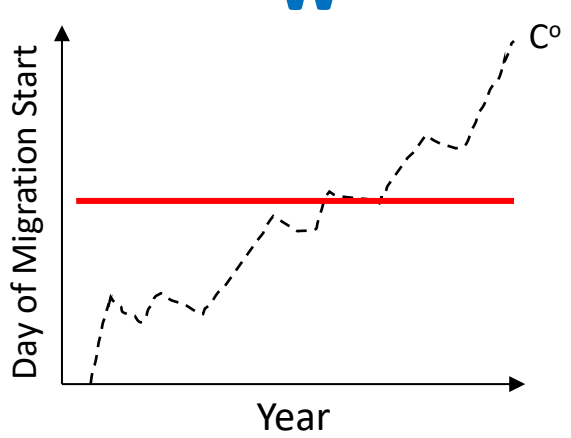
Research question

H0: Average land temperature increase has had no effect on the migration start over the years

S



W



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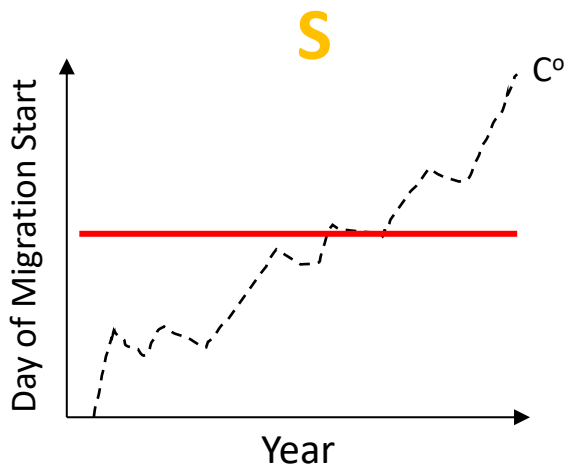
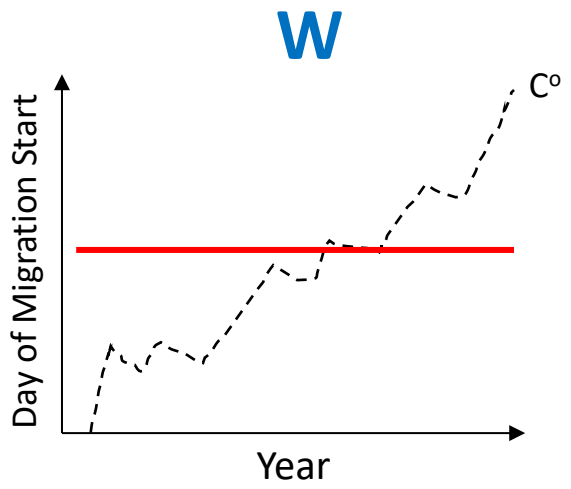
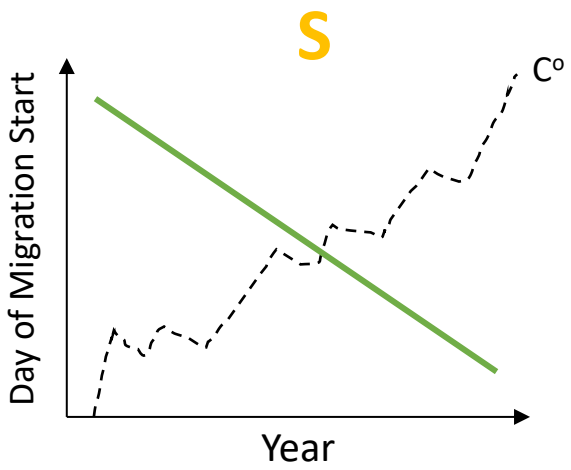
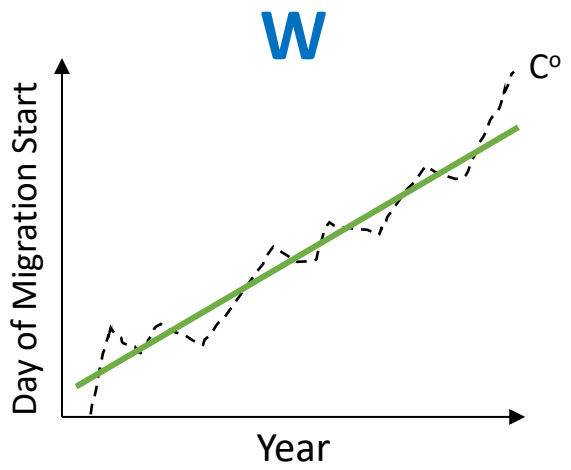




H1: Average land temperature increase has had an effect on the migration start over the years
(- effect on **summer migration** start; + effect on **winter migration** start)





Data Wrangling Roadmap

Initial data cleaning

Unfiltered data

181 017 instances

Remove marked outliers

Individual = ID + year

One location per day

>= 3000 km of total movement

Exclude ind. w 1000+ km between two days

>= 90 days of data

Migration labelling

Rolling sum distance of last 5 days

Latitude change from previous day

Applying the labelling rules

Migration statistics

Secondary data cleaning and temperature data merging

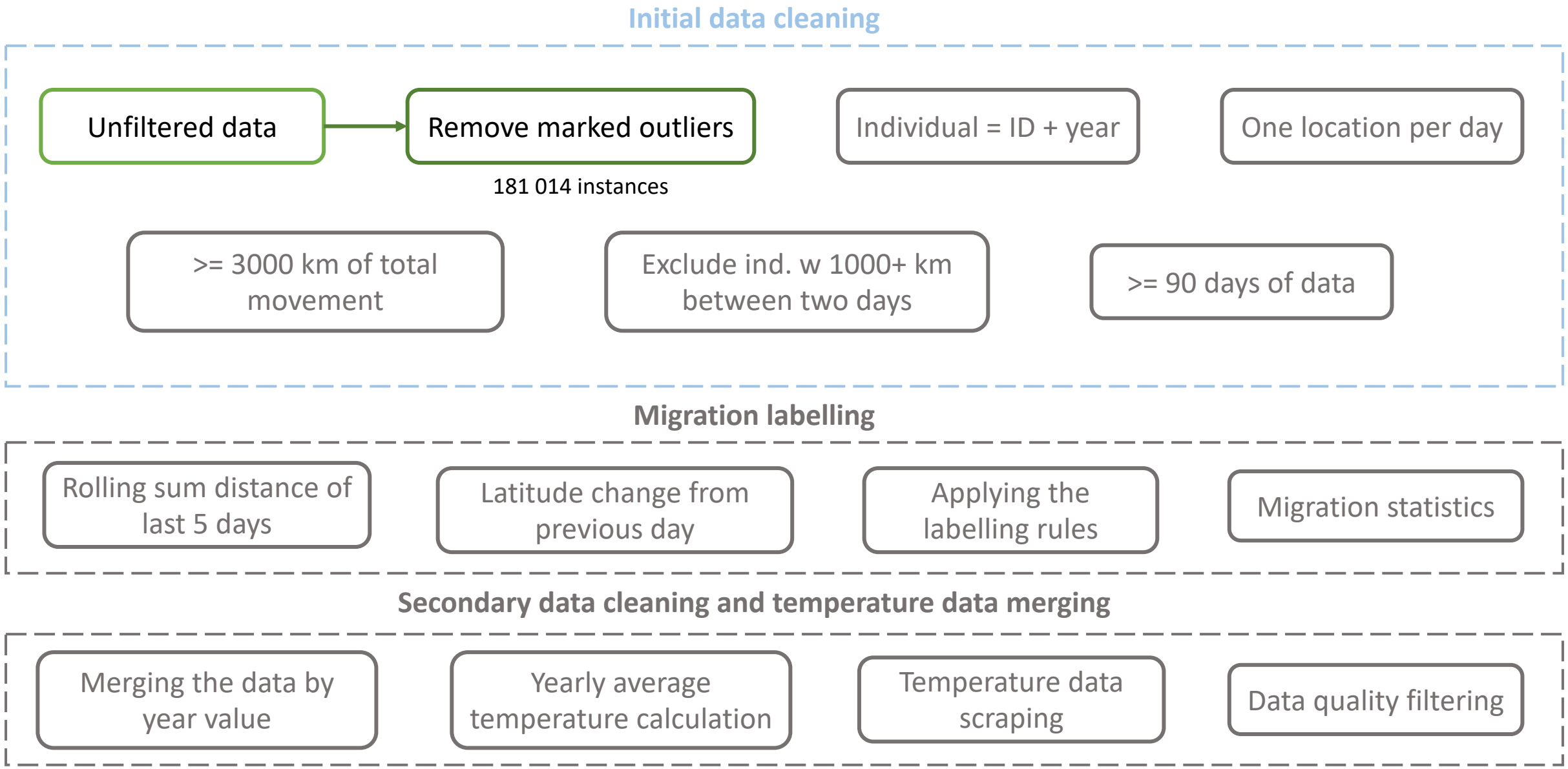
Merging the data by year value

Yearly average temperature calculation

Temperature data scraping

Data quality filtering

Data Wrangling Roadmap



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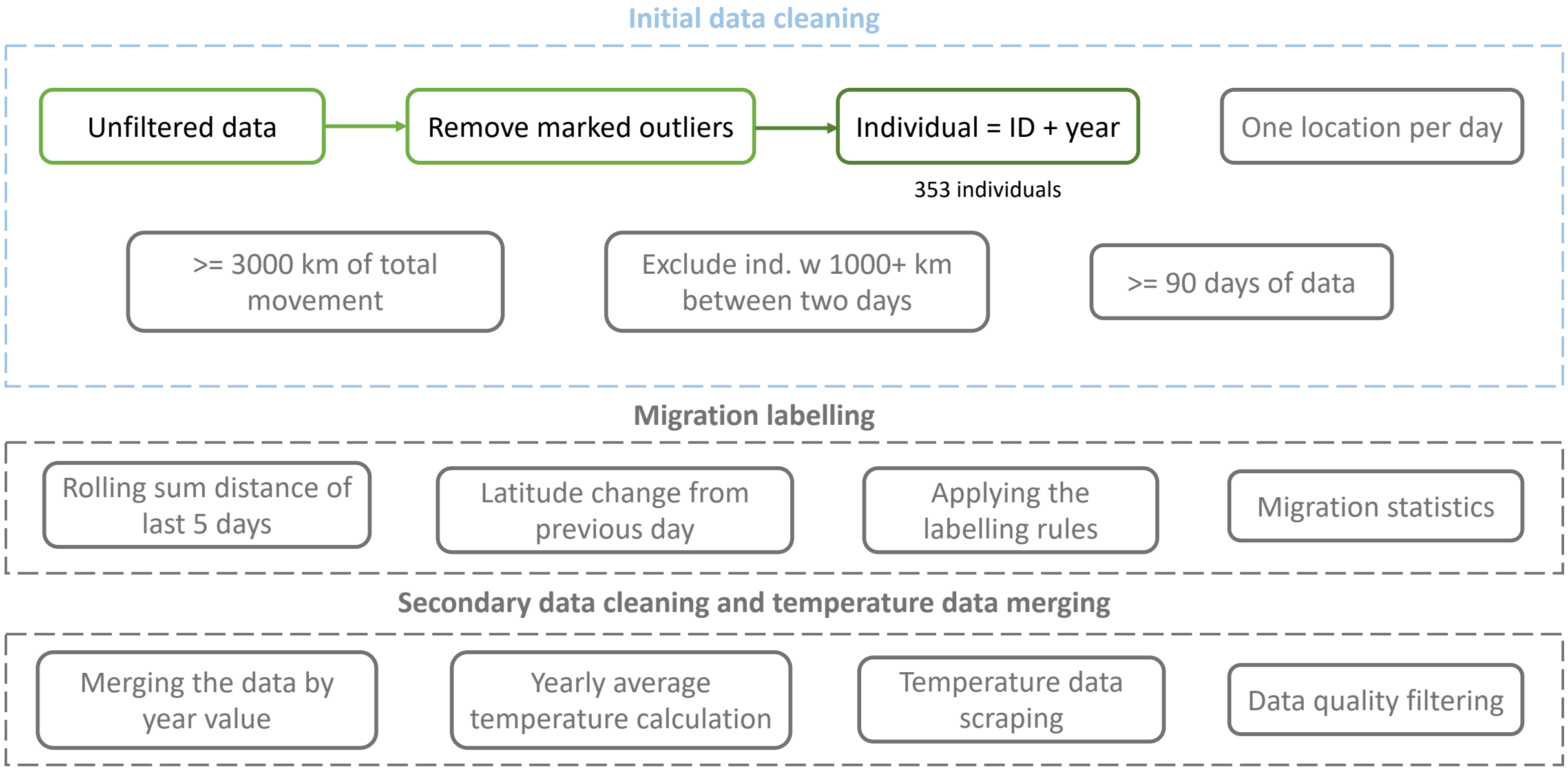

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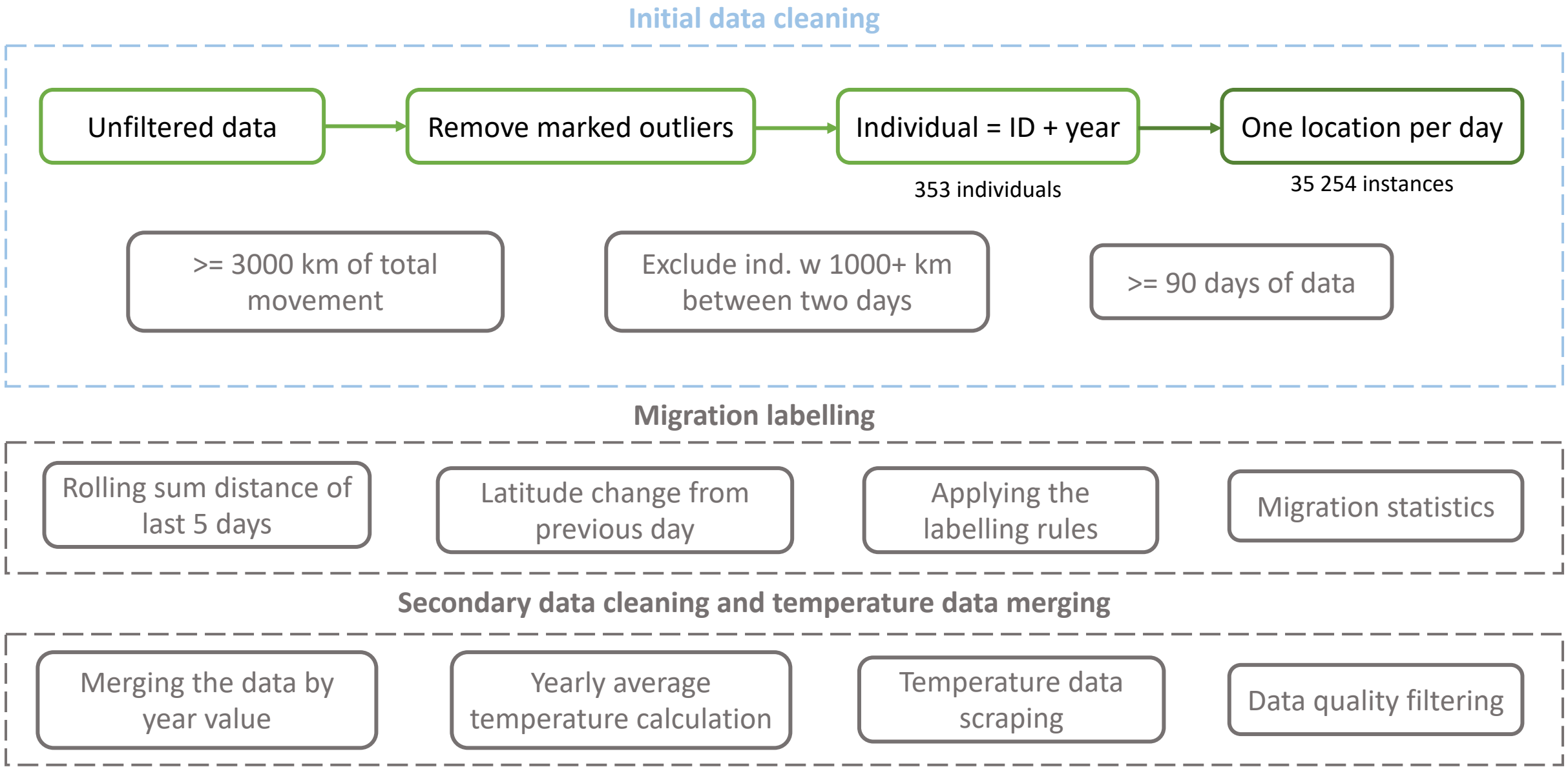

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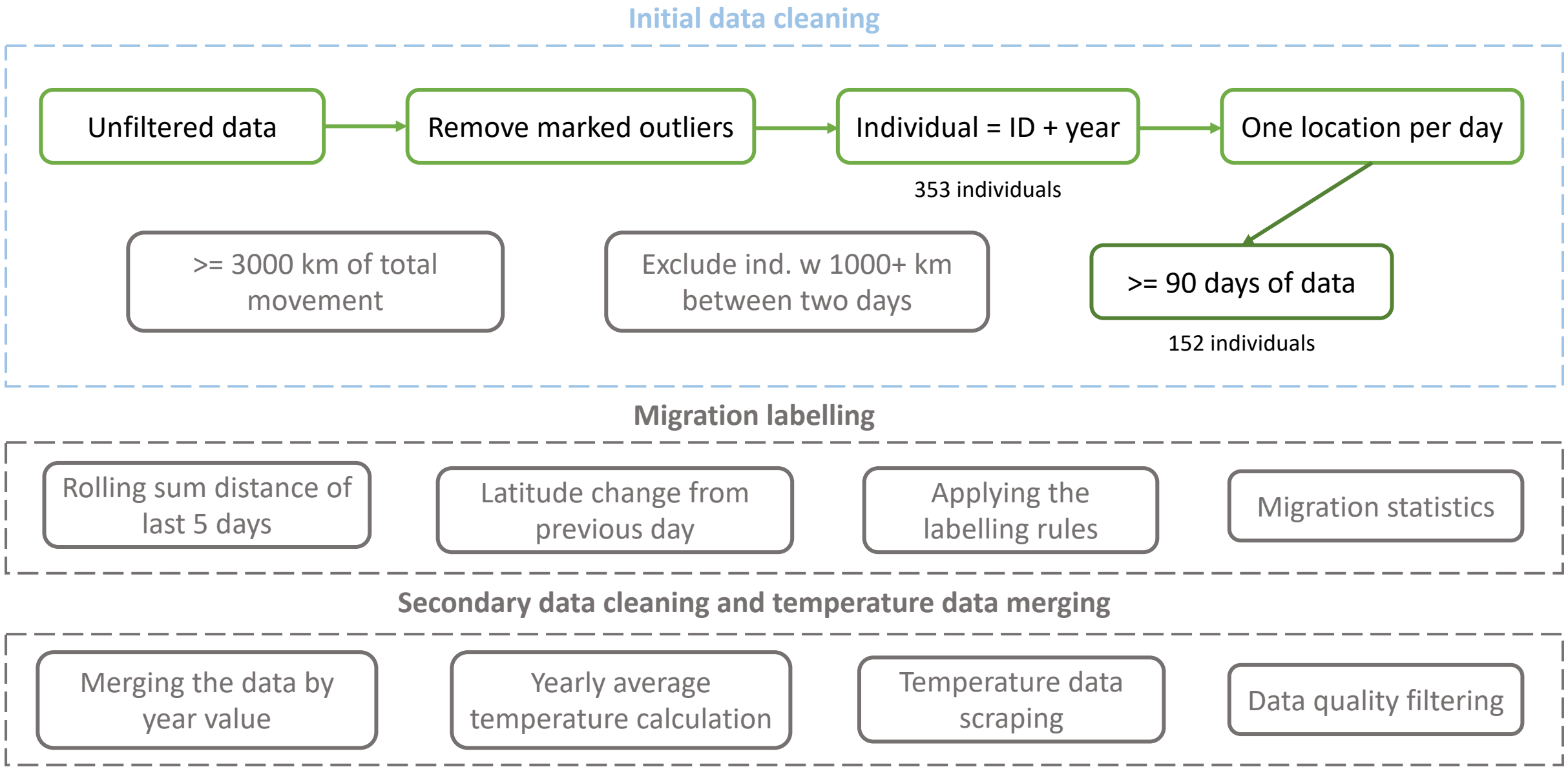

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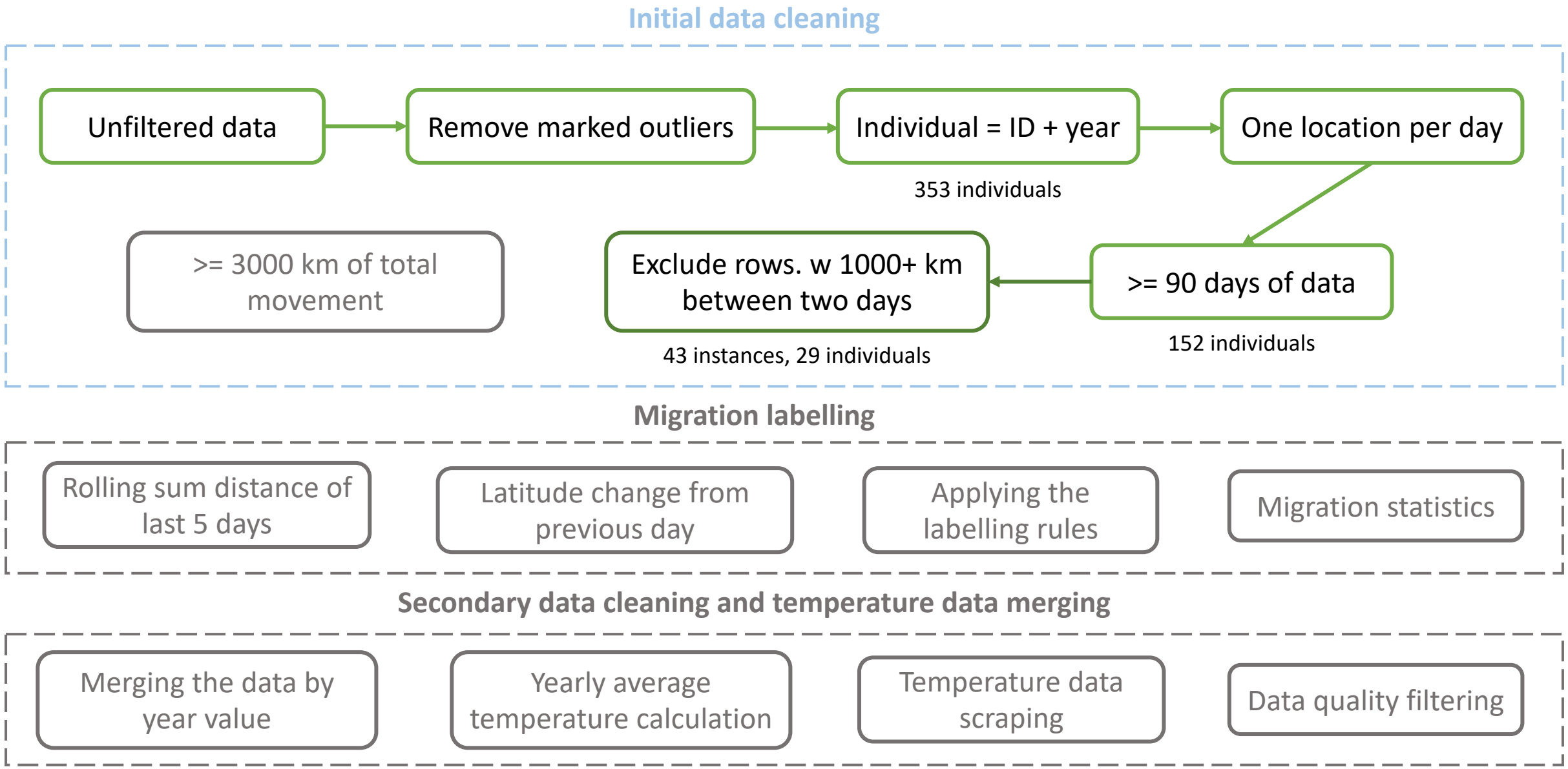

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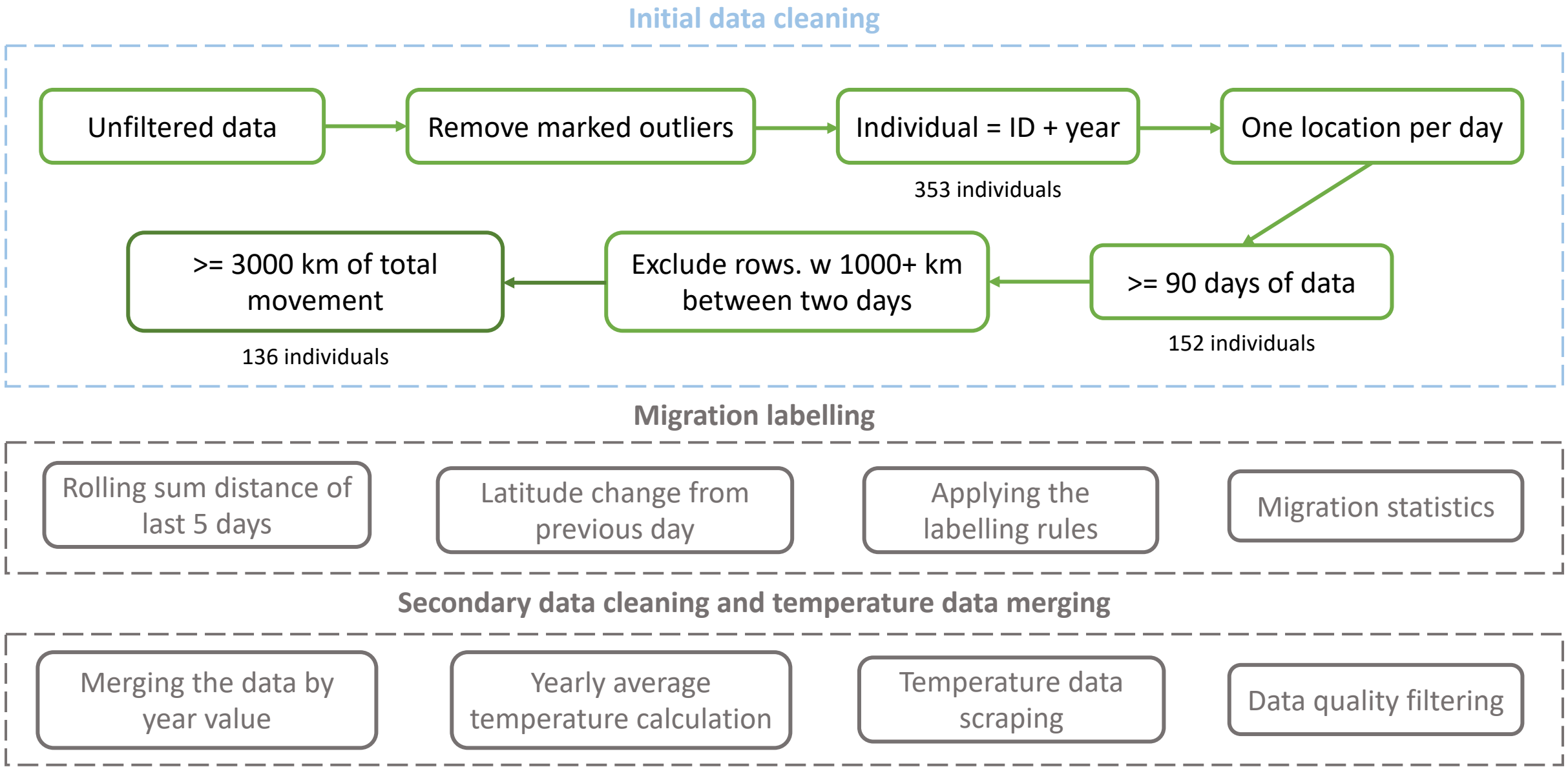

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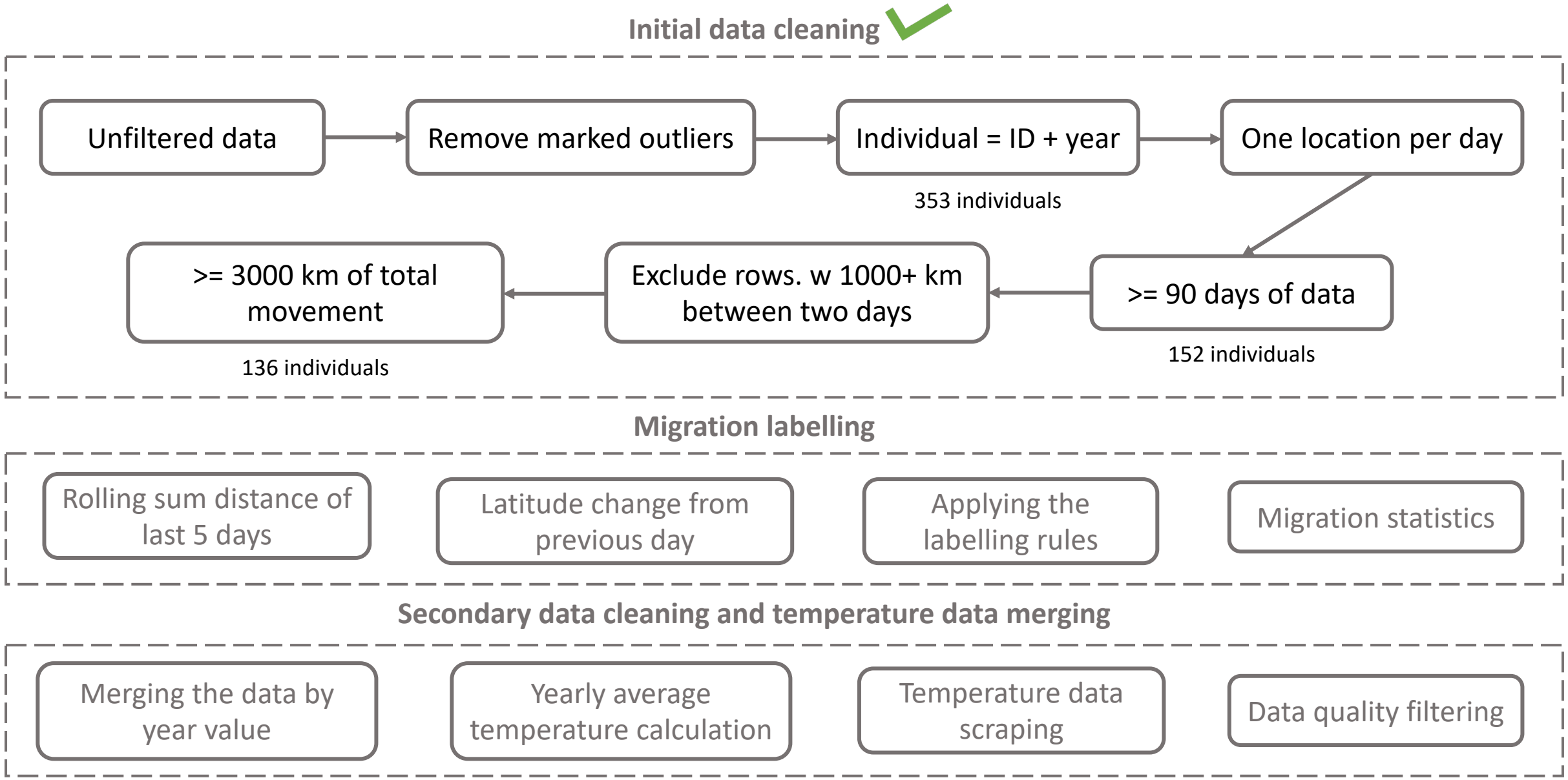

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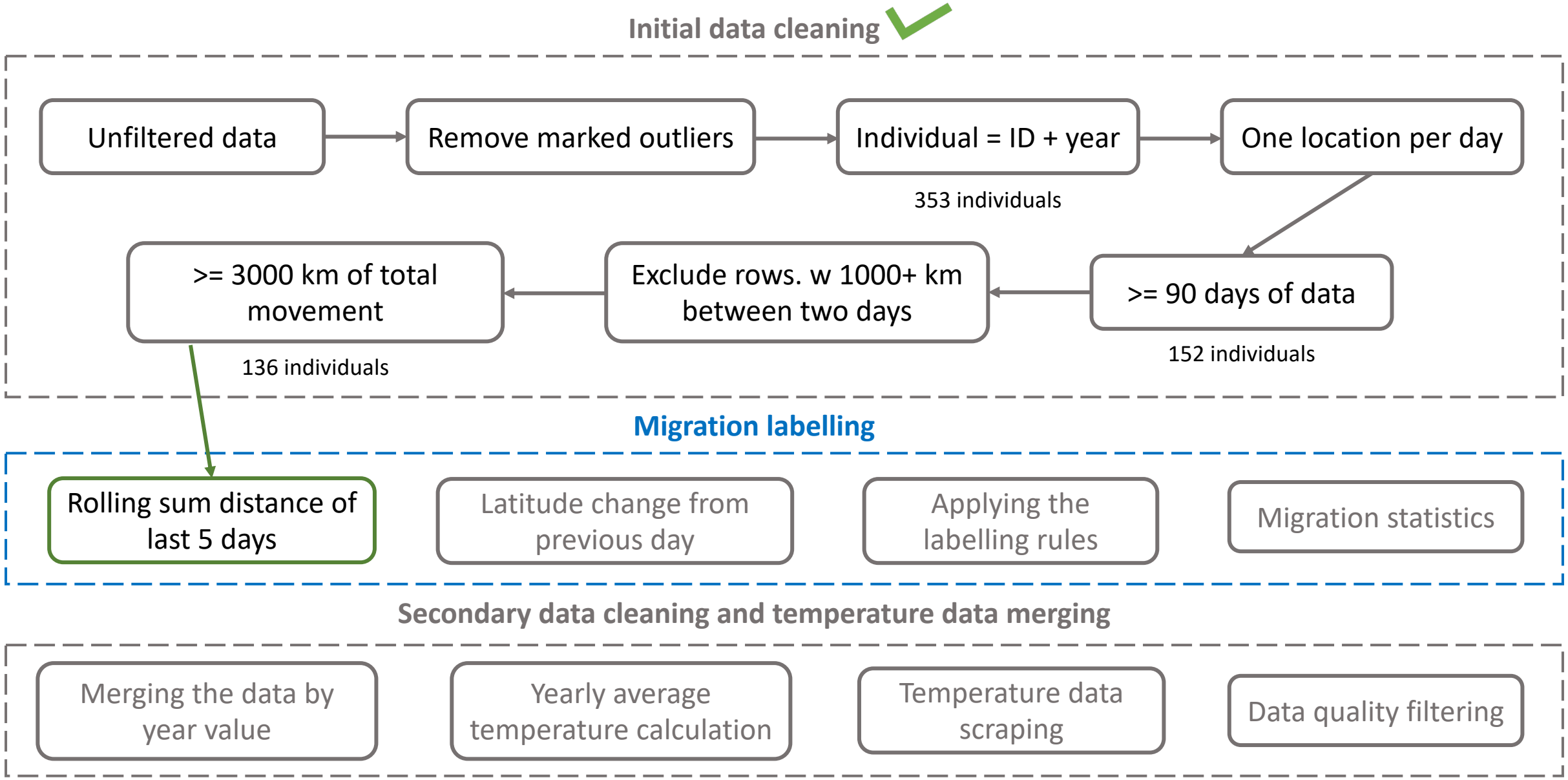

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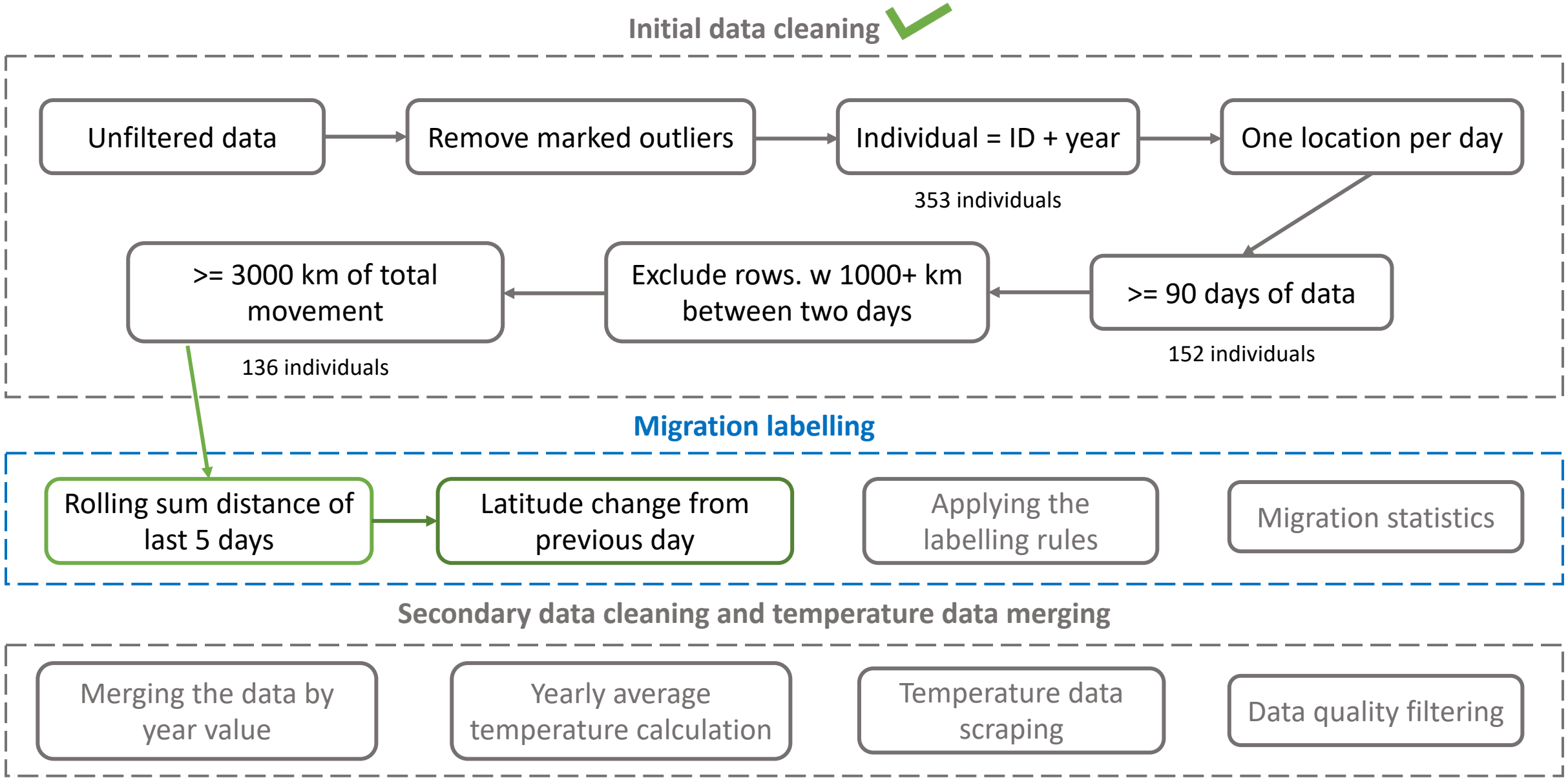
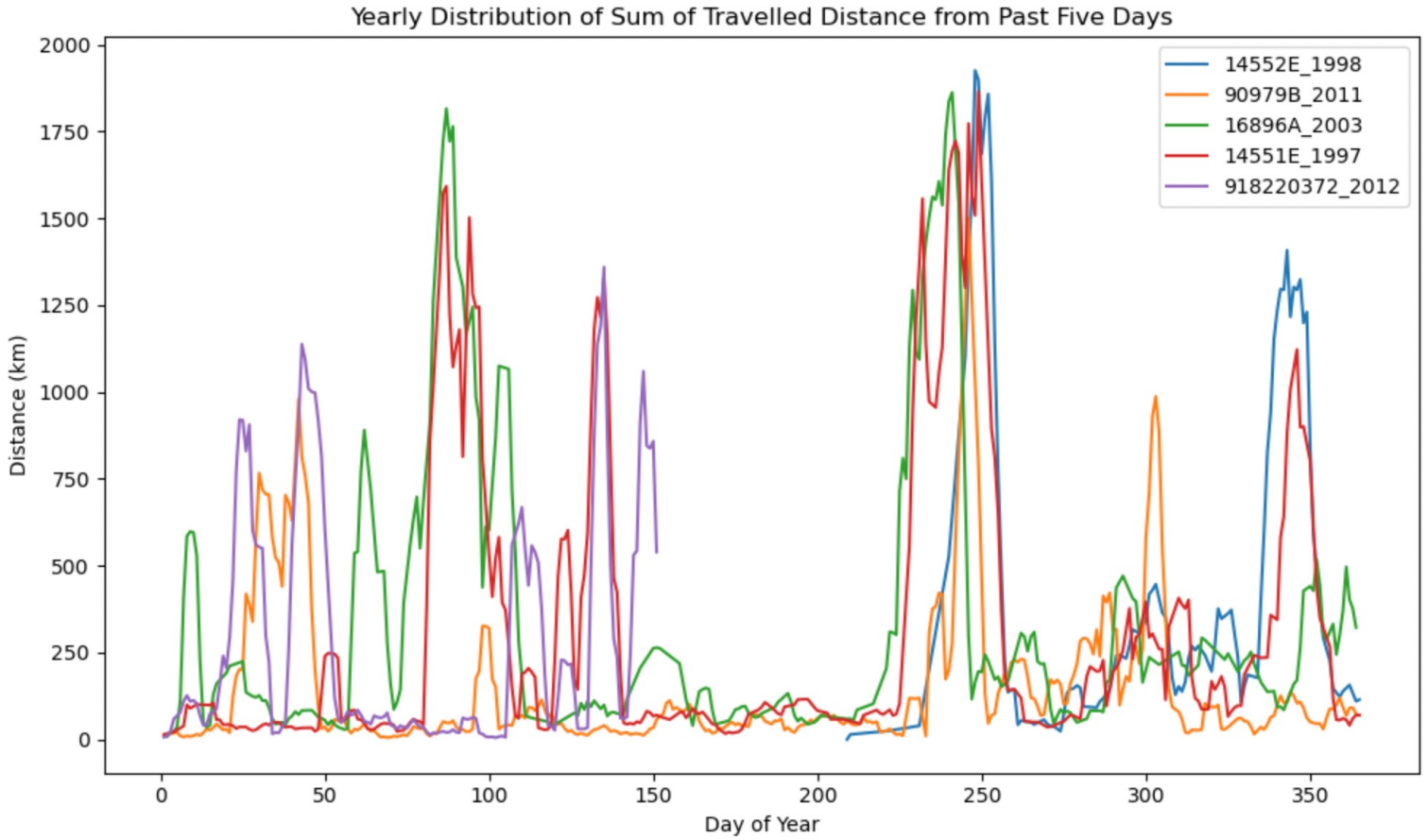


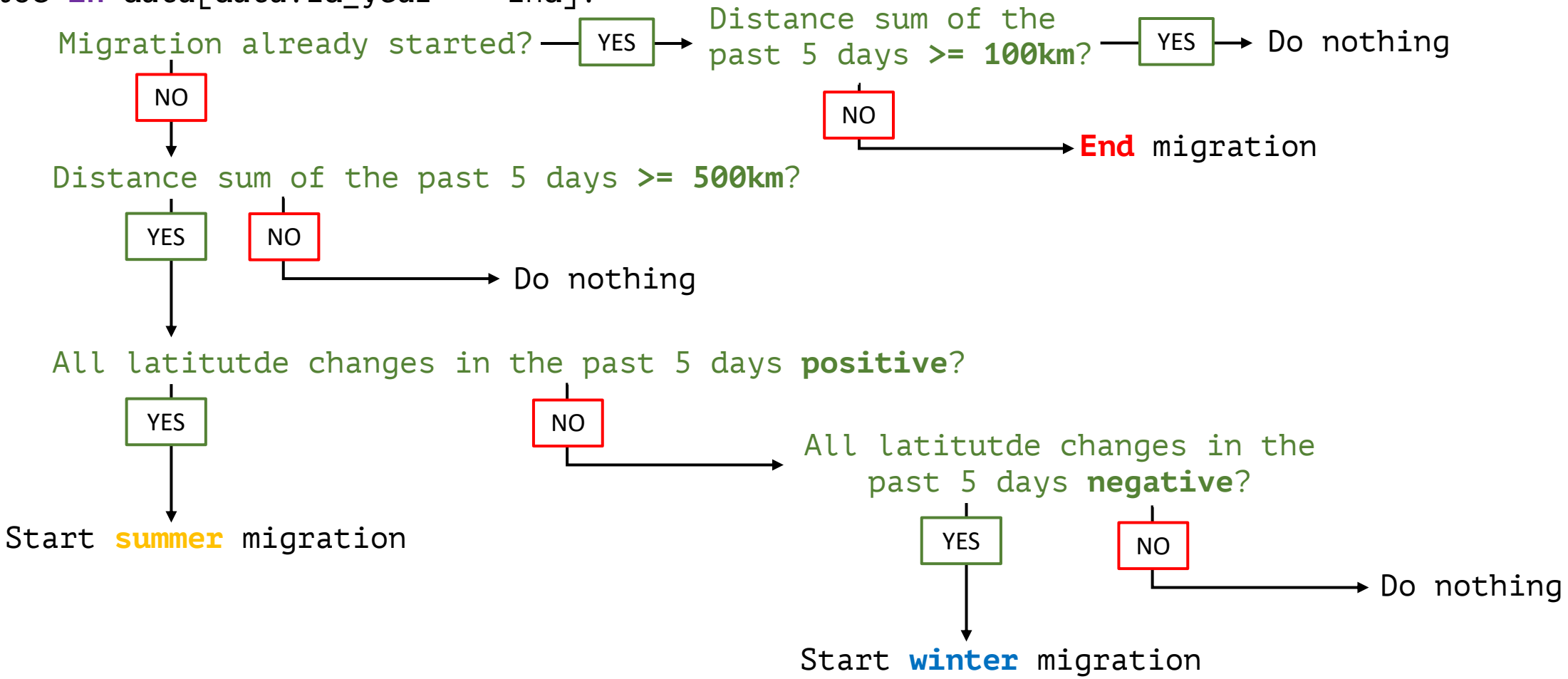
Migration Labelling



How to “find” the **summer** and **winter** migration windows?

Migration Labelling

```
for ind in data.id_year.unique():
    for loc in data[data.id_year == ind]:
```



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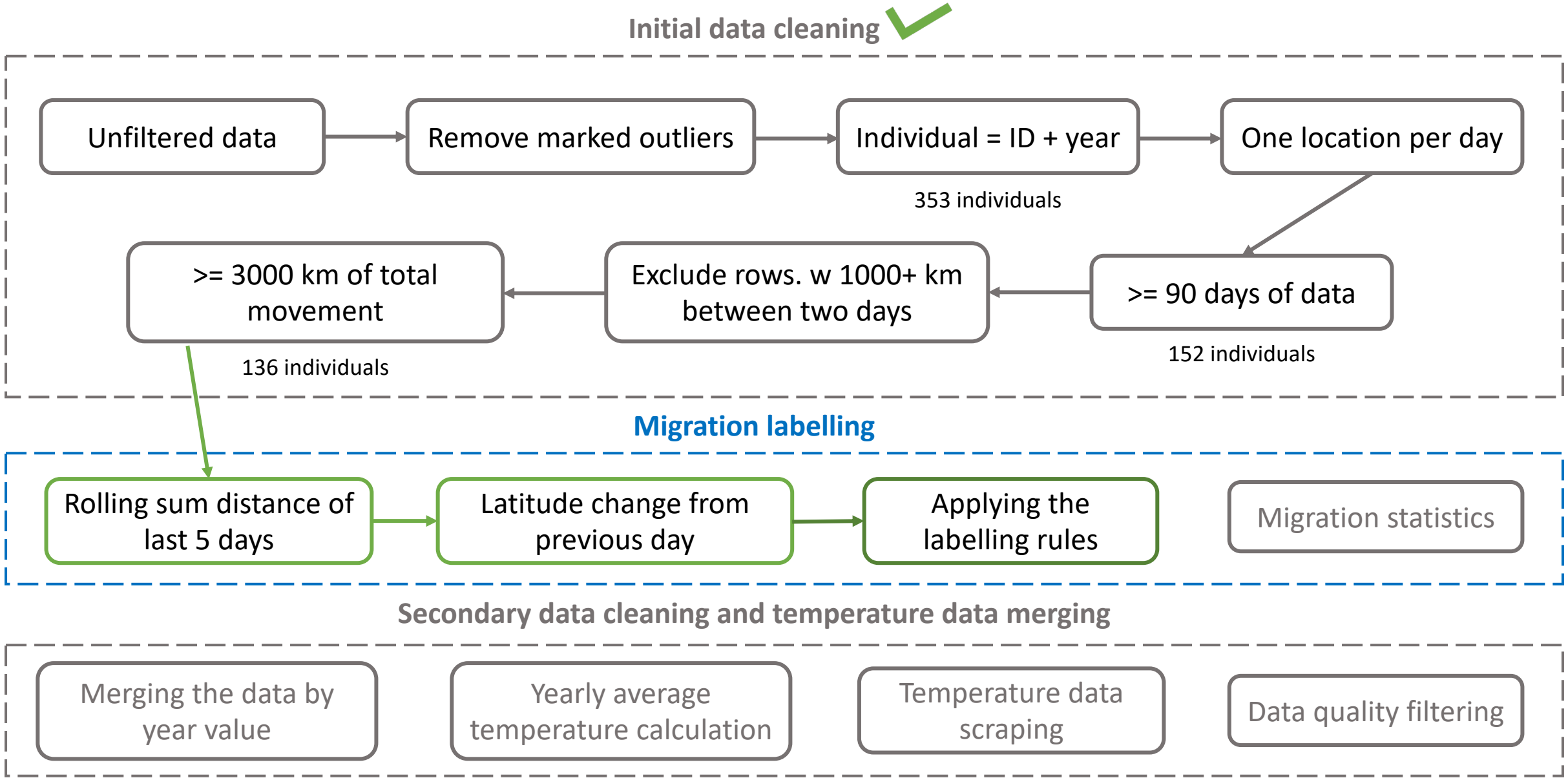
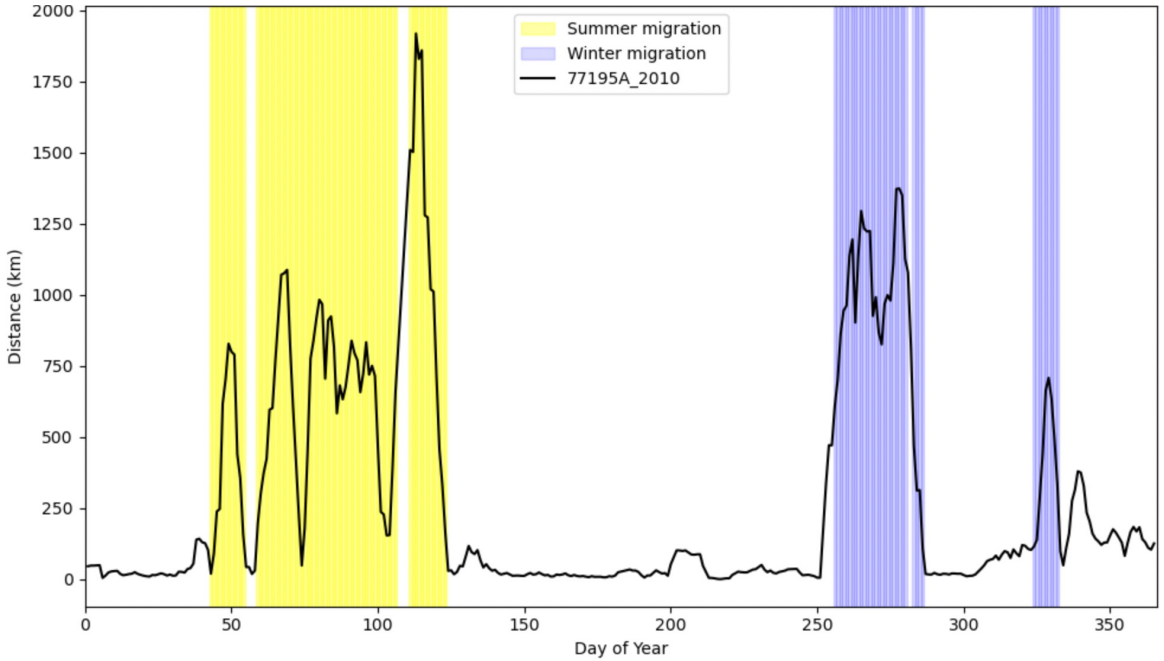
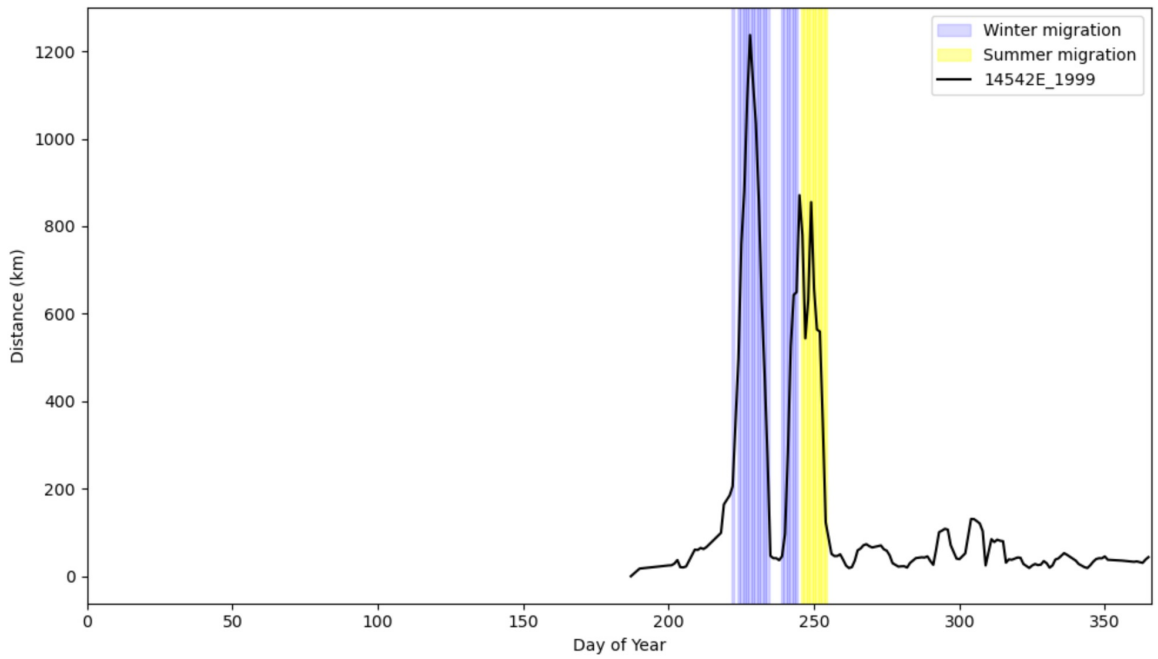


Migration Labelling

Successful labelling



Failed labelling



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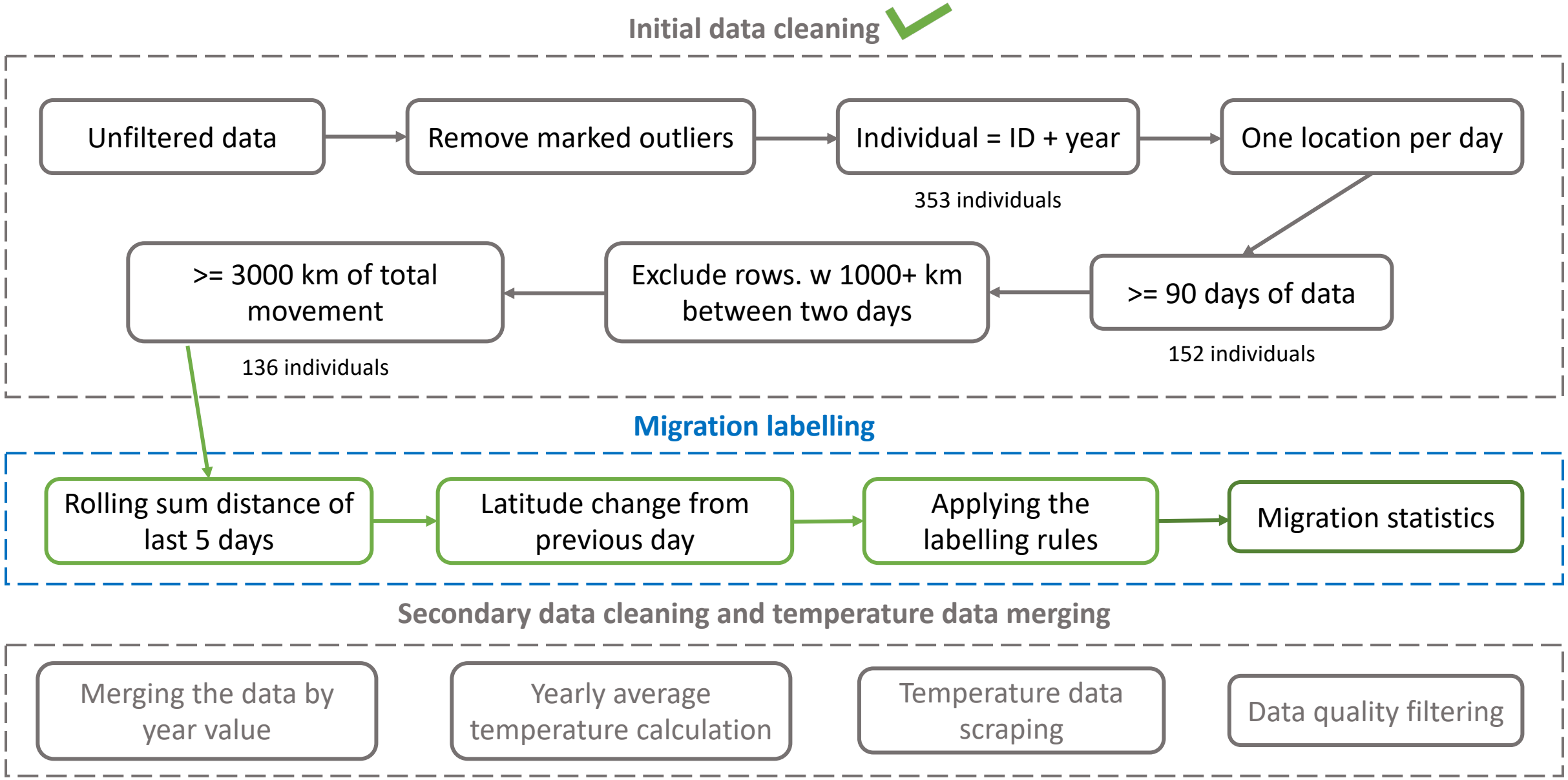


Migration Statistics

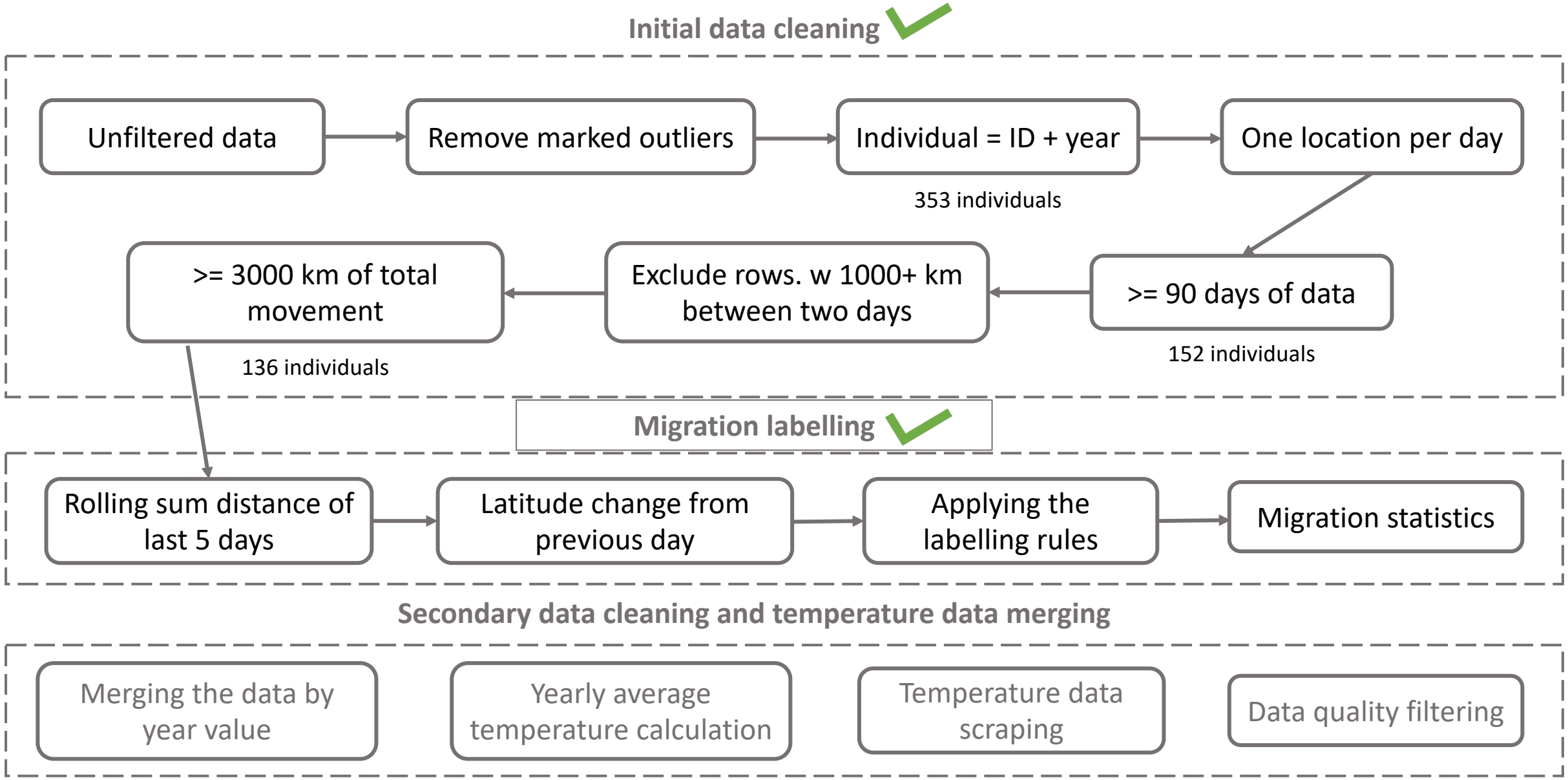
This step involves characterising different aspects of the migration windows of each individual

Further time series quality filtering and data analysis will be based on variables calculated here

Migration variables:

- Total migration period in days (**S** & **W** separate)
- First day of migration (**S** & **W** separate)
- Last day of migration (**S** & **W** separate)
- Number of migration windows (**S** & **W** separate)
- Length of the shortest window (**S** & **W** separate)
- **S** window before **W** window (0/1)

Data Wrangling Roadmap



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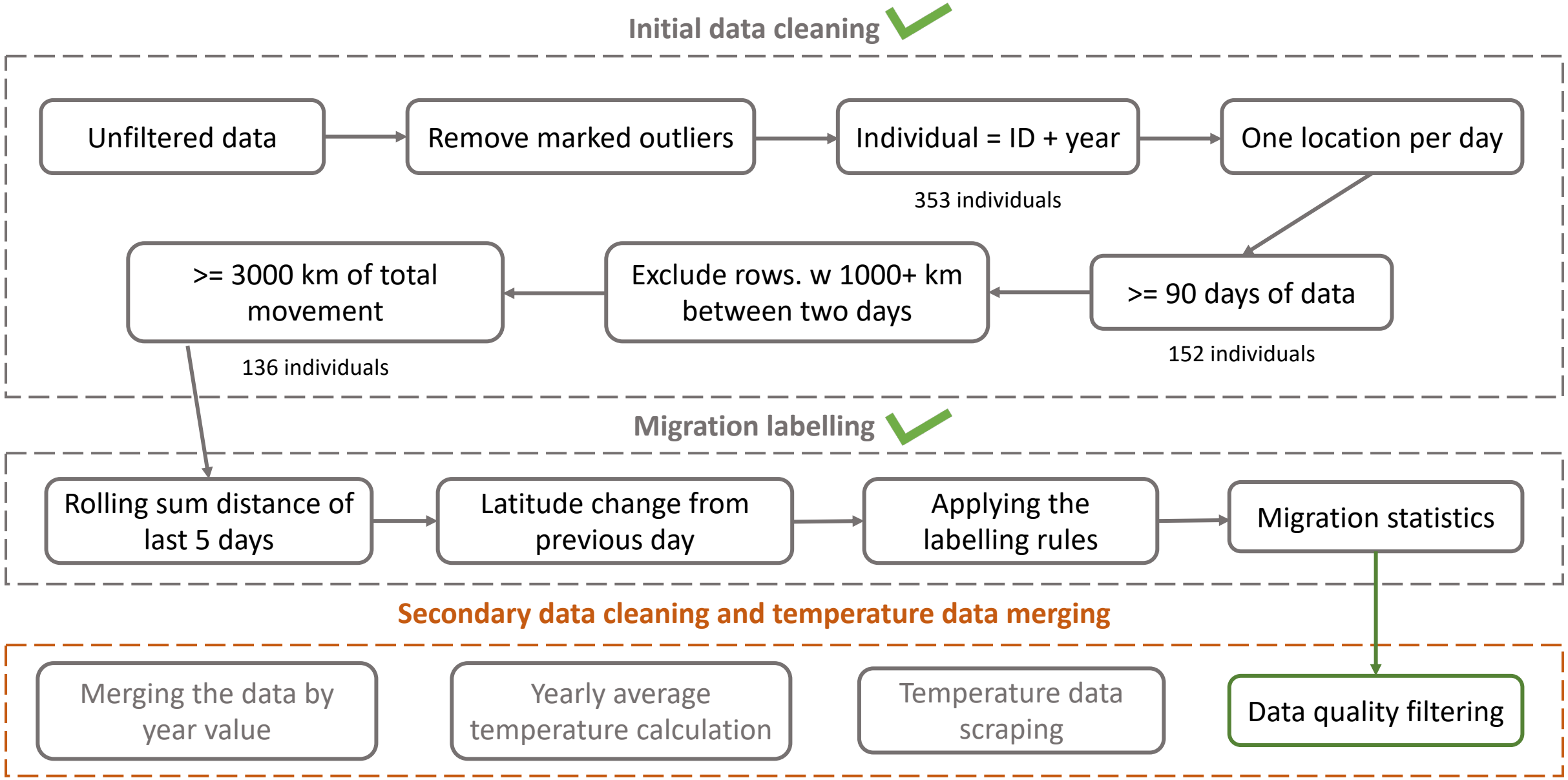


Data Quality Filtering

How to filter out the timeseries where migration labelling “worked”?

High Quality (HQ) timeseries:

```
'S_before_W' == 1 &
'shortest_S_window' >= 14 &
'shortest_W_window’ >= 14 &
'first_S' <= (366/2) &
'first_W' >= (366/2)
```

→ 24 individuals

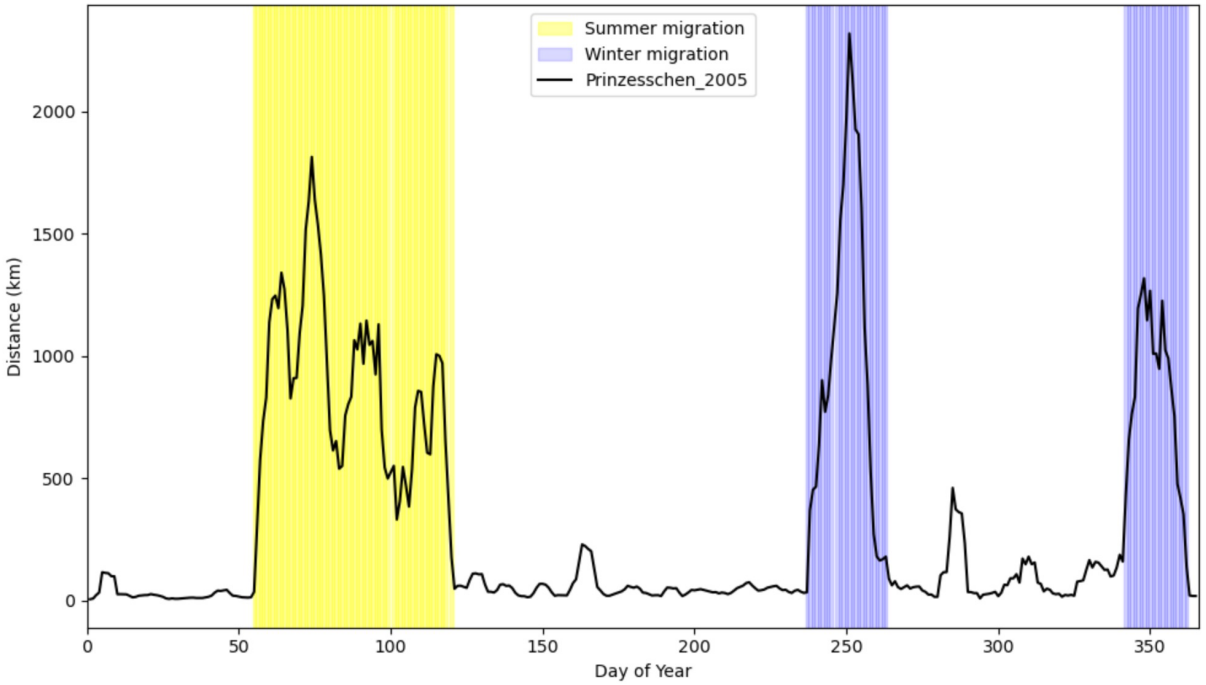
Medium Quality (MQ) timeseries:

```
'S_before_W' == 1 &
'shortest_S_window’ >= 14 |'shortest_S_window' == -1 &
'shortest_W_window’ >= 14 |'shortest_W_window' == -1 &
'first_S' <= (366/2) | first_S' == -1 &
'first_W' >= (366/2) | first_W' == -1
```

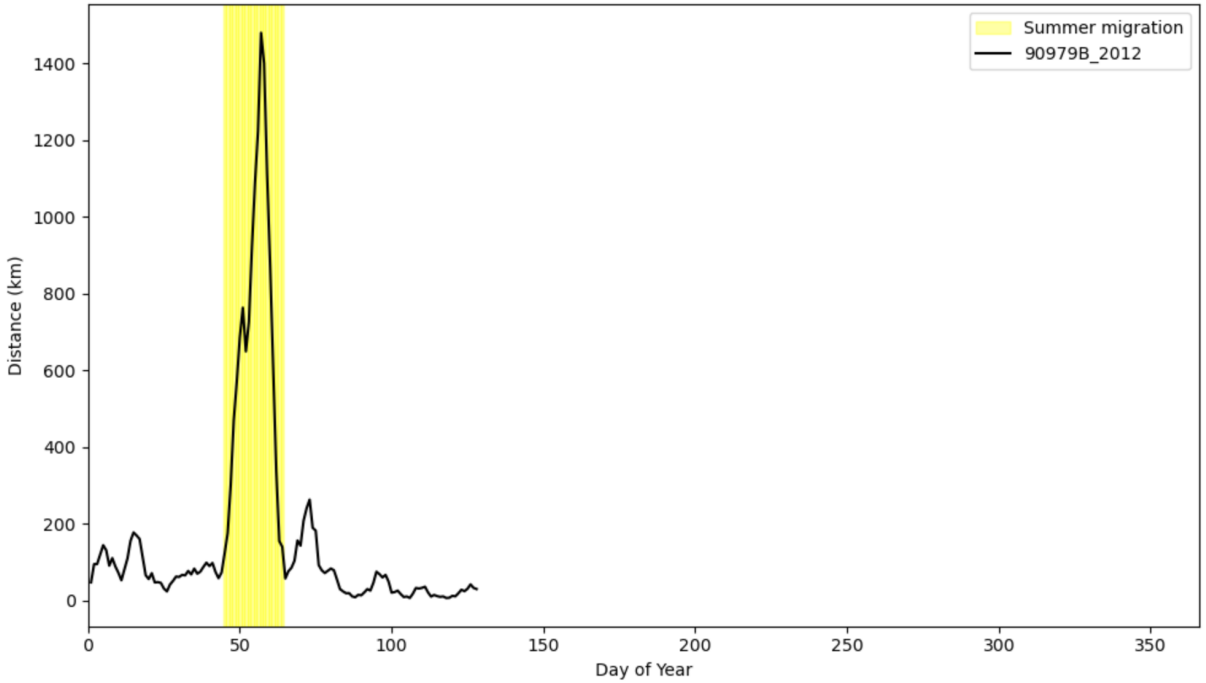
→ 35 individuals

Data Quality Filtering

High Quality timeseries



Medium Quality timeseries



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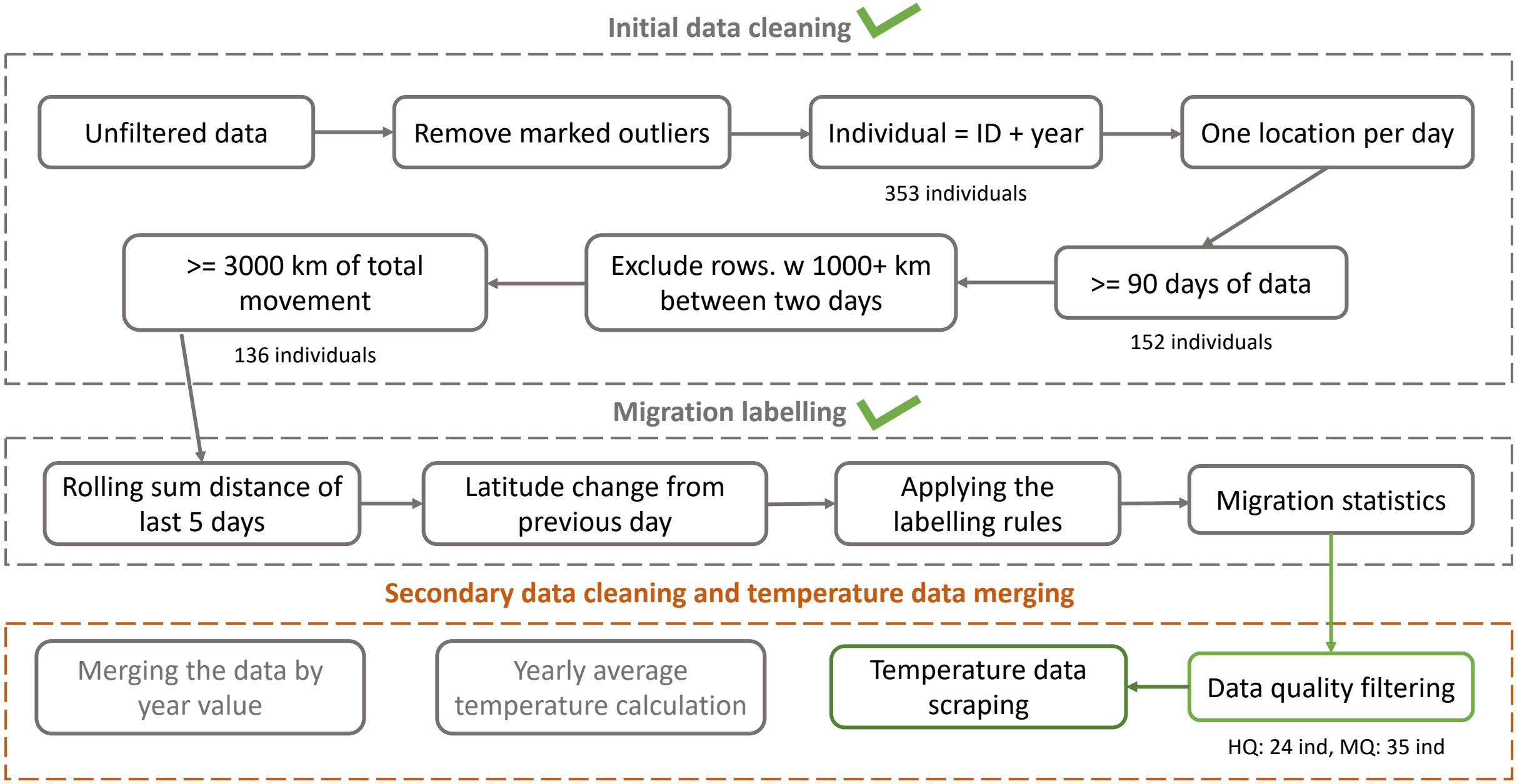

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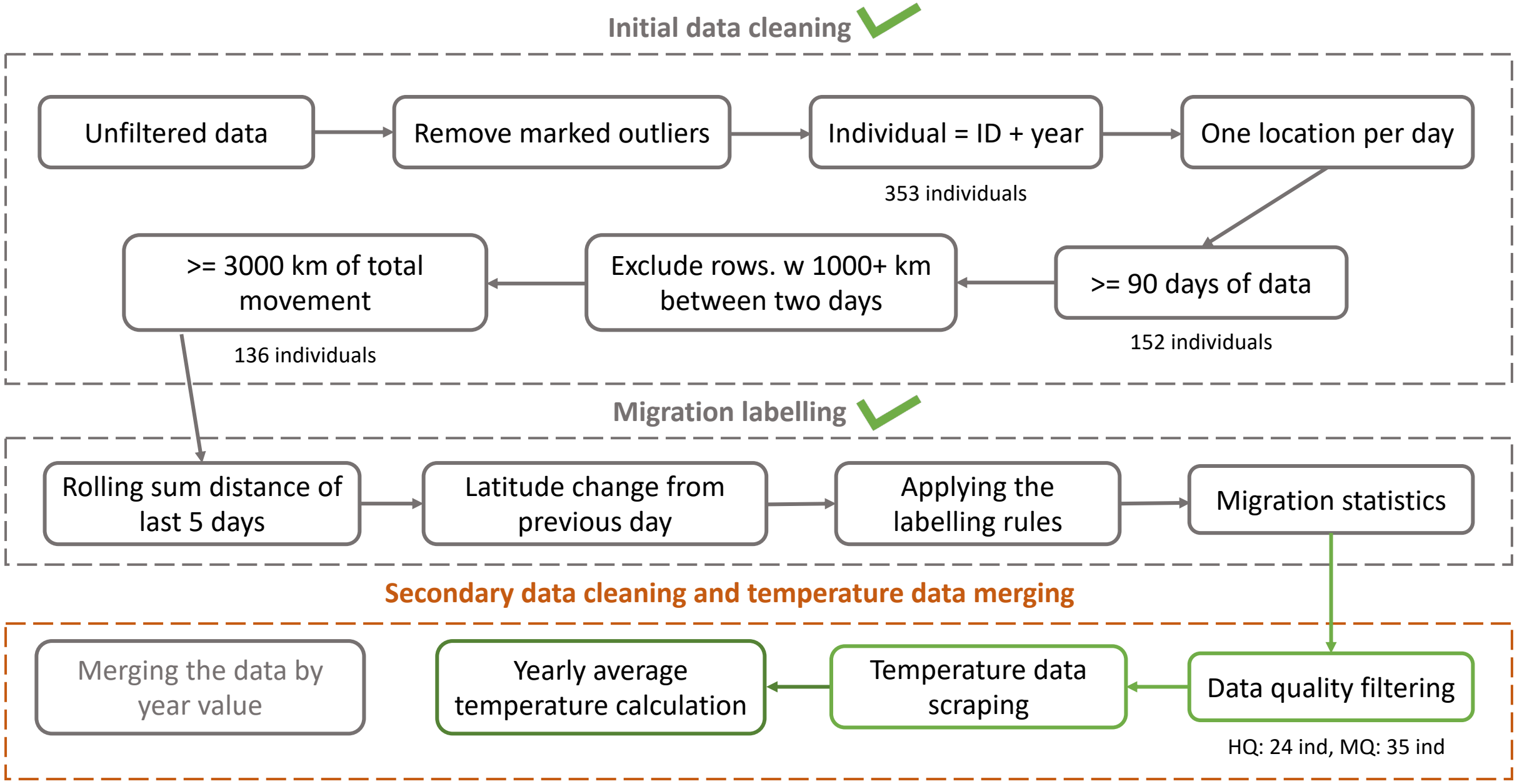

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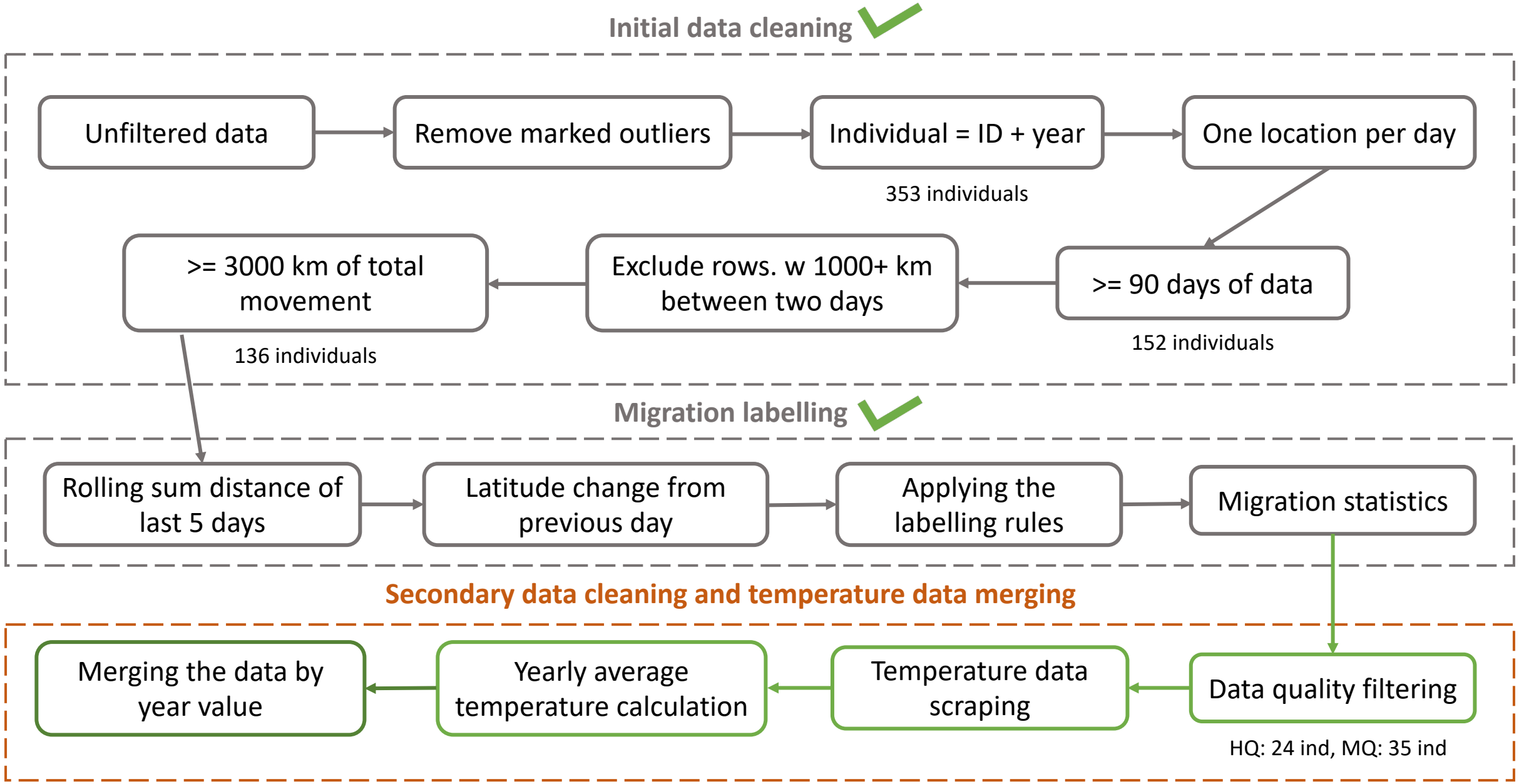

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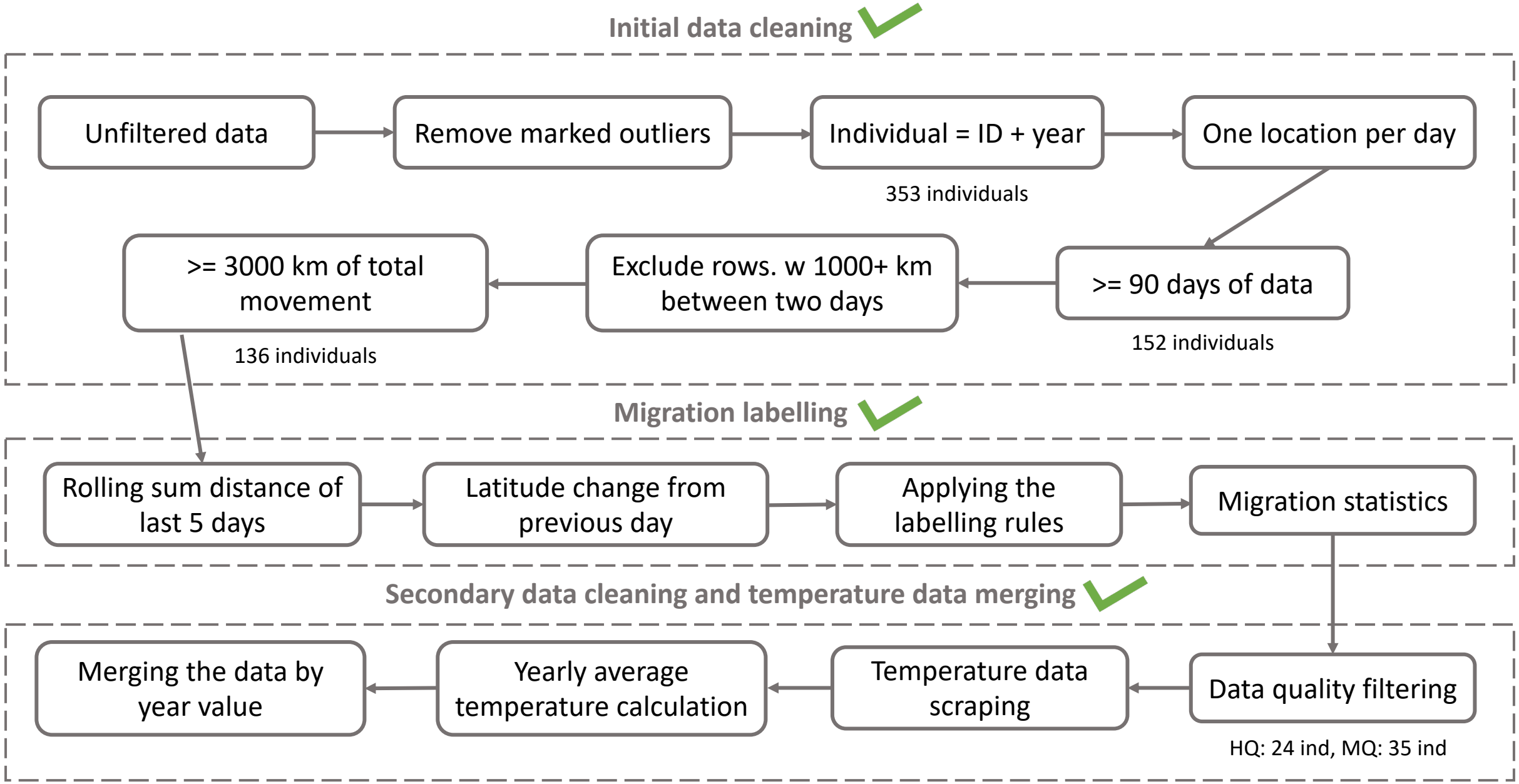
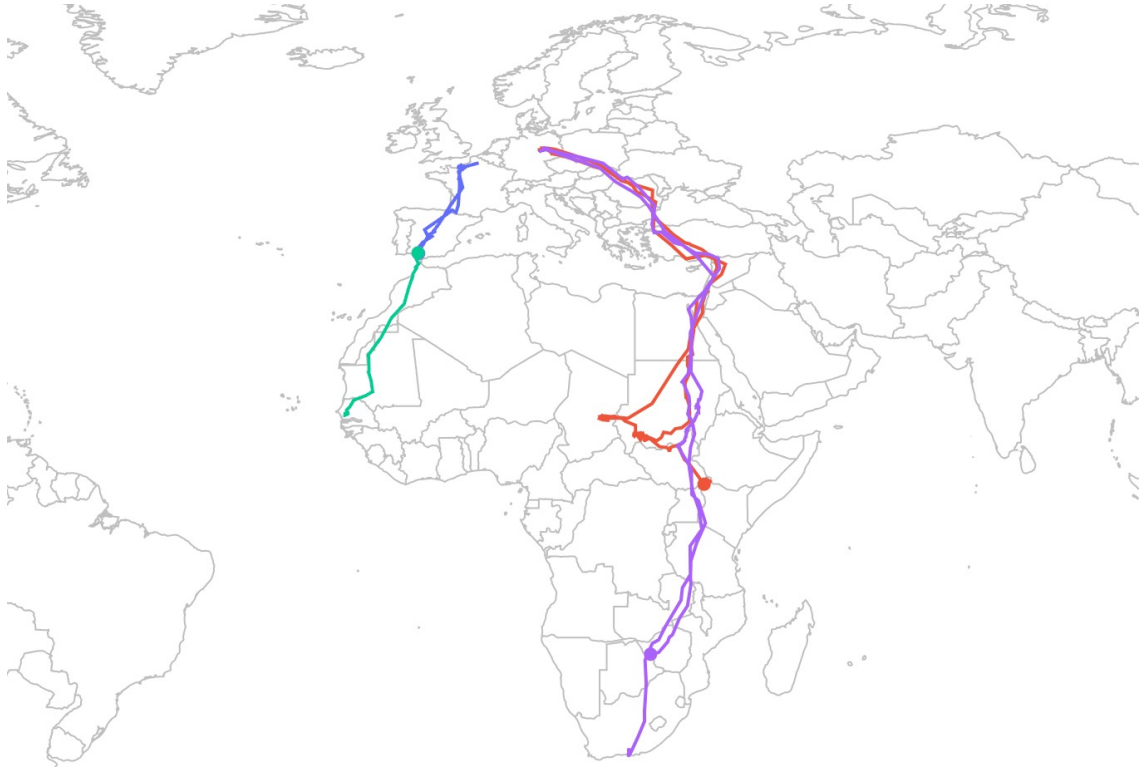


Migration Path Clustering

White storks use **multiple** migration paths

Choice of the path can have a considerable effect on the migration behaviour parameters



How to cluster line objects meaningfully?

Migration Path Clustering

Calculate **overview features** of the Geotrail objects (individual lines)

↓

total distance, maximum/minimum latitude & longitude

↓

Standardize the features & apply **K-means** clustering
(use elbow plot to determine the k-value)

HQ data

K = 4

MQ data

K = 2

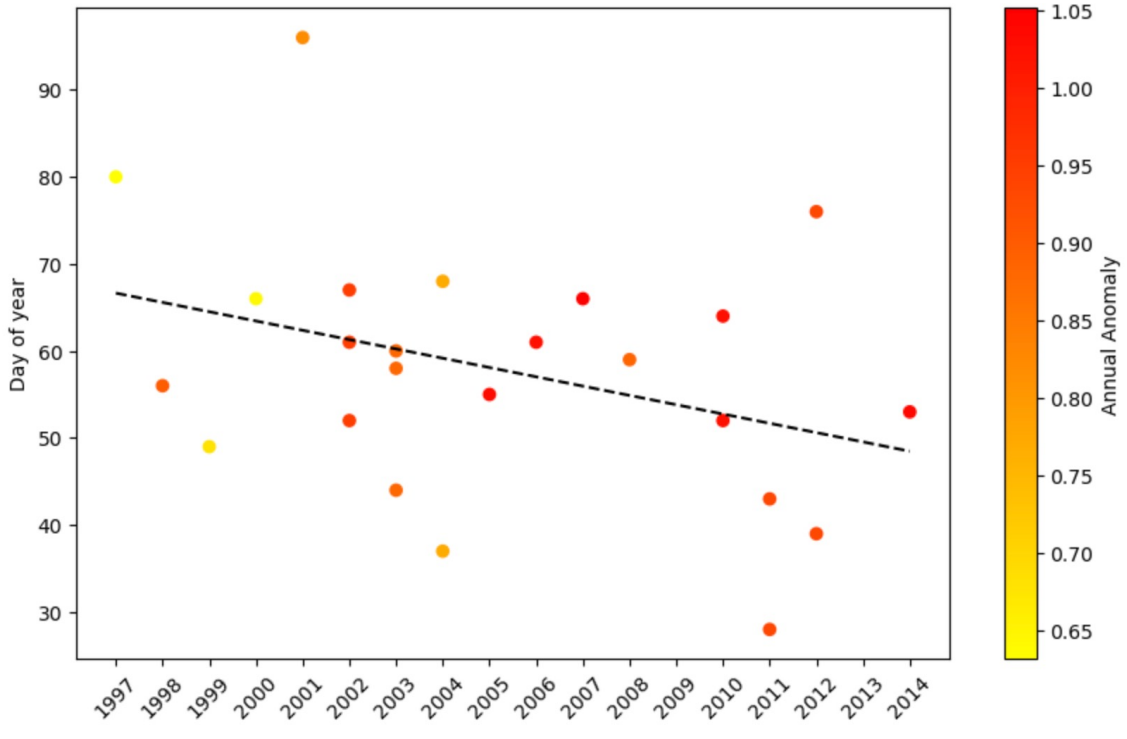
Correlation Analysis

Start of migration x Year

HQ data

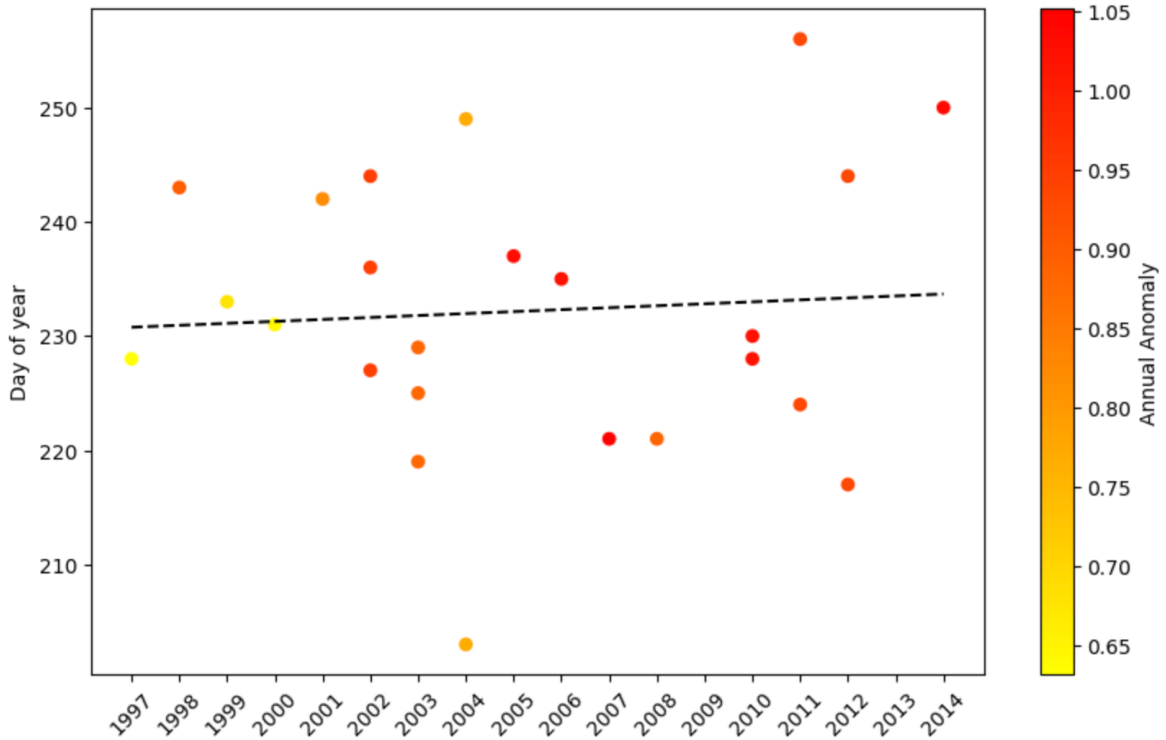
Summer migration

cor = -0.355



Winter migration

cor = 0.068



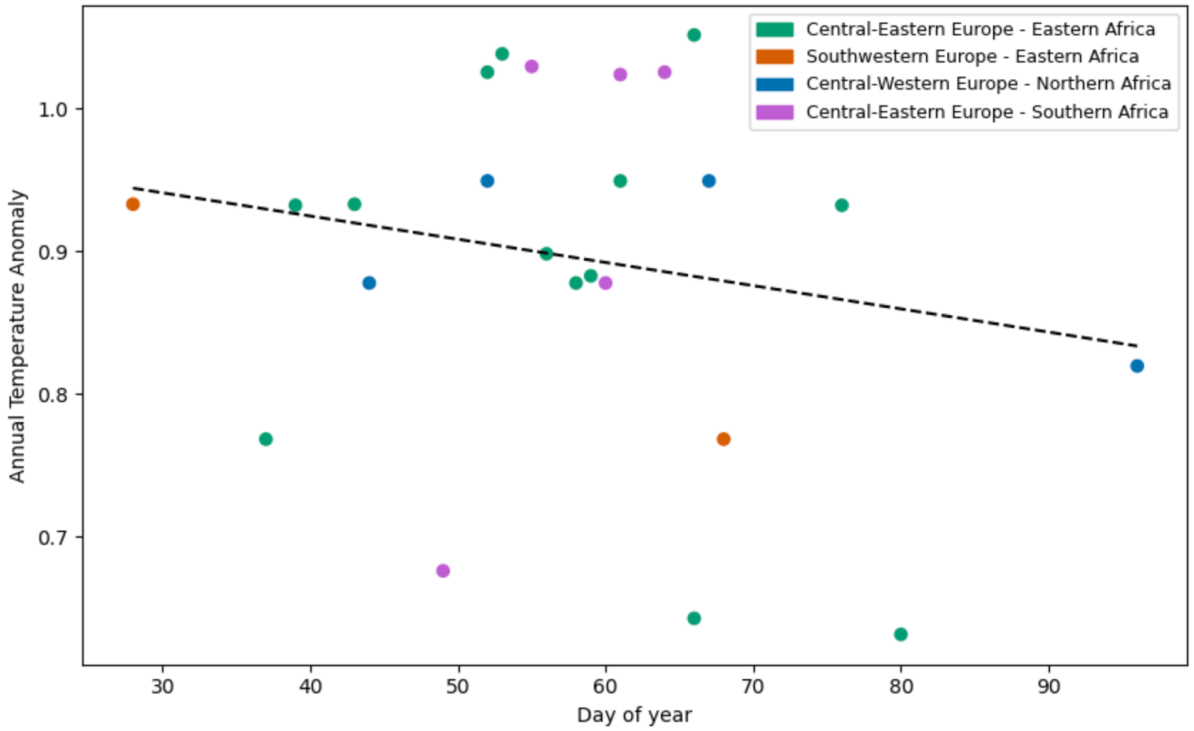
Correlation Analysis

Start of migration x Temperature anomaly

HQ data

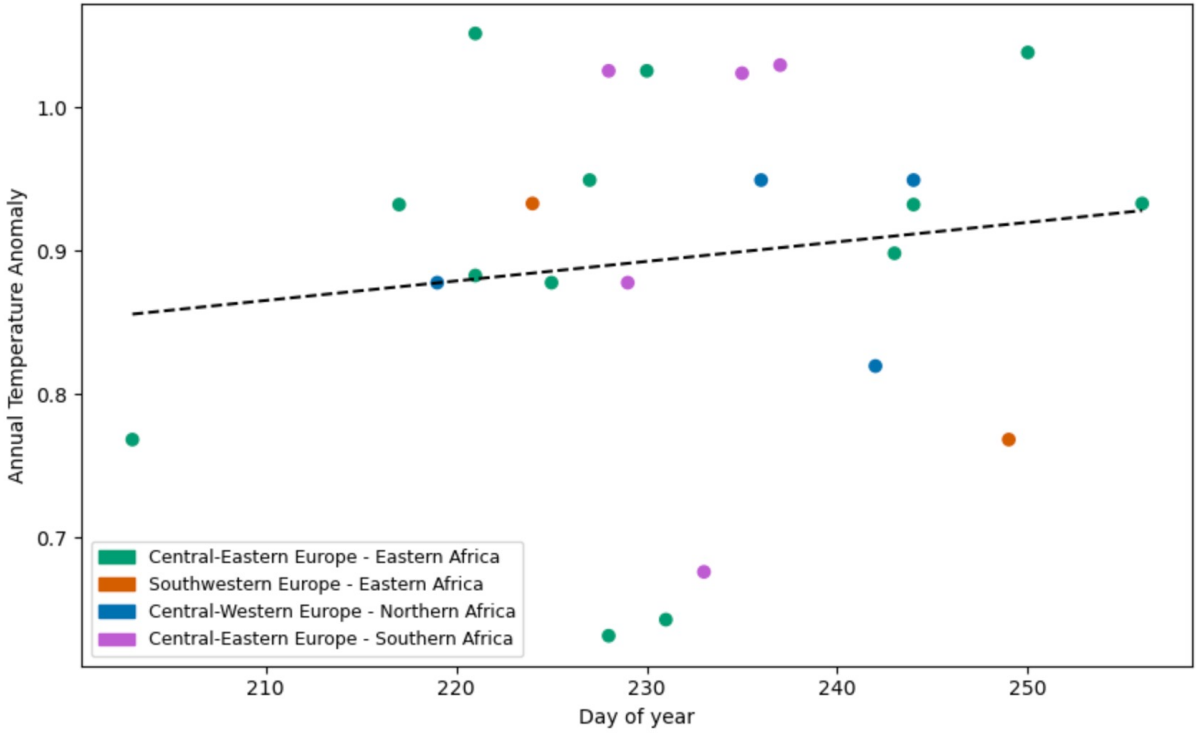
Summer migration

cor = -0.192



Winter migration

cor = 0.135



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(GLMM)

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Generalized linear mixed-effect model
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Only **24** (or 35) **individuals**

16 different **test groups**

1-3 individuals per group

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Conclusion

Migration behaviour change tendencies can be observed over the years on the tracked white storks

Individuals tend to start their **summer** migration **earlier** and begin the **winter** migration **later**

But it must be kept in mind that (weak) correlation ≠ causation**!**

Unfortunately the experiment set up does not allow for a reliable statistical analysis...

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Possible improvements:

- Make the **labelling algorithm** more robust
- Hand-label some individuals to create a training set for a possible **ML labelling solution**
- Make the data quality filtering conditions more realistic
- Find more optimal methods for migration path clustering
- Use **location-based** temperature data
- Gather more quality GPS data(!)
- Discuss the approaches with someone who knows about white stork **phenology**

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