Toward Lagrangian simulations of EUREC4A/ATOMIC cloud regimes

Steven Boeing, work with the EUREC4A and DEPHY team (Leif Denby, Peter Blossey, Roel Neggers, Jan Kazil, Pornampai Narenpitak, Lorenzo Tomassini, Romain Roehrig, Stephan De Roode, Leo Saffin, Zhiqiang Cui, Ralph Burton, Alan Blyth)

Cloud-circulation interactions are the biggest uncertainty in climate projections

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- Trade-wind cumulus clouds are ubiquitous.

  1.5 to 4.5°C spread in climate model projections: largely due to tropical low clouds*.

- Aerosol, cloud and precipitation processes are sensitively coupled to the larger-scale dynamics.

Goal of Research: understand processes controlling response of trade-wind cumulus clouds to changing environmental conditions in our warming climate.

* e.g. Bony and Dufresne 2005; Vial *et al.* 2013.

Cloud Feedbacks and Climate Sensitivity

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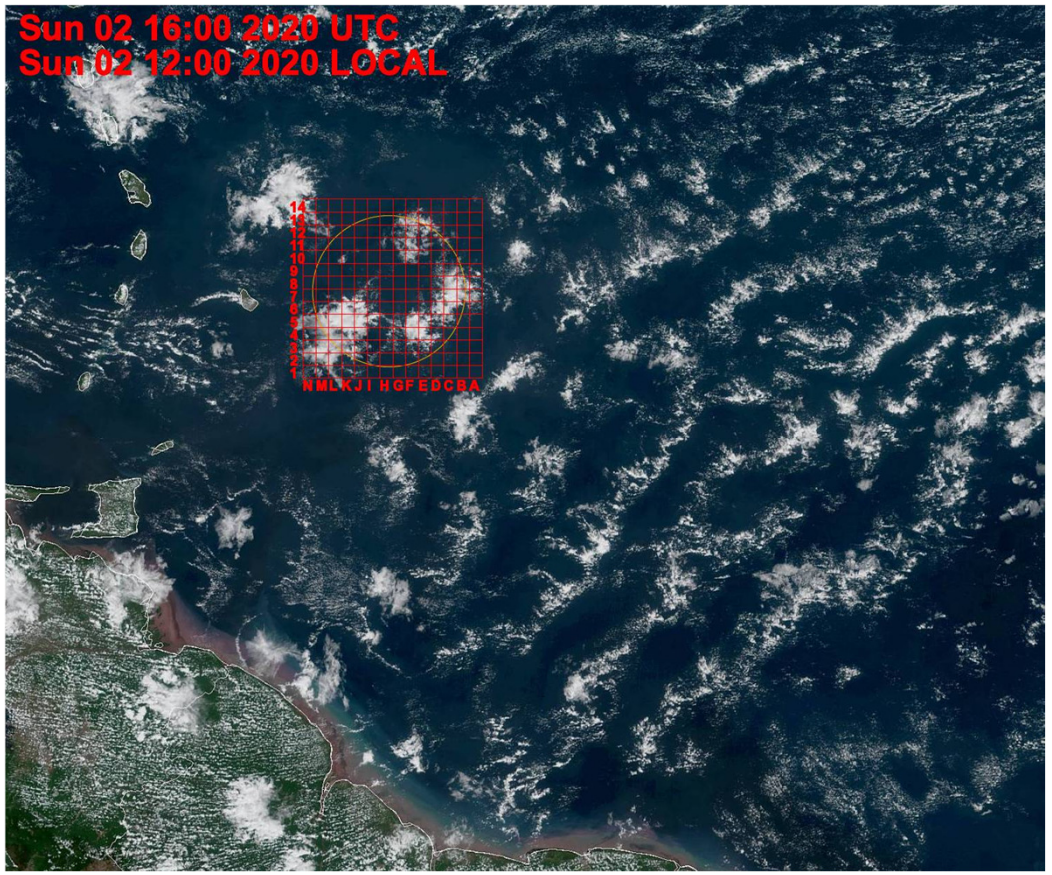
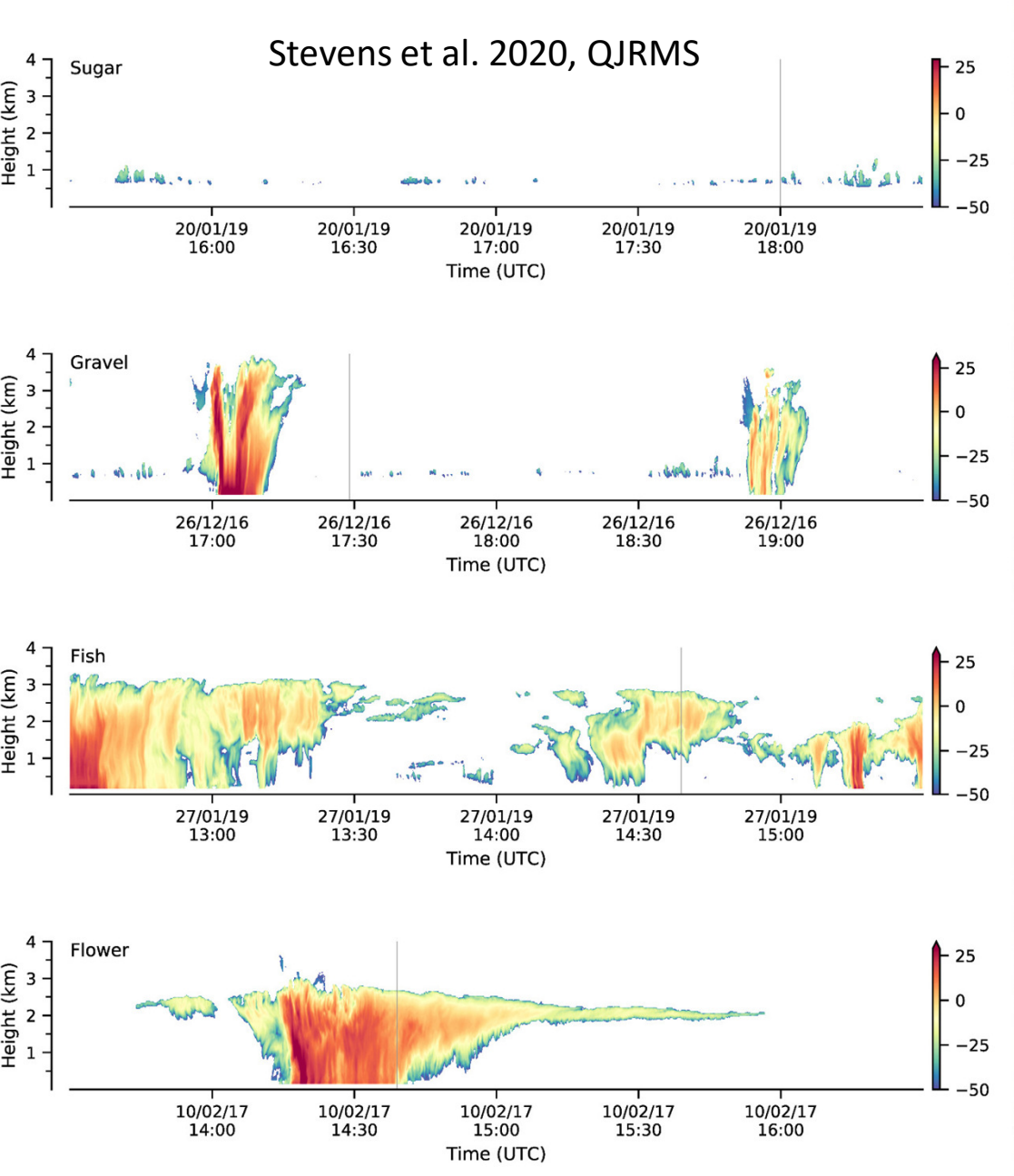
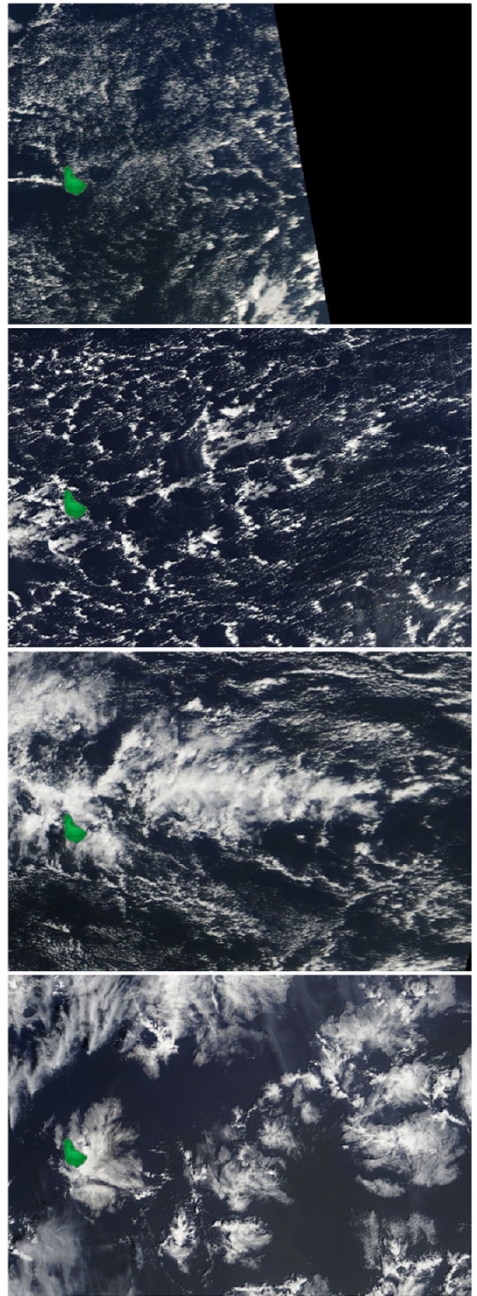


- Uncertainty is associated with the mesoscale organisation of clouds
- Not well represented in models (issues even at convection-permitting resolutions)
- Typically not the focus of past observational campaigns

Stevens et al. 2020, QJRMS





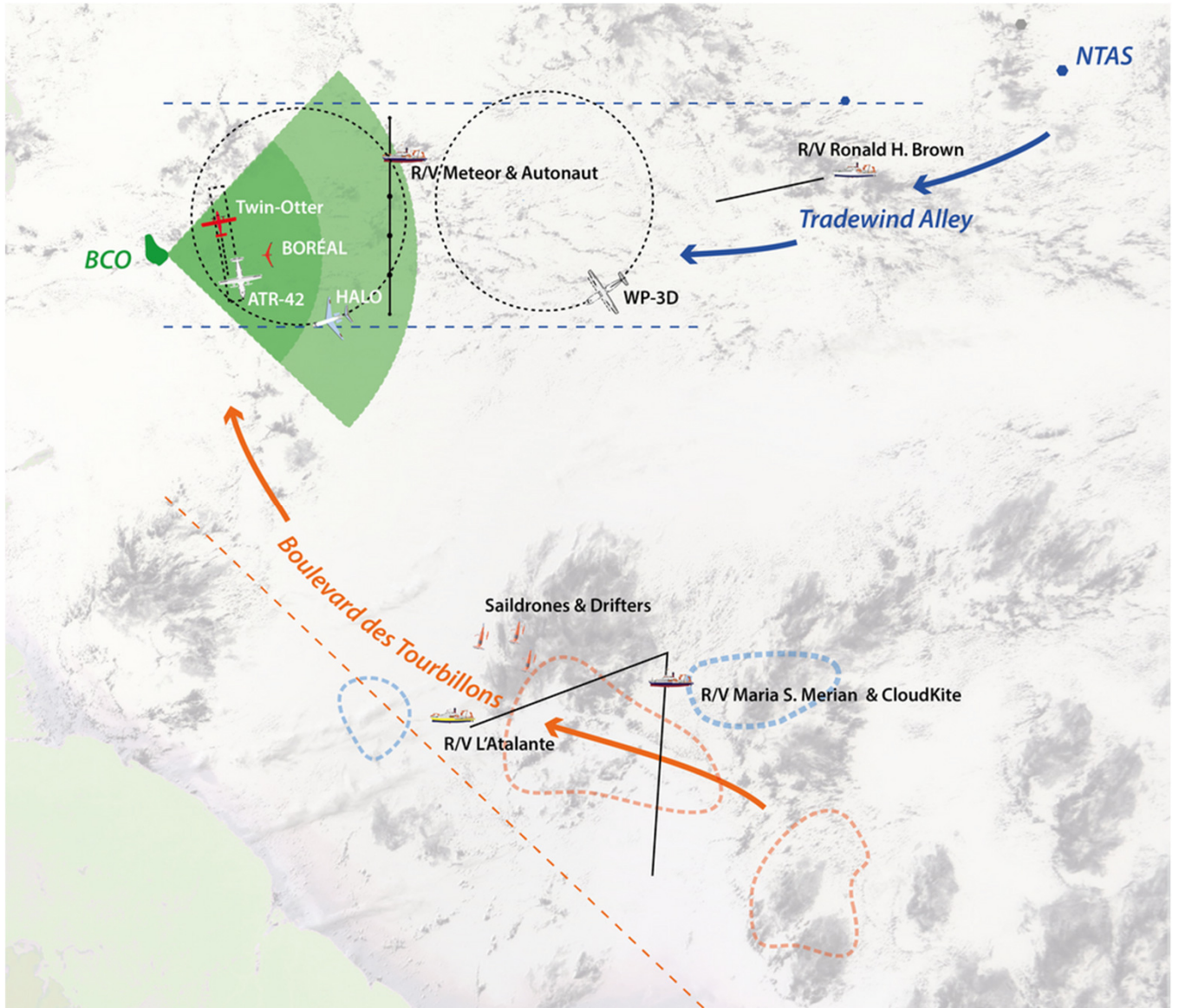
Sugar

Gravel

Fish

Flowers

EUREC4A: Jan/Feb 2020



Aircraft

- HALO
- ATR
- **Twin Otter**
- P3
- Boreal

Ships

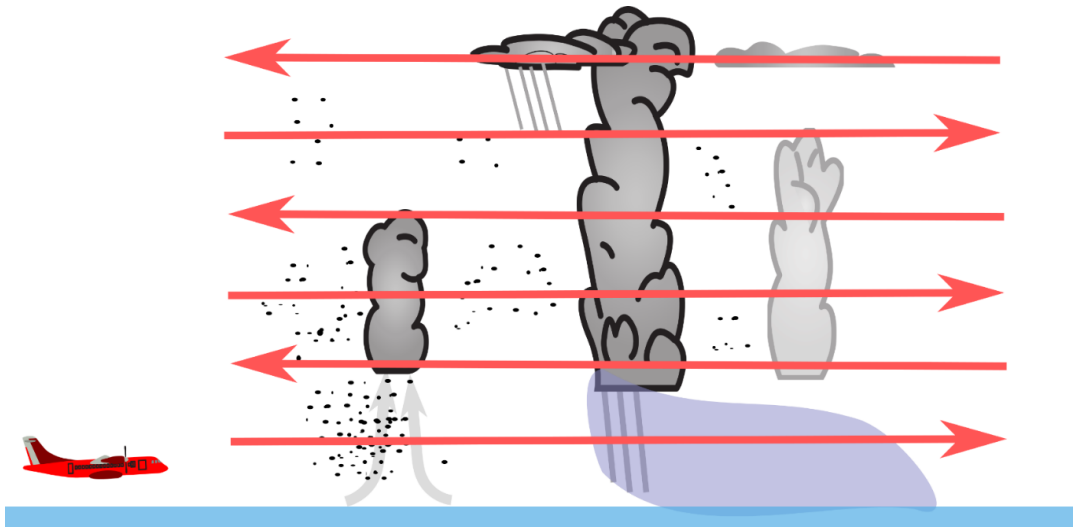
- Ron Brown
- Meteor
- Merian
- L'Atalante
- Autonaut
- Saildrones

Ground Sites

- BCO
- NTAS Buoy
- **Ragged Point**
- PoldiRad

- Long flight legs at several altitudes, targeting clouds and BL features; occasional sampling of individual clouds.
- Key observations: BL structures aerosols (CCN and Ultra-giant CCN); cloud base; cloud droplet number concentration; cloud properties; formation of warm rain; development of rain and rainshaft; downdraughts; gust front and cold pools; new cloud formation; detrainment layer.

Cumulus clouds as seen from the Twin Otter



Large-Eddy Simulation within EUREC4A

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- Understand influence of large-scale forcings like subsidence and moisture advection through systematic sensitivity experiments
- Warm rain process in different regimes
- Cold pools: mixing, gust fronts
- Boundary-layer structures
- Behaviour of detrainment layers (think of e.g. persistence/droplet sizes)
- Isotopes (Blossey/Noone/Bailey/Galewsky)

- 25m simulations (10s of kms): warm rain formation, BL structures, cold pools.
- 100m simulations (~200 km) : detrainment layers, organisation, cold pools.

Lagrangian LES modelling

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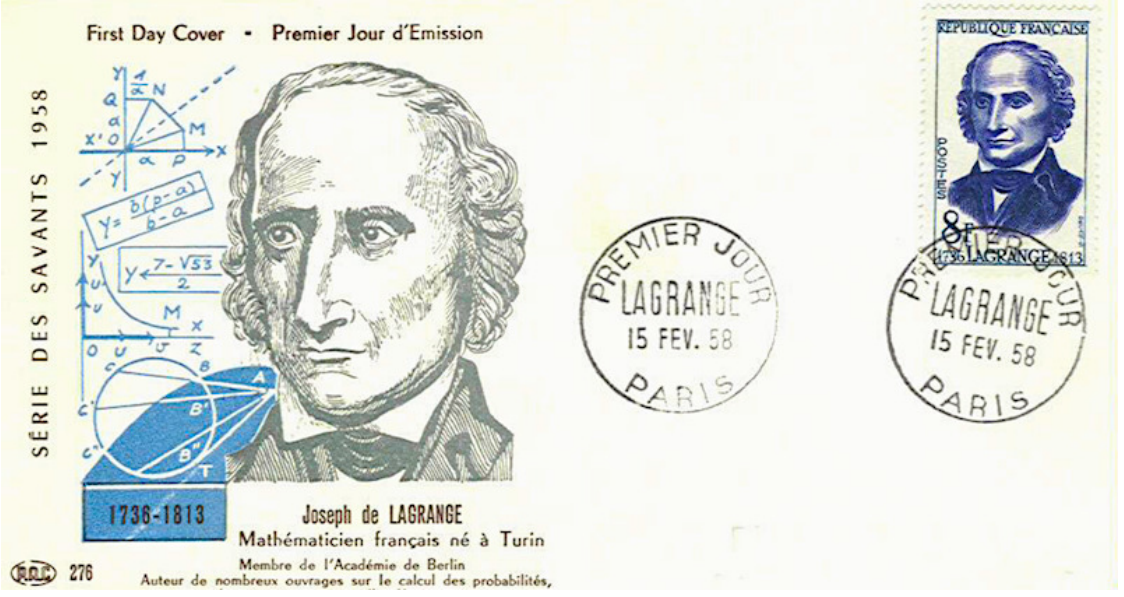
- Idealised cases, along NWP-like setups run by Tomassini, Lock et al.
- Demi-Lagrangian: box moving along trajectory at a given level (e.g. 950hPa), with advection of heat/moisture/momentum at other levels
- Setups can also be used for single- or multi-column parametrisation development.



Driving the LES (Denby, Boeing)

- LES with **semi-realistic forcings** ever more popular Continuous LES at observational sites like Cabauw/Julich, field campaigns.
- **EUREC4A**: desire to base LES on **reanalysis** (model level, hourly), possibly corrected using observations.
- Met Office/NERC cloud model default input format based on **text files**.
- Efforts to use standardised formats **(DEPHY format)**
- Aim for a tool that is relatively easy to use, configure (input files) and modify. Ensure meta-data about file creation retained.

Lagtraj (https://github.com/EUREC4A-UK/lagtraj/)

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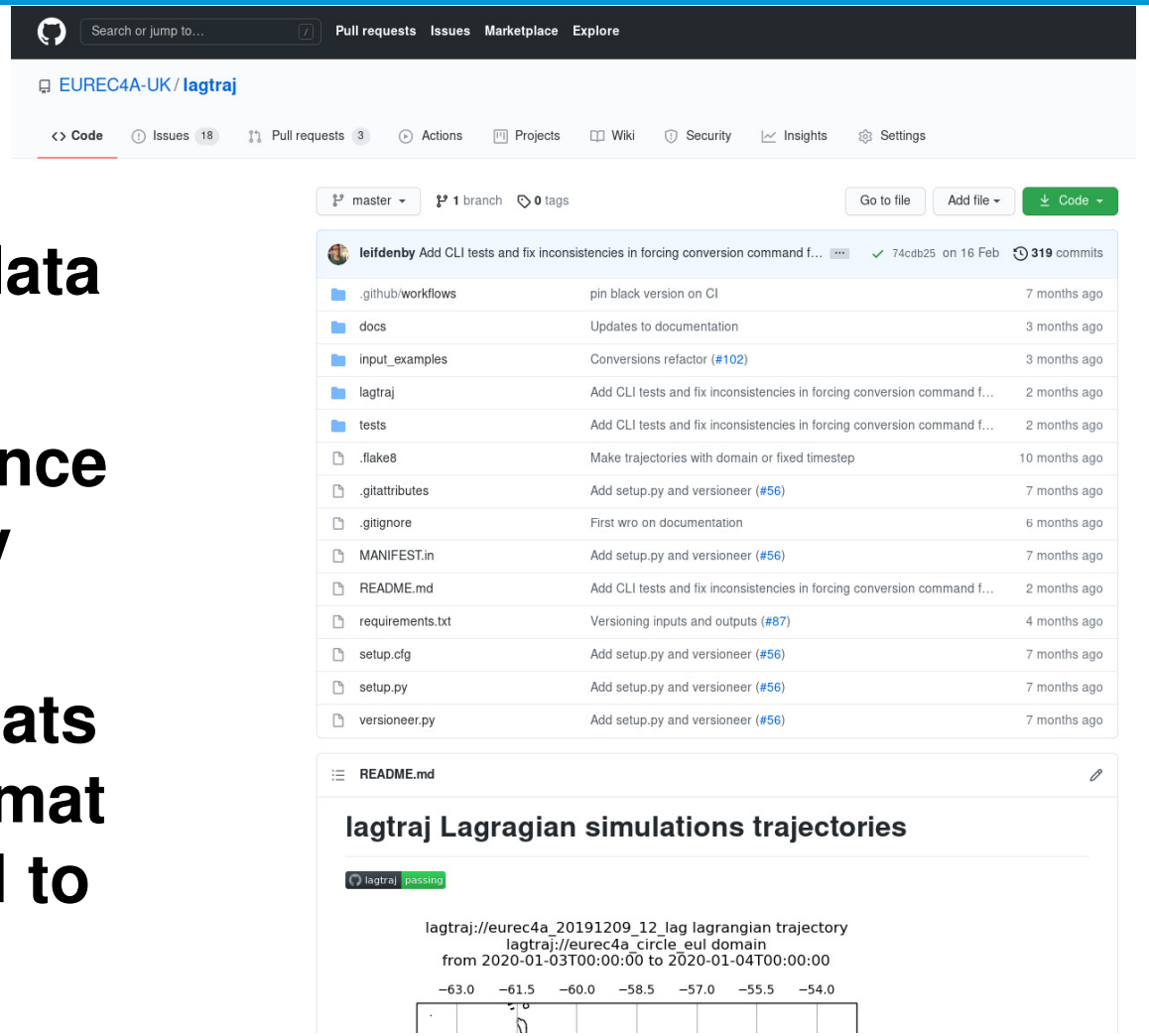
1) Download ERA5 reanalysis data
2) Create trajectories
3) Extract forcings like subsidence and moisture advection (largely retaining ERA5 data format)
4) Conversion to standard formats
5) Run MONC using DEPHY format input. Forcing files can be used to derive SCM input as well.



Lagtraj (https://github.com/EUREC4A-UK/lagtraj/)

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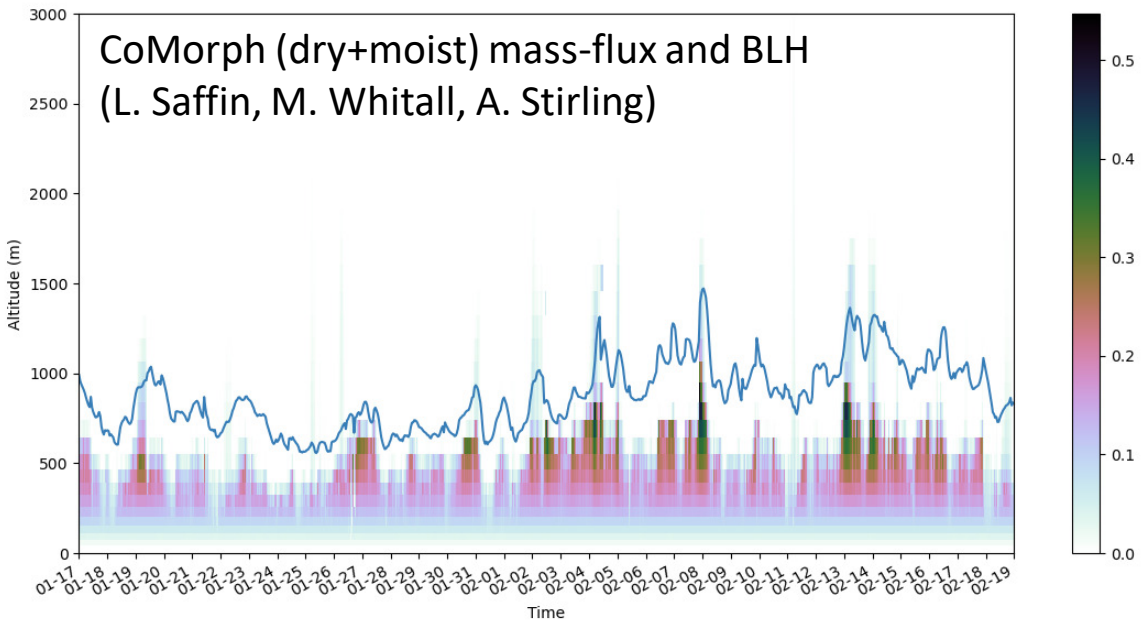
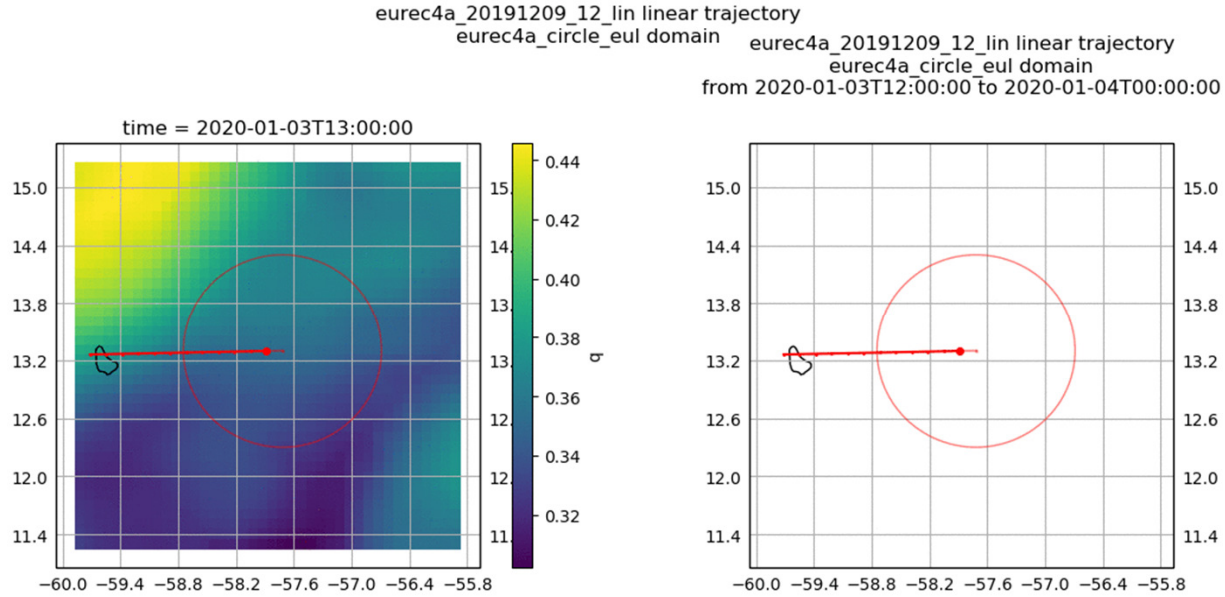
- **YAML** configuration files for each step

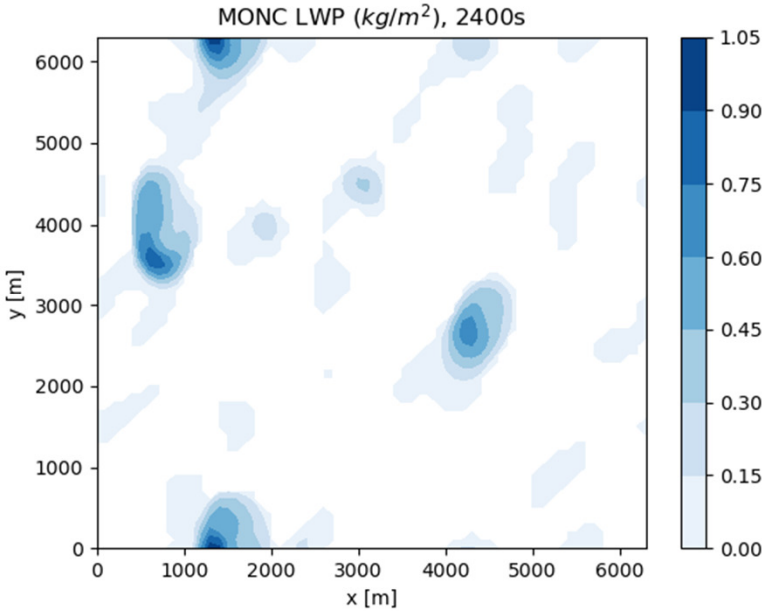
```
python -m lagtraj.domain.download lagtraj://eurec4a_north_atlantic 2020-01-30 2020-02-02
python -m lagtraj.trajectory.create lagtraj://eurec4a_20200202_12_lag
python -m lagtraj.forcing.create lagtraj://eurec4a_20200202_12_lag --conversion lagtraj://dephy
```

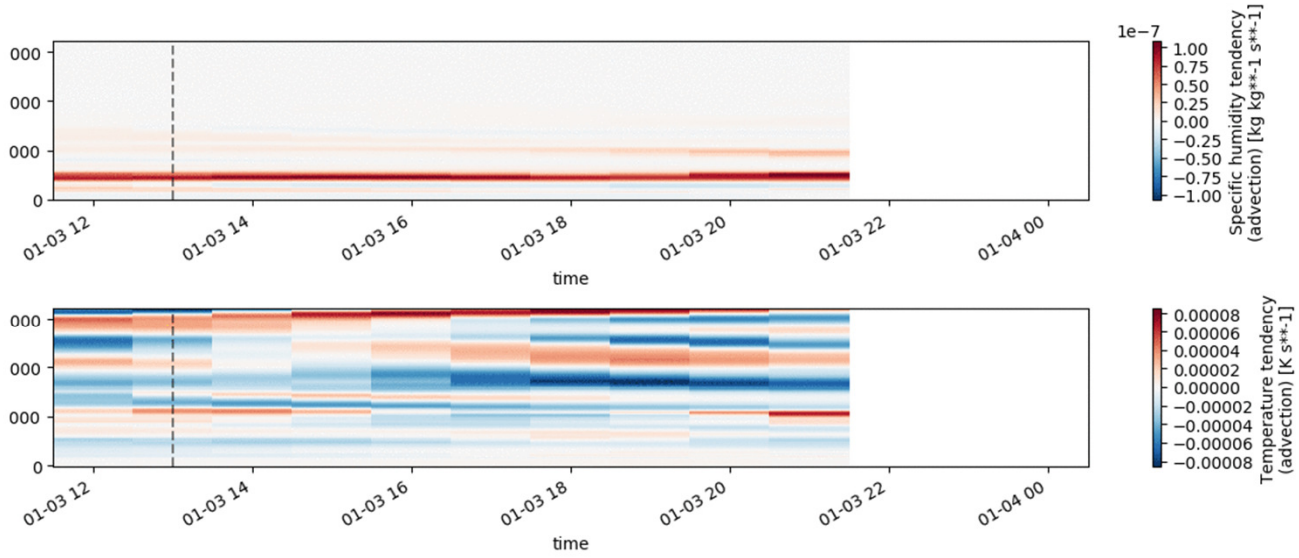
- **Input**: ERA5, to be extended with observations
- **Internals:** xarray datasets, numba-optimised (e.g. regression, interpolation to height)
- **Unit test** (pytest) and **versioning**
- **Standardised output**
  CF-compliant, based on ERA5 format
  KNMI Parameterisation Testbed
    DALES
    SAM
  iDEPHYx (DEPHY+extensions)
    Met Office NERC Cloud model (UM) CoMorph parametrisation
    …
    Extensions: time dependency



- Close to first release
- MONC now running with iDEPHYx inputs
- Plans: BL structures, effects of organisation and cloud-scale processes on mixing, interactions between microphysical processes(e.g. warm rain formation, evaporation), forcing sensitivity.







LES tests with SAM (Feb 5, Peter Blossey)

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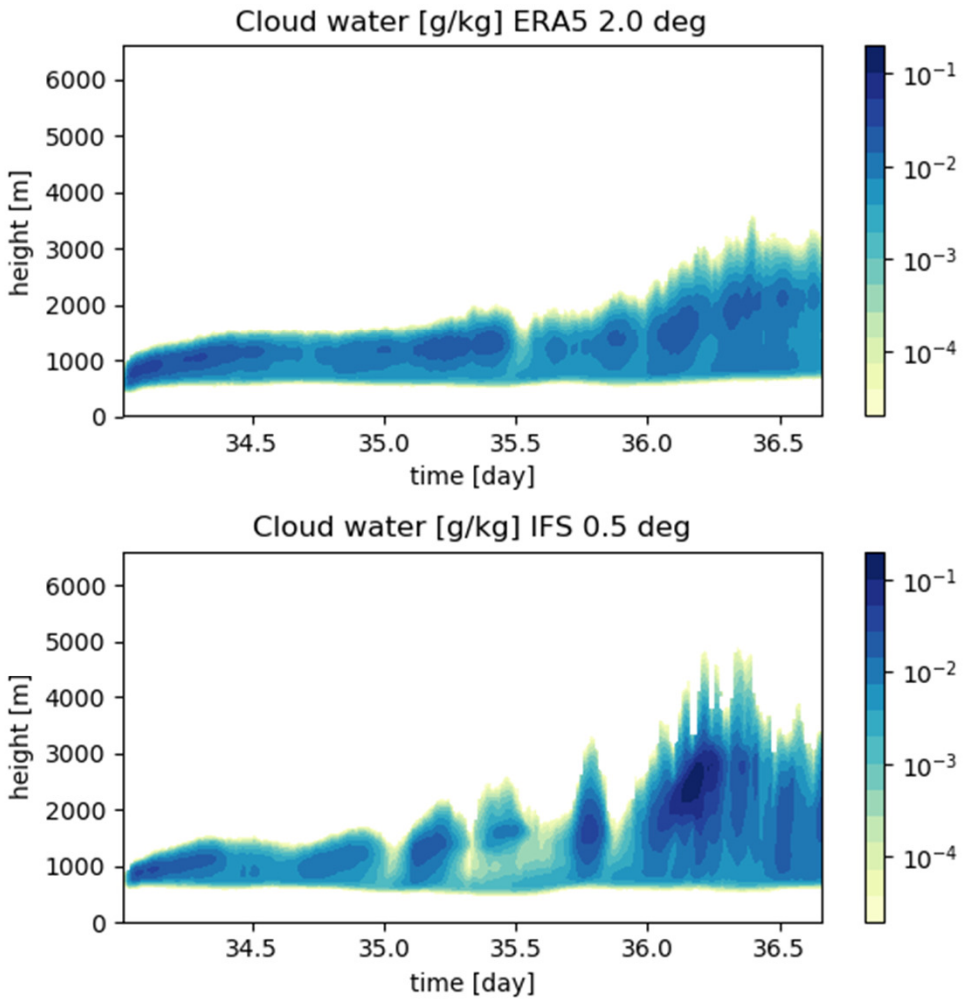

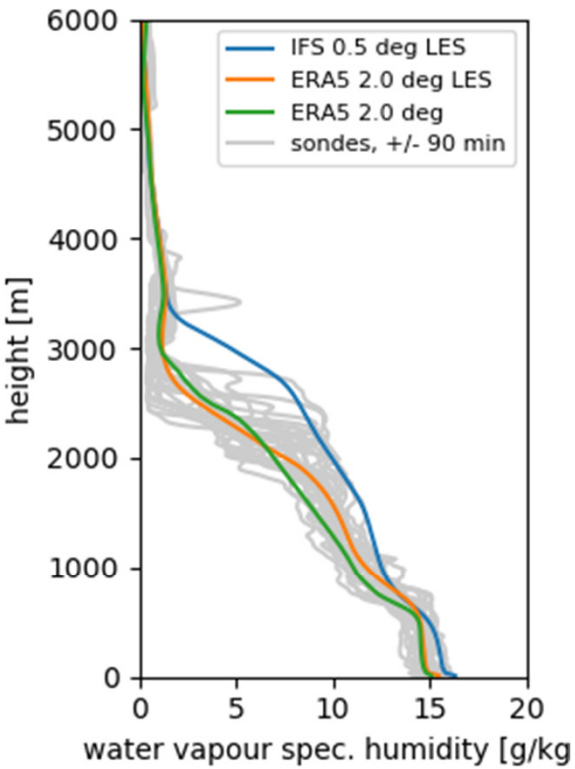

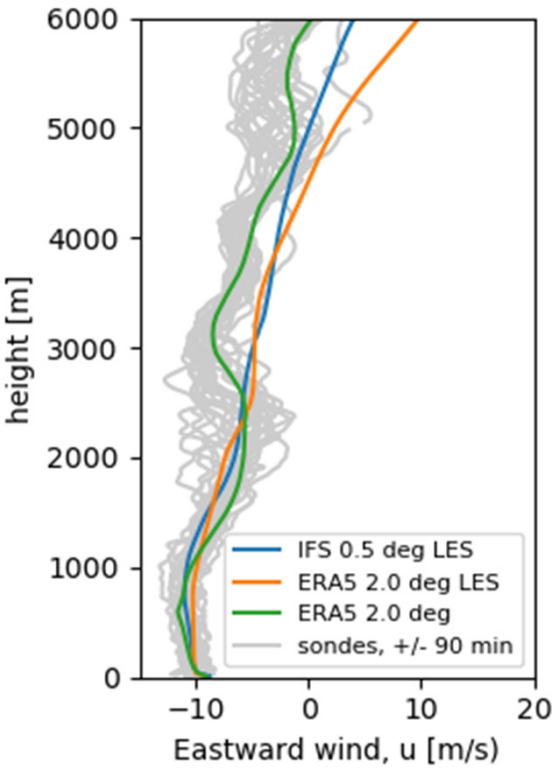

Comparison against same case driven with previous 0.5 deg. IFS forcings (Roel Neggers, meanwhile also 2 deg).

First results with SAM (Blossey)

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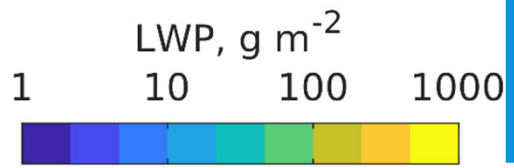

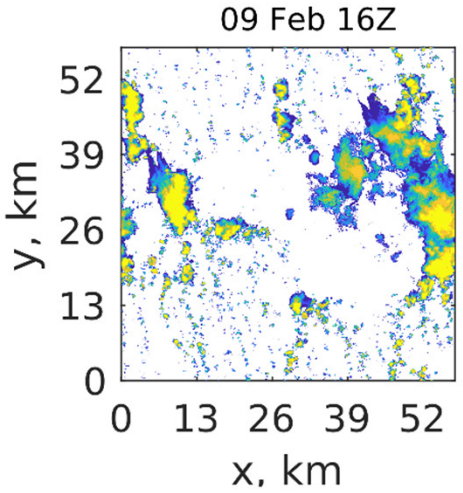

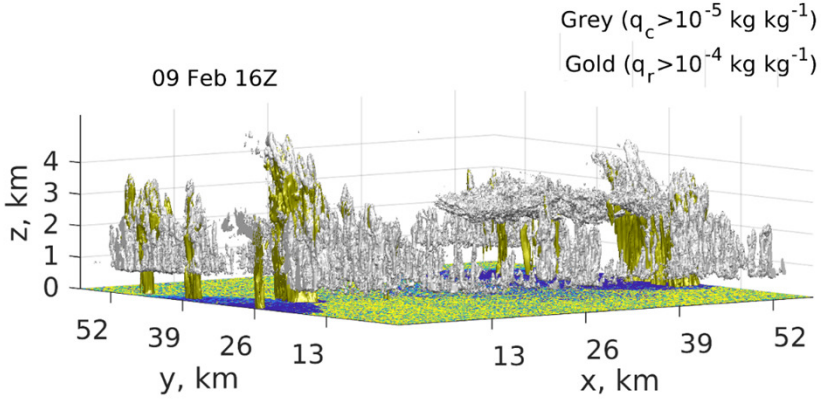

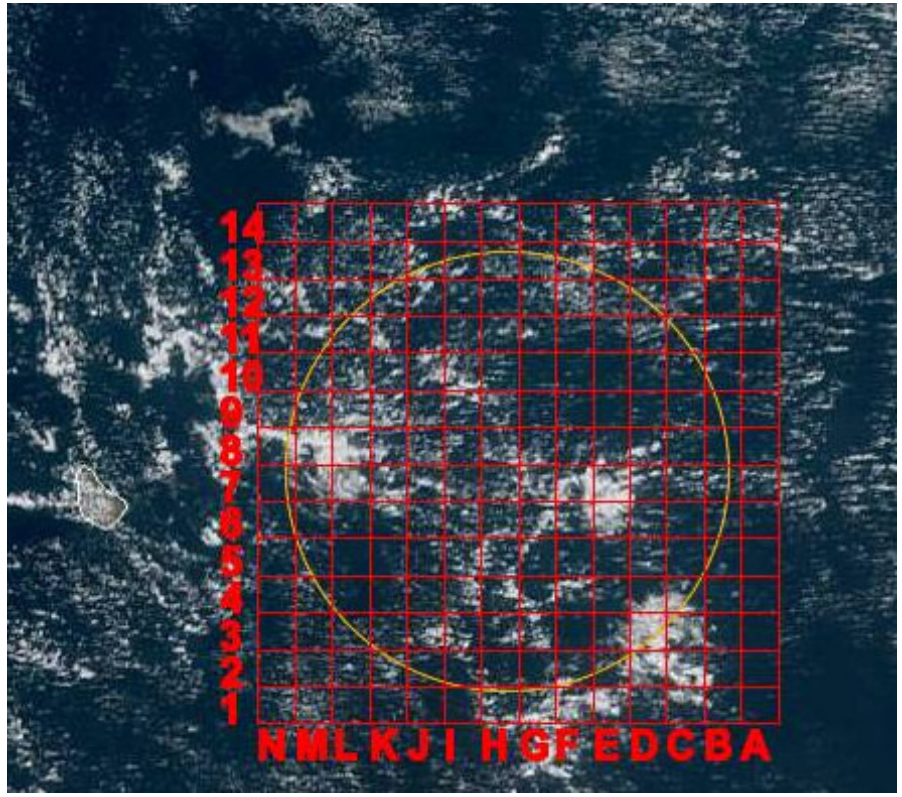

Key points

- EUREC^{4}A campaign: low tropical clouds, organisation and coupling to large-scale
- Observations and modelling across scales
- Lagtraj: flexible tool, could be useful for future projects

Figure

Le chien Idéfix, détail d'une peinture murale des personnages de la BD Astérix, de Goscinny et Uderzo. Lieu : Rue de la Buanderie 33/35 (Washuisstraat 33/35), École maternelle 8/2, ville de Bruxelles, Belgique.

https://commons.wikimedia.org/wiki/File:Id%C3%A9fix.JPG