#### 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)

#### <u>Cloud-circulation interactions are the biggest</u> <u>uncertainty in climate projections</u>



• Trade-wind cumulus clouds are ubiquitous.

1.5 to 4.5°C spread in climate model projections: largely due to tropical low clouds<sup>\*</sup>.

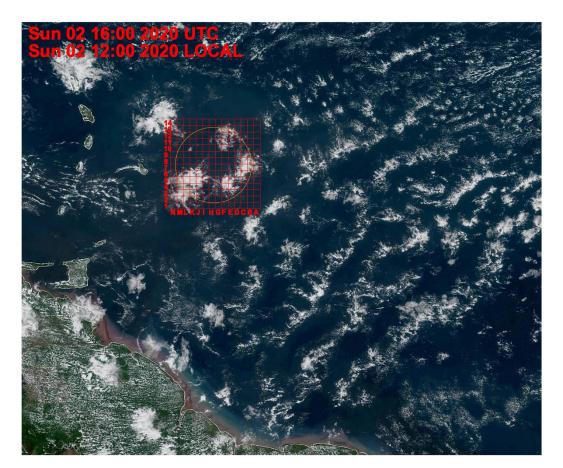
• Aerosol, cloud and precipitation processes are sensitively coupled to the larger-scale dynamics.



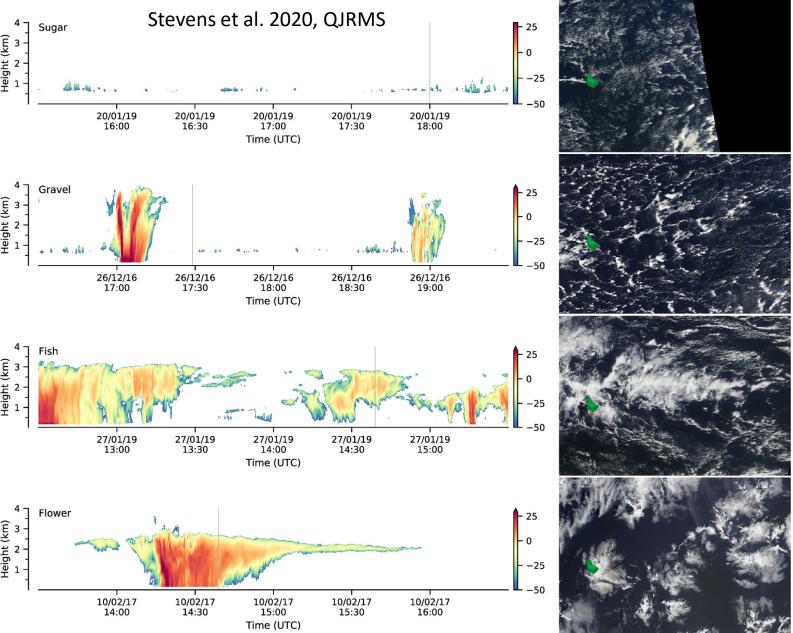
<u>Goal of Research</u>: understand processes controlling response of trade-wind cumulus clouds to changing environmental conditions in our warming climate.

#### **Cloud Feedbacks and Climate Sensitivity**





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



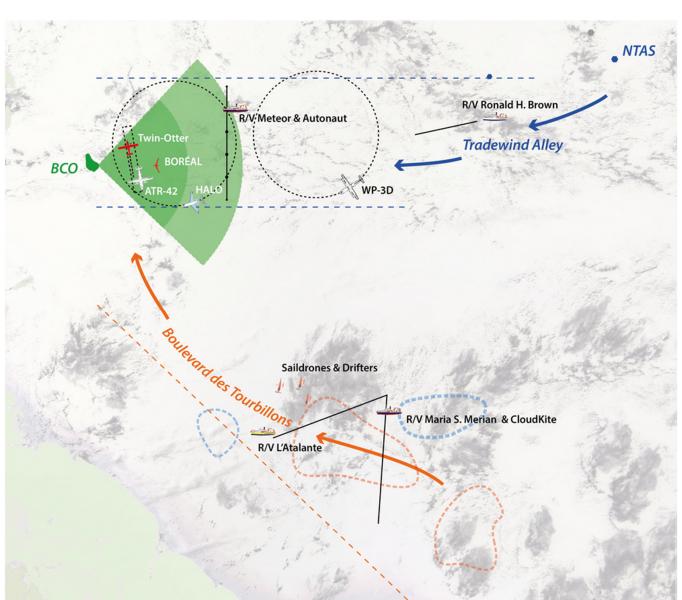
# Sugar



# Fish

## Flowers

#### EUREC4A: Jan/Feb 2020



#### Aircraft

- HALO
- ATR
- Twin Otter
- P3
- Boreal

#### Ships

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

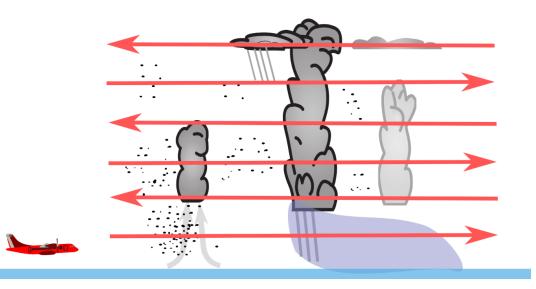
#### **Ground Sites**

- 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

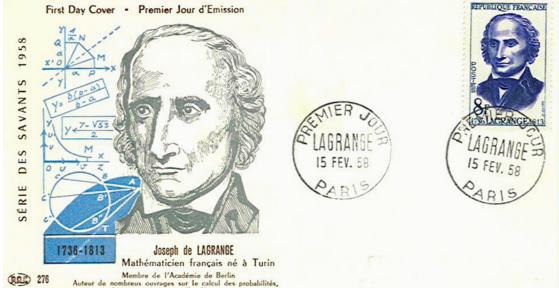
#### Large-Eddy Simulation within EUREC4A

- 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.

- 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.



### Lagtrai (https://github.com/E

Settings

<> Code ① Issues 18 17	Pull requests 3 () Actions [1] Pro	jects 🛄 Wiki	
	🥵 master 👻 🕻 branch 🗞	0 tags	
I) Download ERA5 reanalysis data		Ieifdenby Add CLI tests and fix inconsistencies in ford	
i j Dowinodu Eriks reanalysis uala	.github/workflows	pin black ver	
	docs	Undates to (	

- 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.

U	lendenby Add CLI lests and fix inc	consistencies in forcing conversion command f 🧰 🗸 74cdb25 on 16 Feb	🔁 319 ci
	.github/workflows	pin black version on Cl	7 mont
	docs	Updates to documentation	3 mont
	input_examples	Conversions refactor (#102)	3 mont
	lagtraj	Add CLI tests and fix inconsistencies in forcing conversion command $f_{\cdots}$	2 mont
	tests	Add CLI tests and fix inconsistencies in forcing conversion command $f \ldots$	2 mont
D	.flake8	Make trajectories with domain or fixed timestep	10 mont
D	.gitattributes	Add setup.py and versioneer (#56)	7 mont
۵	.gitignore	First wro on documentation	6 mont
Ľ	MANIFEST.in	Add setup.py and versioneer (#56)	7 mont
D	README.md	Add CLI tests and fix inconsistencies in forcing conversion command $f_{\cdots}$	2 mont
ß	requirements.txt	Versioning inputs and outputs (#87)	4 mont
Ľ	setup.cfg	Add setup.py and versioneer (#56)	7 mont
0	setup.py	Add setup.py and versioneer (#56)	7 mont
۵	versioneer.py	Add setup.py and versioneer (#56)	7 mont
:=	README.md		
1	agtraj Lagragia	an simulations trajectories	

from 2020-01-03T00:00:00 to 2020-01-04T00:00:00 -61.5 -60.0 -58.5 -57.0 -55.5 -54.0

-63.0

Security

Pull requests Issues Marketplace Explore

EUREC4A-UK / lagtraj

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

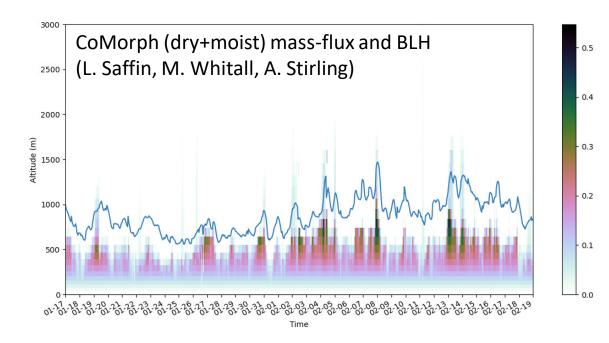
- **YAML** configuration files for each step

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



**UNIVERSITY OF LEEDS** 

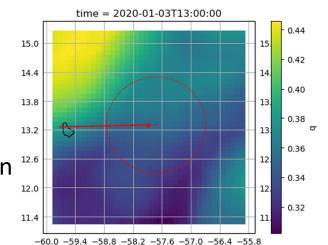
- Close to first release

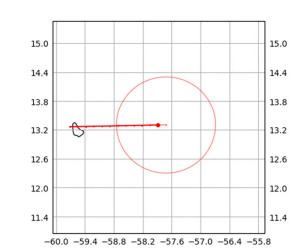
- MONC now running with iDEPHYx inputs

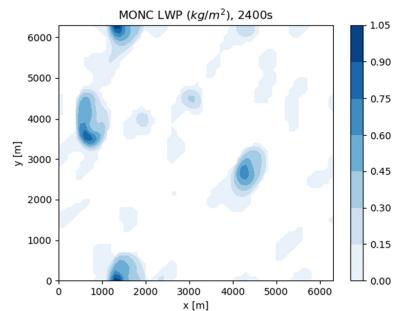
Plans: BL structures, effects of
 organisation and cloud-scale
 processes on mixing, interactions between
 microphysical processes(e.g. warm rain
 formation, evaporation), forcing
 sensitivity.

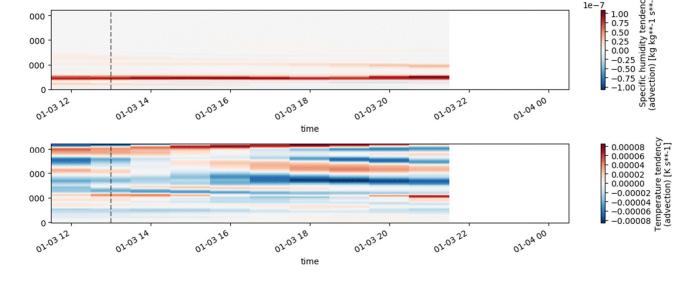
défix mural in

Brussels









eurec4a\_20191209\_12\_lin linear trajectory eurec4a\_circle\_eul domain eurec4a\_20191209\_12\_lin linear trajectory eurec4a\_circle\_eul domain

from 2020-01-03T12:00:00 to 2020-01-04T00:00:00

#### LES tests with SAM (Feb 5, Peter Blossey)

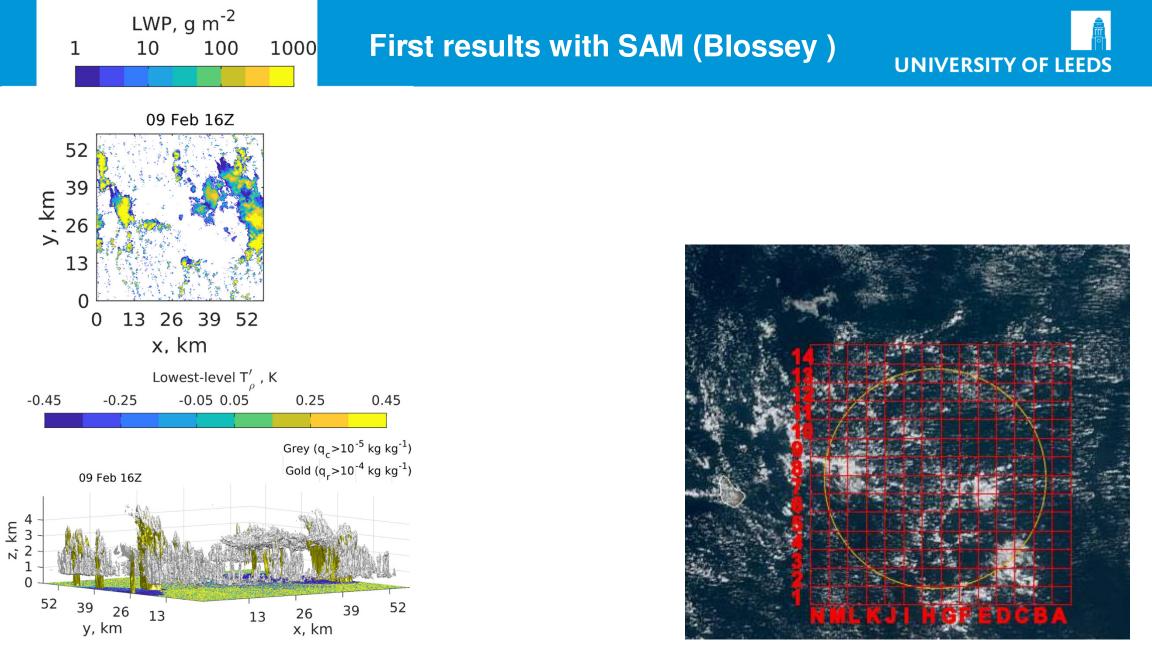
time [day]

#### Cloud water [g/kg] ERA5 2.0 deg - 10<sup>-1</sup> 6000 6000 6000 5000 IFS 0.5 deg LES · 10<sup>-2</sup> ERA5 2.0 deg LES height [m] 4000 ERA5 2.0 deg 5000 5000 sondes, +/- 90 min 3000 10-3 2000 4000 4000 $10^{-4}$ 1000 height [m] height [m] 0 34.5 35.0 35.5 36.0 36.5 3000 3000 time [day] Cloud water [g/kg] IFS 0.5 deg 2000 2000 - 10<sup>-1</sup> 6000 5000 IFS 0.5 deg LES 1000 1000 · 10<sup>-2</sup> ERA5 2.0 deg LES height [m] 4000 ERA5 2.0 deg sondes, +/- 90 min 3000 $10^{-3}$ 0 0 10 5 15 20 -1010 20 0 2000 0 Eastward wind, u [m/s) water vapour spec. humidity [g/kg $10^{-4}$ 1000 0 Comparison against same case driven with previous 0.5 deg. 35.5 36.0 34.5 35.0 36.5

IFS forcings (Roel Neggers, meanwhile also 2 deg).

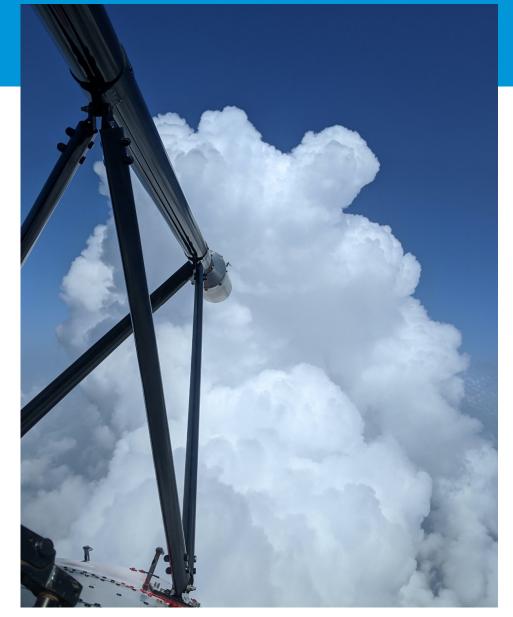
13

**UNIVERSITY OF LEEDS** 



#### Key points

- EUREC<sup>4</sup>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



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