WRF - FLEXPART simulations for Chacaltaya (CHC)

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Objectives

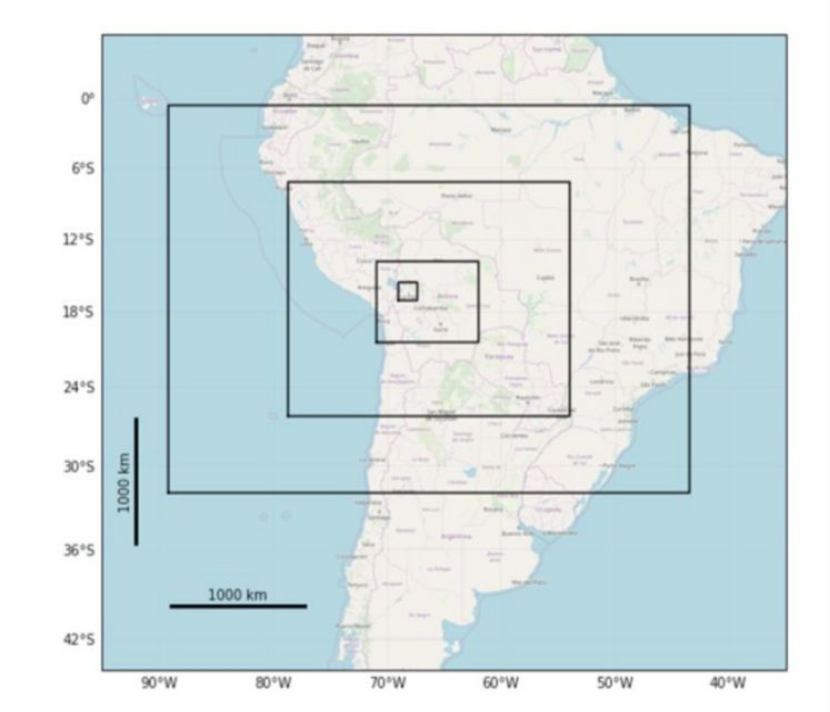
- Understand the Meteorology at CHC
- Create a dataset that quantifies the source area of air masses arriving at CHC with 1 hourly resolution.
  - Can be used to interpret measurements at CHC
- Quantify the influence of La Paz on CHC
- Quantify the influence of Sabancaya Volcano on CHC
- Compare results to the previous analysis done with Hysplit

The Weather Research and Forecasting Model (WRF)

- Mesoscale numerical weather prediction system
- Community model developed and maintained by NCAR / NCEP
- Use by researchers and as an operational forecast model
- Updates released every ~6 months (current version is 4.0 released in June 2018)
- Needs boundary / initial conditions from a global model / reanalysis
- Eulerian model (fixed grid)

Nested domains

- WRF can be run with multiple nested domains
- “Dynamical downscaling”
- The inner domains are smaller and have smaller grid spacing than the outer domains.
- Need to “step down” gradually from reanalysis resolution.
- Here we use 4 nests: grid spacing 36 km, 9 km, 3 km, 1 km



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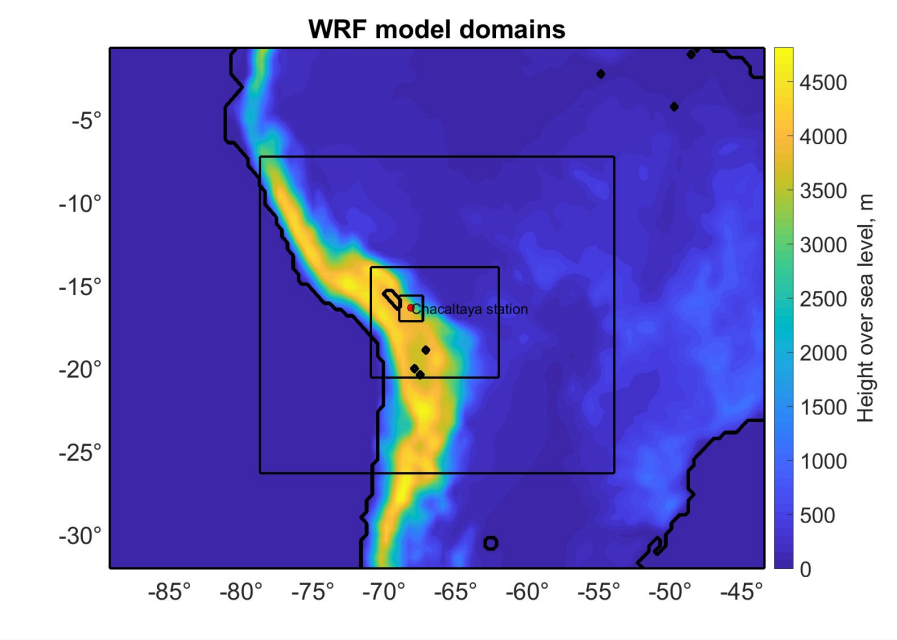


Lake temperature problems

- WRF can be set up in many different ways
- Need to carefully configure the model and check the results are sensible
- We discovered that the surface temperature of Lake Titicaca was much colder (10°C) in the model than in reality
- Major problem - causes the wrong stability of the boundary layer above the lake
- Fixed by forcing the model lake temperature to be the same as the monthly mean observations

Month	Water surface temp. (°C)	Air temp. (°C)
Jan	17.2	11.1
Feb	17.3	11.4
Mar	17.5	12.0
Apr	16.5	10.8
May	15.4	10.7
Jun	14.3	10.1
Jul	13.7	9.7
Aug	14.0	9.7
Sep	14.7	10.5
Oct	15.5	10.9
Nov	16.4	11.7
Dec	16.9	11.6

Pillco Zolá et al., 2019: Modelling Lake Titicaca's daily and monthly evaporation

FLEXPART

- Lagrangian Dispersion model
- Can be used in forward or backward mode
- Calculates the position of thousands of particles as a function of time
  - Gives an estimate of uncertainty / variability
  - Can also do simple trajectories
- Temporal and spatial resolution of the input / driving meteorological data is critical.
- If the input data is at 50 km grid spacing and every 6 hours, FLEXPART can only resolve large-scale features and will not capture winds driven by topography.

Method taken here

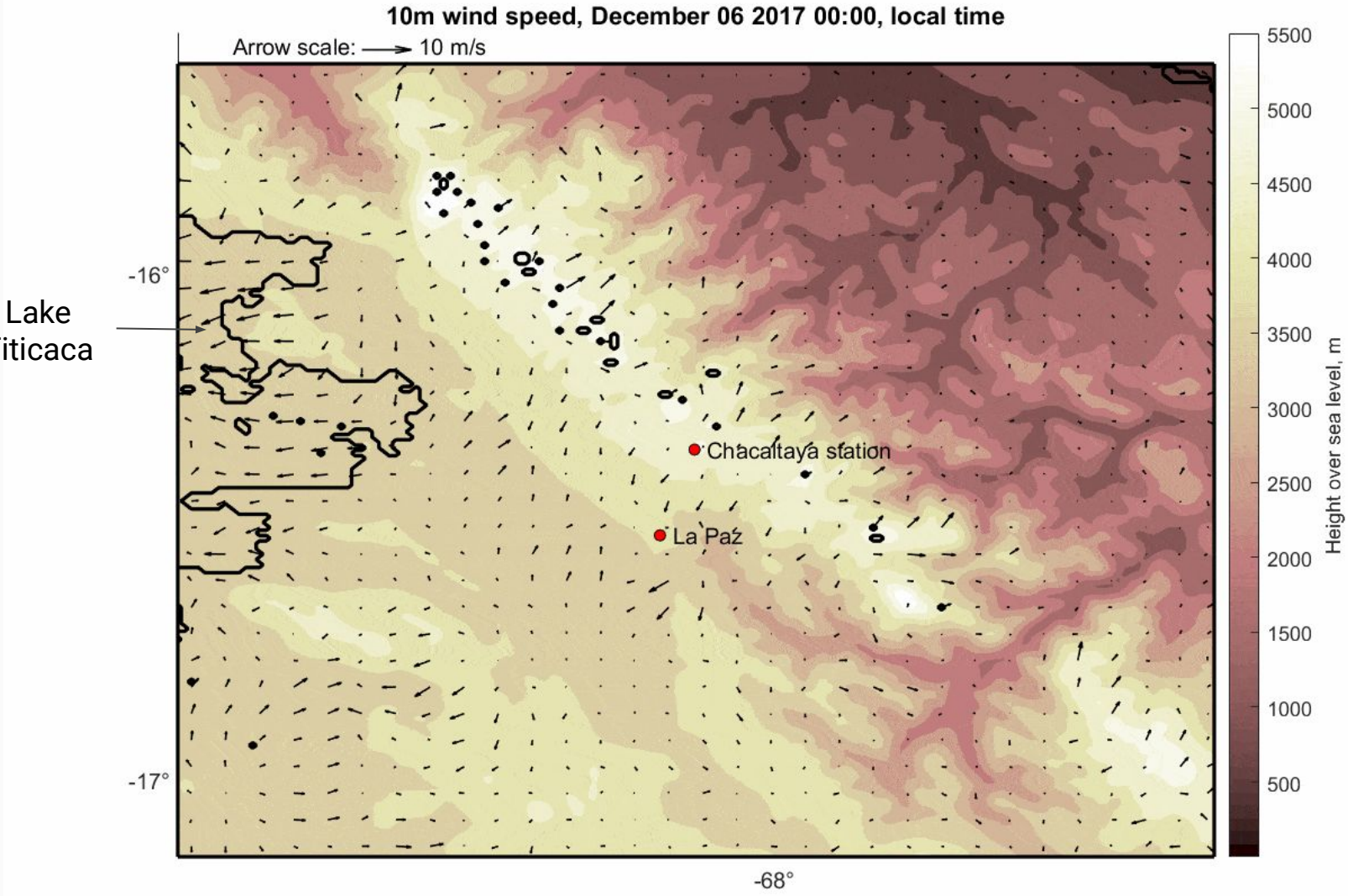
- Run a 6 month WRF simulation
- To keep it close to reality, we use “nudging” of the outer domain
  - Impact of nuding was studied
- Output variables in all 4 domains, inner domain data is output most often - every 10 minutes.
- **Use the WRF output as input to FLEXPART**
- Do backward simulations every hour from Chacaltaya
  - Release height is 10 m
  - Release 20 000 particles
- Particles advected backwards for 96 hours (4 days)

Computational Issues and Current Status

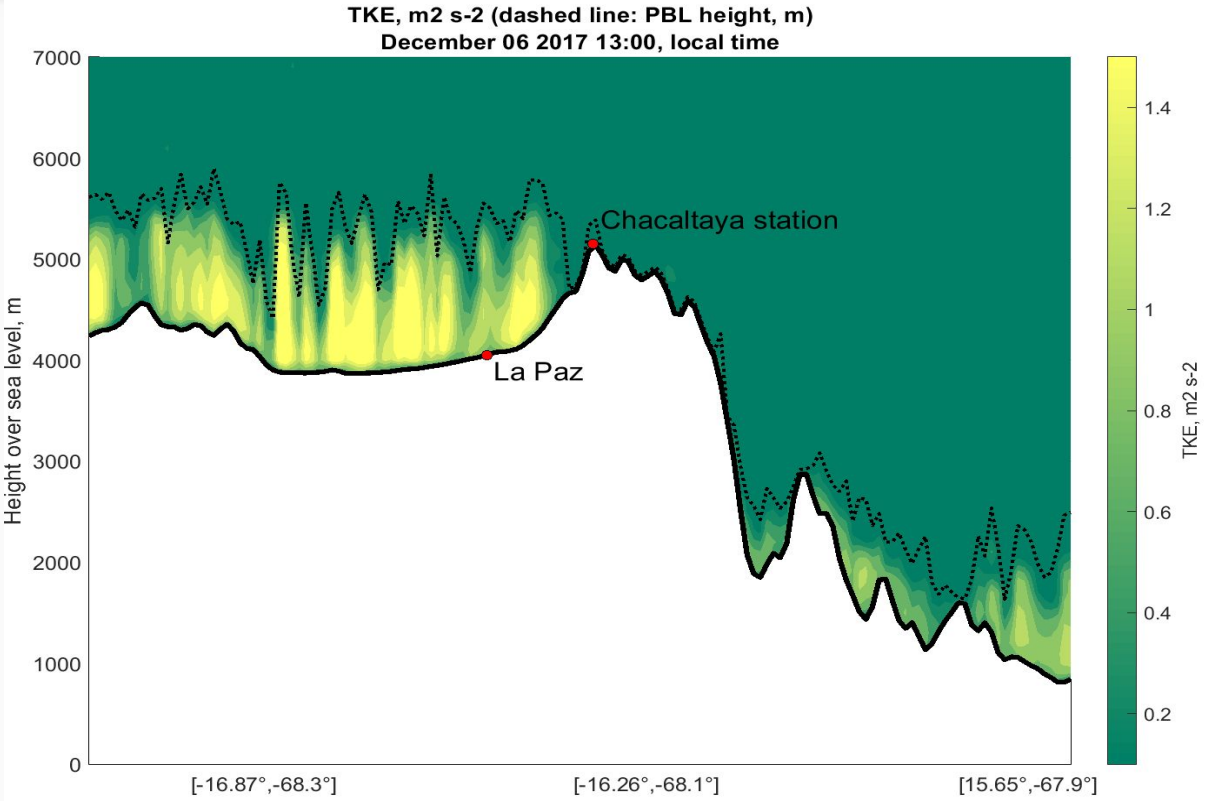
- The WRF simulations are computation expensive
- CSC computers are very busy / full so jobs need to queue
- Lots of additional meteorological information will be available though
  - boundary layer depth, surface fluxes, temperature and wind vertical profiles
  - Can be used for many other studies
- Currently 3 months of WRF simulations are complete
- FLEXPART simulations are cheaper to run but need to wait until the WRF simulations are ready
- Currently 3 month FLEXPART simulations are ready.

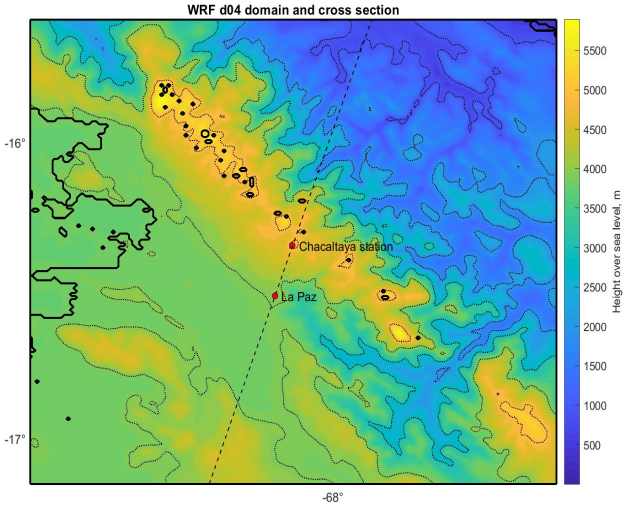
Preliminary results based on 3 months are now presented

WRF output example: 10-m wind speed (vectors)



Example of WRF output: Turbulent Kinetic Energy (TKE) and BL depth





Cross section of TKE and BL depth from La Paz to Chacaltaya.

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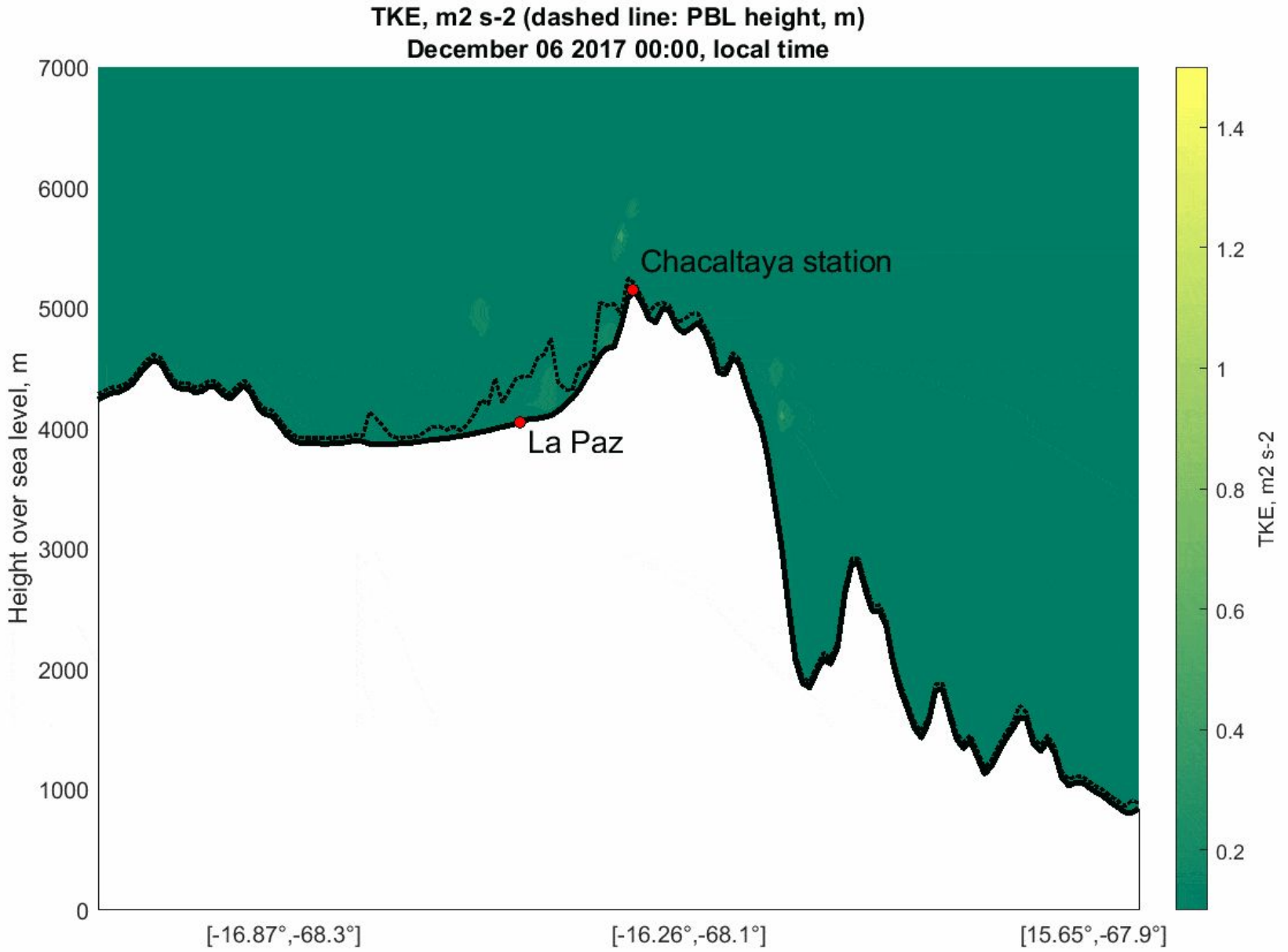
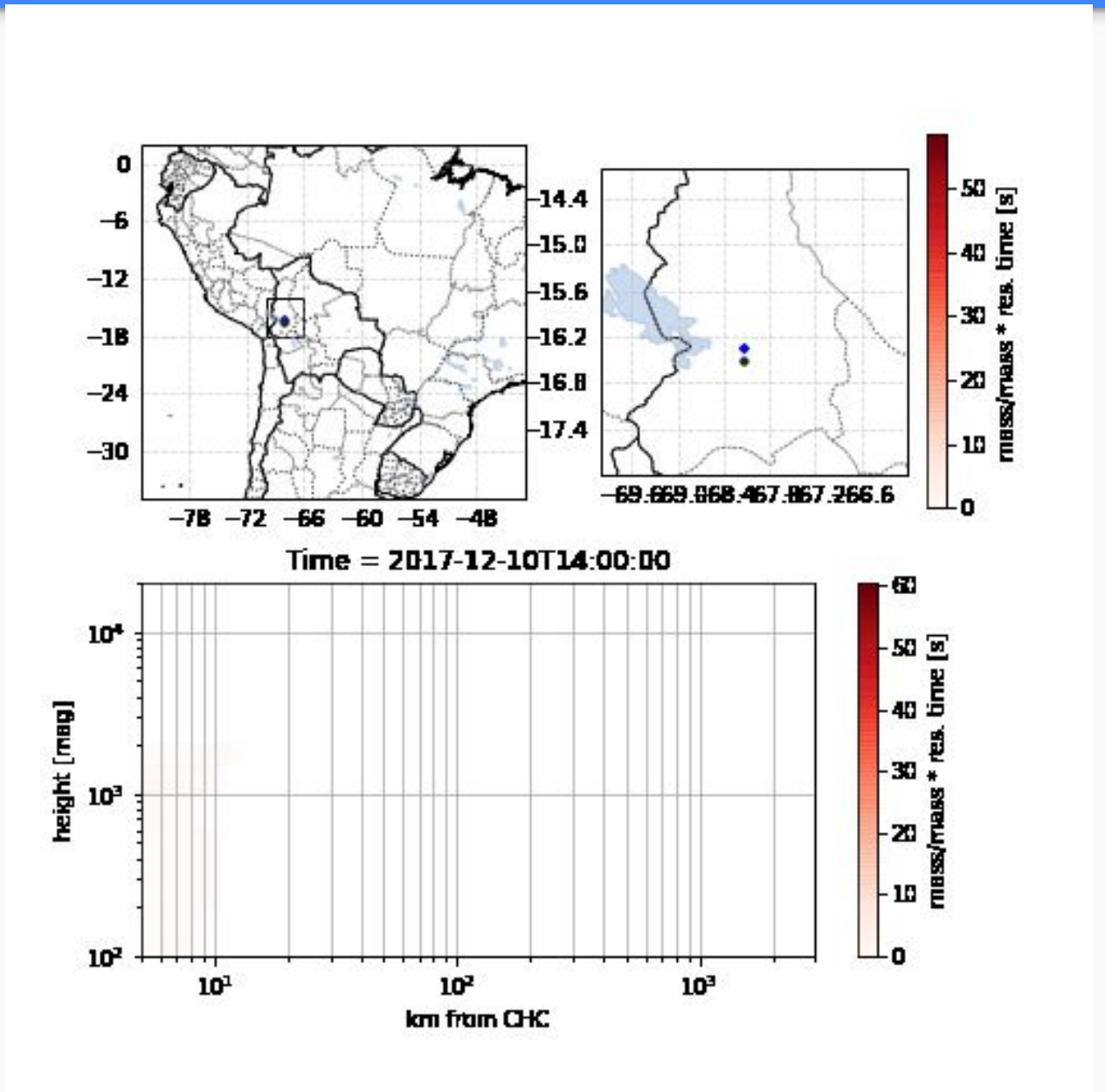


FLEXPART output - one example from one release

96 hour backward run starting at CHC.

- Lower Center: height above ground [m]
- Logarithmic scale!

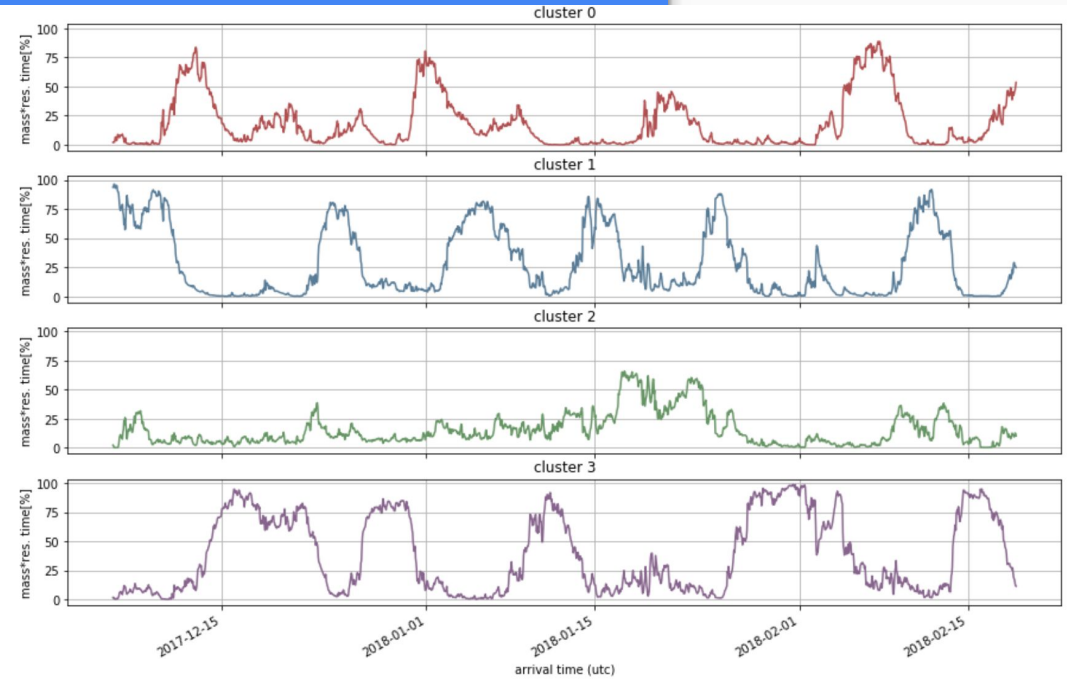


Planned diagnostics to share with others

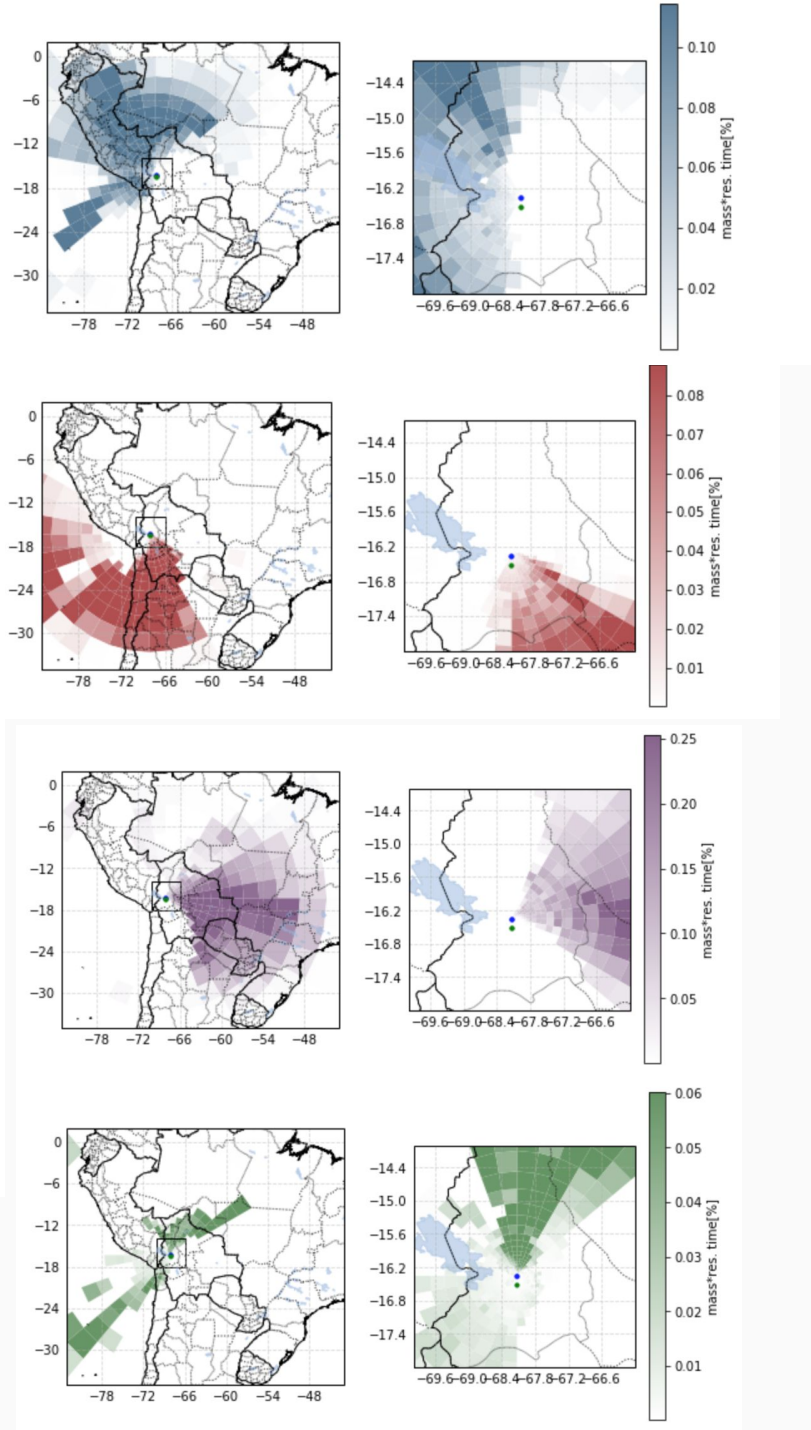
- Animations of particles spreading out look really nice but are not easy to quantify, use in other studies
- Plan to use a similar analysis method to that used before with Hysplit trajectories
  - Interpolate FLEXPART to a polar grid centered on CHC
  - Use the 96 hour integrated response time
  - Apply automated clustering
- Once the 6 month analysis is done. Final clusters areas + time series of influence will be shared.
- Special case studies can also be done for particular time periods.

Clustering Analysis on FLEXPART output

- General picture:
  - 4 clusters



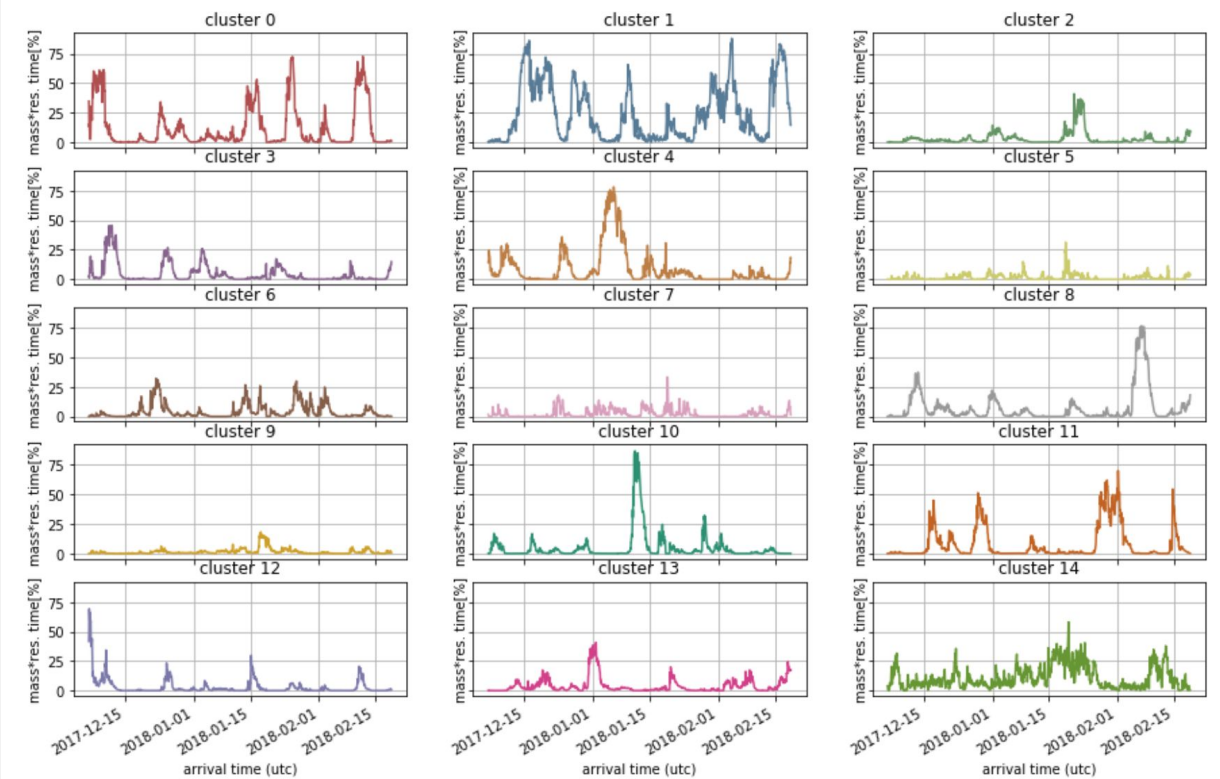
Note different colour scales on the right



More info at:
https://github.com/daliagachc/flexpart_management/blob/master/flexpart_management/notebooks/run_2019-06-10_11-10-03_/flex_output_4%20clusters.ipynb

Clustering Analysis on FLEXPART output

- Detailed picture:
  - 15 clusters



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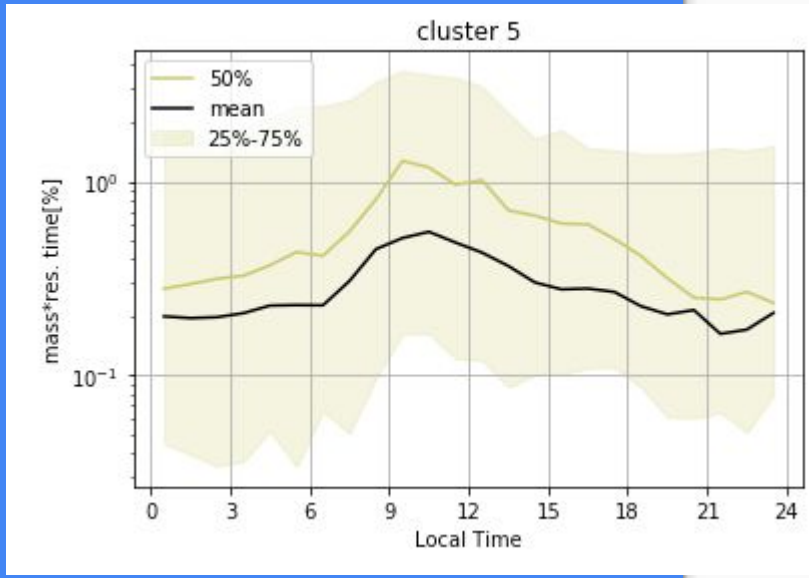
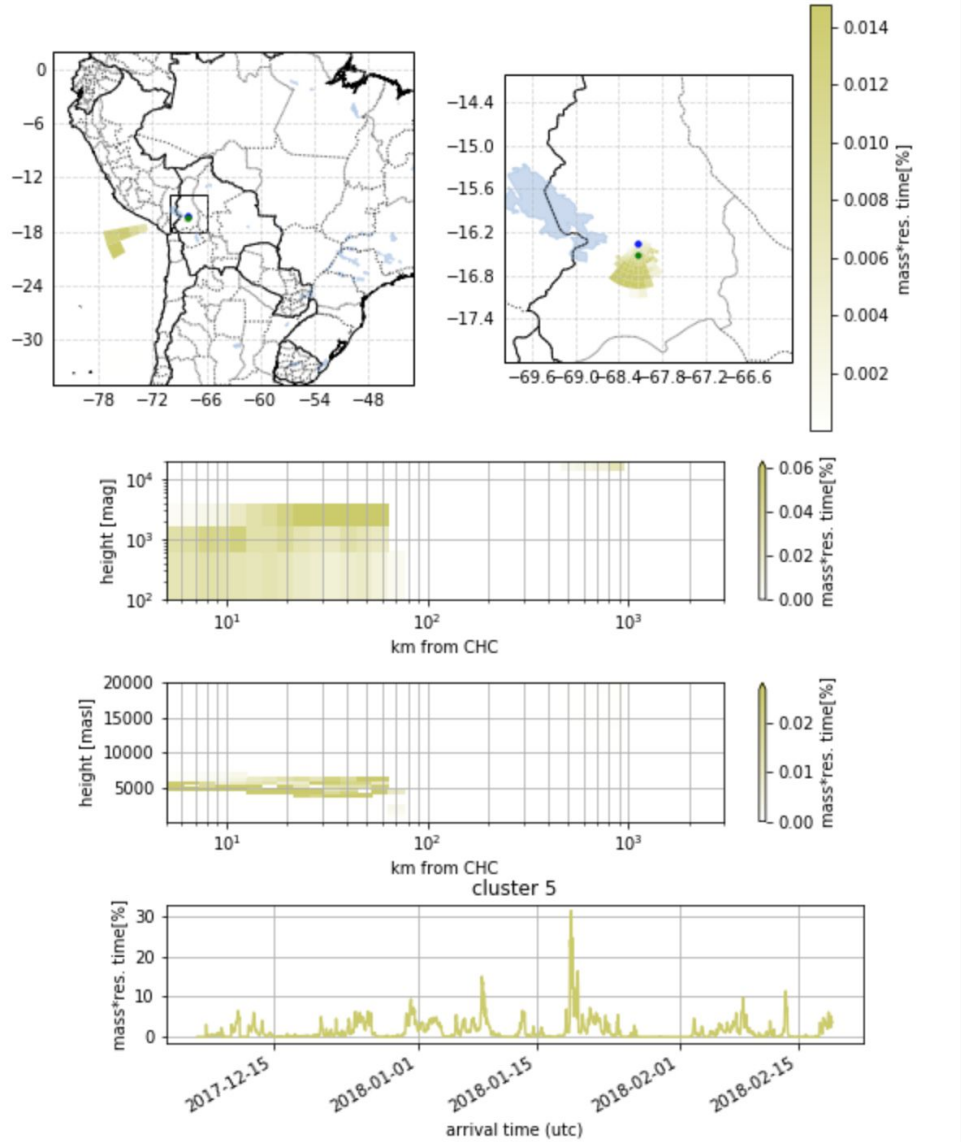
Clustering Analysis on FLEXPART output

- La Paz Cluster (from 15 clusters)





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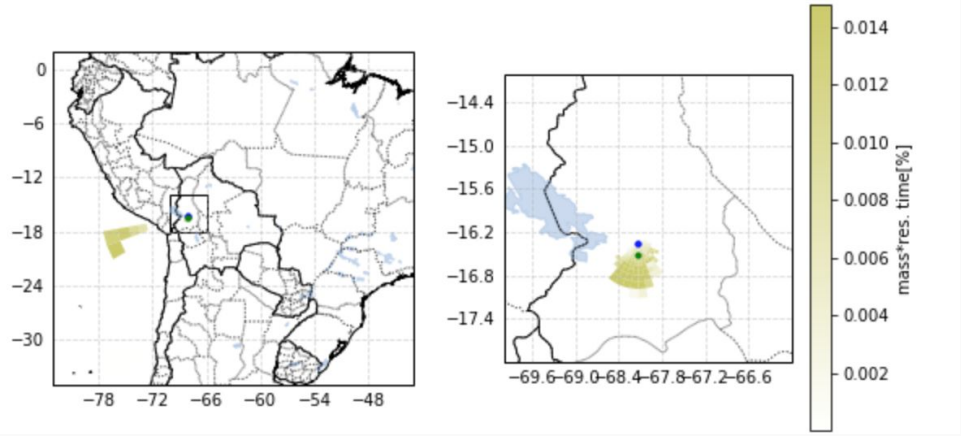
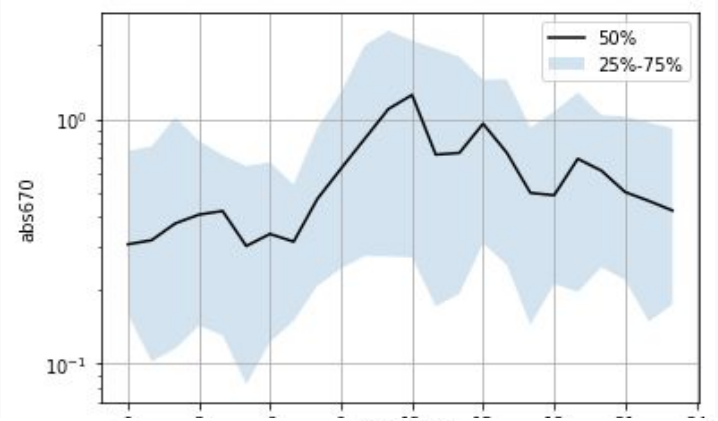
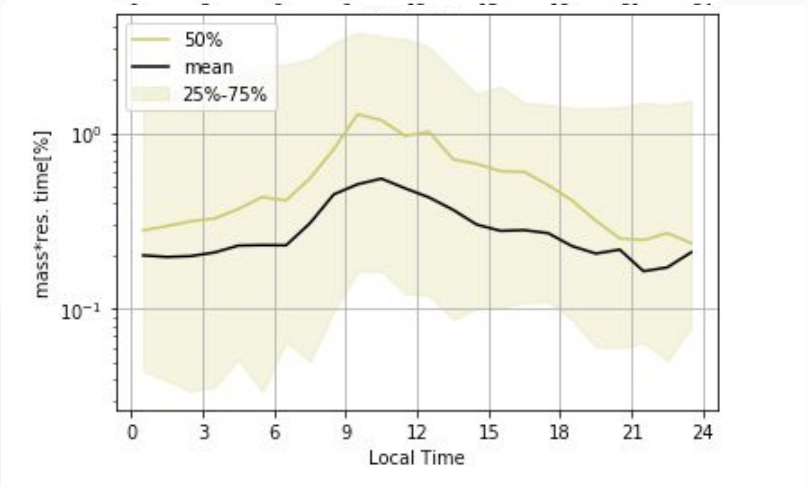
Clustering Analysis on FLEXPART output

- Comparison abs670 at CHC (~bc from MAAP) to La Paz Cluster
- Double peak in BC due to rush hour in La Paz







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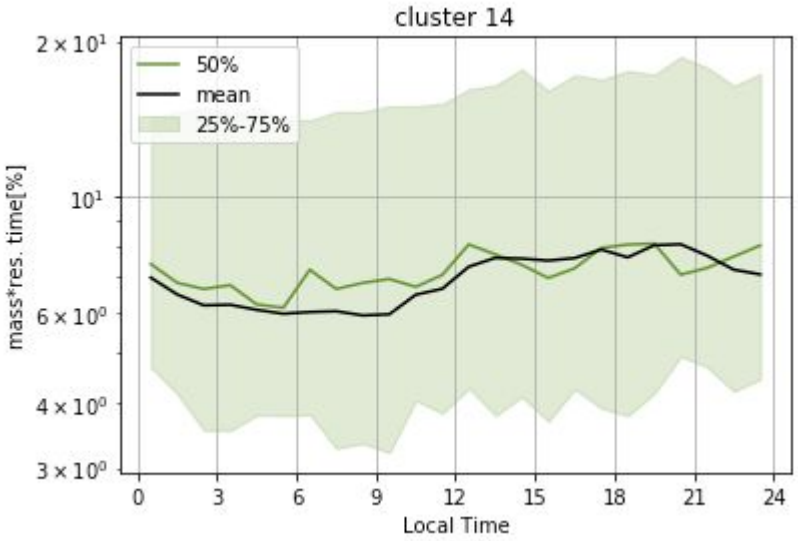
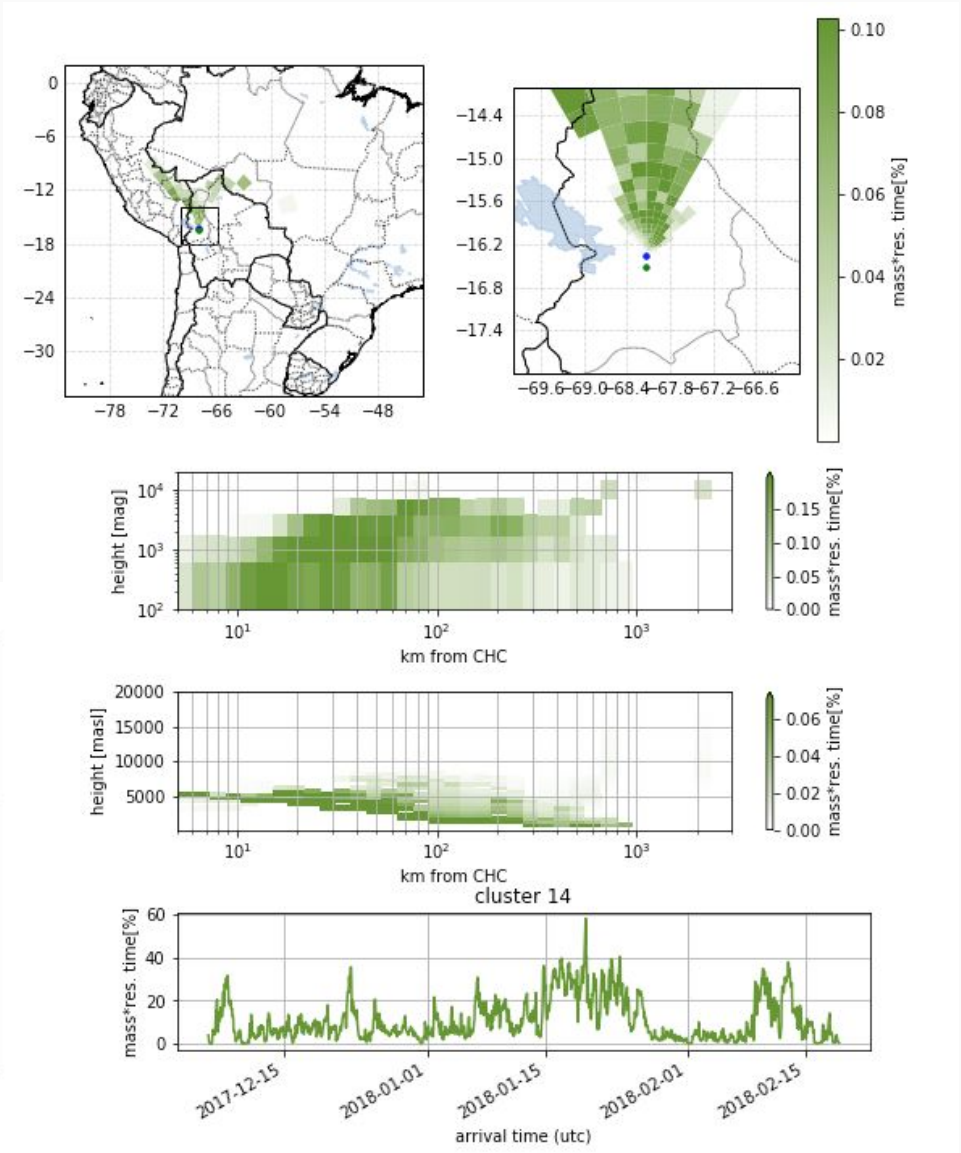
Clustering Analysis on FLEXPART output

- Low Lands North Cluster (from 15 clusters)





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Preliminary Conclusions

- The WRF simulations now provide a reliable estimate of the meteorology
  - Not perfect, some biases at night in stable conditions.
- The clustering method is effective at reducing the huge data volumes to a user friendly data set.
- Air arriving at Chacaltaya arrives from all sectors during the 3 month period.
- Diurnal pattern of air masses arriving from La Paz is resolved and resembles measurements of black carbon.

Some Comments

- **Results are preliminary** - 3 months is a relatively short time.
- Data available now via github (see links) can be used for initial analysis but you will need to repeat the analysis in ~1 month with the final data set
- Response function from FLEXPART will be available every hour
  - Contains much more detailed information
  - Useful for case studies.
- Specific requests for “unique” / specialised data should be directed to Diego via github (add an issue)

Future plans

- Clustering needs to be repeated once all WRF simulations are complete
  - WRF simulations will finishing running in ~10 days
  - FLEXPART simulations + cluster analysis expected to take ~20 days.
- Distribute final data set to others when it is ready
- Start preparing a manuscript which
  - Describes the methodology, diagnostics and data set.
  - Quantifies where air masses arriving at CHC originate from in a horizontal and vertical sense
  - Assesses correlations between source regions and local wind direction
- Publish the data set / obtain a DOI for the data so it can be cited correctly.

Paper aim

Quantify the source regions of air arriving at CHC using both meteorological and surface type clusters and ascertain the relative contribution of boundary layer, shallow convection layer and free tropopshere air.

Quantify the source regions of air arriving at CHC using surface type clusters and ascertain the relative contribution of boundary layer, shallow convection layer and free tropopshere air. Identify the large-scale synoptic conditions associated with each of these clusters.

Link synoptic patterns to the geographical clusters.

Role of shifting Hadley Cell, ITCZ

Thank you

Example of WRF output

Cross section of TKE and BL depth from La Paz to Chacaltaya + map of location. + static plot of TKE from one time when the PBL is deep

TKE = turbulent kinetic energy