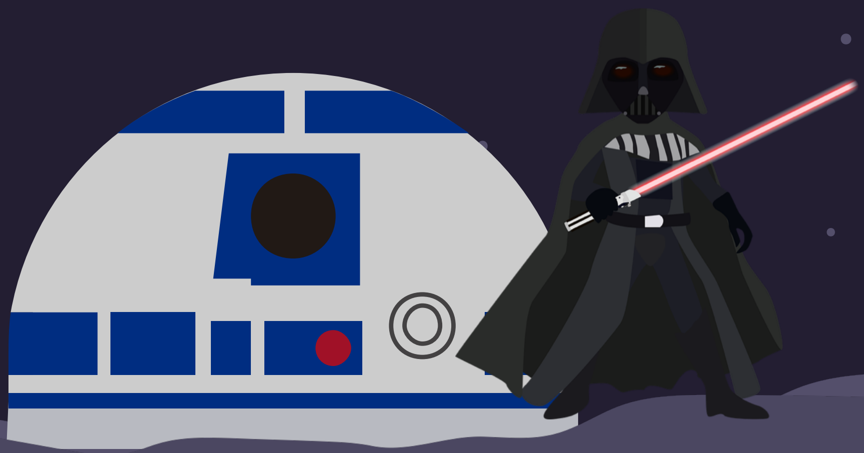
Tell me where and when, can I tell you your Na?

Pierre Haguenauer, Ron Holzlöhner



May the Na be with you

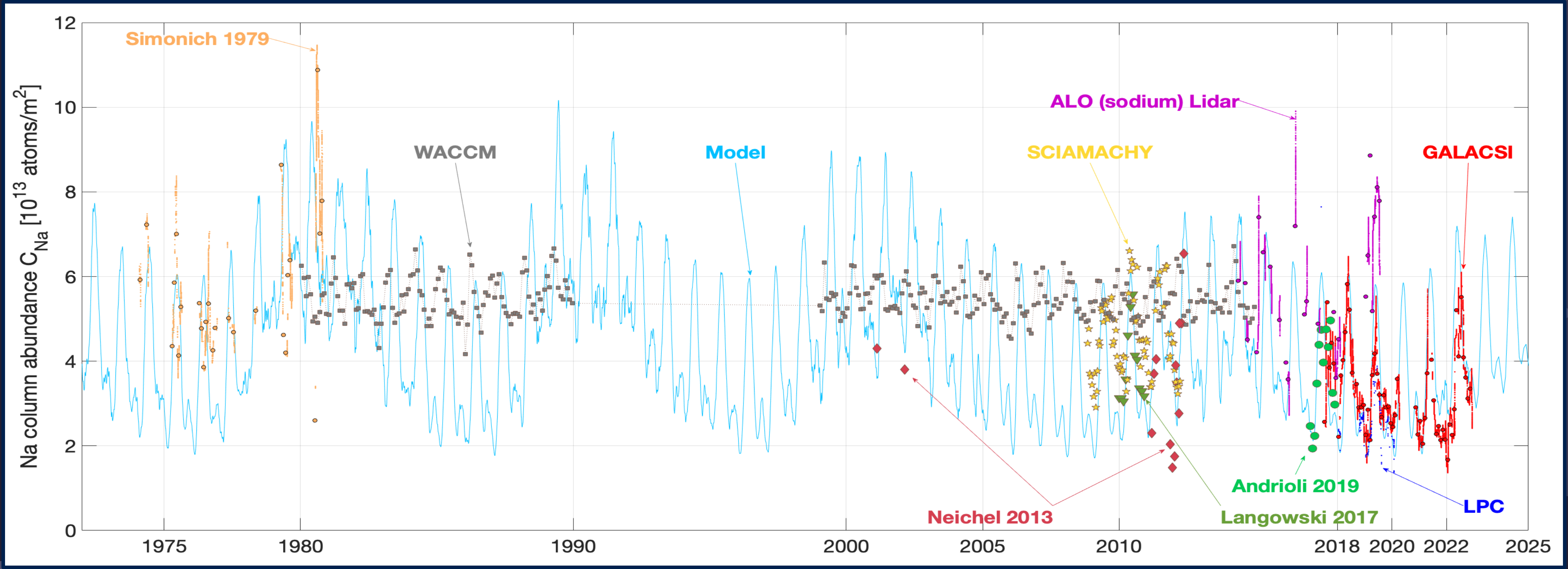
1. Why trying to set a model of Na?
2. Na density at Paranal latitude
3. Getting more data for a global Earth model
4. Yearly model
5. Sun cycle
6. Conclusions

Prediction and model, why?

- AO developments are often using one number of return flux for LGS, with some boundaries.
- Short-term, medium-term, long-term evolutions not much integrated. Partly due to lack of data in the AO instrumentation community.
- Instruments developments take 10+ years, with then operation for 15+ years. Long-term variations are important.
- Optimisation of night planning knowing the possible return flux in coming weeks/months.
- Observatories at different locations on Earth; need to consider also this parameter.
- Can we develop a SW program to predict the Na column abundance and its standard deviation as a function of the following parameters:
  - Latitude, longitude.
  - Day of the year.
  - Year (capture the influence of the Sun cycle; climate change? Other effects?).

Desperately seeking data @ 23S

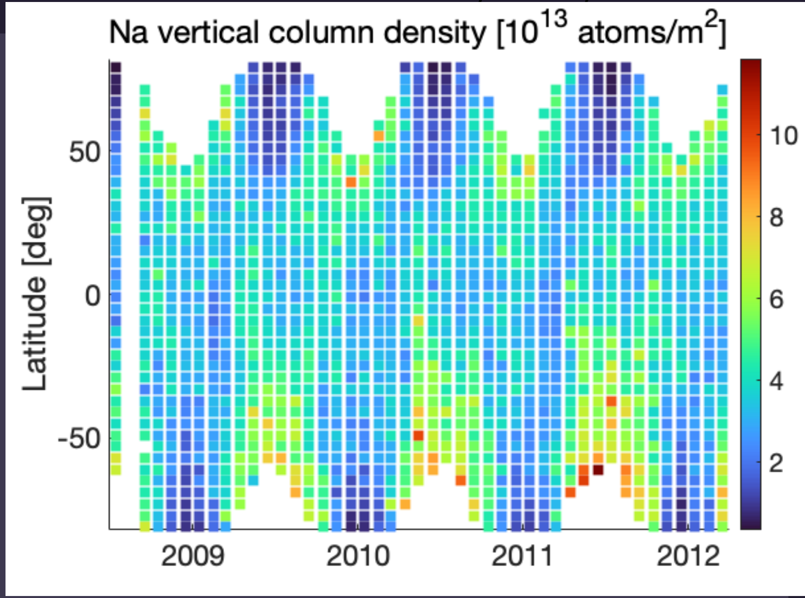
- Mix of data found:
  - From observatories: GALACSI/GRAAL + LPC, Haguenauer+ 2022, Paranal; Neichel+ 2013, Gemini, Cerro Pachón.
  - From LIDARs: Simonich+ 1979, São José dos Campos, Brazil; ALO sodium Lidar, Cerro Pachón.
  - From atmosphere studies: SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography); Langowski+ 2017; Andrioli+ 2019.
  - From atmosphere models: WACCM (Whole Atmosphere Community Climate Model).

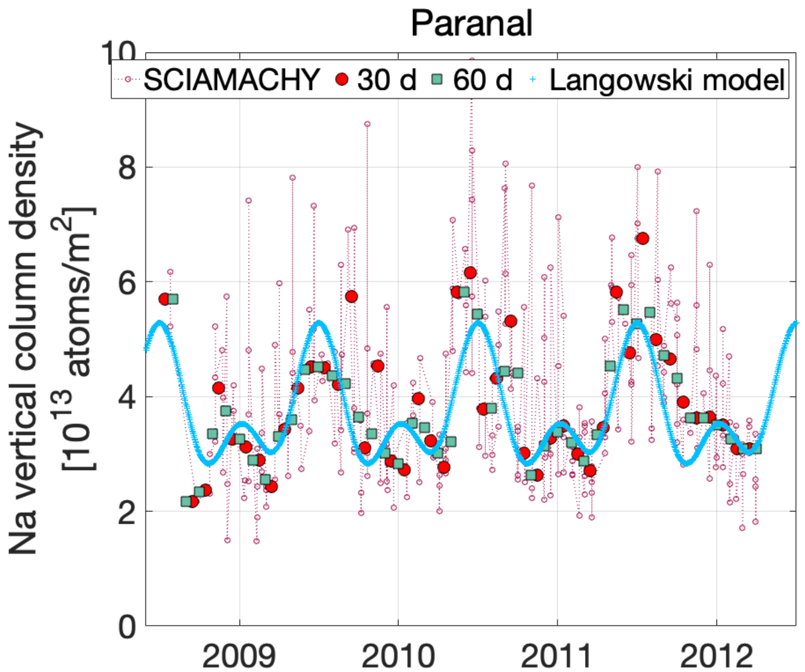


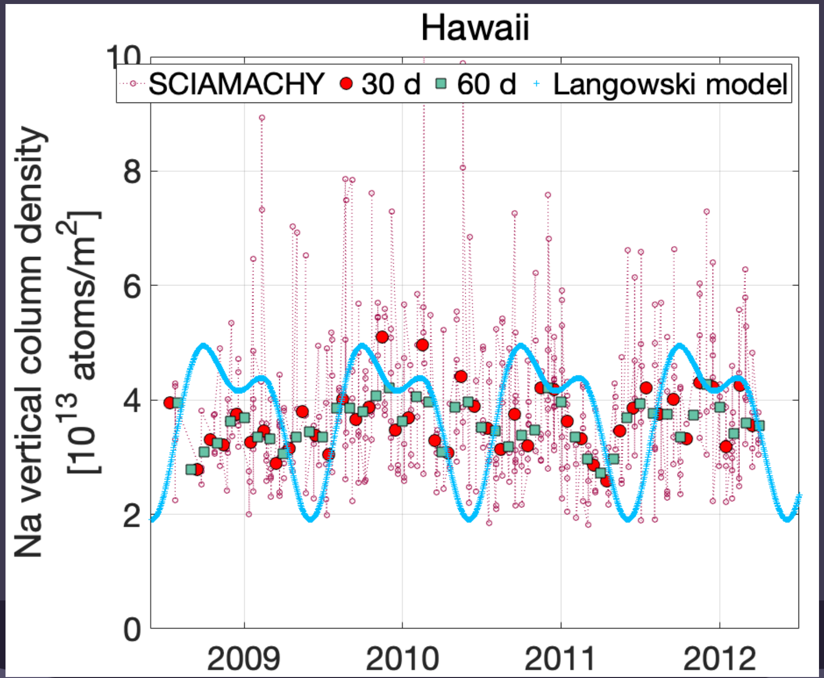
Satellite Data

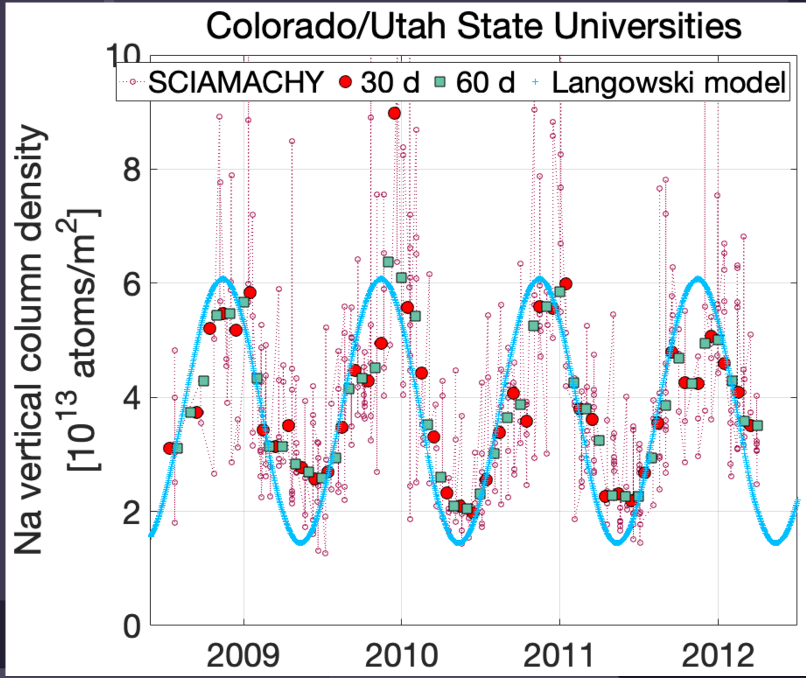
- SCIAMACHY (SCanning Imaging Absorption spectrometer for Atmospheric CHartographY) instrument on ESA's environmental research satellite ENVISAT. Measurements twice per month for a full day each, between 75km and 150km.
- Langowski model based on SCIAMACHY, GOMOS and OSIRIS satellite data.

Day of the year



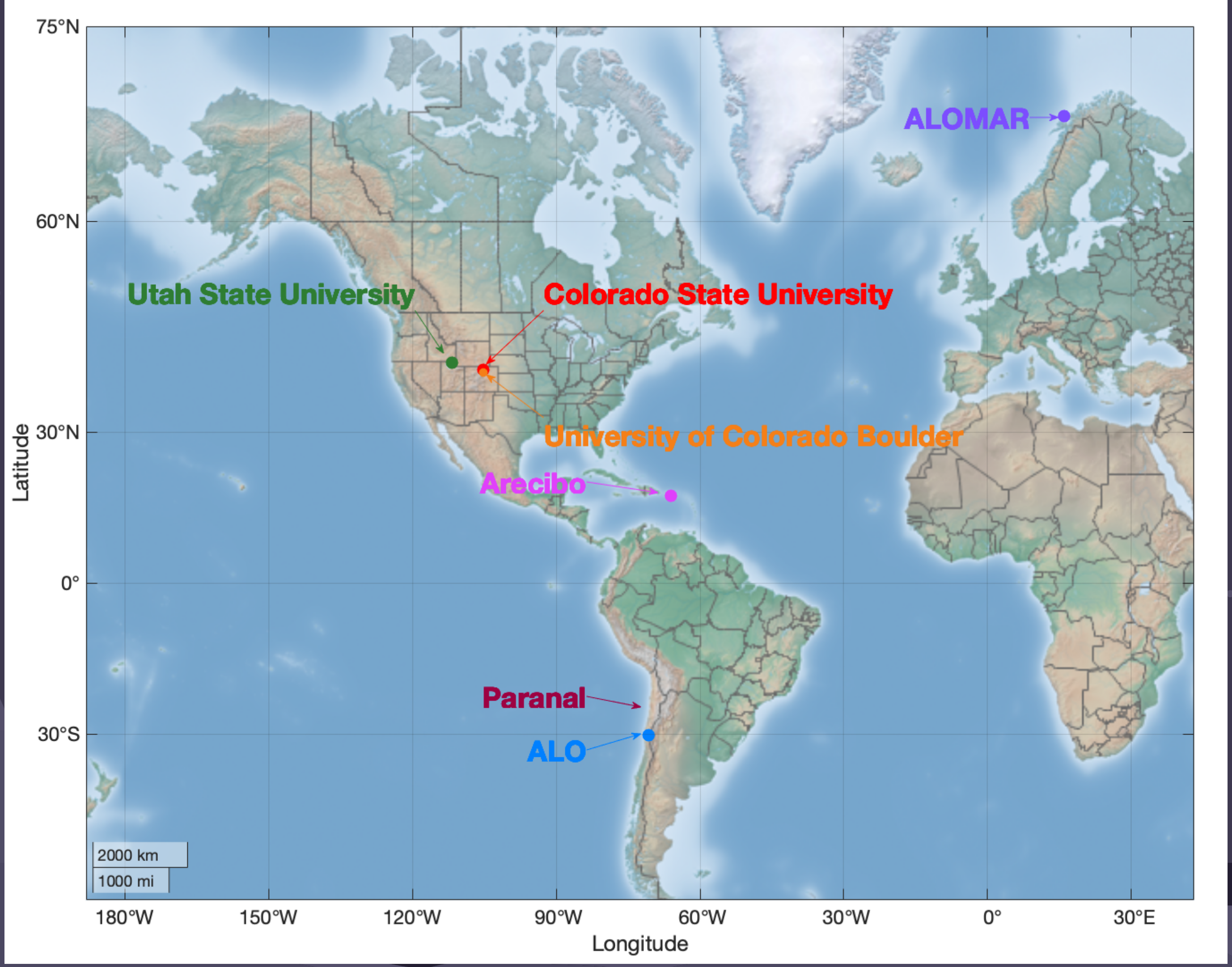






Lidar

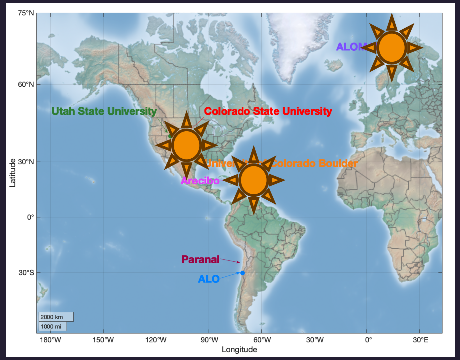
- Important database of LIDAR data exists. Publicly available.
- Very different locations on Earth.
- But time coverage and frequency of measurements very variable between locations.

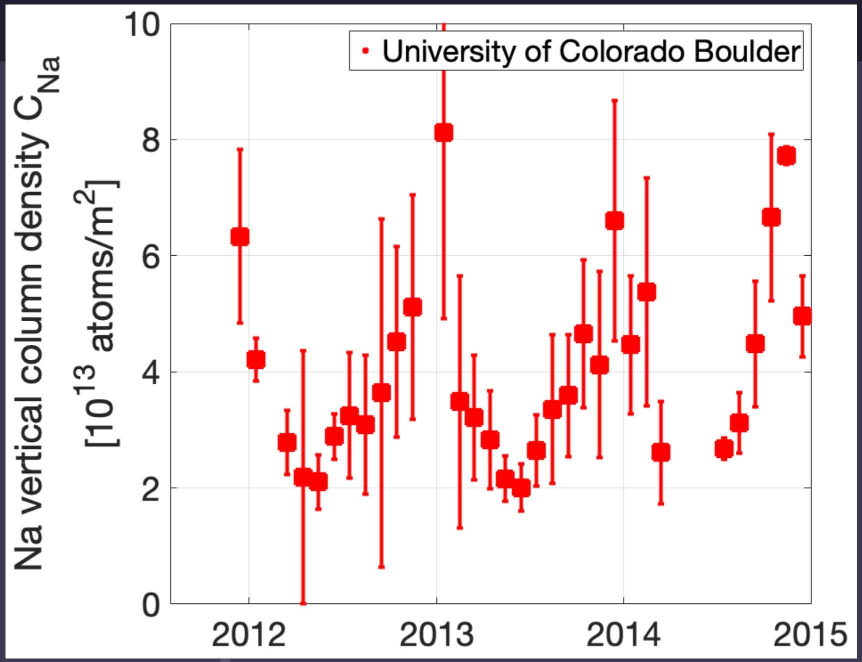


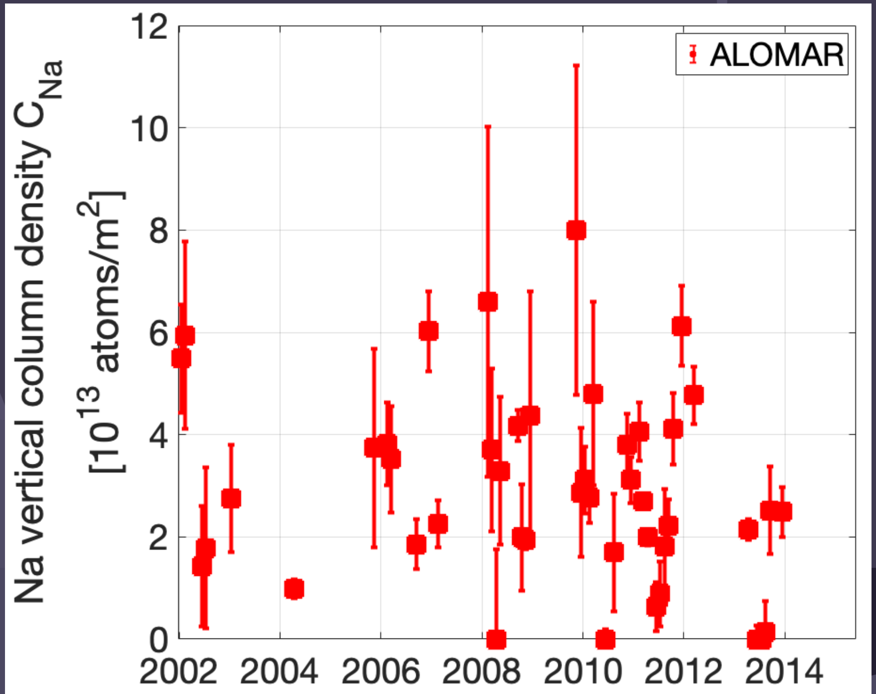
Data coverage?

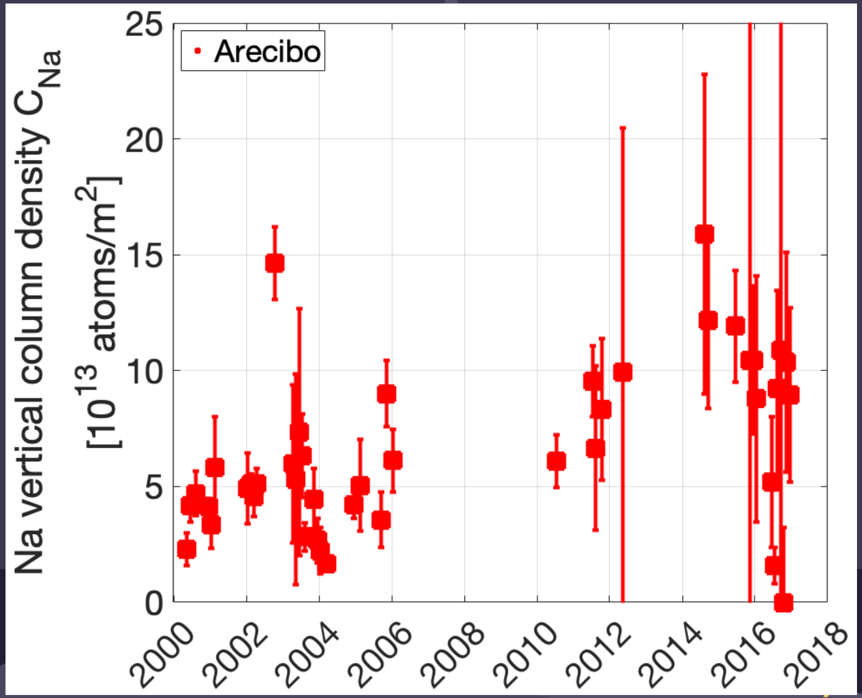
LIDAR data

- ALOMAR: Covering a good range of time, but only few measurements.
- ARECIBO: Covering a good range of time, but only few measurements.
- UCB: Good amount of data, but not covering a big range of time. Not enough time range to fit a Sun cycle.



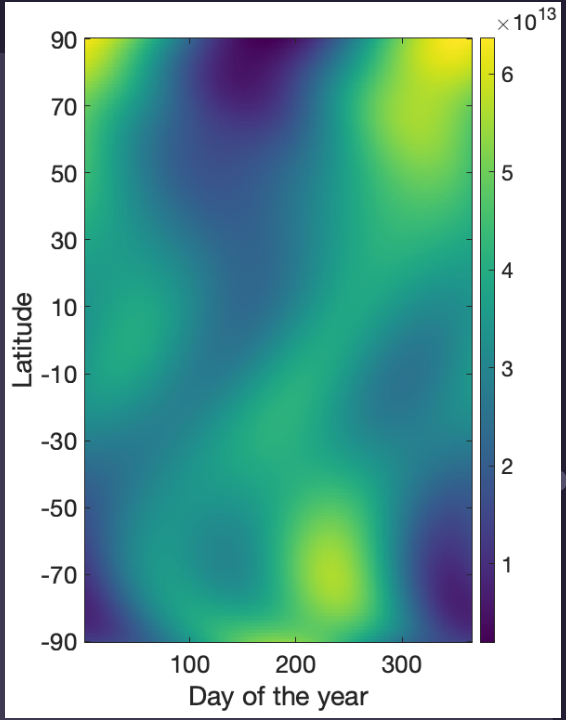


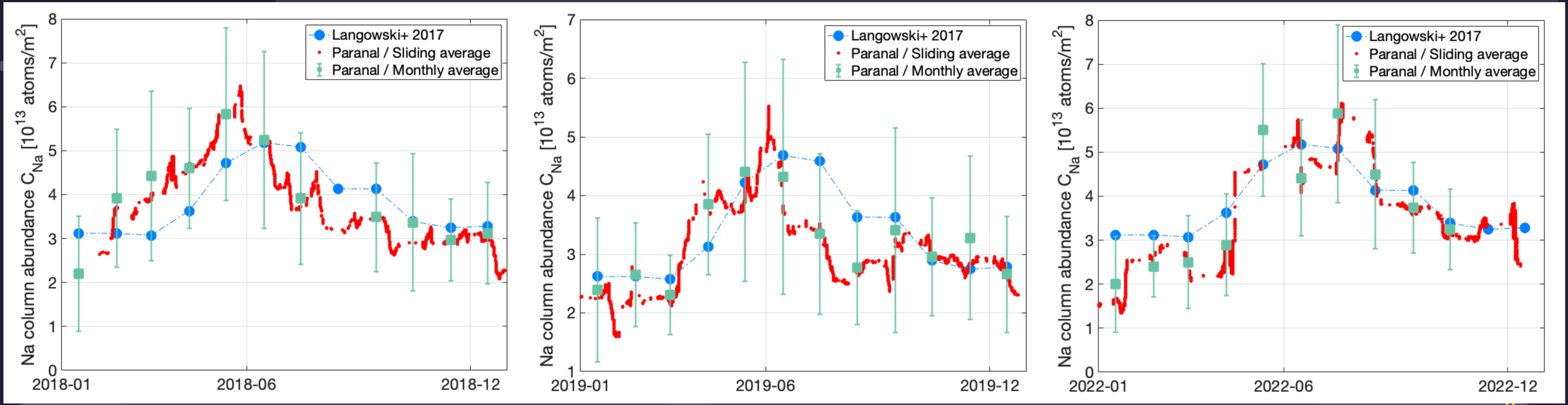




Yearly modeling

- Yearly semi-empirical model from Langowski+ 2017. Global level of the model adjusted to reflect the global one of Paranal each year. Comparison for three complete years of Paranal measurements:
  - 2018: similar evolution but Paranal trend in advance of phase to the model.
  - 2019: increase of the Na coherent with the model but decrease starting earlier.
  - 2022: good match.
- There might be other effects in the atmosphere leading to these phasing differences.





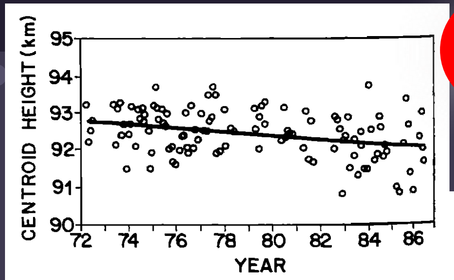
Sun cycle and Na?

But does the Sun cycle really influence the Na layer or not?

Clemesha+, Geophysical Research Letter, 1992.

Lidar data: 1972-1987

- No measurable solar cycle effect.

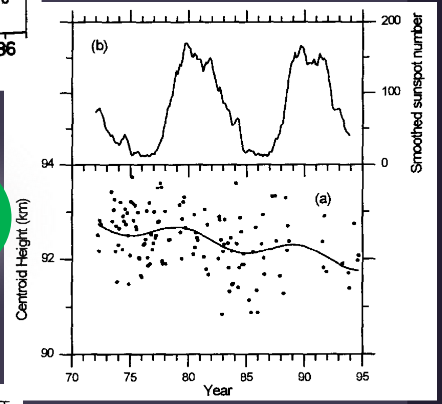


No

Clemesha+, J. of Atm. and Solar-Terrestrial Physics, 1997.

Lidar data: 1972-1994

- 10-year solar cycle effect on the change of centroid height with an amplitude of 170+/-110 m.

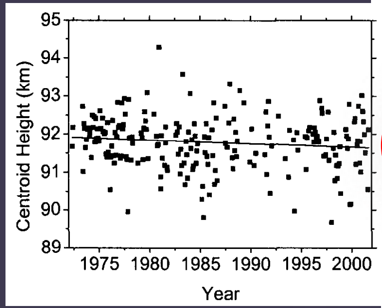


Yes

Clemesha+, Adv. Space Res., 2003.

Lidar data: 1972-2001

- Negligible amplitude for an 11-years fit on the centroids data.
- Important month to month variations of the centroid heights, but no long-term trend.



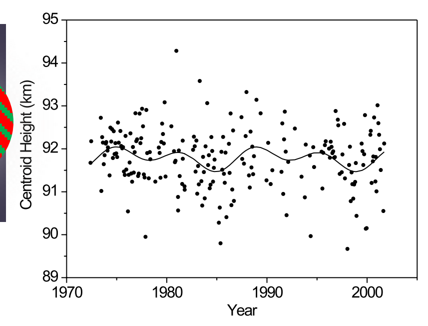
No

Clemesha+, J. of Geophysical Research, 2004.

Lidar data: 1972-2001

- Fit with 7- and 14-years harmonics, with amplitudes of 182+/-95 m and 145+/-94 m.

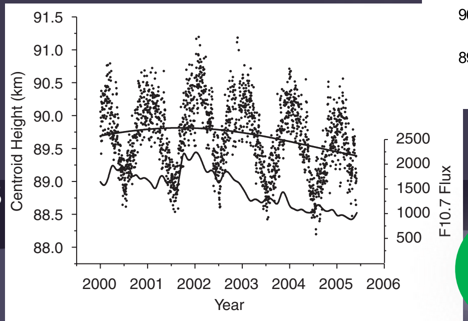
Yes but No



Clemesha+, J. of Atm. and Solar-Terrestrial Physics, 2006.

Meteor radar data: 2000-2005

- Evolution of height distribution of meteor trails shows an 11-years trend, amplitude of 540 m.



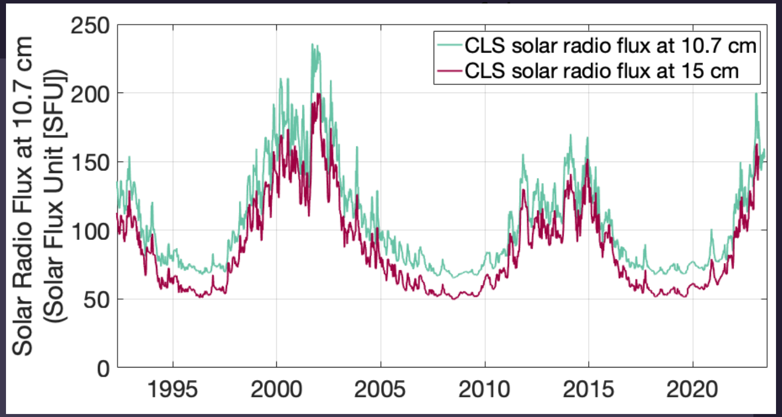
Yes

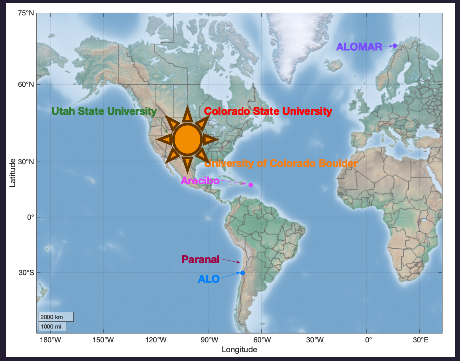
Sun cycle effect.

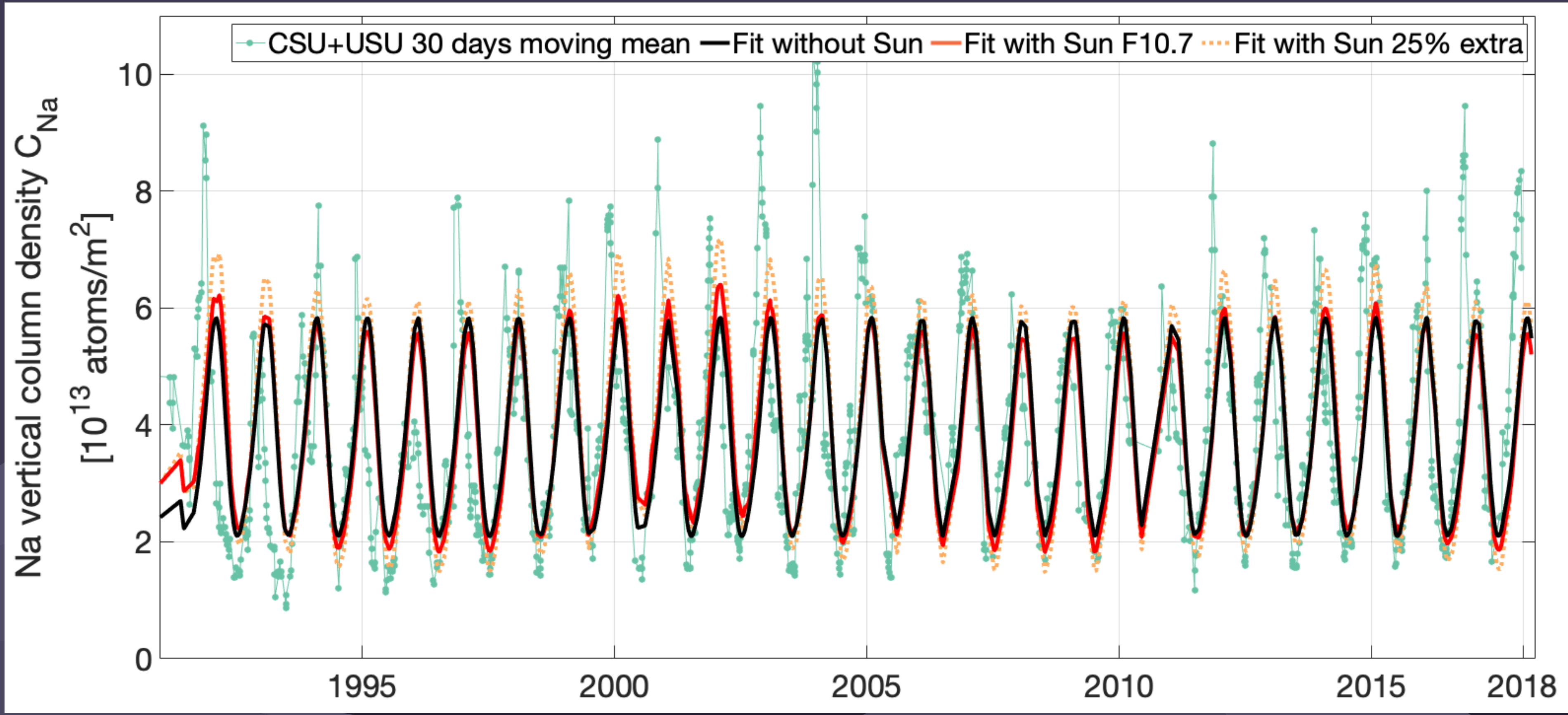
- Fit including annual, semi-annual, and Sun cycle effects:

$$Na_{fit} = \alpha + \delta\, F_{30} + A\cos(2\pi t + t_2) + B\cos(4\pi t + t_4)$$

- With F30 the 30 days moving average of the solar radio flux at F10.7cm (in FSU).
- Fitting gives a relative sensitivity to the Sun cycle of **16.5% per 100 SFU**.

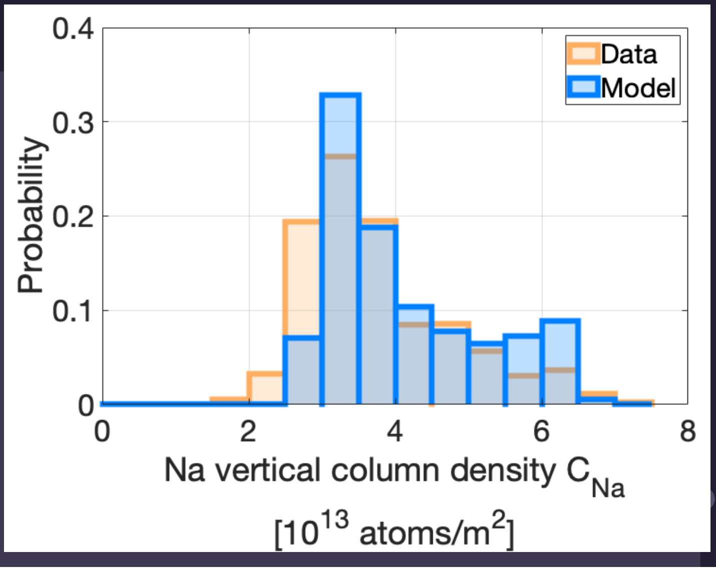


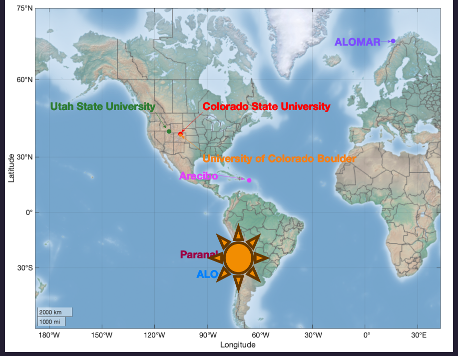


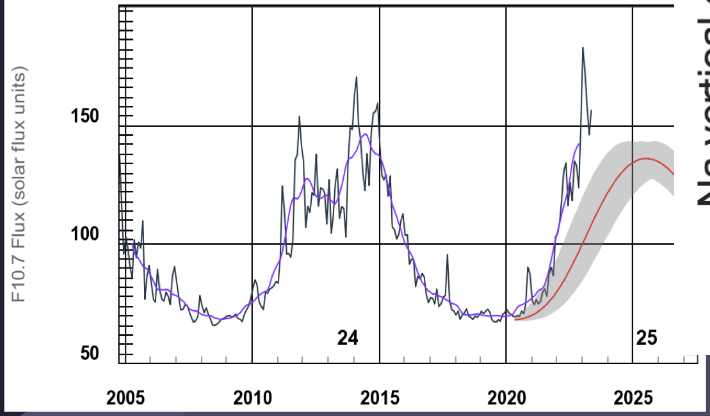


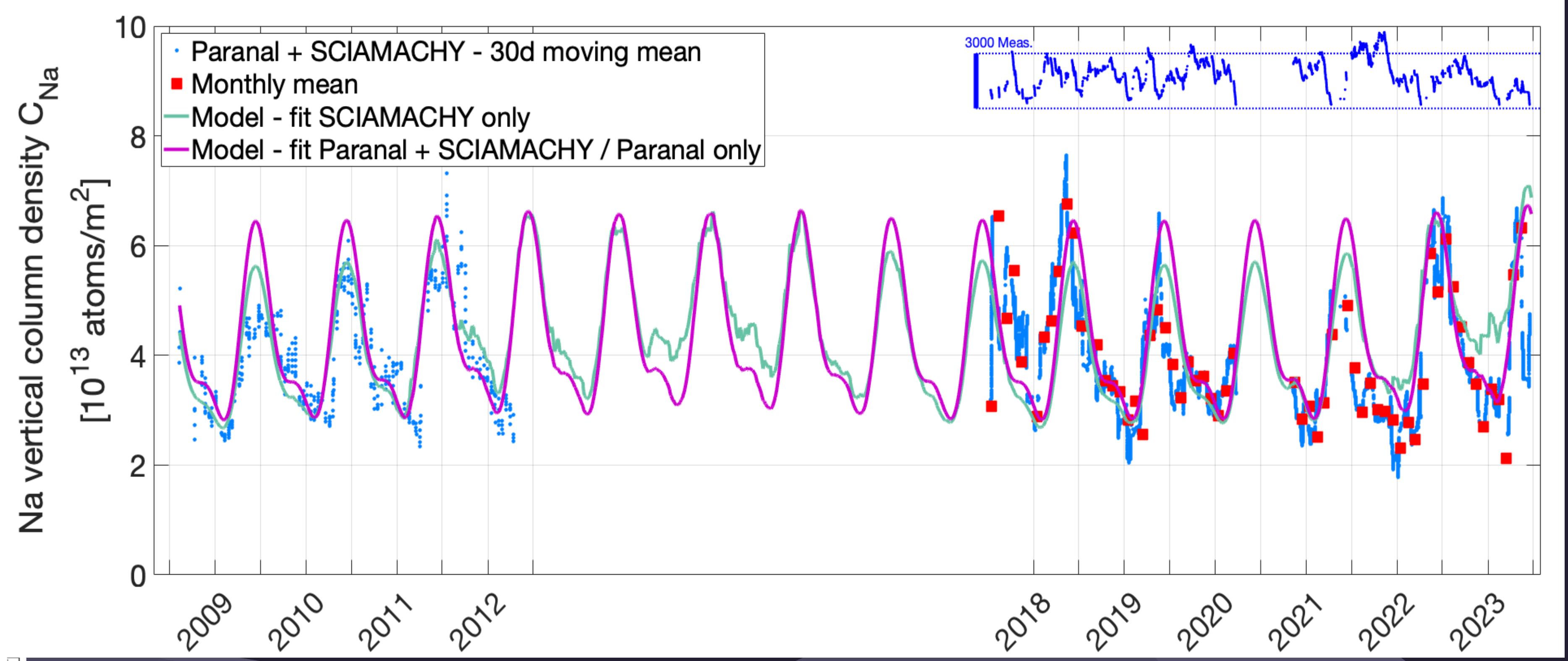
Sun cycle effect @Paranal latitude

- Can we derive the Sun cycle effect into a model for the Paranal latitude with a shorter time coverage?
- Paranal and SCIAMACHY data for 23S combined.
- Same model for the fit as the CSU+USU data. Weights for fitting between high and low Na adjusted due to incomplete Sun cycle.
- Fitting gives a relative sensitivity to the Sun cycle of **9% per 100 SFU (45% per 100 SFU if fitting SCIAMACHY only).**

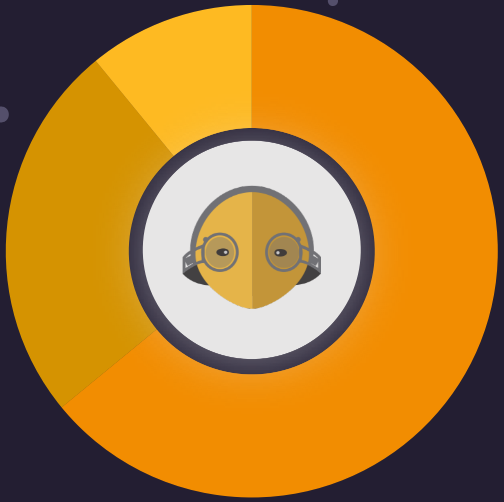








Conclusions



- Na density can be retrieved from AO telemetry data. Automatic logging allows generating a very good dataset.
- More data sets available from other observatories, LIDAR measurements, Earth atmosphere observation satellites. But it is not always easy to combine the datasets and be sure they compare.
- Annual and semi-annual models in good agreement with measurements, available for all latitudes.
- Sun cycle influence found in some data set around the world, but not much reported and quantified.
- Computed Na column abundance matches atmosphere studies:
  - Seasonal variations linked to temperature
  - 11 years cycle correlated to Sun activity
  - Semi-annual variations linked to dynamic and chemistry of the Mesosphere
- Many more effects can affect the Na density: Meteor showers, gravity waves propagation in the atmosphere, sudden stratospheric warmings, anomalies in the Earth magnetic field, global warming, ...
- Statistics of Na density available for development of future instruments.

Thank you!

This is the LGS way...