



Ariel 1st Italian WorkShop

Rome Oct 2nd - 3rd, 2018

ARTECS:

the

Trieste Exoclimates Archive

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A. Provenzale⁽³⁾, L. Silva⁽¹⁾, G. Taffoni⁽¹⁾, J. Vladilo⁽¹⁾, S. Zorba⁽¹⁾

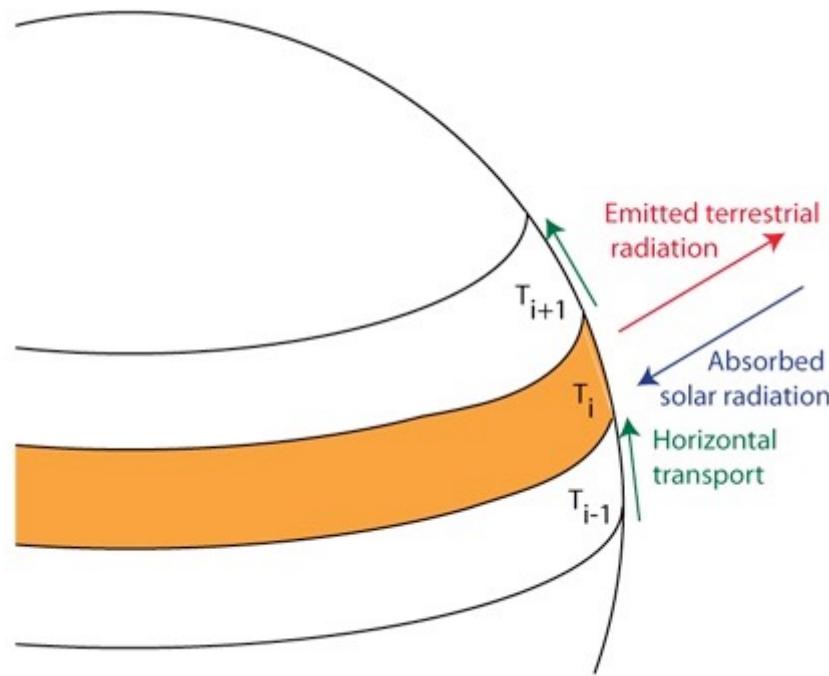
⁽¹⁾INAF/ Trieste Astronomical Observatory

⁽²⁾CNR / ISAC-Torino

⁽³⁾CNR / IGG - Institute of Geosciences and Earth Resources, Pisa

<http://wwwuser.oats.inaf.it/exobio/climates>

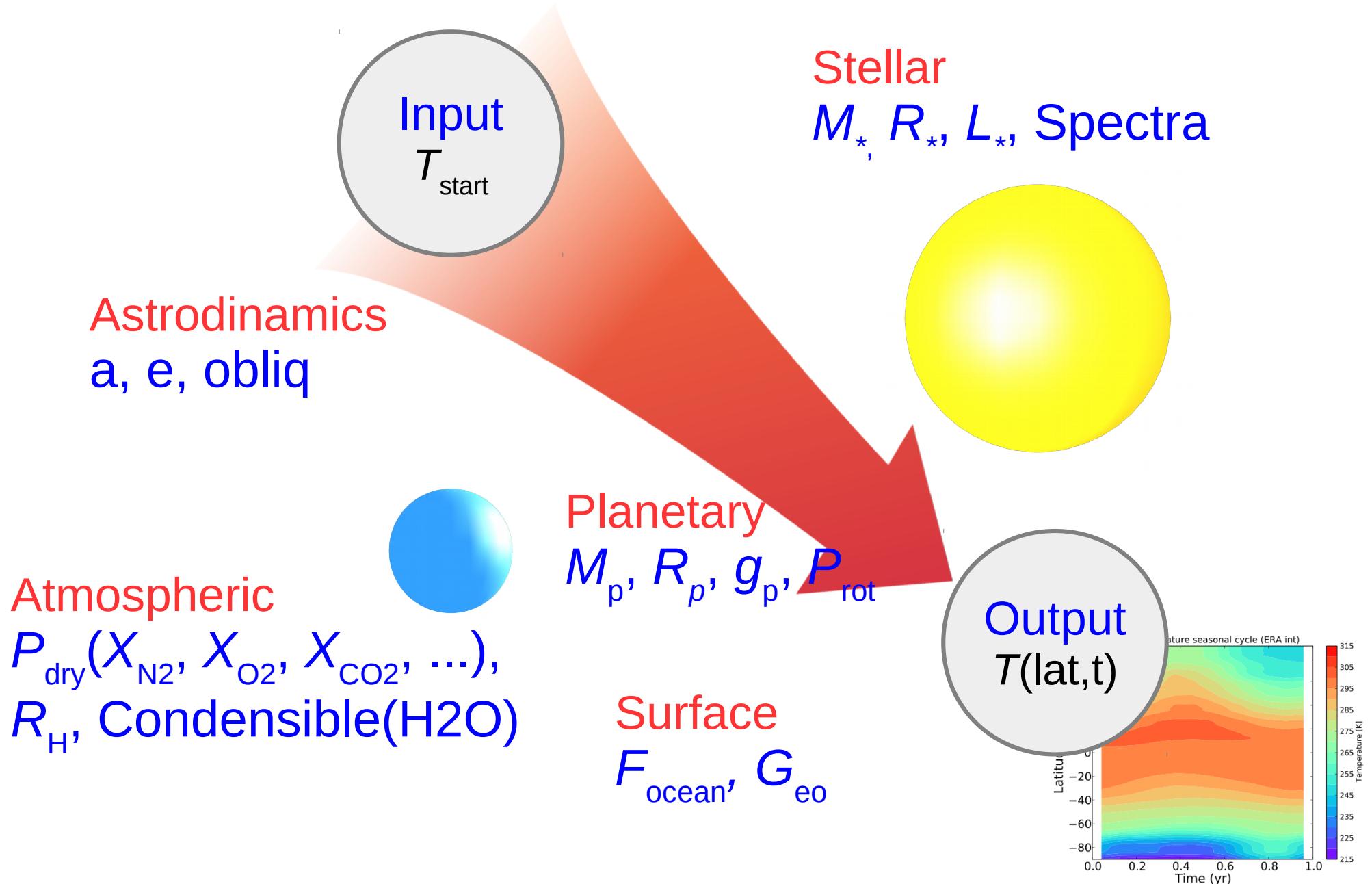
Earth Like Surface Temperature Model (ESTM)



- ESTM (Vladilo et al. 2013, 2015):
 - 1d model (lat) + time dependence (orbital motion)
 - EBM calibrated on 3D Global Circulation Models (GCM)
 - Radiative equilibrium
 - Long v.z. short wave radiation transport
 - Meridional transport
 - Albedo accounts for: surface A., radiative transport in a column => top of atmosphere albedo
 - Accounts for distribution of “continents” (rock outside ocean) and ices (distribution parameter)

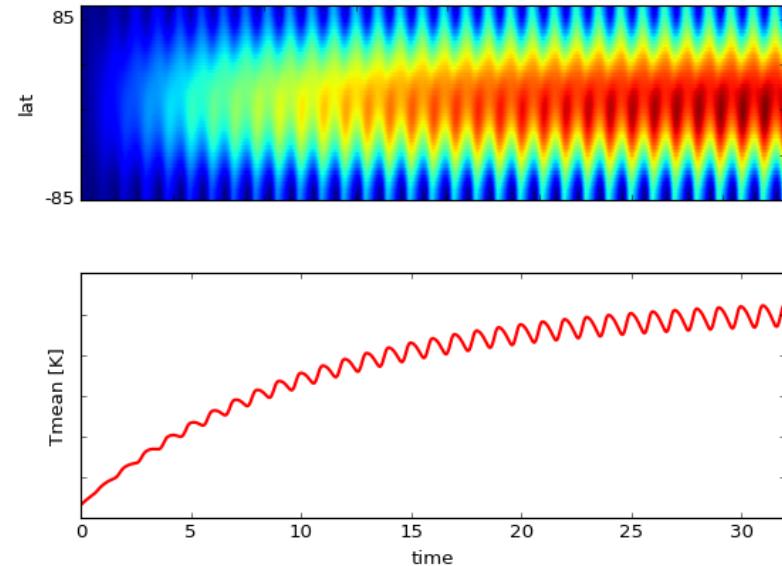
<http://wwwuser.oats.inaf.it/exobio/climates>

ESTM Parameters

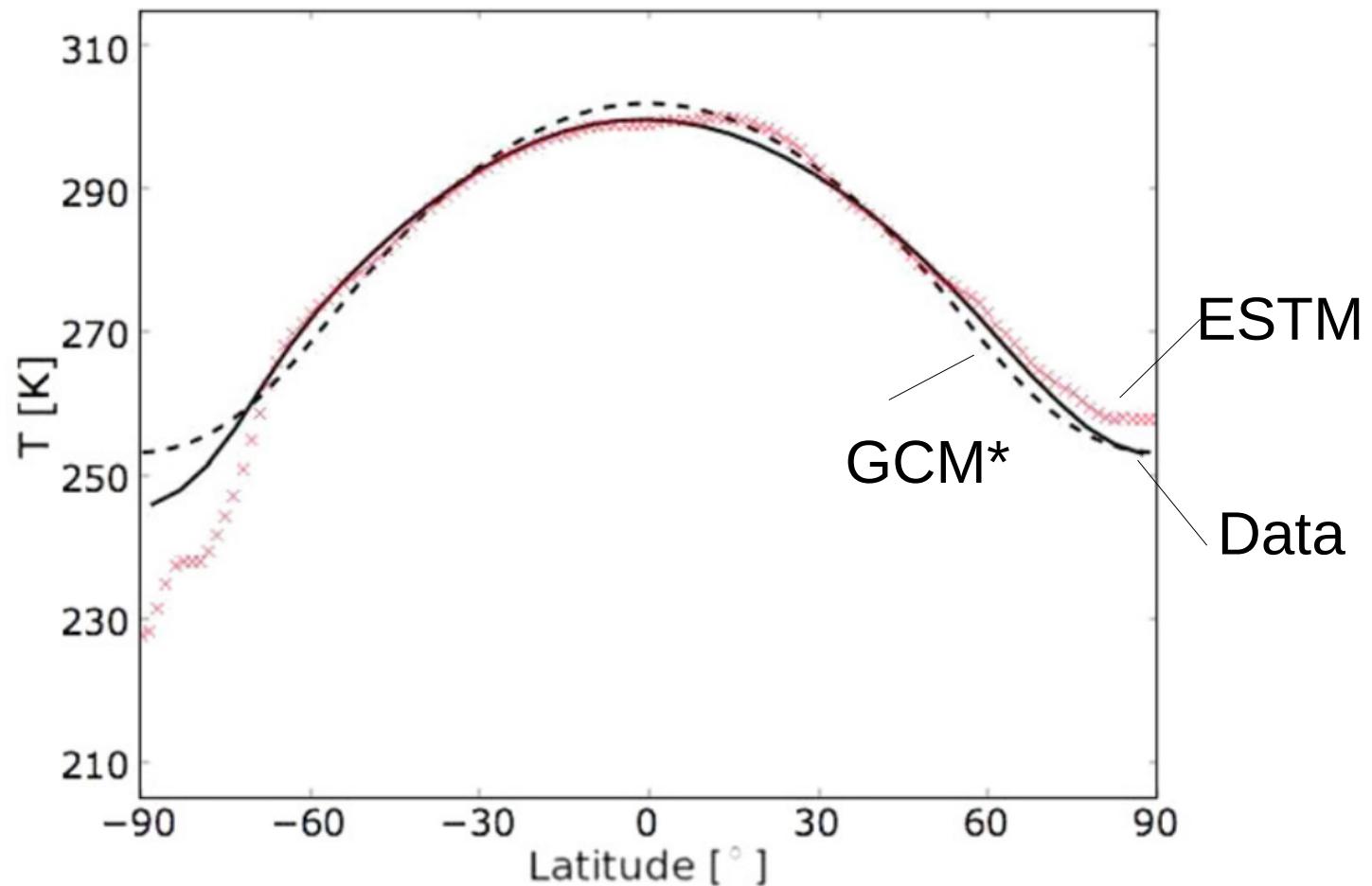


Running ESTM

- out of equilibrium
“initial conditions” for atmosphere (p_s, T_s) are taken
- ESTM model is evolved until equilibrium conditions (limiting cycle) are reached
 - $N < 150$ Orbits, 10 - 15 min
 - GCM 10^2 or 10^3 hours or more



Comparison with Earth



(*Kaspi, Y., & Showman, A. 2014,
arXiv:1407.6349)

ESTM Limitations

- Limitations (current):
 - Earth like planets (no giants)
 - Thin atmosphere
 - Condensable: H₂O
 - Obliquity < 45 deg (meridional circulation)
 - ✓ - Rotation period shorted or about one day, not tidally locked
 - No chemical evolution of atmosphere, but it is possible to play with Green House gasses, example: P_CO₂
 - ✓ - Solar like stars

Post Processing Metadata

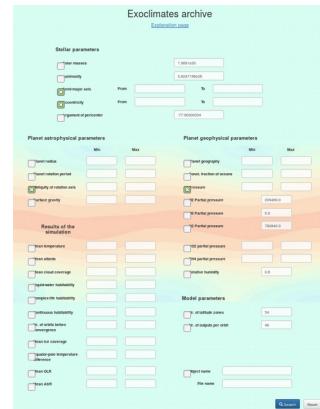
- Derived quantities from the model or statistics drawn on the model
 - Abitability parameters (already present)
 - Atmospheric optical depth (next release)
 - Extinction spectra (planned)
- As a function of model starting parameters

Link Models to Observations

The Archive

<http://wwwuser.oats.inaf.it/exobio/climates>

- Hosted at INAF IA2 in Trieste
 - Based on a systematic set of simulations produced with ESTM
 - Selecting set of simulation according to combinations of search parameters
 - Download metadata and model in form of FITS files



Download						Rows displayed	20
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Exoclimates archive

[Explanation page](#)

Stellar parameters

Solar masses

1.9891e30

Luminosity

3.8247196e26

Eccentricity

From

To

eccentricity

From

To

Argument of pericenter

-77.06300354

Planet astrophysical parameters

Planet radius

Min

Max

Planet rotation period

Min

Max

Oblliquity of rotation axis

Min

Max

Surface gravity

Min

Max

Results of the simulation

Mean temperature

Min

Max

Mean albedo

Min

Max

Mean cloud coverage

Min

Max

Liquid-water habitability

Min

Max

Complex-life habitability

Min

Max

Continuous habitability

Min

Max

Nr. of orbits before convergence

Min

Max

Mean ice coverage

Min

Max

Equator-pole temperature difference

Min

Max

Mean OLR

Min

Max

Mean ABR

Min

Max

Planet geophysical parameters

Planet geography

Min

Max

Const. fraction of oceans

Min

Max

Pressure

Min

Max

O₂ Partial pressure

Min

Max

O₃ Partial pressure

Min

Max

O₂ Partial pressure

Min

Max

H₂ partial pressure

Min

Max

Relative humidity

Min

Max

Model parameters

Nr. of latitude zones

54

Nr. of outputs per orbit

48

Object name

Exo-1

File name

Exo-1

Search

Reset

- Hosted at <http://exoclimate.s3-website-us-east-1.amazonaws.com>
- Based on the ESTM model
- Selecting parameters in search page
- Downloading results

[Download ▾](#)

Rows displayed

20

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[Download](#) ▾

Rows displayed

20

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- ④ Create tar from selected
 - ④ VOTable (all query results - 2548 rows)
 - ④ URL list (all query results - 2548 rows) .txt

ESTIM1.1.01-10.02.2017-00002.TTS.QZ

vOTable

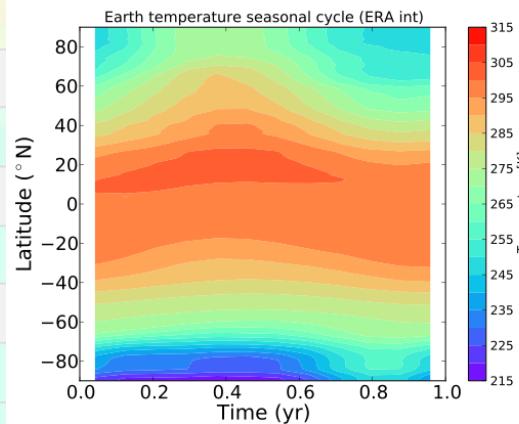
Text file to be used with wget

File Edit View Bookmarks Tools Settings Help

New Open Save Save As Close Undo Redo
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Line 1, Column 1

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- ✗ 2018-02-02-files-busur.txt
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- ✗ 2018-02-02-edfg0oacdf-part-1.xml
Fri Feb 02 13:00:59 CET 2018
- ✗ 2018-02-02-edfg0oacdf-part-2.xml
Fri Feb 02 13:00:59 CET 2018

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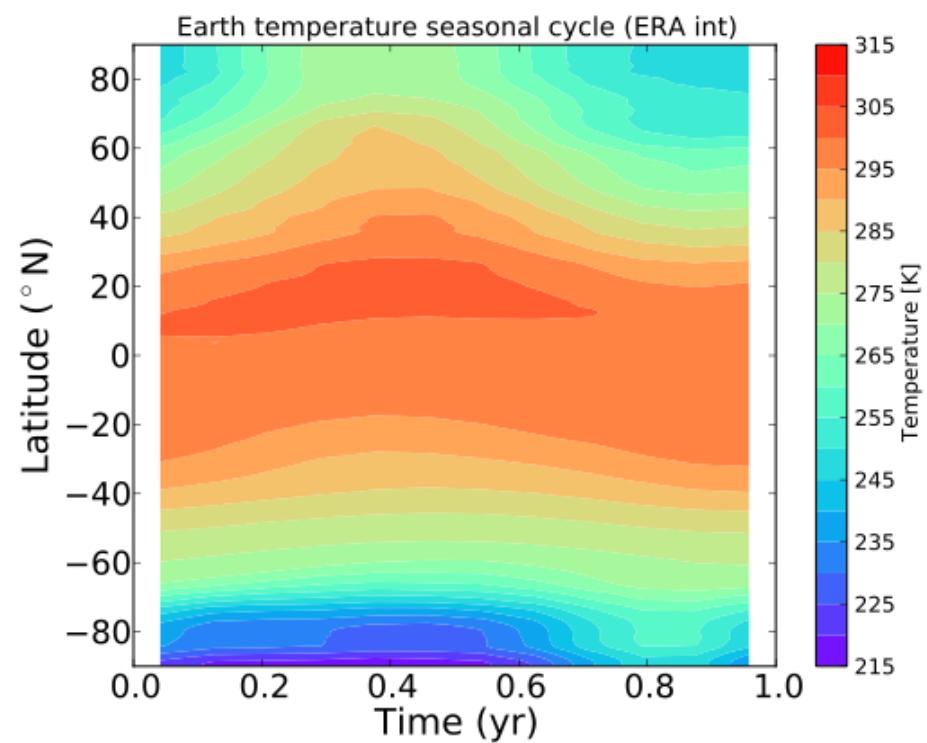
SAMP Service Download as XML

Total results: 2548

The Archive

<http://wwwuser.oats.inaf.it/exobio/climates>

- FITS files gzipped
 - ~10 K -> 50 K
 - 48 (Time) x 54 (lat)
 - HDU 0 – METADATA
 - HDU 1 – Binary Table
 - Latitude
 - Longitude
 - Surface Temperature
 - HDU ... future expansion

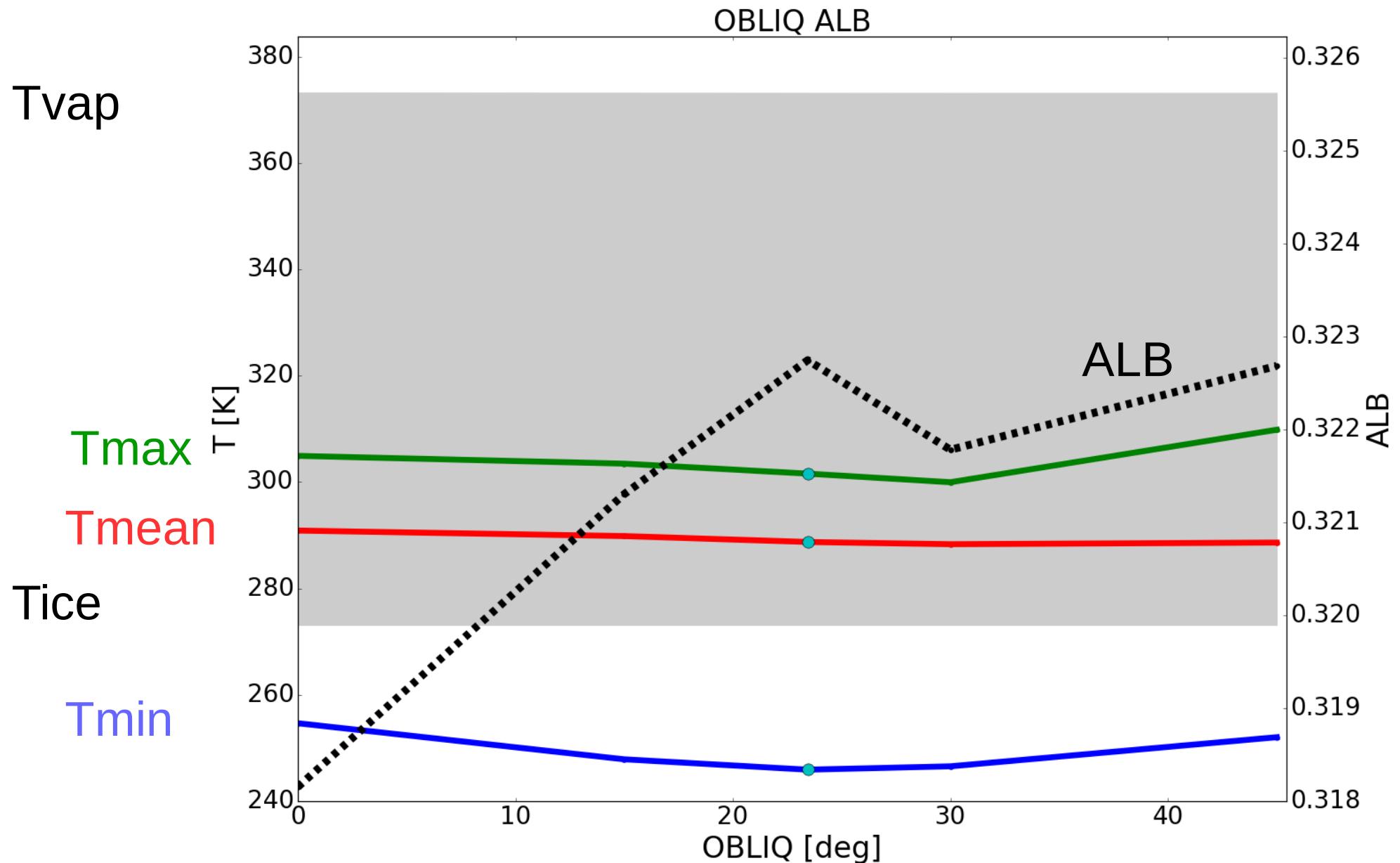


TAP Python Interface

```
> import artecs  
  
> atap=artecs.exop_pubbllic_tap()  
  
> atap.EXPLAIN()  
  
> atap.keys()  
  
> tab=atap.search('(0.7 <= SMA) and (SMA <=3.)')  
  
> tab.FO_CONST.unique()  
  
> tab.to_csv('/tmp/pippo.csv',sep=' ')  
  
> MAP=atap.get_map(tab.URL[0])
```

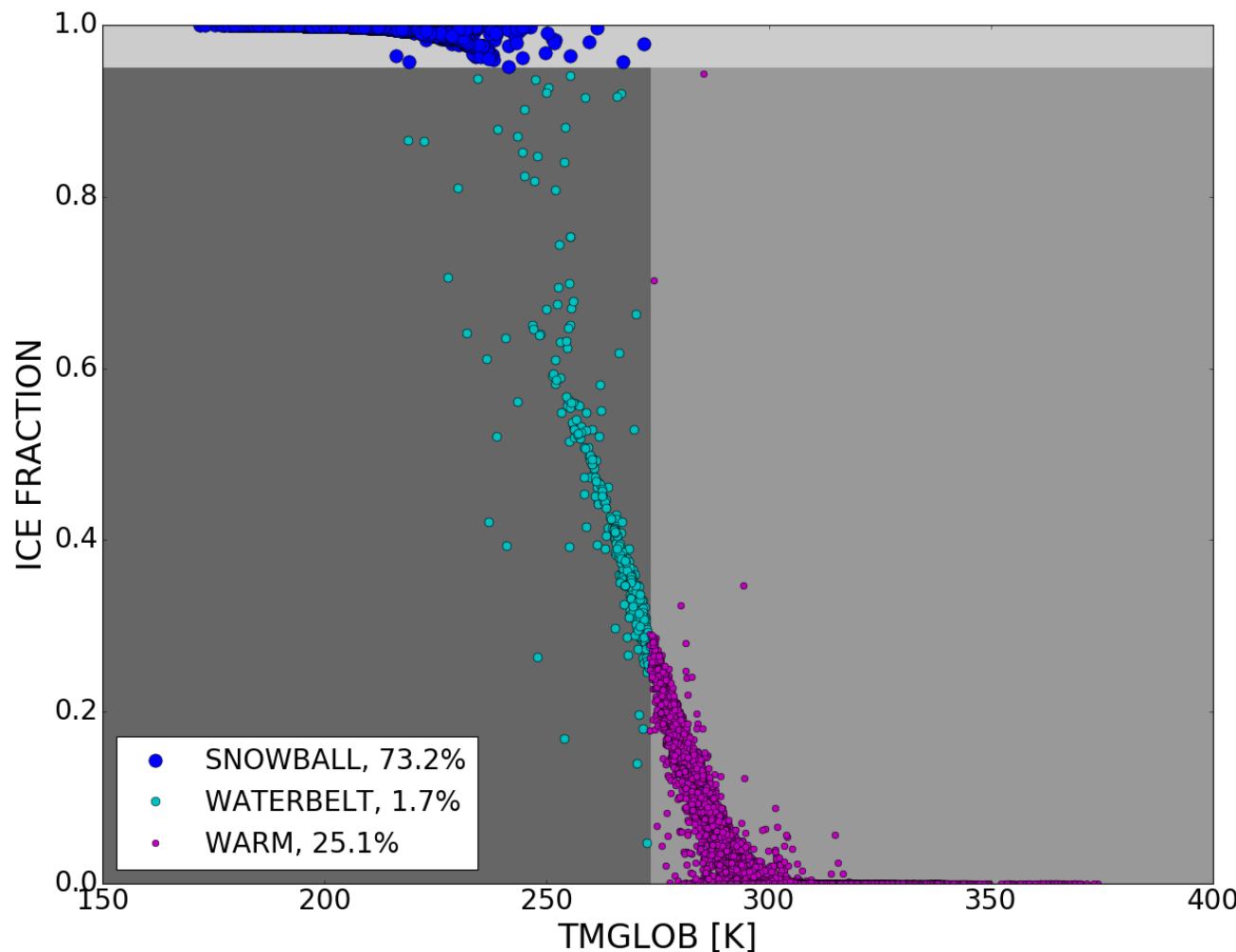
Stimulated by a discussion with A. Zinzi, ESA - ASDC

Example: Earth Climate and OBLIQ

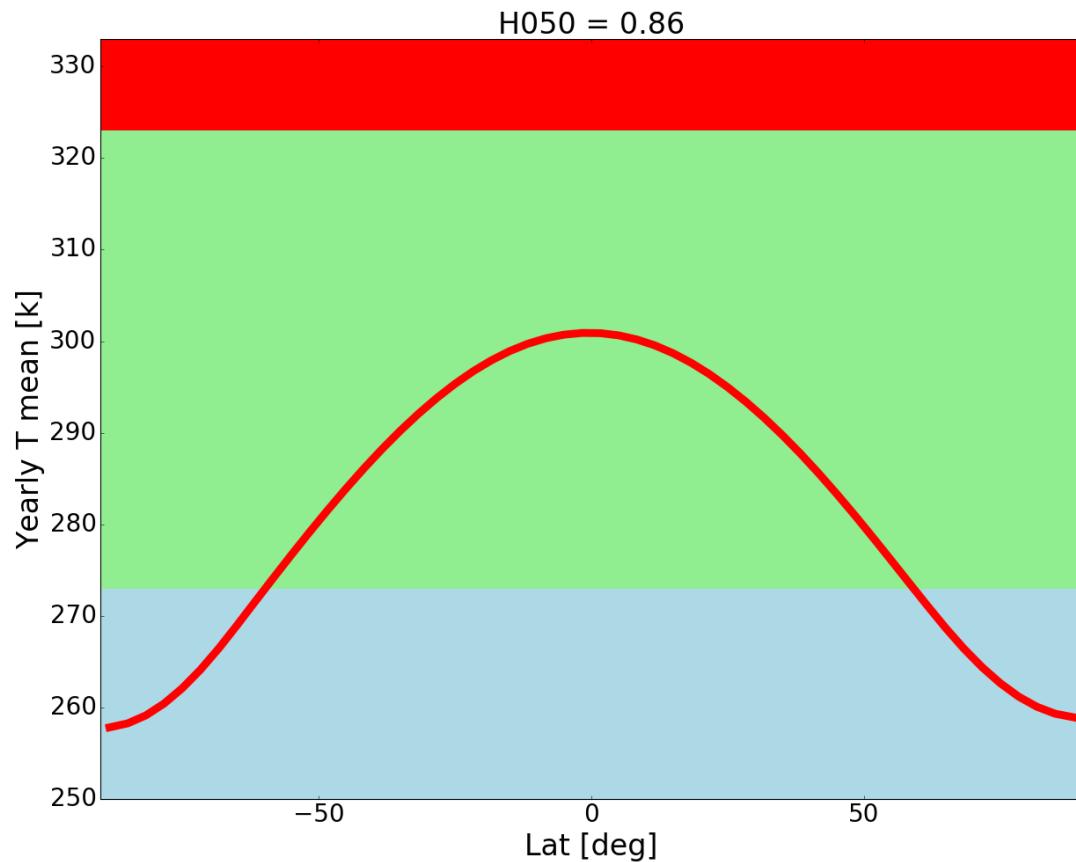


Example: Classification

Simple two parameters classification



Habitability index: h_{050}



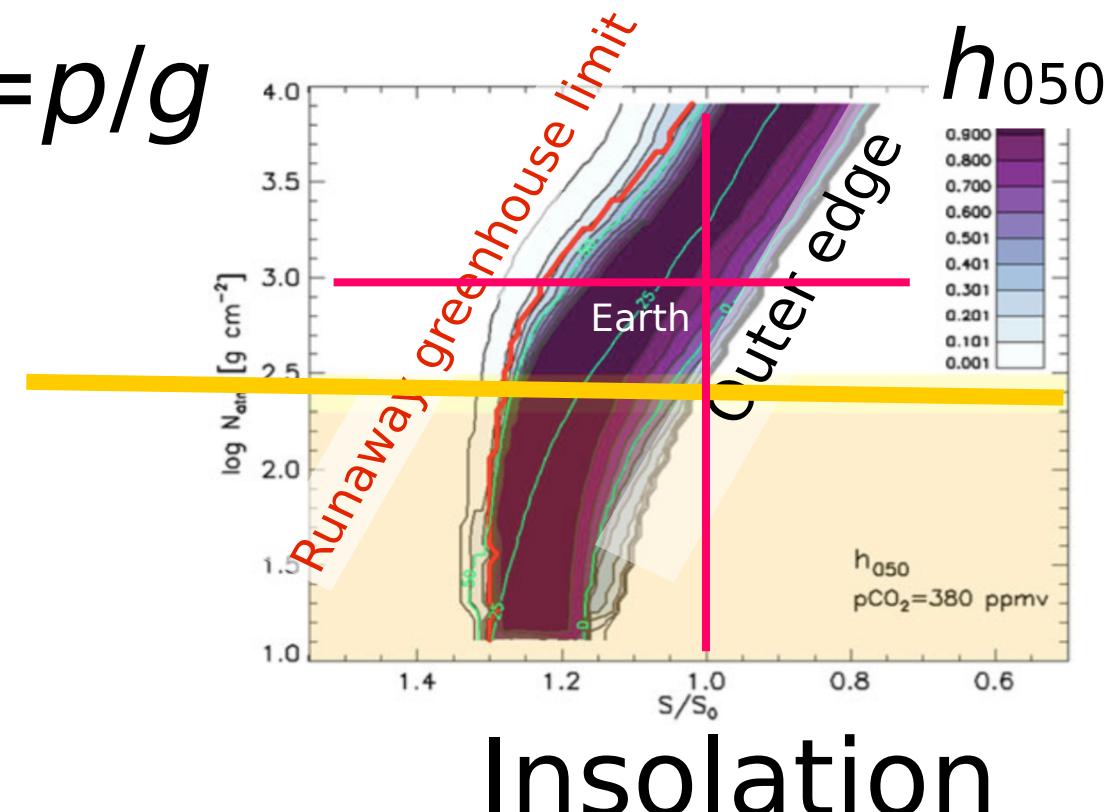
H_{050} = fraction of surface
 $0^\circ\text{C} < T < 50^\circ\text{C}$

Habitability and Atmospheric Mass

$p\text{CO}_2 = 380 \text{ ppmv}$

$$N_{\text{atm}} = p/g$$

Decreasing N_{atm} below
 $\sim 300 \text{ g/cm}^2$
does not help to decrease
the greenhouse effect



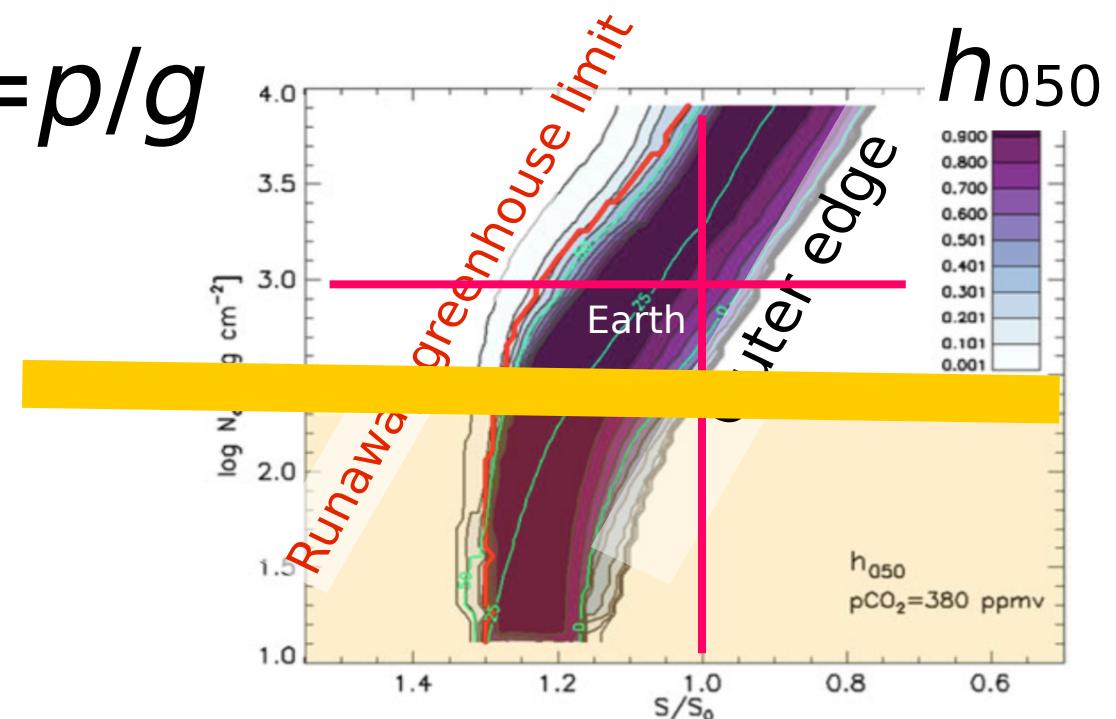
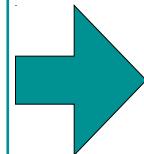
Insolation

Habitability and Atmospheric Mass

$p\text{CO}_2 = 380 \text{ ppmv}$

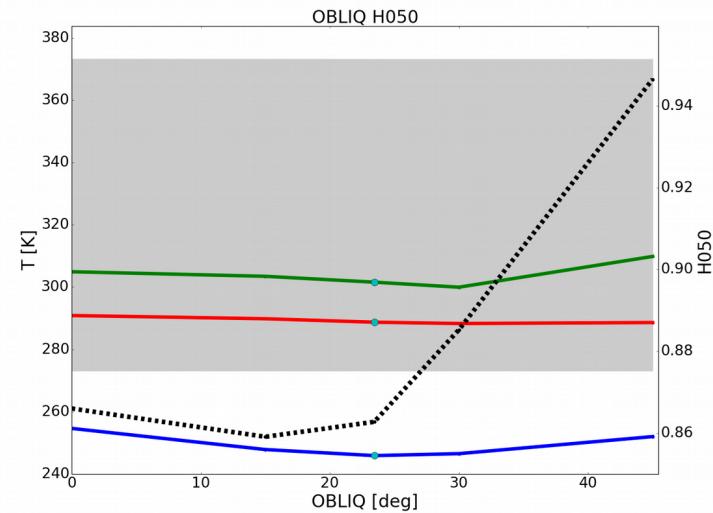
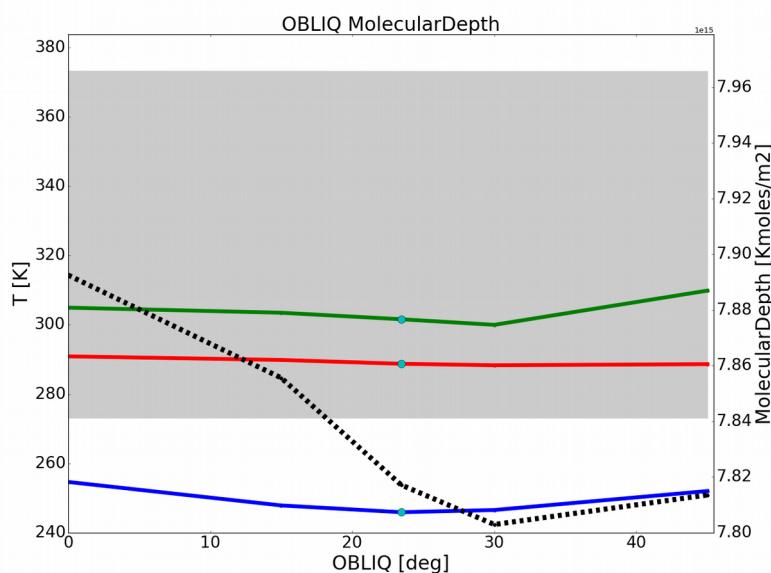
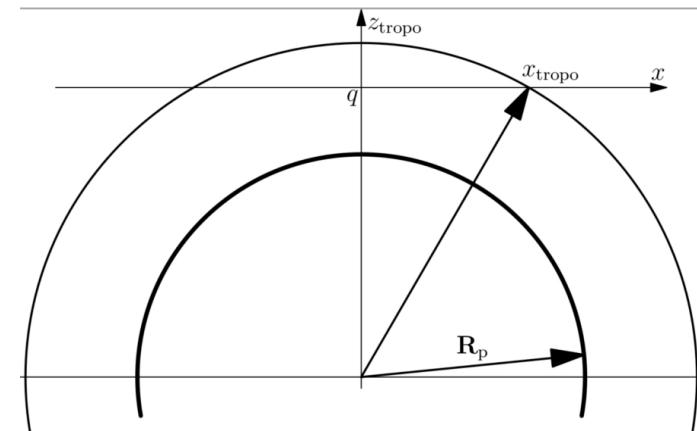
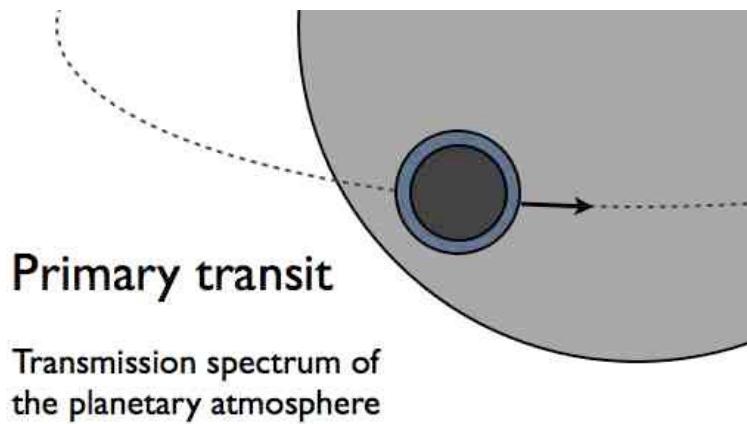
$$N_{\text{atm}} = p/g$$

Surface dose of 100
mSv/yr
of Galactic cosmic
rays
(Atri et al. 2013)

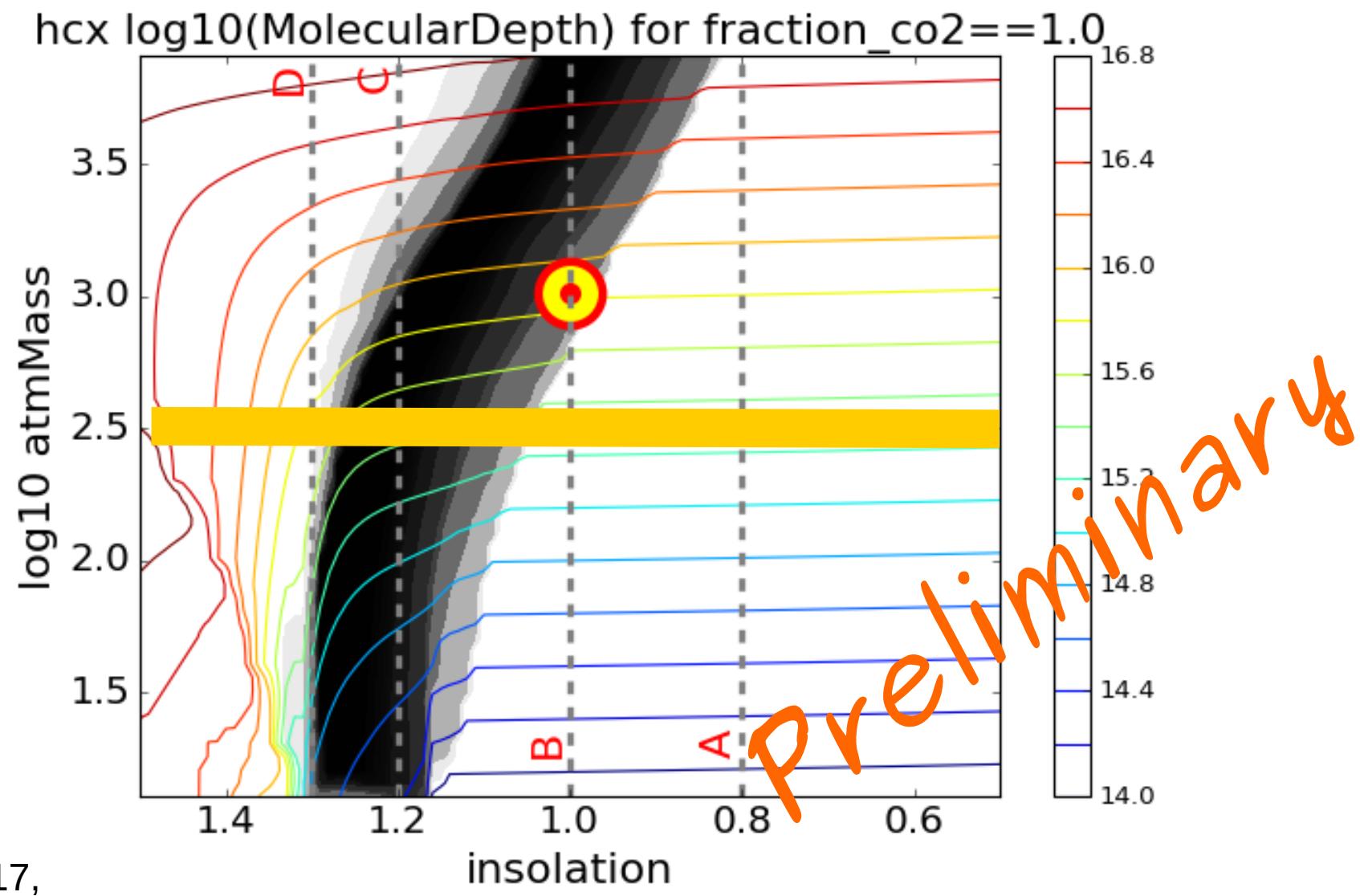


Insolation

Atmospheric Optical Depth

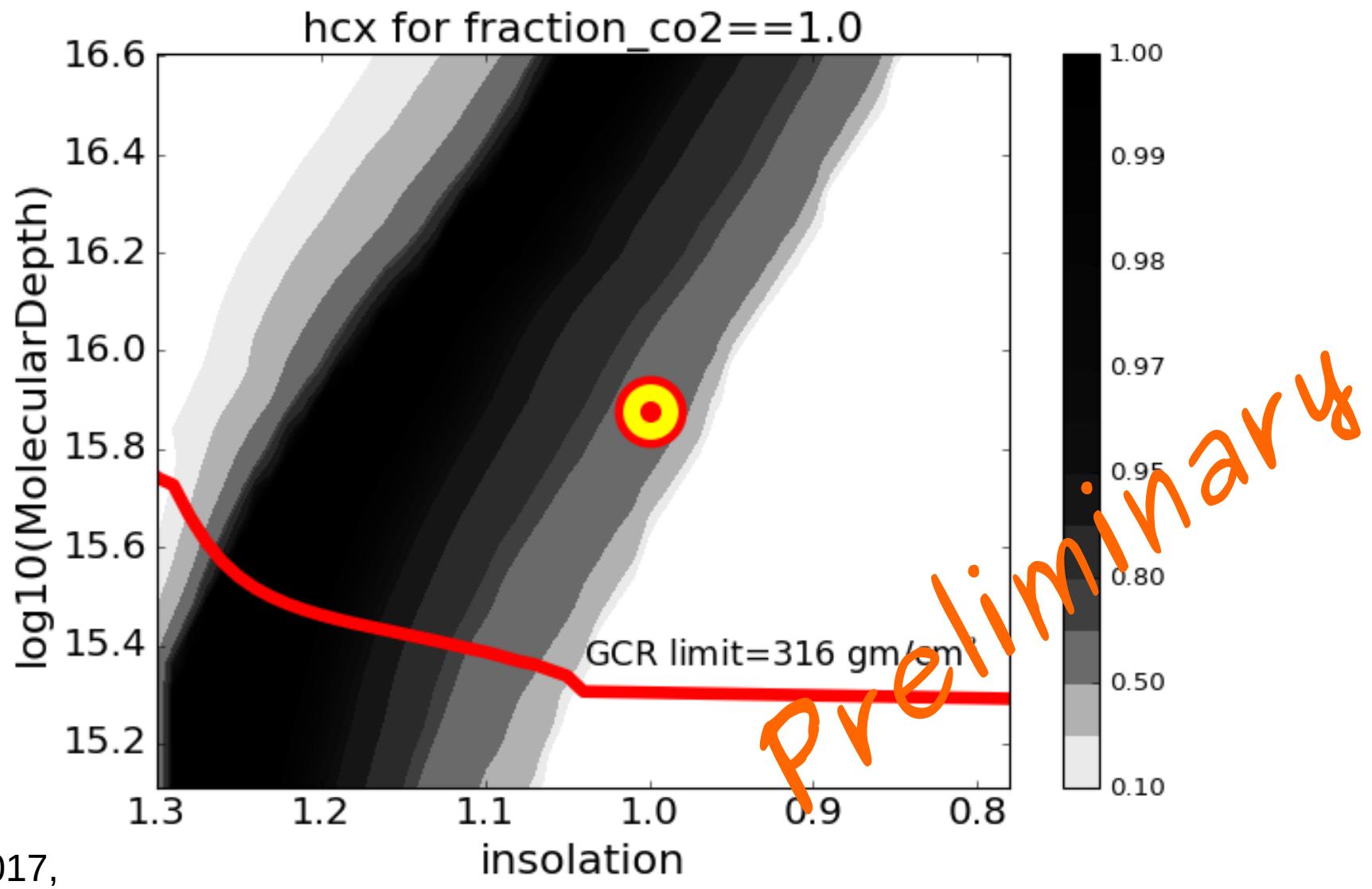


Optical Depth and Habitability



(Silva et al 2017,
Maris, Silva, Vladilo, Murante 2018 in preparation)

Optical Depth and Habitability



(Silva et al 2017,

Maris, Silva, Vladilo, Murante 2018 in preparation)

Data Model

45 parameters

Astrodinamics
 a, e, obliq

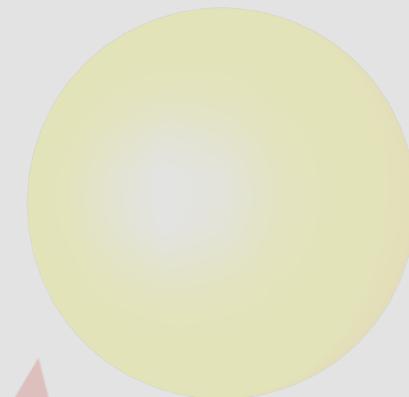
Atmospheric
 $P_{\text{dry}}(X_{\text{N}2}, X_{\text{O}2}, X_{\text{CO}2}, \dots)$,
 R_{H} , Condensible(H₂O)

10 Classes



Minimum
parameters
description

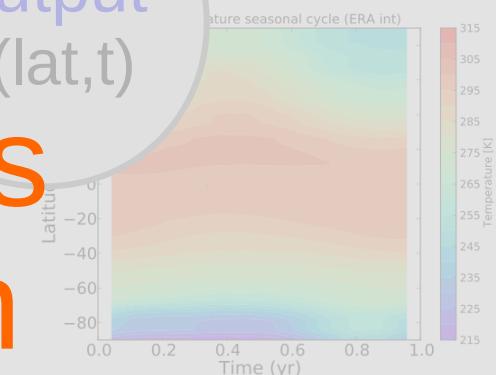
Stellar
 M_*, R_*, L_* , Spectra



Planetary
 $M_p, R_p, g_p, P_{\text{rot}}$

Output
 $T(\text{lat}, t)$

Surface
 $F_{\text{ocean}}, G_{\text{eo}}$



Data Model

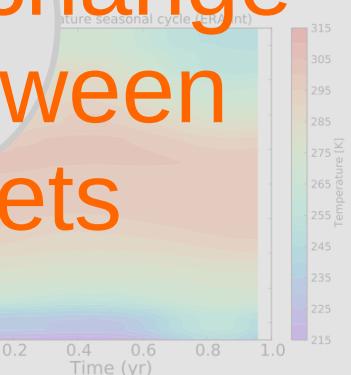
Exo-Planetary Systems Data Model Meeting

INAF-OAPd, Padova, 20-21/09/2018

Astro-dynamics

<https://www.asterics2020.eu/dokuwiki/doku.php?id=open:wp4:wp4exodm>

to define a data description and interchange format to allow uniform exchange between observations and models for exoplanets



New Activities

- Link with ASDC-ASI ExoplAn3T (Angelo Zinzi)

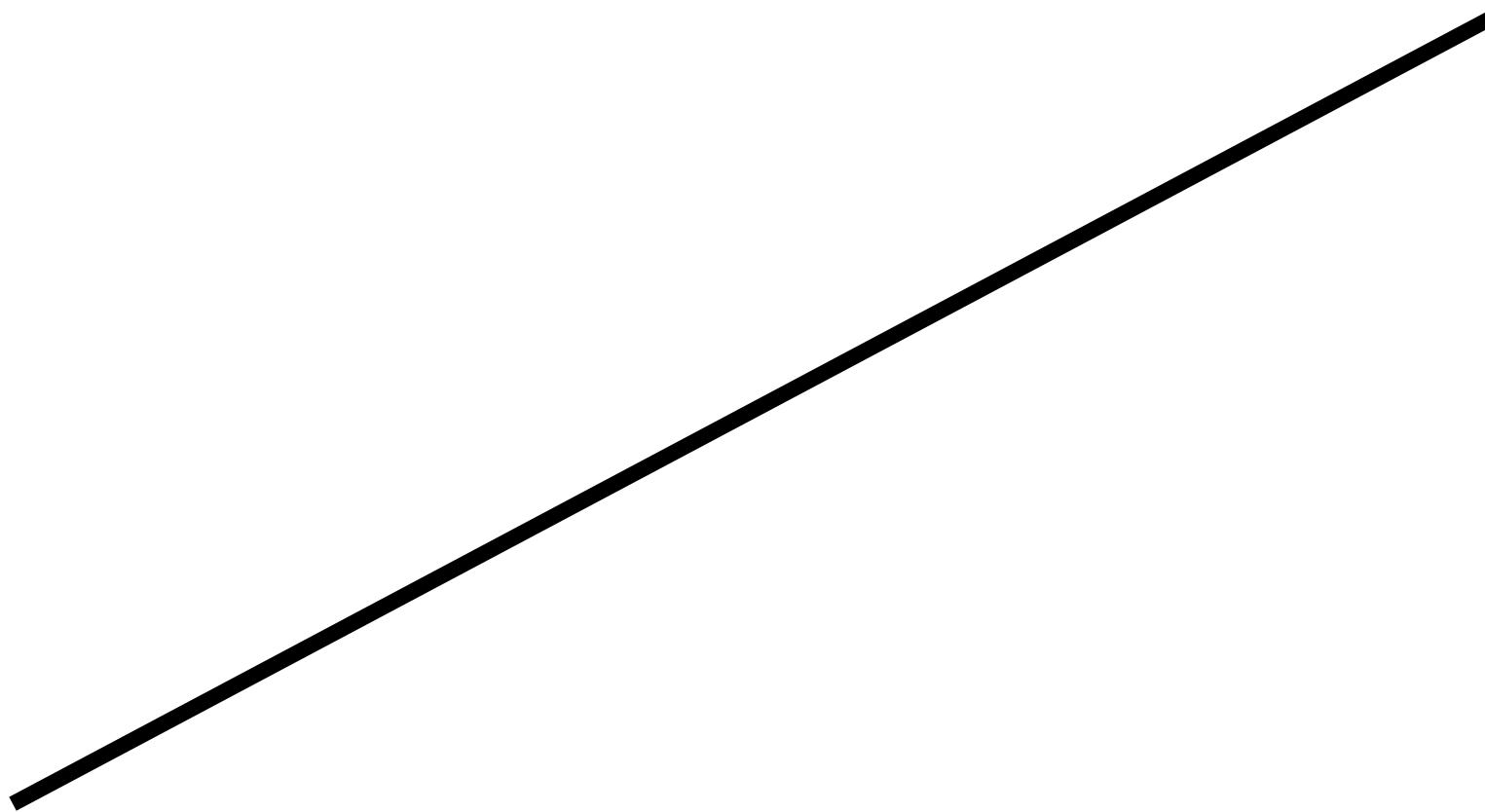


- A PhD student, Paolo Simonetti, will join us in Nov/Dec
- Working to include ExArt, the radiative transfer code of Arusu G.
- Working to link PLASIM
- Link with ESA Space Missions: Euclid, Ariel?

Future

<http://wwwuser.oats.inaf.it/exobio/climates>

- Extend the archive
 - 21 Ksim
 - 200 Ksim
 - option for 1 – 2 Msim
- Python tools to work with archive
- Improve ESTM (ex.: M class stars ,  vegetation 
- Subset of simulations with PLASIM (3D model)
- Link to observables (reflectance / extinction)
- Link to ASDC exoplanet archive (A.Zinzi)



Example: Earth Climate and OBLIQ

