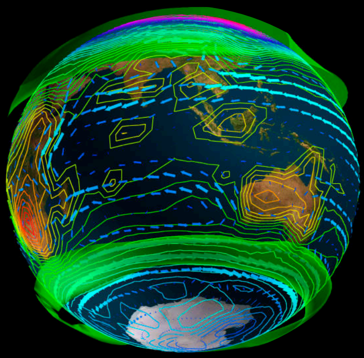
MODELING EARTH-LIKE PLANETS WITH GLOBAL CLIMATE MODELS

Illeana Gómez-Leal[1],
Lisa Kaltenegger[1]
Valerio Lucarini[2], Robert Boschi[2], Edilbert Kirk[2]

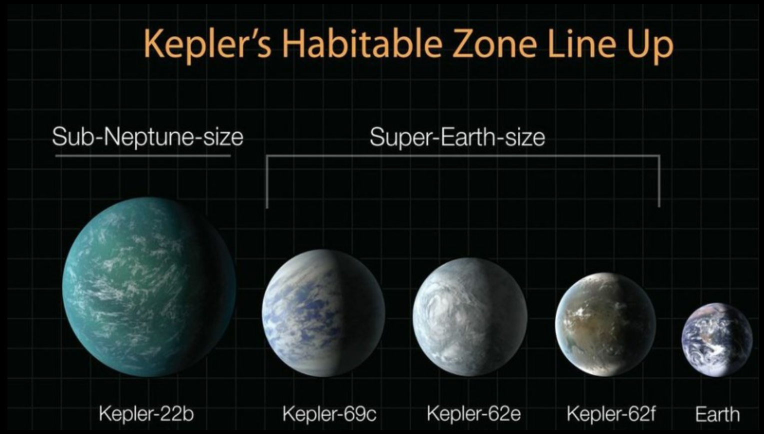
[1] Carl Sagan Institute. Cornell University, Space Sciences Building, Ithaca NY14850, USA.
[2] Theoretical Meteorology group. Klimacampus, University of Hamburg. Grindelberg 5, 20144 Hamburg. Germany

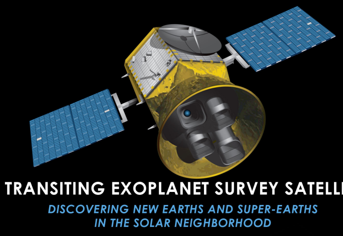
OUR AIM:



SIMULATE
POSSIBLE CLIMATES

A TOOL FOR
OBSERVATIONS





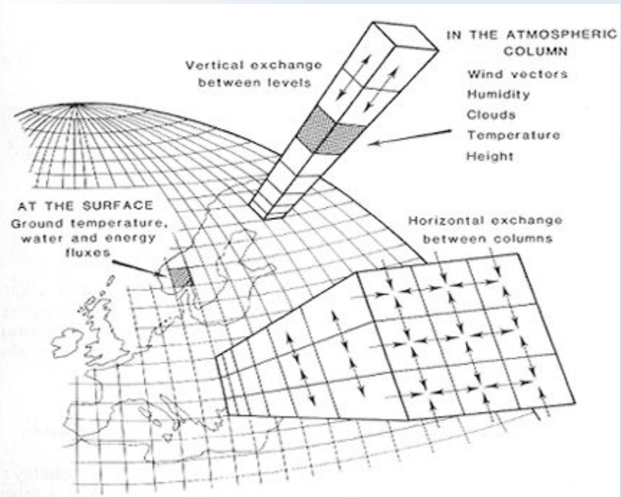
TERRESTRIAL PLANETS ARE COMMON
~30% of Earth-like planets in the HZ of G-K stars (Kepler mission, Batalha talk, Petigura et el. 2013).

TESS :
_VIS; NIR (0.5 -1)microns

JWST :
IR (0.5 -28)microns

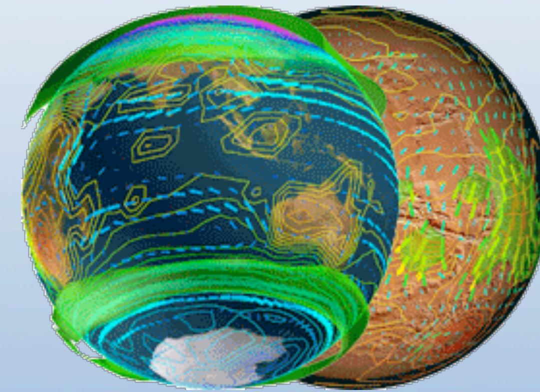
PLATO :
_VIS; NIR (0.5 -1)microns

GLOBAL CLIMATE MODELS



3D Dynamical core

Parametrized physics
Radiation
Boundary layer
Convection
Clouds
Orography



- Soil module
- Ocean Model
- Sea Ice Model
- Glaciers, snow, ice
- Carbon cycle
- etc...

Atmospheric tracers
Transport by winds
Turbulent mixing
etc...

Chemistry module

GLOBAL CLIMATE MODELS

Variables:

Upward/Downward fluxes

SW band (0.1-5)µm : UV-NIR
LW band (5-20)µm : MIR

Temperature

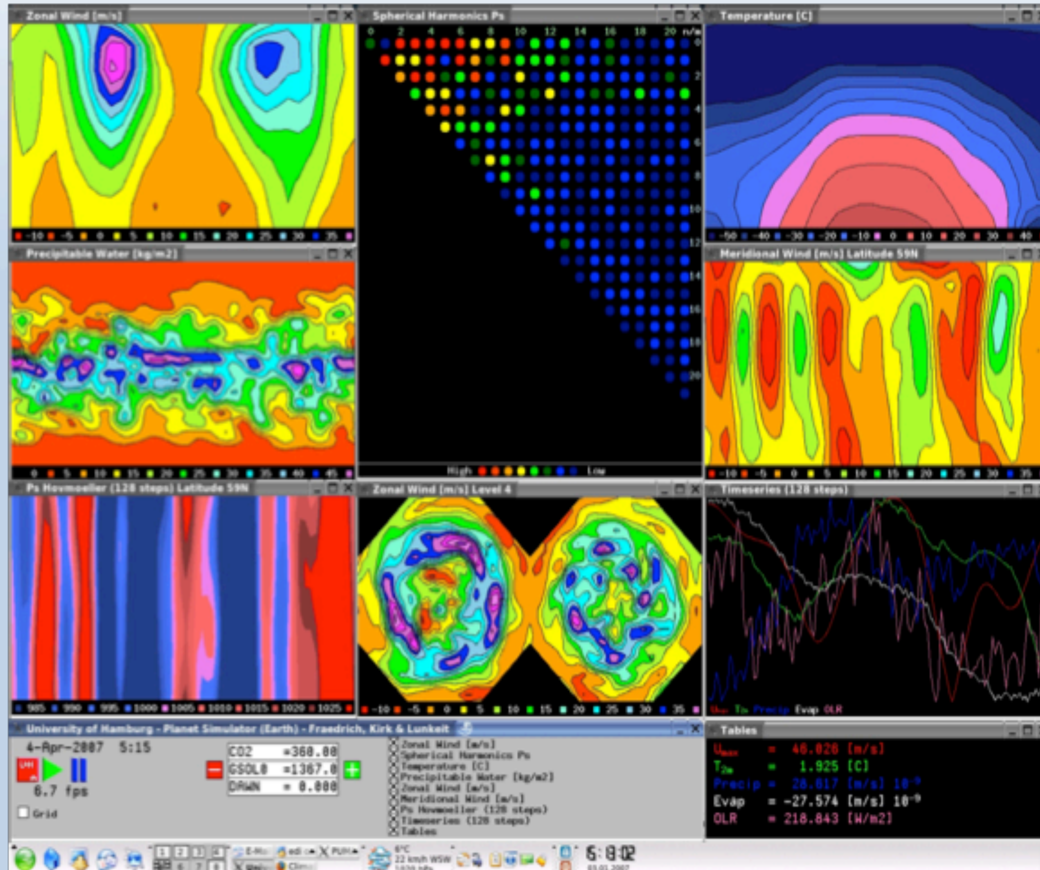
Cloud cover

Wind fields

Ice/Snow cover/thickness

Humidity

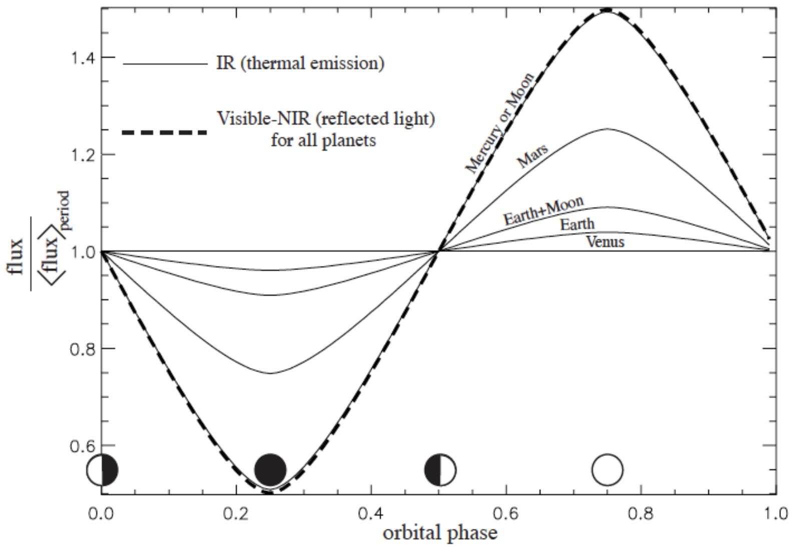
etc...

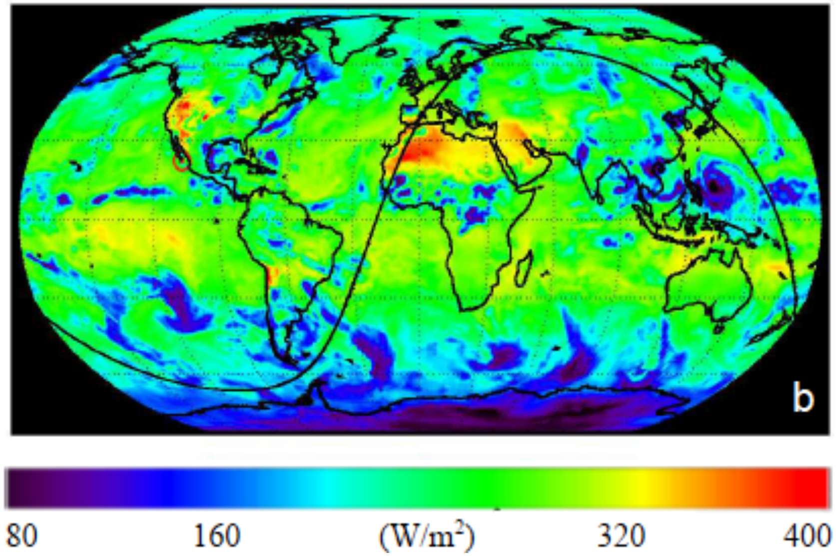


Planet Simulator (poster Nicolas Iro)

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

EMISSION OF EARTH-LIKE PLANETS





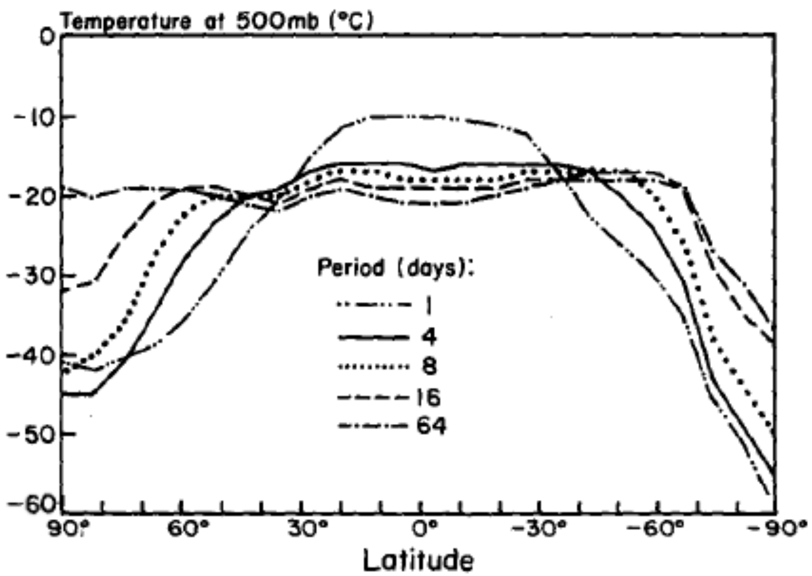
- The maximum and minimum are not correlated with the illuminated phase.

- They depend on the properties of the planet: surface, clouds, seasons, etc…

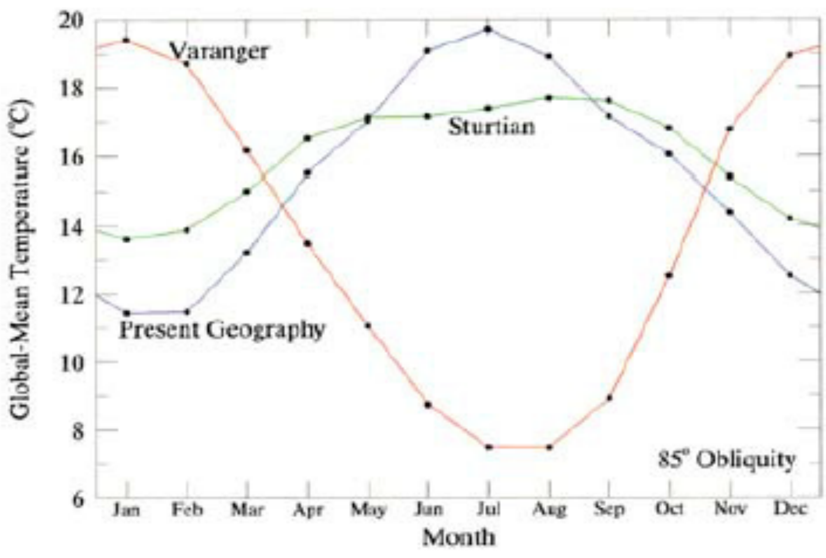
EMISSION OF EARTH-LIKE PLANETS

- *Orbital parameters:* *eccentricity, obliquity, rotation, etc…*

- *Atmosphere, cloud formation, feedbacks, distribution of the continents, …*

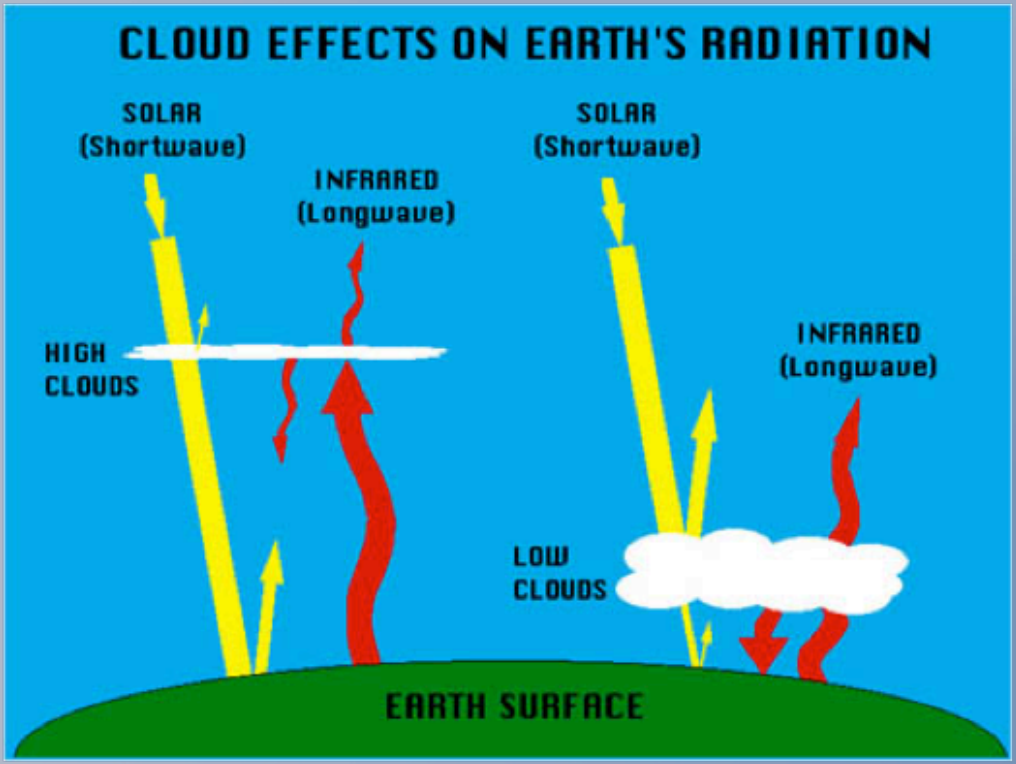


Del Genio & Suozzo (1989)



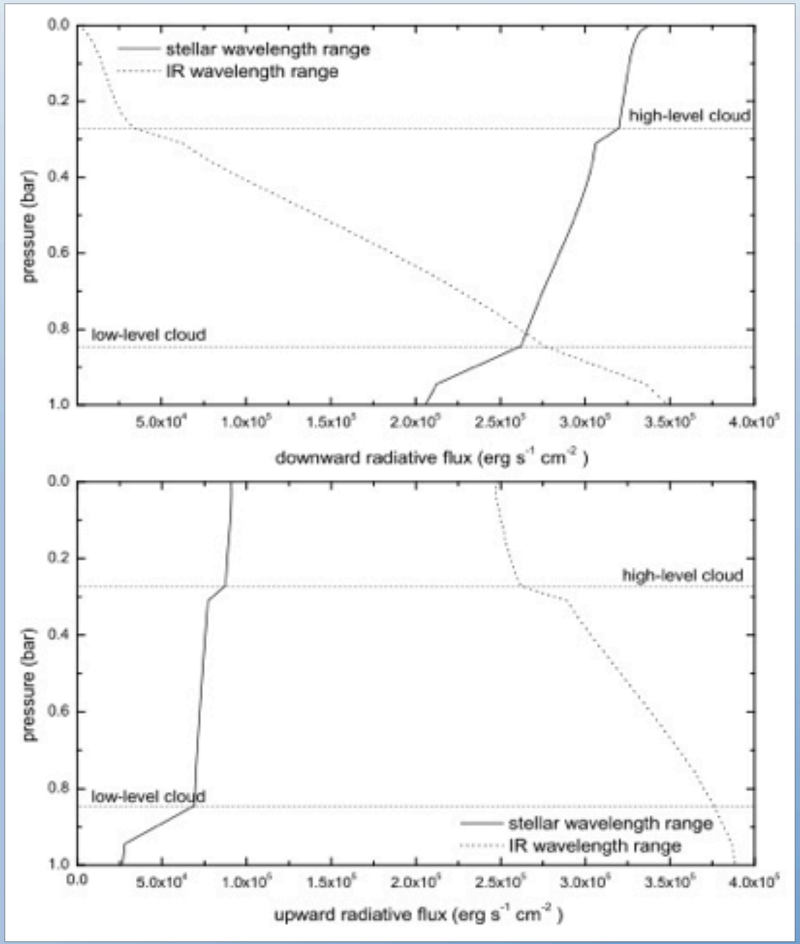
Williams and Pollard (2003)

EMISSION OF EARTH-LIKE PLANETS



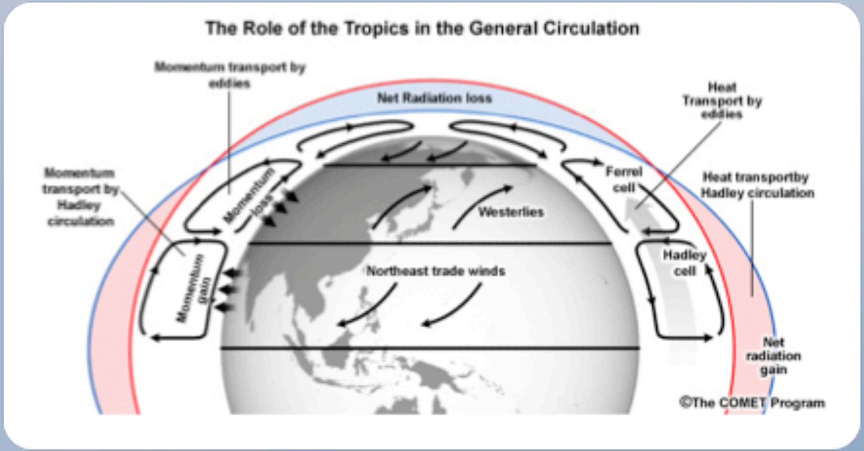
High clouds (5-13km) - low albedo, ice cristals

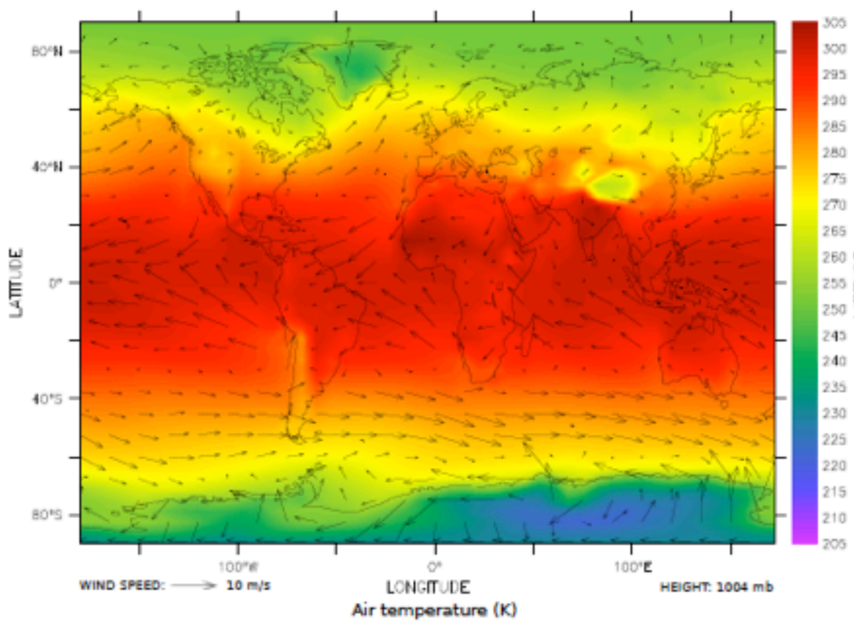
Low clouds (0-2km) - high albedo, water droplets

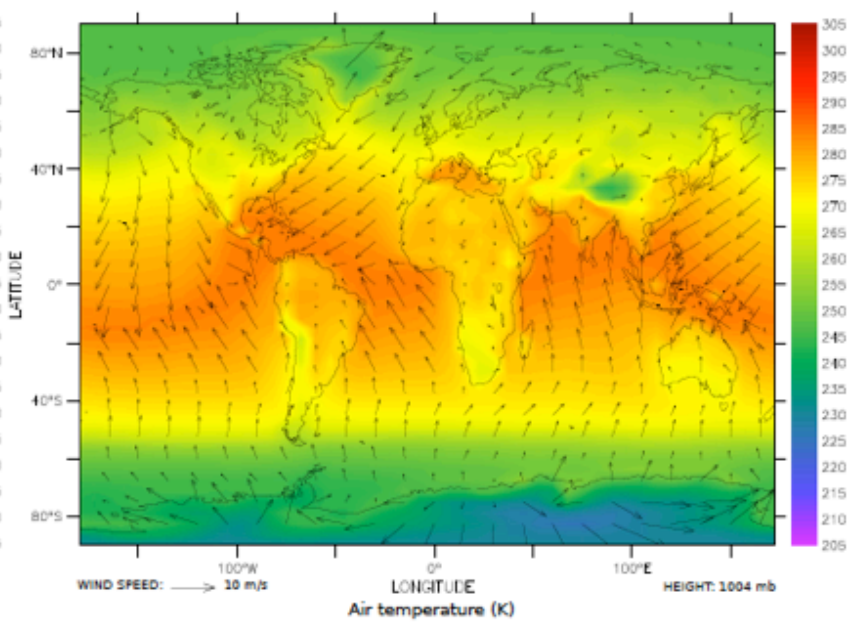


Kitzmann et al, 2010, A&A 511, A66

EXAMPLES: Planets in a terrestrial orbit

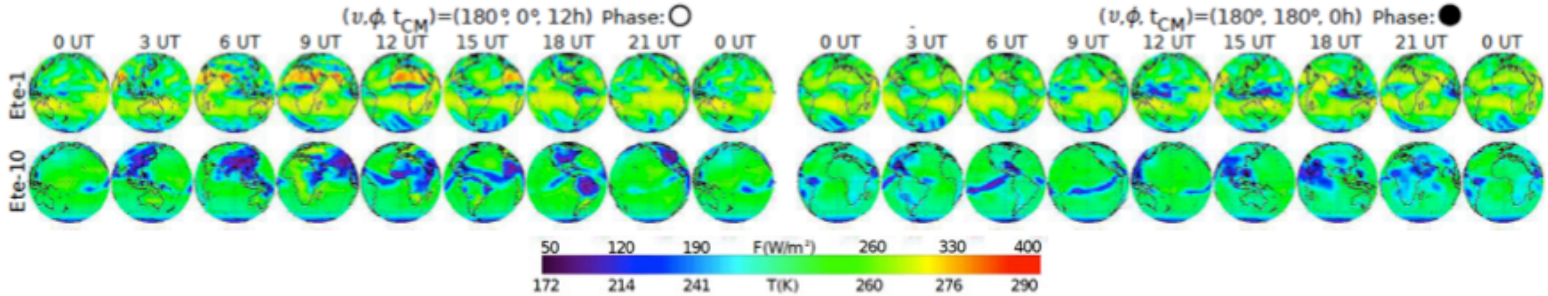




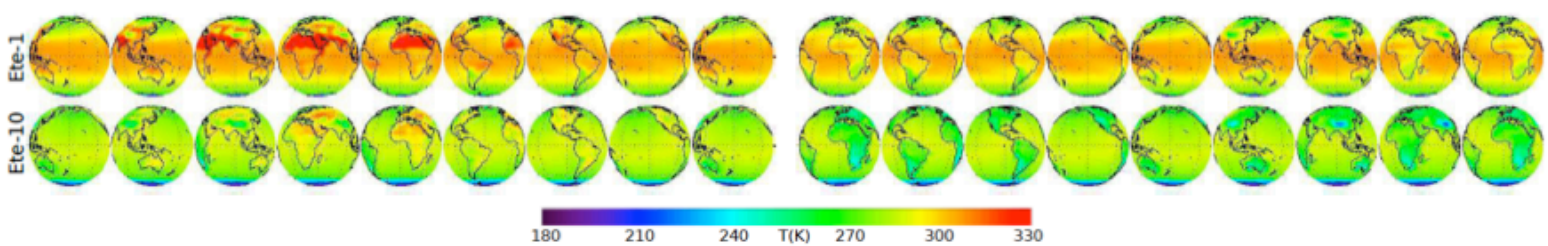


EXAMPLES: Planets in a terrestrial orbit

Top-of-the atmosphere

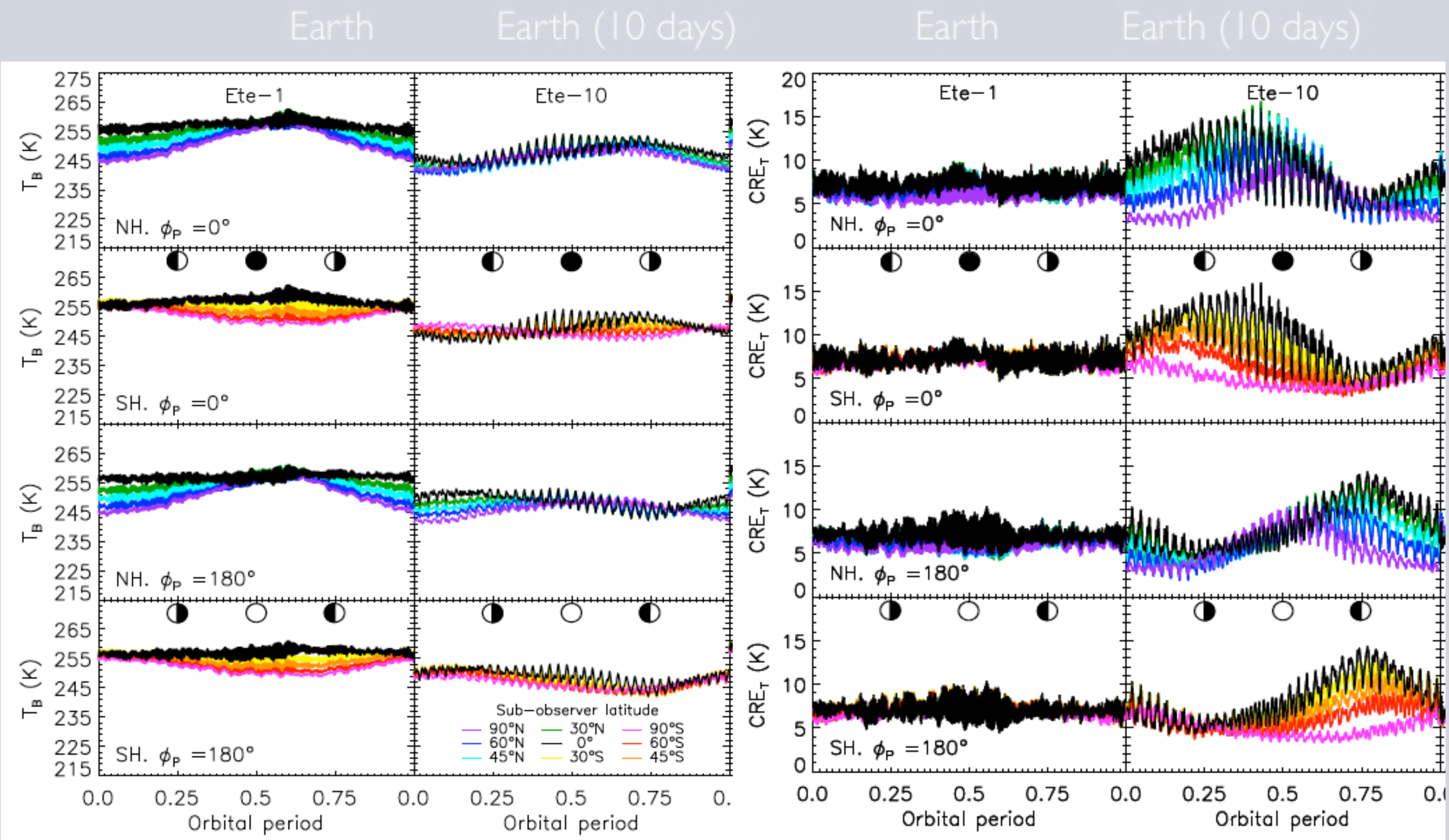


Surface



EXAMPLES: Planets in a terrestrial orbit

Cloud Radiative Effect

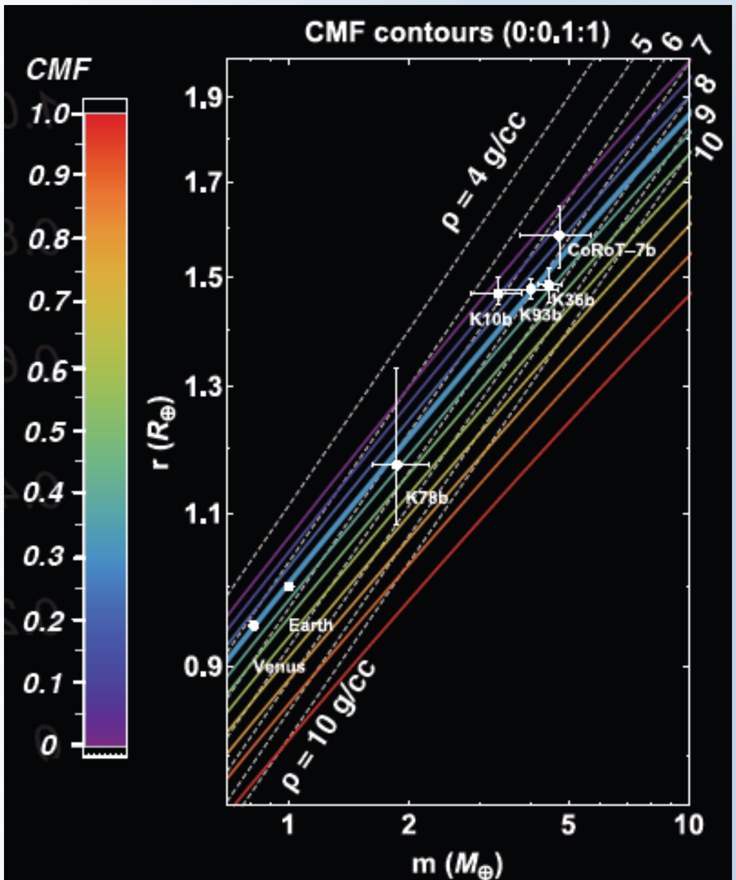


Gómez-Leal. 2013 (thesis)

MODELING SUPER-EARTHS

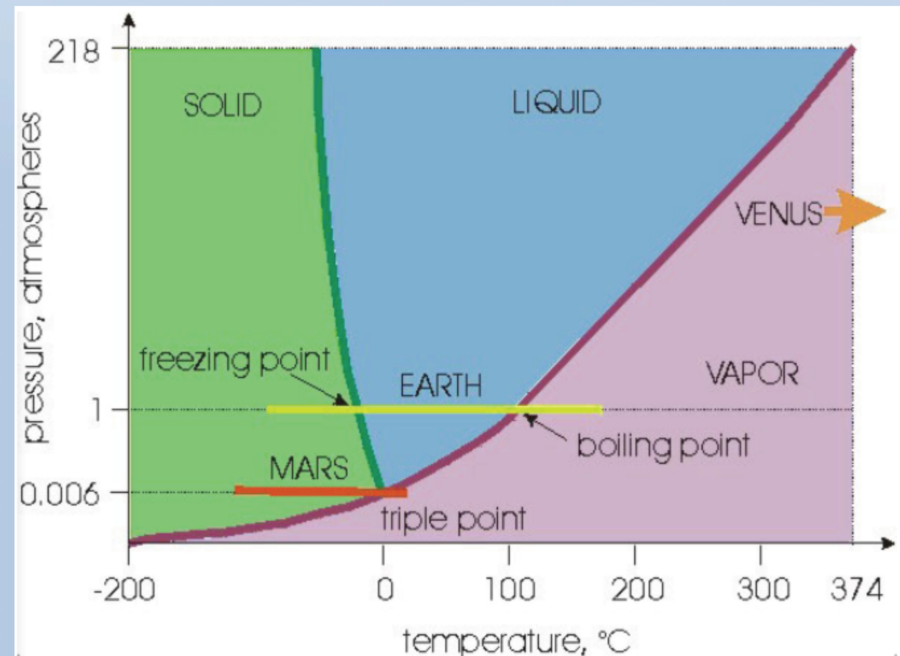
Mass-Radius relation:

$$\rho/\rho_\oplus = (R/R_\oplus)^{0.73} \quad M/M_\oplus = (R/R_\oplus)^{3.73}$$



Zeng, Jacobsen & Sasselov, submitted

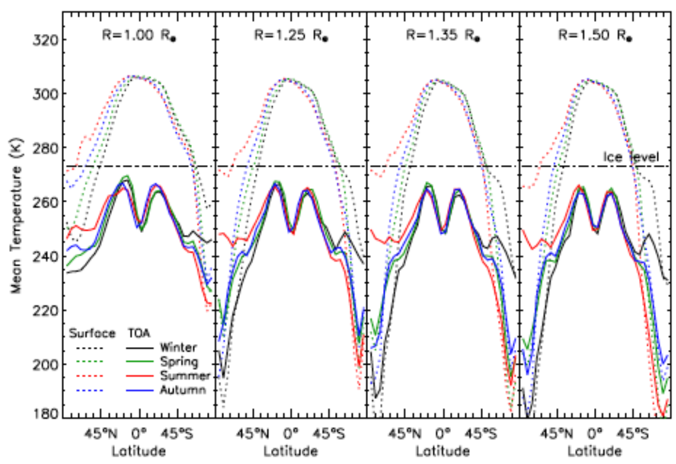
Adapt variables to the new conditions:
g, P_{surf}, L_v (T), …

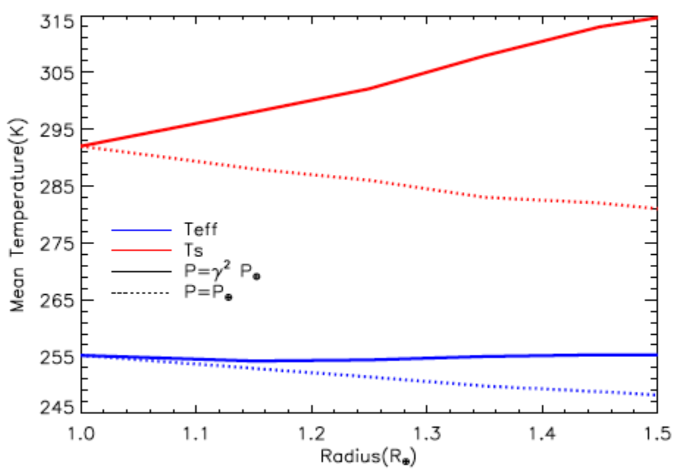


PHASE DIAGRAM OF WATER

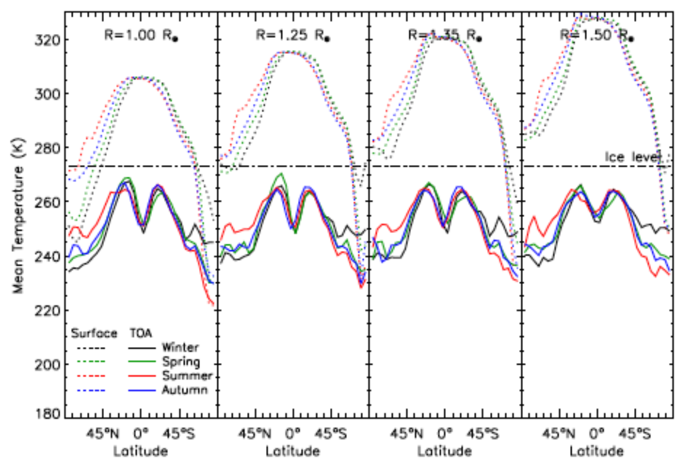
MODELING SUPER-EARTHS

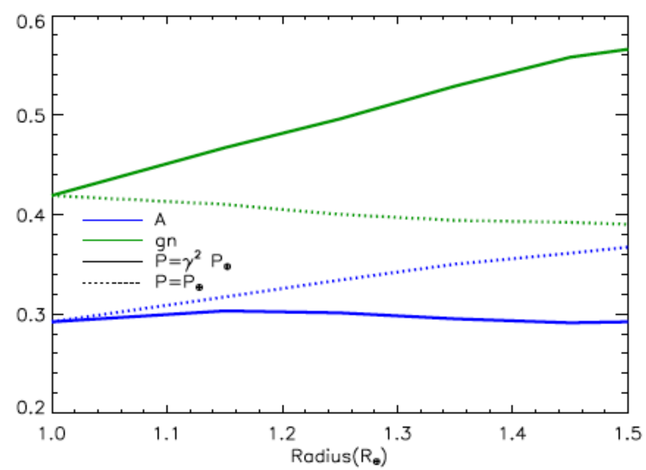
A.- *Conserving Earth values*





B.- *Scaling M_atm/M_pl*





SUMMARY

3D models allow us to reproduce:
- The circulation of the atmosphere and the ocean
- The diurnal cycle of temperature in the surface
- Continental distribution, etc…

It is important to keep the complexity of the models in order to account for
- Cloud formation
- Feedbacks

We must study the parameter space to validate the model for the new conditions. and improve:
- The spectral bands
- Stellar type
- Chemical abundances, etc…