MODELING EARTH-LIKE PLANETS WITH GLOBAL CLIMATE MODELS

Illeana Gómez-Leal¹, Lisa Kaltenegger¹, Valerio Lucarini², Robert Boschi², Edilbert Kirk²

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 al. 2013).
GLOBAL CLIMATE MODELS

3D Dynamical core

Parametrized physics
- Radiation
- Boundary layer
- Convection
- Clouds
- Orography

Atmospheric tracers
- Transport by winds
- Turbulent mixing
- etc...

Chemistry module

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

EMISSION OF EARTH-LIKE PLANETS

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

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

EXAMPLES: Planets in a terrestrial orbit

The Role of the Tropics in the General Circulation

- Momentum transport by eddies
- Net Radiation loss
- Heat Transport by eddies
- Heat transport by Hadley circulation
- Net radiation gain
- Westerlies
- Hadley cell

Northeast trade winds

© The COMET Program
EXAMPLES: Planets in a terrestrial orbit

Top-of-the atmosphere

Surface
EXAMPLES: Planets in a terrestrial orbit

Cloud Radiative Effect

Earth          Earth (10 days)          Earth          Earth (10 days)

NH. $\phi_p = 0^\circ$

SH. $\phi_p = 0^\circ$

NH. $\phi_p = 180^\circ$

SH. $\phi_p = 180^\circ$

Sub-observer latitude:
- 90°N
- 30°N
- 0°
- 30°S
- 90°S

Orbital period

Gómez-Leal 2013 (thesis)
MODELING SUPER-EARTHS

Mass-Radius relation:

\[ \frac{\rho}{\rho_\oplus} = (\frac{R}{R_\oplus})^{0.73} \quad \frac{M}{M_\oplus} = (\frac{R}{R_\oplus})^{3.73} \]

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

PHASE DIAGRAM OF WATER

Zeng, Jacobsen & Sasselov, submitted
MODELING SUPER-EARTHS

A. - Conserving Earth values

B. - Scaling $M_{atm}/M_{pl}$
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…