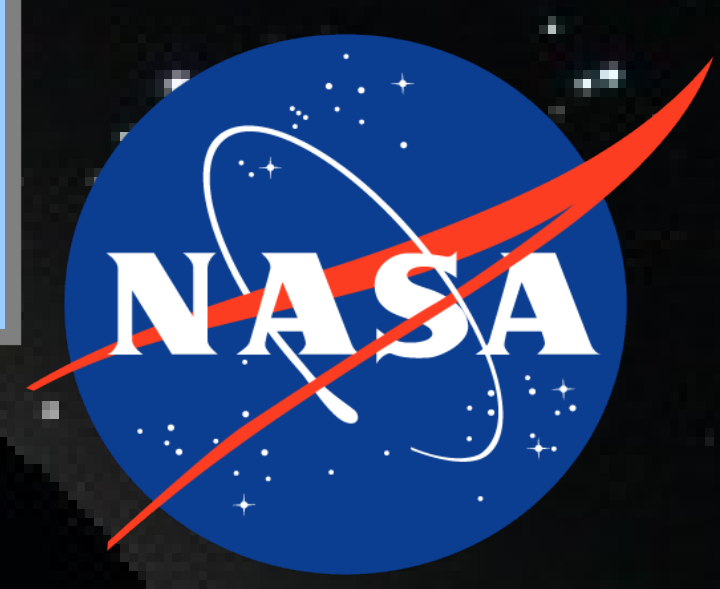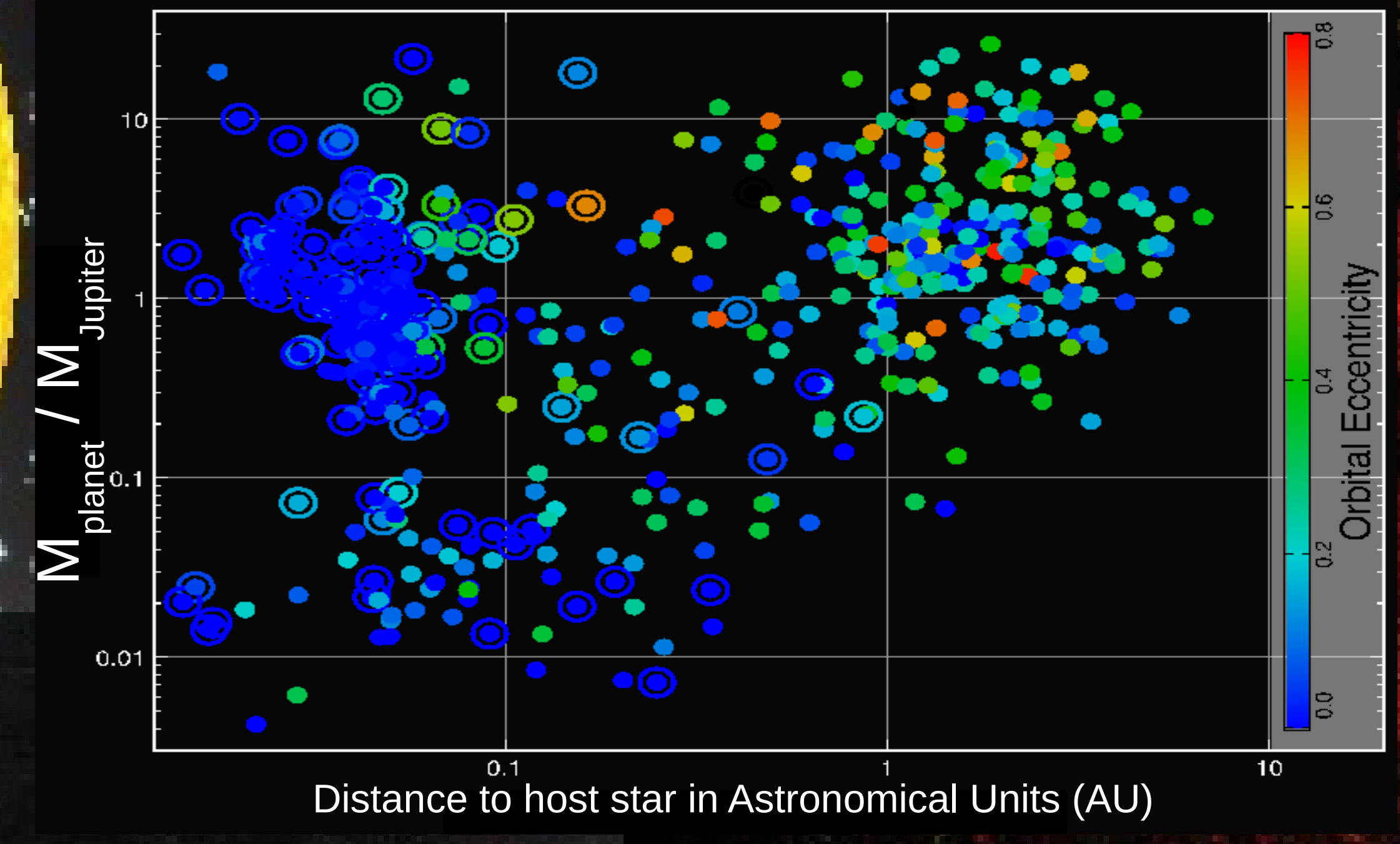# The Effect of Orbital Eccentricity on Climate and Habitability

Jeremy Schnittman and Luke Oman
NASA Goddard Space Flight Center
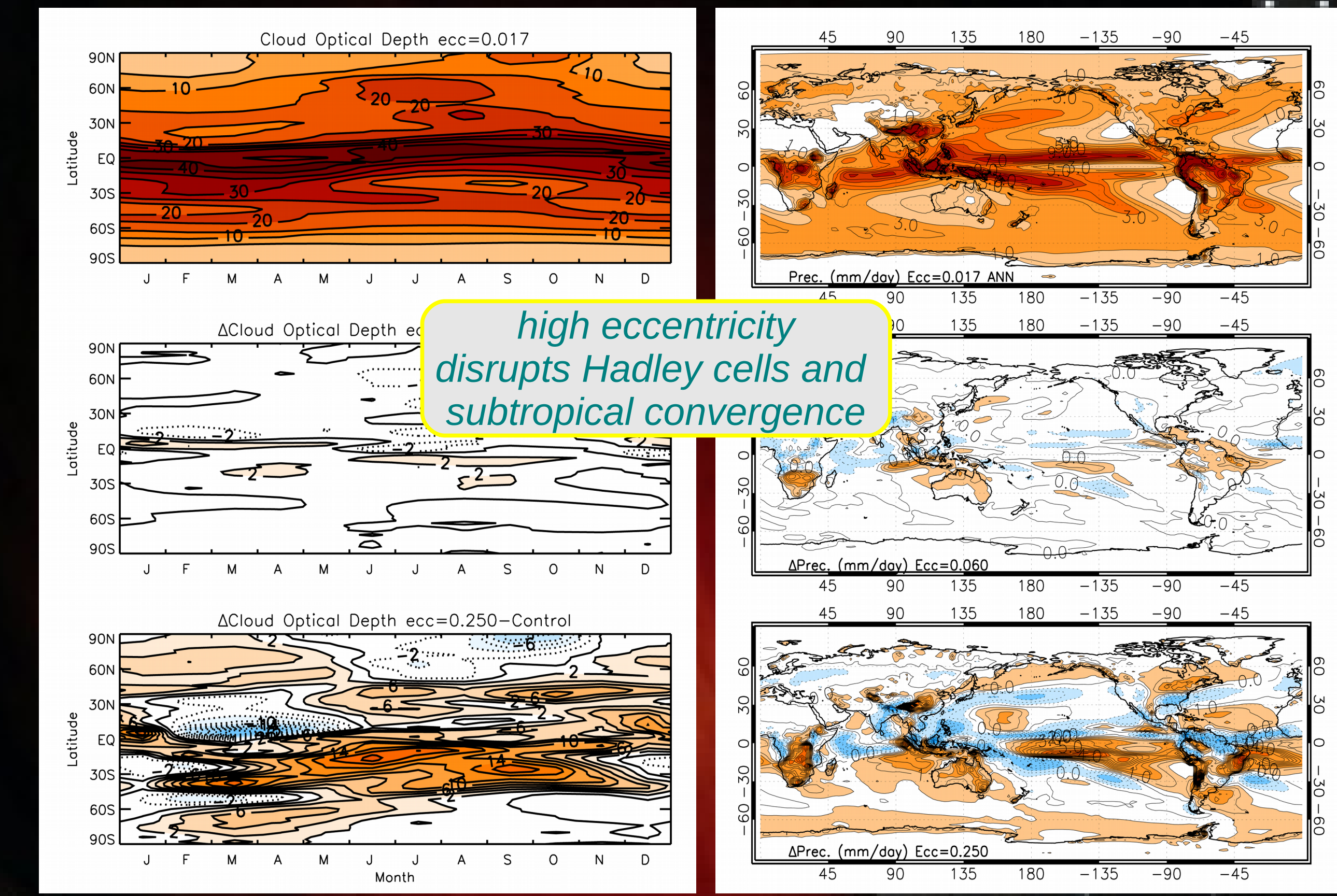Sellers Exoplanet Environments Collaboration (SEEC)

Mass and orbital properties of > 600 known exoplanets
(exoplanets.org)

Eccentricity affects climate on Earth through the Milankovitch cycles

shift of seasons from obliquity- to eccentricity-driven

How does eccentricity vary on other planets?

higher eccentricity → higher insolation

$$\ell = \dot{f} r^2 = \sqrt{GMa(1-e^2)}$$

$$F = \frac{L}{4\pi r^2}$$

$$\langle F \rangle = \frac{1}{P} \int_0^P F dt = \frac{1}{P} \int_0^{2\pi} L(df/\ell) = \frac{2\pi L}{P\ell}$$

$$\langle F(e) \rangle \approx \langle F(0) \rangle (1 + e^2/2)$$

$$T_{eq}(e) \approx T_{eq}(0)(1 + e^2/8)$$

$$\dot{r} \sim [\cos f, \sin f, 0]$$

$$\hat{n} = [\sin\varepsilon\cos\varpi, \sin\varepsilon\sin\varpi, \cos\varepsilon]$$

$$\langle F_{abs}(\hat{n}) \rangle = \frac{1}{P} \int_0^P dt \frac{(1-\alpha)(\hat{n})L}{4\pi r^2} \hat{n} \cdot \hat{r}$$
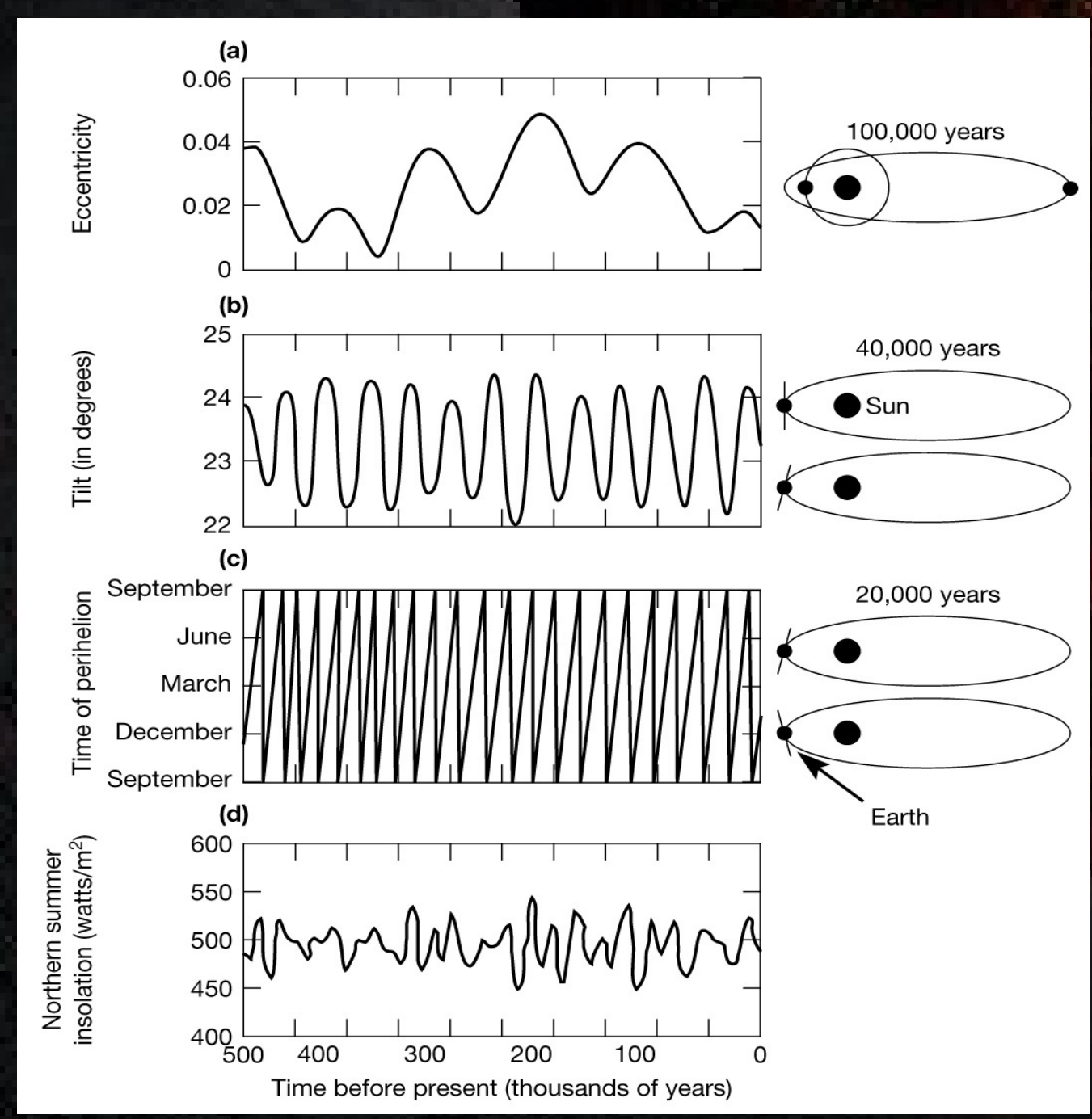
Ran GCM simulations of Earth with e=0.017, 0.06, and 0.25

- Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM)

- **Fully Coupled:**
  - GEOS-5 General Circulation Model
  - Dynamic Ocean – Modular Ocean Model (MOM) version 4
  - Dynamic Sea Ice – CICE version 4.1
  - StratChem – Stratospheric Chemistry Module

  Atmosphere
  - 2° latitude x 2.5° longitude horizontal resolution
  - 72 vertical layers from the surface to 80 km
  Ocean
  - 1° latitude x 1° longitude horizontal resolution
  - 50 vertical layers

- Initialized with present day Earth concentrations of greenhouse gases, ozone depleting substances, and an aerosol climatology
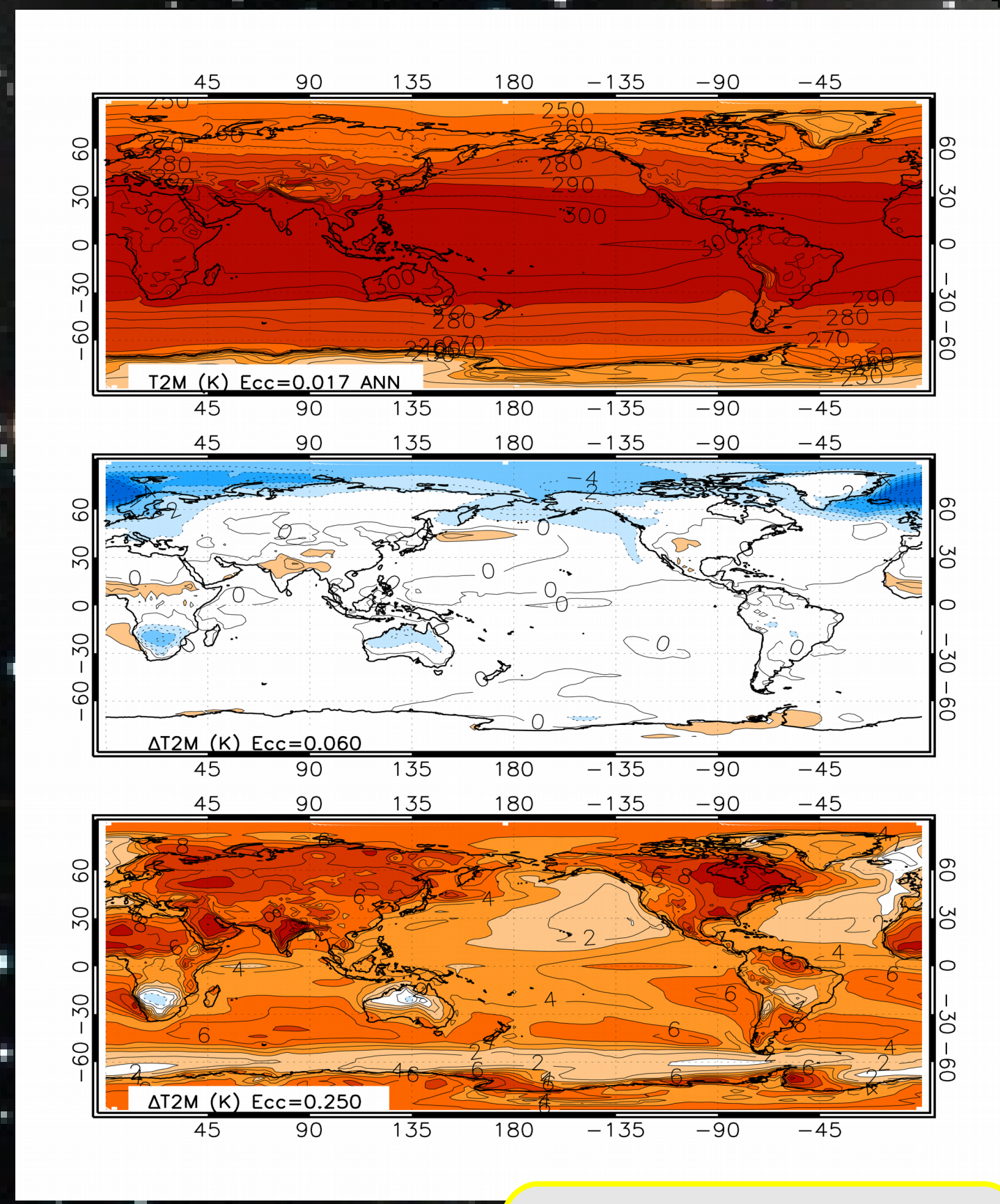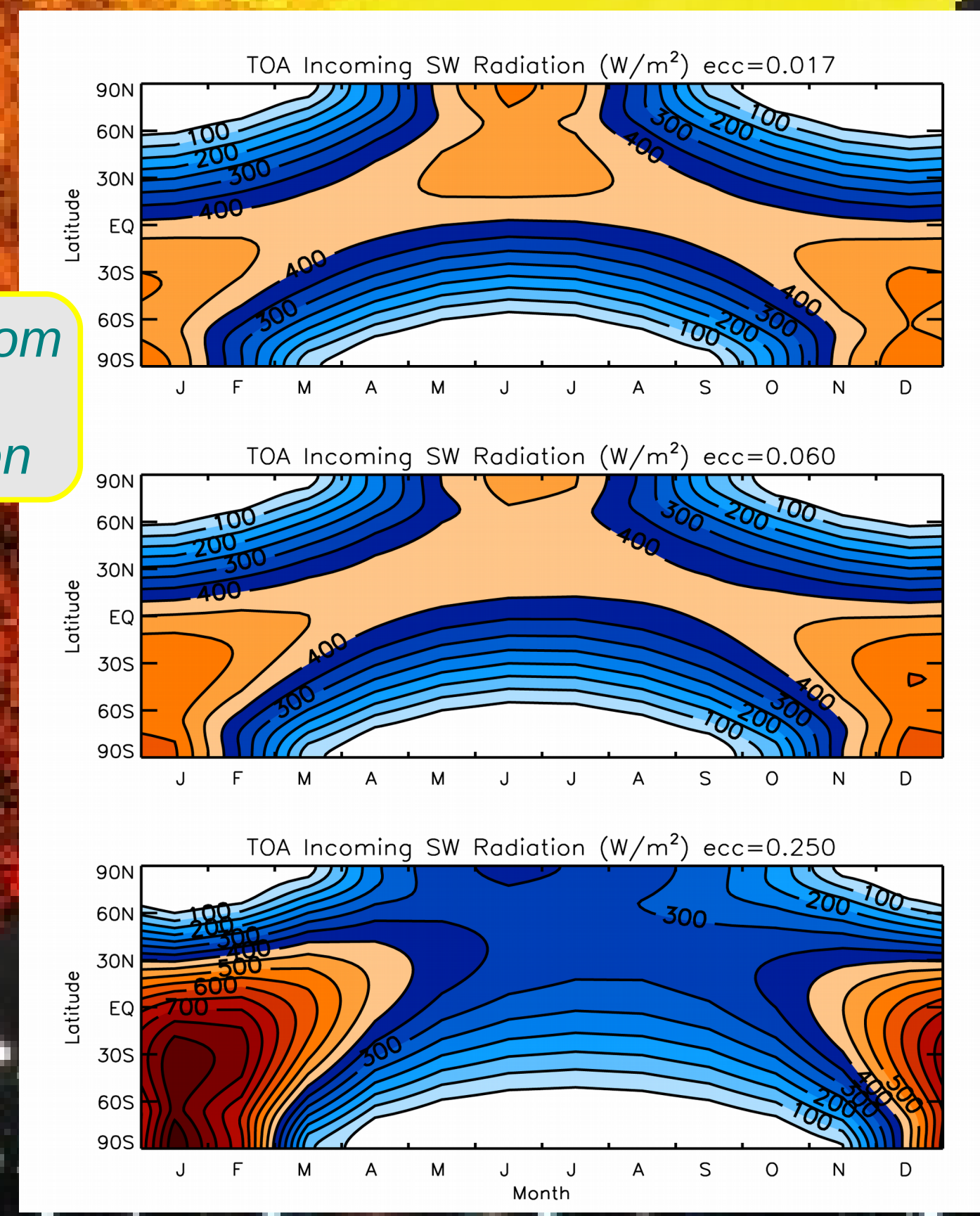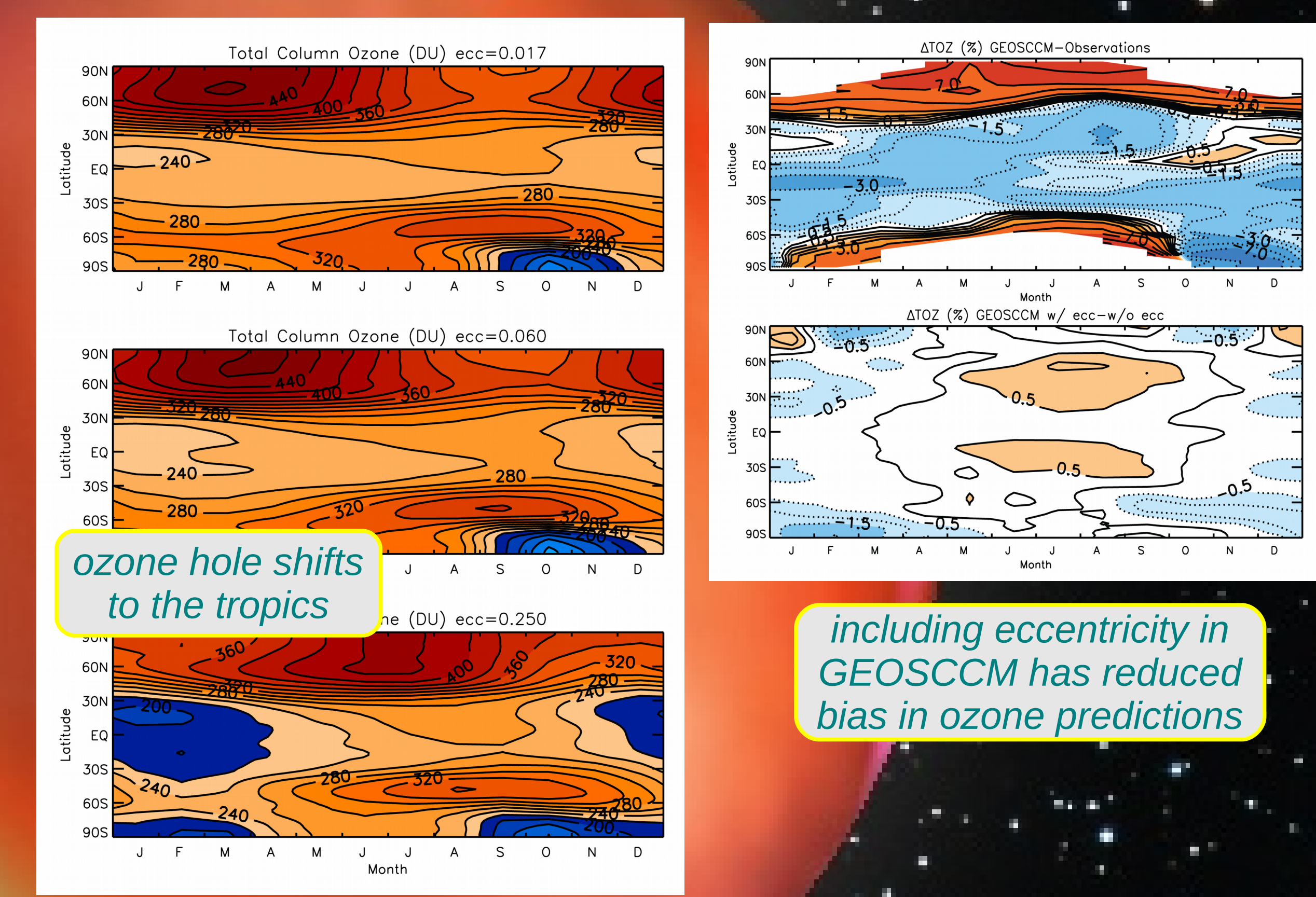

clear effects of non-linear feedback on climate

Effects on cloud coverage and precipitation

high eccentricity disrupts Hadley cells and subtropical convergence

Effects on photochemistry and ozone

ozone hole shifts to the tropics

including eccentricity in GEOSCCM has reduced bias in ozone predictions

greater temperature gradients increase transport between troposphere and stratosphere, decreasing average age of air (AOA)

Global Avg. Monthly Mean SST (K)

Ecc. = 0.017
Ecc. = 0.060
Ecc. = 0.250