Spatial and Temporal Distribution of Clouds Observed by MODIS onboard the Terra and Aqua Satellites

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With contributions from
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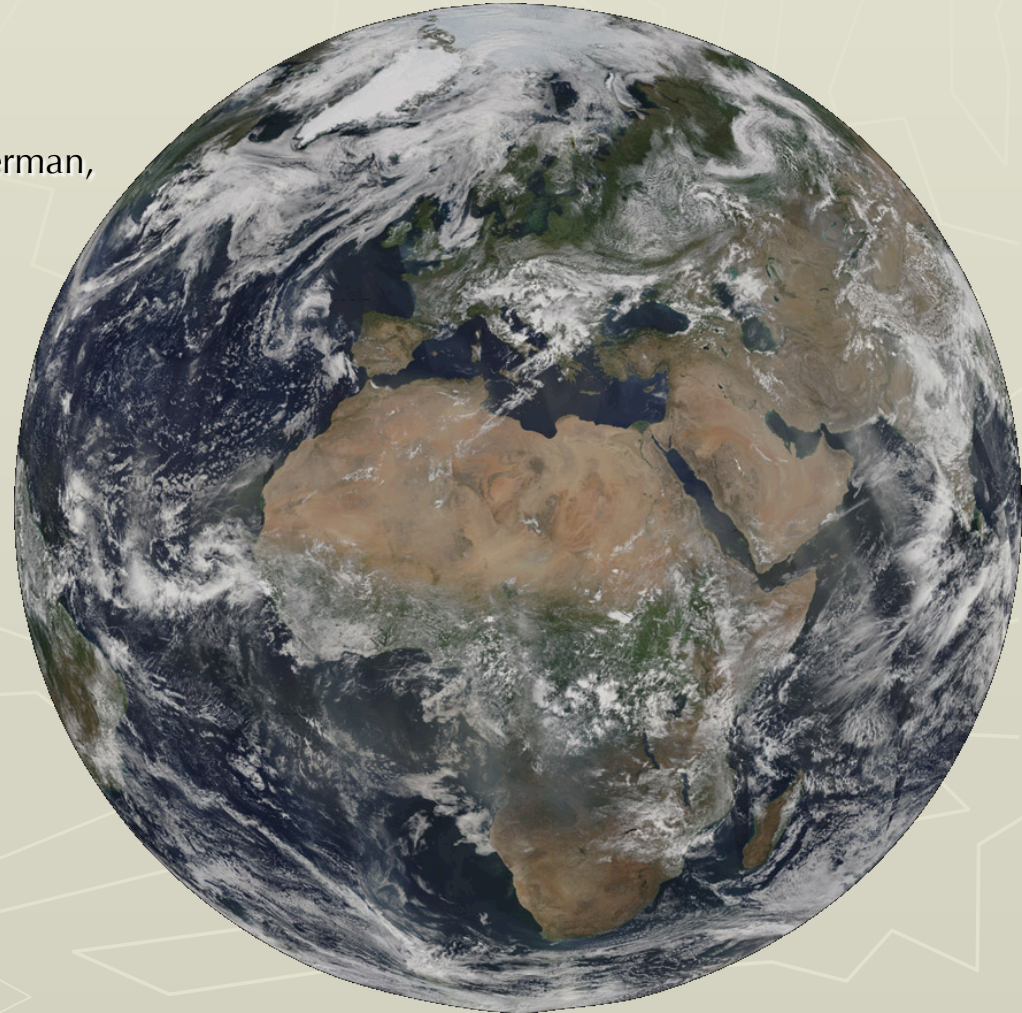
- Global-level cloud properties
  - Cloud fraction
  - Cloud top properties
  - Cloud optical & microphysical properties
  - Histograms and joint histograms



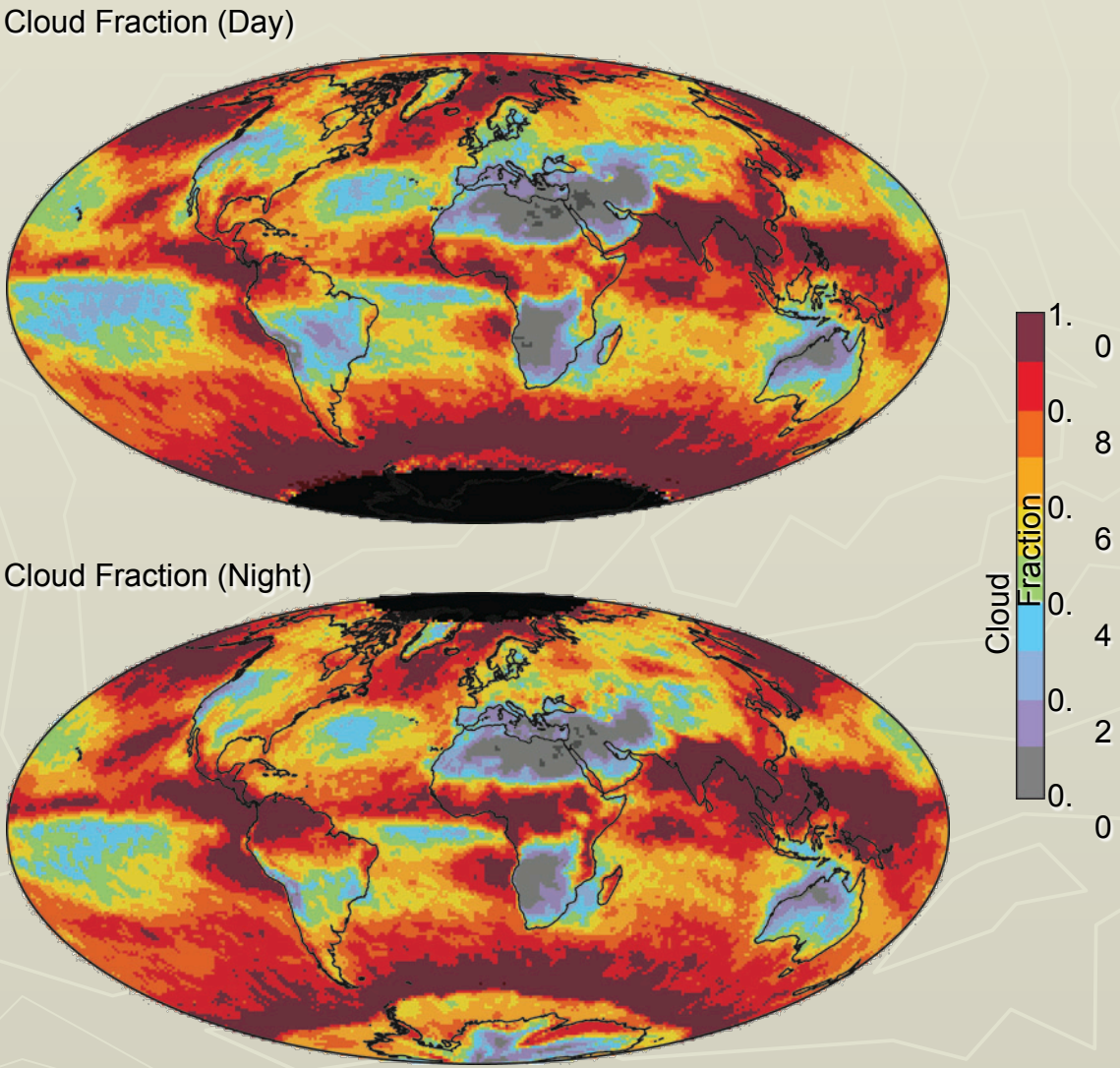
MODIS Cloud Product
(modis-atmos.gsfc.nasa.gov)

- Pixel-level (level-2) products
  - Cloud mask for distinguishing clear sky from clouds
  - Cloud radiative and microphysical properties
    - ✓ Cloud top pressure, temperature, and effective emissivity
    - ✓ Cloud optical thickness, thermodynamic phase, and effective radius
    - ✓ Thin cirrus reflectance in the visible
- Gridded time-averaged (level-3) atmosphere product
  - Daily, 8-day, and monthly products
    - ✓ $1° \times 1°$ equal angle grid
    - ✓ Mean, standard deviation, marginal probability density function, joint probability density functions

Monthly Mean Cloud Fraction
(S. A. Ackerman, R. A. Frey et al. – Univ. Wisconsin)

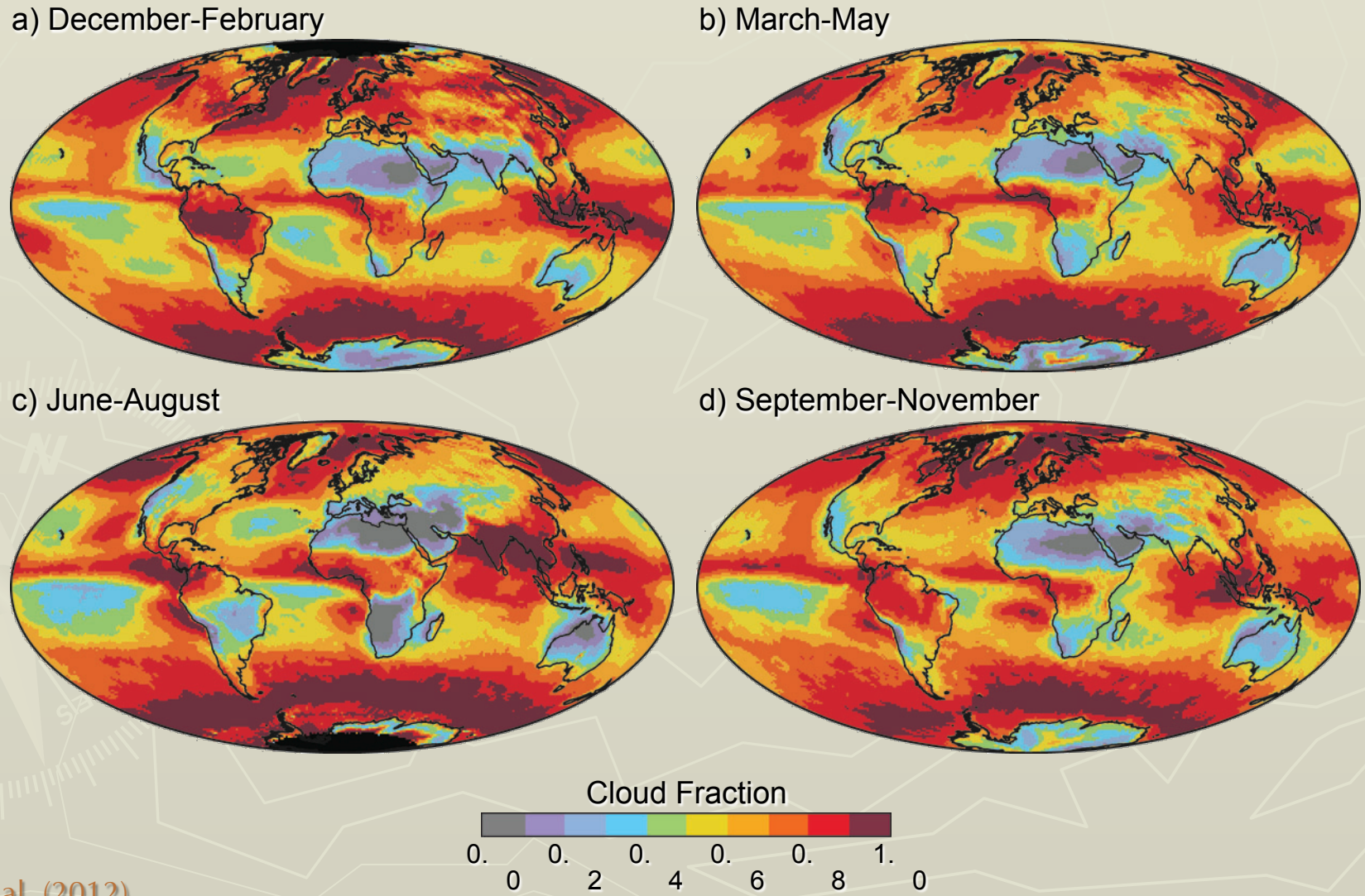
Aqua/MODIS

- Cloud fraction similar during day and night
  - Large cloud amount
    - ✓ Southern ocean
    - ✓ ITCZ
    - ✓ North Atlantic
    - ✓ Indonesia and western tropical Pacific
  - Small cloud amount
    - ✓ Subtropical gyres over the ocean
    - ✓ Deserts
    - ✓ Antarctica
    - ✓ Greenland



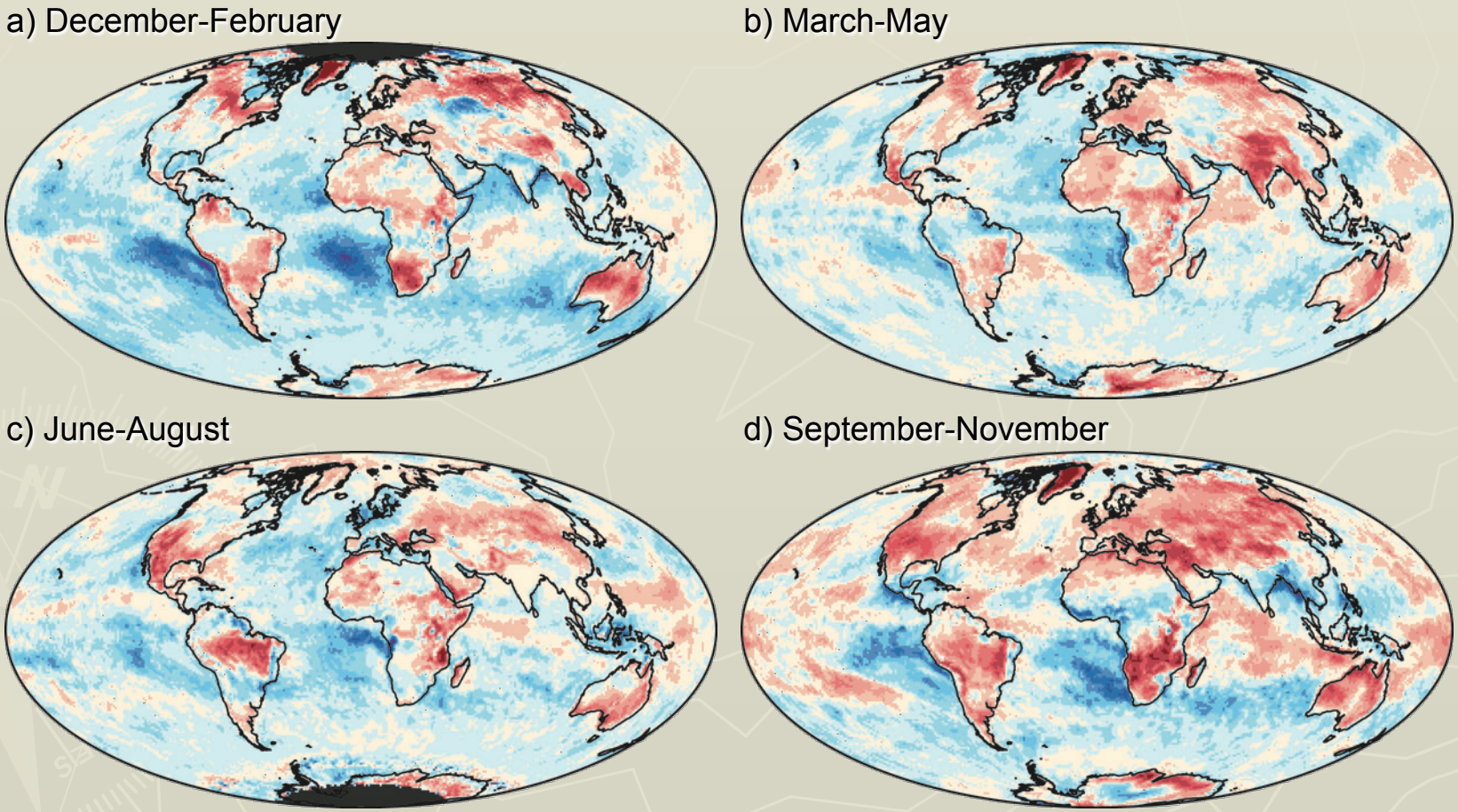
Seasonal Mean Daytime Cloud Fraction

Aqua (2002-2011)



King et al. (2012)

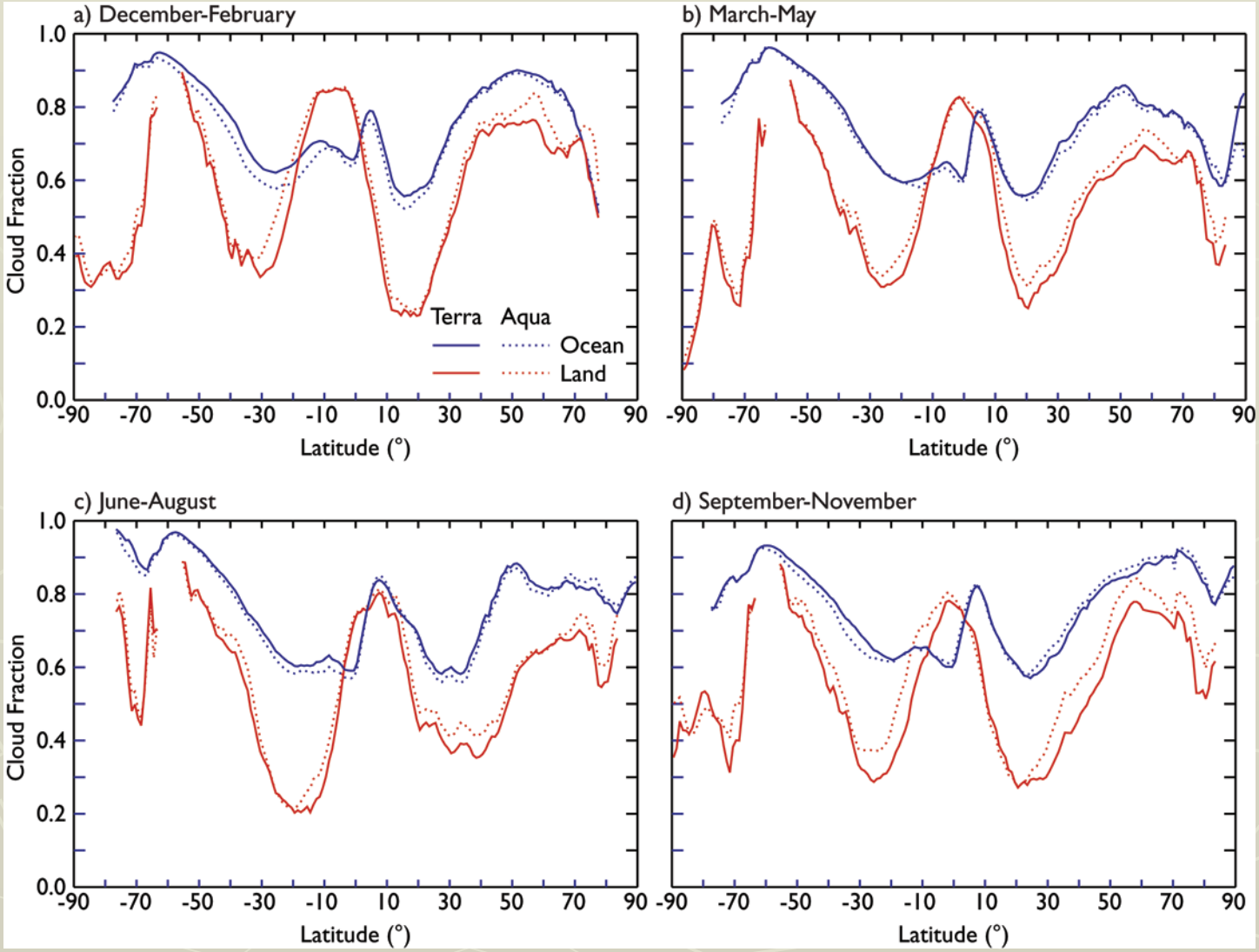
Aqua-Terra Daytime Cloud Fraction
(September 2002-August 2011)



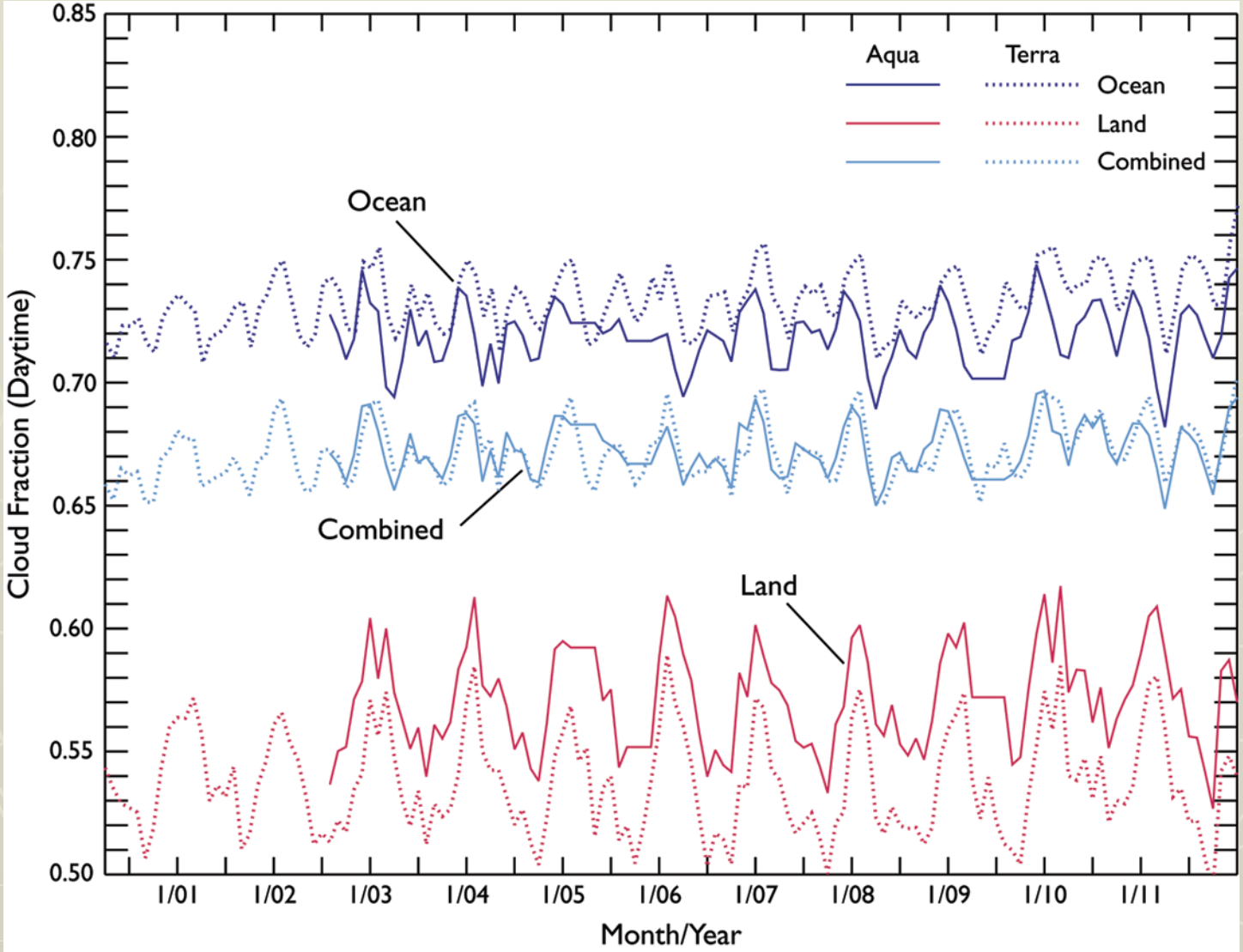
King et al. (2012)

Zonal Mean Daytime Cloud Fraction

Terra (2000-2011) and Aqua (2002-2011)

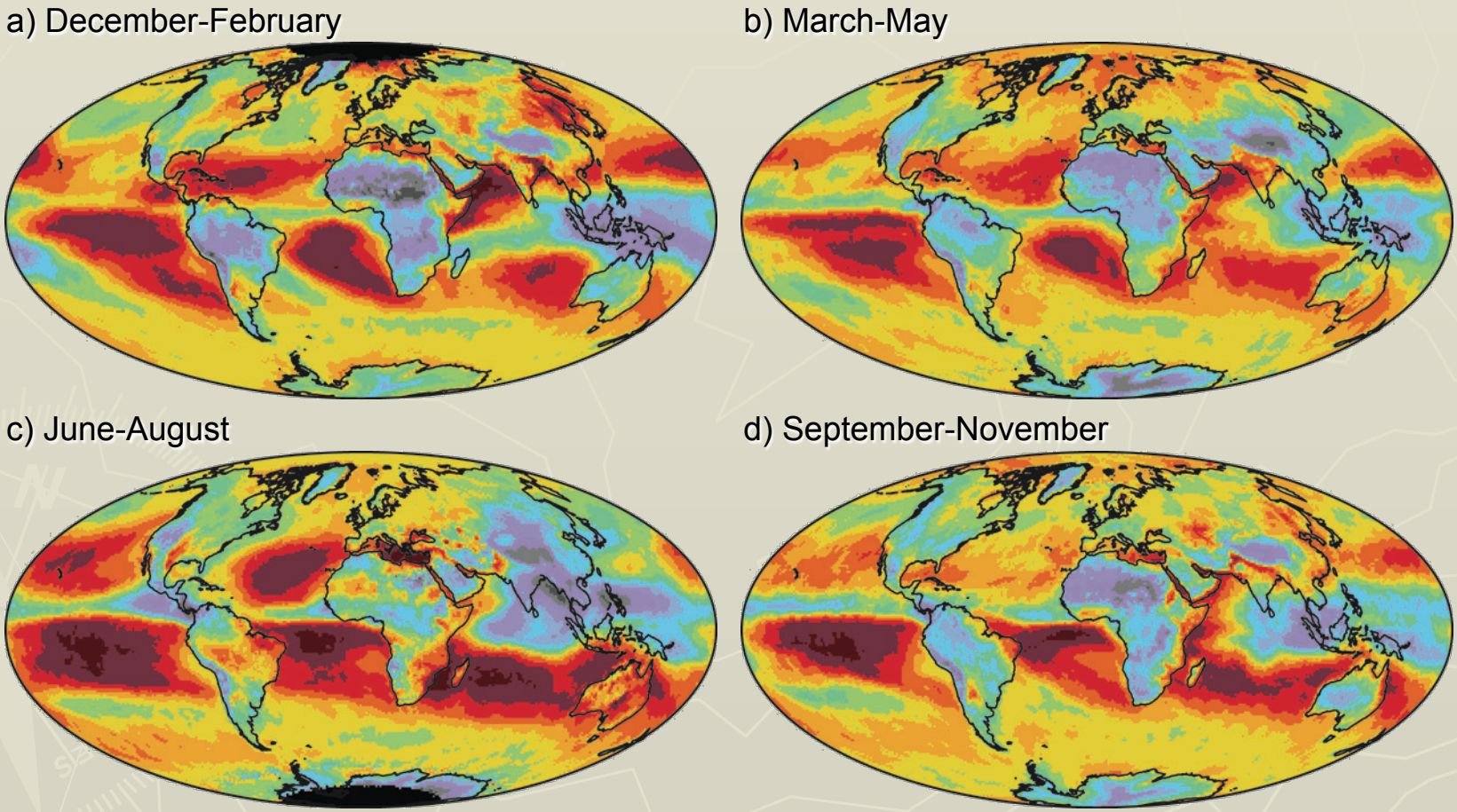


Time Series of Cloud Fraction during the Daytime
(March 2000-December 2011)



Seasonal Mean Daytime Cloud Top Pressure

Aqua (2002-2011)



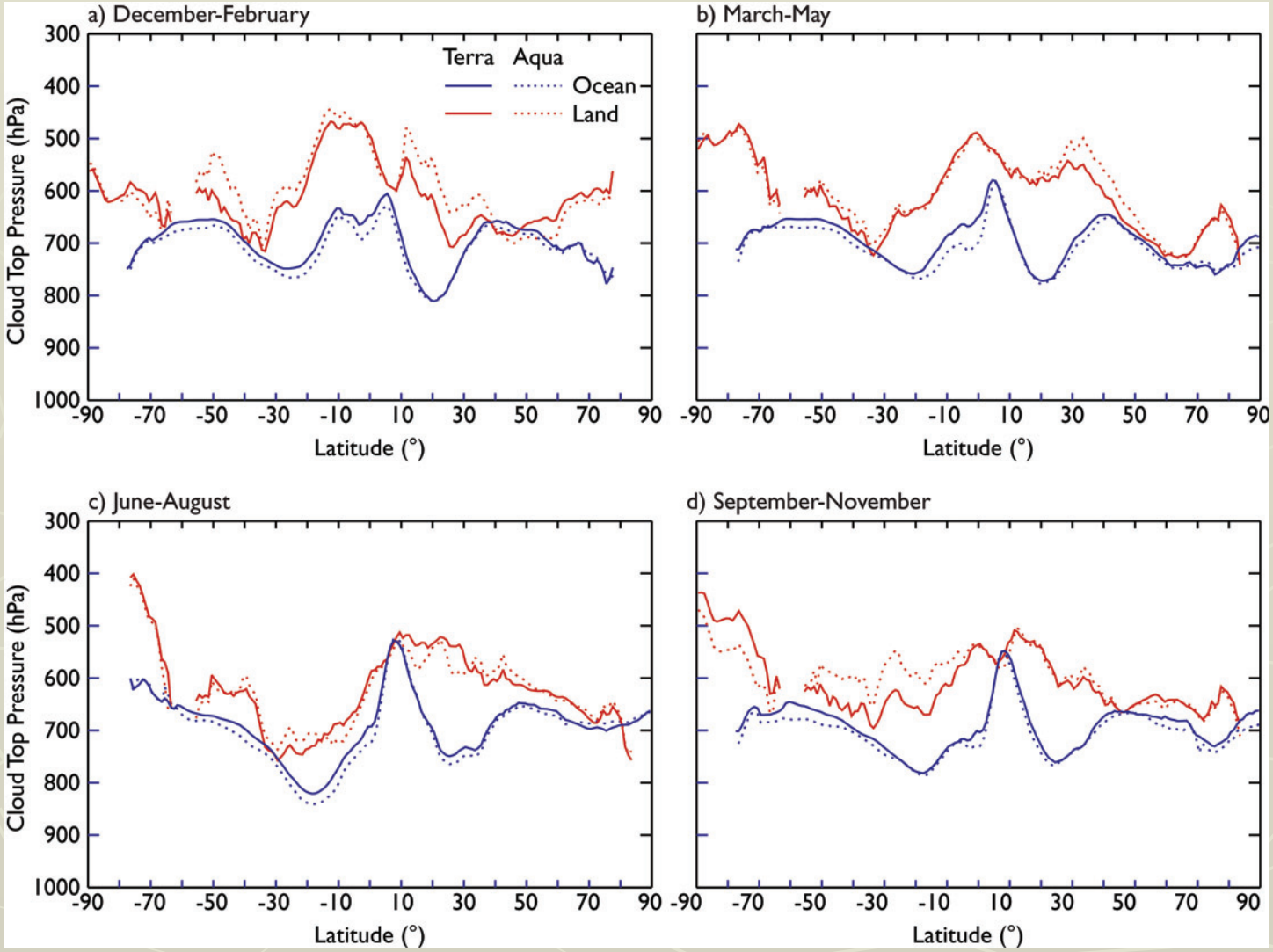
Cloud Top Pressure (hPa)

300 400 500 600 700 800 900 1000

King et al. (2012)

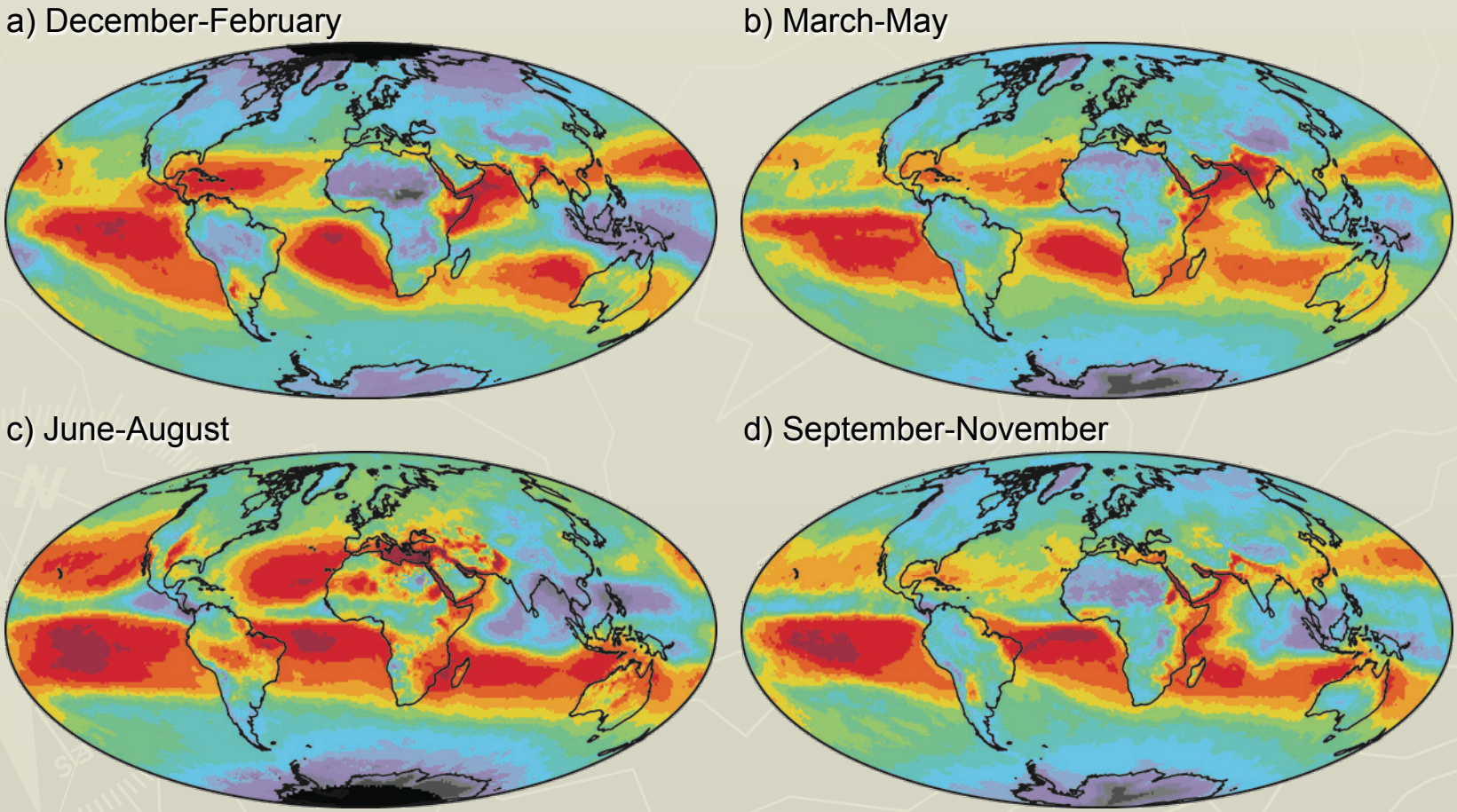
Zonal Mean Daytime Cloud Top Pressure

Terra (2000-2011) and Aqua (2002-2011)



Seasonal Mean Daytime Cloud Top Temperature

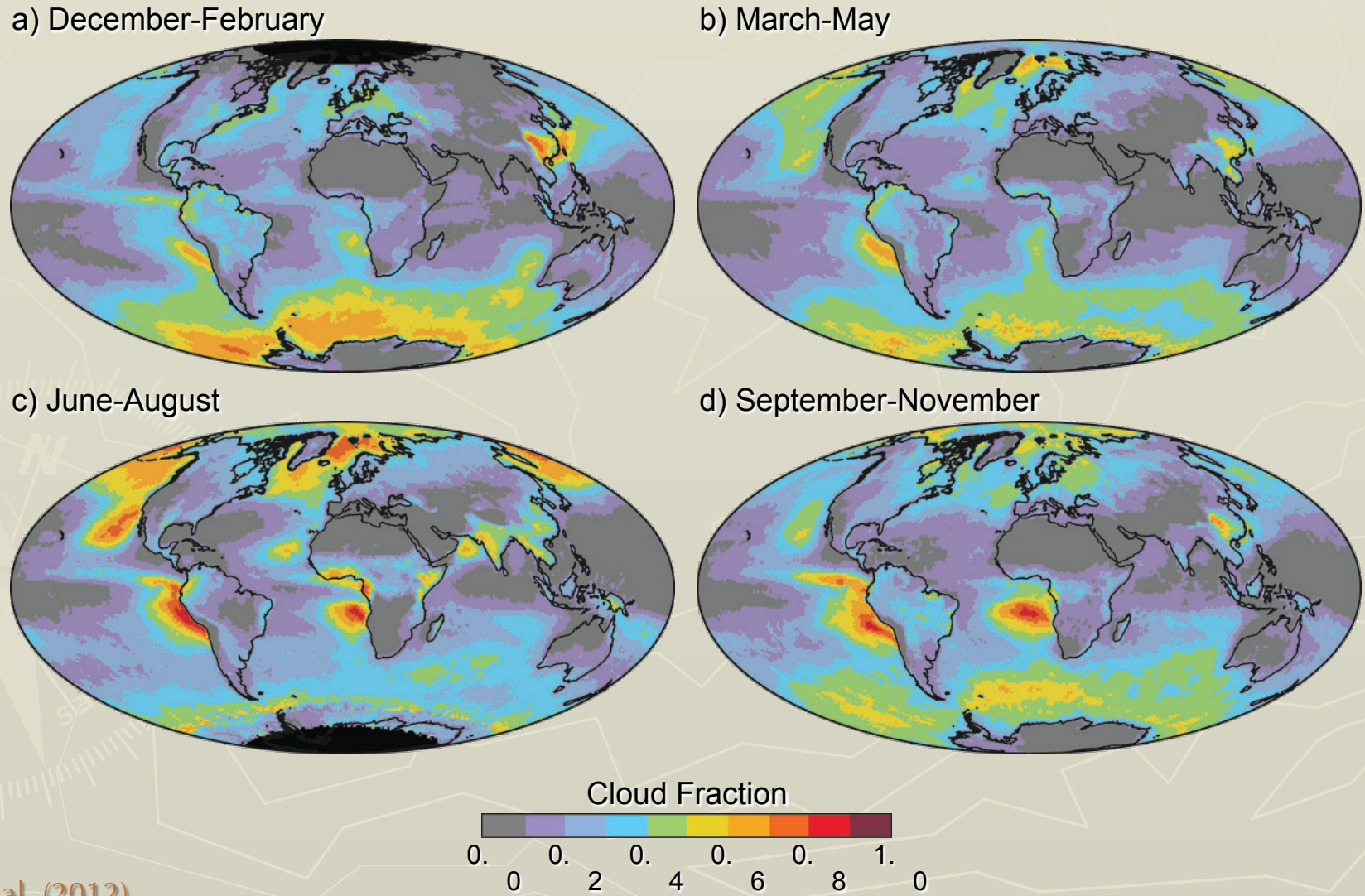
Aqua (2002-2011)



King et al. (2012)

Seasonal Cloud Top Fraction for Liquid Water Clouds

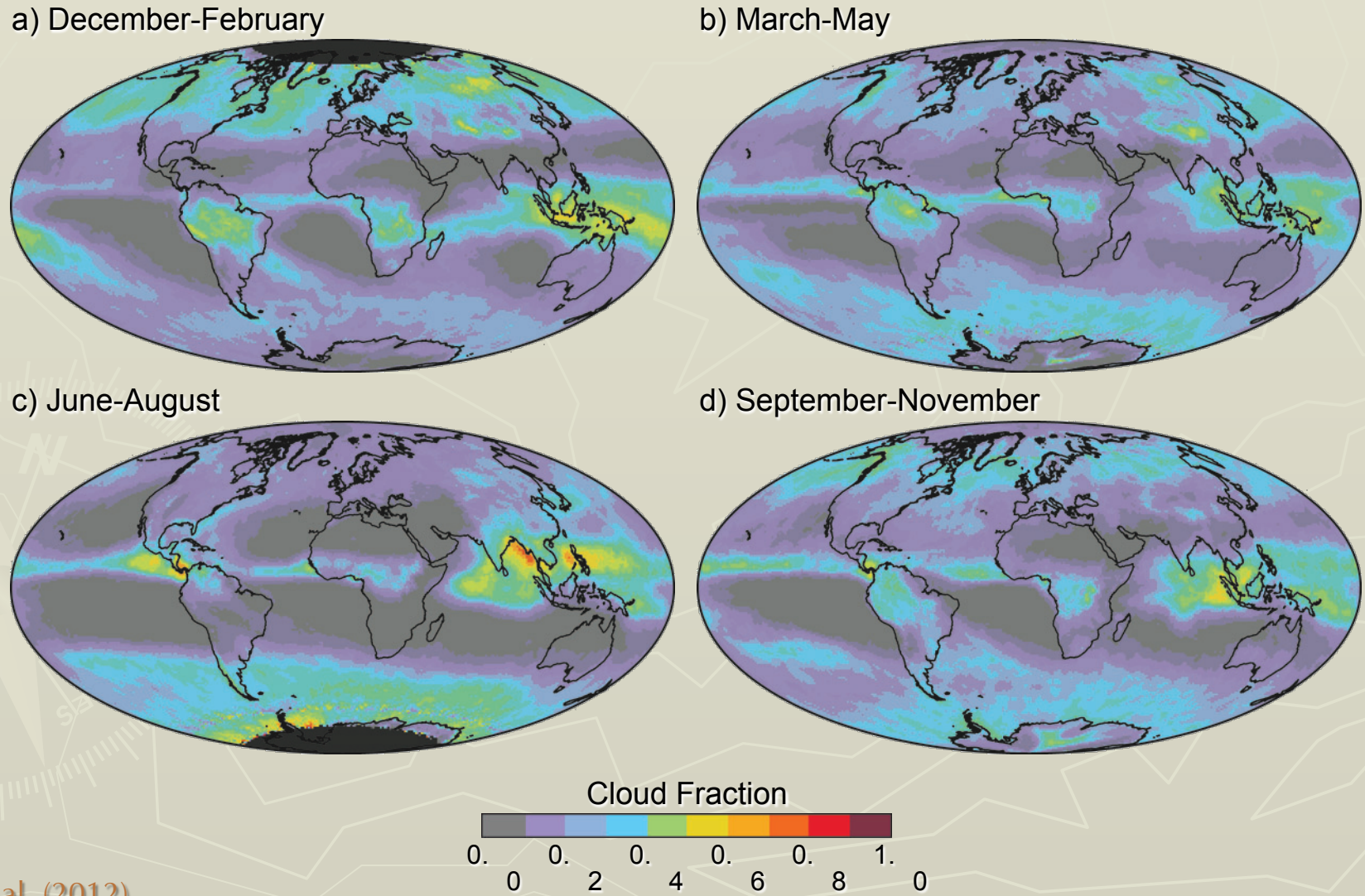
Aqua (2002-2011)



King et al. (2012)

Seasonal Cloud Top Fraction for Ice Clouds

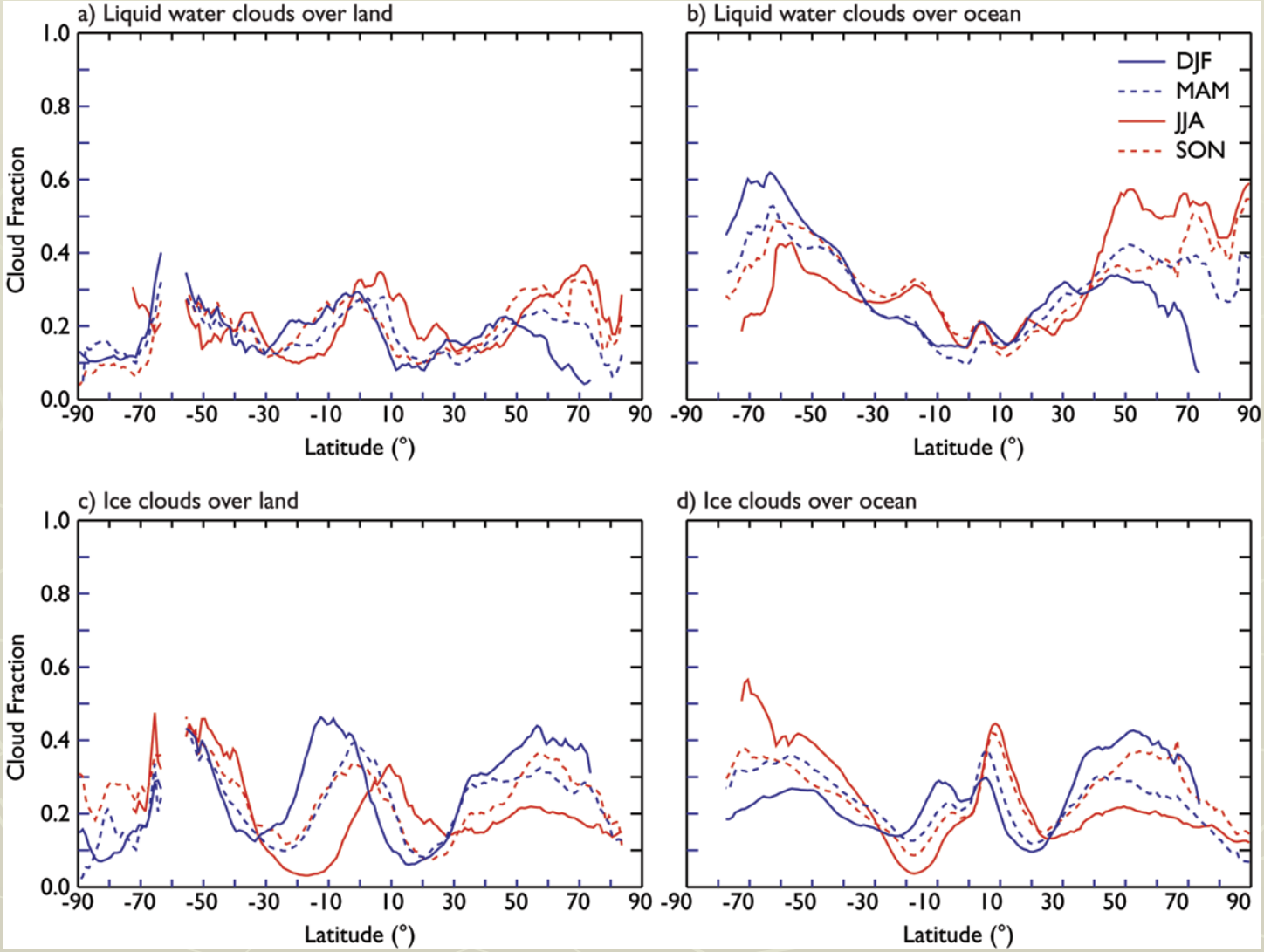
Aqua (2002-2011)



King et al. (2012)

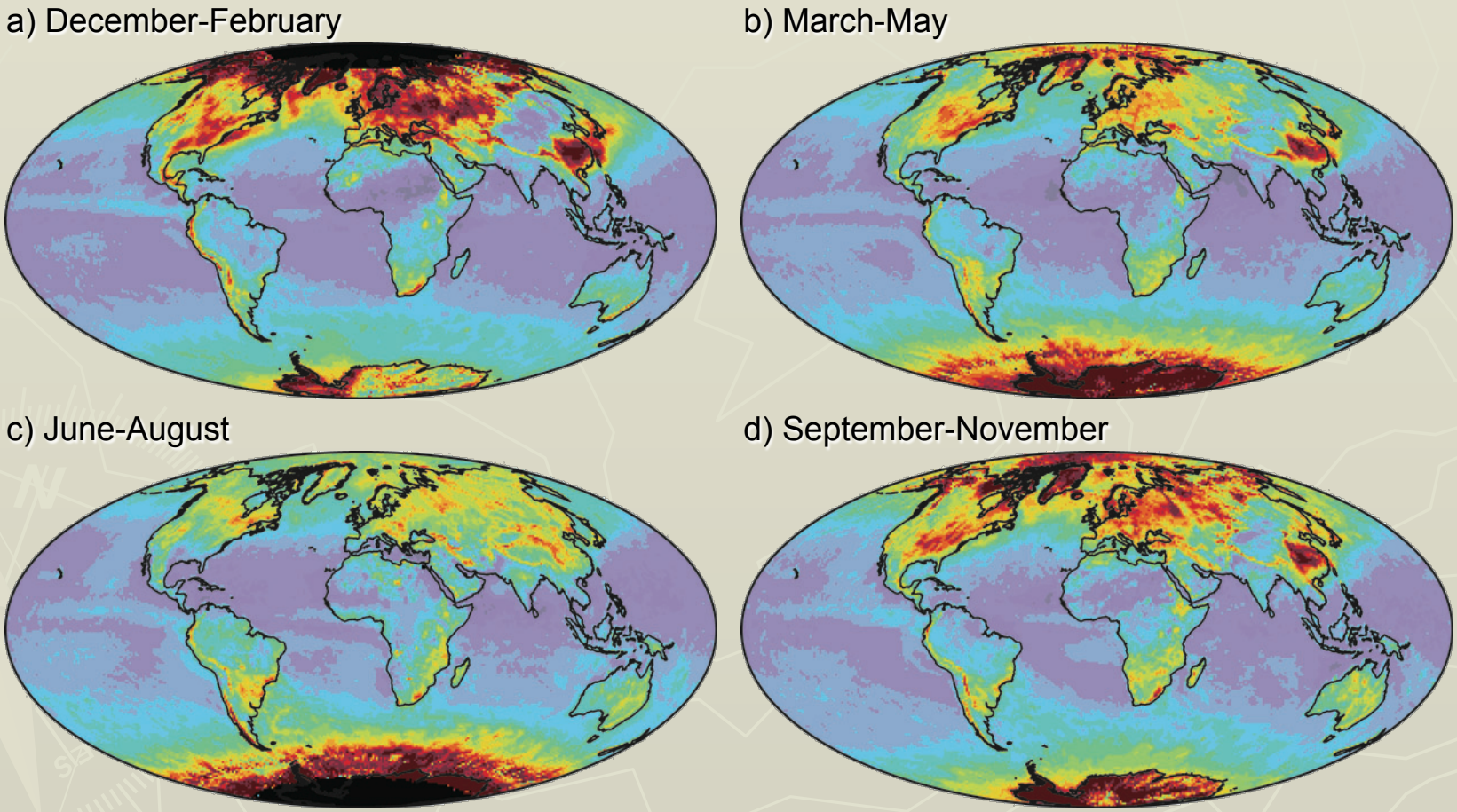
Zonal Mean Cloud Fraction for Liquid Water & Ice Clouds

Aqua (2002-2011)



Seasonal Cloud Optical Thickness for Liquid Water Clouds

Aqua (2002-2011)



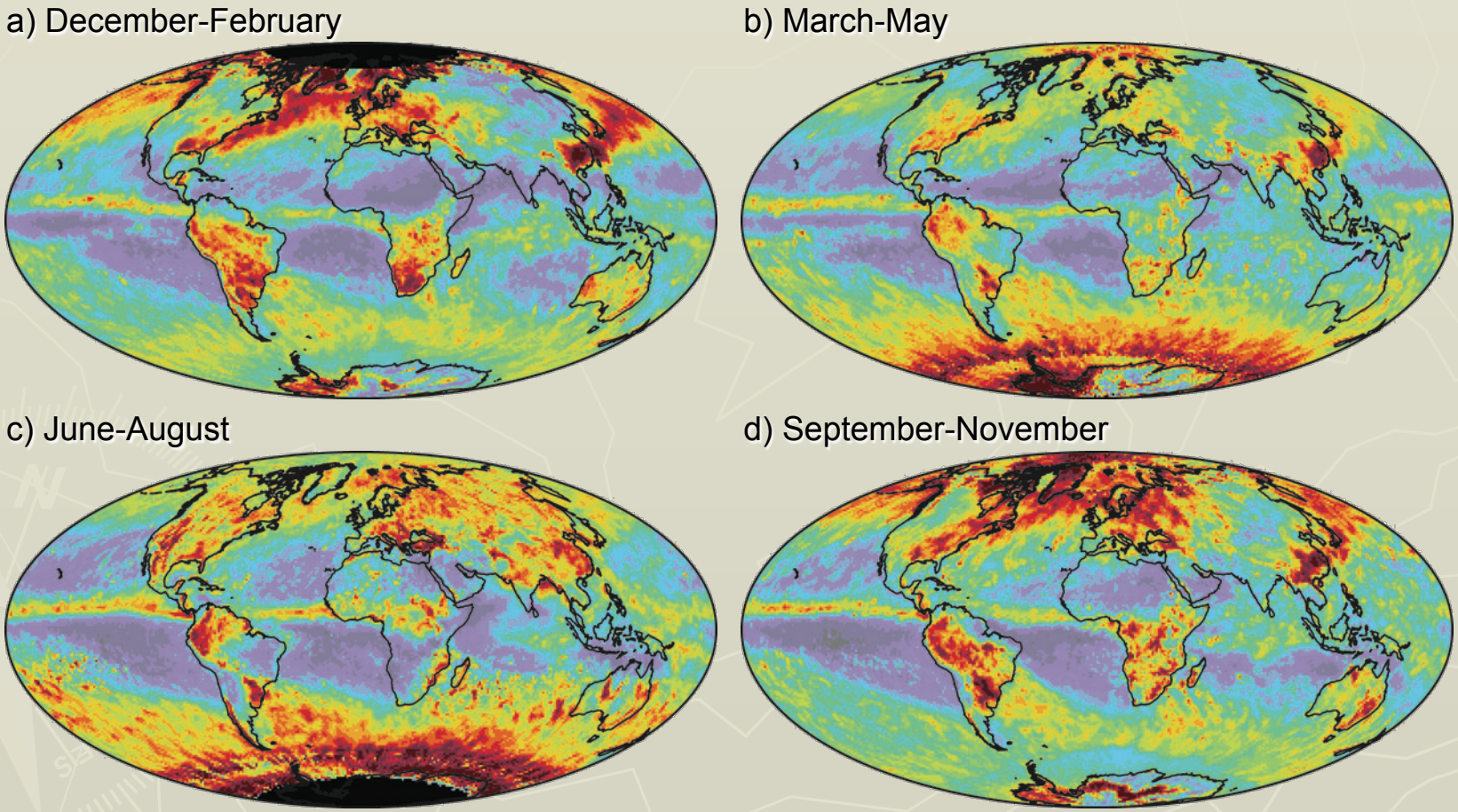
Cloud Optical Thickness

0 4 8 12 16 20 24 28 32

King et al. (2012)

Seasonal Cloud Optical Thickness for Ice Clouds

Aqua (2002-2011)



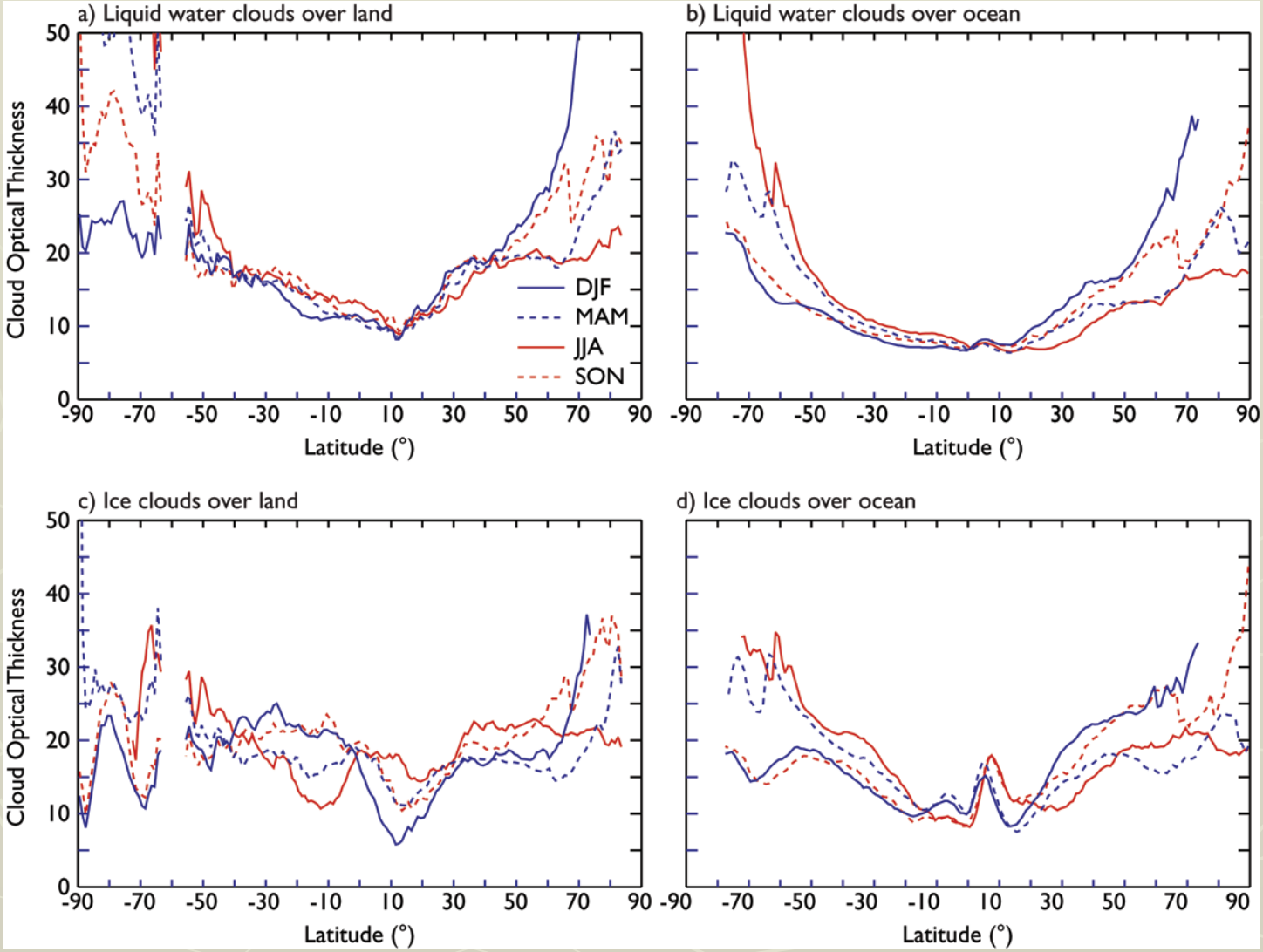
Cloud Optical Thickness

0 4 8 12 16 20 24 28 32

King et al. (2012)

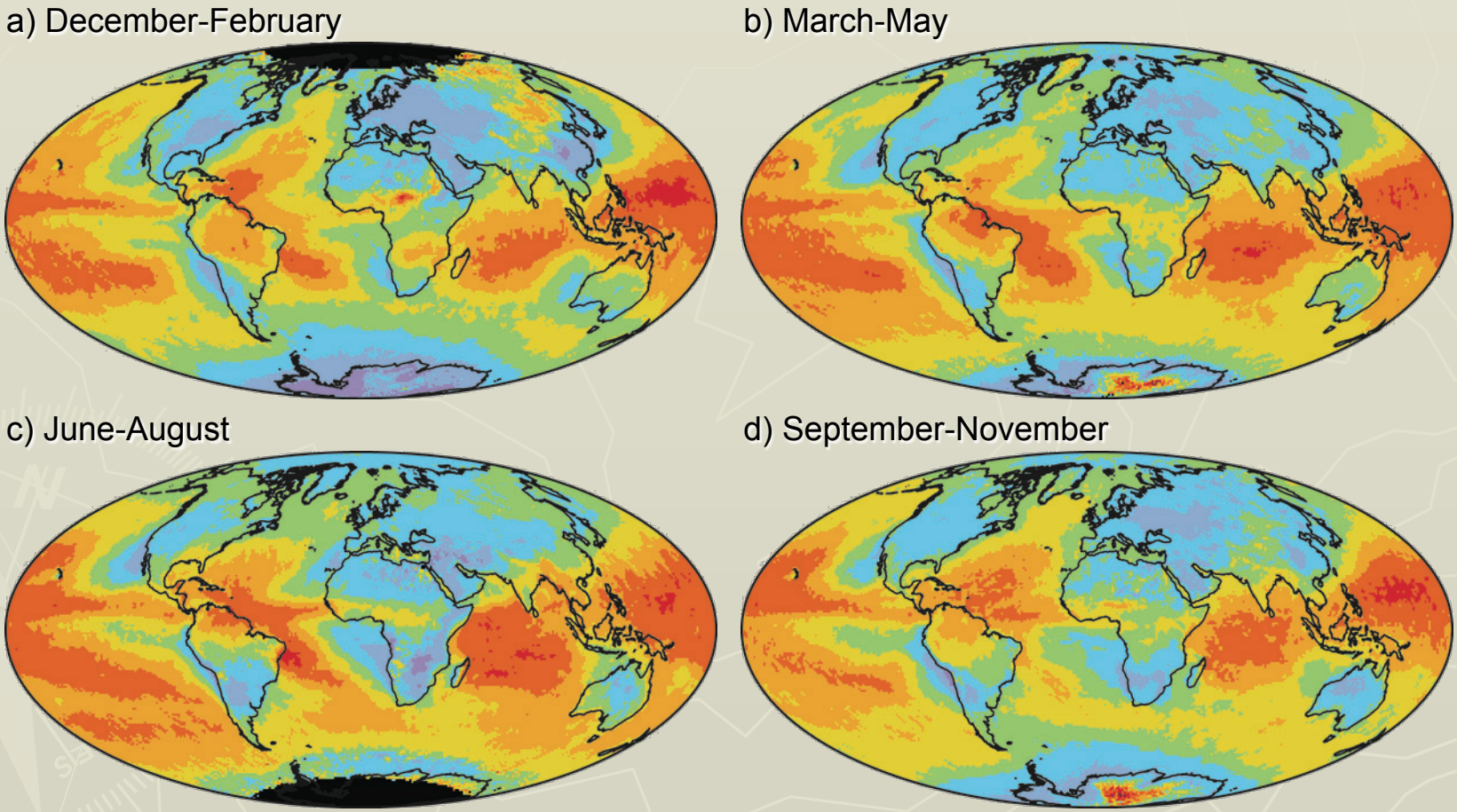
Zonal Optical Thickness for Liquid Water & Ice Clouds

Aqua (2002-2011)



Seasonal Cloud Effective Radius for Liquid Water Clouds

Aqua (2002-2011)



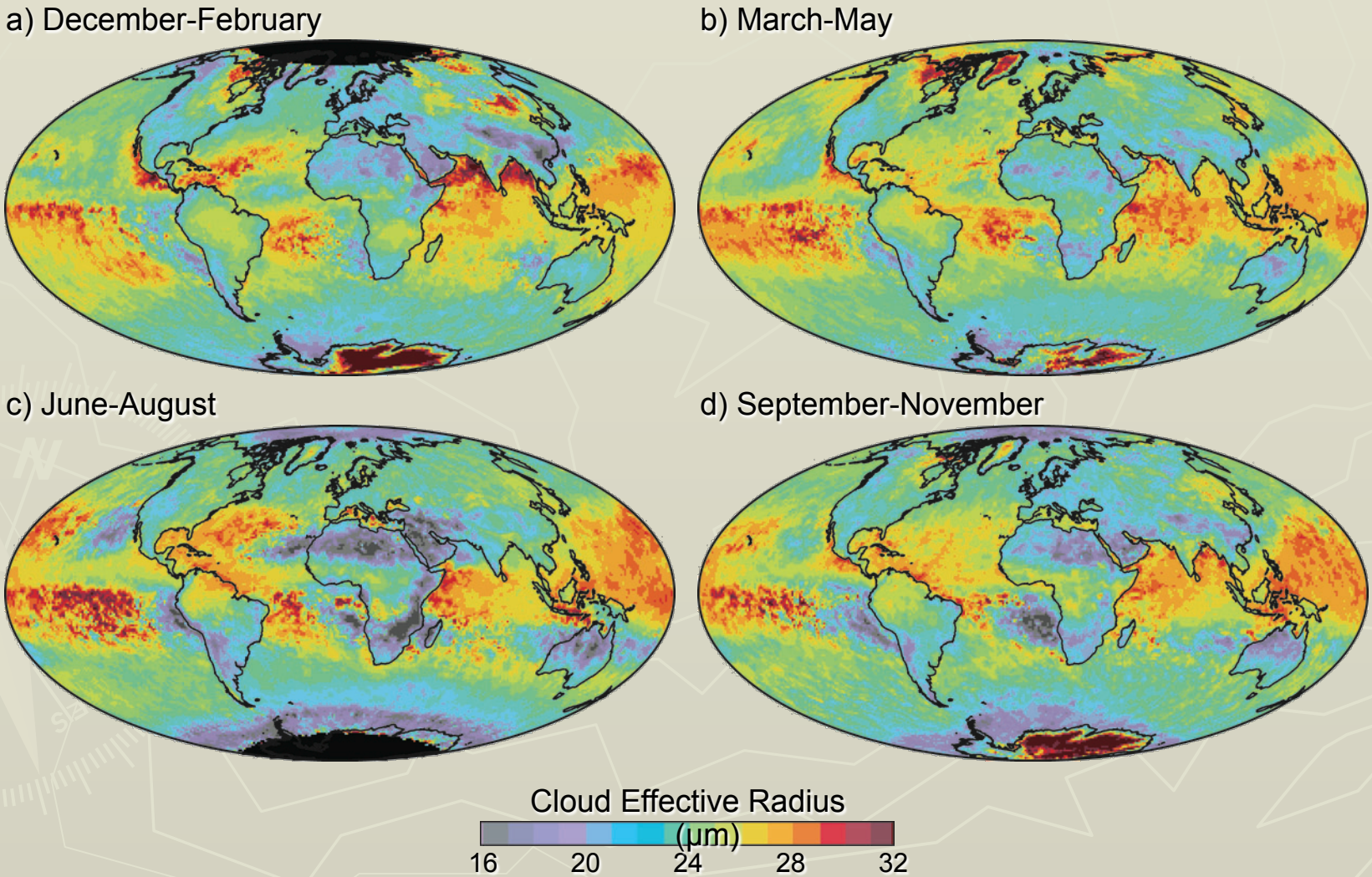
Cloud Effective Radius (μm)

5 9 13 17 21 25

King et al. (2012)

Seasonal Cloud Effective Radius for Ice Clouds

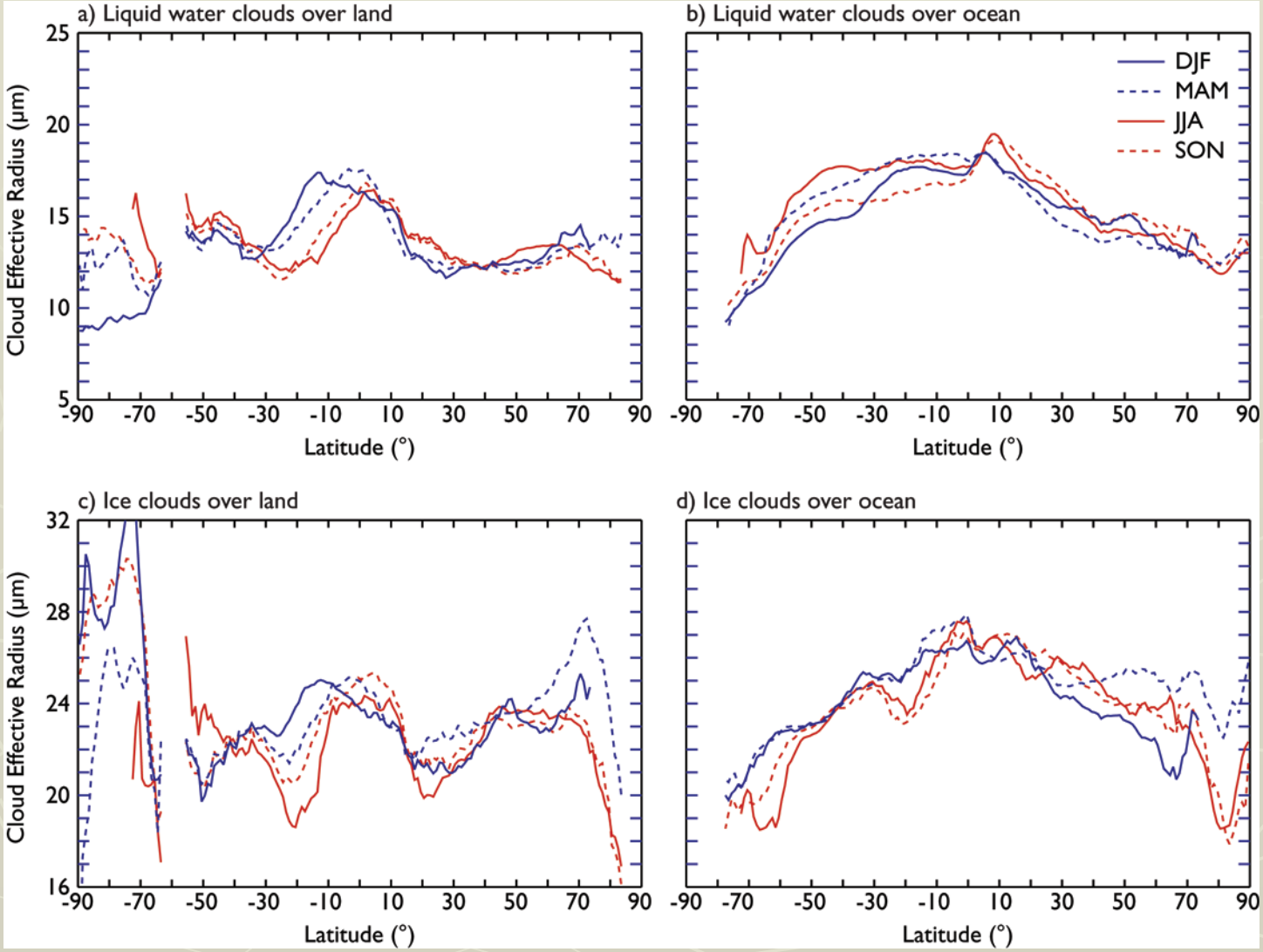
Aqua (2002-2011)



King et al. (2012)

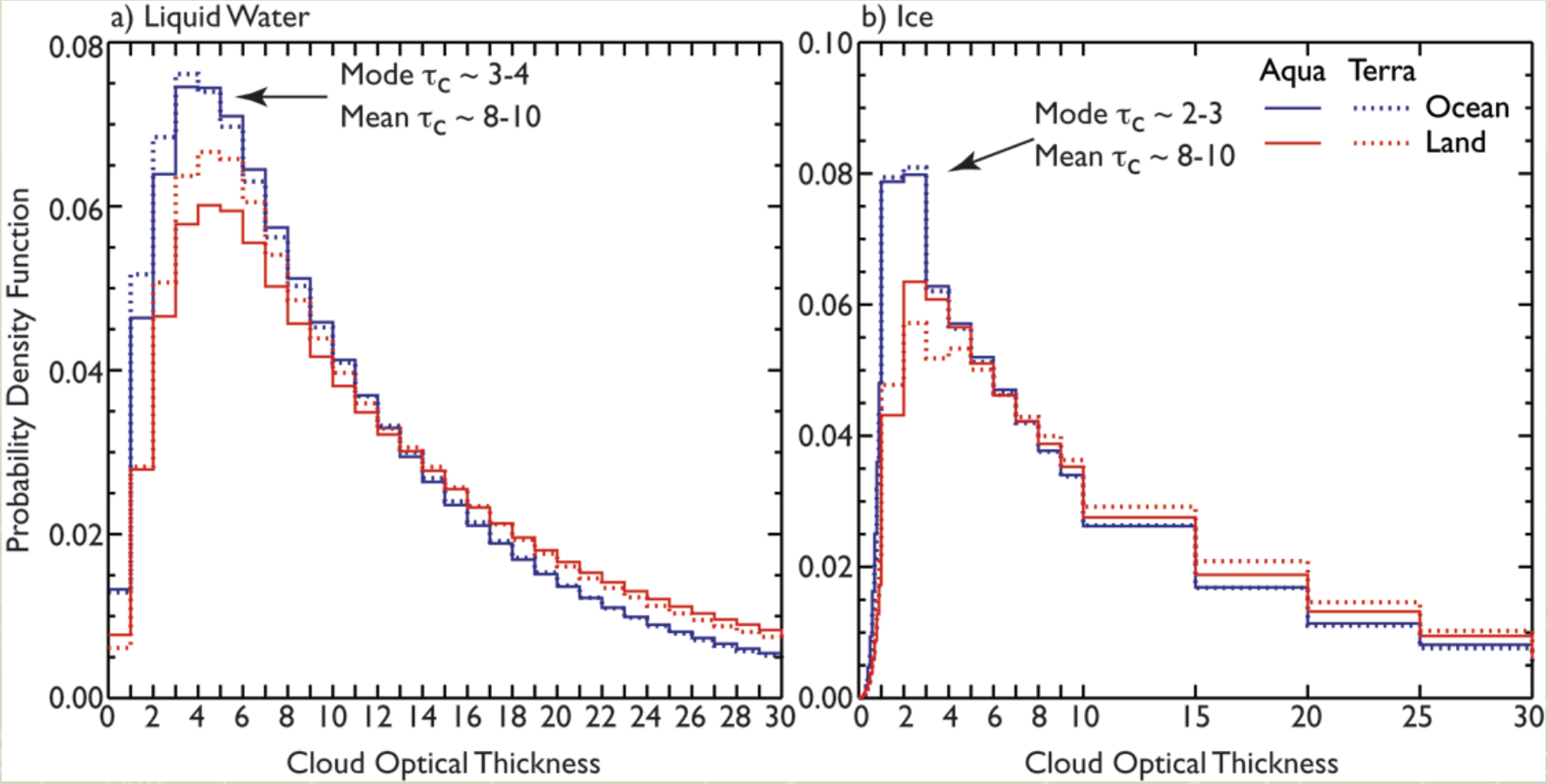
Zonal Effective Radius for Liquid Water & Ice Clouds

Aqua (2002-2011)



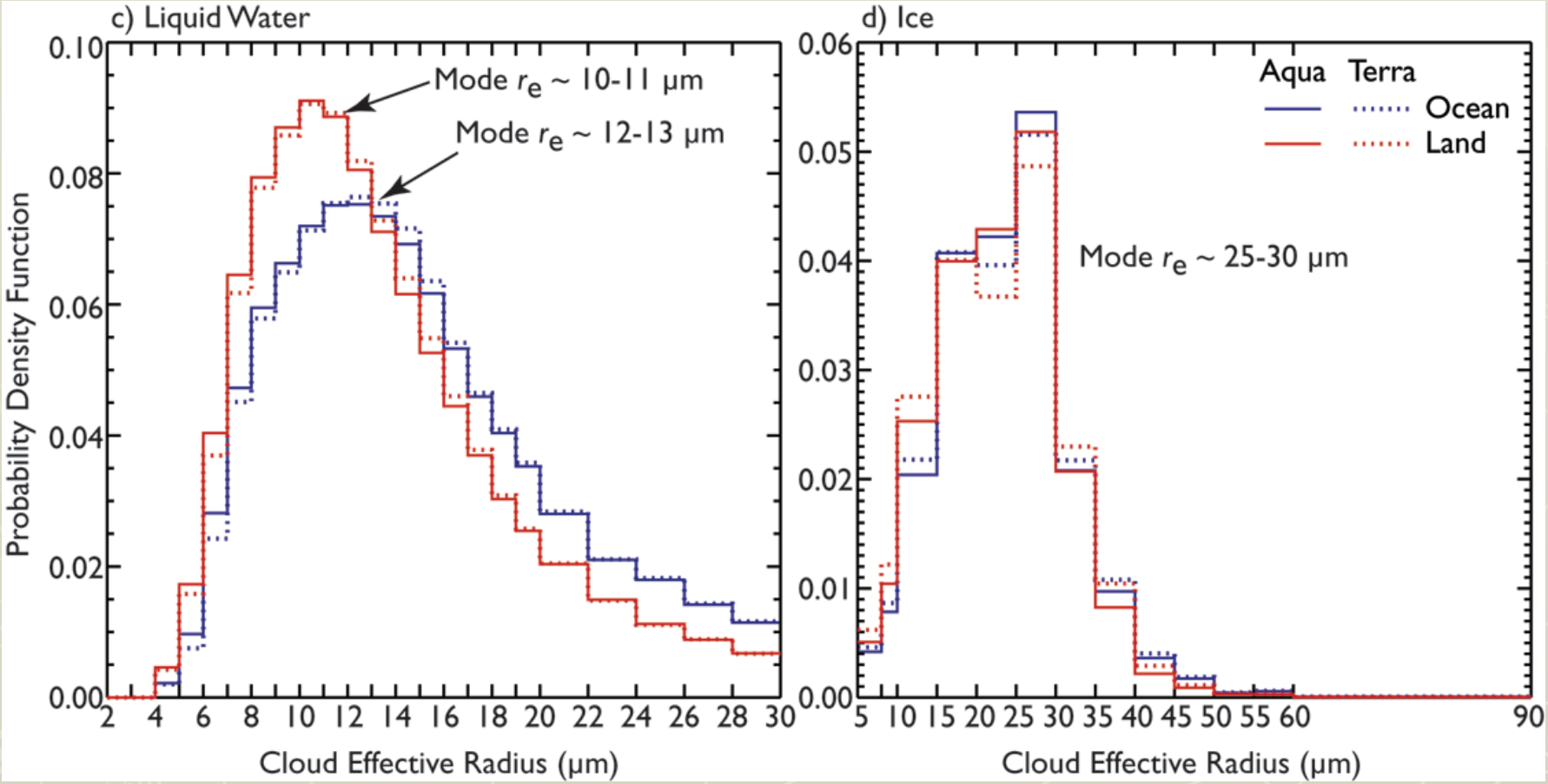
Probability Distribution of Cloud Optical Thickness

July 2006 (Global)



Probability Distribution of Cloud Effective Radius

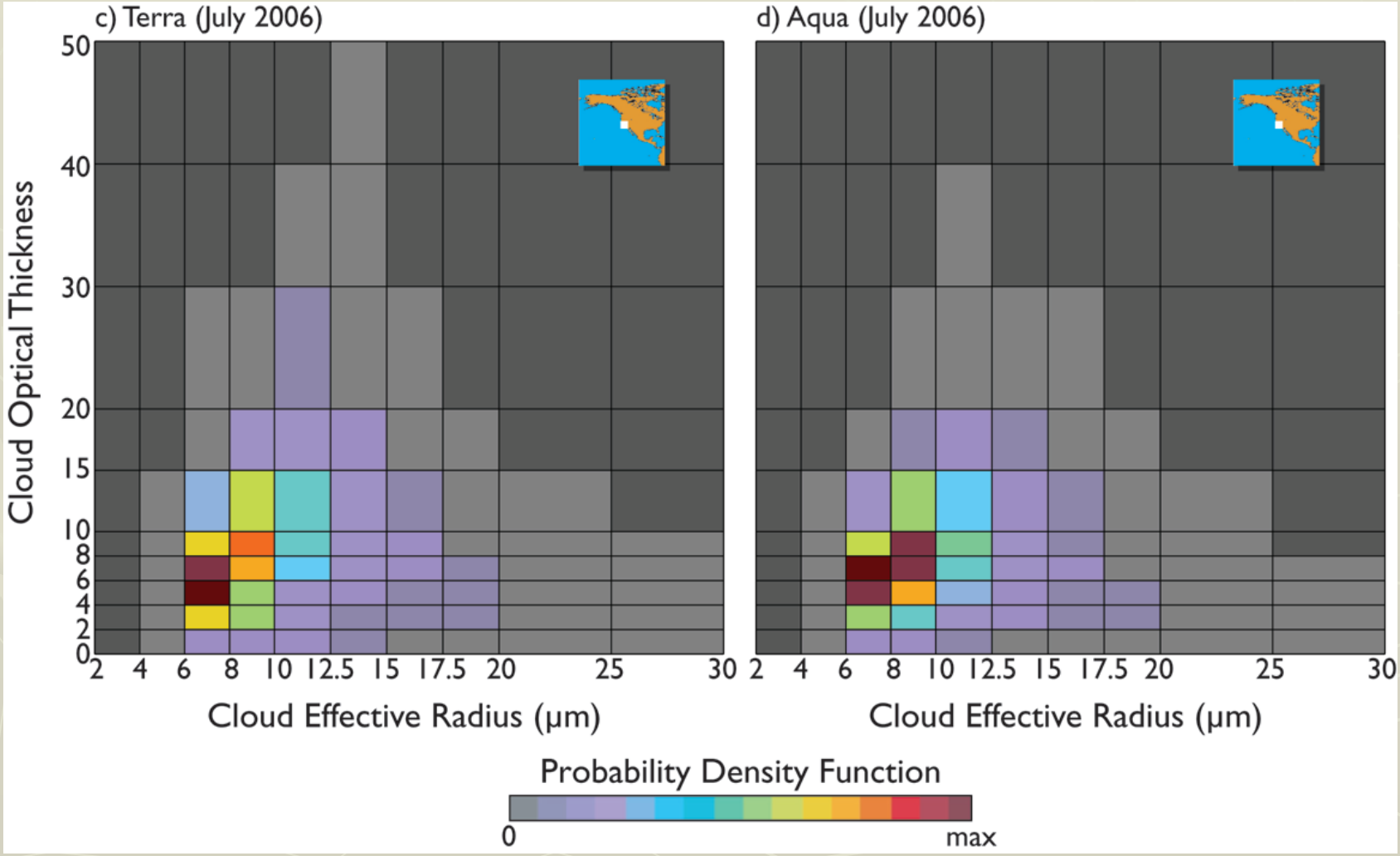
July 2006 (Global)



MODIS τ_c vs r_e Joint Histograms

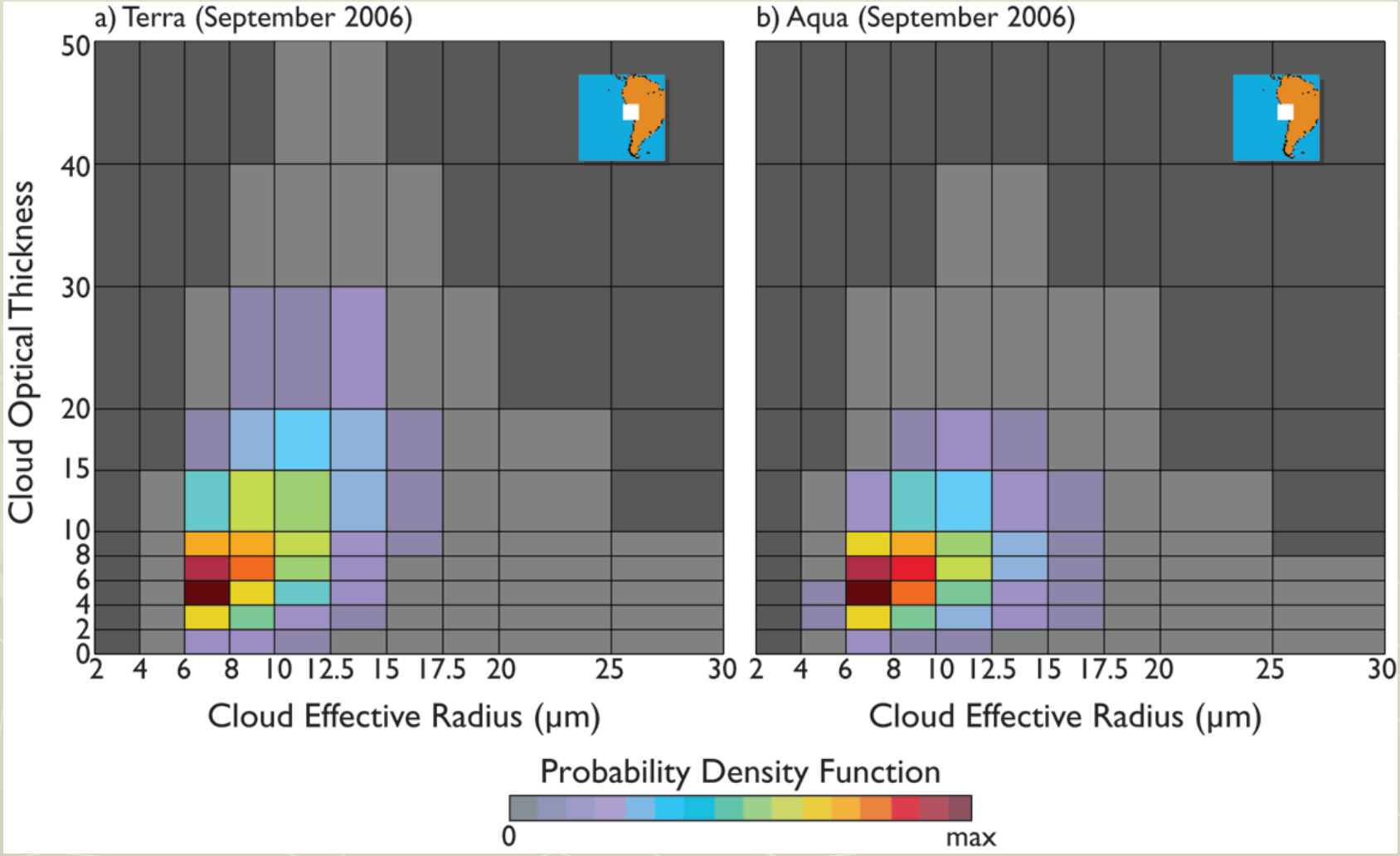
Liquid Water Clouds over Ocean

32°-40°N, 117°-125°W



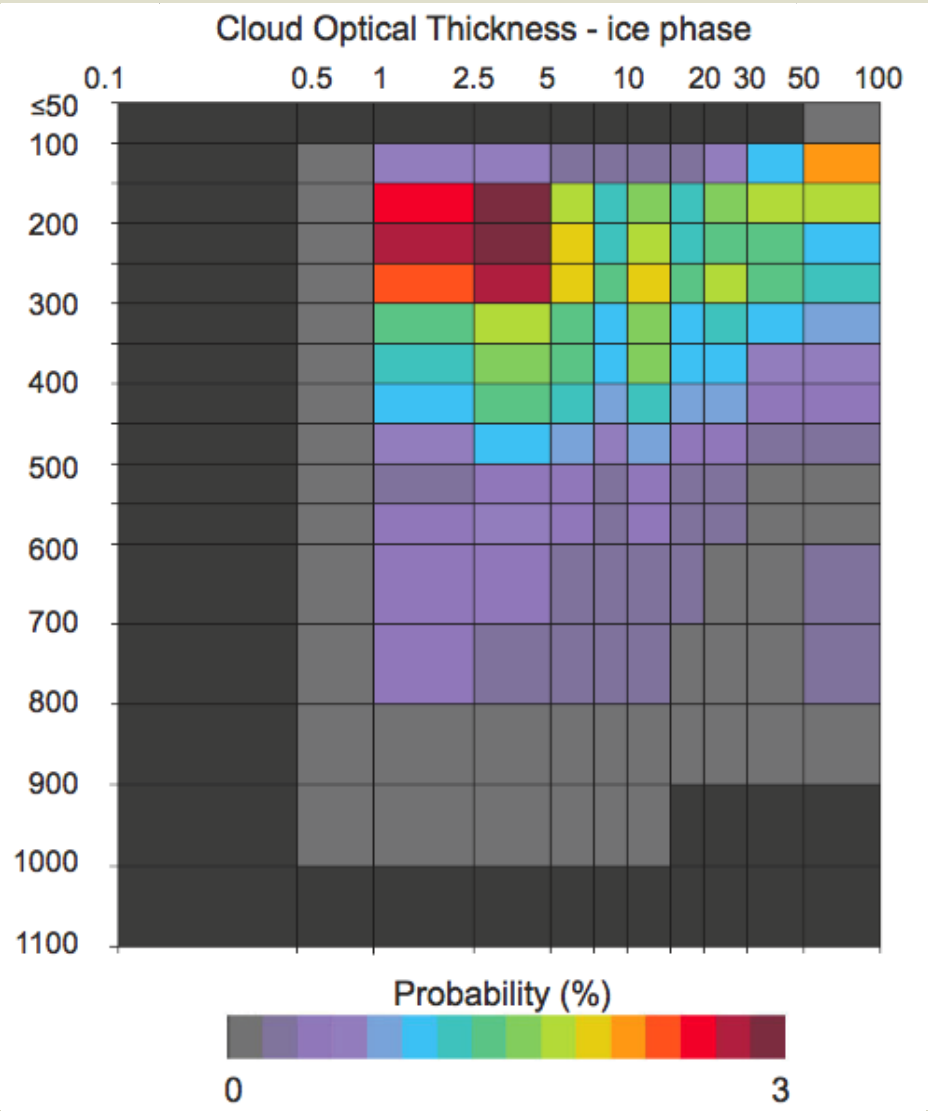
MODIS τ_c vs r_e Joint Histograms
Liquid Water Clouds over Ocean

12°-24°S, 68°-80°W



MODIS and ISCCP-like τ_c vs p_c Joint Histograms

50°N-50°S
Terra
August 2001



Summary and Conclusions

- Cloud fraction nearly the same during daytime and nighttime
  - Higher over ocean (~72%) than land (~55%)
  - Higher over land in afternoon and ocean in morning
  - Global average of 66%-69%
    - ✓ Higher during northern winter
- Cloud top properties
  - Higher clouds (cloud top pressures lower by 100 hPa) over land than ocean
  - Coldest cloud tops (colder than 230 K) generally occur over Antarctica and high clouds in the tropics
- Cloud optical properties
  - Separate for the first time liquid water vs ice clouds
  - Effective radius of liquid water clouds higher over ocean than land
    - ✓ Mode radius is 10-11 μm over ocean and 12-13 μm over land, with long tail
    - ✓ Effective radius larger by 2-3 μm in the southern hemisphere than the northern hemisphere
- Joint probability density function of cloud optical, physical, and microphysical properties a good test for General Circulation Models