

Photometric Variation of Earth and Solar Planets as Point Sources

Yuka Fujii (ELSI, Tokyo Tech.)

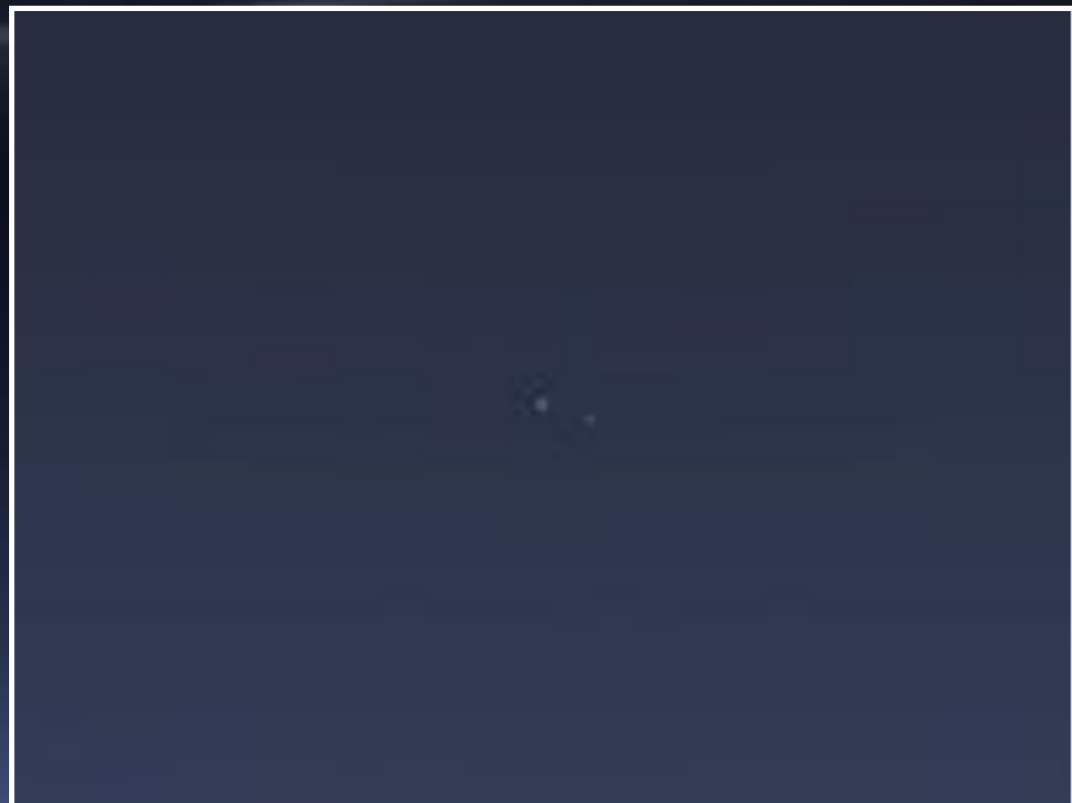
Lunch Talk

Aug. 2, 2013 @ 神戸



A Pale Blue Dot

taken by NASA's Cassini Spacecraft
on July 19, 2013 from 5:27 p.m. to 5:42 p.m. EDT



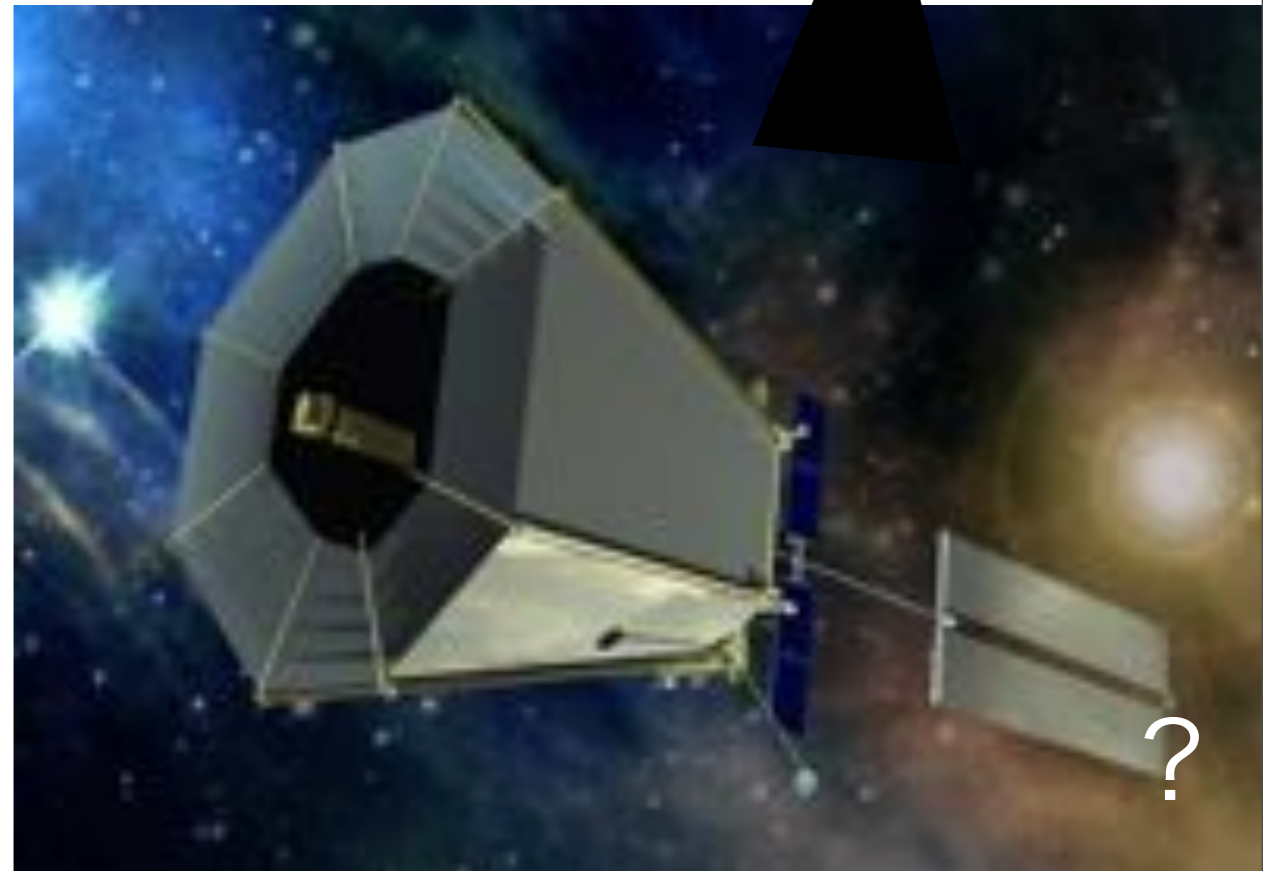
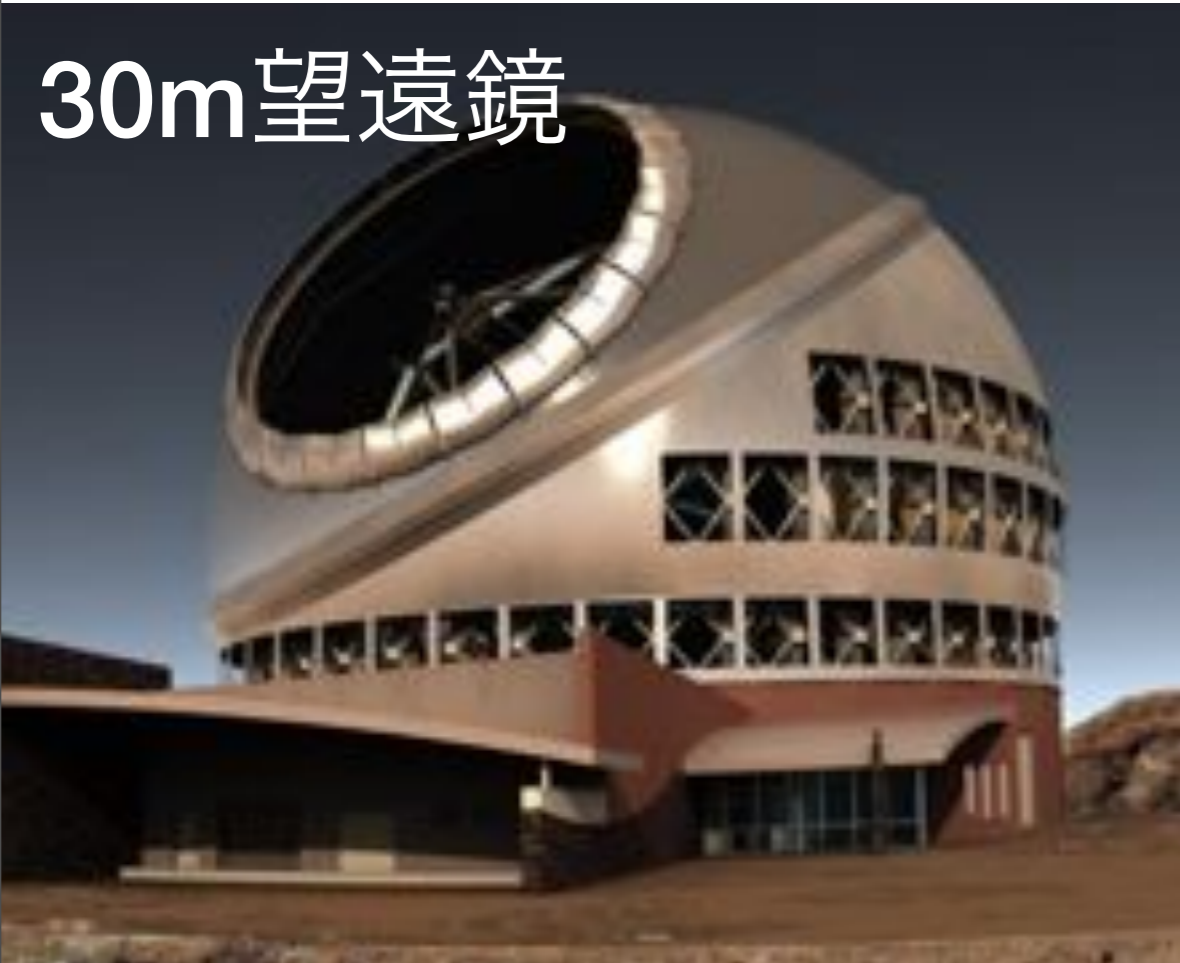
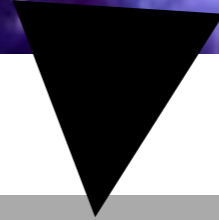
Future Prospects



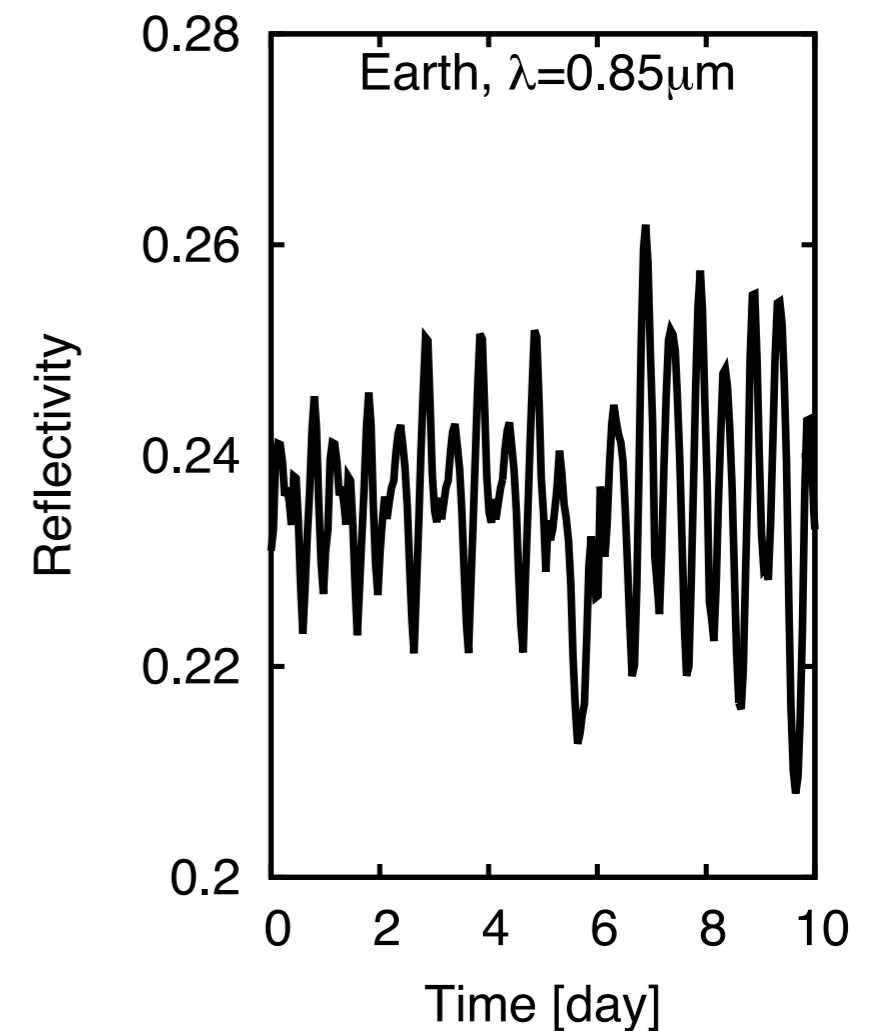
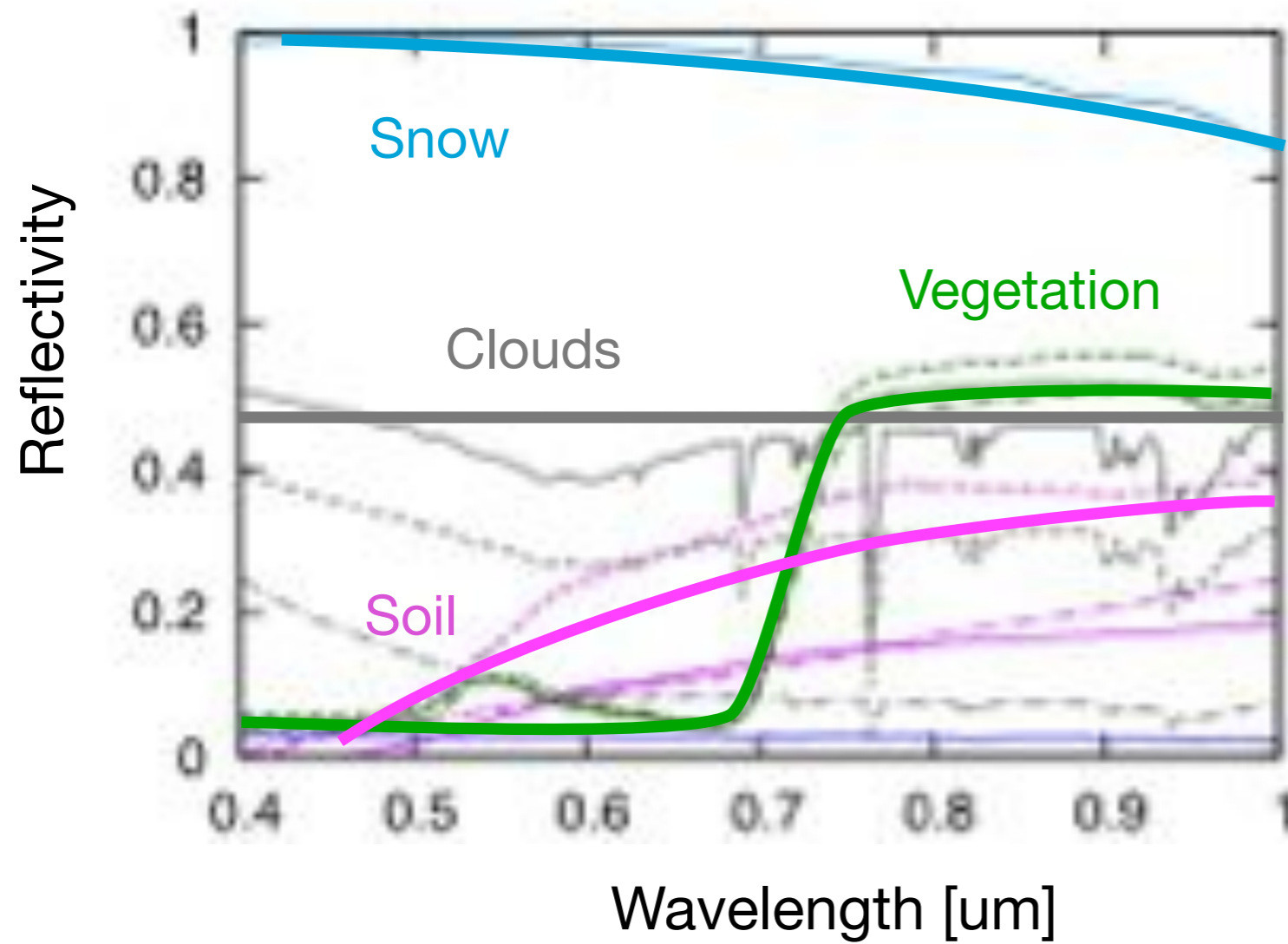
2010

2020

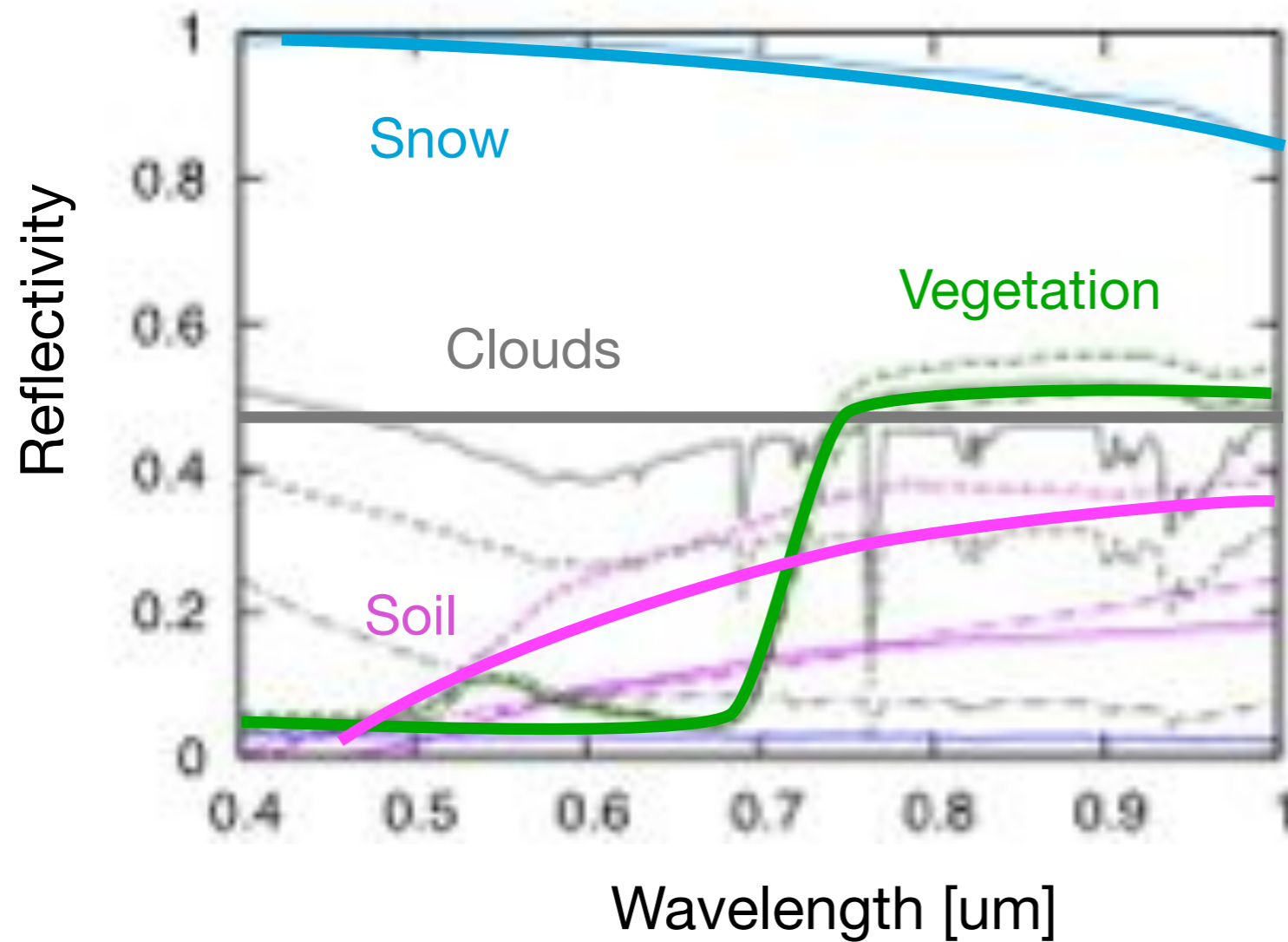
2030



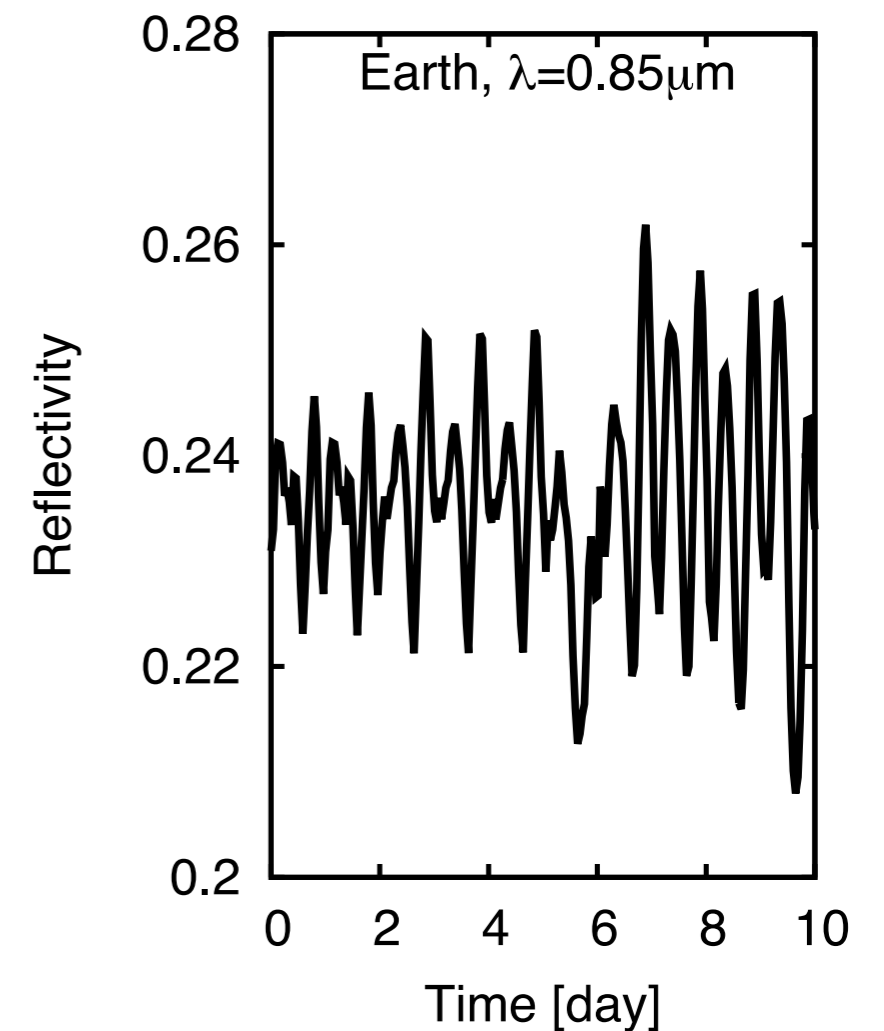
Earth: Color Variation



Earth: Color Variation



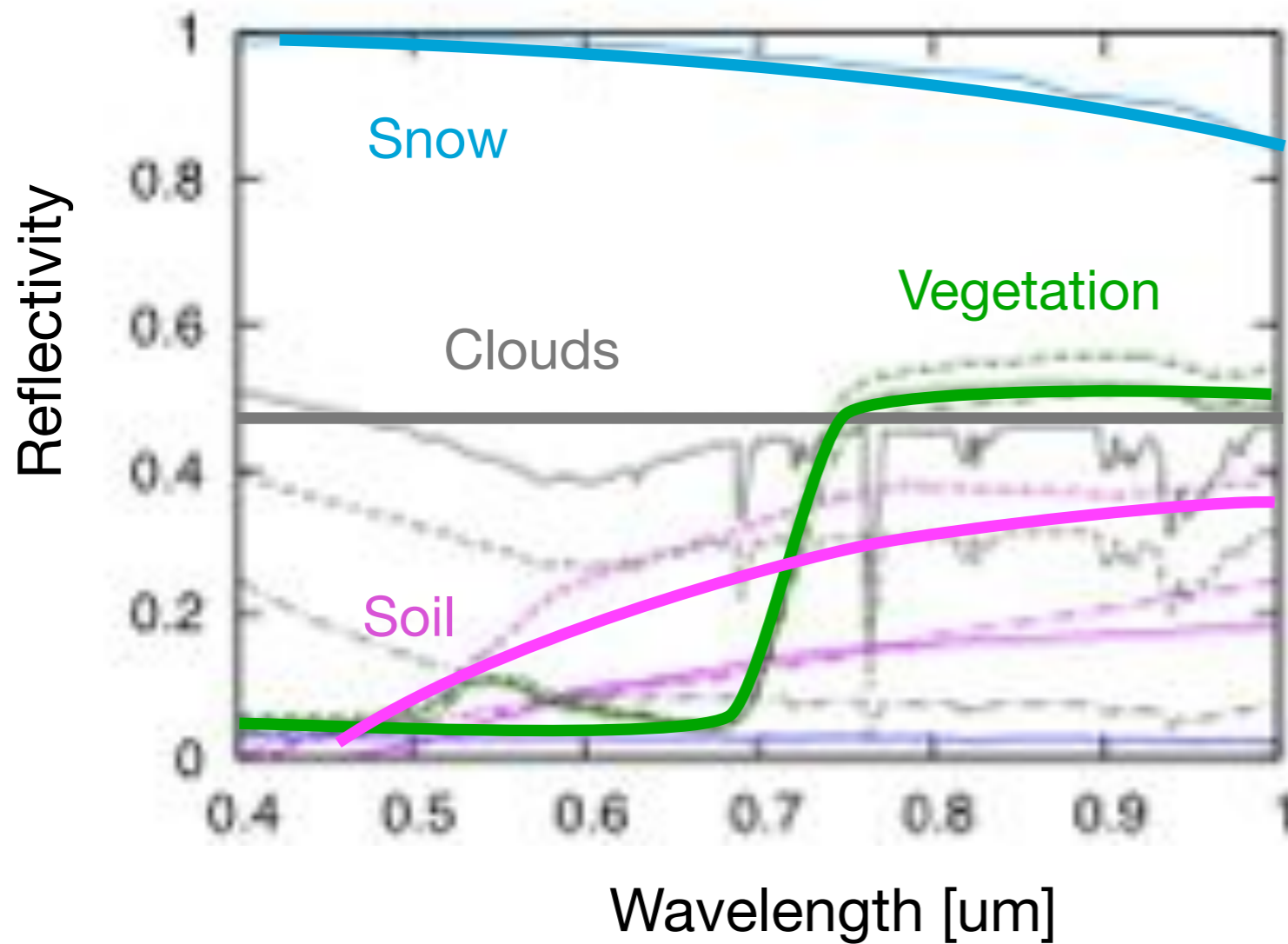
► Simulated 10-day light curve of Earth as a point source



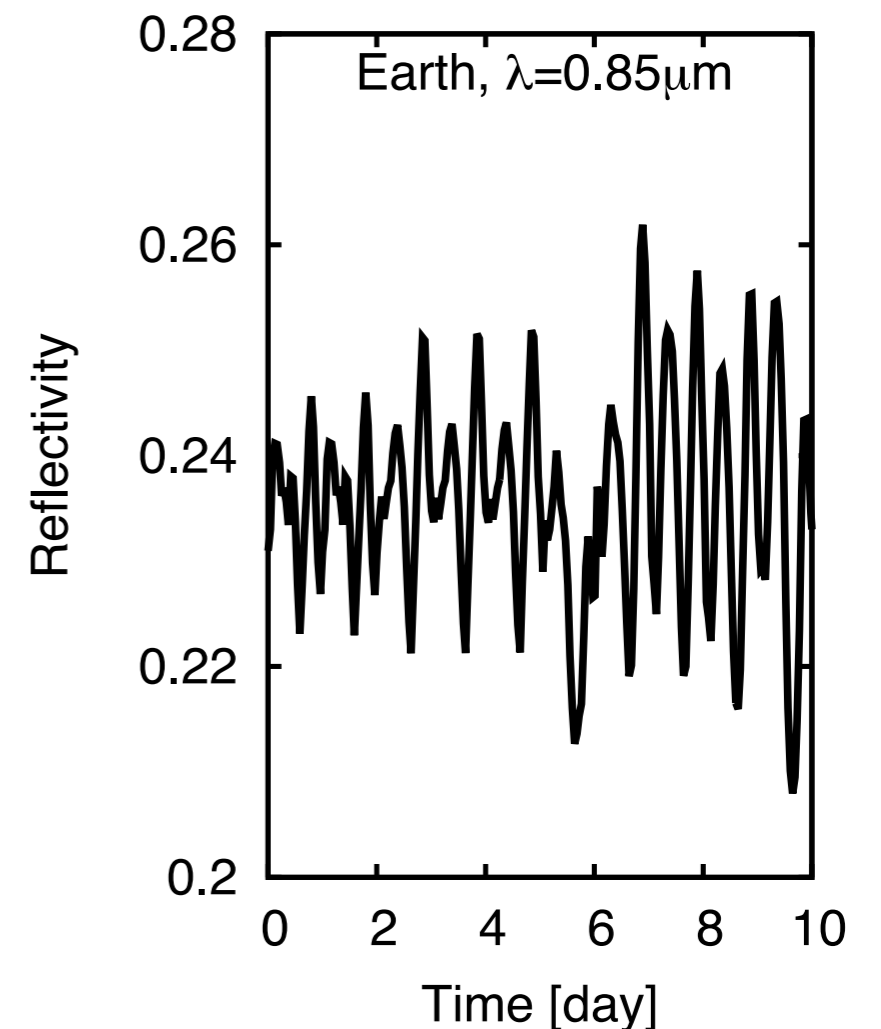
Earth: Color Variation



- ▶ Reflection spectra of surface materials



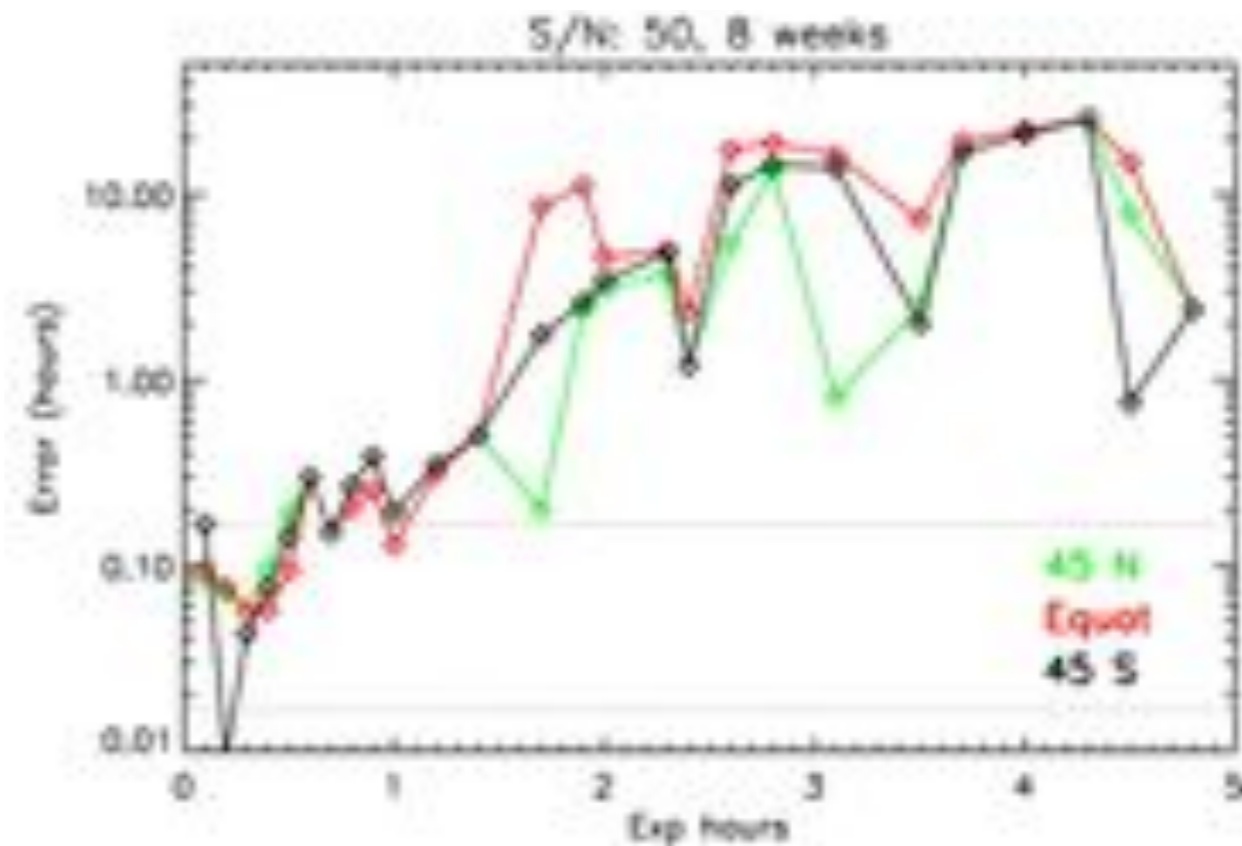
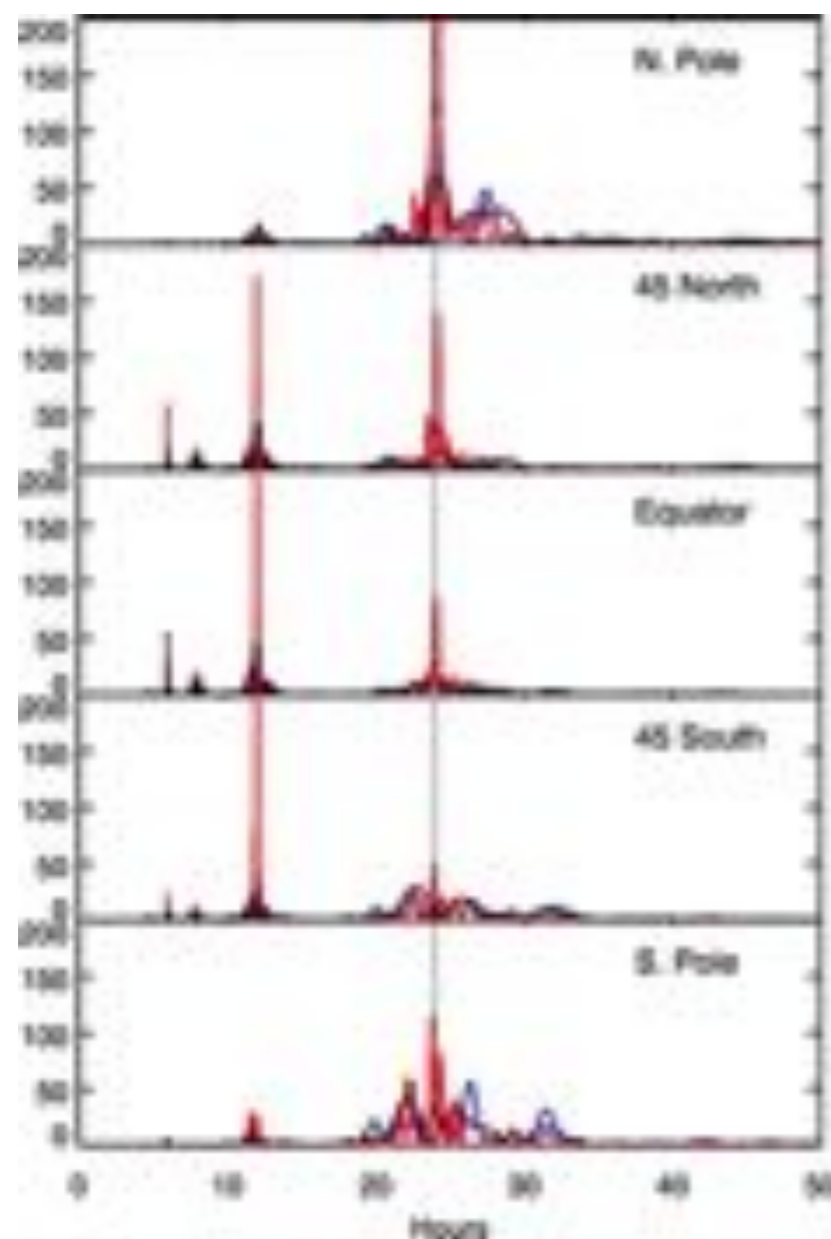
- ▶ Simulated 10-day light curve of Earth as a point source



Identifying Spin Rotation Period

Pallé+ 2008

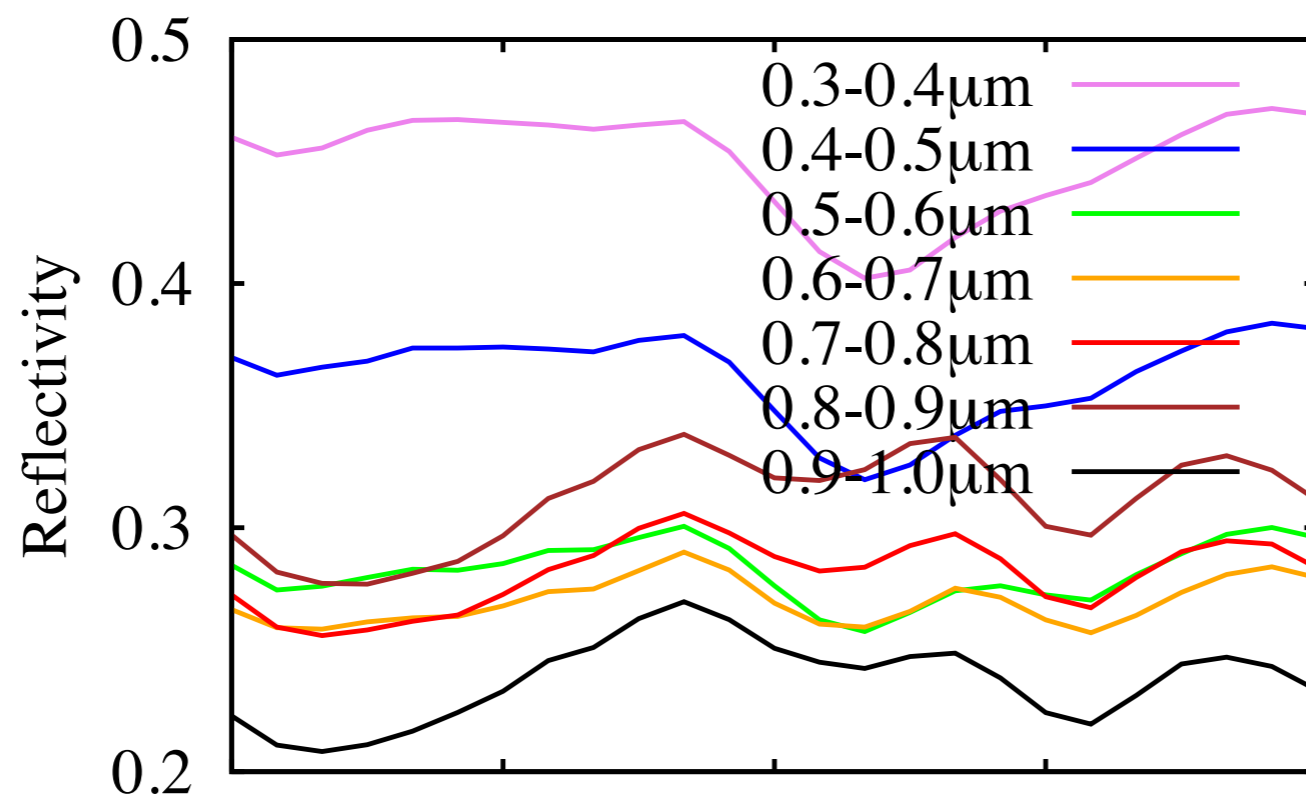
black line: 2 weeks
blue line: 4 weeks
red line: 8 weeks



※ Rotation Period of the Earth can be successfully determined by Fourier and auto-correlation analysis.

Earth: Daily Color Variation

Livengood+ 2011

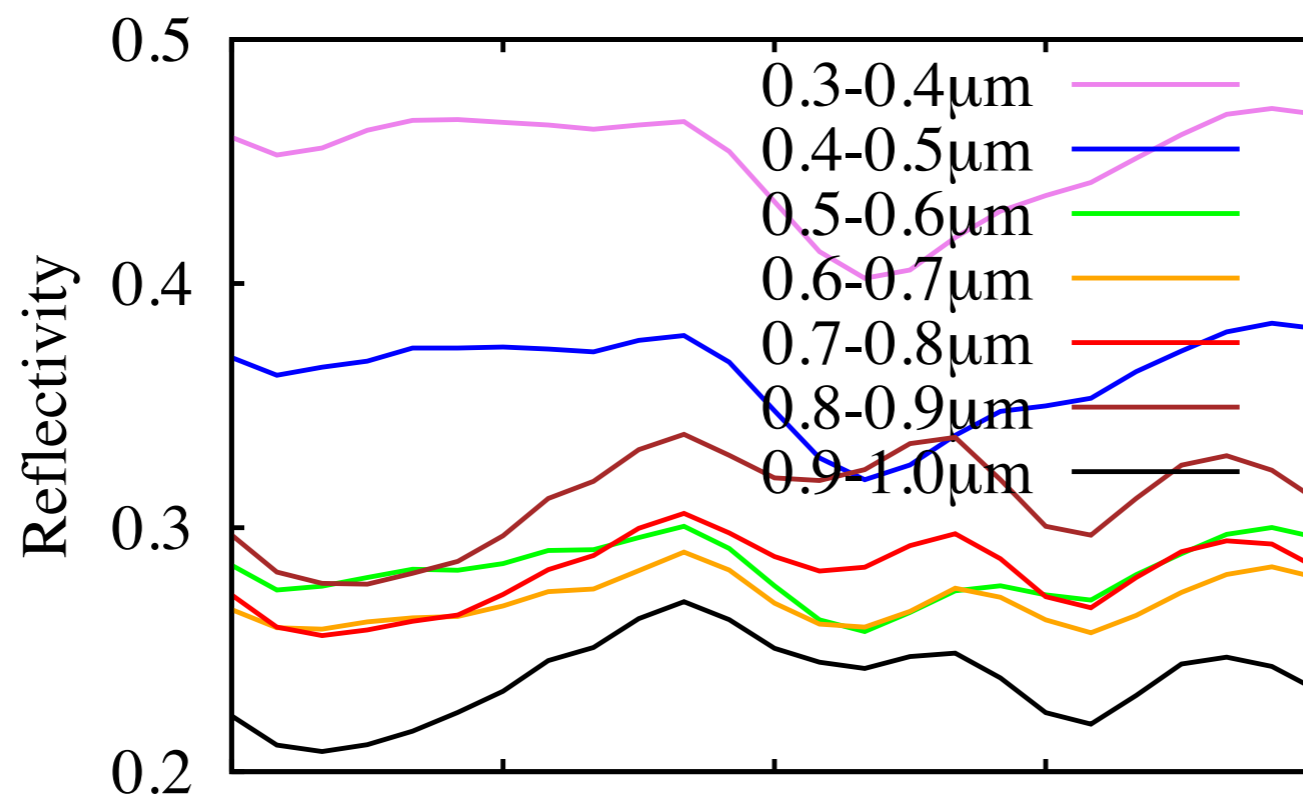


0 6 12 18 24
Time from Start of Observation [hr]

Earth: Daily Color Variation

► Space-based Observation by NASA's EPOXI mission

Livengood+ 2011

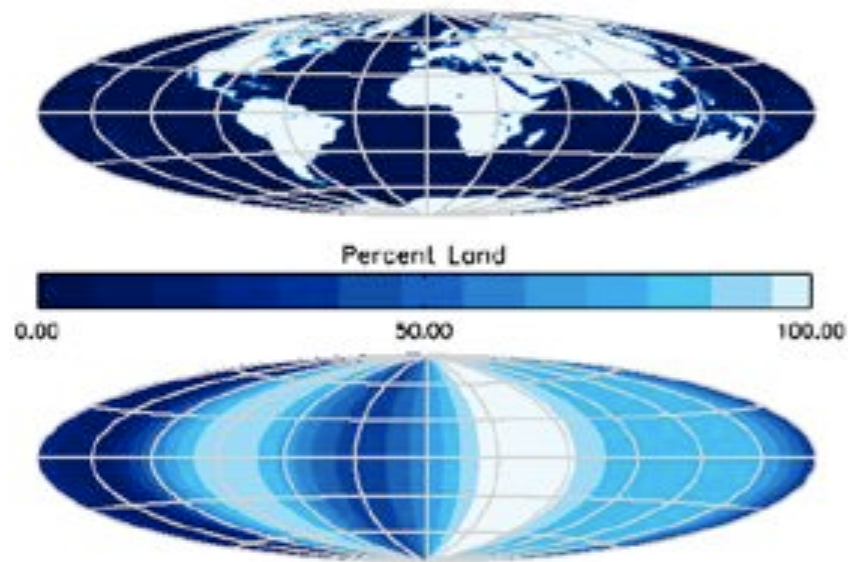


0 6 12 18 24
Time from Start of Observation [hr]

Earth: Inversion of Daily Color Variation

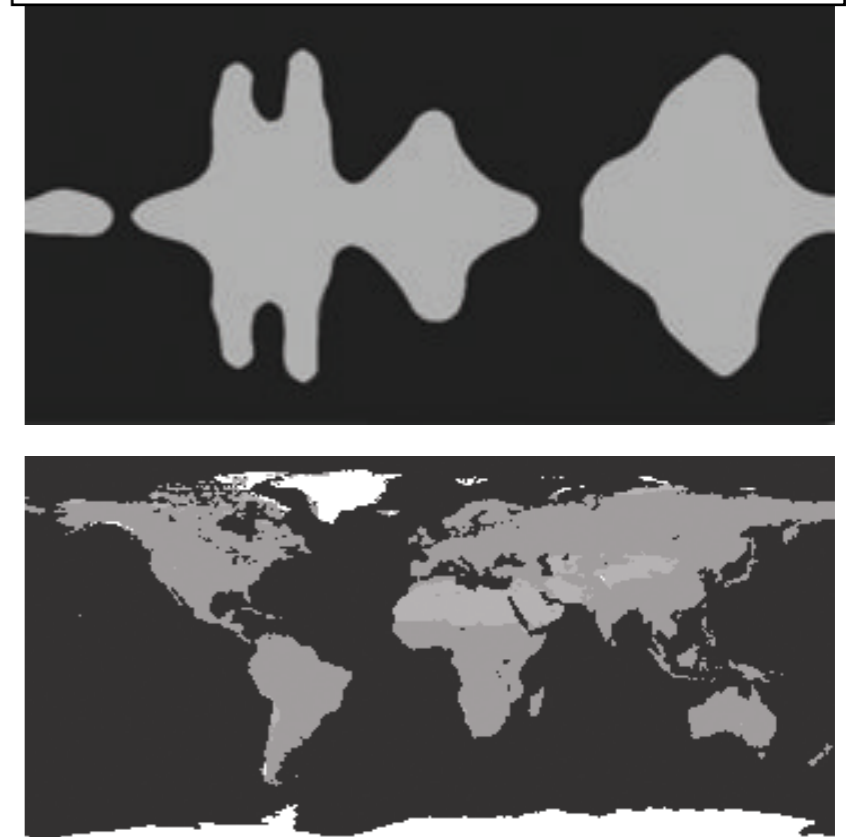
PCA eigenspectra mapping

Cowan+ 2009, 2011

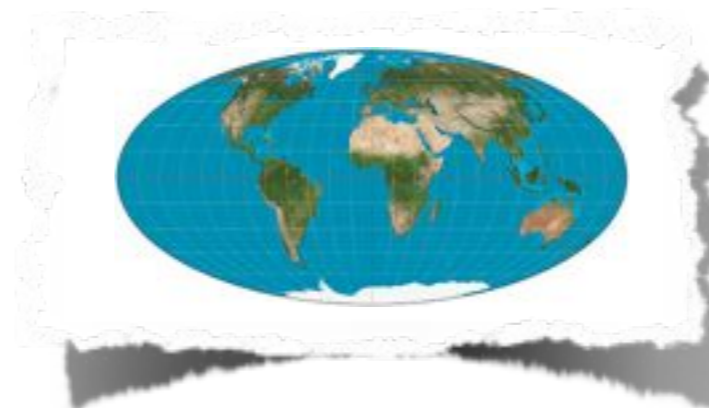
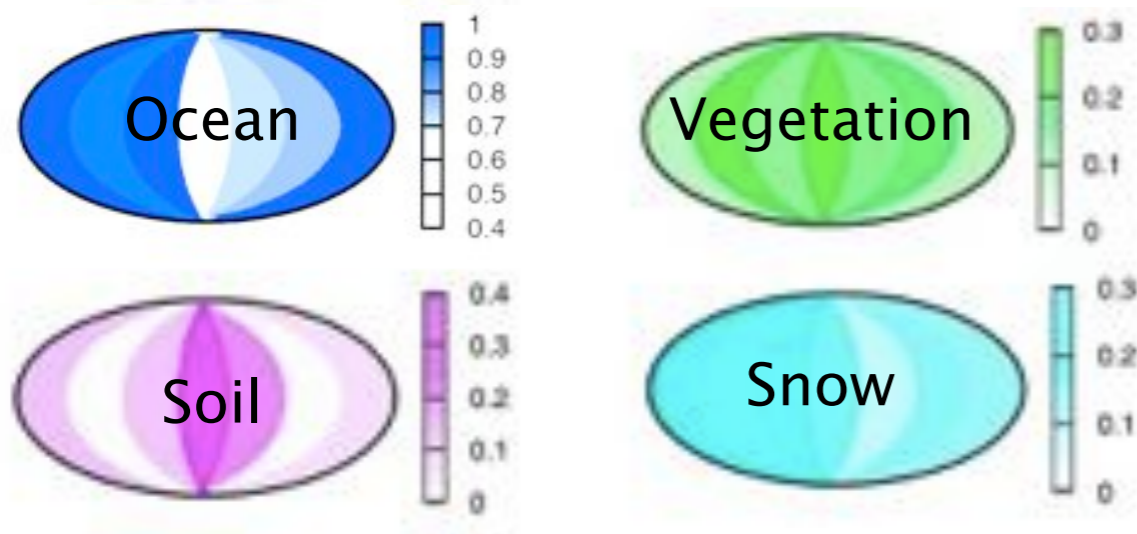


PCA eigenspectra mapping

Oakley & Cash 2009

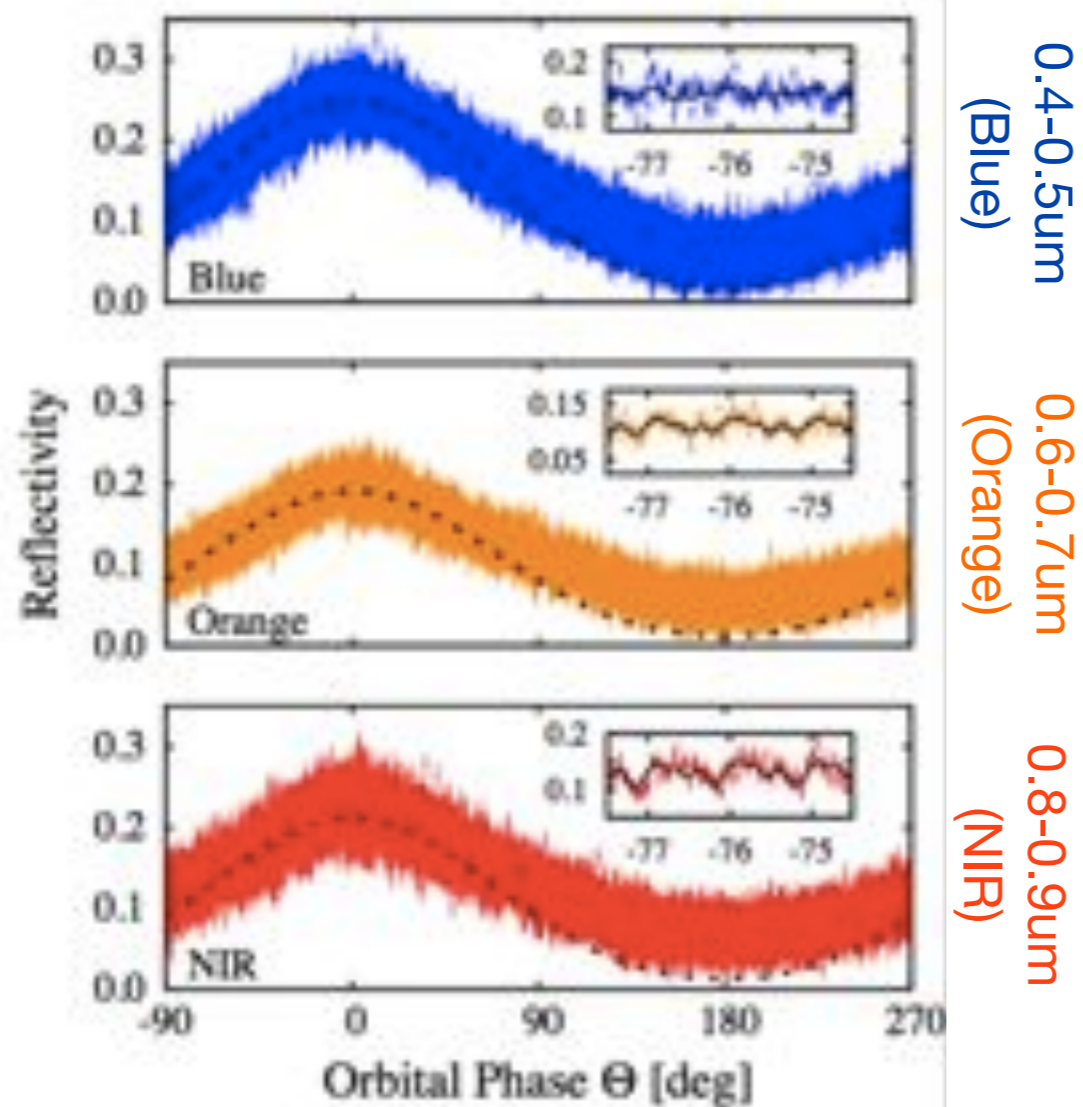
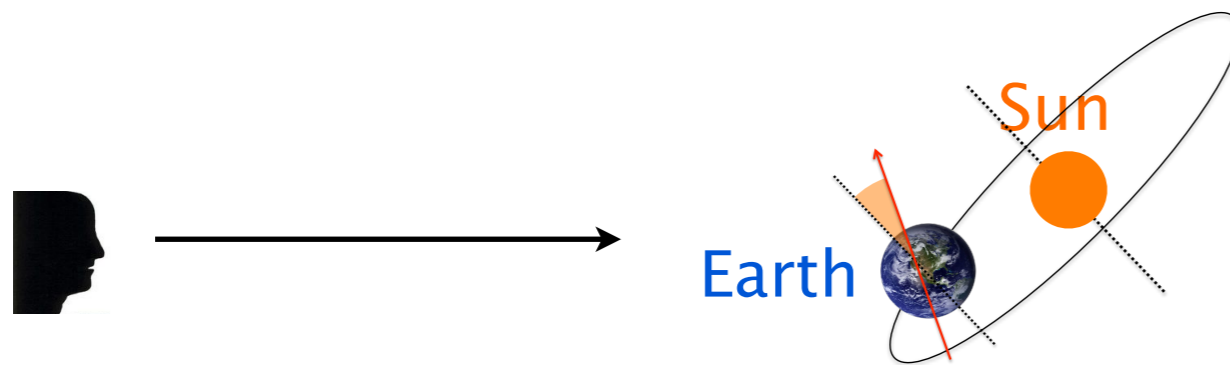


Decomposition w/ albedo template *Fujii+ 2010, 2011*



Earth: Yearly Color Variation

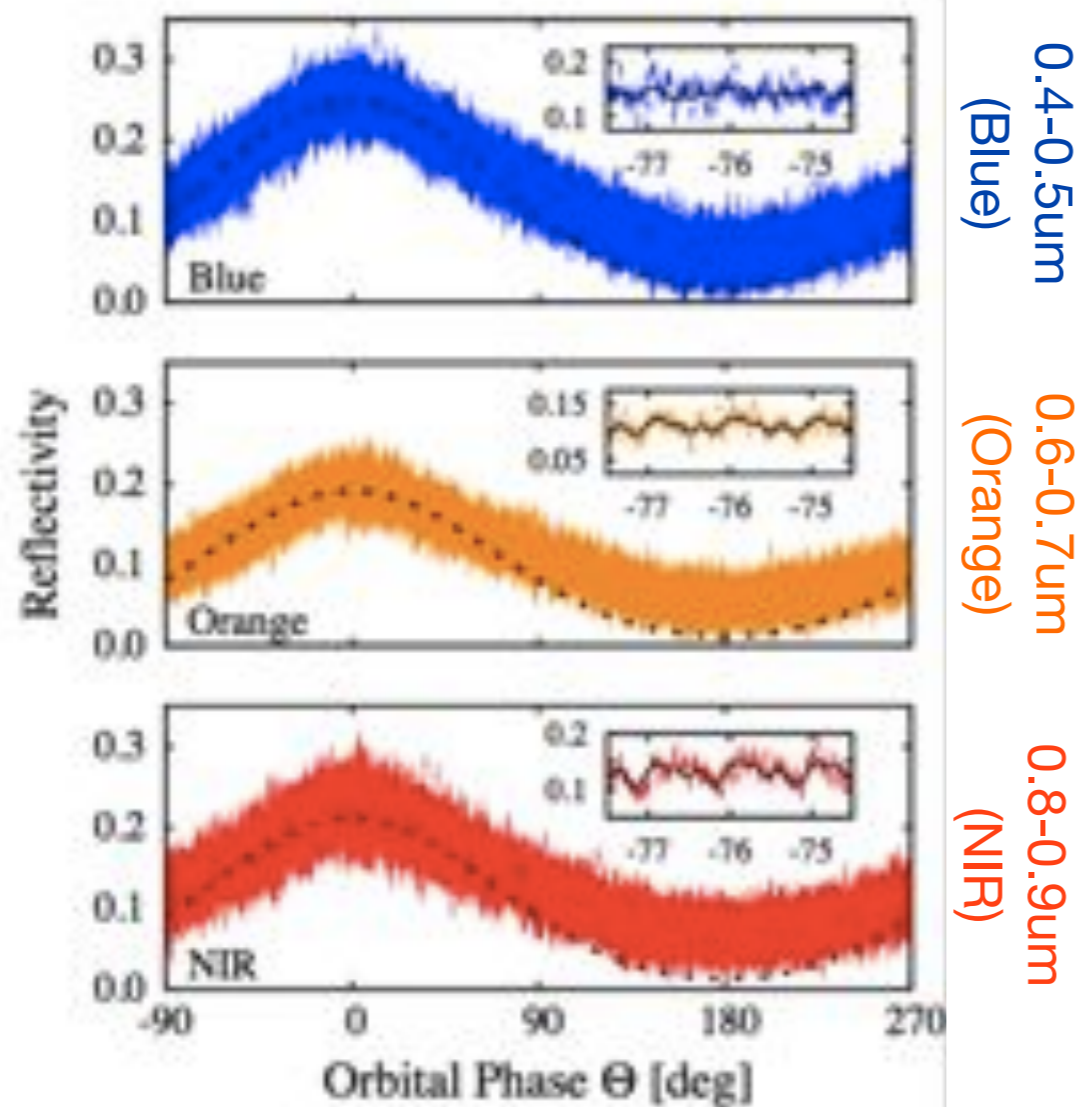
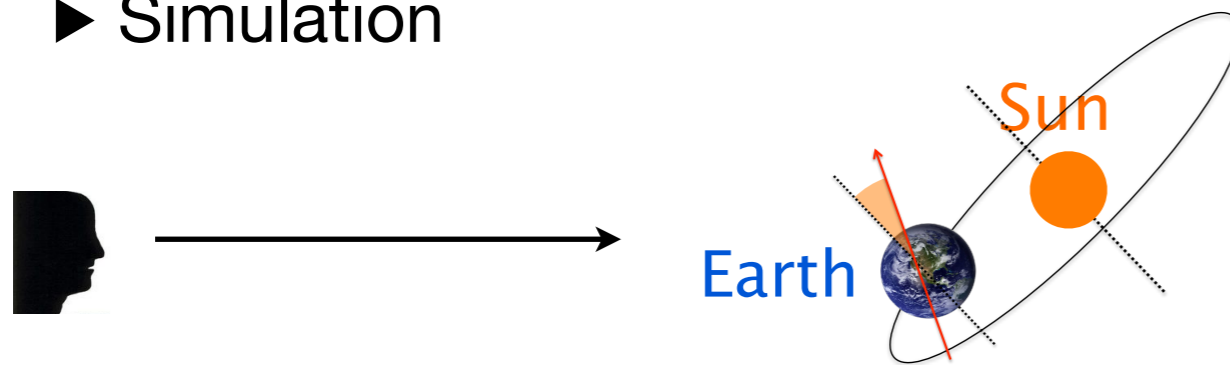
Kawahara & YF 2010, 2011, YF & Kawahara 2012



Earth: Yearly Color Variation

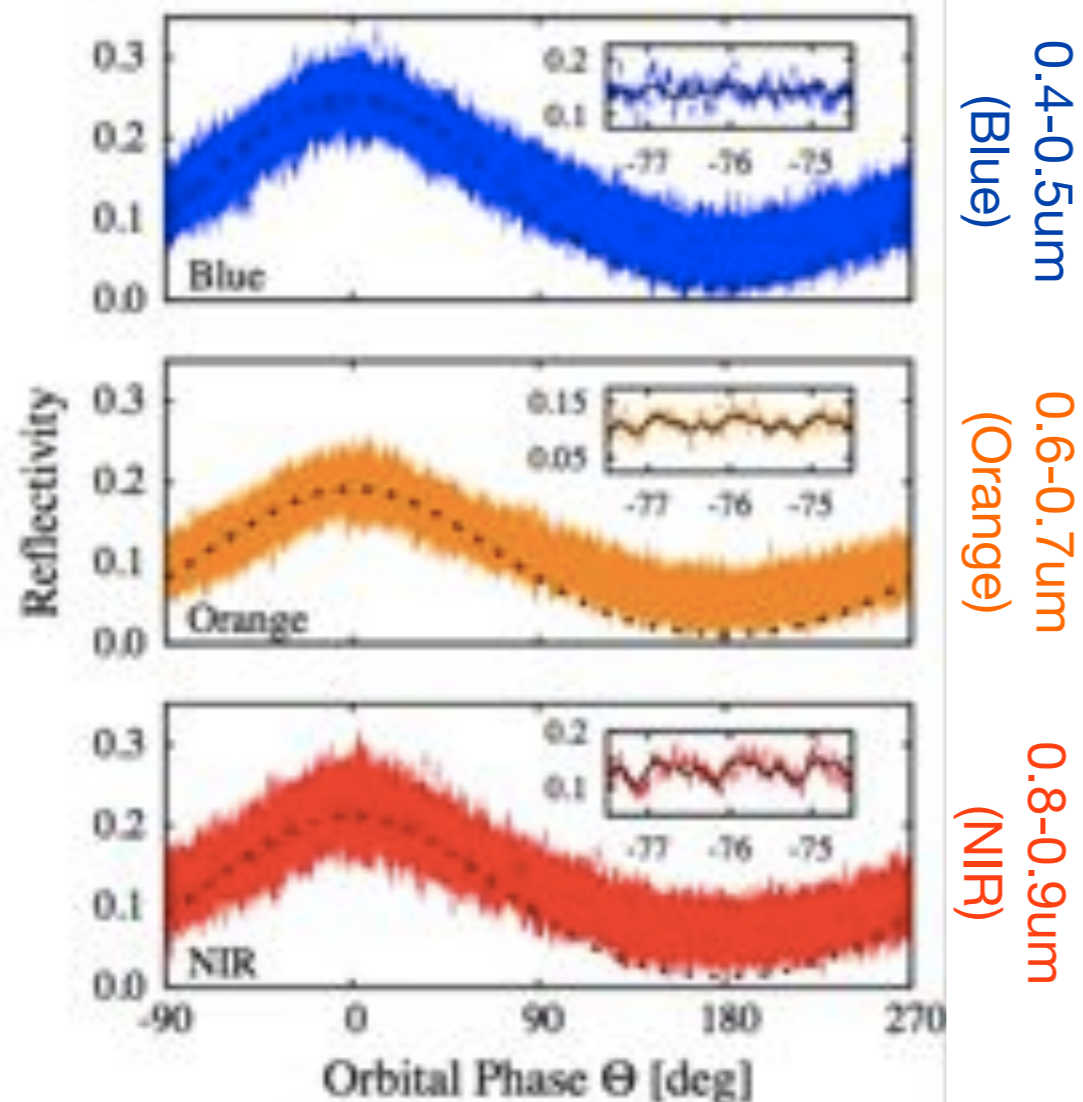
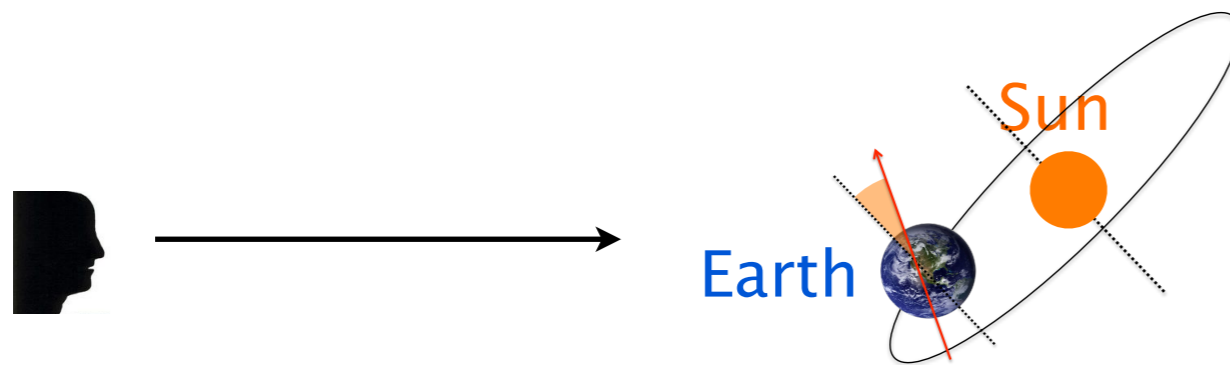
Kawahara & YF 2010, 2011, YF & Kawahara 2012

► Simulation

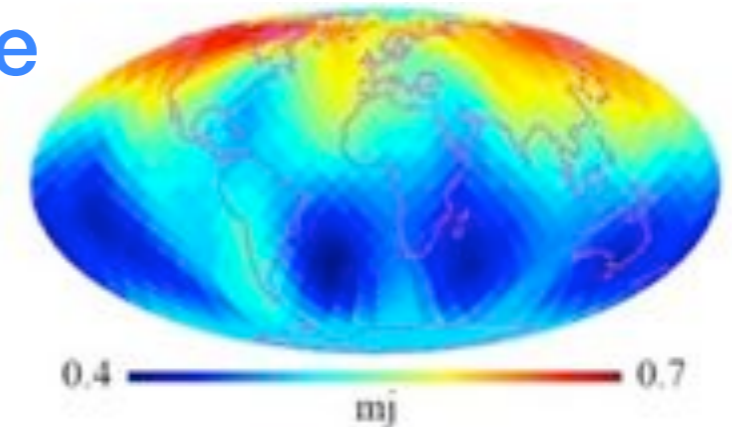


Earth: Inversion of Yearly Color Variation

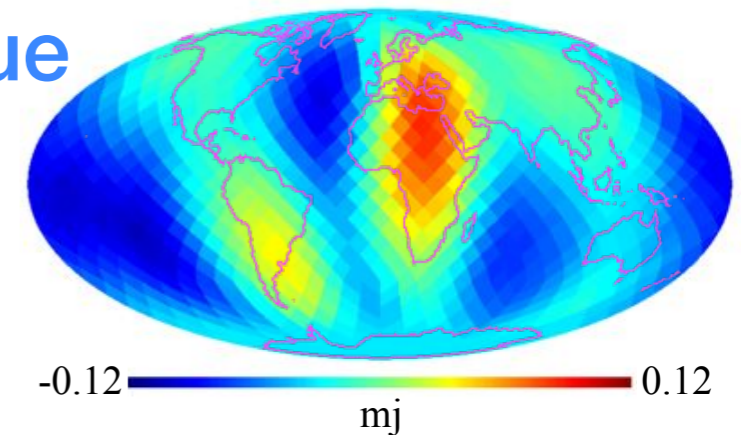
Kawahara & YF 2010, 2011, YF & Kawahara 2012



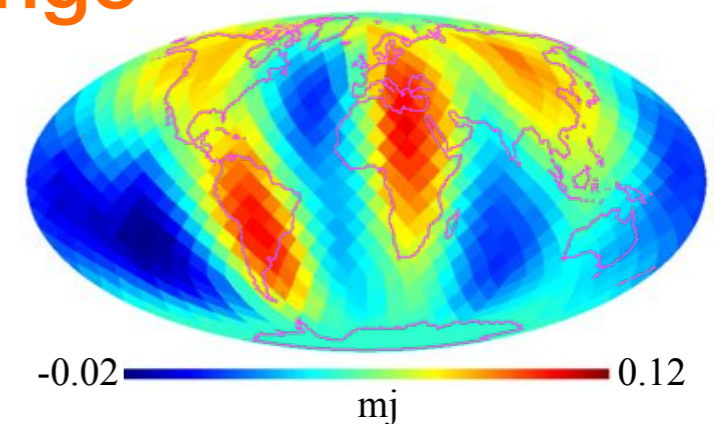
Blue



NIR-Blue



NIR-Orange

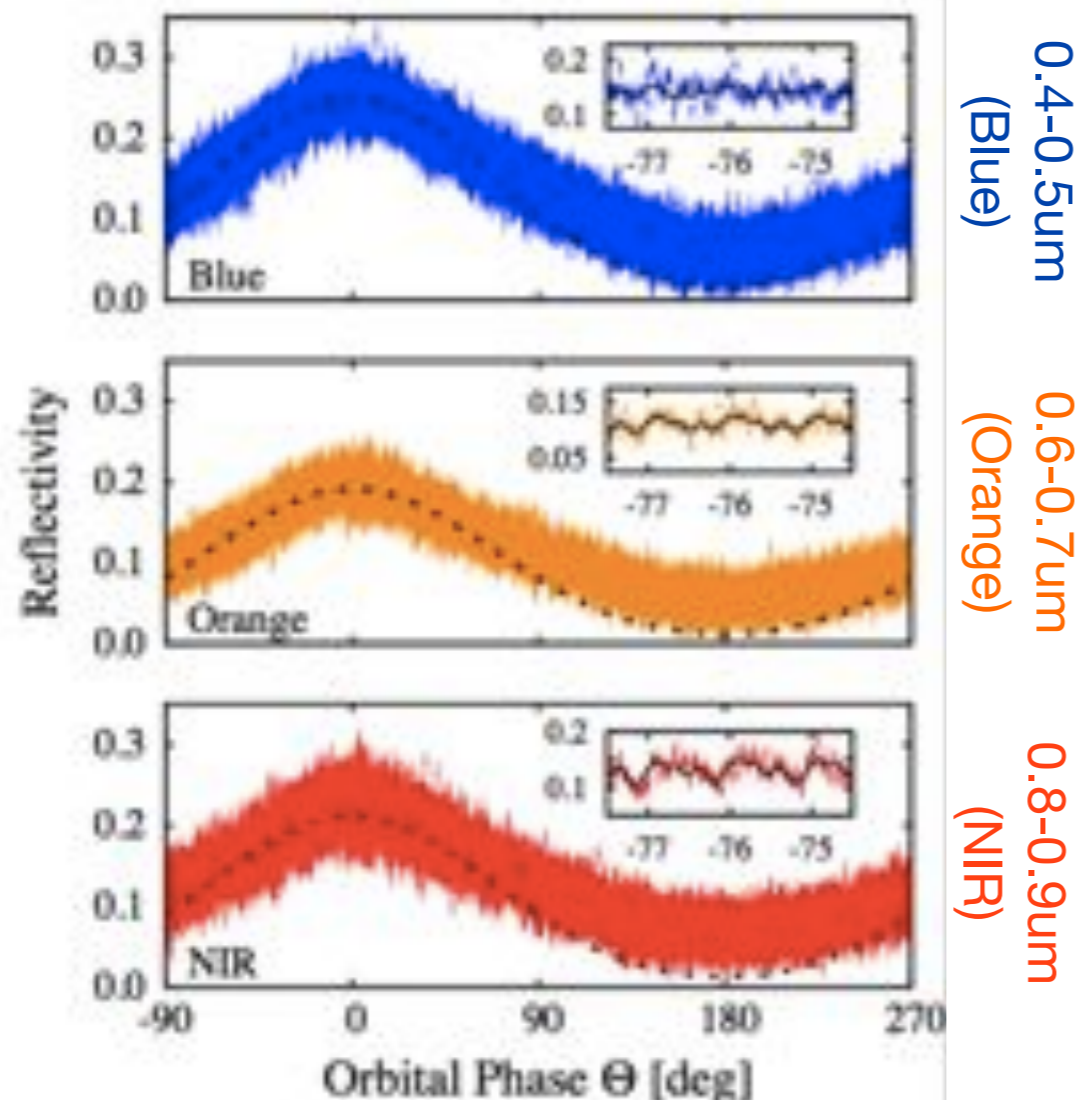
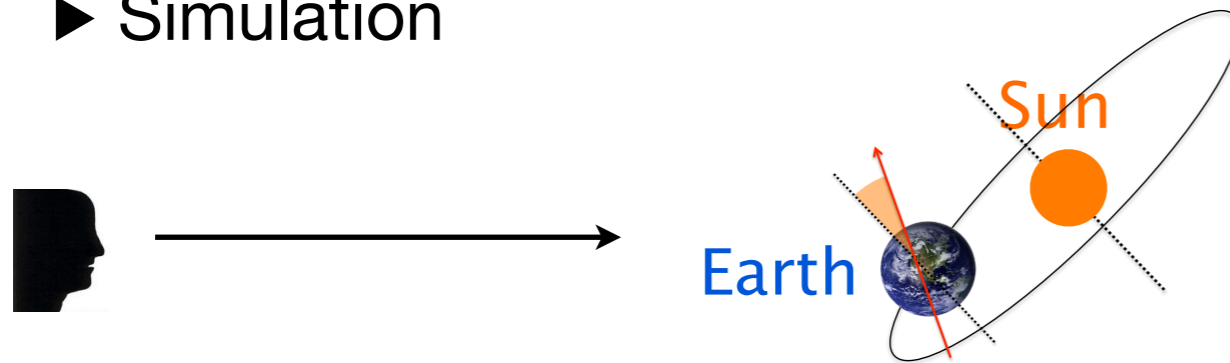


※ noise per frame = 0.01

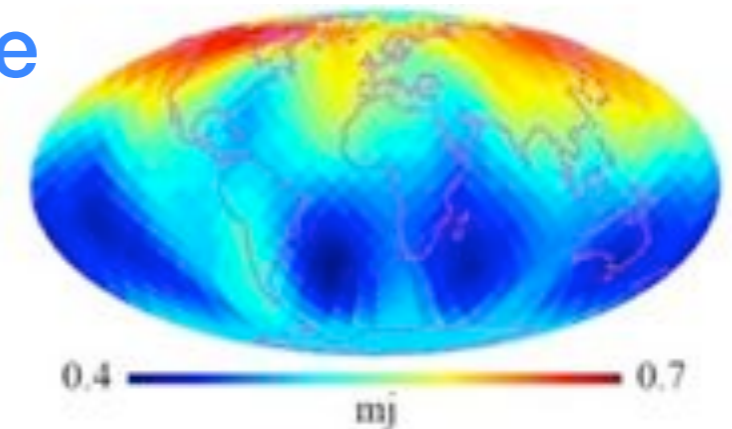
Earth: Inversion of Yearly Color Variation

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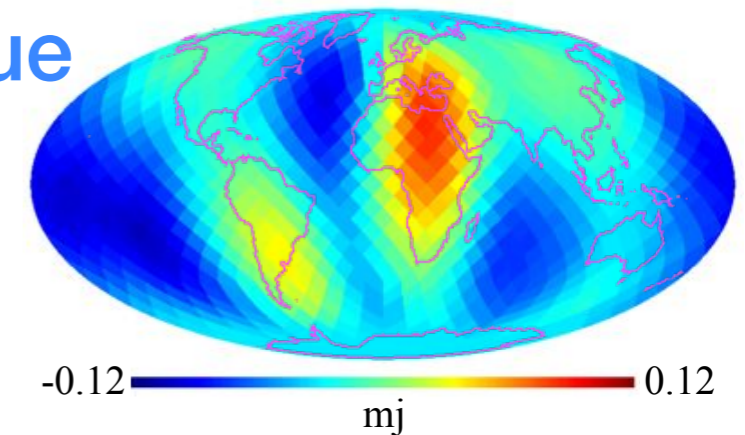
► Simulation



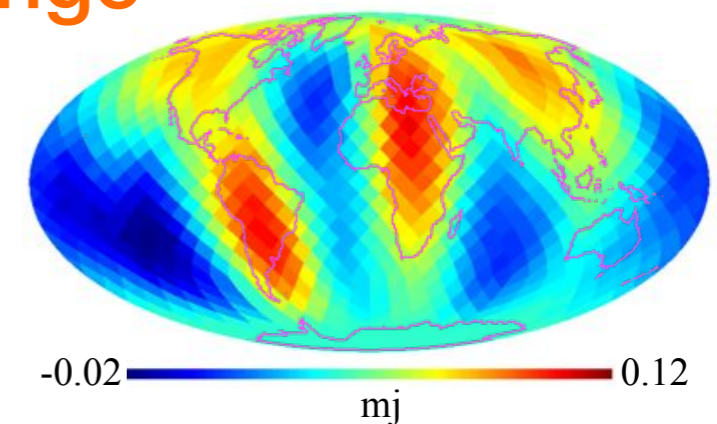
Blue



NIR-Blue



NIR-Orange

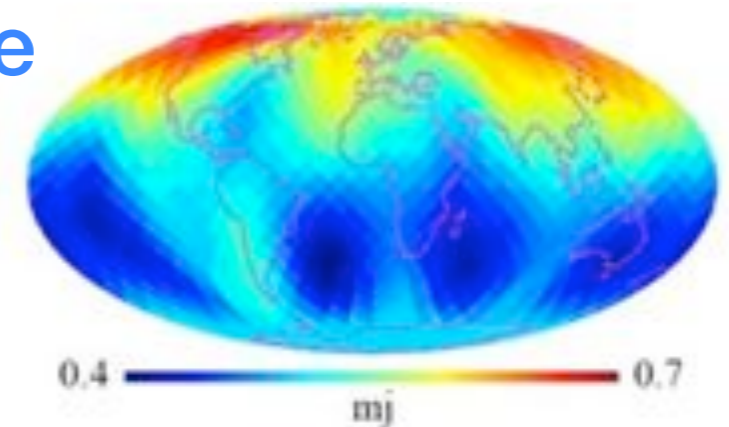


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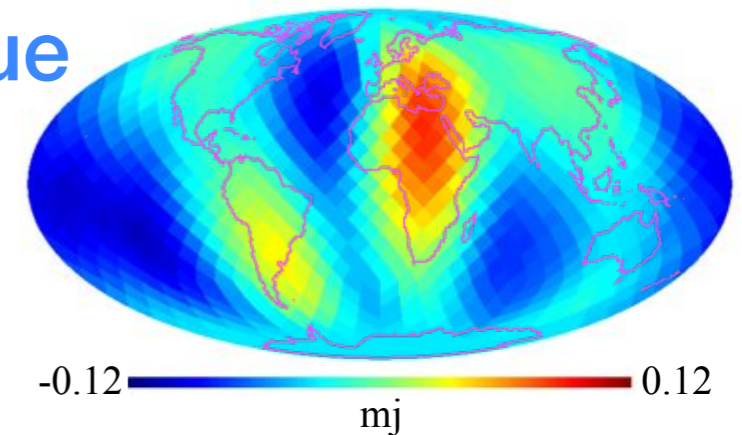
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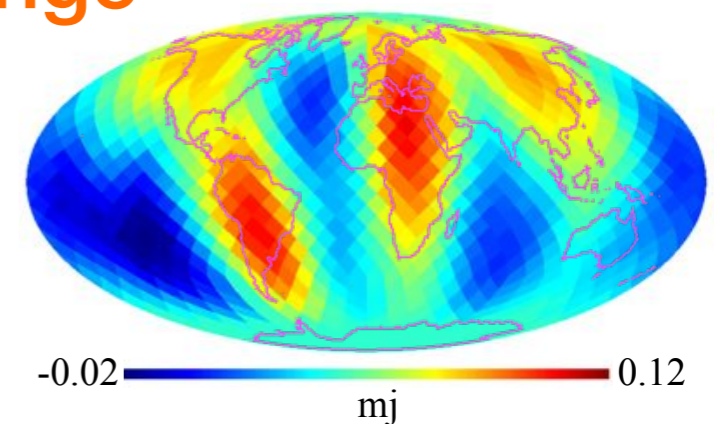
Blue



NIR-Blue



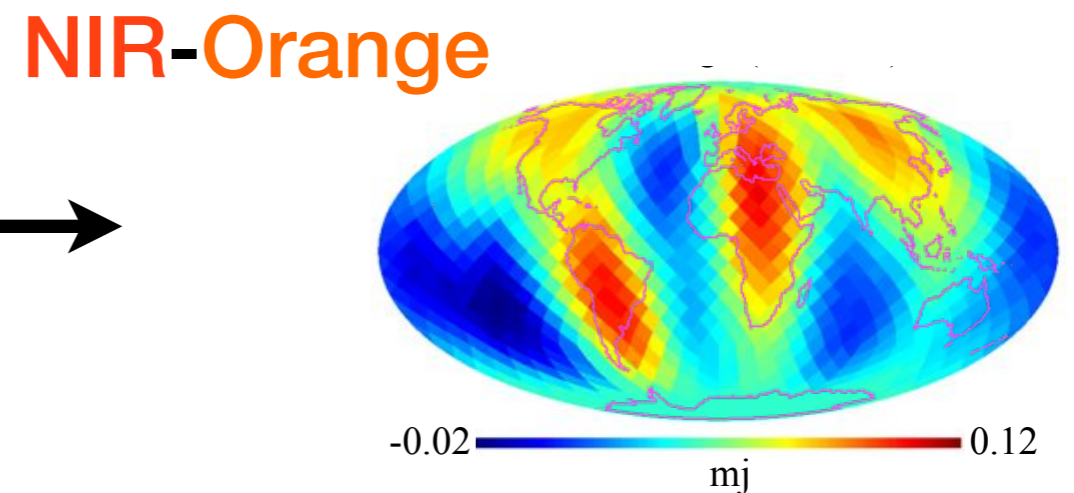
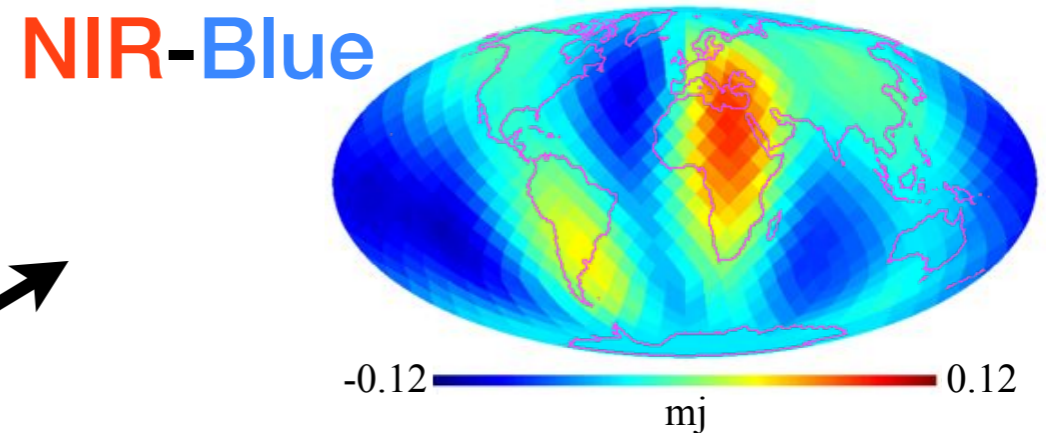
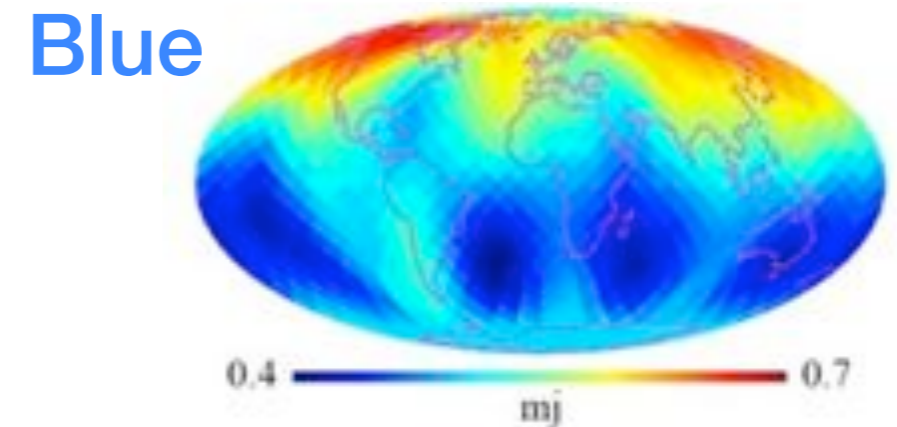
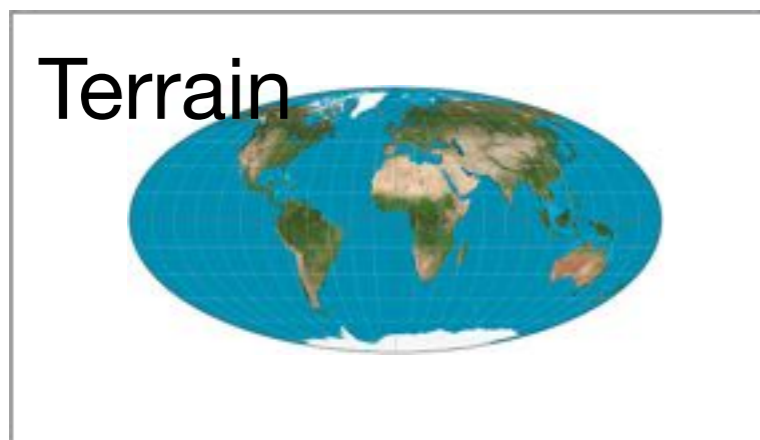
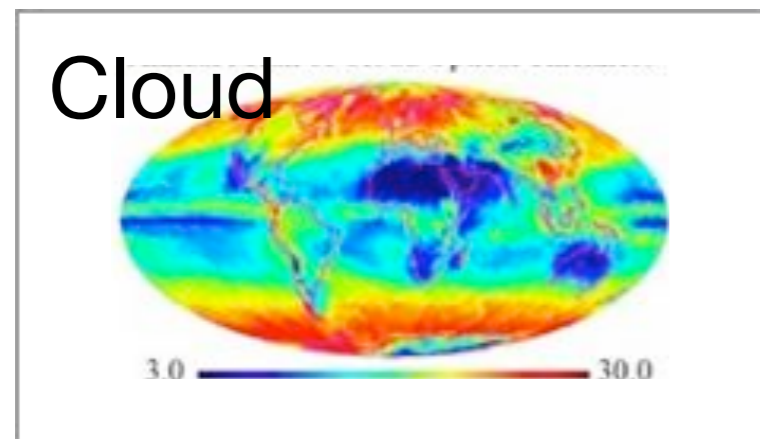
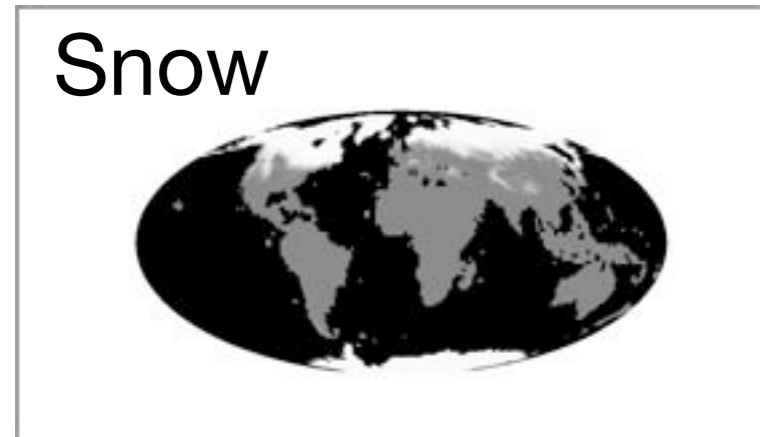
NIR-Orange



※ SN per frame = 100

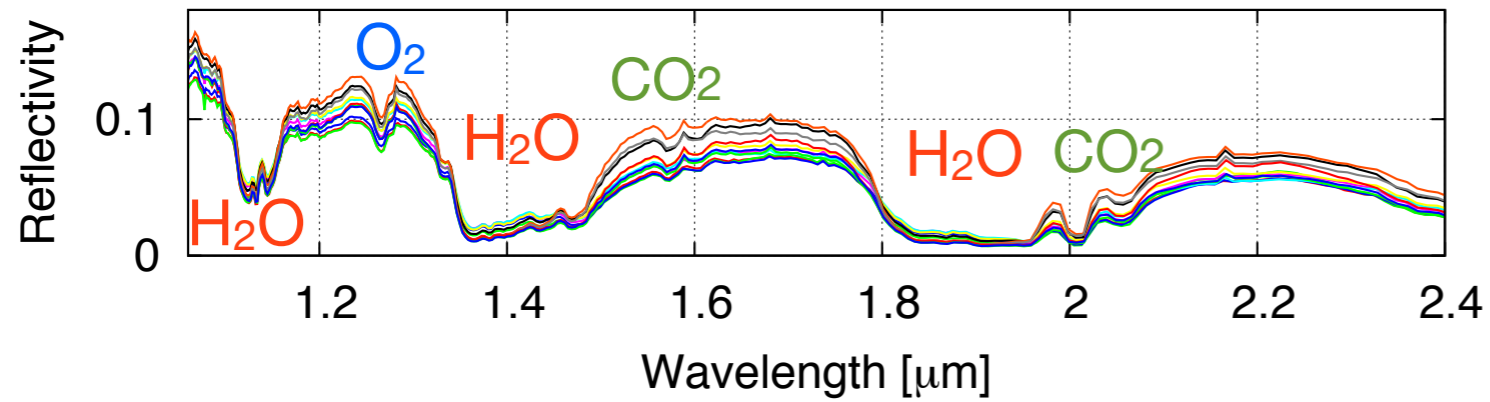
Earth: Inversion of Yearly Color Variation

Kawahara & YF 2010, 2011, YF & Kawahara 2012

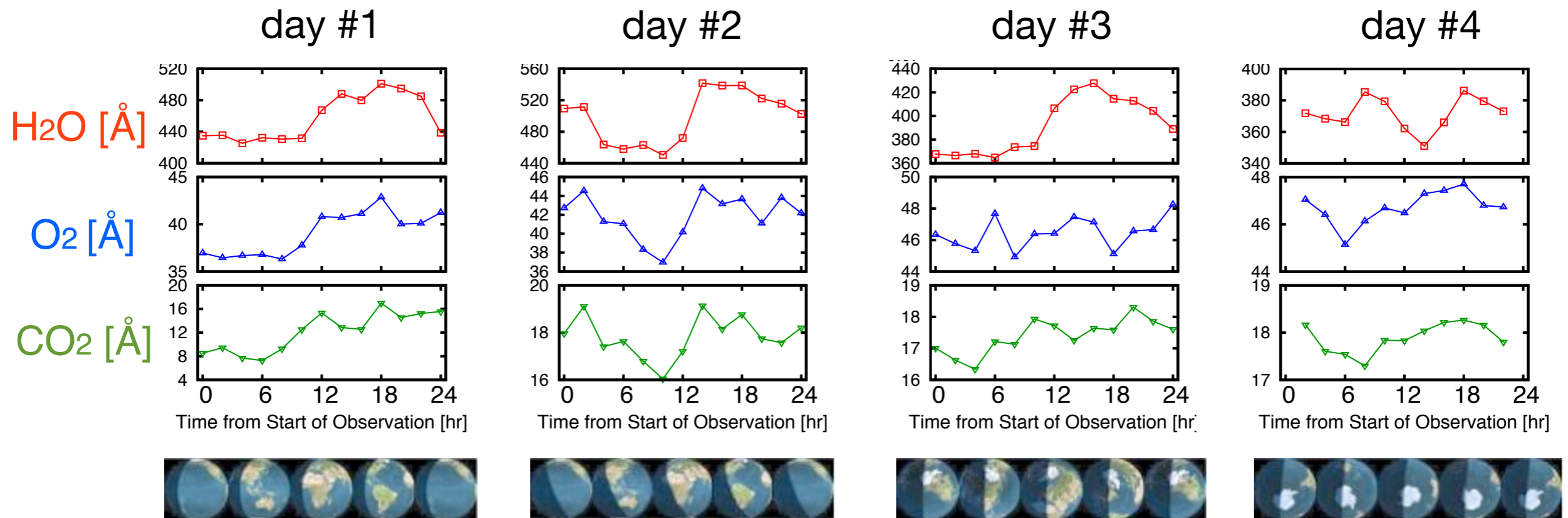
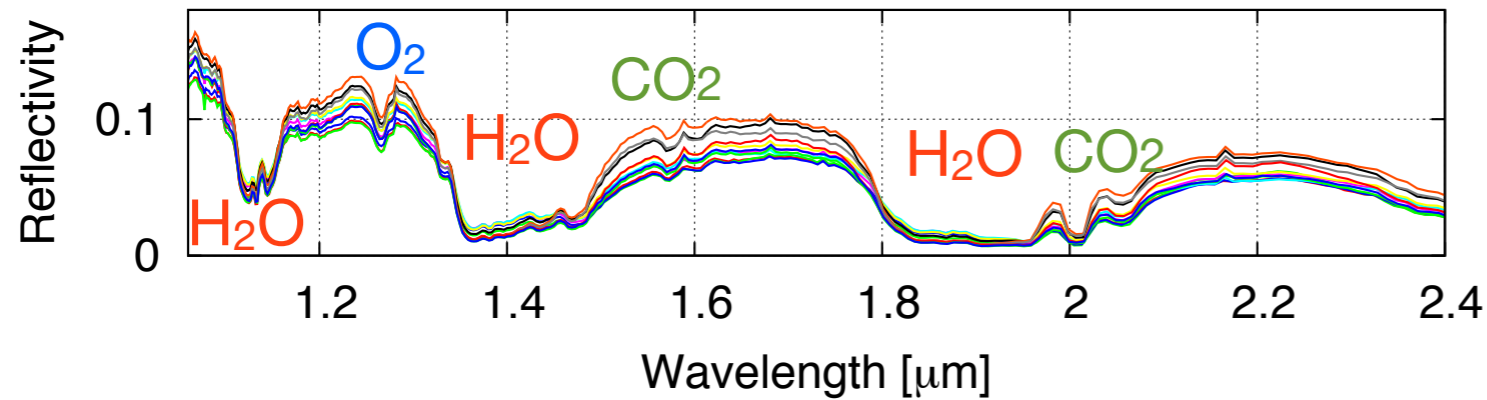


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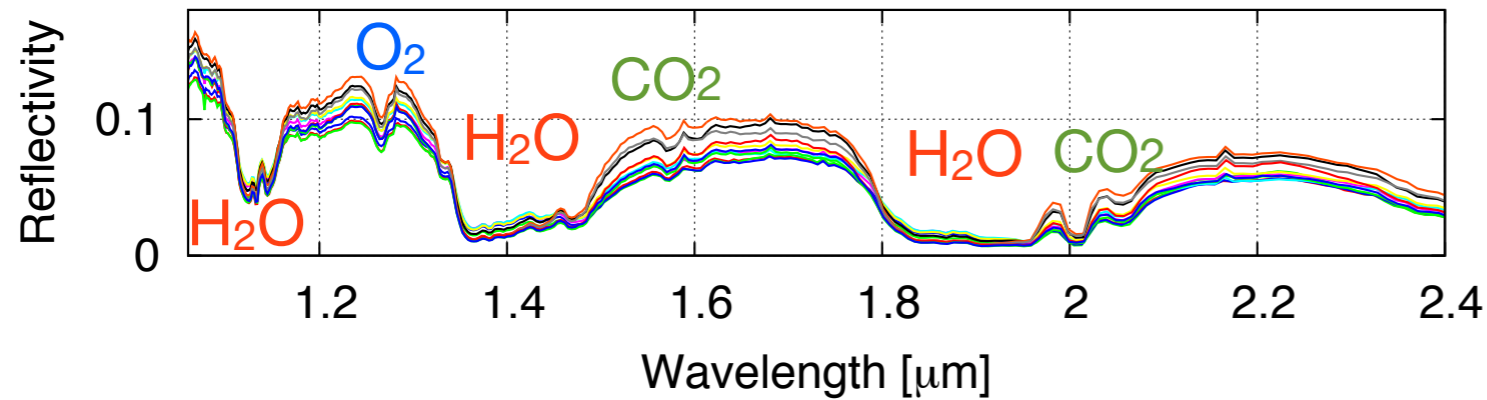
Earth: Spectral Variation



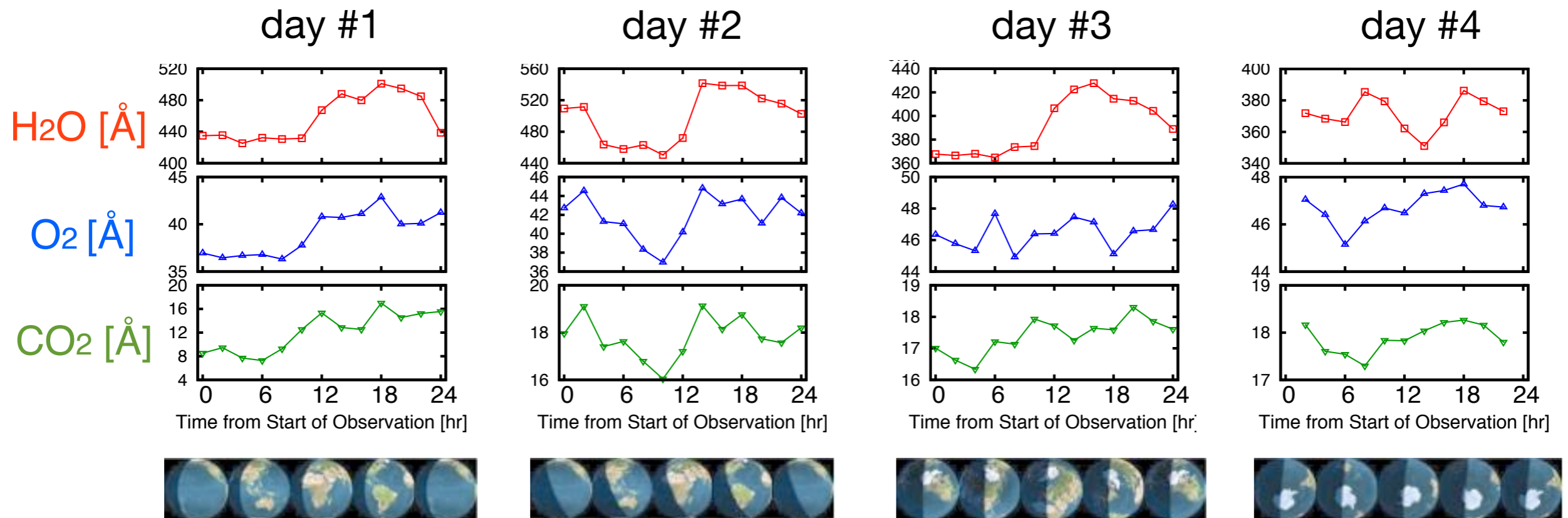
Earth: Spectral Variation



Earth: Spectral Variation



► Observed variation of equivalent width of molecular absorption bands



Interpretation of Spectral Variation

1. Partial cloud cover

2. Inhomogeneity of Atmosphere

O_2 , CO_2 :

well-mixed



long Mean Residence Time in Atmosphere

H_2O :

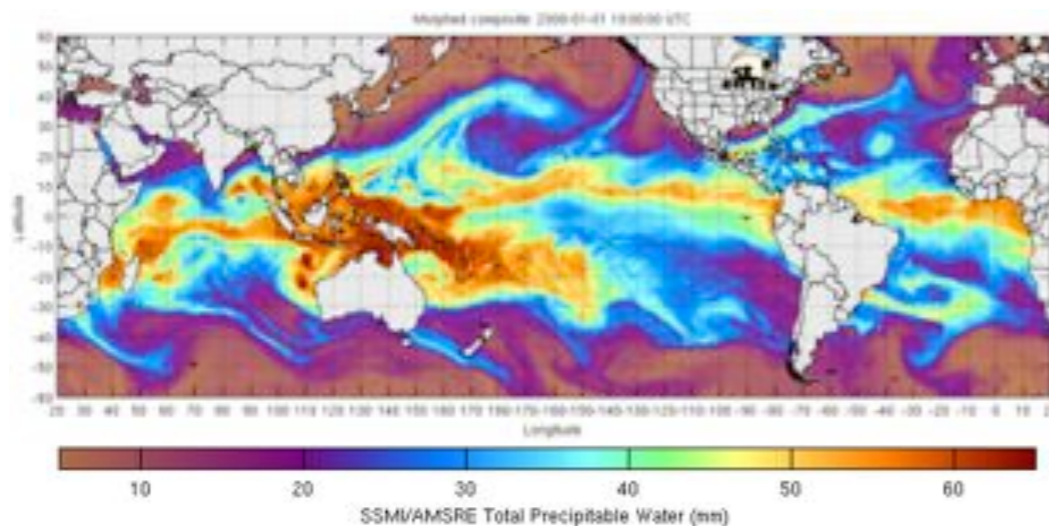
Not mixed horizontally/vertically



Very short Mean Residence Time in Atmosphere



Phase transition in the surface layer among liquid/ice (ocean)



Interpretation of Spectral Variation

1. Partial cloud cover

2. Inhomogeneity of Atmosphere

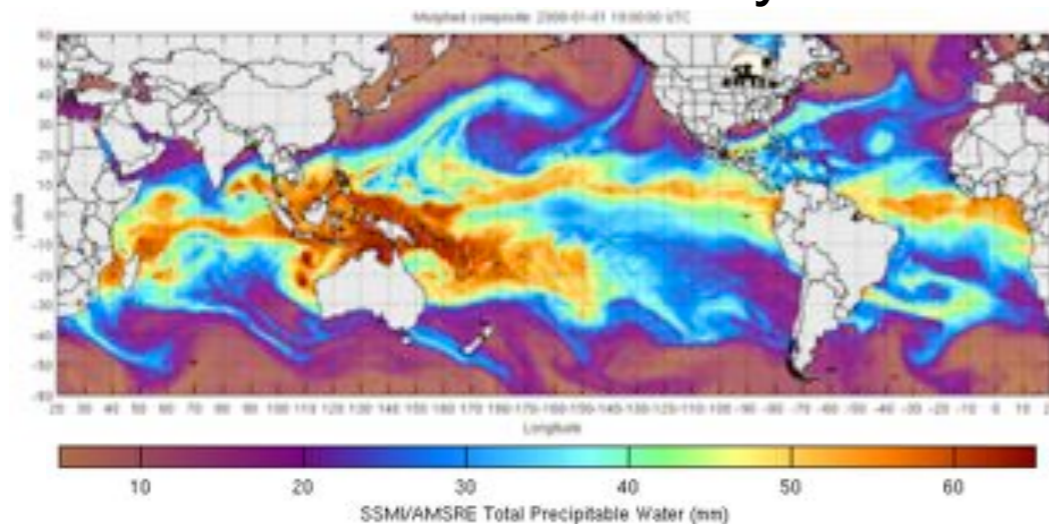
O_2 , CO_2 :

well-mixed



long Mean Residence Time in Atmosphere

► Water Column Density



H_2O :

Not mixed horizontally/vertically



Very short Mean Residence Time in Atmosphere



Phase transition in the surface layer among liquid/ice (ocean)

Short Summary

- From time series of imaged data of the Earth, *in principle*, we may be able to obtain
 - Spin rotation rate
 - Partial cloud cover
 - Inhomogeneity of surface (ocean/continents/snow)
 - Inhomogeneity of atmosphere (=> water phase transition)



Beyond Earth

Ongoing = Preliminary Work