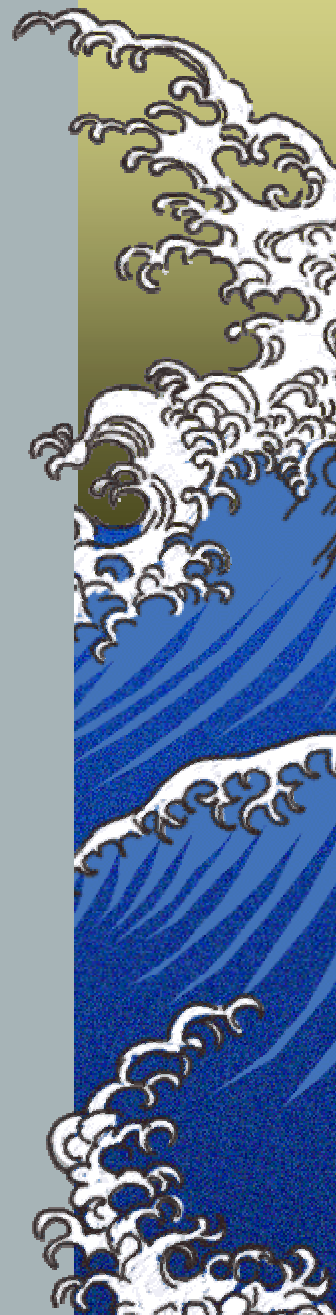
Changes in the Earth's reflectance over the past two decades

E. Pallé

Big Bear Solar Observatory, NJIT



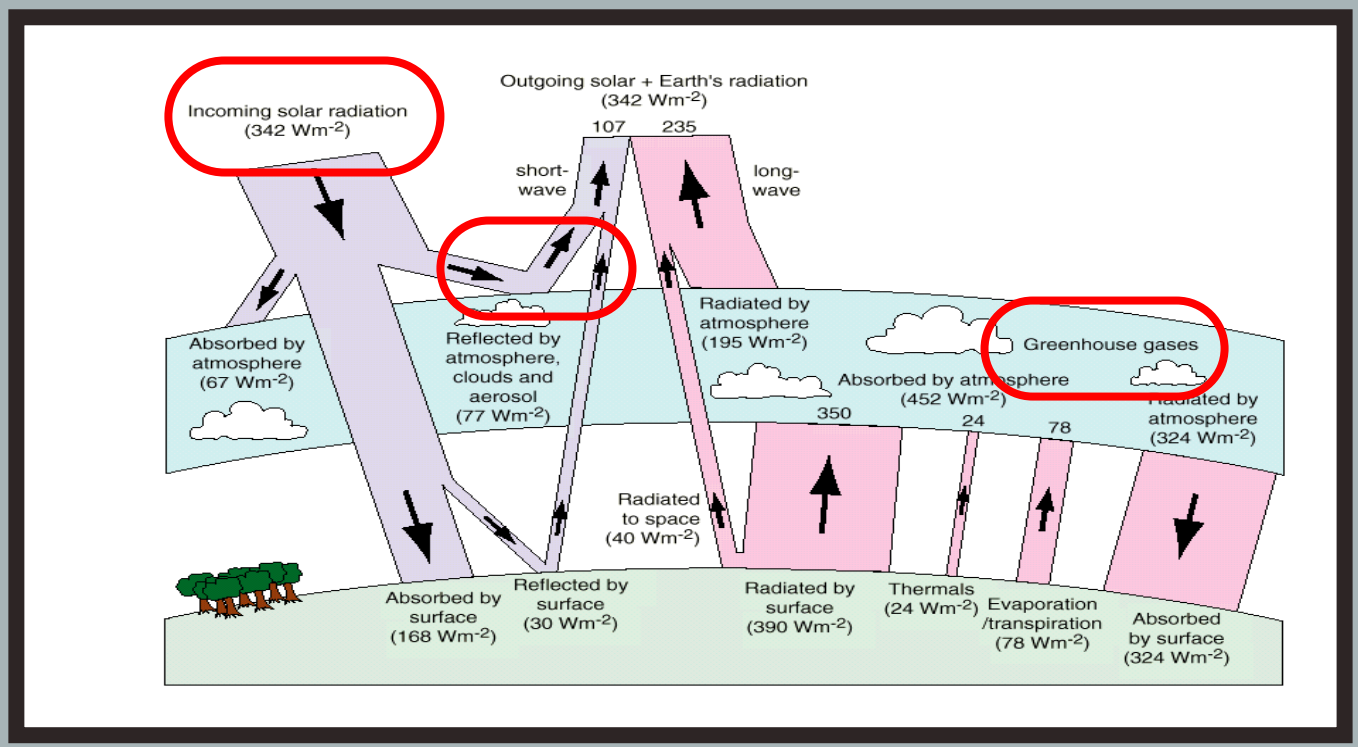
Earthshine Photometry goals

- *Observe earthshine to determine absolutely calibrated, large-scale, high-precision measurements of the earth's reflectance*
- *Look for secular, seasonal and long-term variations in the albedo (like over a solar cycle)*
- *Transient phenomena like El Niño or volcanic eruptions*
- *Simulate the observational results*
  - *Compare with observations*
  - *Calibrate treatment of cloud cover*

The Albedo, a climate driver

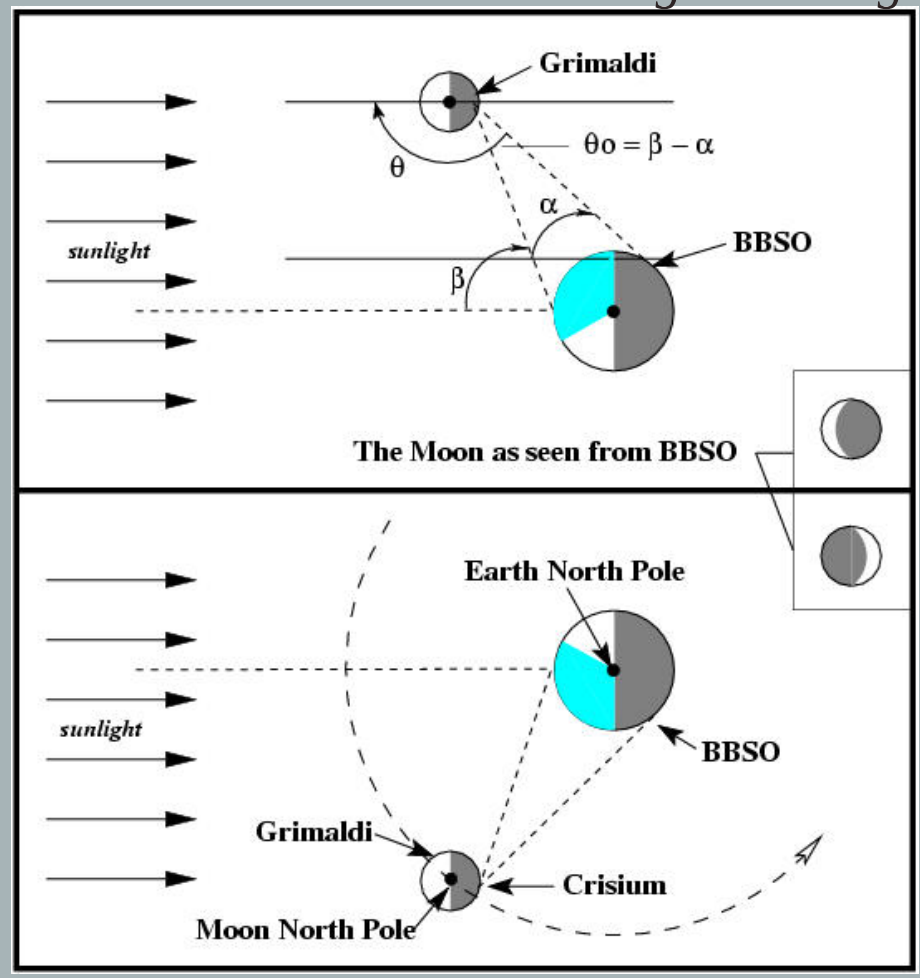
- The net sunlight reaching Earth drives the climate system.
- About 30% of incident sunlight is reflected back to space

$$T_s^{\,4} = \frac{C}{4\sigma(1-g)}(1-A)$$



Earthshine measurements of the Earth's large-scale reflectance

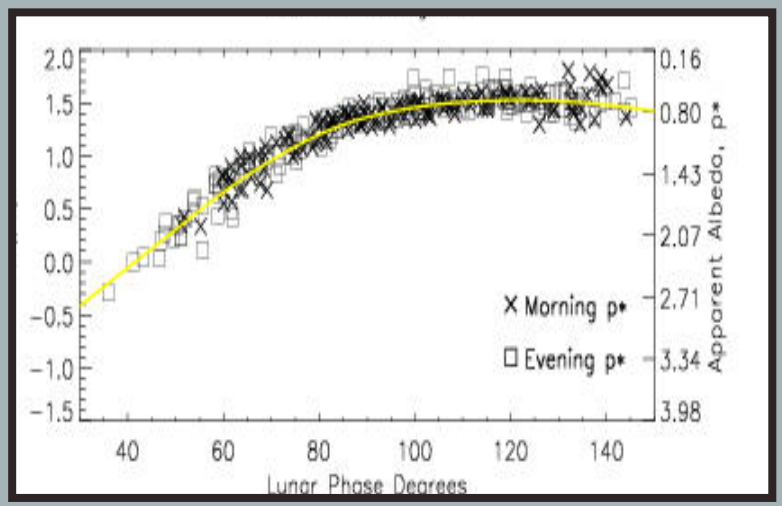
- *The Earthshine is the ghostly glow on the dark side of the Moon*
- *Origin of Earthshine first explained by Leonardo da Vinci*
- *First measured by Danjon beginning in 1927-34 and by Dubois 1940-60.*
- *ES/MS = albedo (+ geometry and moon properties)*

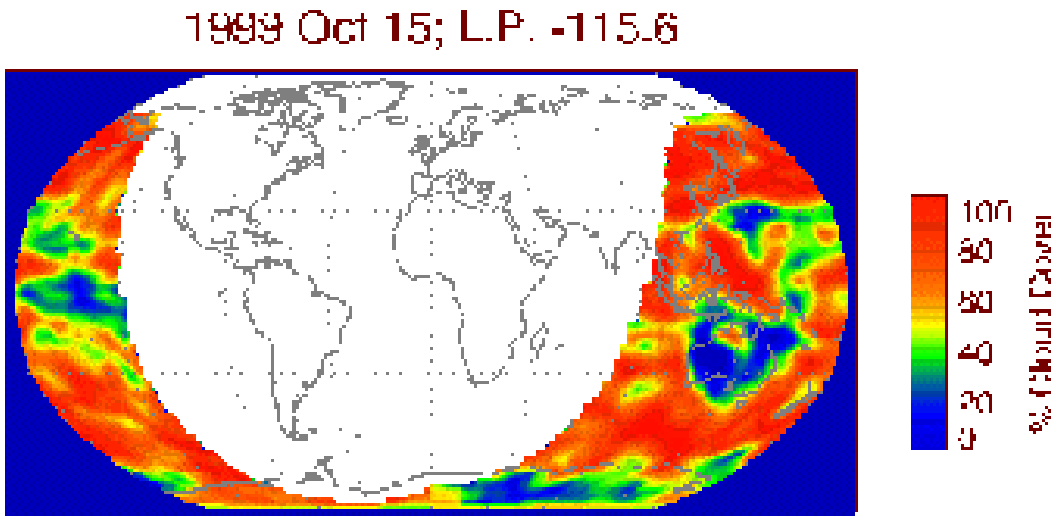


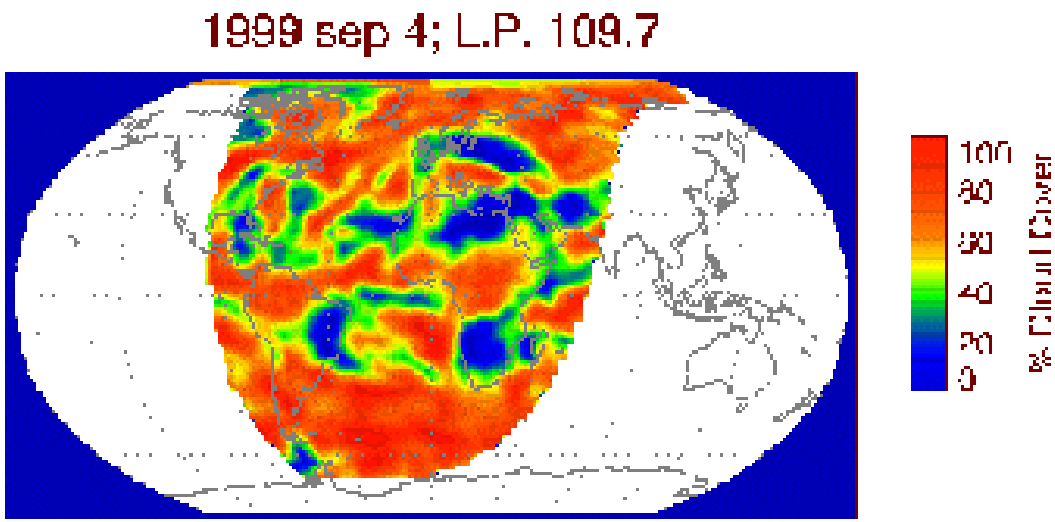
The Effective and Bond Albedos

- *On any one night, we measure p^*, the effective (or apparent) albedo (1 direction). (different Sun-Earth-Moon reflection angle)*
- *To obtain the Bond albedo, A, we integrate over all phases of the moon at monthly/yearly time scales*

$$A = \frac{2}{3}\int p^* f_L(\theta)\sin(\theta)d\theta$$







Clod cover maps for the areas contributing to the albedo:

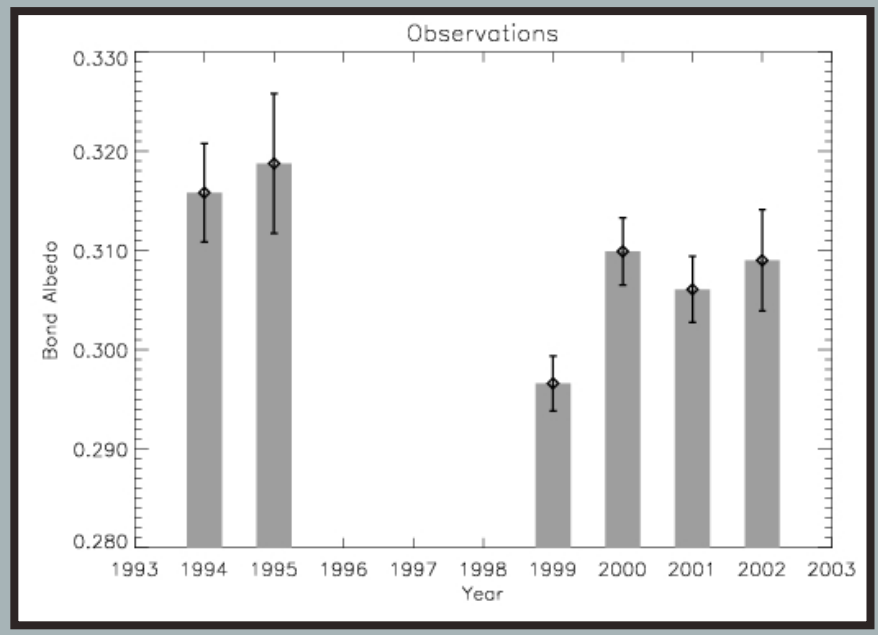
- In the sunlight
- Visible from the Moon

Two typical nights of observation from BBSO

Albedo Annual Means

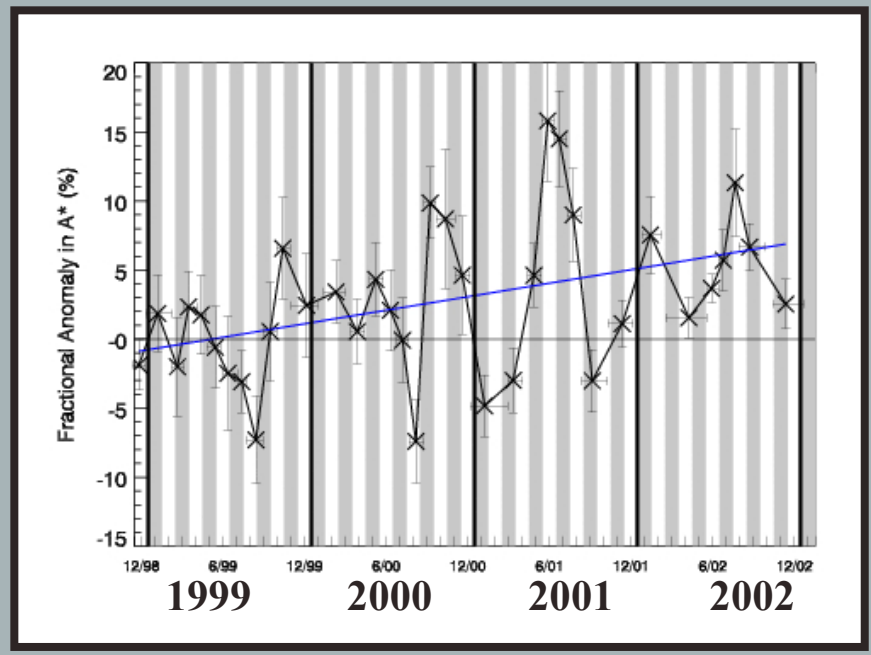
Data for 1994-95 is less reliable

Year	Albedo	σ	% Error	Observations
1999	*0.297*	*0.003*	*1.0%*	*117*
2000	*0.310*	*0.003*	*1.1%*	*105*
2001	*0.306*	*0.003*	*1.1%*	*89*
2002	*0.309*	*0.005*	*1.5%*	*75*



Seasonal Changes

The observations show a seasonal variation in albedo of about 20%



Changes in the Earth's albedo over the last 20 years

- Earthshine data: **December 1998 – present**
- ISCCP data: **June 1983 – September 2001** (to be updated)

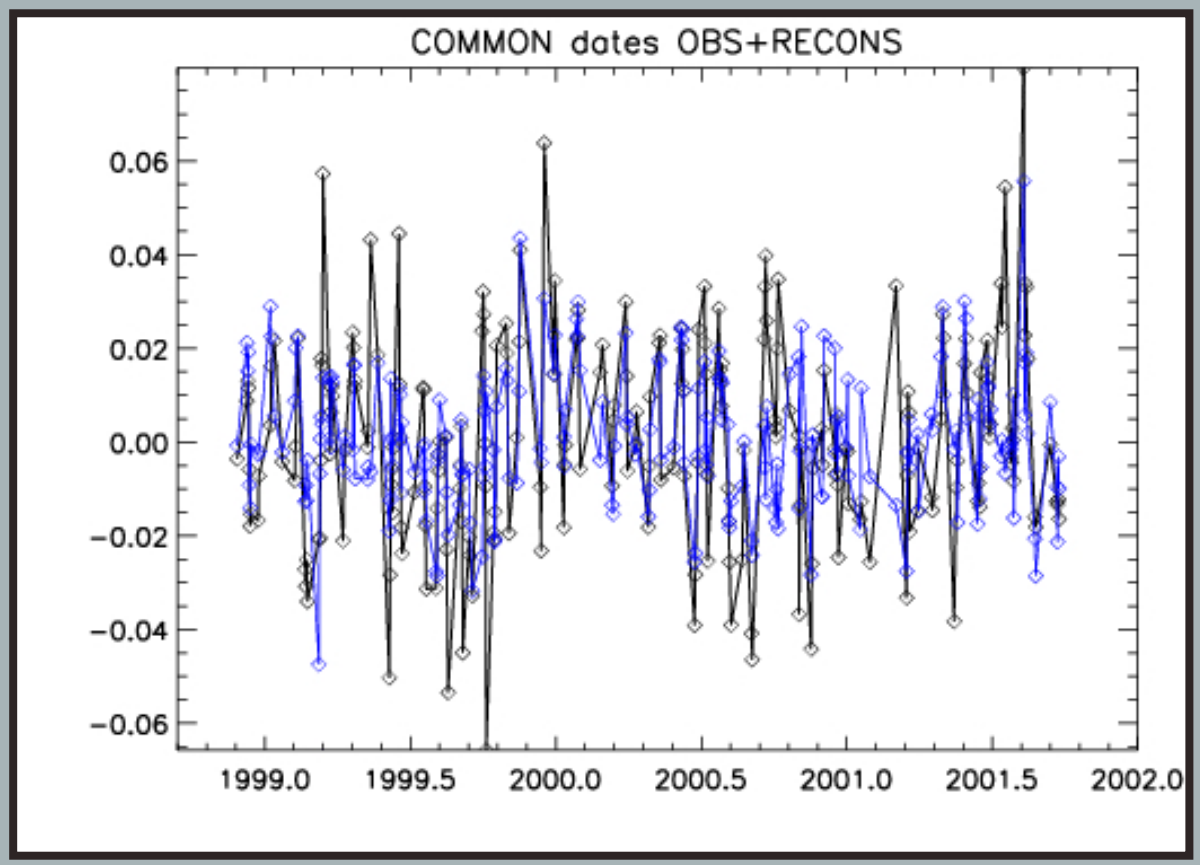
- Over the common period we do a multiple regression (comparison) of the different cloud properties for the time and area covered by observations.

- We find a relationship between the cloud variables and the albedo measured at BBSO.

- This allows us to reconstruct the earth's albedo as seen from BBSO since 1983.

Multiple regression on p*

Common period December 1998 – September 2001



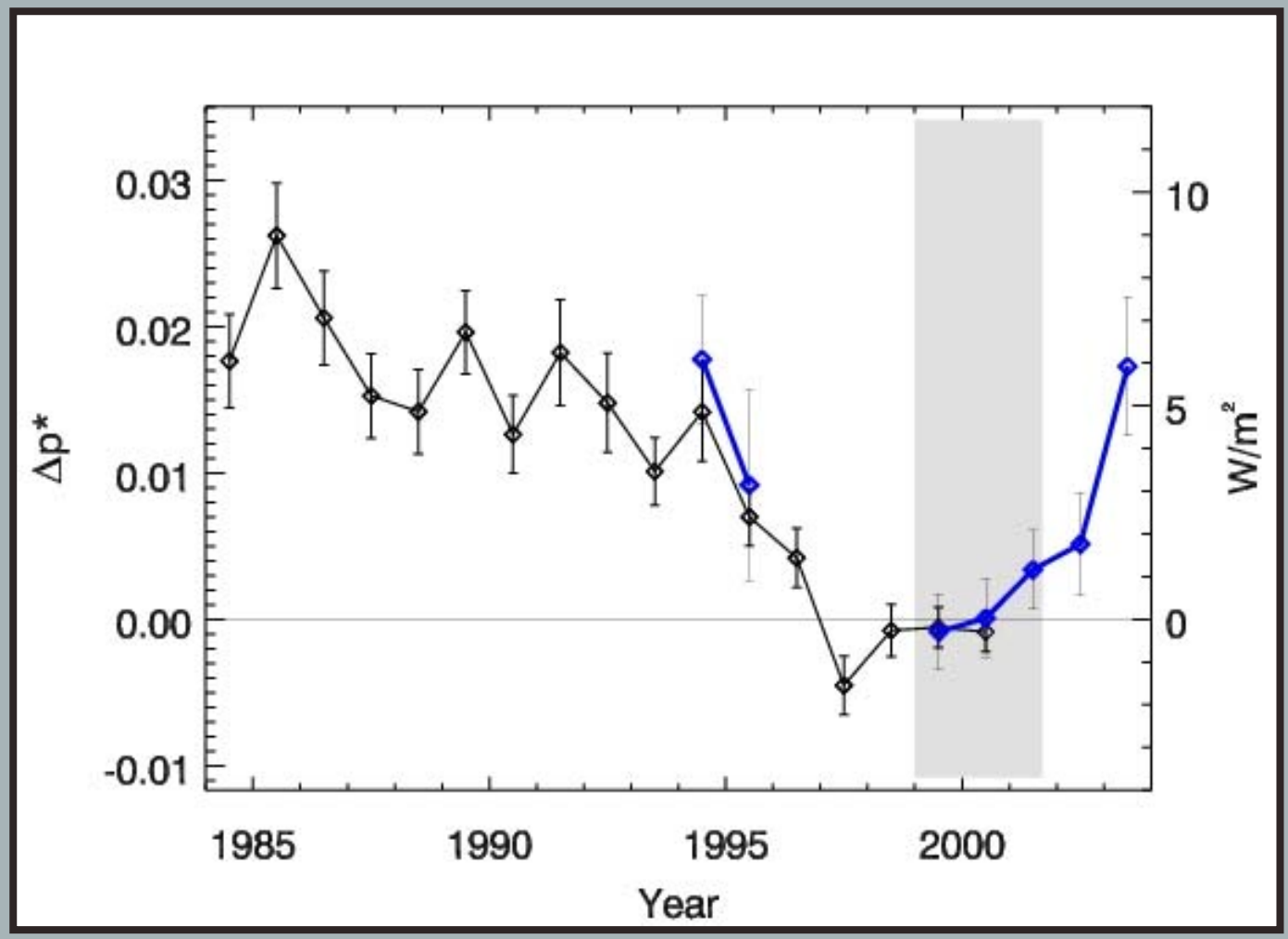
Regress On:

- ✓ *cloud cover*
- ✓ *optical thickness*
- ✓ *surface reflectance*

Earth's albedo 1983-2003

Albedo ⇩

Effective Ground-level solar Irradiance ⇧



And we are <u>not</u> alone: tropical satellite data OLR and SW

Climatic Implications

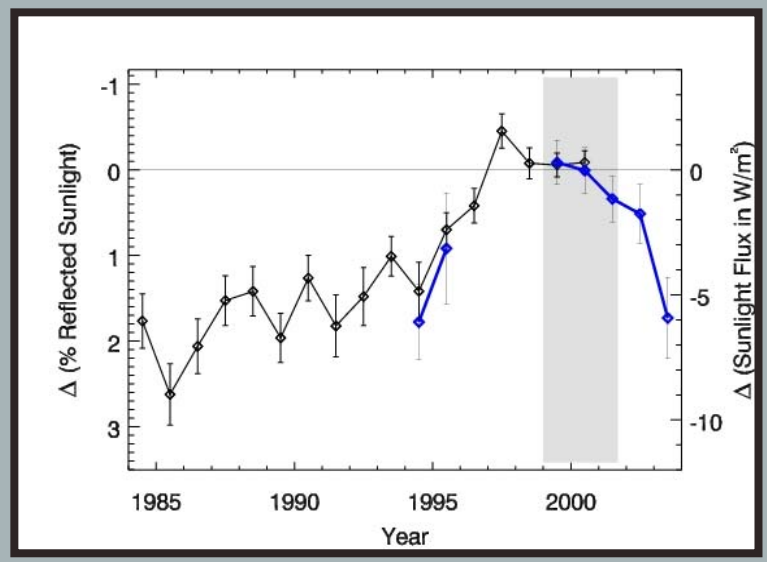
•The albedo decrease implies a climate forcing of ~7 W/m^2

•This is “equivalent” to a ~2% increase in the solar irradiance over just two decades.

•Satellite data: Solar irradiance variations from maxima to minima are about 0.1% Factor 20!!

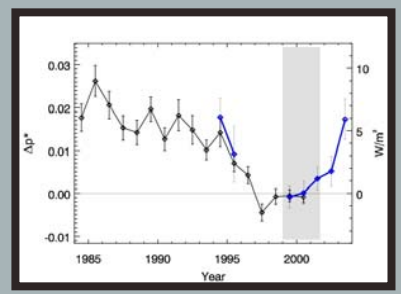
•Global warming since 1900 due to GHG is estimated to be around ~2.4 W/m^2.

•Different Timescales, ***need to know*** what happens at longer time scales.



Conclusions

- *The earth's albedo may be much more variable than previously thought*
- *The climate models fail to reproduce this results. No explanation so far.*
- *Why is the albedo (clouds) changing? That may be a major contribution to GW.*
- *Are these changes due to GHGs? …. No*
- *Are these changes solar? …. humm!!*
- *Are they natural variability? ….. probably*




The End

Earthshine Future Directions

- *Set-up global network, so we can do whole earth and obtain monthly averaged albedos*

ES1- BBSO, California

ES2- CrAO, Crimea

ES3- Yunnan Observatory, China

ES4- Canary Islands, Spain

- *Improve models to allow altitude dependent cloud cover and a better scene parameterization*
- *Comparison to satellite albedo records*

References

- *Pallé E, Goode P.R., Montañes-Rodriguez P., Koonin S.E., Changes in Earth's albedo over the past 20 years, Science, in press, 2004.*

- *Qiu J., Goode PR, Pallé E, Yurchyshyn V, Hickey J, Montañes-Rodriguez P., Chug MC, Kolbe E, Brown CT, Koonin SE, Earthshine and the Earth's albedo I: Precise and large-scale nightly measurements, Journal Geophysical Research, 108 D22, 2003.*

- *Pallé E, Goode PR, Qiu J, Yurchyshyn V, Hickey J, Montañes-Rodriguez P., Chu MC, Kolbe E, Brown CT, Koonin SE, Earthshine and the Earth's albedo I: Precise and large-scale nightly measurements, Journal Geophysical Research, 108 D22, 2003.*

- *Goode PR, Qiu J, Yurchyshyn V, Hickey J, Chu MC, Kolbe E, Brown CT, , Koonin SE, Geophysical Research letters, 2001.*