

# CLOUD FRACTION: CAN IT BE DEFINED AND MEASURED? AND IF WE KNEW IT WOULD IT BE OF ANY USE TO US?

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**Cloud Properties, Observations, and their Uncertainties**

*[www.ecd.bnl.gov/steve](http://www.ecd.bnl.gov/steve)*

CLOUD FRACTION: CAN IT BE DEFINED  
AND MEASURED? AND IF WE KNEW IT  
WOULD IT BE OF ANY USE TO US?

## CONCLUSIONS

No.

No.

No.

*I come to bury cloud fraction, not to praise it.*

*- Shakespeare, 1599*

# WHAT IS A CLOUD?

## *AMS Glossary of Meteorology (2000)*

A *visible aggregate* of minute water droplets and/or ice particles in the atmosphere above the earth's surface.

**Total cloud cover:** Fraction of the sky hidden by all *visible clouds*.

## *Clothiaux, Barker, & Korolev (2005)*

Surprisingly, and in spite of the fact that we deal with clouds on a daily basis, to date there is *no universal definition of a cloud*. . . .

Ultimately, the definition of a cloud *depends on the threshold sensitivity* of the instruments used.

## *Ramanathan, JGR (ERBE, 1988)*

Cloud cover is a *loosely defined term*.

## *Potter Stewart (U.S. Supreme Court, 1964)*

I shall not today attempt further to define it, but *I know it when I see it*.

# WHY DO WE WANT TO KNOW CLOUD FRACTION, ANYWAY?

Clouds have a strong impact on Earth's radiation budget:  $-45 \text{ W m}^{-2}$  shortwave;  $+30 \text{ W m}^{-2}$  longwave.

Slight change in cloud fraction could augment or offset greenhouse gas induced warming – cloud feedbacks.

Getting cloud fraction “right” is an evaluation criterion for global climate models.

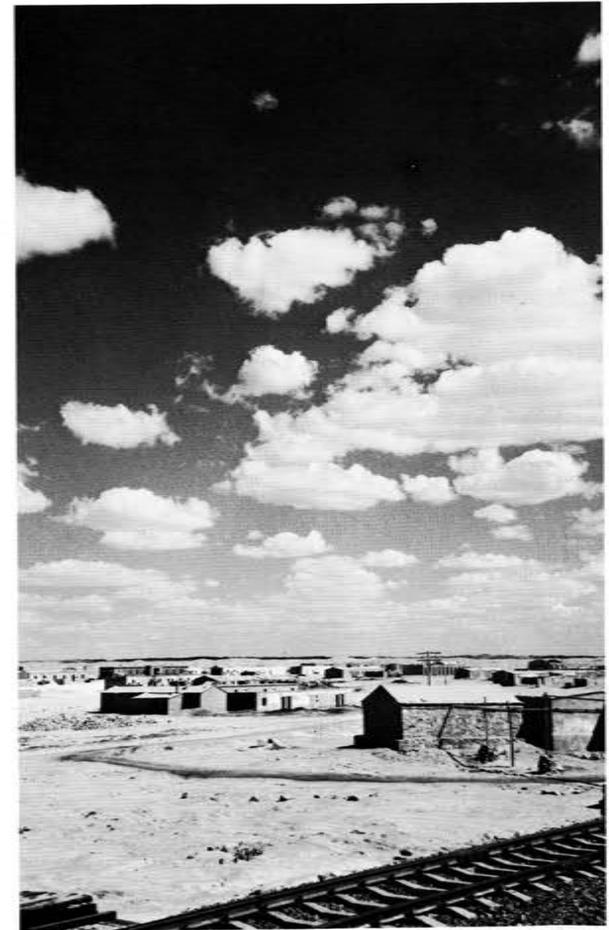
October 1986



### Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land



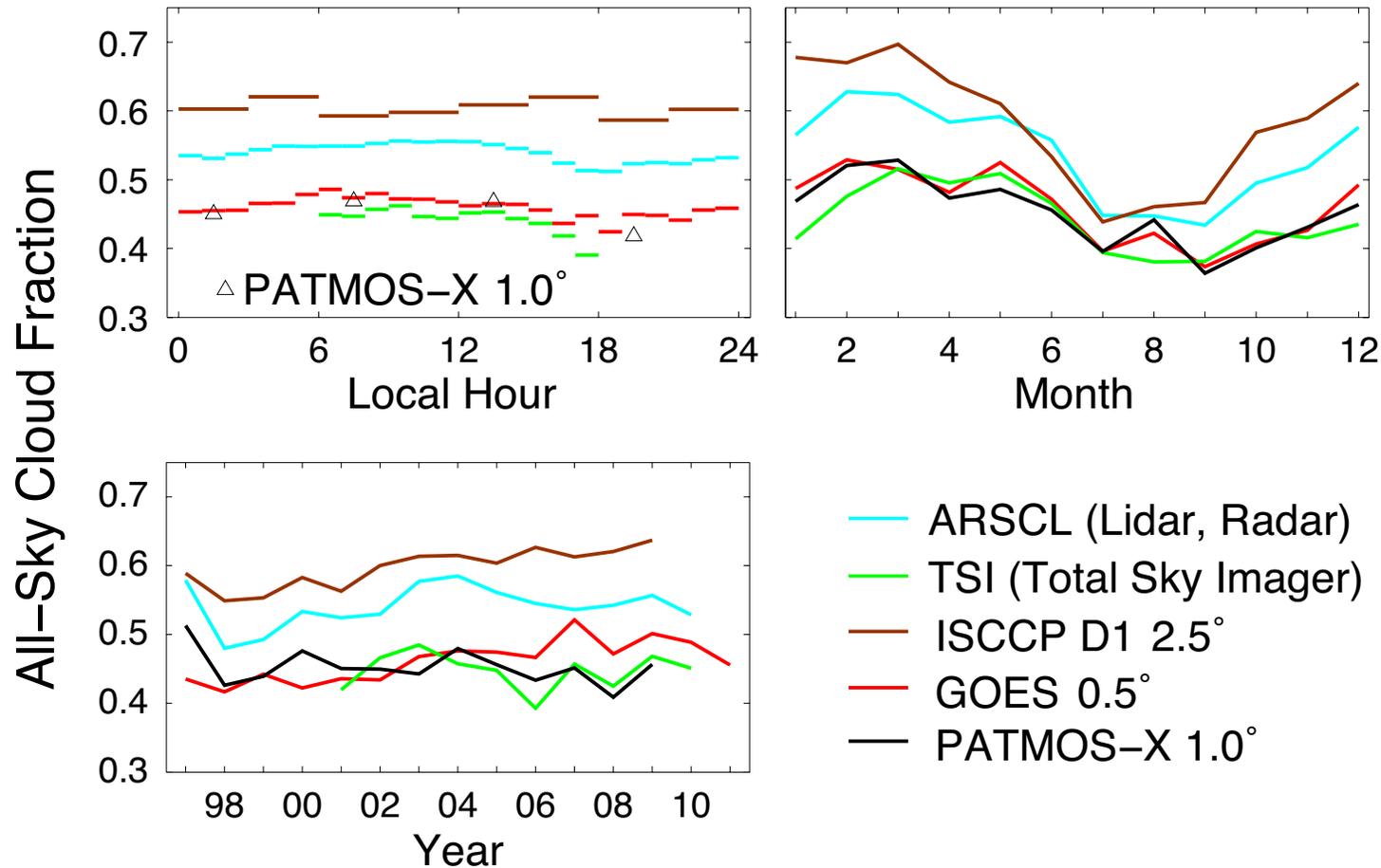
Domain	Observations Millions	Cloud cover %
Land	116	52.4
Ocean	43.3	64.8
Global	159	61.2



*Warren, Hahn, London, Chervin, Jenne*

# CLOUD FRACTION BY MULTIPLE METHODS

2 Surface, 3 satellite methods at U.S. Southern Great Plains; 10 years data

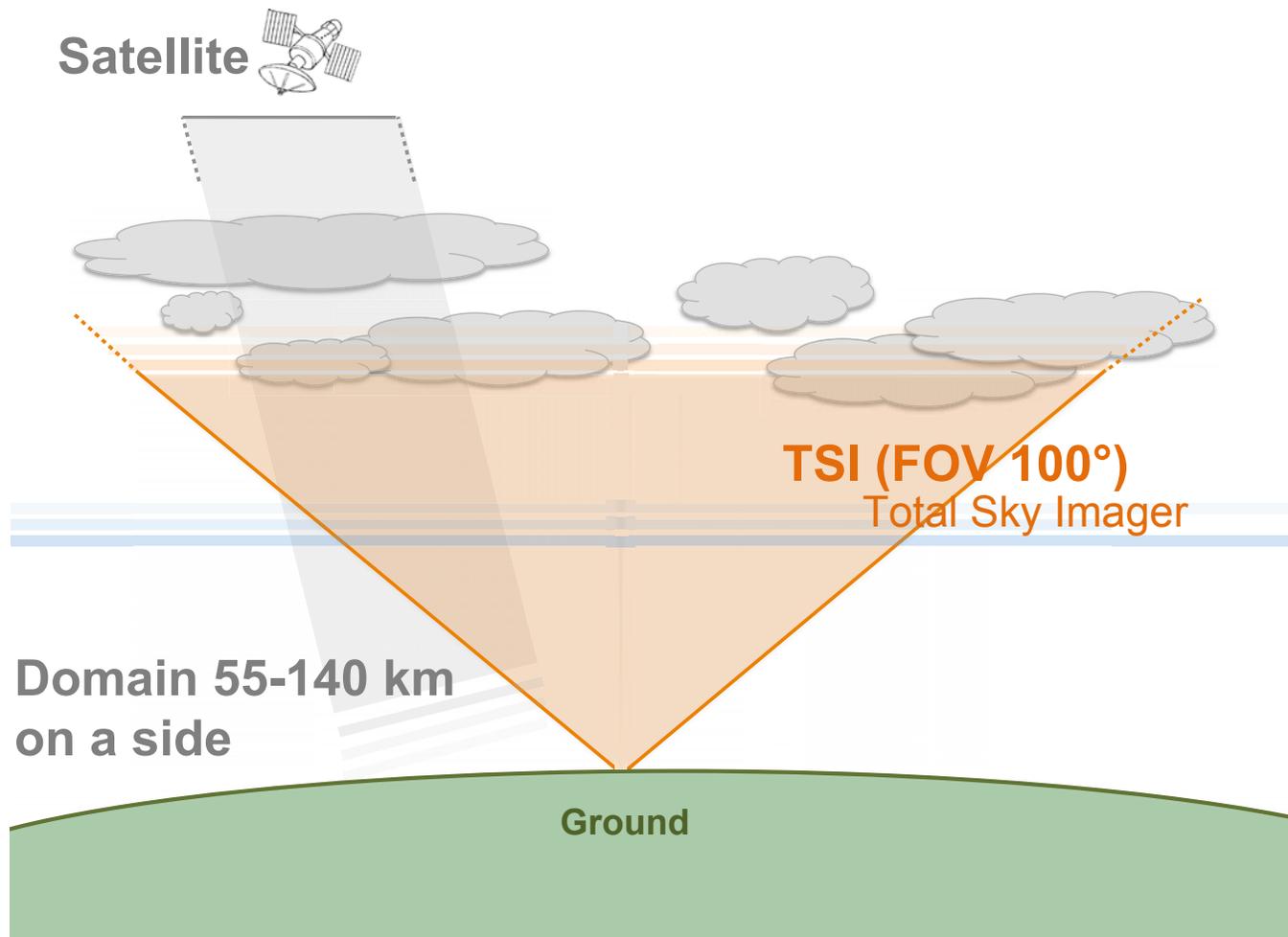


Wu, Liu, Jensen, Toto, Foster & Long, JGR, in review

Different methods yield *substantial systematic differences in the mean*.

Error of 0.1 in cloud fraction is  $\sim 9 \text{ W m}^{-2}$  in shortwave,  $6 \text{ W m}^{-2}$  in longwave.

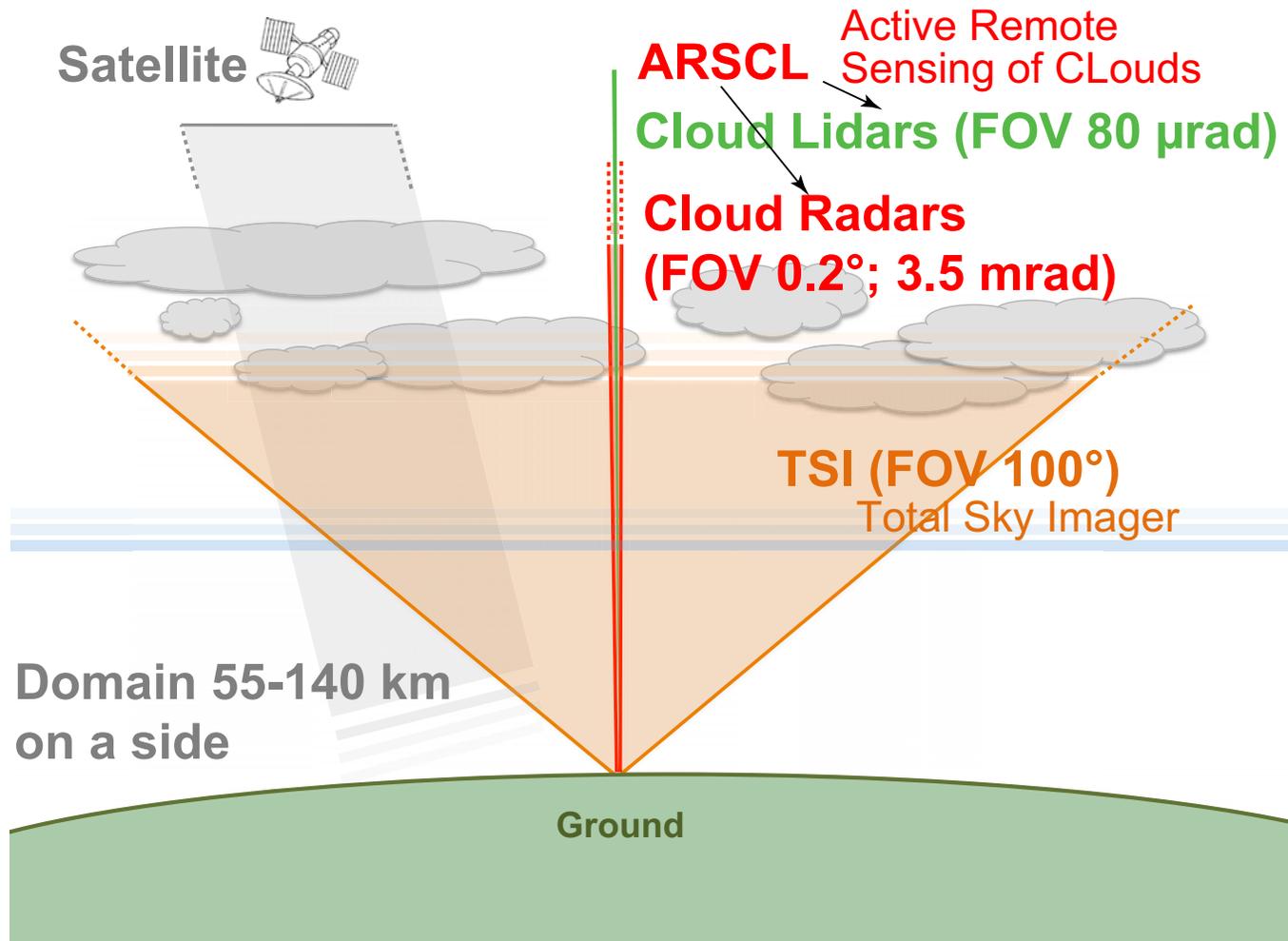
# MULTIPLE APPROACHES TO DETERMINING CLOUD FRACTION



*Modified from Wu, Liu, Jensen, Toto, Foster & Long, JGR, in review*

Although different approaches yield different instantaneous, local CF, they would be expected to yield the same *average* CF.

# MULTIPLE APPROACHES TO DETERMINING CLOUD FRACTION



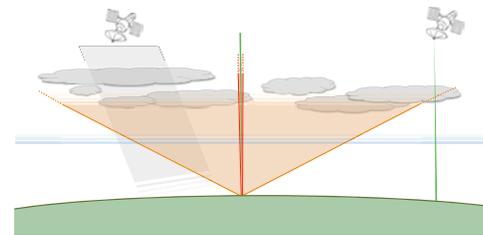
*Modified from Wu, Liu, Jensen, Toto, Foster & Long, JGR, in review*

Although different approaches yield different instantaneous, local CF, they would be expected to yield the same *average* CF.

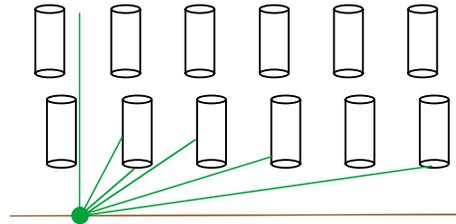
# REASONS FOR DIFFERENCES IN MEASURED CLOUD FRACTION

## *Trivial*

Mismatch of spatial and/or temporal domain.

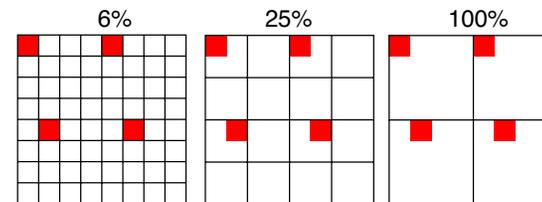


View angle –  
sidewall effect –  
cloud aspect ratio.

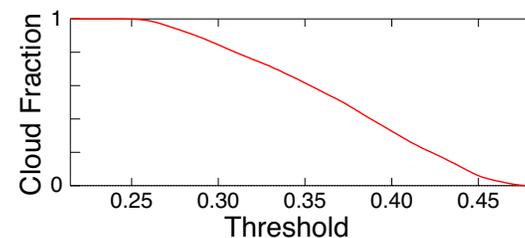


## *Intrinsic*

Spatial resolution.

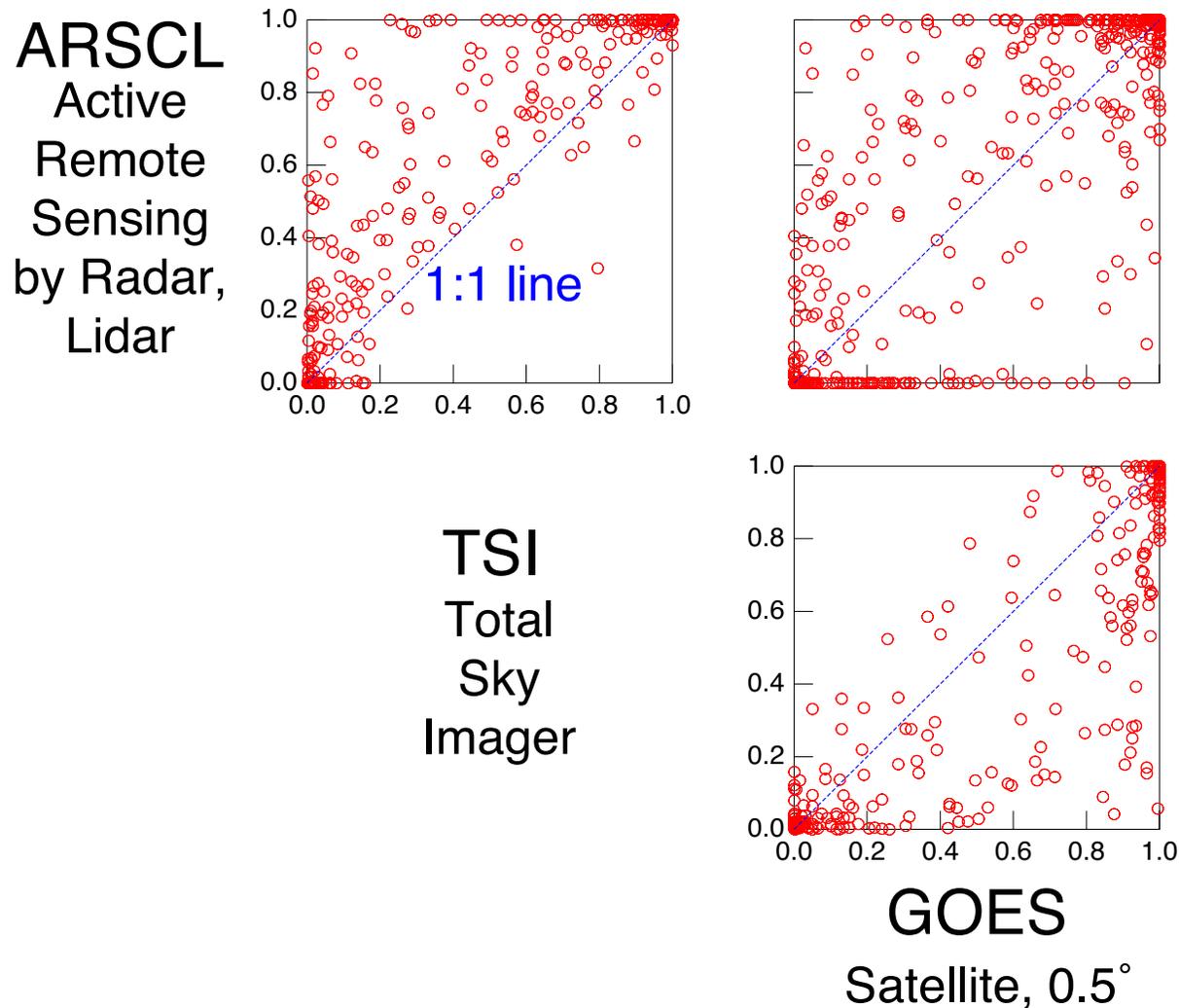


Threshold.



# COMPARISON OF CLOUD FRACTION BY DIFFERENT METHODS

Hourly cloud fraction at SGP by multiple methods, May, 2009

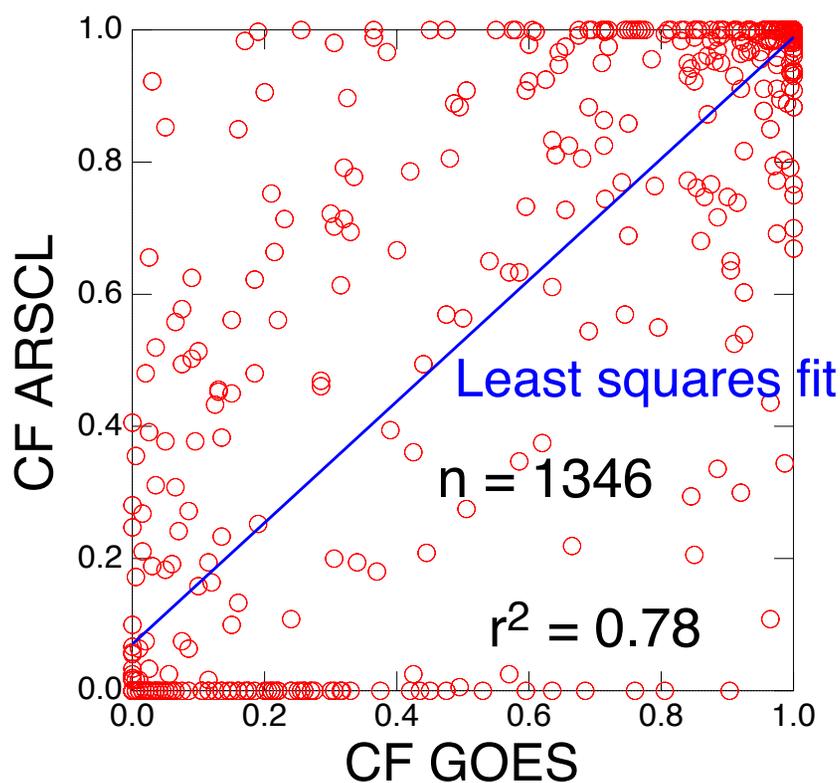


Comparison plots show some skill but substantial differences.

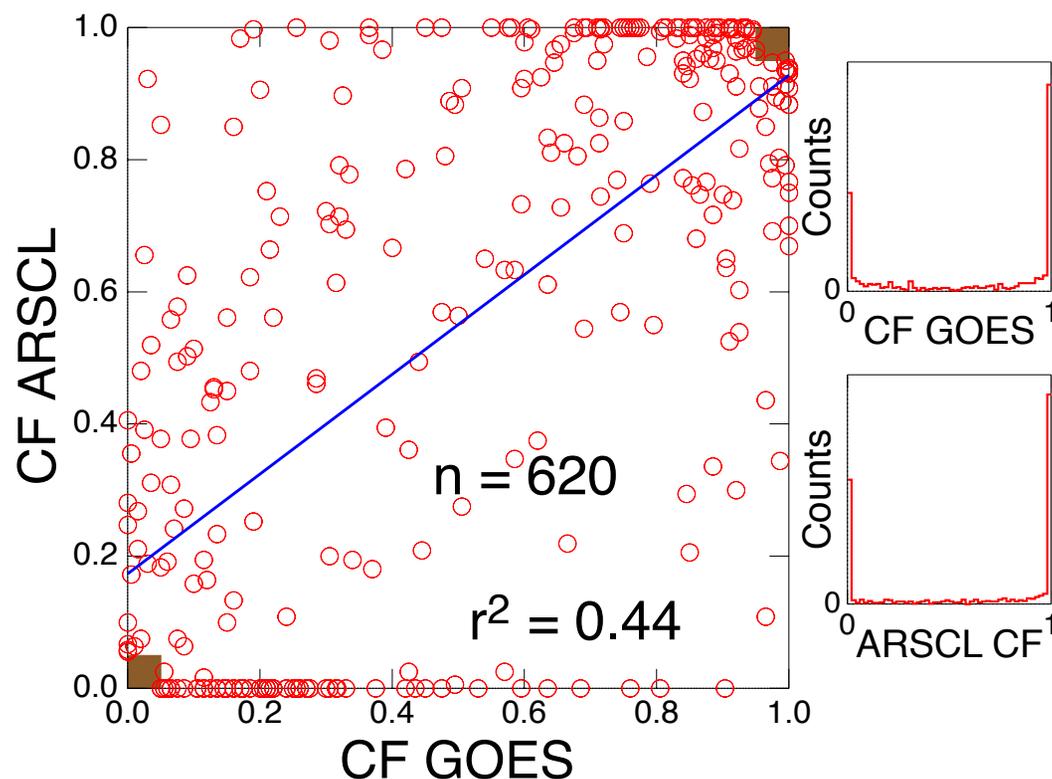
# CORRELATION IS DOMINATED BY ONES AND ZEROES

Hourly cloud fraction at SGP by ARSCL AND GOES, May, 2009

All points, May, 2009



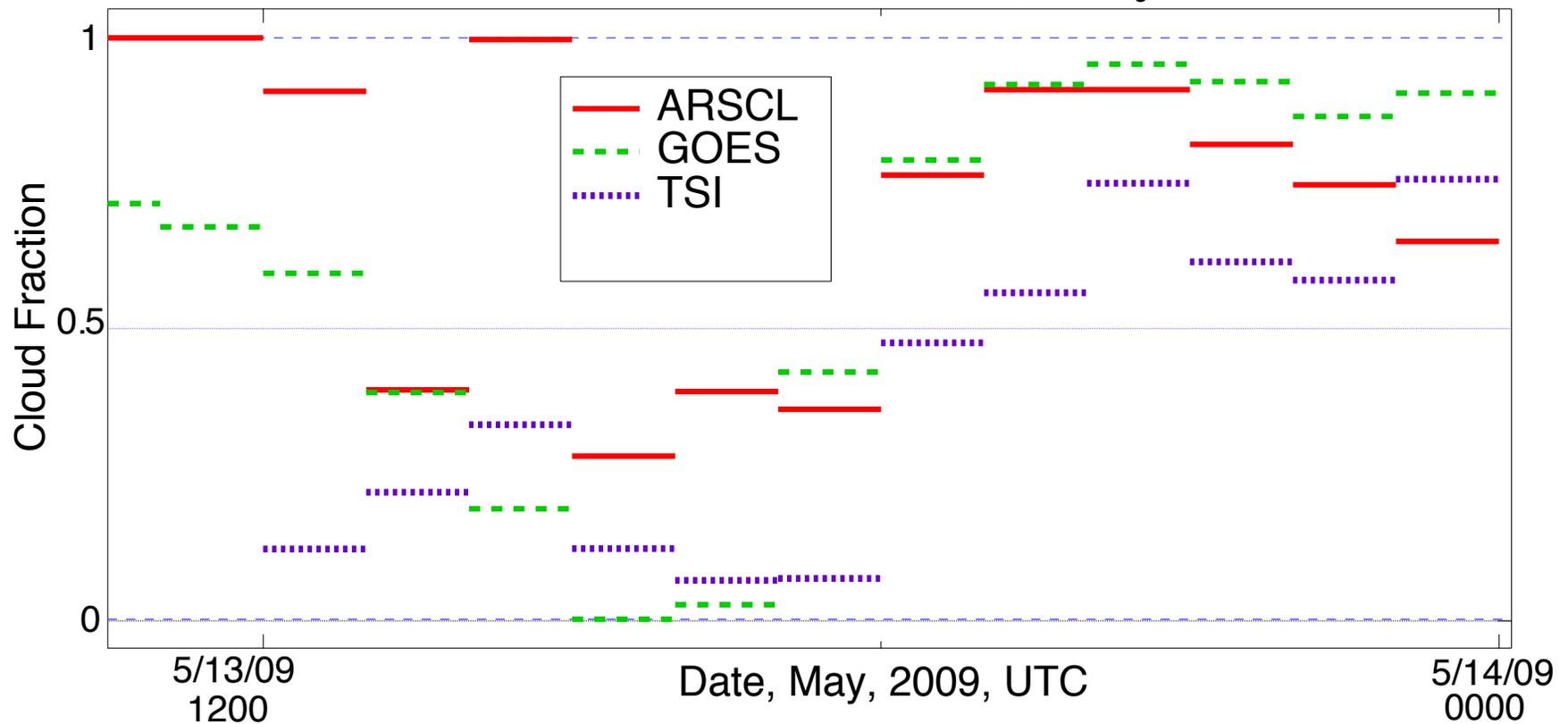
Points within 5% of 0 or 1  
in both data sets excluded



Excluding all-cloud and no-cloud scenes reduces variance accounted for by the regression from 78% to 44%.

# TIME SERIES OF CLOUD FRACTION BY MULTIPLE METHODS

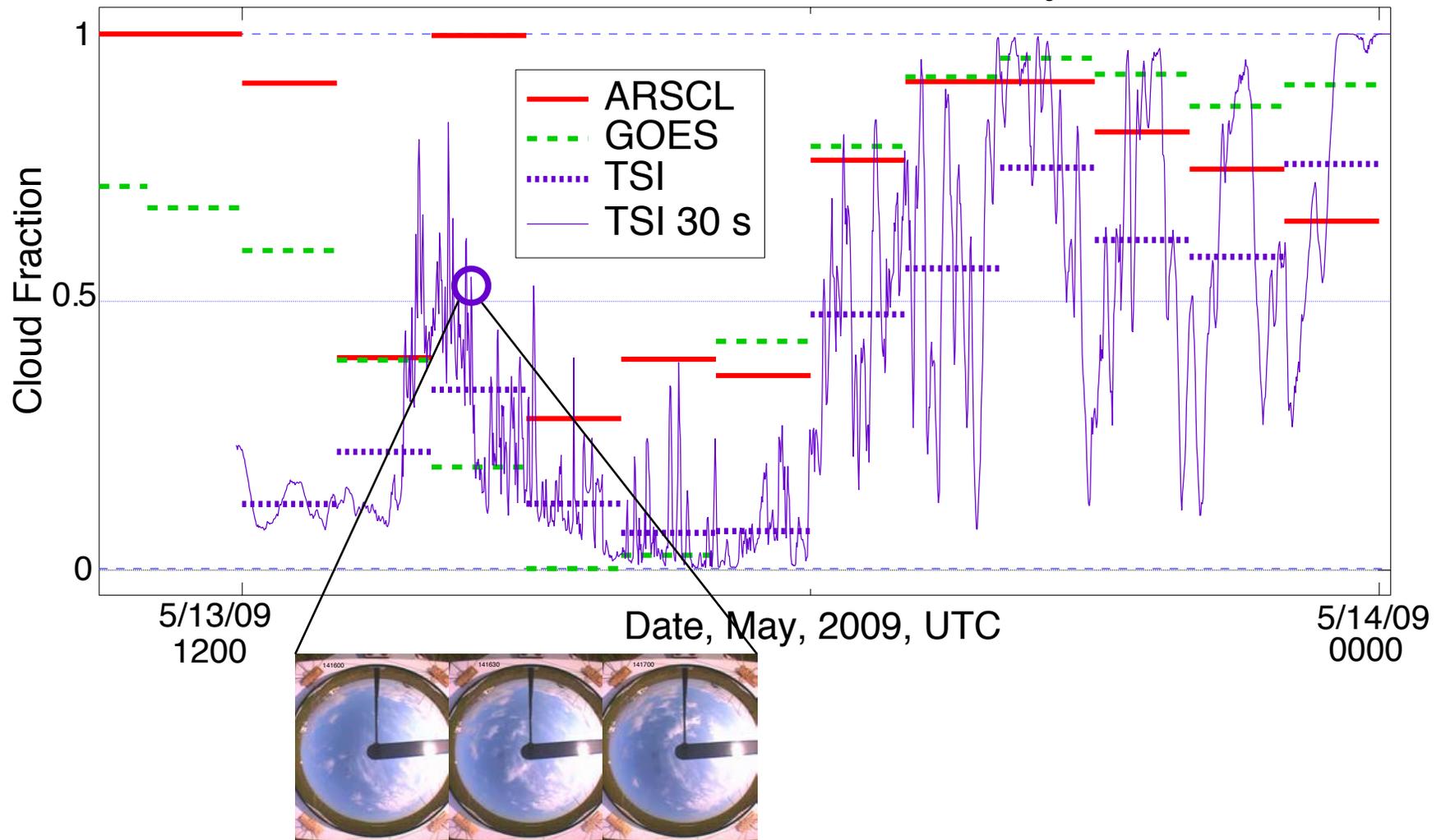
ARM SGP site (north central OK) May 13, 2009



Substantial variation among methods.

# TIME SERIES OF CLOUD FRACTION BY MULTIPLE METHODS

ARM SGP site (north central OK) May 13, 2009

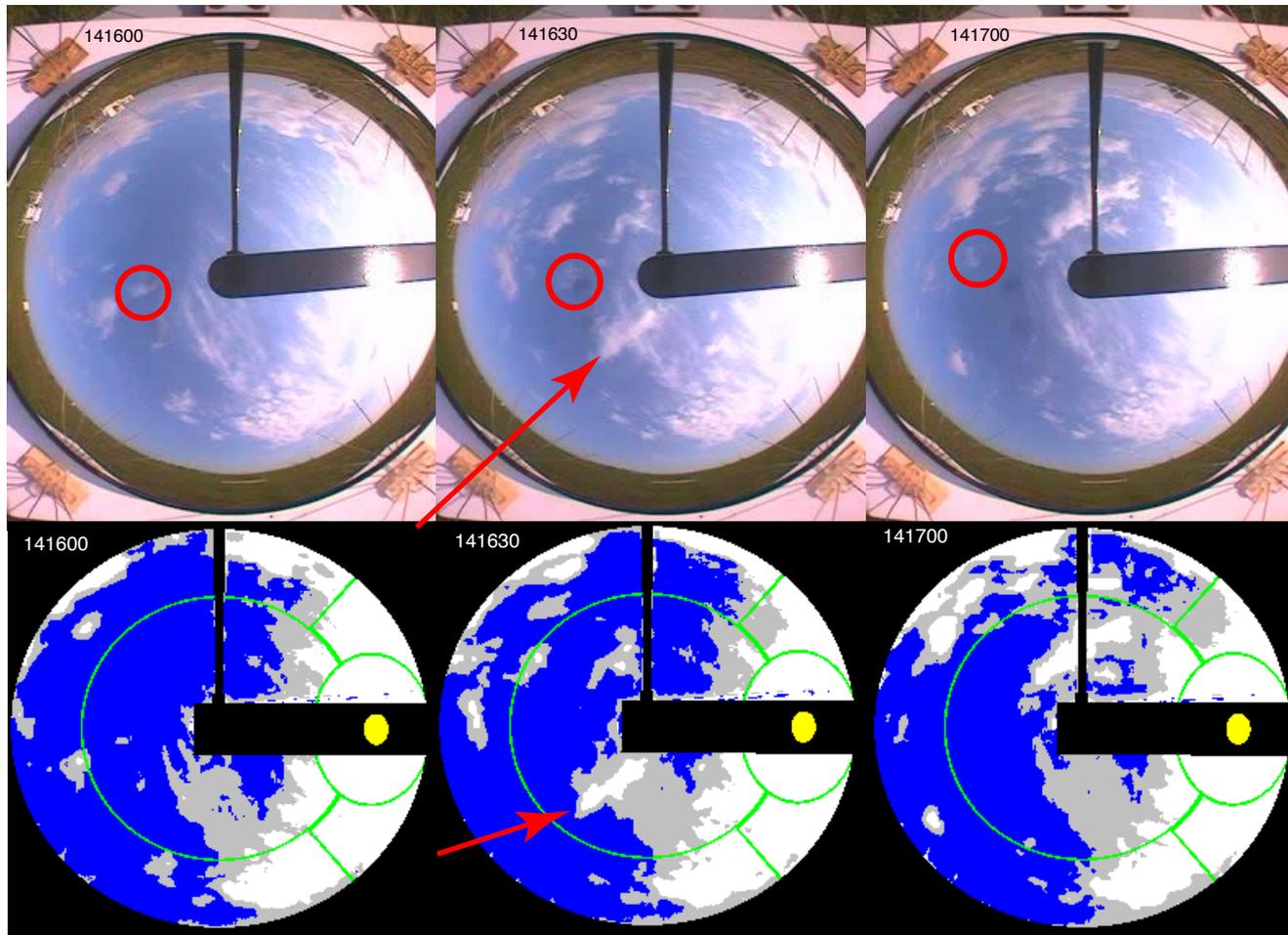


Substantial variation among methods.

Substantial fluctuation in TSI images taken at 30-second intervals.

# TOTAL SKY IMAGES AND CLOUD MASKS FROM TSI ALGORITHM

ARM SGP site (north central OK) May 13, 2009, 1416-1417



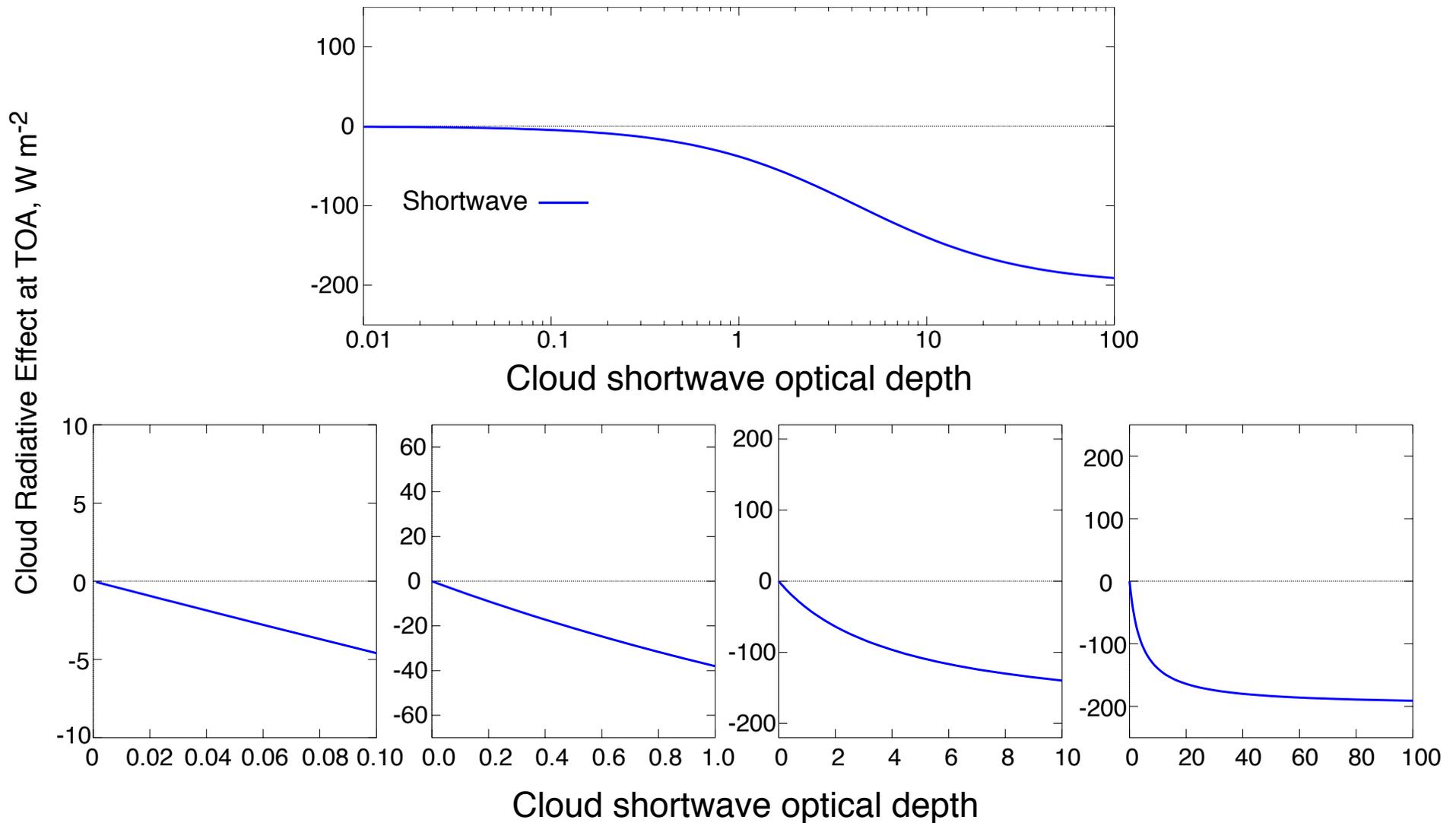
TSI threshold misses thin visible clouds

Substantial changes at 30-s intervals as clouds are blown by wind.

# CLOUD RADIATIVE EFFECT

Dependence on shortwave optical depth and cloud-top temperature

24-Hour average CRE, north central Oklahoma, at equinox

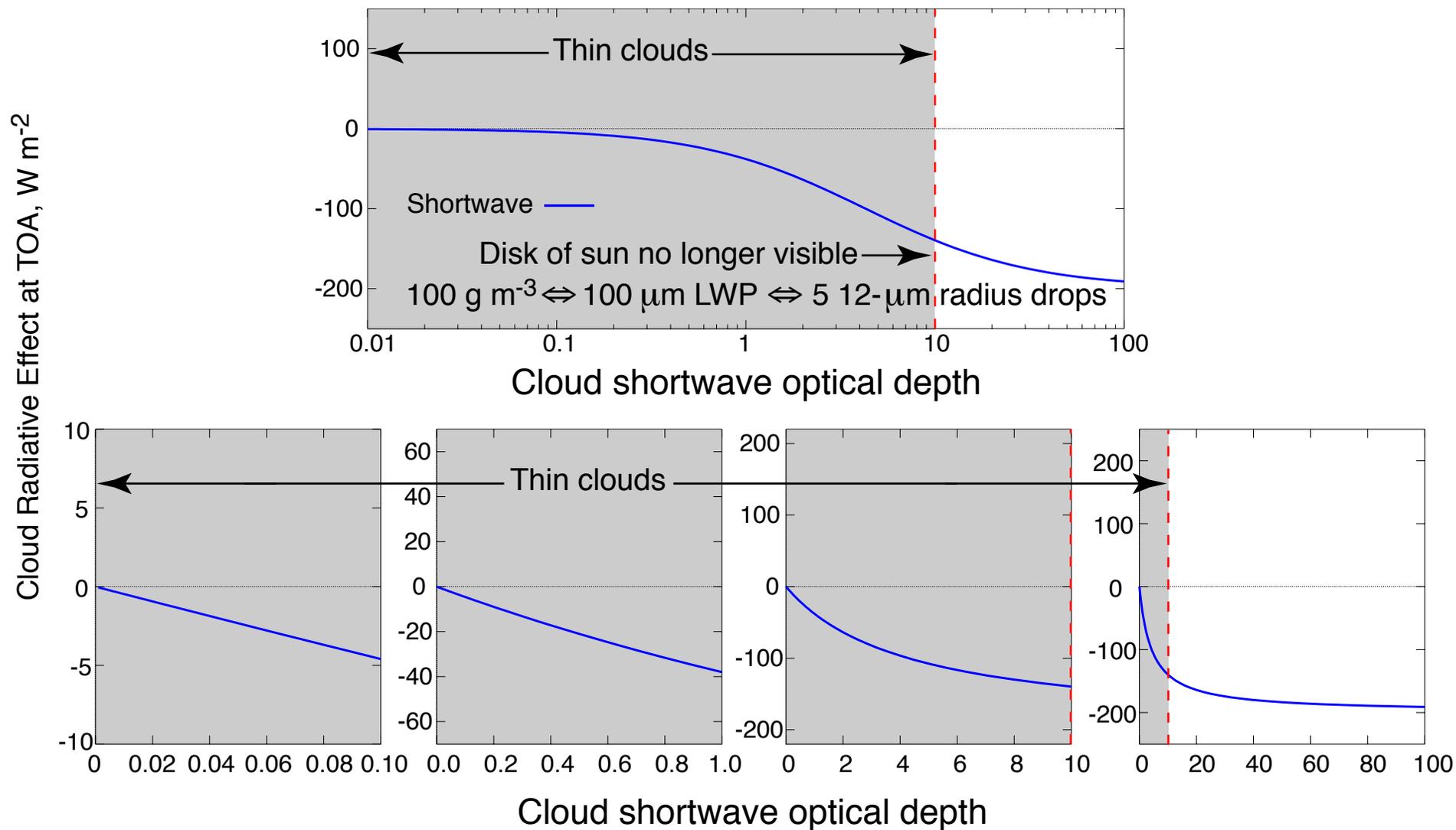


CRE is initially linear in optical depth, saturating at high optical depth.

# CLOUD RADIATIVE EFFECT

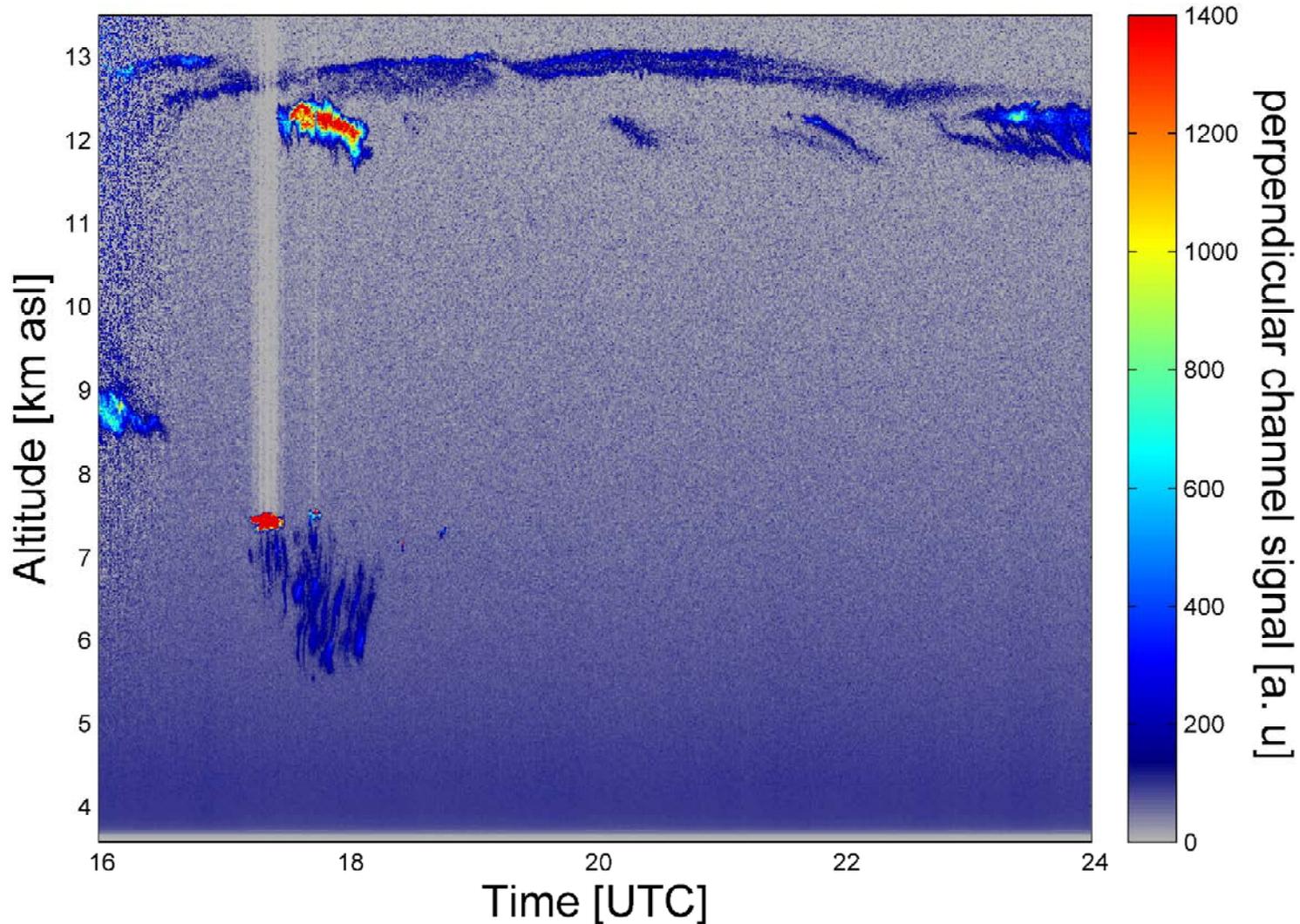
Dependence on shortwave optical depth and cloud-top temperature

24-Hour average CRE, north central Oklahoma, at equinox



Even clouds of very low optical depth exert substantial radiative effect.

# PERSISTENT **VERY THIN** CIRRUS AT MIDLATITUDE SITE



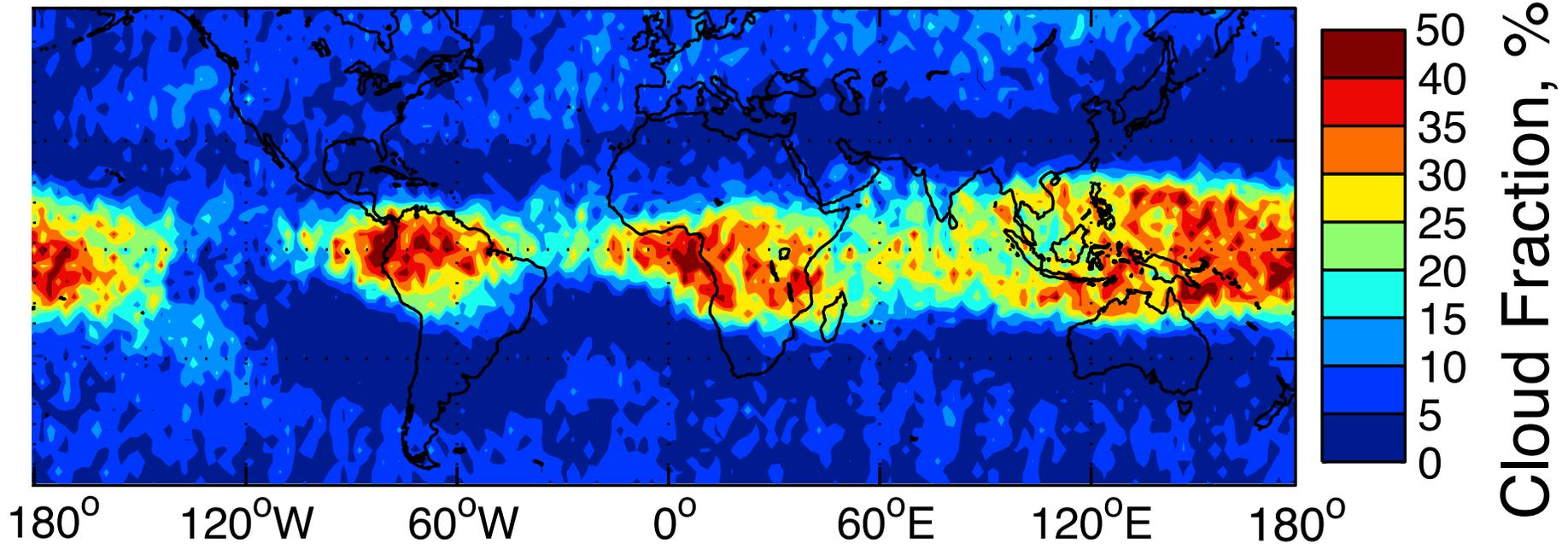
*Kienast-Sjögren et al., 9<sup>th</sup> Int. Symp. on Tropospheric Profiling, 2012*

Optical depth of cirrus layer estimated from lidar return as **0.003 to 0.004**.

# OPTICALLY THIN CLOUDS CAN BE PREVALENT IN TROPICS

Subvisible cirrus detected by lidar from space, DJF

$$0.01 \leq \tau \leq 0.03$$

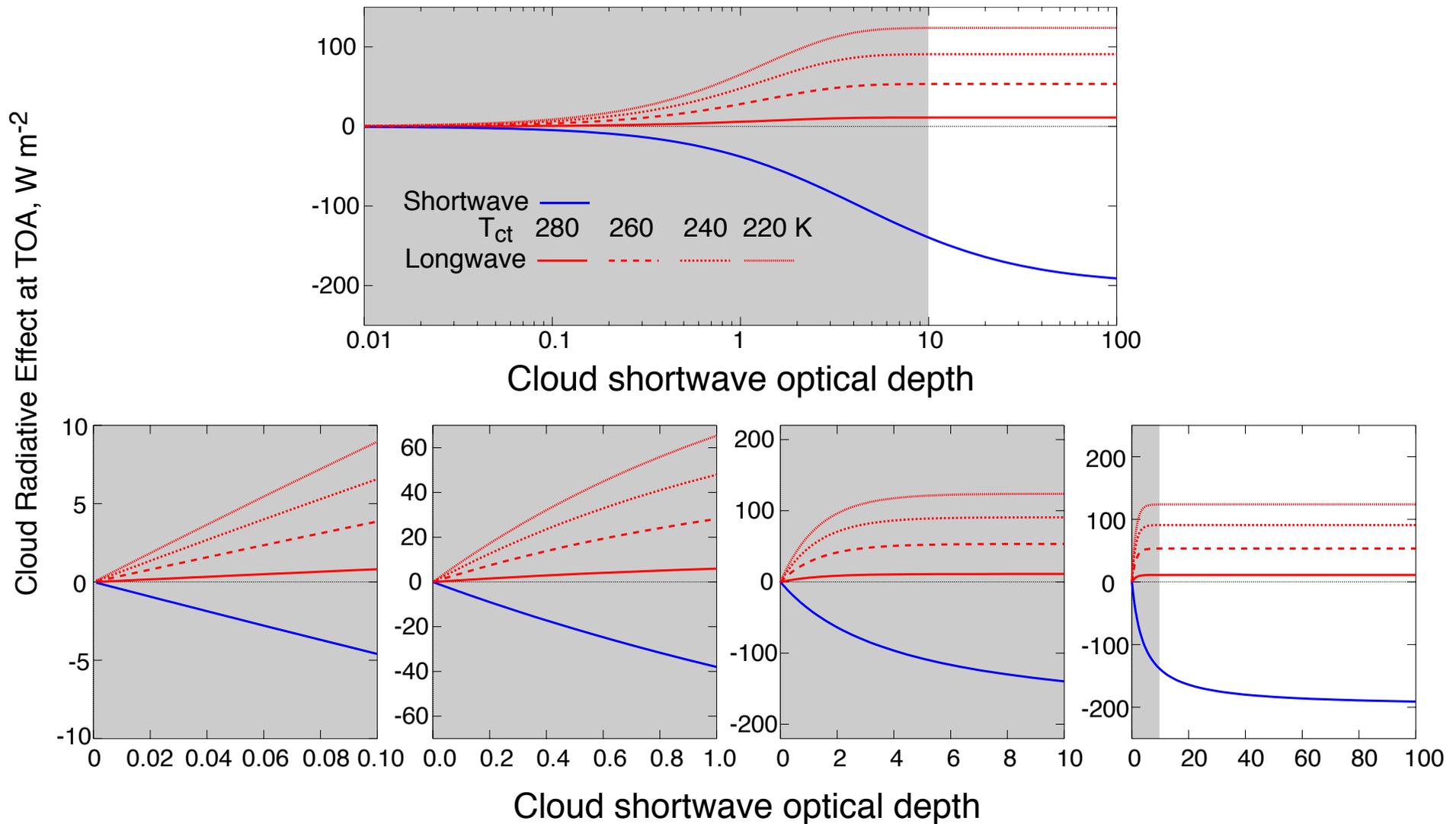


*Martins Noel & Chepfer, JGR, 2011*

# CLOUD RADIATIVE EFFECT

Dependence on shortwave optical depth and cloud-top temperature

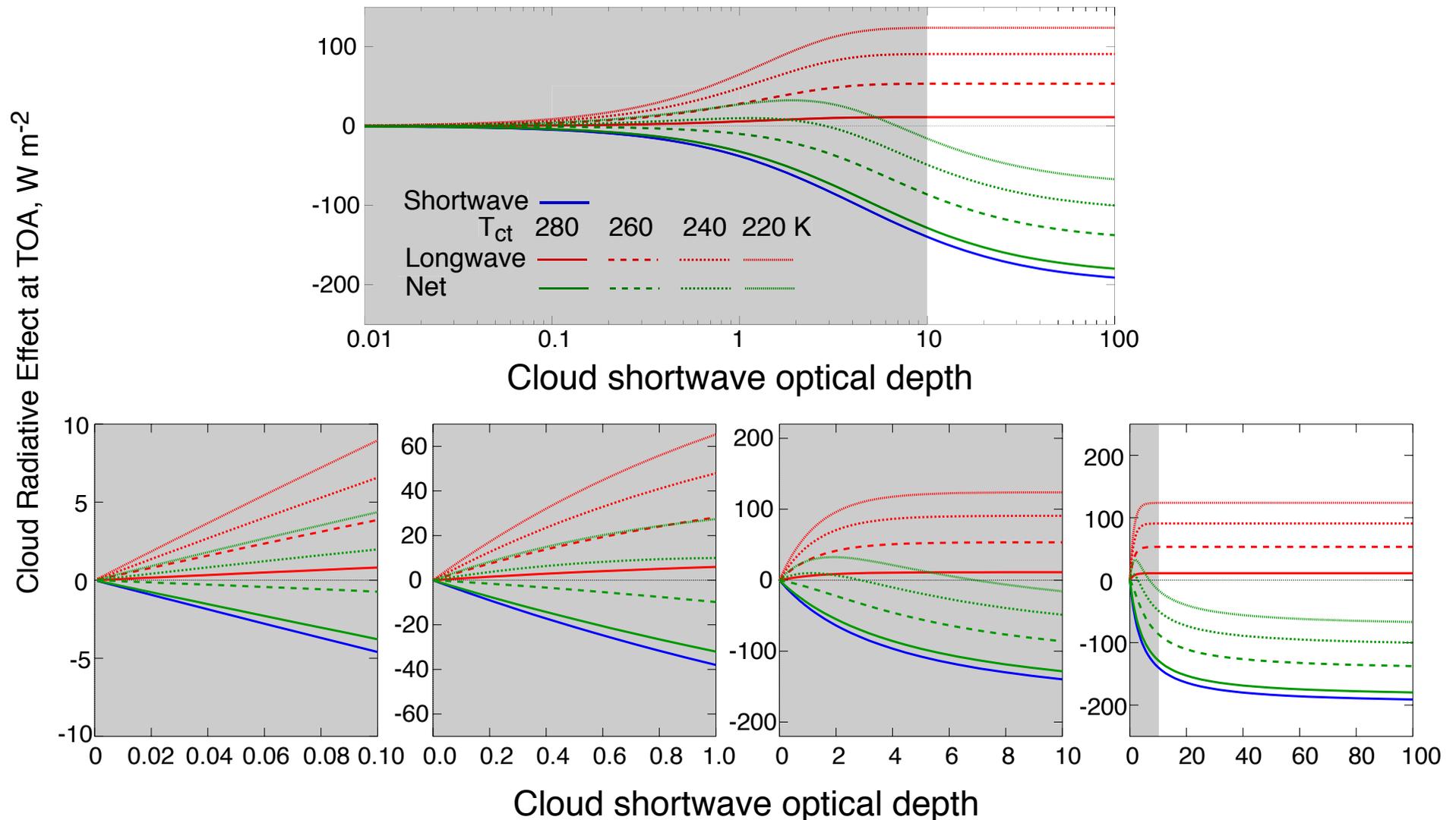
24-Hour average CRE, north central Oklahoma, at equinox



Longwave CRE also initially linear; saturates; depends on cloud-top temp.

# CLOUD RADIATIVE EFFECT

Dependence on shortwave optical depth and cloud-top temperature  
24-Hour average CRE, north central Oklahoma, at equinox



Net CRE depends on optical depth and cloud-top temperature *even in sign*.  
Knowledge of cloud fraction *tells you nothing* about the cloud radiative effect.

# A FOOL'S ERRAND

Threshold photometric determination of cloud fraction

Natural color photo



What is the cloud fraction?

# A FOOL'S ERRAND

## Threshold photometric determination of cloud fraction

Natural color photo

$\text{Red}/(\text{Red} + \text{Blue})$



Examine ratio  $\text{Red}/(\text{Red} + \text{Blue})$ , common cloud discrimination technique.

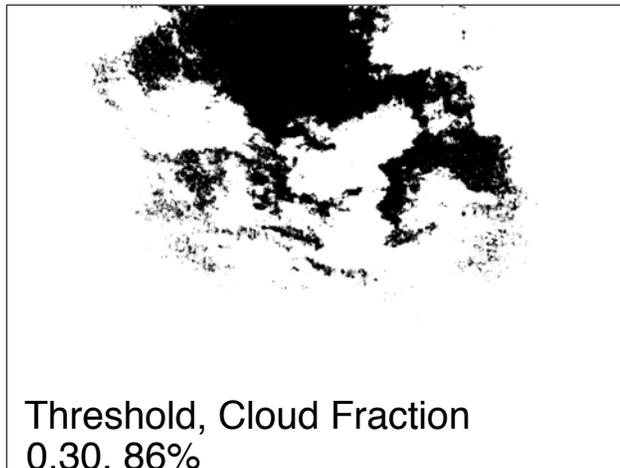
# A FOOL'S ERRAND

## Threshold photometric determination of cloud fraction

Natural color photo



Red/(Red + Blue)



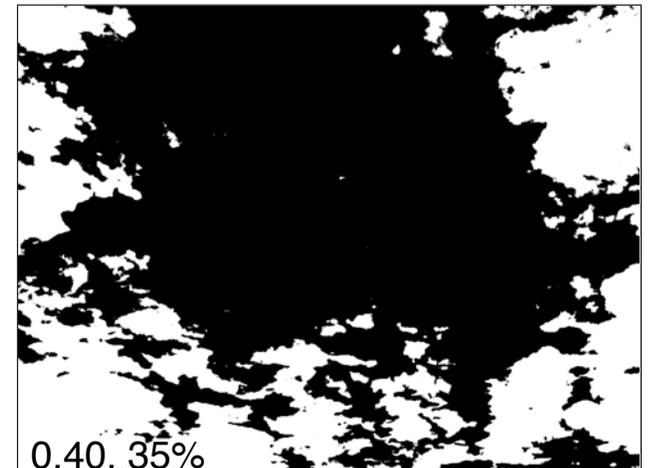
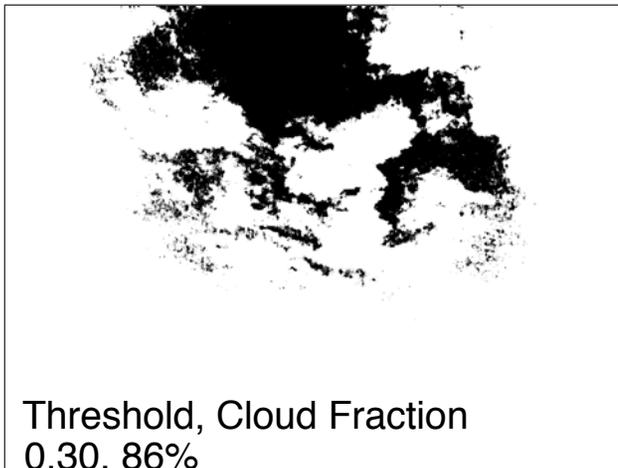
Apply cloud mask with threshold  $R/(R+B) \geq 0.30$ . Cloud fraction 86%.  
Threshold is too low.

# A FOOL'S ERRAND

## Threshold photometric determination of cloud fraction

Natural color photo

Red/(Red + Blue)



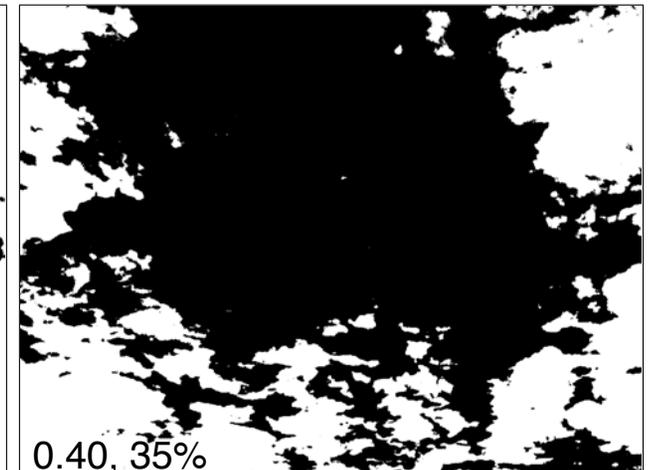
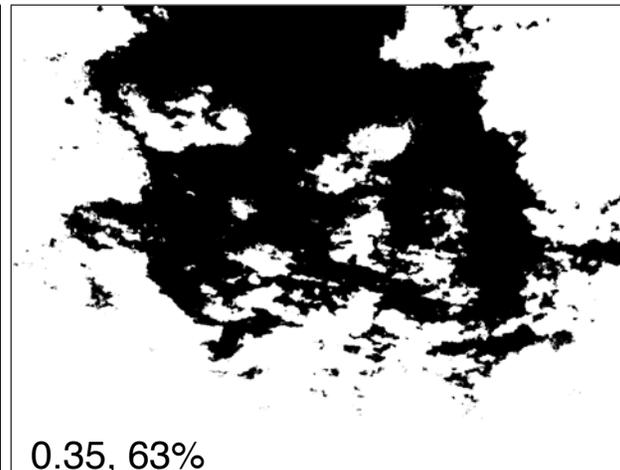
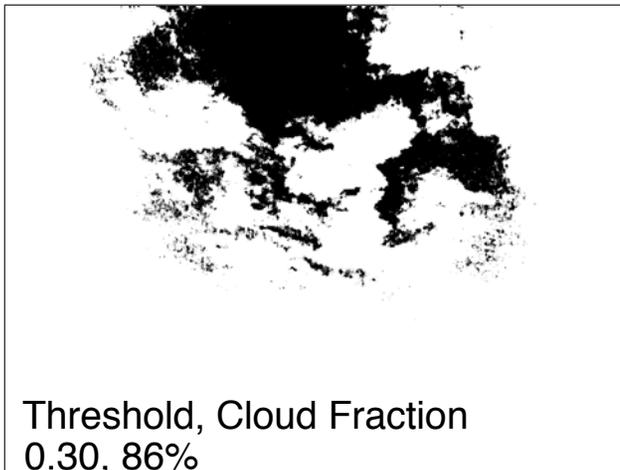
Try threshold 0.40. Cloud fraction is 35%.  
That threshold is too high.

# A FOOL'S ERRAND

## Threshold photometric determination of cloud fraction

Natural color photo

Red/(Red + Blue)



Try threshold 0.35. Cloud fraction is 63%.

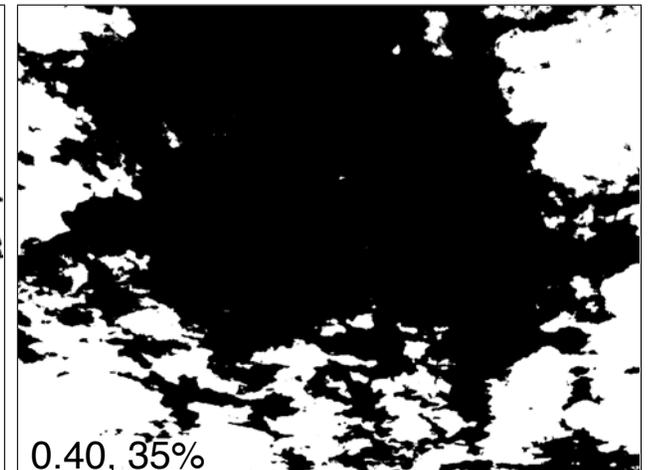
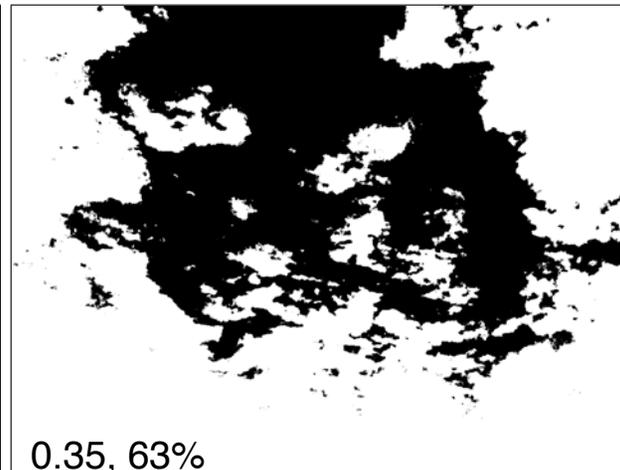
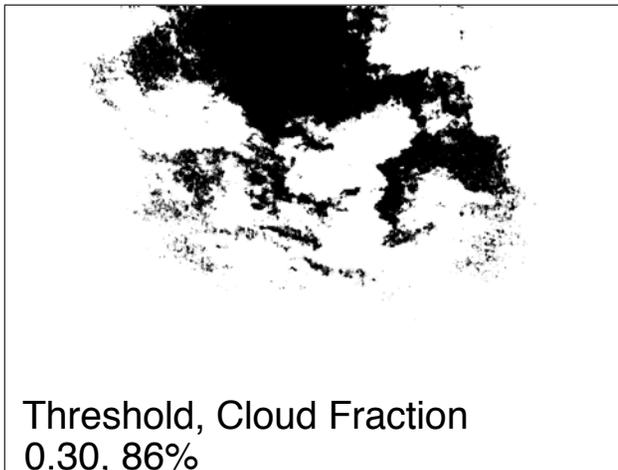
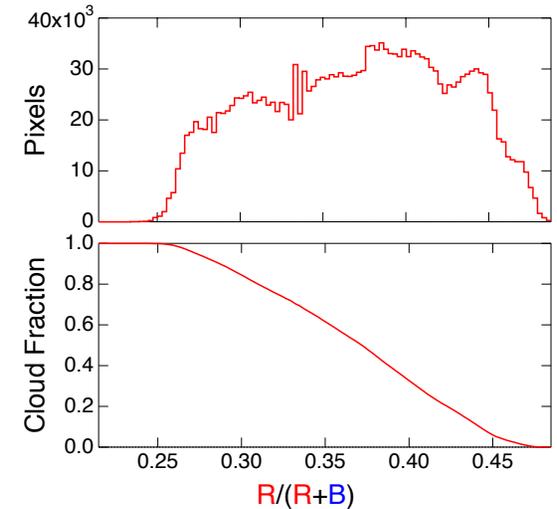
There is no “just right”. False positives and false negatives.

# A FOOL'S ERRAND

## Threshold photometric determination of cloud fraction

Natural color photo

Red/(Red + Blue)



Examination of cloud fraction as function of  $\text{Red}/(\text{Red} + \text{Blue})$  threshold. There is no unique threshold.

CLOUD FRACTION: CAN IT BE DEFINED  
AND MEASURED? AND IF WE KNEW IT  
WOULD IT BE OF ANY USE TO US?

## CONCLUSIONS

No!

No!

No!



*Cloud fraction is dead! Do not resuscitate.*