Spectrally-invariant properties of clouds in transition zones during MAGIC

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Motivations

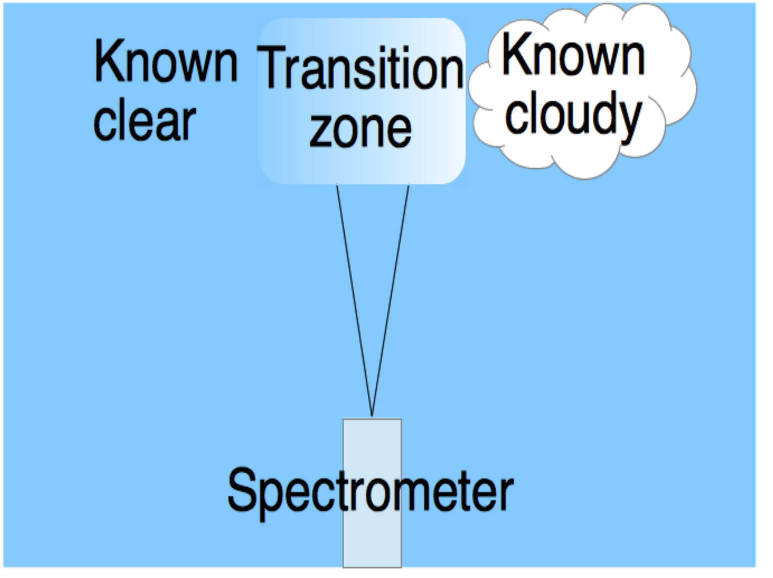
- MAGIC's time-resolved hyper-spectral measurements reveal more details of cloud types/structure as well as cloud aerosol interactions.

- Retrievals of cloud and aerosol properties depend on accuracy of radiance measurements. We want to know how effective it can be to use redundant hyper-spectrum radiation measurements from SSFR and SASze in studying the cloud properties near cloud edges.

Transition zone

- What is transition zone?

- Why it is important to study the cloud in transition zone?



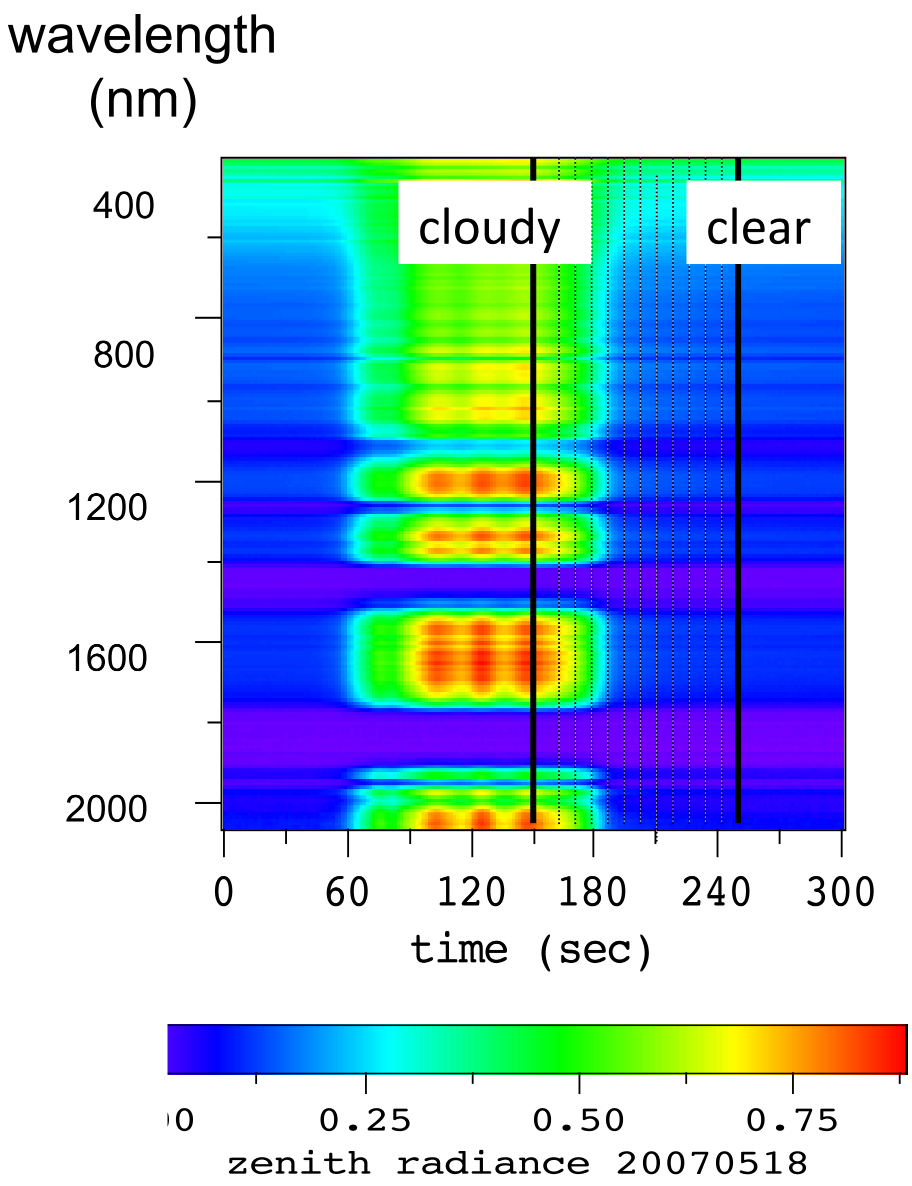
Intr. To Spectral invariance
(1) spectrum in the transition zone

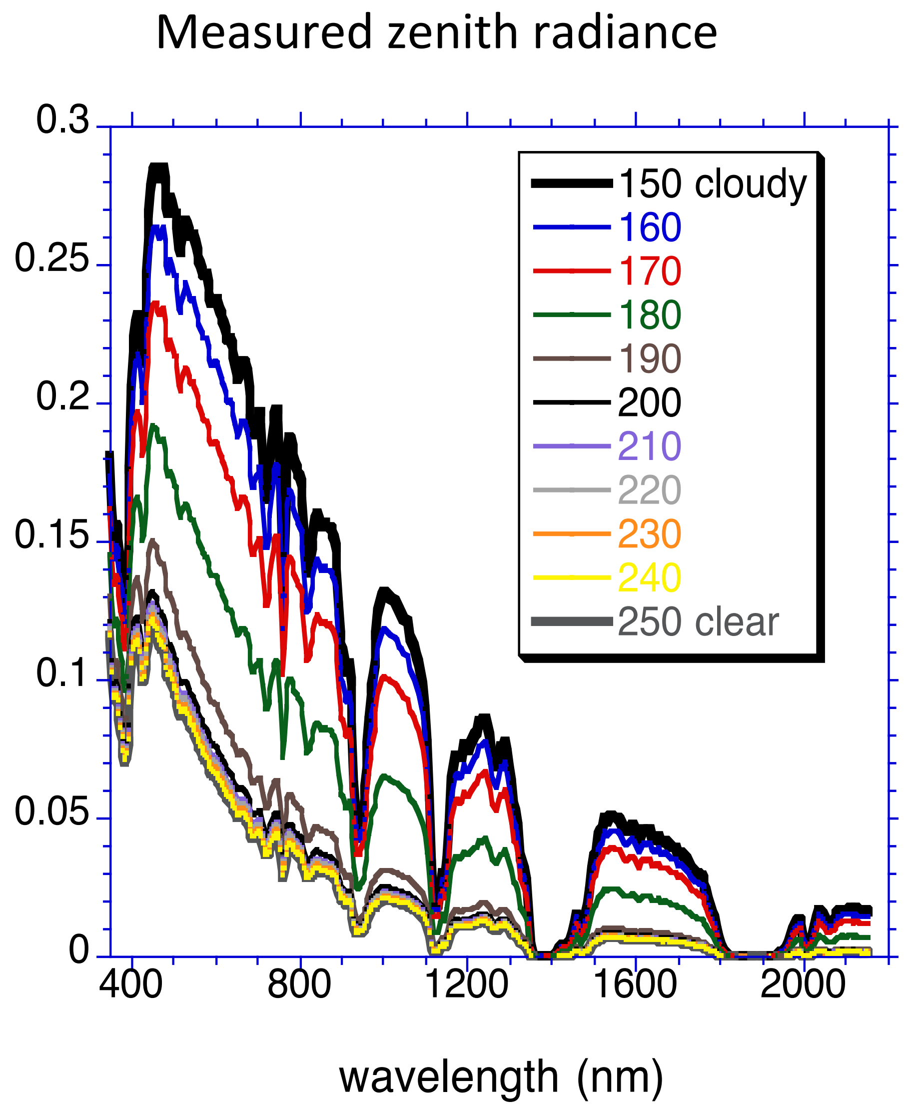
300 s of SWS data, 18 May 2007, SZA=45°

250 s; cloud base height = 2 km

circled cloud passed thru SWS field of view

SWS data, 18 May 2007, SZA=45°





Spectral-invariant hypothesis

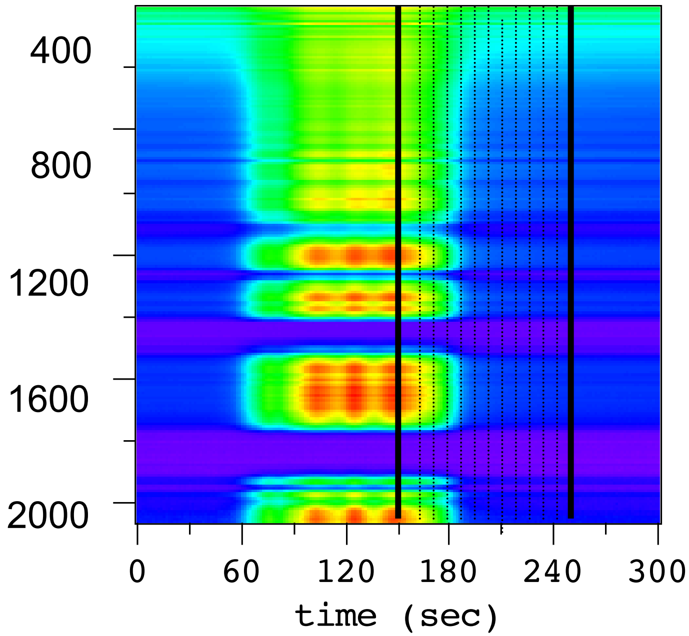
$$I_{transition}(\lambda) = aI_{cloudy}(\lambda) + bI_{clear}(\lambda)$$

$$\frac{I_{transition}(\lambda)}{I_{clear}(\lambda)} = a\frac{I_{cloudy}(\lambda)}{I_{clear}(\lambda)} + b$$

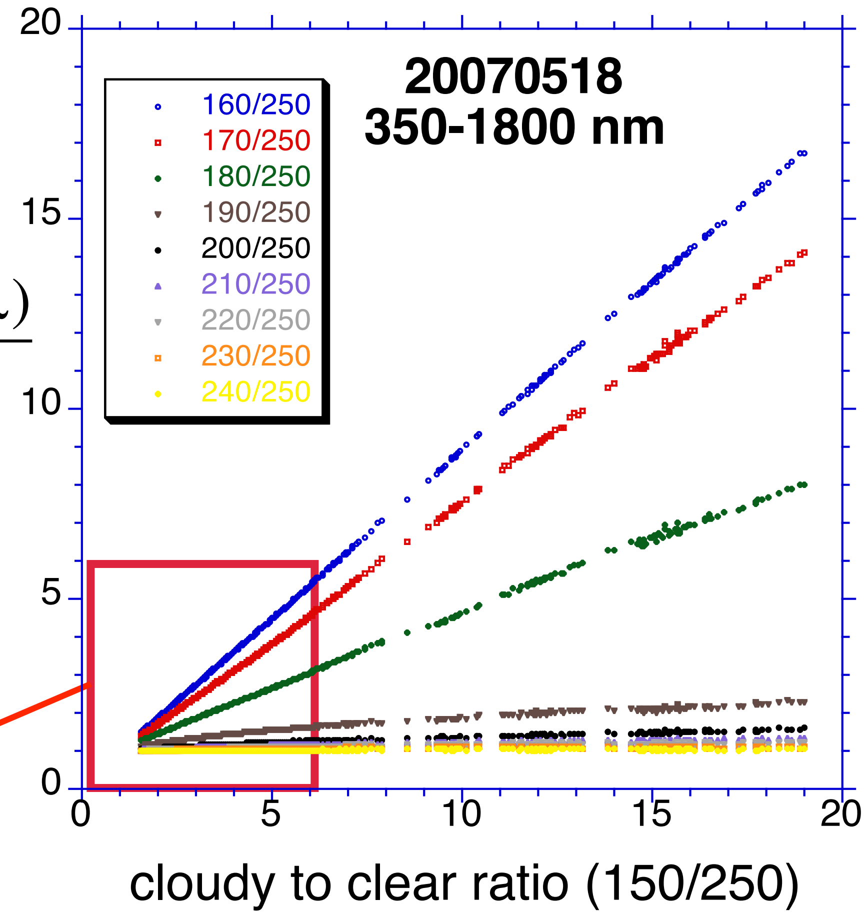
$$y(\lambda) = ax(\lambda) + b$$

e.g. A. Marshak et al, 2009, 2011; J.C. Chiu, et al, 2010.

Testing spectral-invariance hypothesis with SWS data

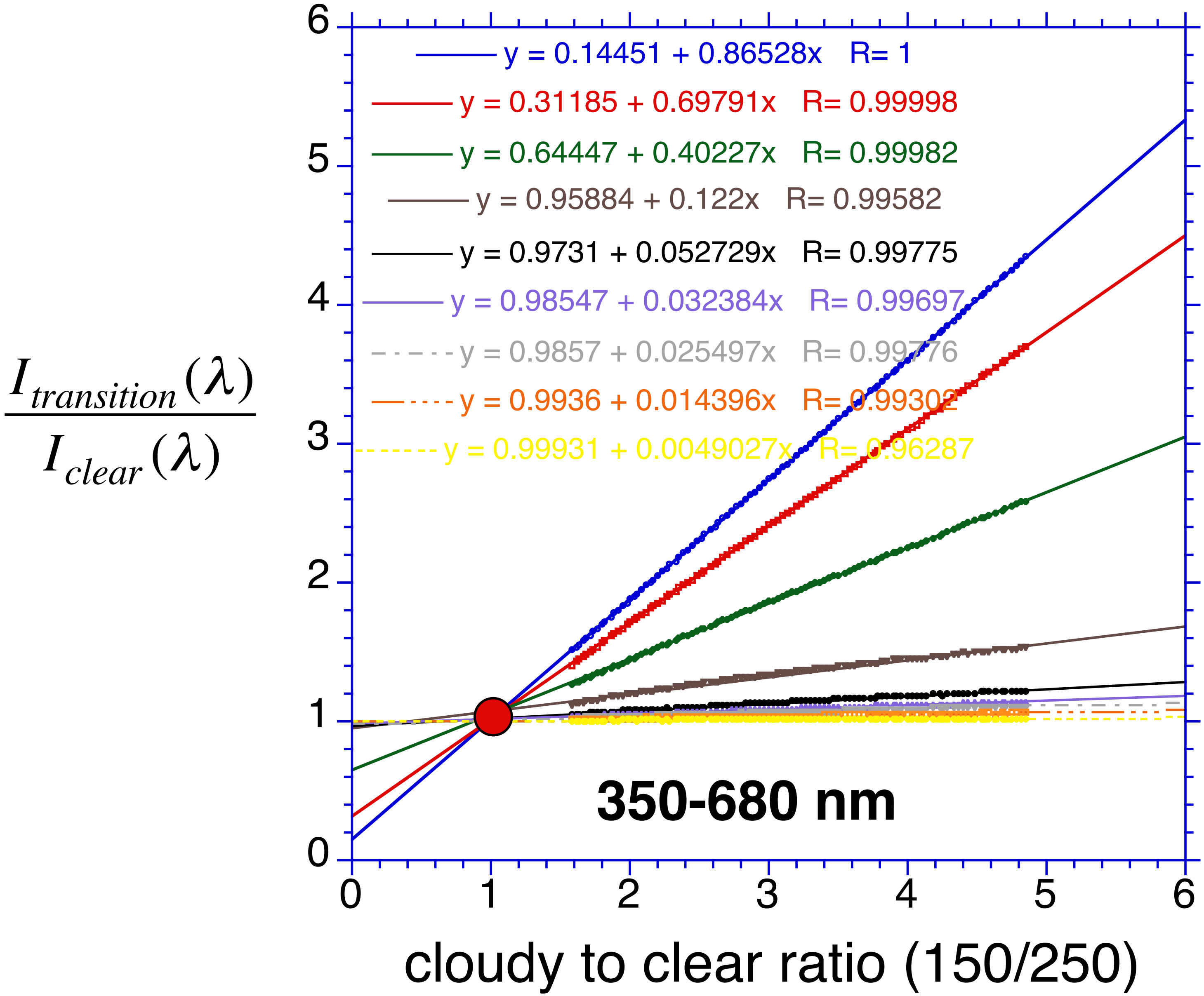


$$\frac{I_{transition}(\lambda)}{I_{clear}(\lambda)}$$



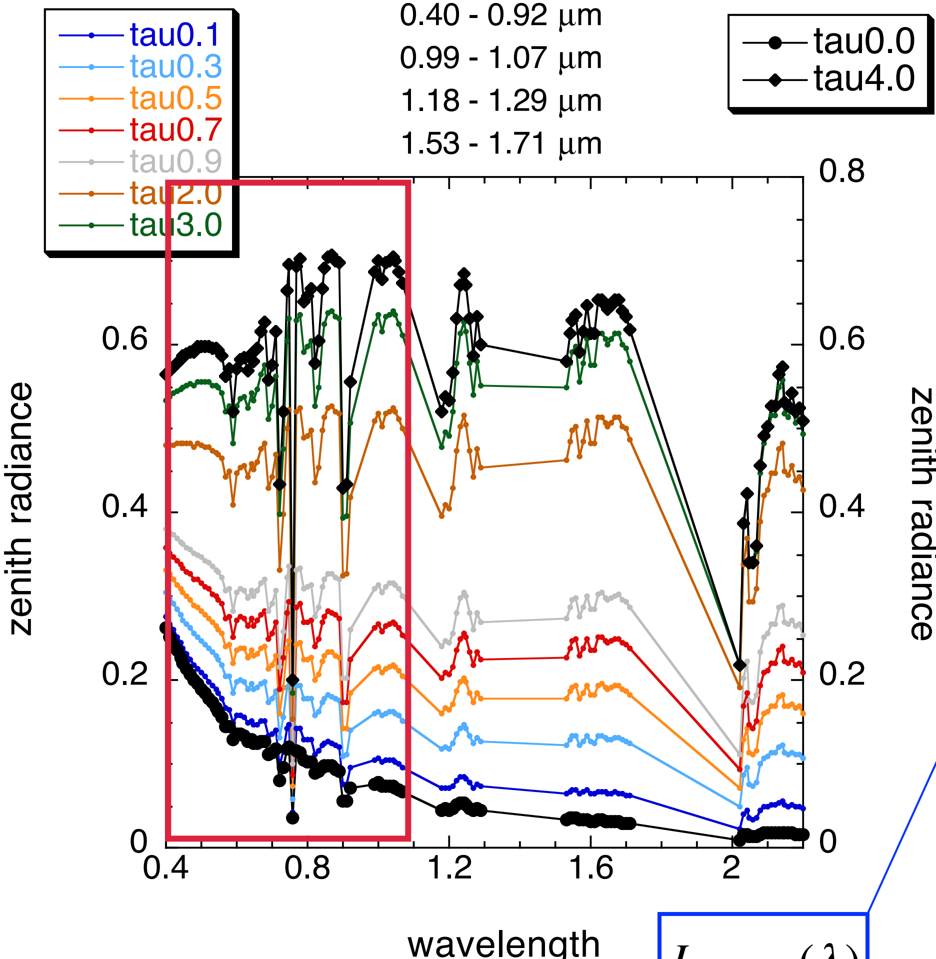
we zoom in on this region on next slide

$$\frac{I_{transition}(\lambda)}{I_{clear}(\lambda)} = a\frac{I_{cloudy}(\lambda)}{I_{clear}(\lambda)} + b$$

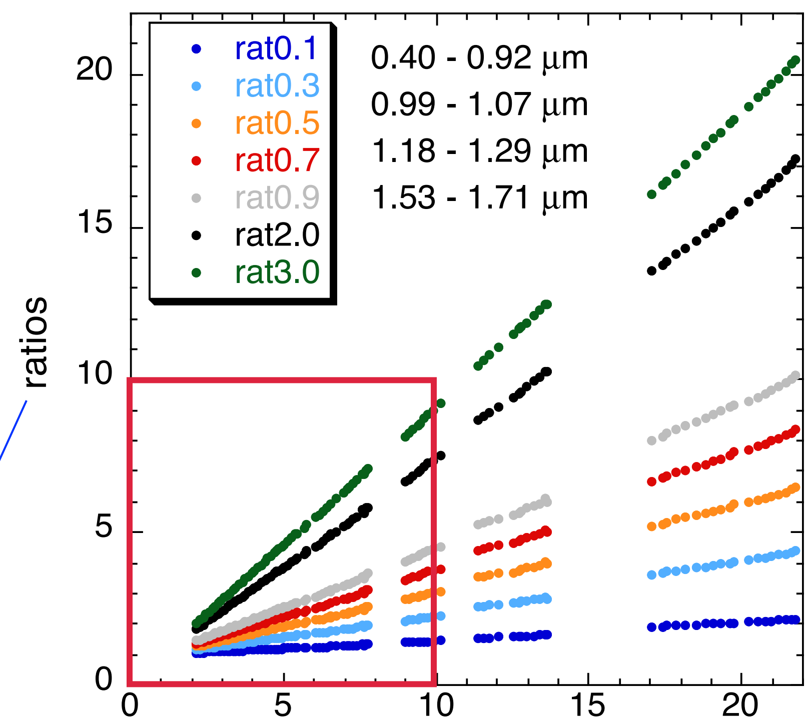


y = 0.14451 + 0.86528x R= 1
y = 0.31185 + 0.69791x R= 0.99998
y = 0.64447 + 0.40227x R= 0.99982
y = 0.95884 + 0.122x R= 0.99582
y = 0.9731 + 0.052729x R= 0.99775
y = 0.98547 + 0.032384x R= 0.99697
y = 0.9857 + 0.025497x R= 0.99776
y = 0.9936 + 0.014396x R= 0.99302
y = 0.99931 + 0.0049027x R= 0.96287
$\frac{I_{transition}(\lambda)}{I_{clear}(\lambda)}$
350-680 nm
cloudy to clear ratio (150/250)
0
1
2
3
4
5
6

Testing with SBDART model: spectra omitting absorption bands (l), spectral-invariant plot (r)

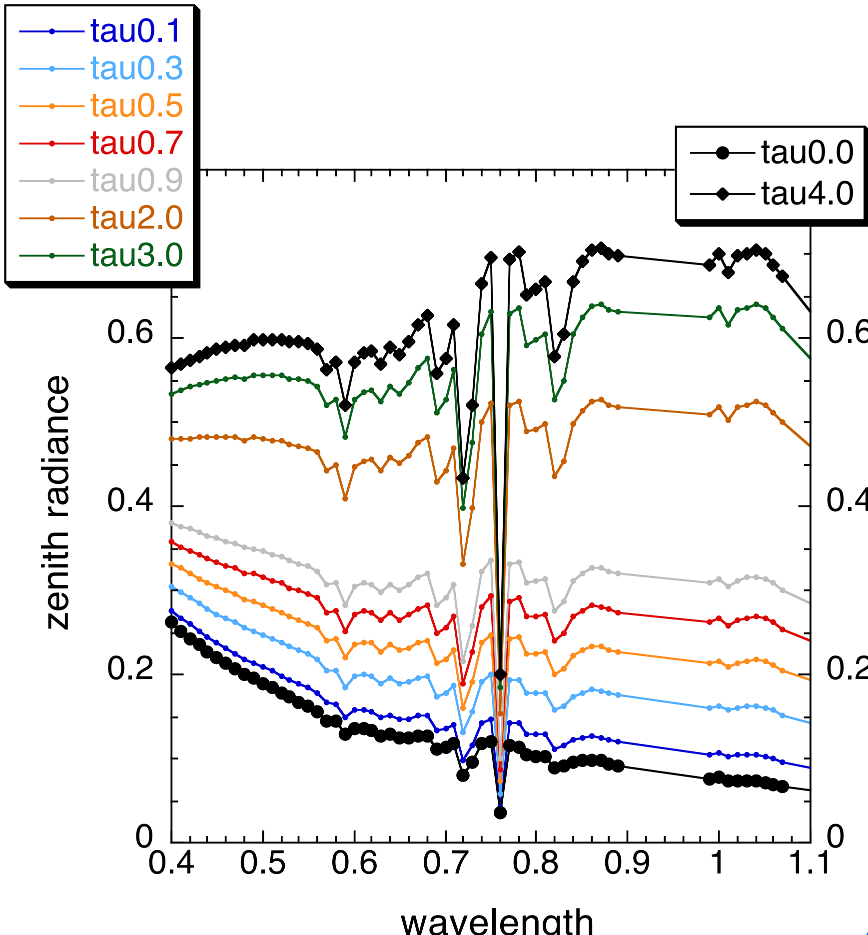


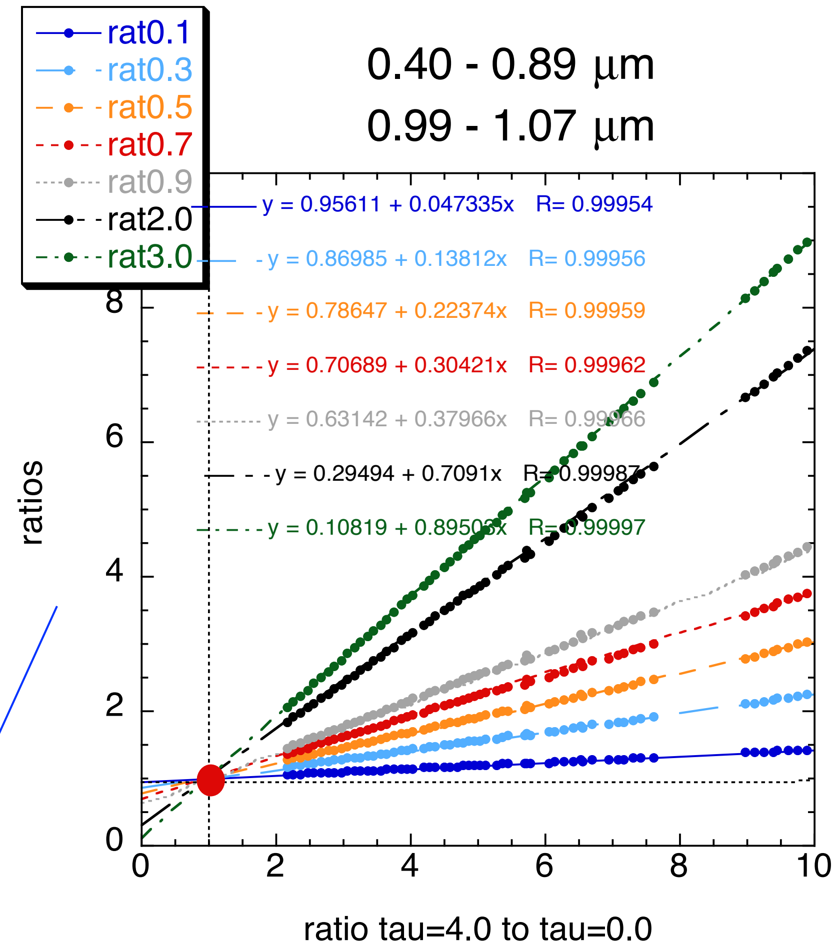
zooming in on red-box regions in next slide



ratio tau=4.0 to tau=0.0

$$\frac{I_{transition}(\lambda)}{I_{clear}(\lambda)} = a\frac{I_{cloudy}(\lambda)}{I_{clear}(\lambda)} + b$$





$$\frac{I_{transition}(\lambda)}{I_{clear}(\lambda)} = a\frac{I_{cloudy}(\lambda)}{I_{clear}(\lambda)} + b$$

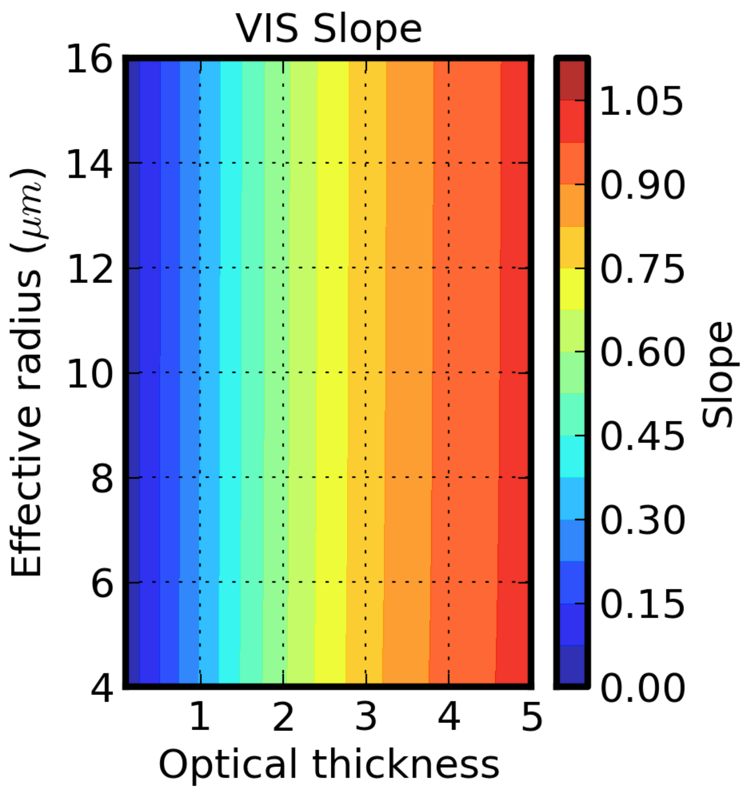
Intr. To Spectral invariance (2) applications

- How do we apply the discoveries to help us understand the cloud property in the transition zone.

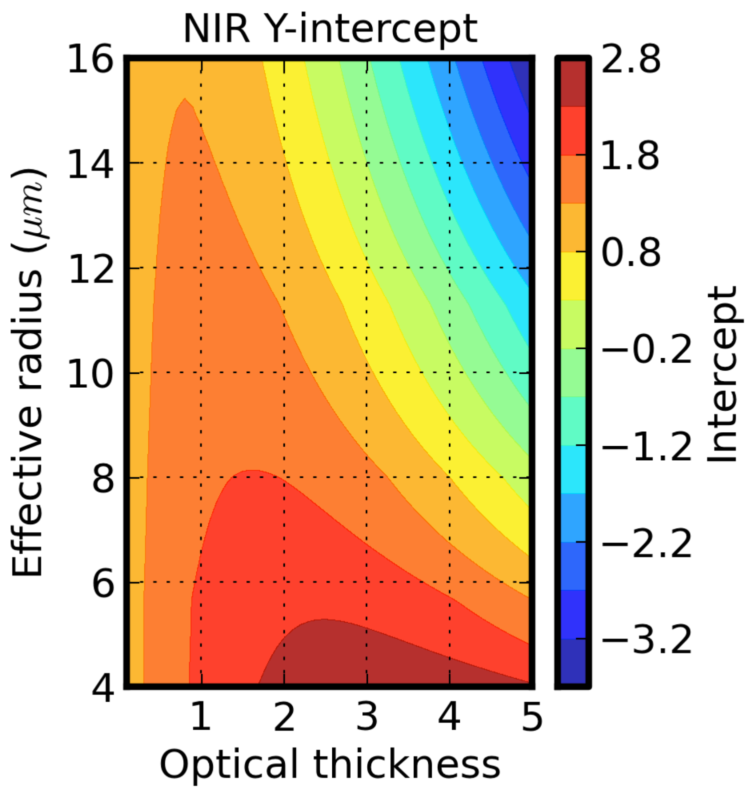
  – Observing the variations of the *a* and *b.*
  – NIR intercept are significantly affected by the effective radius of droplet.
  – VIS slopes are affected by the cloud optical depth.

Modeled slope and intercept

400 - 870 nm



1530 -1660 nm



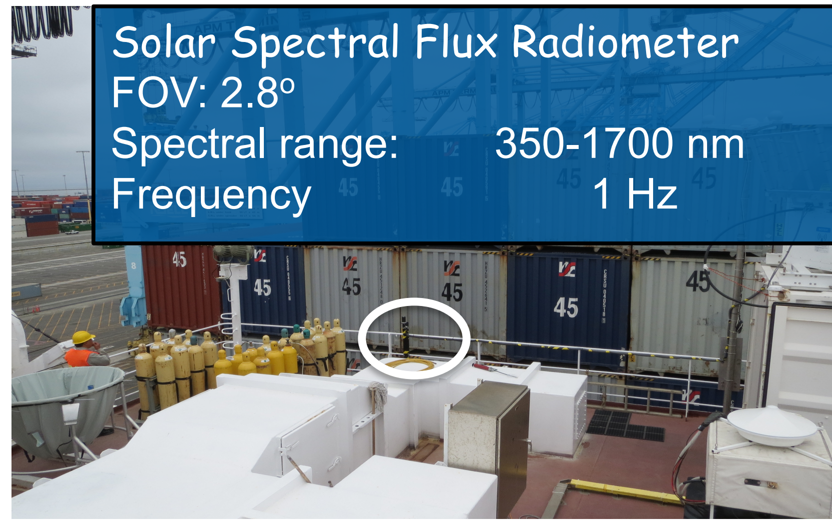
Radiation Instruments

Solar Array Spectrophotometer

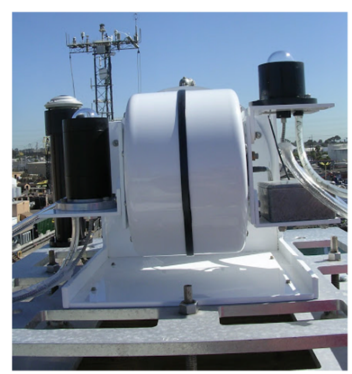
SAS-Ze

CIMEL Sunphotometer operated in cloud mode

CIMEL

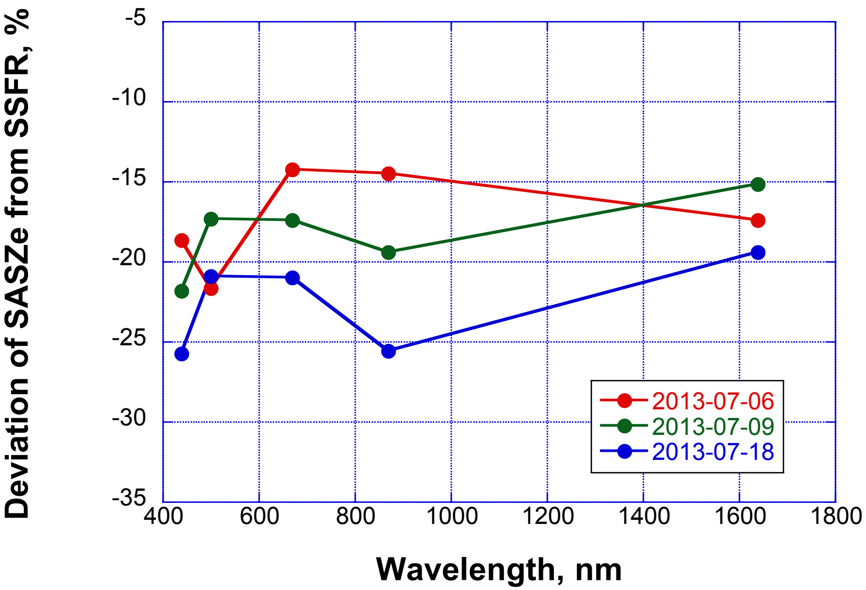


SSFR

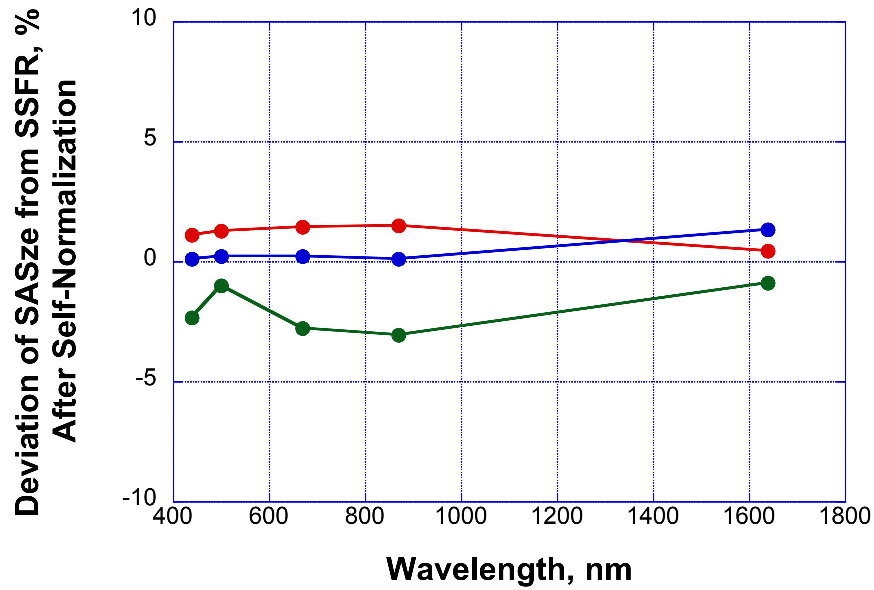


Same family (NASA Ames) as the Shortwave Spectradiometer (SWS) at SGP

The difference between the two hyper-spectrum instruments



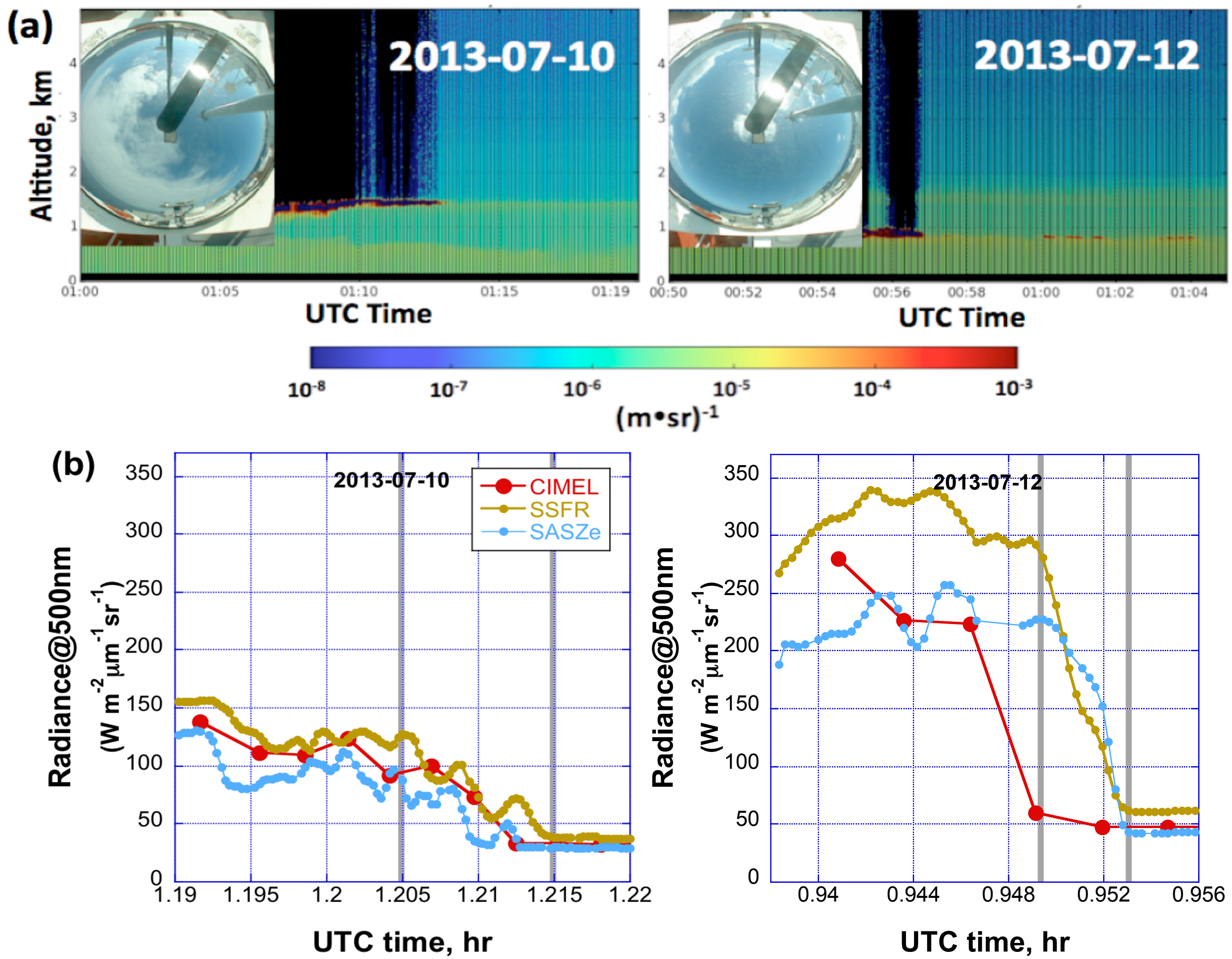
Before self-normalization



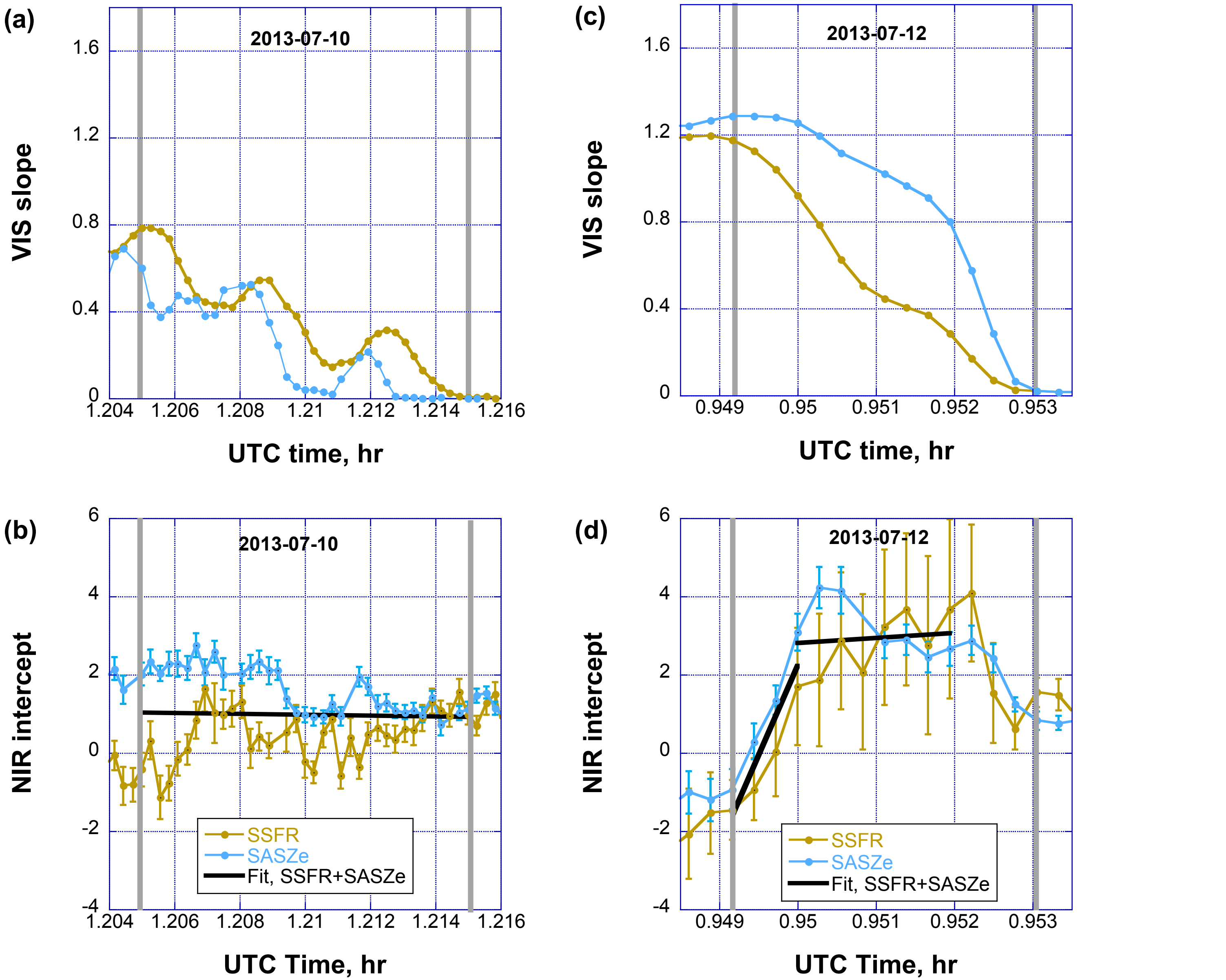
after self-normalization

$$I'(t, \lambda) = I(t,\lambda)/I(t_0,\lambda)$$

Two examples



The HSRL lidar profiles and TSI (Total Sky Imager) images during cloudy-to-clear sky transitions on 2013-07-10 (**Upper left**) and on 2013-07-12 (**Upper right**). (**a**) and (**b**) are zenith radiances @500nm from 3 instruments on 07-10 and 07-12, respectively.

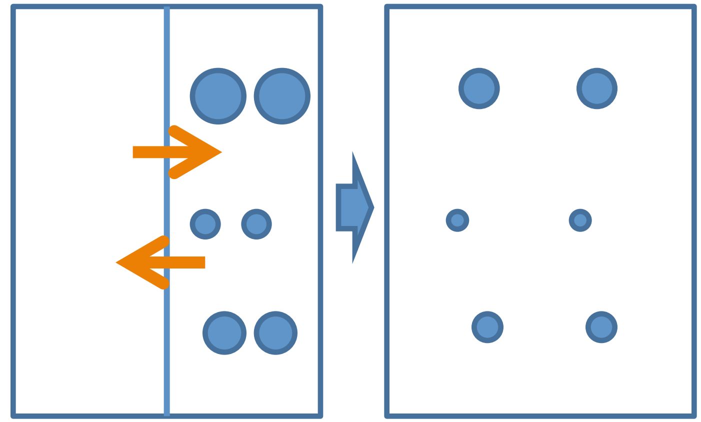


Time-series of slopes and intercepts calculated for both instruments. **Left Column**: case of 2013-07-10 . **Right Column**: case of 2013-07-12. (**a**) and (**c**) VIS slope. (**b**) and (**d**) NIR intercept.

Two limiting scenarios in cloud and air mixing:

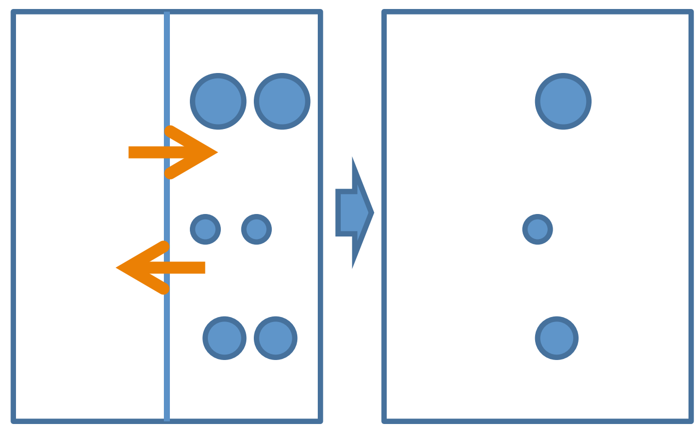
Homogeneous Mixing
Drier air penetrates the cloud before cloud drop evaporates.

Reduction in size of *all* droplets but no substantial change in the number of cloud droplets.



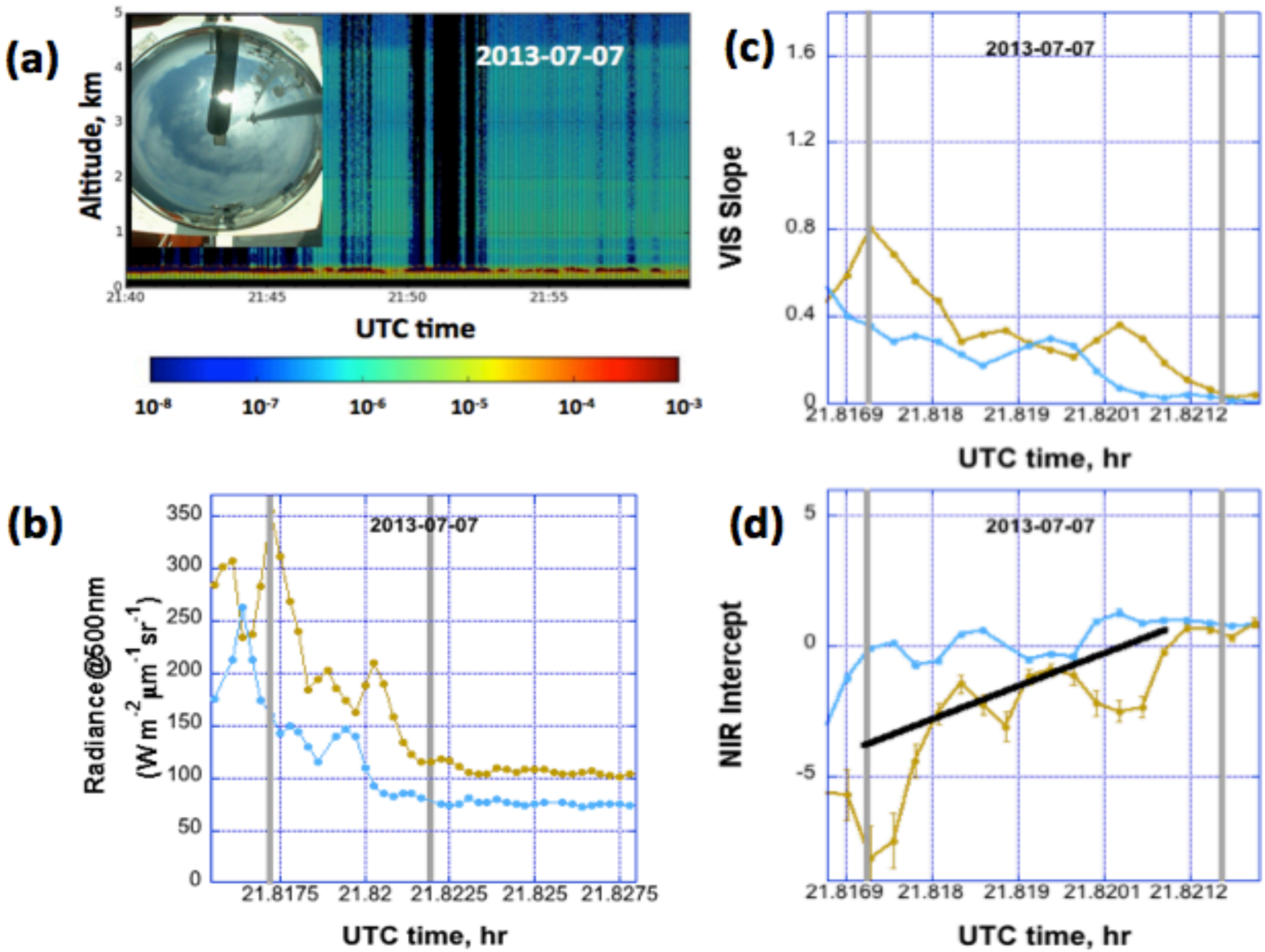
Inhomogeneous Mixing
Cloud drop evaporates before dry air penetrates the entirety of the cloud.

Reduction in the droplet number concentration for droplets of *all* sizes but no change in the cloud drop spectrum.



e.g. Baker et al. (1980); Baker and Latham (1982); Lehmann et al., (2009); Lu et al., (2013)

Another example



Case of 2013-07-07 with a transition time ~21:49:00. **(a)** is the HSRL lidar profiles and TSI (Total Sky Imager) images during cloudy-to-clear sky. (**b**) are zenith radiances @500nm from 2 instruments. **(c)** is the VIS slope. **(d)** is the NIR intercept.

Summary:

- In the spectral-invariant approx., the VIS slope is determined by cloud opt. depth, while the NIR intercept is negatively correlated with droplet sizes.
- In the cloud-to-clear transition zones, ~2/3 cases of NIR intercept do not change significantly near cloud edges.
- Results indicate that cloud-air mixing is predominantly inhomogeneous near cloud edges.
- The spectrally invariant method and the redundant hyper-spectrum measurements co-work effectively for providing cloud droplet size information in transition zone.