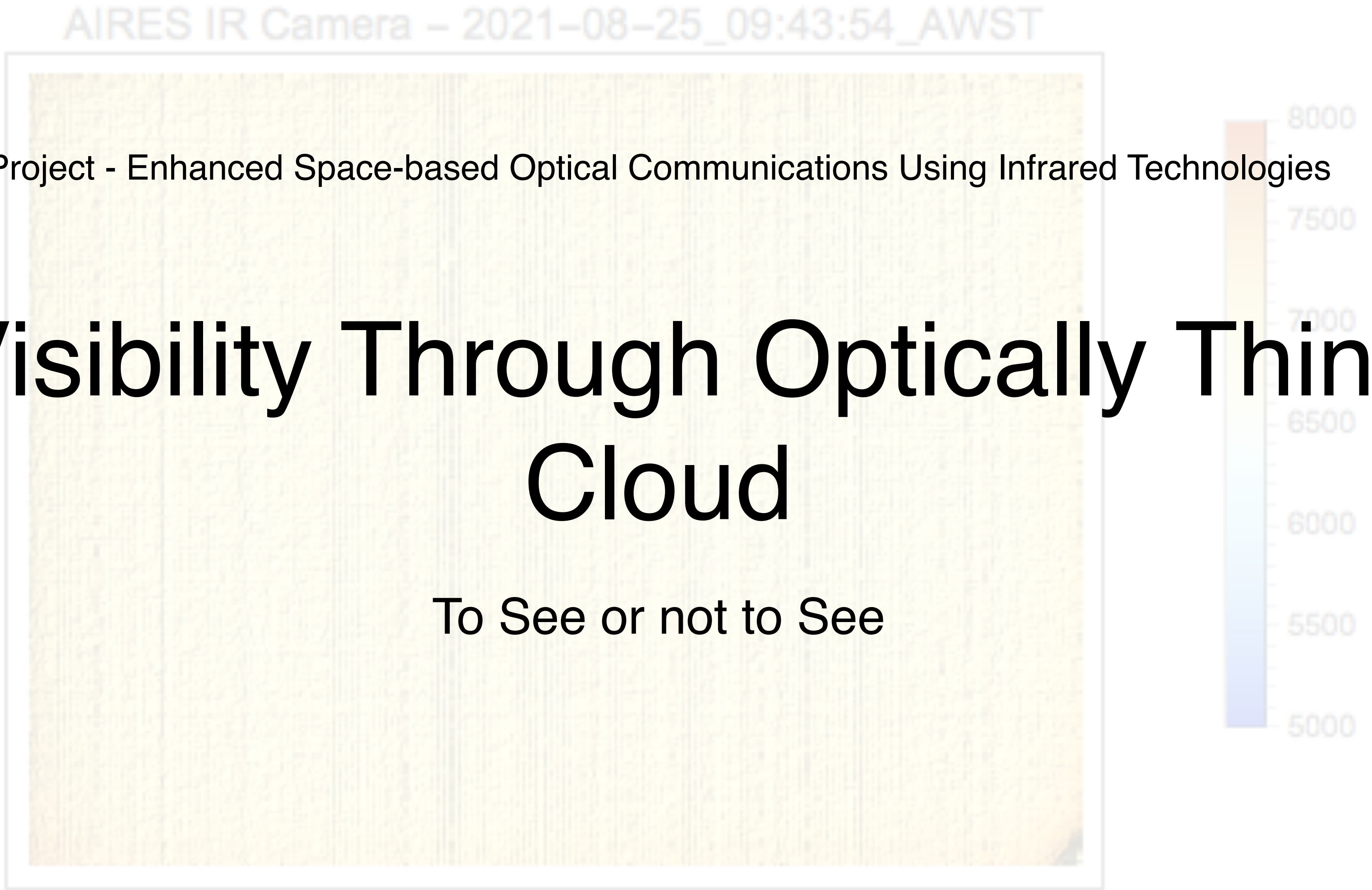
Project - Enhanced Space-based Optical Communications Using Infrared Technologies

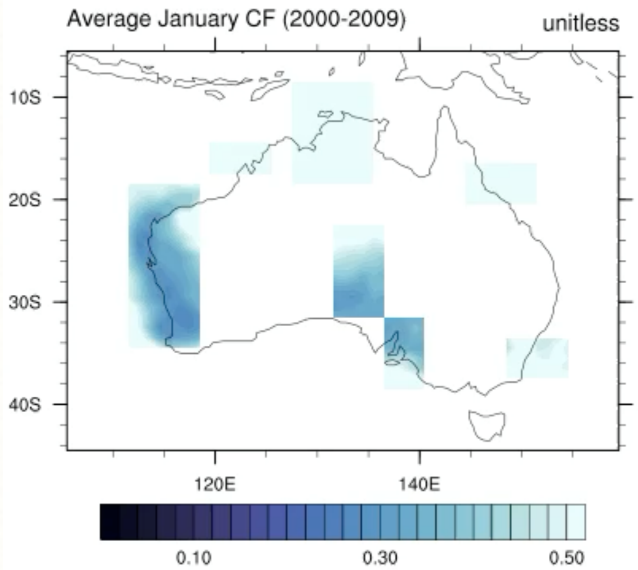
Visibility Through Optically Thin Cloud

To See or not to See



CLOUD COVER ANALYSIS
1979 - 2018

Subcontract Report to UWA



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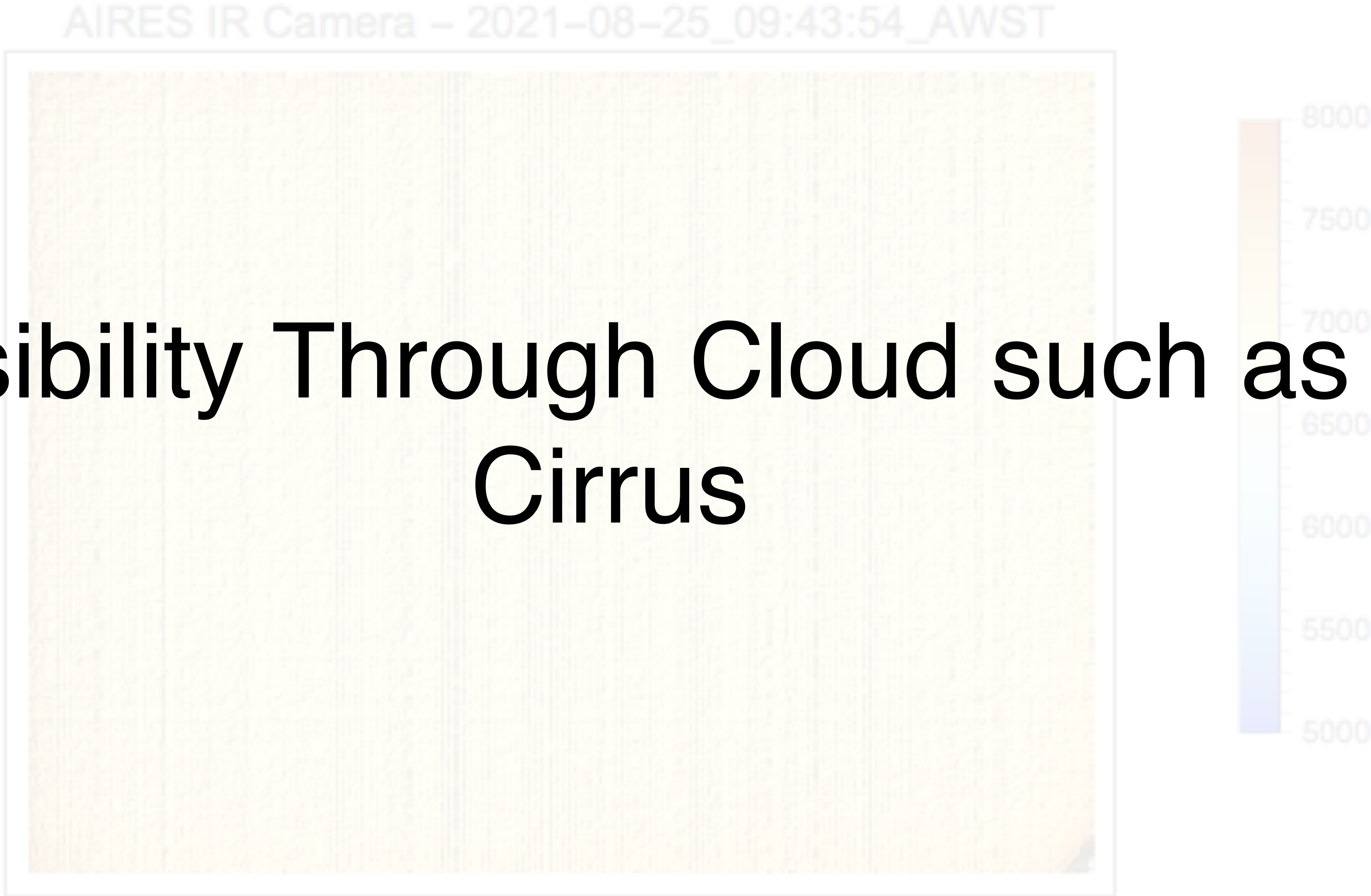
Visibility Through Cloud such as Cirrus



Cloud optical depth measured with ground-based, uncooled infrared imagers

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ABSTRACT

Recent advances in uncooled, low-cost, long-wave infrared imagers provide excellent opportunities for remotely deployed ground-based remote sensing systems. However, the use of these imagers in demanding atmospheric sensing applications requires that careful attention be paid to characterizing and calibrating the system. We have developed and are using several versions of the ground-based "Infrared Cloud Imager (ICI)" instrument to measure spatial and temporal statistics of clouds and cloud optical depth or attenuation for both climate research and Earth-space optical communications path characterization. In this paper we summarize the ICI instruments and calibration methodology, then show ICI-derived cloud optical depths that are validated using a dual-polarization cloud lidar system for thin clouds (optical depth of approximately 4 or less).

Keywords: cloud optical depth, infrared imaging, remote sensing

AIRES IR and Optical Camera

Beer's Law

With respect to the atmosphere

$$I = I_0 e^{-m\tau}$$

Atmospheric optical depth - natural log of the ratio of incident to transmitted light

Direct solar irradiance (Wm^{-2}) measured at the surface

Solar irradiance (Wm^{-2}) at the top of the atmosphere

Geometrical factor that allows for the slant line-of-sight through the atmosphere

[from Shaw et. al.]

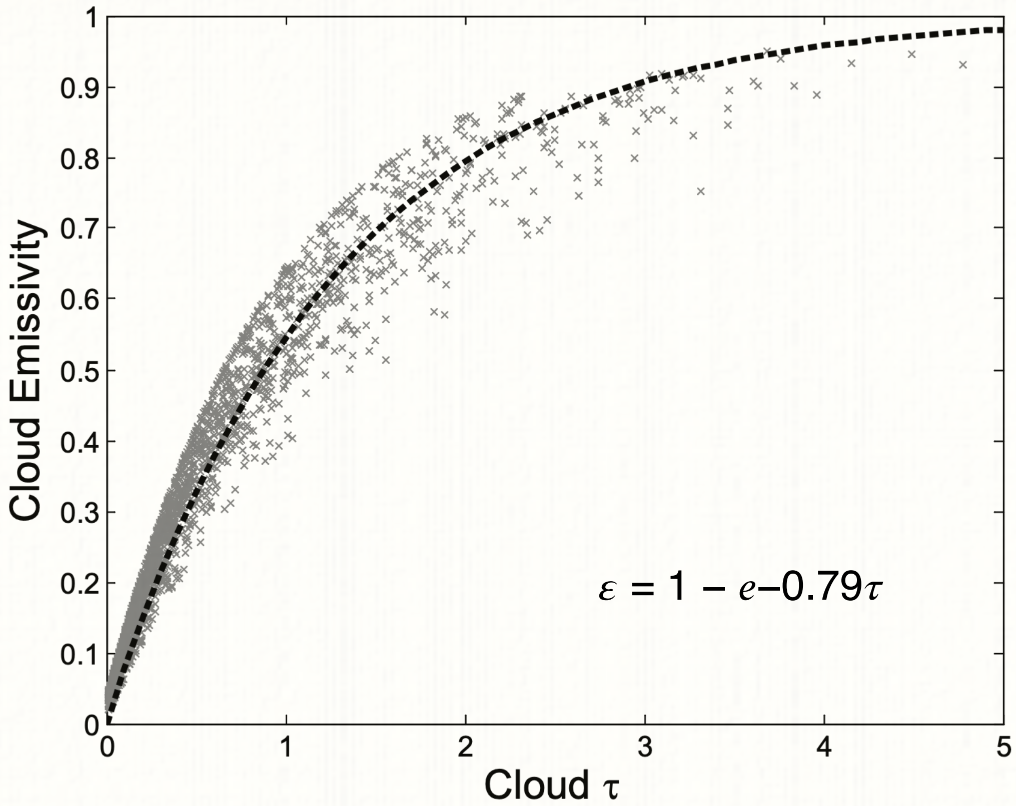
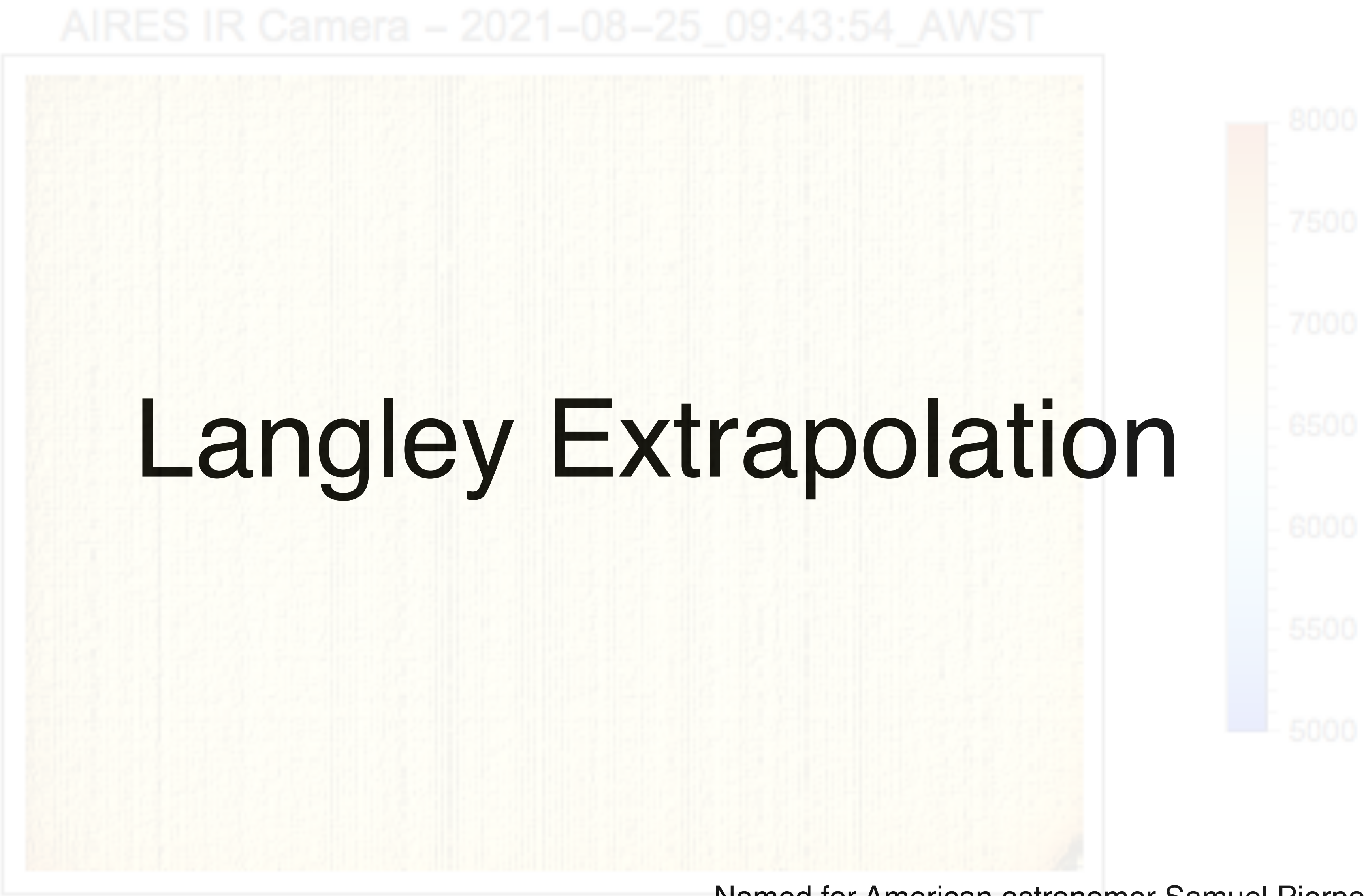


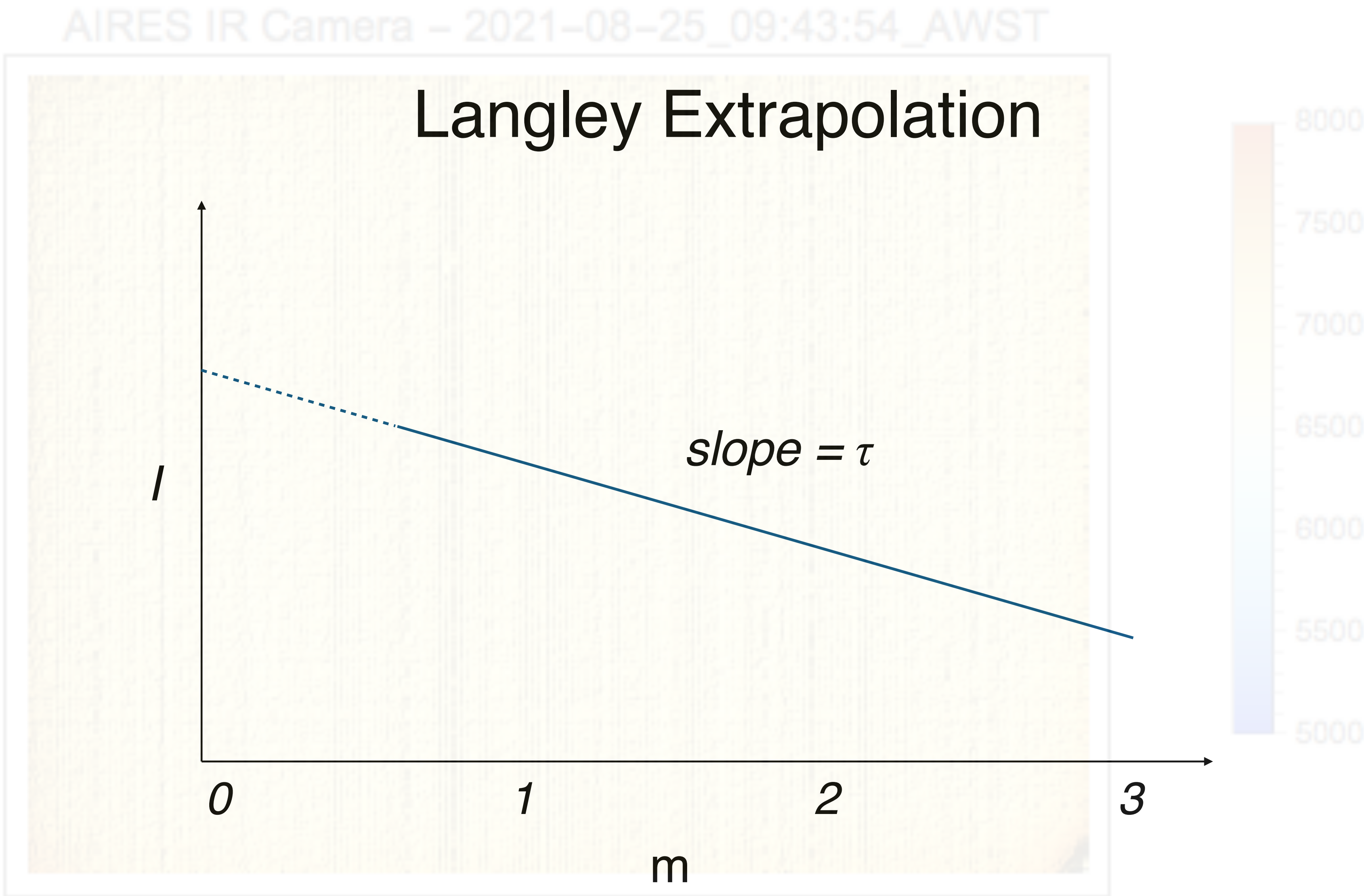
Figure 2. Relationship between infrared cloud emissivity and visible cloud optical depth (τ), with the dashed line representing eq. (1) and the × symbols representing lidar measurements of visible cloud optical depth at the ARM SGP site.

Langley Extrapolation



Named for American astronomer Samuel Pierpont Langley

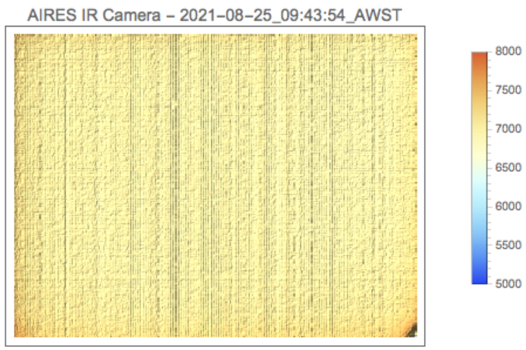
Langley Extrapolation



Our Studies - Radiative Transfer for Clear Sky and Cloudy Sky

Resources:

- Aires Infrared/visible camera built by collaborator Dr Fred Prata.
- Radiosonde data captured at Perth airport giving atmospheric pressure, temperature and humidity data.
- Himawari 8 meteorological satellite.
- Hyperspectral radiometer.
- Other sources and databases.

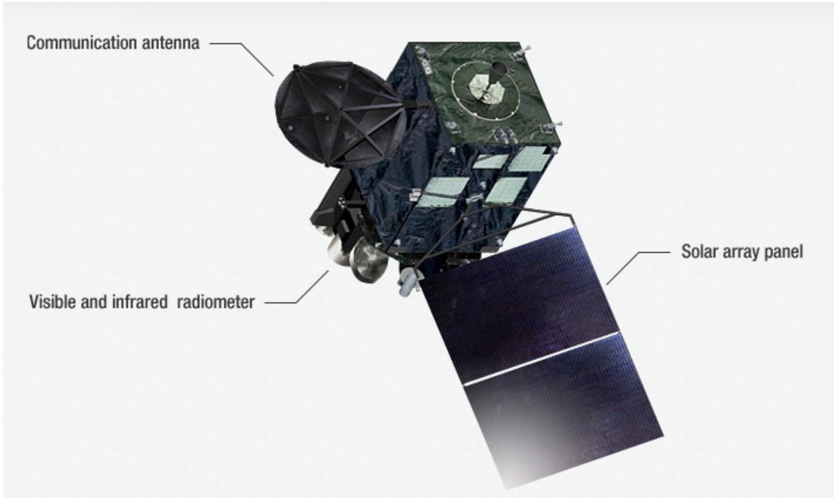


- Looking up

Radiosonde data

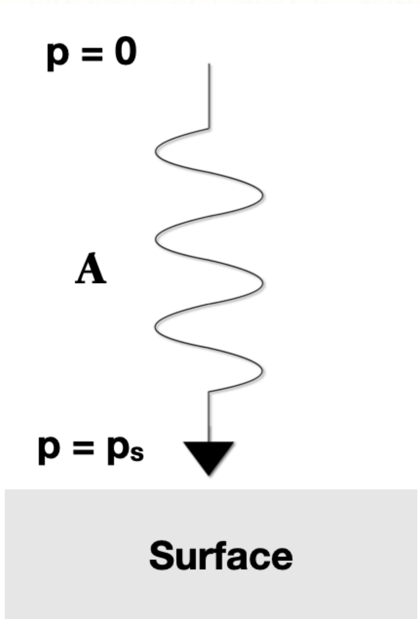
PRES	HGHT	TEMP	DWPT	RELH	MIXR	DRCT	SKNT	THTA	THTE	THTV
hPa	m	C	C	%	g/kg	deg	knot	K	K	K
1025.0	20	11.8	3.8	58	4.93	65	15	282.9	296.9	283.8
1019.0	69	12.0	3.4	56	4.83	75	18	283.7	297.4	284.5
1015.0	102	12.2	3.2	54	4.77	72	21	284.1	297.7	285.0
1011.0	134	13.8	0.8	41	4.03	69	23	286.1	297.7	286.8

- Immersed in the atmosphere



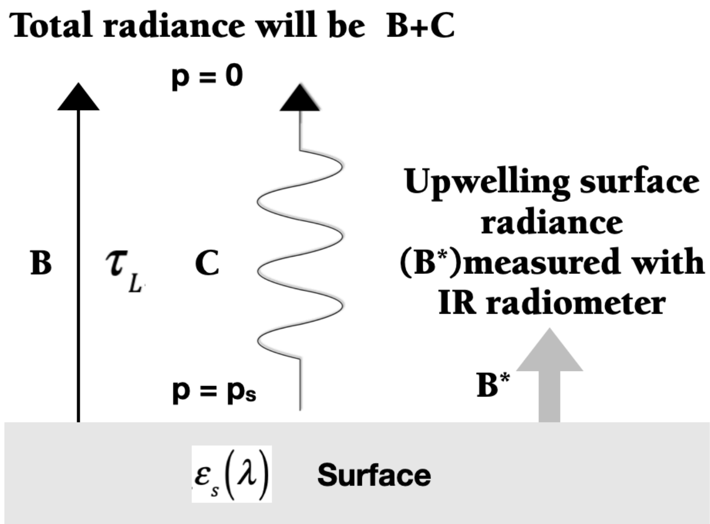
- Looking down

Our Studies - Radiative Transfer for Clear Sky and Cloudy Sky



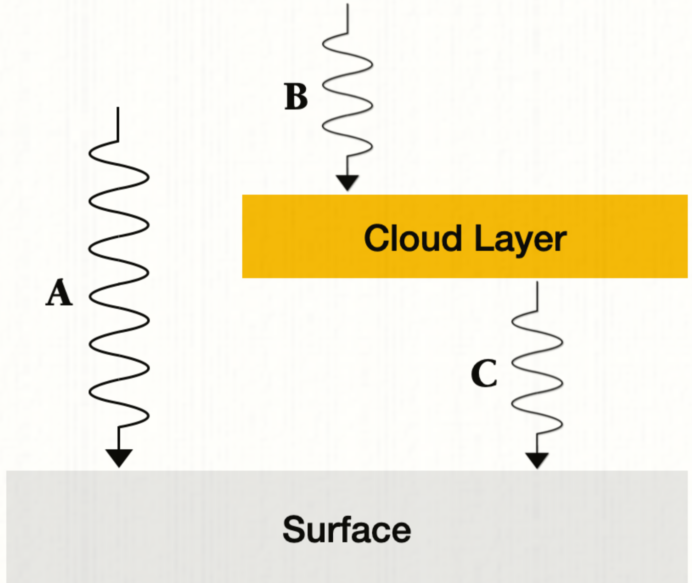
The downwelling atmospheric radiance may be measured with an upward viewing radiometer. $B\lambda(Tp)$ is the Planck function for temperature T at pressure level p for wavelength λ.

Our Studies - Radiative Transfer for Clear Sky and Cloudy Sky



The 3 components of the atmospheric radiative transfer that relate to a cloud / no-cloud situation. Term A represents the clear sky column downwelling radiance. Terms **B** and **C** represent radiances associated with a cloudy sky. **B** corresponds to the atmospheric downwelling radiance from the top of atmosphere down to the top of the cloud. **C** represents the downwelling radiance from the atmospheric column at the cloud base down to the surface.

Our Studies - Radiative Transfer for Clear Sky and Cloudy Sky



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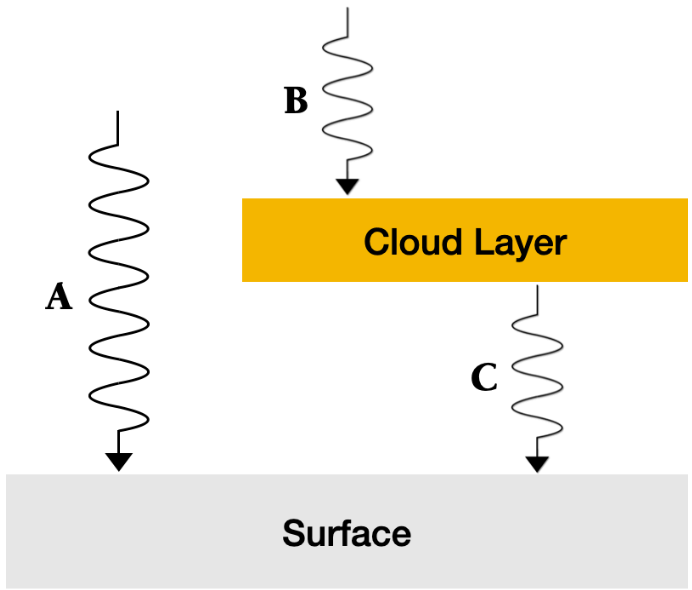


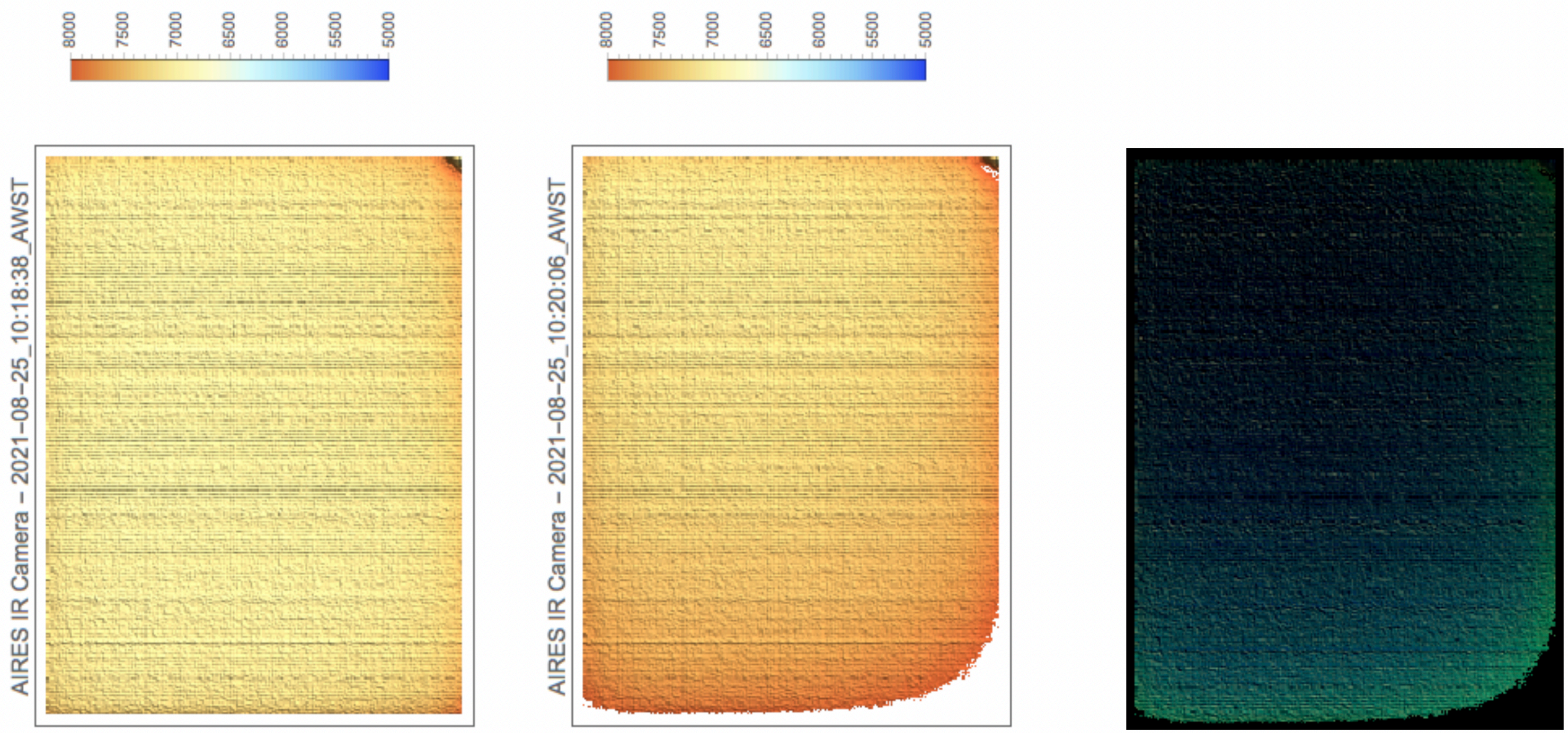
If the cloud is very a thin cloud we make the assumption that:

Radiance A = Radiance B + Radiance C.

Hence,

Radiance C = Radiance A – Radiance B

Our Studies - Radiative Transfer for Clear Sky and Cloudy Sky



Sky temperature looking vertically (image 1), at 60° elevation (image 2) and the difference of the two (image 3).