Global Observations of the Limb and Disk (GOLD): Temperature Measurements

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Abstract

The Global-scale Observations of the Limb and Disk (GOLD) mission of opportunity is an ultraviolet imaging spectrograph that will fly on a geostationary satellite to measure densities and temperatures in the thermosphere and ionosphere. From this vantage point, GOLD will observe emissions from an entire hemisphere (disk) and the horizon (limb) of the Earth. Atmospheric temperatures can be determined from both. Such temperature measurements are essential to answering a vital science question: What is the response of the thermosphere to geomagnetic and solar forcing? The altitude profile of the N_2 LBH emission on the Earth's limb will be used to determine the temperature of the atmosphere in the 150 to 300 km range using the scale height of the emission. The GOLD instrument is designed to make this measurement with an altitude resolution of 30 km. Given the sensitivity of the instrument and observations at tangent altitudes of 150-300 km are adequate to deduce the exospheric temperature with an accuracy of ±50 K. The measurement sequence allows limb profiles to be made every hour over the latitude range from 45S to 45N. On the disk temperatures near 150 km (±30 km) are measured using high spectral resolution observations of the N_2 emissions. Previous work with data from the ARGOS satellite and modeling of the observations from GOLD indicate the temperatures on the disk can be determined to ±30 K (±15 K) on time scales of ½ half (two) hour(s). Thus, GOLD provides adequate temporal and spatial resolution to answer one of the most important science questions regarding the space environment.

Summary

GOLD will measure temperatures on the disk using the high resolution channel and the temperature dependence of the LBH bands. Simulations show that the disk temperatures will be retrieved with an uncertainty between 6 and 13 K, depending upon location and local time.

Temperature profiles on the Earth's limb will also be measured by GOLD using the low resolution channel. The integrated LBH band system will provide the exospheric temperature to an accuracy of ±30 K on the daytime limb.

GOLD will provide many other measurements important for Space Weather and Forecasting. See the poster by R. Eastes in this session for details.

GOLD Investigation Goals

Answer the central question of the NASA Living with a Star Program: What is the global-scale response of the thermosphere and ionosphere to forcing in the integrated Sun-Earth system?

GOLD science questions have direct correspondence to LWS/Geospace objectives

GOLD Science Questions

1. What is the global-scale response of the thermosphere and ionosphere to geomagnetic forcing?
2. What is the global-scale response of the thermosphere and ionosphere to changing EUV radiation?
3. What are the solar & geospace causes of small-scale ionospheric density irregularities?
4. What are the global-scale tidal amplitude and phase variations?

LWS/Geospace General Objectives

A. Determine the effects of solar and geospace variability on the atmosphere enabling an improved specification of the neutral density in the thermosphere.

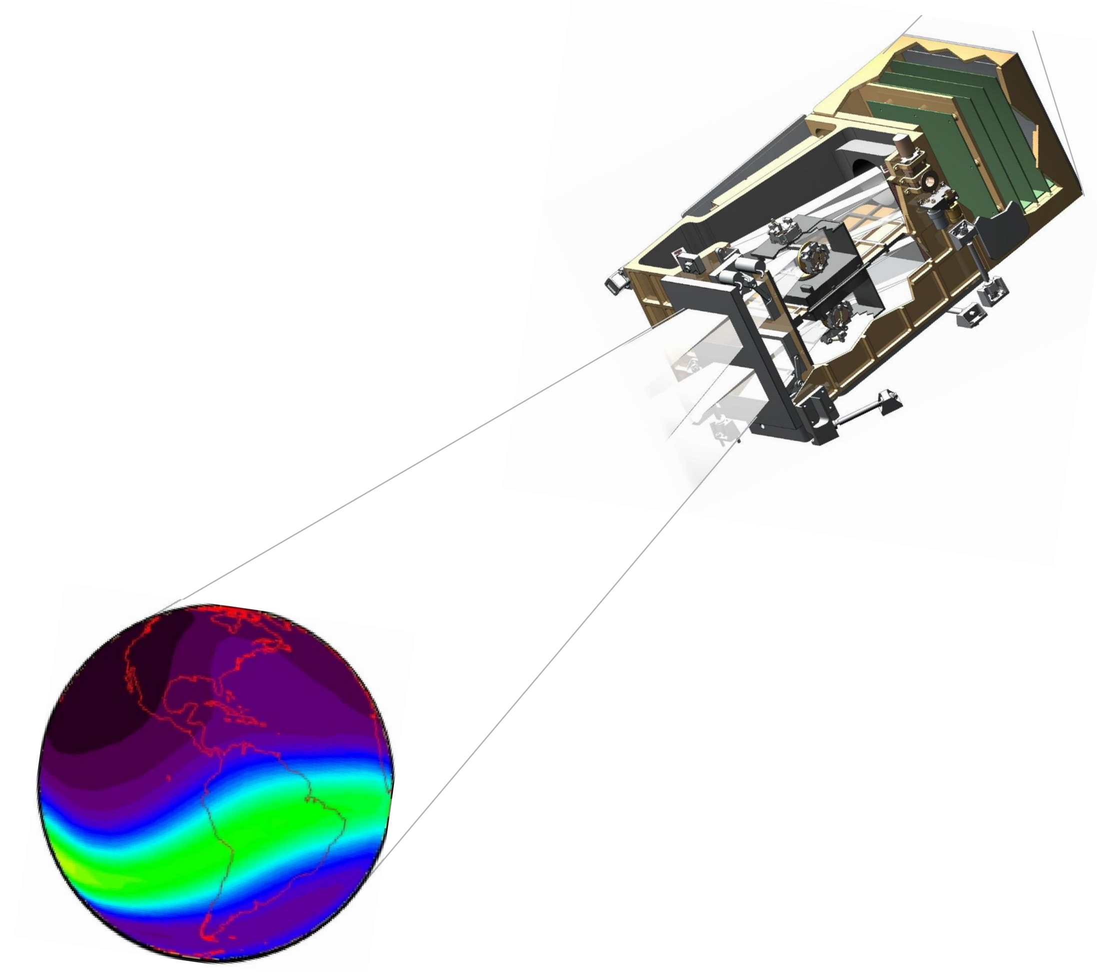
B. Determine the effects of long and short term variability of the Sun on the global-scale behavior of the ionospheric electron density

C. Determine the solar and geospace causes of small-scale ionospheric density irregularities in the 100 to 1000 km altitude region.

Goals determine observations

GOLD Observations

1. First global-scale (disk) neutral temperature measurements (from N_2 Lyman-Birge-Hopfield [LBH] band rotational temperatures at 150±30 km)
2. O/N_2 column density ratios (from dayside oxygen 1356 Å & LBH observations)
3. Electron density variations in latitude and longitude (oxygen 135.6 nm emissions from O^+ + e)
4. O_2 density profile at altitudes of 150-240 km (day and night) by stellar occultation
5. O emission profiles (day, from observations of 1356 Å) on the limb
6. Electron density vertical profile (night, oxygen 1356 Å emissions from O^+ + e) on the limb
7. Limb temperature measurements



GOLD provides temperature measurements from limb observations

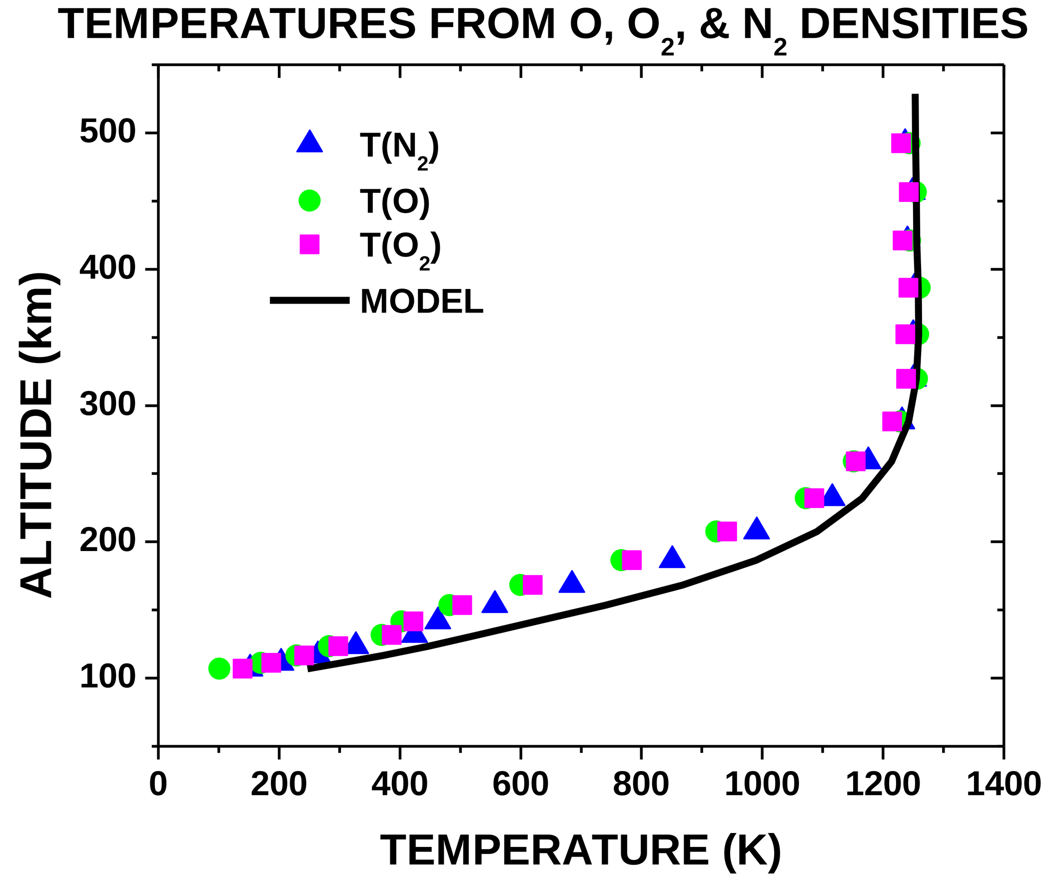
An important measurement made by GOLD is the exospheric temperature of the Earth's atmosphere. The temperature can be derived from the density profile of any atmospheric species. For a species in diffusive equilibrium, the temperature, T, as derived from the number density at two heights h and h_0 ($h > h_0$) is:

$$T = \frac{\Delta h m g}{k_B - \ln\frac{n}{n_0}} - T\ln\frac{T_0}{T}$$

$\Delta h = h - h_0$
T is the temperature at height h
T_0 is the temperature at height h_0
m is the molecular mass
n is the number density at height h
n_0 is the number density at height h_0
g is the gravitational acceleration
k_B is Boltzman's constant

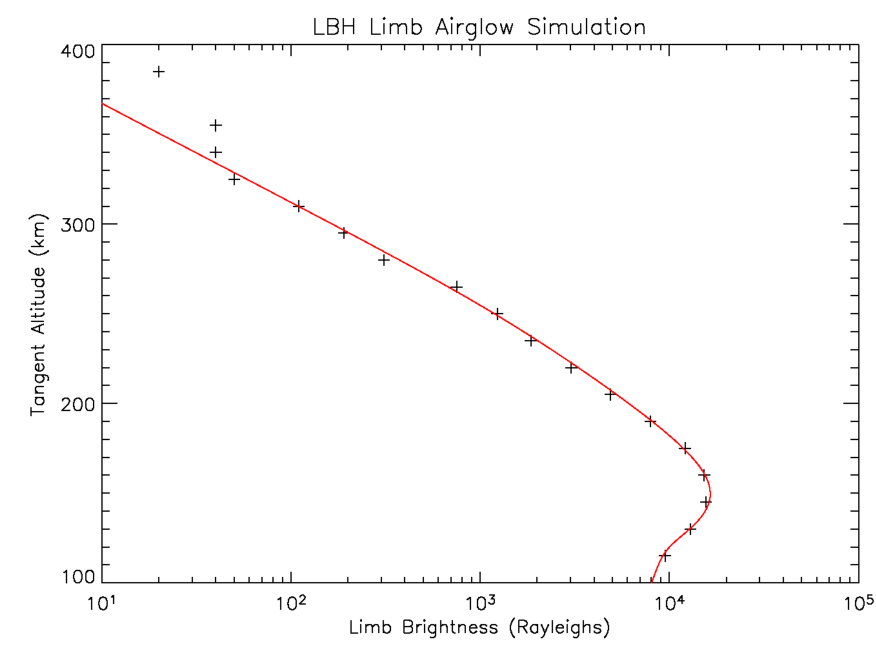
COMMENTS: For $T=T_0$, the 2nd term on the right is 0 and the temperature can be determined from the change in number density alone.

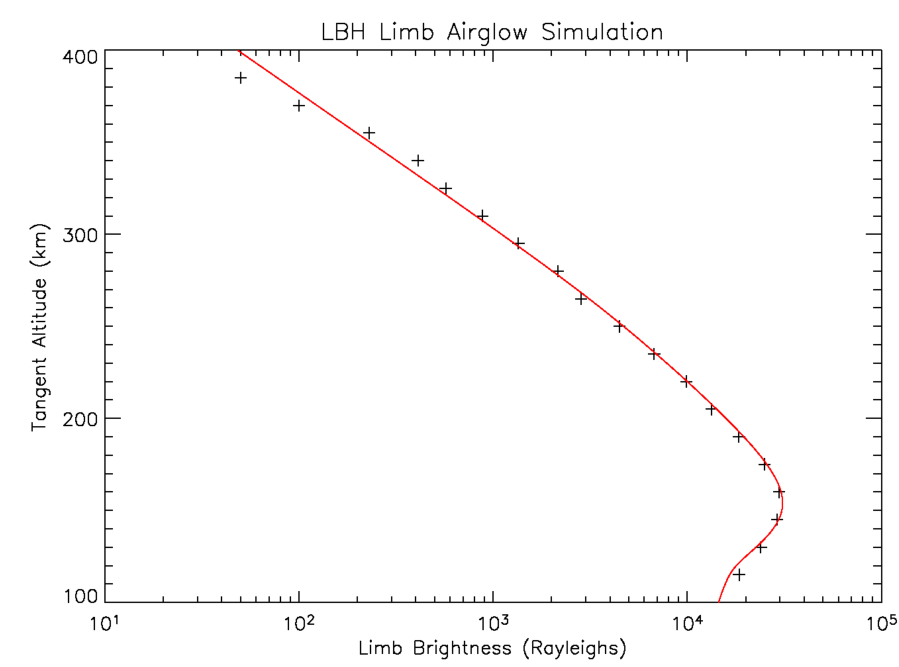
The plot below compares the model temperatures (black curve) with those derived from the model density profiles of N_2, O_2, and O using the above formula. This is essentially a proof of concept argument that the exospheric temperature can be accurately derived from density profiles that will be measured by GOLD.



LBH limb measurement simulations

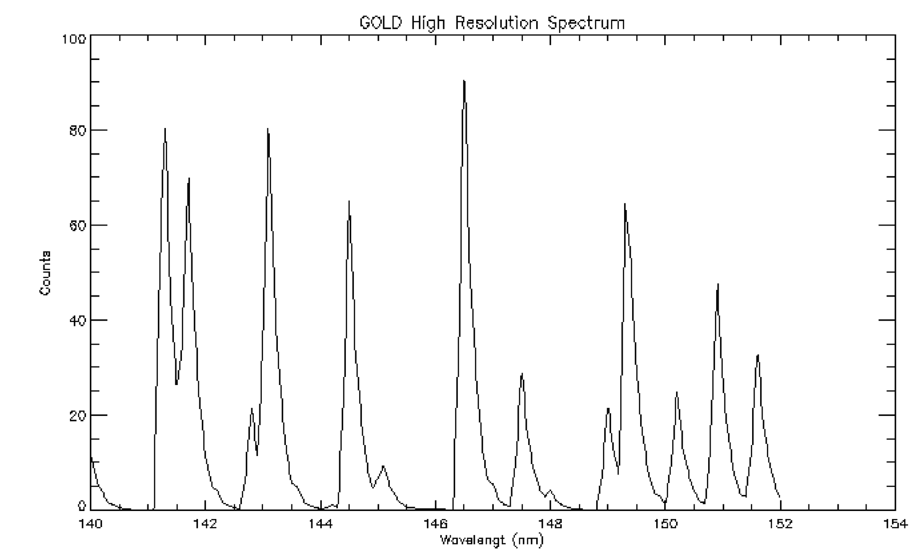
GOLD limb measurements of LBH emission from N_2 provide the opportunity to derive temperatures by fitting the emission profile above the altitude where absorption is important (~200 km). The LBH emission emulates the molecular nitrogen profile and thus can be used to determine the exospheric temperature by fitting the top side scale height. Below is a simulation of this technique.



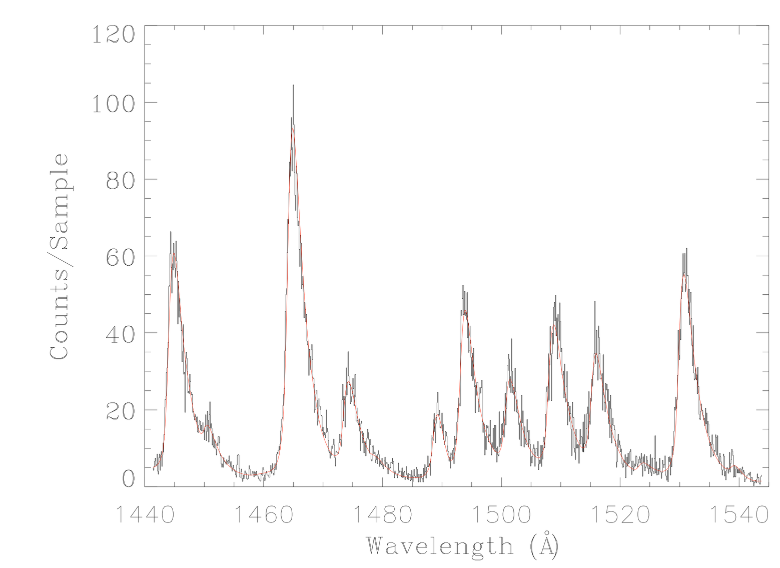


Simulated limb profiles of LBH emissions, with noise, for two exospheric temperatures (T_{inf}). The upper panel is for T_{inf} = 967 K and the lower panel is for 1256 K. The data are fit in the 200-300 km region to determine T_{inf}. The error on the determination of T_{inf} is approximately 30 K.

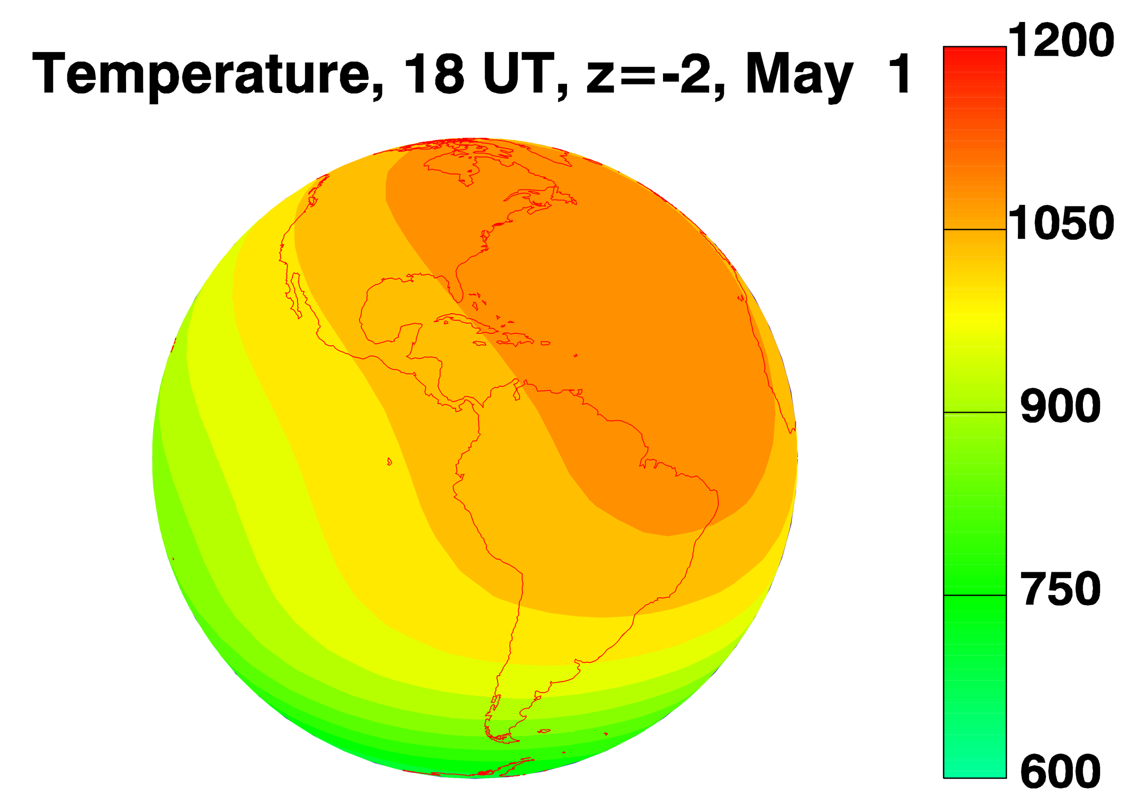
GOLD provides temperature measurements on the Earth's disk

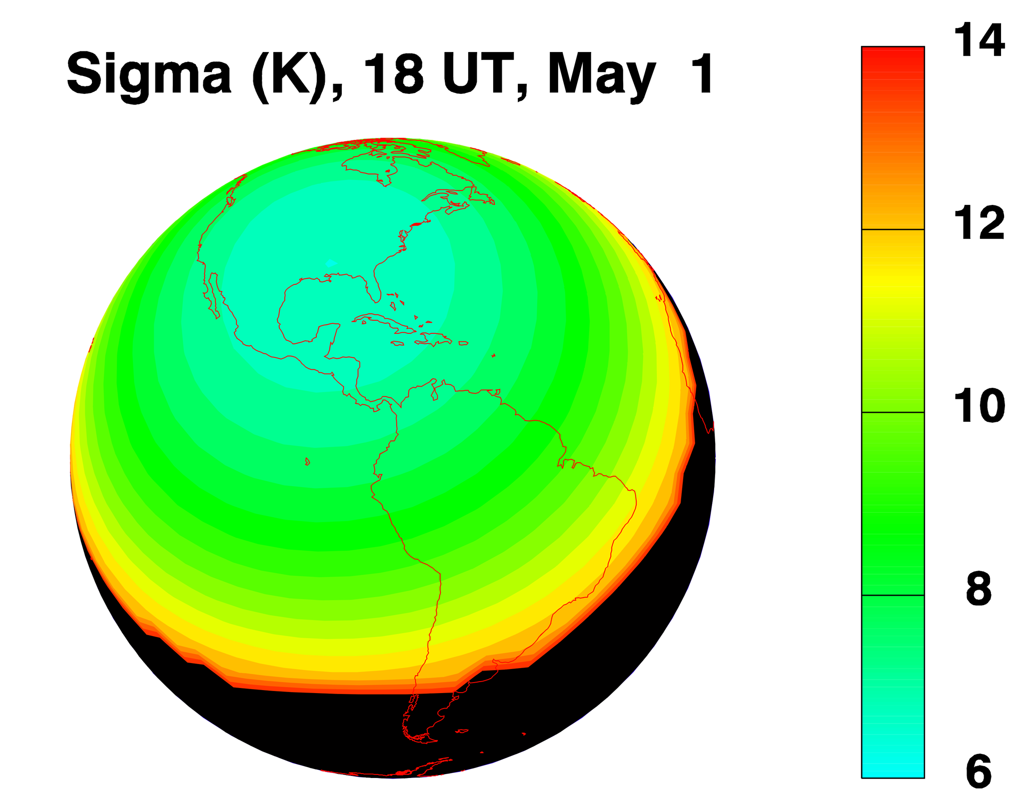


Model calculation of the Lyman-Birge-Hopfield (LBH) bands of N_2. The spectral resolution (1.3 Å) and wavelength range used here are representative of what will be used by GOLD. Simulated spectra are calculated by scaling to the appropriate brightness and adding noise (as shown to the right).



Simulation of the high resolution channel using a synthetic spectrum. The black line represents measured counts at 2 hours/image, 500 km spatial resolution, 1.3 Å spectral resolution, and 70 degrees Solar Zenith Angle. The red line is a fit to the spectrum used for temperature retrieval.





(Left) Temperatures from TIEGCM calculations for altitudes near 180 km. Geomagnetically quiet conditions in May 1997 (near solar maximum) are used in this calculation. The viewing geometry and location used are those planned for the observations. (Right) Uncertainties in the temperatures retrieved near 180 km when using simulated data. These uncertainties are based on the scatter in the temperatures obtained from retrievals using simulated data. The simulations used 1.3 Å resolution, solar zenith angles of ≤70 degrees, and a 2 hour per image cadence.