

Universidad de Chile
Departamento de Geofísica

Introducción a la Meteorología y Oceanografía (2011)

Transferencia Radiativa I (Radiación Solar)

Prof. René Garreaud
www.dgf.uchile.cl/rene

Introducción a la Meteorología – Rad. Solar

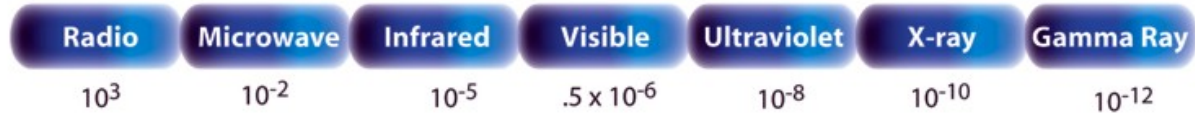
UCH/FCFM/DGF – R. Garreaud

THE ELECTROMAGNETIC SPECTRUM

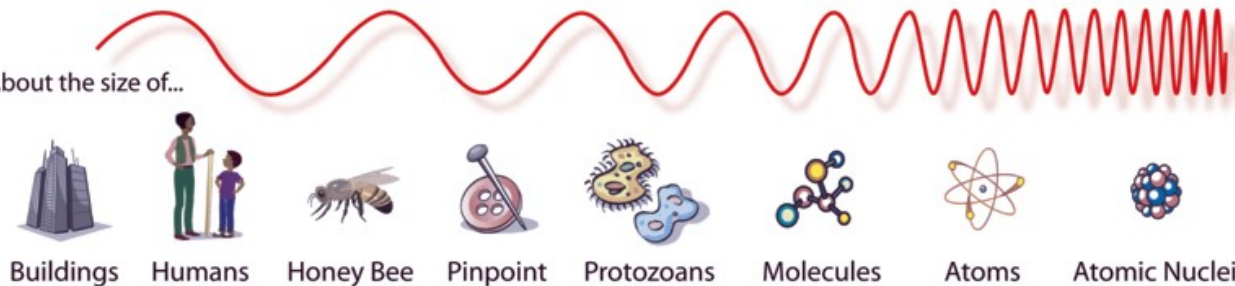
Penetrates
Earth
Atmosphere?



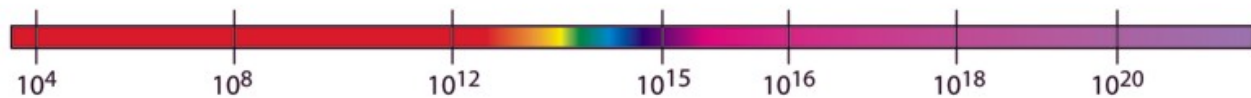
Wavelength
(meters)



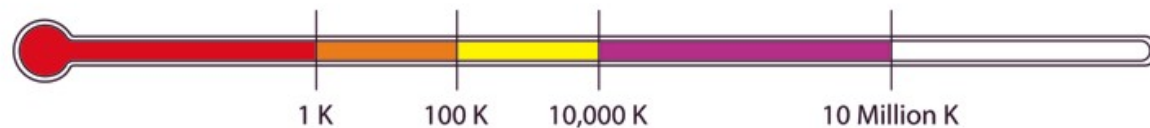
About the size of...



Frequency
(Hz)

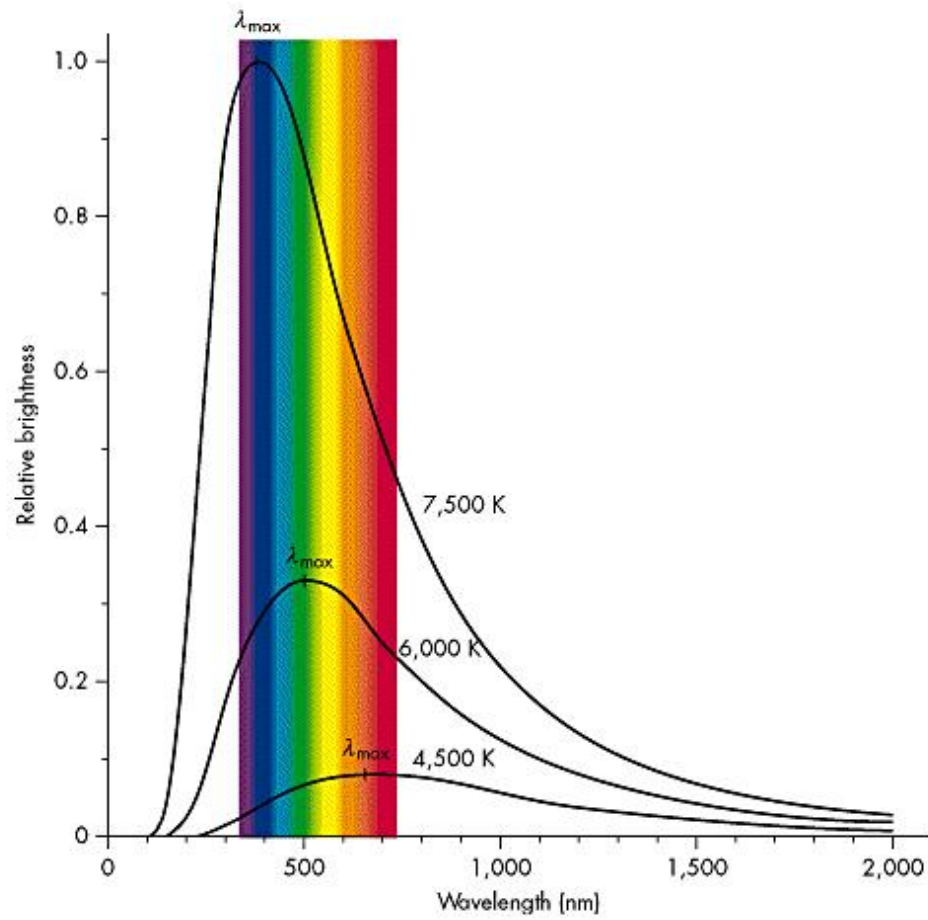


Temperature
of bodies emitting
the wavelength
(K)

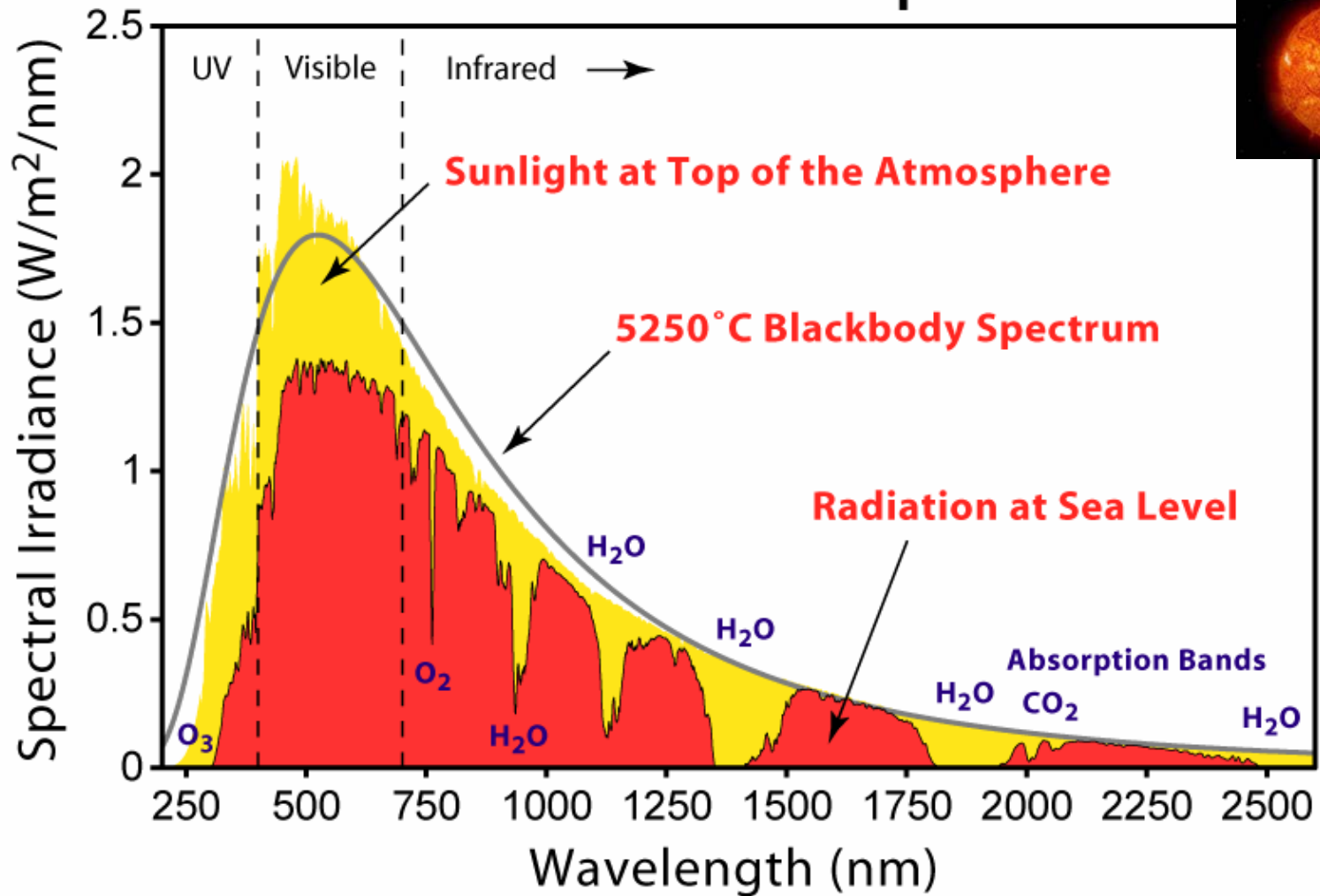


Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

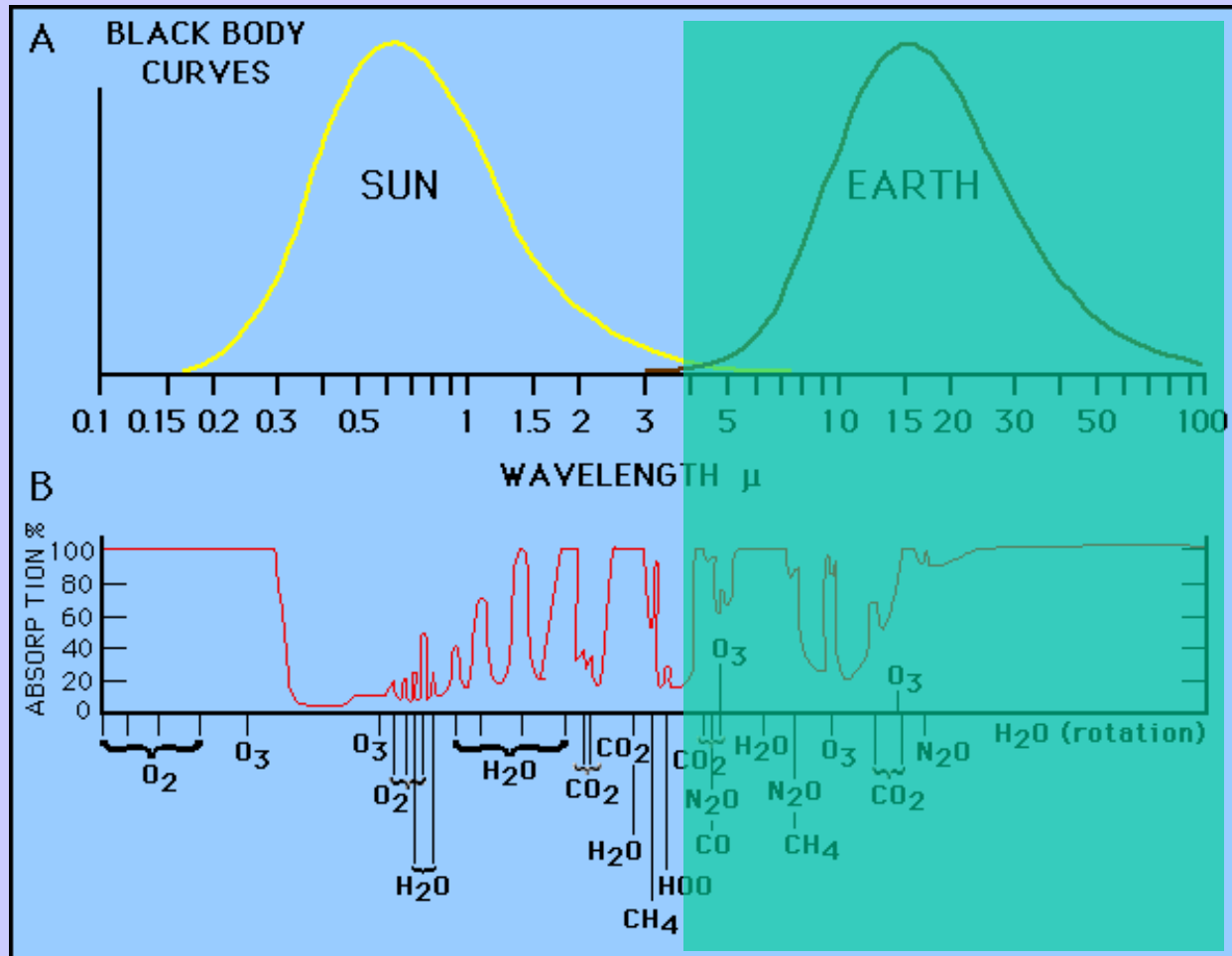


Solar Radiation Spectrum



Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



En su paso por la atmósfera, la radiación solar sufre absorción y dispersión debido a las moléculas de aire y aerosoles. En promedio, la absorción de la RS es solo de un 20%, pero muy efectiva en el rango de los rayos gama y UV.

Constante Solar: Cuanta energía recibimos del sol

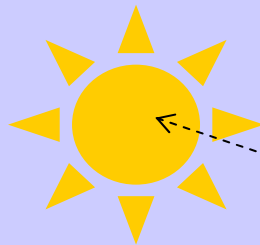
La energía emitida por el sol por unidad de area

$$E = \sigma T_s^4$$

Energía total que emite el sol

$$I = 4 * \pi * R_s^2 * E$$

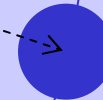
Energía por unidad de area a la distancia de la tierra:



$$CS = I / (4 * \pi * D_{t-s}^2) = 1397 \text{ W/m}^2$$

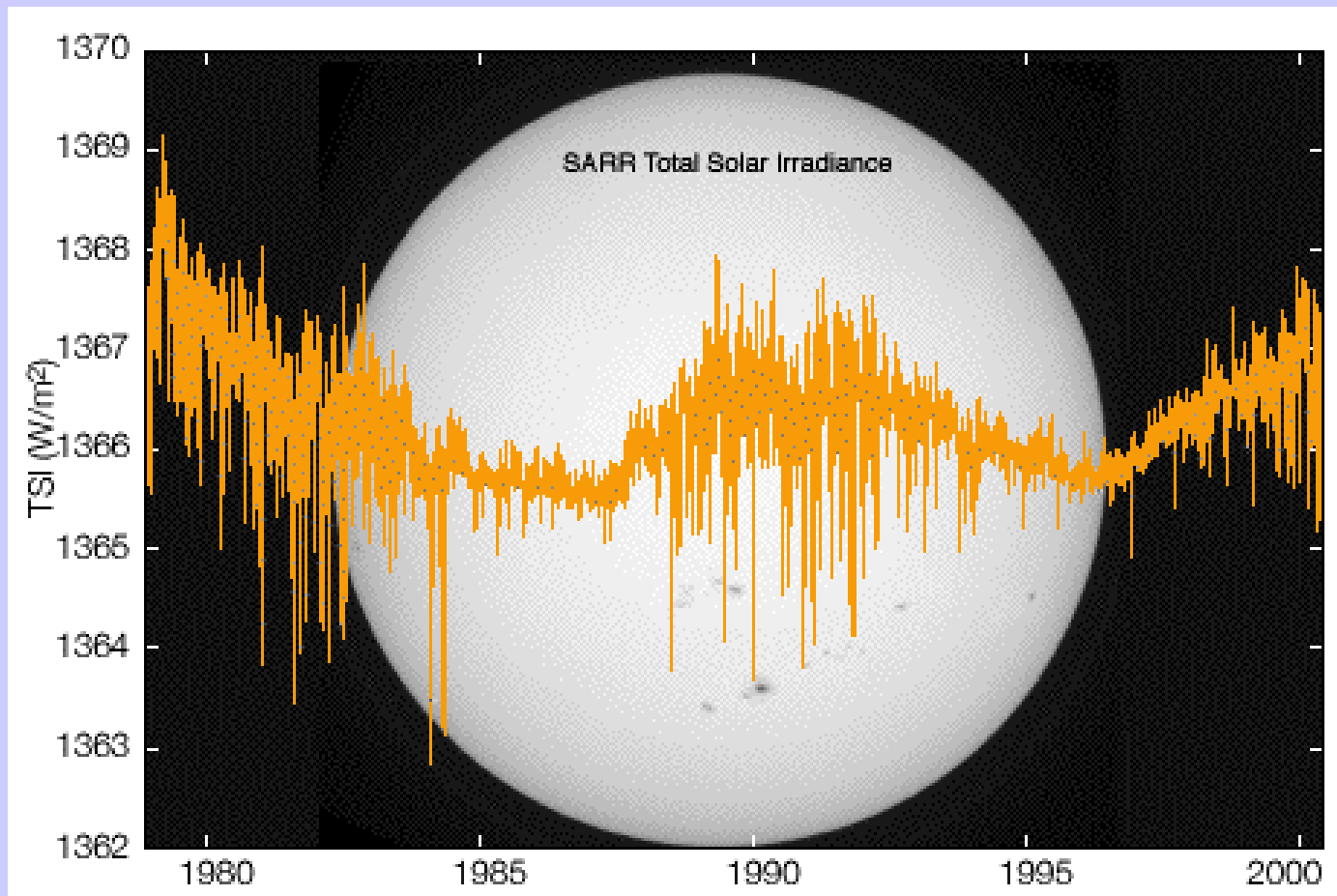
D_{t-s}

Tarea: Determinar CS para cada planeta



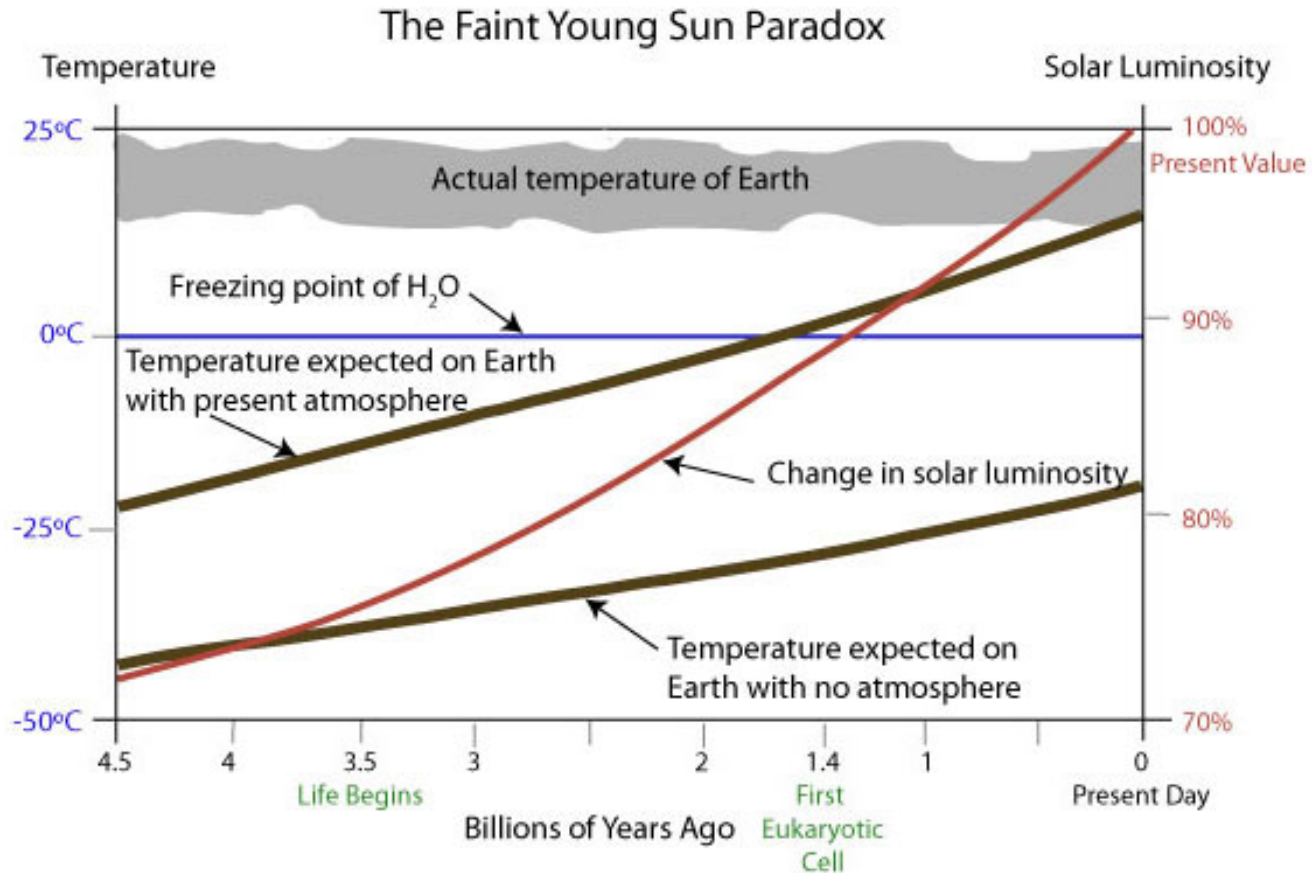
Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



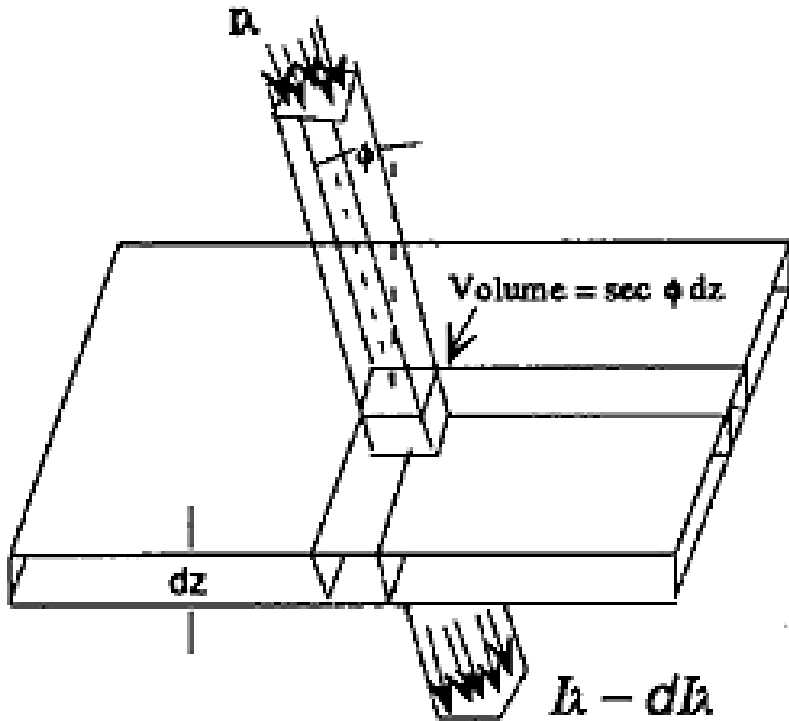
Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



Even though the Sun was about 30% dimmer than it is now, the temperature on Earth has been more or less stable.

Introducción a la Meteorología – Rad. Solar
UCH/FCFM/DGF – R. Garreaud



$$dI_\lambda = -I_\lambda \rho k_\lambda ds$$

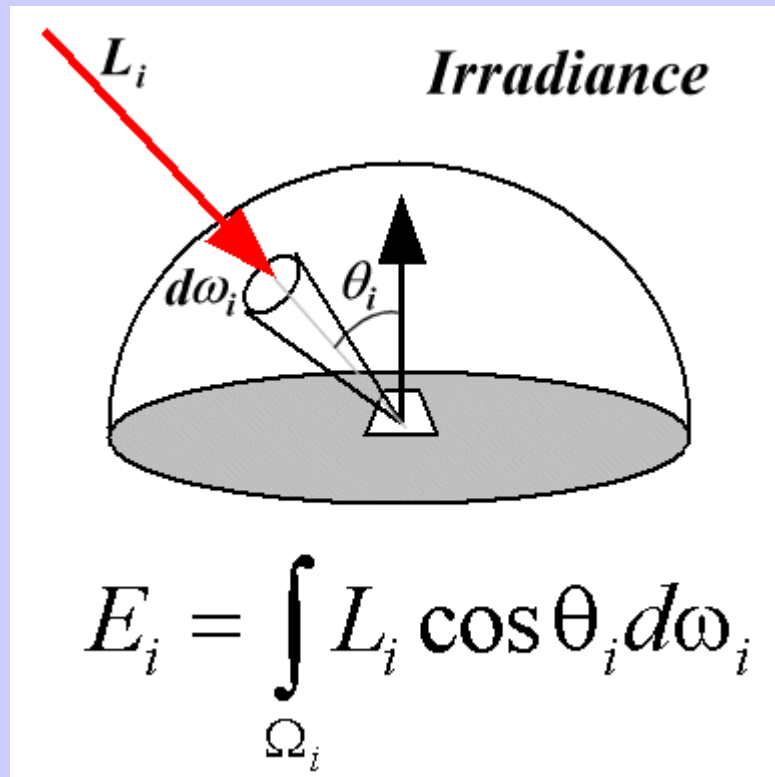
$$I_\lambda(z) = -I_\lambda(\infty) \exp(-\tau_\lambda \sec \phi)$$

$$\tau_\lambda = \int_z^\infty k_\lambda \rho dz$$

Conceptos claves

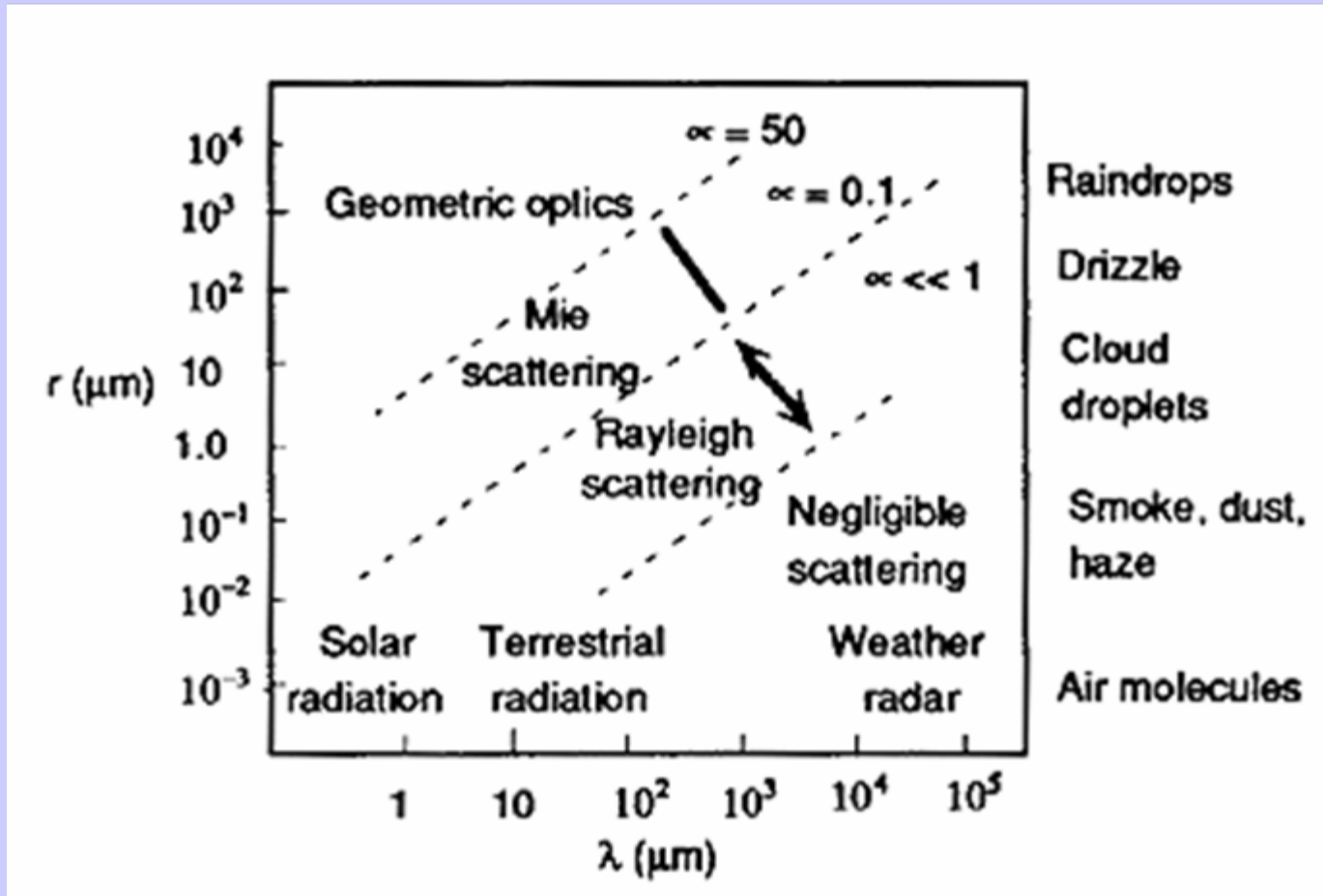
L, I = Intensidad o radianza [$\text{Wm}^{-2}\text{sr}^{-1}$]

E, F = densidad de flujo o irradianza
[Wm^{-2}]



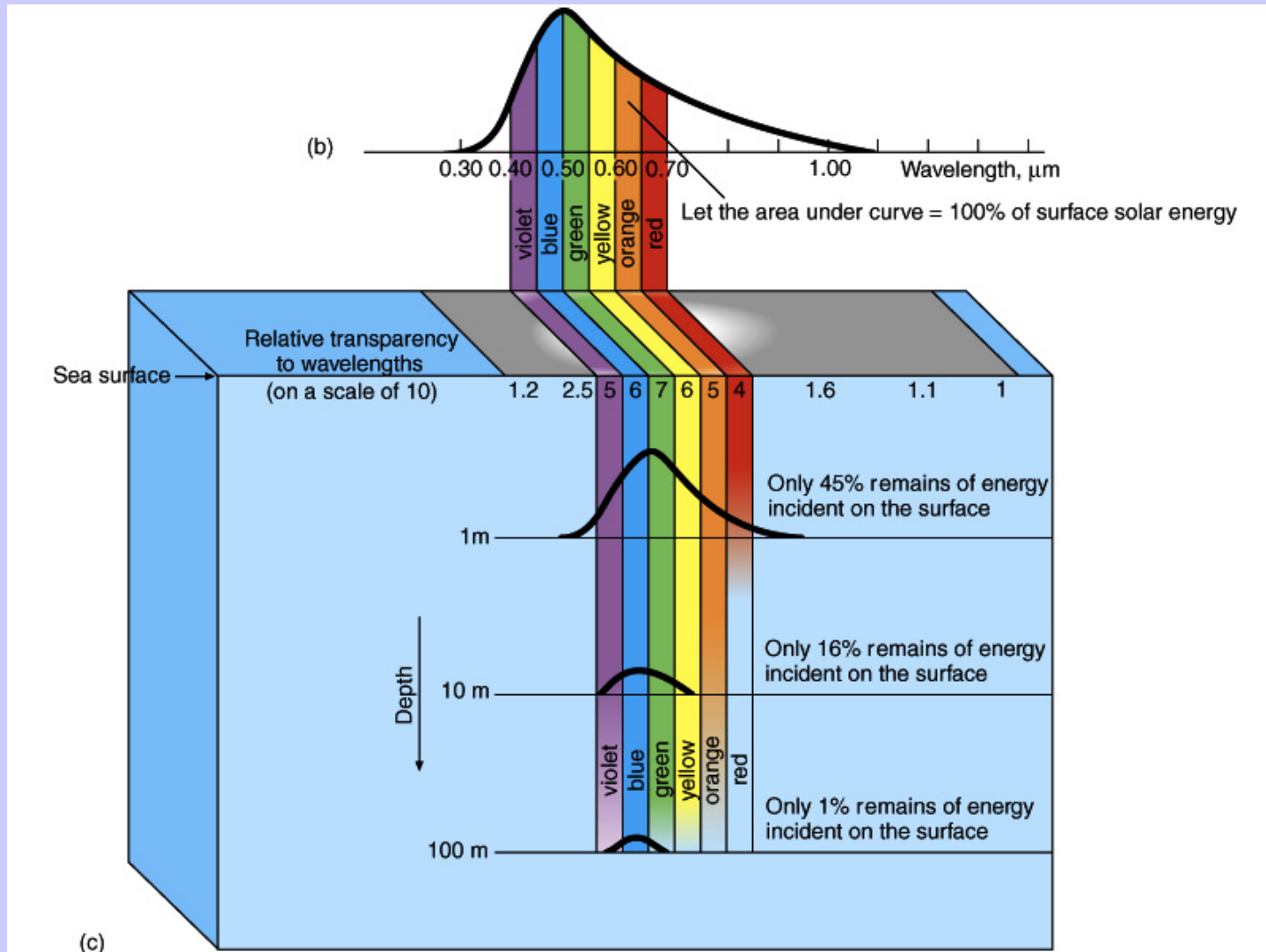
Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

El Planeta Tierra es (aprox) esférico e inclinado respecto al plano orbital (23.5° actualmente)

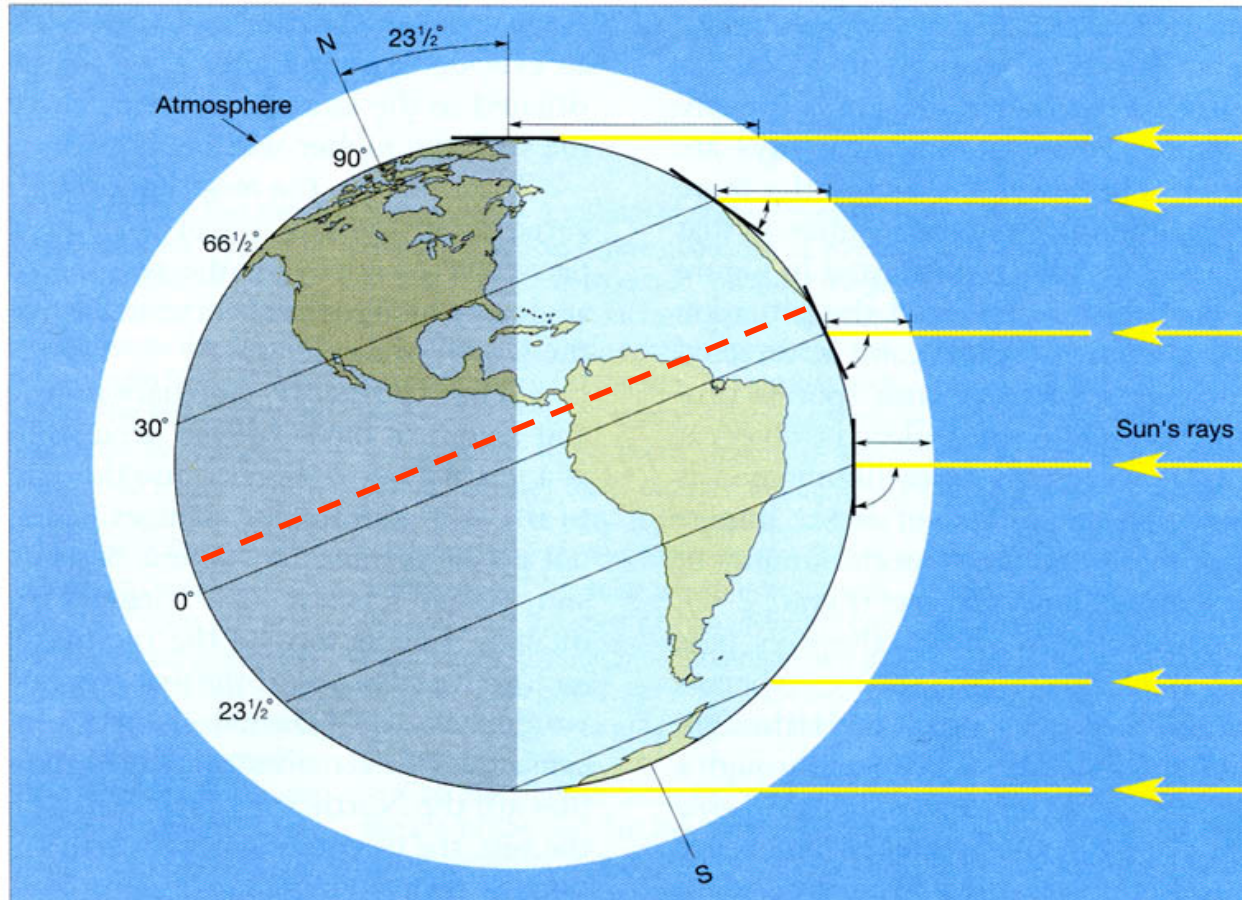


Figure 2•2 Rays striking the earth at a low angle must traverse more of the atmosphere than rays striking at a high angle and thus are subject to greater depletion by reflection and absorption.

Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

La inclinación de la tierra, combinado con el movimiento de traslación de la tierra produce la alternancia de las estaciones: máxima energía solar en HS o HN. Factor de segundo orden: excentricidad de la orbita terrestre (4% menos que el promedio en Enero, actualmente)

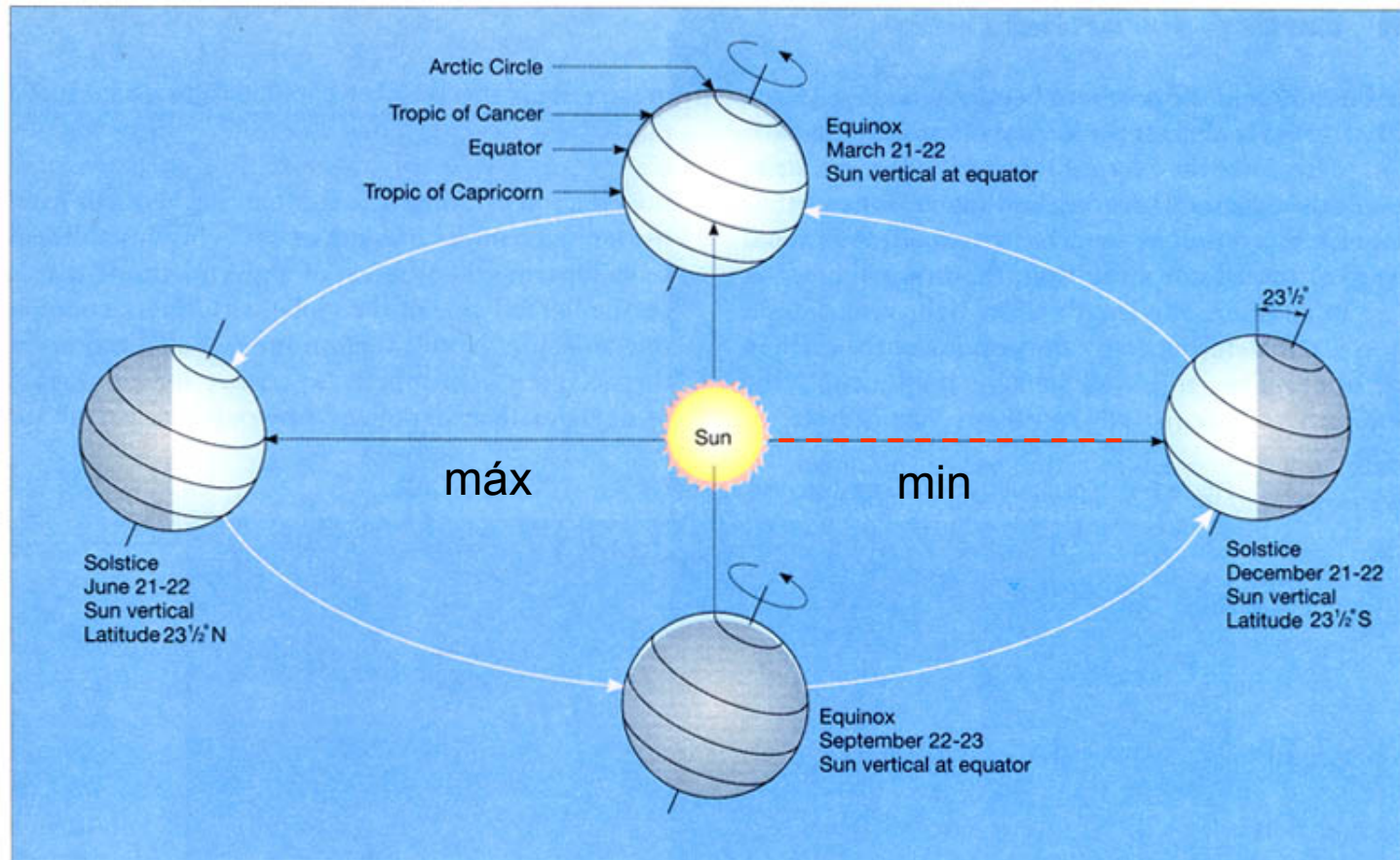
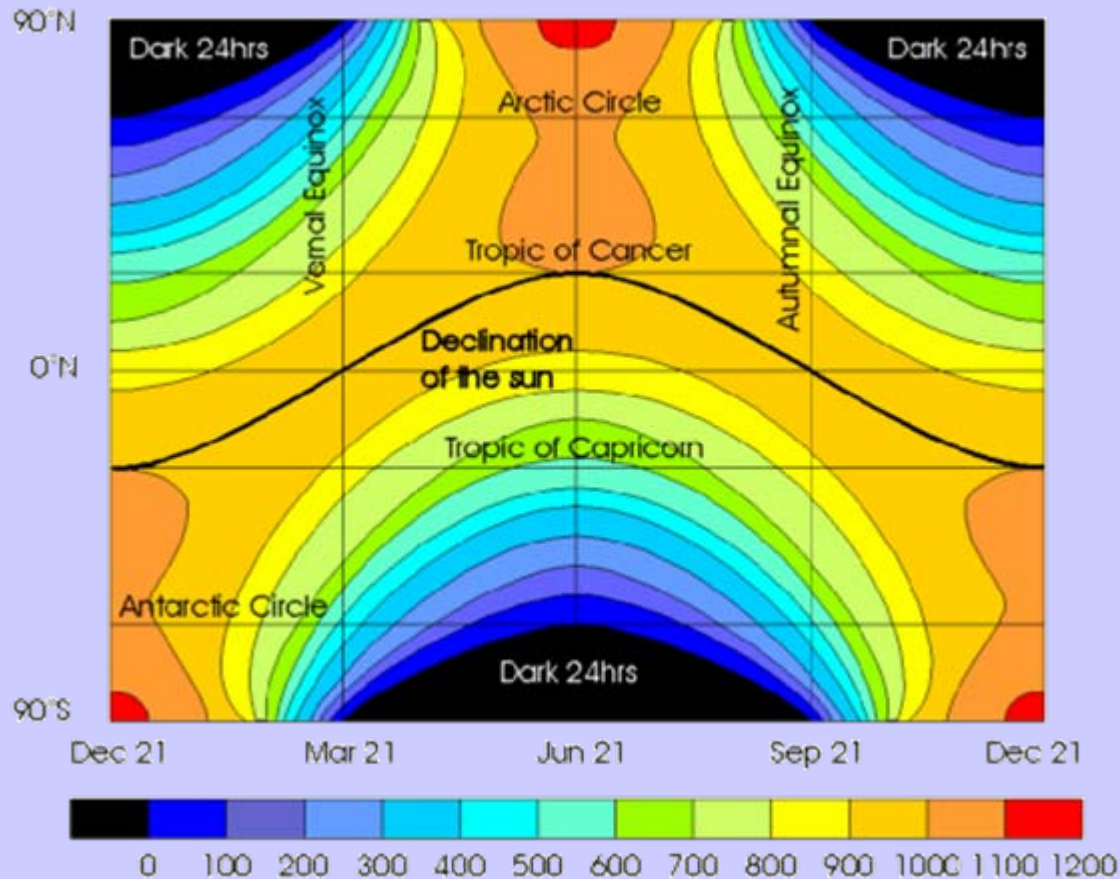


Figure 2•3 Earth–sun relationships.

Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

Alternancia de estaciones produce cambios en la energía solar (al tope de la atmósfera) que reciben distintas latitudes a lo largo del año



Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

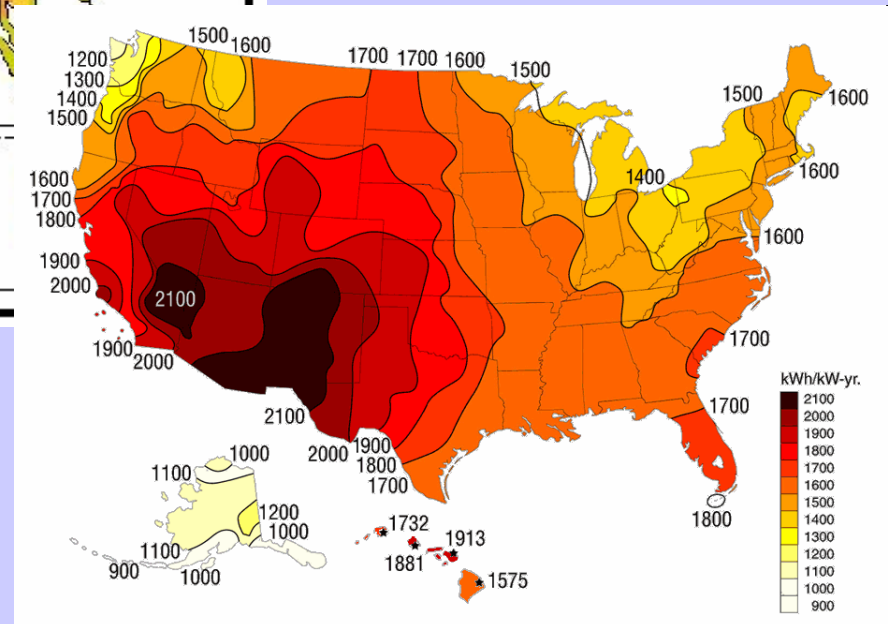
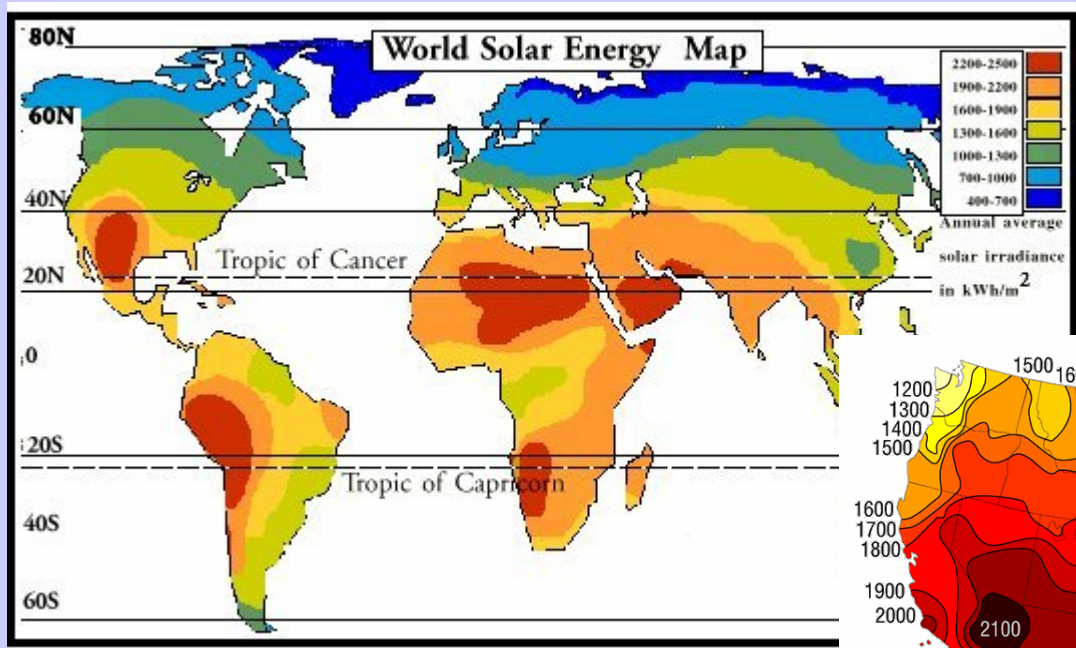
Aplicación importante: energía solar - Conceptos claves:

- * Radiación solar global (directa + difusa)
- * Insolación diaria
- * Mediciones versus simulaciones



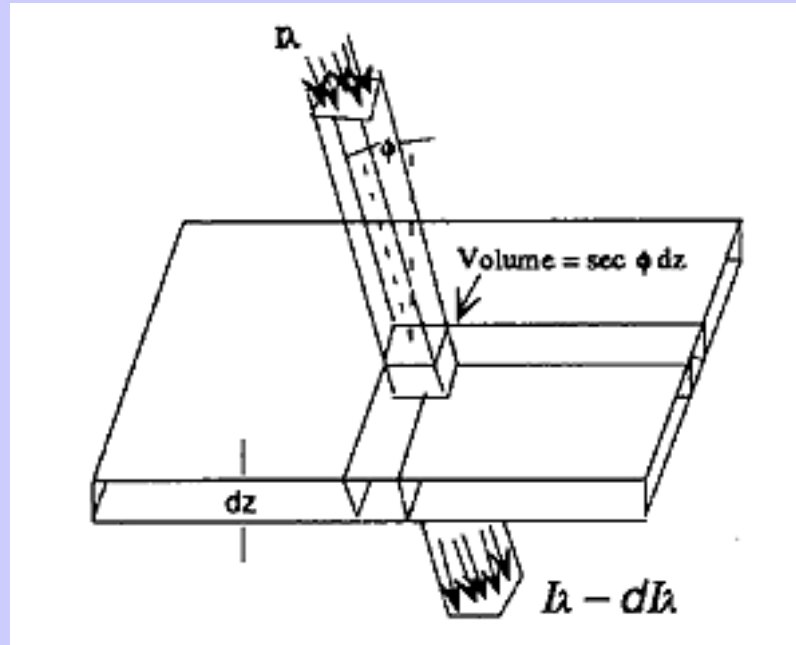
Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



Para Chile, ver el explorador de Energía solar y eólica en:
<http://quique.dgf.uchile.cl/EnergiaRenovable/Explorer2/>

Introducción a la Meteorología – Rad. Solar
 UCH/FCFM/DGF – R. Garreaud



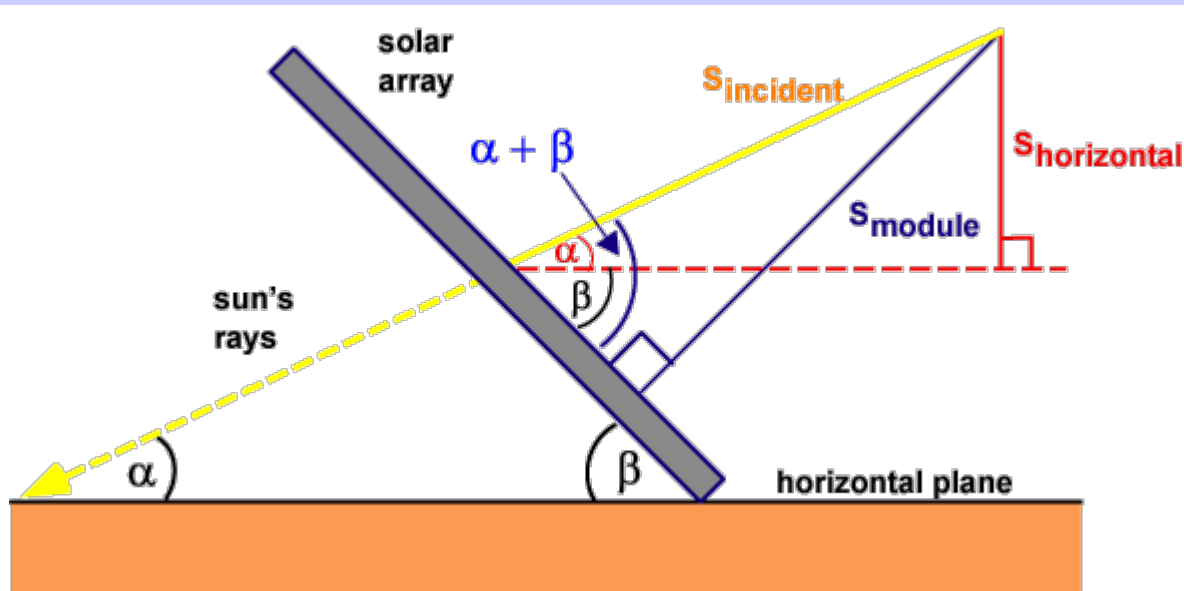
$OC \downarrow = CS' \cos(\chi) T_N$ Radiación incidente en plano horizontal

$$\cos(\chi) = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos(h)$$

$$T = T(\chi, \text{nubes}, \text{altura}, \text{etc.....})$$

Todo lo que necesita saber sobre calculo de RSOL:

<http://pvcdrom.pveducation.org/index.html>



$$Elevation = \sin^{-1}[\sin \delta \sin \phi + \cos \delta \cos \phi \cos(HRA)]$$

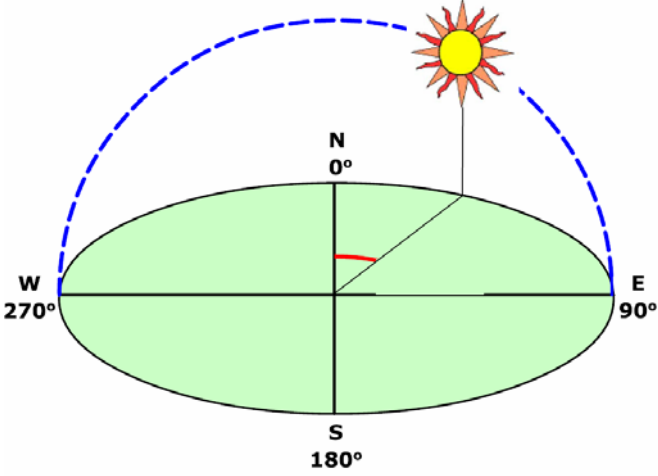
$$Azimuth = \cos^{-1} \left[\frac{\sin \delta \cos \phi - \cos \delta \sin \phi \cos(HRA)}{\cos \alpha} \right]$$

Todo lo que necesita saber sobre calculo de RSOL:

<http://pvcdrom.pveducation.org/index.html>

At solar noon, the azimuth angle is 0°

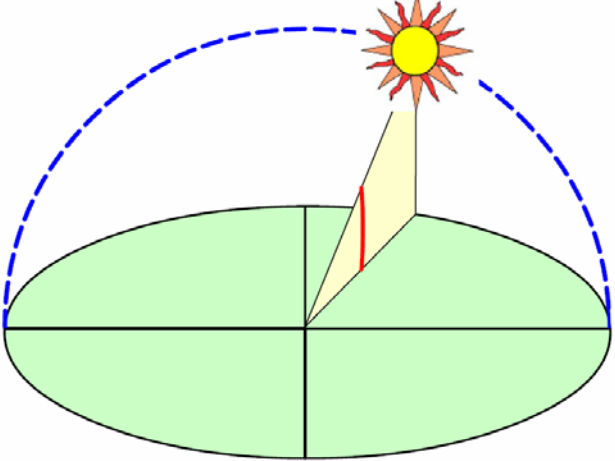
Click to Continue



The diagram shows a green elliptical ground plane with a vertical axis labeled 'N' at 0° and 'S' at 180°. A horizontal axis is labeled 'W' at 270° and 'E' at 90°. A sun is positioned directly above the North axis. A dashed blue arc represents the sun's path. A red line indicates the sun's position at 0° azimuth.

The maximum elevation angle occurs at solar noon.

Click to Continue



The diagram shows the same green elliptical ground plane. A sun is positioned above the North axis. A yellow shaded area represents the sun's path. A red line indicates the sun's position at its maximum elevation angle.

$$Elevation = \sin^{-1}[\sin \delta \sin \phi + \cos \delta \cos \phi \cos(HRA)]$$
$$Azimuth = \cos^{-1} \left[\frac{\sin \delta \cos \phi - \cos \delta \sin \phi \cos(HRA)}{\cos \alpha} \right]$$

PVCDROM
Honsberg & Bowden

You are on the old site. The new site is at:
www.pveducation.org/pvcdrom

Welcome
 Instructions
 Expand All Close All

Chapter 1
 Introduction

Chapter 2
 Properties of Sunlight
Basics of Light
 Properties of Light
 Energy of a Photon
 Photon Flux
 Spectral Irradiance
 Radiant Power Density
Blackbody Radiation
 Blackbody Radiation
Solar Radiation
 The Sun
 Solar Radiation in Space
 Solar Radiation Outside Earth's Atmosphere
Terrestrial Solar Radiation
 Solar Radiation at Earth
 Atmospheric Effects
 Air Mass
 Motion of the Sun
 Solar Time
 Declination Angle
 Elevation Angle
 Azimuth Angle
 The Sun's Position
 *Sun Position Calculator
 Sun's Position to High Accuracy
 Solar Radiation on a Tilted Surface
 Arbitrary Tilt and Orientation
 Calculation of Solar Insolation
Solar Radiation Data
 Measurement of Solar Radiation
 Analysis of Solar Radiation Data
 Typical Meteorological Year Data
 Average Solar Radiation
 Isoflux Contour Plots
 Sunshine Hour Data
 Cloud Cover Data
 Questions

Chapter 3
 PN Junctions

Chapter 4
 Solar Cell Operation

Chapter 5
 Design of Silicon Cells

2.18. Sun Position Calculator

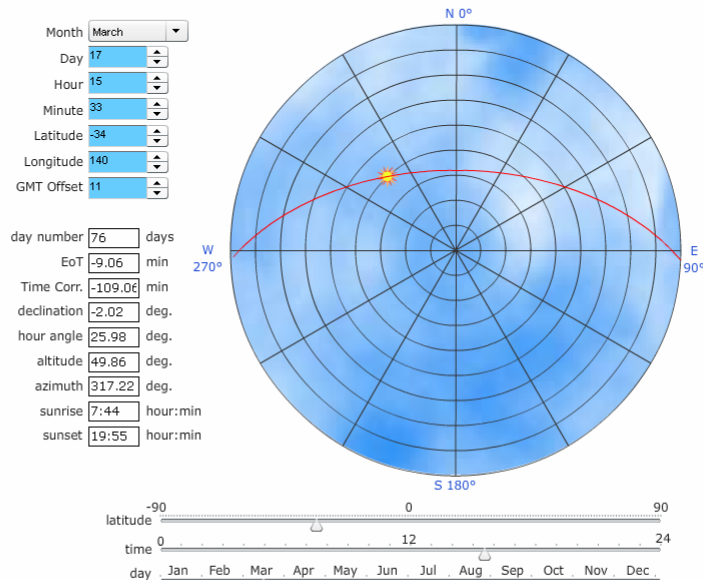
Using the equations on the previous page, the position of the sun in the sky can be determined from the observer's location and the time of day. In the top blue squares, enter the observer's location and time of day.

Time and Date

The time is given as 24 hour time and the minutes are entered separately. Thus for 5:15 pm, enter 17 in the hour box and 15 in the minute box.

Longitude, Latitude and Time Zone (GMT)

Longitude, latitude and time zone of locations throughout the world are available at www.timeanddate.com. Minutes of longitude and latitude are entered as fractions, so 17° 30' becomes 17.5. Enter locations with an east longitude as negative. For daylight saving (summer time), subtract 1 hour from the given values. Generally speaking, locations east of Greenwich (UK) are positive and locations west of Greenwich are negative. There are other services that will determine your approximate latitude and longitude from your IP address. For example ip2location.com.

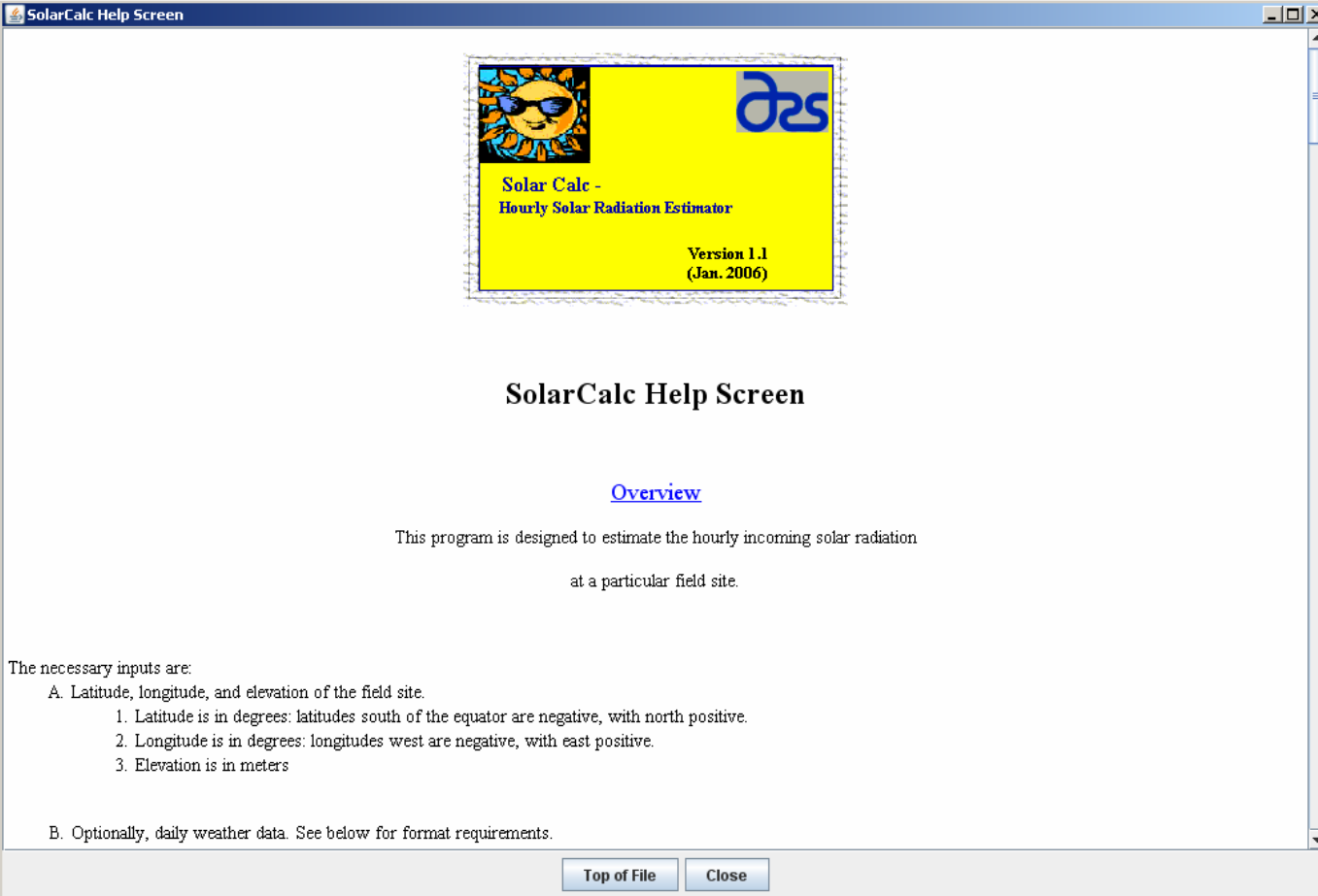


The graph on the right shows the position of the sun's azimuth and elevation angles projected onto a two-dimensional plane. An elevation angle of 90° corresponds to the stage when the sun is directly overhead and appears in the centre of the graph. An elevation angle of 0° corresponds to the point when the sun is on the horizon, and appears on the outer edge of the graph. The azimuth angles are marked around the graph's edge, so an azimuth angle of 0° is at the top of the graph. The graph is best understood by trying a number of times and locations and seeing where the azimuth and elevation angles plotted.

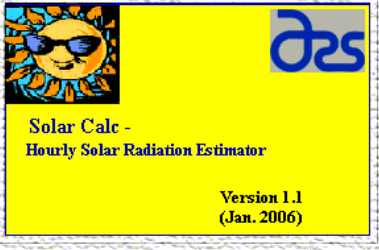
Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

<http://www.ars.usda.gov/services/software/>



SolarCalc Help Screen



Solar Calc -
Hourly Solar Radiation Estimator

Version 1.1
(Jan. 2006)

SolarCalc Help Screen

[Overview](#)

This program is designed to estimate the hourly incoming solar radiation
at a particular field site.

The necessary inputs are:

A. Latitude, longitude, and elevation of the field site.

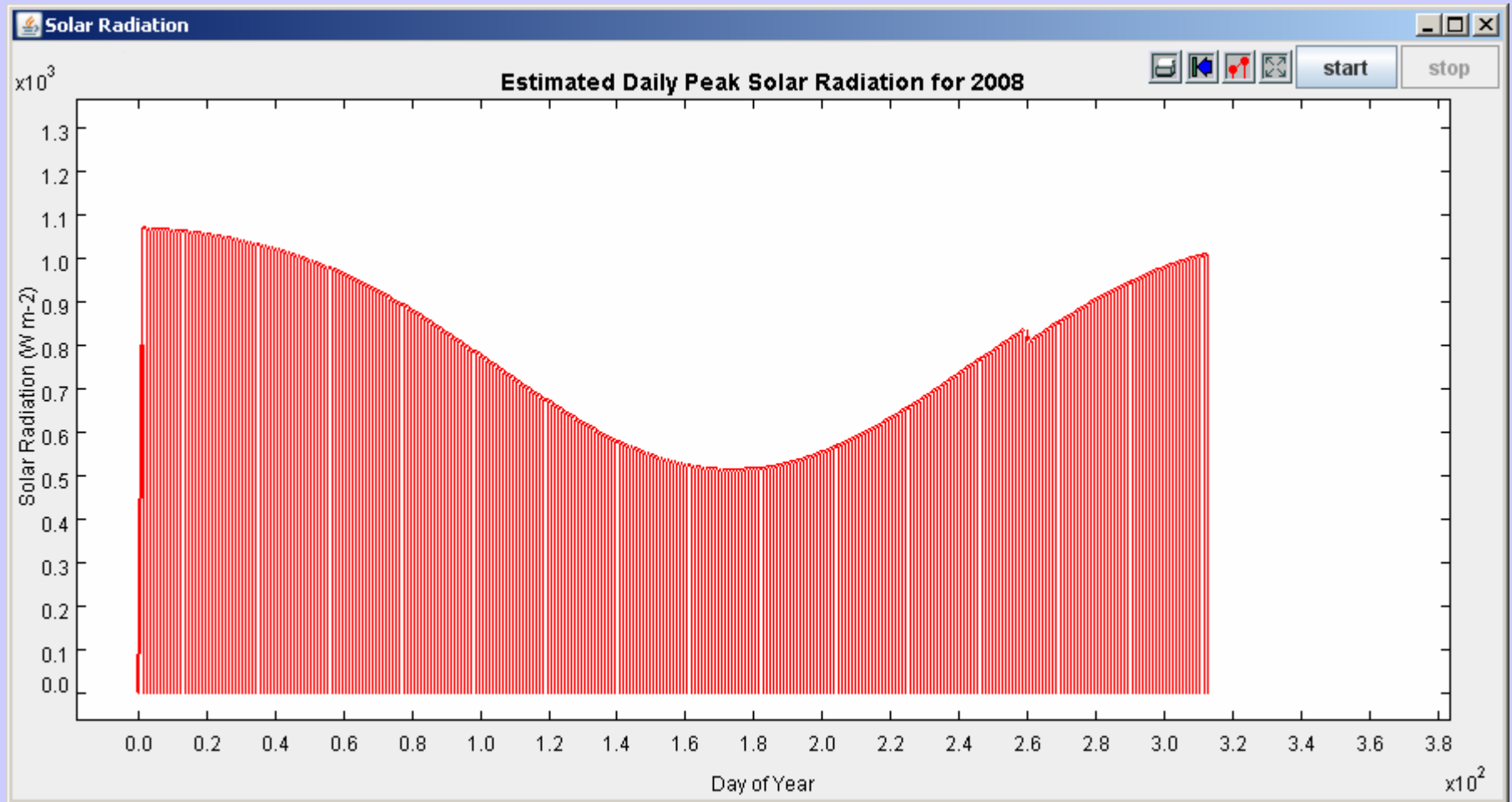
1. Latitude is in degrees: latitudes south of the equator are negative, with north positive.
2. Longitude is in degrees: longitudes west are negative, with east positive.
3. Elevation is in meters

B. Optionally, daily weather data. See below for format requirements.

Top of File Close

Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



Introducción a la Meteorología – Rad. Solar
UCH/FCFM/DGF – R. Garreaud

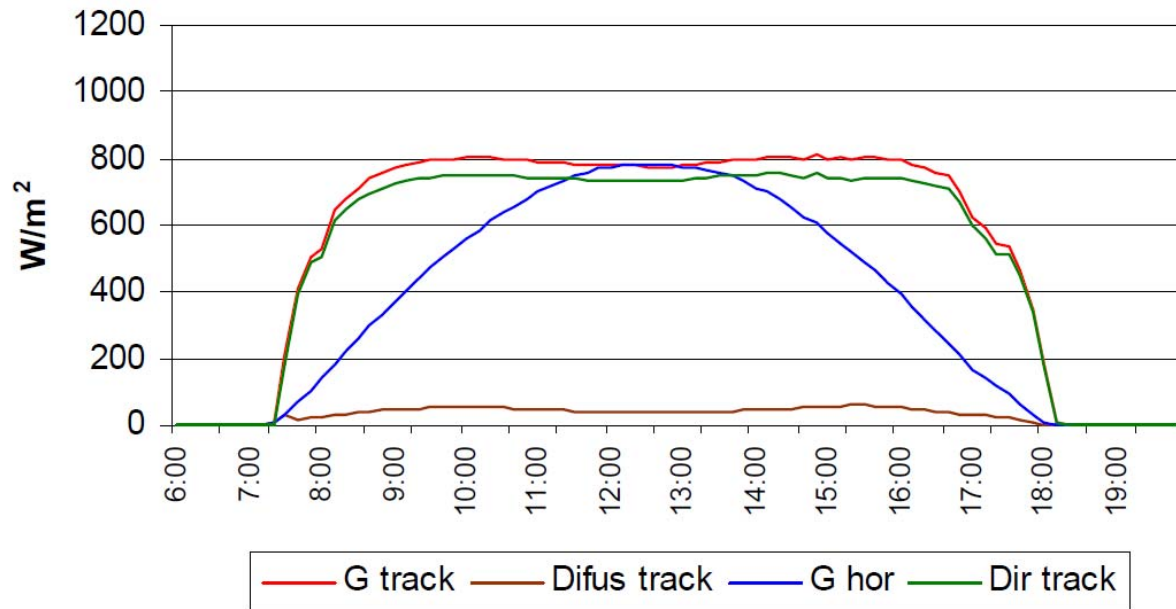


Figura 1: Vista completa de la estación

Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud

Perfil diario, 13.06.09



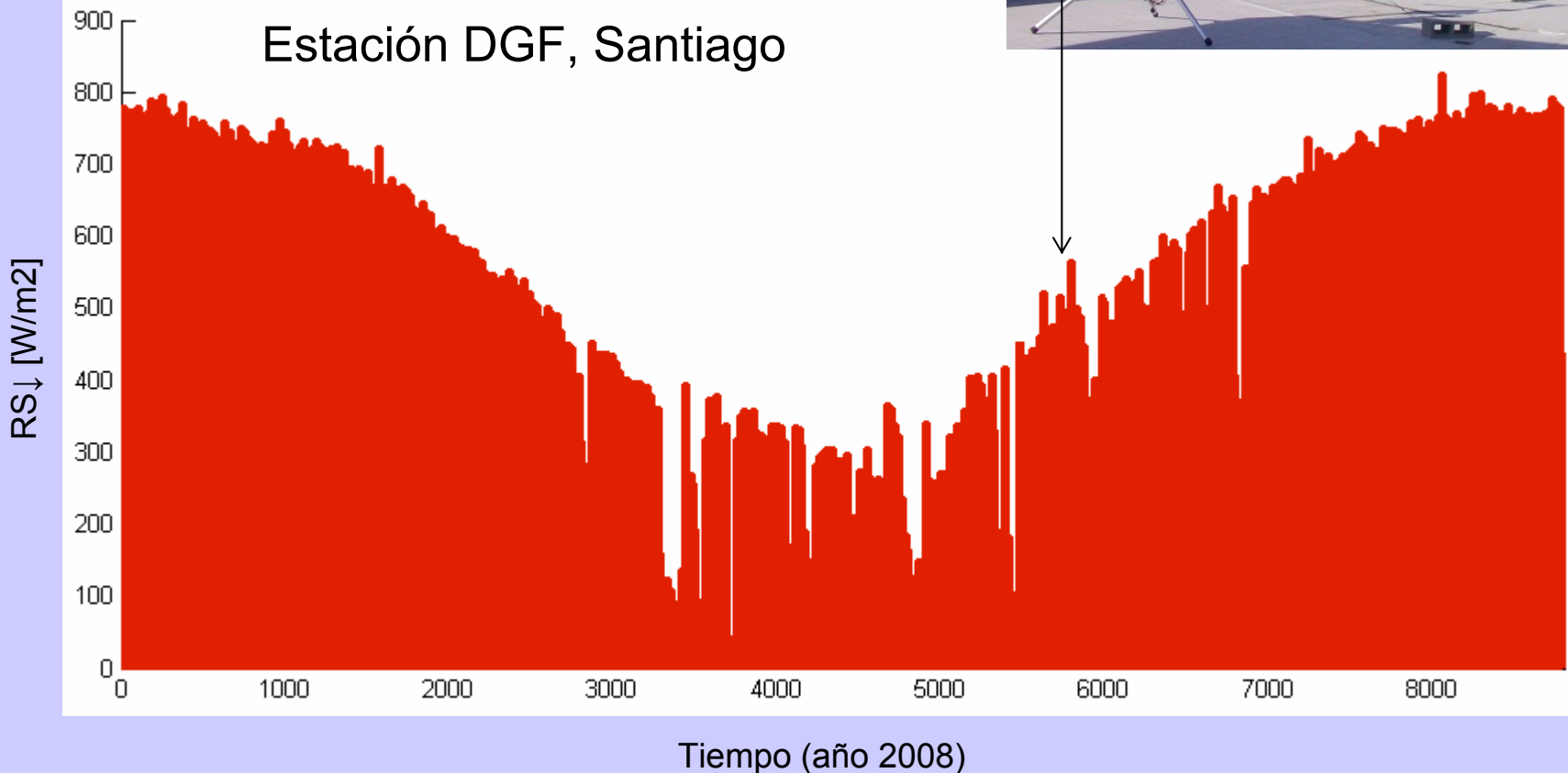
Radiación global horizontal:	5.17	kWh/m ² día
Radiación global en seguimiento:	7.72	kWh/m ² día
Radiación difusa en seguimiento:	0.44	kWh/m ² día
Radiación directa en seguimiento:	7.27	kWh/m ² día

Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DGF – R. Garreaud



Estación DGF, Santiago



Introducción a la Meteorología – Rad. Solar

UCH/FCFM/DTG – R. Garreaud

