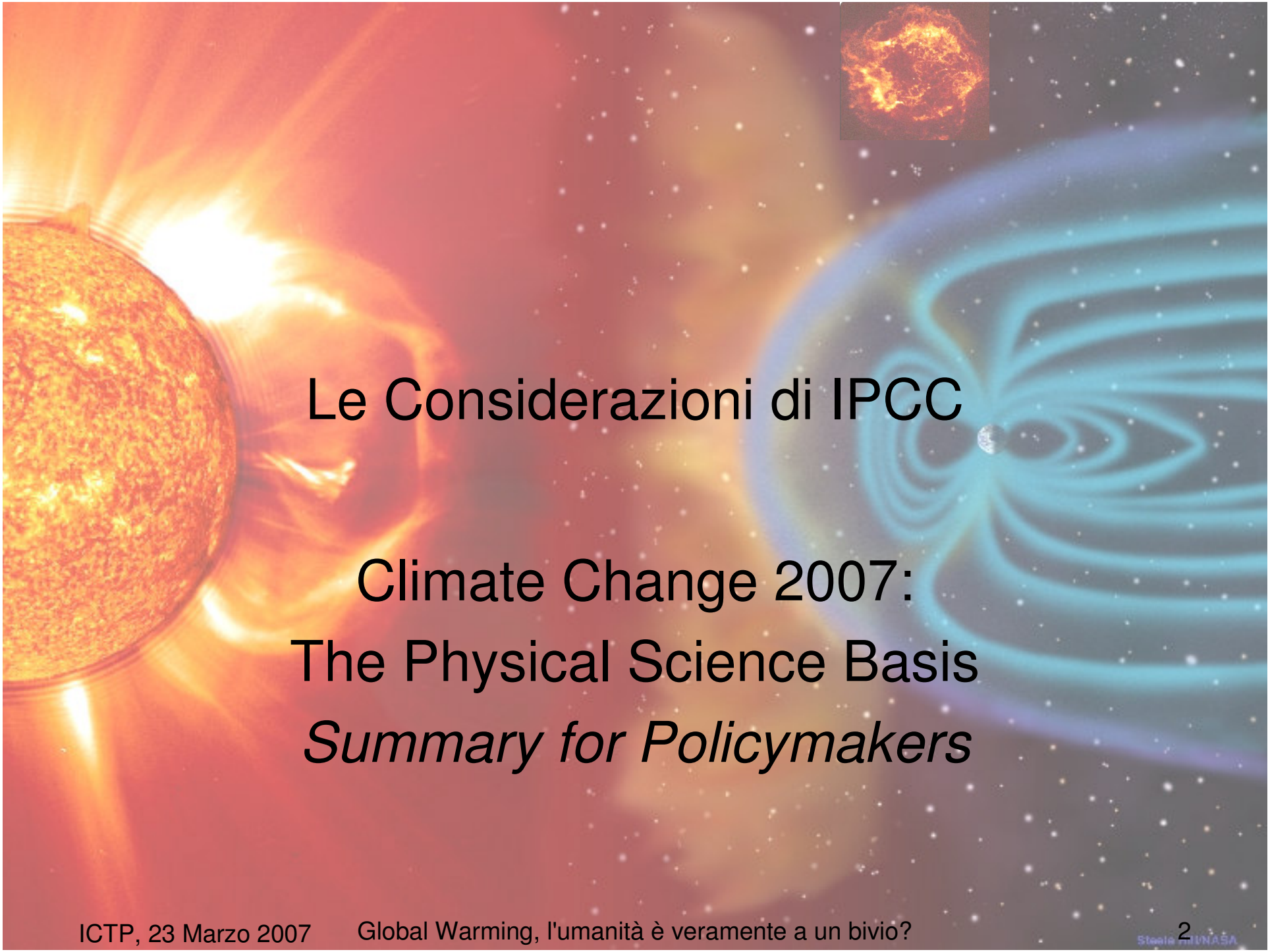
Il ruolo della Meteorologia Spaziale nella comprensione dei cambiamenti climatici

Mauro Messerotti
INAF-Osservatorio Astronomico di Trieste
Dipartimento di Fisica, Università di Trieste



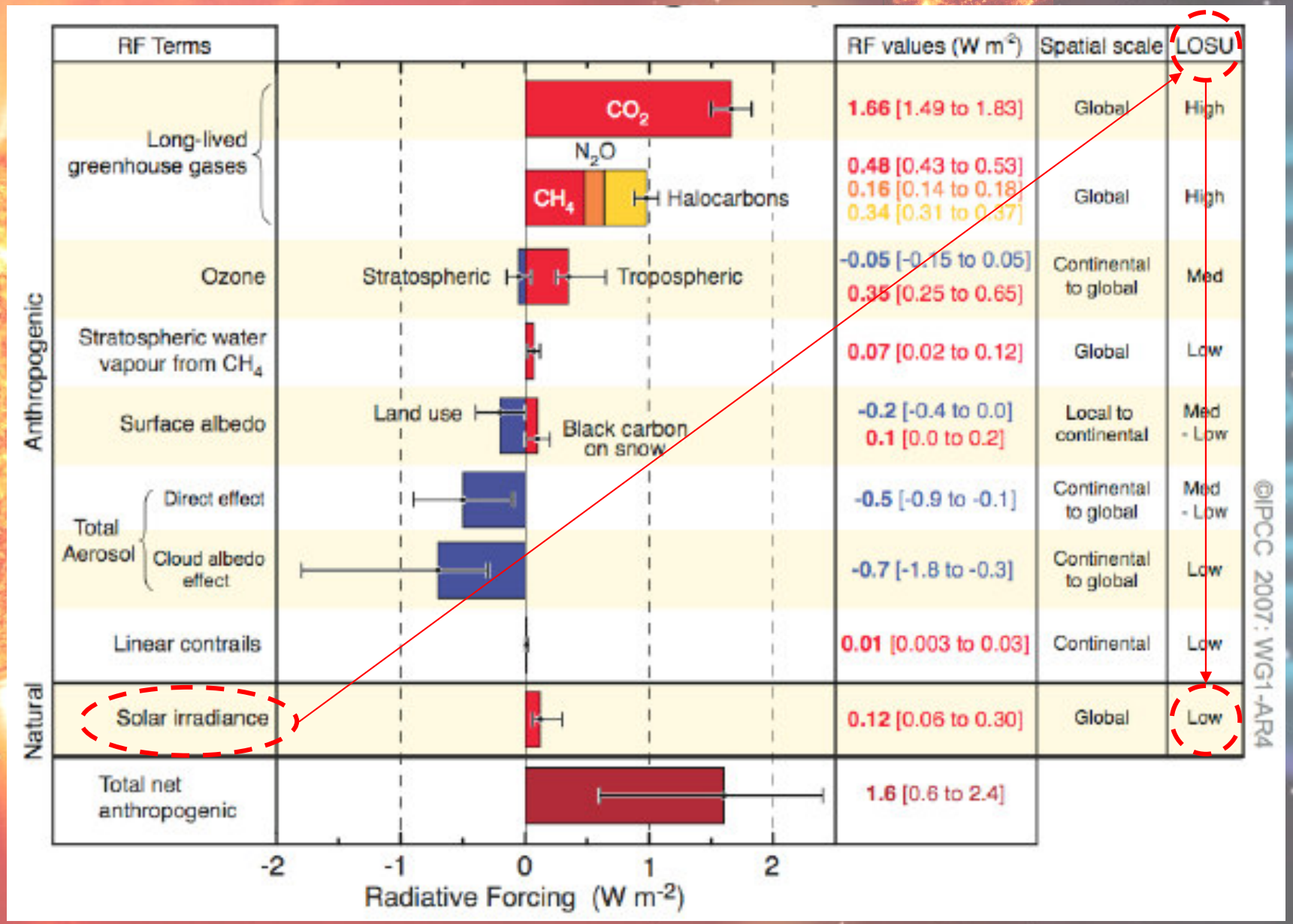
Le Considerazioni di IPCC

Climate Change 2007:
The Physical Science Basis
Summary for Policymakers

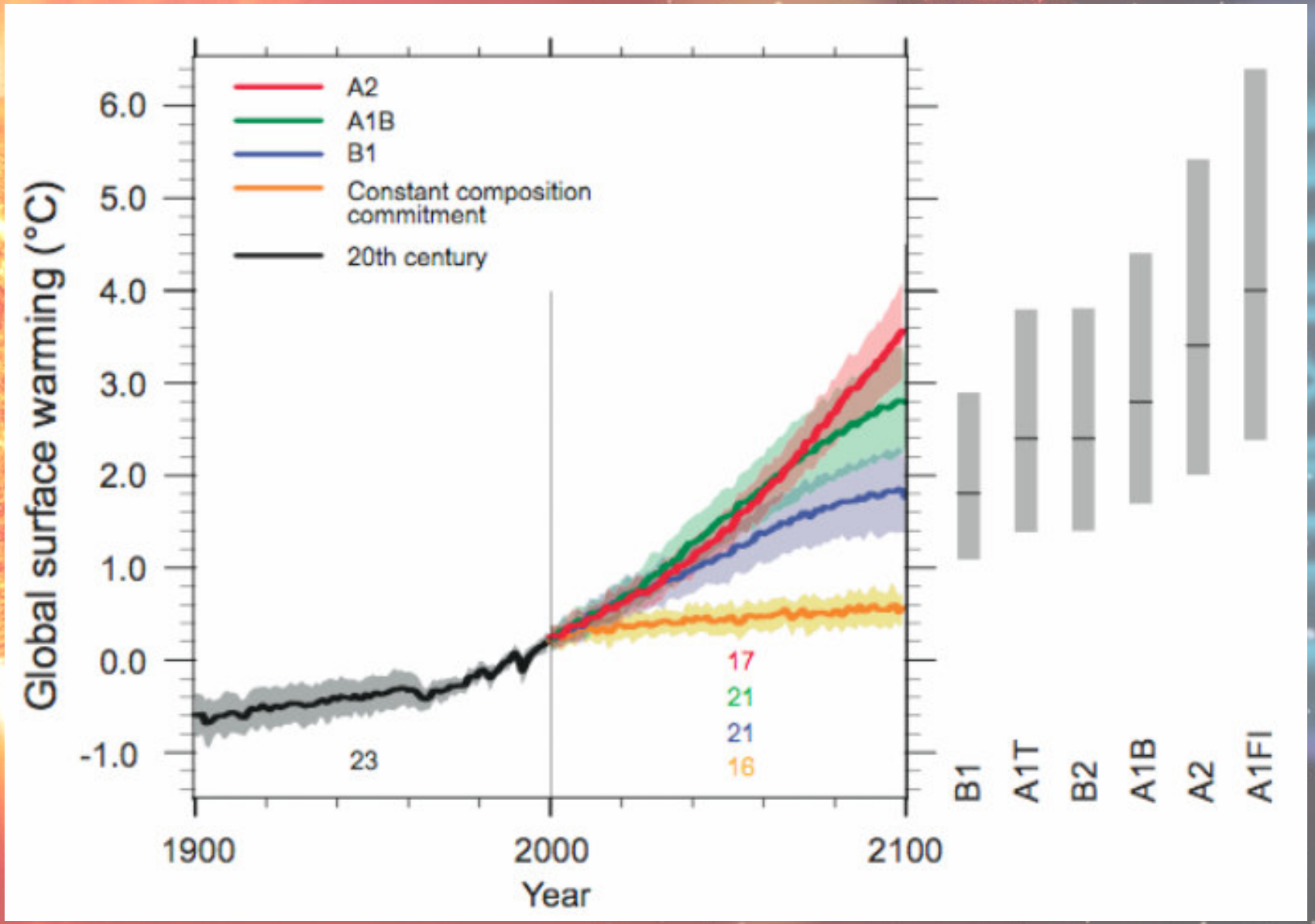
Eventi Meteorologici Estremi: Tendenze, Influenza dell'Uomo, Proiezioni Future secondo IPCC 2007

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend [b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely* [c]	*Likely* [e]	*Virtually certain* [e]
Warmer and more frequent hot days and nights over most land areas	*Very likely* [d]	*Likely (nights)* [e]	*Virtually certain* [e]
Warm spells / heat waves. Frequency increases over most land areas	*Likely*	*More likely than not* [f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not* [f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not* [f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis) [g]	*Likely*	*More likely than not* [f, h]	*Likely* [i]

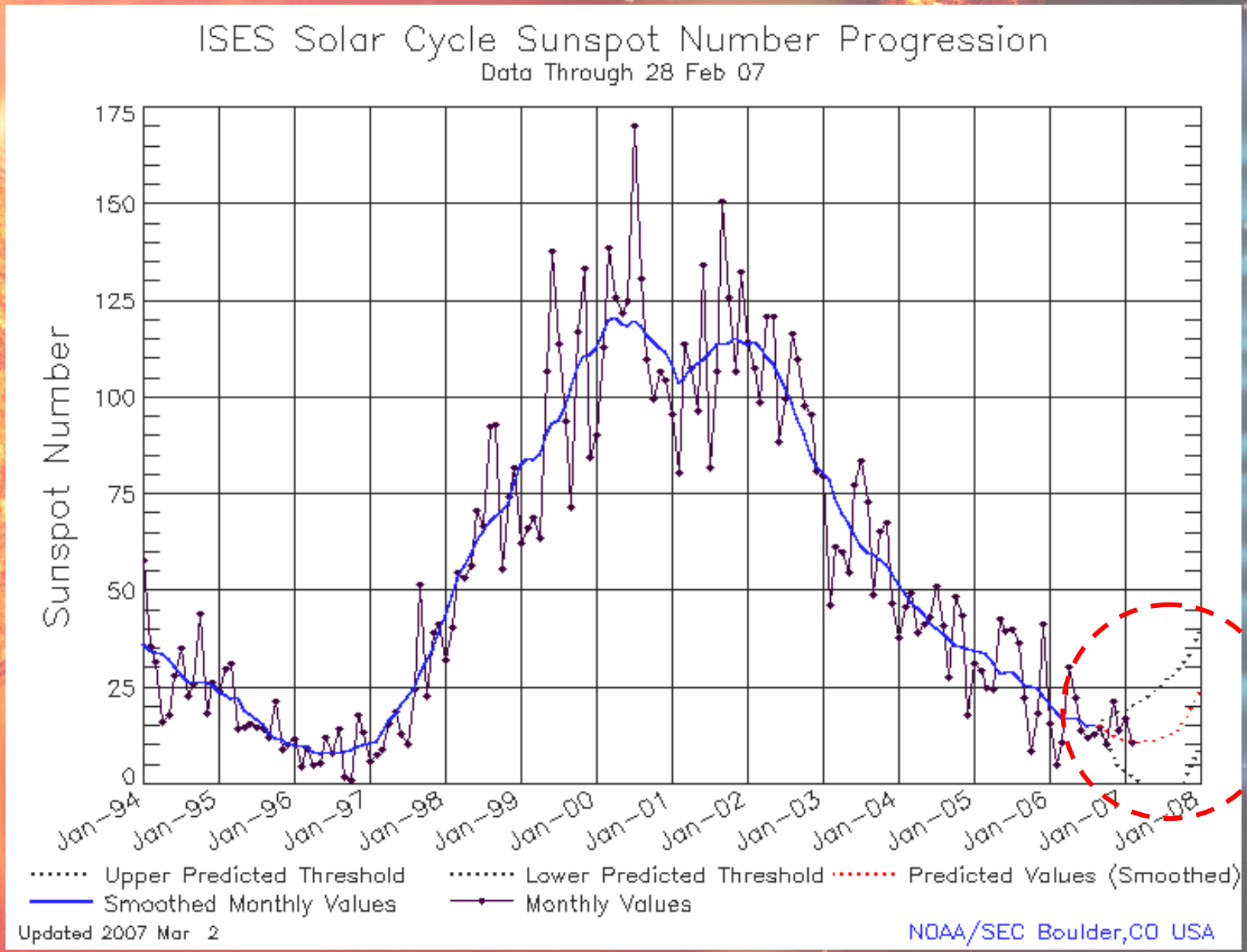
La Forzante Radiativa secondo IPCC 2007



Possibili Scenari Futuri del Riscaldamento Globale secondo IPCC 2007

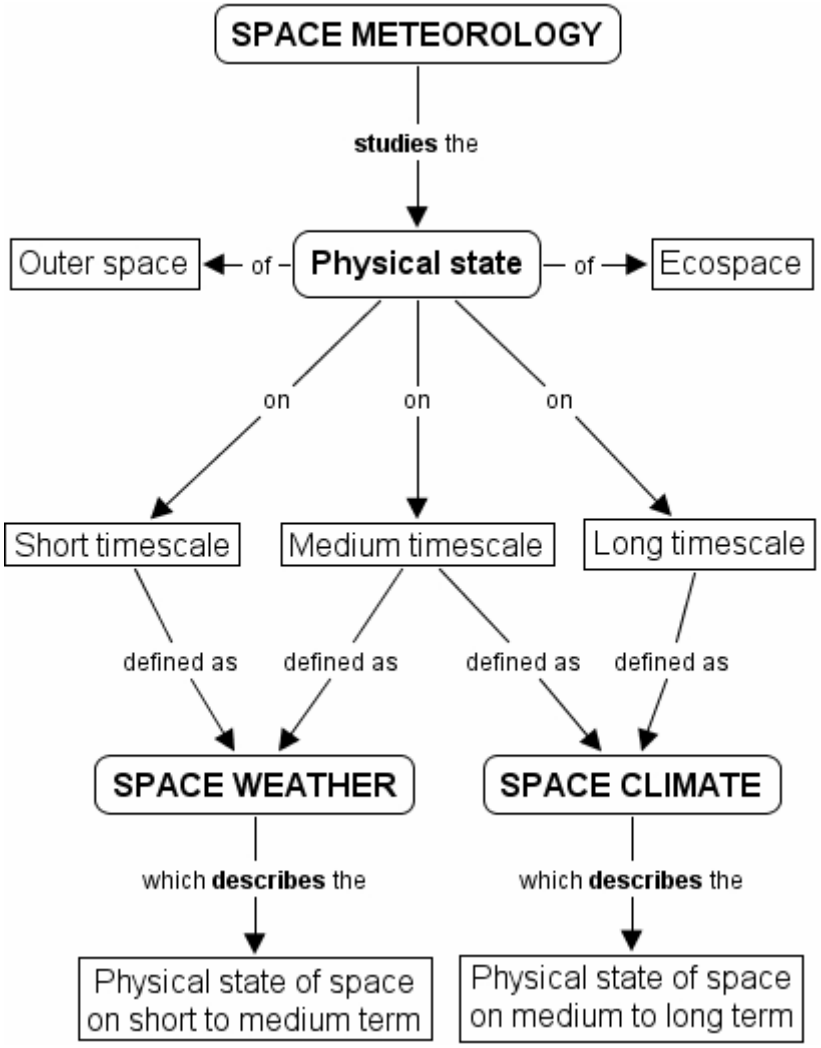


Previsioni sull'Evoluzione del Ciclo di Attività Solare




La Meteorologia Spaziale
Definizioni

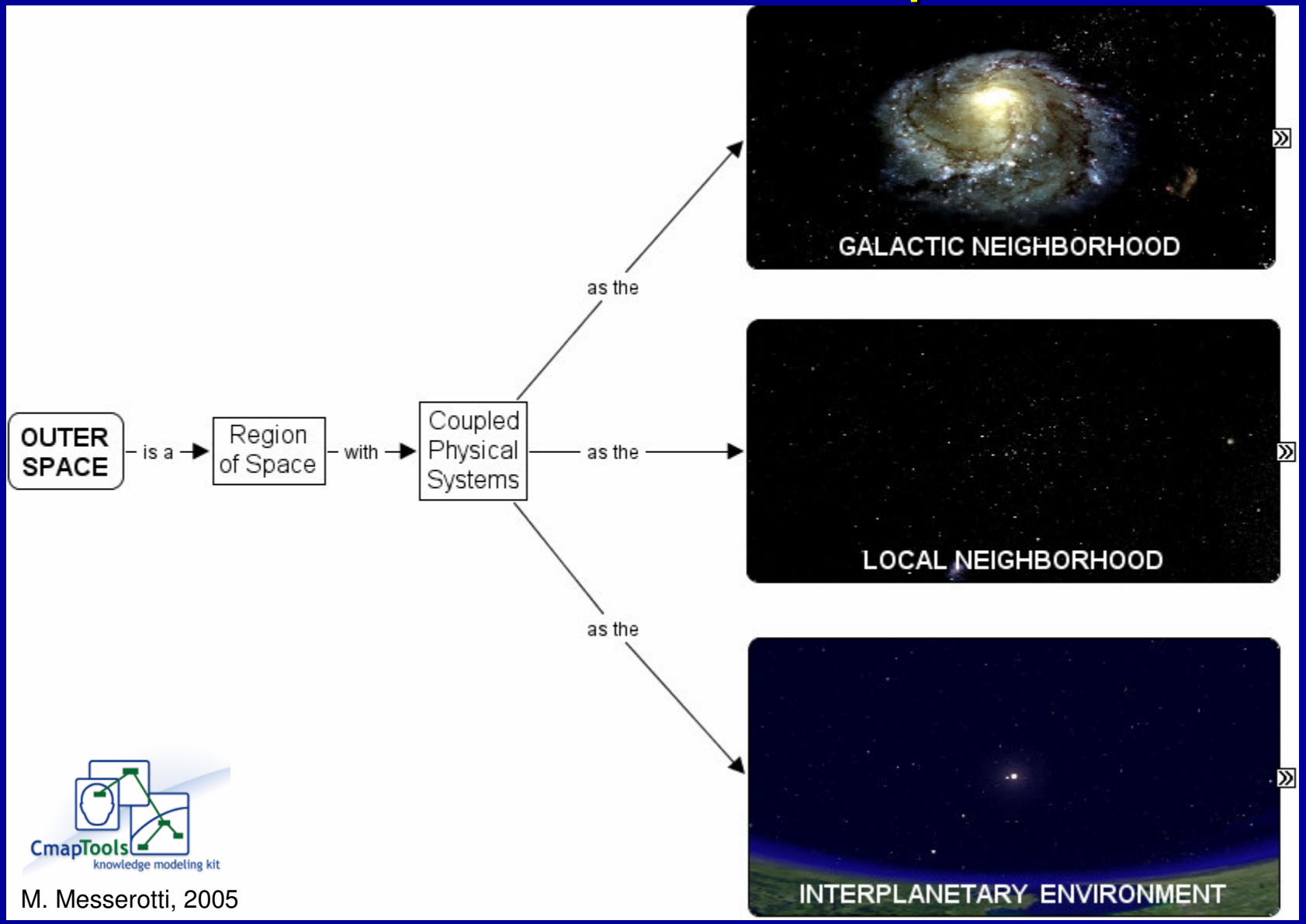
Definition of Space Meteorology



CmapTools knowledge modeling kit

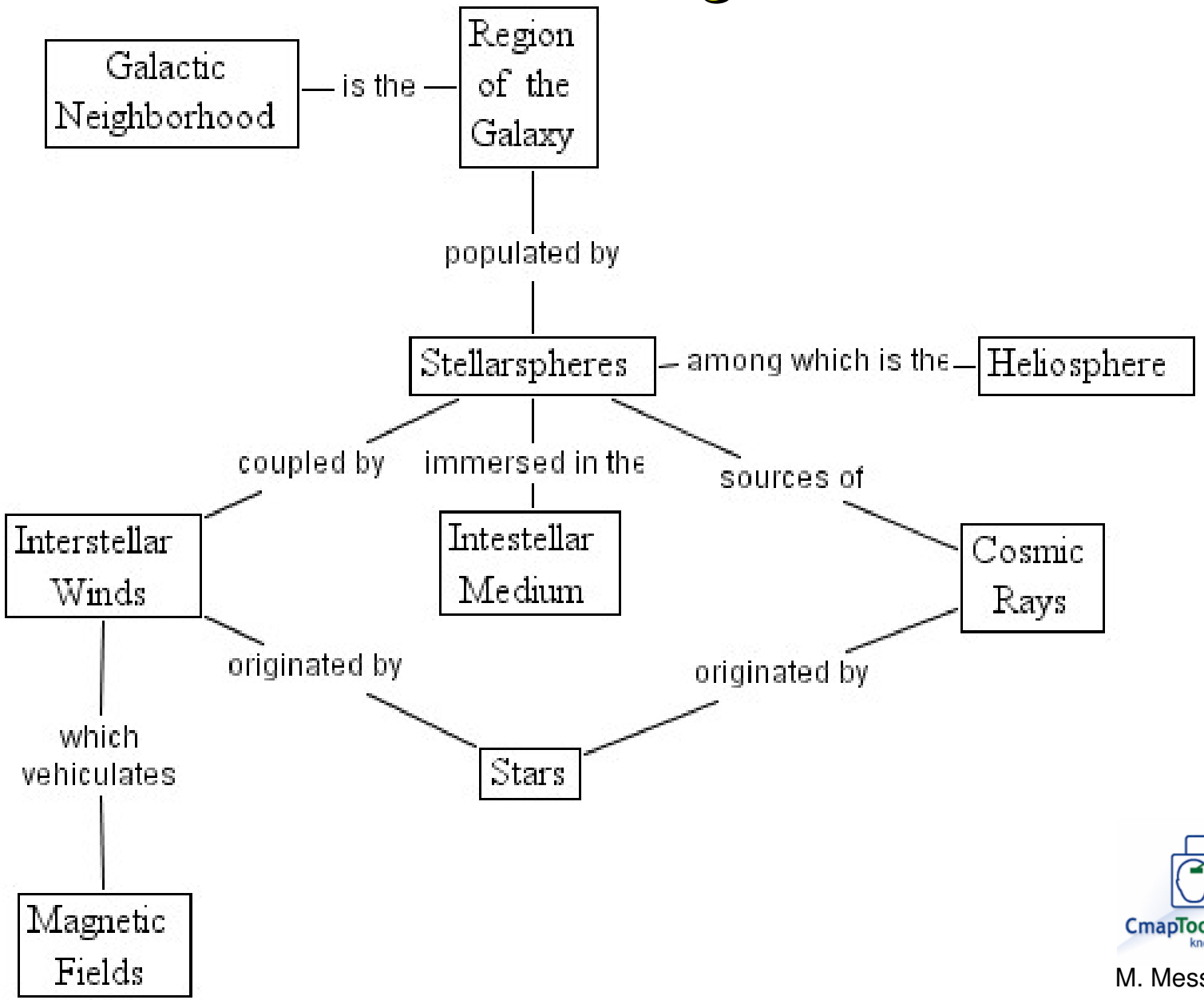
M. Messerotti, 2005

Definition of Outer Space



M. Messerotti, 2005

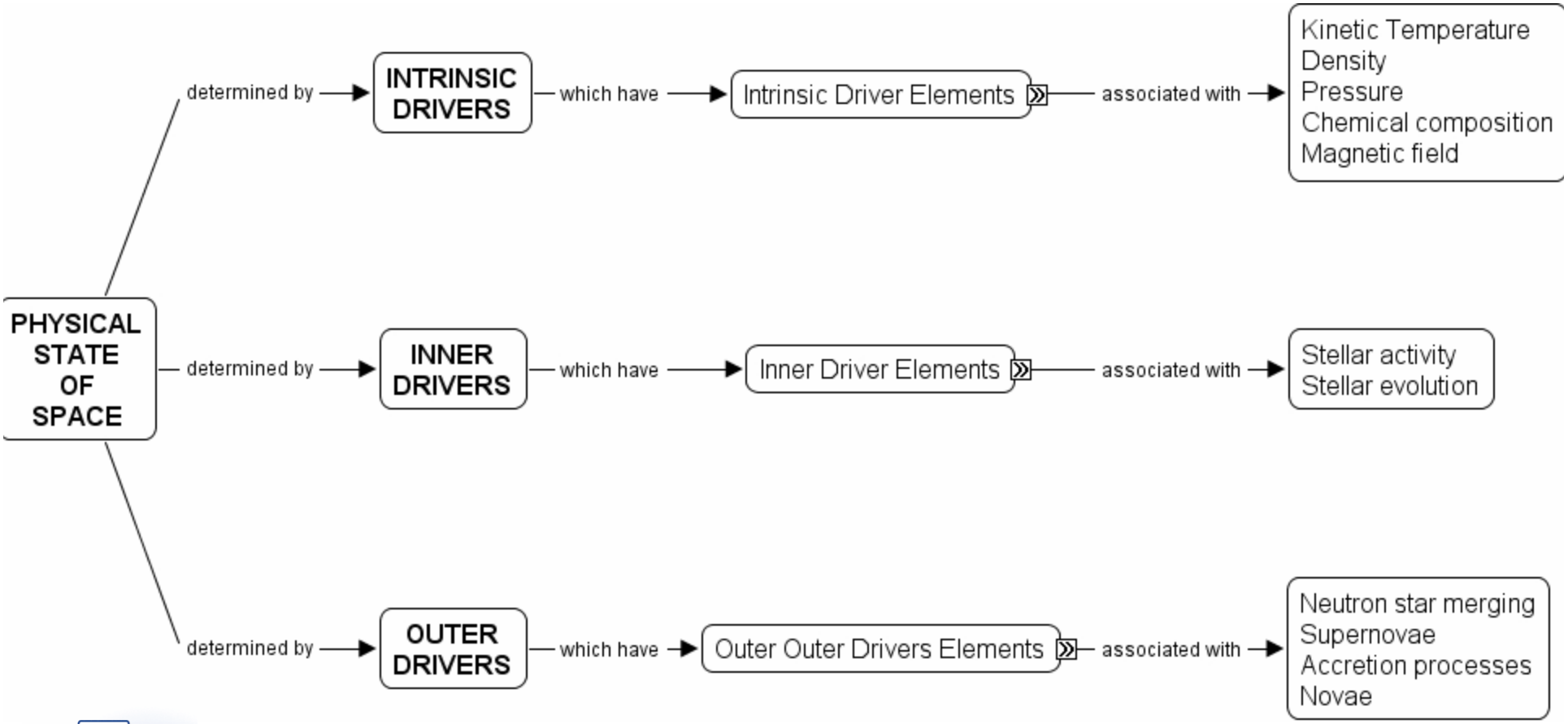
The Galactic Neighborhood



CmapTools knowledge modeling kit

M. Messerotti, 2005

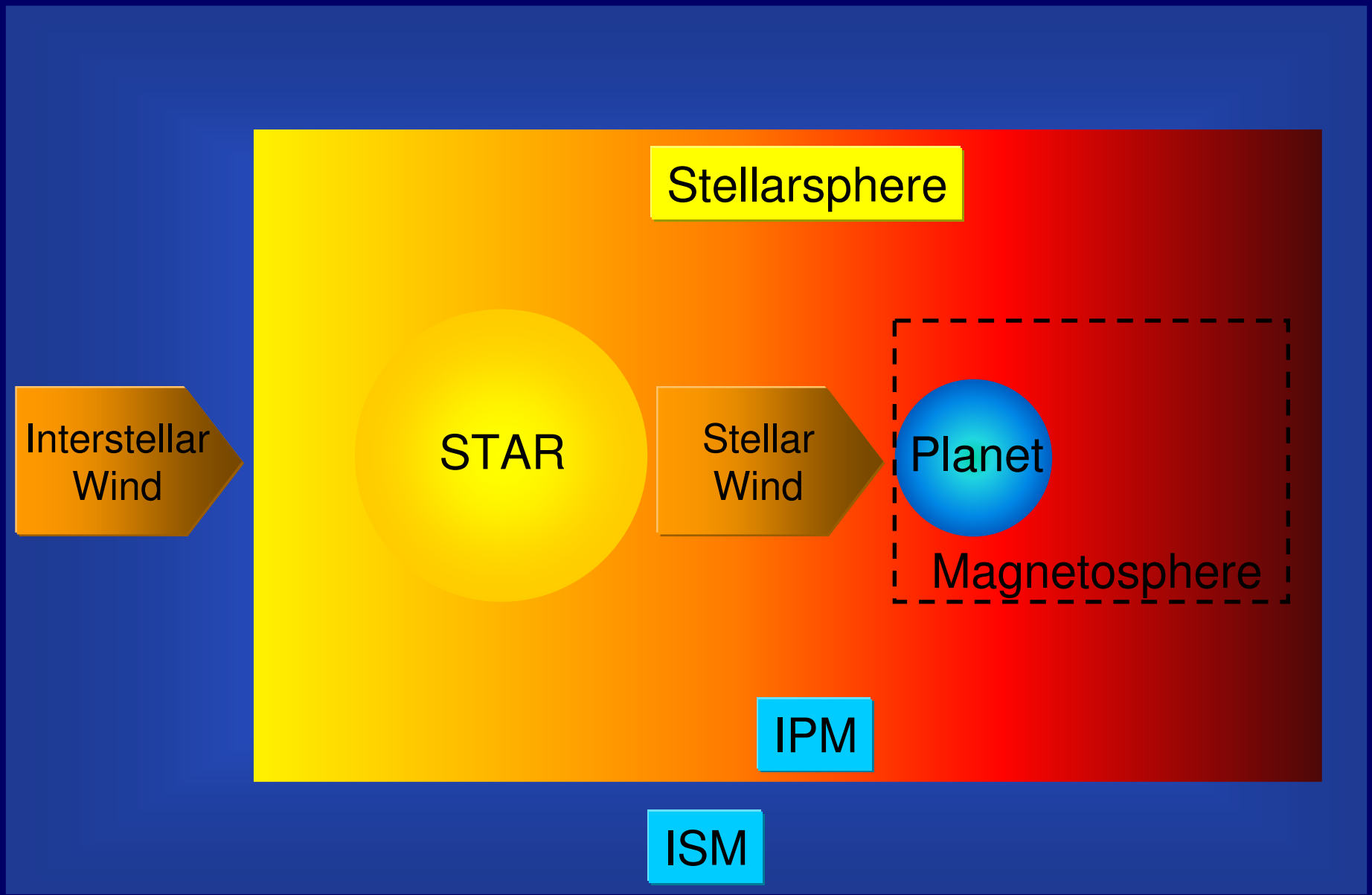
Characterization of the Physical State of Space



CmapTools knowledge modeling kit

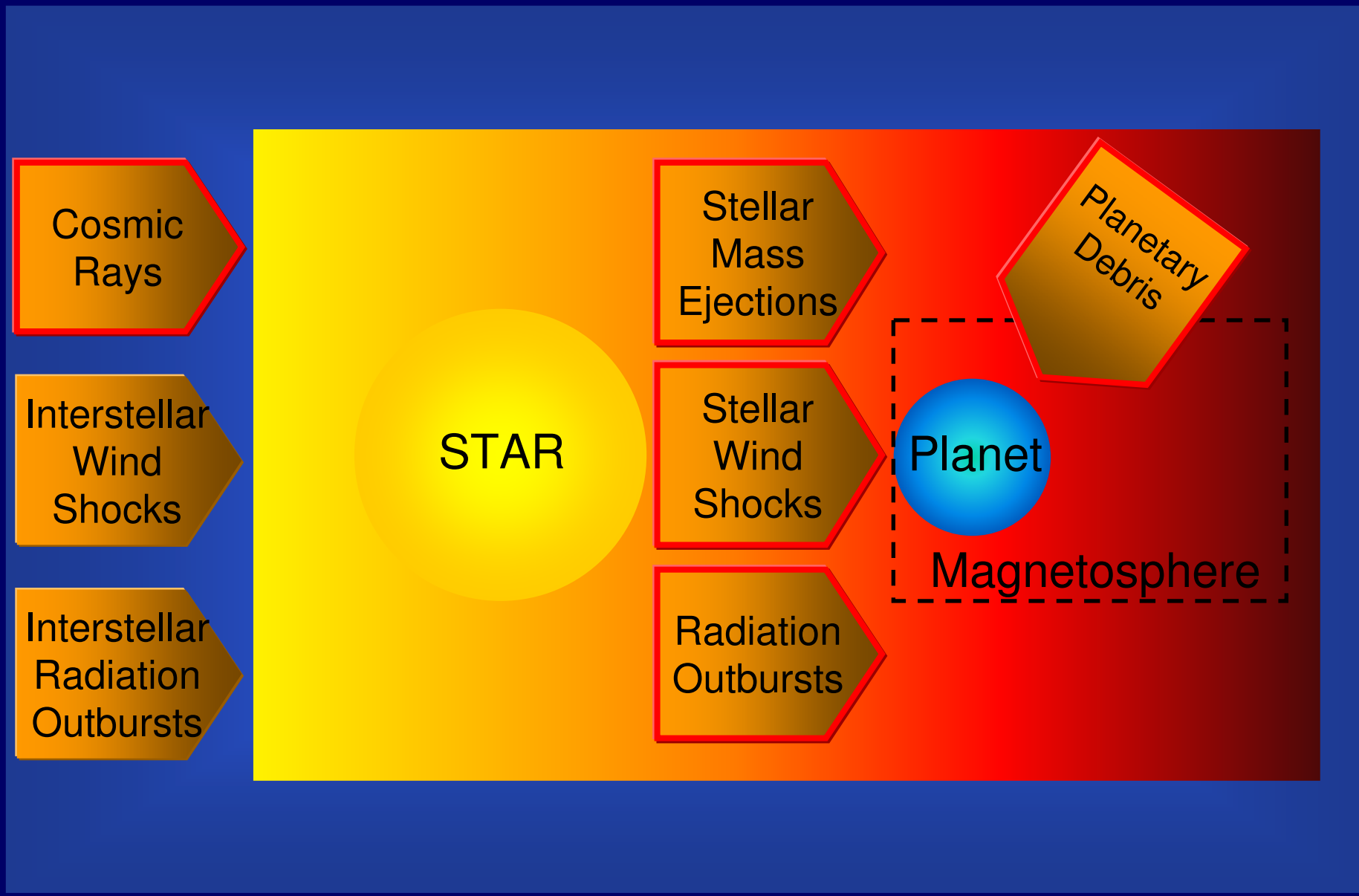
M. Messerotti, 2005

SCHEME OF A STELLAR ENVIRONMENT



Messerotti (2003, 2005)

PERTURBATIONS IN THE STELLAR ENVIRONMENT



Messerotti (2003, 2005)

STELLAR SPACE METEOROLOGY DRIVERS

- STAR
  - L, M, R, Te, cc
  - Magneticity
  - Variability → IRRADIANCE & ENERGETIC PARTICLE VARIATION
  - Wind → PARTICLE FLUX VARIATION
- PLANETARY SYSTEM
  - Orbital dynamics → FLUX CAPTURE AREA VARIATION
  - Population diversity

Messerotti (2003, 2005)

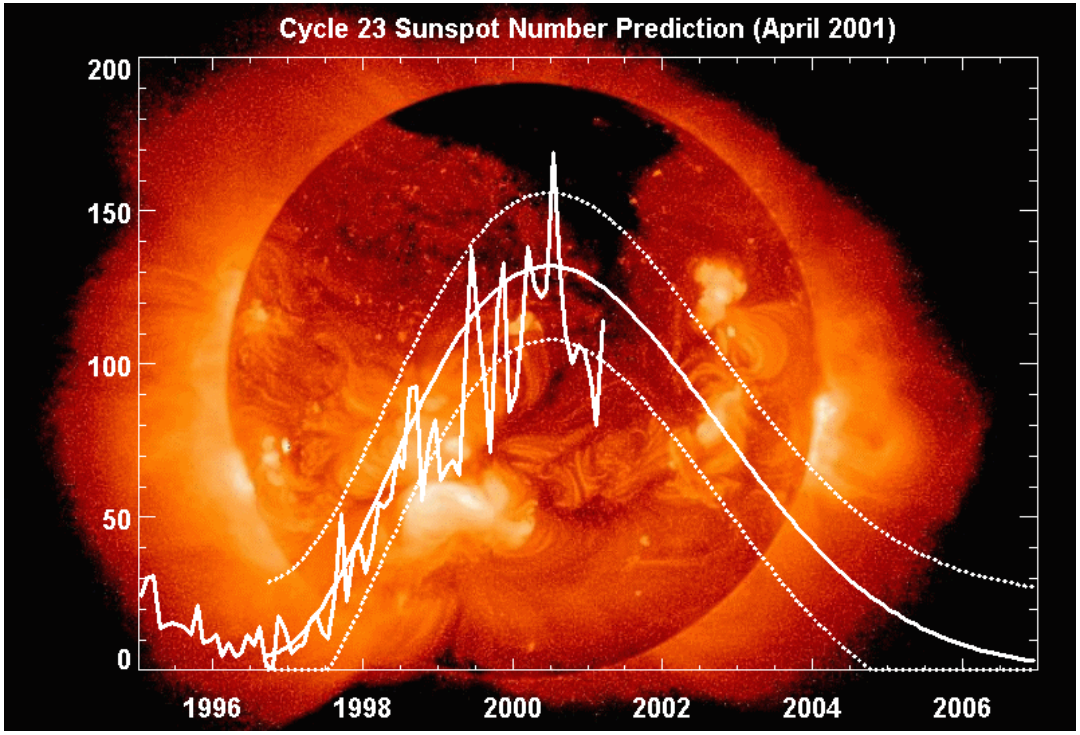
PLANETARY RESPONSE DRIVERS

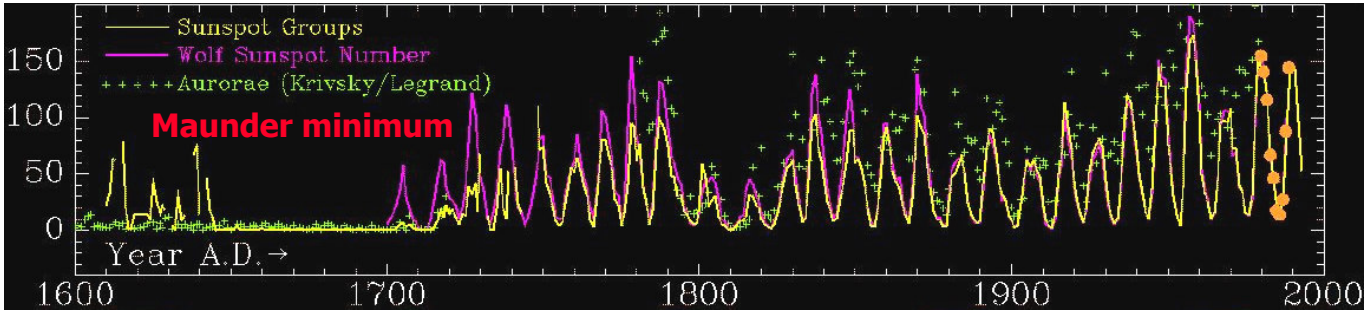
- Mass
- Radius
- Density
- Surface morphology → FLUX REFLECTIVITY
- Atmosphere → ENERGY STORAGE
- Magnetosphere → PARTICLE SHIELDING & ENERGY STORAGE
- Orbital Dynamics → FLUX CAPTURE AREA LONG-TERM VARIATION

Messerotti (2003, 2005)


Possibili Forzanti Spaziali
del Clima Terrestre
Radiazione e Particelle
dal Sole e dalla Galassia

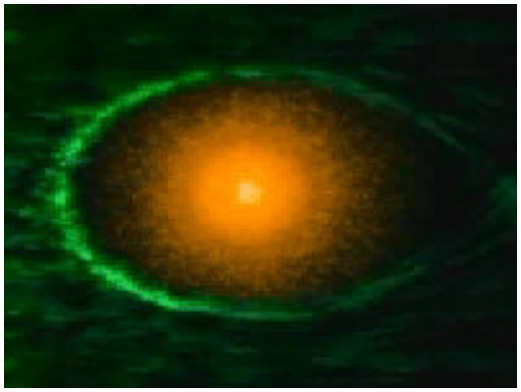
Il Ciclo di Attività Solare

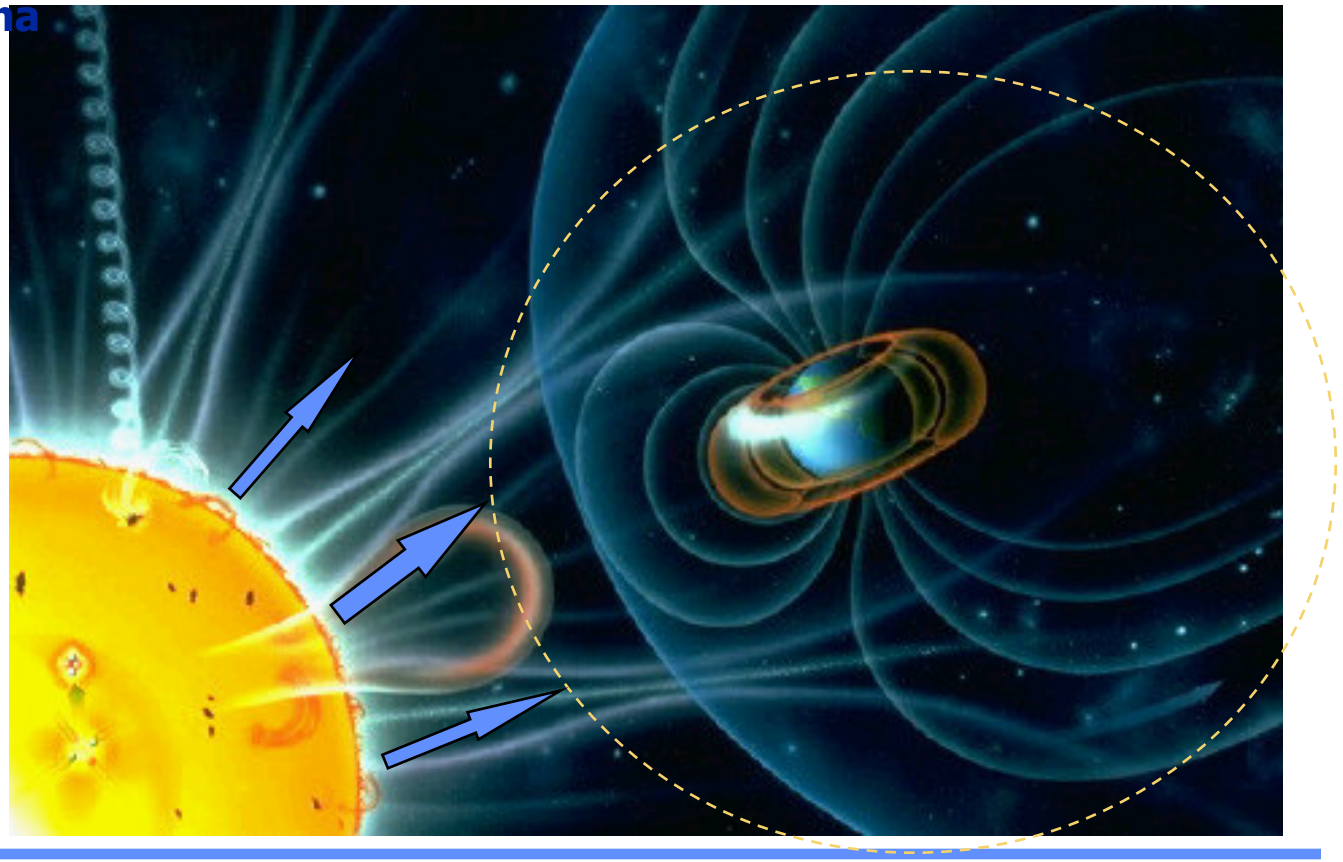




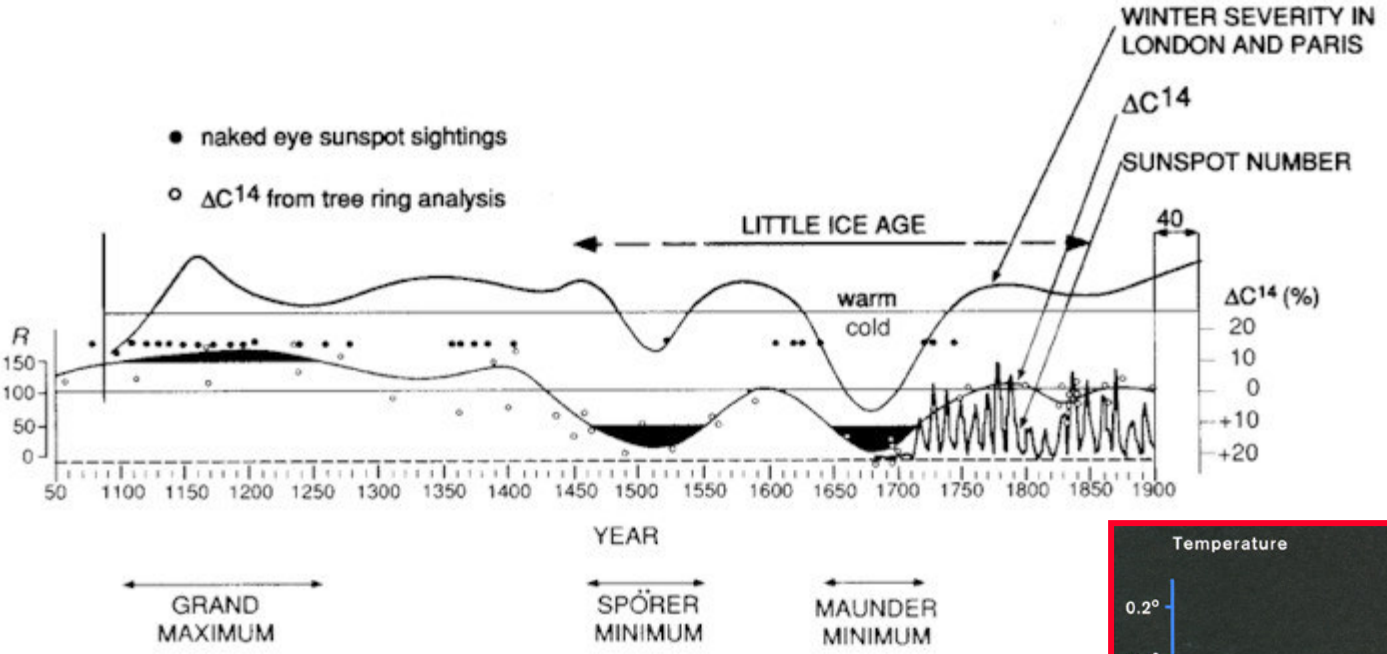
Che cos'è il Vento Solare?

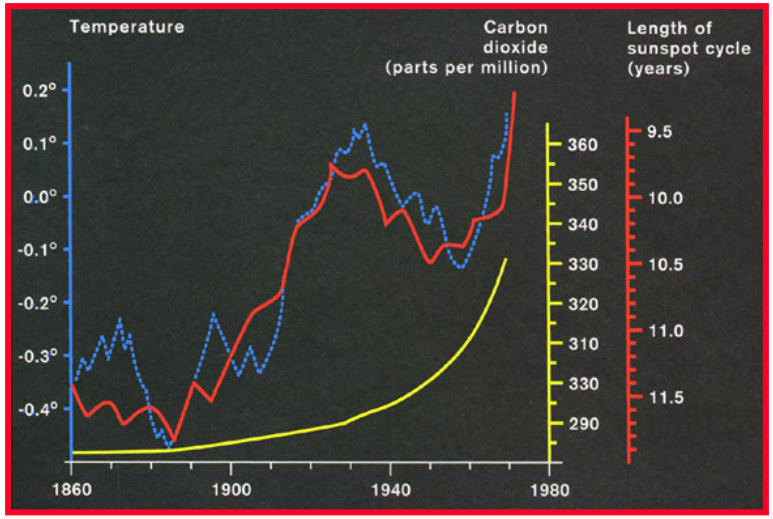
- Un flusso costante di particelle fluisce dalla corona solare, con una temperatura di circa 1 milione di gradi e con una velocità di circa 450 km/s. Il Vento Solare si estende oltre l'orbita di Plutone (circa 5900 milioni di chilometri). Il disegno mostra come esso eserciti una pressione sulla magnetosfera della Terra e ne determini così la forma (linea punteggiata).





Cicli Solari e Variazioni Climatiche

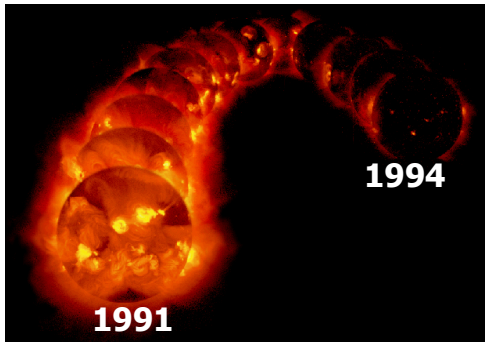


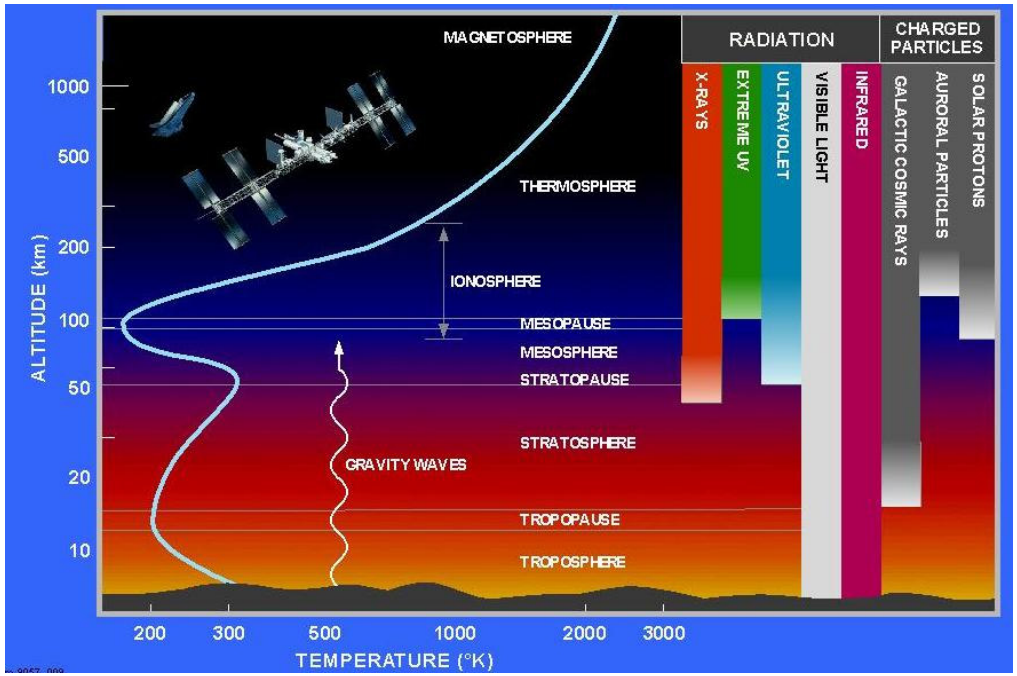


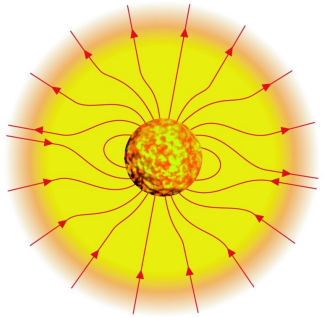
- **11 anni: Ciclo delle macchie (Schwabe)**
- **22 anni: Ciclo Magnetico (Hale)**
- **80-90 anni: Gleissberg**
- **180-210 anni: Seuss**

Il Sole ed il Riscaldamento Globale

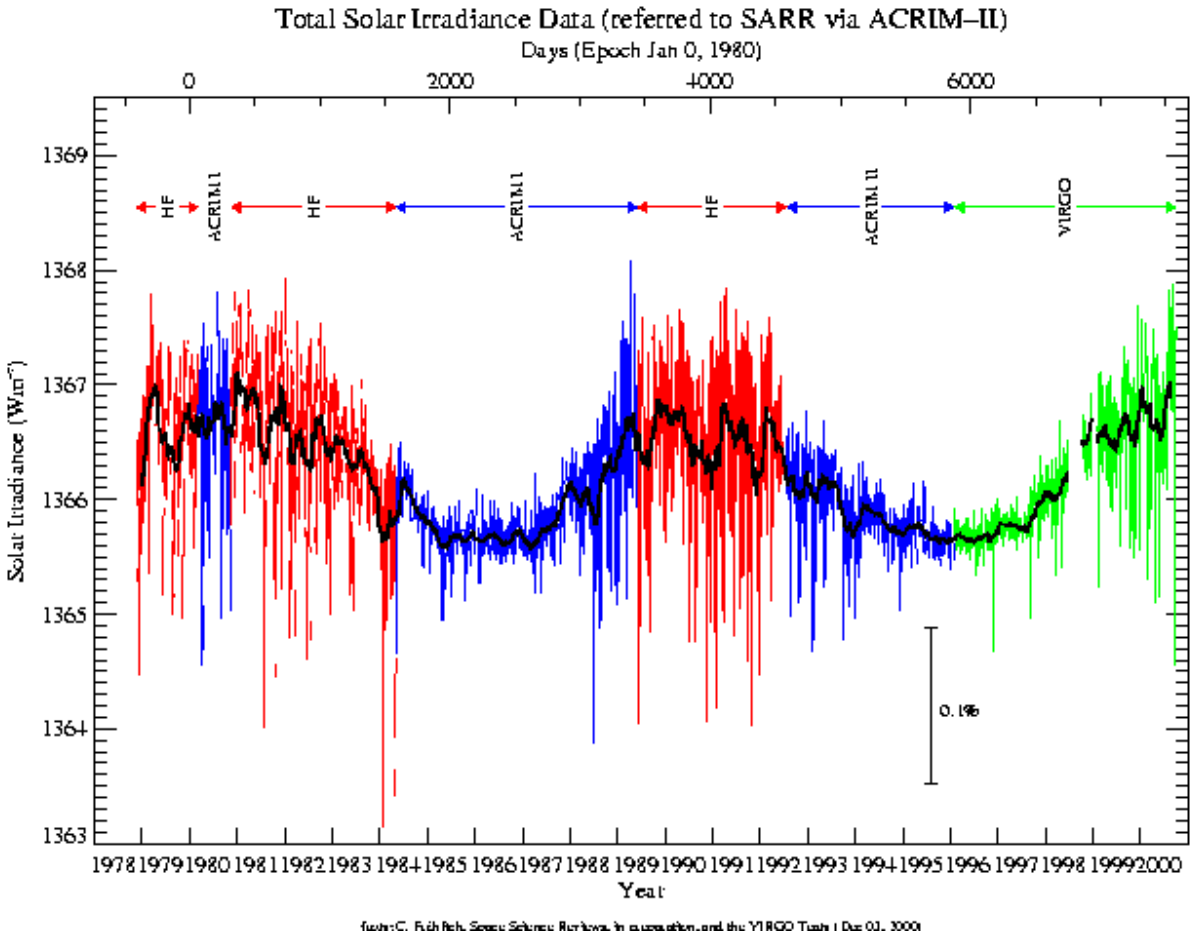
- **Variazione a lungo termine della radianza totale ("energia totale")**
  - **Si assume che giustifichi solo in parte il riscaldamento globale**
- **Variazione a lungo termine della radiazione UV/EUV:**
  - **Cambiamenti della chimica (ozono), temperatura ecc. nell'atmosfera terrestre. Potrebbe determinare variazioni climatiche.**
- **Variazione a lungo termine del campo magnetico del Sole**
  - **Modula i Raggi Cosmici ed il Vento Solare**



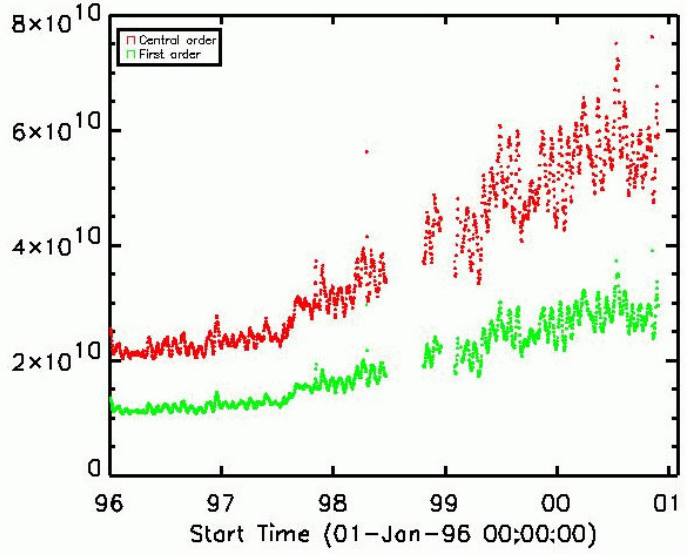




Misure della Radianza Solare
Il Sole come Stella



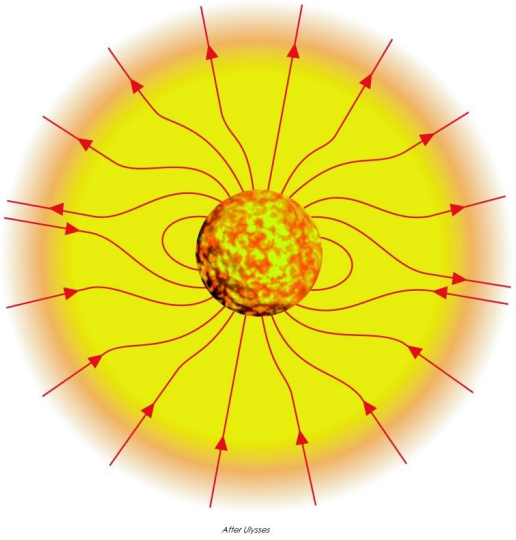
- **VIRGO – Radianza solare totale**
- **CDS: Radianza spettrale EUV a 307-380 Å e 515-632 Å e 69 immagini del disco solare riprese ogni mese**
- **SEM (CELIAS): Flusso EUV integrato sul disco da 1-500Å e 260-340 Å (He II 304 Å)**

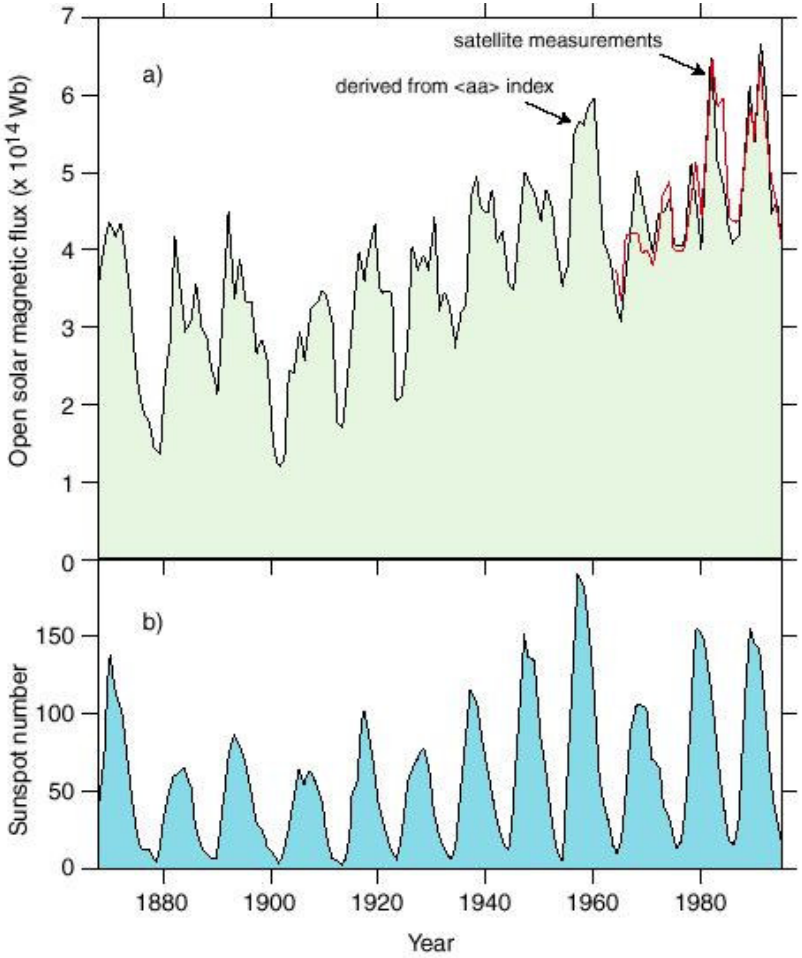


Variazioni del Flusso Magnetico Solare

- **Il flusso magnetico solare è aumentato di un fattore pari a 2,3 dal 1901**

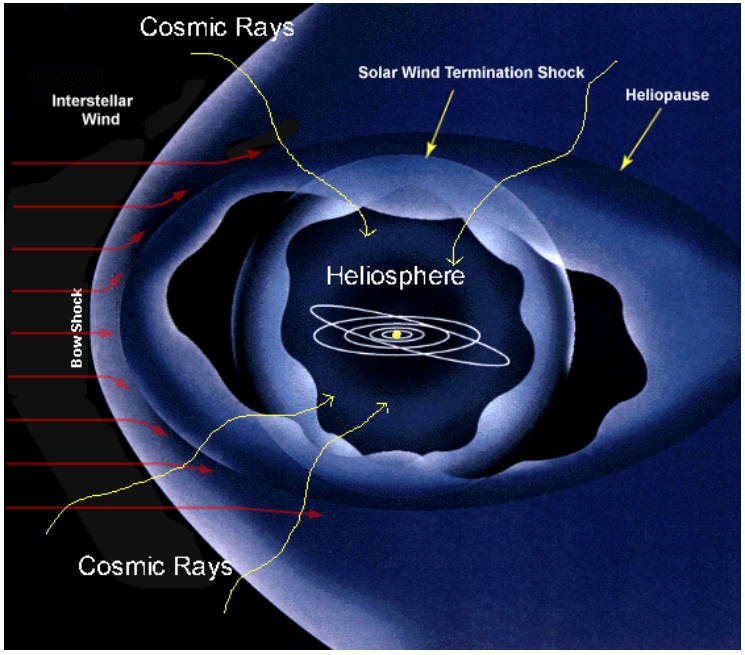
- **Le variazioni a lungo termine della radianza solare totale possono da sole spiegare:**
  - **L'aumento di temperatura del 52% fra il 1910 ed il 1960**
  - **L'aumento del 31% dal 1970**

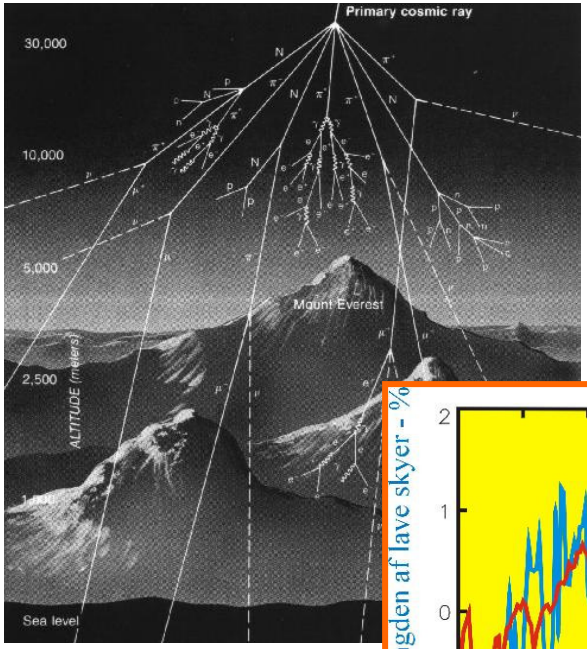


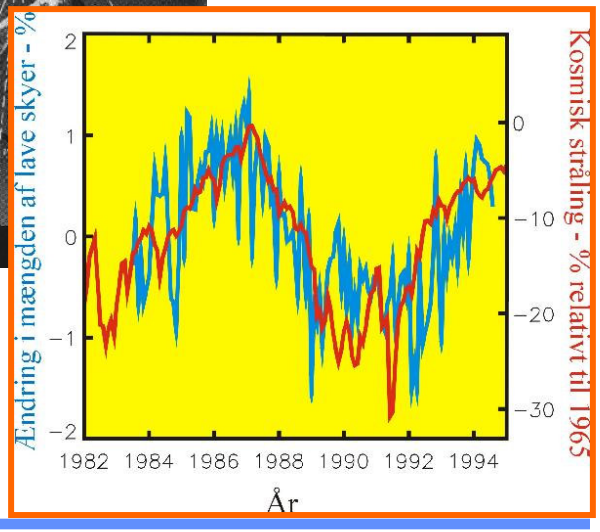


I Raggi Cosmici e le Nuvole

- **Variazioni dell'attività solare e del campo magnetico solare modificano la quantità di particelle cosmiche, che penetrano nel Sistema Solare (e nell'atmosfera della Terra).**





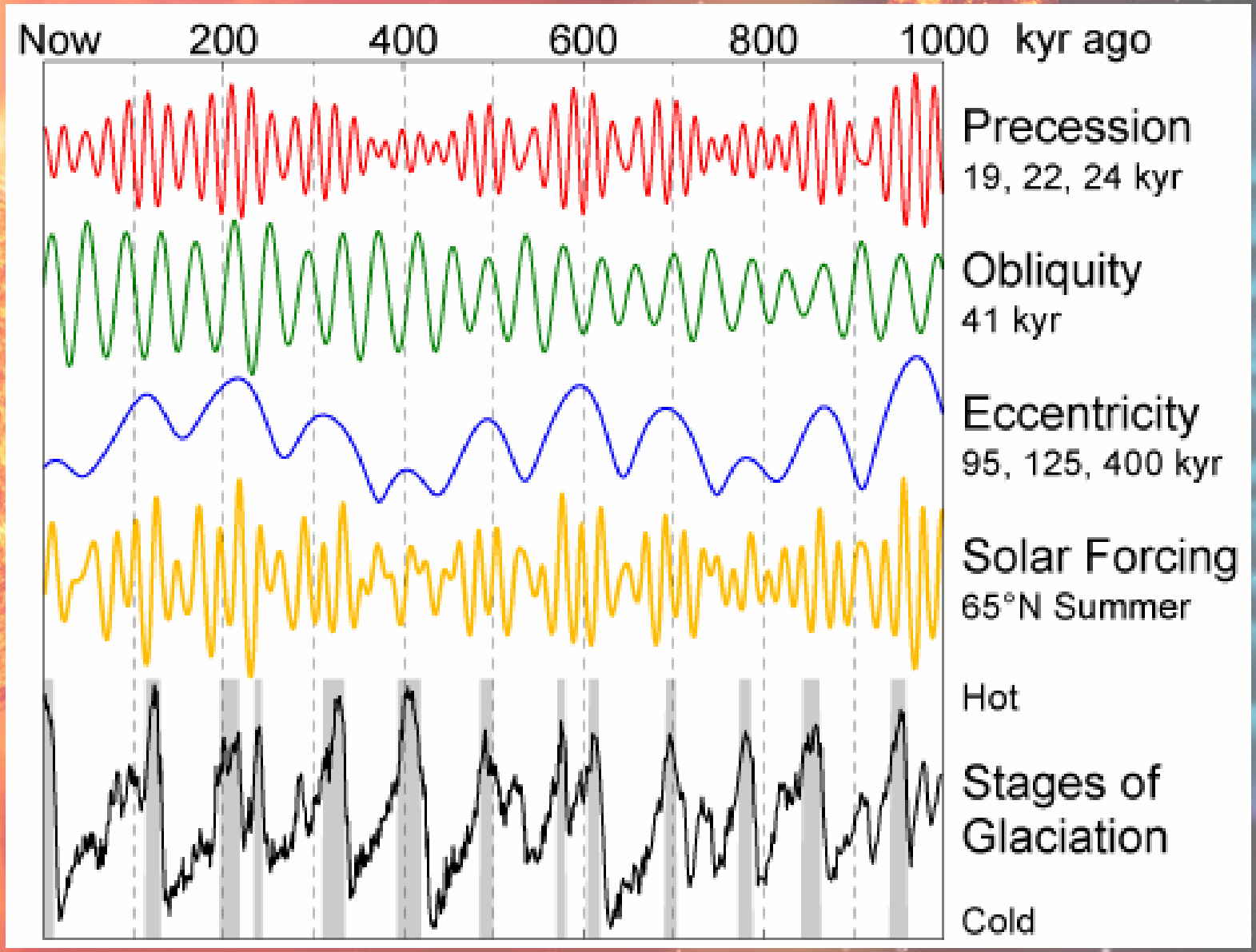


- **E' stata trovata una forte correlazione fra il flusso di raggi cosmici e le nuvole basse**
- **La copertura nuvolosa globale è un importante fattore per la determinazione del clima**

Periodicità Climatiche

La Teoria di Milankovitch

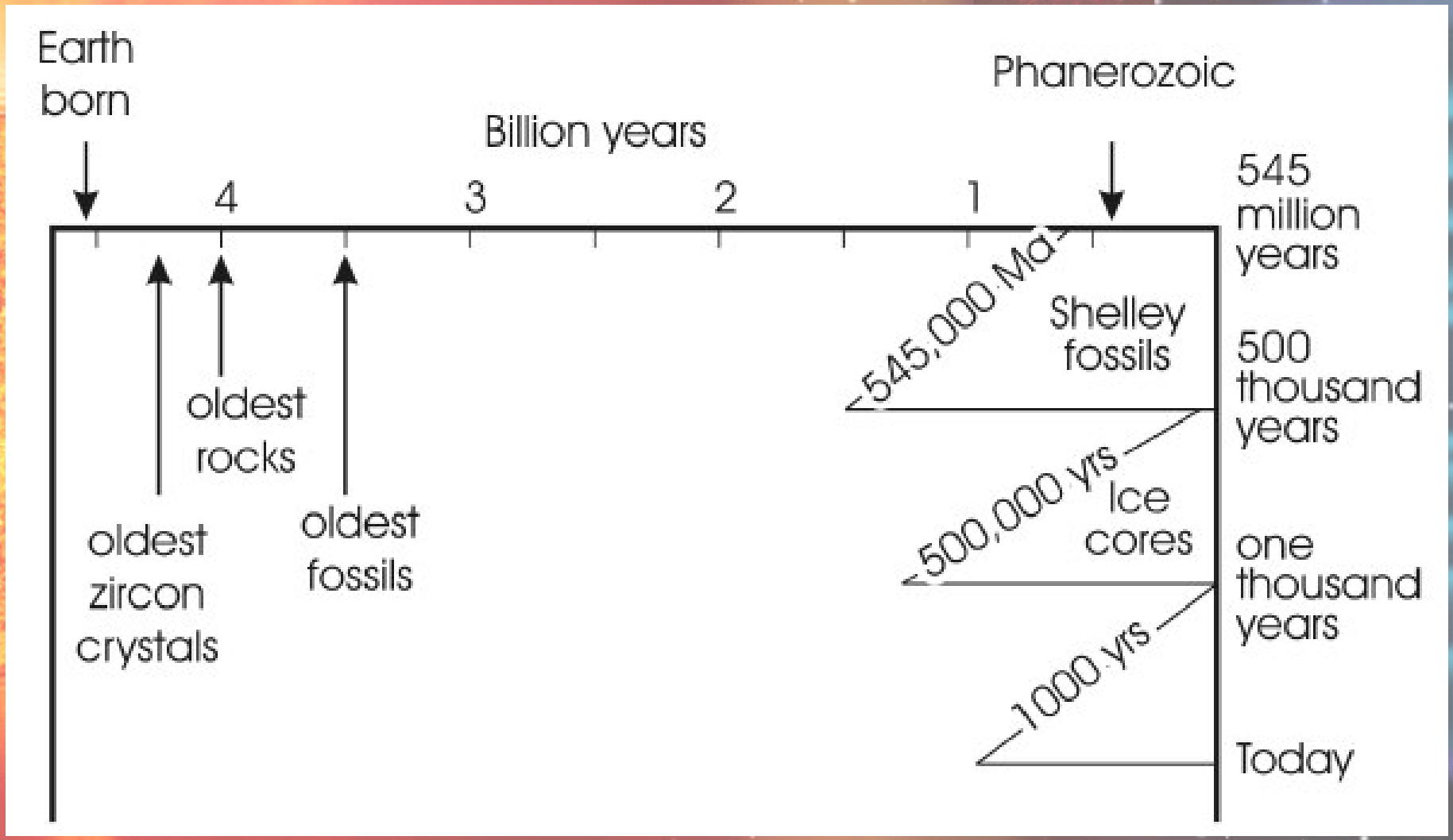
Periodicità delle Glaciazioni



Forzanti Spaziali del Clima Terrestre

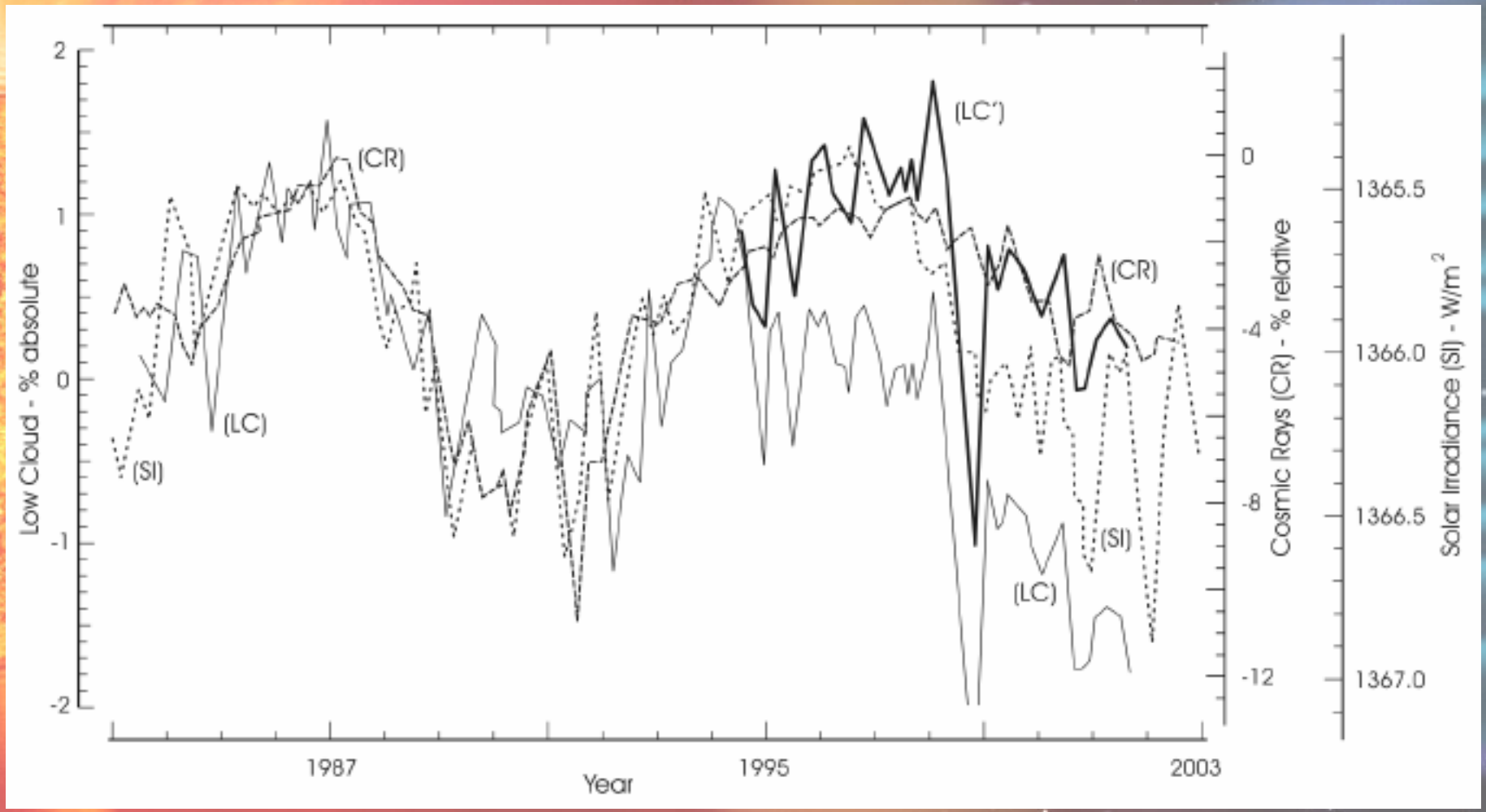
La Lezione del Paleoclima

Time Scales and Proxies of Earth Paleoclimate



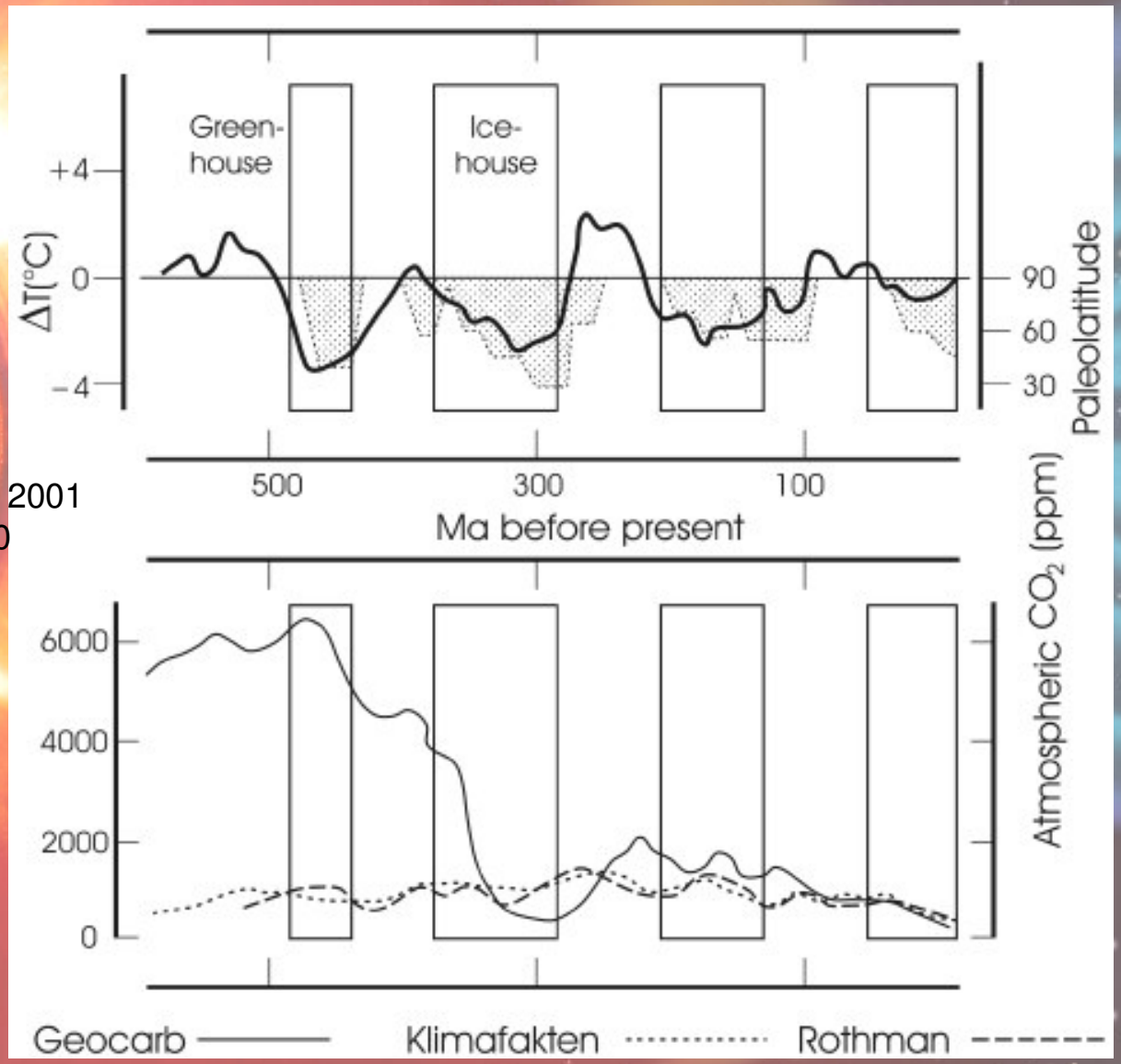
J. Veizer, 2005

Solar Irradiance (SI), Galactic Cosmic Ray Flux (CR) and Low Cloud Cover (LC)



Marsh and Svensmark, 2003; Marsh, 2005

Phanerozoic Climatic Indicators and Reconstructed pCO_2 Levels

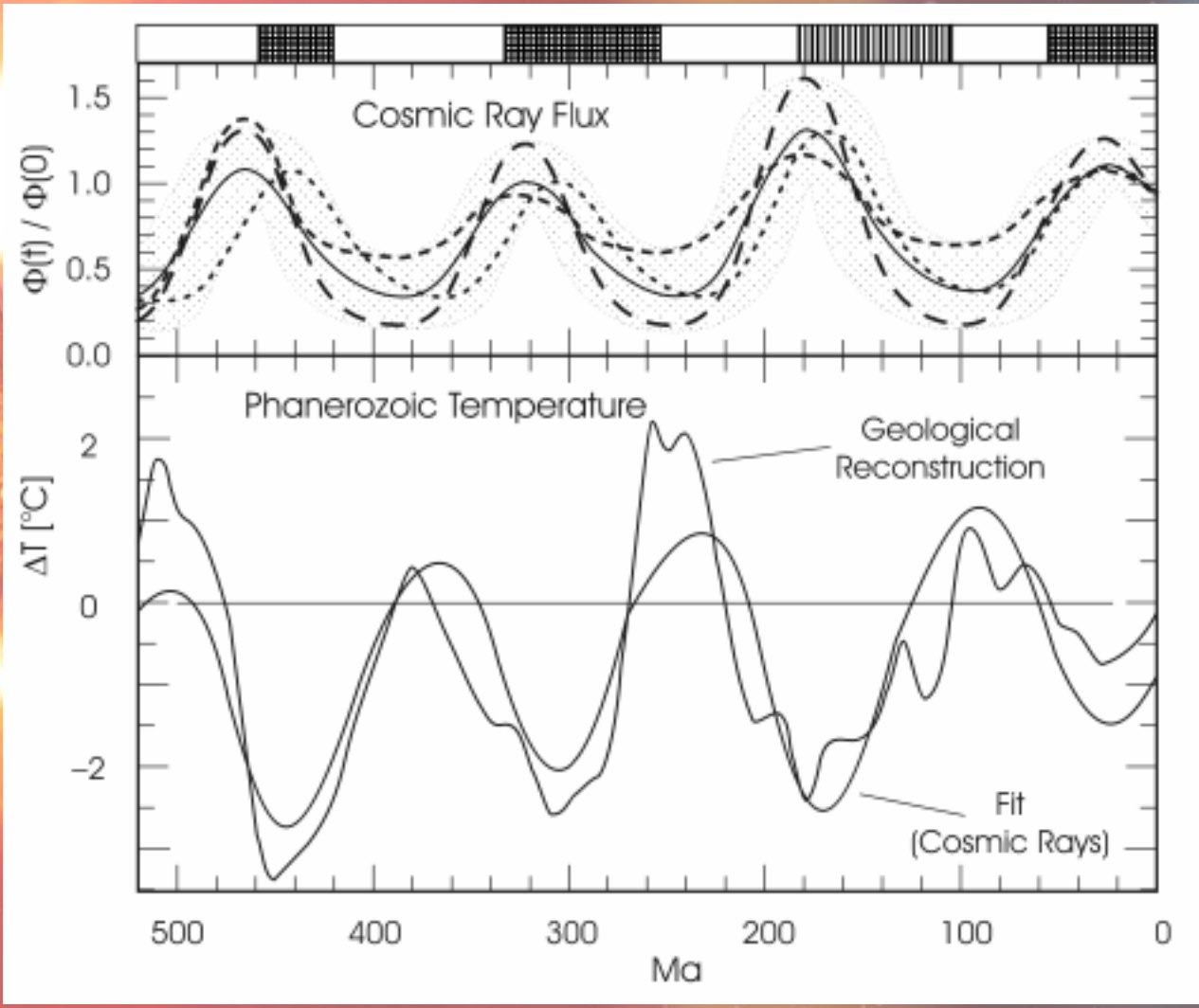


Veizer et al., 2000
Berner & Kothavala, 2001
Berner & Streif, 2000
Rothman, 2002

P – 10 My

CO_2 is not the driver

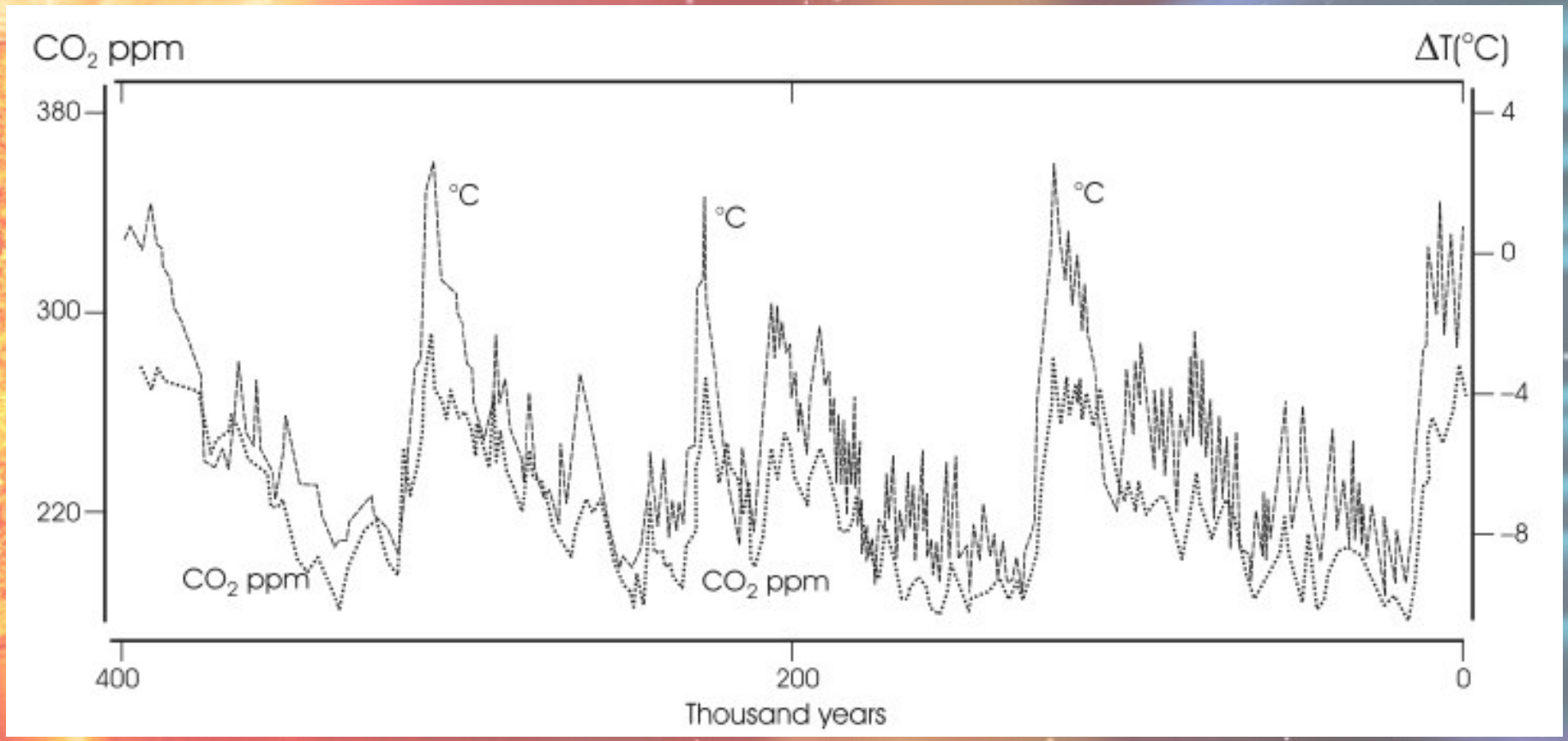
Cosmic Ray Flux and Tropical Seawater Temperature Variations over the Phanerozoic



CRs are the candidate driver

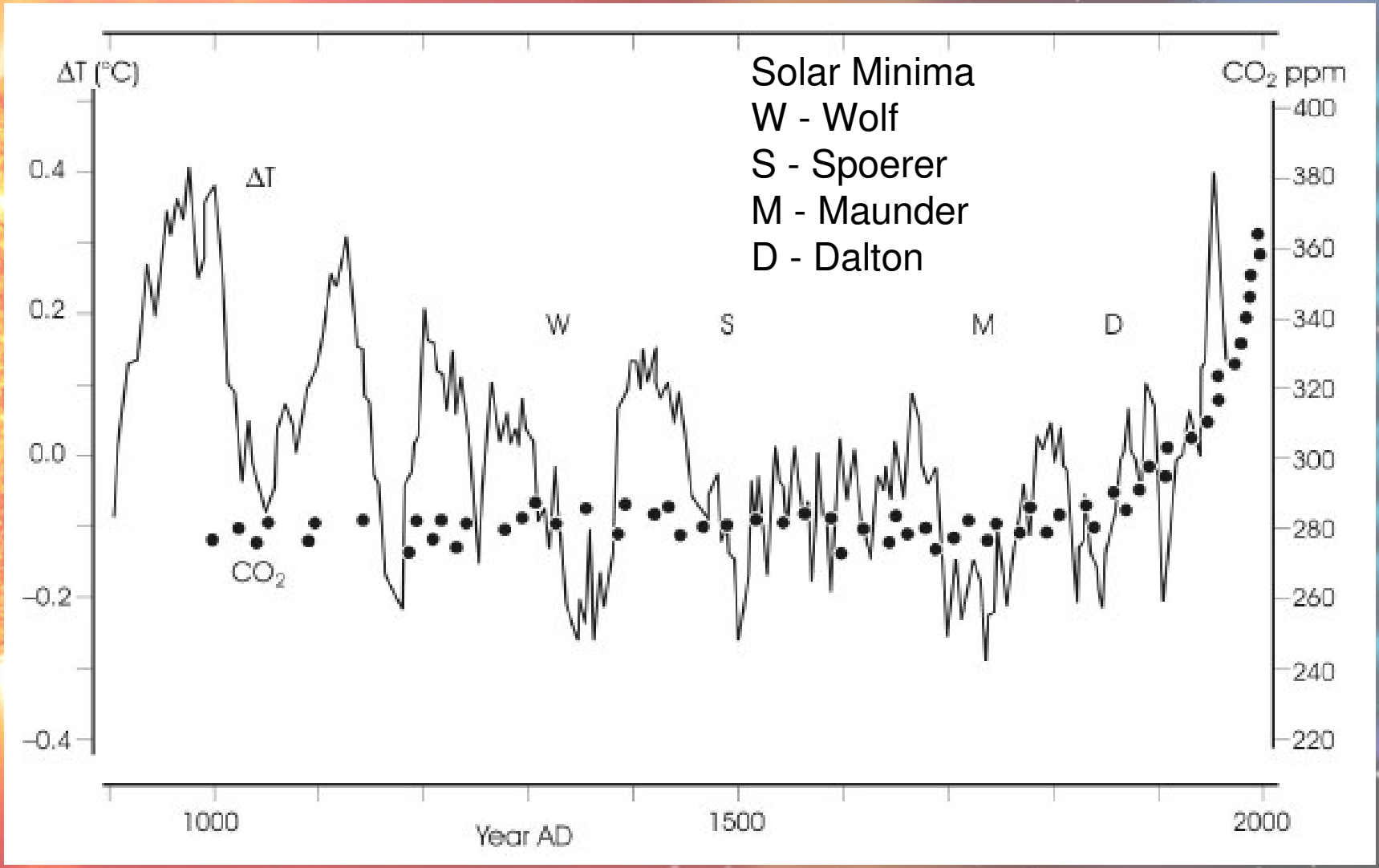
Shaviv and Veizer, 2003

Antarctic (Vostok) Ice Core Data for the Last 400,000 Years



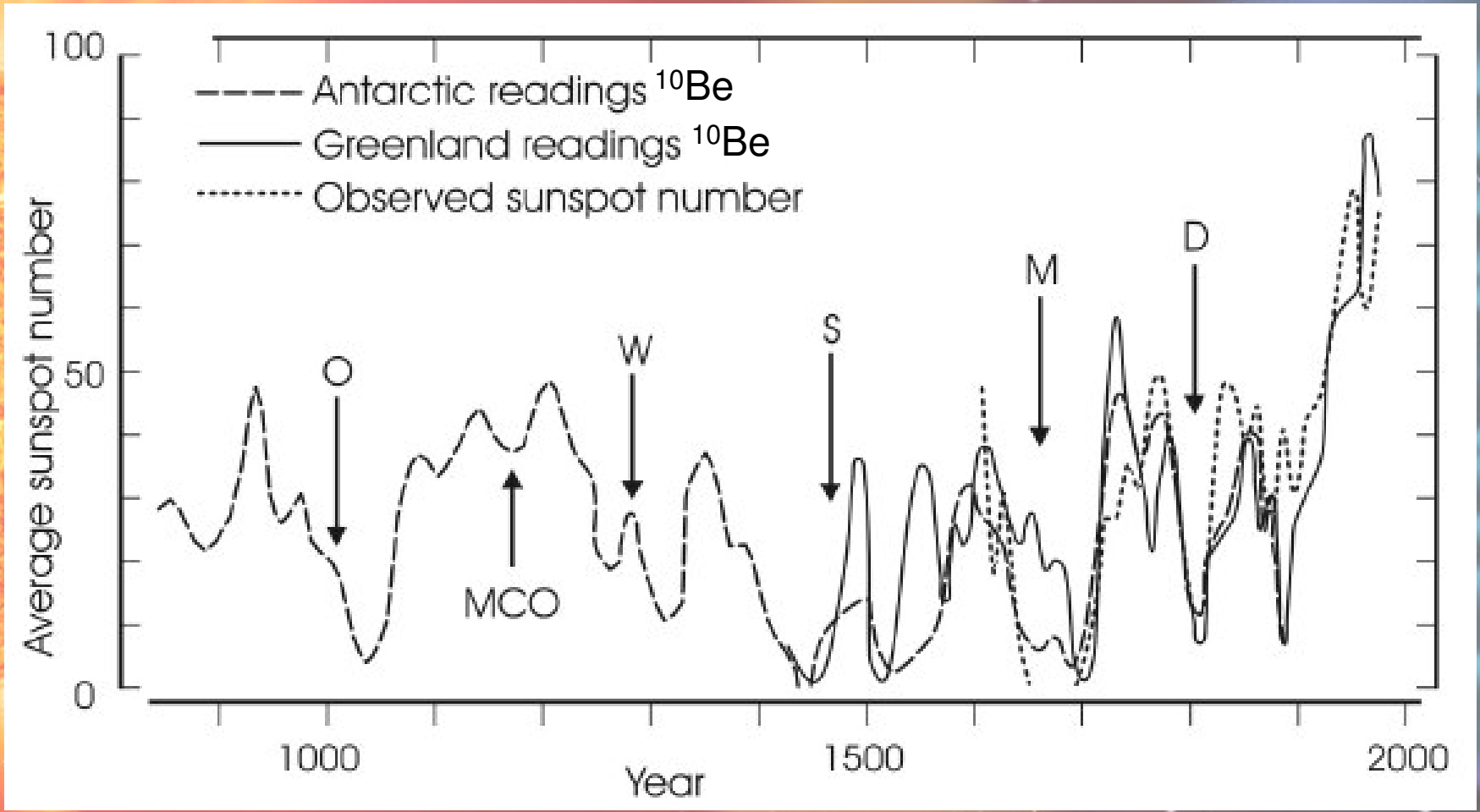
High resolution studies show that at times of cold to warm transitions, temperature changes come first, leading CO_2 changes by several centuries (e.g. Vakulenko et al., 2004). CO_2 levels would be a response not a driver, eventually a temperature amplifier.

Temperature Change and CO_2 Records of the Last Millennium from a Greenland Ice Core



Berner and Streif, 2000

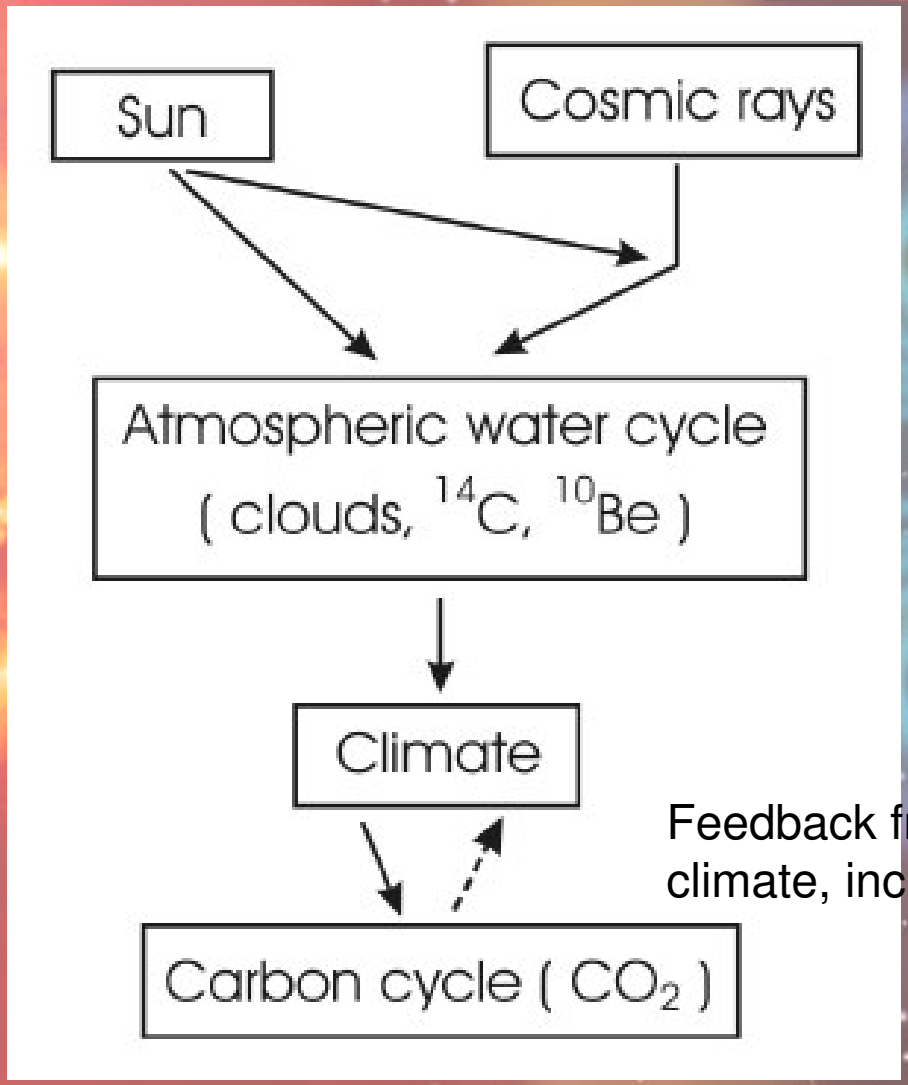
Time Series of Sunspot Number



Usoskin et al., 2003

O - Oort Solar Minimum
MCO - Medieval Climate Optimum
Very high solar activity in the last 60 years since 8000 years

A Model Based on Space Forcing as a Primary Climate Driver



Feedback from the biosphere on climate, including anthropogenic

Veizer, 2005