

INTEGRATING the INTERCONNECTED

Bob Bishop

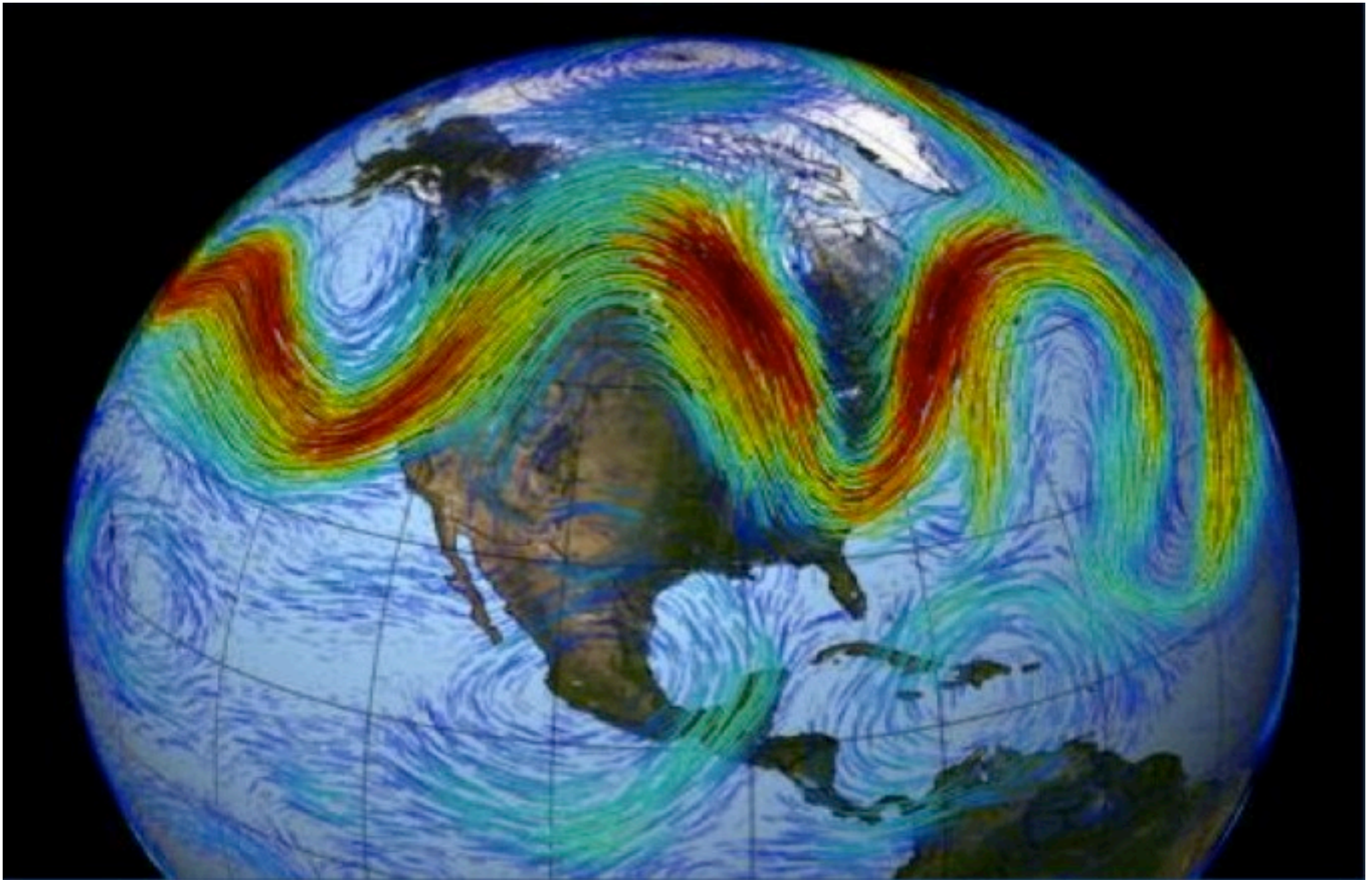
Founder & President: ICES - Geneva

Co-Founder: CRC - Seattle

Everything is linked!

- Everything is interconnected
- Everything is teleconnected
- Everything is telecoupled

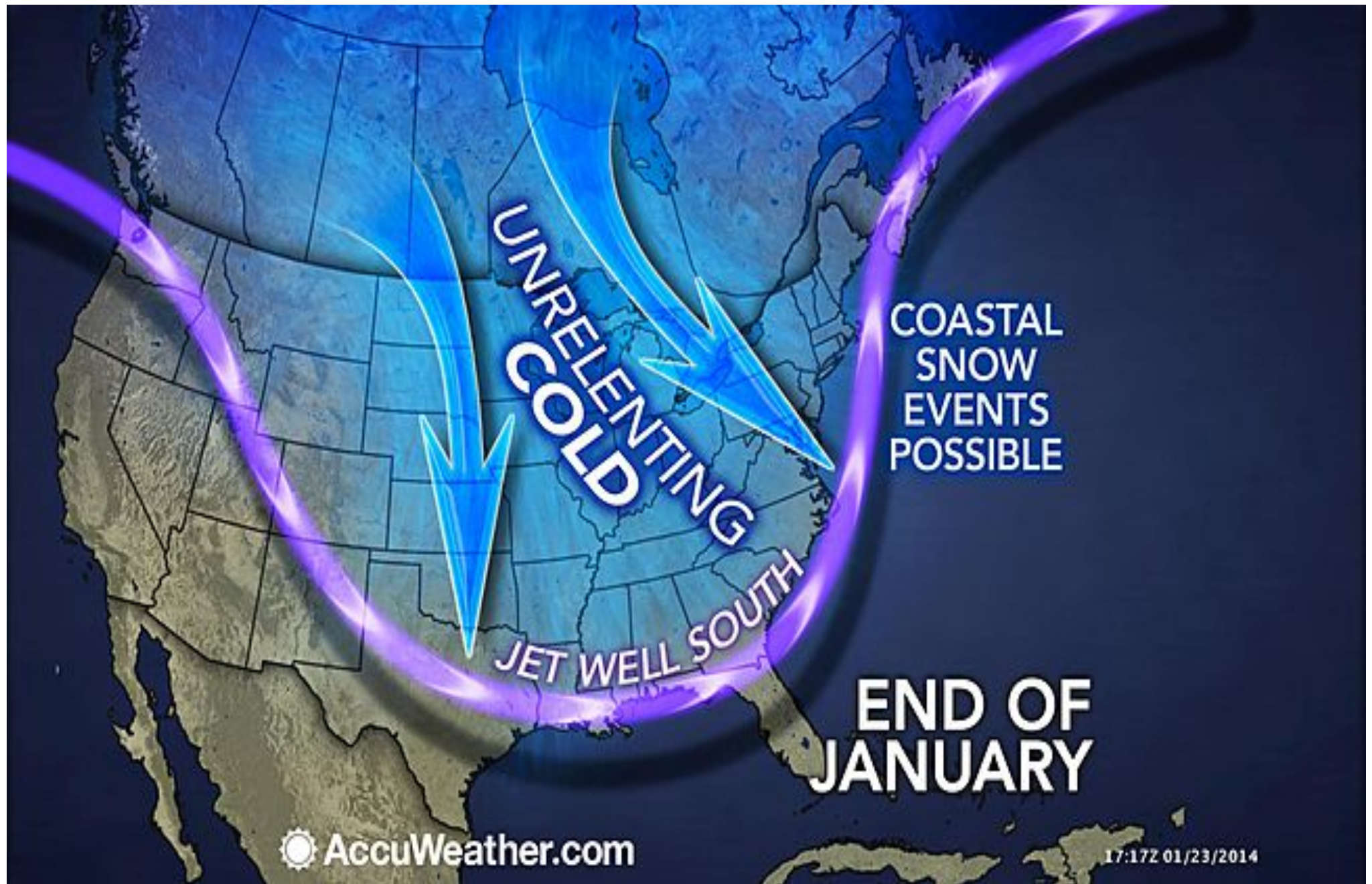
The Polar Vortex (meandering jet stream) ...



50,000 flight cancellations & countless accidents



Blasting the US East Coast 4x in 40 days!



Whereas the US Southwest suffers epic drought



Both are 'coupled system' response to Arctic warming



Arctic warming, loss of sea-ice, changing albedo



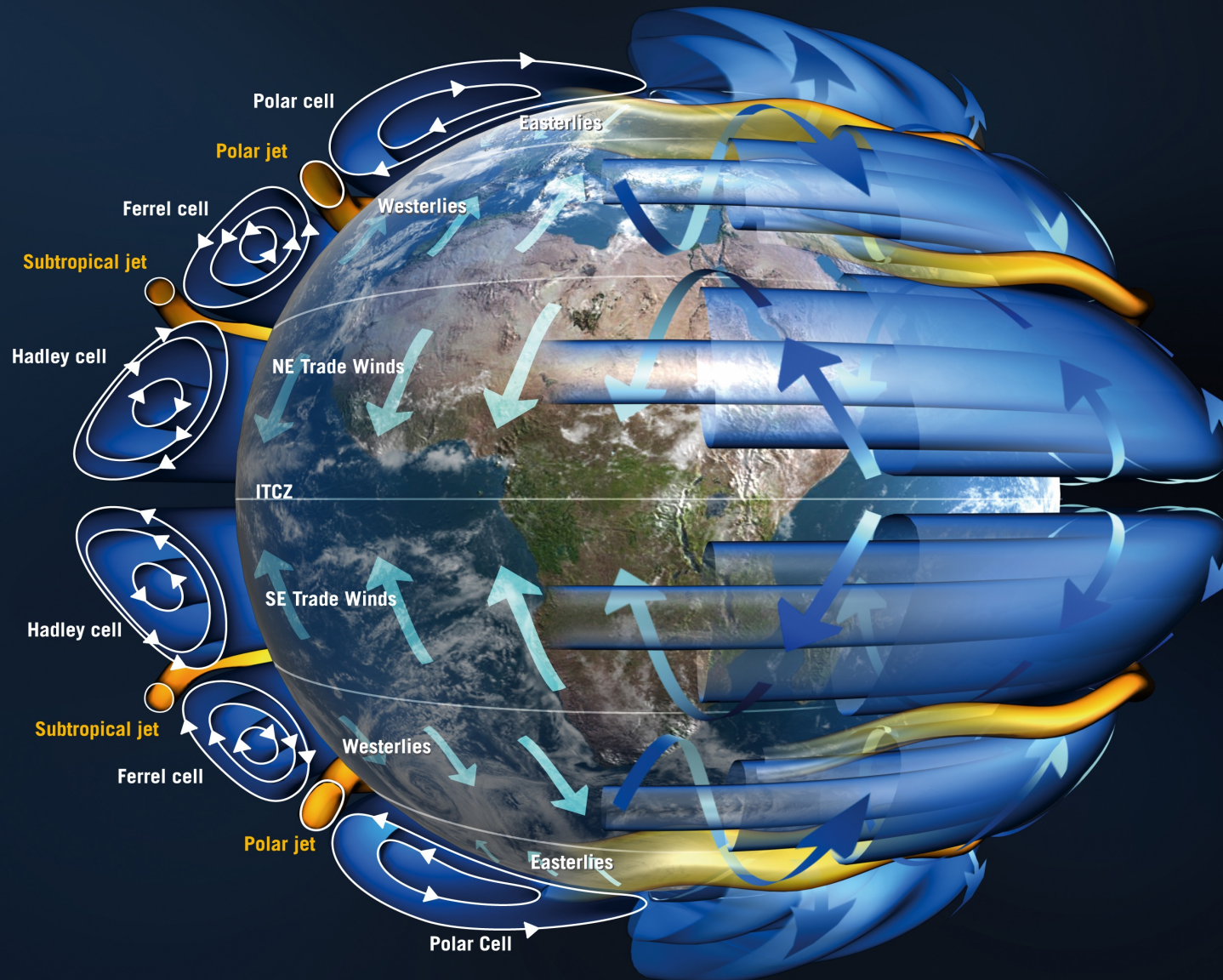
Surface-Sky Coupling: advection, convection, diffusion



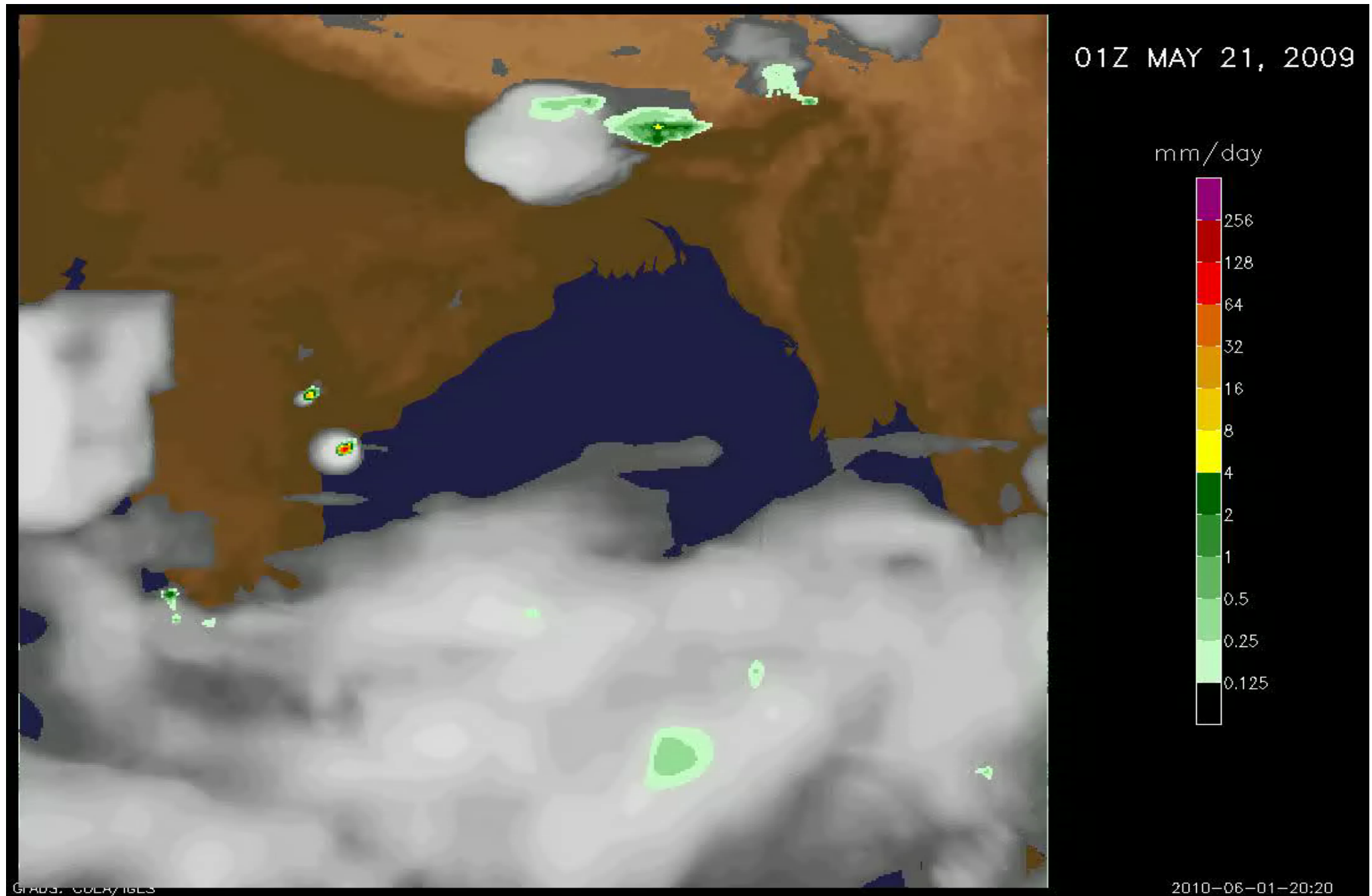
And these couplings are easily disrupted



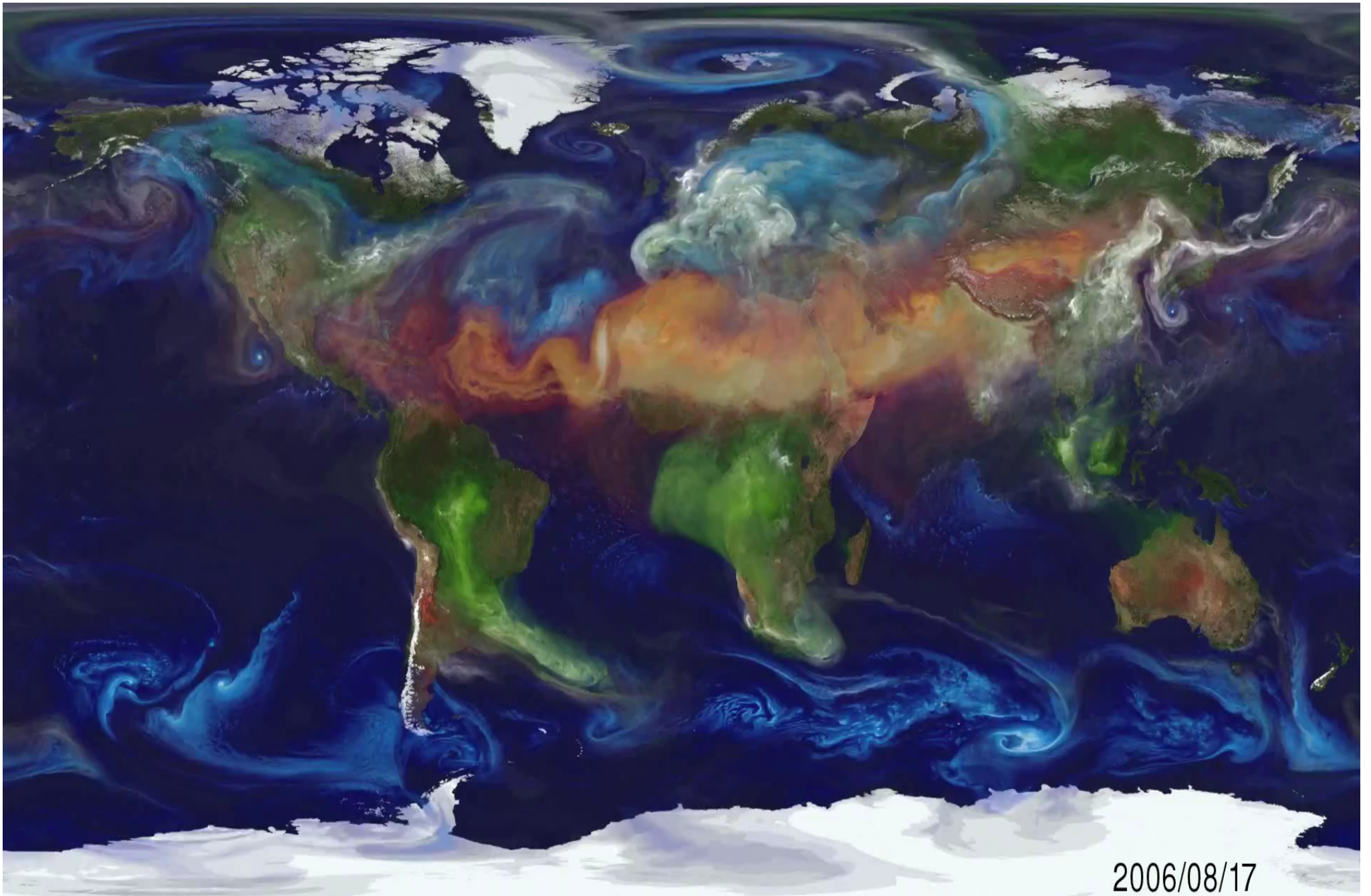
Coupling of winds to land & ocean is very complex!



Telecoupling oscillations: ENSO, IPO, AMO, MJO



Telecoupling via aerosol dispersion

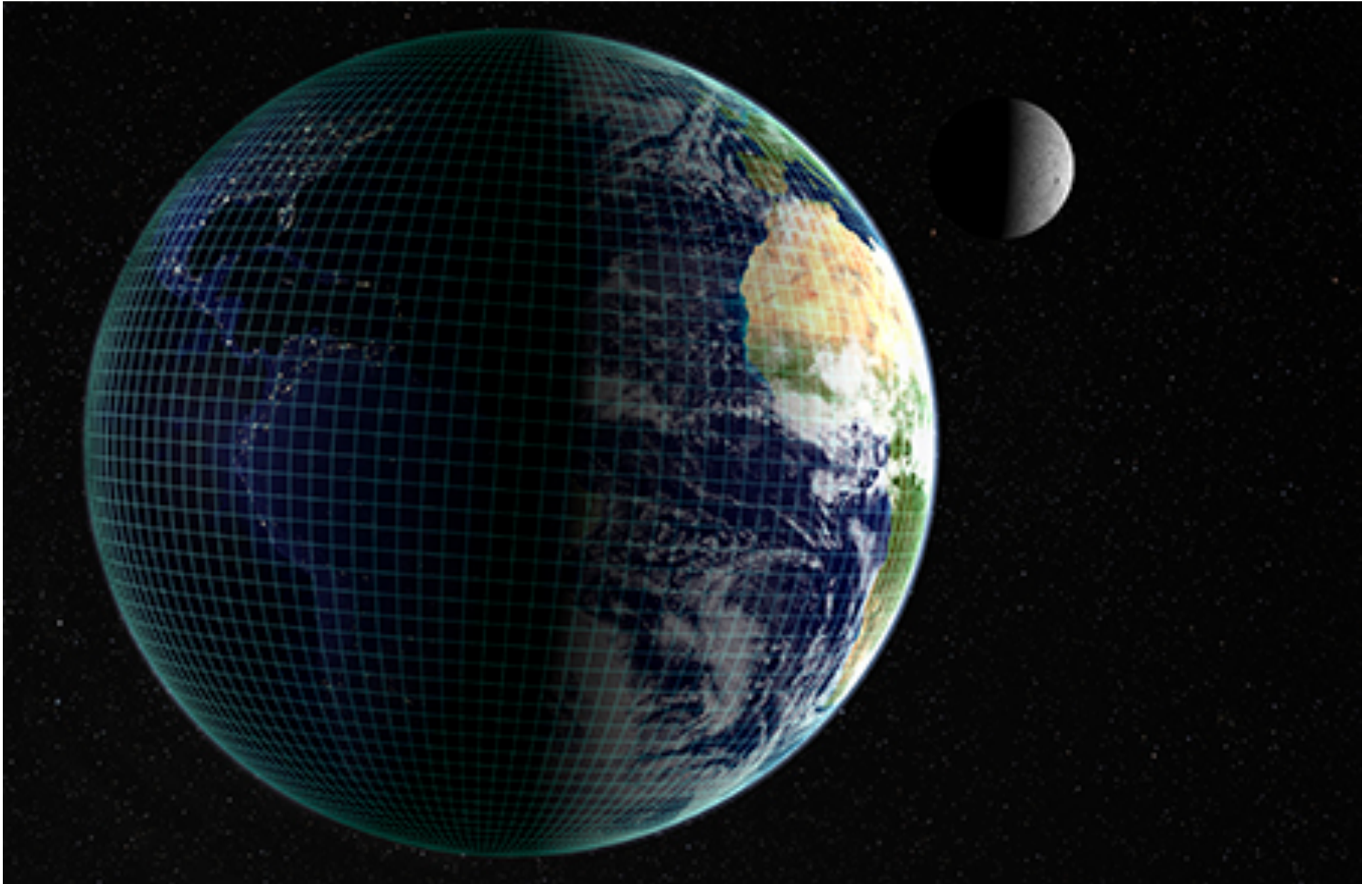


2006/08/17

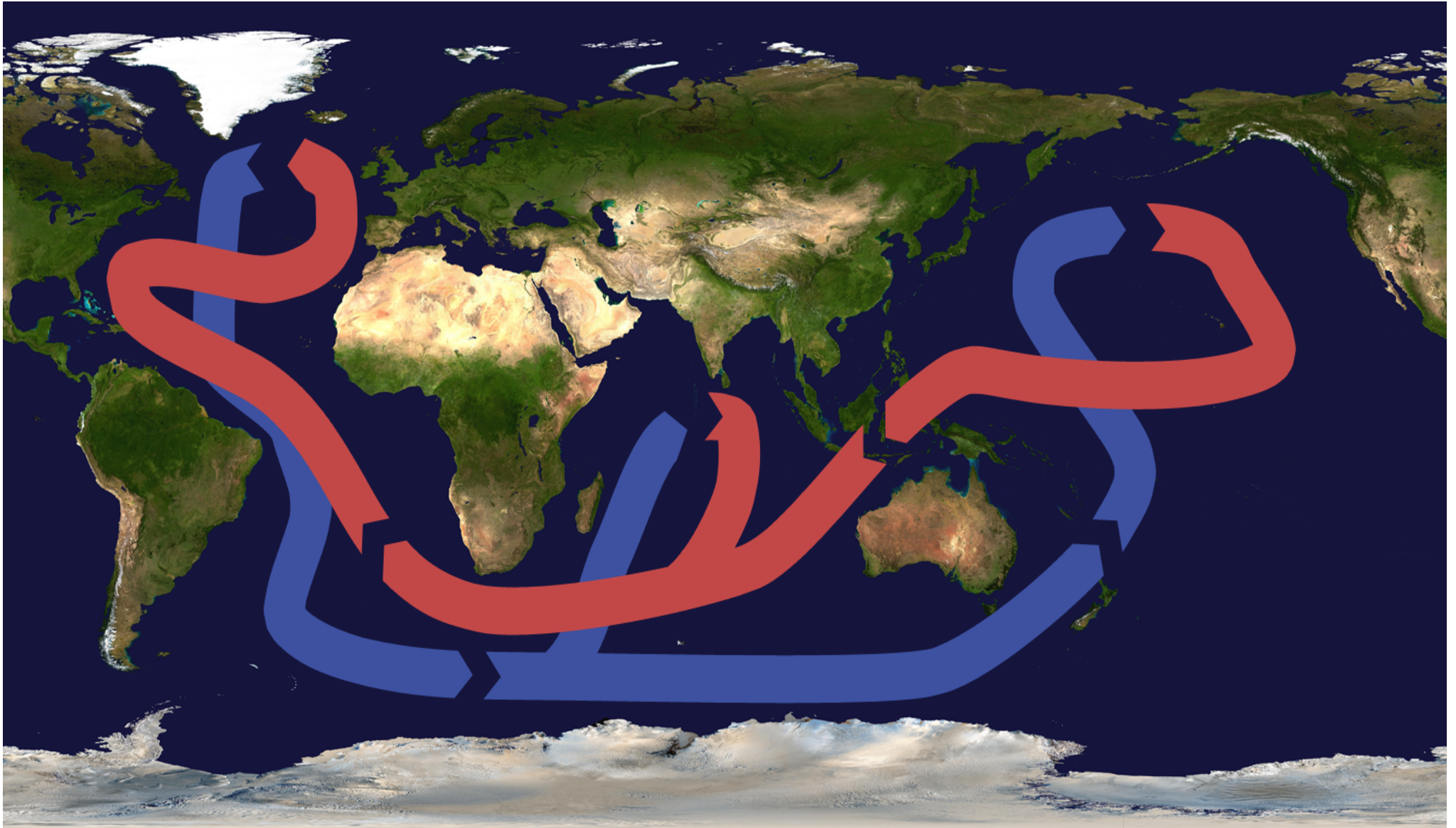
Telecoupling can occur over great distances and on different time frames

- Winds - days/weeks/months/seasons/years
- Oceans - decades/centuries/millennia
- Geological - ages/epochs/periods
- Cosmological - eras/eons

The Earth and Moon make a beautiful coupled system

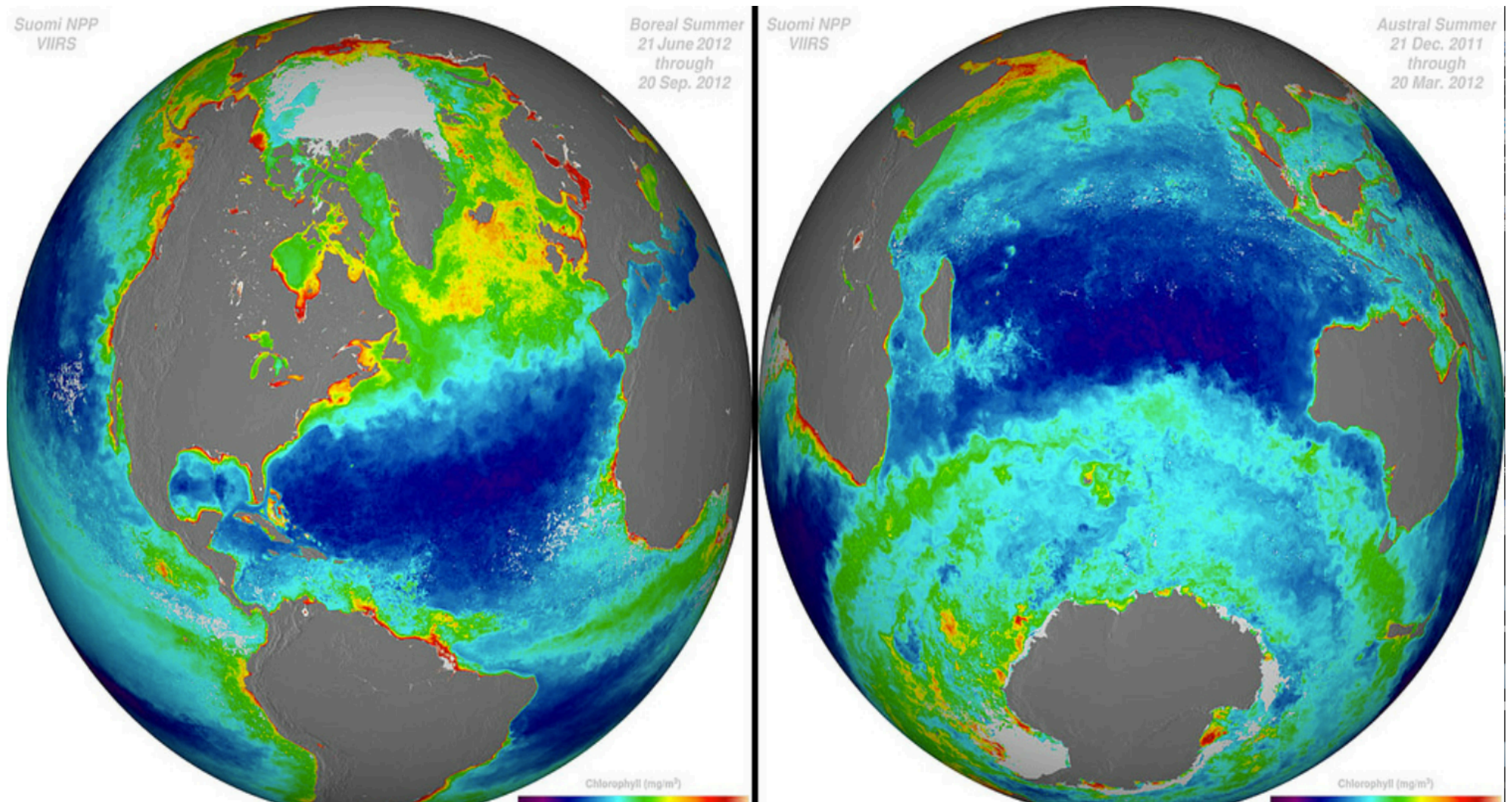


The Great Ocean Conveyor Belt



Thermohaline circulation by Brisbane CC BY-SA 3.0 using
NASA Goddard Space Flight Center images from Visible Earth

Ocean biota are telecoupled by the Conveyor Belt



North Pacific Gyre



3D view of the Great Ocean Conveyor Belt

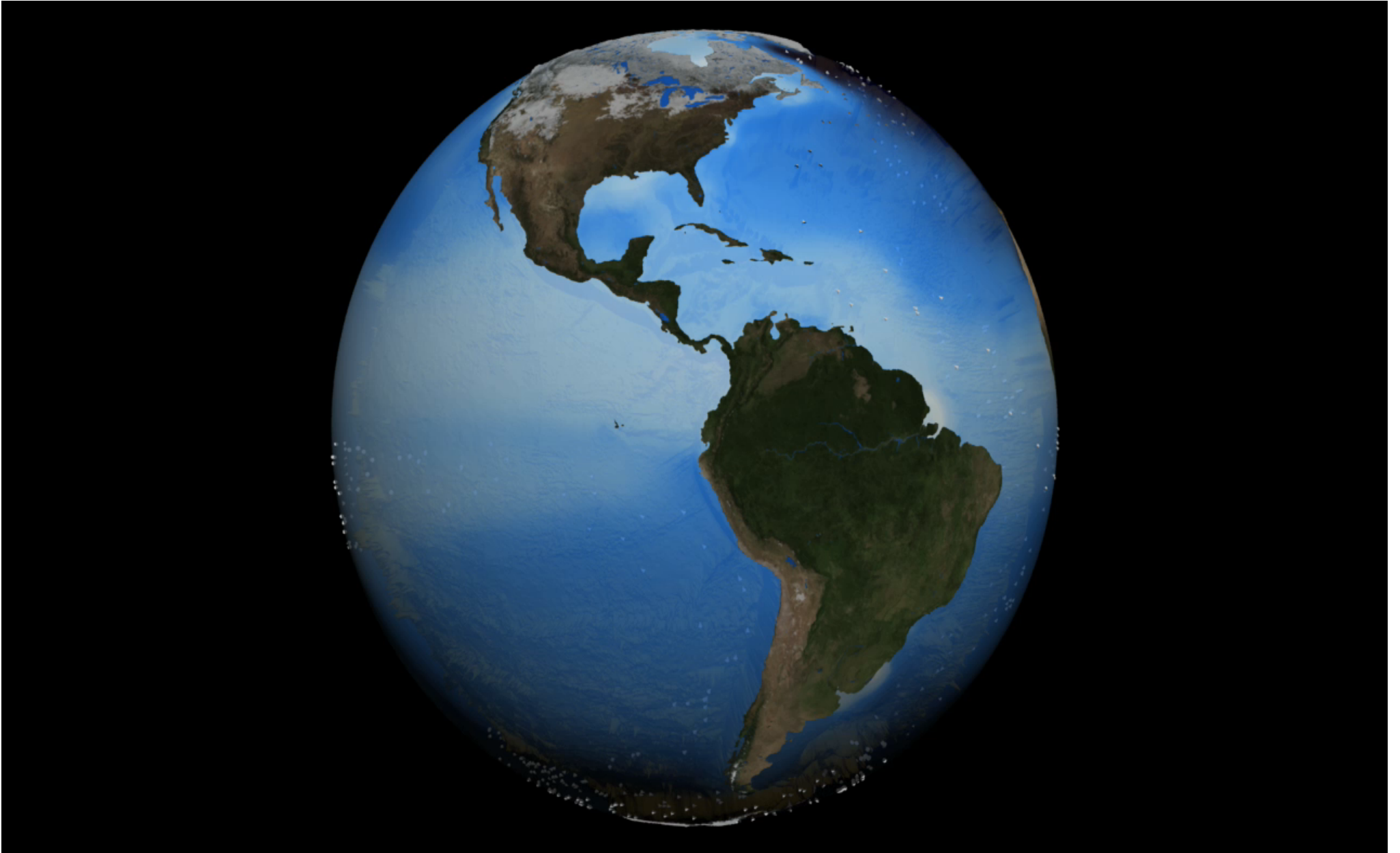
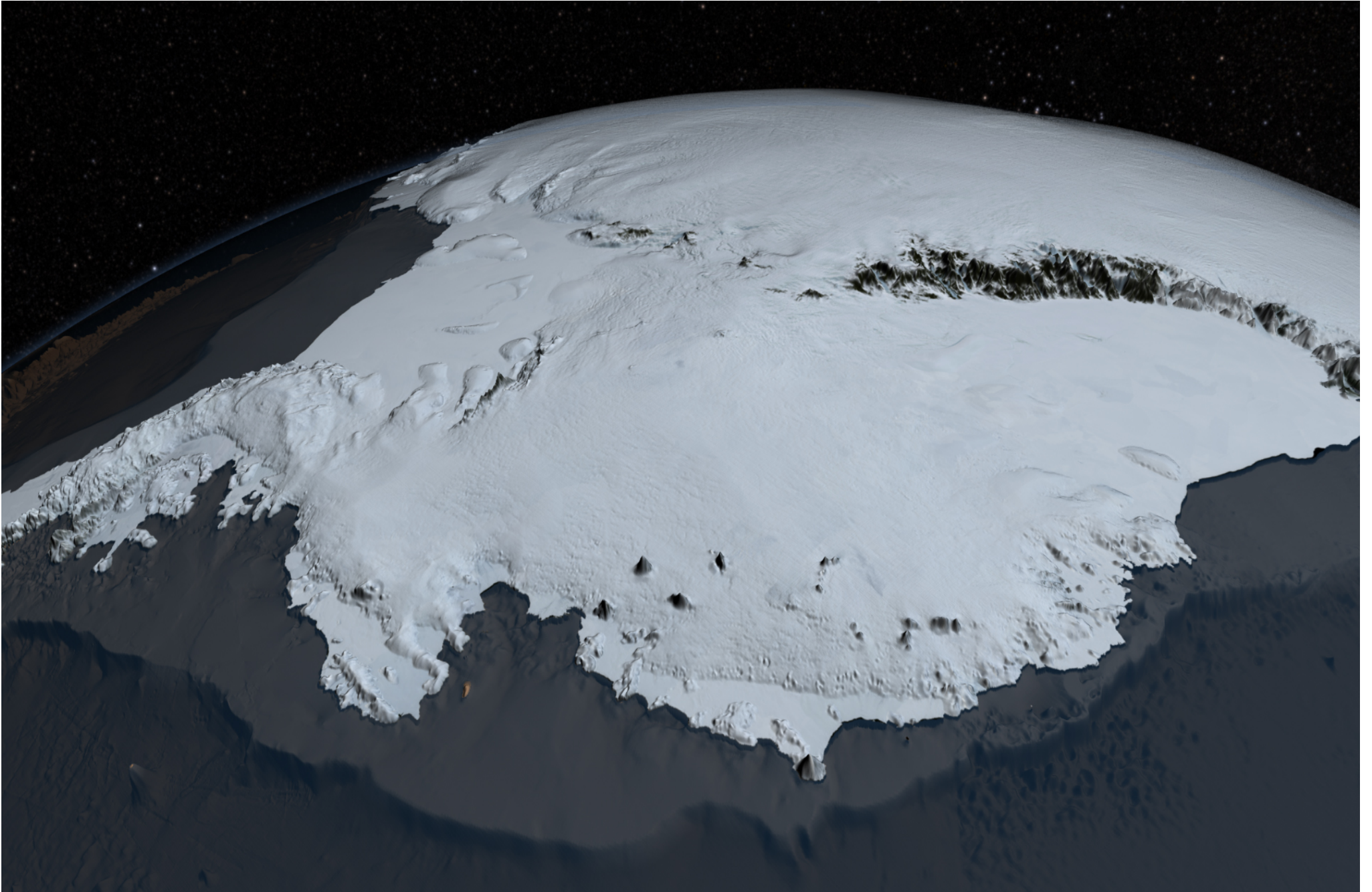
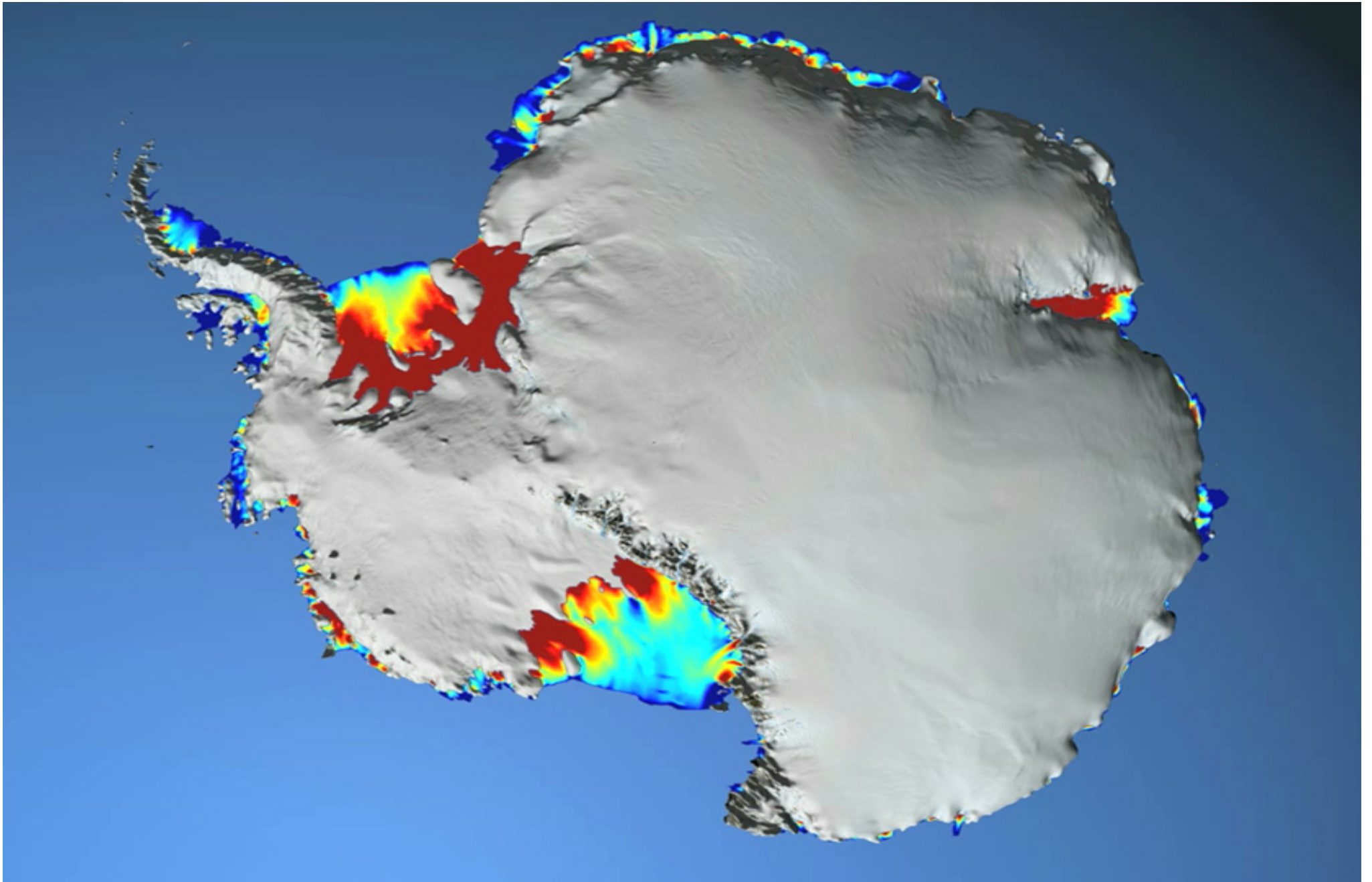


Image credit: NASA

Antarctica: a continent of 14M km²



14 million km² of ice cap – and thinning!



Accelerating flow of glaciers into the sea!

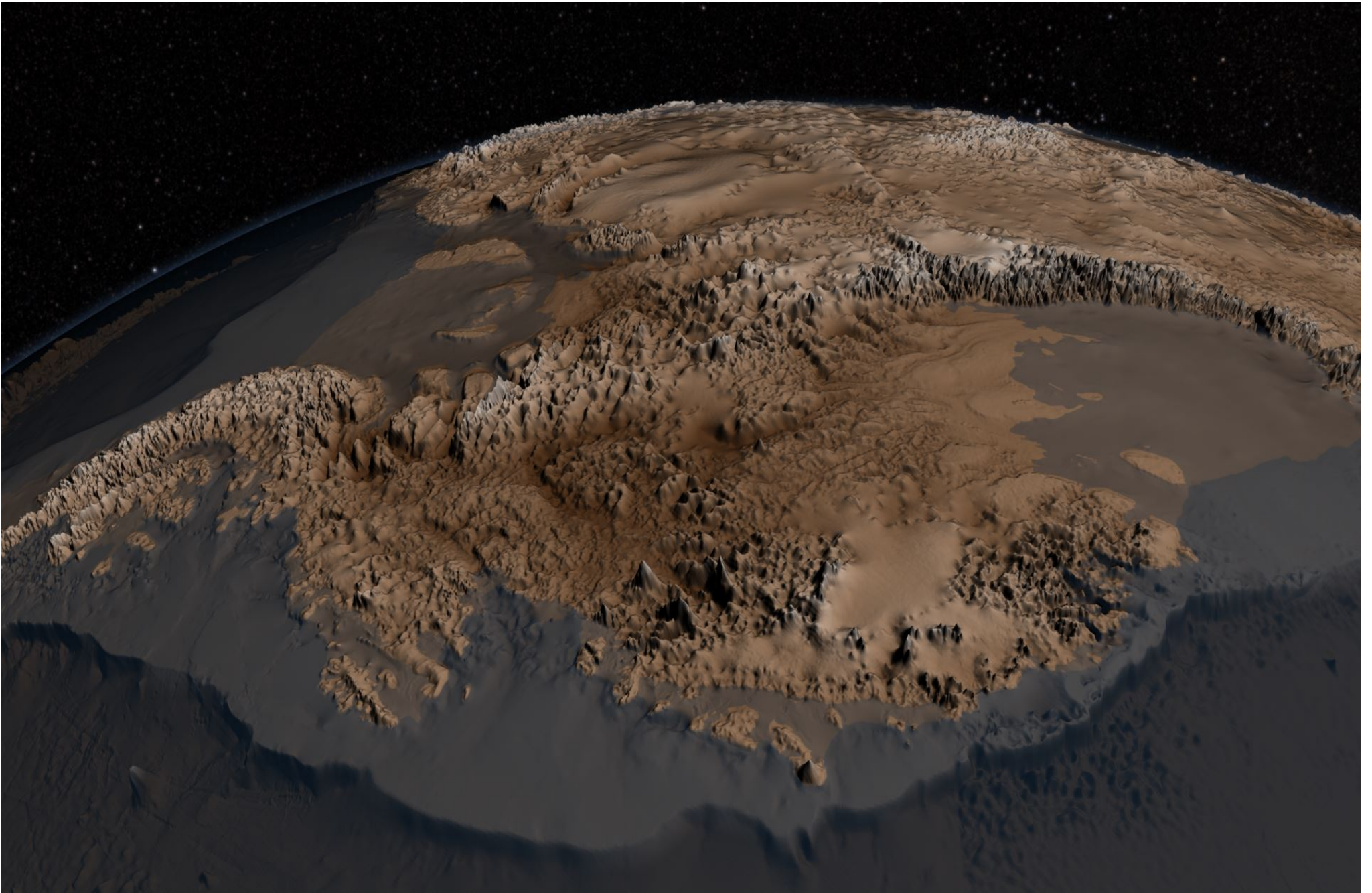


Image credit: Nasa Data credit: ESA

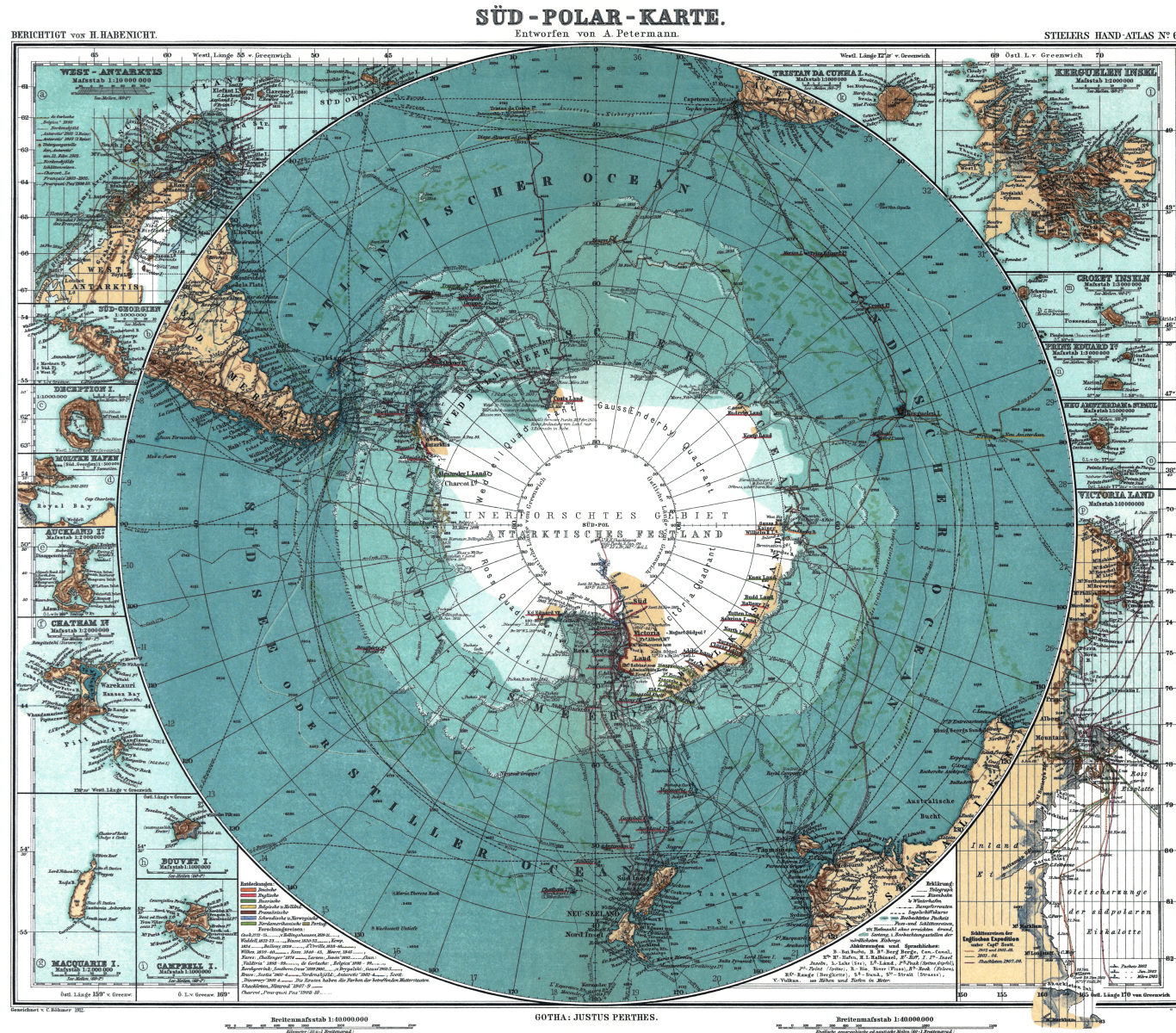
Average ice thickness: 3 km



Underneath all that ice is a rugged terrain ...



Circumpolar Southern Ocean couples the world

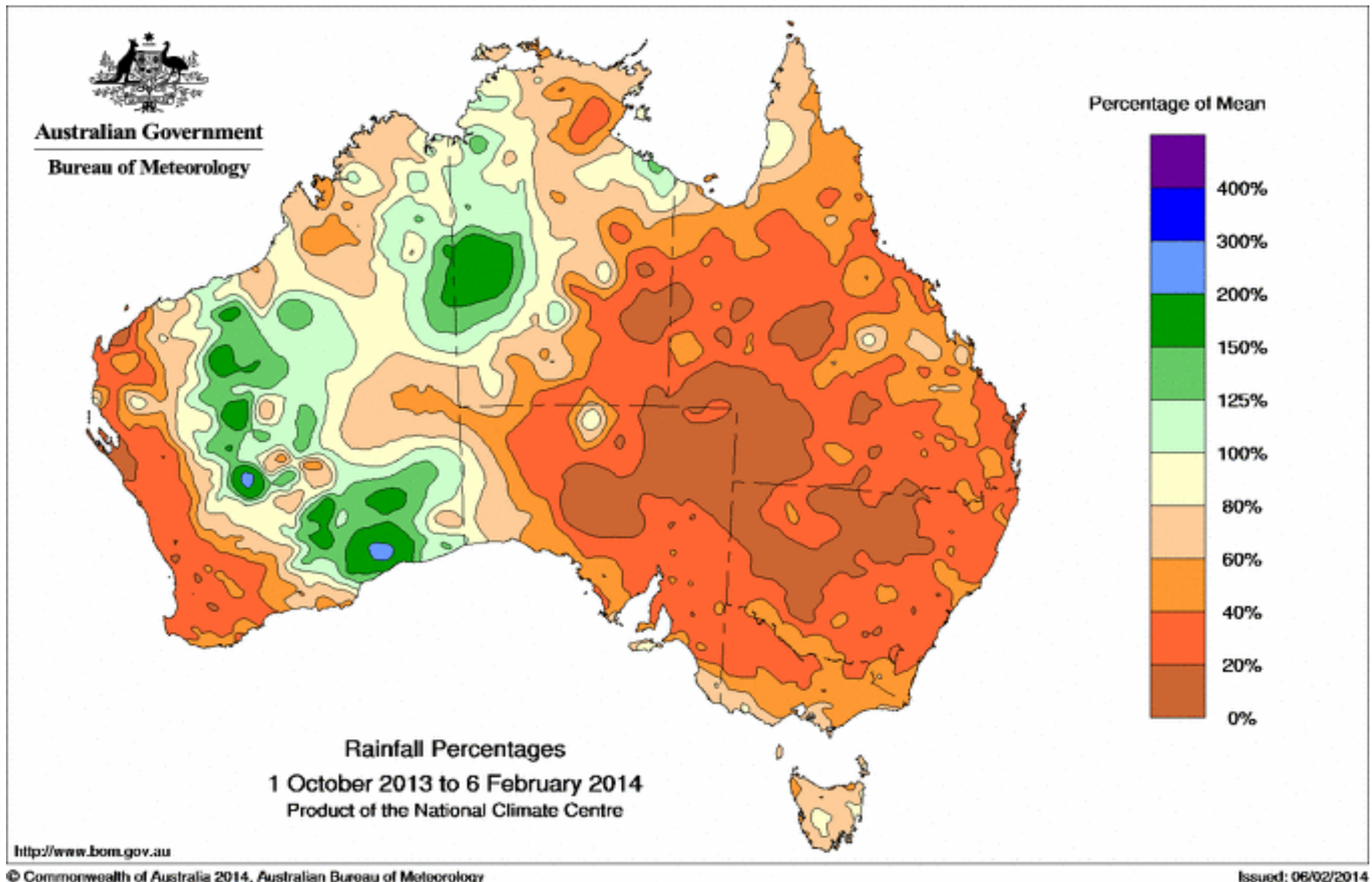


Petermann, A. from Stieler's Hand-Atlas, No. 6, 1912 Library of Congress, Geography and Map Division: g9800 ct000774 via Wikimedia Commons

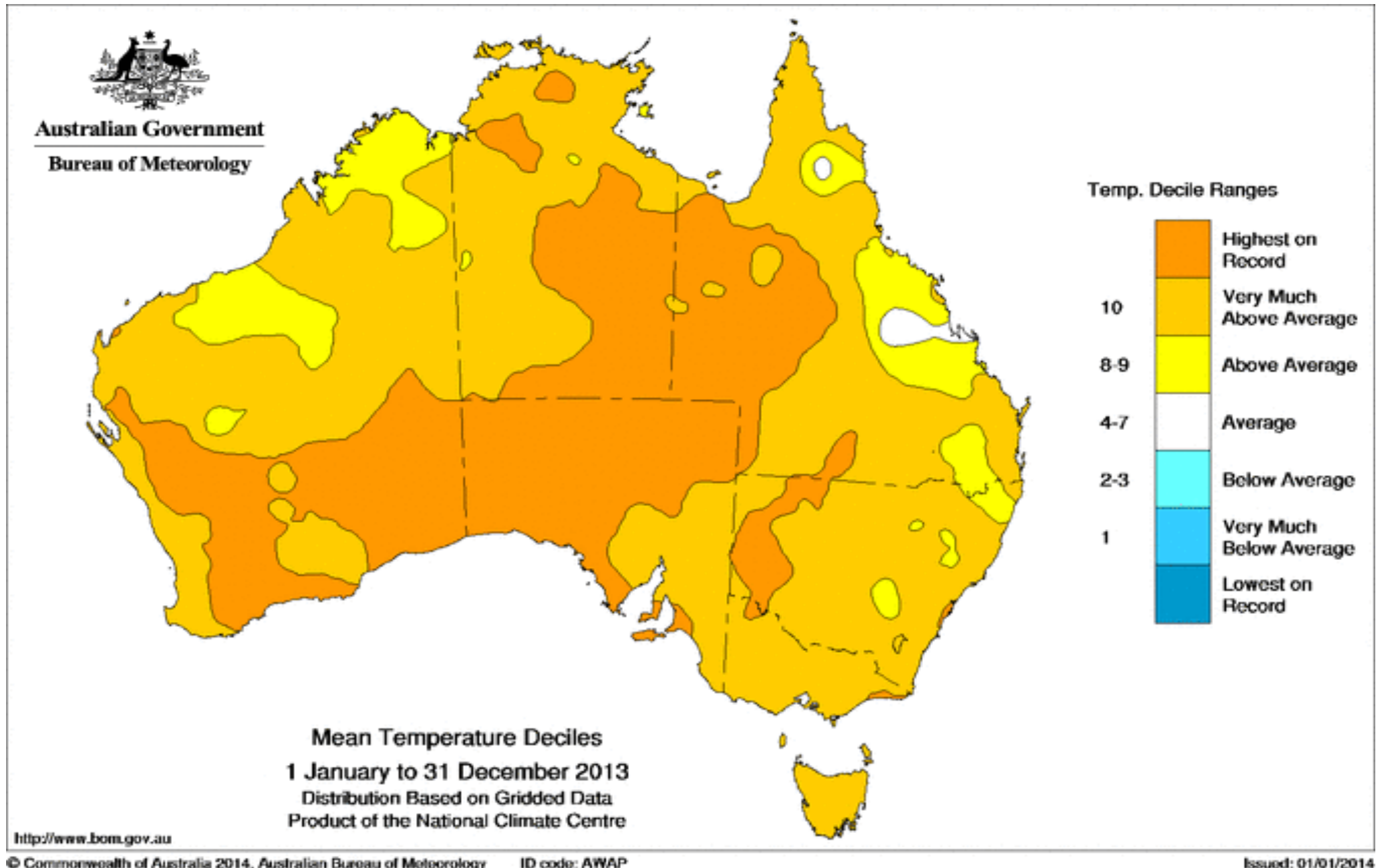
Southern Ocean from Encounter Bay - Australia

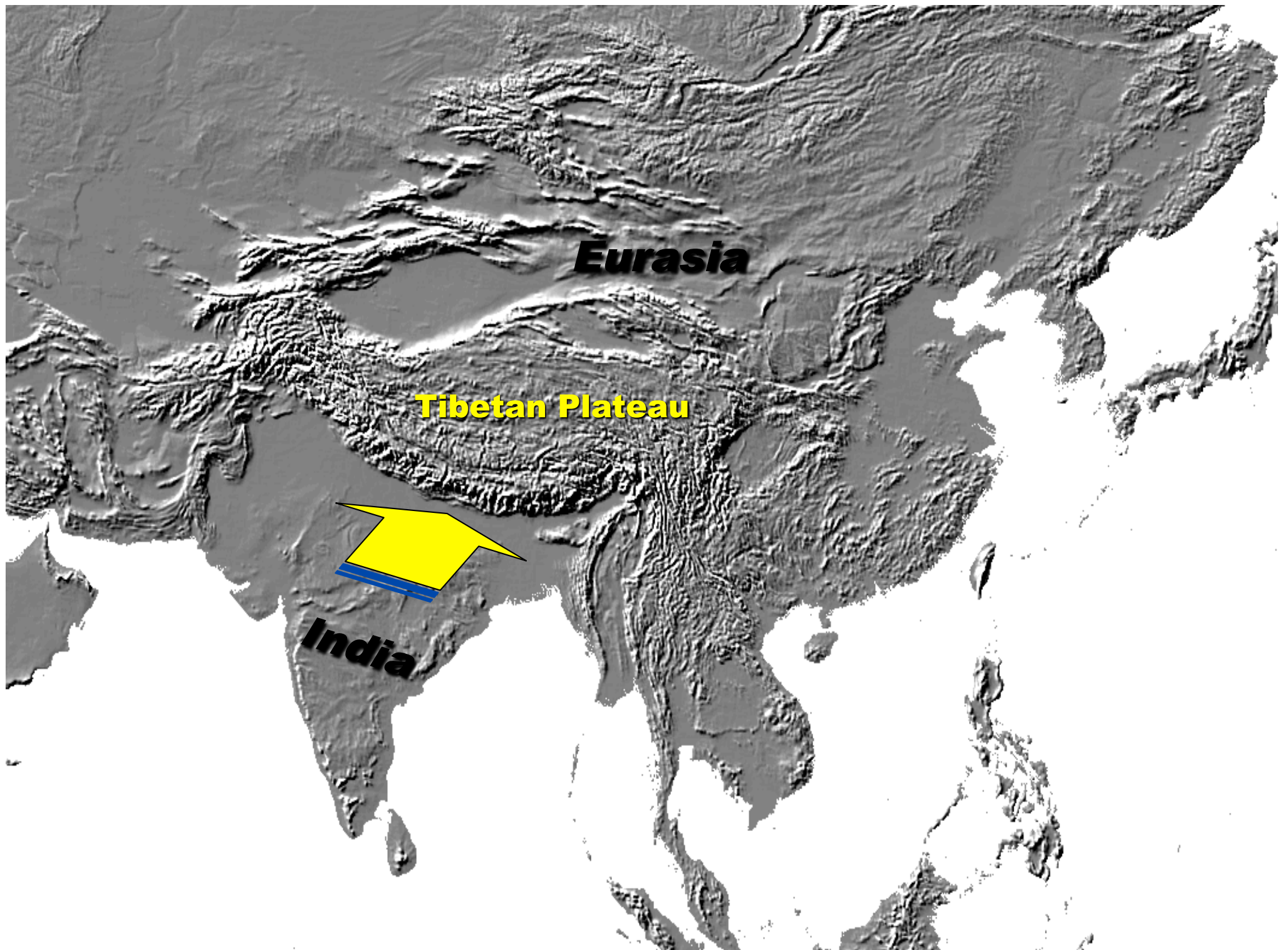


Australia: Recent 4 months rainfall



Australia: 12-monthly mean temperature decile



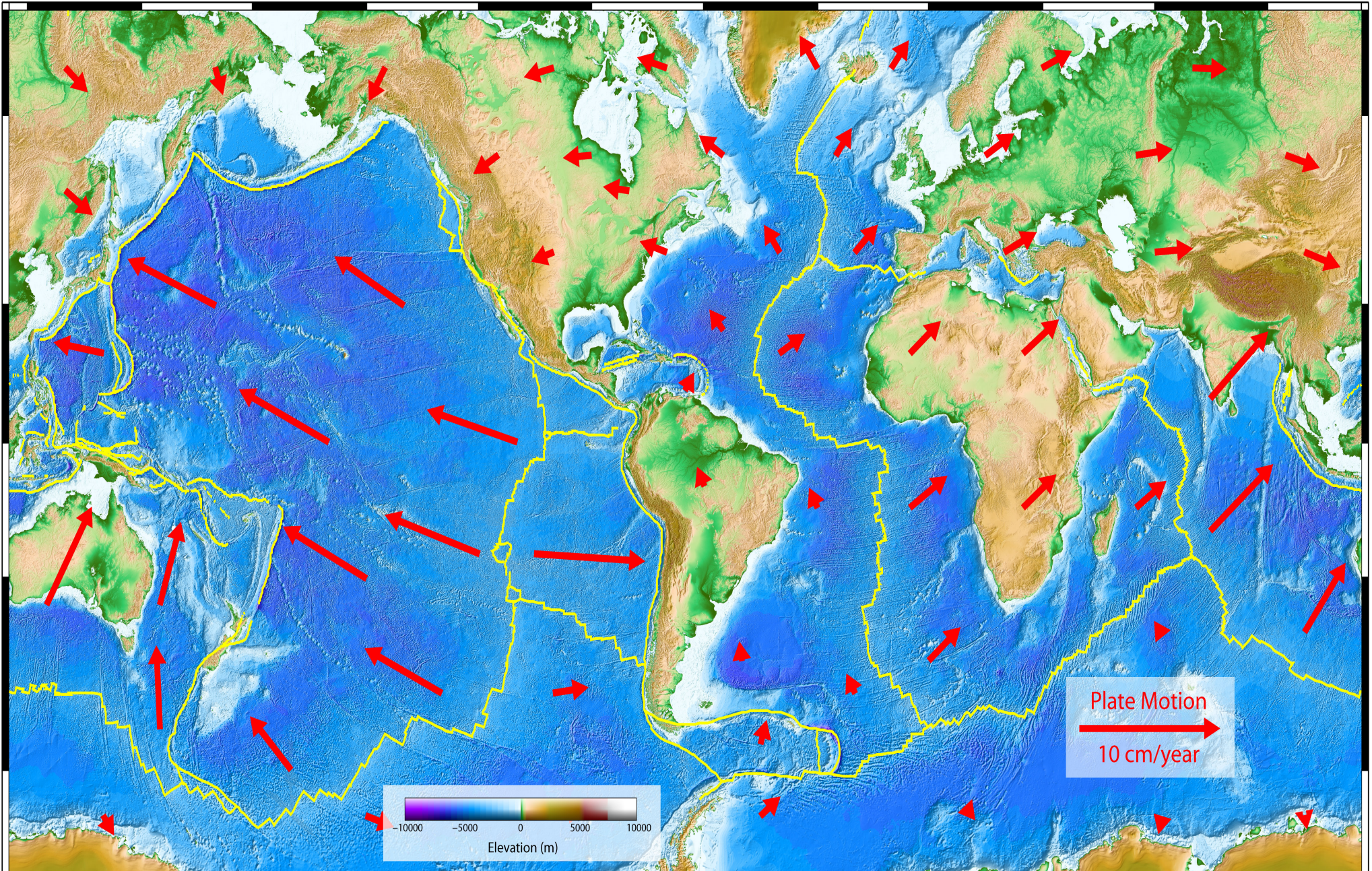


Eurasia

Tibetan Plateau

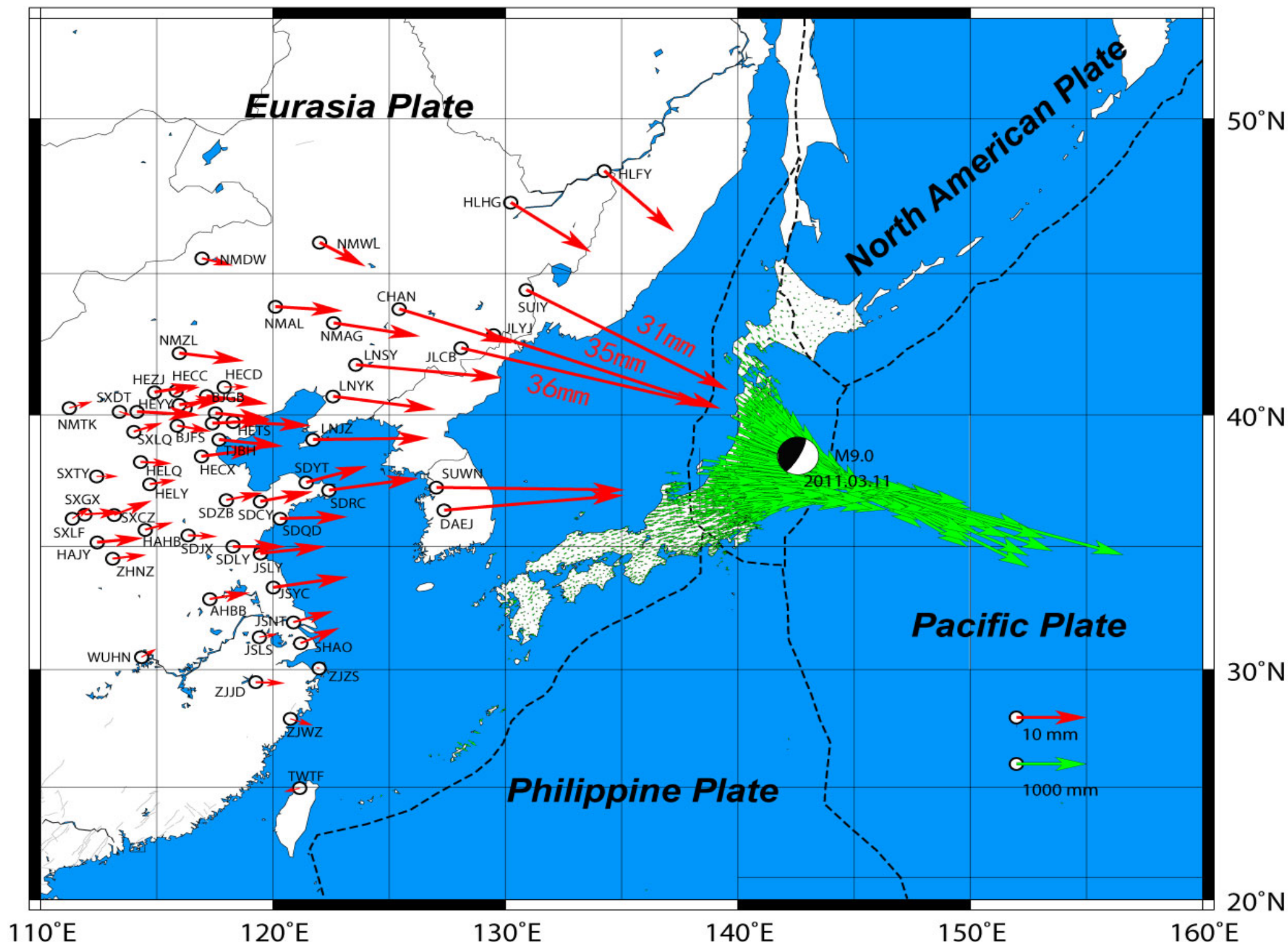
India

Plate Tectonics, Continental Drift & Subduction prevail



The Ring of Fire includes 452 major volcanoes!





Cascading domino effects ... Japan, 03.11.2011



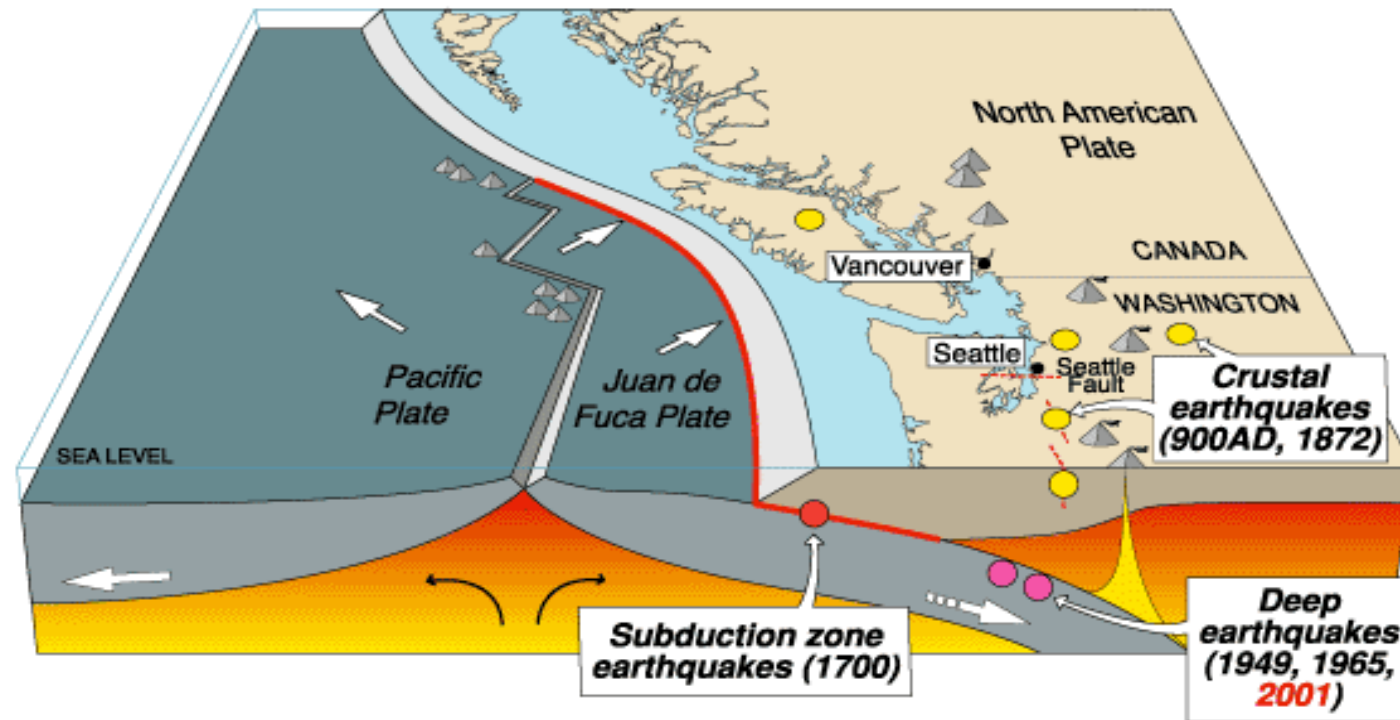
U.S. Navy photo by Mass Communication Specialist 3rd Class Kevin B. Gray/Released)

Japan: impact across all of society

- M9.0 earthquake offshore
- 10m tsunami strikes NE coastline of Japan
- Water surge to 45m height in coastal valleys
- 400,000 structures destroyed + 18,500 lives
- Global manufacturing supply chain disrupted
- 3 nuclear reactors meltdown - towns evacuated
- TEPCO bankrupt, Prime Minister Kan resigns
- Switzerland & Germany decommit nuclear power
- Global nuclear industry standards changed forever
- Will Fukushima be resolved before Tokyo Olympics 2020?

Is Cascadia the mirror image of Japan (Tohoku)?

Cascadia earthquake sources

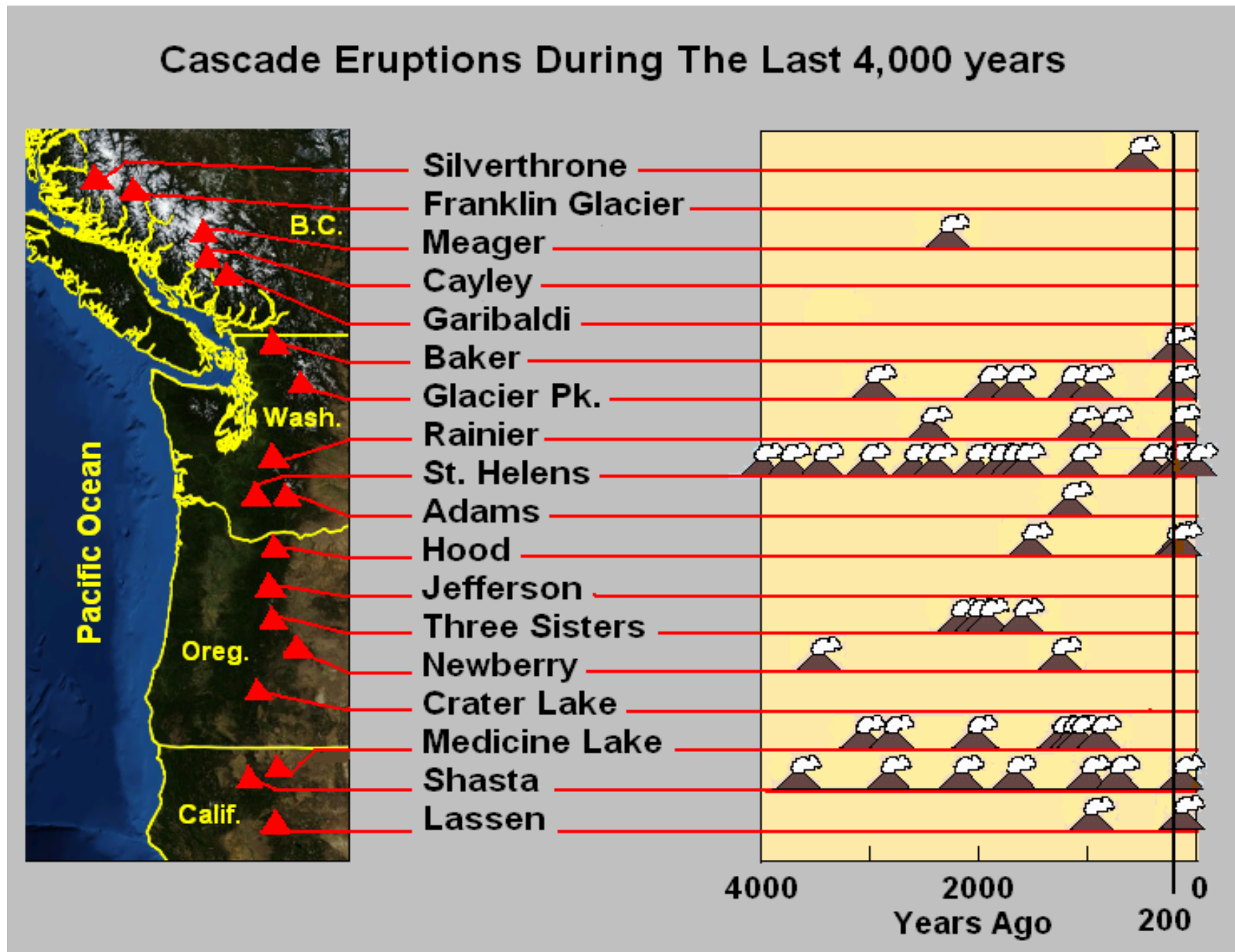


| Source | Affected area | Max. Size | Recurrence |
|---------------------------|---------------|-----------|-----------------|
| ● Subduction Zone | W.WA, OR, CA | M 9 | 500-600 yr |
| ● Deep Juan de Fuca plate | W.WA, OR, | M 7+ | 30-50 yr |
| ● Crustal faults | WA, OR, CA | M 7+ | Hundreds of yr? |

Cascadia Subduction Zones & Volcanoes



The plumbing of 18 Cascadia volcanoes is connected!



Mount St. Helens eruption 1980



Growing interconnectivity of risks

natural-social-economic

- Sequential collapse
- Synchronous collapse
- Multiple synchronous collapse

Recent natural-social-economic cascading crises

- 2000 SE Asia smoke haze
- 2003 European heatwave
- 2004 Sumatra tsunami
- 2005 Hurricane Katrina
- 2007 England floods
- 2008 Wechuan earthquake
- 2010 Haiti earthquake
- 2010 Icelandic ash cloud
- 2010 Russian heatwave
- 2010 Deepwater Horizon oil spill
- 2011 Pakistan floods
- 2011 Queensland floods
- 2011 US Midwest drought
- 2012 Superstorm Sandy
- 2013 North German floods
- 2013 Supertyphoon Haiyan

Integrating Nature's physical & organic diversity

- Unitary
- Harmony
- Holistic View

Are we ready for Modeling the Whole Earth System?

... as a system of systems

... with complex non-linear interactions

Blue Marble from Apollo 17

(taken from 45,000km on December 7, 1972 at 10:39 UTC)



Wildlife migrations require a borderless world

- Wildebeest & zebras – Africa Serengeti
Arctic caribou – Alaska, Canada
- Humpback whales & whale sharks – Pacific, Australia
Emperor penguins & elephant seals – Antarctica
Salmon – Pacific & Atlantic
Red crabs – Australia
- Monarch butterflies – North America
White storks – Israel
Flamingos – Kenya
Cranes - Nebraska
Bats – Texas

All of the 'wicked problems' are multi-science:

- Food security
- Water security
- Energy security
- National security
- Resource depletion
- Protection of biodiversity
- Protection of planet Earth

Our monoculture of infrastructure/investments

- Short term oriented
- Insufficient reserves
- Insufficient resilience
- Many single points of failure
- Weak digital security – private, corporate, IP
- Dearth of effective & affordable insurance products
- High frequency trading, financialization of food & water
- ‘Stranded assets’ – on the books at full value, but unusable



**Helping guide the successful transformation of human society
in an era of rapid climate change and frequent natural disasters.**

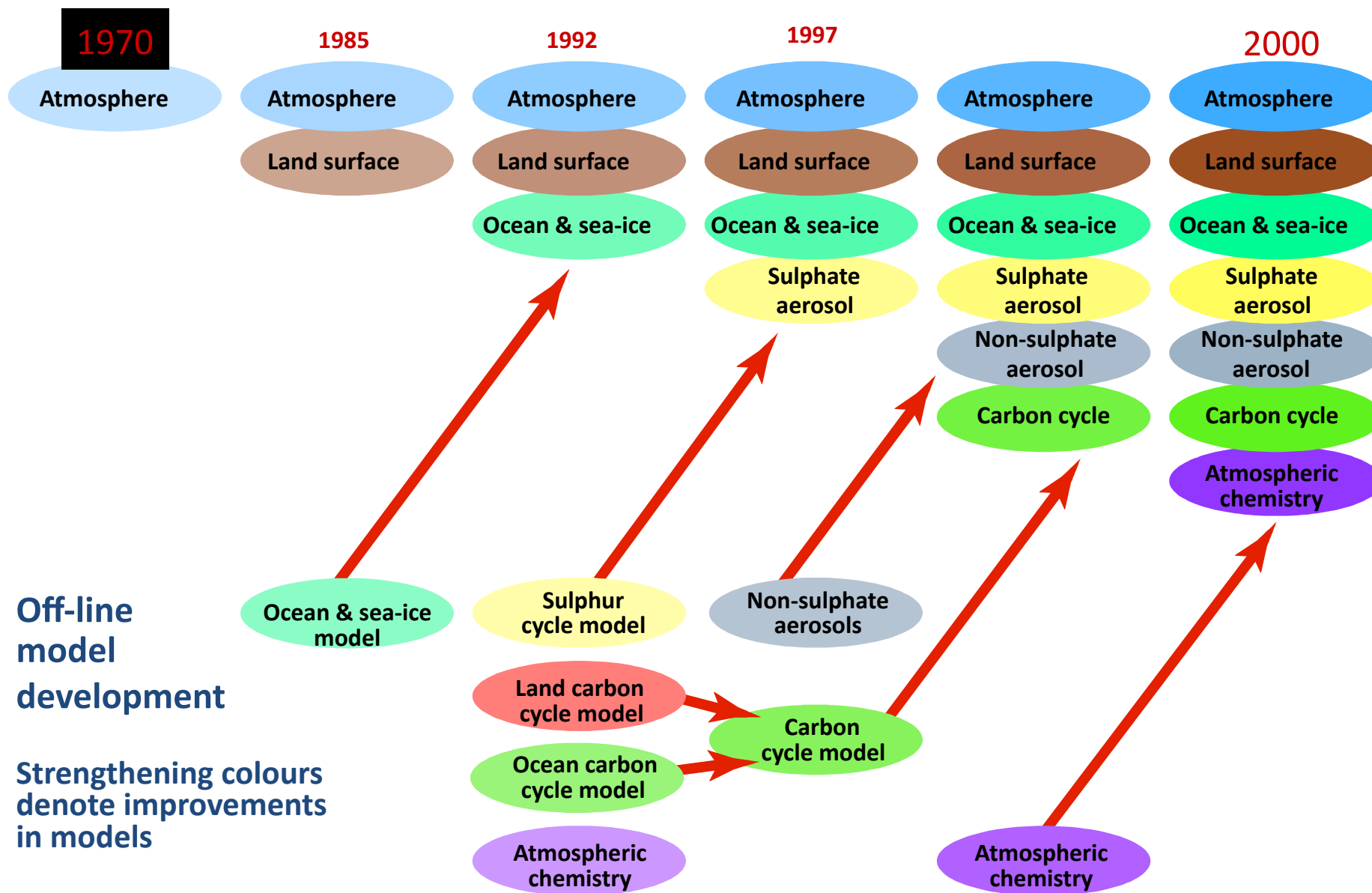
www.icesfoundation.org

Modelling the Whole Earth System
– a challenge whose time has come!

Modeling the Whole Earth System

- using HPC as a modeling platform
 - simulation-based research has no limits
 - each field of science has its own unit of analysis
- which must be coupled or embedded in a new framework

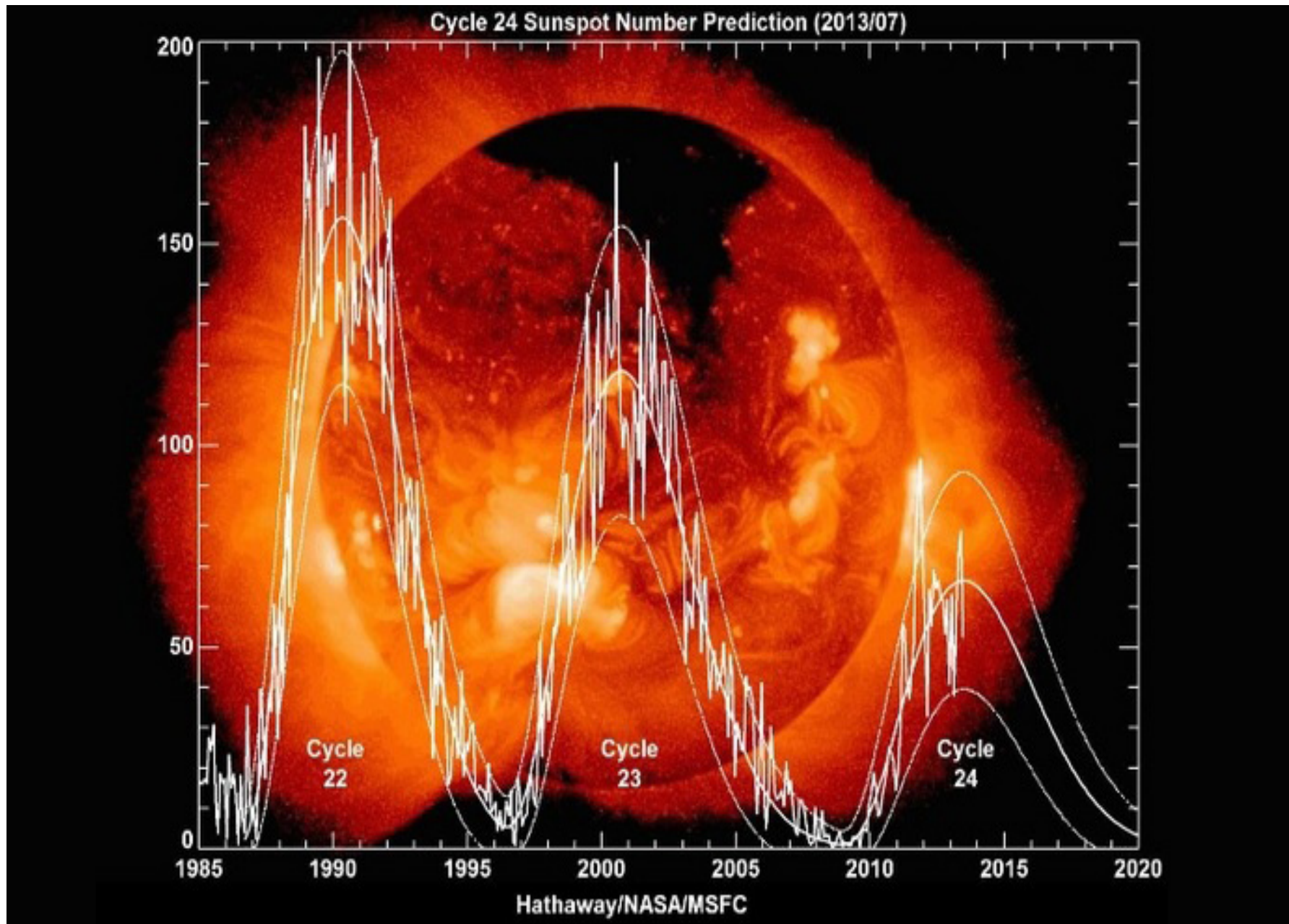
Towards Comprehensive Earth System Models



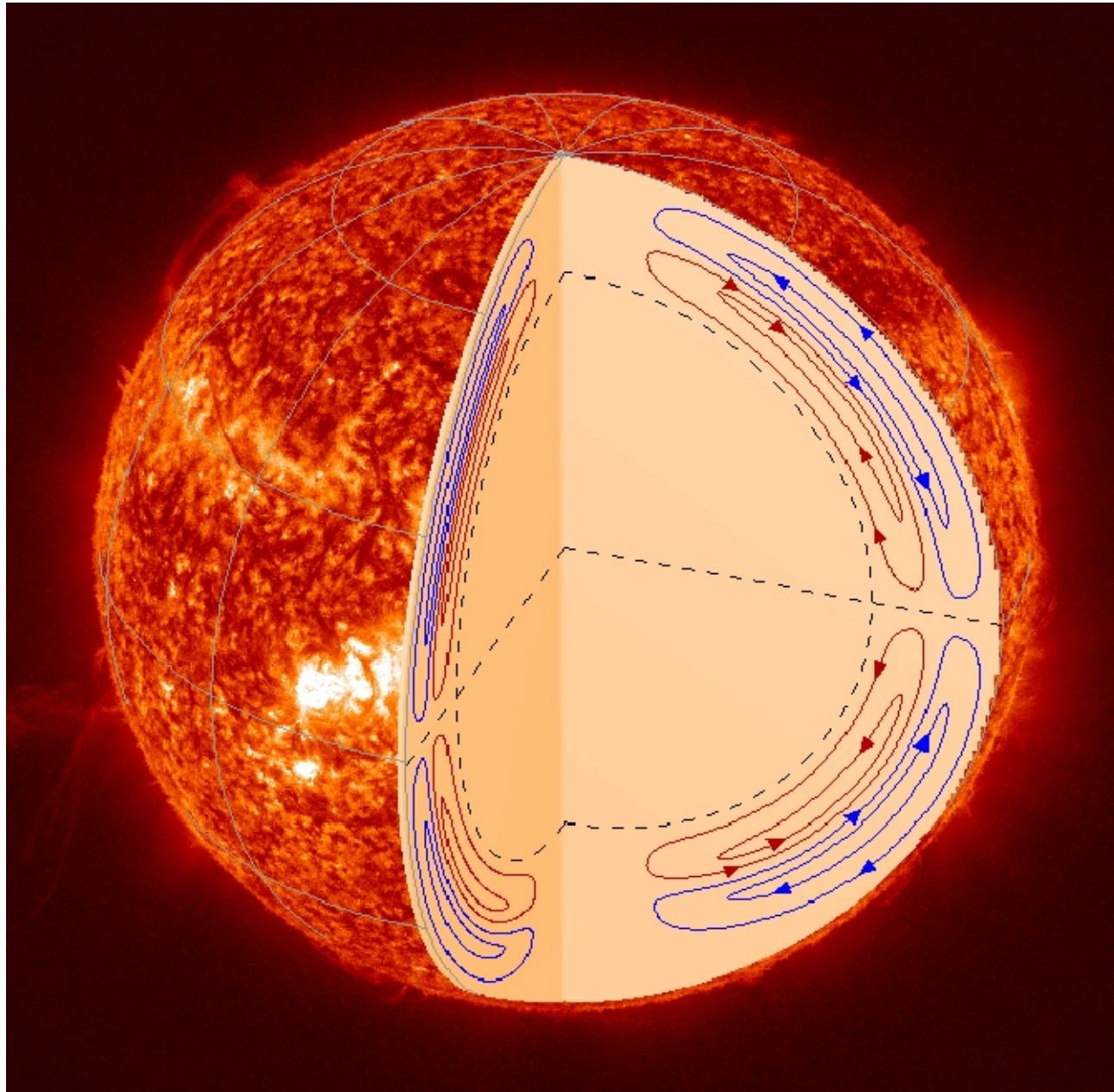
To model the Earth, first model the Sun!



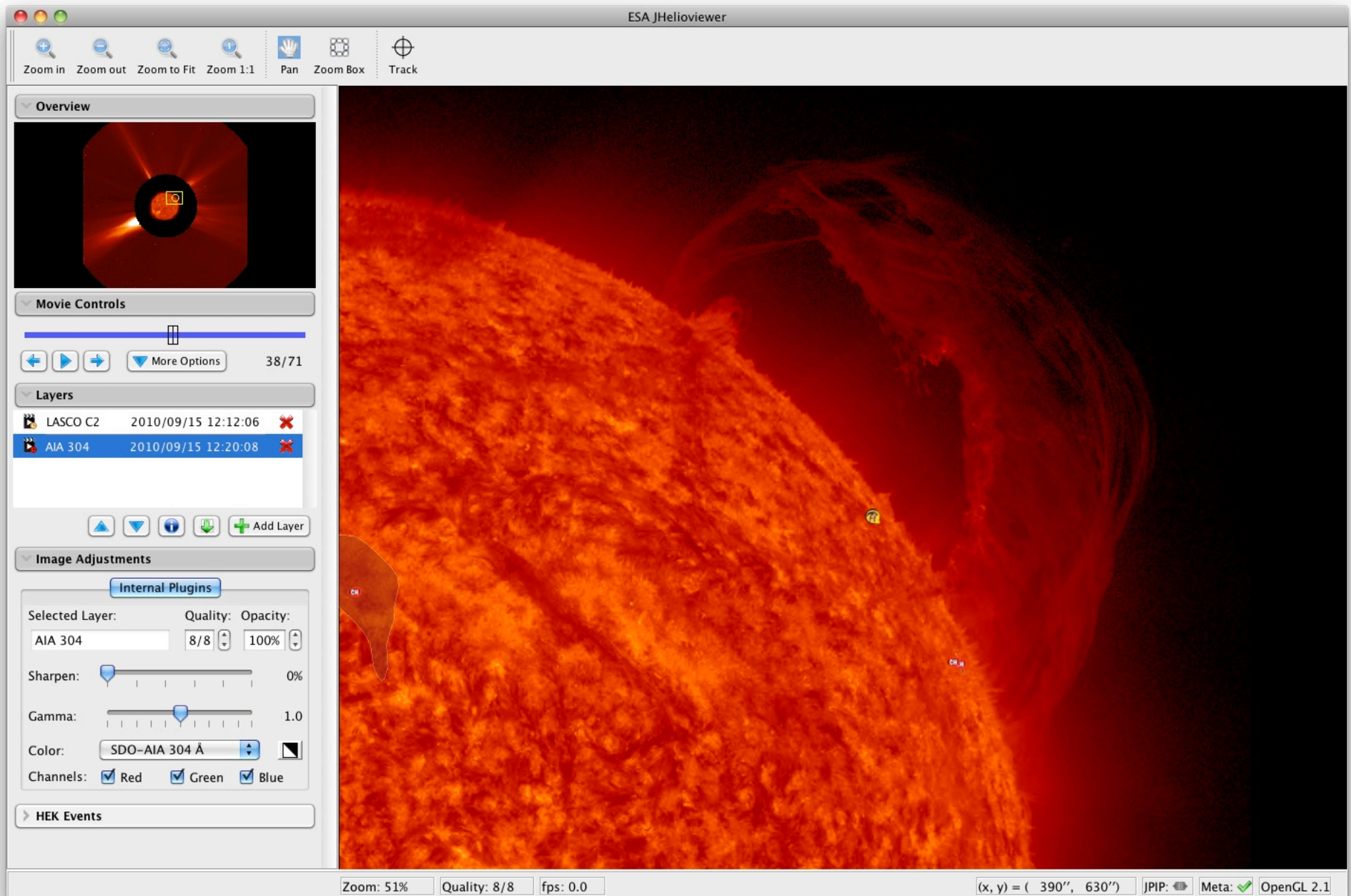
The Sun's 11-year solar cycle is a major control signal



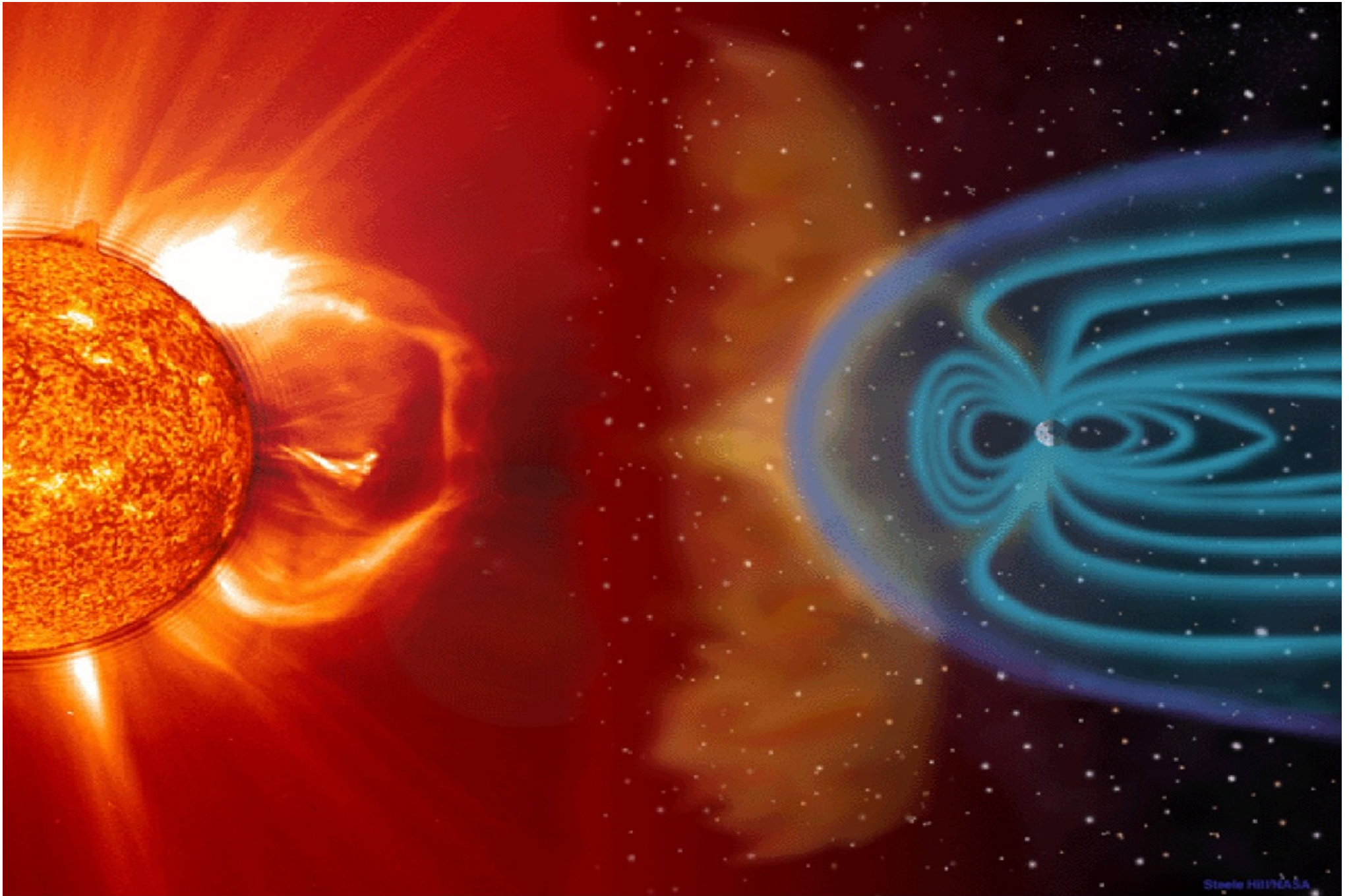
The Sun's internal structure is complex and dynamic



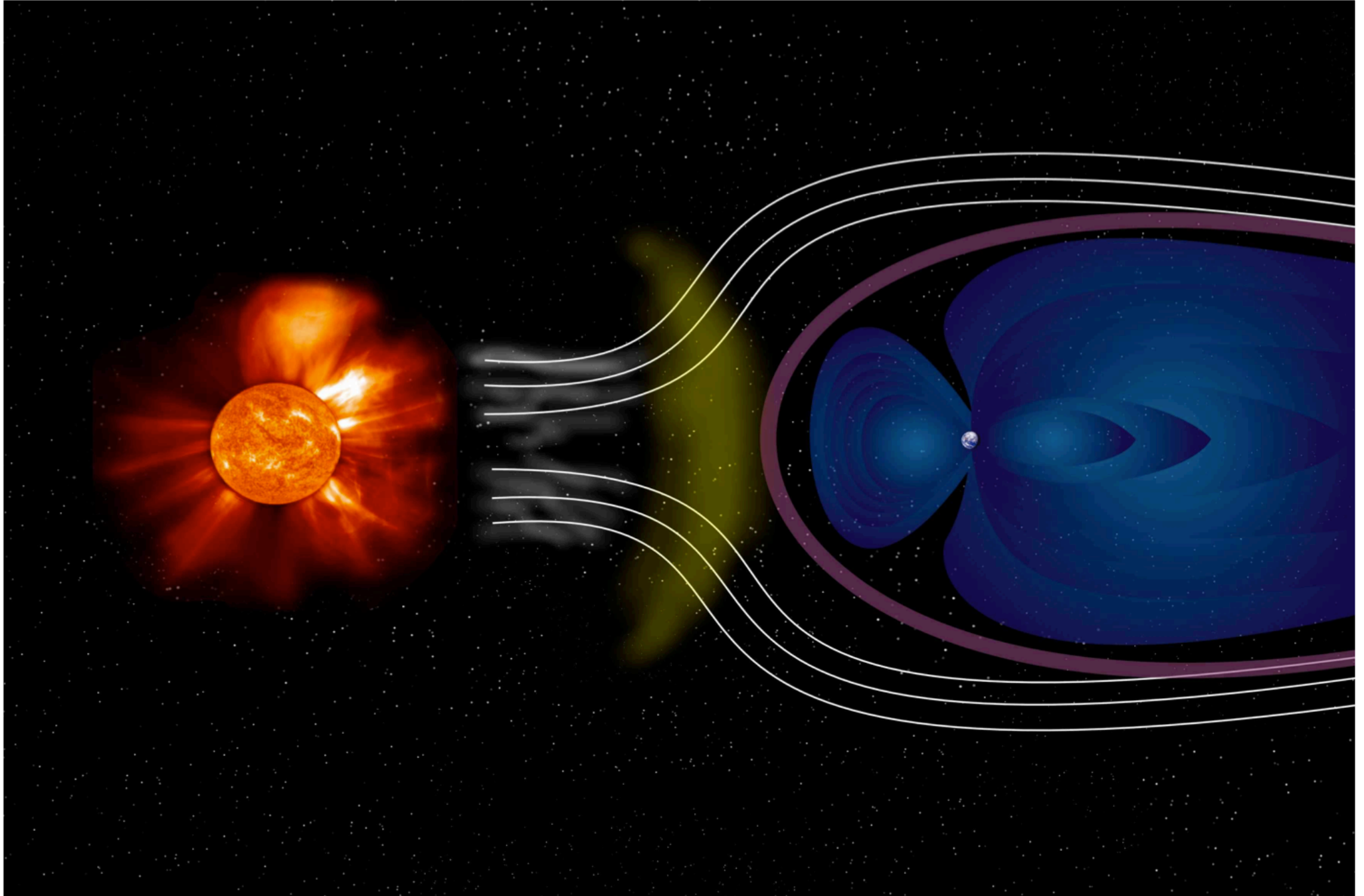
Magnetic loops extend for millions of km into space



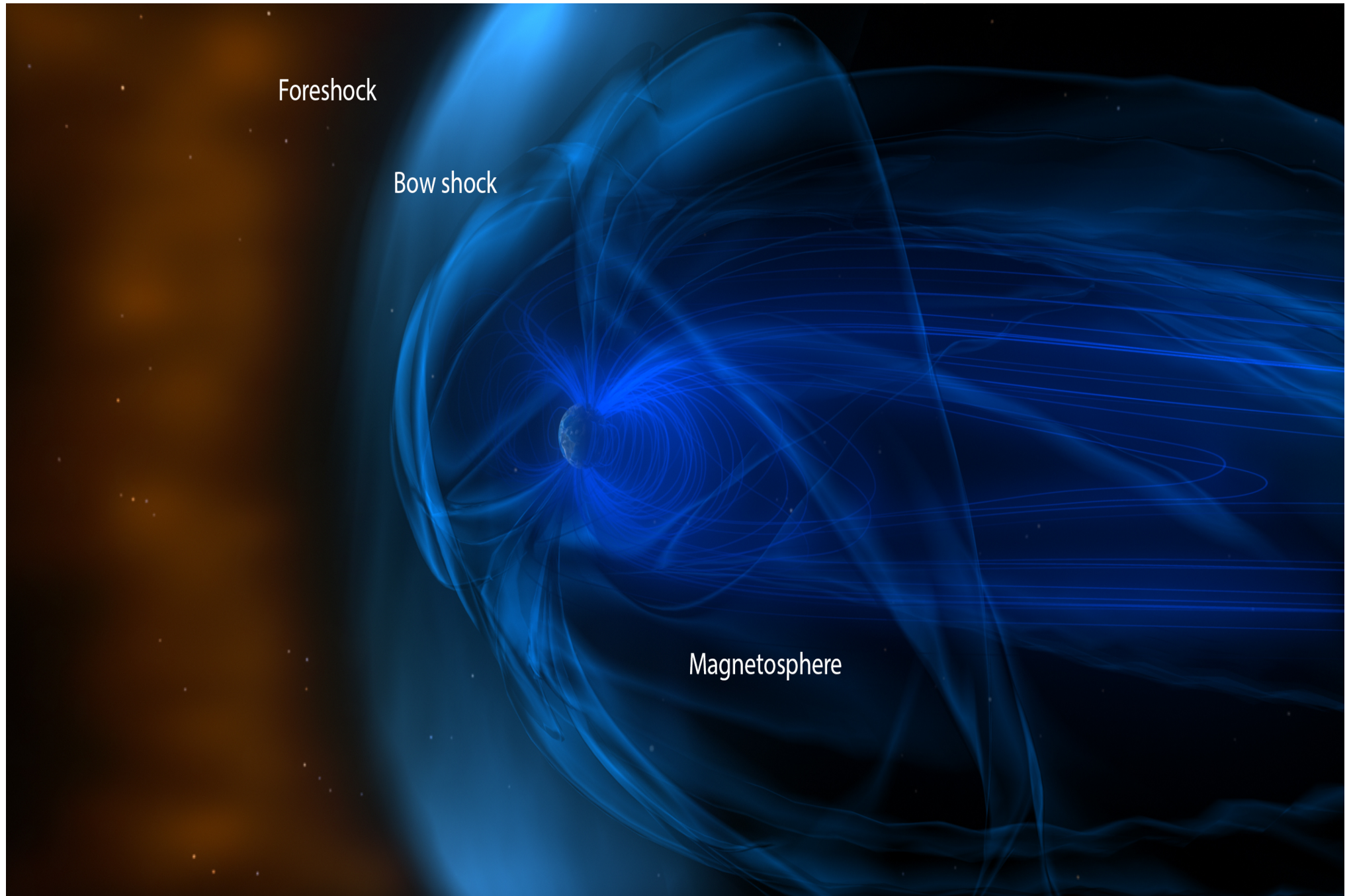
Creating 'space weather' between Sun & Earth



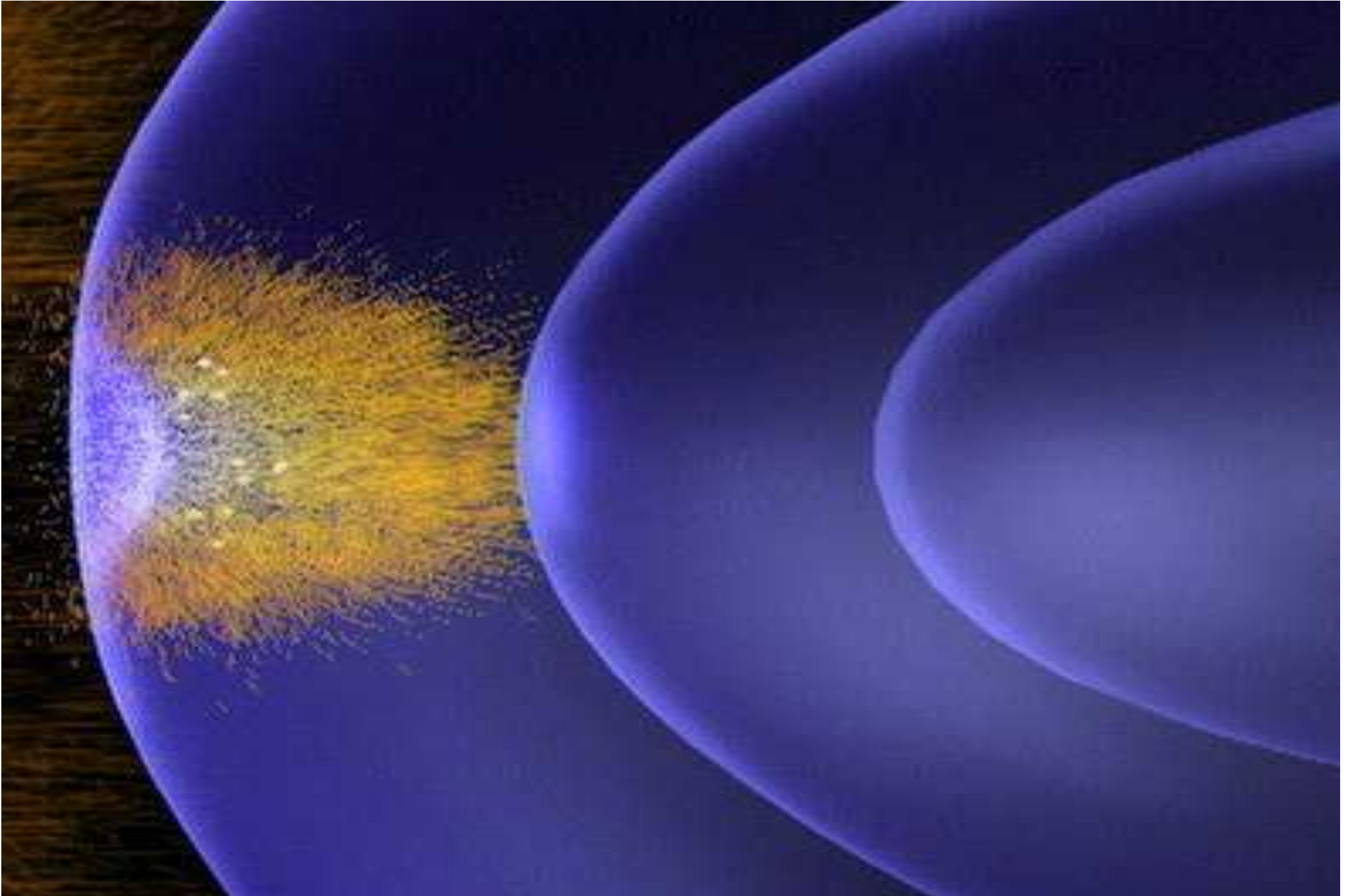
Earth's magnetosphere acts as a deflection shield



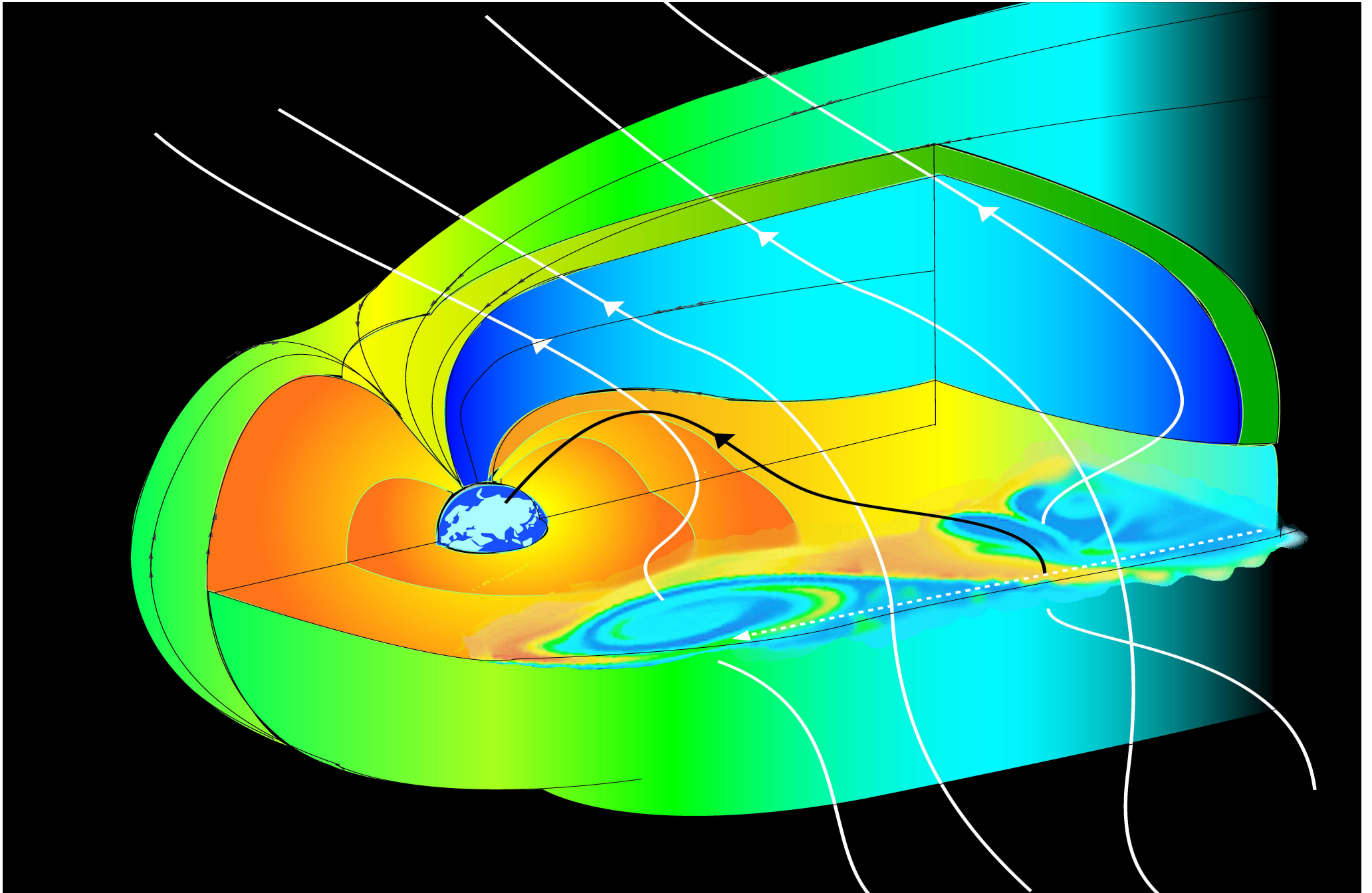
Everything in continuous motion at the same time!



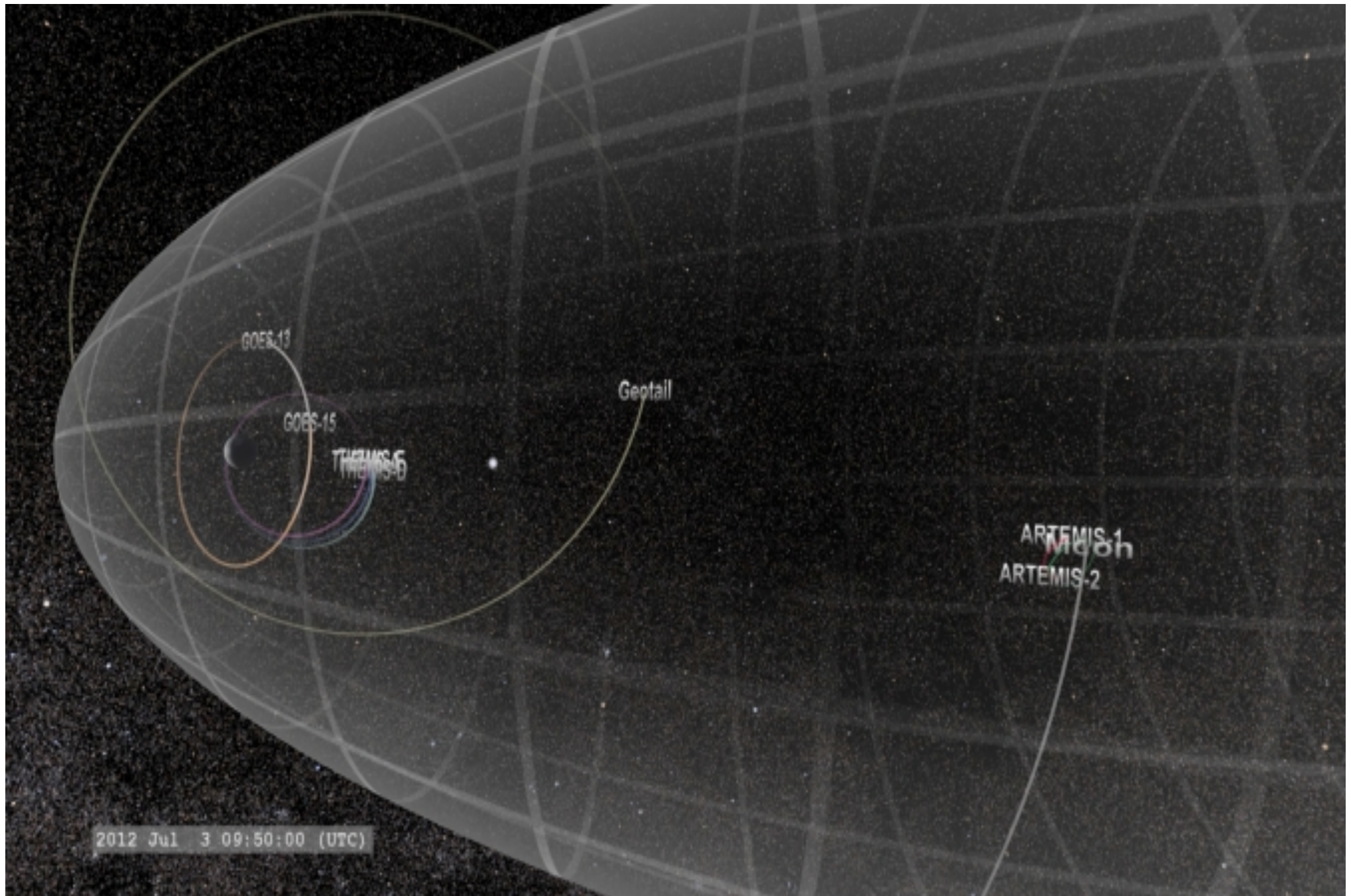
With large leakage currents ...



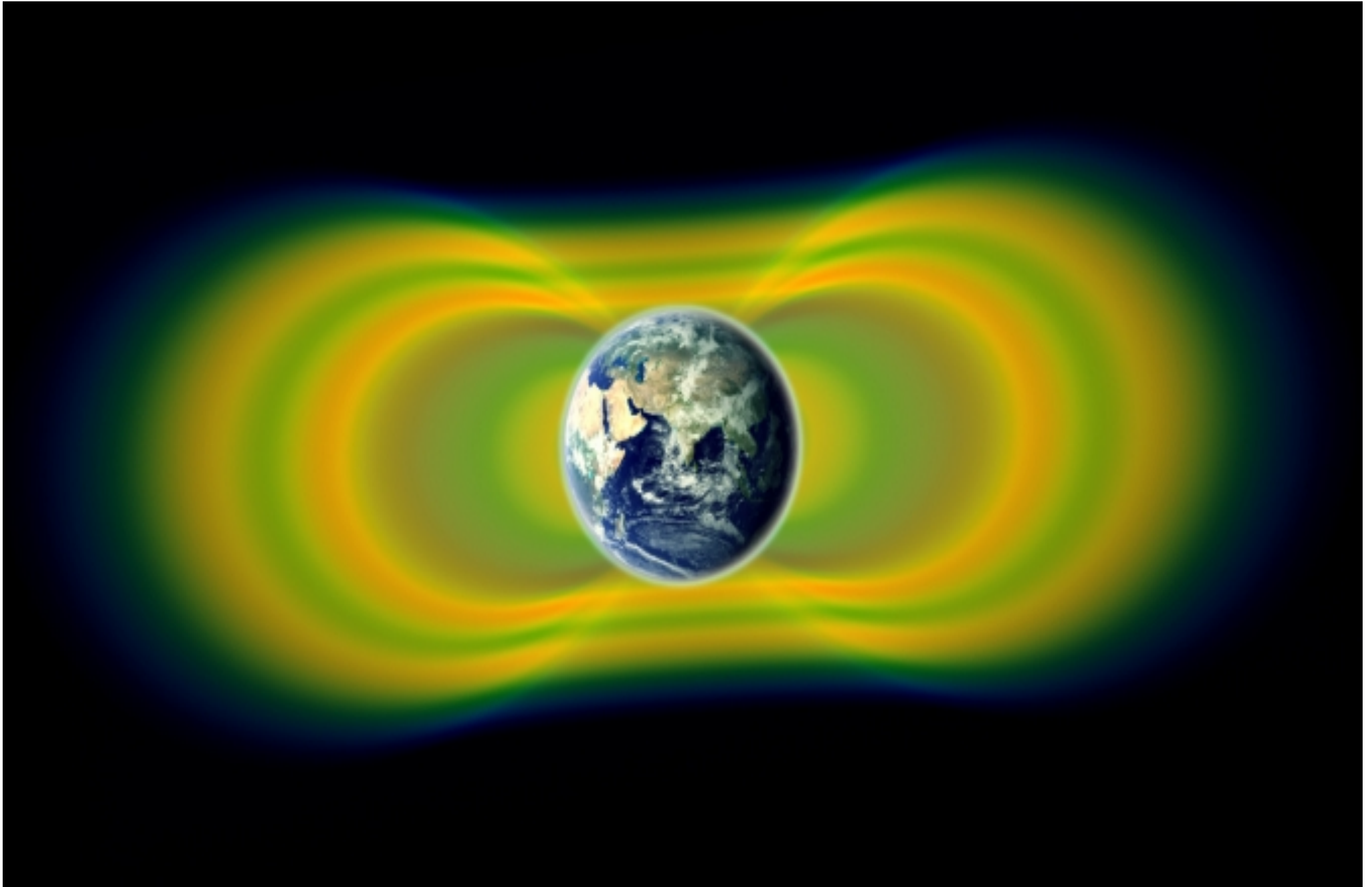
... and enormous electric fields



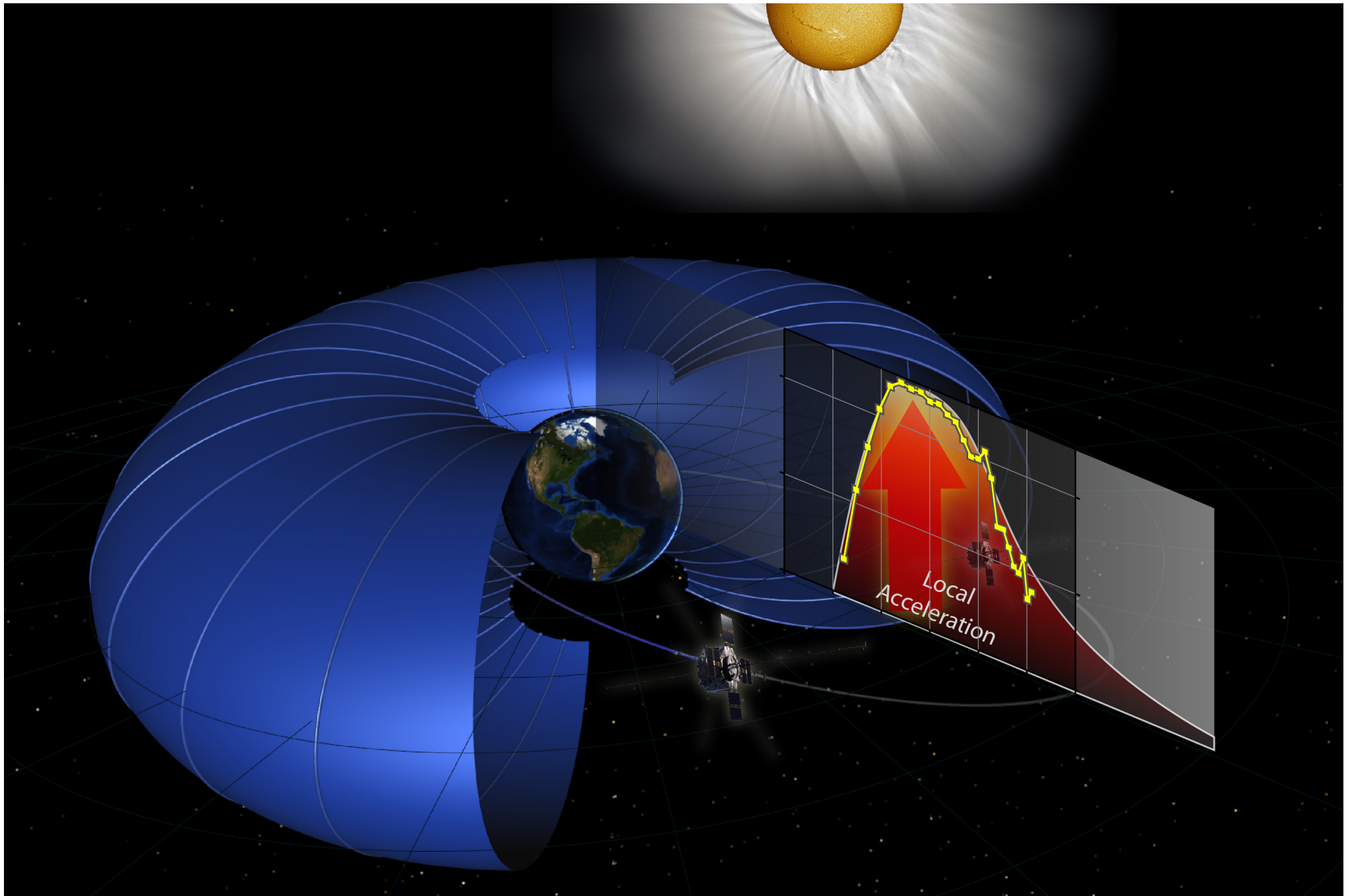
... causing energy transfers within the magnetosphere



... which feed Earth's 3 Van Allen plasma belts



... that accelerate electrons, protons & ions



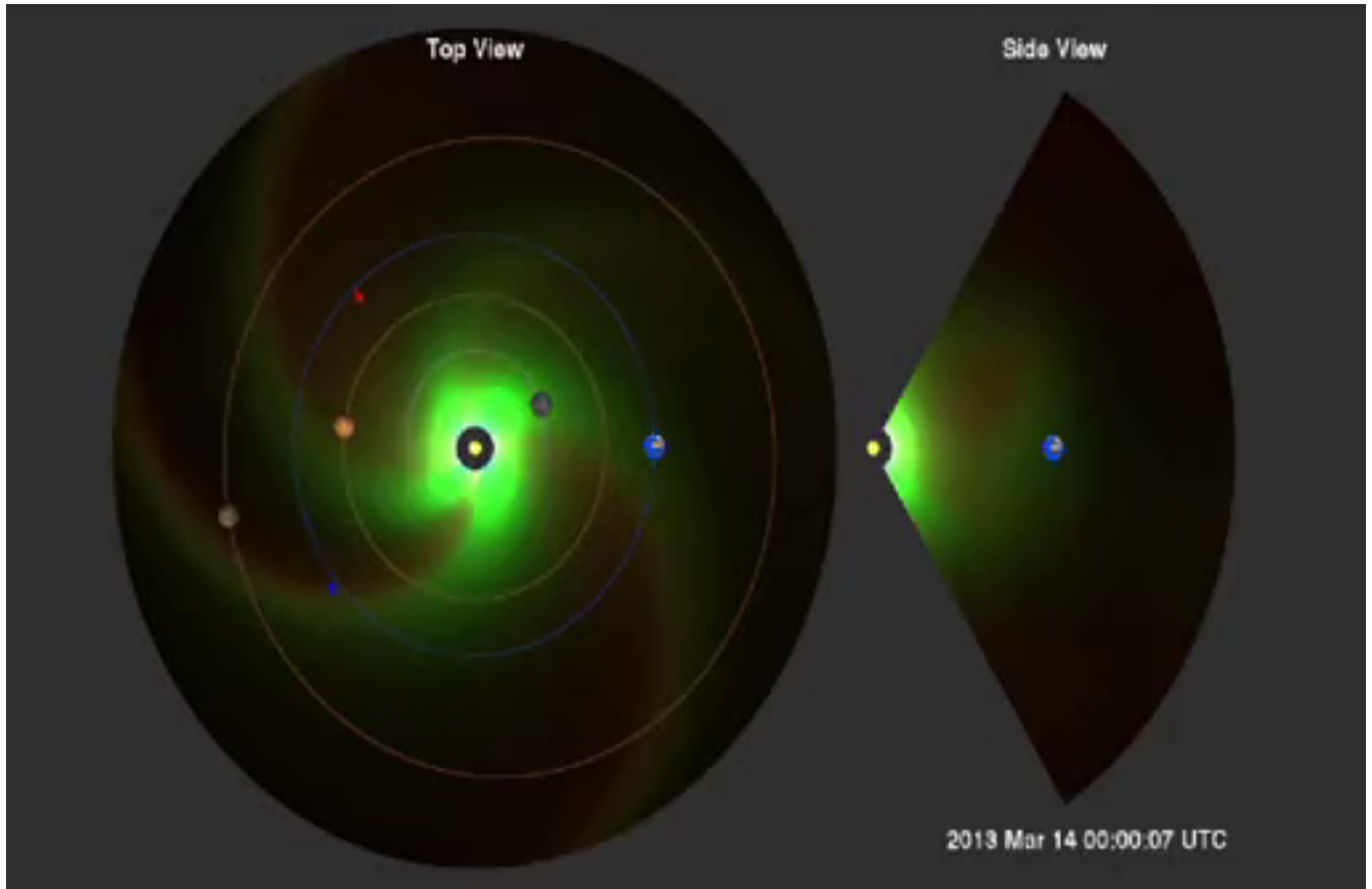
... that bleed down to the Earth's ionosphere



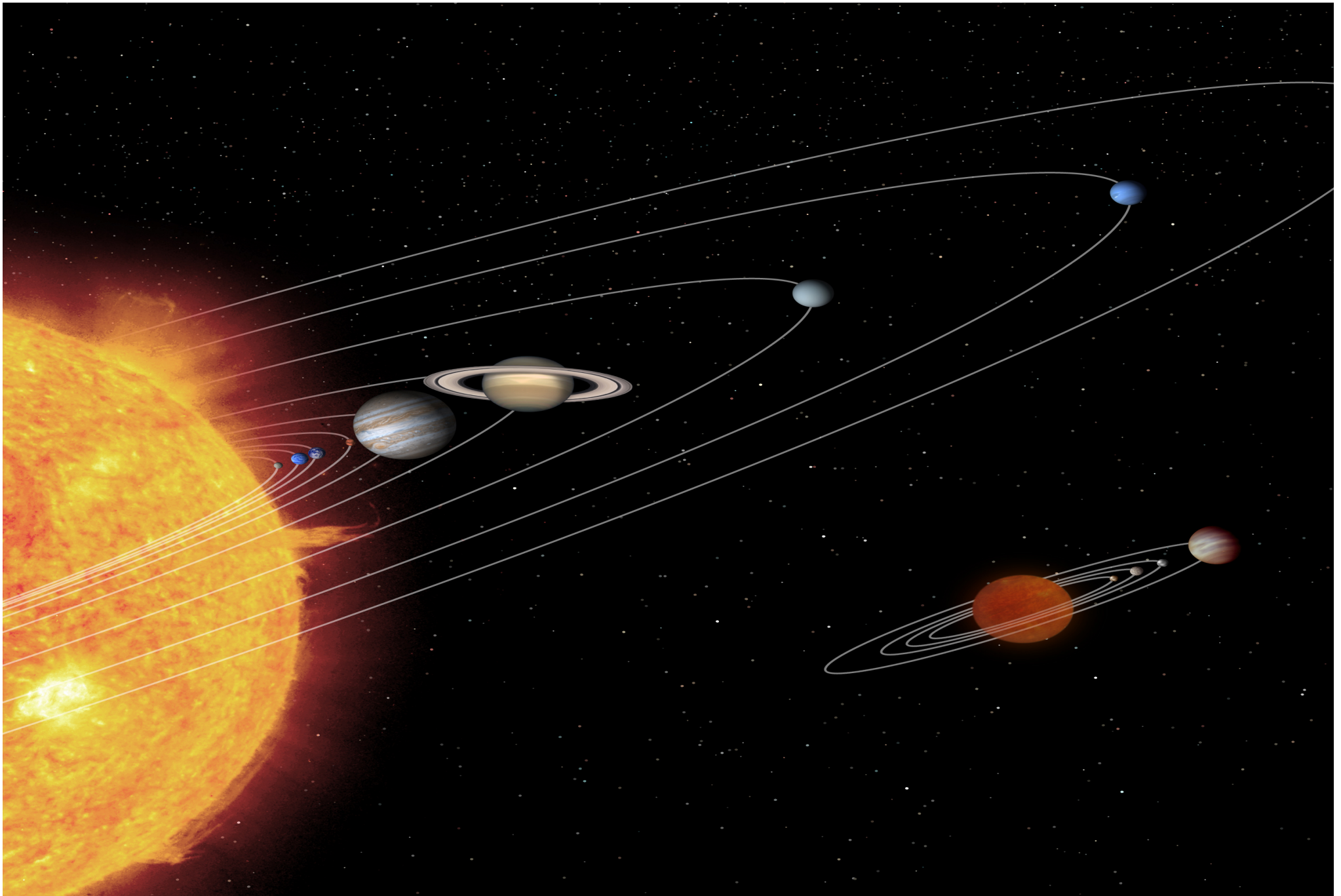
Causing geomag superstorms – Carrington event 1859



Coronal Mass Ejection of 03.14.2013



Indeed, our Solar System is highly interconnected

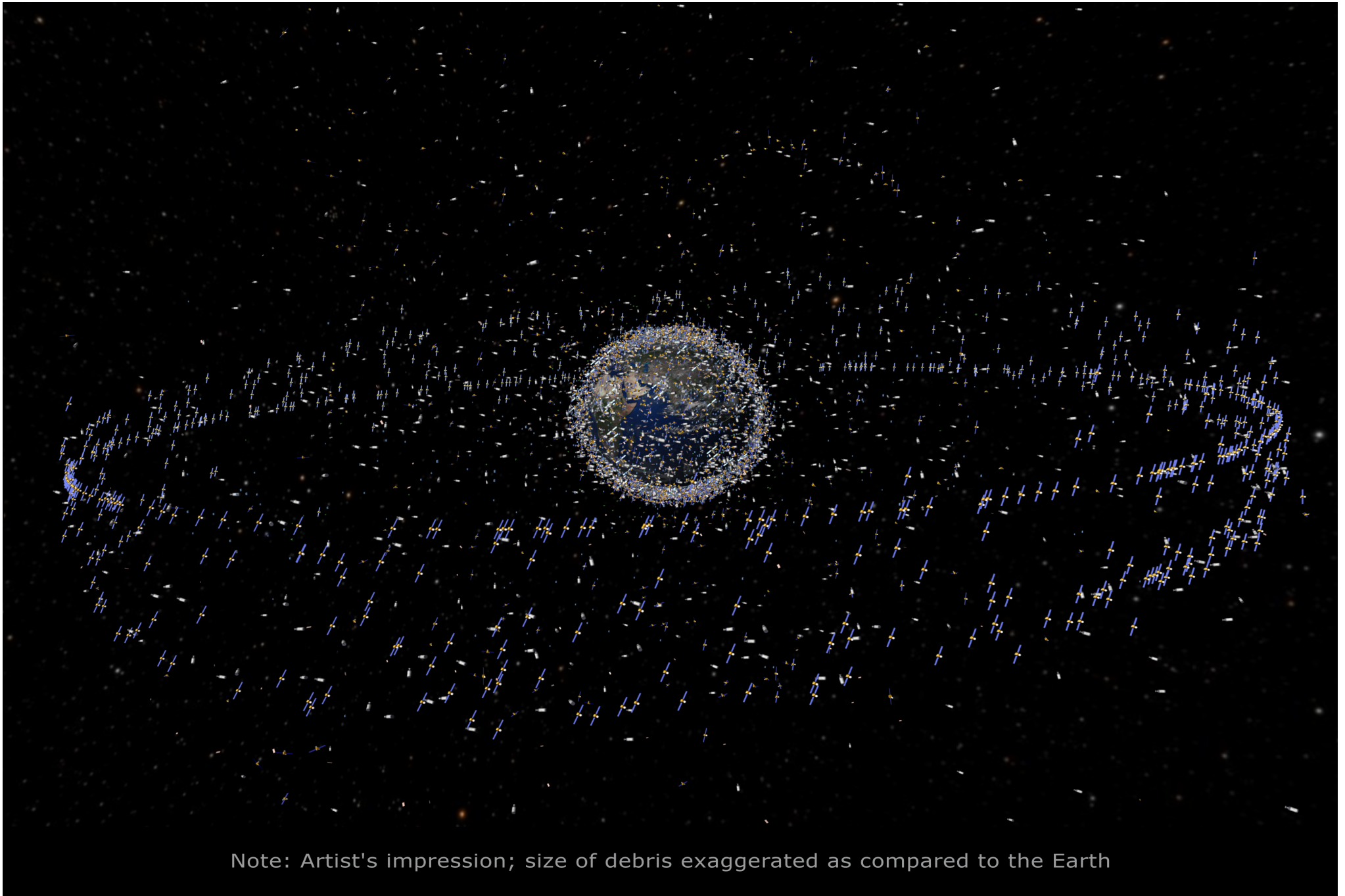


Jupiter alone = 300 x mass of Earth and has 67 moons



Image credit: NASA

In addition, millions of NEOs capable of striking Earth



Note: Artist's impression; size of debris exaggerated as compared to the Earth

Shown by the meteorite over Chelyabinsk 15.02.2013

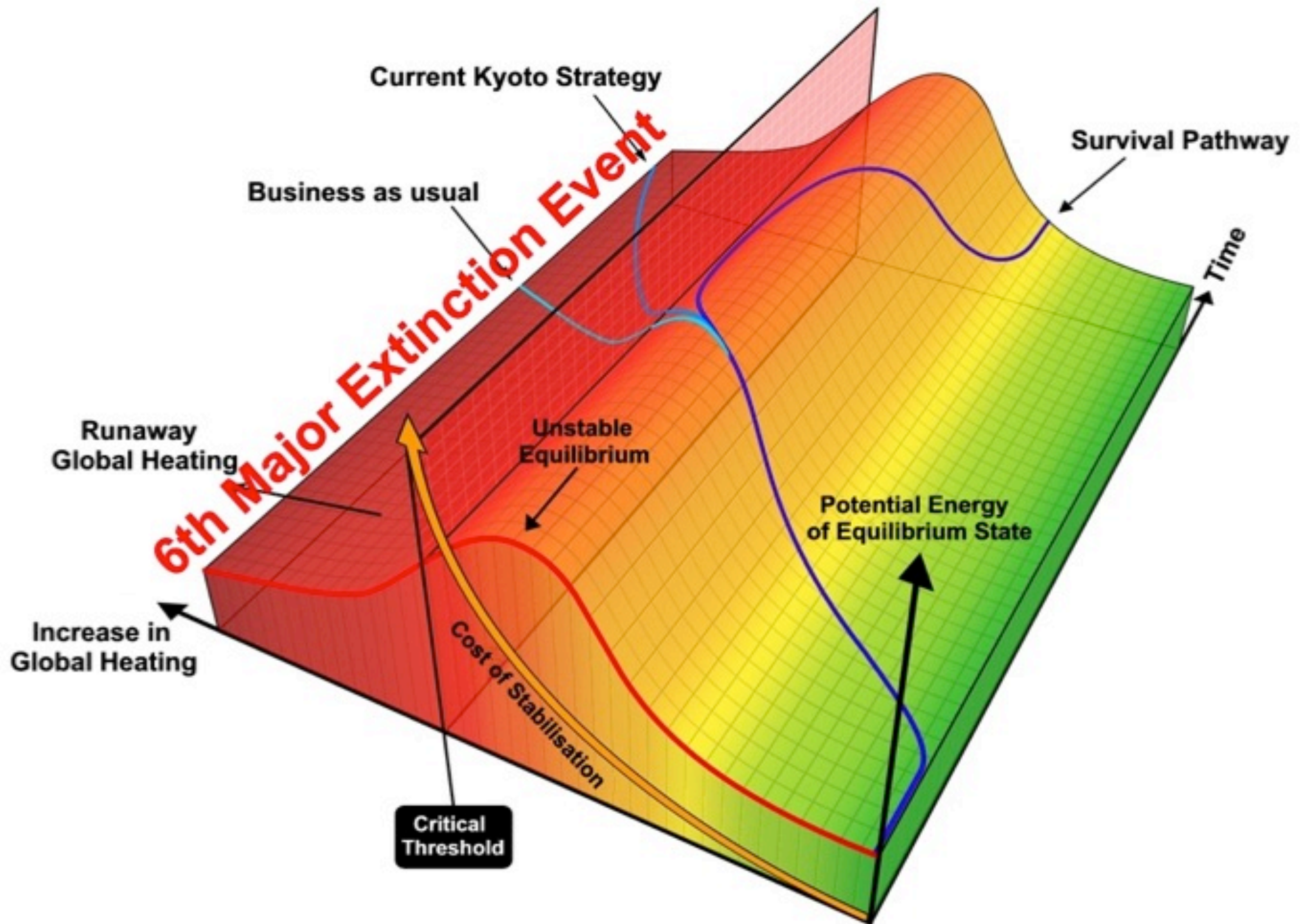


Mathematically, we can describe this with

- Topology
- State Space, Phase Diagrams
- Feedbacks, Attractors, Basins of Attraction

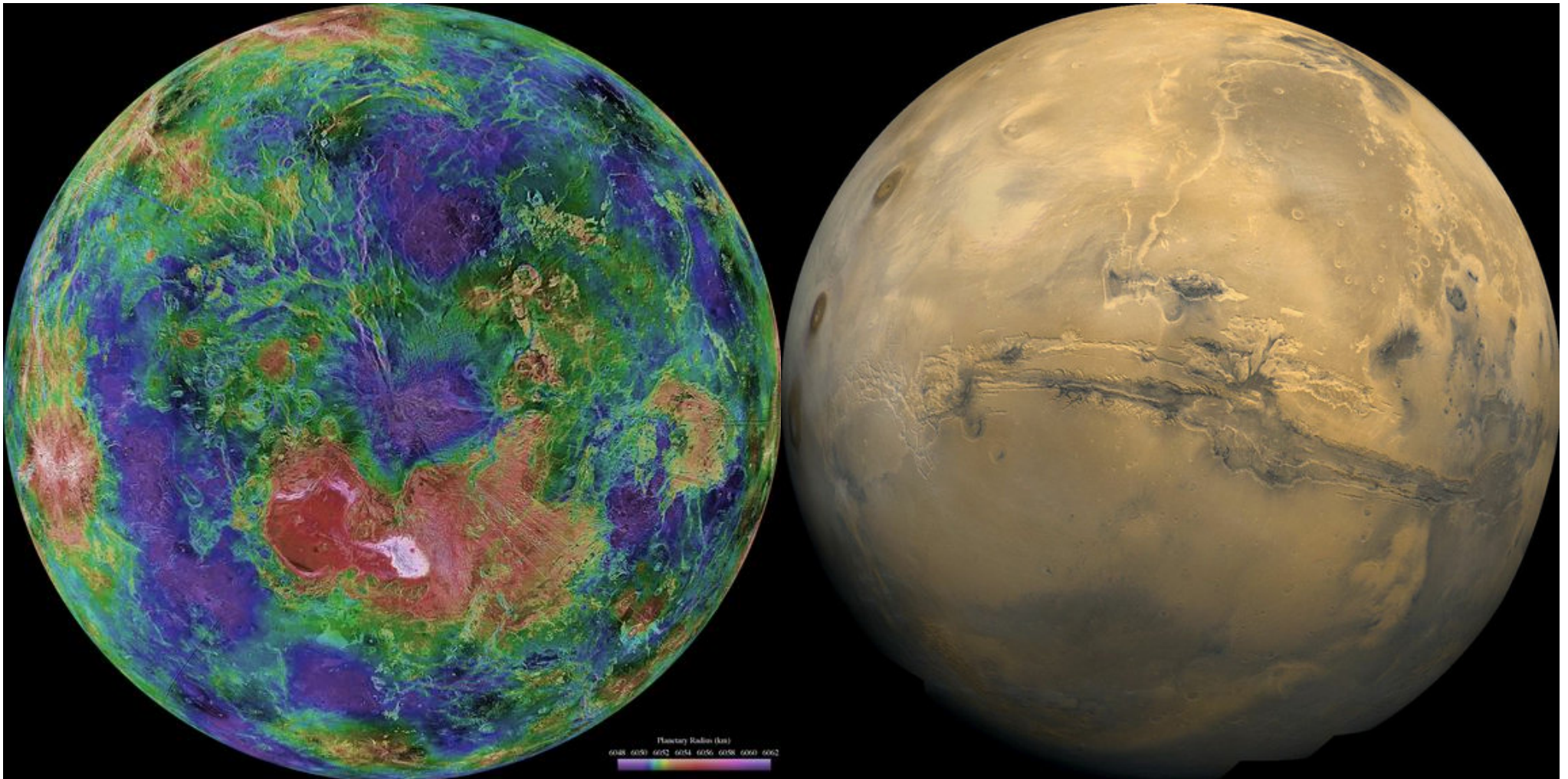
Within which we can postulate ...

- Thresholds
- Tipping points
- Planetary boundaries
 - Fractal boundaries
 - Interacting boundaries
- Safe Operating Space (SOS)



Bifurcation Analysis

Could Future Earth = Venus? Mars?



Interconnected challenges
require
Interconnected resources!



Cascadia Resilience Center

International Centre for Earth Simulation

