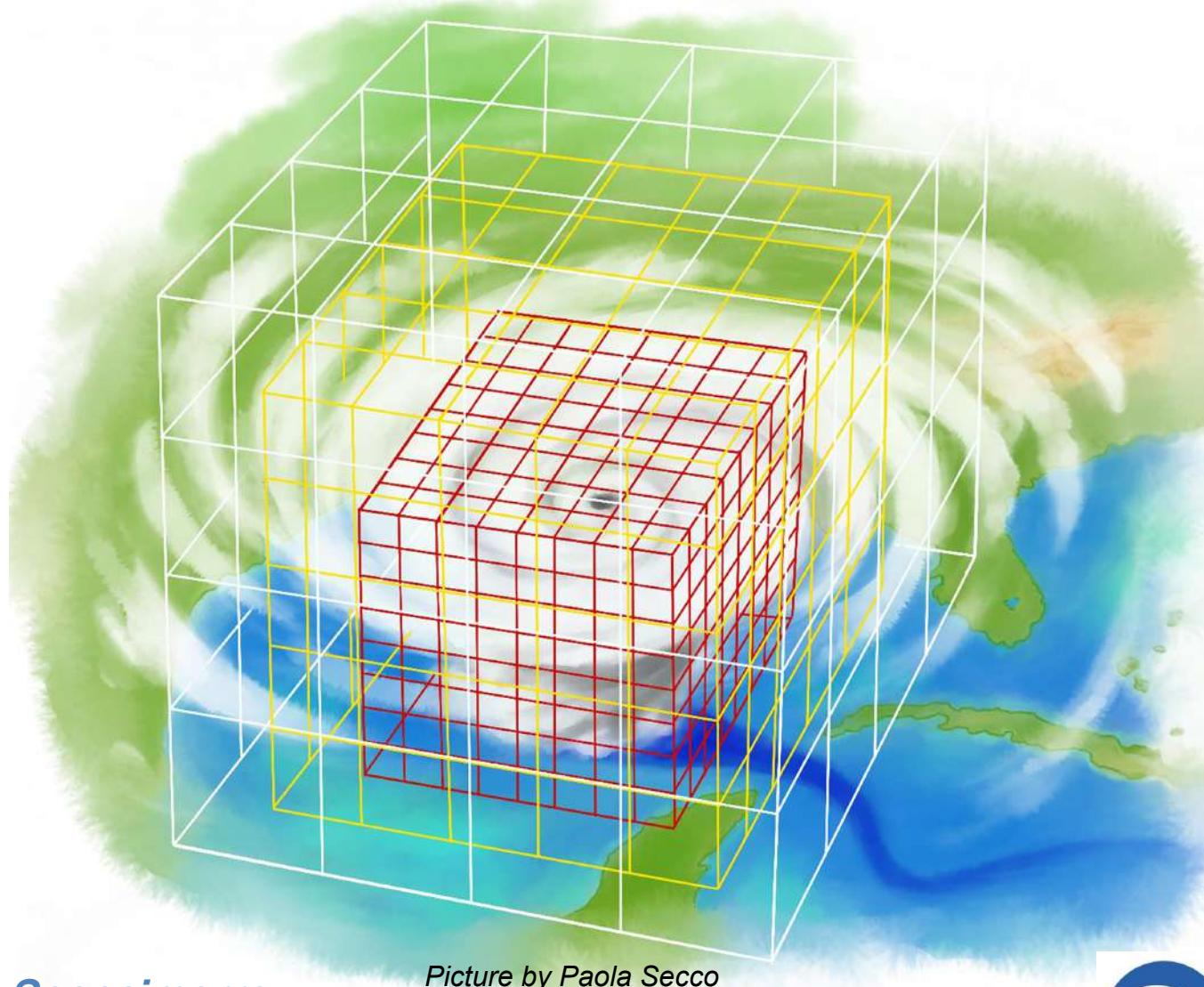


CAMBIAMENTI CLIMATICI, CICLONI TROPICALI E VARIAZIONI DEL LIVELLO DEI MARI



Picture by Paola Secco

Enrico Scoccimarro
Fondazione CMCC

Assessing North Atlantic tropical cyclone tracks and evolution – CMCC

+ http://www.cmcc.it/article/assessing-north-atlantic-tropical-cyclone-tracks-and-evolution

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RESEARCH ACTIVITIES A scientific portrait

CMCC AND THE SOCIETY Activities and Services for Institutions, Companies, Associations

Home » TEC – the CMCC blog » Assessing North Atlantic tropical cyclone tracks and evolution

News

05/02/2015

Extreme events Models Tropical cyclones



The impact of tropical cyclones on societies makes it important to understand how their characteristics, dynamics and trends might change in the future. Therefore a realistic representation of the North Atlantic tropical cyclone tracks is crucial as it allows, for example, explaining potential changes in US landfalling systems.

In a new study recently published on *Journal of Climate* a team of scientists (among them, CMCC researcher E. Scoccimarro from CSP Division) examined the ability of recent climate models to represent North Atlantic tropical cyclone tracks.

CC NASA Goddard Space Photo and Video @Flickr.com

EVENTS

- ICCG Webinar on Water Challenges in the Agricultural Sector
- International Journalism Festival: "Climate Change: the challenge to journalism"
- II International Conference on Fire Behaviour and Risk
- Climate Cinema 2015

[View all »](#)

TAG CLOUD

Adaptation Climate Change Impacts Climate Change Risks Climate Projections Emission-Reduction Goals Energy Efficiency ETS - Emission trading scheme Extreme events Forestry GCM GCMs

The euro Mediterranean Center on Climate Change (CMCC) mission is to investigate and model our climate system and its interactions with society to provide reliable, rigorous, and timely scientific results to stimulate sustainable growth, protect the environment, and to develop science driven adaptation and mitigation policies in a changing climate.

FONDAZIONE CMCC

<http://www.cmcc.it>

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Meteo o Clima?

Il **TEMPO METEOROLOGICO** è lo stato dell'atmosfera in un dato momento e in un certo luogo.

“Come sarà il tempo domani a...?”



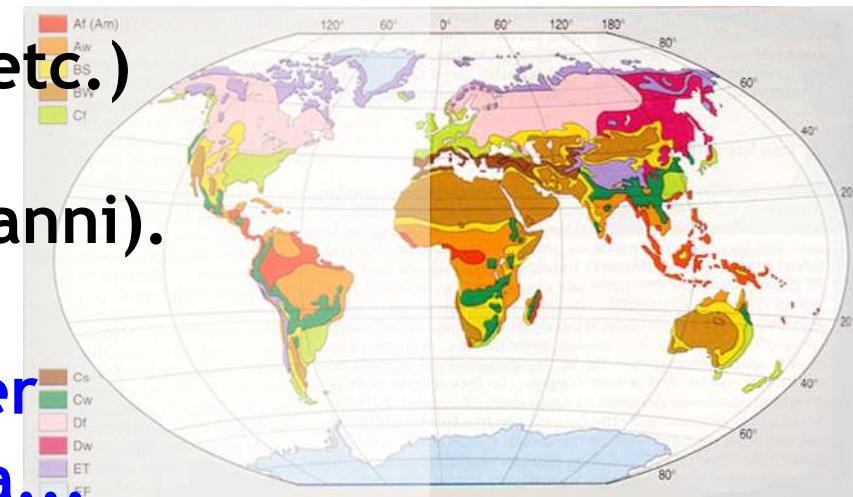
è la domanda che ci poniamo prima di fare una gita...

Il **CLIMA** rappresenta le condizioni “medie” di una certa zona (temperatura, precipitazioni, umidità, vento, etc.) considerando

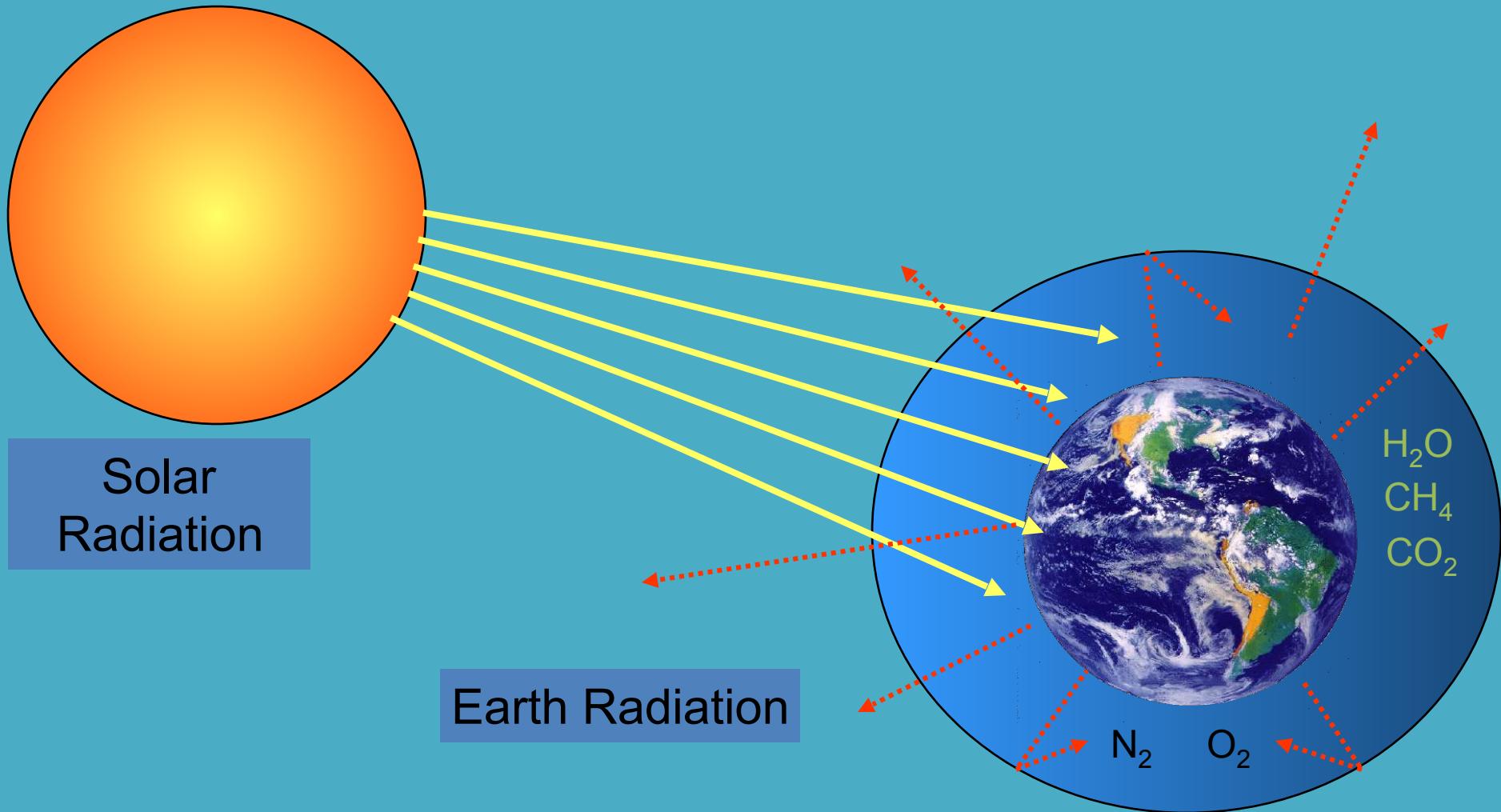
un arco di tempo più lungo (30 anni).

“Com'è il clima a...?”

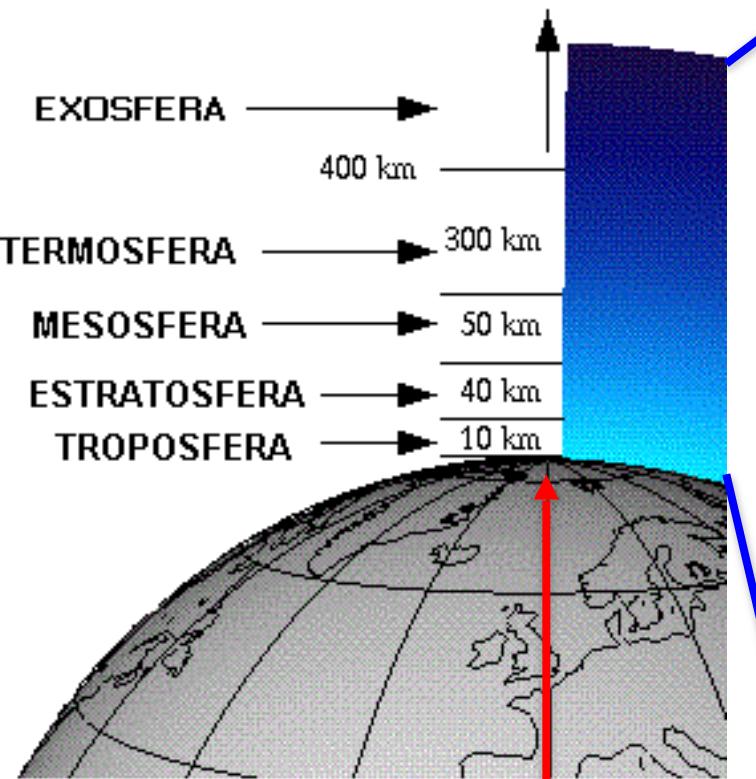
è la domanda che ci poniamo per scegliere una località di vacanza...



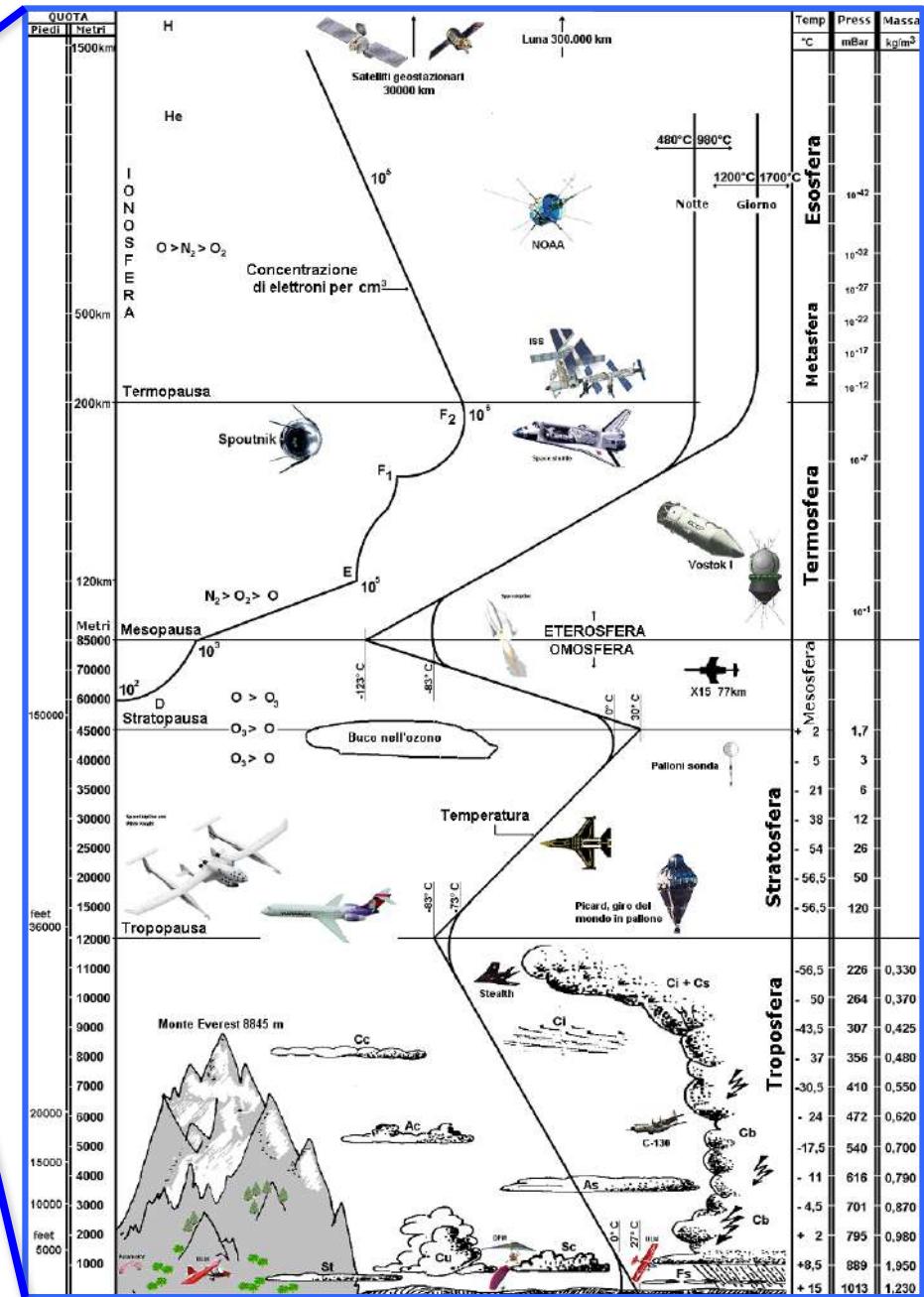
The Climate Machine

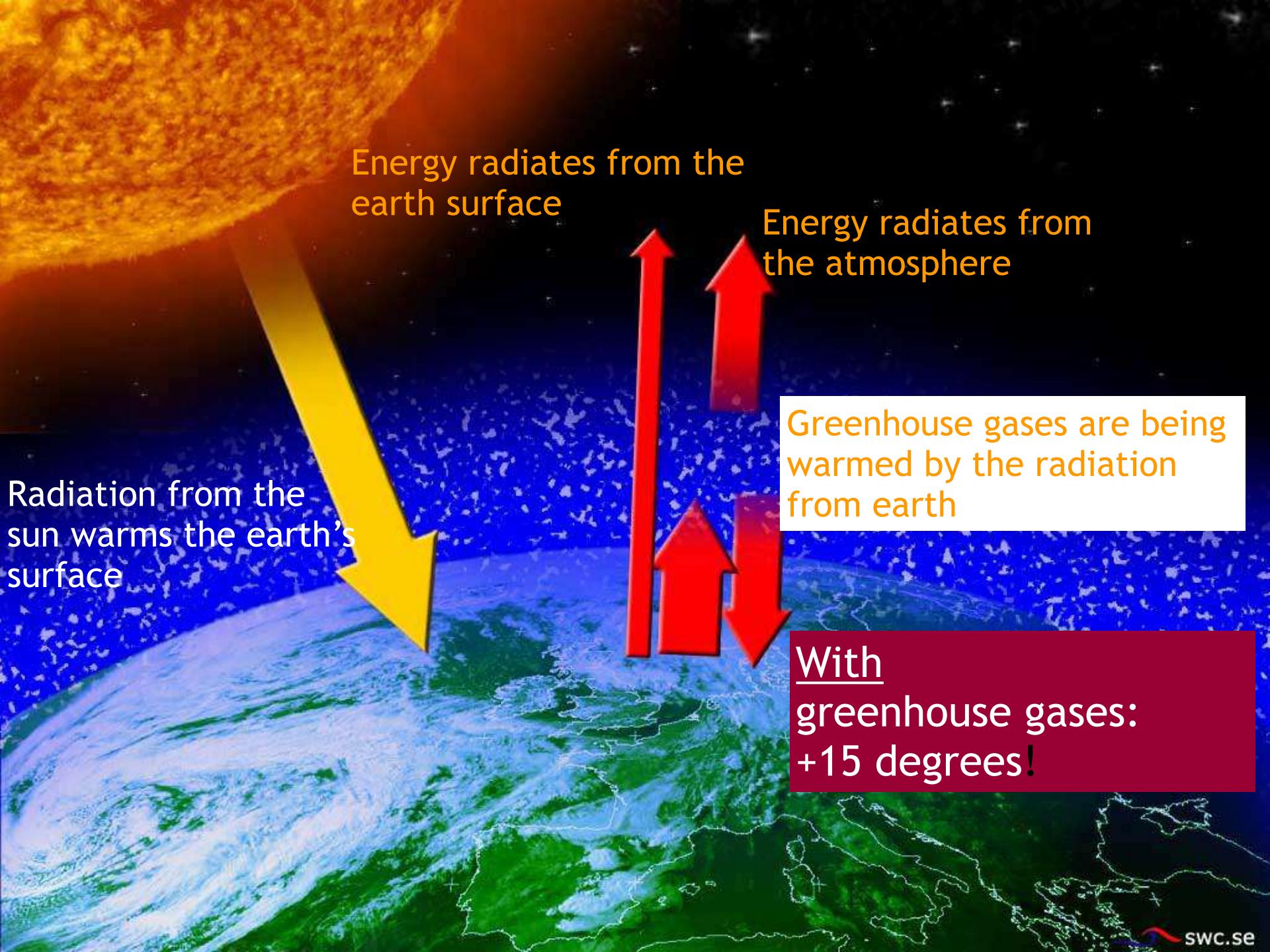


Lo spessore della troposfera



Raggio terrestre? 6000 km!





Radiation from the sun warms the earth's surface

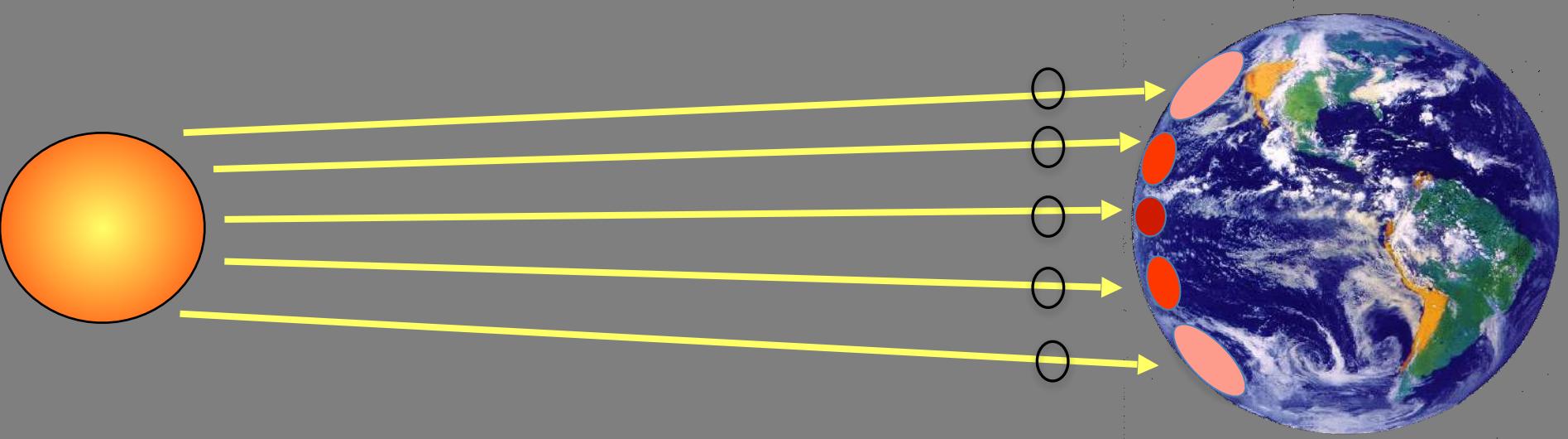
Energy radiates from the earth surface

Energy radiates from the atmosphere

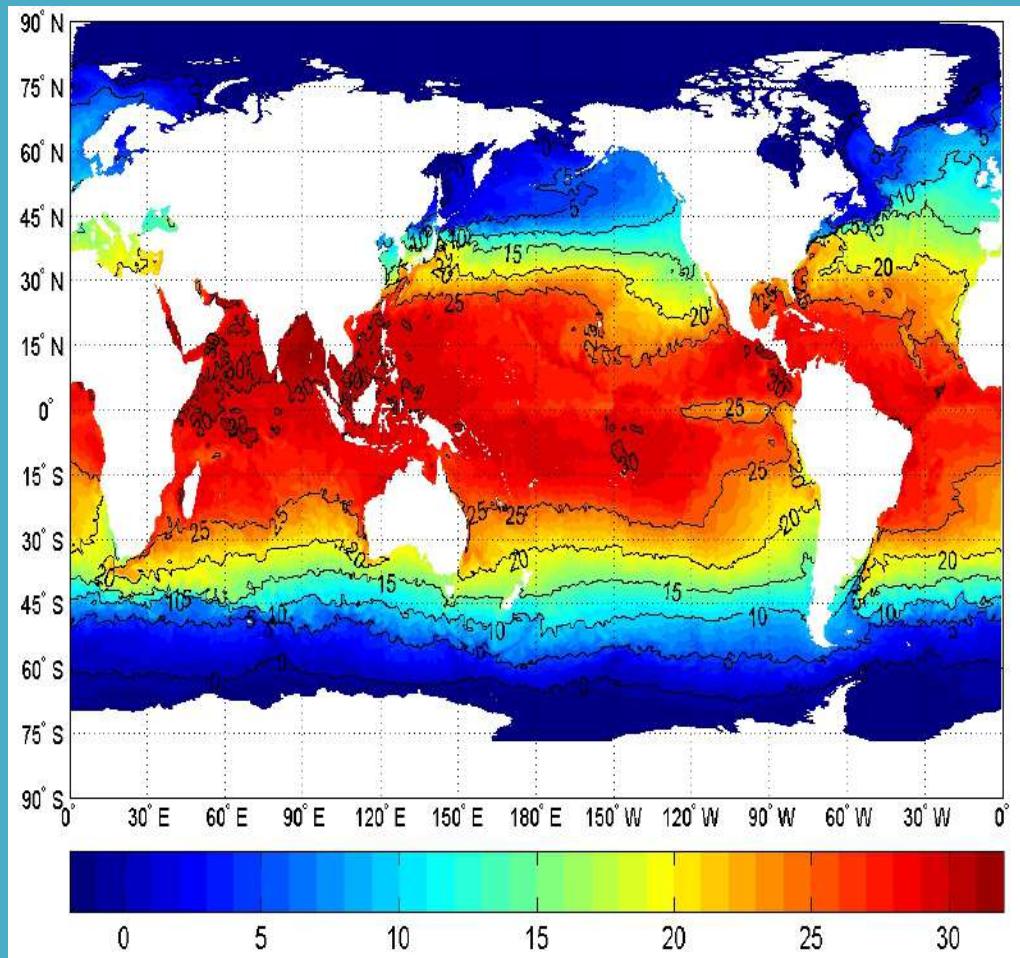
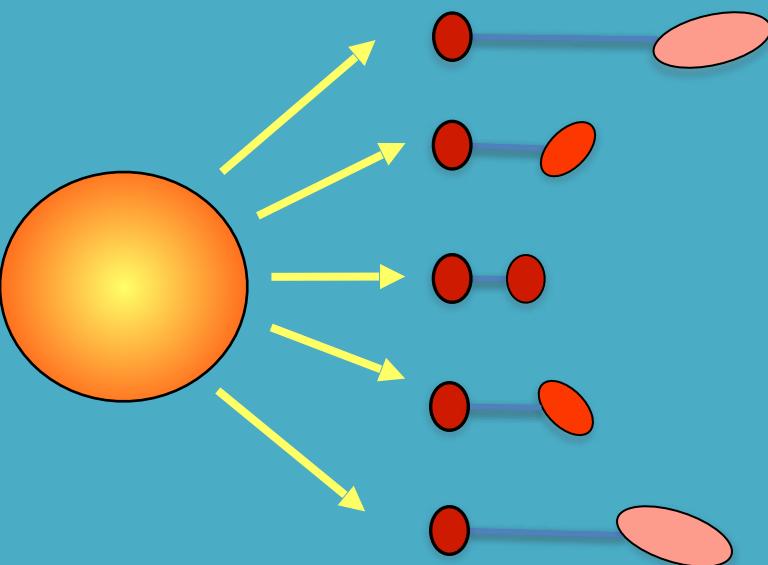
Greenhouse gases are being warmed by the radiation from earth

With
greenhouse gases:
+15 degrees!

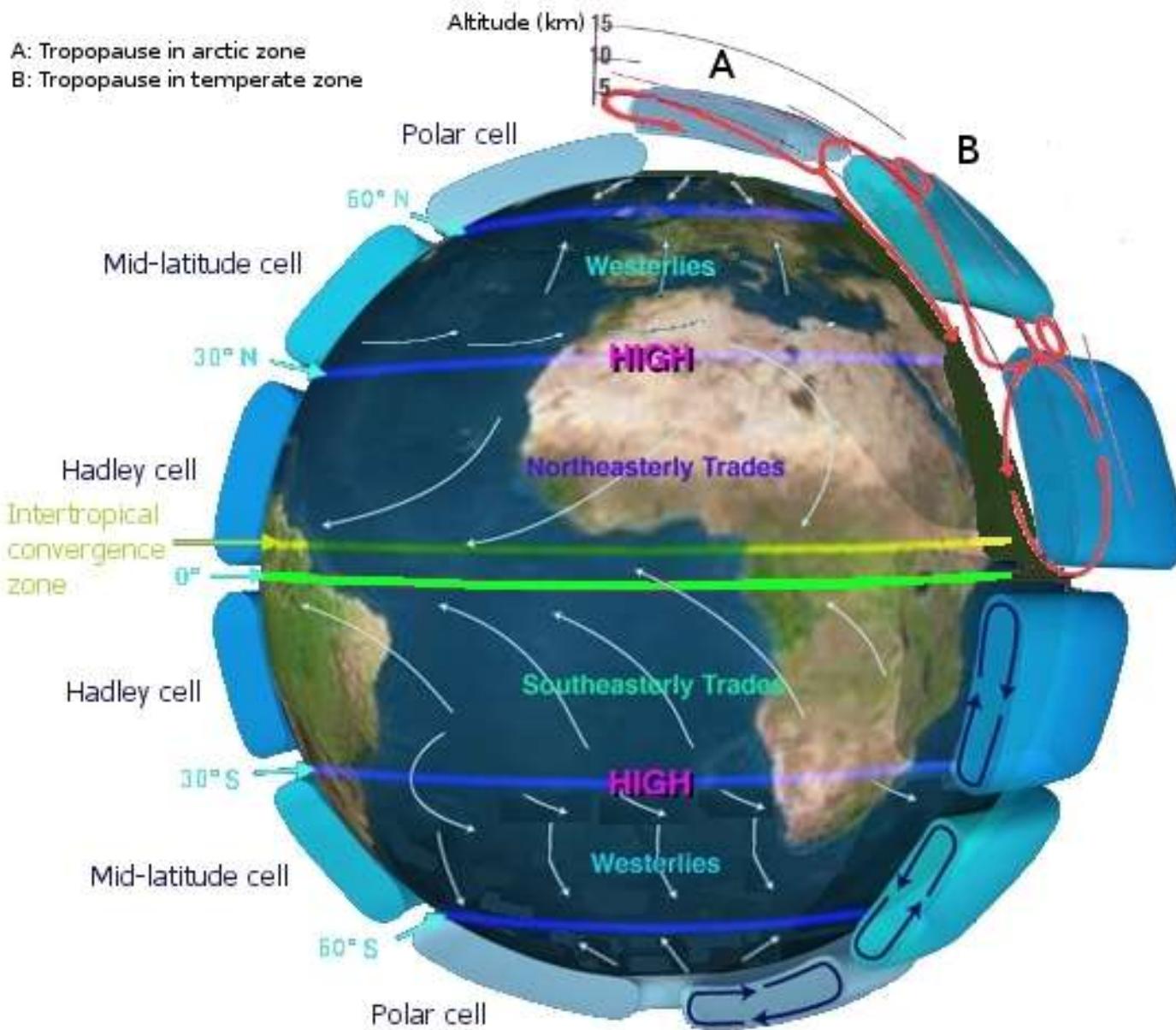
Come il sole riscalda il pianeta terra



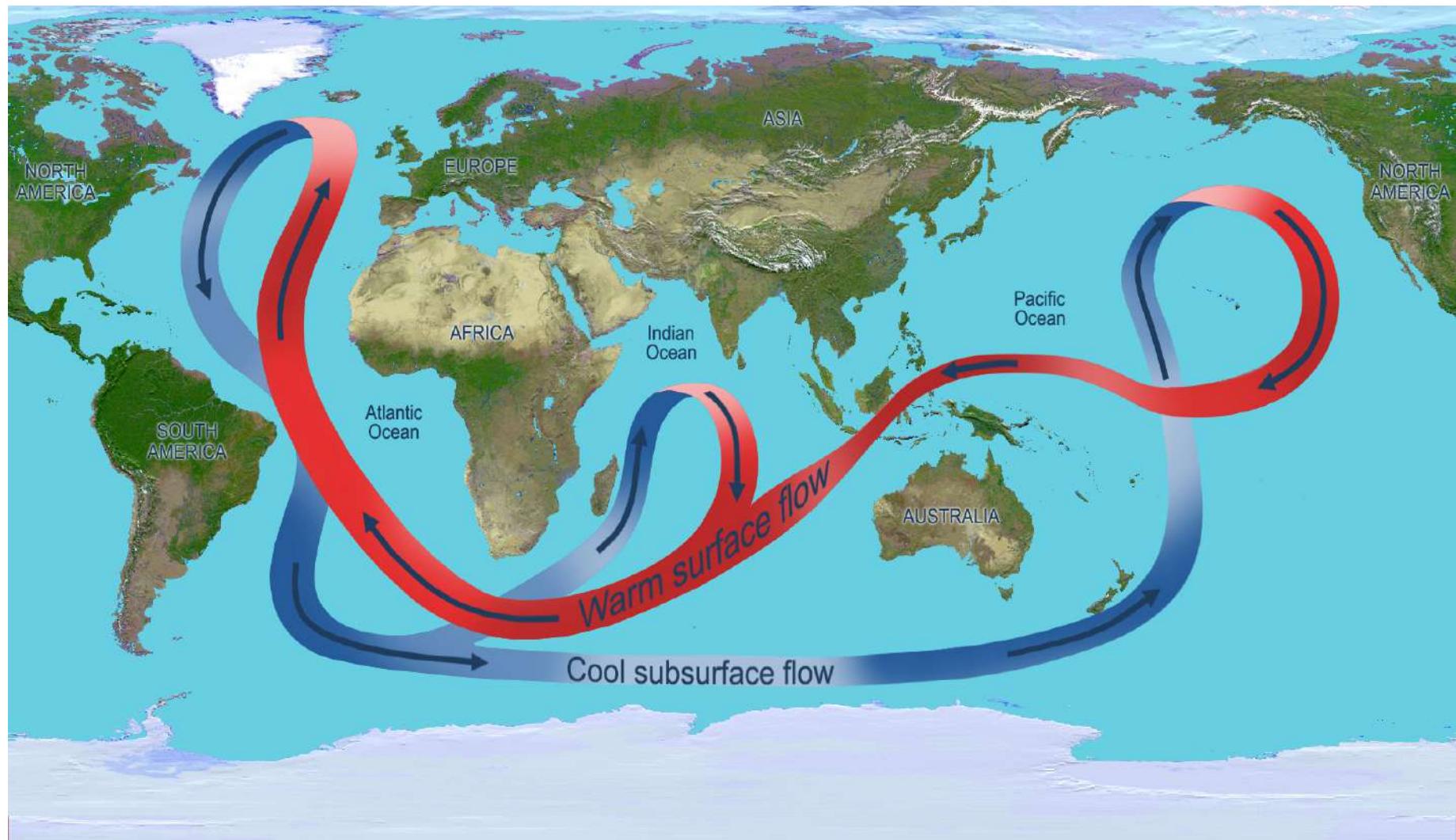
Climatologia della temperatura superficiale dell'oceano (SST - Sea Surface Temperature [$^{\circ}$ C])



La circolazione atmosferica



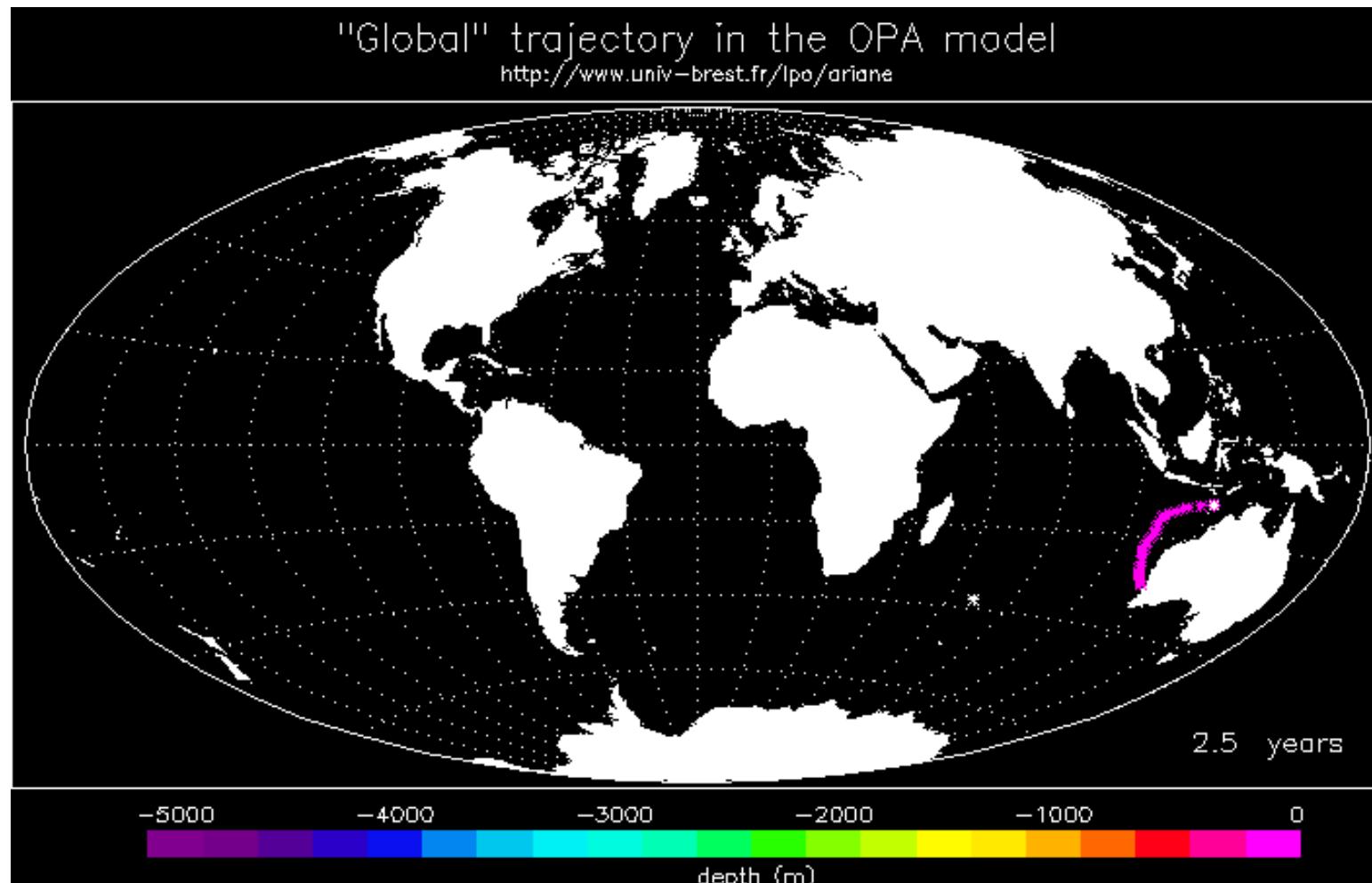
La circolazione oceanica



rosso = caldo

blu = freddo

The Ocean Circulation (OGCM results)



Cosa sono i cambiamenti climatici?

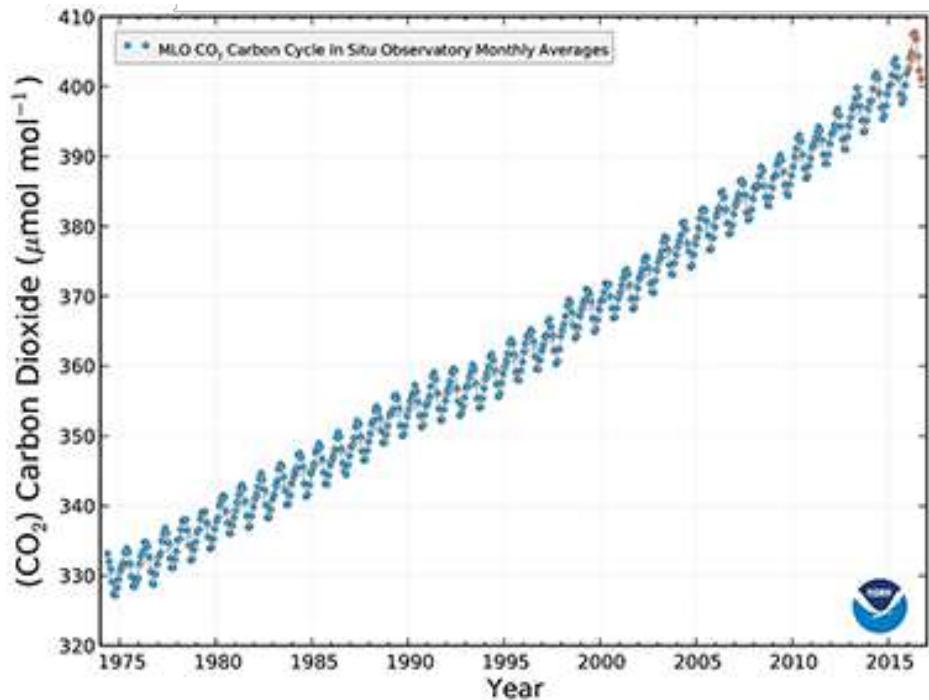
CAMBIAMENTO CLIMATICO si riferisce ad una variazione significativa sia dello “stato medio” che della “variabilità” del clima che persista per un tempo “lungo” (circa 30 anni).

Cambiamenti climatici si sono verificati su scale temporali molto lunghe (centinaia di migliaia di anni) x cause “esterne” (variazioni orbitali,...).

Nell’ultimo secolo però’..

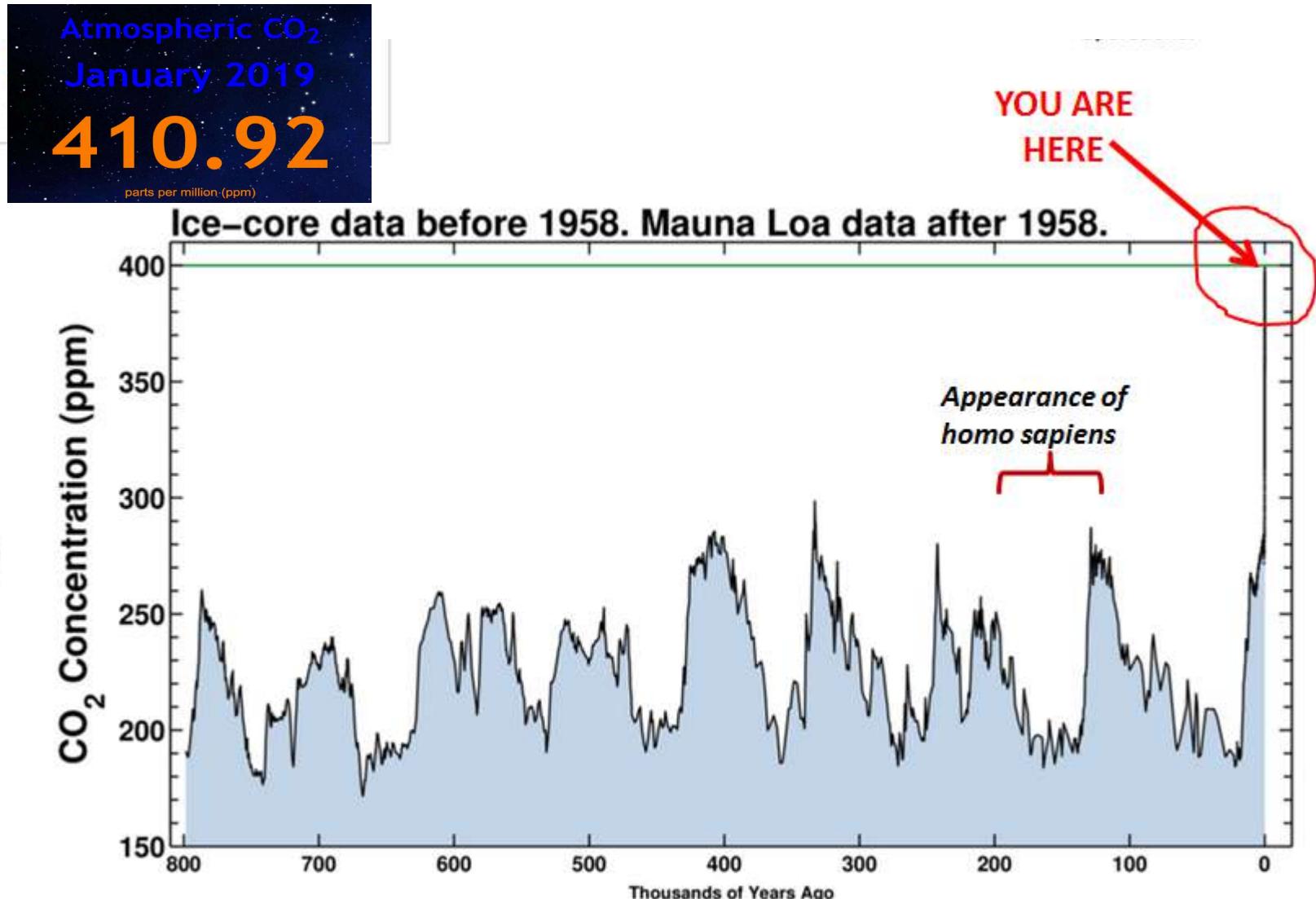
Changes in atmospheric CO₂ concentration

main GHGs are : CO₂, CH₄, H₂O



<http://www.esrl.noaa.gov/gmd/ccgg/iadv/>

Why “unprecedented perturbation”?



Source: <http://keelingcurve.ucsd.edu/>



Il Destino delle Emissioni di Anidride Carbonica [CO₂]

$1.1 \pm 0.7 \text{ PgC y}^{-1}$



$7.7 \pm 0.5 \text{ PgC y}^{-1}$

+



$4.1 \pm 0.1 \text{ PgC y}^{-1}$

47%



2.4 PgC y^{-1}

27%

Calculated as the residual of
all other flux components



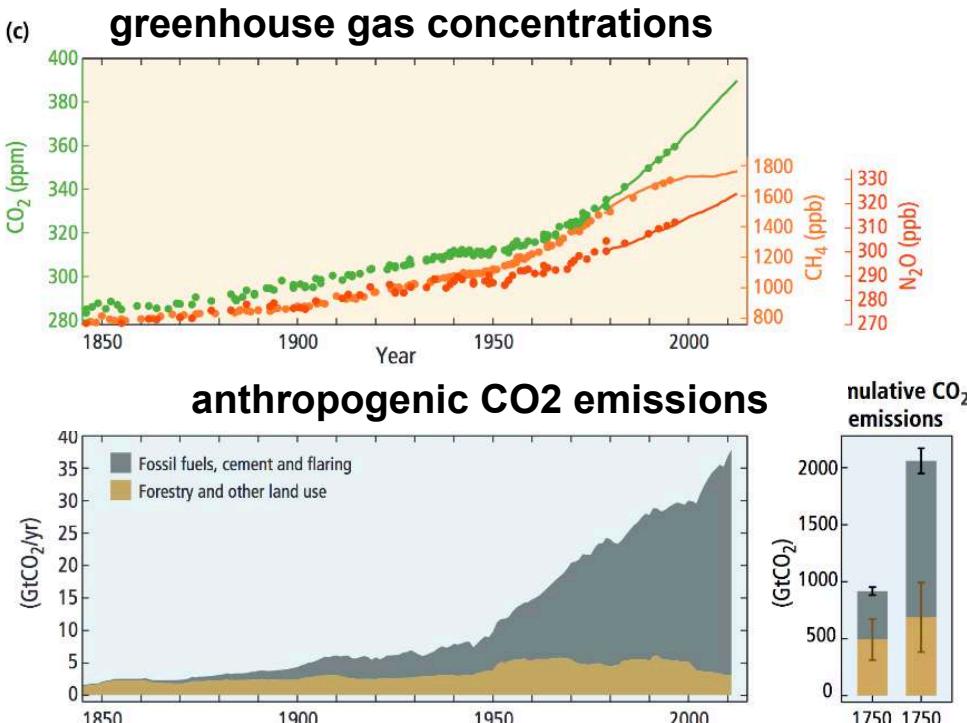
26%

$2.3 \pm 0.4 \text{ PgC y}^{-1}$

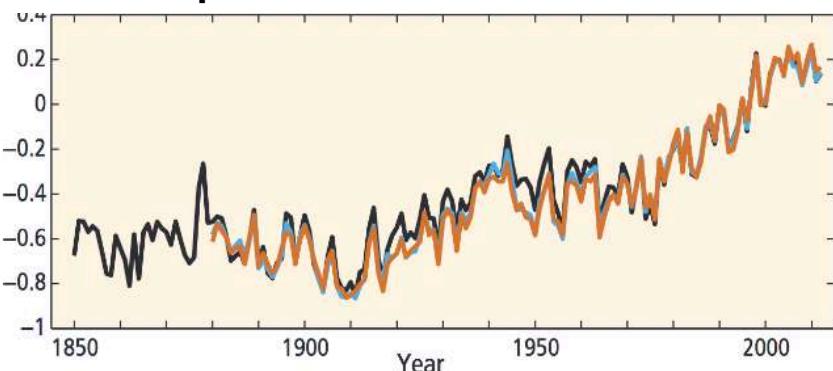
Average of 5 models



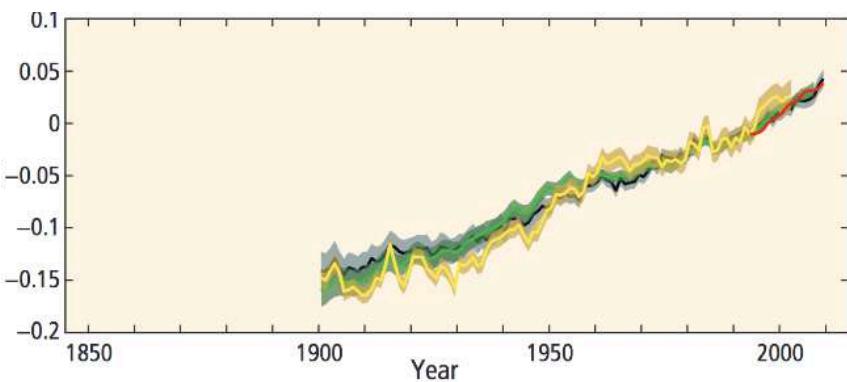
Climate Change in the recent past



Temperature Anomalies wrt 1986:2005



Sea Level Anomalies wrt 1986:2005



Human influence on the climate system is clear, and recent anthropogenic emissions of green-house gases are the highest in history.

Ref: IPCC AR5 Summary for Policy makers

Variazioni nell'estensione del ghiaccio Artico

September 1979



September 2007

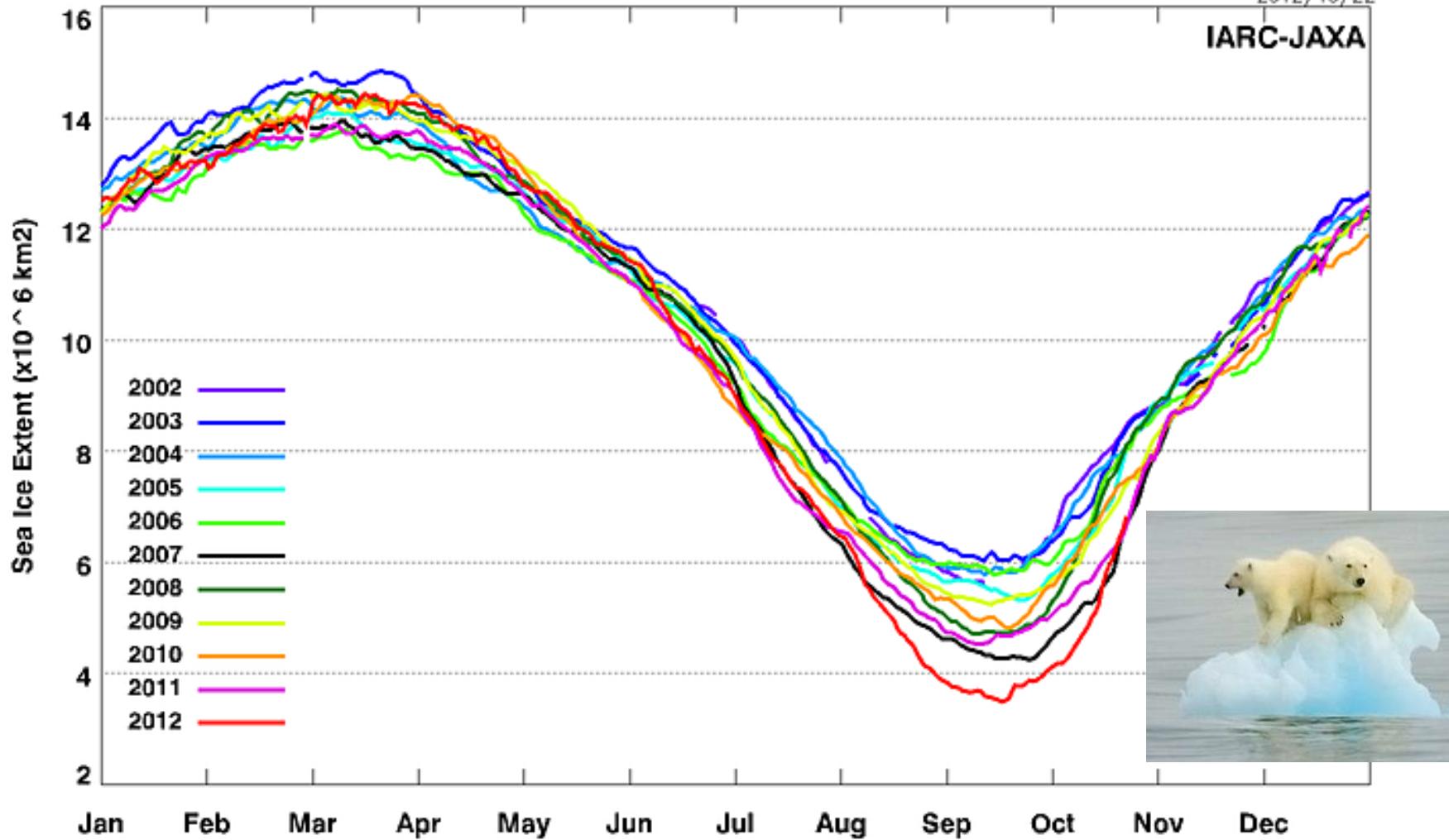


Variazioni nel ciclo stagionale dell'estensione del ghiaccio Artico

Arctic Sea Ice Extent

2012/10/22

IARC-JAXA



Variazioni nell'estensione dei ghiacciai

1893



2008



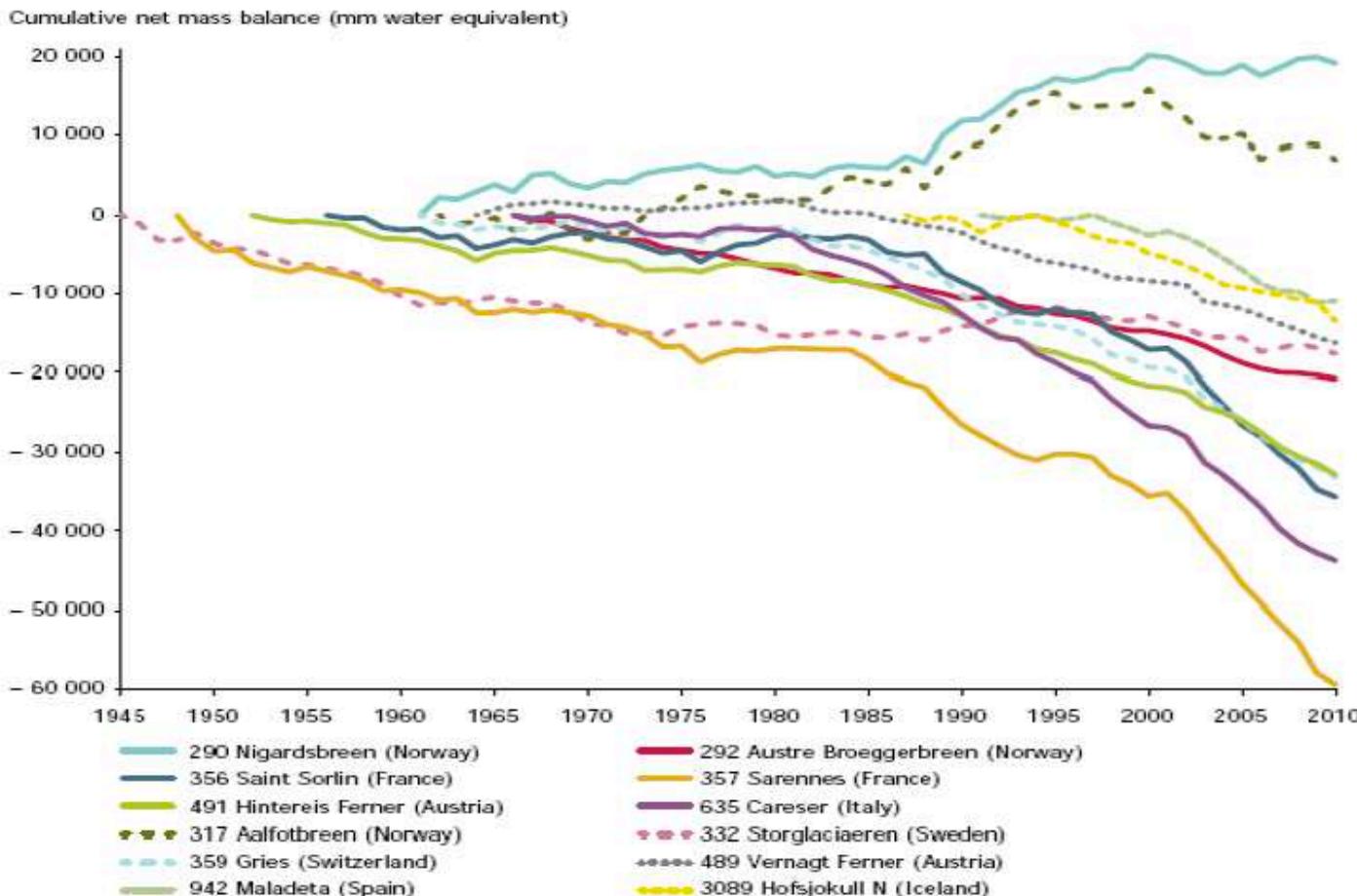
Ghiacciaio della Vedretta di Vallelunga

Muir and Riggs Glaciers



Impatto sui ghiacciai alpini

Figure 2.14 Cumulative specific net mass balance of European glaciers (1946–2010)

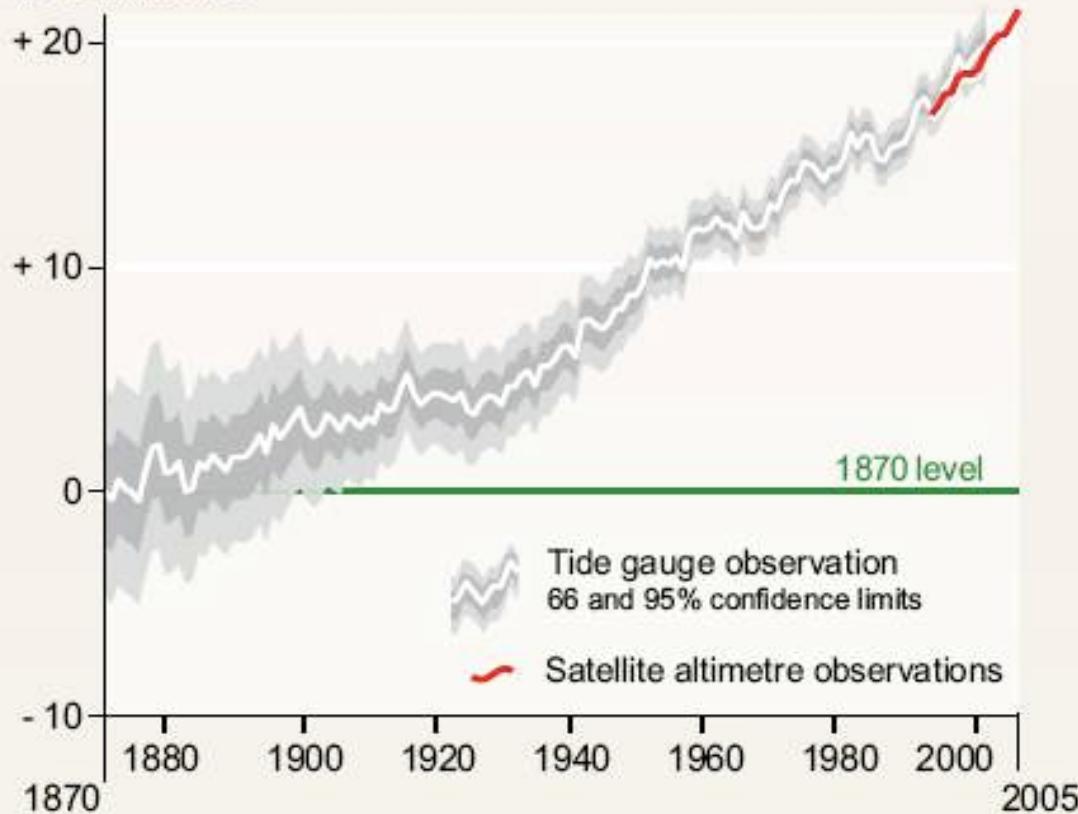


Source: Fluctuation of Glaciers Database (FoG), World Glacier Monitoring Service (<http://www.wgms.ch>), 2011; data for 2010 are preliminary.

Variazioni dell'altezza del livello del mare

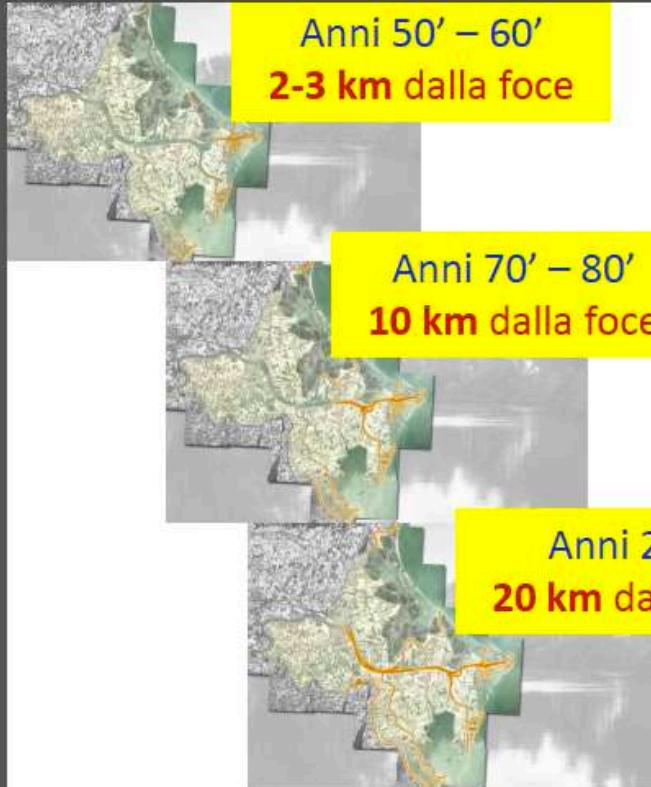
Global mean sea level

Change of sea level
in centimetres



Source: Hugo Ahlenius, GRID-Arendal 2008, updated from Church and White 2006.

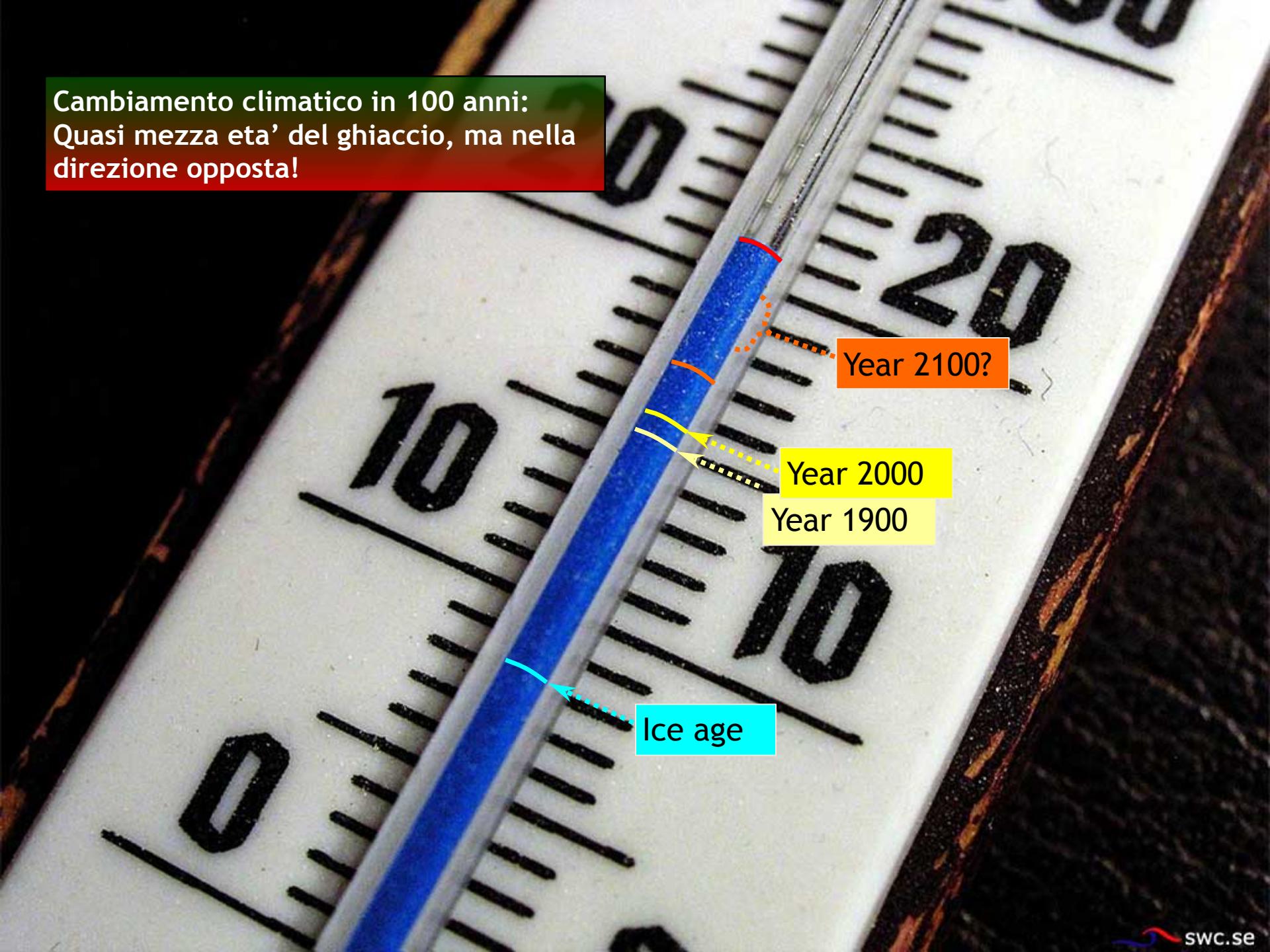




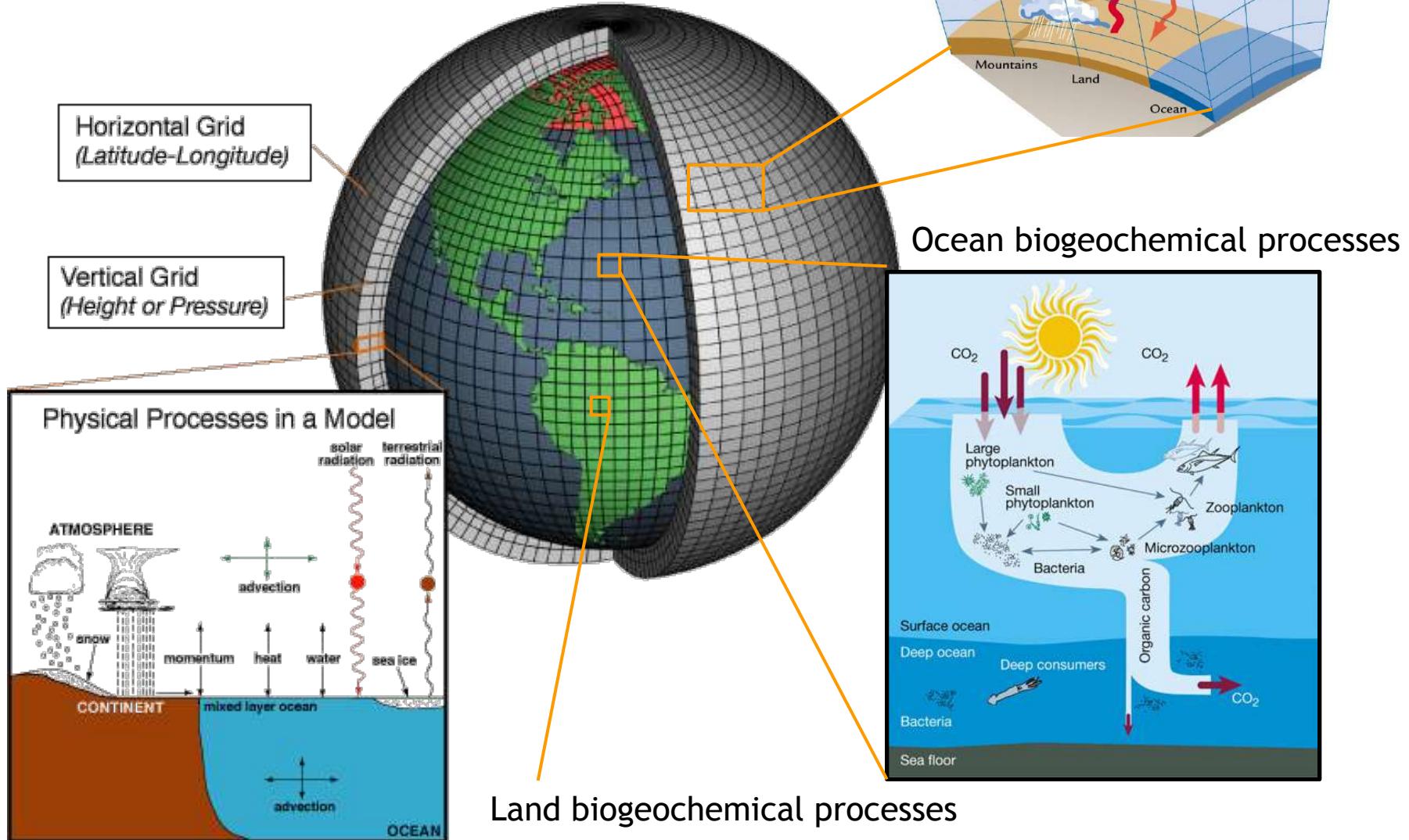
La risalita del cuneo salino nel delta del Po



Cambiamento climatico in 100 anni:
Quasi mezza età del ghiaccio, ma nella
direzione opposta!

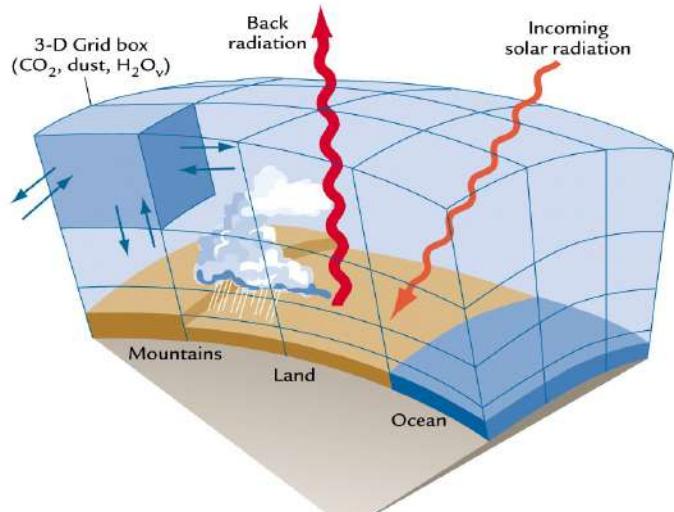


I modelli numerici di simulazione del Sistema Terra



Climate Models as a tool to investigate potential future GHGs Repr. Conc. Pathways

- Investigation tools
 - Prognostic models of the general circulation of the ocean and atmosphere
 - Based on physical equations of mass and energy balance
 - Discretized numerical solutions on given spatial grids



Two main classes:

- General Circulation Models (GCMs, global)
- Regional Climate Models (RCMs, regional)

Two main configurations:

- Standalone (Atmosphere OR Ocean only -> boundary conditions needed)
- Coupled (Atmosphere-Ocean coupled -> no external boundary conditions).

An educational climate model can be found at <http://edgcm.columbia.edu/>

An example of Fully Coupled General Circulation Model (GCM) : CMCC-CM2



River routing

River Transport Model RTM (0.5°)



Atmosphere

Community Atmosphere Model*
CAM4 (FV, 1° & $1/4^\circ$, 26 levels, interactive & prescribed aerosols)



Coupler / Driver

CPL7



Sea Ice

Community Ice CodE
CICE4
(multi-category, same resolution as ocean)



Ocean

Nucleus for European Modelling of the Ocean
NEMOv3.6 $1/4^\circ$; 50 levels



Land / Vegetation

Community Land Model
CLM4.5



Climate Models can be used to investigate different radiative forcing paths in terms of: GHGs (CO₂, CH₄, H₂O) Aerosols, Ozone etc. emissions or concentrations

Ref: Fogli et. al 2014, Scoccimarro et al. 2017, Cherchi et al. 2018



CMCC High Performance Computing System

NEC SX9
Vector Machine



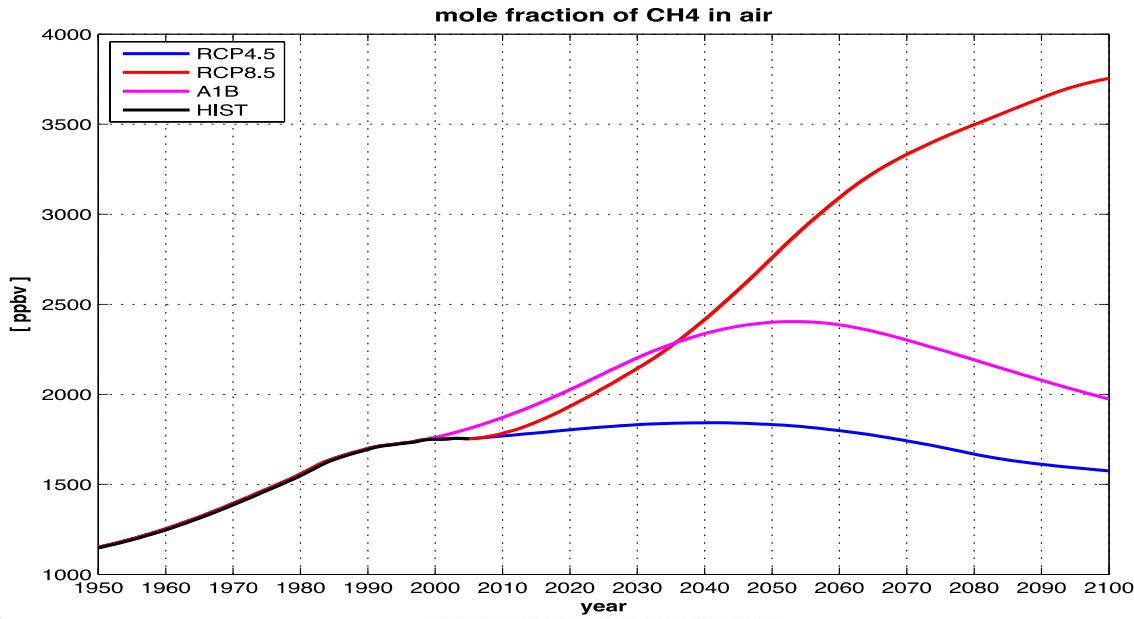
IBM Power 6
Cluster



Esistono diversi possibili scenari di Emissione di Gas Serra

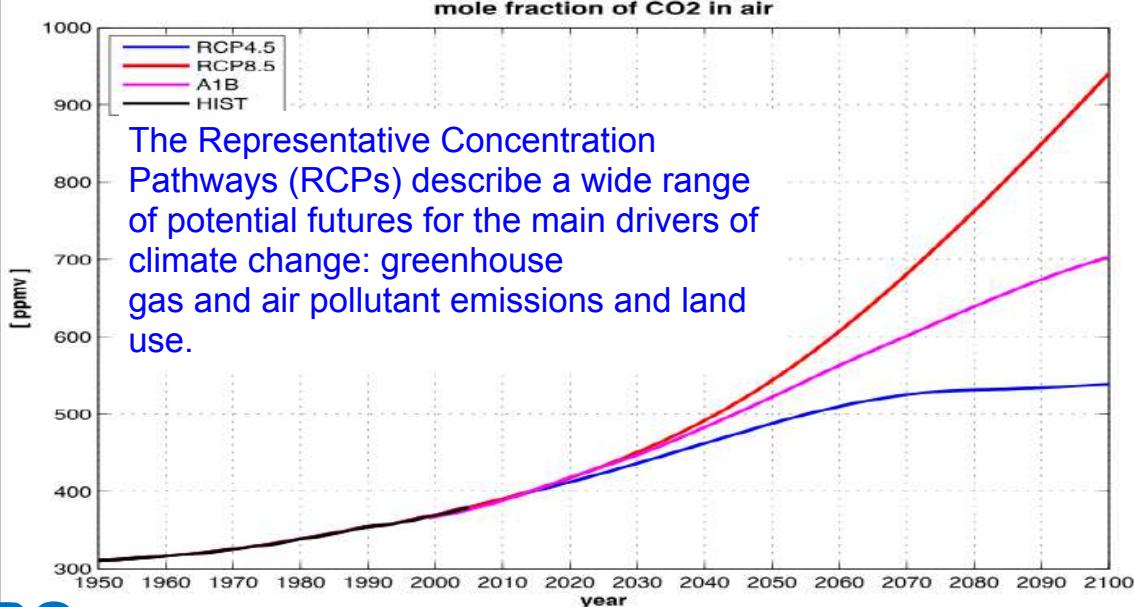
METANO

Metano e Anidride Carbonica
sono due gas serra



[CH₄]

ANIDRIDE
CARBONICA



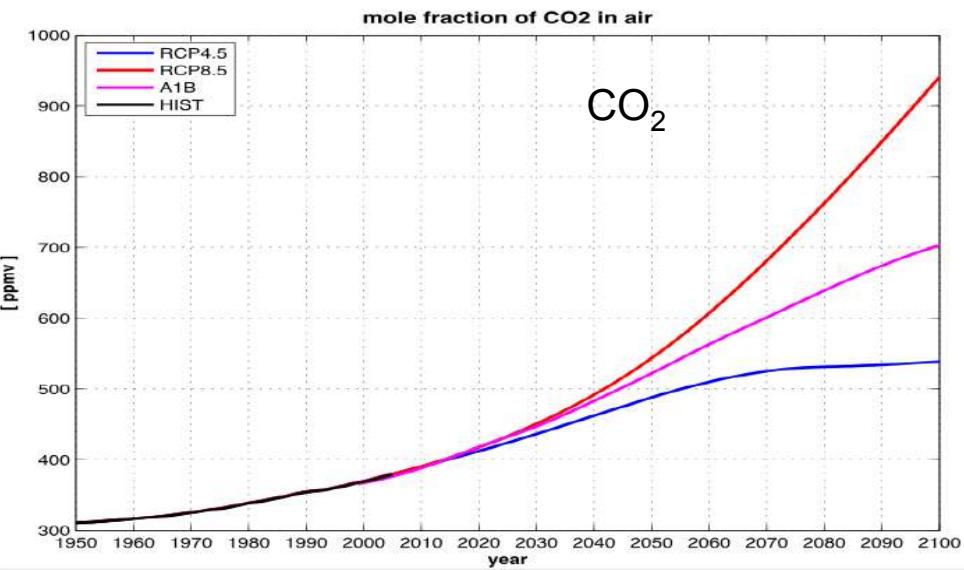
[CO₂]

TEMPO



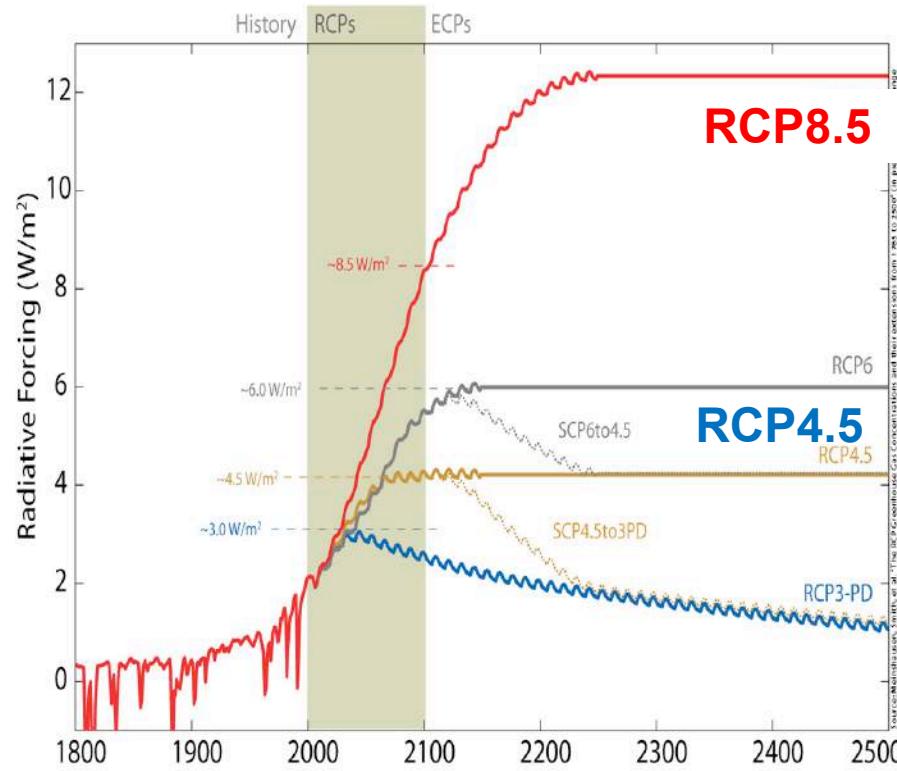
The Representative Concentration
Pathways (RCPs) describe a wide range
of potential futures for the main drivers of
climate change: greenhouse
gas and air pollutant emissions and land
use.

Future potential radiative scenarios



The scenarios cover the range from high emission futures to scenarios consistent with the 2°C target.

The Representative Concentration Pathways (RCPs) describe a wide range of potential futures for the main drivers of climate change: greenhouse gas and air pollutant emissions and land use.

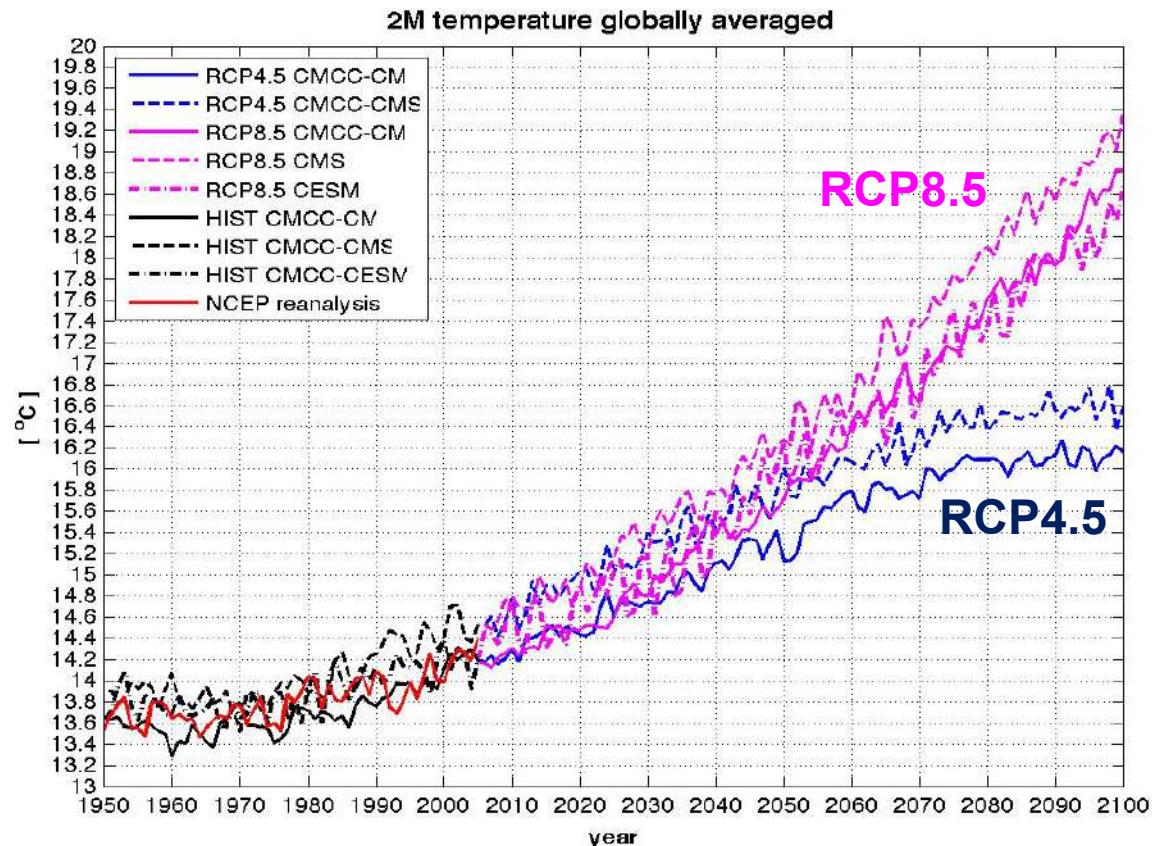


RCP = CMIP5 Representative Concentration Pathways

Future potential radiative scenarios

Different **modeling groups** worldwide provide simulations for the past and for the **future scenarios**, following **common protocols** defined by the Coupled Model Intercomparison Project (CMIP, last available CMIP5) to create a dataset useful for the preparation of the Intergovernmental Panel on Climate Change Assessment Report (AR, last available AR5)

Based on the different RCP chosen, different global temperature
Increases are expected:
as an example
RCP4.5 leads to about 2.5°C
Increase
and
RCP8.5 leads to more than 5°C
increase.



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A high-angle aerial photograph of a tropical cyclone, likely a hurricane or typhoon. The image shows a large, well-defined eye at the center, surrounded by concentric bands of white and grey clouds. The horizon is visible in the distance under a clear blue sky.

Fenomeni Atmosferici curiosi: I cicloni tropicali!

Based on Kerry Emanuel HSS talk Science and
Education Symposium 2010

Quando e dove nascono i cicloni tropicali?

- Nascono sugli oceani, nelle zone tropicali calde
- L'evaporazione porta acqua in atmosfera che poi condensa, forma nubi e viene rilasciato calore in quota.
- Il “cuore caldo” che si forma in quota facilita a sua volta i moti convettivi che richiamano aria dalle regioni periferiche.
- Le masse d'aria che convergono verso il centro, iniziano a roteare e il sistema di temporali sparso si aggrega in una unica struttura: **il ciclone tropicale**.

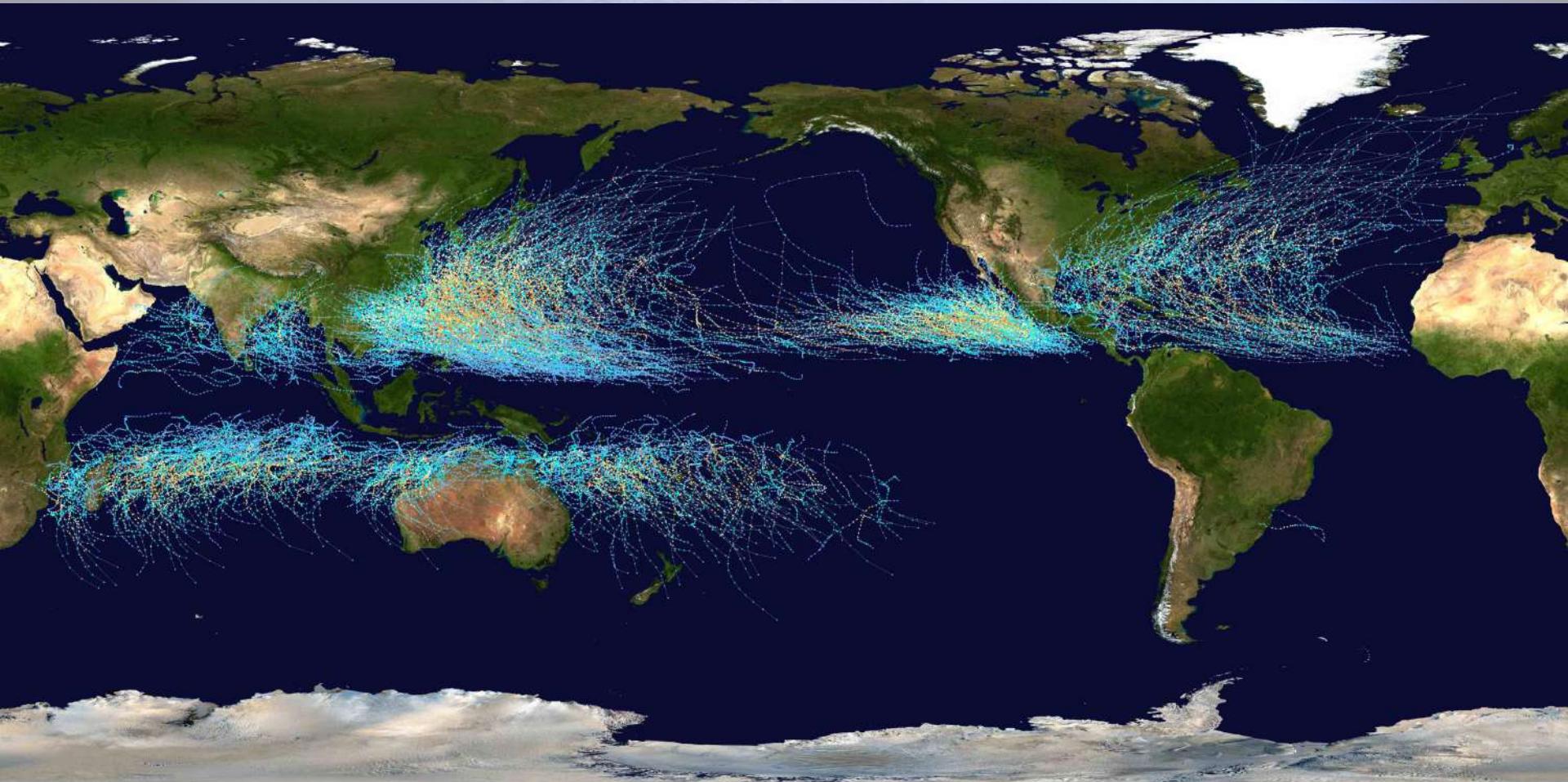
Classificazione dei cicloni tropicali

- I cicloni tropicali (Tropical Cyclones) nella loro forma più intensa (venti più forti) ovvero quando i venti superano i 33 m/s di velocità vengono chiamati:
Uragani (Hurricanes) intorno alle coste degli Stati Uniti
Tifoni (Typhoons) nell'Ovest dell'Oceano Pacifico e
Cycloni (Cyclons) nell'Oceano Indiano e nell'Emisfero Sud.
- In base alla velocità possono assumere una diversa classe seguendo la scala di saffir-simpson.



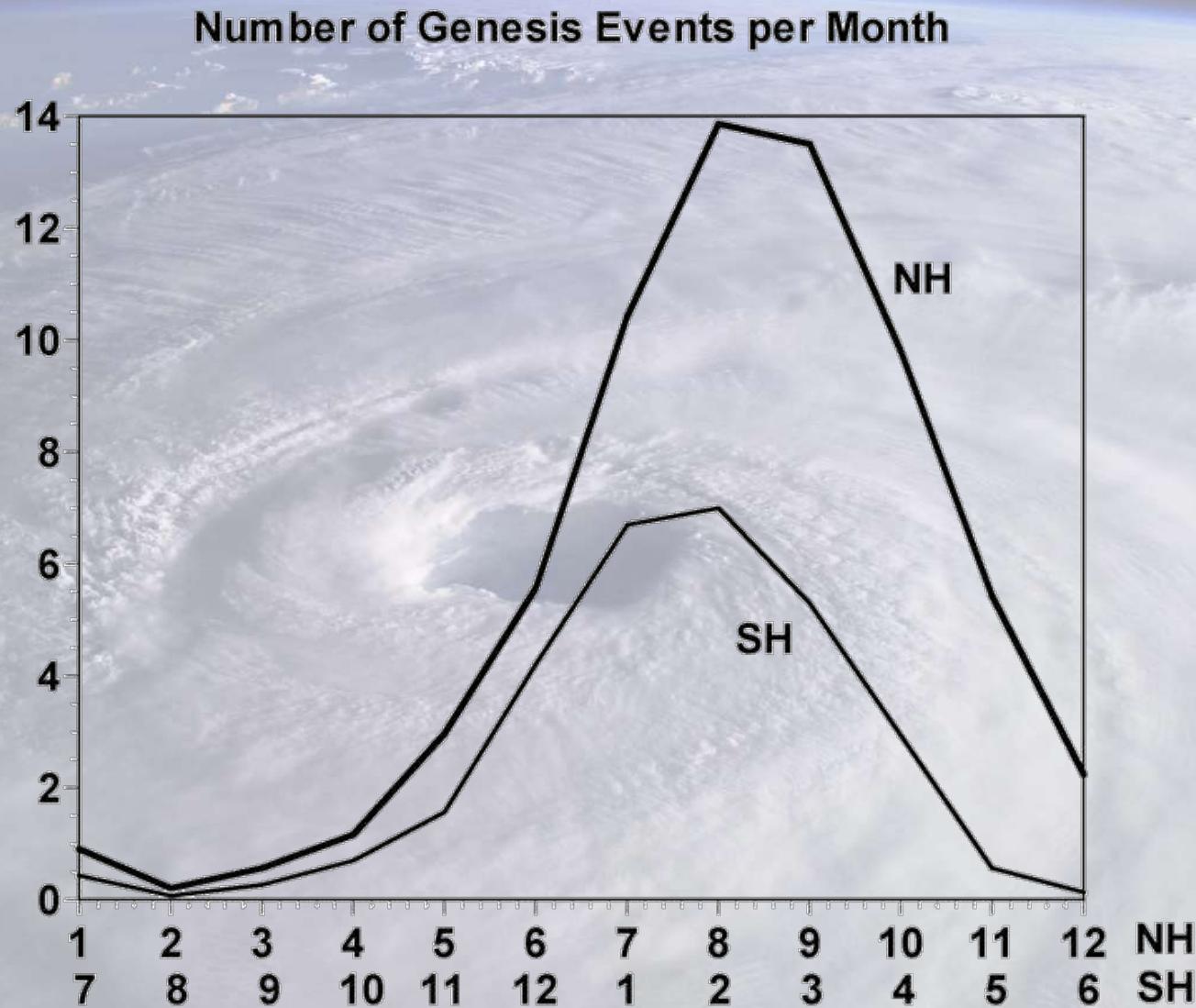
Saffir-Simpson Hurricane Scale		
Category	Wind Speed	
	mph	knots
5	≥156	≥135
4	131-155	114-134
3	111-130	96-113
2	96-110	84-95
1	74-95	65-83
Non-Hurricane Classifications		
Tropical Storm	39-73	34-64
Tropical Depression	0-38	0-33

Tracks of all tropical cyclones, 1985-2005

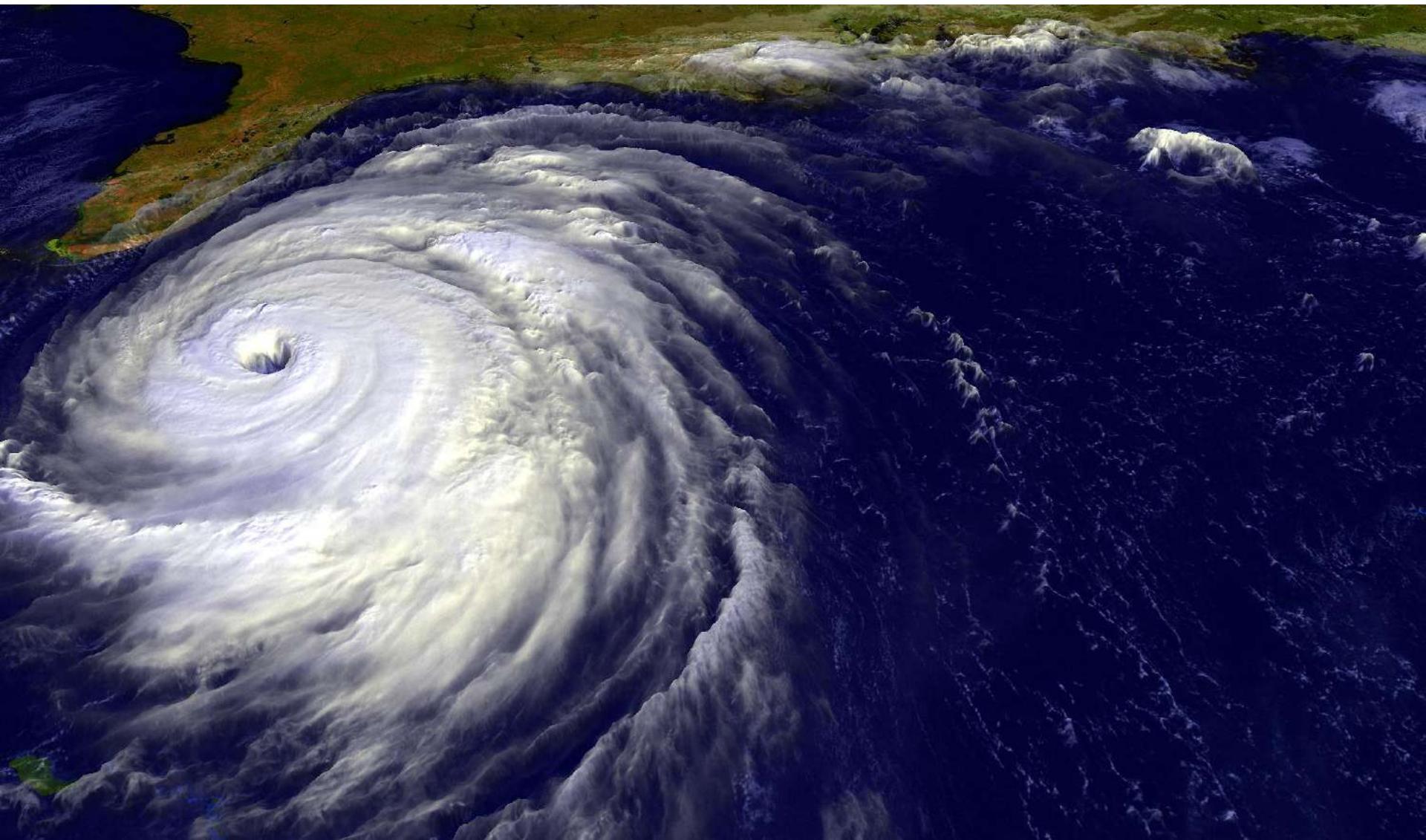


I cicloni Tropicali nascono sull'oceano alle latitudini tropicali ma non all'equatore xe' qui la Forza di Coriolis e' nulla

Ciclo annuale del numero di cicloni tropicali per emisfero



The View from Space

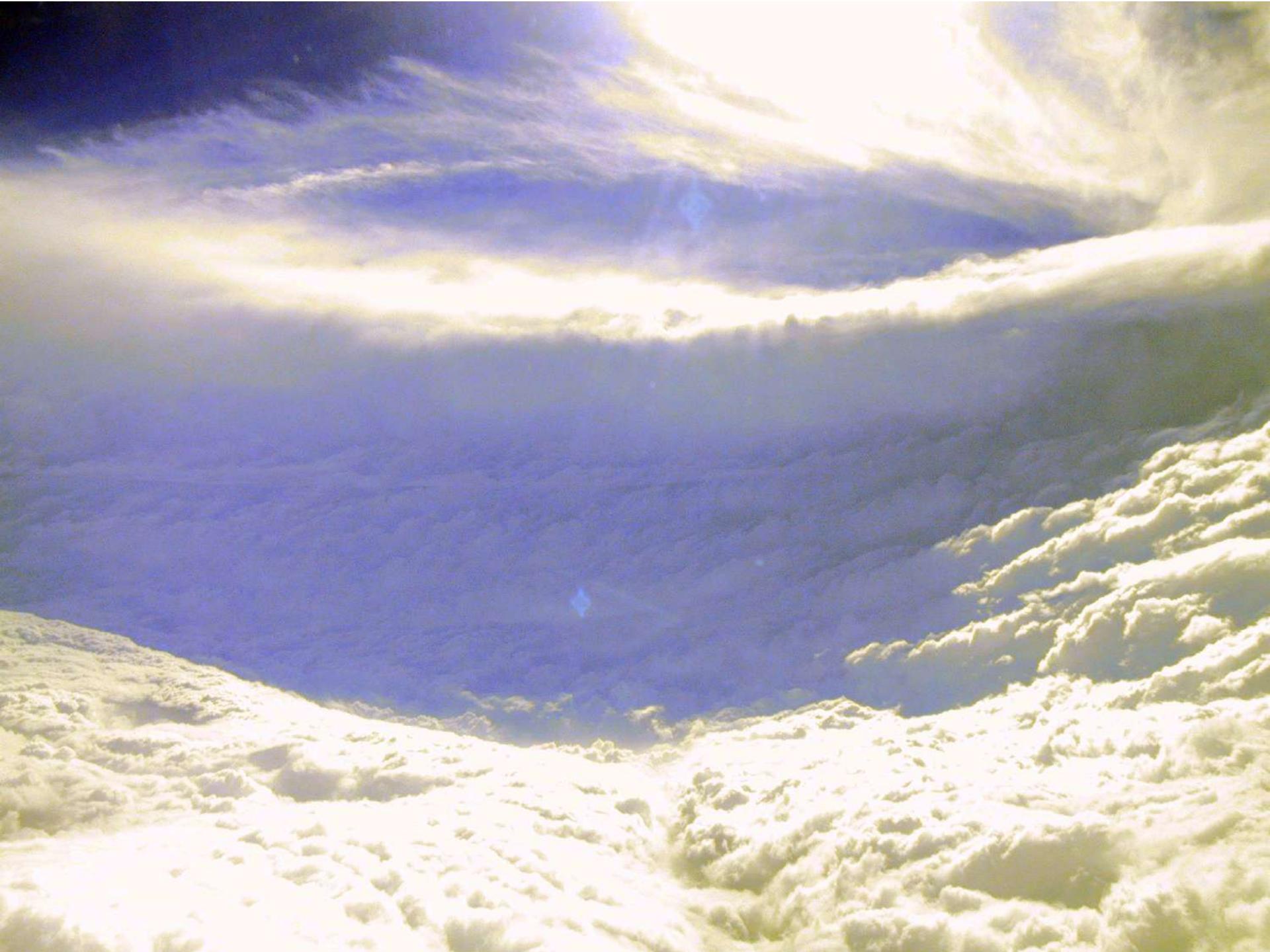




The View from the Air

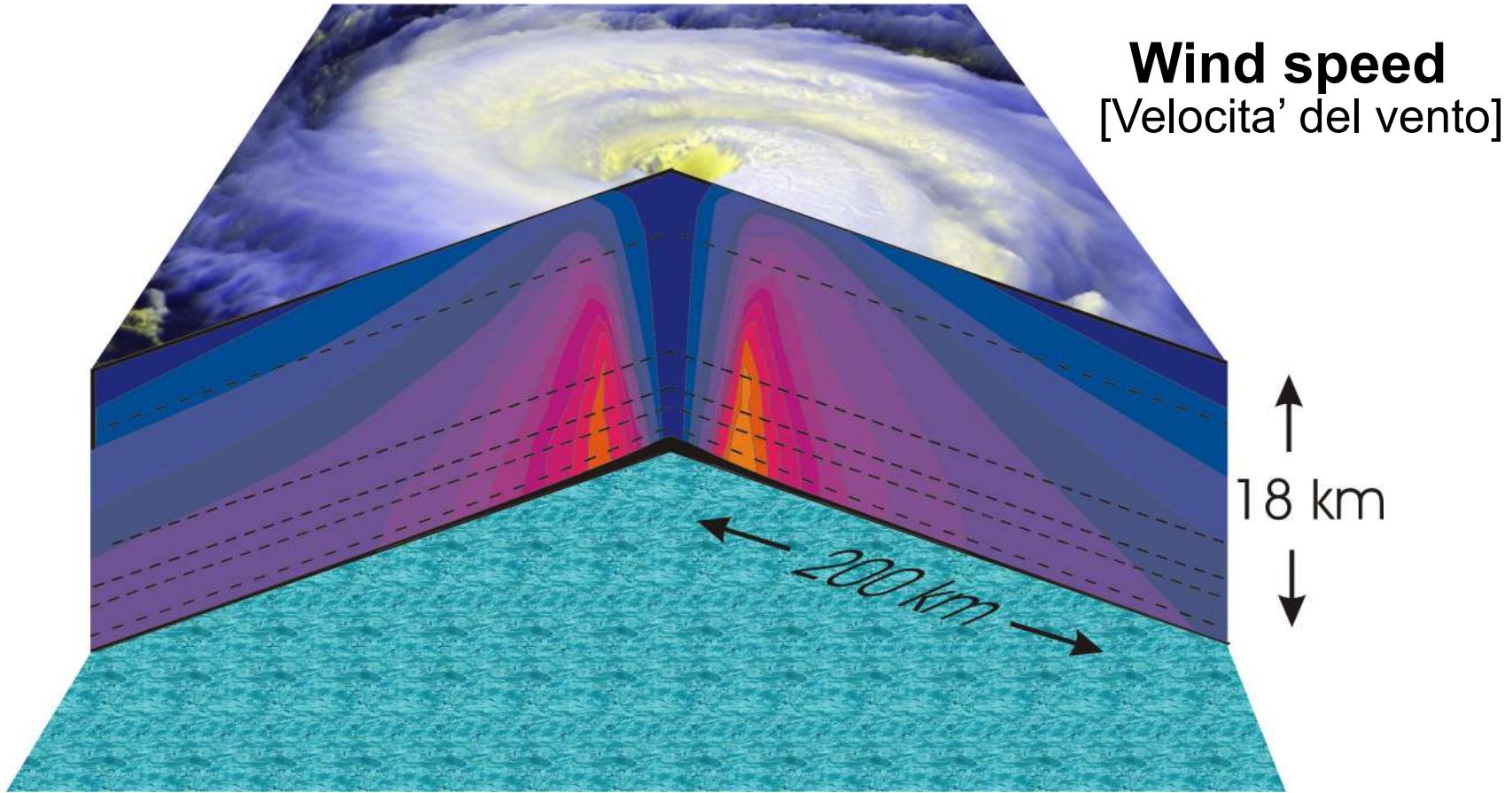






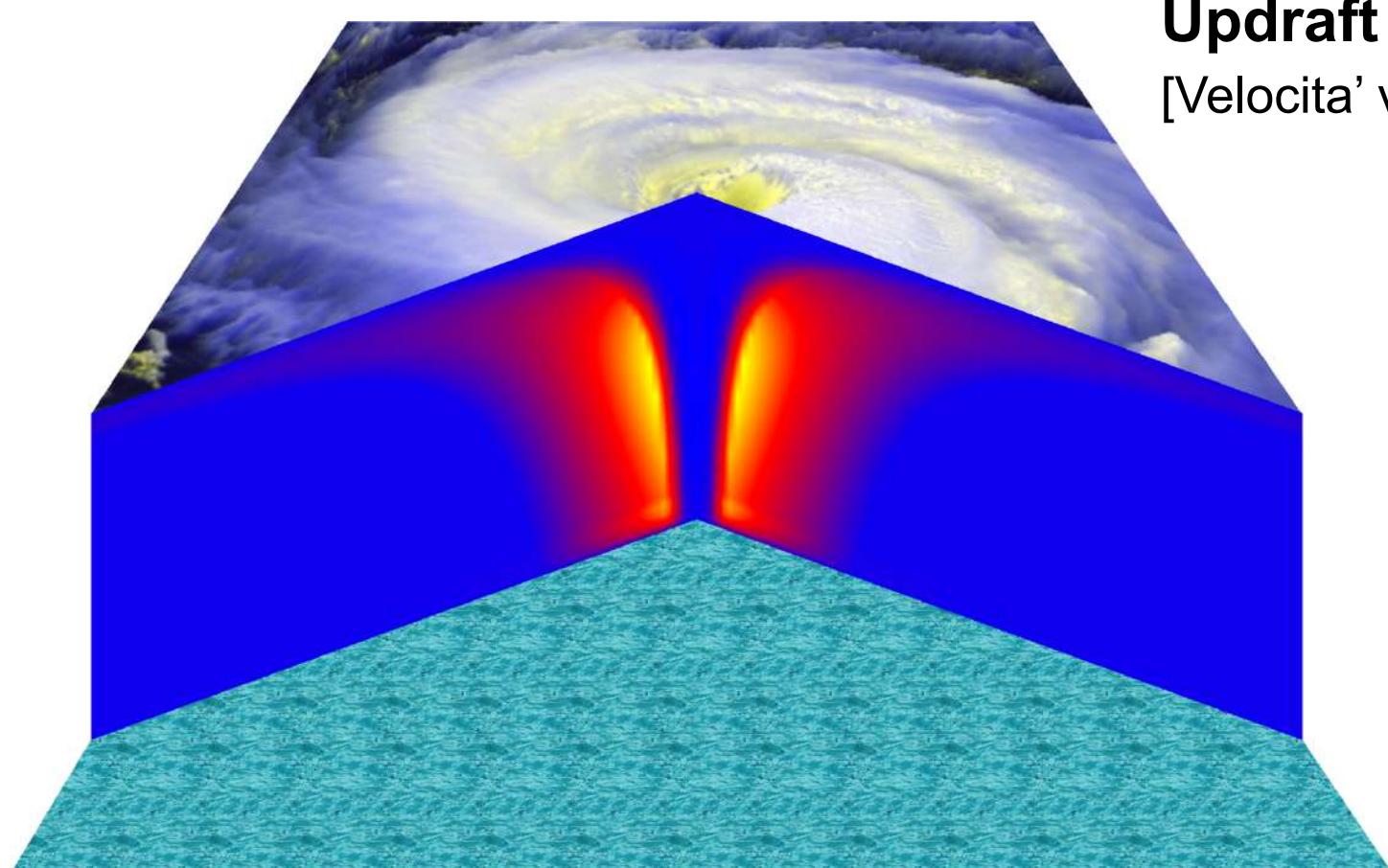


Hurricane Structure



Rosso: velocita' del vento alta,
fino ad oltre 250 km/h !

Hurricane Structure

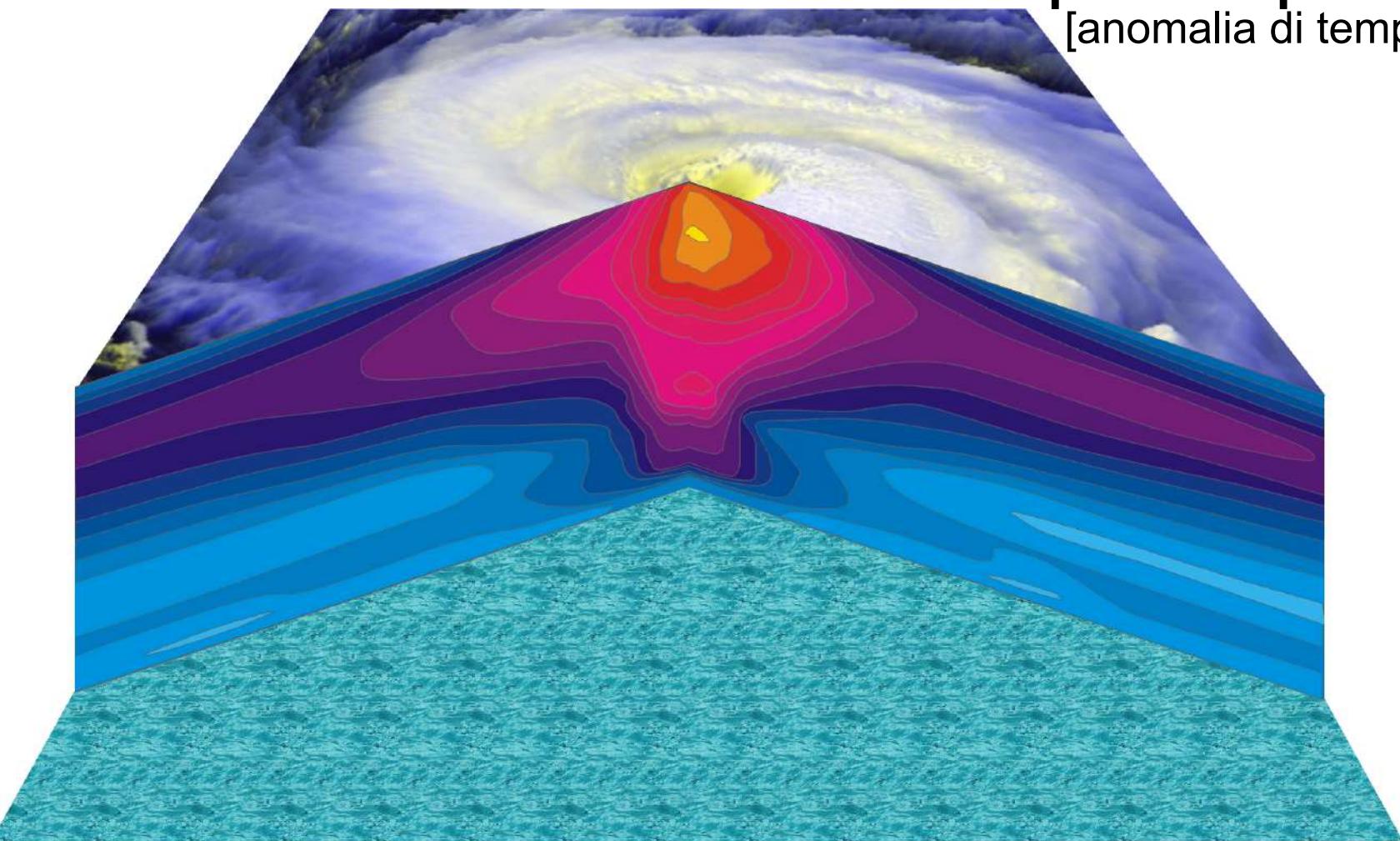


Updraft Speed
[Velocita' verticale]

Rosso: velocita' verticale alta, ovvero
l'aria sale, si raffredda, condensa, piove
erilascia energia !

Hurricane Structure

Temperature perturbation
[anomalia di temperatura]



Rosso: Il rilascio di energia per condensazione
scalda gli strati alti e si forma un cuore caldo
che alimenta a sua volta la risalita dell'aria dalla superficie

Tropical Cyclone modelling under a changing climate

The two main approaches to dynamically model Tropical Cyclones **TCs** under a climate perspective are through **Hurricane Models** and **Climate Models**. Both classes of models evaluate the numerical equations governing the climate system. A hurricane model is an objective tool, designed to simulate the behavior of a tropical cyclone representing the detailed time evolution of the vortex. Considering the global scale, a climate model can be an atmosphere (or ocean)-only general circulation model (GCM) or a fully coupled general circulation model (CGCM).

We'll now focus on TC representation in Climate Models

REFERENCES:

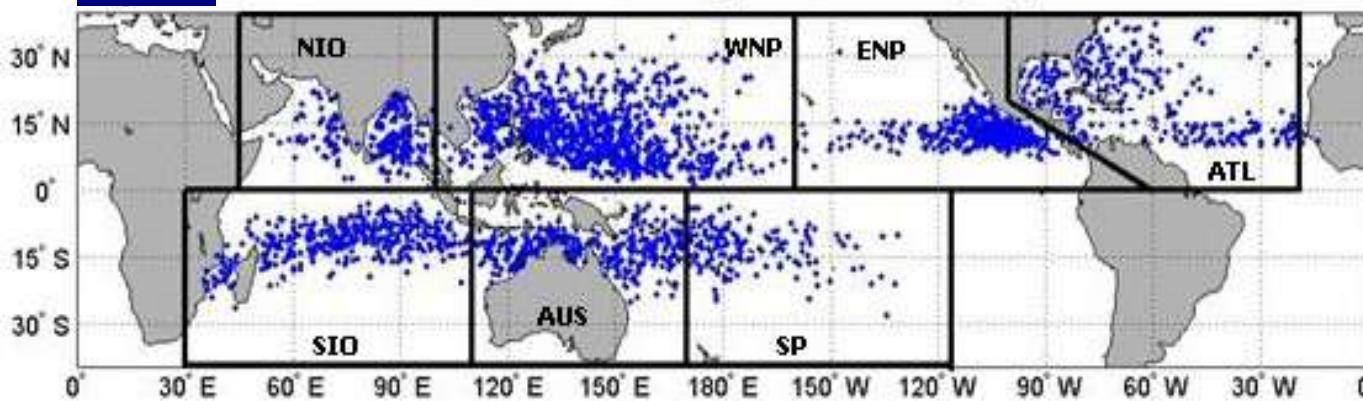
- Scoccimarro E.: Modelling Tropical Cyclones in a changing climate. "Oxford Research Encyclopedia of Natural Hazard Science". Oxford University Press. DOI:10.1093/acrefore/9780199389407.013.22 (2016)

Tropical Cyclones as represented by CMCC General Circulation Models

Tropical Cyclone tracks starting points 1970-1999

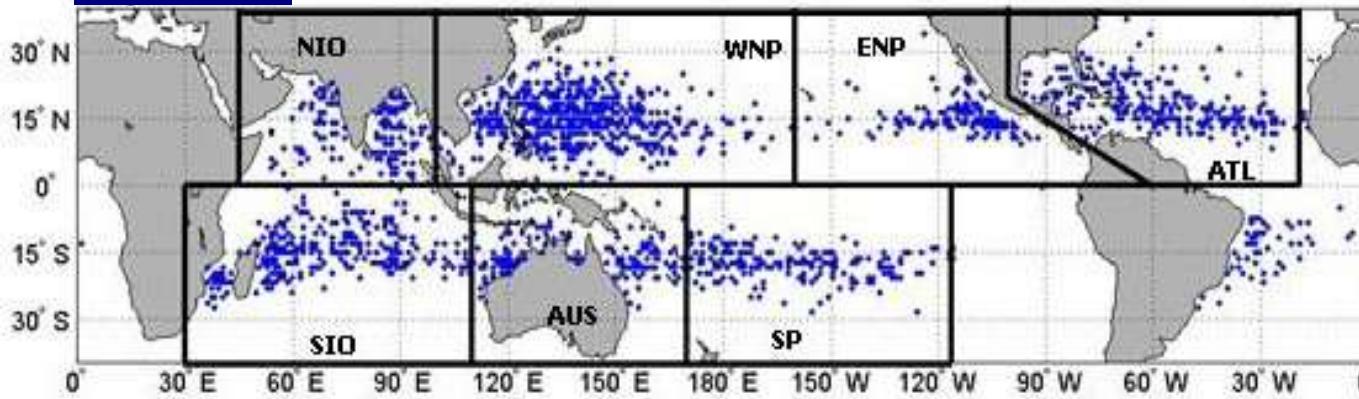
Observ.

OBS TCs tracks starting point 1970-1999 [30 y]



CMCC Model

ingv-sxg TCs tracks starting point 1970-1999 [30 y]



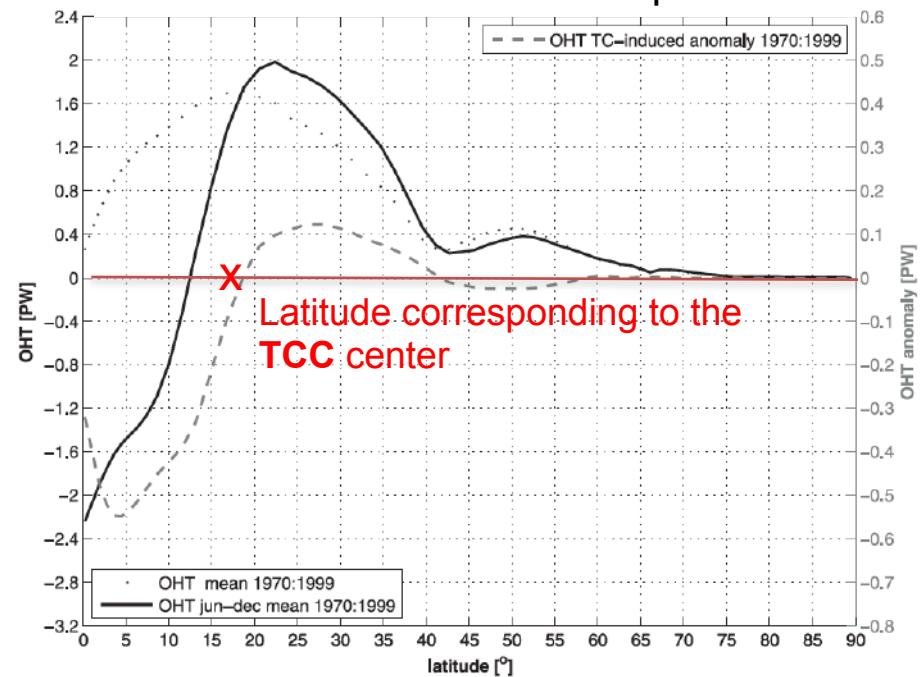
2008
INGV-SXG (100 km)
Tropical Storms
2013
CMCC-CM (80 km)
Cat 1 Hurricanes
2017
CMCC-CM2-VHR4 (25 km)
Cat 5 Hurricanes

Actually, only **3** climate models worldwide demonstrated ability in representing cat-5 Hurricanes: **CMCC-CM2**, HiFLOR , CESM
[Scoccimarro et al. 2017] [Murakami et al. 2015] [Small et al. 2014]

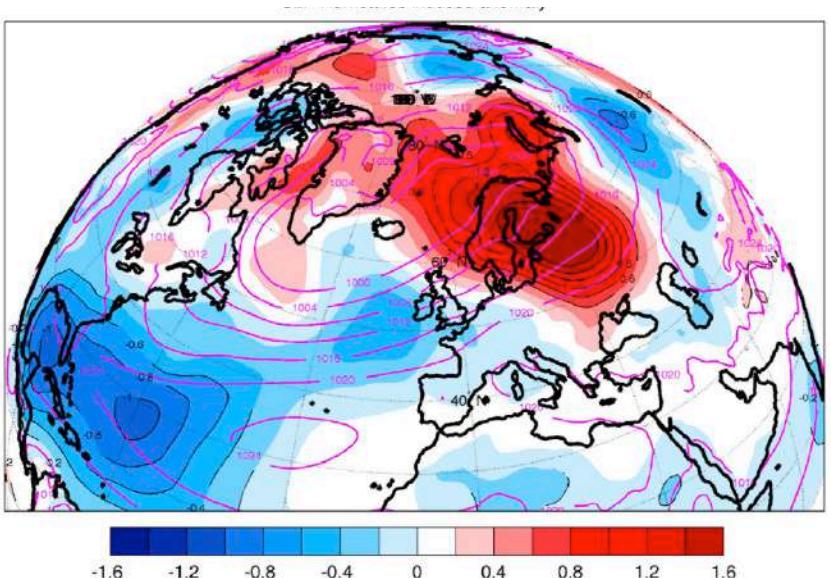
Tropical Cyclones research activity at CMCC

NH Ocean Heat Transport

CMCC-CM (CMIP5)



SLP Hurricane induced anomaly (ERA-Int)

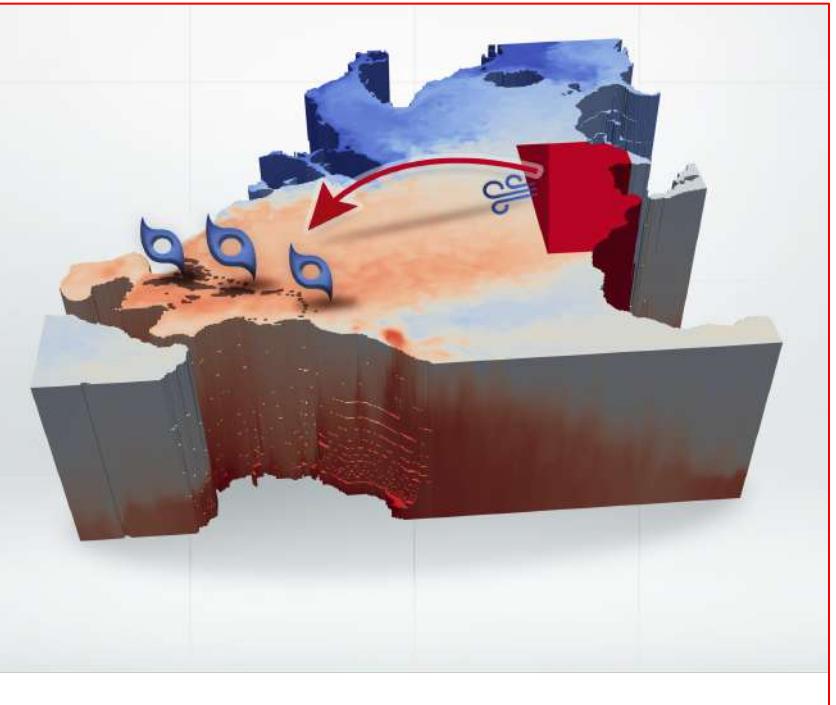


A large **Tropical Composite-Cyclonic** structure (TCC) was identified both using observed and Model data sets. The **TCC** fingerprint on the zonal winds is coherent with the minimum of Sea Level Pressure associated with the TCC center in the sub-tropical ocean. This is reflected in **TC induced ocean heat transport** (Scoccimarro et al. 2011) and **linked to a teleconnection with The Arctic Ocean** (Scoccimarro et al. 2012).

REFERENCES:

- Walsh, K., Lavender S., Murakami H., Scoccimarro E., Caron L.P., Ghantous M.: The Tropical Cyclone Climate Model Intercomparison Project. "Hurricanes and Climate Change" ISBN: 9048195098 (2nd ed.), Springer (2009)
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REMOTE SUBSURFACE OCEAN TEMPERATURE AS A PREDICTOR OF ATLANTIC HURRICANE ACTIVITY



References:

Scoccimarro E., Bellucci A., Storto A., Galdi S., Masina S., Navarra A.: Remote sub-surface ocean temperature as a predictor of Atlantic hurricane activity.
Proceedings of the National Academy of Sciences - PNAS October 2018 doi: 10.1073/pnas.1810755115

Remote subsurface ocean temperature as a predictor of Atlantic hurricane activity

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Edited by Kerry A. Emanuel, Massachusetts Institute of Technology, Cambridge, MA, and approved September 24, 2018 (received for review June 22, 2018)

Predicting North Atlantic hurricane activity months in advance is of great potential societal significance. The ocean temperature, both in terms of North Atlantic/tropical averages and upper ocean heat content, is demonstrated to be a significant predictor. To investigate the relationship between the thermal state of the Atlantic Ocean and the tropical cyclone (TC) activity in terms of accumulated cyclone energy (ACE), we use observed 1980–2015 TC records and a 1/4° resolution global ocean reanalysis. This paper highlights the nonlocal effect associated with eastern Atlantic Ocean temperature, via a reduction of wind shear, and provides additional predictive skill of TC activity, when considering subsurface temperature instead of sea surface temperature (SST) only. The most active TC seasons occur for lower than normal wind shear conditions over the main development region, which is also driven by reduced trade wind strength. A significant step toward operationally reliable TC activity predictions is gained after including upper ocean mean temperatures over the eastern Atlantic domain. Remote effects are found to provide potential skill of ACE up to 3 months in advance. These results indicate that consideration of the upper 40-m ocean average temperature improves upon a prediction of September Atlantic hurricane activity using only SST.

hurricanes | Atlantic Ocean | seasonal predictions | subsurface ocean | tropical cyclones

Statistical (1–8), dynamical (9–12), and hybrid statistical–dynamical (13–16) tropical cyclone (TC) activity predictions benefit from climate precursors typically provided by the ocean state (17–19). This is consistent with the ocean forcing the atmosphere on long-term timescales and being the primary energy reservoir for TC development (18). Atmospheric predictors, such as the trade wind strength in the Caribbean, are also critical for Atlantic TC development (4, 5).

One of the parameters used to quantify TC intensity for a period (typically a season) is accumulated cyclone energy (ACE) (20), an integrated quantity involving storm duration, intensity, and number. It is equal to the squared wind speed of each TC summed every 6 h and over all of the TCs active in a basin. Many research centers routinely issue ACE seasonal forecasts, corresponding to the upcoming season in April and May, through their ensemble prediction systems, and a few of them are based on fully coupled general circulation models. Also, a statistical–dynamical hybrid system has demonstrated the possibility of making skillful predictions of North Atlantic ACE when initializing the forecast model in November of the previous year (17). However, this forecasting system is limited by the complexity of the development phase and the high computational costs required to run the ensemble forecasts.

In the present work, we show that a significant source of predictability for TC activity resides in the upper 40-m ocean thermal structure, in the eastern Atlantic. We also show that our index outperforms the predictive ability of SST over the main development region (MDR).

For the present analysis, we use the Atlantic hurricane database (HURDAT2) (21) as archived in the International Best Track Archive for Climate Stewardship for the computation of the monthly Atlantic ACE over the 1980–2015 period. Furthermore, to

obtain detailed information on the ocean state, we base our analysis on a state-of-the-art global ocean reanalysis (22) where observational ocean data are assimilated (see *SI Appendix* for details).

To investigate the relationship between ACE, sea surface temperature (SST), and the large-scale variability modes of the Atlantic Ocean, we also use the Atlantic Meridional Mode (AMM) (23) and the Atlantic Multidecadal Oscillation (AMO) (24) indices (<https://esrl.noaa.gov/psd/data/climateindices/list/>), together with atmospheric reanalysis data [ERA-Interim (25), used to force the ocean reanalysis system], including 10-m wind as well as 300- and 850-mb wind speeds, which are necessary for the computation of the vertical wind shear.

TCs and the Ocean

The variability of the upper-ocean temperature modulates TC count and intensity at different timescales (26–37). Meanwhile, TCs have a role in the modulation of the thermal and dynamical structure of the ocean (38–40). Despite some recent findings (27, 40) indicating that strong TCs can impact the deep ocean (up to 1,000 m), most studies suggest that TC interaction with the ocean is mainly confined between the surface and depth of 100 m (41–43). TC intensity and translation speed are important factors in determining this TC–ocean interaction, but also important is the upper ocean stratification, primarily represented by the depth of the mixed layer (44, 45). Large-amplitude positive SST anomalies can cause high TC intensity, but a more robust evaluation of the energy available for TC development can be obtained considering the ocean heat content (34). Also it has been previously suggested that the subsurface temperature better reflects how much heat is stored in the upper Atlantic Ocean (46–48). It has been established that considering the upper ocean heat content, instead of the SST, as a predictor in statistical

Significance

A nonlocal effect associated with eastern Atlantic Ocean temperature provides additional predictive skill of tropical cyclone activity when compared with the well-known local modulation effect associated with sea surface temperature. The most active tropical cyclone seasons occur for lower than normal wind shear conditions and less intense trade winds, which are associated with higher eastern Atlantic sea surface temperature. A significant step toward operationally reliable predictions of tropical cyclone activity is gained after including upper ocean mean temperatures (upper 40-m averages) over the eastern Atlantic domain with remote effects providing potential skill up to 3 months in advance.

Author contributions: E.S. designed research; E.S. performed research; E.S., A.B., A.S., S.G., S.M., and A.N. analyzed data; and E.S. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

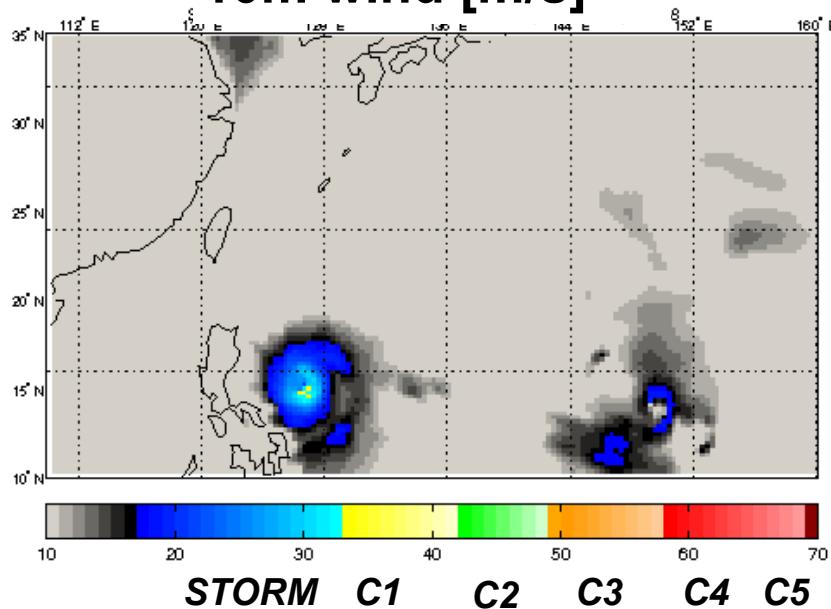
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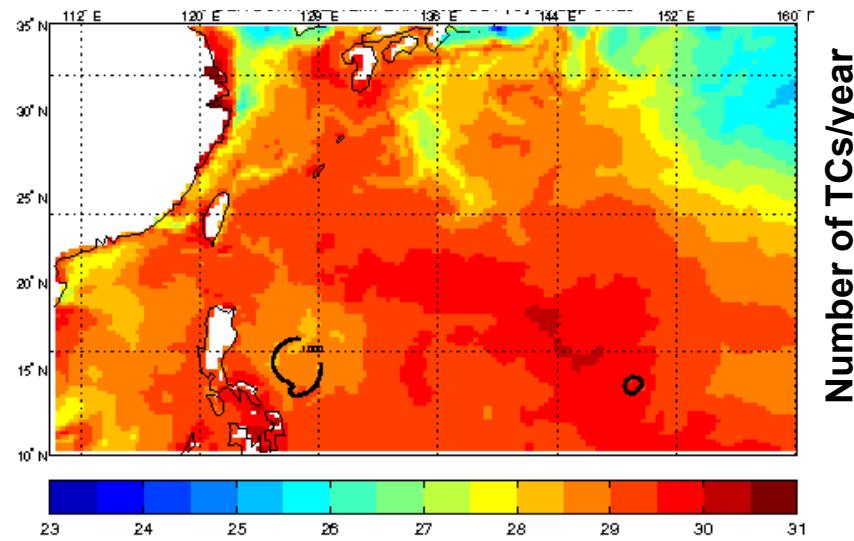
This article contains supporting information online at www.pnas.org/lookup/doi/10.1073/pnas.1810755115/DCSupplemental.

Esempio di Interazione tra Tifone e Oceano:

10m wind [m/s]



SST [patterns] and SLP [contours]



6h steps covering two days

Il vento fa divergere l'acqua in **calda** in superficie e quindi acqua fredda tende a risalire dagli strati sottosuperficiali **raffreddando la superficie dell'oceano** e quindi riducendo l'energia disponibile x il ciclone stesso

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CAMBIAMENTI CLIMATICI, CICLONI TROPICALI E VARIAZIONI DEL LIVELLO DEI MARI

OUTLINE

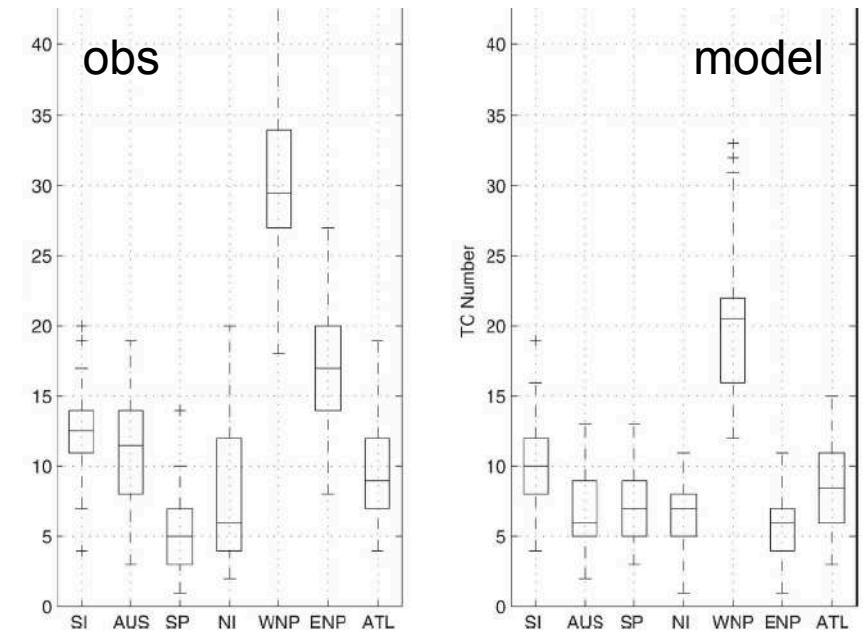
- Clima e Cambiamenti Climatici: il supporto fornito dalla modellistica numerica

- I Cicloni tropicali: cosa sono? Riusciamo a simularli numericamente?

- Variazioni indotte dai cambiamenti climatici sull' attivita' ciclonica tropicale

- Interazione tra i cicloni tropicali e la costa

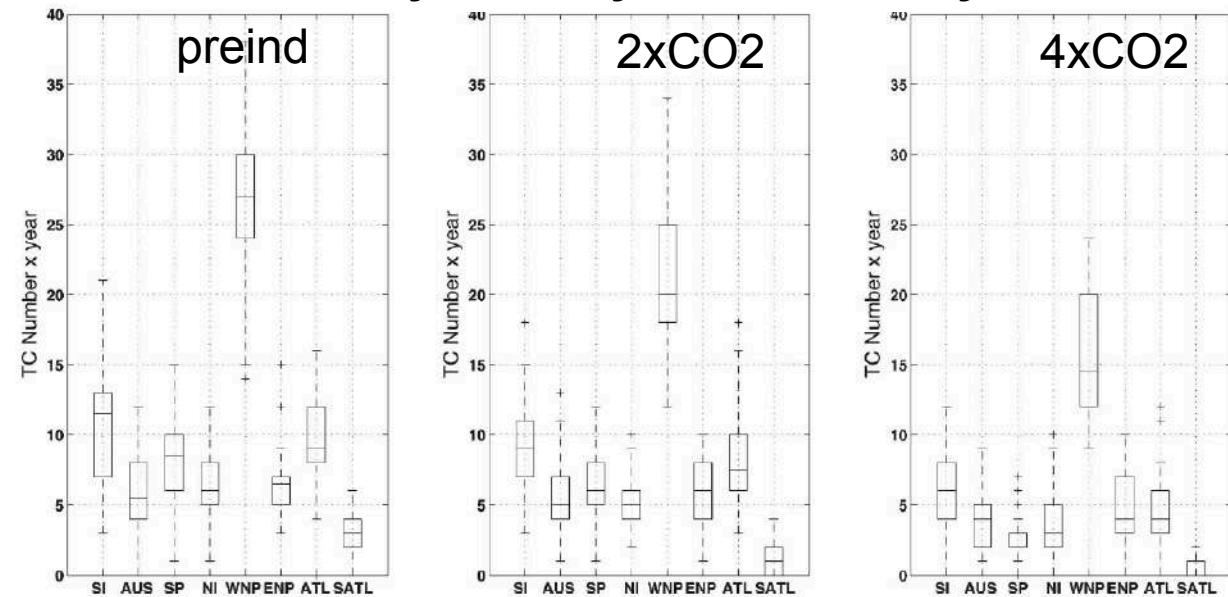
Yearly TC n. by basin in current climate



The **reduced occurrence of TCs** is linked to the **larger** potential energy barrier (**CIN**) Found when the CO₂ Concentration is increased.

Despite the reduced number of TCs there is evidence of an **increase** in their intensity in terms of **precipitation**. This might be related with the **increase of CAPE** found in the warmer climate.

Yearly TC n. by basin over 30y



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Tropical Cyclones research activity at CMCC

CMCC-CM (HWG US-CLIVAR)

CMCC took part to the US-CLIVAR Hurricane Working Group.

U.S. CLIVAR
The U.S. Climate Variability and Predictability Research Program (CLIVAR)
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Hurricane Science

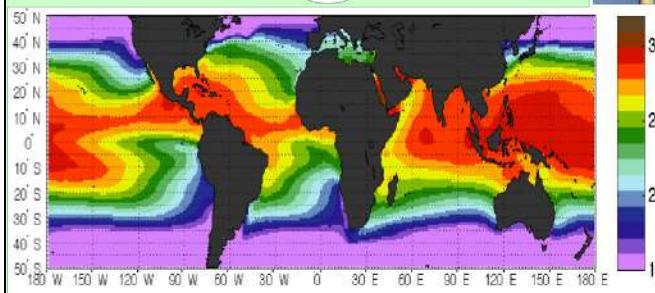
- Seasonal Forecasting for Tropical Cyclones – Timothy LaRow, Hui Wang, and In-Sik Kang
- Statistical Models for Tropical Cyclone Activity (PDF) – James B. Elsner and Gabriele Villarini
- Tropical Cyclones in Coupled General Circulation Models – Enrico Scoccimarro
- Tropical Cyclones in High-resolution Atmospheric Models – Ming Zhao
- Tropical Cyclone Theory – Kerry Emanuel and Adam Sobel

Proposed Models for Experiments

Model	Resolution	Institution	Contact
ECHAM5	T159 L31	CMCC INGV, Italy	Enrico Scoccimarro
ECHAM6	T126 L95	MPI, Germany	Monika Esch / Lennart Bengtsson
FSU/COAPS	T126 L27	FSU, USA	Tim LaRow
GEOS5	1/2 degree	NASA, USA	Siegfried Schubert
HIRAM2.1	50 km L32	GFDL, USA	Ming Zhao
NASA GISS	1 degree	NASA GISS / Columbia University USA	Anthony del Genio / Adam Sobel
NCEP GFS	T126 L64	NCEP, USA	Hui Wang
NICAM	14km L40	JAMSTEC, Japan	Kazuyoushi Oouchi
Reading/Hadley Center	TBD	U. Reading / UK Met Office, U.K.	Pier Luigi Vidale / Malcolm Roberts
SNUGCM	25-50km, L20	SNU, South Korea	In-Sik Kang

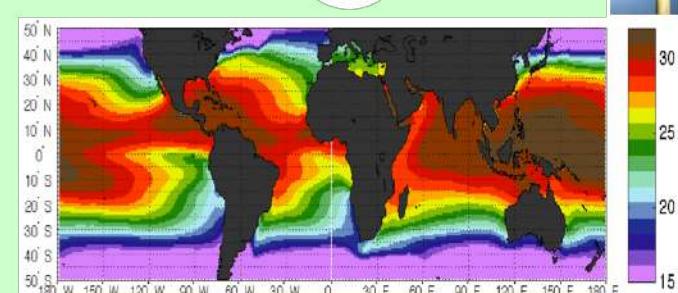
PRESENT CLIMATE (1981-2005 climatology)

CLIM



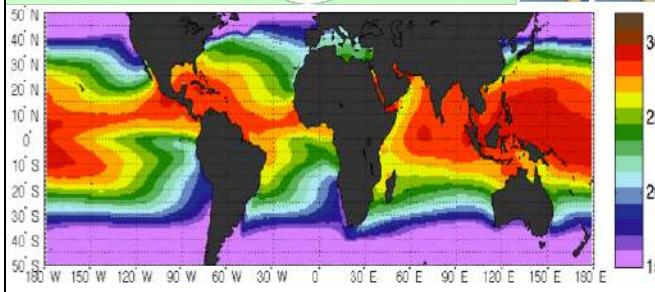
US-CLIVAR HWG experiments used

2K



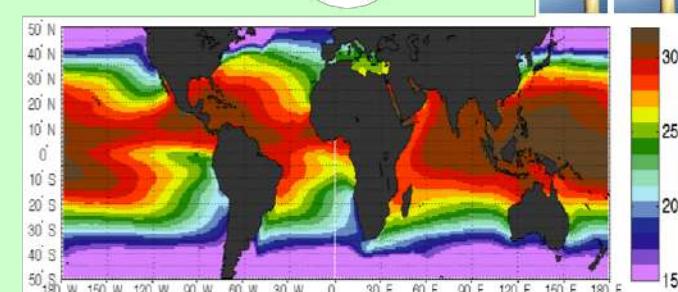
PRESENT CLIMATE with 2*CO₂

2C

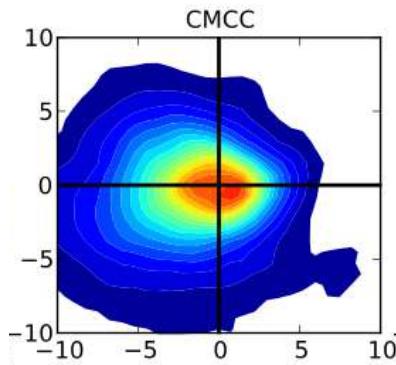
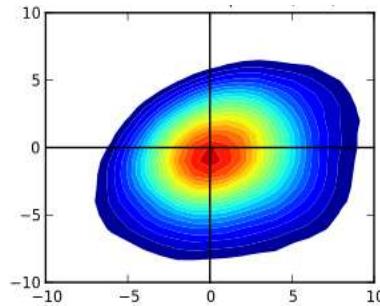


PRESENT CLIMATE +2°K and 2*CO₂

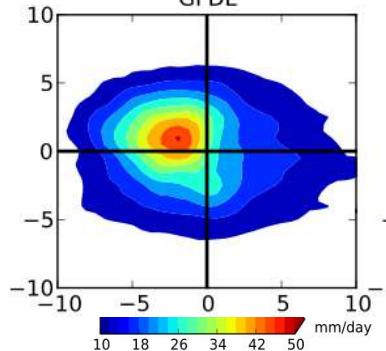
2C2K



10°lon X 10°lat box
following the daily TC path
Scoccimarro et al. 2014



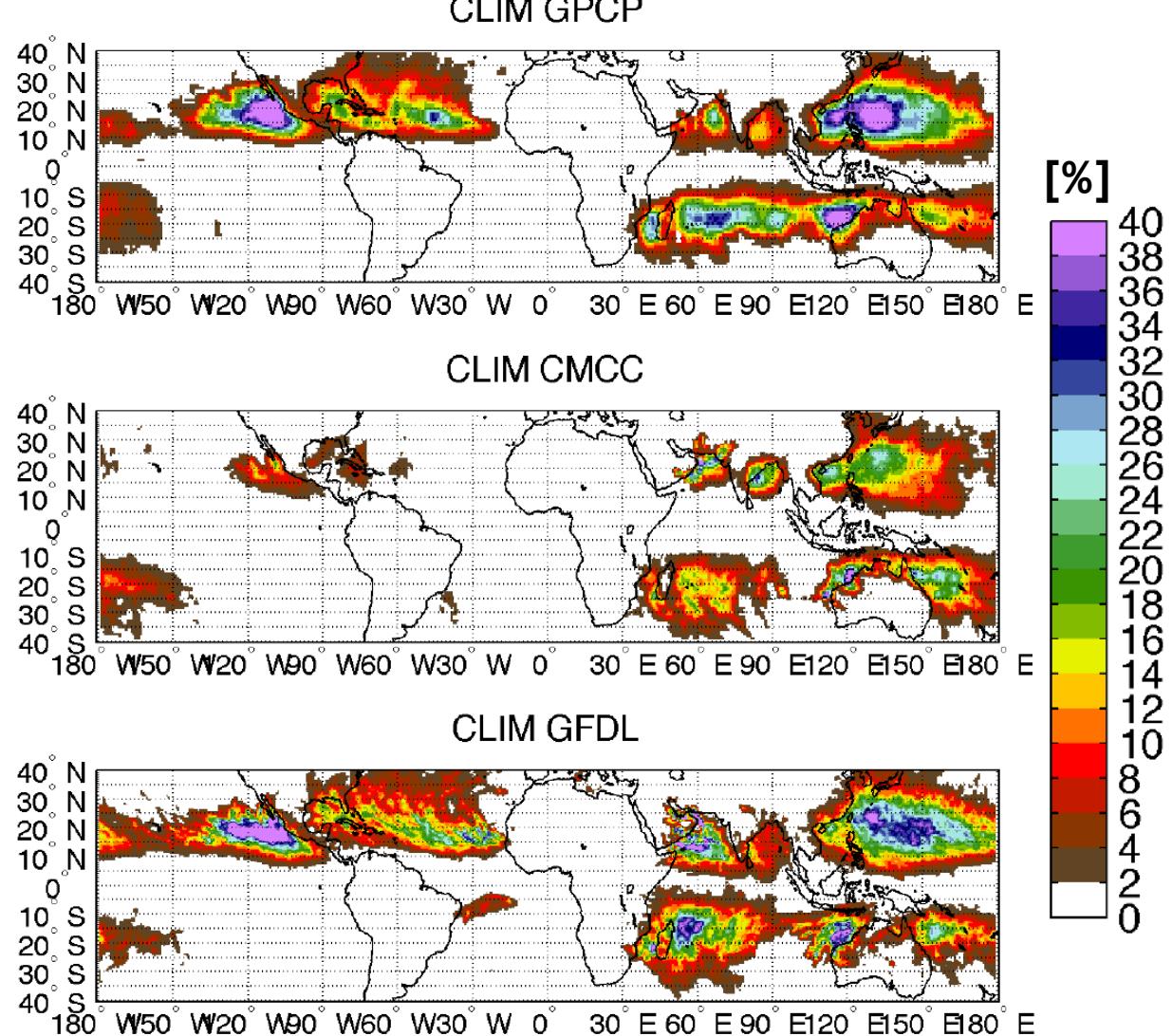
GFDL



CMCC

Fraction of precipitation associated with TCs in the CLIM experimen
[% wrt the total precipitation]

OBS



CLIM GPCP

CLIM CMCC

CLIM GFDL

[%]

40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

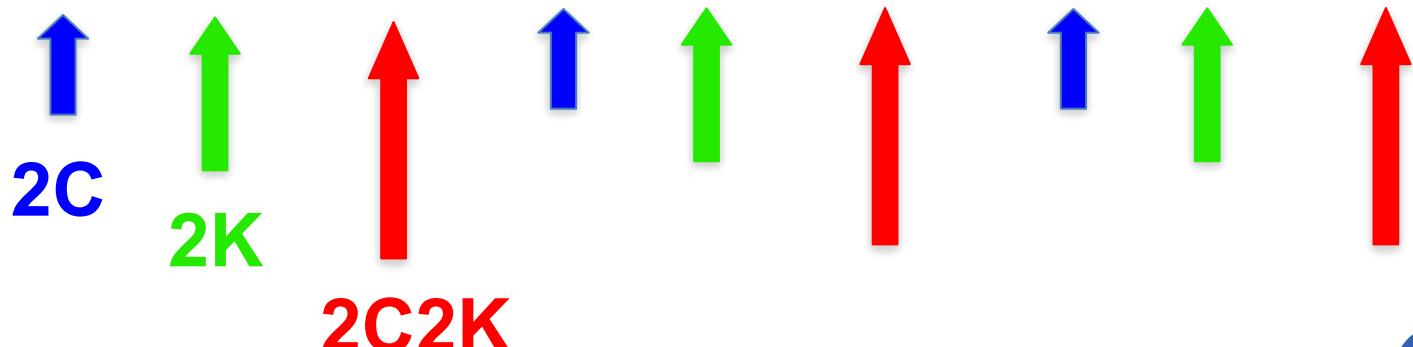
TC precipitation changes [%] wrt the CLIM exp.
 [10° radius area around the center of circulation]
 (10% most intense TCs only)

GFDL (50 km)

CMCC (80km)

CAM5 (25 km)

	GFDL HiRAM			CMCC model			CAM5		
	2×CO ₂	+2K	2×CO ₂ +2K	2×CO ₂	+2K	2×CO ₂ +2K	2×CO ₂	+2K	2×CO ₂ +2K
Global	-6.1	9.1	11.7	-5.4	10.7	12.8	-1.4	13.2	16.5
NH	-8.9	7.8	13.3	-6.7	15.7	17.1	1.3	14.1	16.1
SH	0.4	12.6	8.8	-6.2	0.9	4.5	-8.0	10.1	18.0
North Atlantic	-16.7	18.2	-11.8	-1.8	4.5	11.1	-8.4	-0.4	8.5
East Pacific	-6.5	25.1	17.0	-6.0	14.0	24.3	12.9	17.0	27.8
West Pacific	-5.9	2.5	16.5	-8.1	15.8	14.8	-11.1	17.1	3.7
North Indian Ocean	-17.7	0.2	17.6	1.7	21.0	21.2	-1.5	18.7	19.2
South Indian Ocean	1.1	7.3	5.8	-9.5	-1.8	-1.4	-7.6	16.4	25.6
South Pacific	-0.9	19.9	12.9	-4.5	1.8	5.3	-10.3	-0.3	10.6



CMCC took part to the US-CLIVAR Hurricane Working Group.

The screenshot shows the U.S. CLIVAR website with a red circle highlighting the "Hurricane Working Group" section. This section contains text about the group's formation and objectives, which are also detailed below in the main content area.

Hurricane Working Group

The U.S. CLIVAR Hurricane Working Group was formed in January of 2011 to coordinate efforts to produce a set of model experiments designed to improve understanding of the variability of tropical cyclone formation in climate models.

The scientific objectives of the Hurricane WG include:

- an improved understanding of interannual variability and trends in the tropical cyclone activity from the beginning of the 20th century to present
- quantifying changes in the characteristics of tropical cyclones in a warming climate.

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Hurricane Working Group

Hurricane Working Group	
Gabriel Vecchi, co-chair	NOAA Geophysical Fluid Dynamics Laboratory
Suzana Camargo, co-chair	Columbia University/Lamont-Observatory
Kevin Walsh, co-chair	University of Melbourne, Australia
Lennart Bengtsson	University of Reading, UK
James Elsner	Florida State University
Kerry Emanuel	Massachusetts Institute of Technology
In-Sik Kang	Seoul National University, Korea
Jim Kossin	NOAA National Climatic Data Center
Chris Landsea	NOAA Atlantic Oceanographic and Meteorological Laboratory
Tim LaRow	Florida State University
Kazuyoshi Oouchi	Japan Agency for Marine-Earth Science and Technology
Siegfried Schubert	NASA Goddard Space Flight Center
Adam Sobel	Columbia University
Enrico Scoccimarro	INGV-CMCC, Italy
Gabriele Villarini	University of Iowa
Hui Wang	NOAA NCEP
Michael Wehner	DOE Lawrence Berkeley National Laboratory
Ming Zhao	NOAA Geophysical Fluid Dynamics Laboratory

Cicloni Tropicali in futuro

- Il numero di **cicloni tropicali** (circa 90 ogni anno) e' destinato a **diminuire** in un ambiente piu caldo (atmosfera piu stabile, convezione inibita)
- L'**intensita'** dei **cicloni** che si formeranno e' destinata ad **aumentare** x l'aumentata energia (calore) disponibile in oceano.
- La quantita' di **pioggia** associata ai cicloni tropicali sara' **maggior** in un ambiente piu caldo

CAMBIAMENTI CLIMATICI, CICLONI TROPICALI E VARIAZIONI DEL LIVELLO DEI MARI

OUTLINE

- Clima e Cambiamenti Climatici: il supporto fornito dalla modellistica numerica

- I Cicloni tropicali: cosa sono? Riusciamo a simularli numericamente?

- Variazioni indotte dai cambiamenti climatici sull' attivita' ciclonica tropicale

- Interazione tra i cicloni tropicali e la costa

Interazione tra TCs e regioni costiere

I cicloni tropicali impattano le regioni costiere principalmente tramite:

- venti intensi
- precipitazione intensa
- inondazioni (storm surge) (si stima che oltre la metà delle vittime indotte da TCs nell' Atlanticod dal 1963 al 2012 sia stata causata da storm surge)

L'impatto dell'inondazione costiera indotta da un TC è strettamente dipendente dal livello medio mare sottostante quindi in scenari di cambiamento climatico dobbiamo considerare l'accoppiamento tra variazione dell'attività ciclonica tropicale e la variazione del livello medio del mare.

See also: [Scoccimarro 2018, CMCC foresight: Tropical Cyclone prediction and projection.](#)

Interazione tra TC e regioni costiere

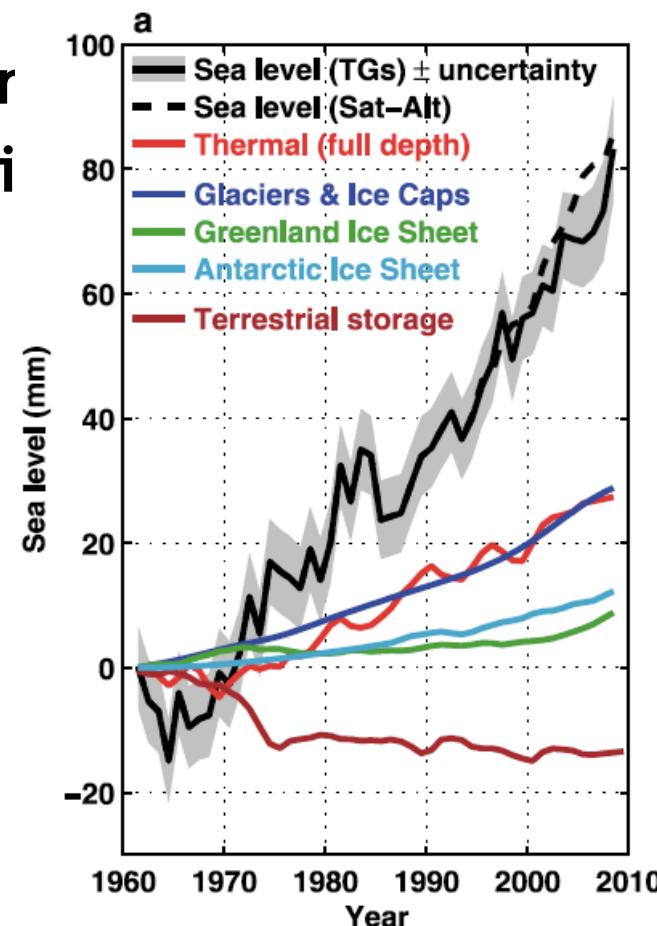
Le variazioni del livello del mare dipendono da:

- Aumento livello medio mare (mean sea level rise)
 - effetto sterico (inalzamento della temperatura)
 - effetto dinamico
 - scioglimento dei ghiacciai terrestri
 - scioglimento dei ghiacci di Antartide e Groenlandia
- Maree (tides)
- Inondazioni (storm surge)



Climate Change increases the base sea-level and thus exacerbates the effects of a storm surge on coastal flooding (Climate Commission 2013)

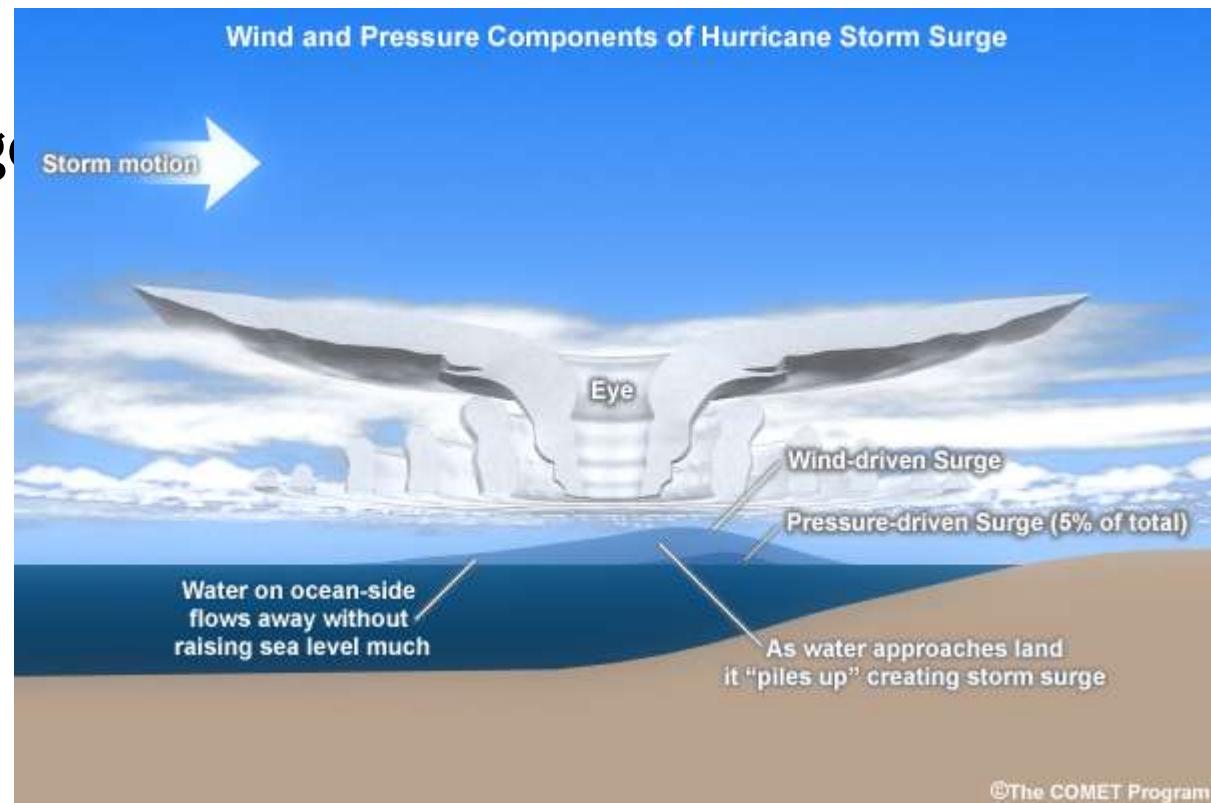
Image from Tropical Cyclones and Climate Change: Factsheet by Climate Council



Interazione tra TC e regioni costiere

La **storm surge** puo' portare all'inalzamento del livello del mare di parecchi metri, dipendentemente dall' intensita' del ciclone associato dall'orientazione della sua traiettoria ripetto alla linea di costa, dalla sua **dimensione e velocita'** di spostamento, nonche' dalla **forma della linea di costa/batimetria**.

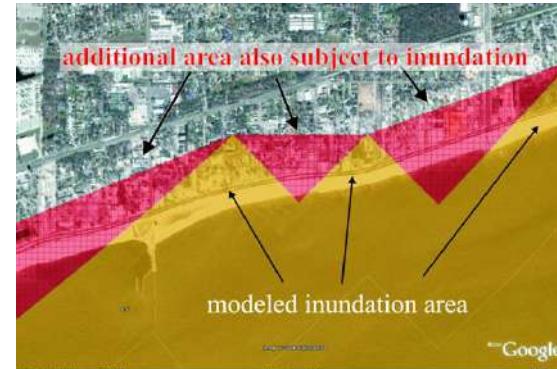
La stessa storm surge puo' poi avere dimensioni e durata differenti.



Interazione tra TC e regioni costiere

-Studi fatti per correlare la storm surge all'intensità del vento, suggeriscono I venti “pre-landfall” (18 ore prima) come i meglio correlati alla “storm surge magnitude”.

Lo stesso TC (pari forma, intensità, velocità, etc.) puo' causare storm surge molto diverse, in base alla zona colpita: una storm source di 5 metri su continental shelf (i.e. Louisiana) , puo' ridursi a 2 metri su zone in cui la pendenza della costa e' maggiore (Miami).



Refs:

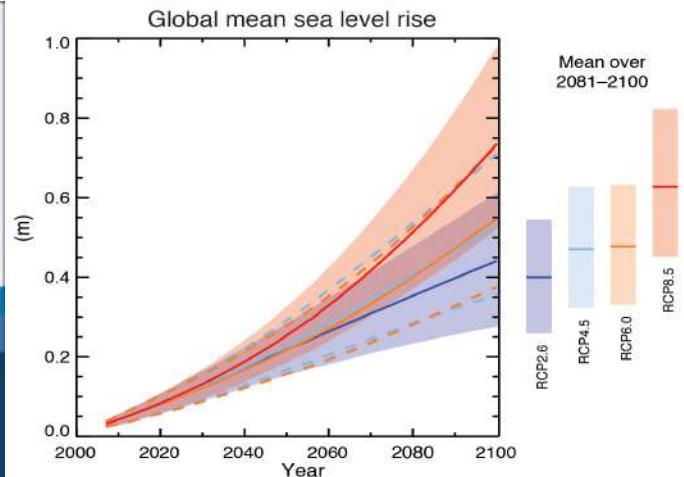
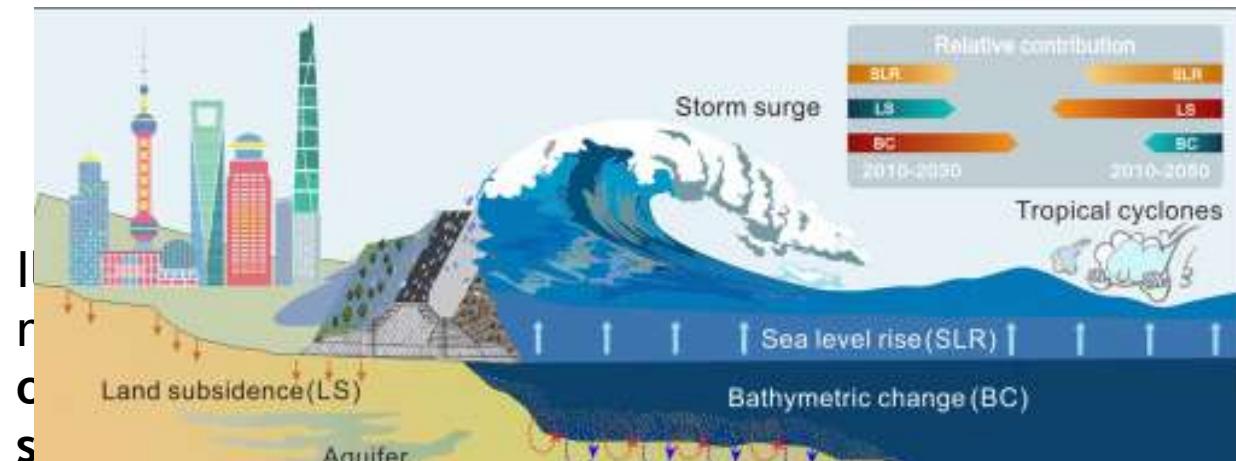
Jordan and Clayson, 2008;
Needham et al 2013;
<https://www.nhc.noaa.gov/>

Interazione tra TC e regioni costiere

- L'impatto dei cambiamenti climatici sul landfall dei cicloni tropicali e' incerto.
- Indipendentemente da questo pero' l'eventuale inondazione indotta da un ciclone al landfall sara' potenzialmente piu' impattante in scenari di clima piu' caldo, come risultato dell'aumentato livello medio mare.
- La linea di costa, in continua evoluzione quindi, si rendera' vulnerabile in tempi/zona diversi/e all'arrivo di un evento meteo estremo quale un ciclone tropicale.
- Questi impatti possono essere parzialmente mitigati tramite strategie di adattamento (incluse strategie di programmazione urbana, costruzione di muri costieri, ridefinizione dei percorsi stradali, etc).

Interazione tra TC e regioni costiere

L'impatto indotto dall' associazione TC - sea level rise, ha quindi forti implicazioni in termini di adattamento, in particolare in Small Island Developing States (SIDS). L'aumentata intensita dei TCs puo' spingere le popolazioni oltre le capacita' di adattamento e quindi indurre evacuazioni temporanee o vere e proprie migrazioni.

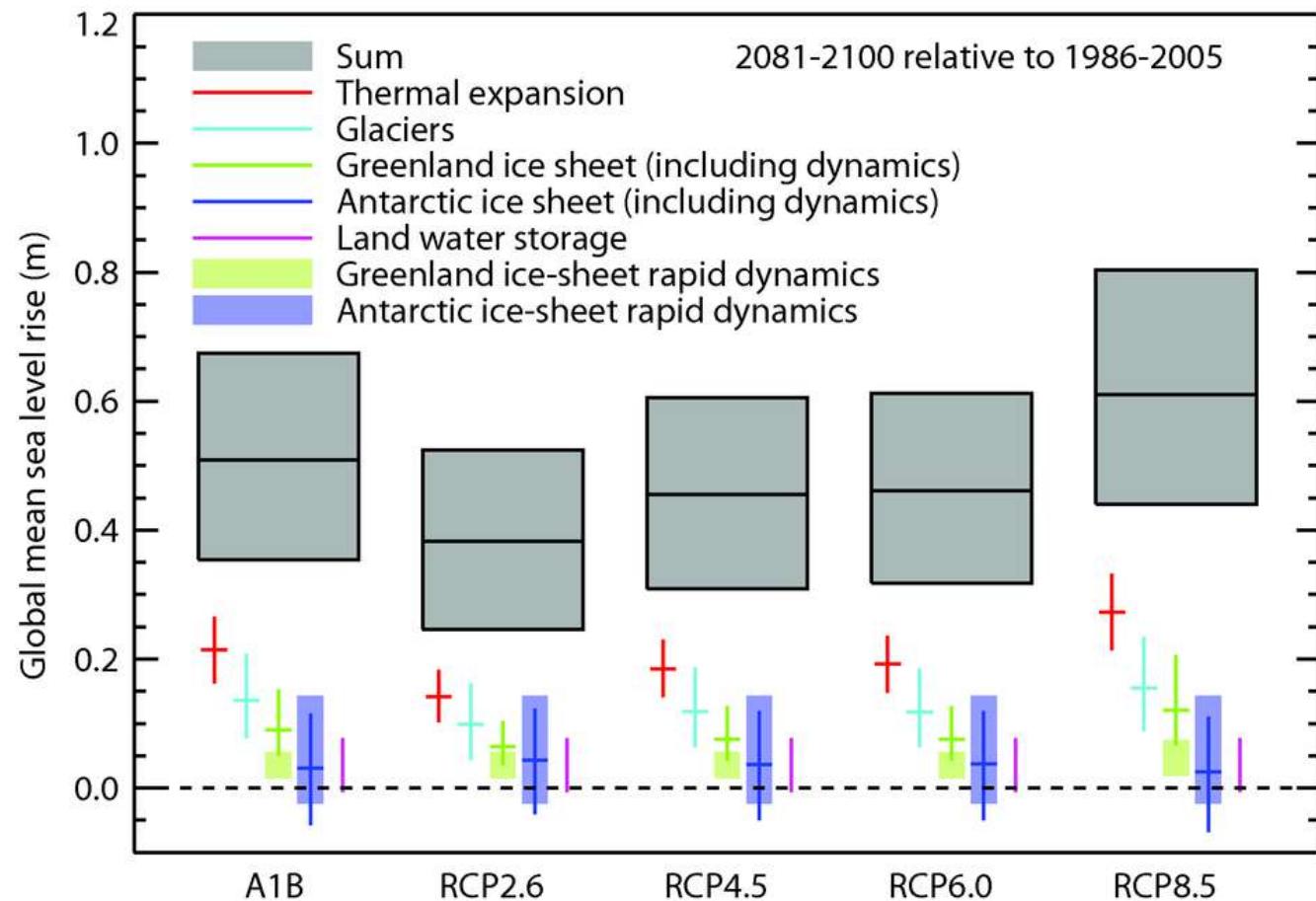


acqua dolce nei depositi dell'isola).

Interazione tra TC e regioni costiere

Le proiezioni di sea level rise sono diverse in base ai diversi scenari (Representative Concentration Pathways RCPs) considerati, ovvero in base al livello di virtuosismo con cui affronteremo il problema delle emissioni di gas serra.

Incrementi del livello medio mare di oltre I 70 cm per la fine del secolo sono ritenuti plausibili seguendo uno scenario business as usual (RCP8.5)

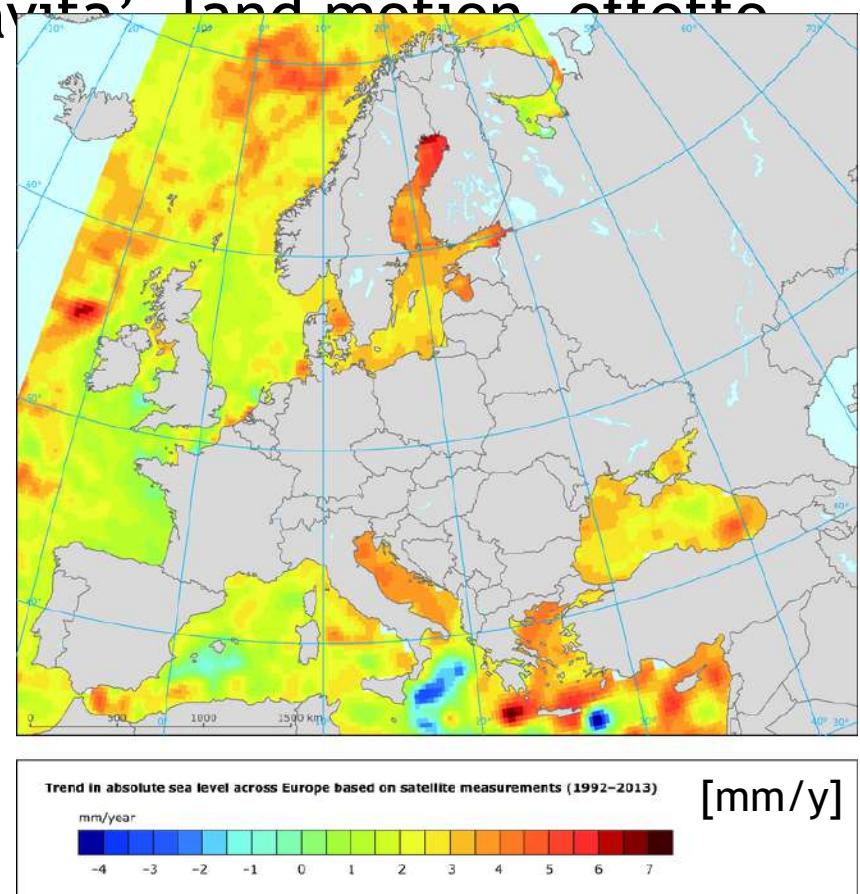


Interazione tra TC e regioni costiere

Le proiezioni di sea level rise sono diverse in base ai diversi scenari

(Representative Concentration Pathways RCPs) considerati, ma anche in base alla regione di interesse, in quanto fattori locali hanno un ruolo determinante (gravità, land motion, effetto dinamico, etc)

Tendenza del sea level rise in Europa dal 1992 al 2013 (misura da satellite).
source: <https://www.eea.europa.eu/>



Interazione tra cicloni e regioni costiere

- Le stime di aumento di livello del mare (media globale) in passato vanno da 1.2 a 1.7 mm/year.
- Nell'ultimo ventennio tale aumento e' accelerato a circa 3 mm/year.
- Le stime per il futuro sono oltre i 3 mm/year, fino a portare a proiezioni di oltre i 70 cm di anomalia per la fine del secolo corrente seguendo lo scenario di emissione peggiore.
- L'aumento dell'intensita' dei TCs associato a tale aumento di mean sea level suggerisce la necessita' di interventi di adattamento costiero.
- Tutte le coste dell'Europa hanno vissuto e vivranno variazioni del livello medio mare, con significative differenze da regione a regione.
- Valori estremi di sea level sono aumentati su certe zone della costa europea, prevalentemente indotte da variazioni nel sea level, non da variazioni in "storm activity".
- La componente "meteorologically driven" e' comunque in aumento nel nord Europa secondo recenti proiezioni.

Interazione tra TC e regioni costiere

Coastal protection:

How coastal cities will protect their infrastructure is less certain.

Here few architecture exercises suggested:

-Floating urbanism <http://www.atdesignoffice.com/>, <http://www.evolo.us/competition/noah%20%99s-ark-sustainable-city/>

-Freedom Ship <http://freedomship.com/>

-Drift city Architecture's response to sea level rise <http://www.archtalent.com/projects/drift-city-architecture-s-response-to-sea-level-rise>

-The big U resilient infrastructure system <https://big.dk/#projects-hud>

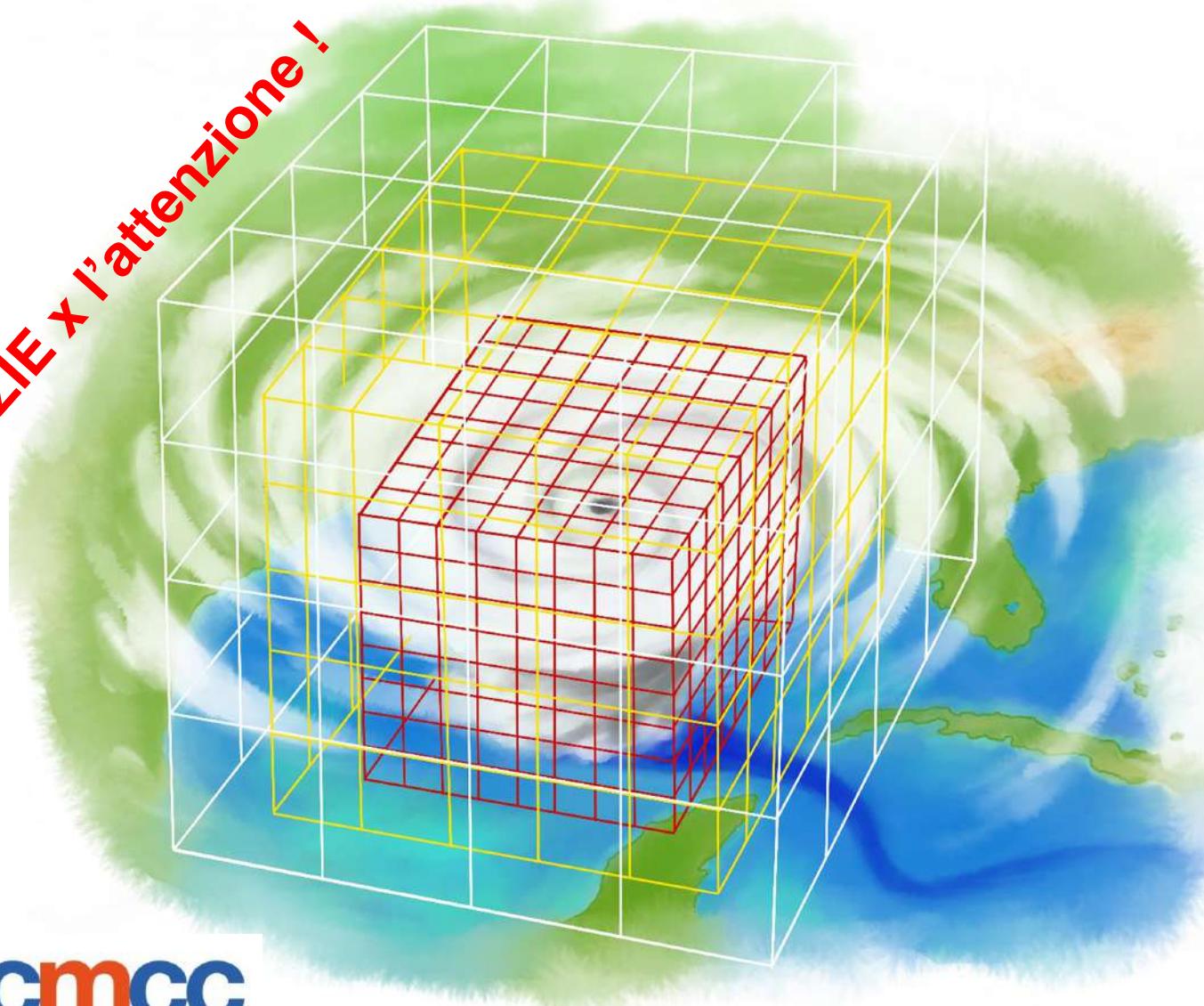
-Floating houses, <http://morphopedia.com/projects/float-house>

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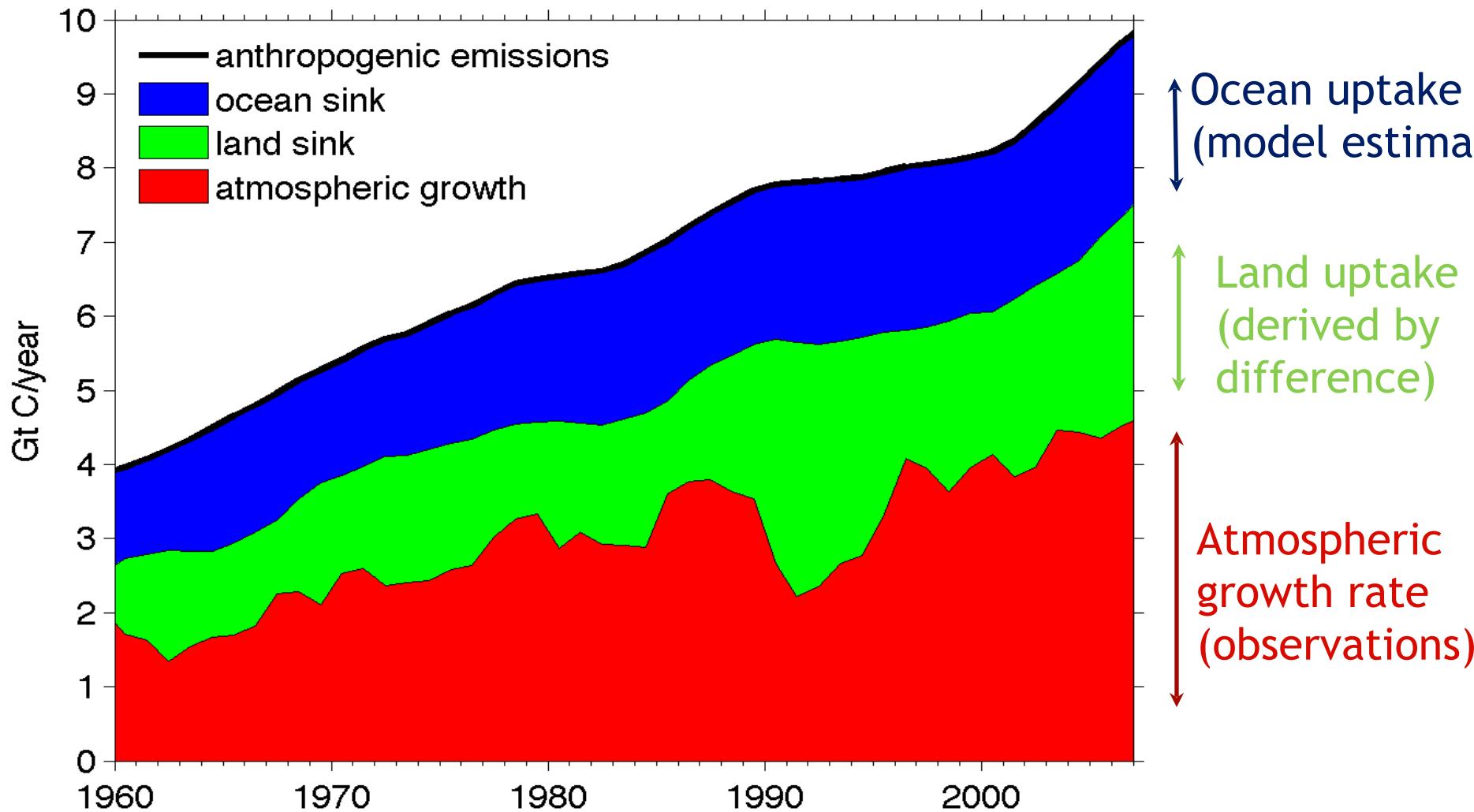


CAMBIAMENTI CLIMATICI, CICLONI TROPICALI E VARIAZIONI DEL LIVELLO DEI MARI

GRAZIE x l'attenzione !



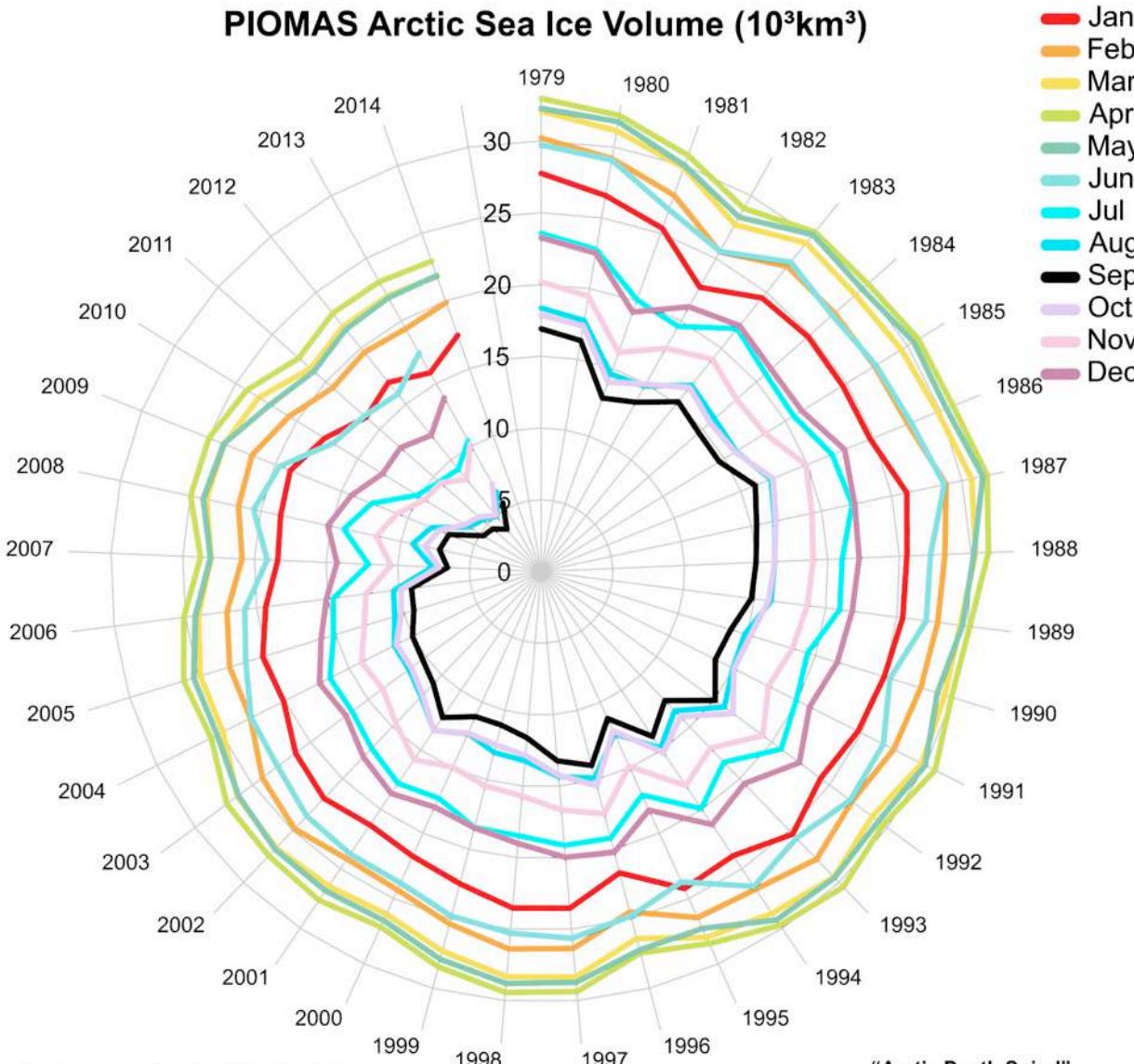
The global carbon cycle



Canadell et al., 2007



Evoluzione dal 1979 ad oggi del volume del ghiaccio Artico



"Arctic Death Spiral"
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