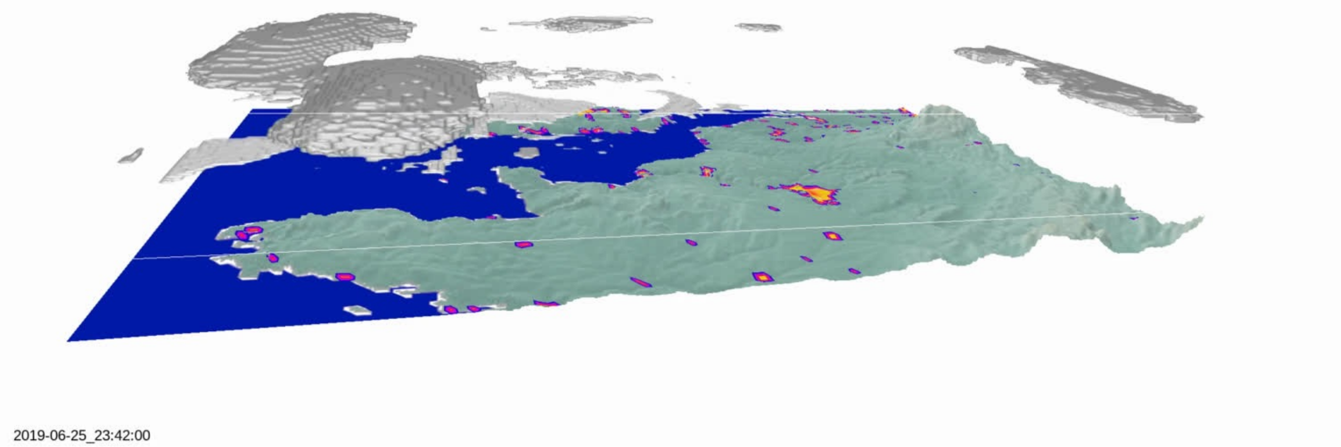
Seminar, LSCE, Davide21 October 2025



Scalar statistics and extreme events in Non-equilibrium systems

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ANR ‘Transition’, University of Rouen’
ADEME ‘Hélios’
Normandy Region
Simulations on CRIANN, Agence de l’Eau …

Agence Nationale de la Recherche
ANR

1. Context and question

Link between the dynamics of

→ Large scales of the system: e.g. , jet stream, waves (Rossby, gravity..), internal variability (daily/annual variations)

and

→temperature fluctuations variability at local, small scales

Context of extreme events ←→blocking

Problem: unravel the mechanisms of genesis, persistence, and dissipation of energy→ focus on extreme events

2. Methodology

First principles + Triple decomposition framework

First principles? Navier Stokes, advection-diffusion of temperature…

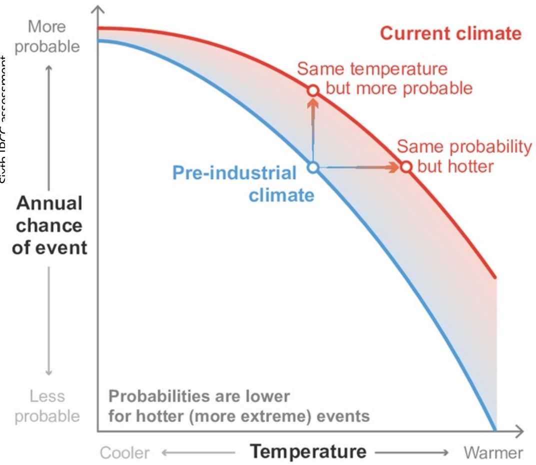
Which form? -constant physical properties of the fluid (constant density, viscosity, D)

-variable density, viscosity

-T/NT interfaces -with phase changes…

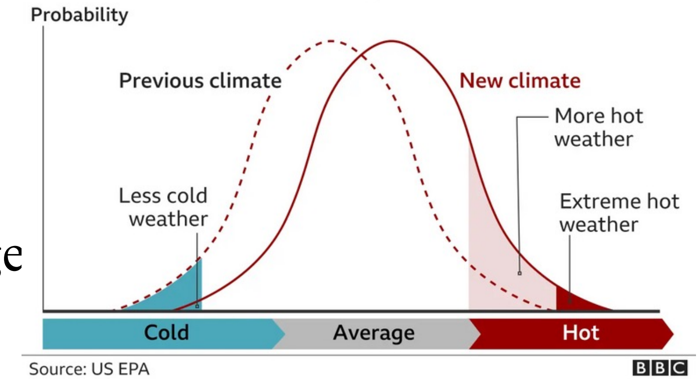
3. Results: June 2019, August 2003

1. Context. Extreme events and climate change, a **multiscale** process

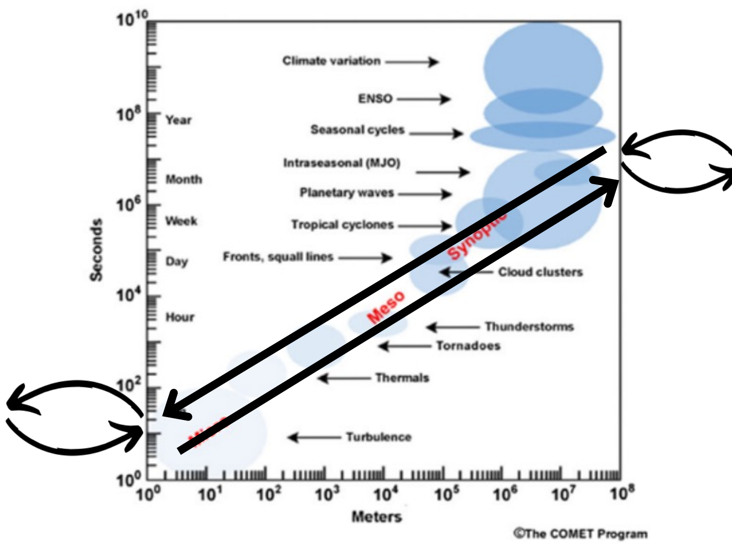


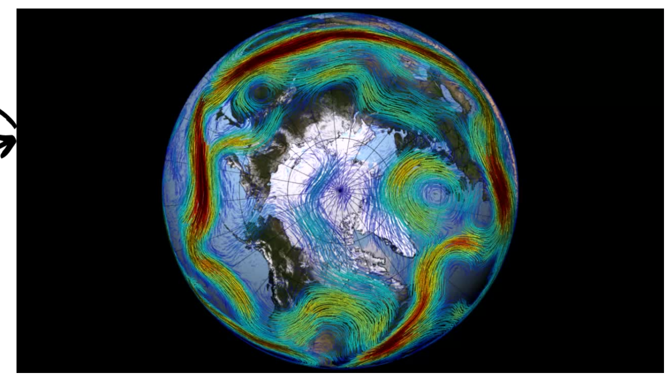
Sixth IPCC assessment report

- Climate change brings more frequent and more intense extreme events.
- Small scales are influenced by large scales but the opposite is also true.

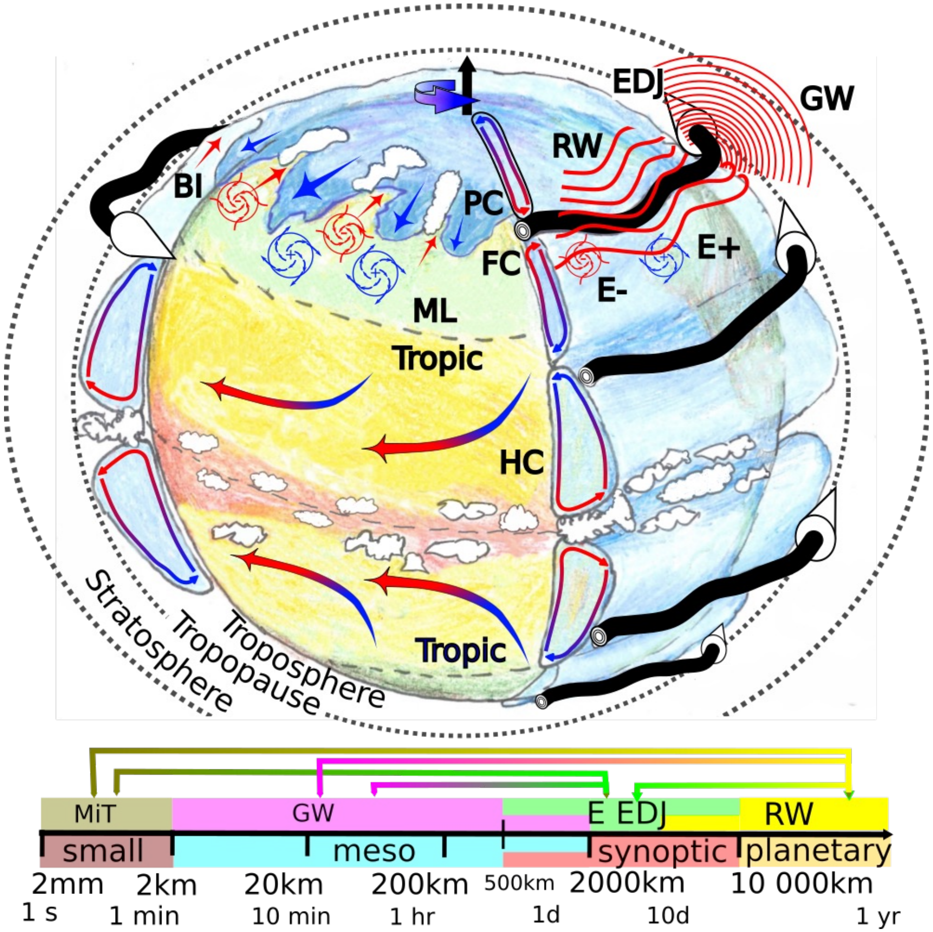


ISTOCK/MARC BRUXELLE





1. Context. Who are the players



Zonal flows:

•Eddy driven jet (EDJ)

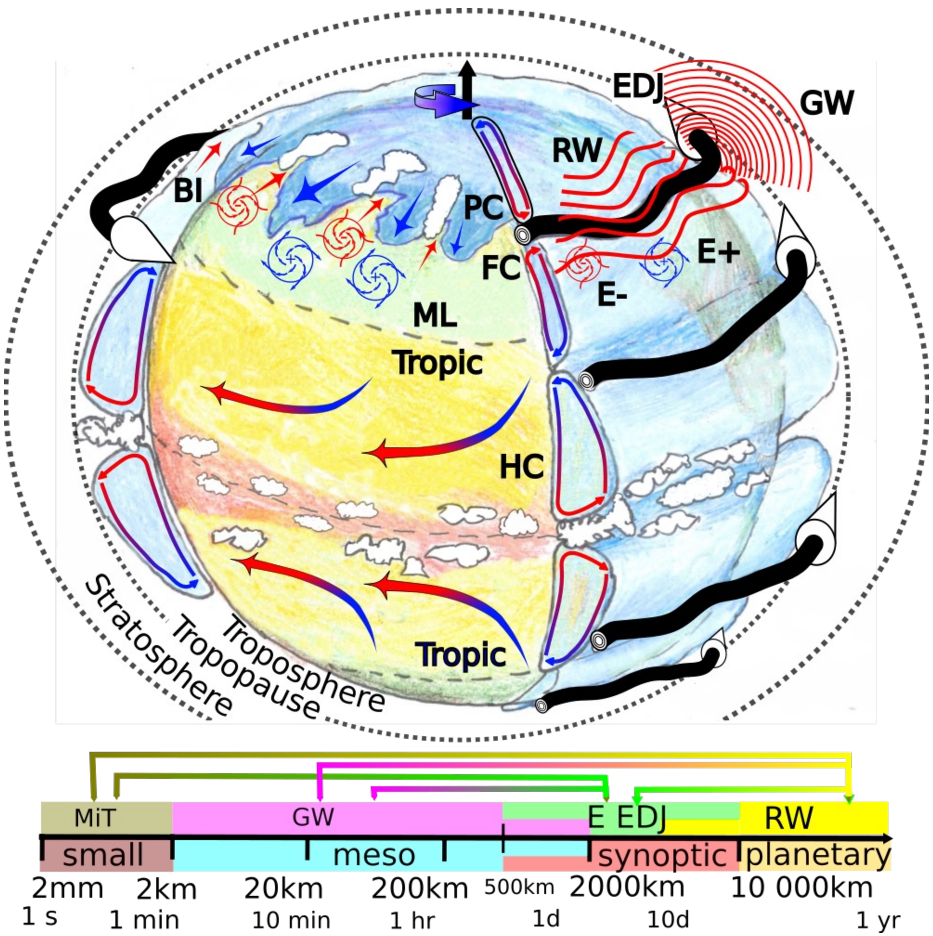
Waves:

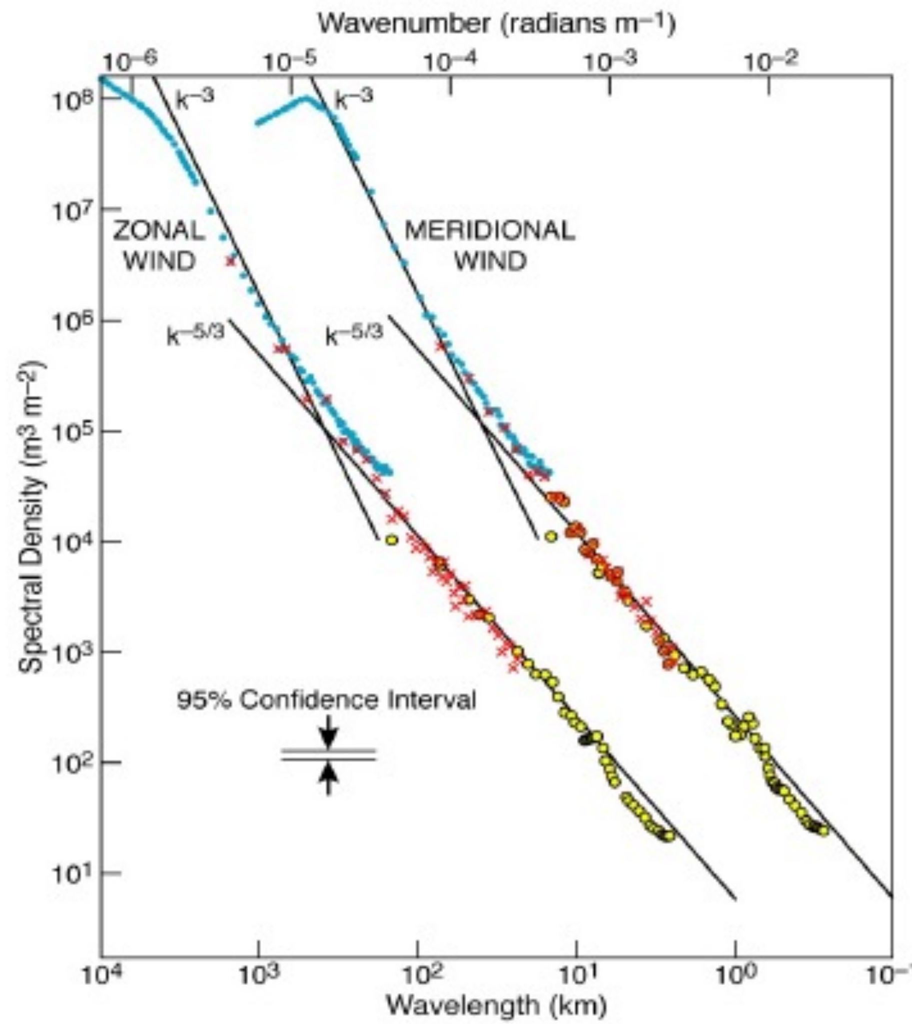
- Rossby waves (RW)
- Gravity waves (GW)

Eddies:

- Cyclones (E-)
- Anti-cyclones (E+)
- Micro-Turbulence (MiT)

1. Context. Who are the players, full spectrum

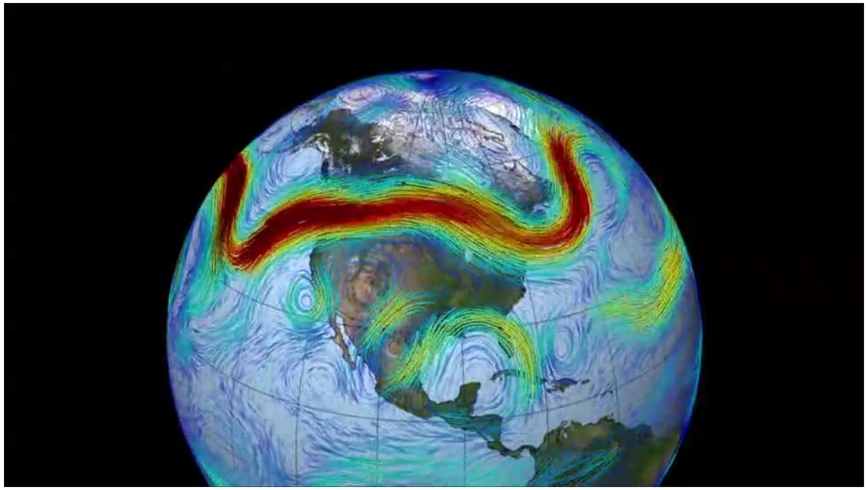


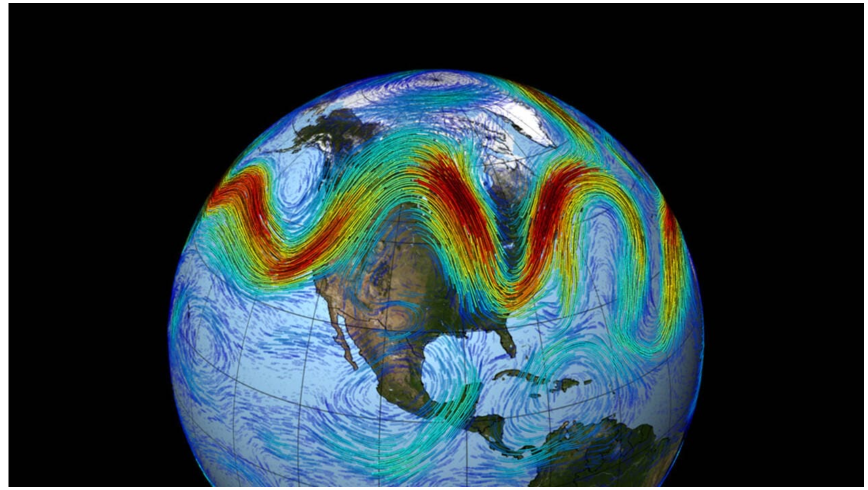


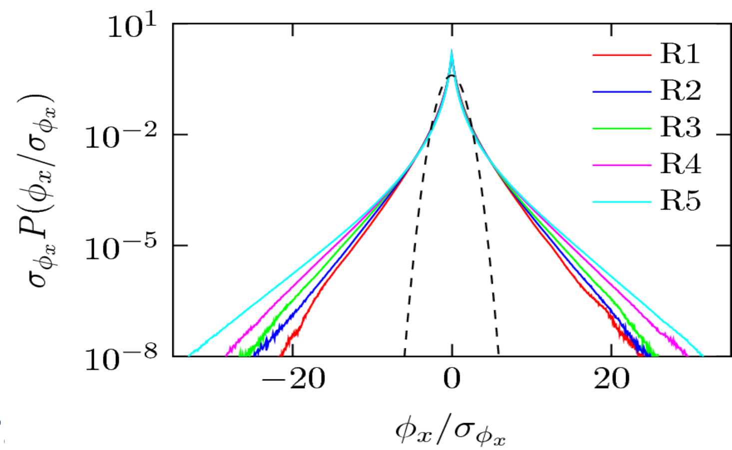
Nastrom and Gage, 1985

All scales/wavenumbers are energetic

1. Context and question







Blocking →Jet stream (periodic motion)→

Local variability of the temperature gradient

Energy source/Production / dissipation/diffusion/tr

= transport equations for temperature fluctuations

-

Focus on d/dt Mn

1. Context. Scenarios for temporal jumps ..
Short time (heat waves, UHI…) and long time (climate…)

Climate and Its Sensitivity

Let's say CO_2 doubles:

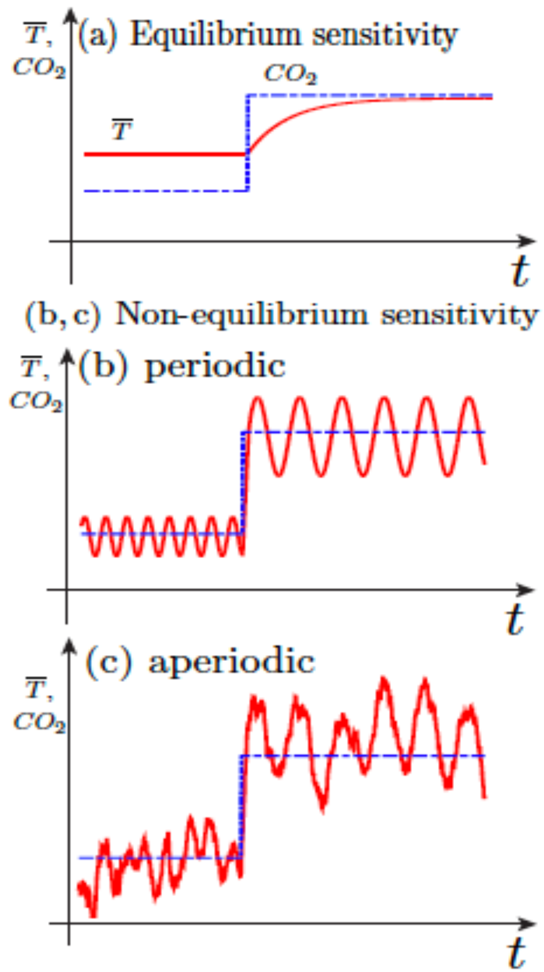
How will "climate" change?

1. Climate is in stable equilibrium (fixed point); if so, mean temperature will just shift gradually to its new equilibrium value.

2. Climate is purely periodic; if so, mean temperature will (maybe) shift gradually to its new equilibrium value. But how will the period, amplitude and phase of the limit cycle change?

3. And how about some "real stuff" now: chaotic + random?

Ghil (in *Encycl. Global Environmental Change*, 2002)



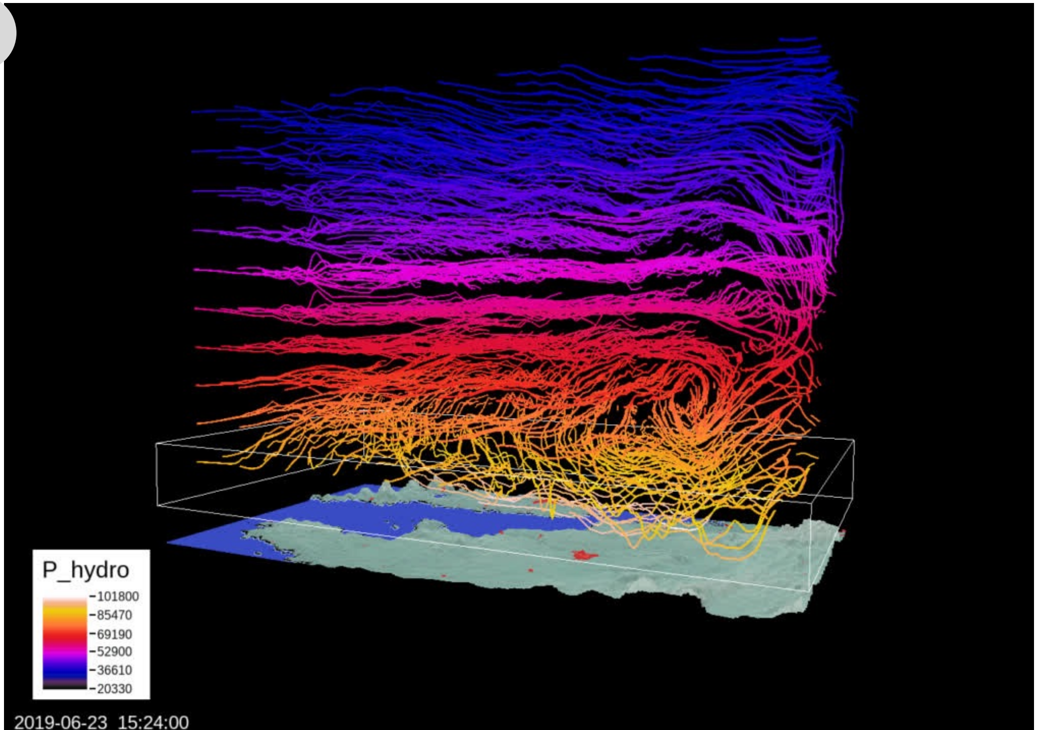
The question: Which is t
'new' state of the system

Dynamical system ←→
Statistical approach

Short times →
long time

2. Methodology. Numerical simulations with WRF

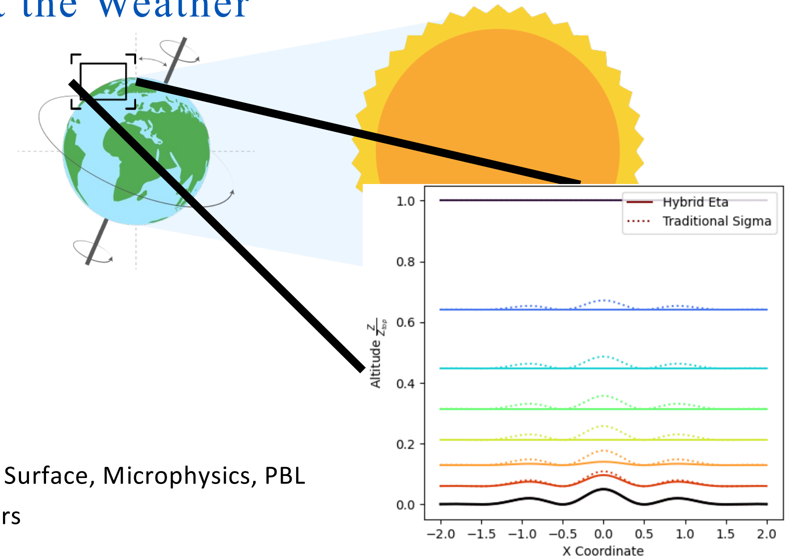
1



THE WRF MODEL

Taking into account all (significant) forces we can predict the Weather

$$\mathbf{F} = m\frac{d\mathbf{v}}{dt} = m\mathbf{a}\,. \xrightarrow[\text{Fluid continuum}]{} \frac{D\mathbf{u}}{Dt} = -\frac{\nabla p}{\rho} + F \longrightarrow$$

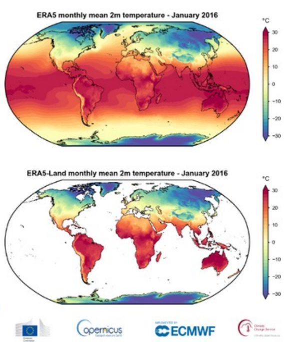


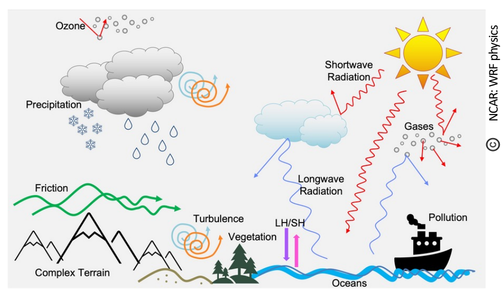
Taking into account Gravity, Centrifugal, Normal forces(Pressure gradient) and influence of topography

$$\partial_t U + (\nabla\cdot\mathbf{V}u) + \mu_d\alpha\partial_x p + (\alpha/\alpha_d)\partial_\eta p\partial_x\phi = \boxed{F_U}$$
$$\partial_t V + (\nabla\cdot\mathbf{V}v) + \mu_d\alpha\partial_y p + (\alpha/\alpha_d)\partial_\eta p\partial_y\phi = F_V$$
$$\partial_t W + (\nabla\cdot\mathbf{V}w) - g[(\alpha/\alpha_d)\partial_\eta p - \mu_d] = F_W$$
$$\partial_t\Theta_m + (\nabla\cdot\mathbf{V}\theta_m) = F_{\Theta_m}$$
$$\partial_t\mu_d + (\nabla\cdot\mathbf{V}) = 0$$
$$\partial_t\phi + \mu_d^{-1}[(\mathbf{V}\cdot\nabla\phi) - gW] = 0$$
$$\partial_t Q_m + (\nabla\cdot\mathbf{V}q_m) = \boxed{F_{Q_m}}$$

What goes here?

Physics(Coriolis, Radiation, Surface, Microphysics, PBL mixing) and Numerical filters





- We use ERA5 reanalysis for the initial state and Boundary conditions

'm'= moist potential temperature
(if all the moisture were condensed and the released latent heat was added to the parcel)

Simulation characteristics

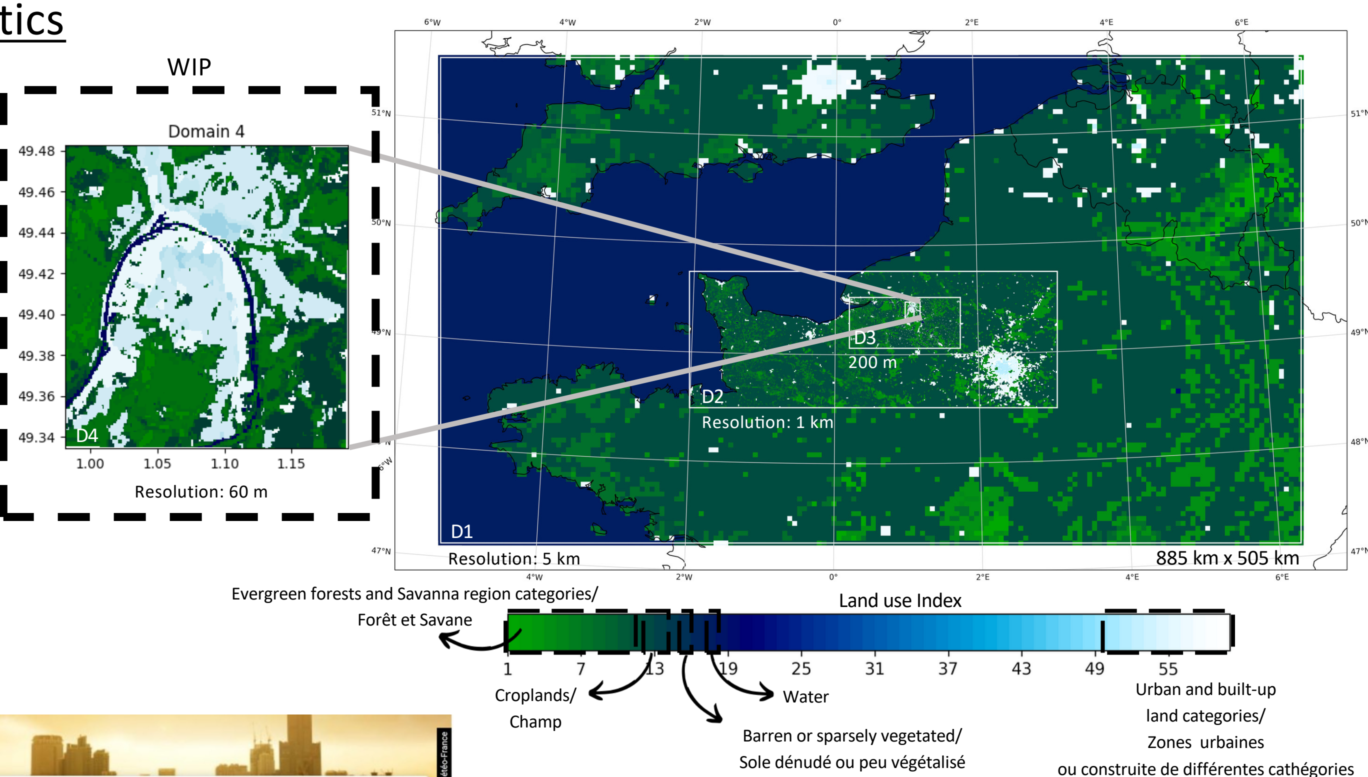
Domains :

D1 = 5km D3 = 200m

D2 = 1km D4 = 60m

Possible change to domains :

- D1 might be expended to include more of the Atlantic
- D4 will be implemented.
- D2 and D3 may be adapted if need be.



Bulletin de santé publique canicule. Bilan été 2019.

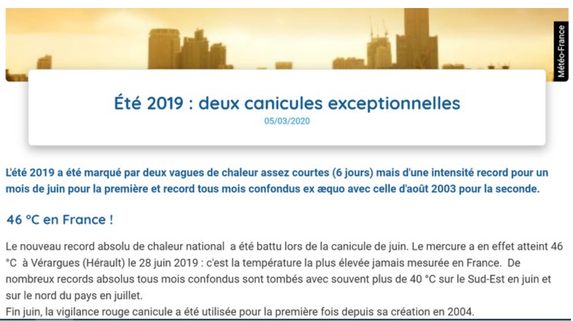
Publié le 9 octobre 2019
Mis à jour le 9 octobre 2019

IMPRIMER PARTAGER

Points clés

L'été 2019 a été marqué par deux canicules très étendues et intenses, avec des dépassements des seuils d'alerte entre le 24 juin et le 7 juillet et le 21 et le 27 juillet. Lors de ces deux canicules, pour la première fois, respectivement 4 et 20 départements, représentant 7 % et 35% de la population Française métropolitaine, ont été placés en vigilance rouge, compte-tenu des températures diurnes exceptionnelles.

Santé publique France



Météo-France

Été 2019 : deux canicules exceptionnelles

05/03/2020

L'été 2019 a été marqué par deux vagues de chaleur assez courtes (6 jours) mais d'une intensité record pour un mois de juin pour la première et record tous mois confondus ex æquo avec celle d'août 2003 pour la seconde.

46 °C en France !

Le nouveau record absolu de chaleur national a été battu lors de la canicule de juin. Le mercure a en effet atteint 46 °C à Vérargues (Hérault) le 28 juin 2019 : c'est la température la plus élevée jamais mesurée en France. De nombreux records absolus tous mois confondus sont tombés avec souvent plus de 40 °C sur le Sud-Est en juin et sur le nord du pays en juillet.
Fin juin, la vigilance rouge canicule a été utilisée pour la première fois depuis sa création en 2004.

Météo-France

Studied time: 24-28 June 2019

Characteristics of the Domain

Domains :

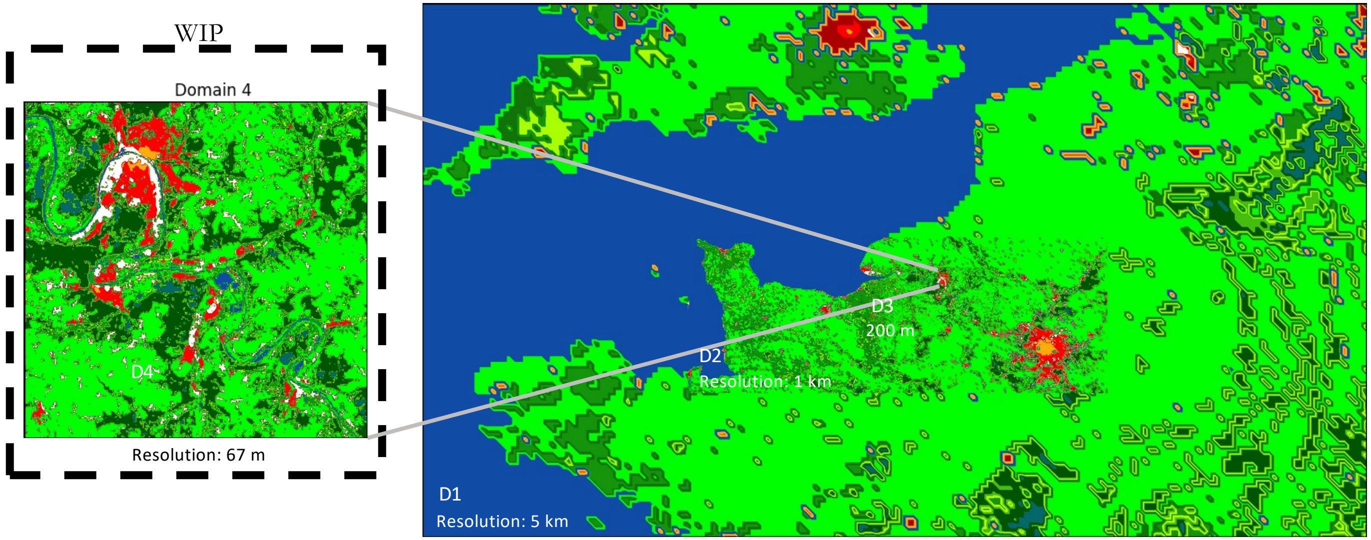
D1 = 885 km x 505 km @5km

D2 = 376 km x 141 km @1km

D3 = 113 km x 53 km @200m

D4 =43 km x 43 km @67m

Land use indices for the different domains



Period of Study:

24-30 June 2019

Bulletin de santé publique canicule. Bilan été 2019.

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Météo-France

Choice of physics, domain, and time of simulation

- Microphysics: THOMPSON

Explicit Forecasts of Winter Precipitation Using an Improved Bulk Microphysics Scheme. Part II: Implementation of a New Snow Parameterization

GREGORY THOMPSON, PAUL R. FIELD, ROY M. RASMUSSEN, AND WILLIAM D. HALL

National Center for Atmospheric Research, Boulder, Colorado*

(Manuscript received 20 September 2007, in final form 19 March 2008)

ABSTRACT

A new bulk microphysical parameterization (BMP) has been developed for use with the Weather Research and Forecasting (WRF) Model or other mesoscale models. As compared with earlier single-moment BMPs, the new scheme incorporates a large number of improvements to both physical processes and computer coding, and it employs many techniques found in far more sophisticated spectral/bin schemes using lookup tables. Unlike any other BMP, the assumed snow size distribution depends on both ice water

- Cumulus scheme for domain 1: GRELL-FREITAS

A scale and aerosol aware stochastic convective parameterization for weather and air quality modeling

G. A. Grell[1] and S. R. Freitas[2]

- BL PBL mixing: YSU (domain 1 & 2)

A New Vertical Diffusion Package with an Explicit Treatment of Entrainment Processes

SONG-YOU HONG AND YIGN NOH

Department of Atmospheric Sciences, Global Environment Laboratory, Yonsei University, Seoul, South Korea

JIMY DUDHIA

Mesoscale and Microscale Meteorology Division, National Center for Atmospheric Research, Boulder, Colorado

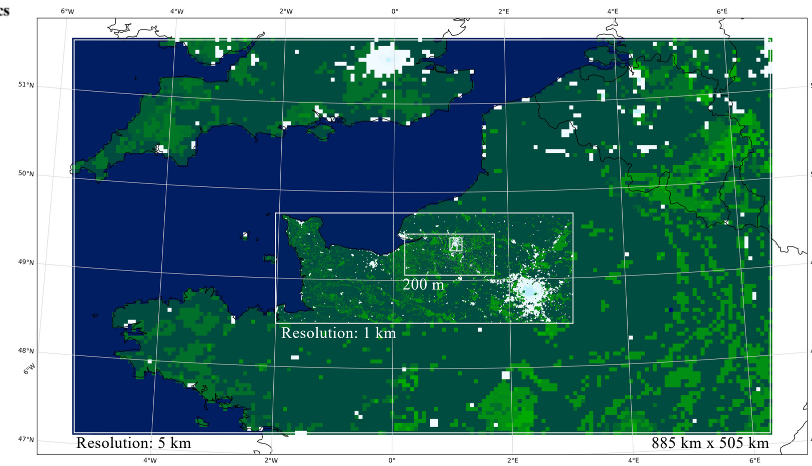
- Radiation:RRTMG

Radiative forcing by long-lived greenhouse gases: Calculations with the AER radiative transfer models

Michael J. Iacono,[1] Jennifer S. Delamere,[1] Eli J. Mlawer,[1] Mark W. Shephard,[1] Shepard A. Clough,[2] and William D. Collins[3,4]

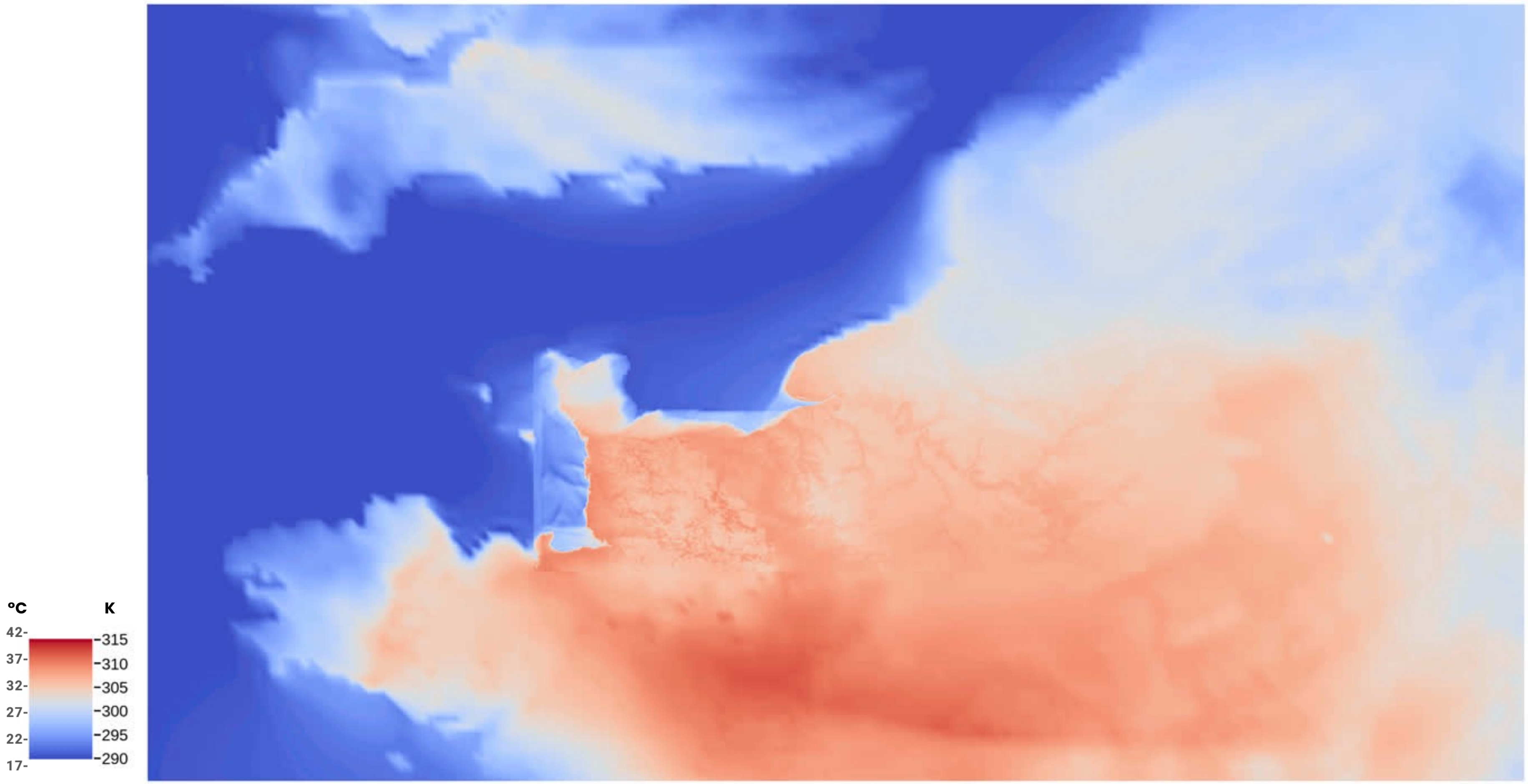
Received 8 February 2008; revised 11 April 2008; accepted 25 April 2008; published 2 July 2008.

- Surface: QNSE (Quasi-Normal Scale Elimination)

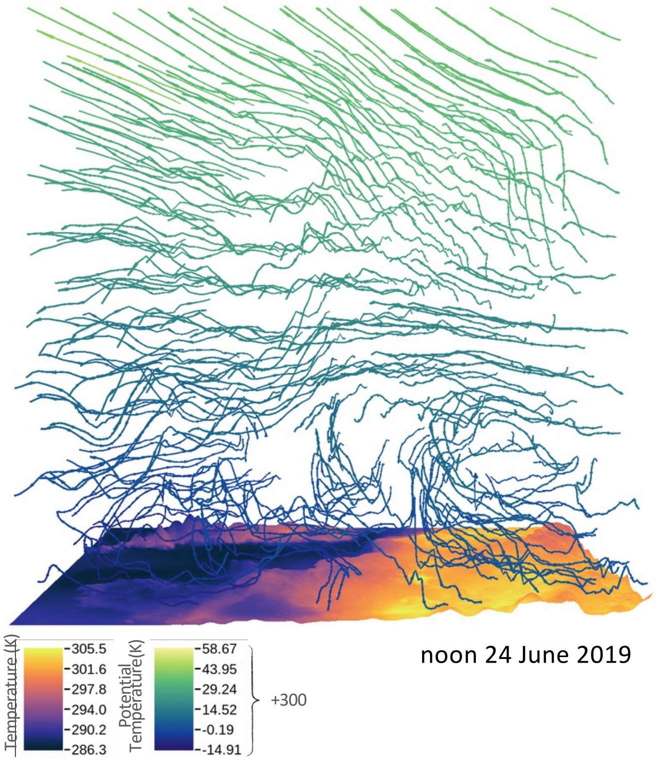


Time period between 24-28 June 2019

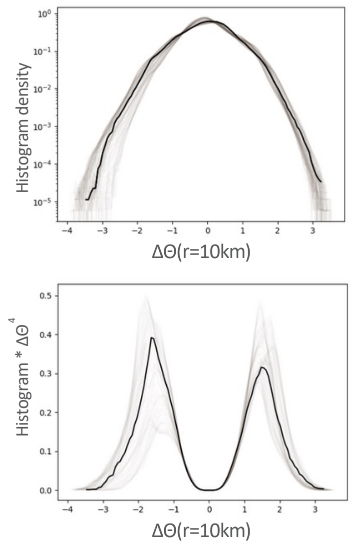
Evolution of the temperature at a level 2m above ground level



Results: Potential temperature spread.

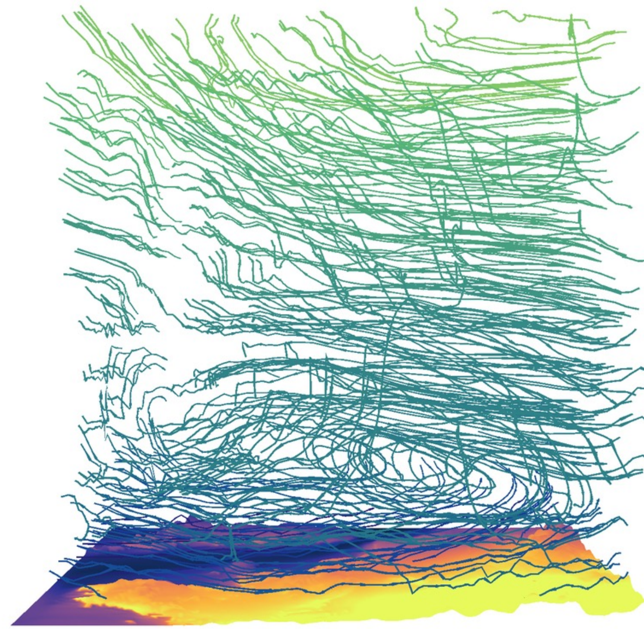


PDFs of potential temperature increment in the PBL

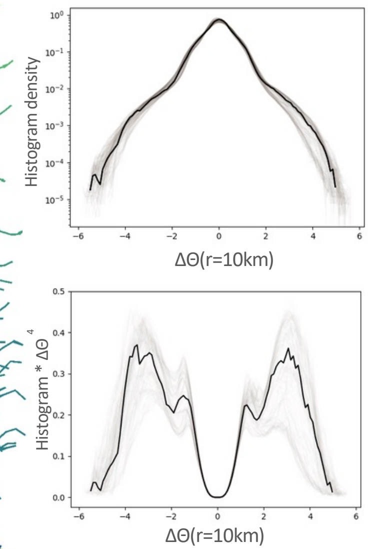


Kurtosis 3.31 ± 0.19

noon 24 June 2019



PDFs of potential temperature increment in the PBL



Kurtosis 6.10 ± 0.34

noon 27 June 2019

Visualization & Analysis Systems Technologies. (2023) Visualization and Analysis Platform for Ocean, Atmosphere, and Solar Researchers (VAPOR version 3.8.0) [Software]. Boulder, CO: UCAR/NCAR - Computational and Information System Lab. doi:10.5281/zenodo.7779648

Turbulent behaviour across layers leads to mixing of scalars like potential temperature extending the tails of increment PDFs, corresponding to more extreme events.