4.2

Lecture 4.2, Consequences of scale invariance [2]

* Temperature scales differently than passive scalars (tracers) and differently to wind speed.

* The intermittency of T is correlated with $J[O_3]$ - what does it imply?

* Example: what does the scaling of T imply for stratospheric water?

* Temperature implies a relevance to climate - what has scaling to say?

ATMOSPHERIC TEMPERATURE

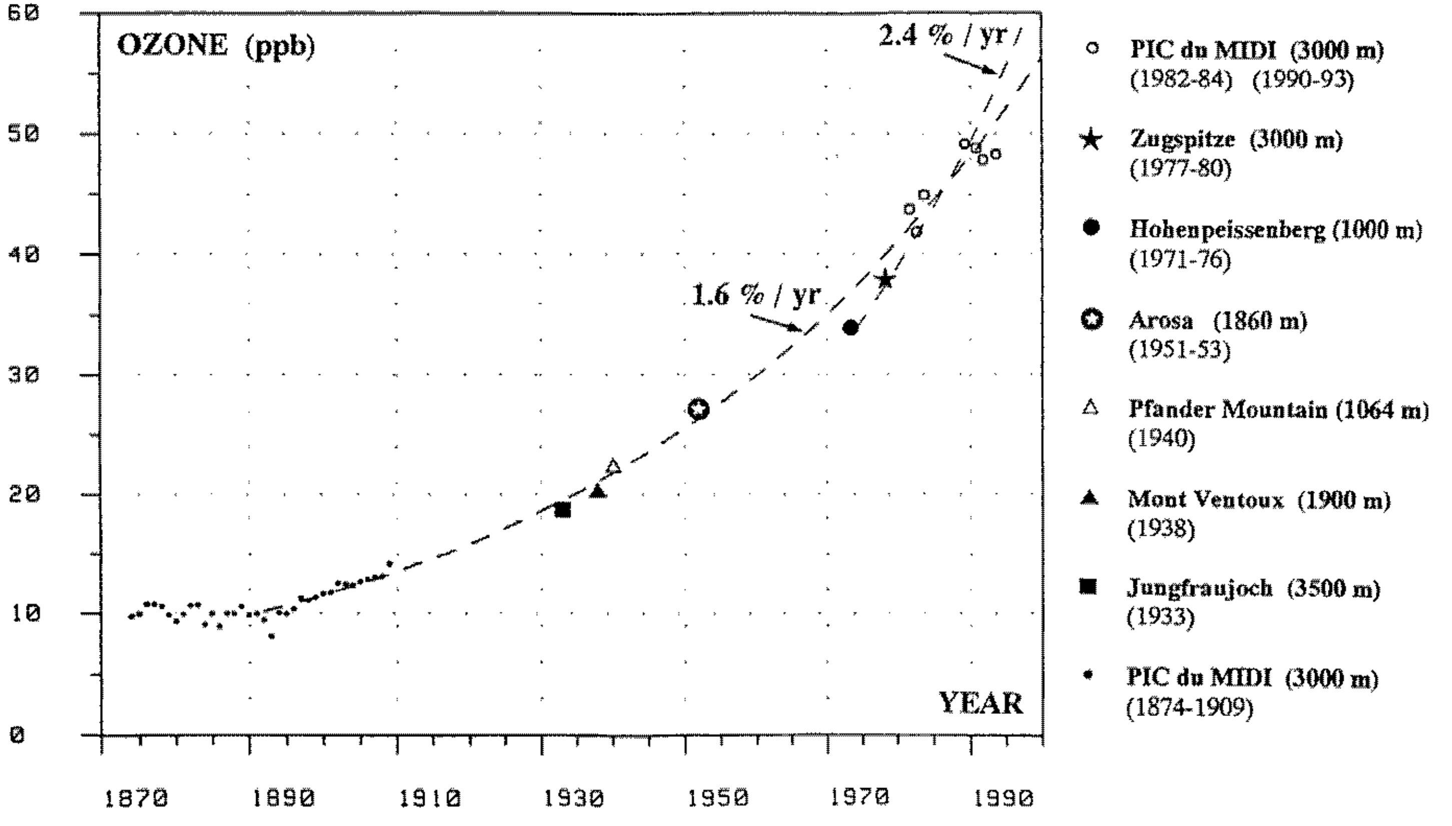
* Intermittency of T is correlated with O_3 photodissociation rate.***
* Horizontally, $H_1(T) = 0.52 \pm 0.02$
* Vertically, $H_1(T) = 0.986 \pm 0.002$

***Will the same thermometer be measuring the same average over molecular speeds in the troposphere and stratosphere? At the surface now as 100 years ago, when the ozone was a factor of 2 to 5 less?

T is well defined operationally, but the implied fat-tailed molecular speed distributions will have consequences (no LTE) for radiation, turbulence and chemistry. T may not be proportional to mean square most probable velocity of air molecules; are molecular and macroscopic T consistent?

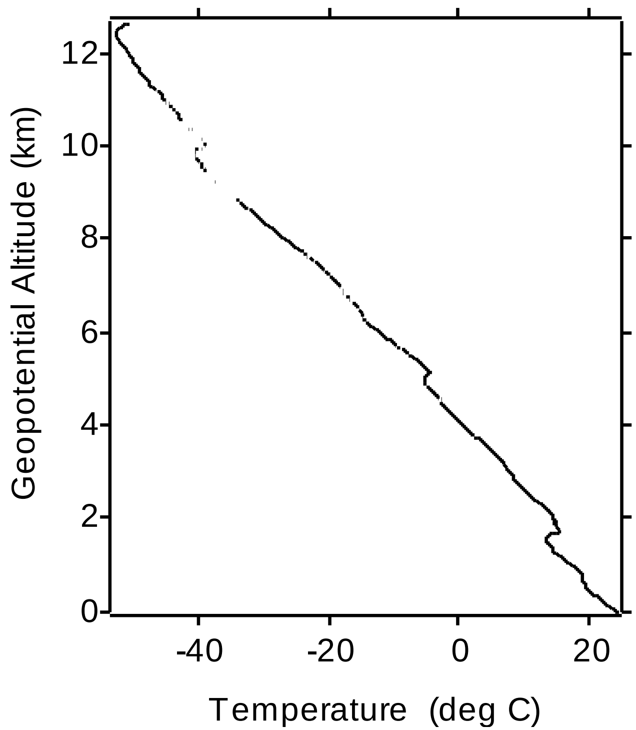
Heat flux and the hydrostatic relation are central. Generalized Scale Invariance has linkages at smallest and largest scales.

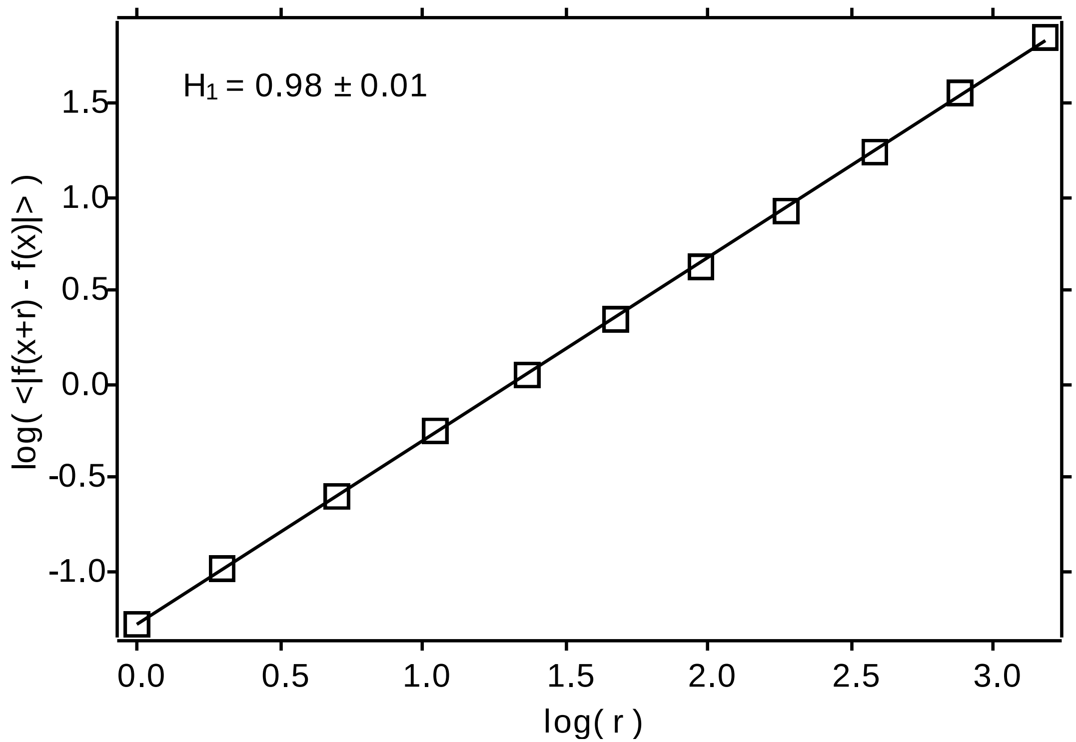
Historical montane surface site observations of ozone:
Marenco et al. (1994),*JGR, 99,* 16617-16632.



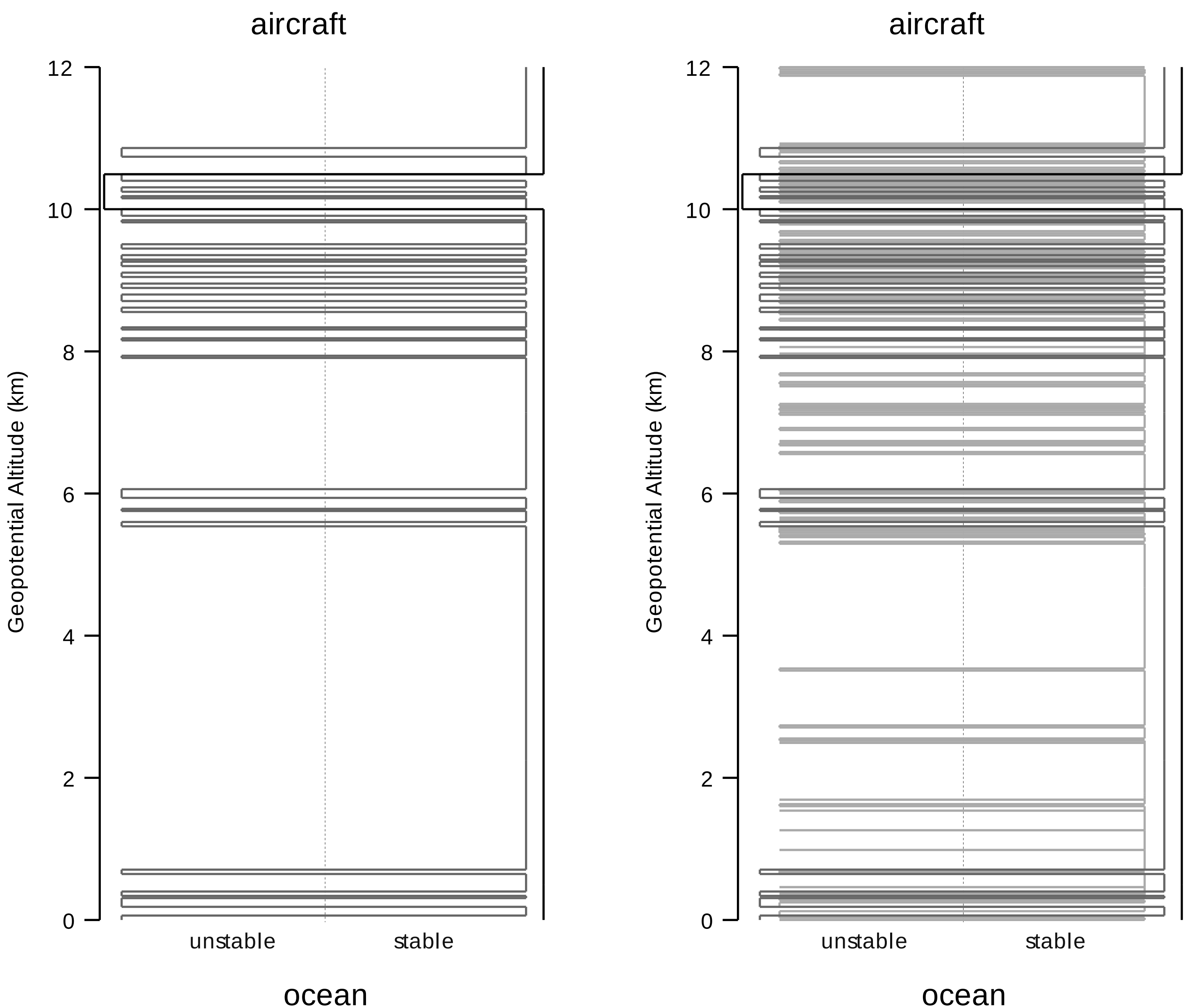
If $J[O_3]$ is correlated with T and $C_1[T]$, what does this mean?

Dropsonde from NOAA G4: (15˚N, 166˚W), 20040304
Temperature & its *H* scaling exponent

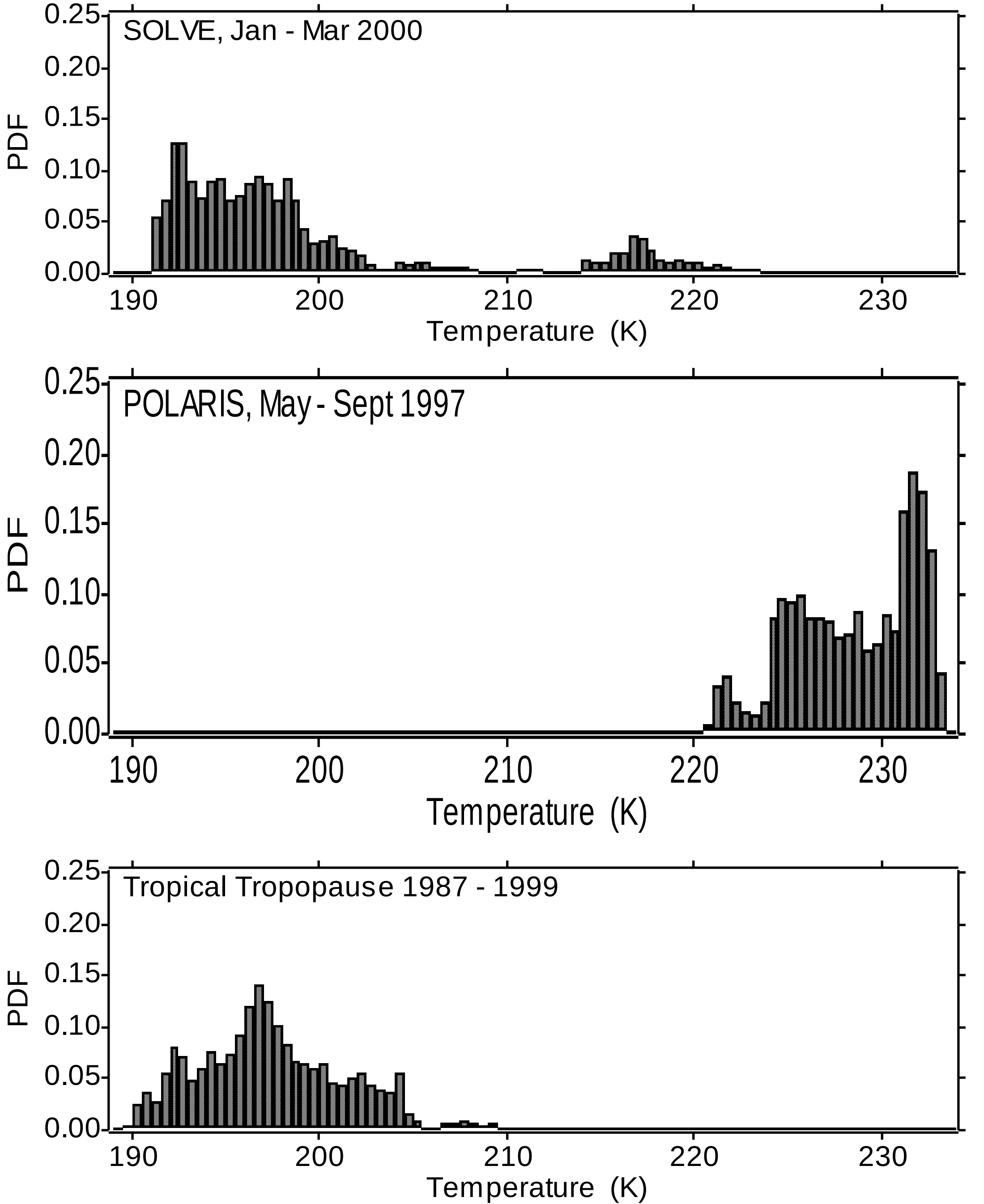




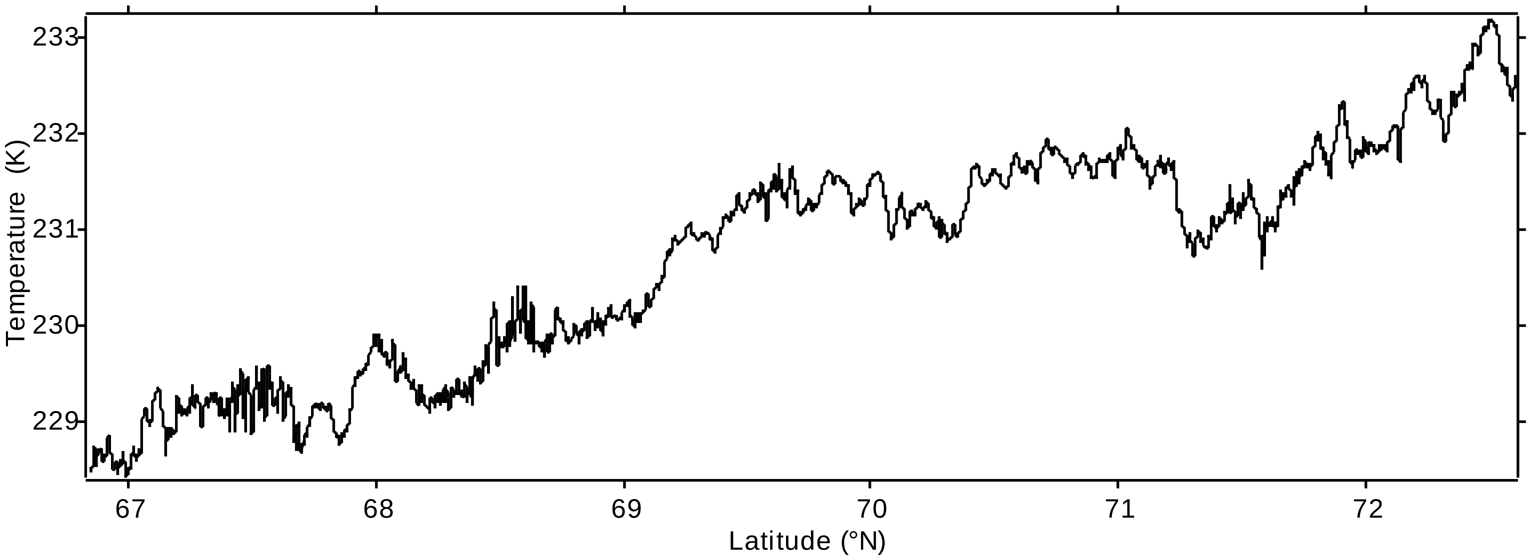
Dynamical stability [Ri>0.25] at 500 & 150 m(left),50 & 10 m(right) Dropsonde (25˚N,157˚W) on 20040229. The 'Russian doll' structure.

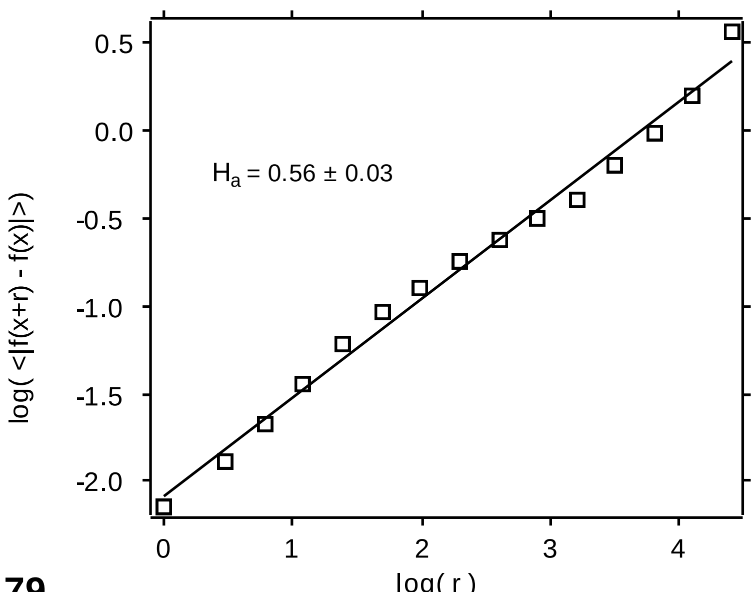


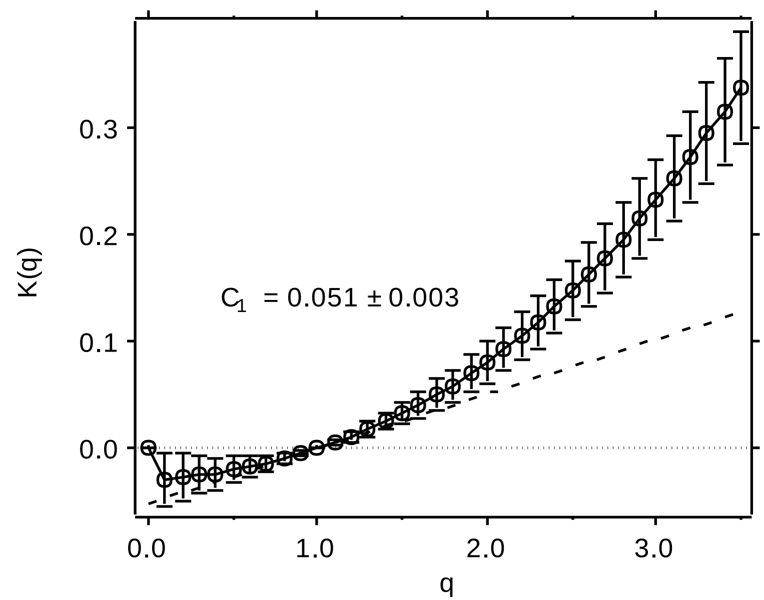
Long-tailed PDFs of temperature, Arctic winter & summer, trop. trop.



Scaling & intermittency of temperature, ER-2, Arctic, 19970506

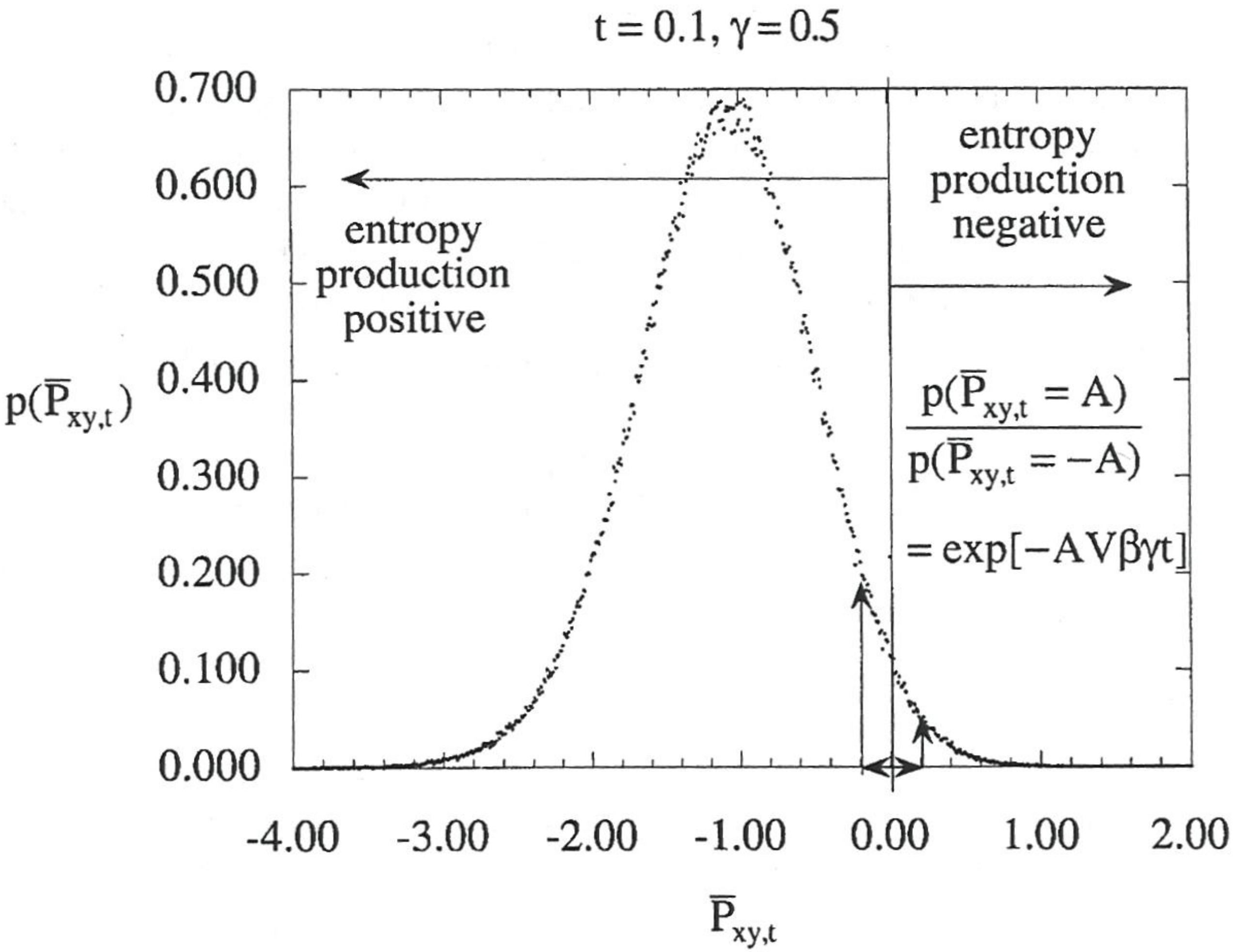




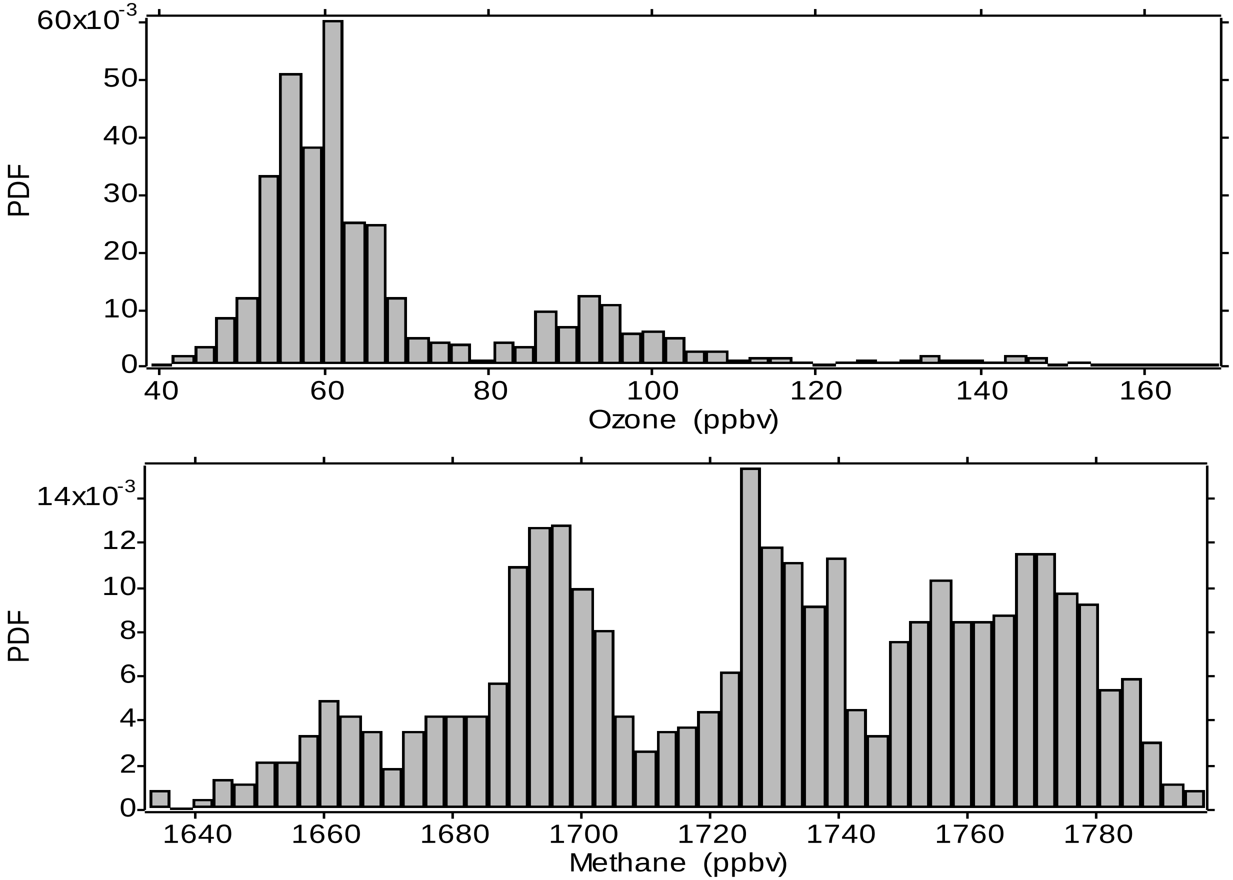


Evans & Searles (2002), *Adv. Phys., 51,*1529-1585. The high speed molecules, a minority, produce order ('flow') while the average majority produce dissipation ('temperature').

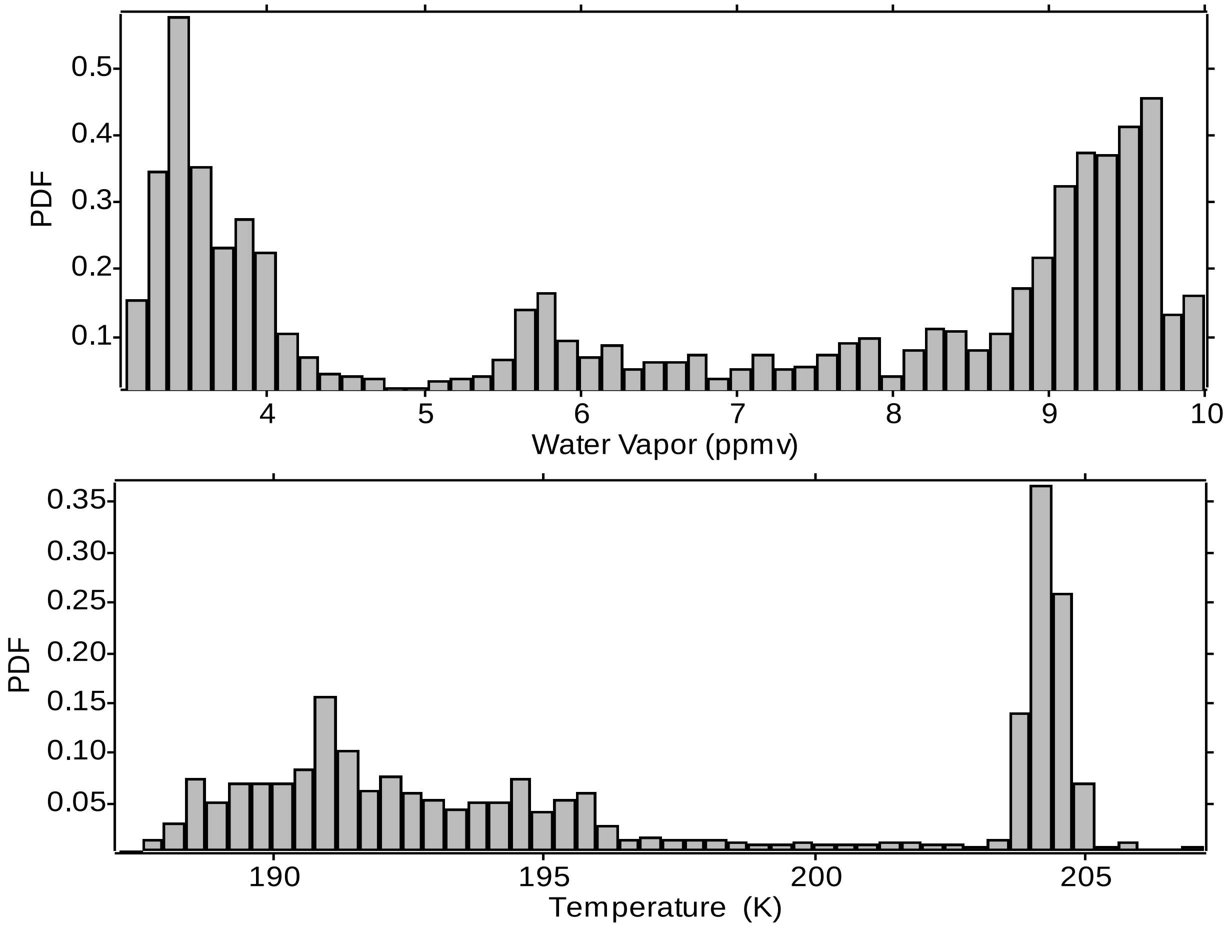
The Fluctuation Theorem



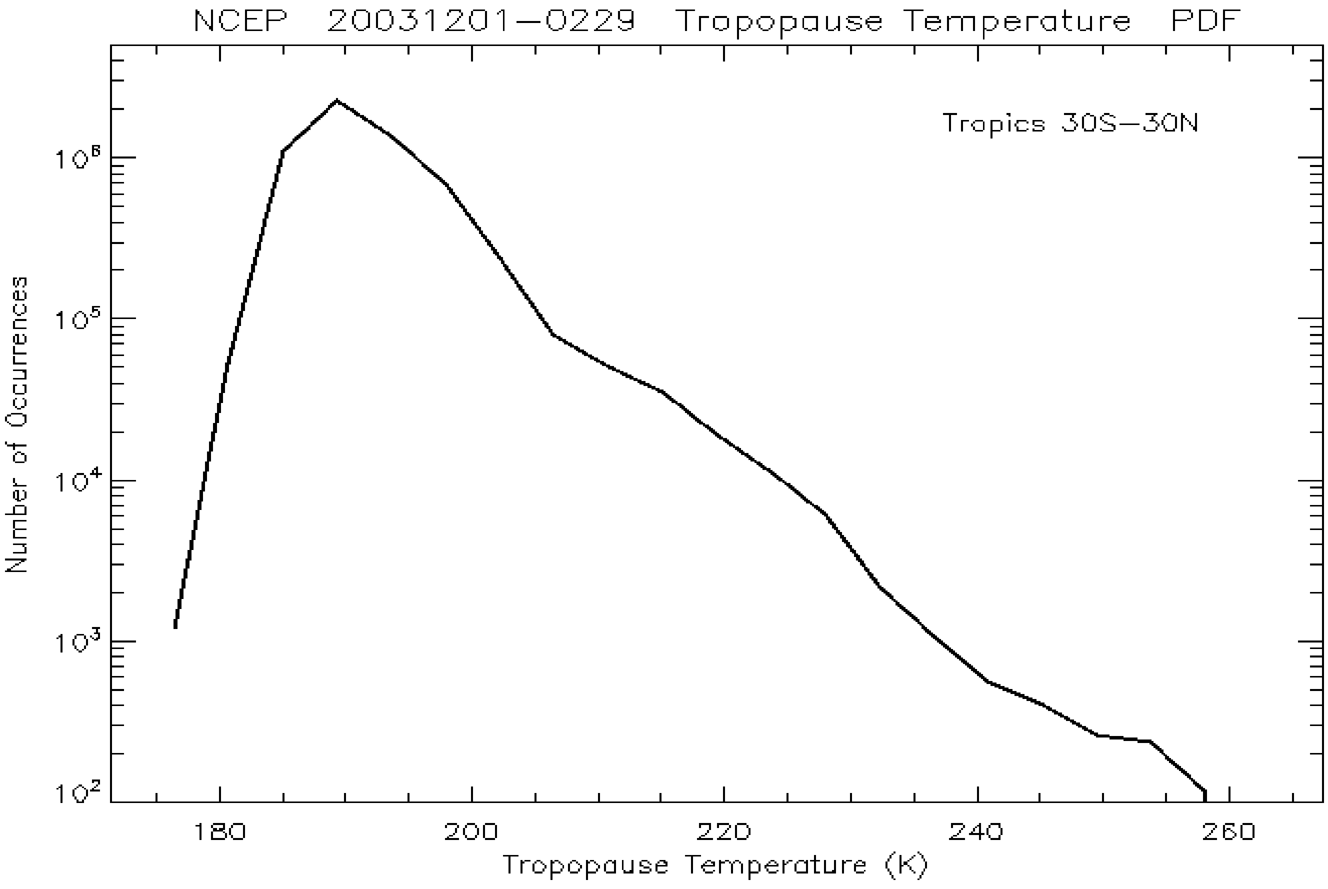
PDFs of O_3 and CH_4 from WB57F flights at (10° N, 84° W) Jan - Feb 2004, for H_2O vapour ≤ 10 ppmv



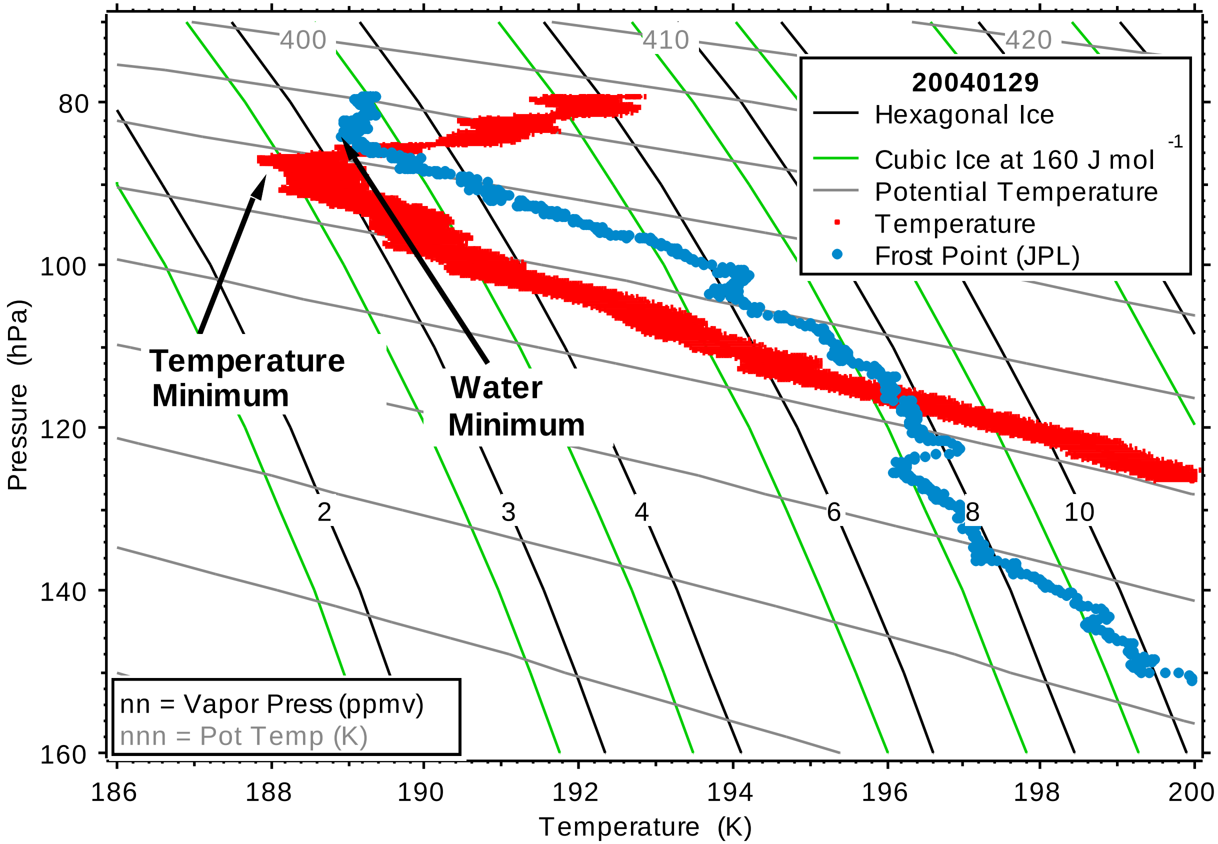
Water vapour and *T*, $H_2O \leq 10$ ppmv, WB57F, (10° N, 84° W), Jan - Feb 2004



PDF of tropopause temperatures, NCEP Analysis, 30° N to 30° S, 20031201 to 20040229 UTC.

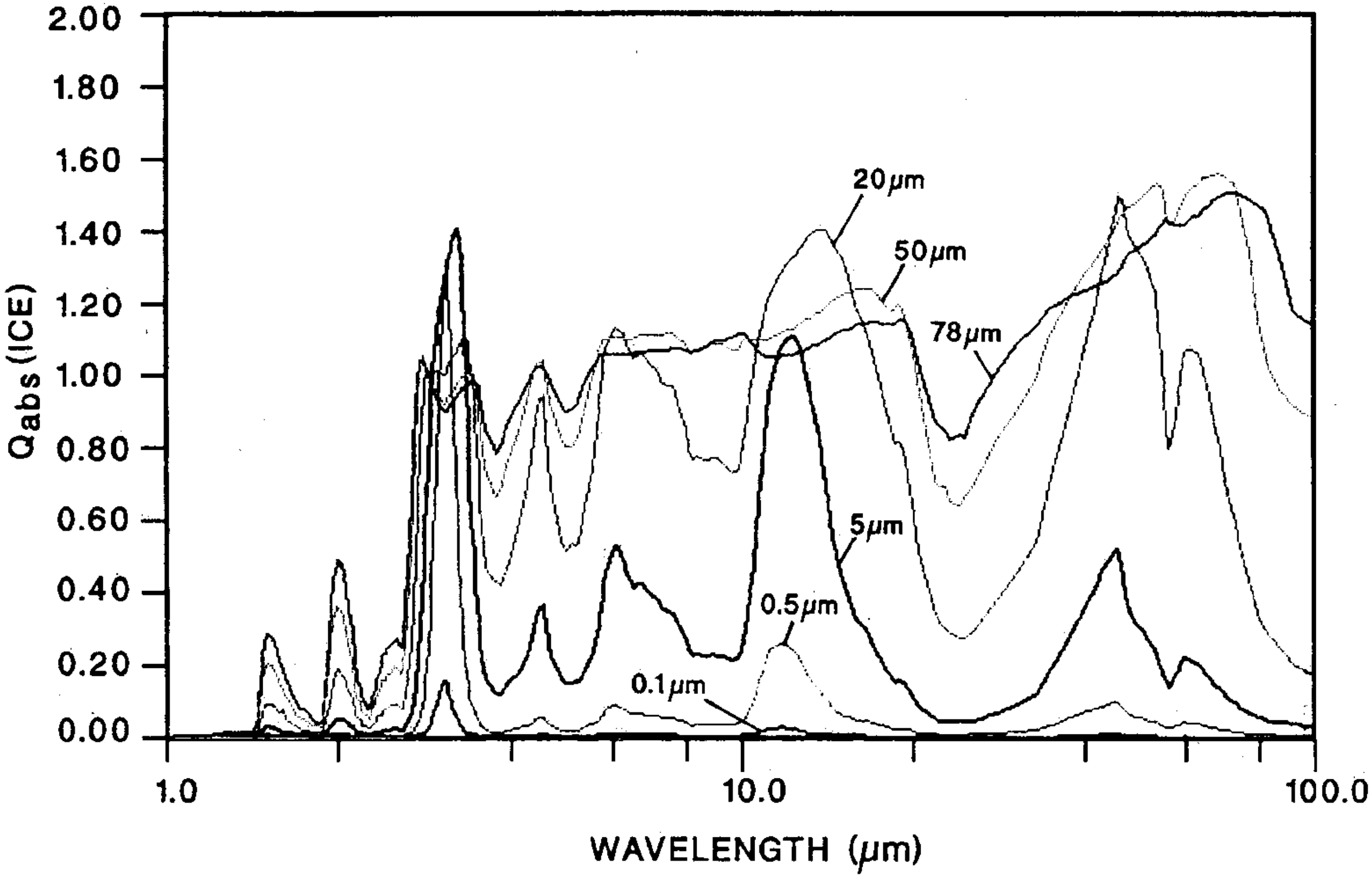


A Mechanism for Dehydration in the Upper Atmosphere



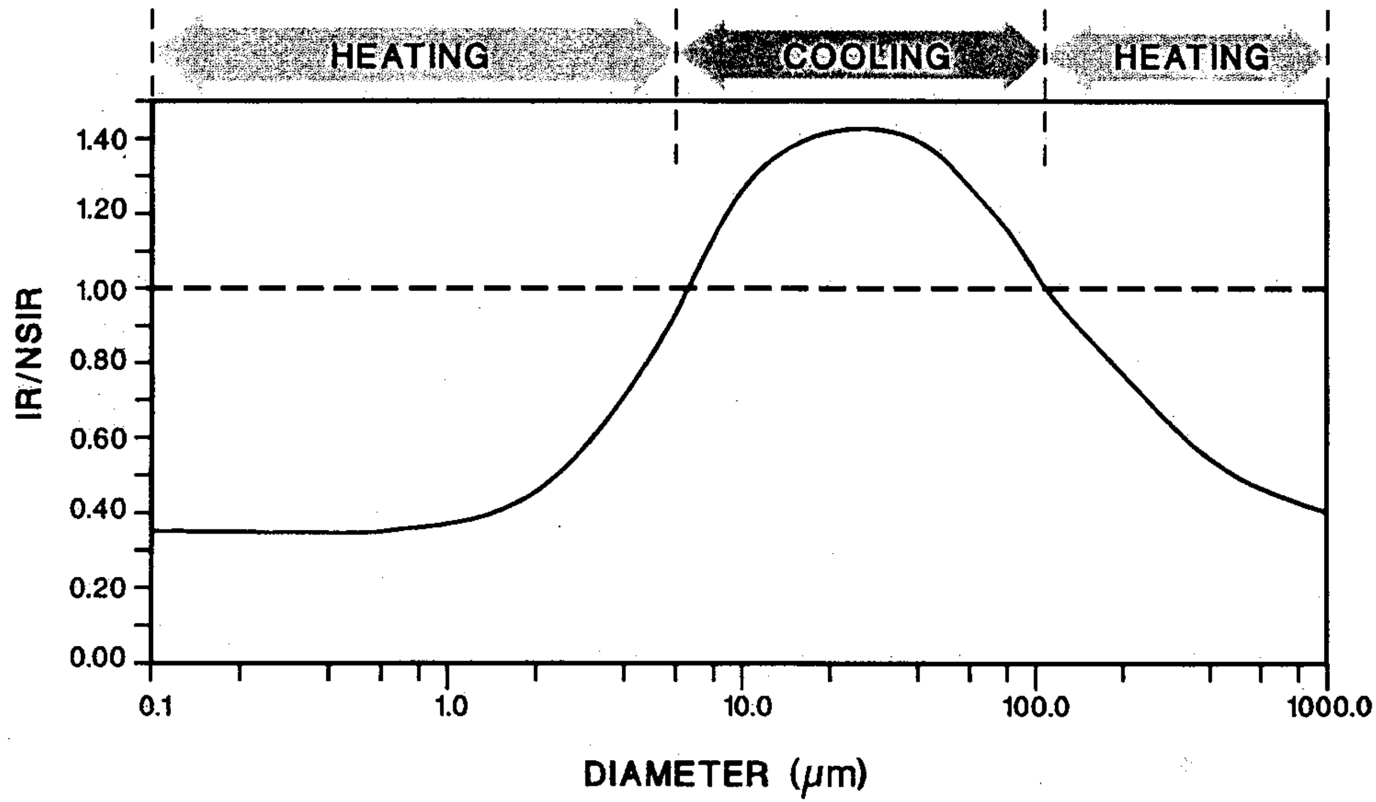
An example showing that over tropical Central America in January 2004 the water vapor minimum was 200-300 metres above an underlying saturated or apparently supersaturated layer; this was the case on every profile. Small ice particles evaporated, and the resulting water vapour condensed on larger particles, leaving a vapour minimum above a saturated layer. This mechanism can account for the final stage in the dehydration of air entering the stratosphere.

Absorption efficiency factor for ice spheres, spectral dependence

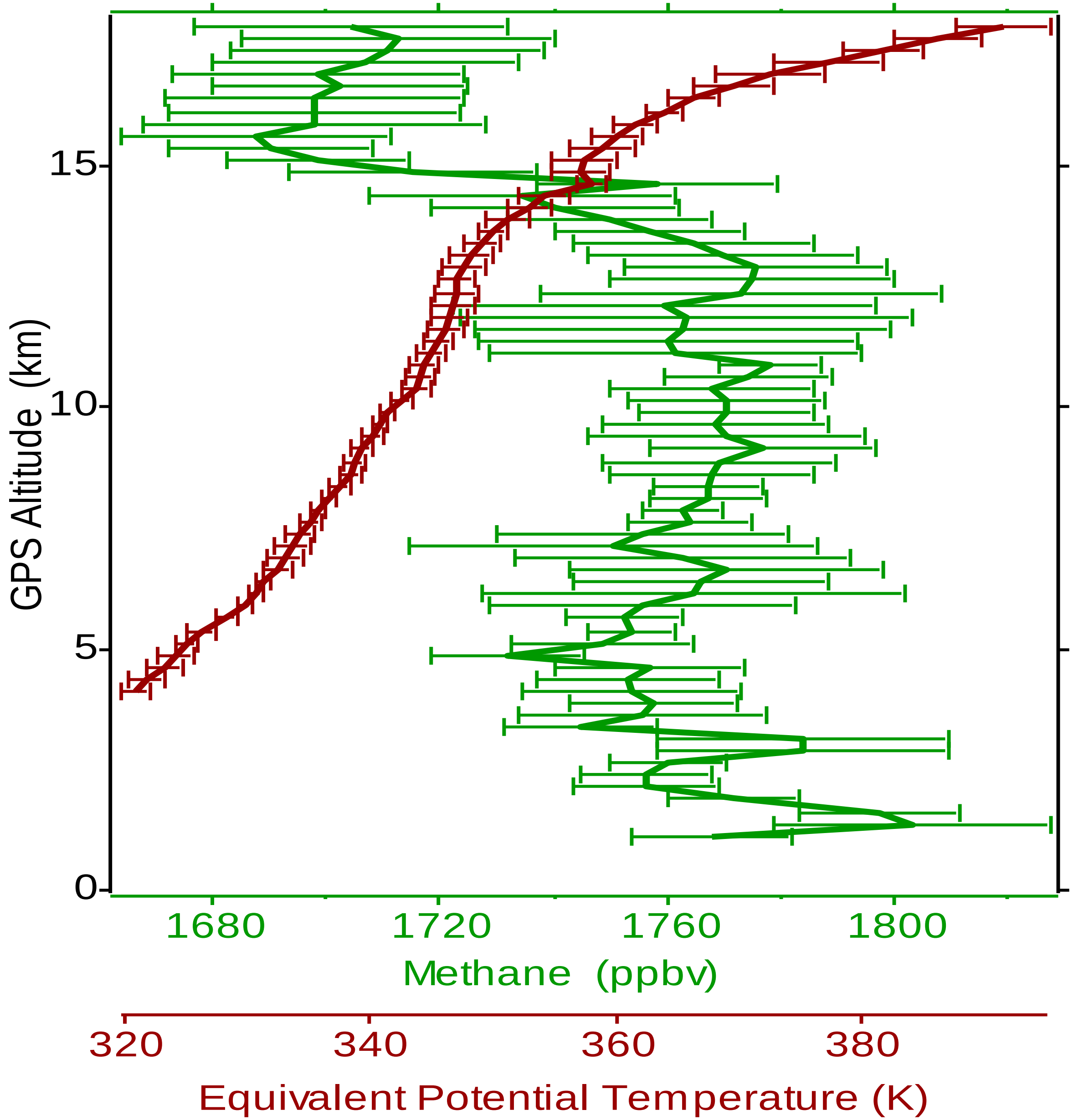


Radiative heating/cooling as a function of particle size, cloud top, 190 K, 0° solar zenith angle

* The small ones absorb and evaporate quickly, the water molecules distilling over to the 10 - 100 micron particles. Accounts for the observed water vapour profiles.



Mean profiles of CH_4 and θ, WB57F, (10° N, 84° W, Jan - Feb 2004



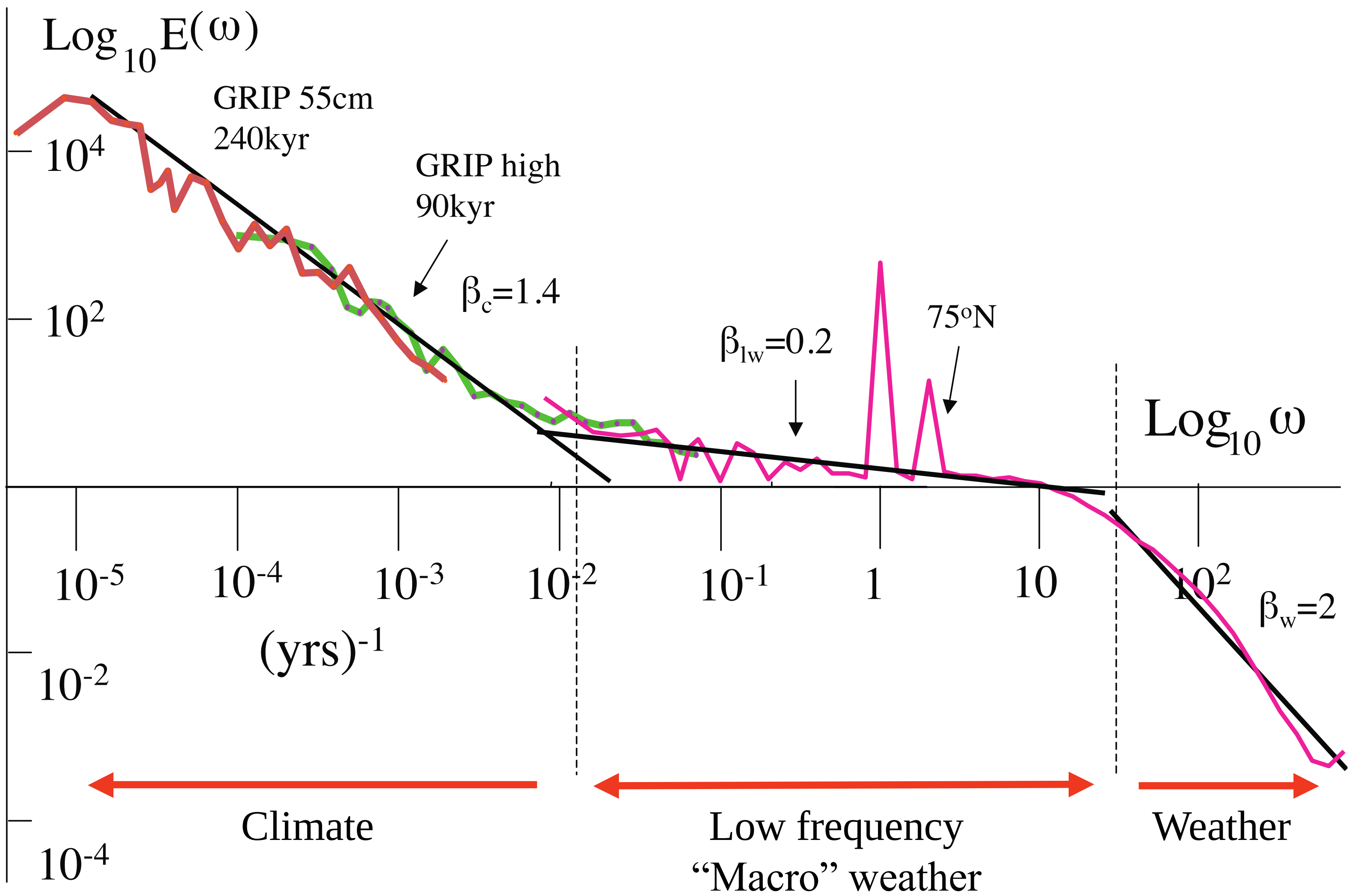
Stratospheric water and scaling at the tropical tropopause

* The lowest water mixing ratios are attained in the lower stratosphere, via distillation of water molecules from small ice particles on to larger ones, which fall under gravity.

* This air is recirculated into the upper troposphere, where the lower methane and water content have influence on climate via their infra-red spectra. There will be ***no one-to-mapping*** of tropopause temperature to stratospheric water content, the PDFs of T and H_2O have long tails from their scale invariance.

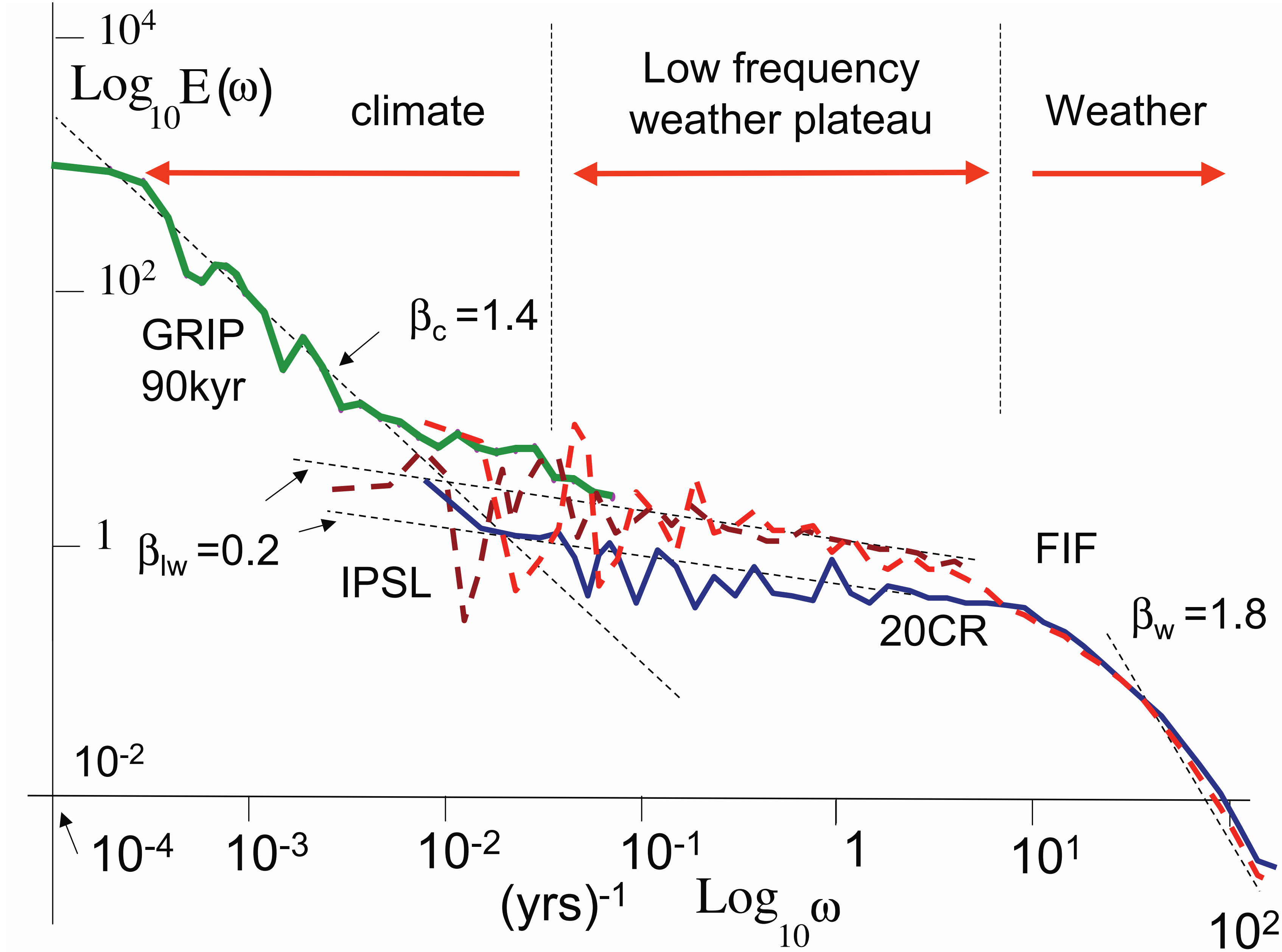
* The methane variability and back trajectories below 12 km indicate a methane source over northern South America [jungle? petroleum industry?].

Transition from ‘weather’ to ‘climate’ in scaling régimes, Lovejoy & Schertzer book. Composite Greenland ice core data.

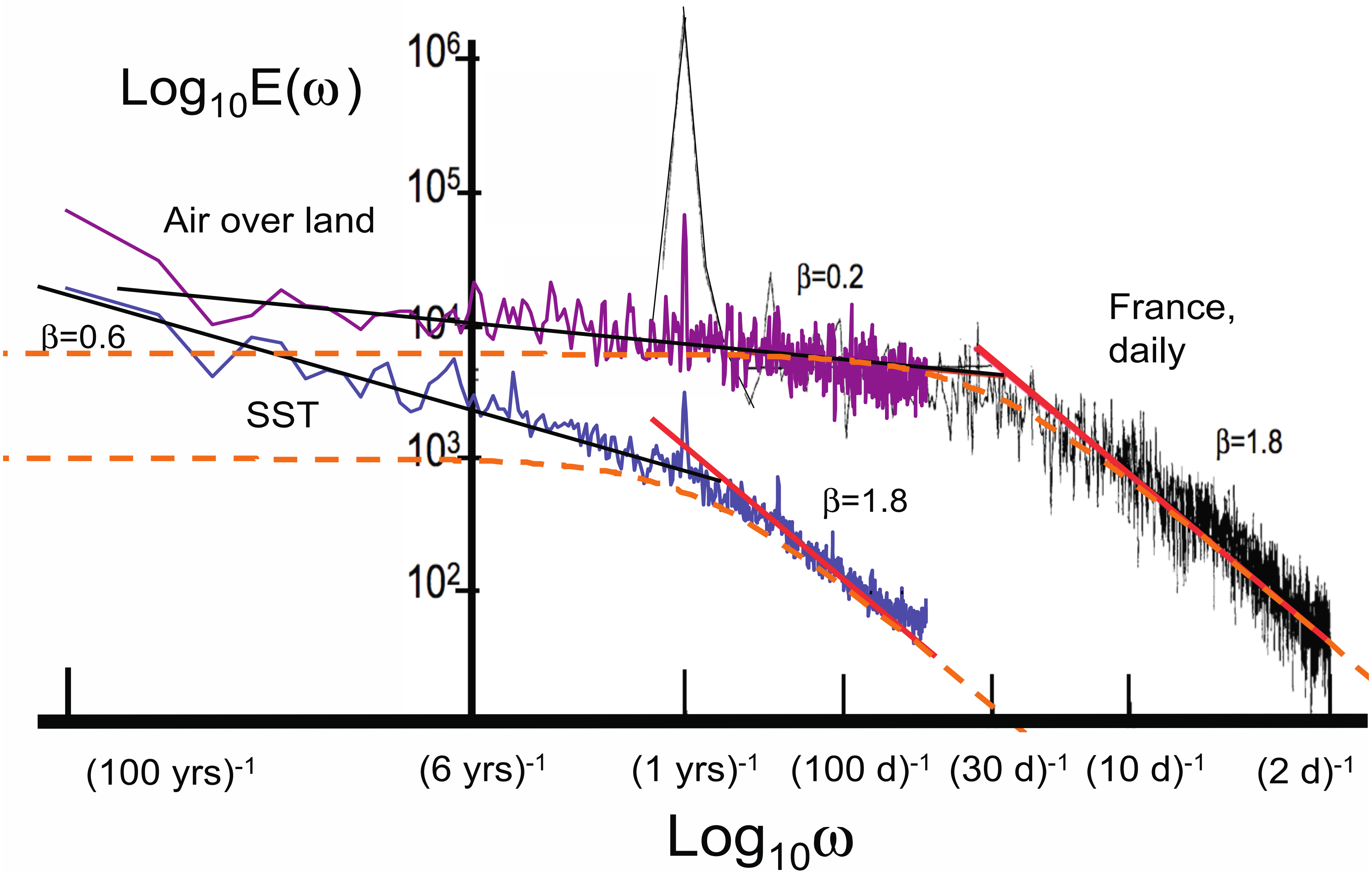


Slide 189

Greenland ice core (GRIP & 20CR) compared to GCM (IPSL)



Transition region: atmosphere(upper) and ocean (lower) compared.



Lecture 4.2, Consequences [2]: Summary

THEORY: Nonlinear interaction among high speed molecules subject to an anisotropy sustains vortices and the overpopulation of fast molecules in the PDF - fluid flow emerges from the Maxwellian 'billiard balls'. Temperature remains defined but is not the mean of the Maxwell-Boltzmann distribution. The high speed molecules produce larger scale order (negative entropy), the ones near the mean are responsible for dissipation (positive entropy).

EVIDENCE: Correlation of H_1(windspeed) with horizontal and vertical measures of jet stream strength. Correlation of temperature intermittency with ozone photodissociation rate.

Jet stream speeds reach Mach 0.7 - half the speed of the most probable speed of N_2 molecules.

* Natural definition of 'weather' and 'climate' appears to emerge from generalized scale invariance analysis of Greenland ice core data, with a transition region between about 10 days and 10 - 100 years mediated by the ocean. *[Lovejoy & Schertzer, 2012]*