Climate Changes: Past & Future (Ch 16) – continued

"Climategate" – Following the theft of data and emails from CRU** in 2009, a number of inquiries and reviews have been completed.

* "the scientific reputation of Professor Jones and CRU remains intact" (*House of Commons Science and Technology Committee*)

* "we saw no evidence of any deliberate scientific malpractice in any of the work of the Climatic Research Unit" (*Lord Oxburgh Science Assessment Panel*)

* "their rigour and honesty as scientists are not in doubt" (*Sir Muir Russell Independent Climate Change Emails Review*)

* "careful examination of the e-mails and their full context shows that the petitioners' claims are exaggerated and are not a material or reliable basis to question the validity and credibility of the body of [climate] science" (*US Environmental Protection Agency*)

**Climate Research Unit of U. East Anglia

Edmonton City Centre Airport
Past 24 Hour Conditions

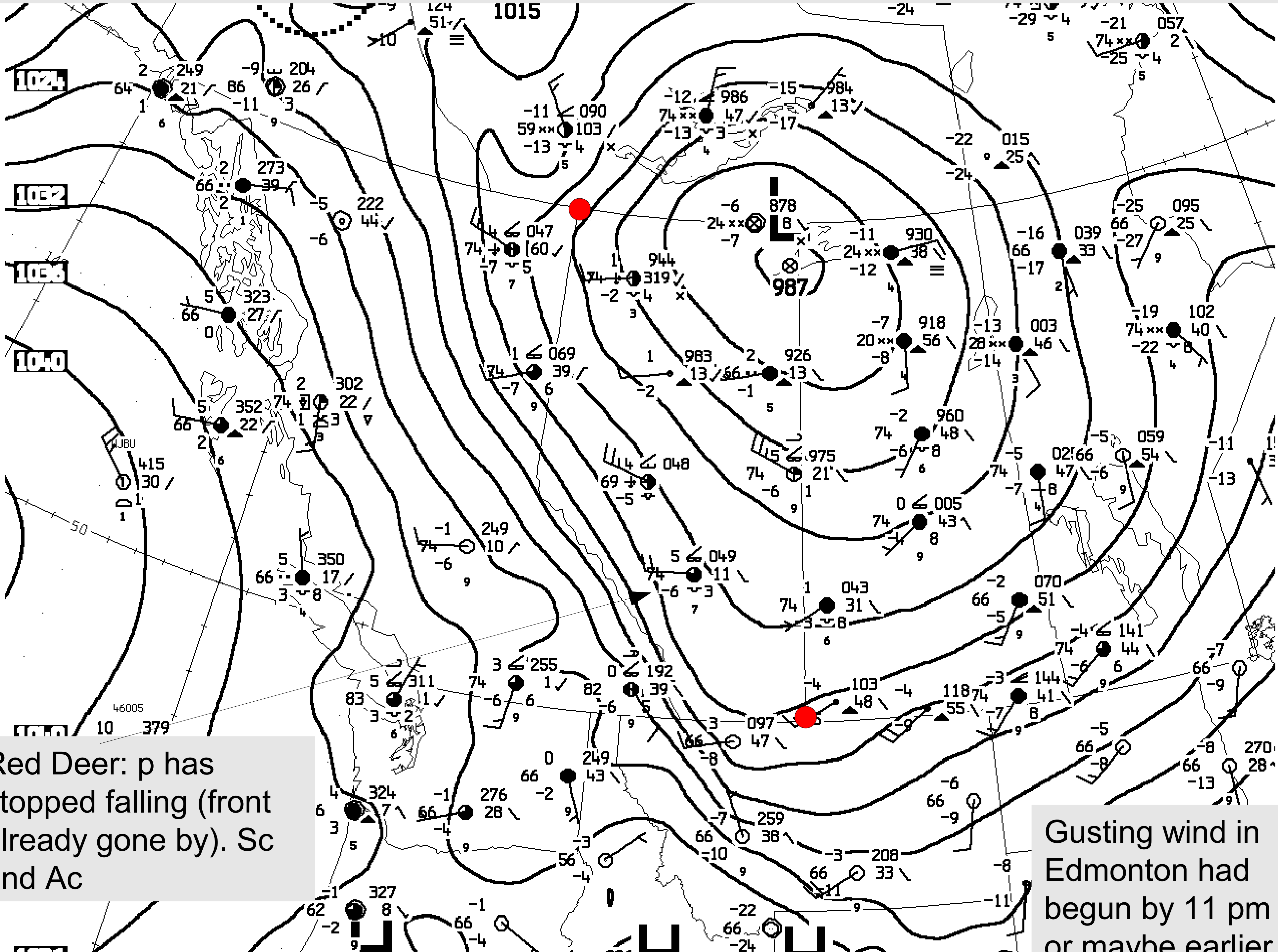
Imperial Units

Date / Time (MST)	Conditions	Temp (°C)	Humidity (%)	Dew Point (°C)	Wind (km/h)	Pressure (kPa)
2 December 2011						
9:00	Light Snow	1	64	-5	NW 35 gust 61	101.0
8:00	Light Snow	1	57	-6	WNW 45	100.8
7:00	Light Snow	1	59	-6	WNW 48 gust 67	100.8
6:00	Light Snow	1	61	-6	WNW 42 gust 63	100.6
5:00	Light Snow	1	59	-6	WNW 46 gust 65	100.6
4:00	Light Snow	2	51	-8	WNW 32 gust 48	100.6
3:00	Light Snow	2	54	-7	WNW 48 gust 63	100.6
2:00	Light Snow	2	51	-7	WNW 37 gust 55	100.5
1:00	Light Snow	3	45	-8	WNW 32 gust 52	100.4
00:00	Light Snow	4	42	-8	WNW 45 gust 54	100.3
1 December 2011						
23:00	Light Drizzle	6	40	-7	WNW 30 gust 54	100.2
22:00	Cloudy	4	54	-4	W 15	100.2
21:00	Cloudy	5	52	-4	W 17	100.3
20:00	Cloudy	4	58	-3	WSW 13	100.4
19:00	Cloudy	3	62	-3	W 5	100.5
18:00	Cloudy	4	61	-3	SSW 11	100.6
17:00	Mostly Cloudy	3	63	-3	SW 8	100.8
16:00	Cloudy	4	63	-3	SSW 11	101.0

Cold Frontal Passage

- pressure falling then rising
- pressure rising after onset of gusts
- wind shifting from SSW to WNW
- onset of light precip
- sudden 3^{o}C drop in T, subsequent rate of cooling not at all dramatic

MSC preliminary surface analysis 06Z Fri 2 Dec. 2011 (11 pm MST Thurs.)

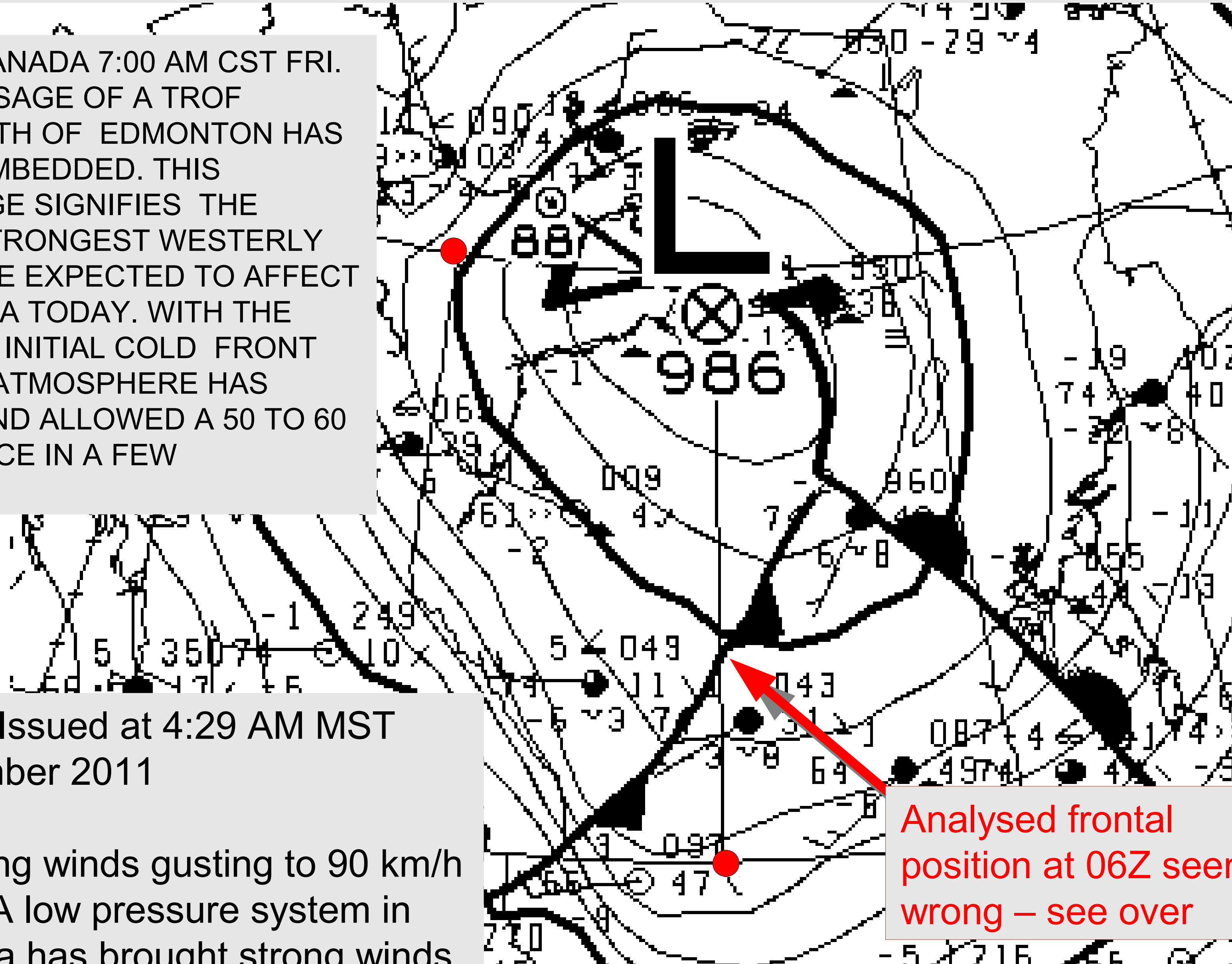


Red Deer: p has stopped falling (front already gone by). Sc and Ac

Gusting wind in Edmonton had begun by 11 pm or maybe earlier

MSC complete surface analysis 06Z Fri 2 Dec. 2011 (11 pm MST Thurs.)

ENVIRONMENT CANADA 7:00 AM CST FRI. DEC. 2 2011. PASSAGE OF A TROF CURRENTLY NORTH OF EDMONTON HAS A COLD FRONT EMBEDDED. THIS FRONTAL PASSAGE SIGNIFIES THE ONSET OF THE STRONGEST WESTERLY WINDS WHICH ARE EXPECTED TO AFFECT MUCH OF ALBERTA TODAY. WITH THE PASSAGE OF THE INITIAL COLD FRONT OVERNIGHT THE ATMOSPHERE HAS DESTABALIZED AND ALLOWED A 50 TO 60 KT JET TO SURFACE IN A FEW LOCALITIES.



Analysed frontal position at 06Z seems wrong – see over

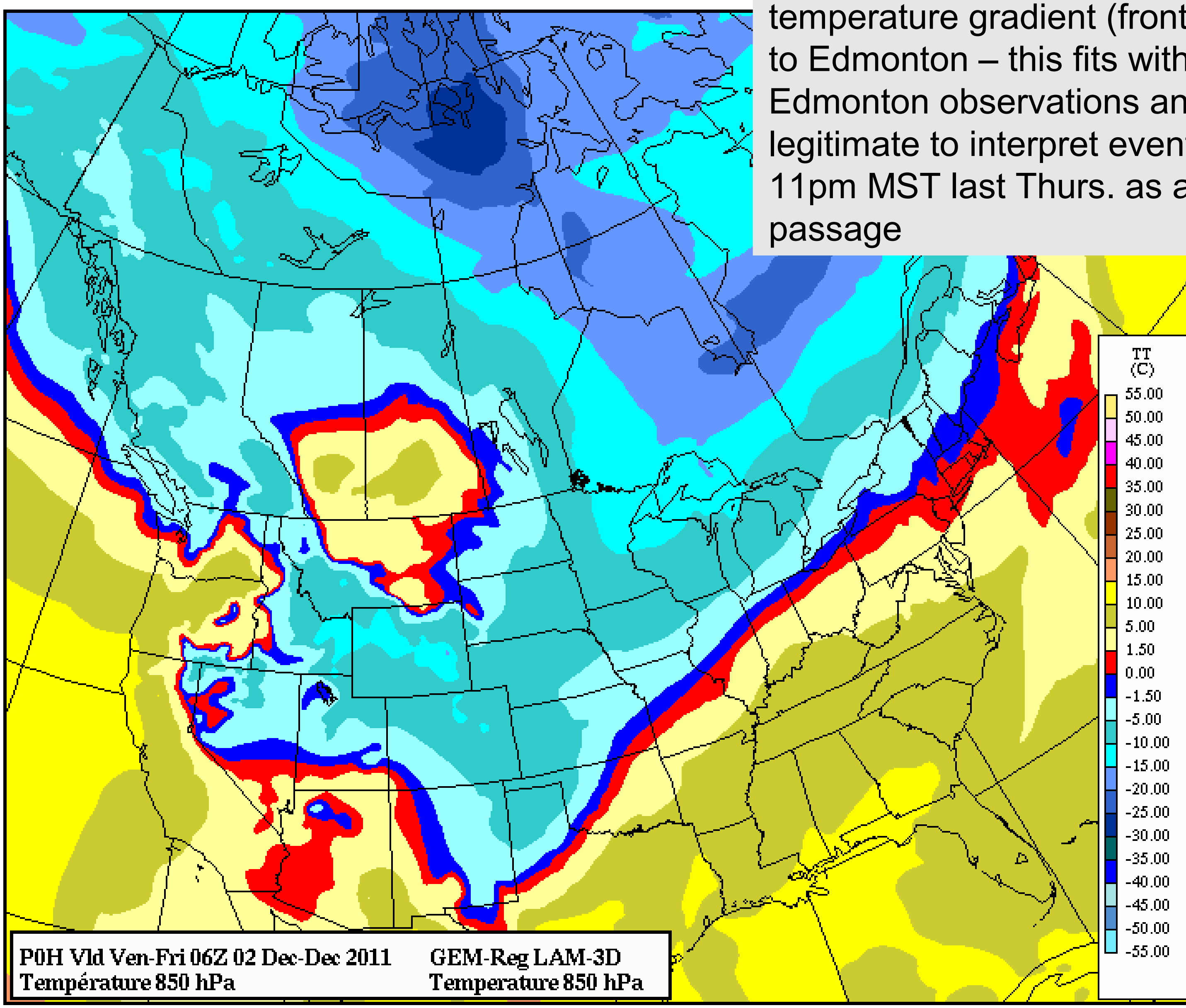
Wind Warning. Issued at 4:29 AM MST Friday 2 December 2011

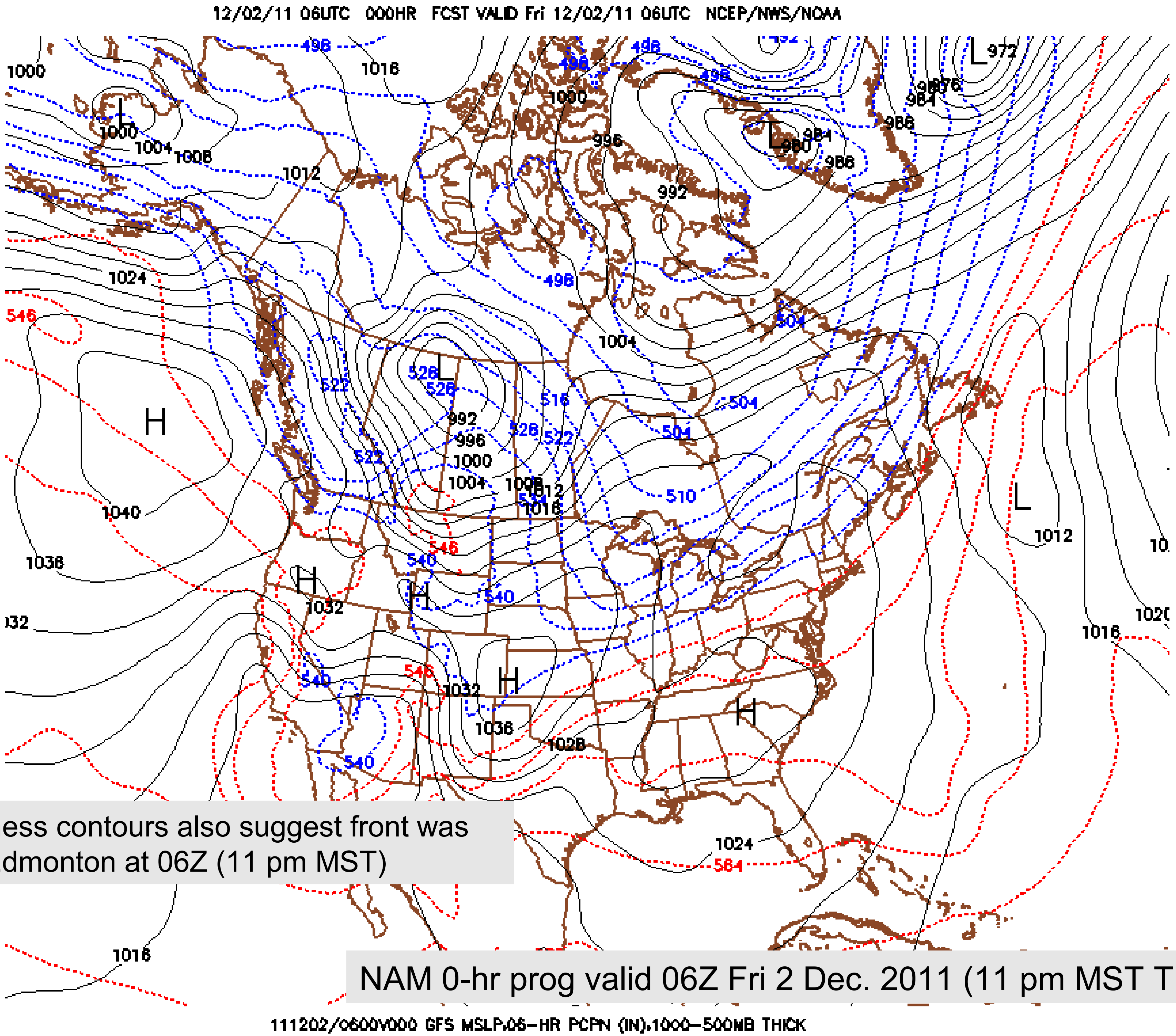
Summary: Strong winds gusting to 90 km/h today. Details: A low pressure system in Northern Alberta has brought strong winds to Central Alberta. Winds over 90 km/h have been reported overnight in the Slave Lake and Spruce Grove areas and are expected to continue today.

Our most blustery frontal passage yet this fall/winter? Plenty of wind; rate of cooling not so noticeable. Events suggest front was at Edmonton between 05 and 06Z

GEM 0-hr prog T_{850} valid 06Z Fri 2 Dec. 2011 (11 pm MST Thurs.)

Notice that a strong horizontal temperature gradient (front) is very close to Edmonton – this fits with the Edmonton observations and makes it legitimate to interpret events around 10-11pm MST last Thurs. as a frontal passage

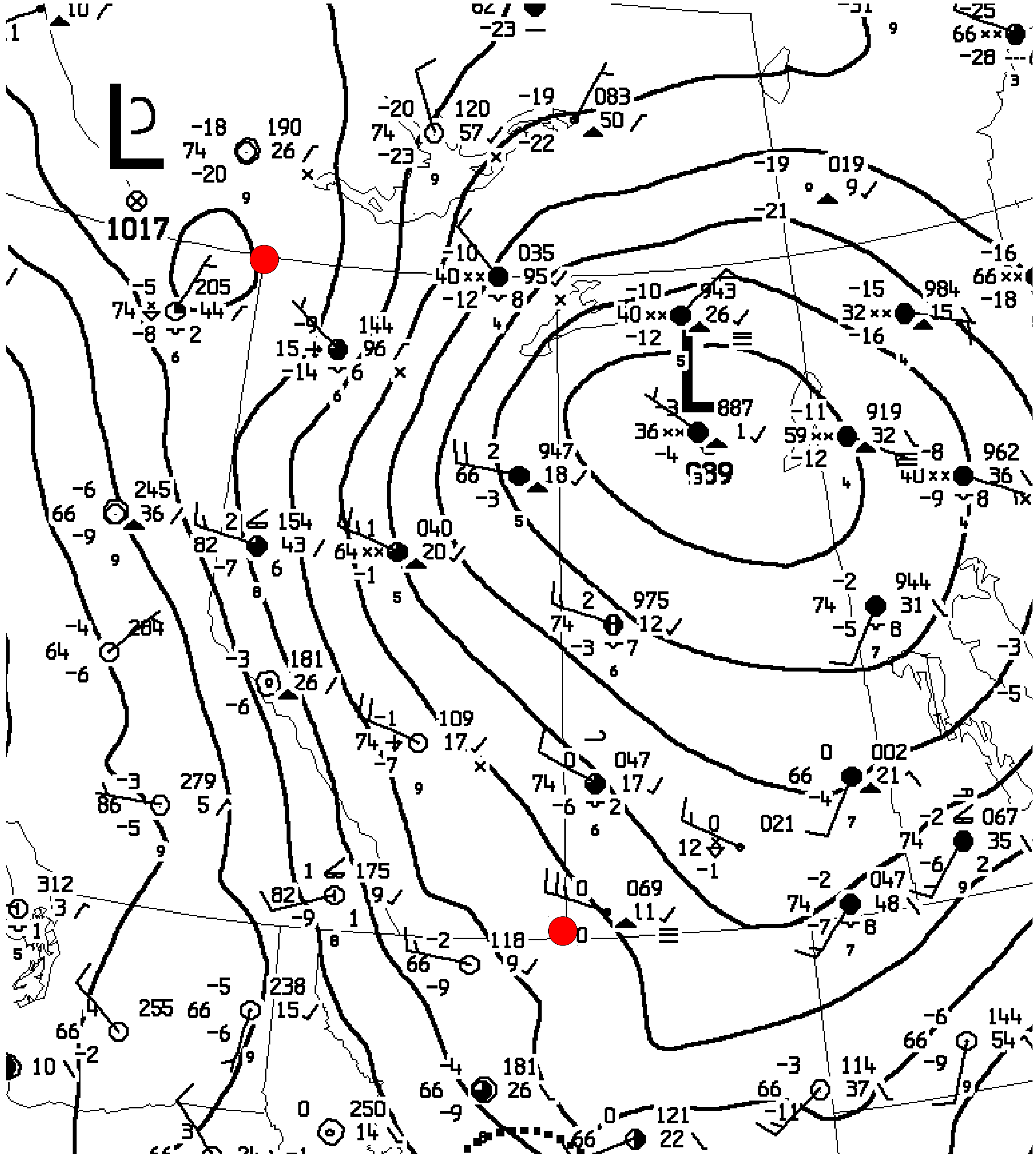




Thickness contours also suggest front was near Edmonton at 06Z (11 pm MST)

NAM 0-hr prog valid 06Z Fri 2 Dec. 2011 (11 pm MST Thurs.)

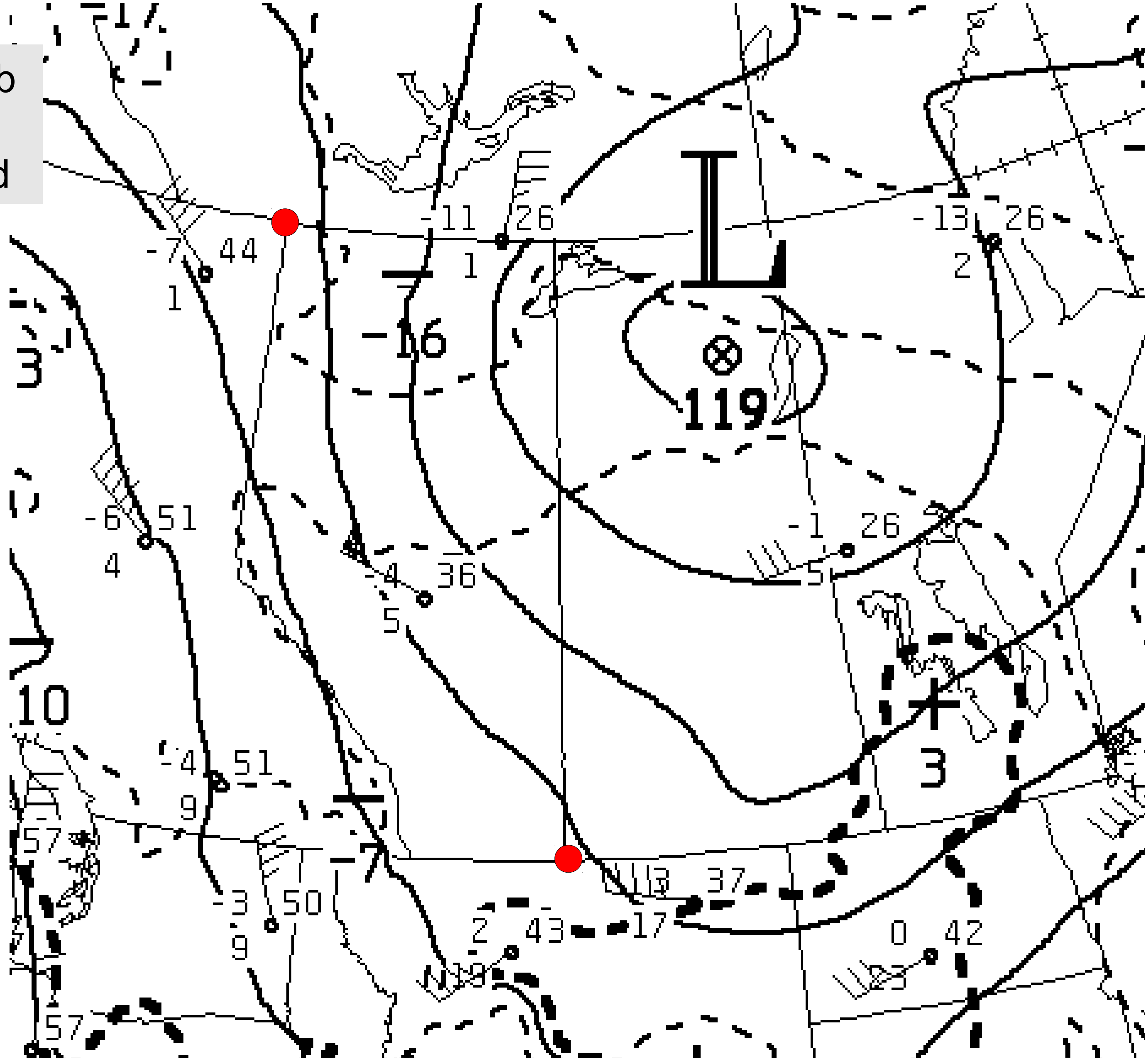
MSC preliminary surface analysis 12Z Fri 2 Dec. 2011 (5 am MST Fri.)



MSC 850 hPa analysis 12Z Fri 2 Dec. 2011 (5 am MST Fri.)

- cold advection over C. Ab

- very strong 850 hPa wind



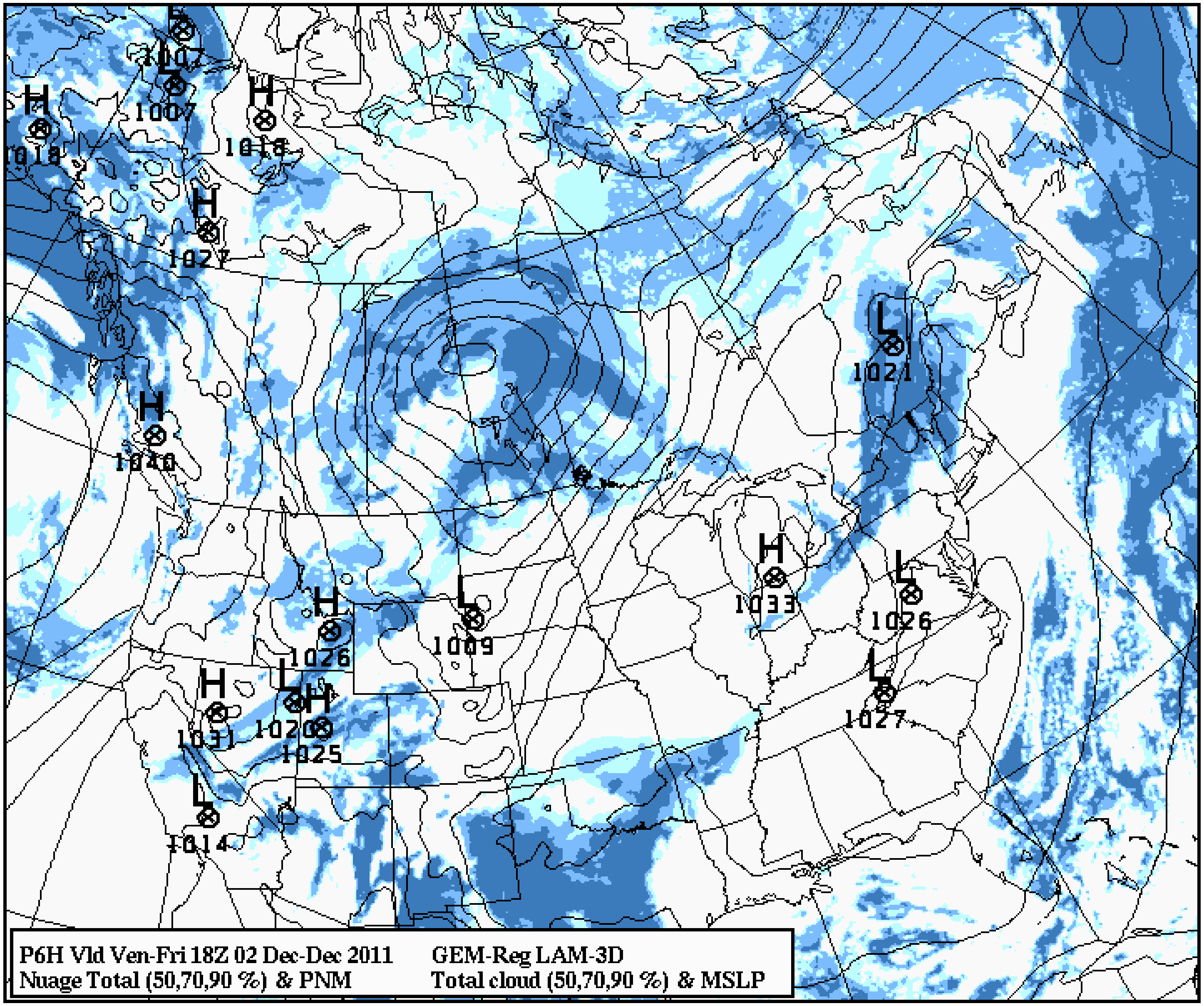
- sun through broken Sc by late morning (a clearing sky after frontal passage is typical)

- 1118 MST two trees blown down (trunks snapped) between CCIS and Assiniboia Hall

GEM 6-hr prog valid 18Z Fri 2 Dec. 2011 (11 am MST Fri.)

- on campus observe sun through broken Sc by late morning (a clearing sky after frontal passage is typical)

- consistent with GEM's prog for total cloud dropping below 50% sky cover by about 11 am



Global mean temperature in the industrial era

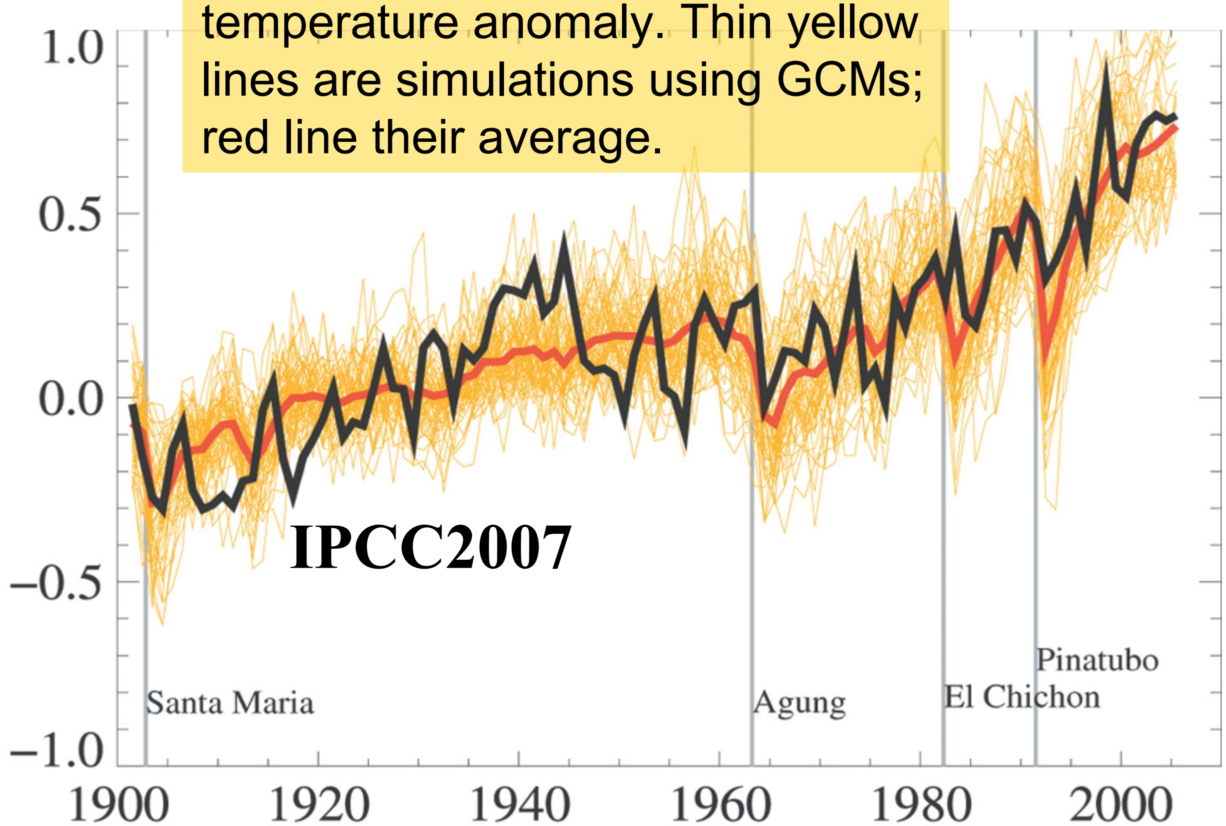
- near surface air temperature taken as the metric, although a far greater quantity of excess heat in the climate system must reside in the oceans (Pielke et al. critique using land sfc temp data as metric)

- thermal inertia of the oceans implies they are slow to equilibrate with short term forcing

- very non-uniform coverage of temperature measurements until 20th century

- care is taken to eliminate biases (e.g. urban heat island)

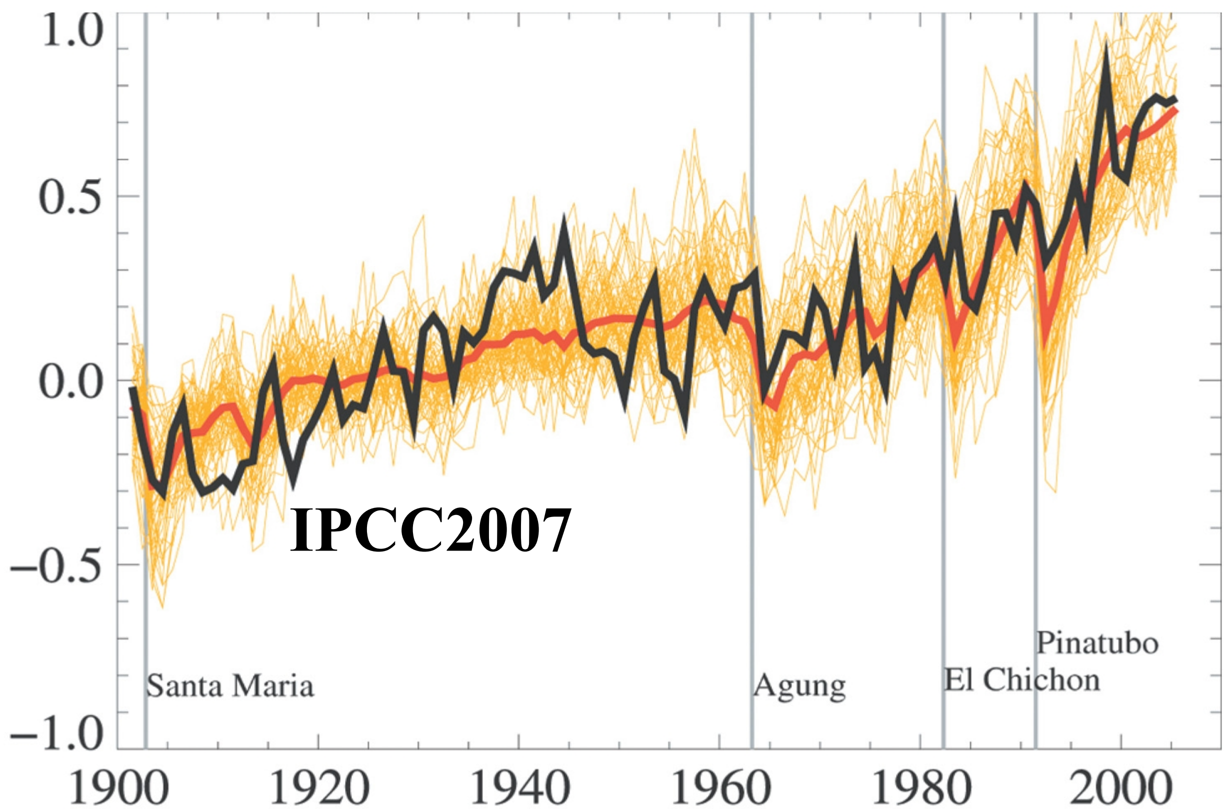
Black line, observed global mean temperature anomaly. Thin yellow lines are simulations using GCMs; red line their average.



Global mean temperature in the industrial era

• Jones et al. (1982): "Our basic data set (for N.H.) was monthly station data originally published by the Smithsonian Institution in various volumes of World Weather Records up to 1960, digitized by the National Center for Atmospheric Research (Jenne, 1975) and updated by NOAA in Monthly Climatic Data for the World (MCDW)"

• "Number of stations ranged from ~300 for the period 1881-1900, to ~1300 during the period 1951-60, subsequently falling to between 800 and 900 for the period 1961-80"



Whether or not it is the best metric of global warming, the record of global mean land surface temperature is not ambiguous

The Economist

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Climate change

The heat is on

A new analysis of the temperature record leaves little room for the doubters. The world is warming

Oct 22nd 2011 | from the print edition   Like 2k   811

This article comments on a new analysis of the terrestrial surface temperature record by a group of “outsiders,” Berkely Earth Surface Temperature group

----

“To build confidence in their methodologies, NASA and NOAA already publish their data and algorithms. Hadley CRU is now doing so...

Berkeley Earth Surface Temperature (group) …

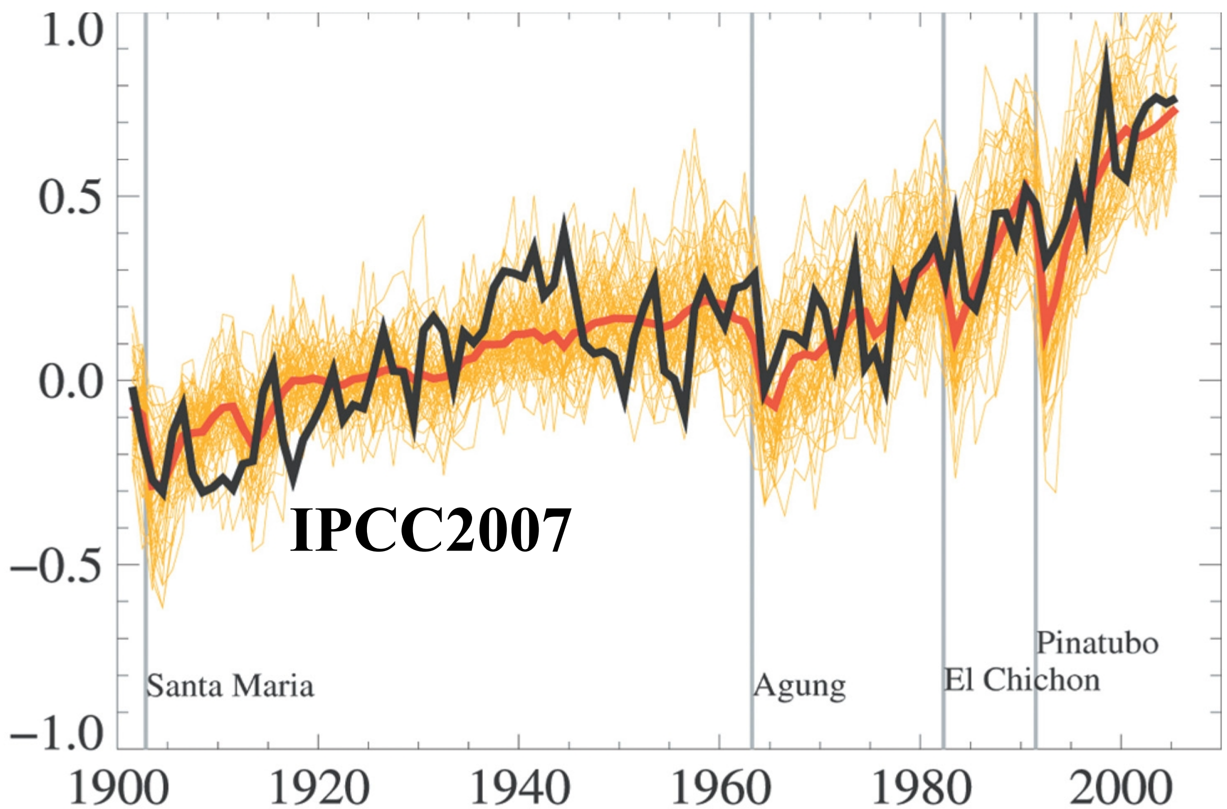
members mostly new to climate science...

(Their) results, as described in four papers currently undergoing peer review, but which were nonetheless released on October 20th, offer strong support to the existing temperature compilations. The group estimates that over the past 50 years the land surface warmed by 0.911°C: a mere 2% less than NOAA’s estimate.”

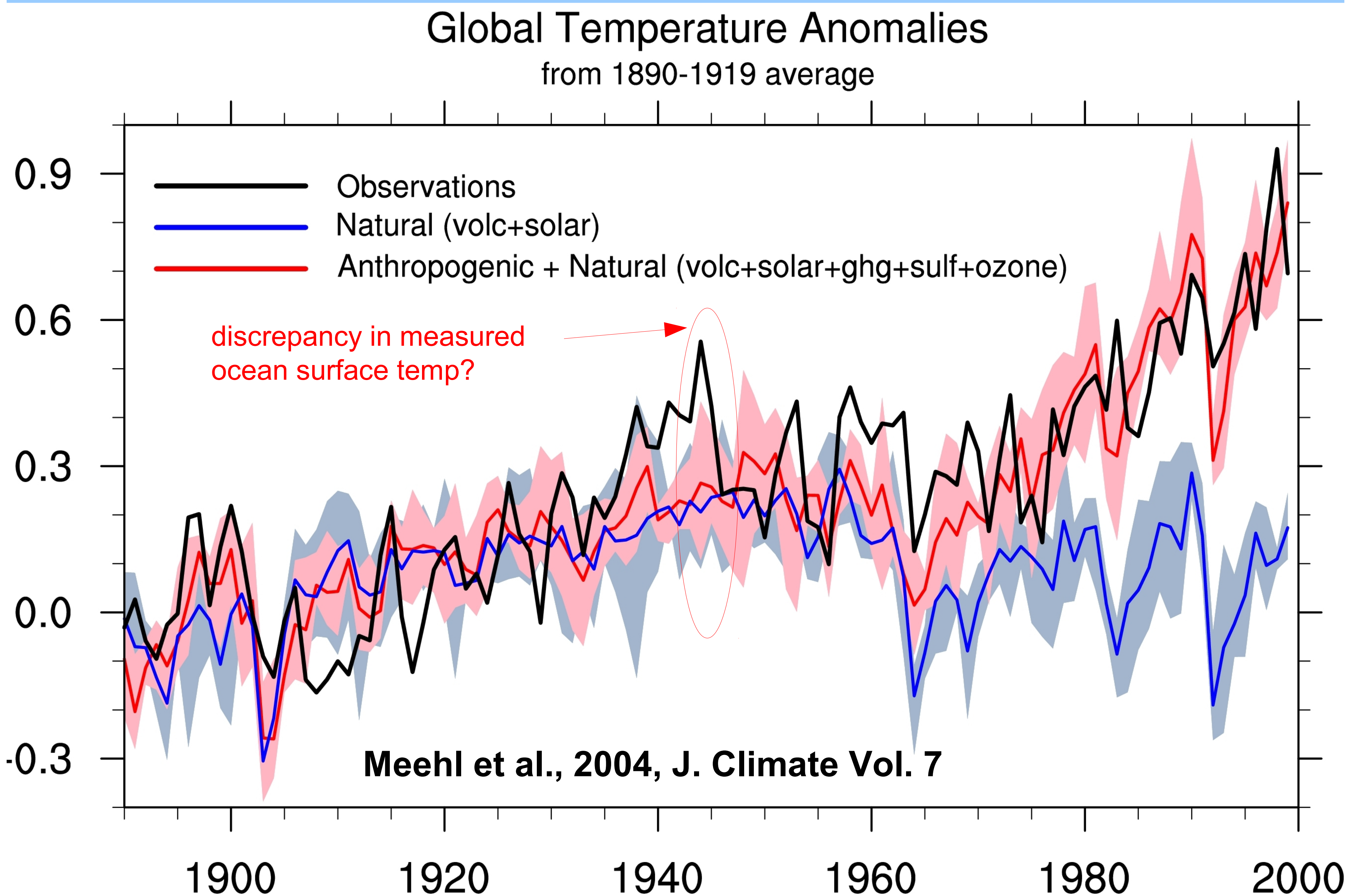
Global mean temperature in the industrial era

• IPCC2007 “Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850)”

The IPCC considered climate predictions from many climate models run independently by many groups – the spaghetti lines in these diagrams. The various models and their performance are documented in the peer-reviewed science literature, e.g. next page:



Global mean temperature in the industrial era



– observed climate versus GCM simulations – proves GHG forcing essential

Global mean temperature in the industrial era

On British ships, crews measured the temperature of seawater collected in a bucket. But since about 1939, most American ships had switched to measuring the temperature of seawater as it was drawn through an intake pipe for use as an engine coolant. Because of heat from the engine room, American measurements were generally higher.

Most of the wartime data came from American ships, with just 20 percent of the readings from British ones. But starting in August 1945, there was an abrupt switch. Nearly half the readings came from British ships. Because those readings are generally colder, Dr. Thompson said, that accounts for the sudden temperature drop.

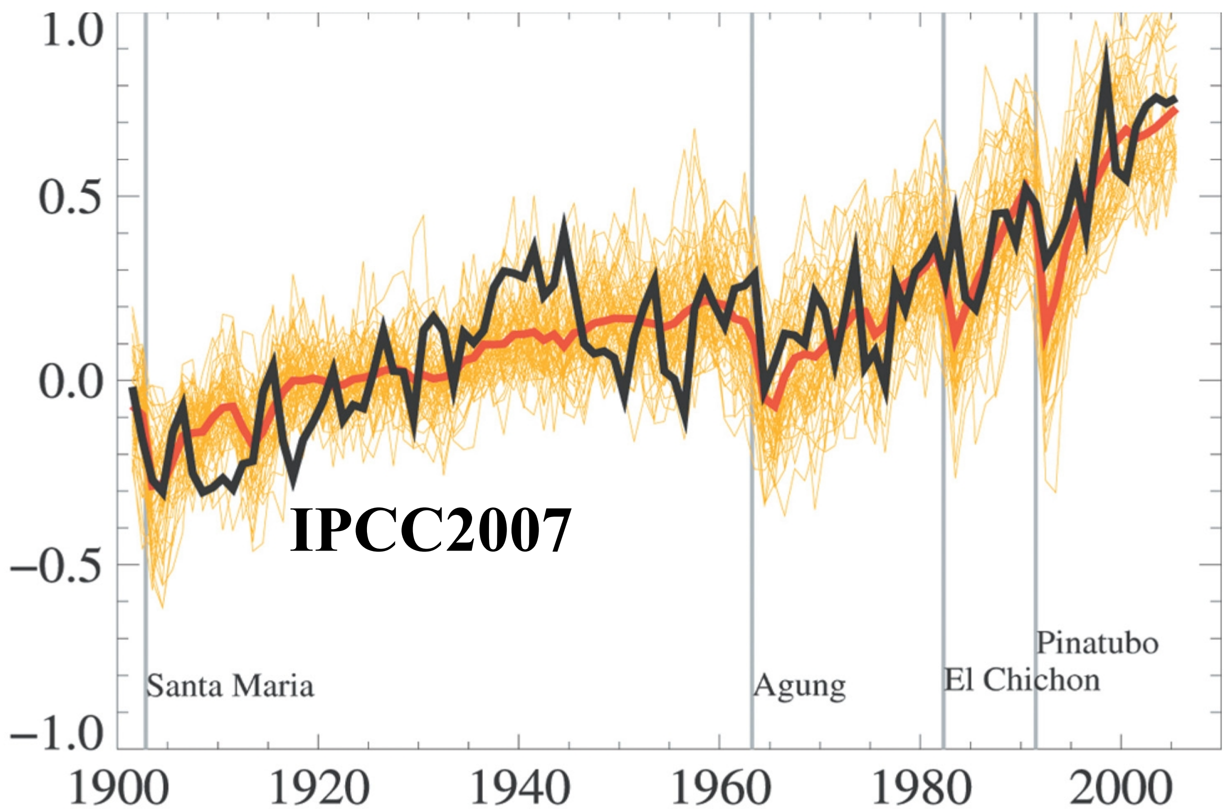
(New York Times, 3 June 2008, reporting a paper in “Nature” by Thomson et al.)

Global mean temperature in the industrial era

• Sun and Hansen (2003): "the most prominent forcings in the past century are increasing anthropogenic greenhouse gases (GHGs) and aerosols; changing solar irradiance also may have contributed significantly… GHG climate forcing is the largest, most accurately known forcing..."

** which entails their parameterizations for aerosol and cloud feedbacks, about which much uncertainty remains

• "Primary factors influencing global mean temperature response in these models, and presumably in the real world, are 1) the climate forcings, 2) the equilibrium climate sensitivity**, and 3) the effective thermal inertia of the ocean" (ibid.)



Explanation of terms

“Equilibrium climate sensitivity” of a climate model: “The equilibrium climate sensitivity refers to the equilibrium change in global mean near-surface air temperature that would result from a sustained doubling of the atmospheric (equivalent) CO_2 concentration ($\Delta Tx2$). This value is estimated, by the IPCC Fourth Assessment Report (AR4) as likely to be in the range 2 to 4.5°C with a best estimate of about 3°C, and is very unlikely to be less than 1.5°C... For a coupled atmosphere-ocean global climate model the climate sensitivity is an emergent property: it is not a model parameter, but rather a result of a combination of model physics and parameters.” (Wikipedia)

“Effective thermal inertia of the ocean”: any change in near surface air temperature will be moderated by atmosphere-ocean heat exchange with the ocean surface boundary layer; and the latter is coupled by mixing (irregular in time and space) with the deeper ocean. Some climate models consist of an AGCM (atmospheric GCM) coupled to a non-dynamic model of the upper ocean (“slab ocean”) – the modeller's choice of the depth (thus, heat capacity) and intensity of mixing of the ocean slab will moderate the response of global mean surface air temperature to external forcing (such as CO_2 doubling)

What are the paleo-climatological lines of evidence?

Many techniques extend the instrumental record. Typically, it is held there is a correlation between the observed quantity, and some climate statistic. There will be some form of "calibration" of the relationship from a known record. Proxy climate indicators *include*:

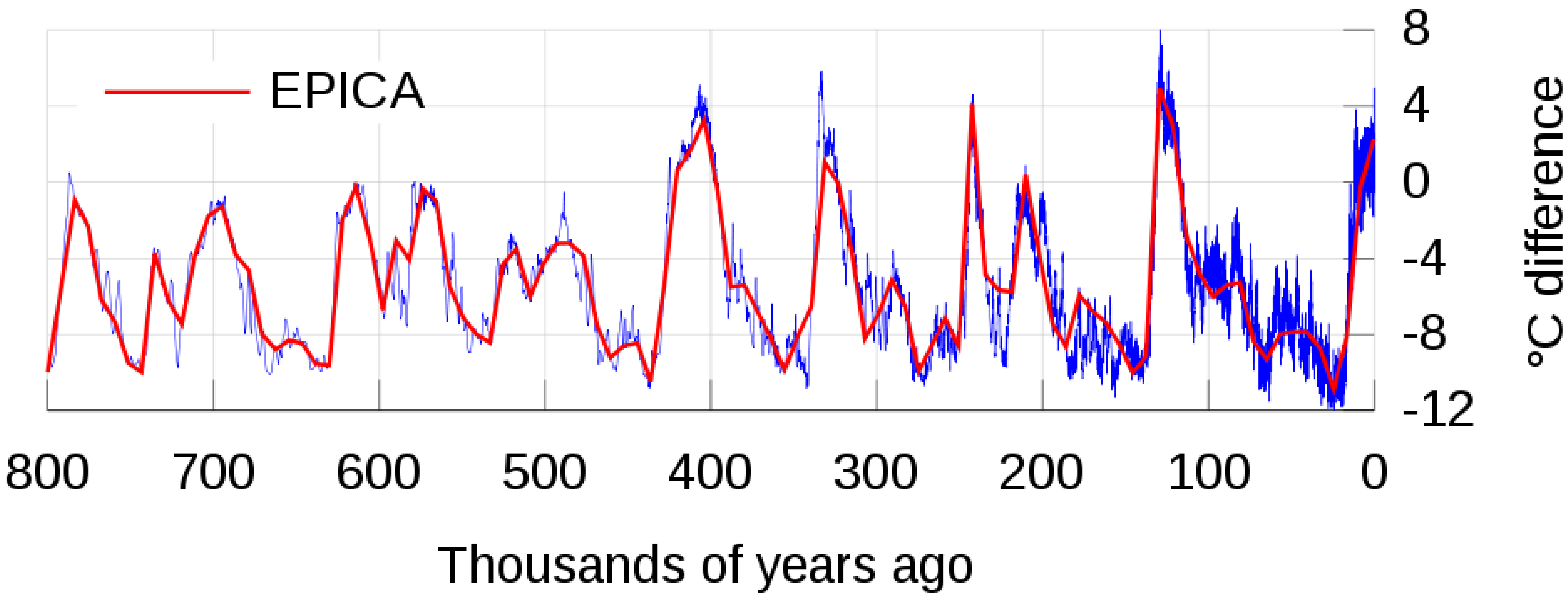
- tree growth rings (going back several Kyr): correlation with temp & precip

- oxygen isotopic content $\delta^{18}O$ (ratio of O^{18} to O^{16} divided by a "standard" value) of sea-floor sediments of marine organisms (calcium carbonate) drawn from "cores" records that ratio in sea water (record covers several MyrBP), and that in turn reflects water temperature as well as local evaporation and freshwater input. Surface ocean waters show a latitudinal gradient in $\delta^{18}O$ from low latitudes (O^{18} rich – preponderance of evaporation over precipitation) to middle lattitudes (O^{18} diluted – preponderance of precip over evap)

- pollen (whose dating connects vegetation types with time)

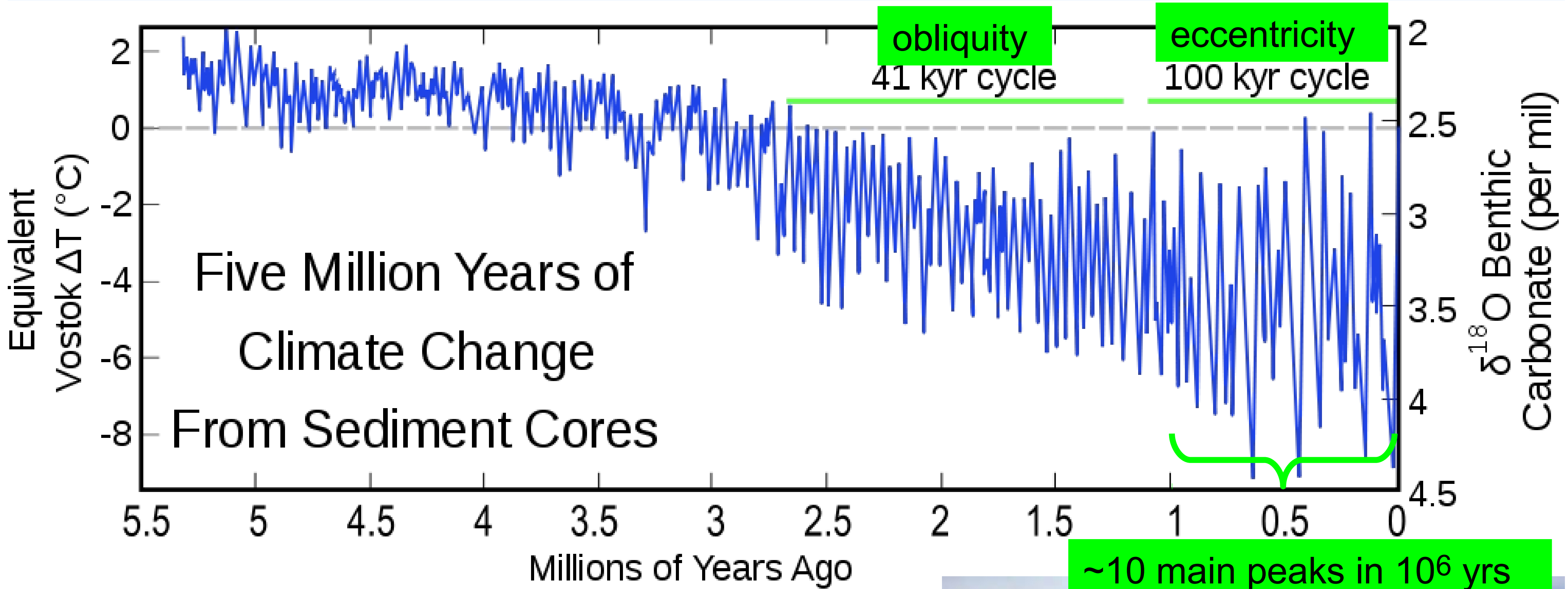
- ice cores (to about 800KyrBP)

What are the paleo-climatological lines of evidence?



- this image from Wikipedia
- this core from Antarctic (as is Vostok core)

What are the paleo-climatological lines of evidence?



~10 main peaks in 10^6 yrs

Lisiecki & Raymo (2005; Paleoceanography, 20, PA1003). Combines measurements from 57 globally distributed deep sea sediment cores. … δ^{18}O in benthic foraminifera... a proxy for total global mass of glacial ice sheets... "exhibits significant coherency with insolation" (i.e. a complex "spectral analysis" of the time series suggests it is driven to some extent by cycles in sun-earth geometry – see over)

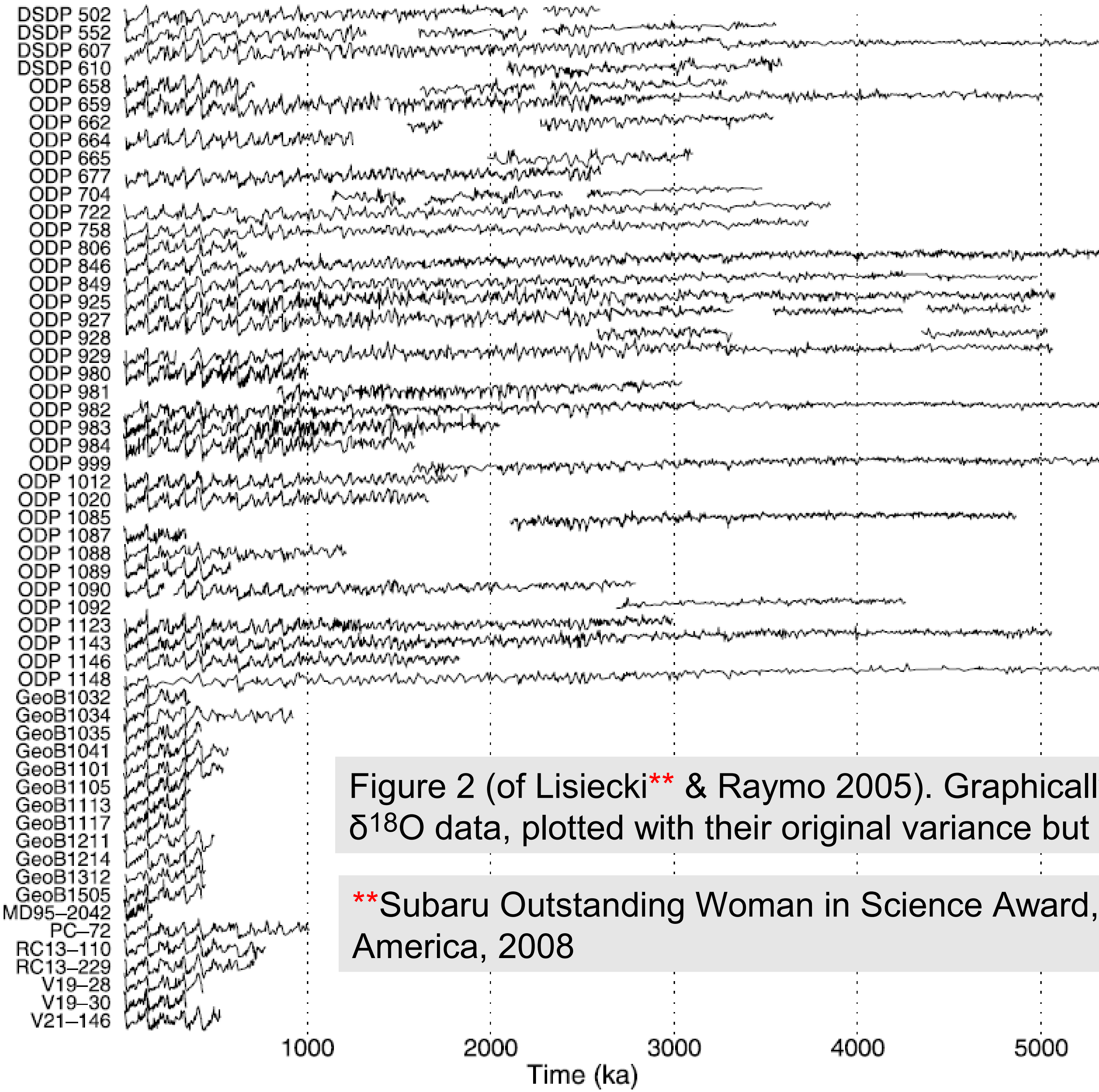
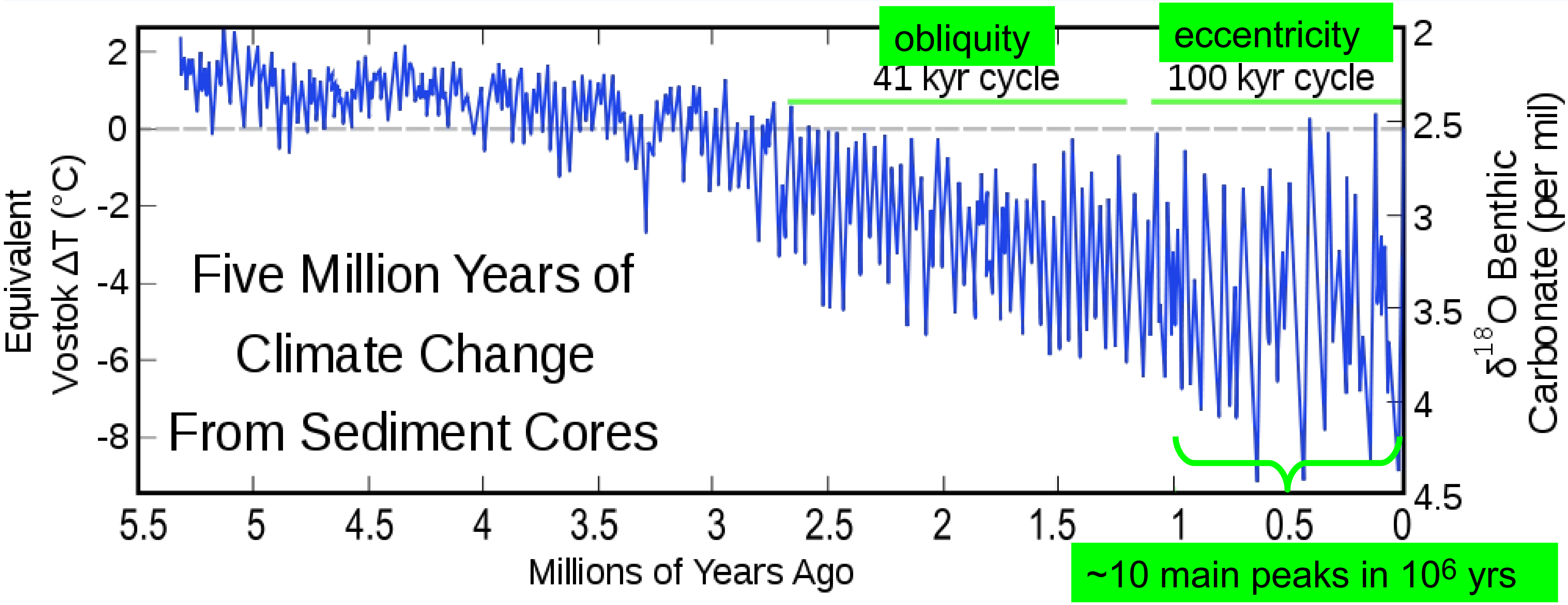


Figure 2 (of Lisiecki** & Raymo 2005). Graphically aligned benthic $\delta^{18}O$ data, plotted with their original variance but offset vertically.

**Subaru Outstanding Woman in Science Award, Geological Society of America, 2008

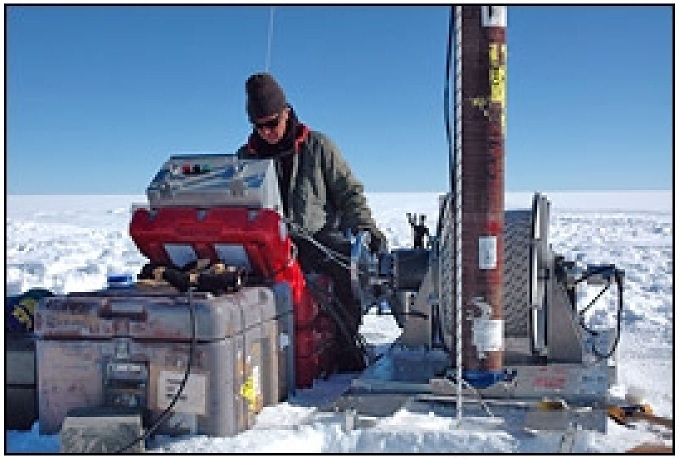
What are the paleo-climatological lines of evidence?

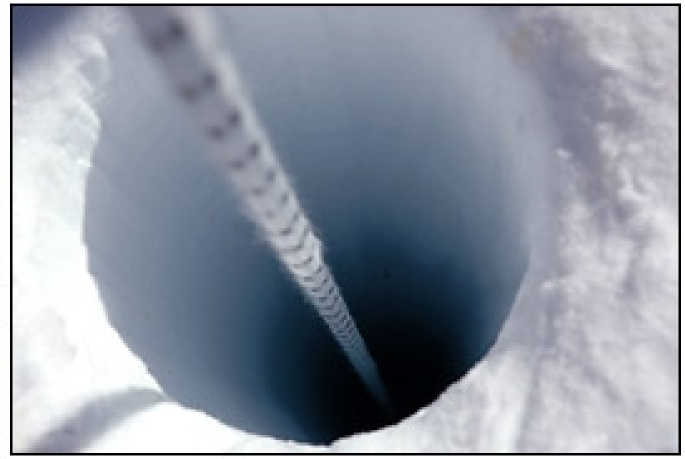


Lisiecki and Raymo constructed this record by first applying a computer aided process of adjusting individual "wiggles" in each sediment core to have the same alignment (i.e. wiggle matching). Then the resulting stacked record is orbitally tuned by adjusting the positions of peaks and valleys to fall at times consistent with an orbitally driven ice model (i.e. phased with the Milankovitch cycles). Both sets of these adjustments are constrained to be within known uncertainties on sedimentation rates and consistent with independently dated tie points (if any). Constructions of this kind are common. However, they **assume** that ice volume is driven by changes in insolation, and *such data therefore cannot be used to establish the existence of such a relationship*. (Wikipedia)

Ice cores

- bubbles in the ice give a direct sample of past air chemistry





Ice cores

- snow that falls during period of warmer climate has higher ratio of ^{18}O to ^{16}O… the connection with temperature is indirect, but experts don't doubt its validity

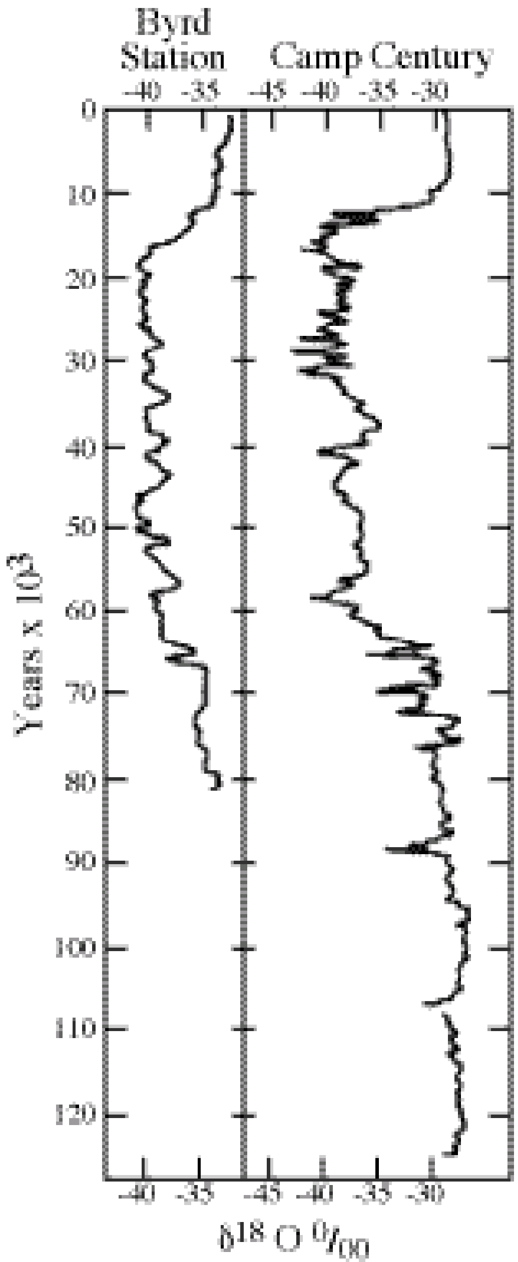
Validity of the temperature reconstruction from water isotopes in ice cores

J. Jouzel,[1] R. B. Alley,[2] K. M. Cuffey,[3] W. Dansgaard,[4] P. Grootes,[3,5] G. Hoffmann,[6] S. J. Johnsen,[4,7] R. D. Koster,[8] D. Peel,[9] C. A. Shuman,[10] M. Stievenard,[1] M. Stuiver,[3] and J. White[11]

Abstract. Well-documented present-day distributions of stable water isotopes (HDO and $H_2{}^{18}O$) show the existence, in middle and high latitudes, of a linear relationship between the mean annual isotope content of precipitation (δD and $\delta^{18}O$) and the mean annual temperature at the precipitation site. Paleoclimatologists have used this relationship, which is particularly well obeyed over Greenland and Antarctica, to infer paleotemperatures from ice core data. There is, however, growing evidence that spatial and temporal isotope/surface temperature slopes differ, thus complicating the use of stable water isotopes as paleothermometers. In this paper we review empirical estimates of temporal slopes in polar regions and relevant information that can be inferred from isotope models: simple,

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 102, NO. C12, PAGES 26,471–26,487, NOVEMBER 30, 1997

Ice-core oxygen isotopic measurements from Greenland (right hand side) and from Antarctica (left hand side). The isotope measurements can be interpreted to yield the global sea surface temperatures to ~160,000 years ago (colder temperatures to the left). The two traces are consistent with each other and depict the most recent glacial period, ending ~15,000 years ago… A decrease of one part per million (ppm) in the $\delta^{18}O$ measurement is equivalent to a reduction in temperature of approximately 1.5^{o}C at the time that the water evaporated from the oceans."



www.globalchange.umich.edu/

• possibility that climate could be affected by changing concentrations of greenhouse gases first put forward by Arrhenius (1896; “On the influence of carbonic acid in the air upon the temperature of the ground”. Philos. Mag., Vol. 41, 237–276)

• mid C20th attempts were made to estimate the equilibrium temperature rise due to doubling of atmos. CO_2, based largely on radiative equilibrium calculations

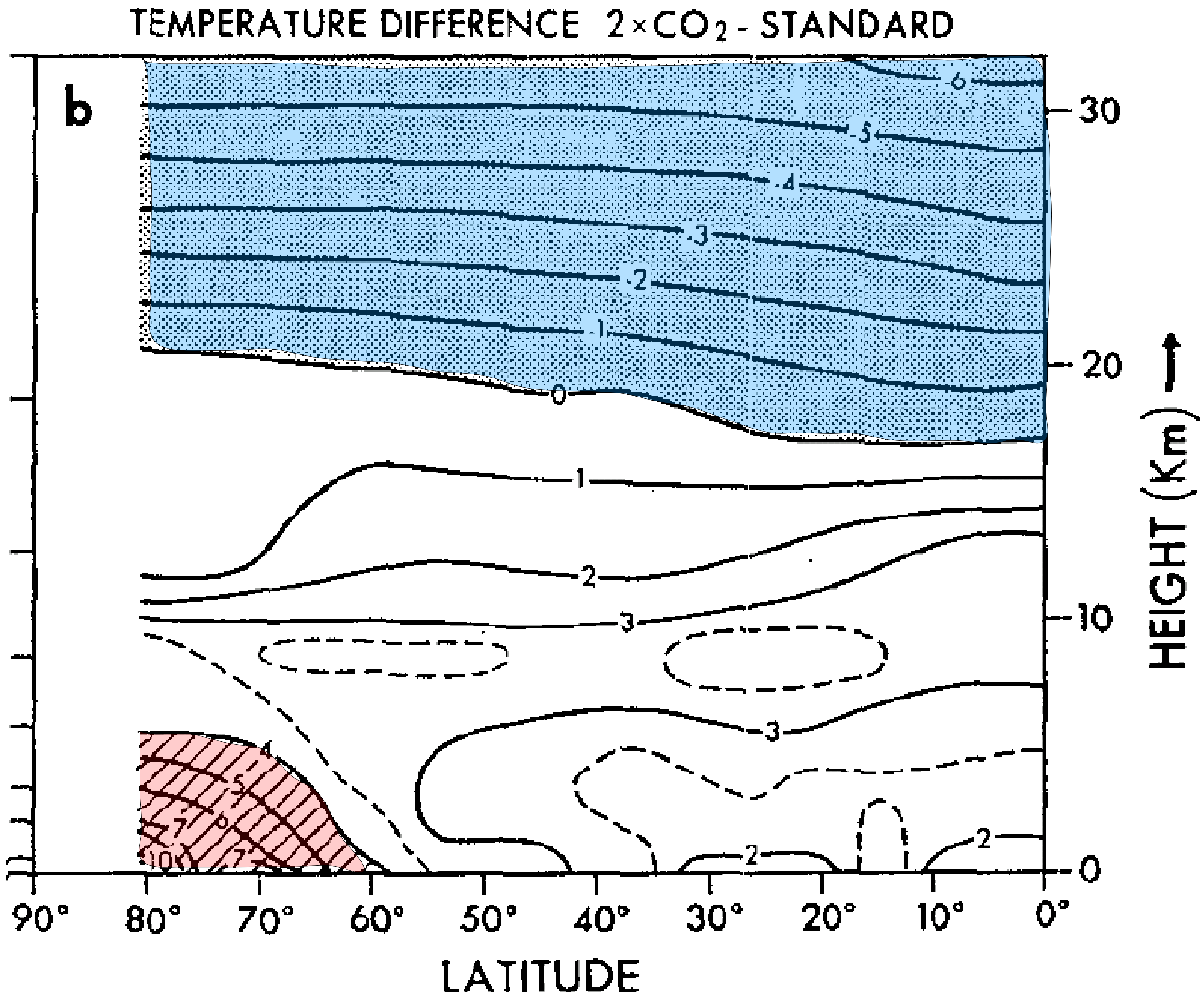
• 1967 importance of convective processes in regulating the surface temperature of the earth was taken into account by Manabe and Wetherald (J. Atmos. Sci. 24, 241-259)

****Mitchell (2004, “Can we believe predictions of climate change?” Quart. J. Royal. Meteorol. Soc., Vol. 130, pp. 2341–2360)**

Zonally averaged atmospheric temperature changes due to doubling atmospheric CO_2.

Contours are every °C, stippled (grey&blue) where negative and cross-hatched (&red) where greater than +4 °C

• from Manabe and Wetherald, 1975, "The effects of doubling the CO_2 concentration on the climate of a general circulation model." J. Atmos. Sci., Vol. 32, 3–15.



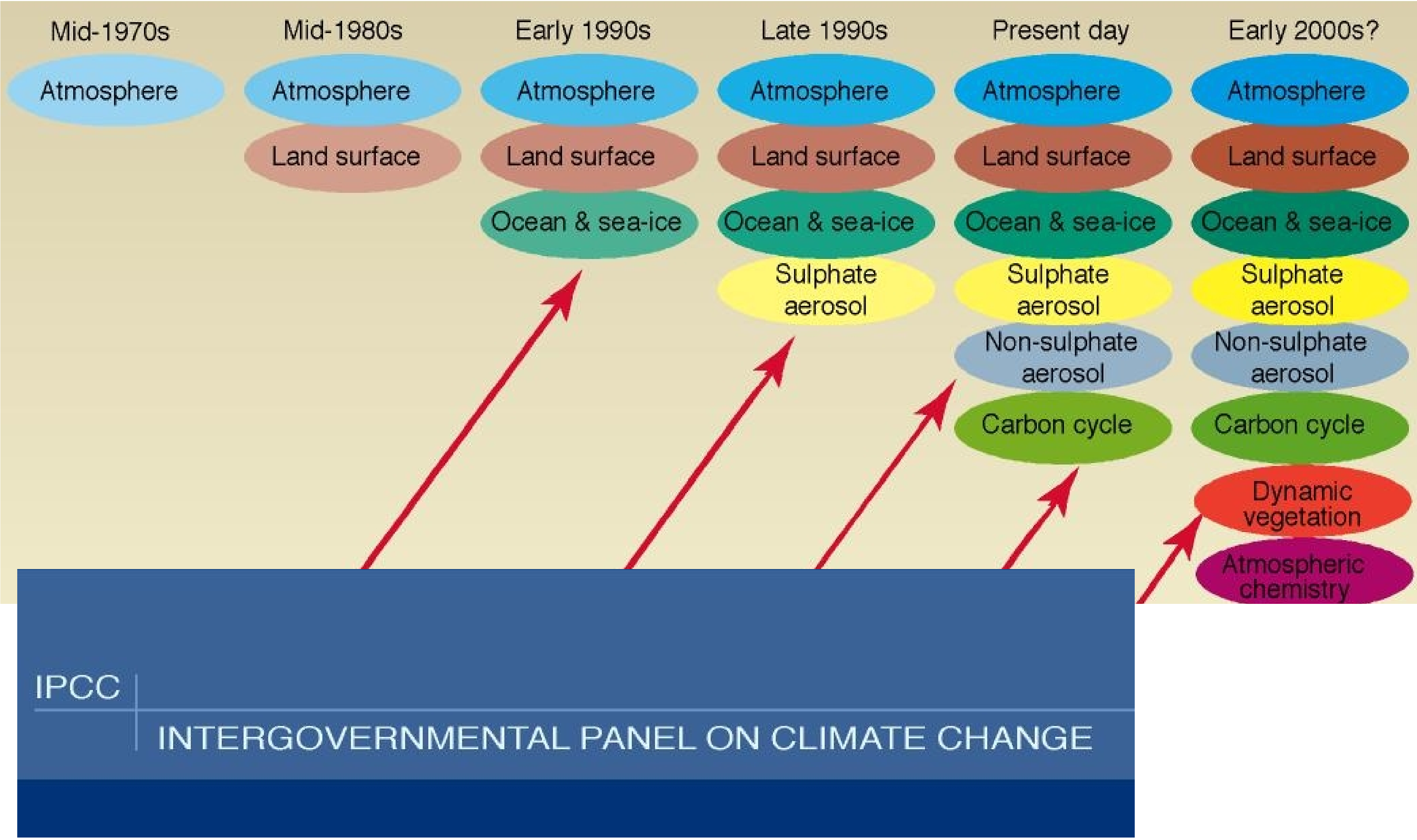
VOL. 32, NO. 1 JOURNAL OF THE ATMOSPHERIC SCIENCES JANUARY 1975

The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model[1]

SYUKURO MANABE AND RICHARD T. WETHERALD

An attempt is made to estimate the temperature changes resulting from doubling the present CO_2 concentration by the use of a simplified three-dimensional general circulation model. This model contains the following simplifications: a limited computational domain, an idealized topography, no heat transport by ocean currents, and fixed cloudiness. Despite these limitations, the results from this computation yield some indication of how the increase of CO_2 concentration may affect the distribution of temperature in the atmosphere. It is shown that the CO_2 increase raises the temperature of the model troposphere, whereas it lowers that of the model stratosphere. The tropospheric warming is somewhat larger than that expected from a radiative-convective equilibrium model. In particular, the increase of surface temperature in higher latitudes is magnified due to the recession of the snow boundary and the thermal stability of the lower troposphere which limits convective heating to the lowest layer. It is also shown that the doubling of carbon dioxide significantly increases the intensity of the hydrologic cycle of the model.

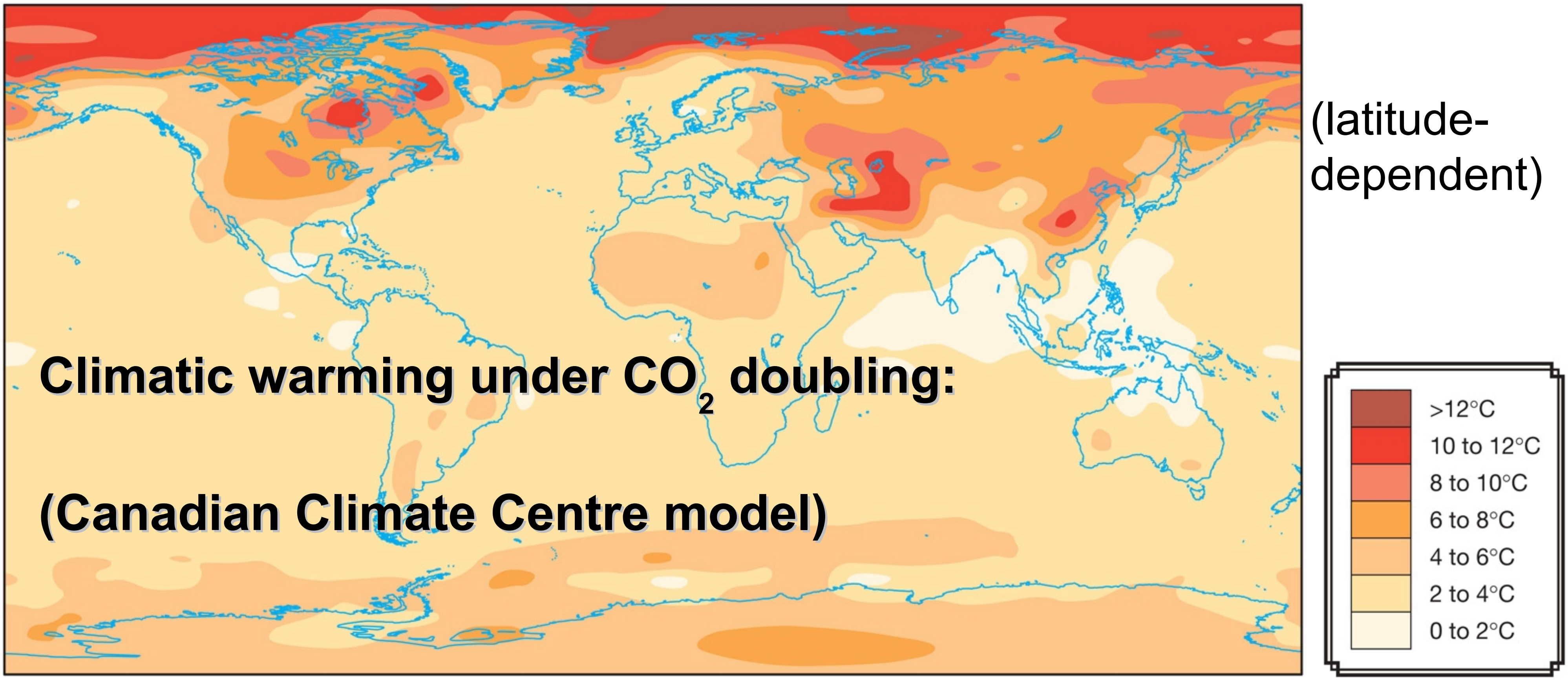
Global Climate Modelling – developing interactions (feedbacks)



By now some GCMs feature “dynamic global vegetation models (DGVMs)” which capture further biogeochemical cycles (e.g. nitrogen)

Current estimates using atmos. models coupled to a simple ocean give a range of 2 to 6°C for global mean temperature response to CO_2 doubling

(latitude-dependent)



(a) DJF $2xCO_2$ – $1xCO_2$ surface air temperature: CCC

How does forecasting climate differ from forecasting weather?

- many more processes, acting on longer timescales, may need to be included:
  - ocean temperature (& salinity) changes
  - ocean circulations influencing CO_2 budget (exchange with deeper ocean)
  - sun-earth geometry changes
  - locations of continents (depending on time scale of simulation)
  - ice sheets and ice packs
  - vegetation responses interacting with CO_2, temperature and humidity
  - natural aerosols (e.g. volcanic sources)
  - anthropogenic gases and particles

- climate simulation computes the equilibrium climate for certain fixed “external” conditions (eg. perhaps fixed ocean temps; fixed CO_2; fixed sun-earth geometry). Thus initial conditions are irrelevant (one integrates for long enough to “forget” the initial condition).

- It may be possible to neglect or simplify some “rapid” processes, and even to neglect a spatial dimension, eg. (1) zonally-averaged models or (2) the U. Victoria “intermediate complexity” climate model treats atmosphere as a well-mixed slab (no vertical gradients)

Uncertainties in Climate Modelling using GCM's

The main uncertainties arise with processes for which we do not have a reliable underlying theory (including cloud formation and dissipation), and processes which are not resolved on the model grid (including transfer of heat, moisture and momentum from the surface, convection and cloud processes)

There remain model parameters which cannot be measured or do not correspond to any measurable quantity, eg. some cloud parametrizations define a relative-humidity threshold above which cloud is allowed to form. Even if there is a single threshold in the real world, it is unlikely that using it would give the correct cloud amount... Small errors in cloud amounts and microphysical properties can produce large errors in the radiative budget, and hence large drifts in surface temperature

R.S. Lindzen** (M.I.T.) argues w.v./cloud & aerosol feedbacks in existing models render their simulations excessively responsive to 2 x CO_2

**Lindzen (30 Nov. 2009, Wall Street Journal) stated IPCC claims were "based on the weak argument that the current models used by the IPCC couldn't reproduce the warming from about 1978 to 1998 without some forcing, and that the only forcing that they could think of was man. Even this argument assumes that these models adequately deal with natural internal variability—that is, such naturally occurring cycles as El Niño, the Pacific Decadal Oscillation, the Atlantic Multidecadal Oscillation, etc..."

“Feedbacks”

“Positive feedbacks” (see Sec. 6-3) are those which reinforce (or act additively with) the original disturbance, eg. the ice albedo feedback.

“Negative feedbacks” oppose the original disturbance. Thus if global warming increases global cloud coverage, increased solar reflection is a negative feedback, but increased absorption of upwelling longwave radiation is a positive feedback. Overall cloud feedback is a complex sum of several feedbacks: until recently (and still?) GCM’s disagreed on overall sign

There are complex feedbacks whose parametrization needs to be refined, e.g. dimethyl sulphide (DMS) gas, released by decay of ocean biota, forms sulphate aerosols that act as CCN: will warmer ocean temperatures mean greater ocean productivity and consequently greater biotic decay rate, causing higher atmospheric concentrations of CCN and changes to cloud amount and type?

- **Four criteria to judge 'is a climate model reliable for predicting climate change?'**

  - physical basis
  - simulation of present climate
  - simulation of historical climate (period of instrumental records, or equilibrium simulation of much more distant climates, e.g. Last Glacial Maximum, 21KyrBP, i.e. 21,000 years ago)
  - numerical weather prediction

"At the LGM, SSTs were decidedly lower than at present. Consequently, there has been more emphasis on simulations with an interactive ocean. Only a few fully coupled simulations have been published to date (forced with reduced CO2, prescribed land ice sheets and changes in orbital forcing), but these all show global-scale cooling broadly consistent with the paleo-climatic reconstructions... there is still little or no confidence in the regional detail predicted by models... most of the range in climate sensitivity across various GCM's is associated with differences in cloud feedback" (Mitchell, 2004, "Can we believe predictions of climate change?" Quart. J. Royal. Meteorol. Soc., Vol. 130, pp. 2341–2360)