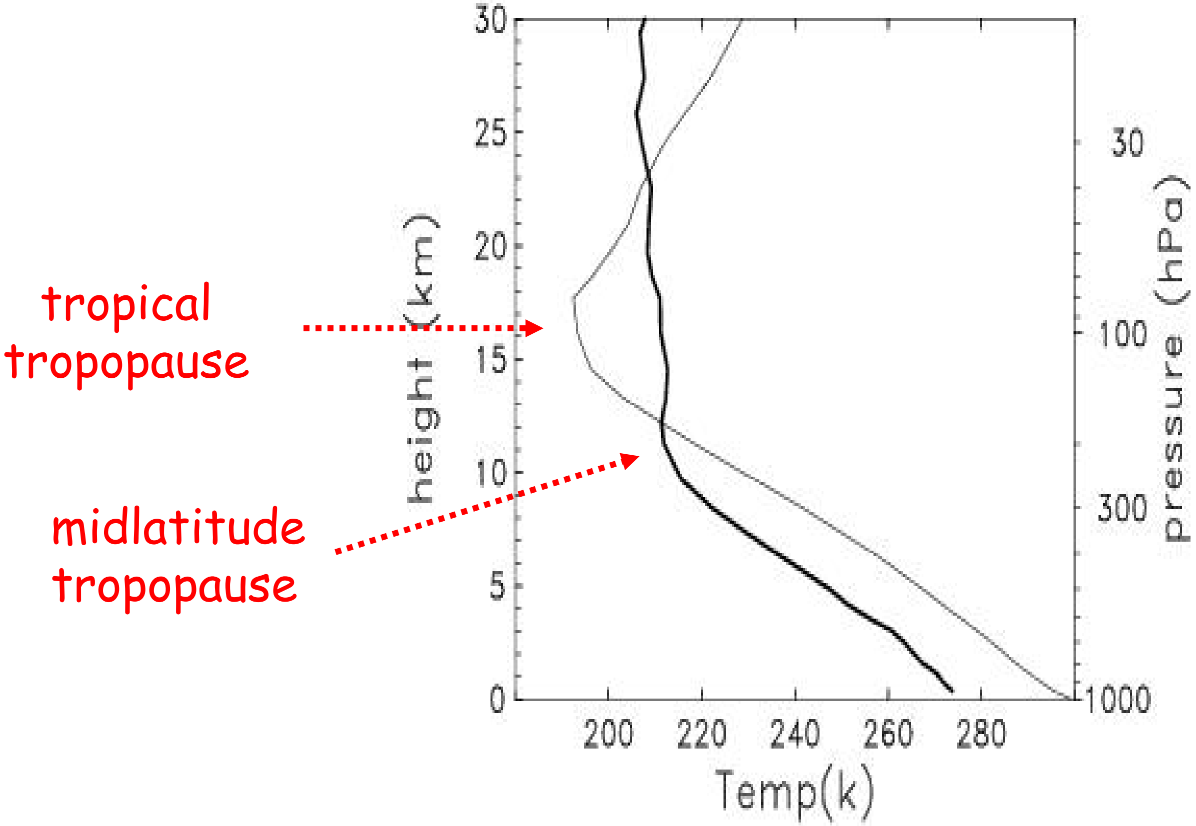
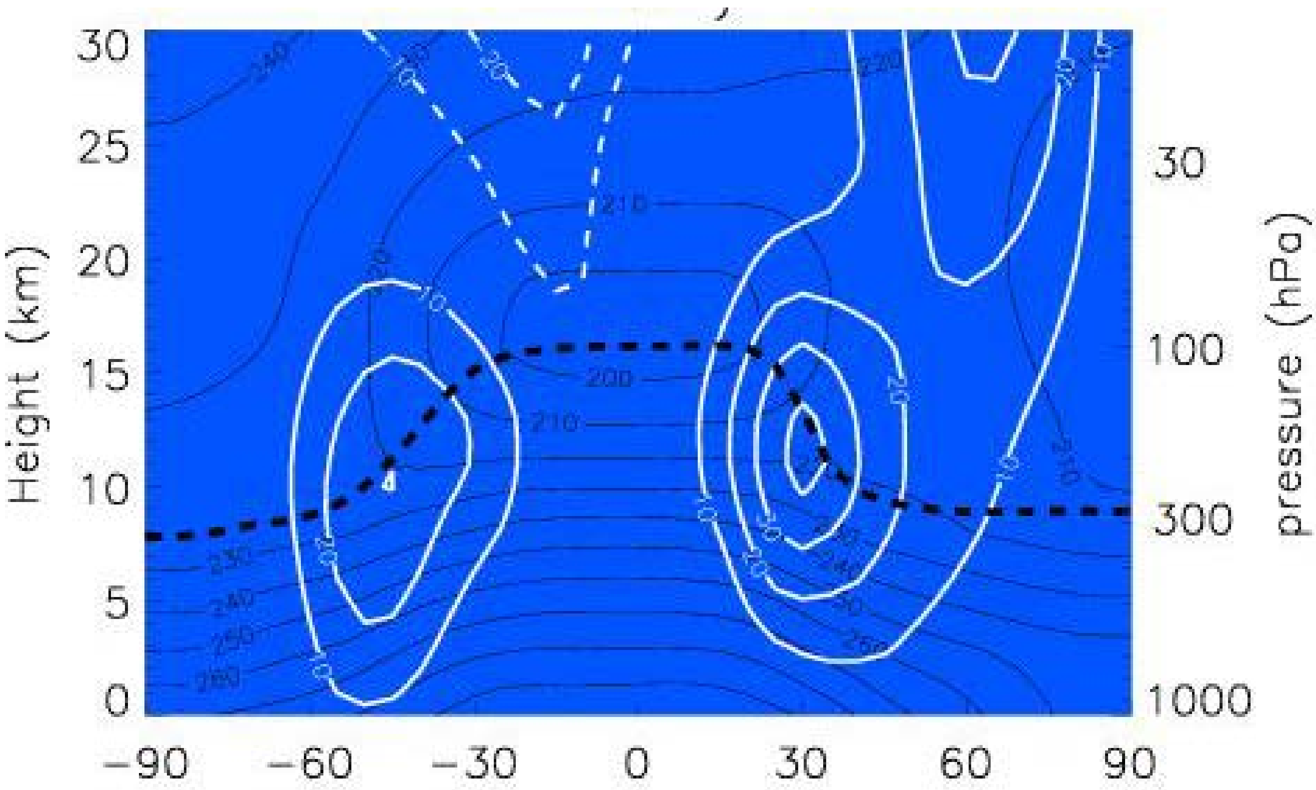
Requirements for monitoring the global tropopause

Bill Randel
Atmospheric Chemistry Division
NCAR

Tropopause is most simply identified by a change in stability (lapse rate)

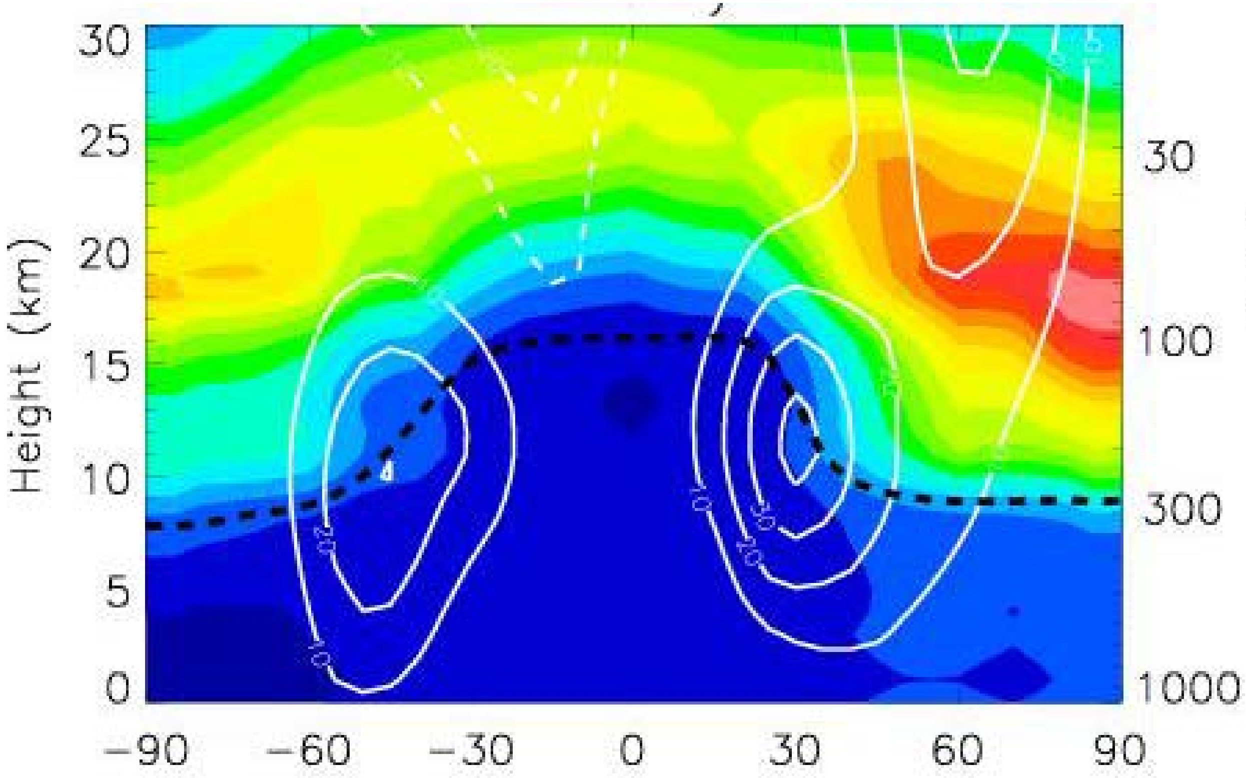


Latitudinal structure of the tropopause



Tropopause separates air masses with different dynamical and chemical characteristics

Ozone



definitions of the tropopause

- Lapse rate tropopause (WMO definition)
- Cold point (most relevant in the tropics)
- Specific value of potential vorticity (PV=2)

  advantage: continuously valued, useful for dynamics/transport studies

  disadvantage: requires meteorological analysis; cannot calculate from temp profiles alone

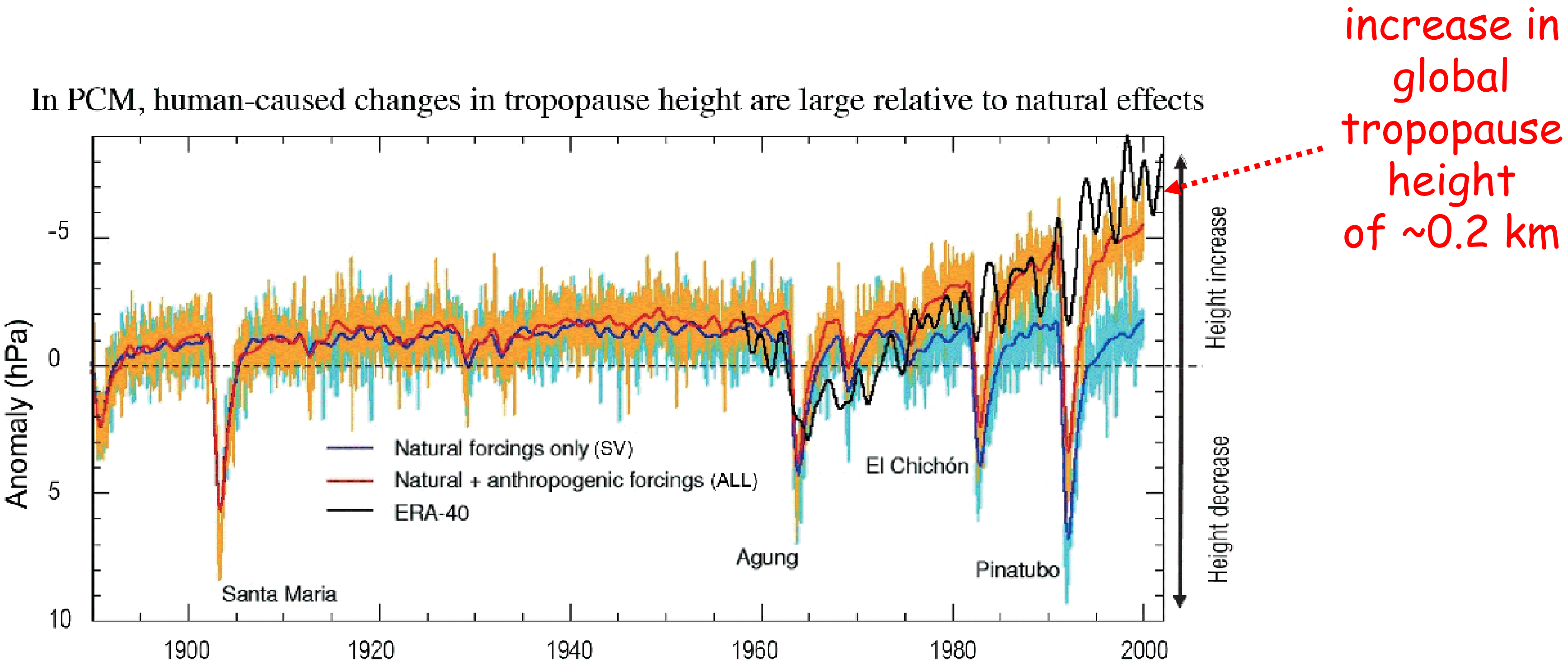
What are the science issues re: tropopause and climate?

- Is the tropopause a sensitive indicator of climate change?
  (if so, what parameters?)

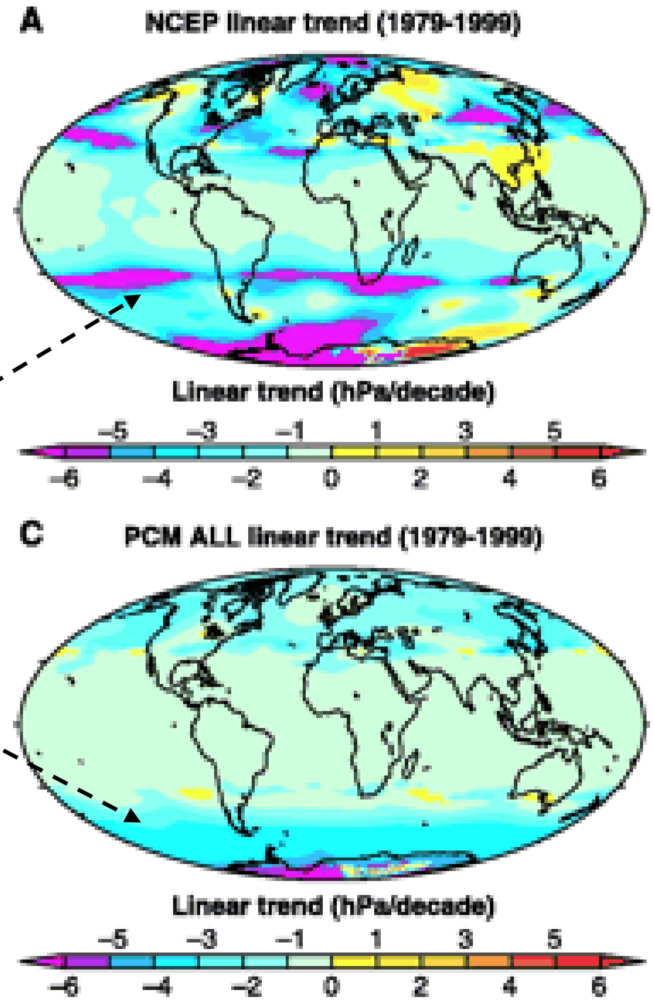
- How is the tropopause related to *long-term* ozone variability?

Contributions of Anthropogenic and Natural Forcing to Recent Tropopause Height Changes

Santer et al. Science, July 2003



Spatial 'fingerprint' of tropopause changes

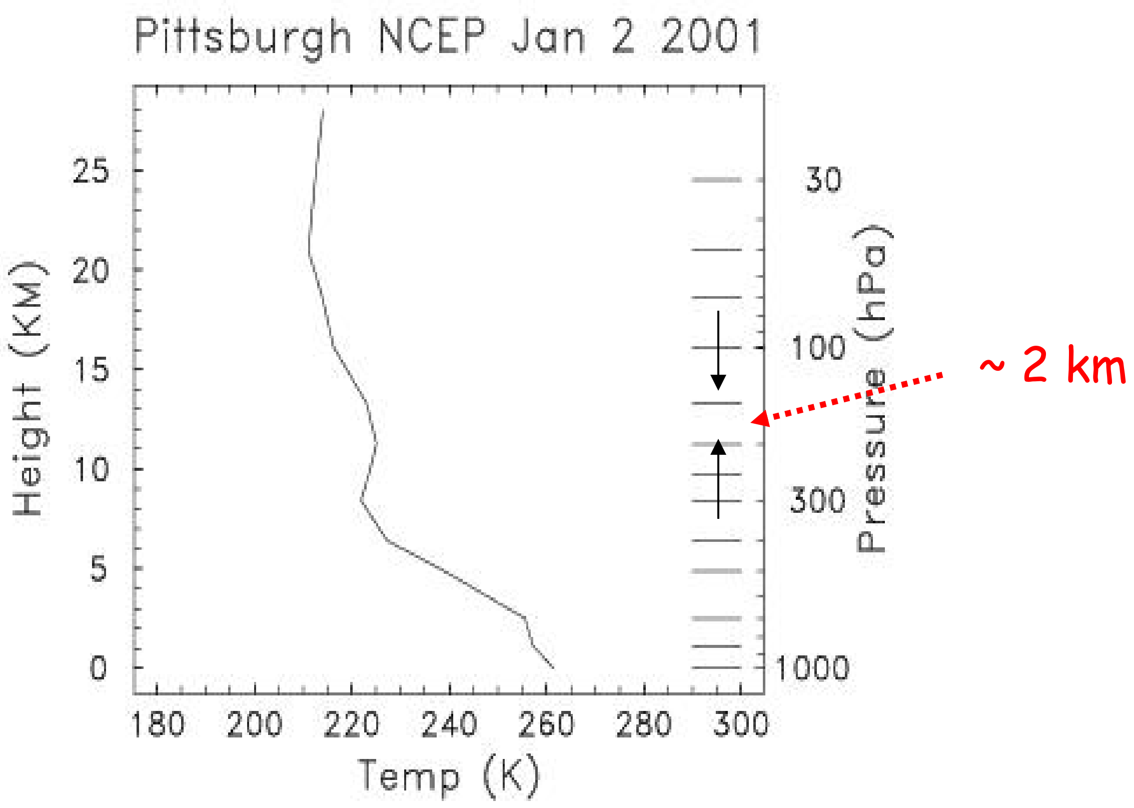


observations (NCEP data)

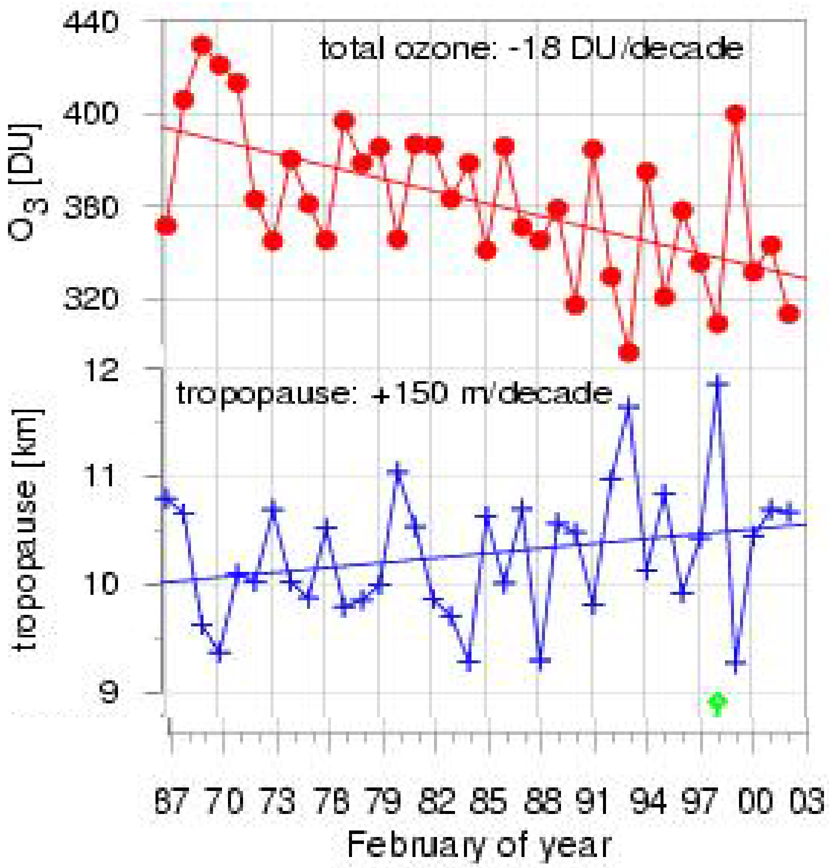
decrease in tropopause pressure (increase in altitude)

climate model with changing CO2, ozone, aerosols, ...

caveat: vertical resolution of models and (some) observations can be ~2 km



Correlation of ozone and tropopause height on short and long time scales



column ozone and tropopause height at Hohenpeissenberg

WMO, 2002 updated from Steinbrect et al 2001

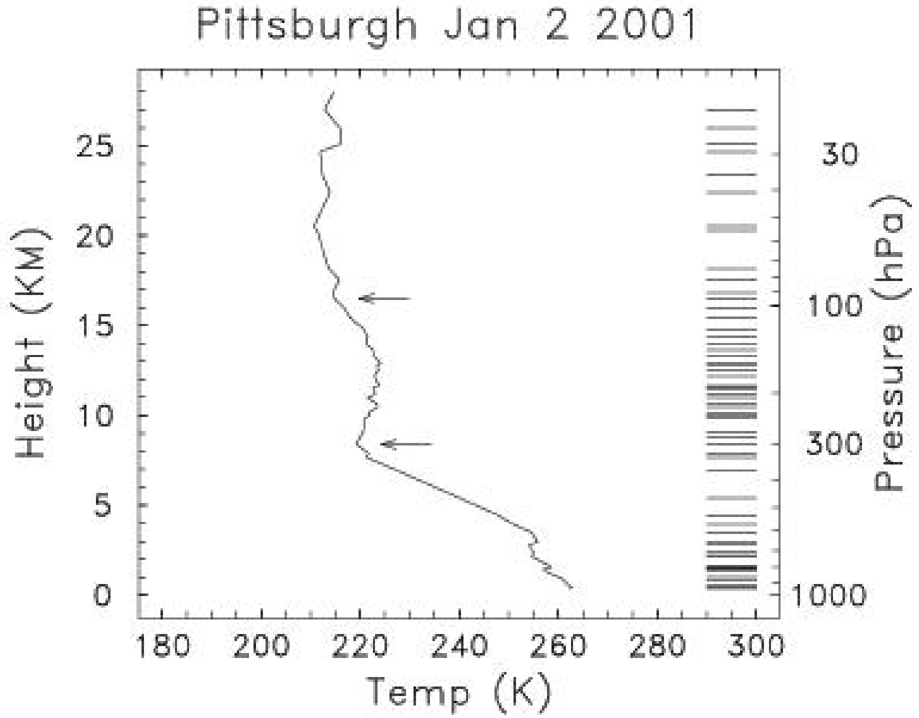
What are the requirements to monitor the tropopause?

- Key point is vertical resolution (plus spatial sampling)

  compare statistics for different measurements:

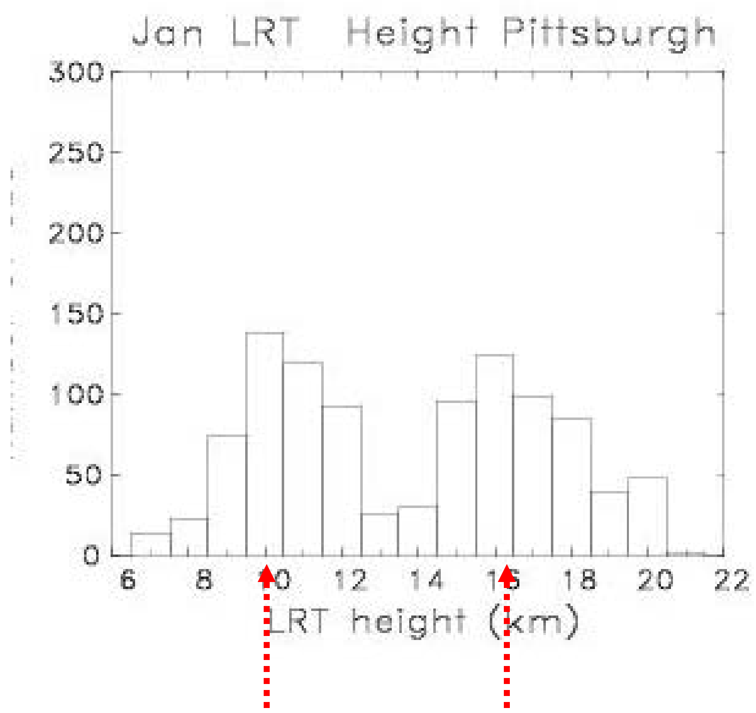
  * radiosondes
  * GPS radio occultation (GPS/MET, CHAMP, SAC-C)
  * operational analyses / reanalyses (ERA40, NCEP)

High resolution radiosonde profile



statistical distribution of tropopause heights from radiosondes at Pittsburgh 1994-2003

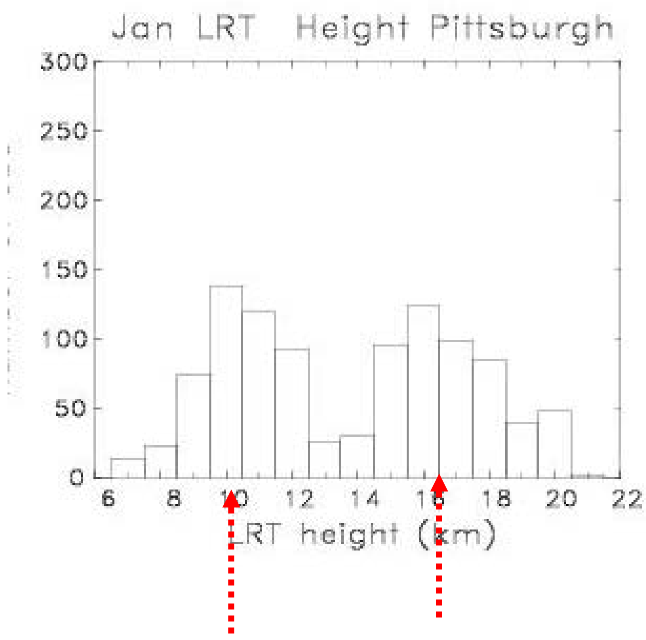
January



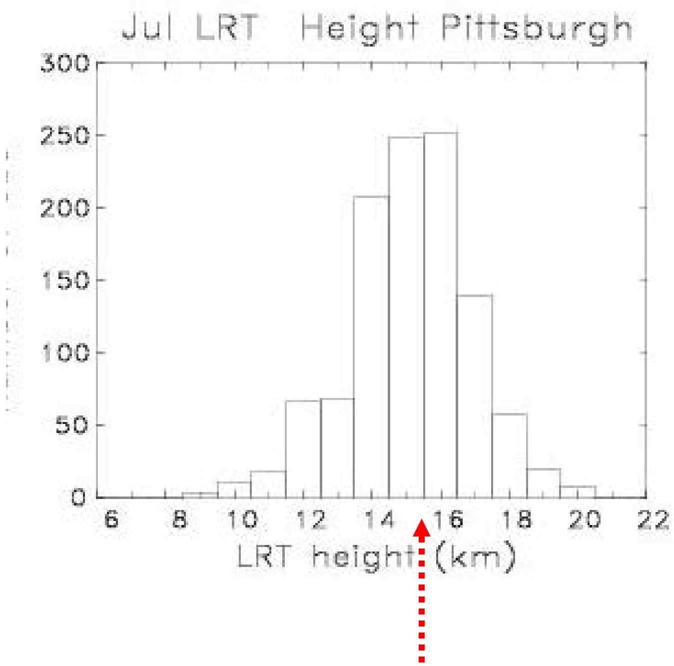
note two maxima

seasonal variation at Pittsburgh 1994-2003

January

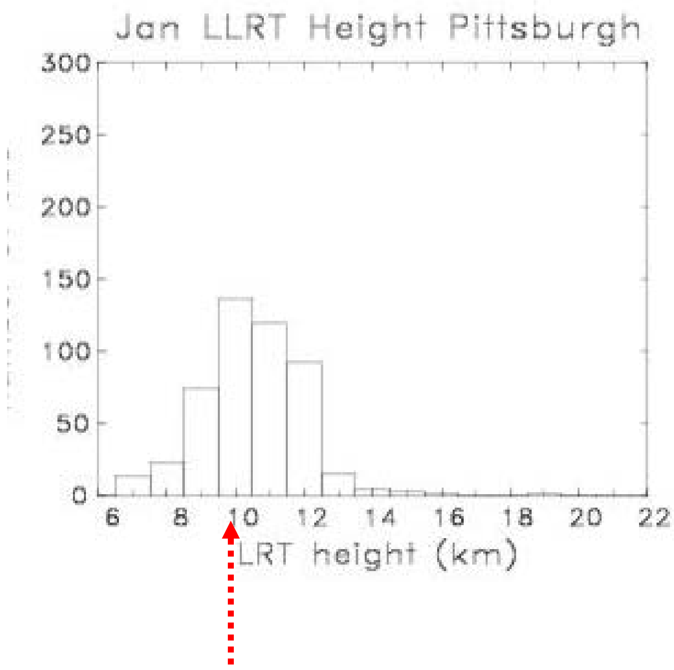


July

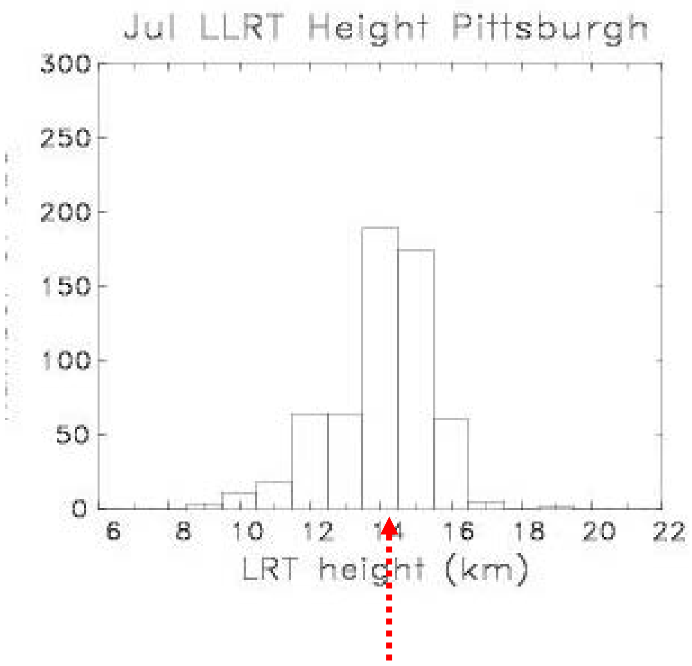


lowest tropopause at Pittsburgh 1994-2003

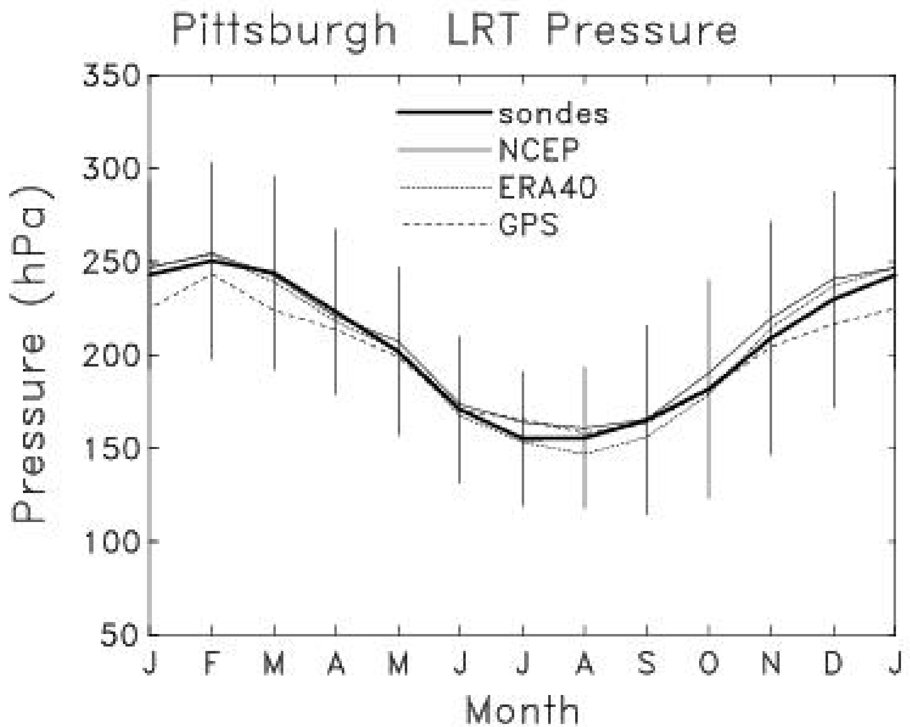
January



July

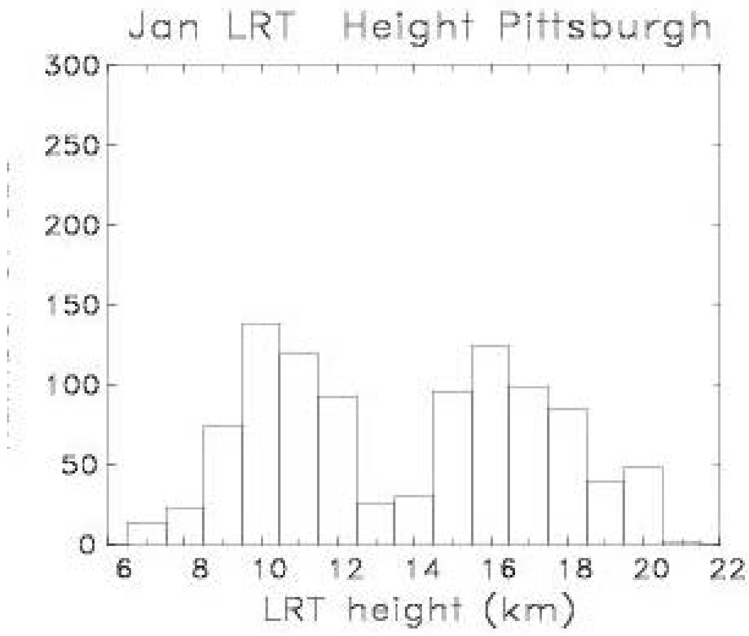


seasonal cycle in tropopause height

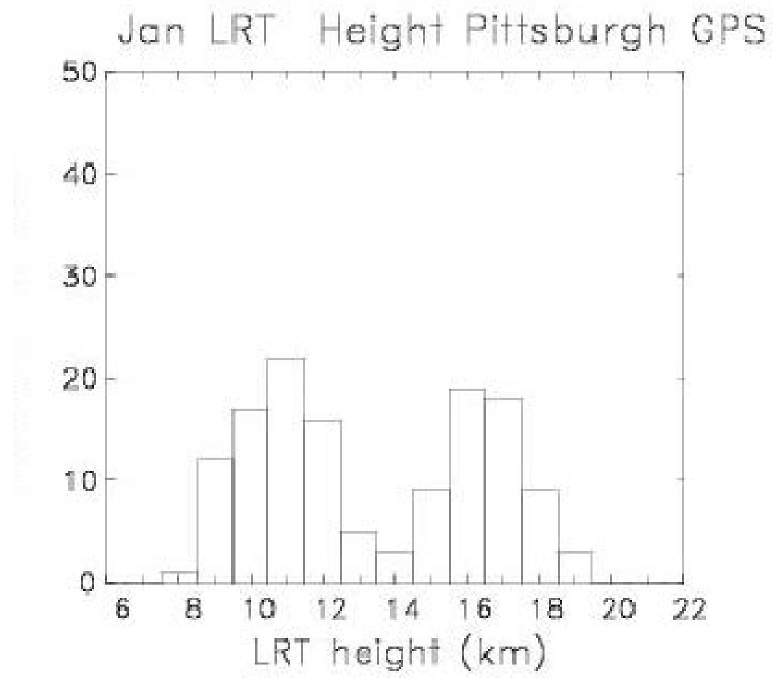


How do tropopause statistics depend on vertical resolution?

radiosondes

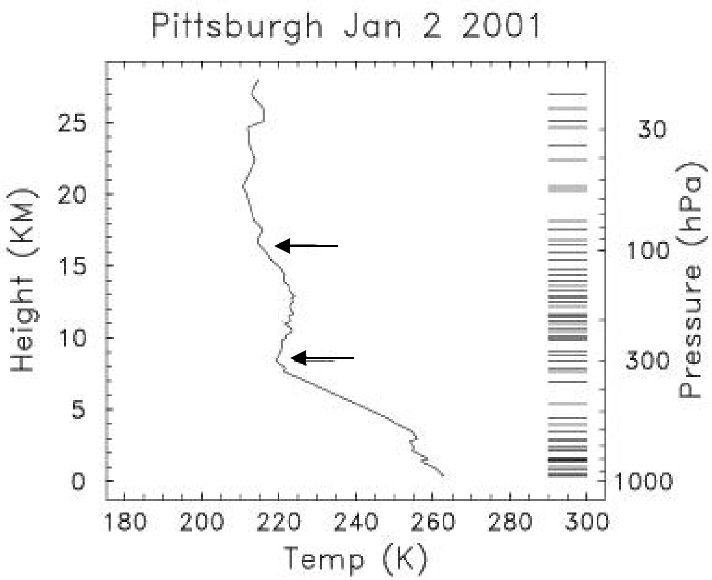


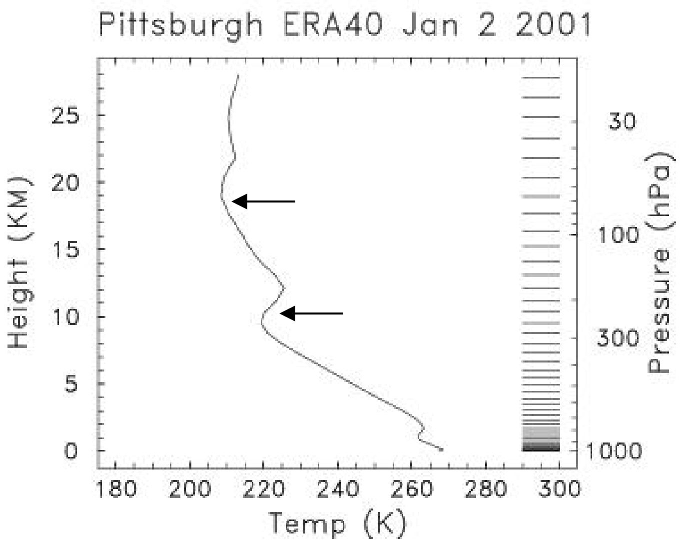
GPS



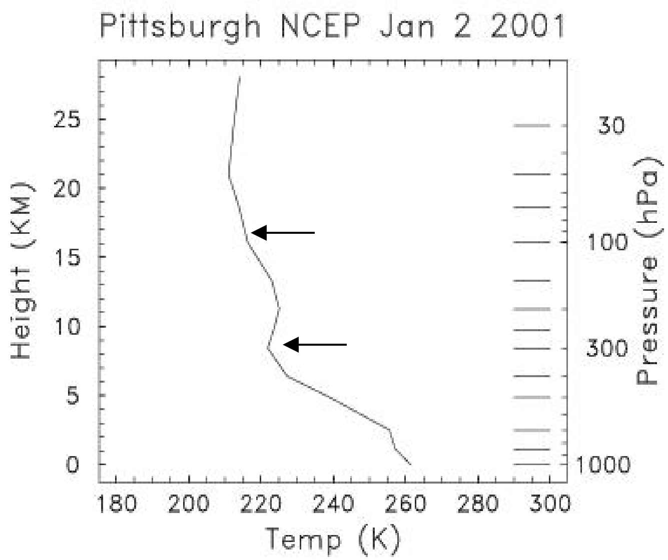
Sondes vs. ERA40 and NCEP

radiosonde





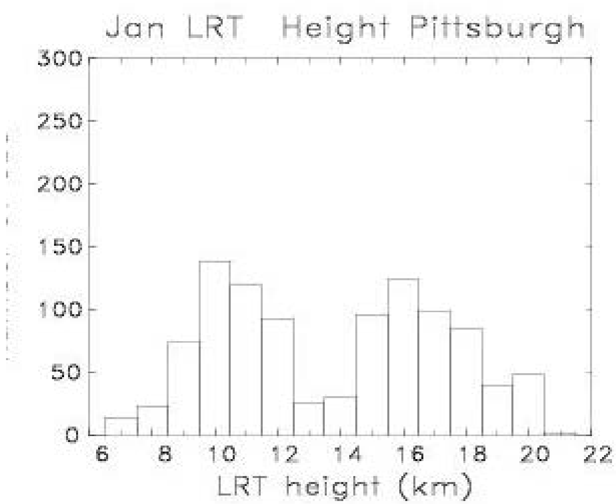
ERA40
(60-level)

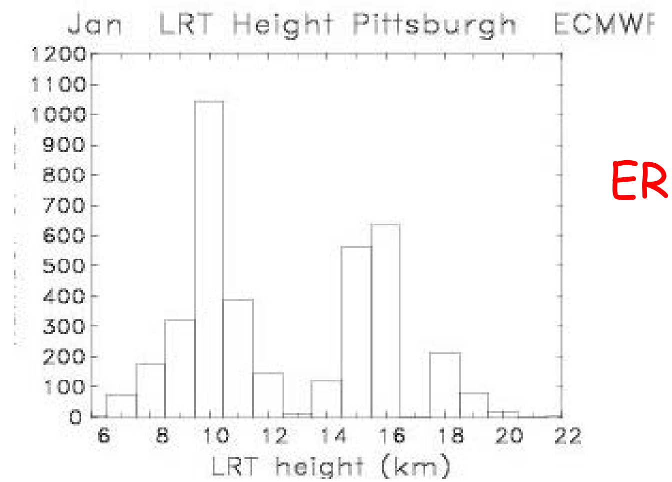


NCEP
(17-level)

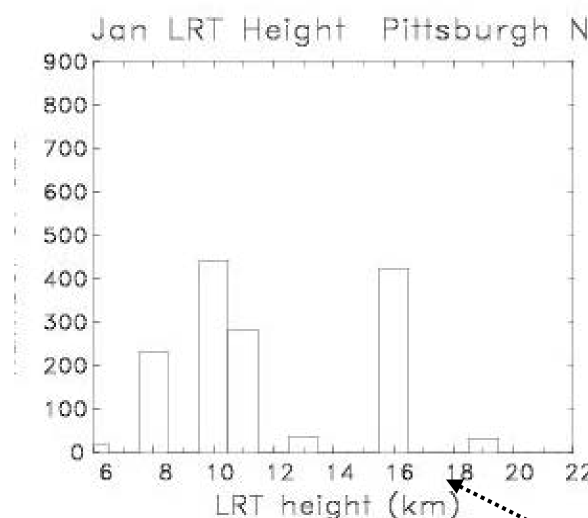
Tropopause statistics from reanalyses

radiosondes





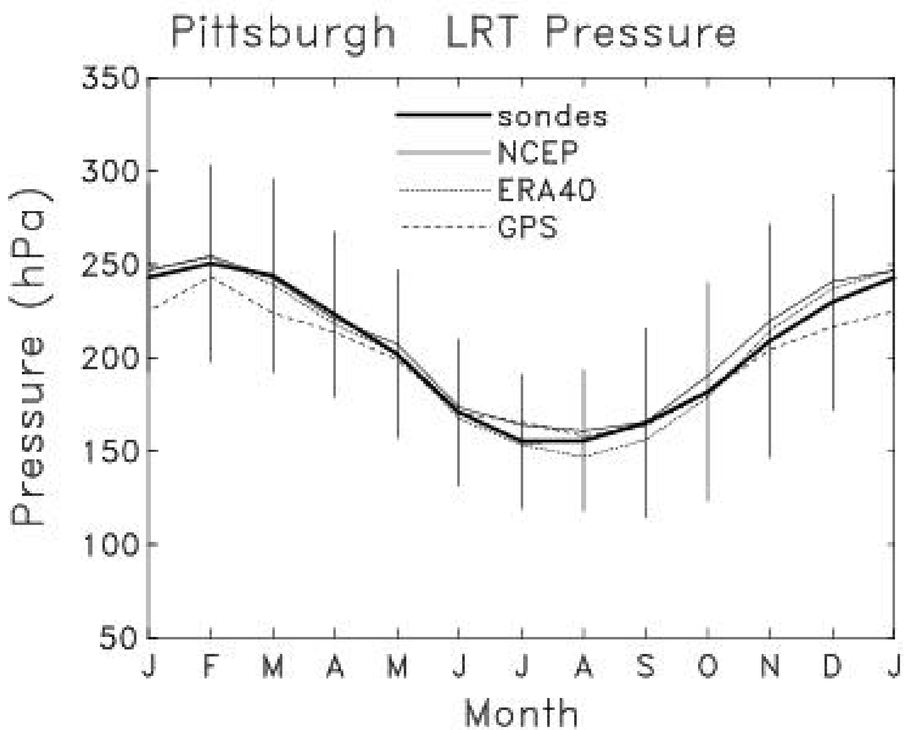
ERA40 (60-level)



NCEP (17-level)

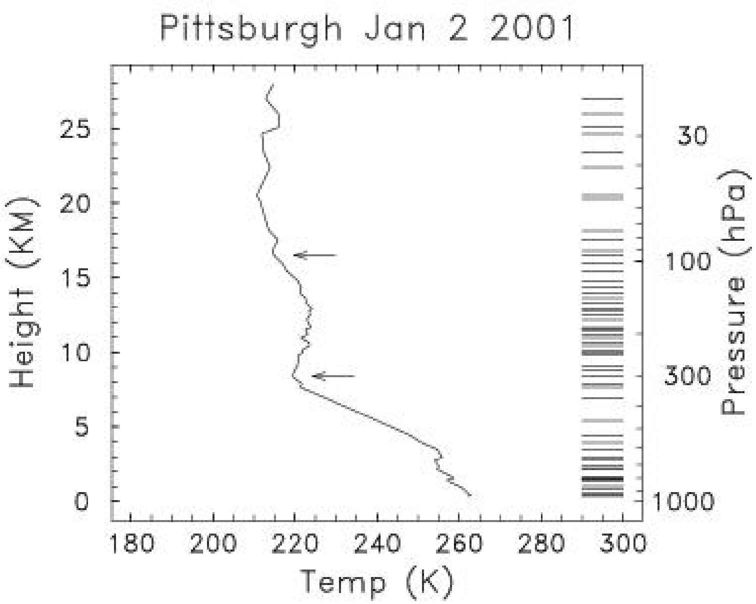
note lower resolution

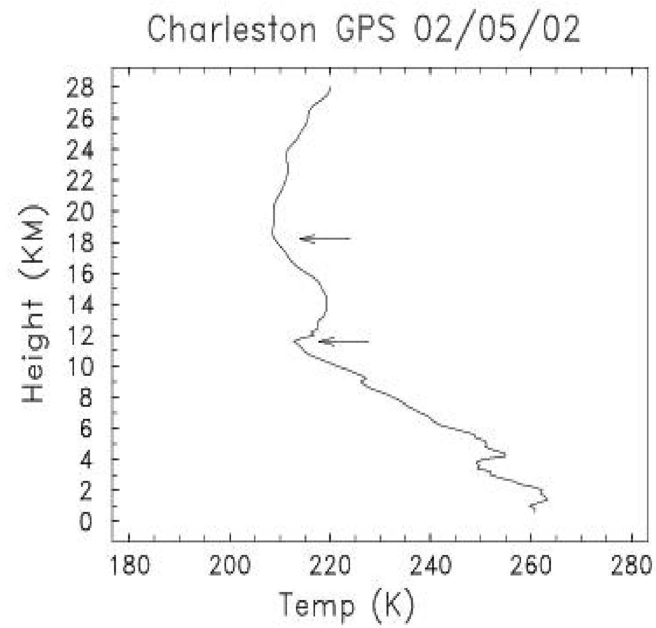
seasonal variation from different data sources



Other statistics: occurrence of multiple tropopauses

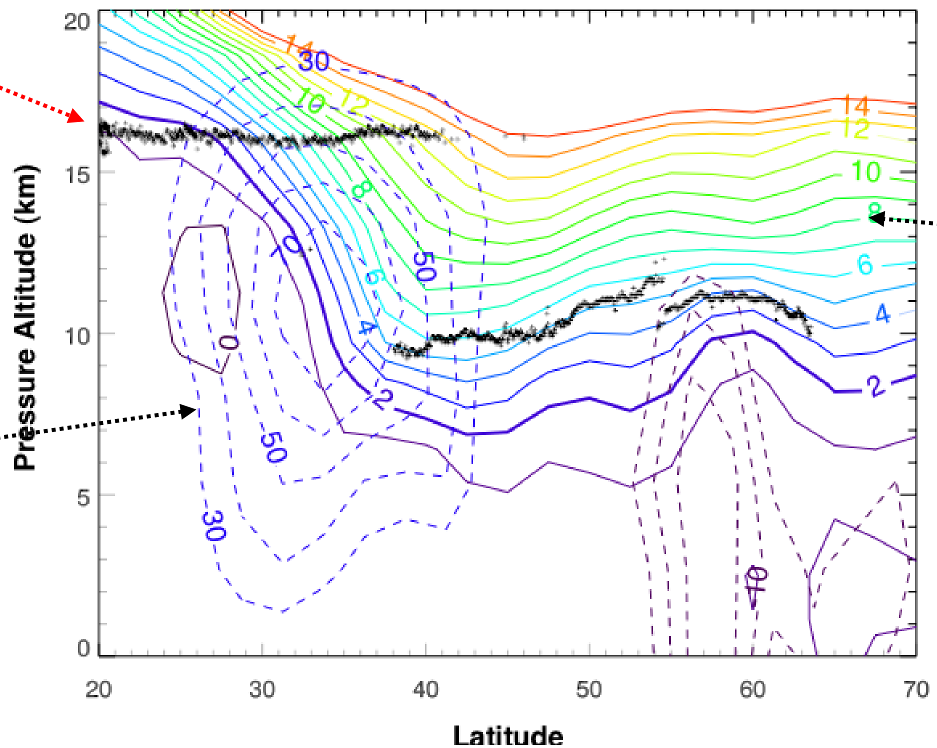
example from GPS data





double tropopause associated with break near subtropical jet

tropopause from aircraft profiler measurements

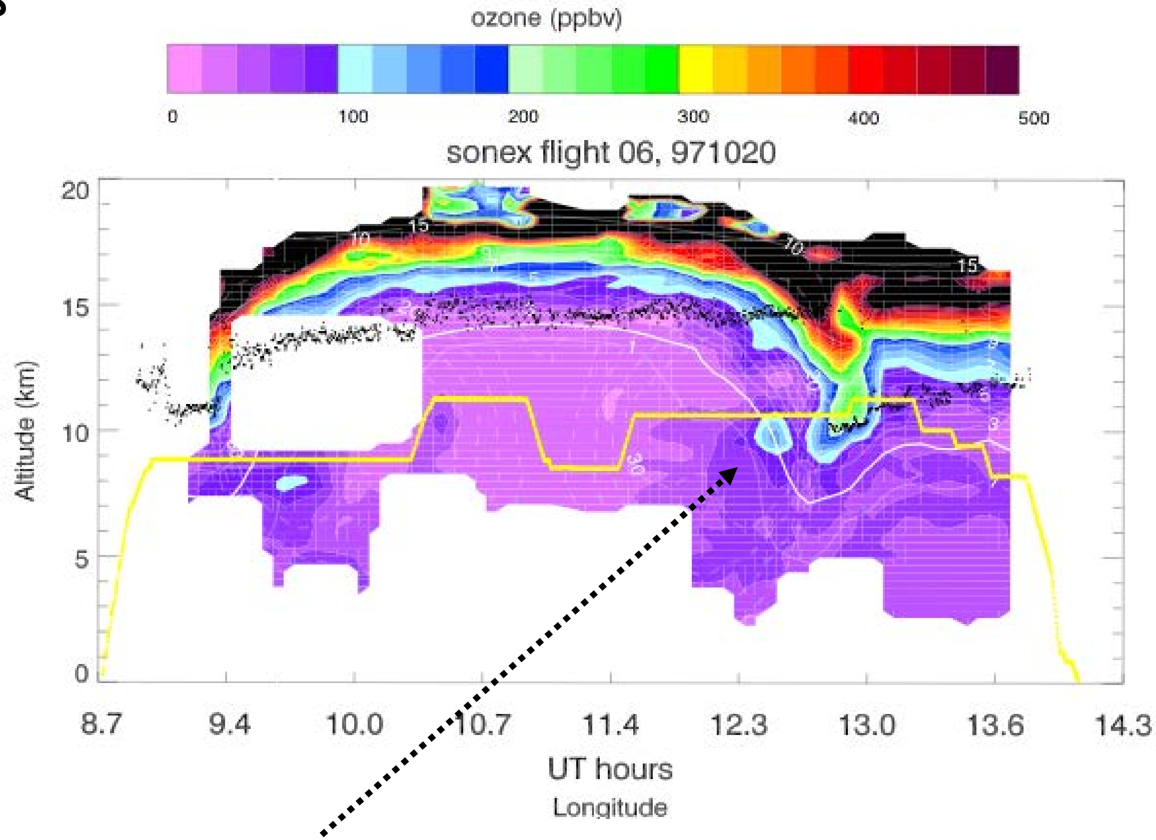


zonal wind (from analysis)

potential vorticity (from analysis)

from Pan et al., JGR, 2004

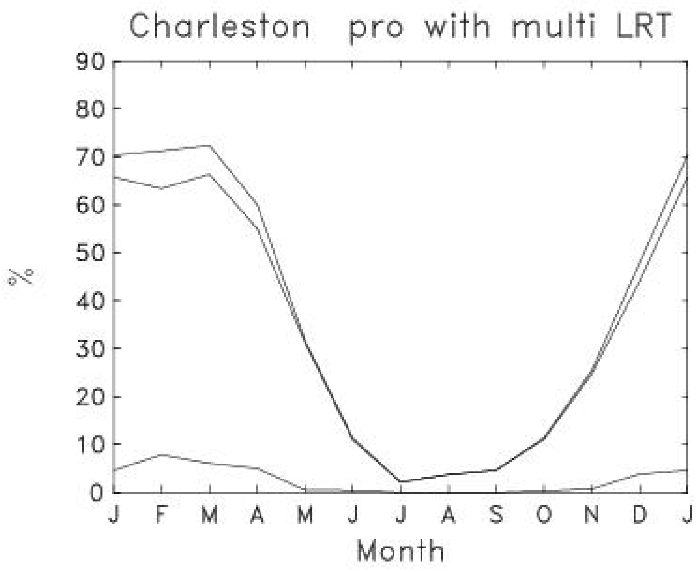
aircraft
ozone
measurements



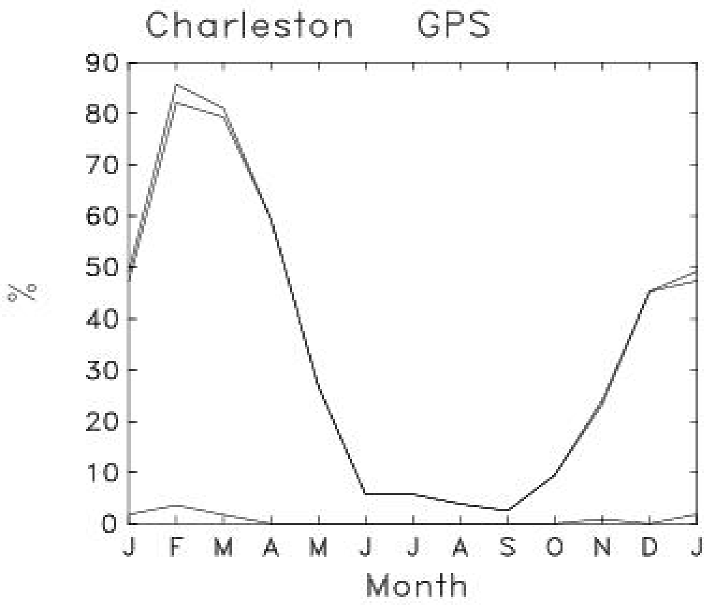
tropopause break associated
with stratospheric intrusion

seasonal variation of profiles with multiple tropopauses

radiosondes

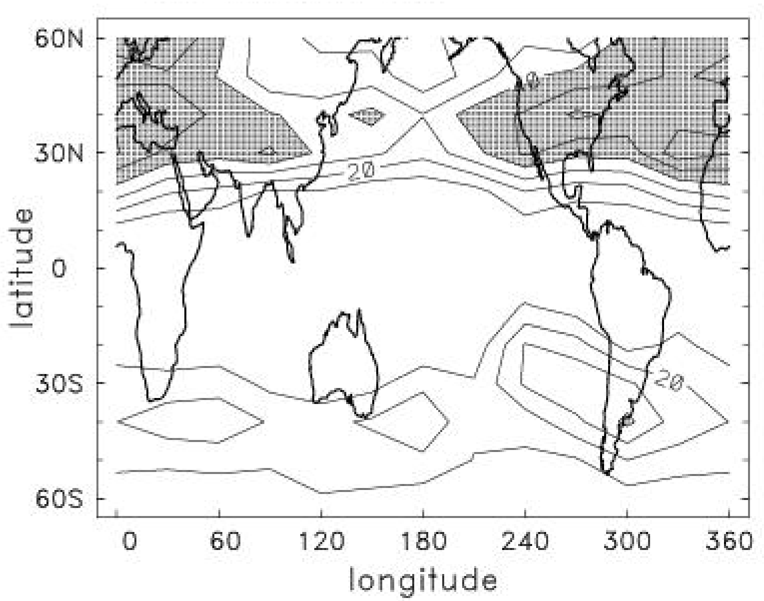


GPS



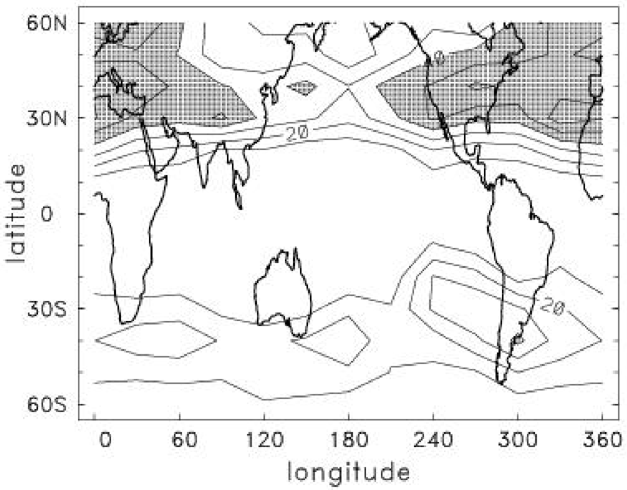
Spatial pattern of multiple tropopauses from GPS data

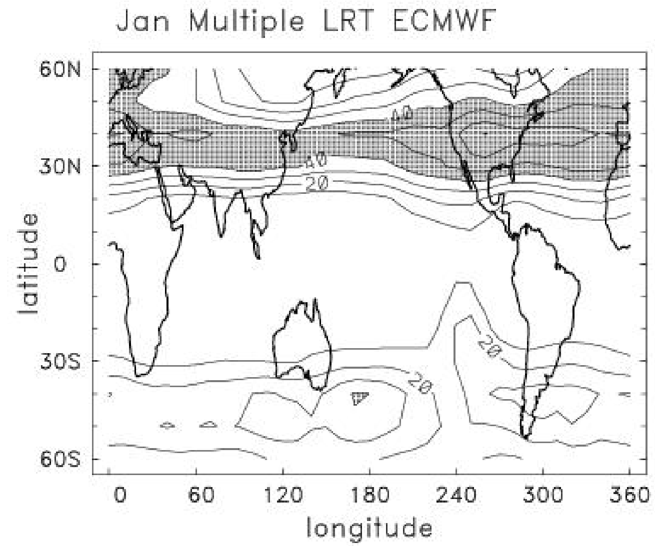
January



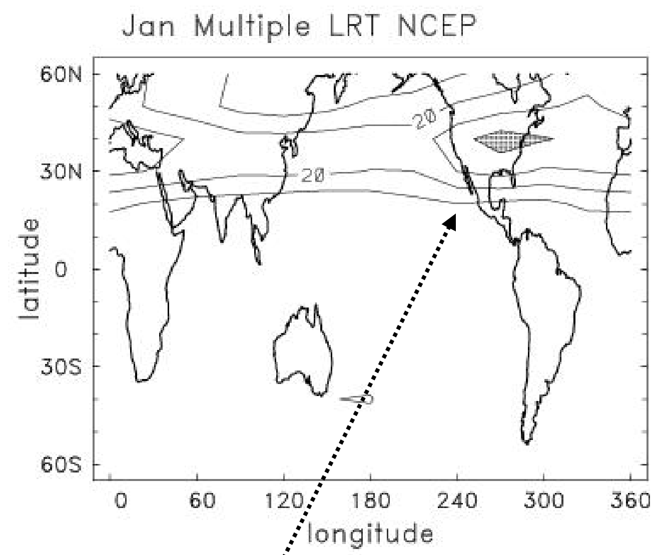
occurence of
multiple tropopauses
in January

GPS





ERA40

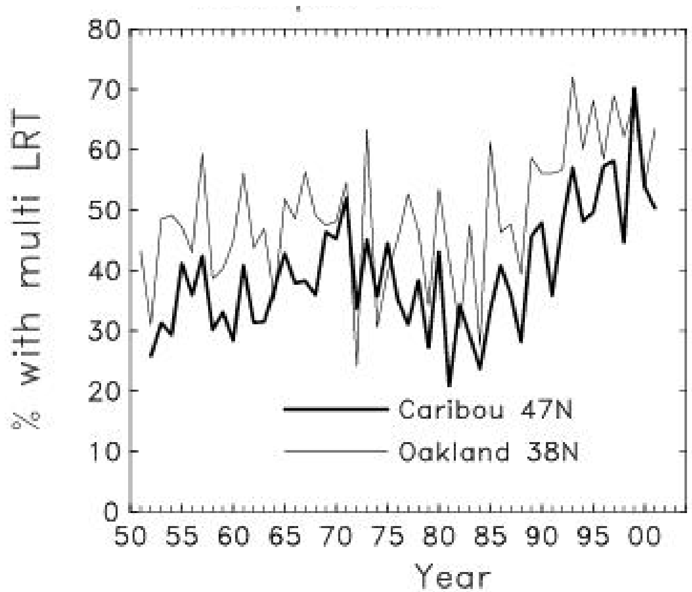


NCEP

undersampled by
lower resolution

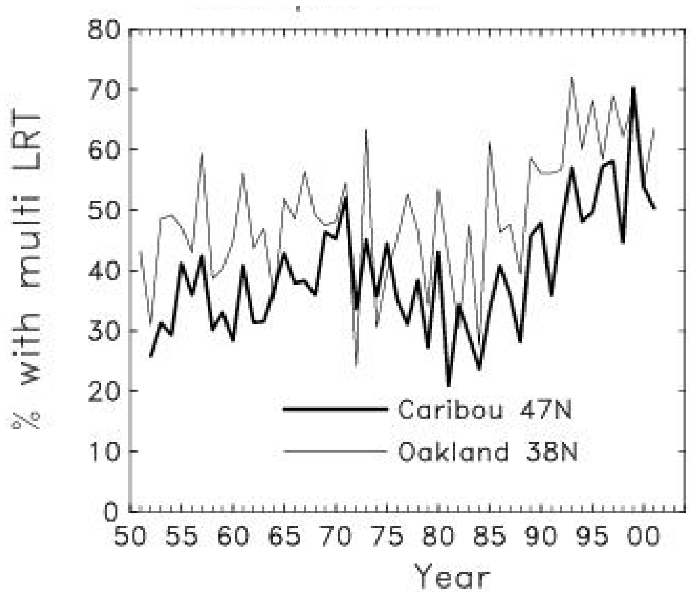
long-term variability in occurrence of multiple tropopauses

fraction of soundings with multiple tropopause

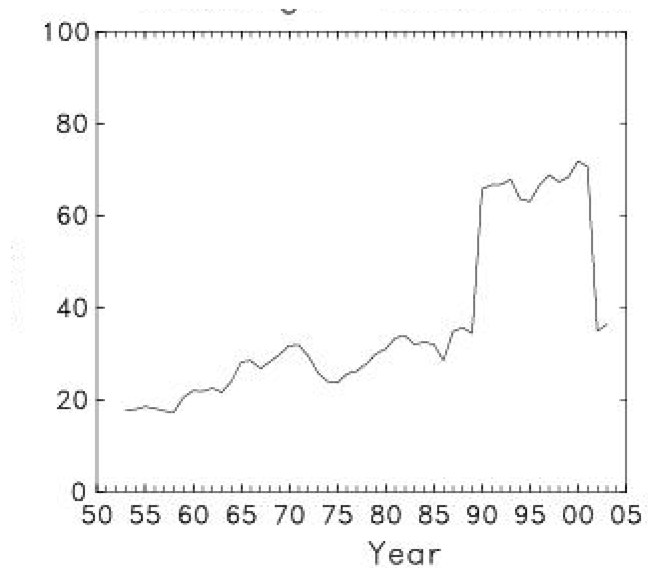


long-term variability in occurrence of multiple tropopauses

fraction of soundings with multiple tropopause



number of levels in sounding

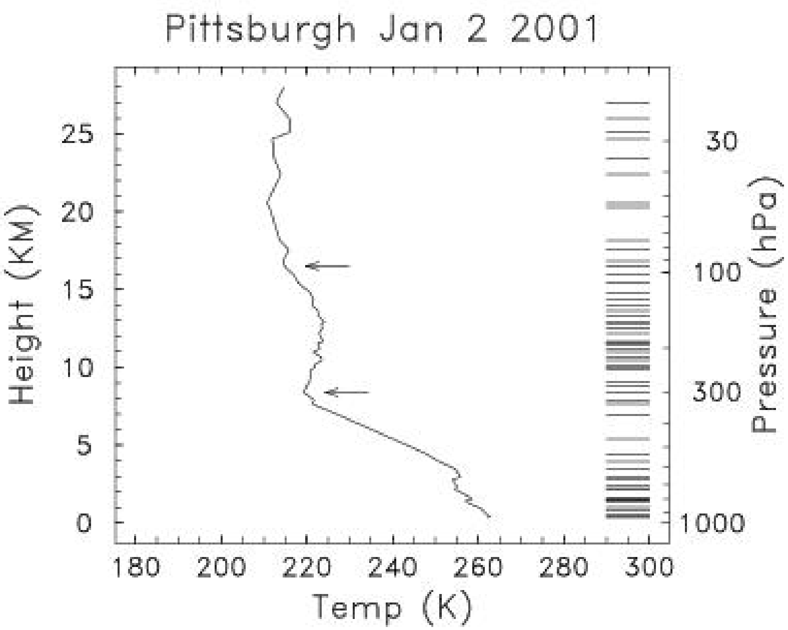


Key points:

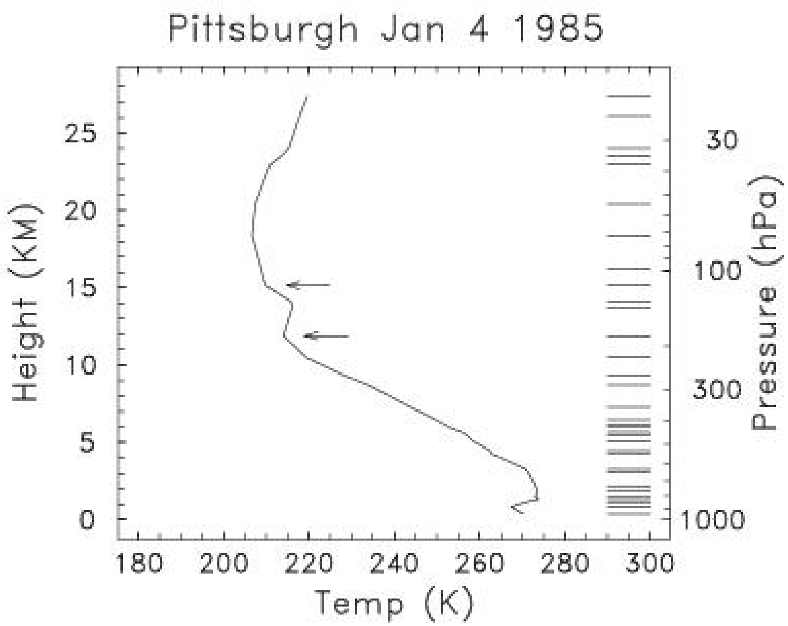
- Vertical resolution important for tropopause statistics (anticipated changes are small...0.1 km/decade)
- Similar statistics derived from radiosondes, GPS and 60-level ERA40 data (resolution ~0.5 – 1.0 km)
- Lower resolution analyses (~ 2 km) undersample variability
- Tropopause closely linked to ozone variability
- Homogenity of data records will likely influence statistics

Increased vertical resolution after ~1995

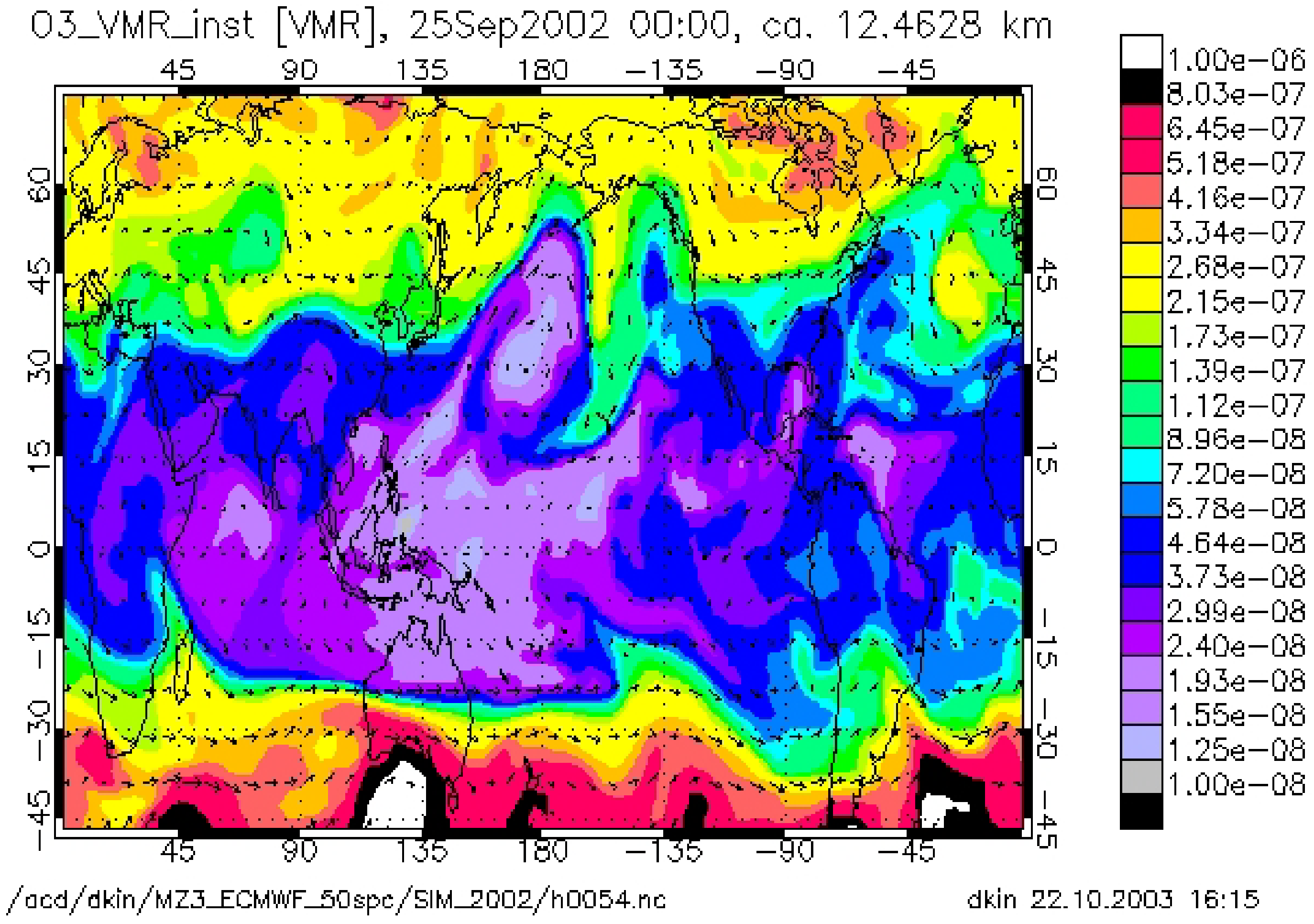
high resolution



lower resolution



12 km 'snapshot' of ozone from MOZART3



Courtesy Doug Kinnison