Mesopause waves and tides as observed by the SuperDARN network

Elsayed R. Talaat

Johns Hopkins University Applied Physics Laboratory

J. Michael Ruohoniemi, Raymond G. Greenwald

Virginia Polytechnic and State University

elsayed.talaat@jhuapl.edu

SuperDARN – new insights into mesopause activity

- Mesopause dynamics dominated by waves
  - Cause of day-to-day, seasonal, and interannual variability
  - Drivers of the mean structure of the mesosphere and lower thermosphere
- SuperDARN meteor wind analysis:
  - Daily specification of tides and planetary waves
  - De-aliasing of tidal modes
  - Non-linear interaction between planetary waves and tides
  - ***Long-term analysis of inter-annual and solar cycle variations***
    - 73-day oscillation, QBO, solar cycle, SSW
    - Six NH radars with >10 years of near continuous data are used:
      - Kapuskasing, Saskatoon, Goose Bay, Hankasalmi, Stokkseyri, Pykkvibaer

Planetary scale atmospheric waves

$$A(\varphi)\cos(s\lambda - \sigma t + mz + \phi)$$

When σ = -1, -2, … (westward diurnal, semidiurnal, …) then wave is a ***tide.***

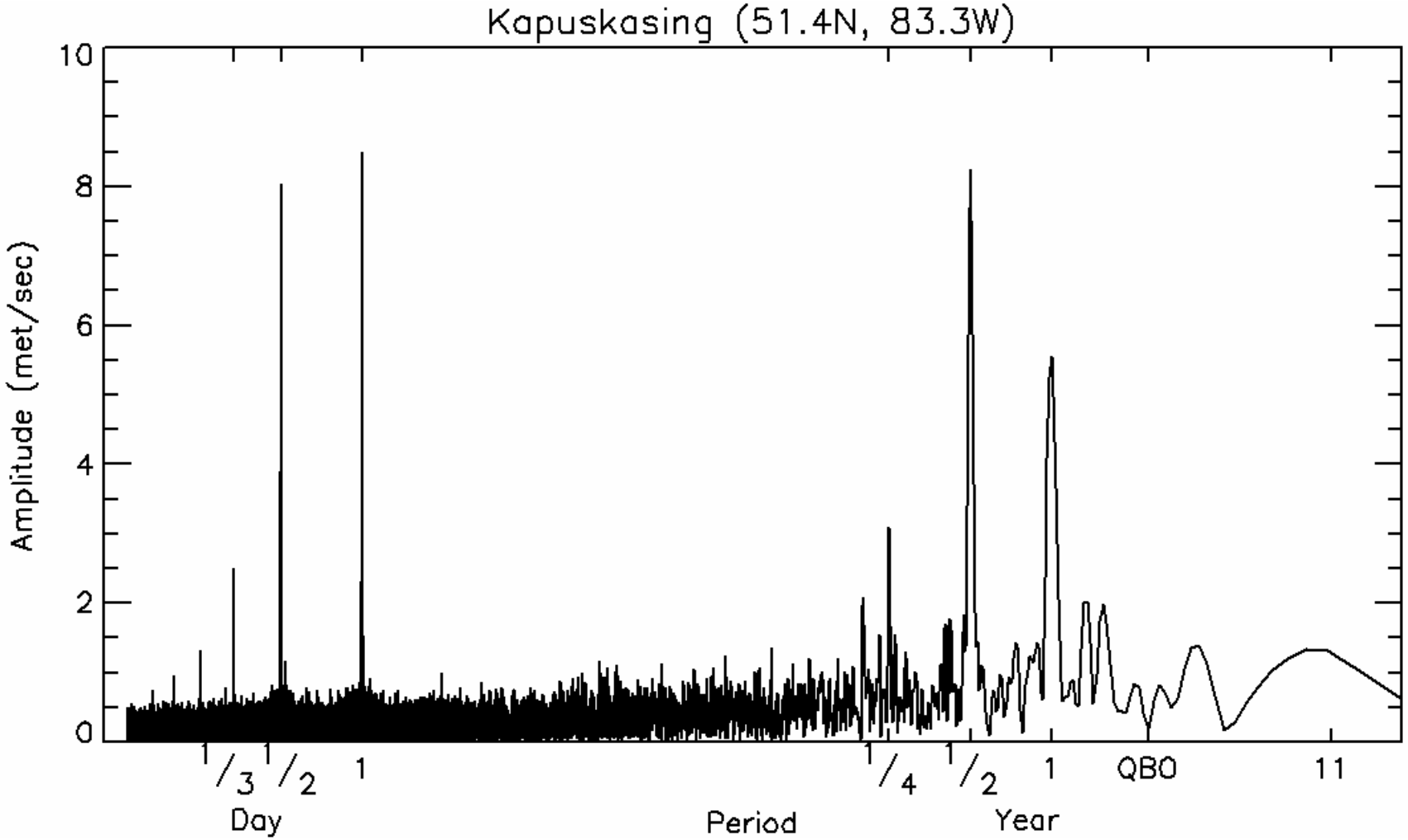
When $-\sigma = s$ then the wave is a function of local time ($t_L \equiv t+\lambda$) – this is called a ***migrating tide***.

When $\sigma = \pm 1, 2, \ldots$ but $\sigma \neq s$ then this is a ***nonmigrating tide.***

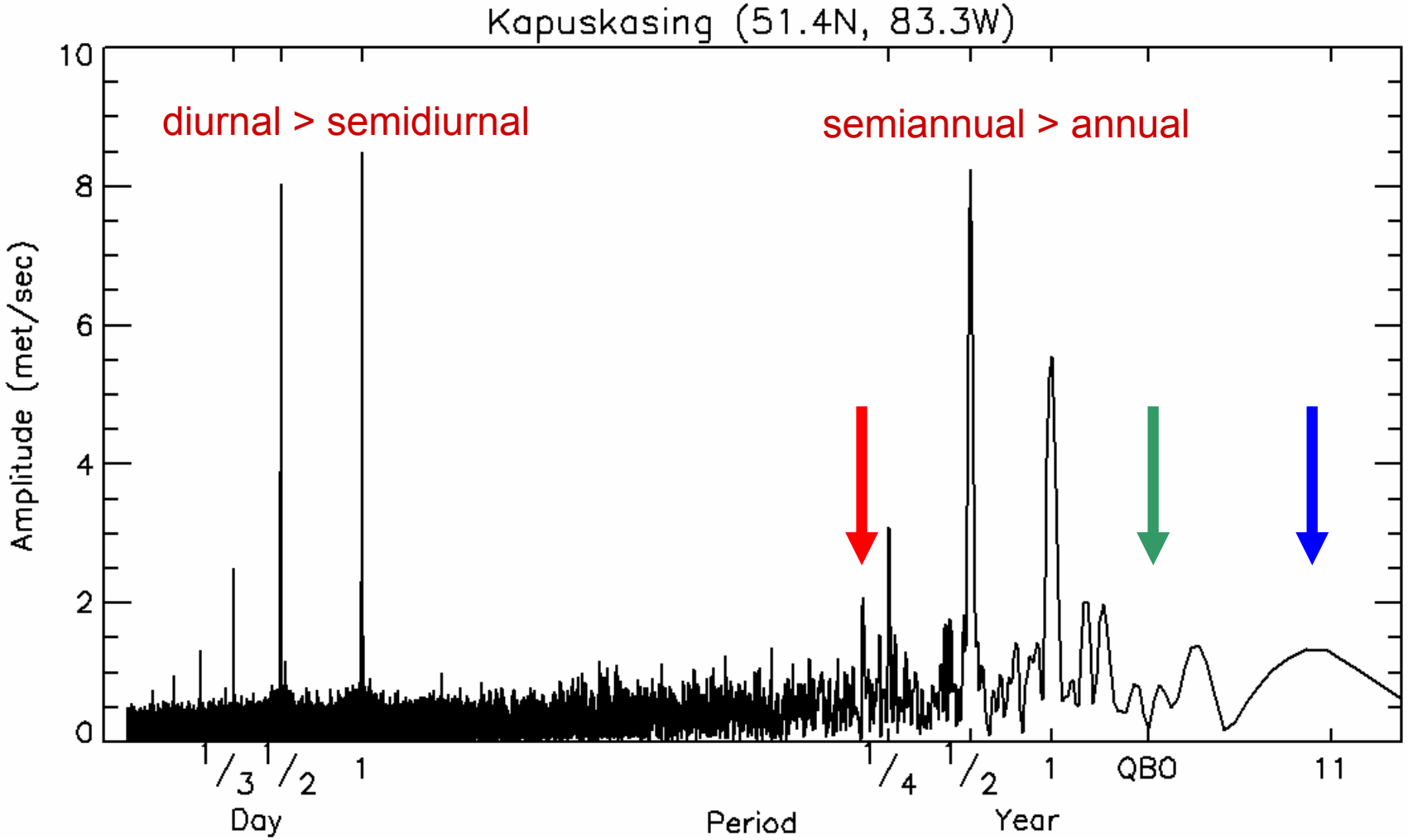
When $\sigma << 1$ and low s then wave is generally a ***planetary wave.***

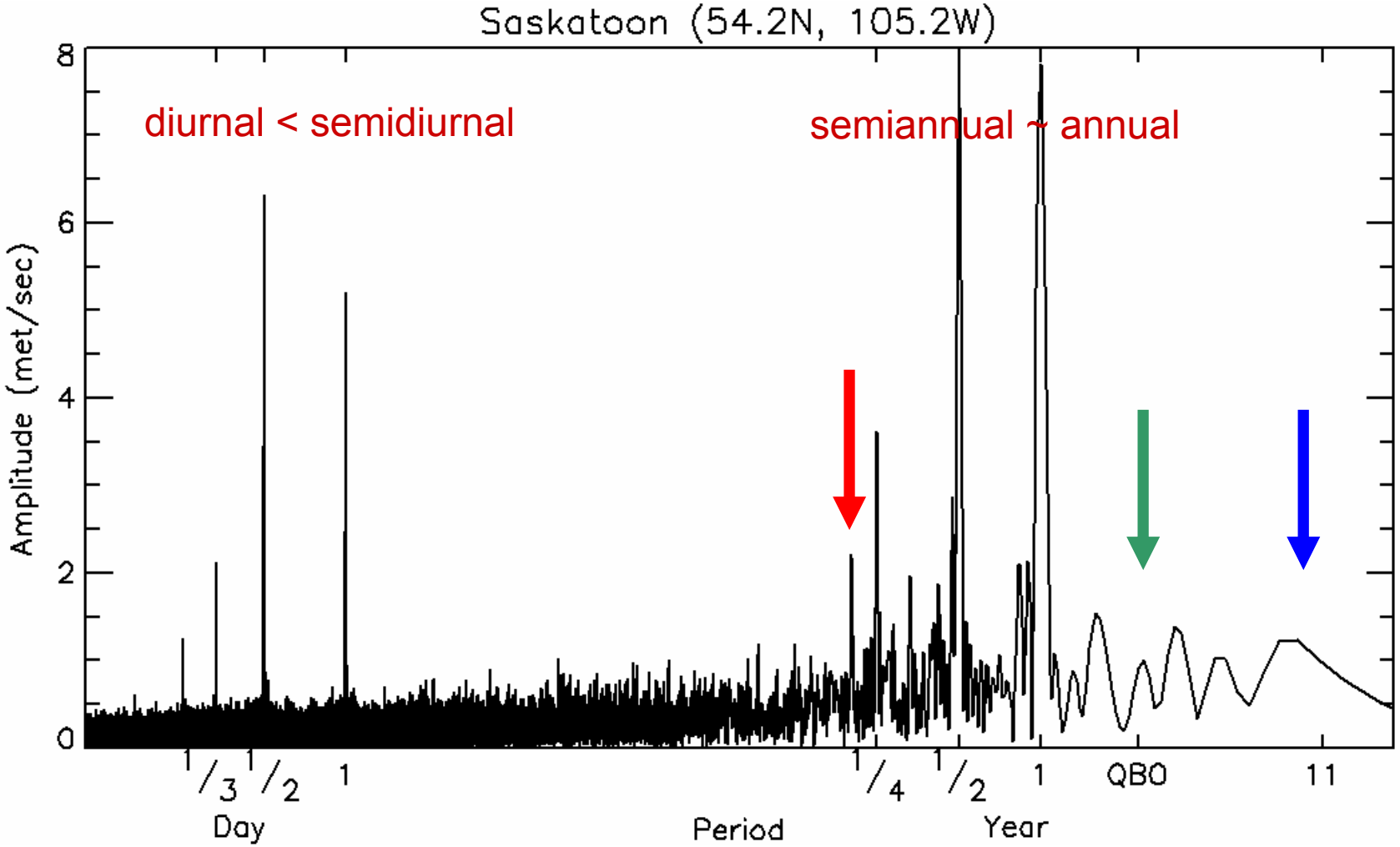
Very short period ($|\sigma| >> 1$) /short horizontal wavelength waves are generally ***gravity waves.***

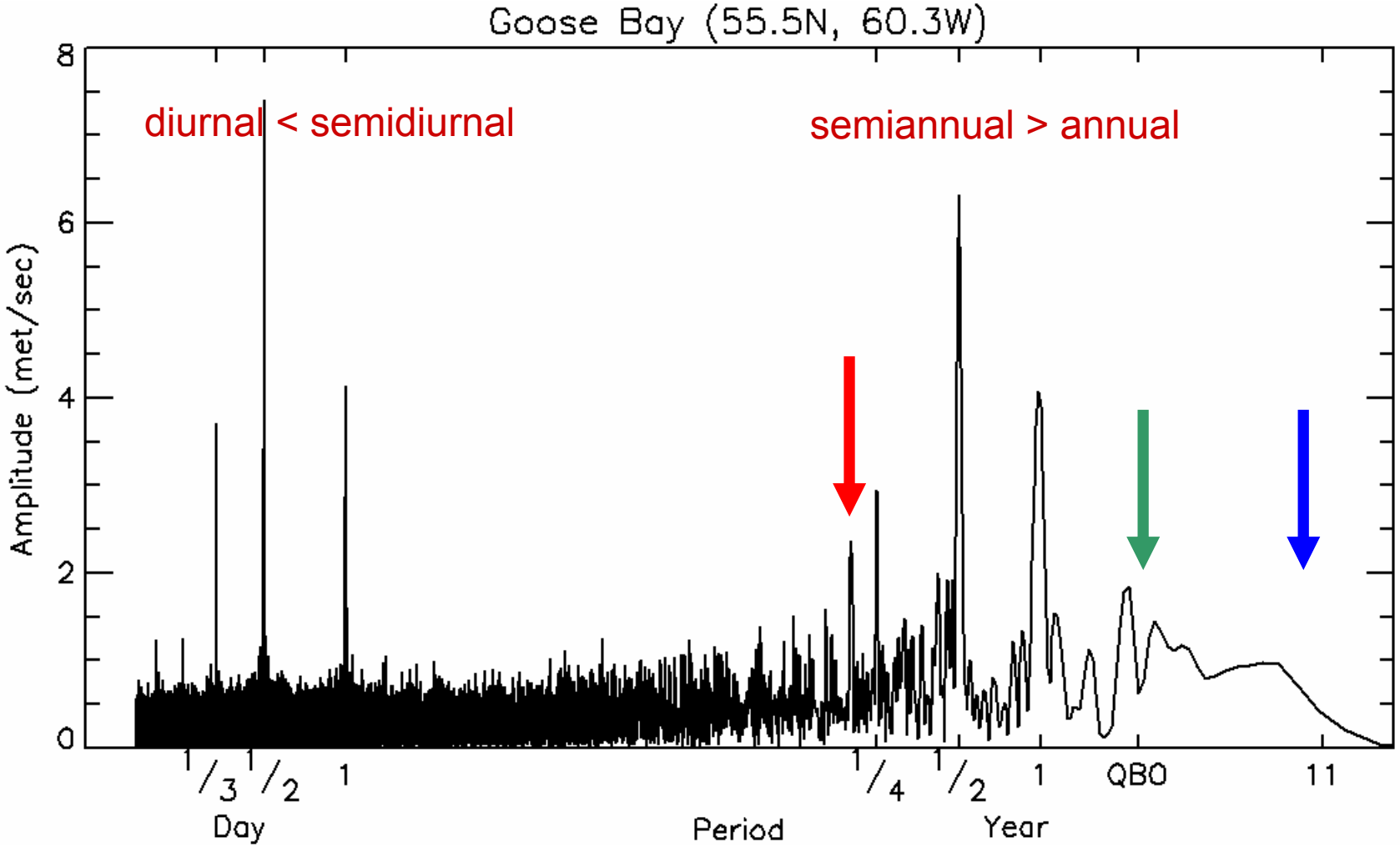
Periodicities in the meridional wind

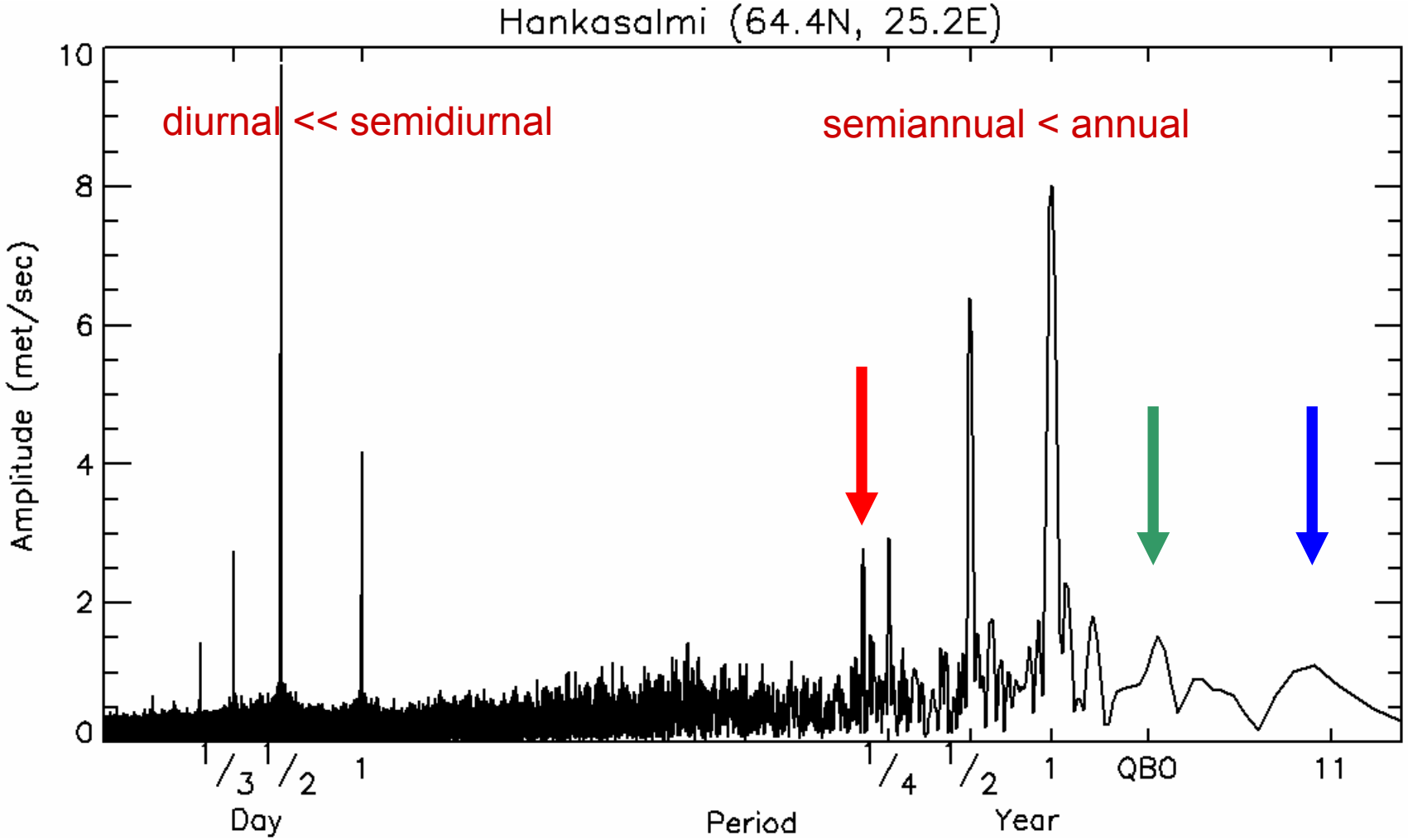


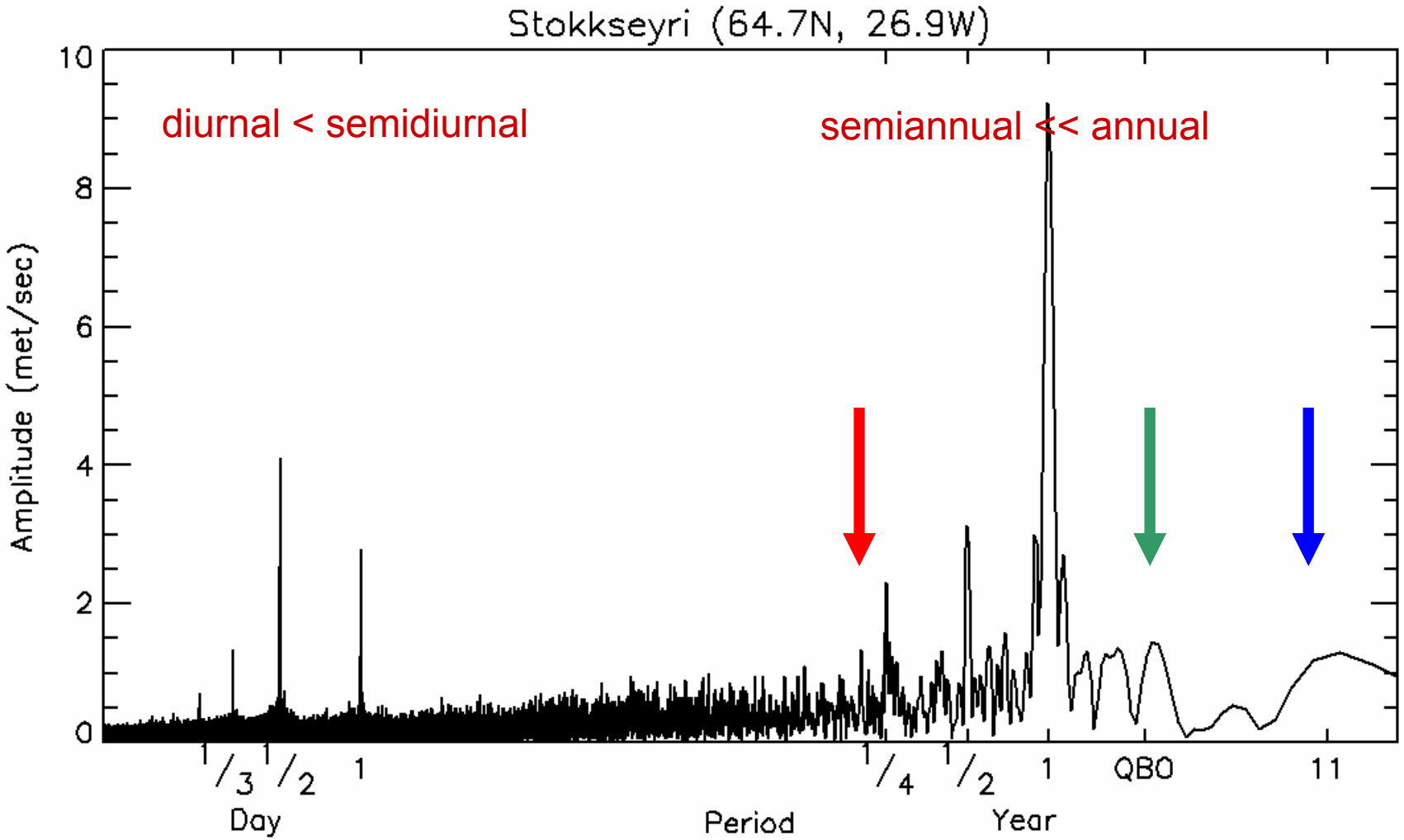
Periodicities in the meridional wind

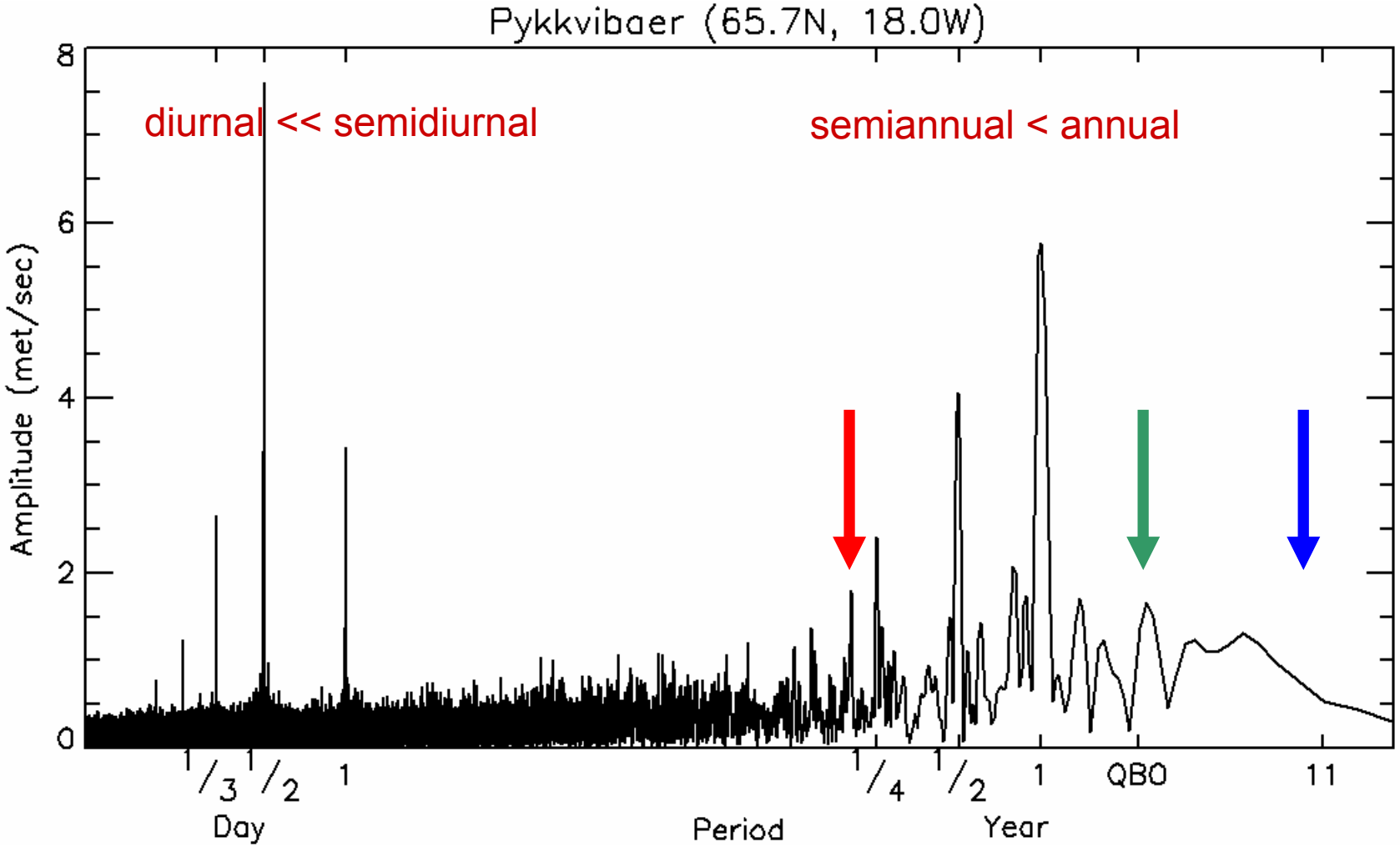



Saskatoon (54.2N, 105.2W)
diurnal < semidiurnal
semiannual ~ annual
Amplitude (met/sec)
0
2
4
6
8
1/3
1/2
1
1/4
1/2
1
QBO
11
Day
Period
Year

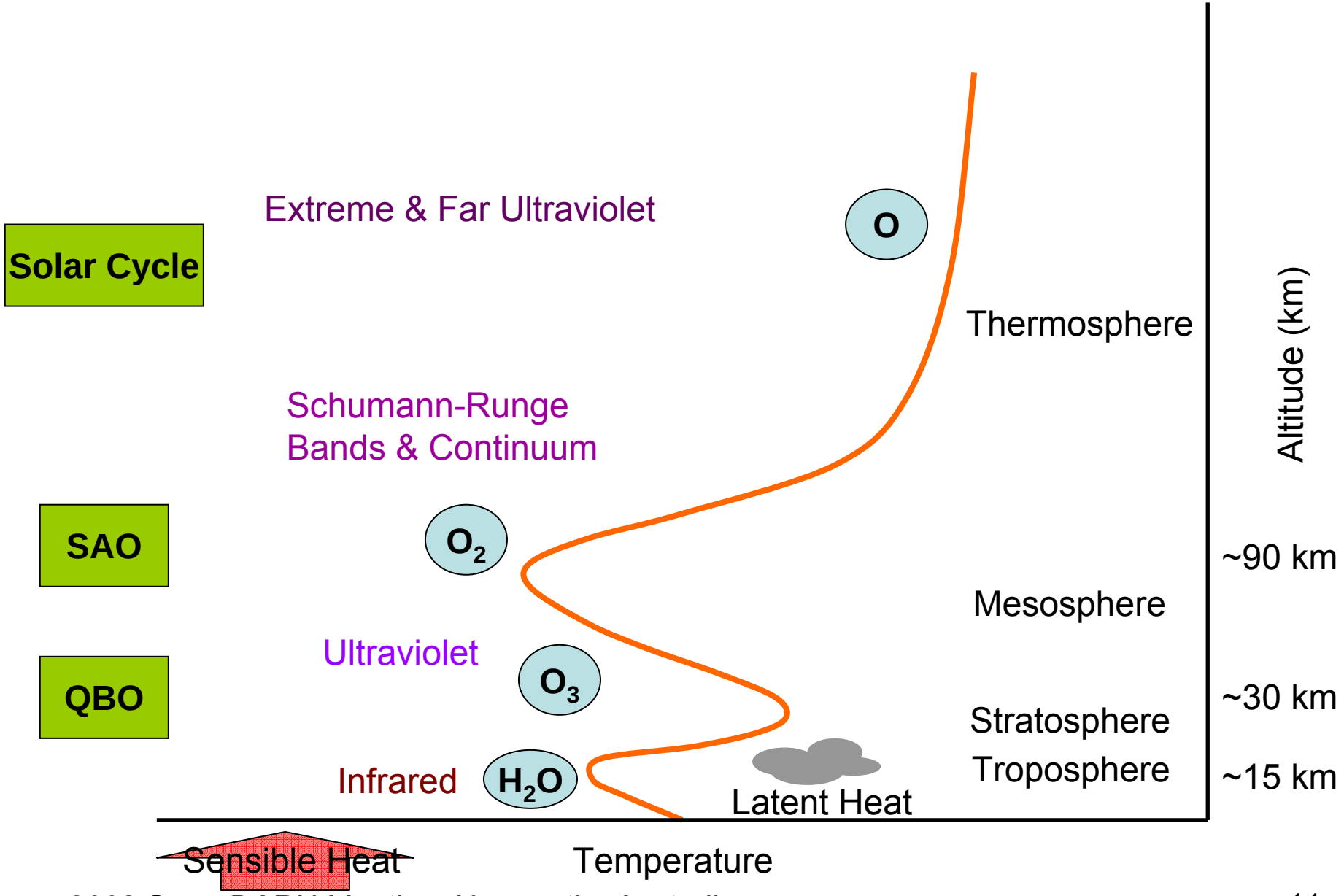

Goose Bay (55.5N, 60.3W)
diurnal < semidiurnal
semiannual > annual
Amplitude (met/sec)
8
6
4
2
0
1/3
1/2
1
1/4
1/2
1
QBO
11
Day
Period
Year

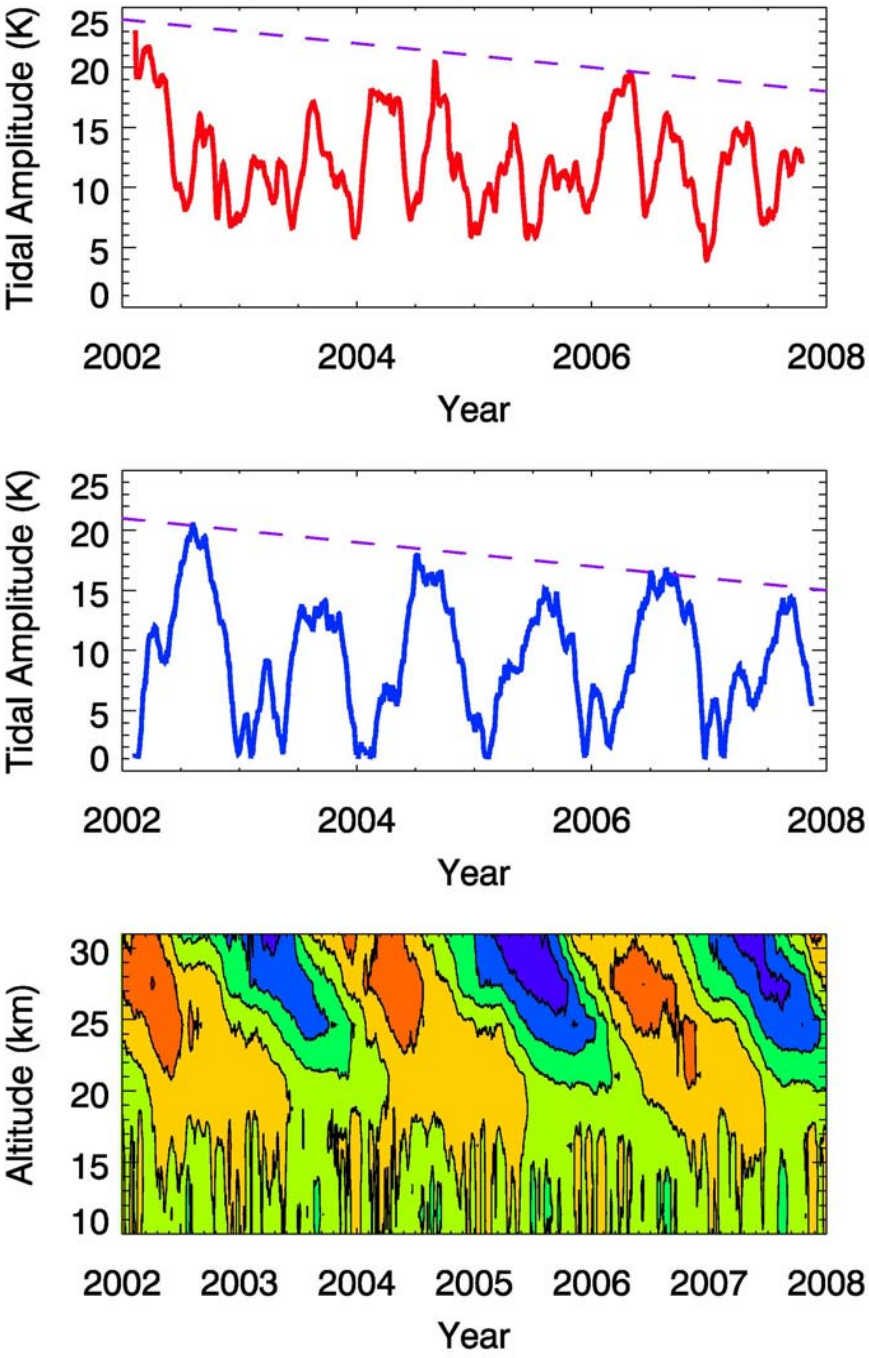

Hankasalmi (64.4N, 25.2E)
diurnal << semidiurnal
semiannual < annual
Amplitude (met/sec)
10
8
6
4
2
0
1/3
1/2
1
1/4
1/2
1
QBO
11
Day
Period
Year


Stokkseyri (64.7N, 26.9W)
diurnal < semidiurnal
semiannual << annual
Amplitude (met/sec)
10
8
6
4
2
0
1/3
1/2
1
Day
1/4
1/2
1
QBO
11
Year
Period


Pykkvibaer (65.7N, 18.0W)
diurnal << semidiurnal
semiannual < annual
Amplitude (met/sec)
0
2
4
6
8
1/3
1/2
1
Day
1/4
1/2
1
QBO
11
Period
Year

Forcing of Thermal Tides

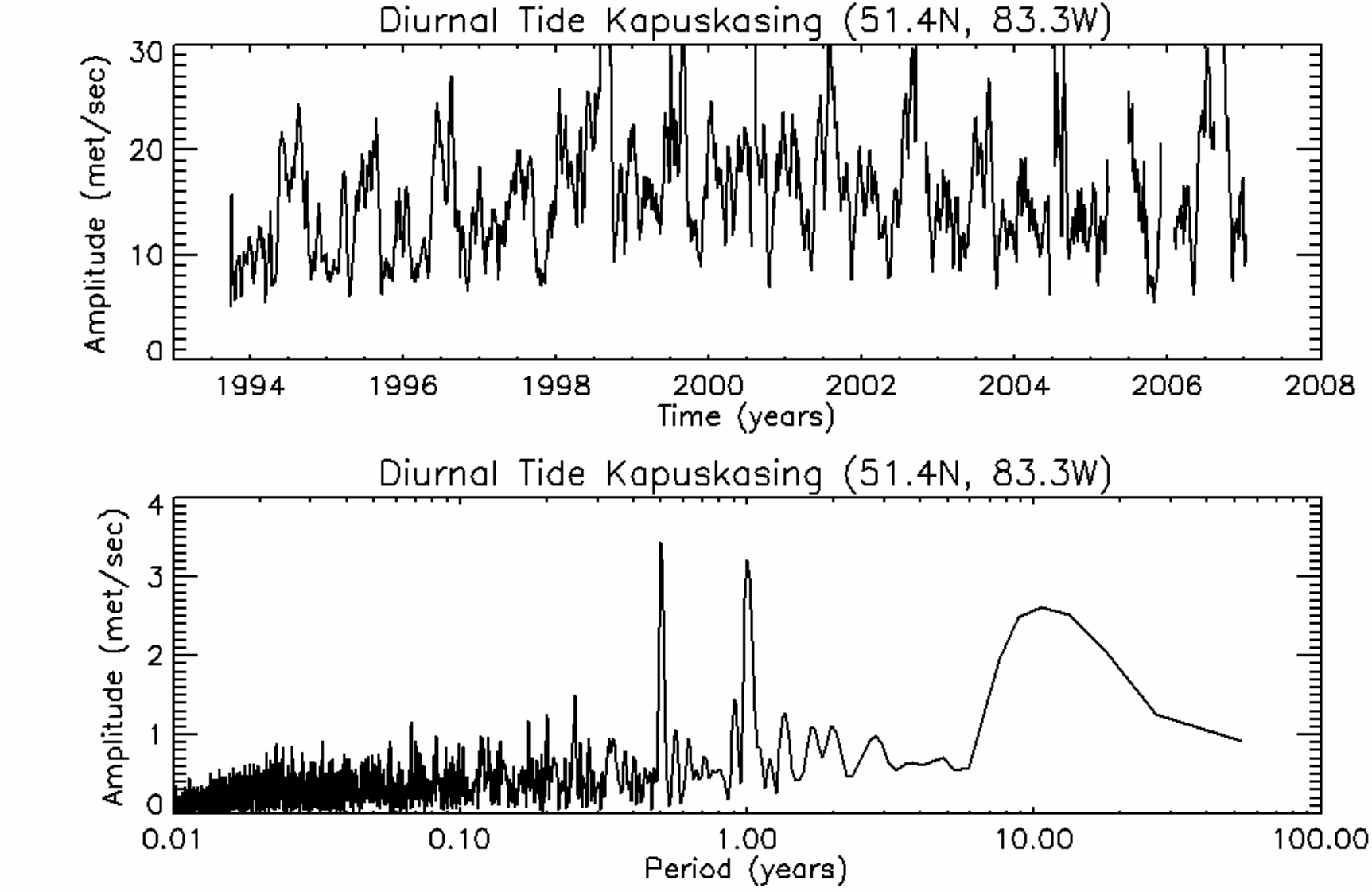




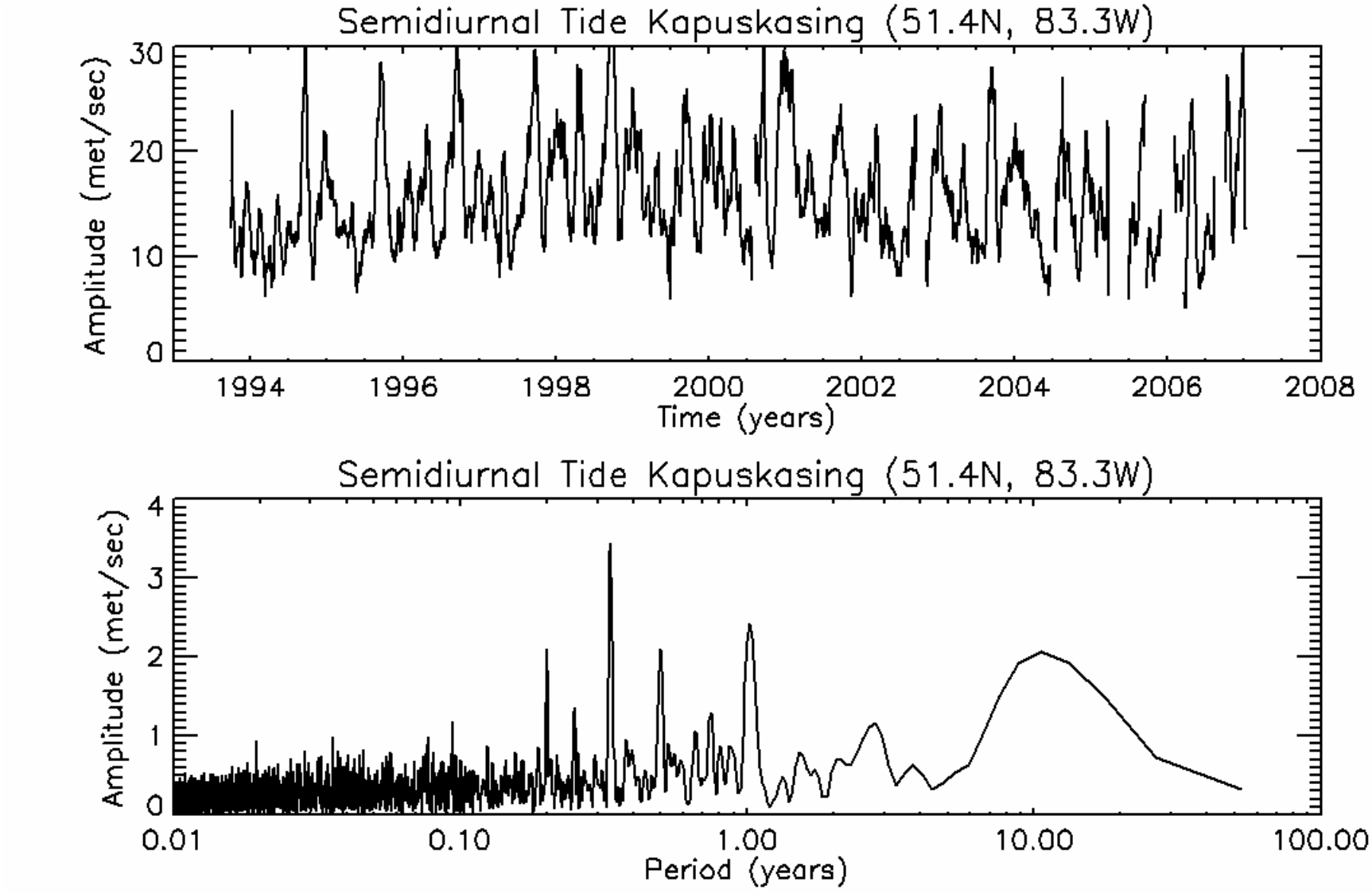
Tides from TIMED/SABER

The migrating (W1) (top) and eastward s=3 diurnal (DE3) (middle) amplitude extracted from TIMED/SABER temperatures (v1.07) at the equator at 90 km and 110 km, respectively. The suppressed amplitudes during 2003, 2005, and 2007 correspond to the westward (blue) phase of the QBO (bottom). Contours are 10 m/sec. Several other tidal modes are of secondary importance.

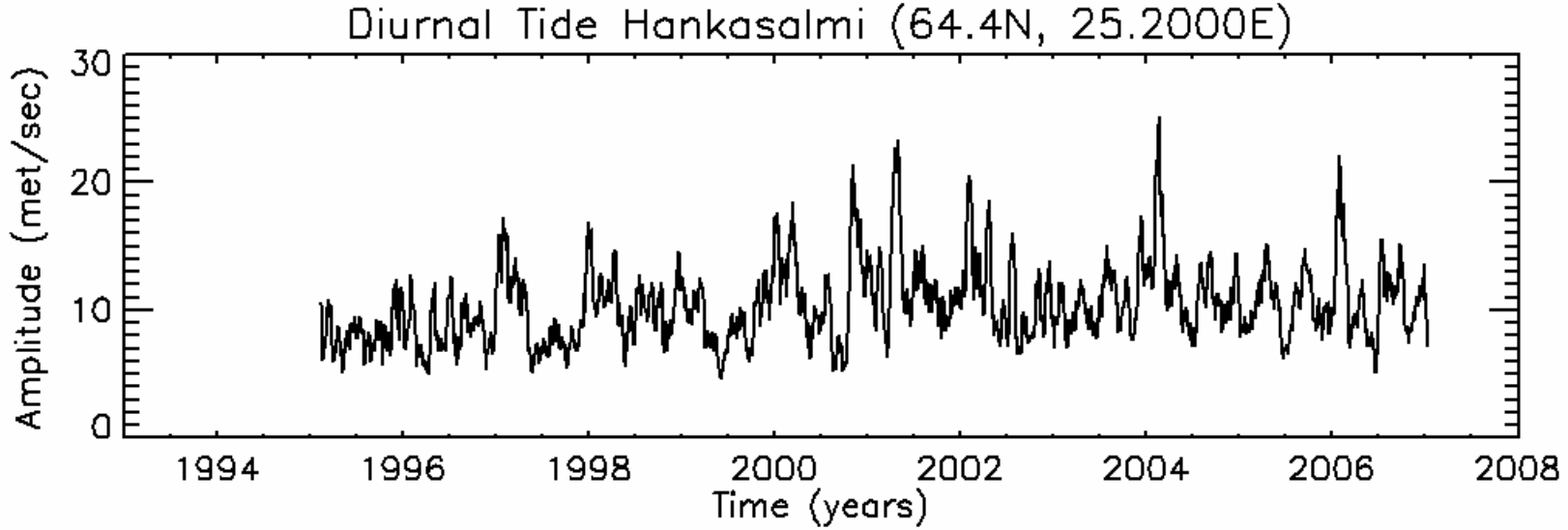
Variability at middle latitudes

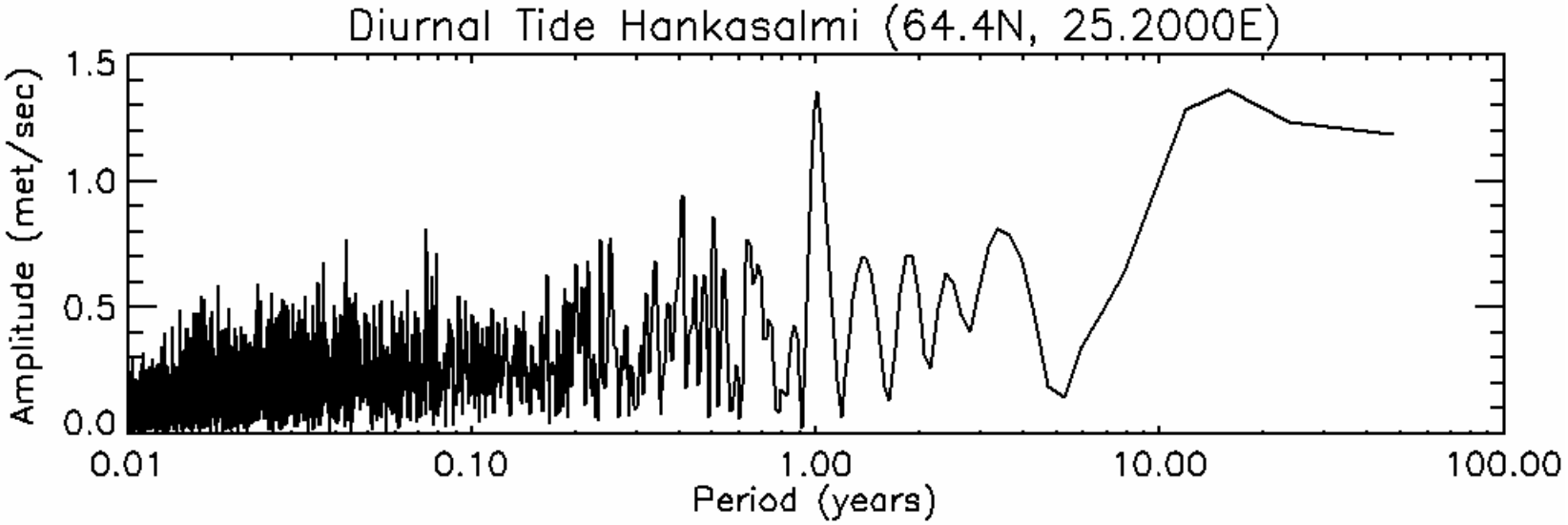


Variability at middle latitudes

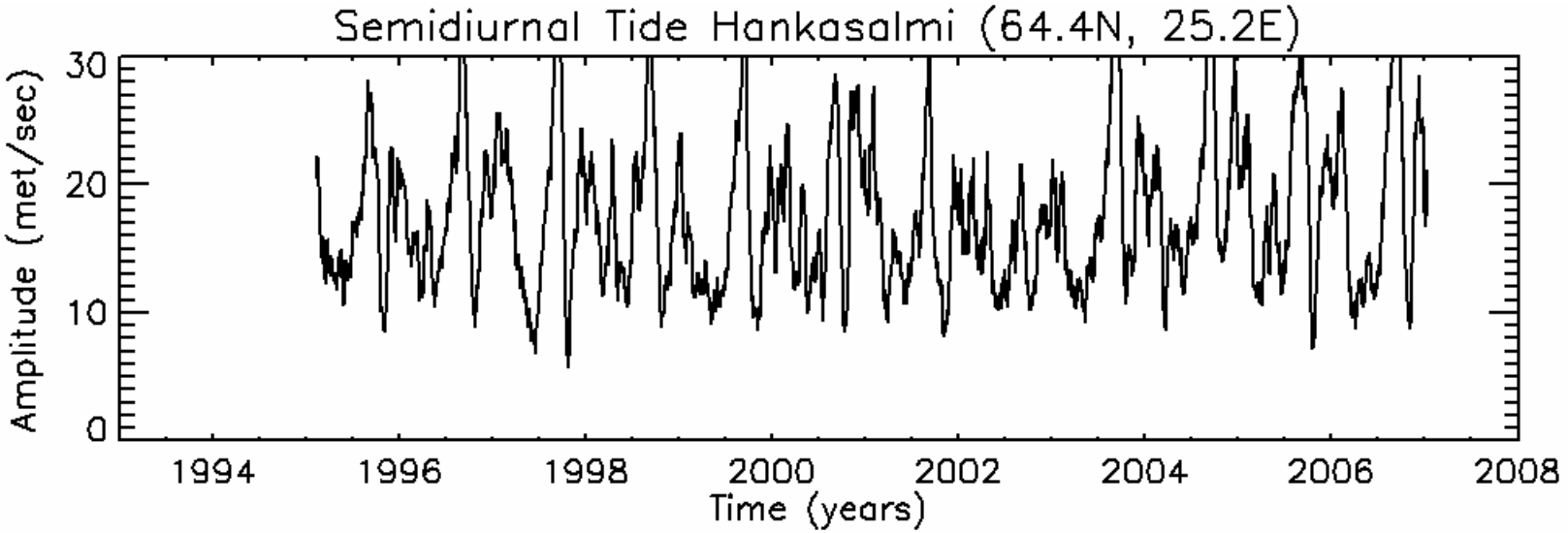


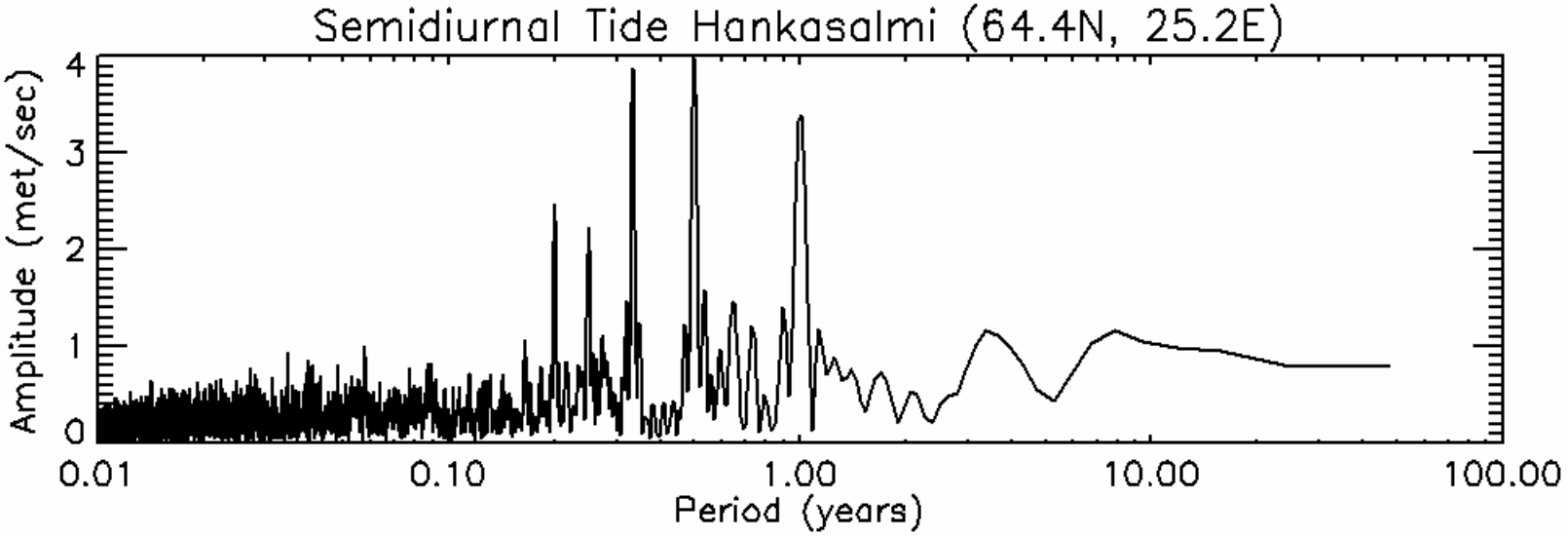
Variability at high latitudes



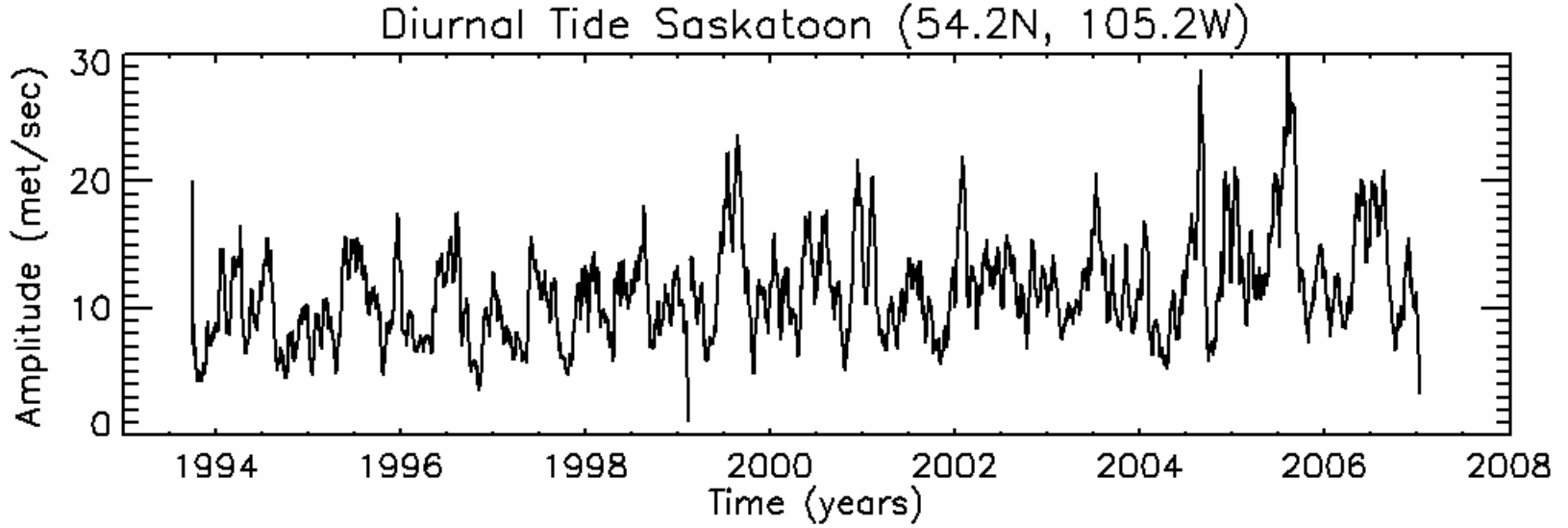


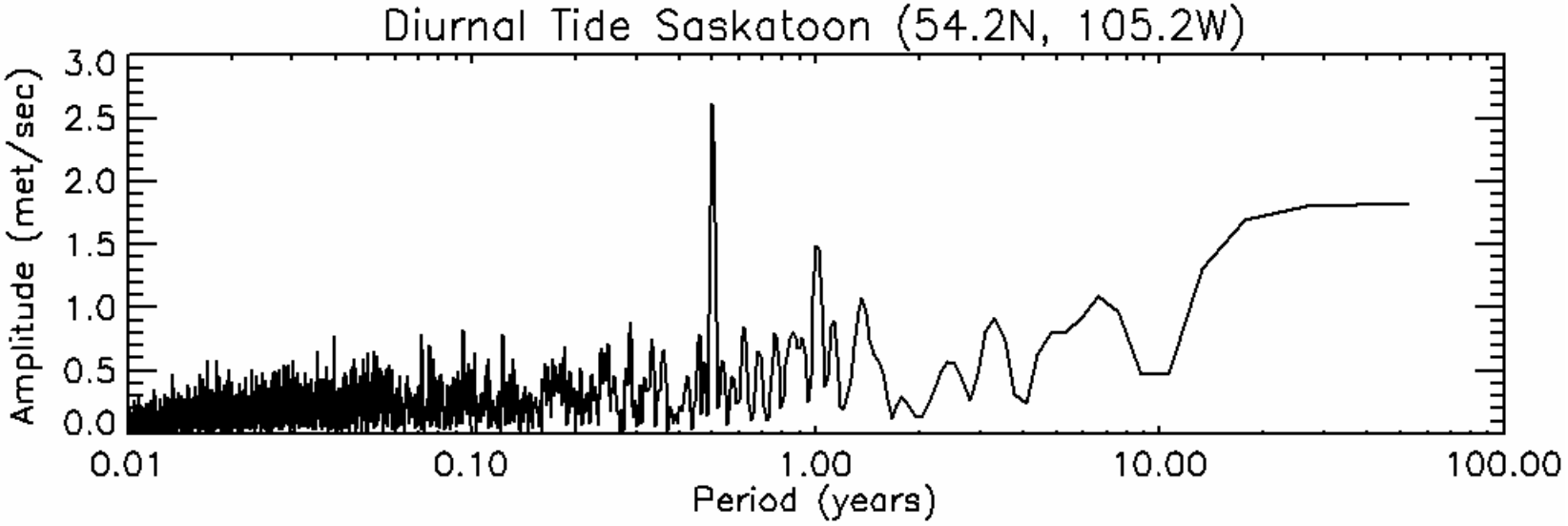
Variability at high latitudes



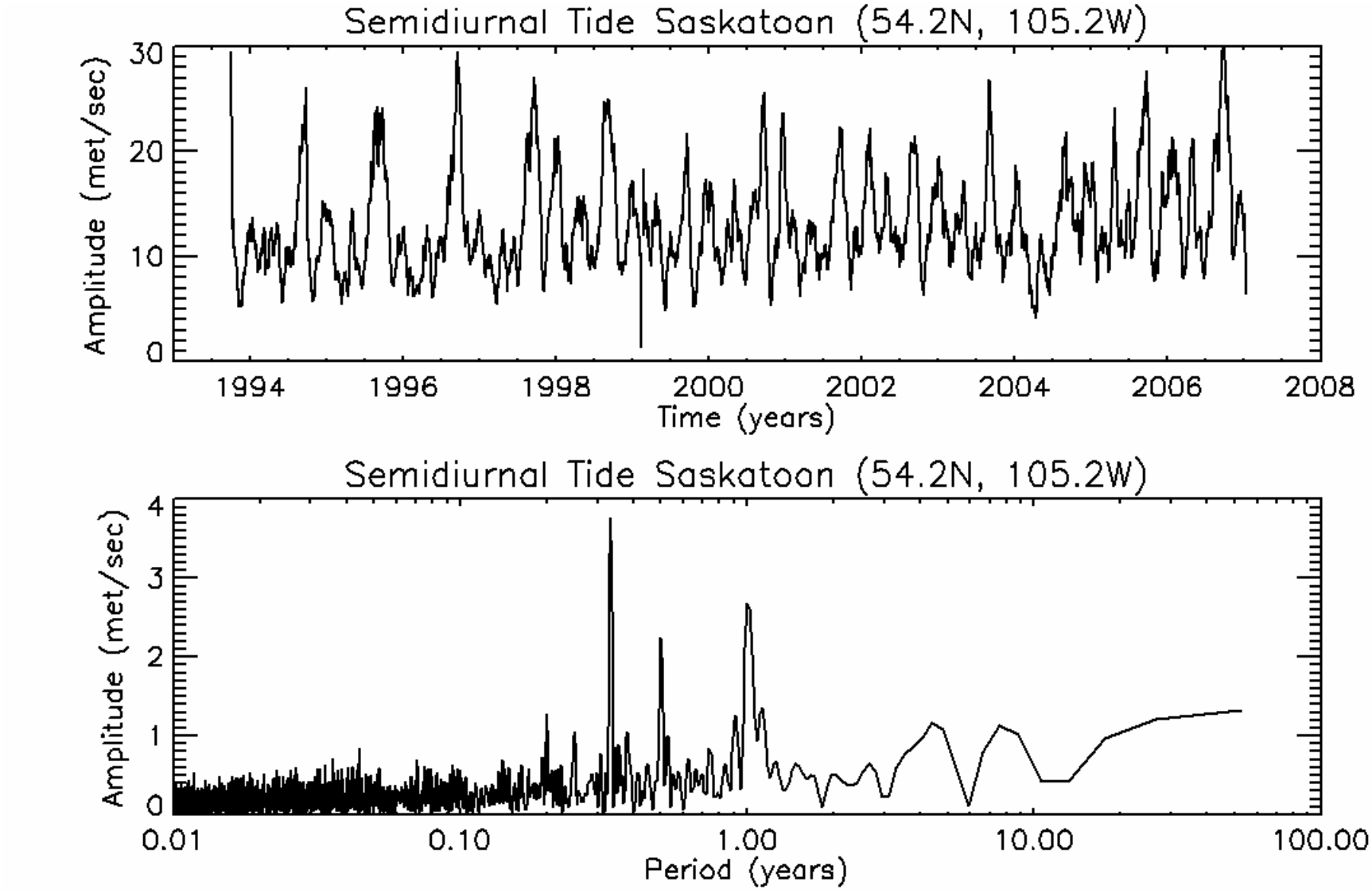


Variability – Saskatoon





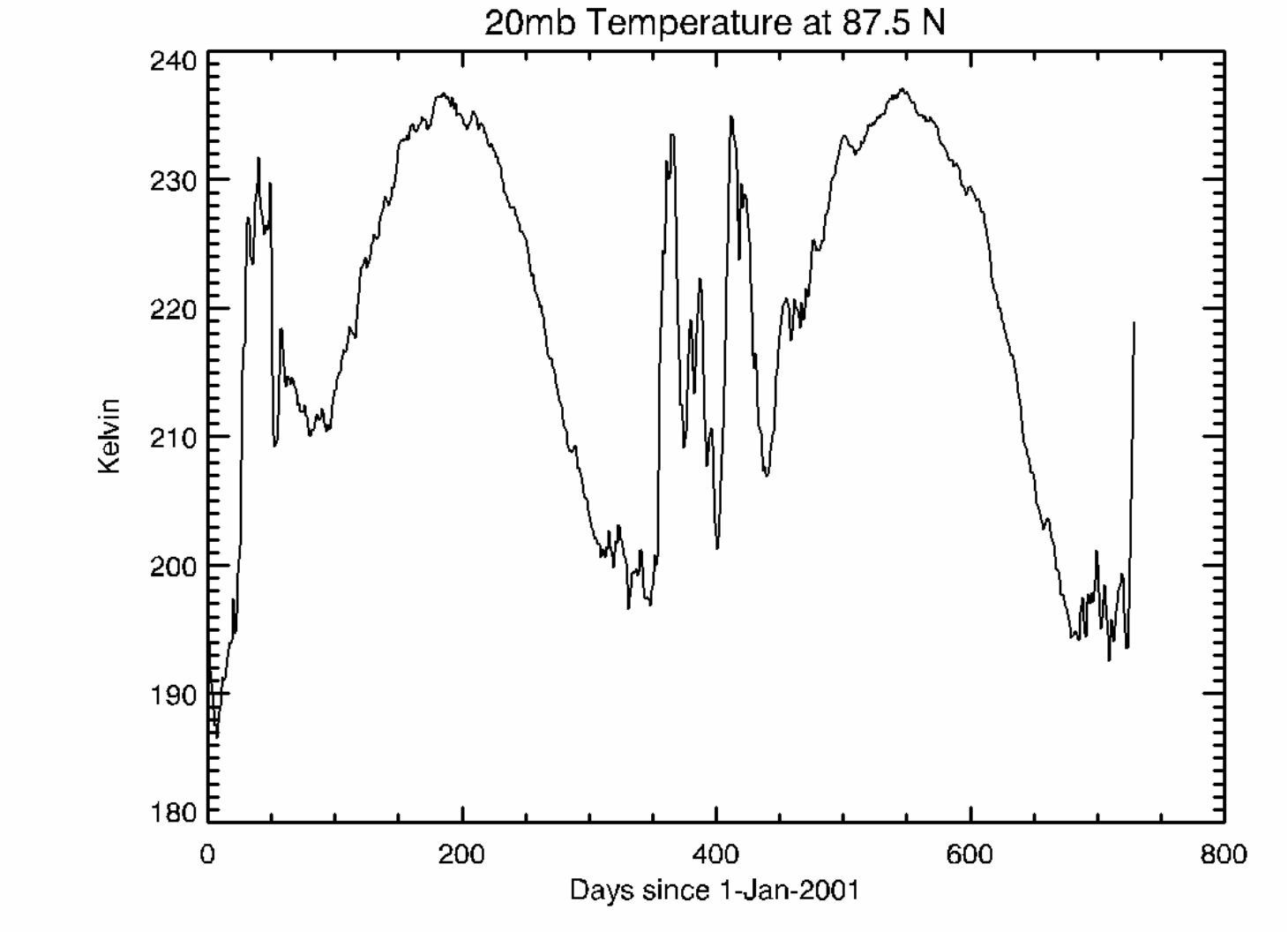
Variability – Saskatoon

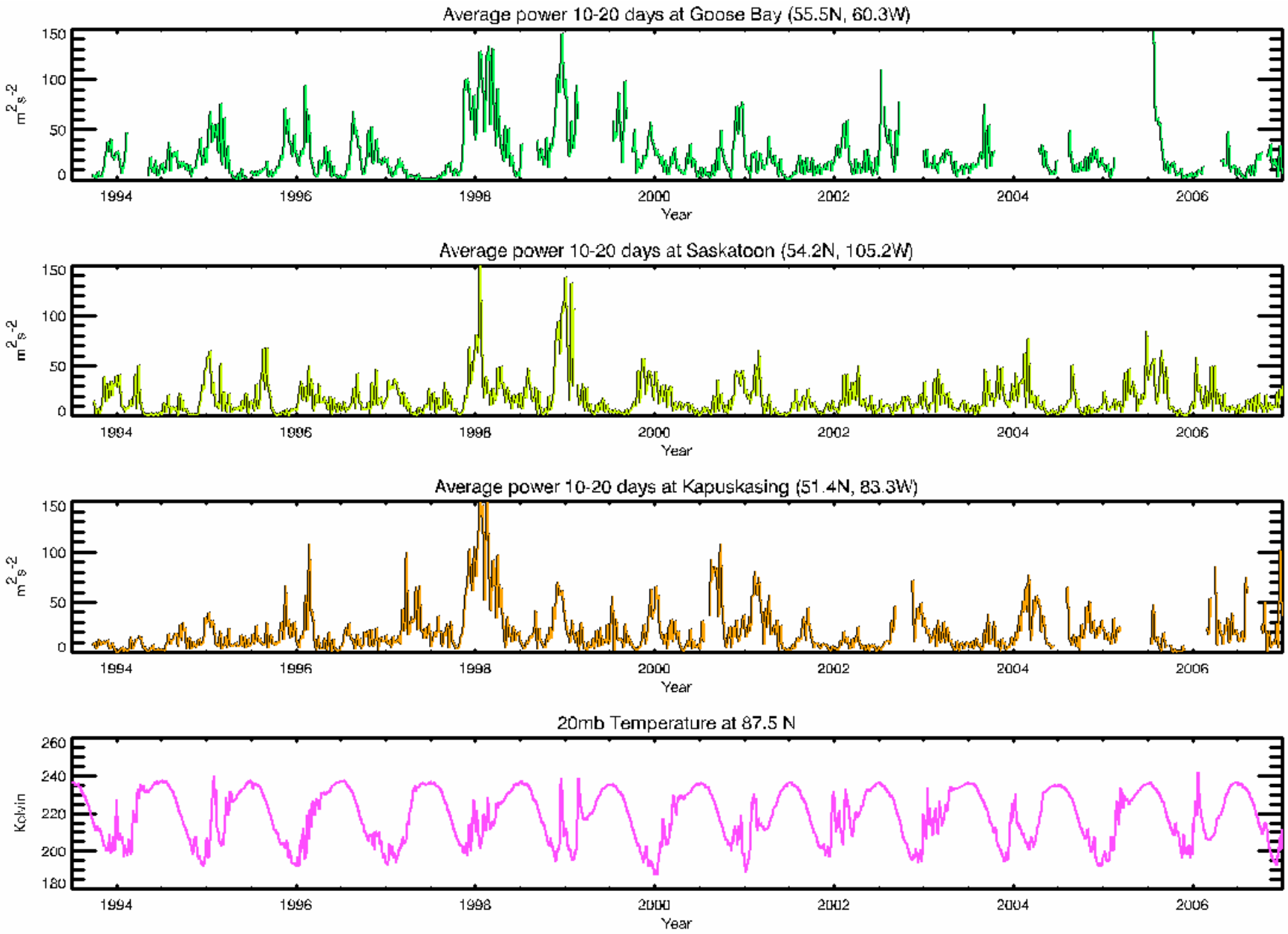


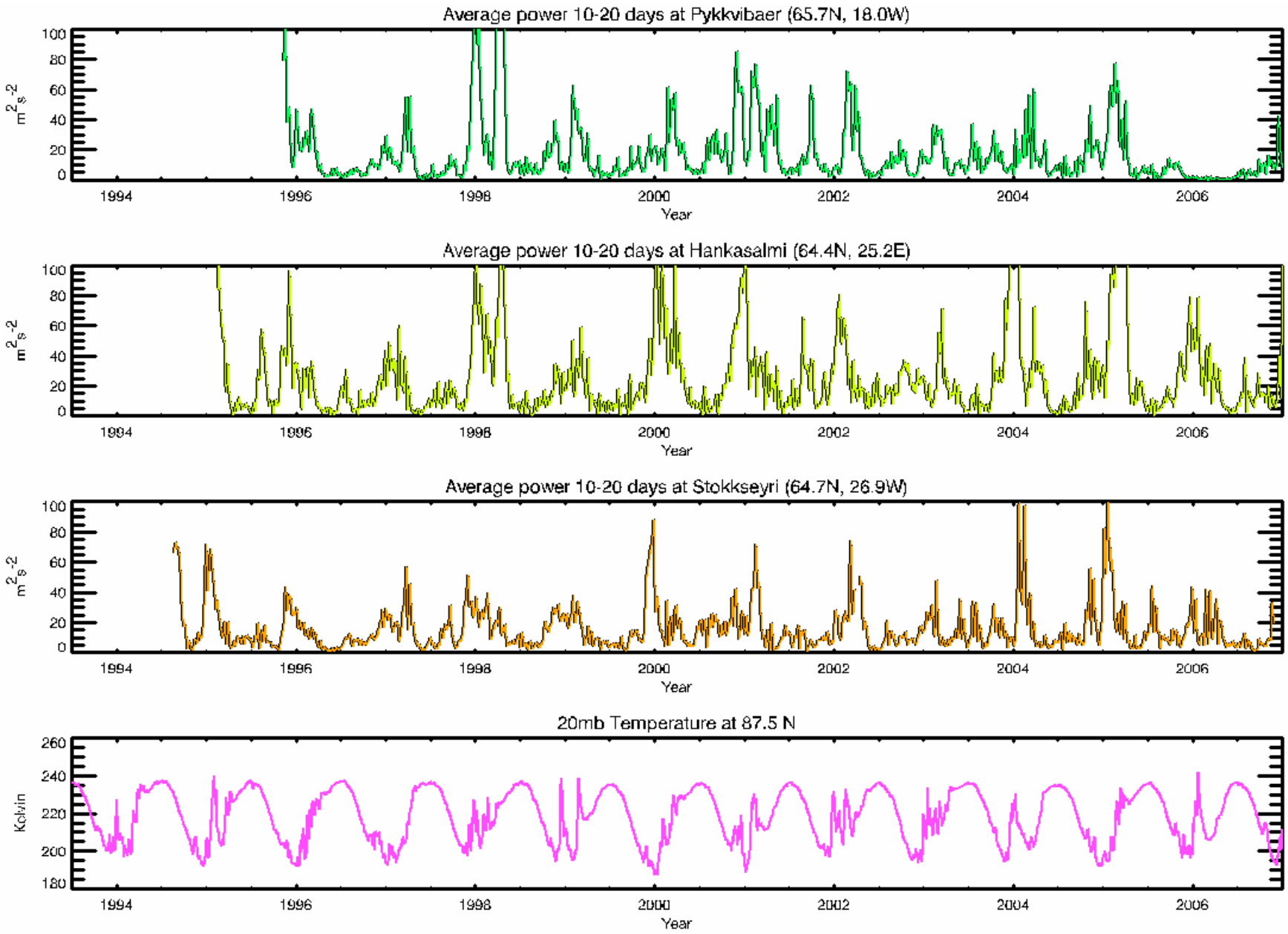
Stratospheric Warming

- Rise in stratospheric temperatures due to the associated breakdown of polar vortex winds
- Northern hemisphere has minor warmings every winter and major warmings every ~ 2 years
- Southern hemisphere rarely has major warmings
- Mesosphere and thermosphere temperature and wind response
- *Connections to low latitude QBO*
- *Planetary wave amplification and propagation*

Sudden Stratospheric Warmings




Average power 10-20 days at Goose Bay (55.5N, 60.3W)
Average power 10-20 days at Saskatoon (54.2N, 105.2W)
Average power 10-20 days at Kapuskasing (51.4N, 83.3W)
20mb Temperature at 87.5 N
m^2 s^-2
Kelvin
Year
1994
1996
1998
2000
2002
2004
2006


Average power 10-20 days at Pykkvibaer (65.7N, 18.0W)
m^2s^-2
Year
Average power 10-20 days at Hankasalmi (64.4N, 25.2E)
m^2s^-2
Year
Average power 10-20 days at Stokkseyri (64.7N, 26.9W)
m^2s^-2
Year
20mb Temperature at 87.5 N
Kelvin
Year
1994
1996
1998
2000
2002
2004
2006

Summary

- At mid- and high-latitudes, a persistent 73-day oscillation observed in the meteor winds. Also seen as a variability in semidiurnal tidal amplitudes.
- Semiannual variation is larger than annual at low-latitudes; vice versa at high-latitudes.
- Semidiurnal tide becomes the dominant tide at mid- and high-latitudes.
- Both diurnal and semidiurnal tide show evidence of solar cycle variability. Not much variation at QBO frequency.
- Significant wave activity seen during SSWs.