Long-term Observations of Middle Atmosphere Dynamics in the Southern Hemisphere
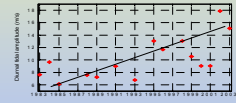
A. J. G. Baumgaertner, A. J. McDonald,
G. J. Fraser, G. Plank
Department of Physics and Astronomy,
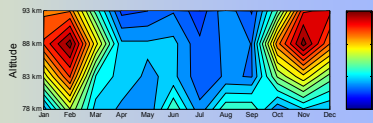University of Canterbury, New Zealand

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Outline

1. Introduction & History
- Instruments and their history
- Datasets
- Analysis techniques

2. Climatology
- Zonal and Meridional winds
- Tides

3. Interannual variations
- Statistical techniques overview
- Initial results

4. Future Work

5. Conclusions

Introduction

The instruments: Medium Frequency (MF) Radars, using the Partial Reflection Spaced Antenna Wind Technique

Locations:
- ☐ Scott Base: 78° S, 167° E, Antarctica
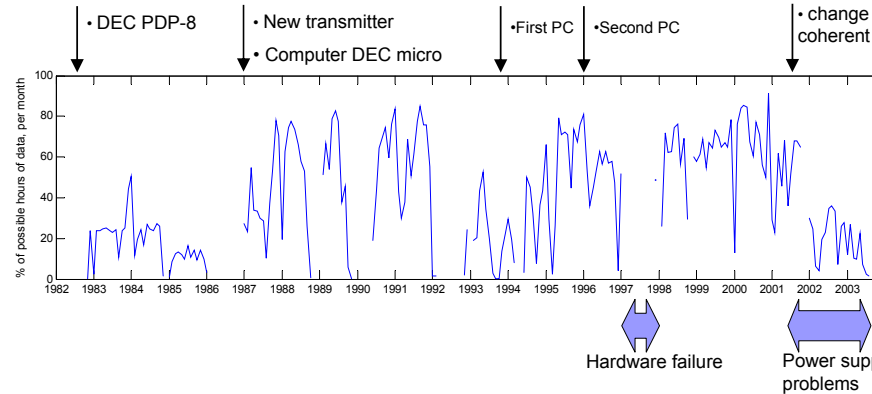- ☐ Christchurch: 44° S, 172° E, New Zealand

Operating frequencies:
- ☐ Scott Base: 2.9 MHz (wavelength 103 m)
- ☐ Christchurch: 2.4 MHz (wavelength 125 m)

The datasets
- ☐ Scott Base: 1982 – 2004
- ☐ Christchurch: 1978 – 2003 available (operation since 1964; 1970 – 1978 can be recovered)
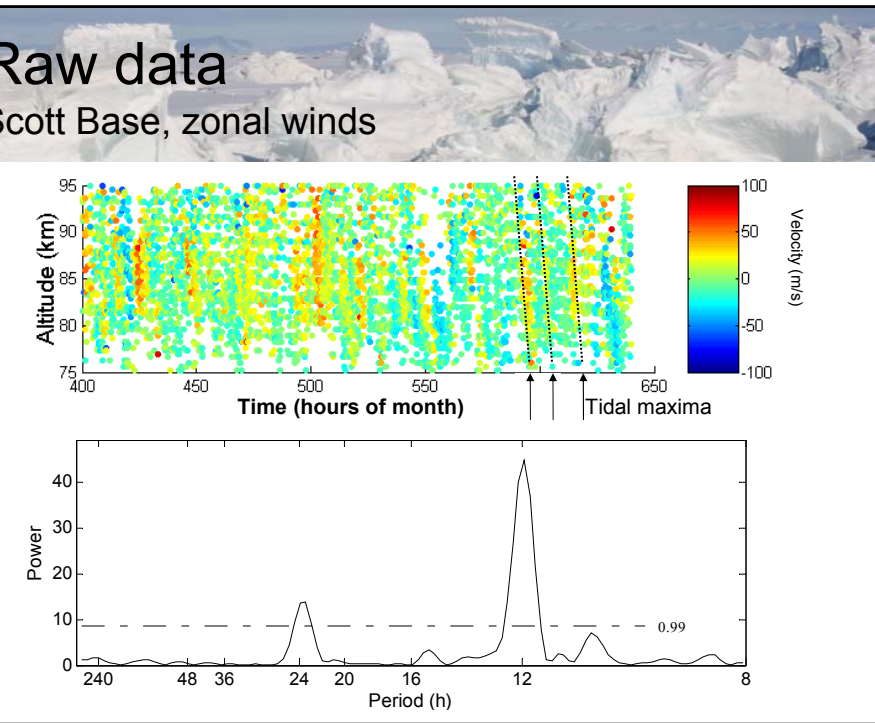
History of the Scott Base radar

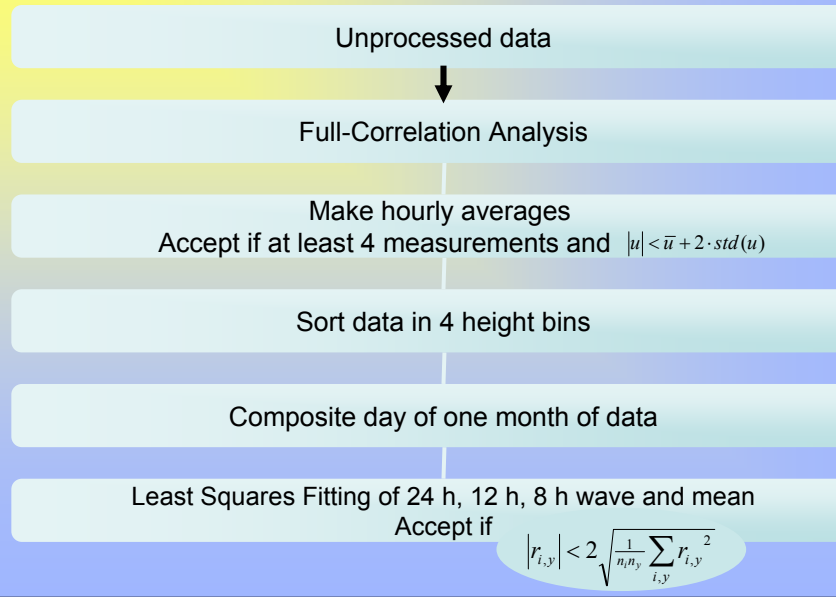Available number of hourly data points per month in percent:

- • DEC PDP-8
- • New transmitter
- • Computer DEC micro
- •First PC
- •Second PC
- • change coherent

% of possible hours of data, per month

1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003

Hardware failure

Power sup problems

Raw data
Scott Base, zonal winds

Mean wind and tidal analysis

Unprocessed data

↓

Full-Correlation Analysis

Make hourly averages
Accept if at least 4 measurements and $|u| < \bar{u} + 2 \cdot std(u)$

Sort data in 4 height bins

Composite day of one month of data

Least Squares Fitting of 24 h, 12 h, 8 h wave and mean
Accept if $\left| r_{i,y} \right| < 2\sqrt{\frac{1}{n_i n_y} \sum_{i,y} r_{i,y}^{\,2}}$
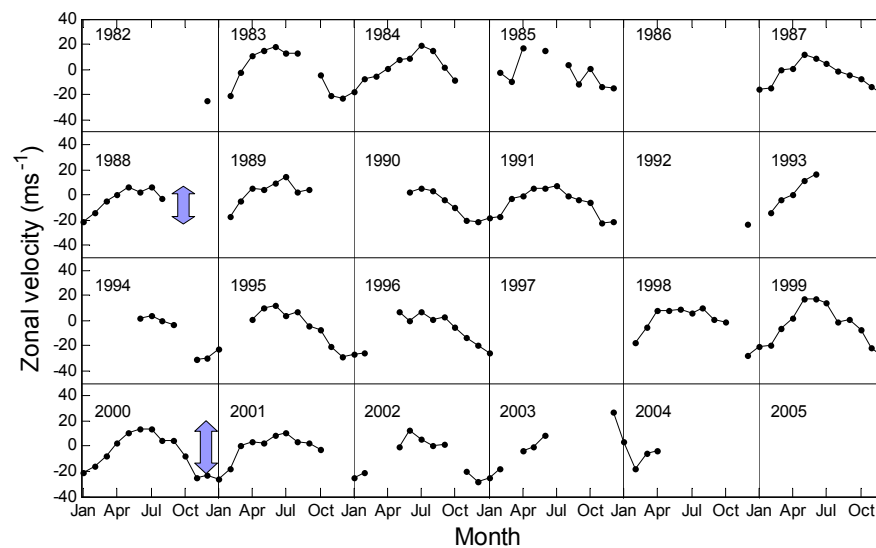
Climatology for 78° South
Mean winds

Zonal mean wind

Meridional mean wind

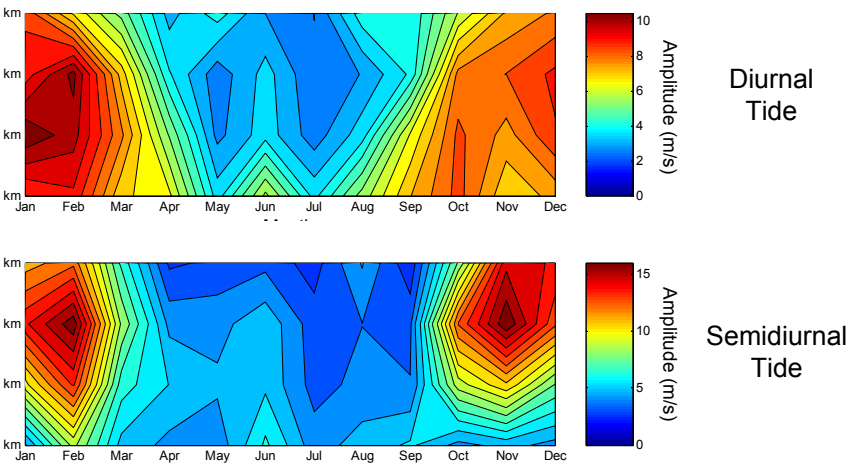# Scott Base zonal winds 1982-today
at 75 – 80 km

Climatology for 78° South
Amplitudes of the diurnal and the semidiurnal tide

Diurnal Tide

Semidiurnal Tide

Effects of multi-year phenomena and long-term trends

- Phenomena studied:
  - ☐ Solar Cycle
  - ☐ Quasi-Biennial Oscillation
  - ☐ Planetary wave activity
  - ☐ Stratospheric circulation effects
- Statistical techniques:
  - ☐ Analysis of Variance (ANOVA)
  - ☐ Regression
  - ☐ Multiple regression
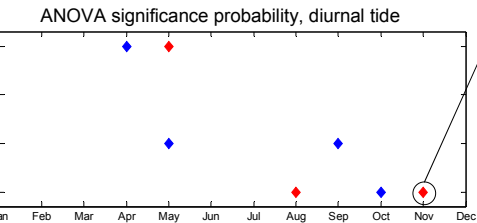 - ☐ Long term periodograms

Statistics I: Analysis of Variance
Method and results for Scott Base

ANOVA test: applied to each month and each height bin
Groups
- All pairs of
  - High (>150 s.f.u.) / low (<110 s.f.u.) solar activity
  - QBO in westerly / easterly phase (>|5| m/s)
- Medium (110-150 s.f.u.) solar activity and QBO phase transition (<|5| m/s)

ANOVA significance probability, diurnal tide

ANOVA table

Source	V	df	V/df	F	Prob
Between groups	21.6	3	7.2	13.2	99.2%
Within groups	2.7	5	0.54		

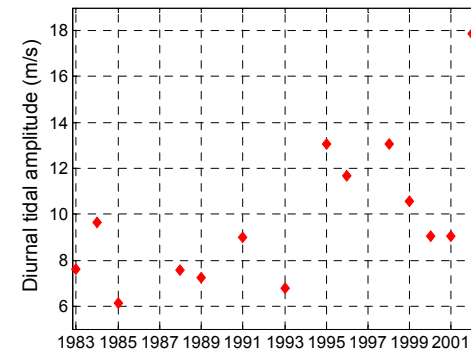Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Between group variance,
probability of significance to ◆ 95%, ◆ 90%

Statistics II: Regression
Results for Scott Base

- Initial analysis shows trends towards higher tidal amplitudes in summer

- The amplitude of the diurnal tide in February, between 1983 and 2003:

Diurnal tidal amplitude (m/s)

18
16
14
12
10
8
6

1983 1985 1987 1989 1991 1993 1995 1997 1999 2001

- Significant (95% level) correlation for all phenomena, however usually **only for one or two months and only for a single height bin**

Statistics III: Multiple regression
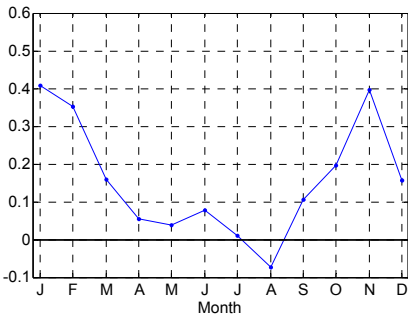## Results for Scott Base

Looking for optimal solutions to $\quad v_{12h} = a_{month}$
$$+ b_{month} \cdot F_{10.7}$$
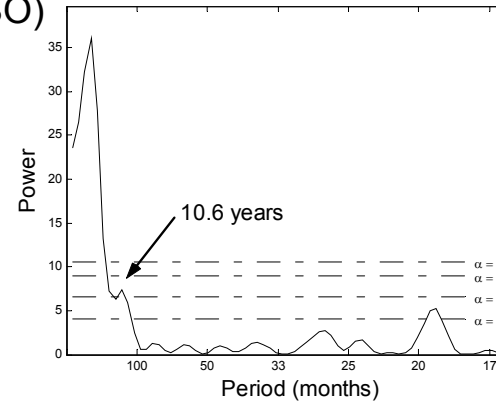$$+ c_{month} \cdot Q_{40hPa}$$
$$+ d_{month} \cdot year$$

Semidiurnal component, parameter d (trend):

(Maximum error: 4.5 m/s)

Statistics IV: Long term periodograms

- For most parameters there is no evidence of significant peaks around 11 years (solar cycle) or 27 months (QBO)
- Possibly some exceptions, e.g. diurnal tide at Christchurch:

Future Work

- Application of different statistical techniques
- Intercomparison with other middle atmosphere observations and models
  - Empirical Orthogonal Functions (EOF) Analysis with other datasets → spatial and temporal variability of wind fields

Conclusions

- The long data set for two southern hemispheric sites has potential for long term studies
- Both data sets show the expected seasonal pattern for mean winds and tides
- Initial analysis shows some influence of the solar cycle and the QBO as well as a long term trend, however, these are significant only for one or two months and only for a single height bin.
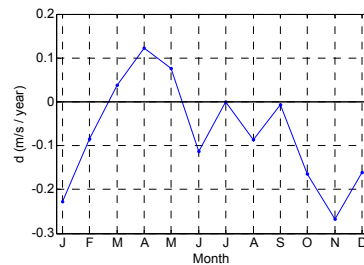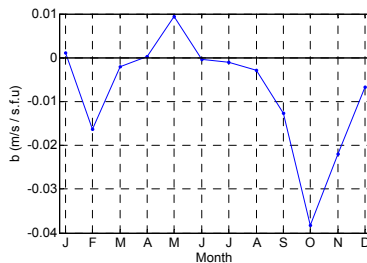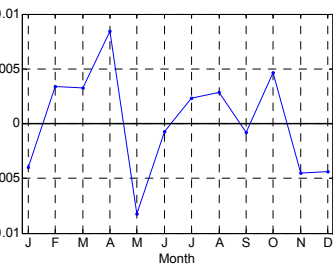
The Christchurch semidiurnal tide
t 80 – 85 km

Statistics I: Analysis of Variance
Results for Christchurch

Statistics II: Multiple regression
Results for Christchurch, semidiurnal component

- Looking for optimal solutions to

$$v_{mean}, v_{24h}, v_{12h} = a_{month}$$
$$+ b_{month} \cdot F_{10.7}$$
$$+ c_{month} \cdot Q_{40hPa}$$
$$+ d_{month} \cdot year$$

- Maximum error: 6.7 m/s

Statistics V: SiNos analysis

SiNos:
Significant Non-stationarities

Analysis of significance as function of time and time-scale, but specifically designed for non-stationary time-series. SiNos maps for mean, variance and the value of the first lag of the ACF.