

Foehn Winds in the McMurdo Dry Valleys:

Implications for climate variability and landscape evolution

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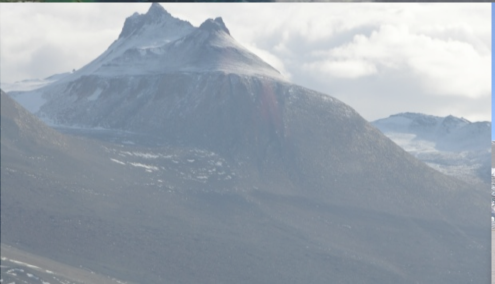
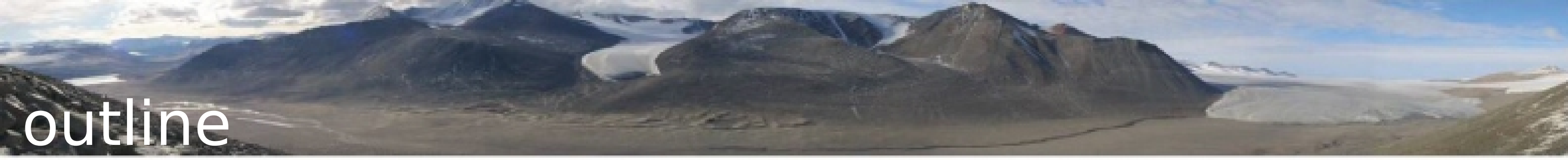




outline

1. INTRODUCTION

Physical setting

Background

2. FOEHN VARIABILITY

Intra- and inter-annual frequency

Effects on temperature regime

Influence of SAM and ENSO

3. LANDSCAPE PROCESSES

Thermal inputs

Melt and stream discharge

Snow persistence

DATA SOURCES:

Automatic weather station (AWS) data:

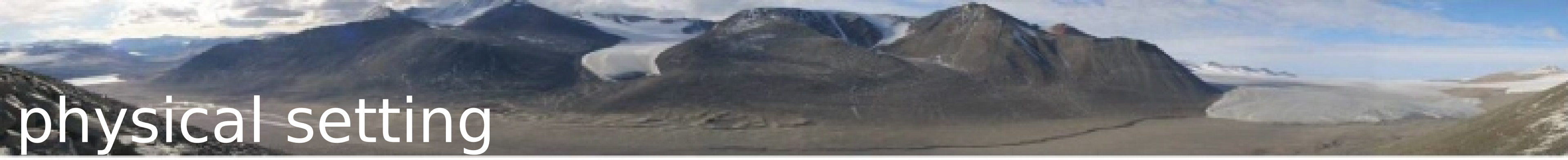
- McMurdo LTER program

Numerical model products:

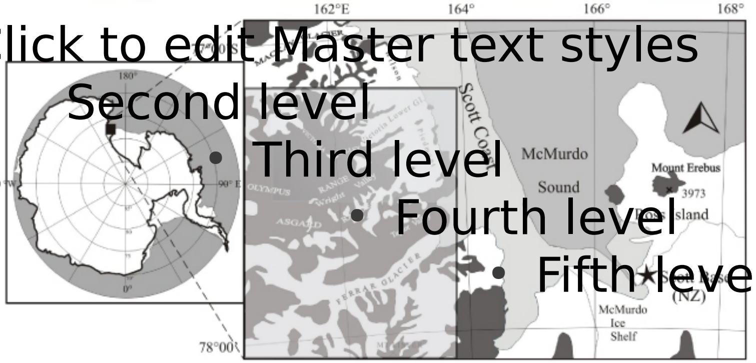
- Antarctic Mesoscale Prediction System (AMPS)
- Japanese Reanalysis Project (JRA-25)

Satellite imagery:

- Landsat 7 ETM+



physical setting



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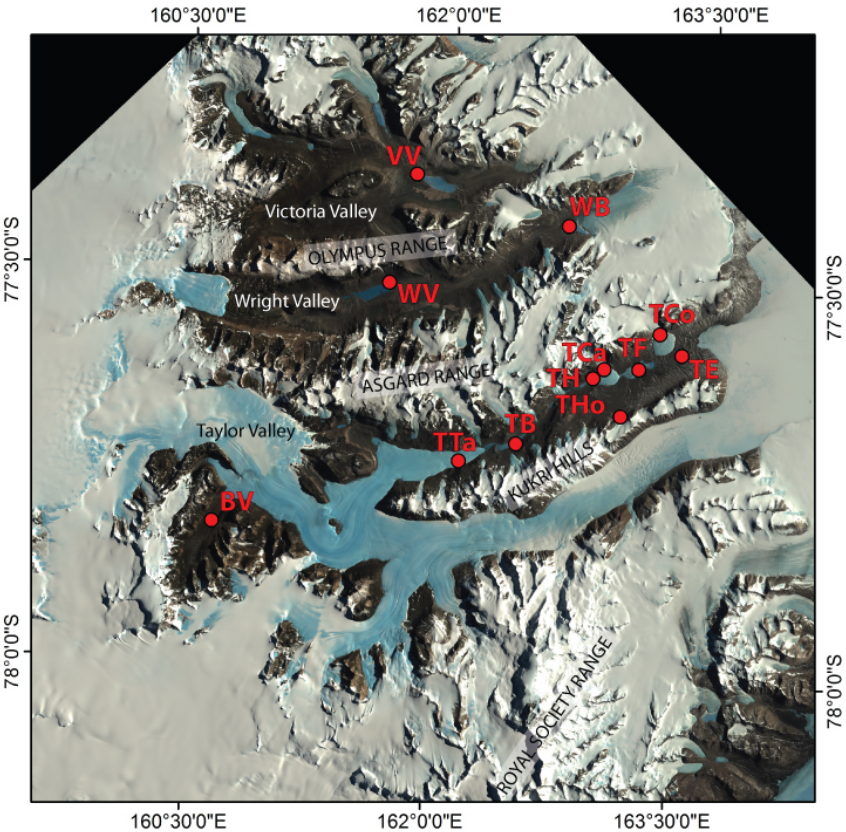
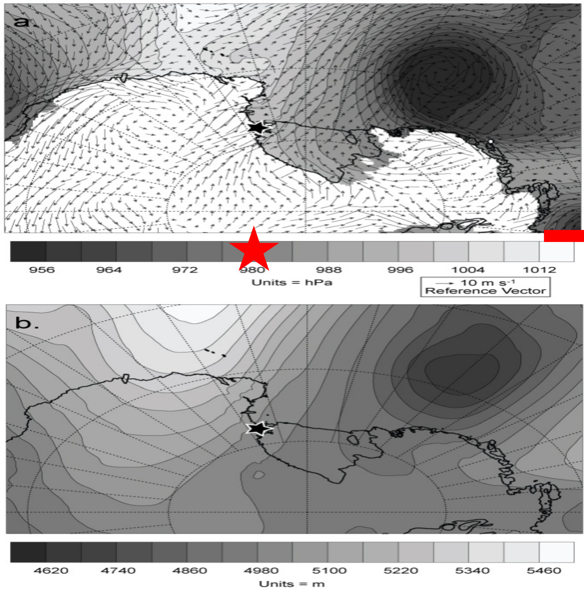


McMurdo Dry Valleys (MDVs):

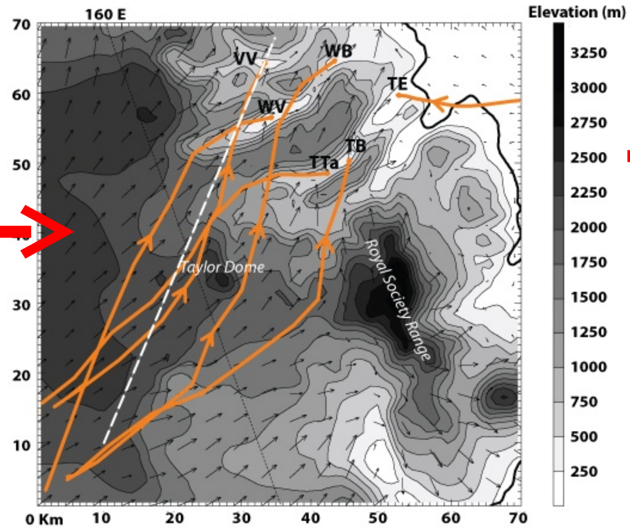
- Largest ice-free area in the Antarctic ~4,800 sq km
- Three large NE - SW trending valleys
  - Mountain ranges ascending ~2000m above valley floor
  - Slow-moving glaciers
  - Perennially ice-covered lakes
  - Summer meltwater streams
  - Diverse microbial and algal communities
  - Extensive sedimentary deposits

background – foehn mechanism

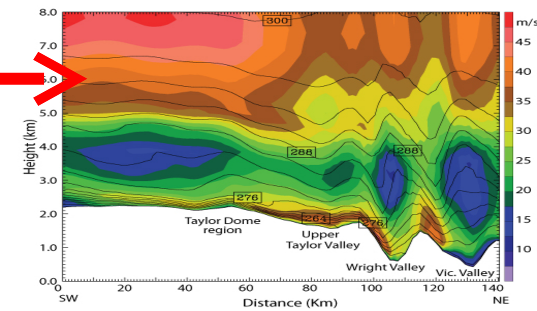
Sea Level Pressure 24 May 2007



Backward trajectory 24 May 2007



Cross section 24 May 2007



- Large cyclones in the Ross Sea region produce strong pressure gradients
- Flow is forced to cross topographic barriers of MDVs, deflected into valleys
- Prominent large-amplitude mountain wave pattern develops: levels > 8 km asl

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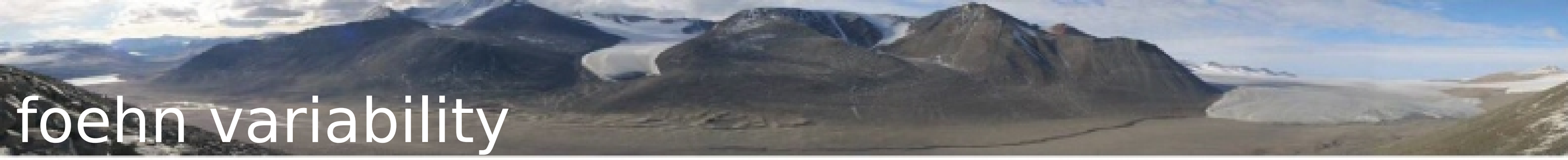
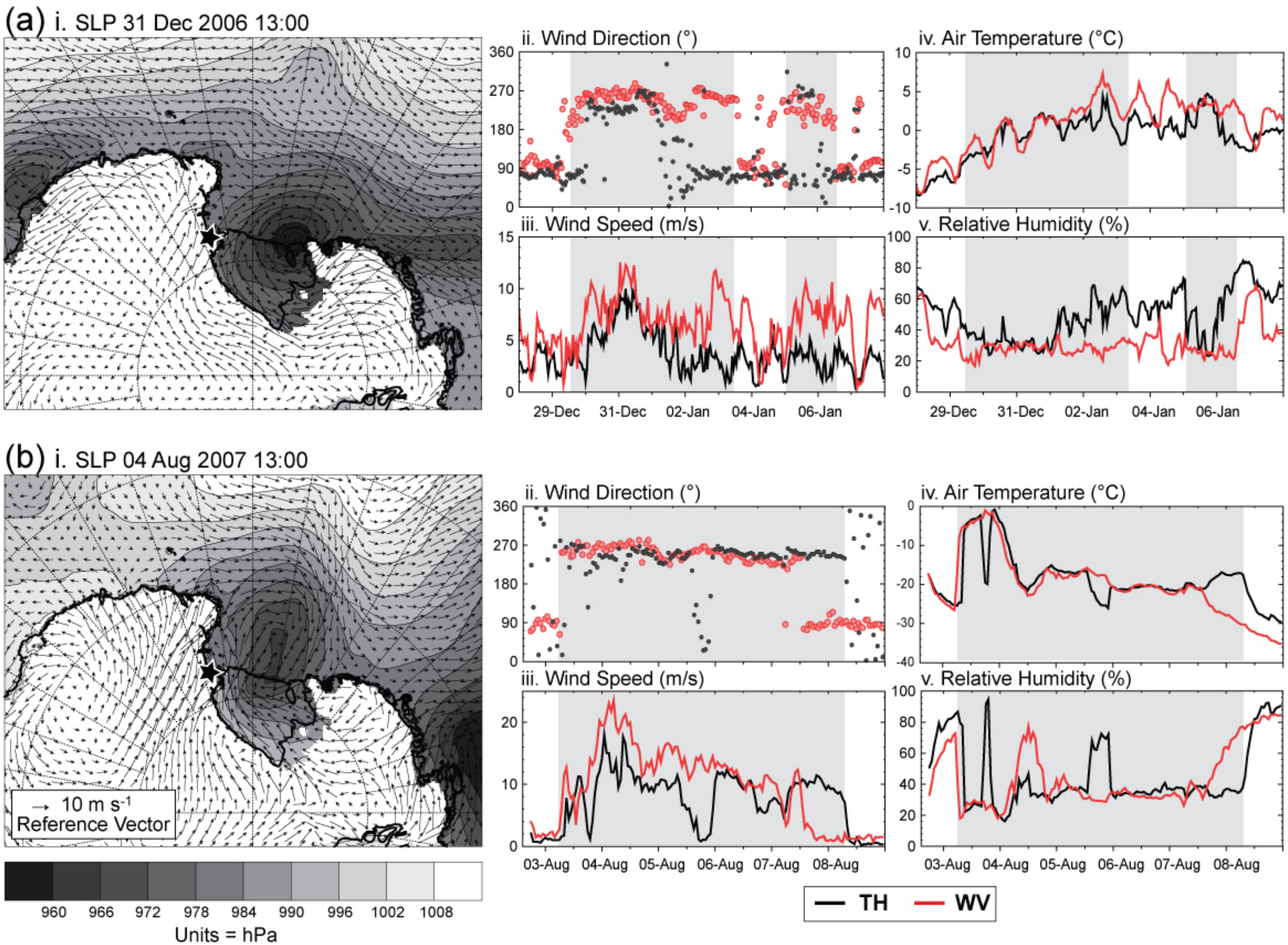
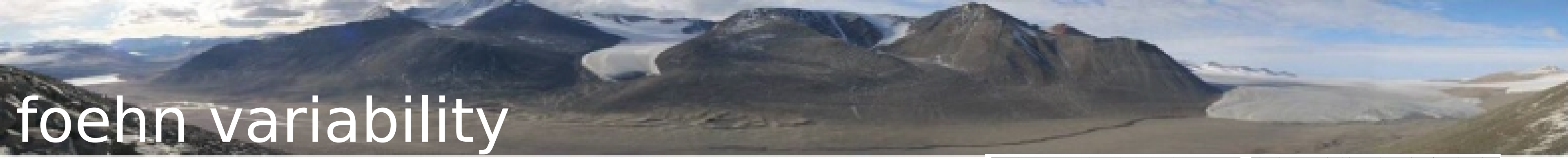


foehn variability

SUMMER

WINTER





foehn variability

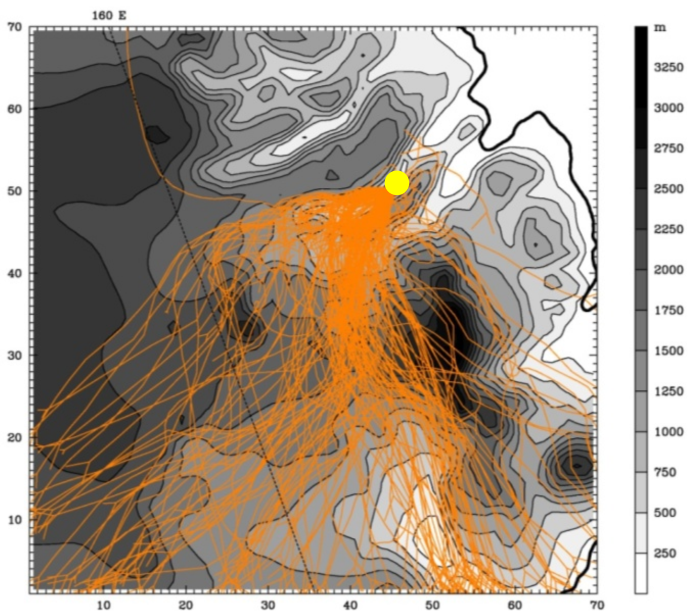
Identification of foehn in AWS records:

§ Foehn criteria identifies onset of foehn events

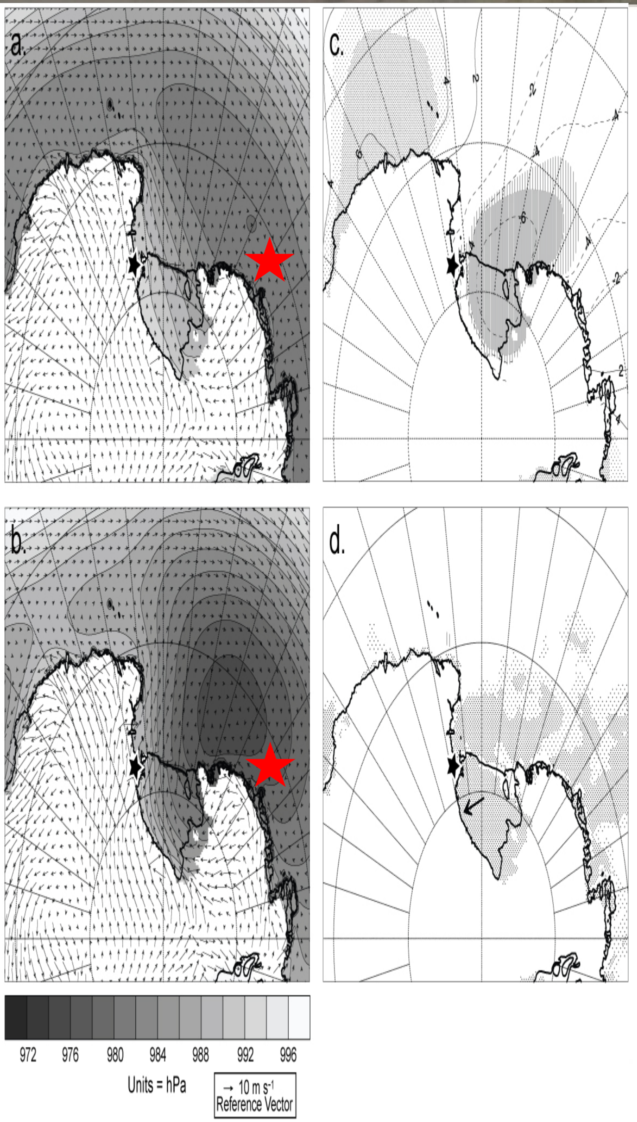
- Wind speed > 5 m/s
- Wind direction from SW
- Warming > +1 °C / hour
- ↓ RH > 5 % / hour

§ “Foehn day”: Day that has identified foehn

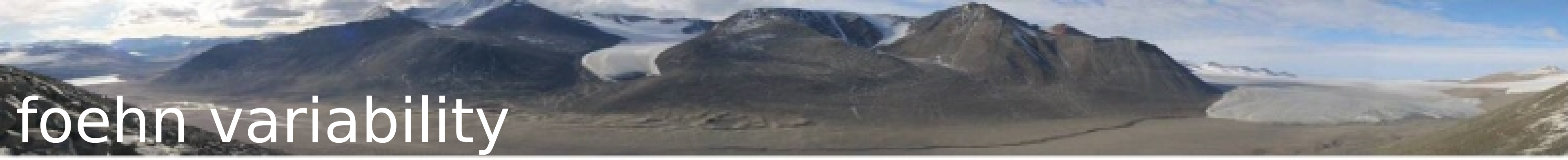
hours



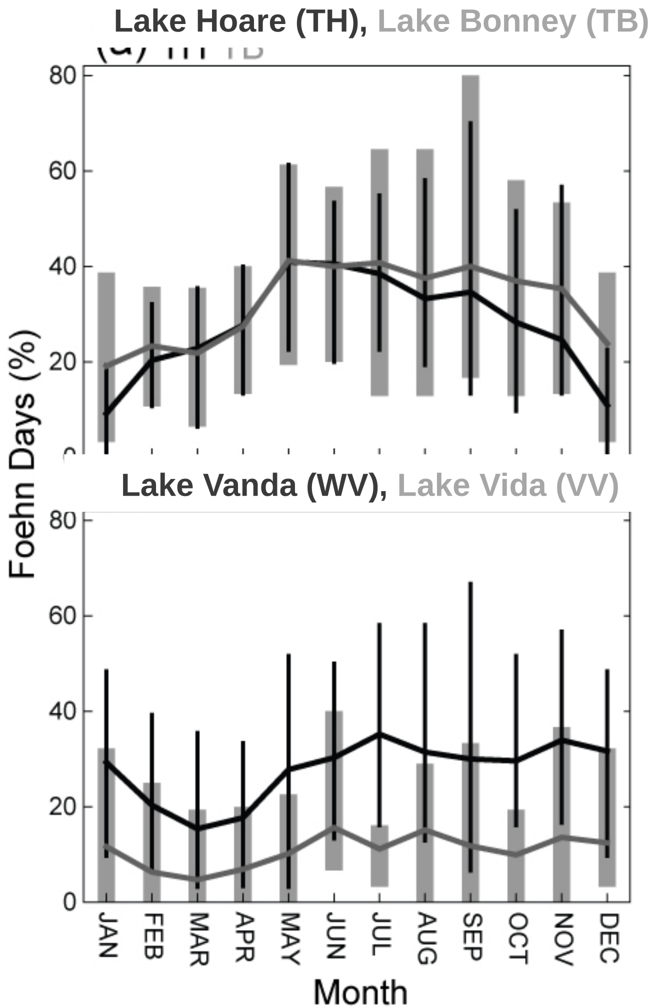
AMPS Backward trajectories for 172 foehn days 2006-2007 at Lake Bonney



AMPS SLP and near-surface wind vector composites (2006 -2007) for: (a) Non-foehn days, (b) Foehn days



foehn variability

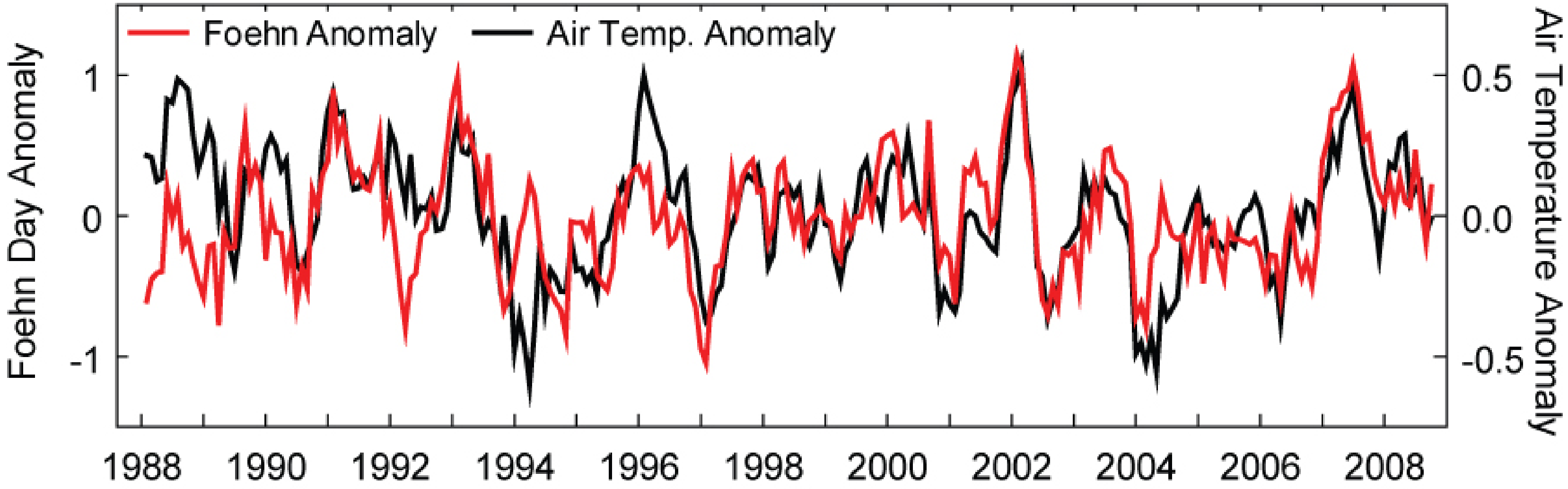


Monthly mean, min and max foehn days for 1996 and 2008.

- Foehn frequency highest in winter
- Lower in summer due to:
  - reduced cyclonic activity in the Ross Sea (Simmonds et al. 2003)
  - increased frequency of strong easterly ‘sea breeze’ → prevents grounding of foehn?
- Reduced foehn in Victoria Valley due to cold air pooling (Doran et al. 2002) → prevents grounding of foehn
- Large variability in foehn occurrence

foehn variability

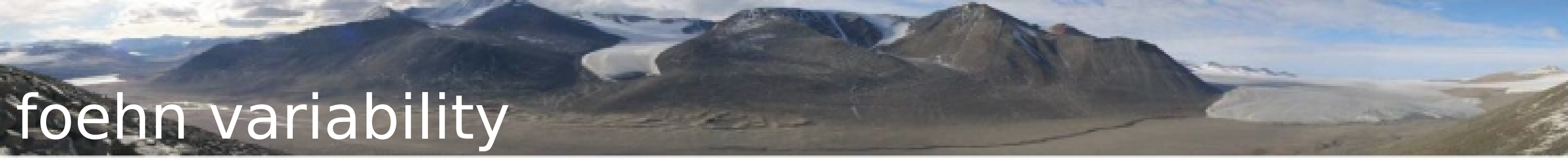
Foehn effect on monthly temperature anomalies



Monthly standardised foehn anomaly and standardised air temperature anomaly for Lake Hoare. Data is smoothed with a 5 month moving average.

- Foehn winds explain **>70%** of the variability in monthly mean air temperature

- Foehn days = **58 %** of days with a mean daily air temperature > 0°C



foehn variability

What drives foehn variability?

		SOI *(NOAA CPC)* *R*	SAMI *(Marshall 2003)* *R*
Foehn Days	DJF	+0.3709	**+0.7482**
	MAM	-0.2963	**-0.7724**
	JJA	+0.0077	-0.3564
	SON	+0.0914	+0.0827
Air Temp.	DJF	-0.0868	+0.0086
	MAM	-0.0703	-0.4986
	JJA	**+0.6818**	-0.0965
	SON	+0.2292	+0.2921

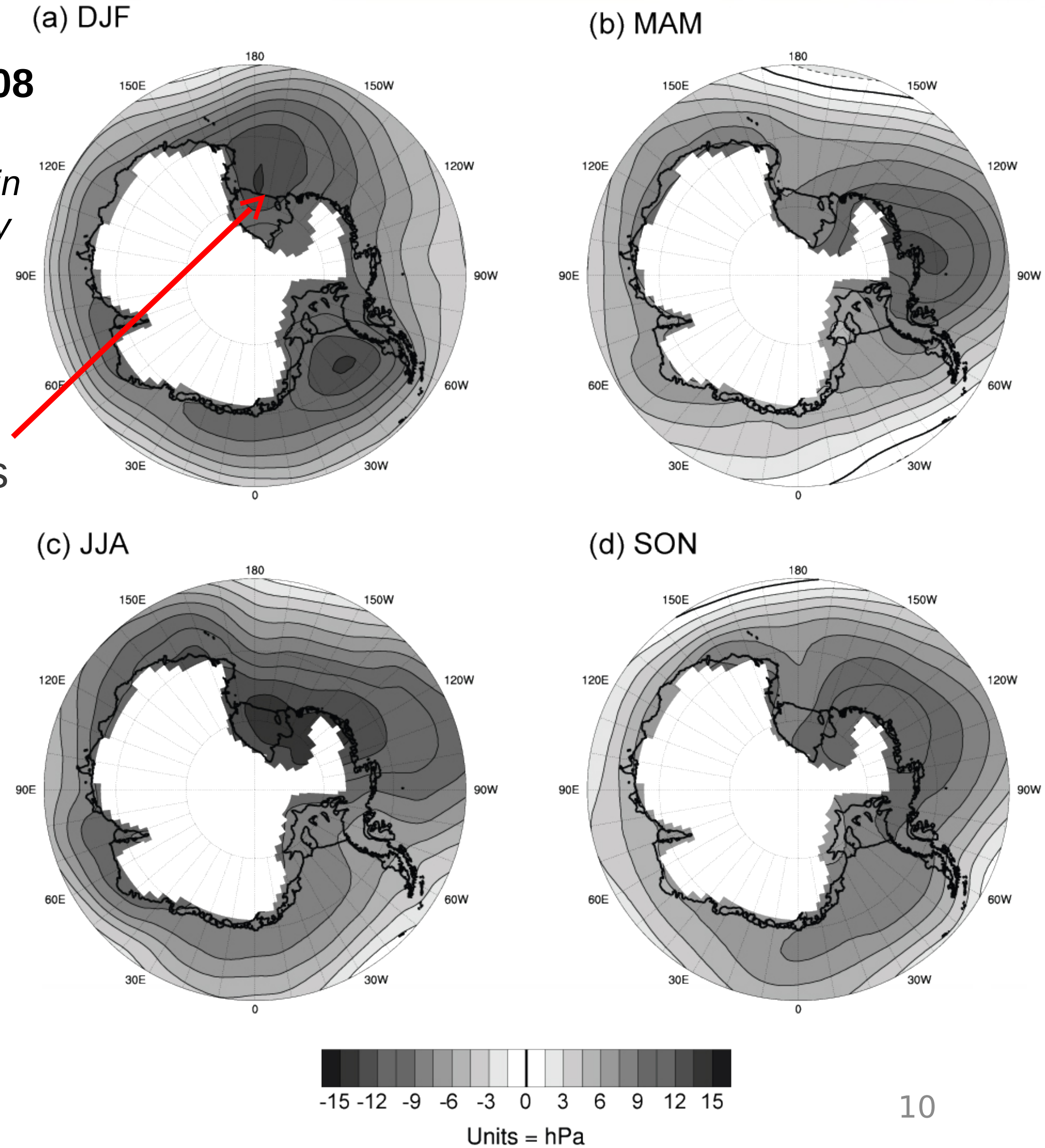
- Cyclone frequency and intensity
- SAM and ENSO known to affect MSLP and cyclonic activity in the region
- May expect positive relationship with SOI and SAMI
  - +ve SOI (La Nina), ↑ Amundsen Sea Low (e.g. Cullather et al. 1996), ↑ *Foehn*
  - +ve SAM, ↑ cyclones around Antarctica (e.g. Pezza et al. 2009), ↑ *Foehn*
- Positive relationship seen in summer foehn and SAM ← Significant for landscape processes
- Positive relationship with winter air temperature and SOI
- Negative relationship with autumn foehn and SAM

foehn variability

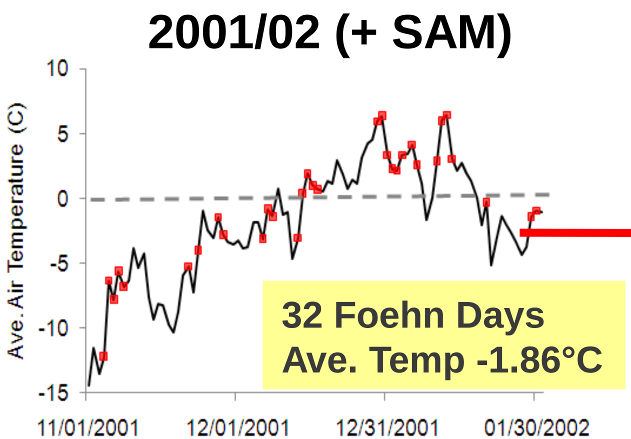
JRA-25 MSLP difference plots 1980-2008

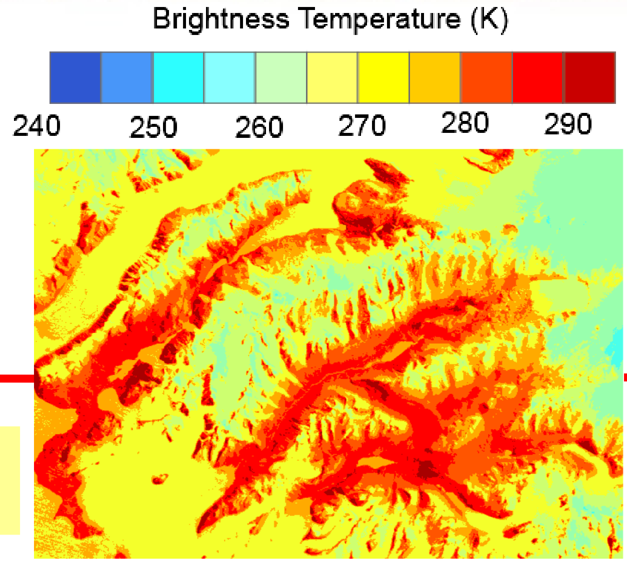
-ve SAMI minus +ve SAMI seasons. Zero line in bold, negative MSLP shown by dashed line only evident for MAM, **plots are mainly positive i.e lower MSLP during +ve SAM**

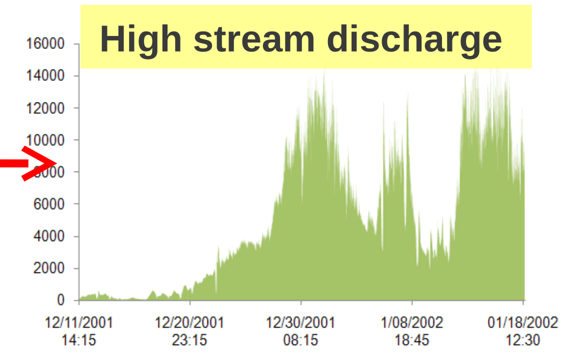
- Large area of pressure differences during SAM summers
- Likely associated with changes in cyclone frequency
- Cause for relationship between SAM and foehn winds in summer

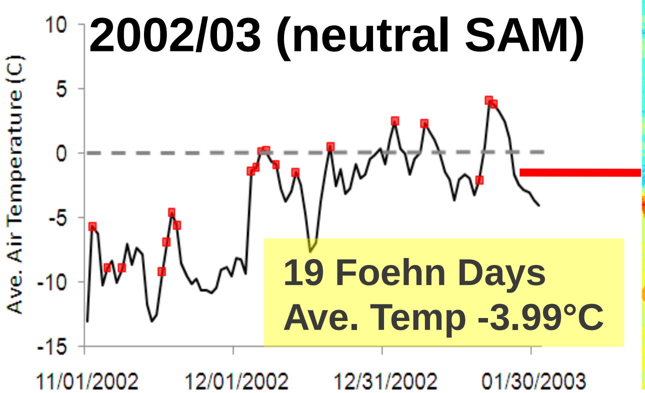


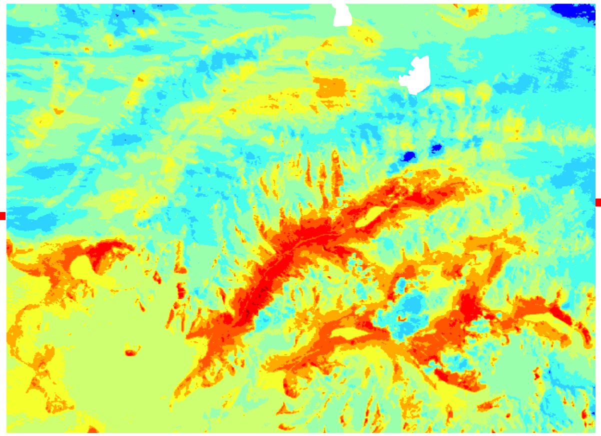
landscape processes

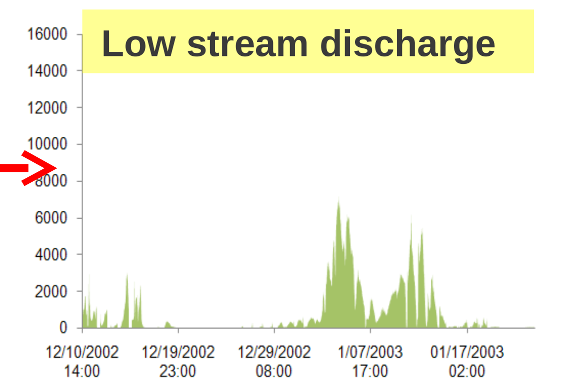








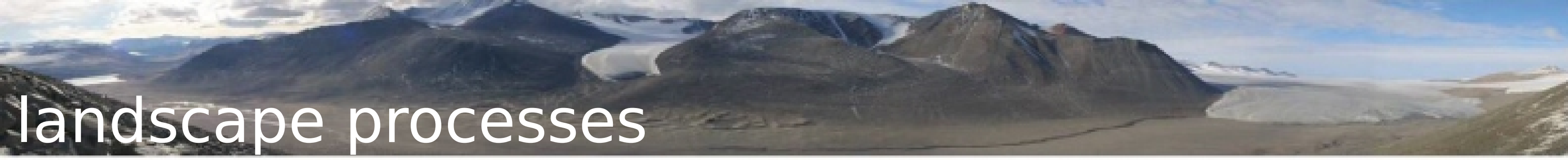




Average daily air temperature and foehn days (red dots) for summer 2001/02 (top) and 2002/03 (bottom).

Landsat 7 ETM+ image of MDV region 21-Nov 2001 (top) and 17-Nov 2002 (bottom). Snow persists longer into the 2002 summer season with less foehn heating. TIR images 28-Dec 2001 (top) and 31-Dec 2001 (bottom).

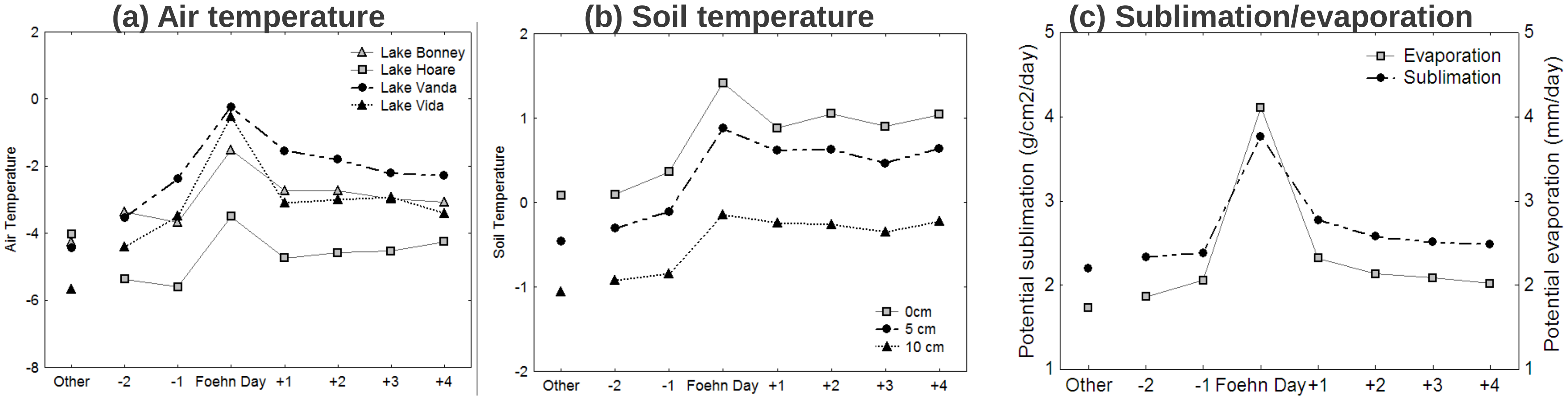
Discharge (L/s) of the Onyx River, Wright Valley during 2001/02 (top) and 2002/03 (bottom) summers.



landscape processes

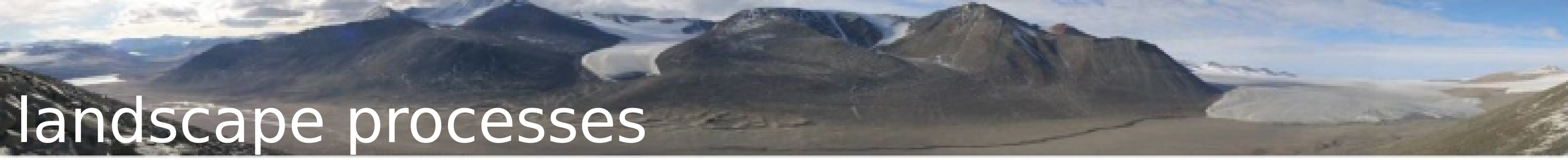
- Small changes in Antarctic circulation and foehn frequency can produce dramatic changes in the climate-landscape system

- Effects of foehn winds outlive the duration of the event
  → Significant lag effects present in meteorological variables



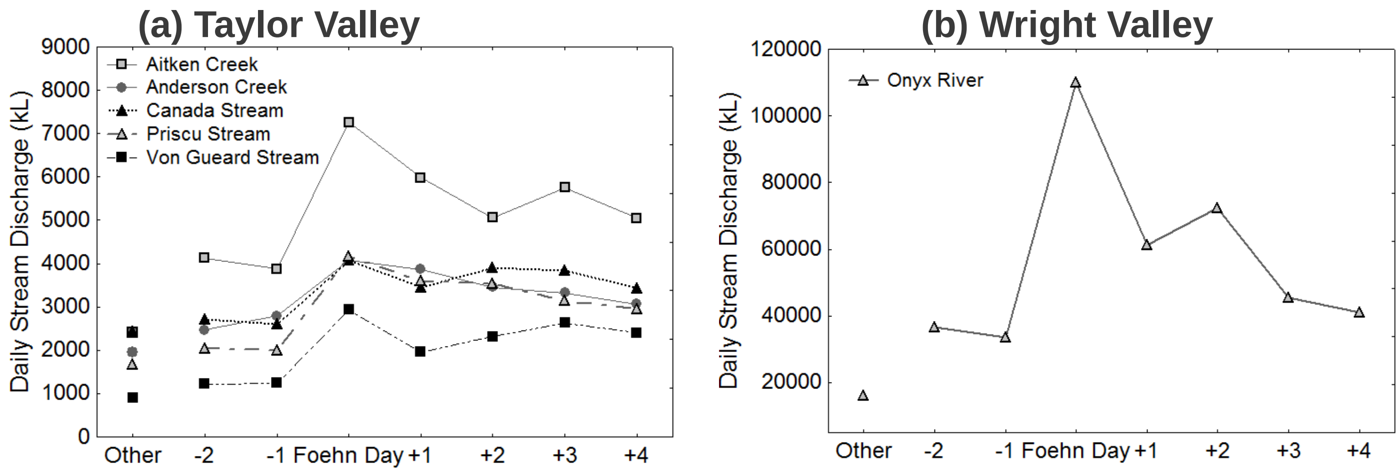
Lag effects of foehn days on meteorological variables in the McMurdo Dry Valleys 1999-2008:

- Negative (-1,-2) = days prior to a foehn day .
- Positive (+1,+2,+3,+4) = days after a foehn event.
- 'Other' = days not occurring in the vicinity of a foehn day.



landscape processes

Stream discharge



The influence of foehn on average daily stream discharge for melt-water streams

- Stream discharge during foehn days in the Taylor Valley is 250% of non-foehn days
- 680% for the Onyx River in the Wright Valley
- The 2001/2002 summer known to be a season of particularly high levels of flow [and foehn]. Even when this summer season is removed, foehn days still contribute to 225% of non-foehn flow.
- Foehn wind regime played a pivotal role in creation and removal of large liquid lakes occupying valley floors in the LGM and early Holocene (e.g. Lyons *et al*., 1998; Hall *et al*., 2001)

summary & implications

- Dense AWS network + high resolution modelling allows important aspects of the MDVs climate system to be uncovered

- Foehn variability caused by:

  - Variability in synoptic circulation - cyclone tracks in the Ross Sea region

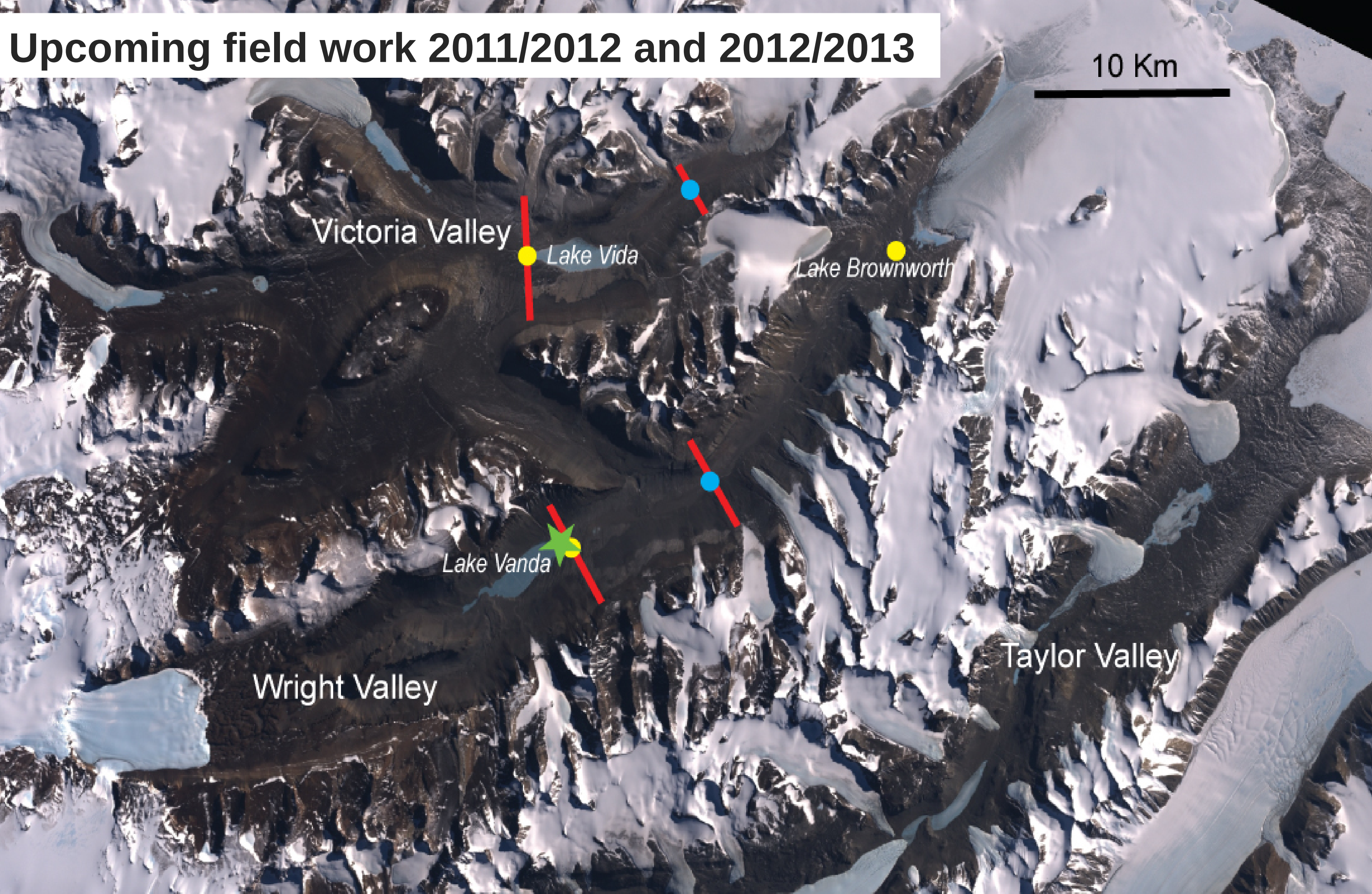
  - ENSO/SAM signal in MSLP and cyclone activity in Ross/Amundsen Seas

  - Intraseasonal variability show MJO forcing *(Steinhoff et al. in prep)*

- Foehn is a mechanism for tropical and hemispheric influences in the MDVs
  → **Future changes in these signals holds important repercussions for the MDVs climate**

- Foehn winds are a vital part of the MDVs environmental system
  → **Driver of landscape variability and change**

Upcoming field work 2011/2012 and 2012/2013

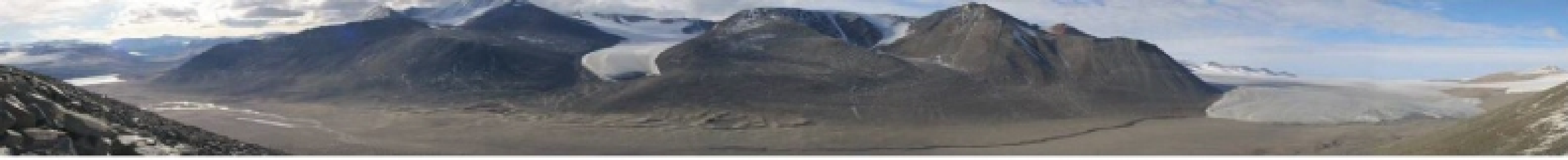


Temperature and RH Transect (HOBO™)

Field observation campaign: 2 x Eddy Covariance Units, Acoustic Sounder, Radiosondes, Instrumented Kite

HOBO™ AWS

LTER AWS



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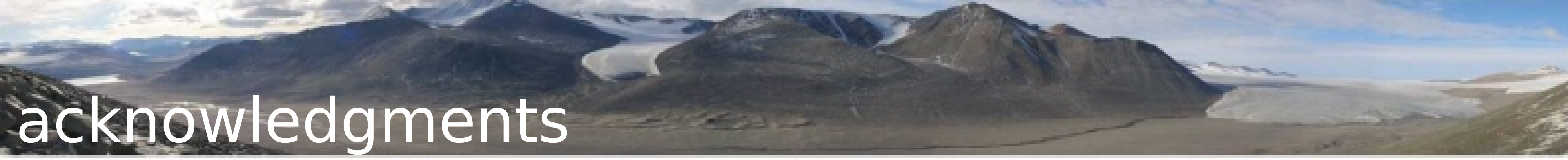

acknowledgments

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Speirs, J., and McGowan, H. 2011: Foehn winds in a polar landscape: a driver of environmental change. *Journal of Geophysical Research* (In prep.)

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