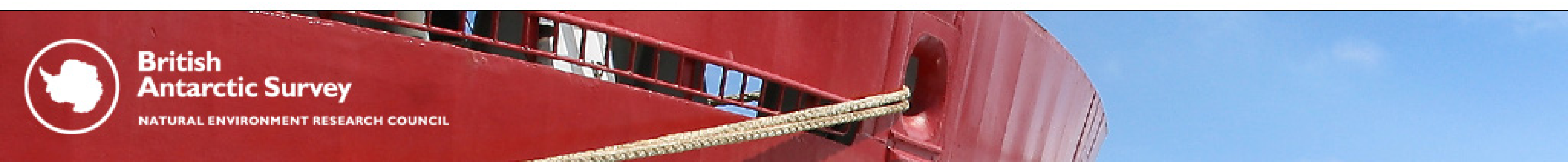
POLAR SCIENCE
FOR PLANET EARTH

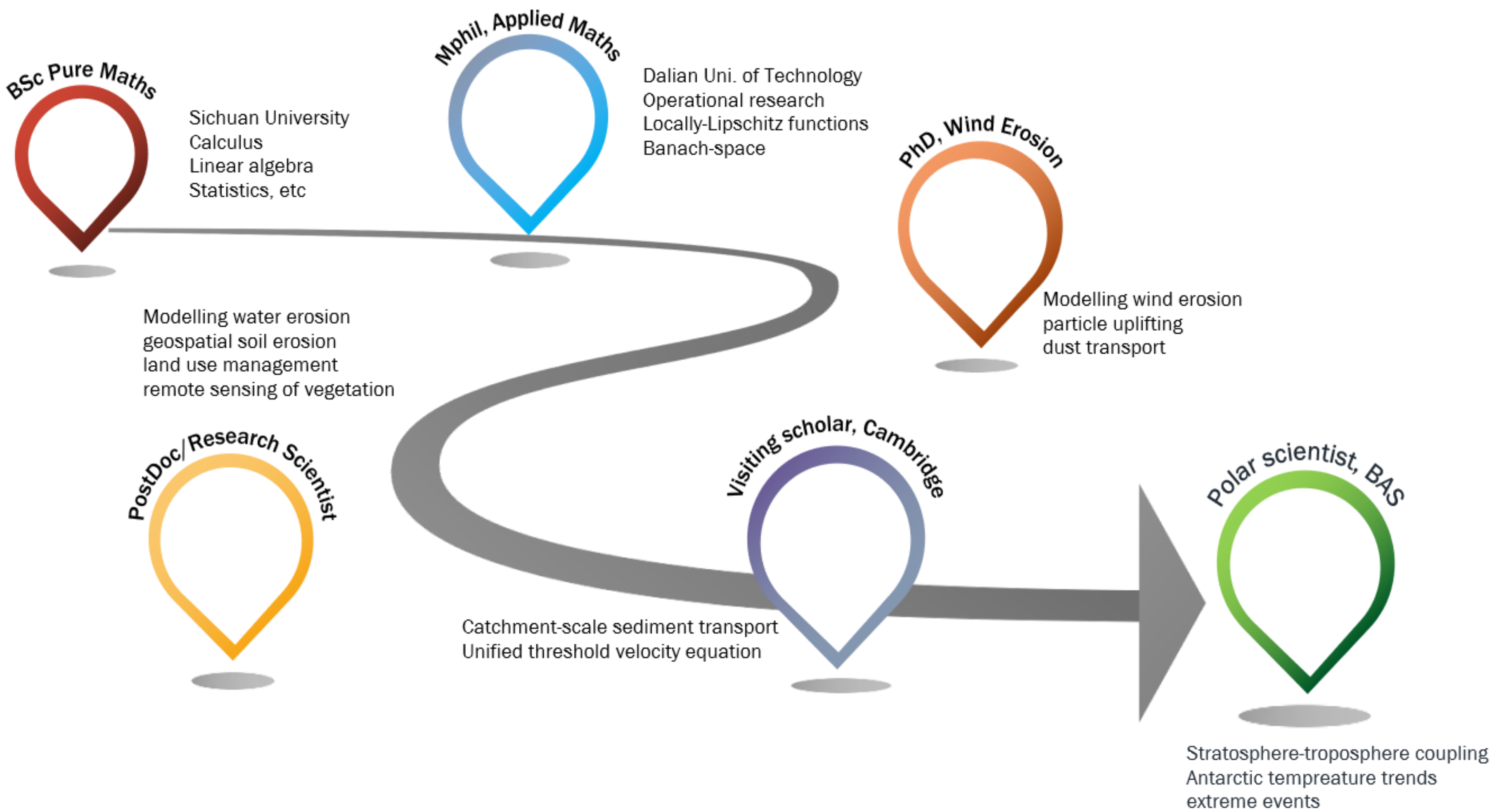
How maths helped one to become a polar researcher ?

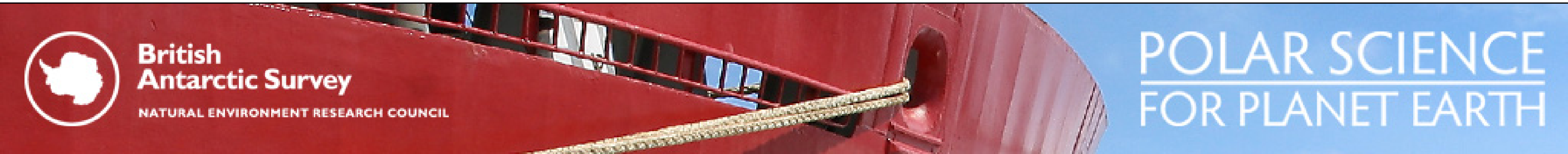
Hua Lu

Women in Mathematics Day on Wednesday, 11th May 2022, University of Reading



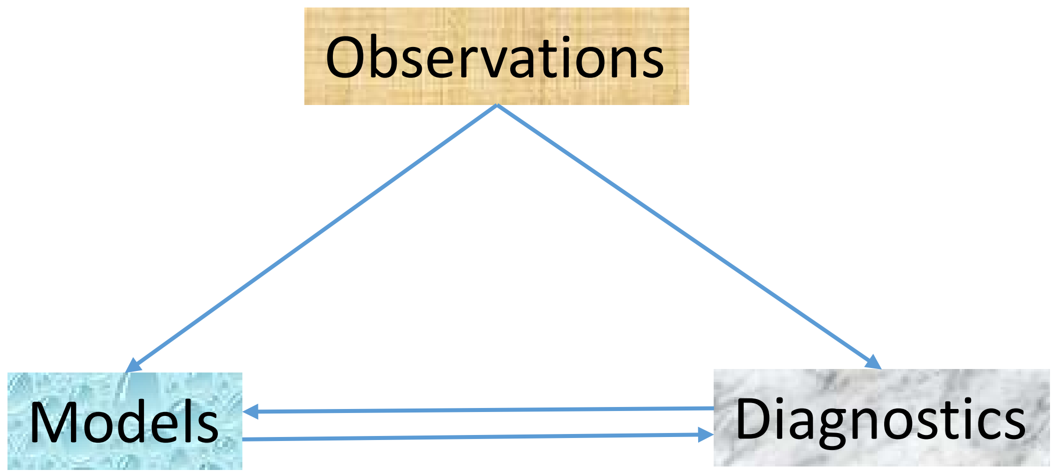
Career path


BSc Pure Maths
Sichuan University
Calculus
Linear algebra
Statistics, etc
Mphil, Applied Maths
Dalian Uni. of Technology
Operational research
Locally-Lipschitz functions
Banach-space
PhD, Wind Erosion
Modelling wind erosion
particle uplifting
dust transport
Modelling water erosion
geospatial soil erosion
land use management
remote sensing of vegetation
PostDoc/Research Scientist
Visiting scholar, Cambridge
Catchment-scale sediment transport
Unified threshold velocity equation
Polar scientist, BAS
Stratosphere-troposphere coupling
Antarctic tempreature trends
extreme events


British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
POLAR SCIENCE
FOR PLANET EARTH

Tools, skills & rationale

- Conceptual / Mathematical / Numerical Modelling / Fluid Dynamics
- Data analysis /Diagnostics development / Statistics
  - extract high-level information from data collected from wind tunnels, weather stations, radar, remote sensors and/or satellite imagery
- Climate or weather prediction models / Reanalysis data sets
- Matlab, python, netcdf, ArcGIS, Fortran77-90
- ***Integrated, Collaborative, and Multidisciplinary Approach***



Mathematical modelling of wind & water erosion

Shahabinejad et al. (EES, 2019)

Mathematical modelling of wind erosion

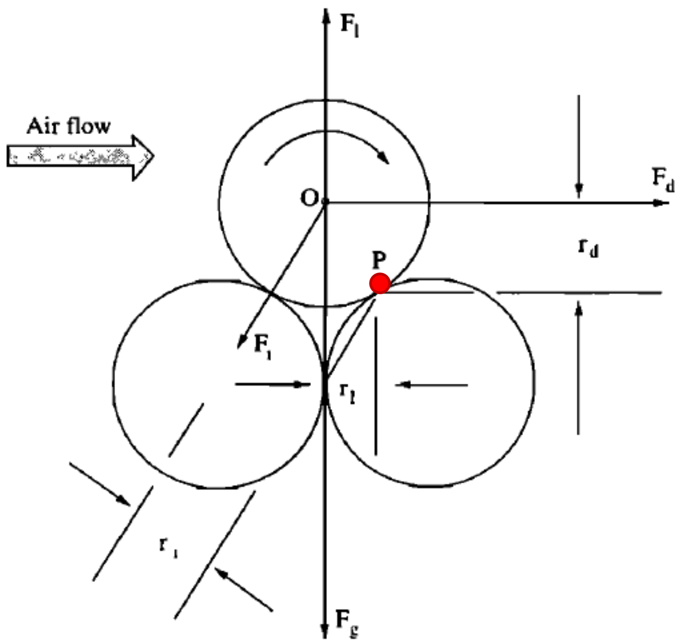


Figure 1. Forces acting on a particle resting on the surface under the influence of an airstream, including the aerodynamic drag F_d, the aerodynamic lift F_l, the gravity force F_g, the moment F_m, and the cohesive force F_i; r_d, r_l, r_m, and r_i are moment arm lengths associated with F_d, F_l and F_g, F_m, and F_i, respectively. O is the center of gravity of the particle, and P is the pivot point for particle entrainment.

Atmospheric Physics | Free Access

A simple expression for wind erosion threshold friction velocity

Yaping Shao, Hua Lu

First published: 01 September 2000 | https://doi.org/10.1029/2000JD900304 | Citations: 416

$$r_d F_d + r_l (F_l - F_g) + r_m F_m - r_i F_i = 0,$$

The balance of forces at the instant of entrainment can be obtained by the summation of the moments about the pivot point P.

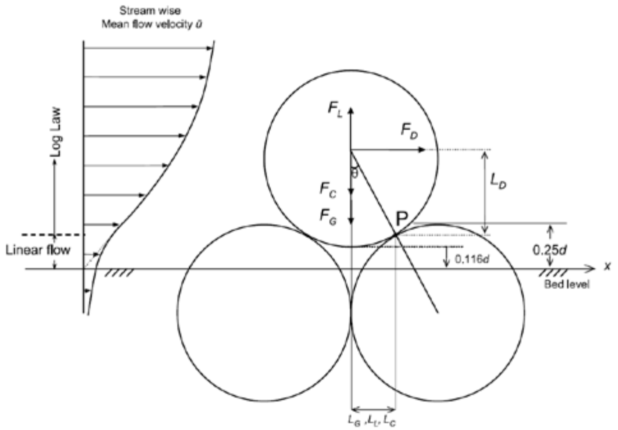
$$u_{*t} = \sqrt{A_N \left(\sigma_p g d + \frac{\gamma}{\rho d}\right)},$$

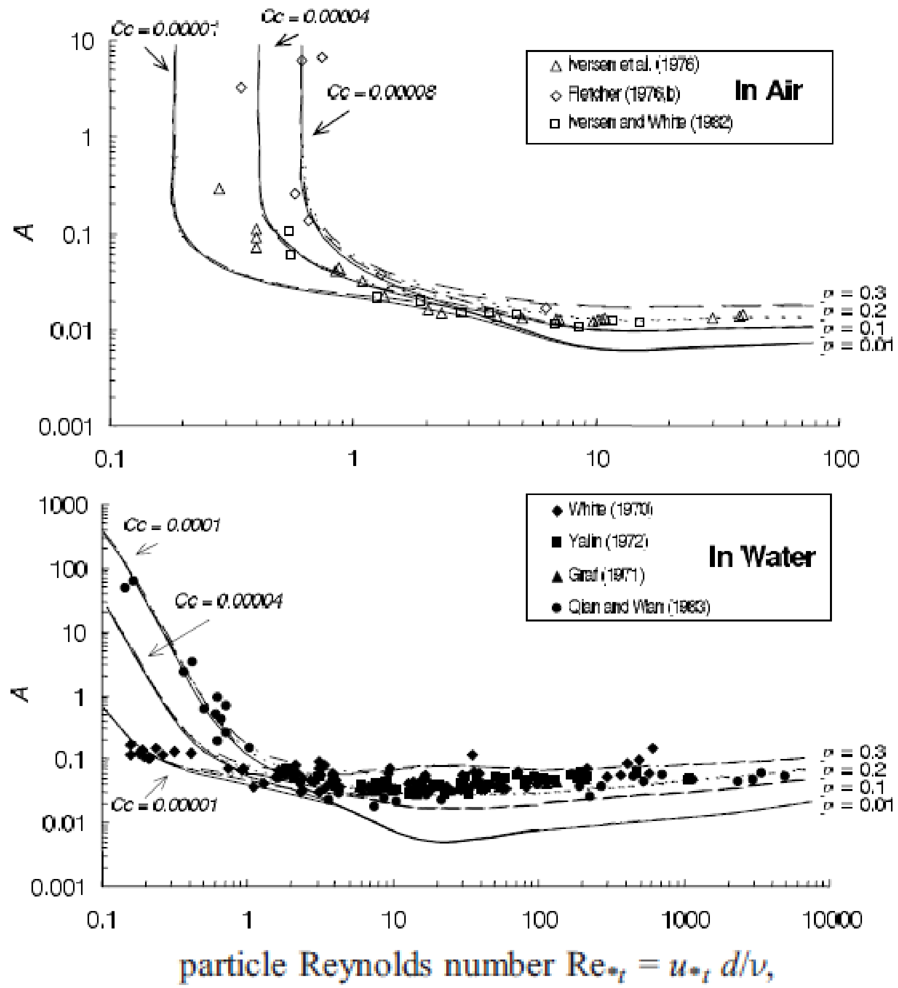
Fit exceedingly well with wind tunnel data

$A_N \approx 0.0123$, $\gamma \approx 3 \times 10^{-4}$ kg s^{-2}

This led to an integrated wind erosion modelling system and the equations have been used by various of dust transport models

Extended to cover entrainment both in air and water





$$u_{*t} = \sqrt{A_N\left(\sigma_p g d + \frac{\gamma}{\rho d}\right)},$$

- Probability distribution of $\overline{u}$
- Laminar & turbulent flows
- Fit well with the data in both air and water

British Antarctic Survey
NATURAL ENVIRONMENT RESEAR

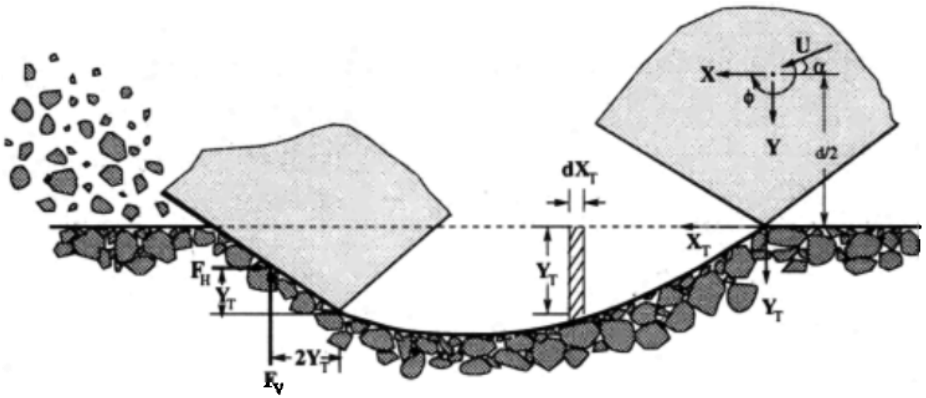
Modeling entrainment of sedimentary particles by wind and water: A generalized approach

Hua Lu, Michael R. Raupach, Keith S. Richards

First published: 30 December 2005 | https://doi.org/10.1029/2005JD006418 | Citations: 20

POLAR SCIENCE FOR PLANET EARTH

Modelling of dust emission by saltation bombardment



A new model for dust emission by saltation bombardment

Hua Lu, Yaping Shao

First published: 01 July 1999 | https://doi.org/10.1029/1999JD900169 | Citations: 139

$$m\frac{d^2X}{dt^2} + pYb = 0 \qquad (1)$$

$$m\frac{d^2Y}{dt^2} + KpYb = 0 \qquad (2)$$

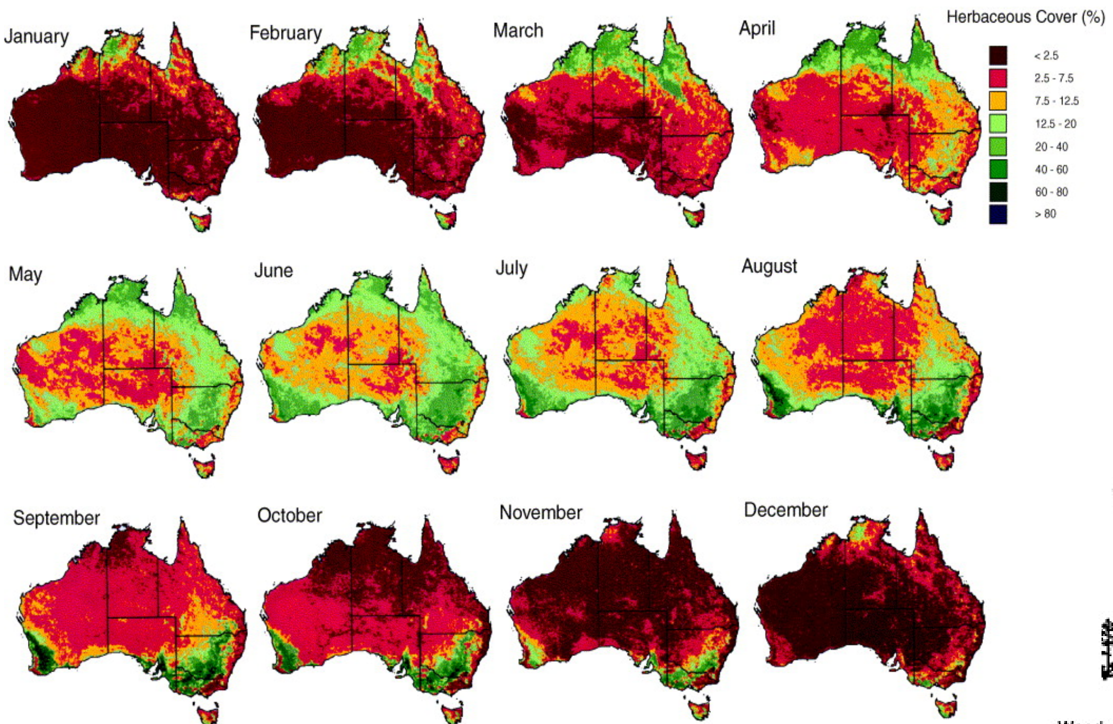
$$I\frac{d^2\phi}{dt^2} + pbY\left(\frac{d}{2} - Y\right) - 2(KpYb)Y = 0 \qquad (3)$$

$$\mathbf{V} = \frac{mU^2}{2}\frac{1}{p}(\sin 2\alpha - 4\sin^2\alpha) + 0.94\pi d^2 b\lambda^3$$

$$\frac{F}{Q} = \frac{C_\alpha g f \rho_b}{2p}\left(0.24 + C_\beta u_* \sqrt{\frac{\rho_p}{p}}\right)$$

This led to an integrated wind erosion modelling system and the equations have been used by various of dust transport models

Remote sensing of vegetation



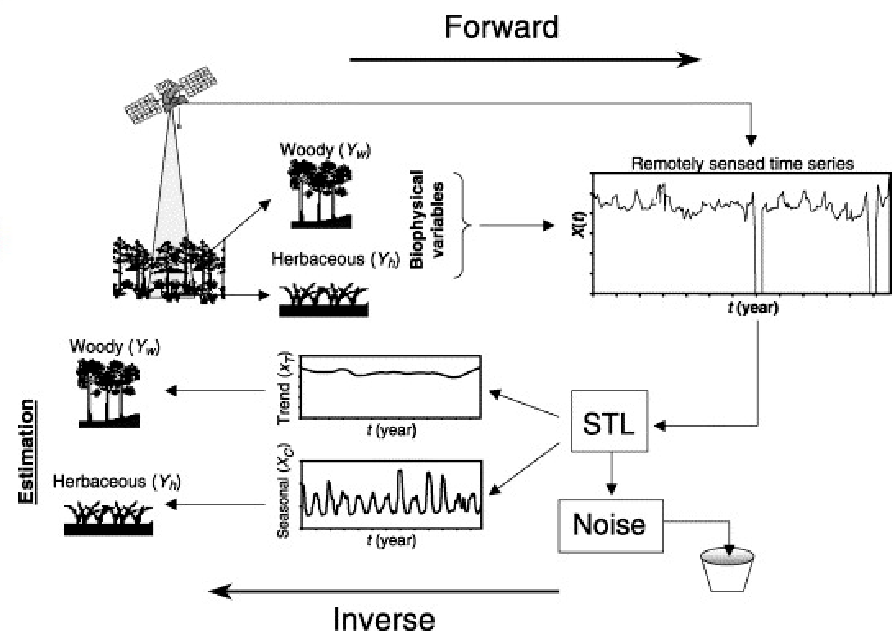
ELSEVIER

Remote Sensing of Environment

Volume 86, Issue 1, 30 June 2003, Pages 1-18

Decomposition of vegetation cover into woody and herbaceous components using AVHRR NDVI time series

Hua Lu, Michael R. Raupach[a], Tim R. McVicar[a], Damian J. Barrett[b]



Seasonal and Trend decomposition using Loess

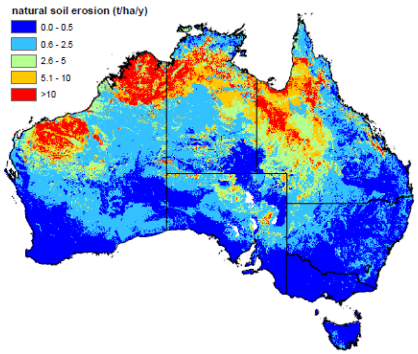
This decomposition method has since been refined and widely used by remote sensing community

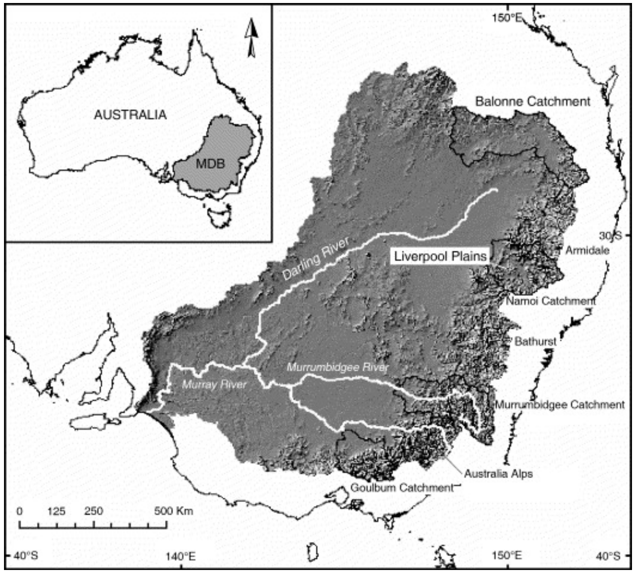
Continental to catchment-scale sediment transport


ELSEVIER
Environmental Modelling & Software
Volume 21, Issue 9, September 2006, Pages 1297-1308

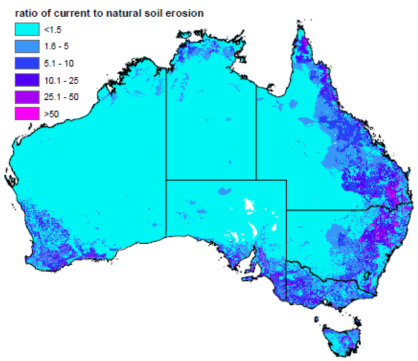
Modelling sediment delivery ratio over the Murray Darling Basin

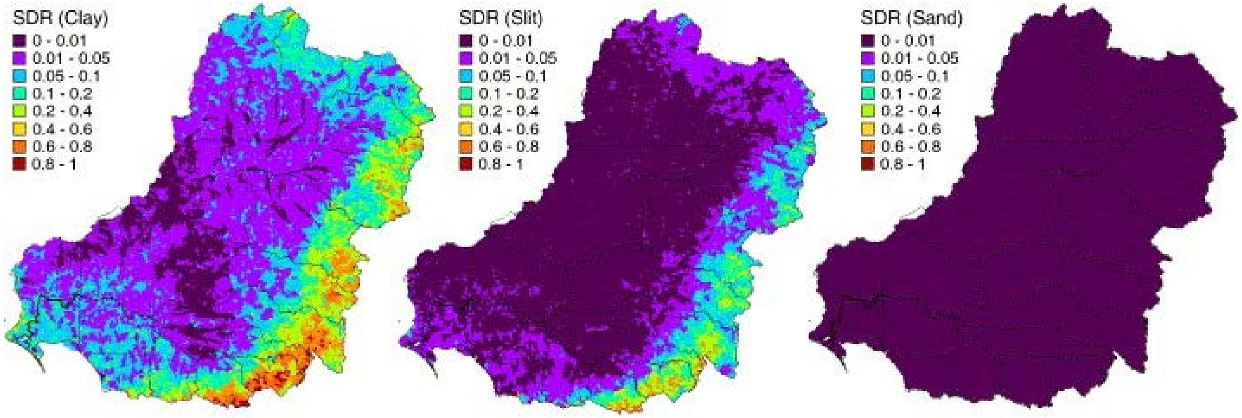
Hua Lu [a, b], C.J. Moran [c], Ian P. Prosser [a]



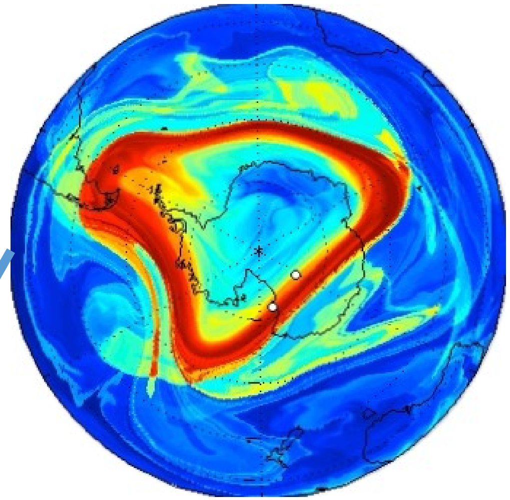


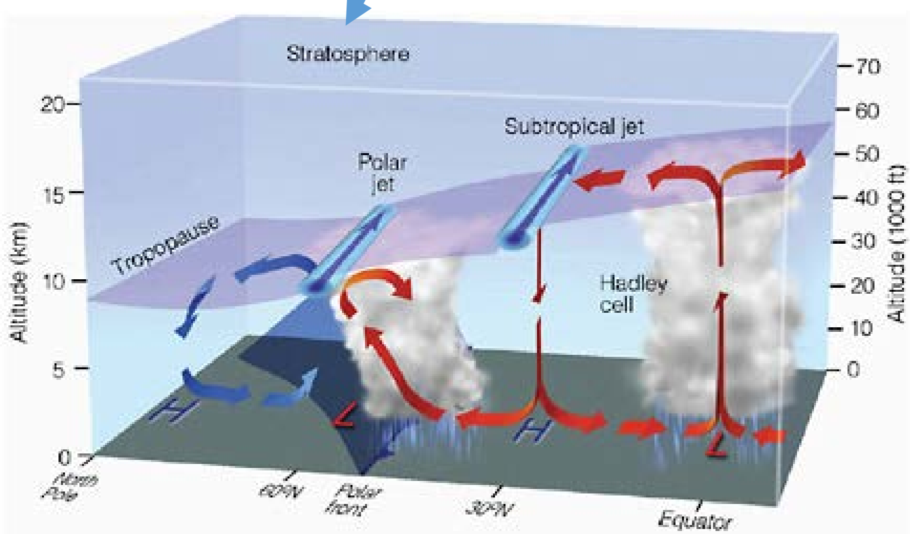
The images were once used by Australian National Museum



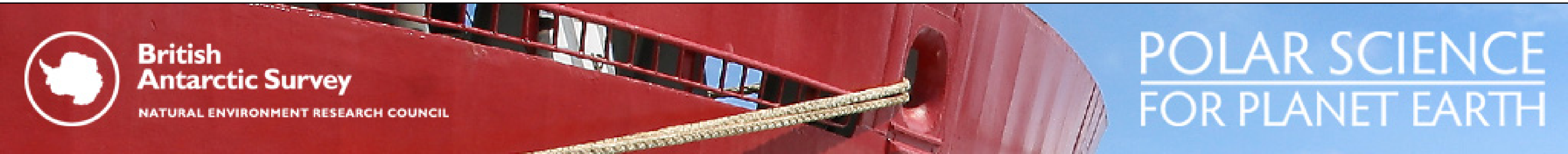


Atmospheric circulations & variability

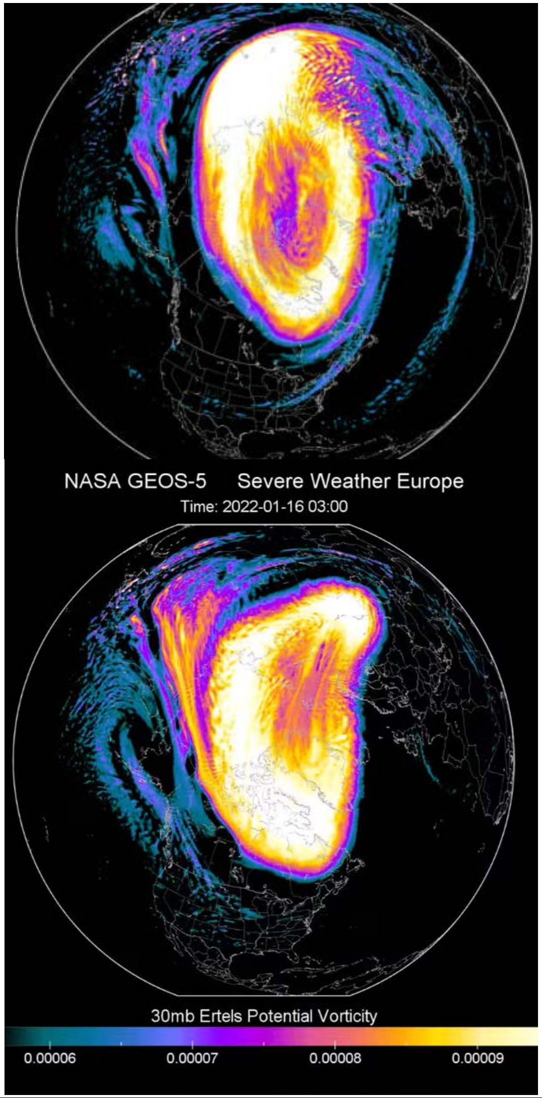


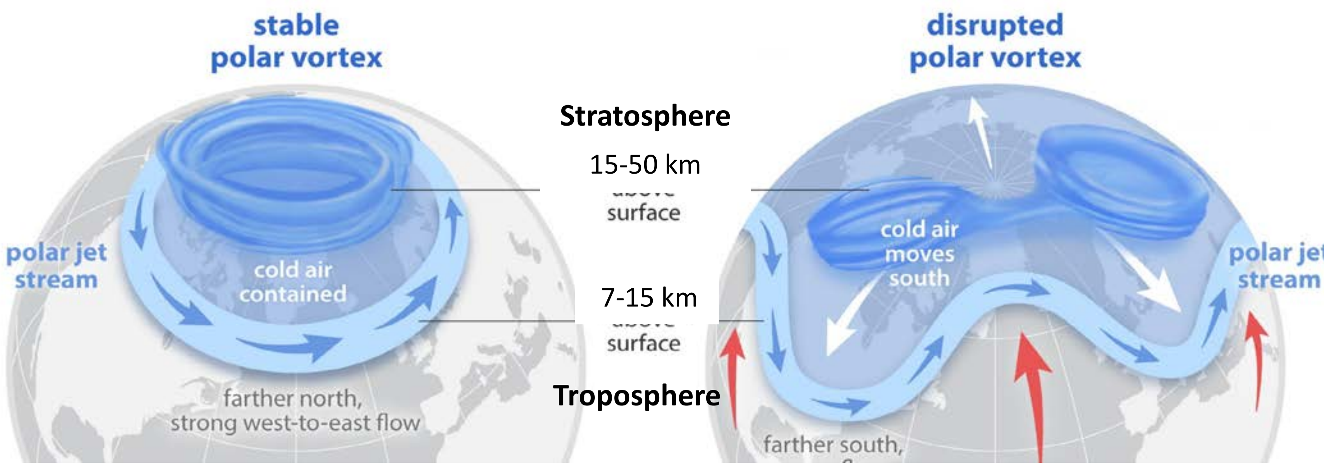


- A complex system that is intrinsically nonlinear and scale dependent
- Small changes or errors in initial or boundary conditions can lead to big difference in model result 30-to 90 days later (referred to as subseasonal to seasonal timescales)
- Uncertainty increases with altitude
- Fluid dynamics or partial differential equations are at the core of studying all these!



Stratospheric polar vortex

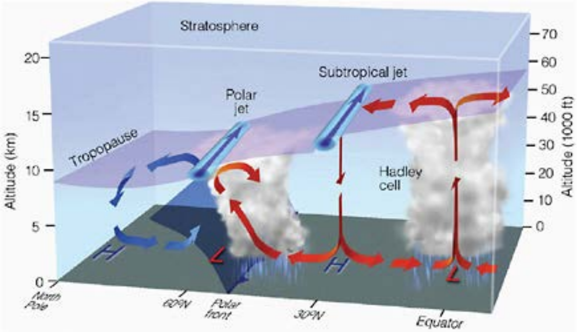


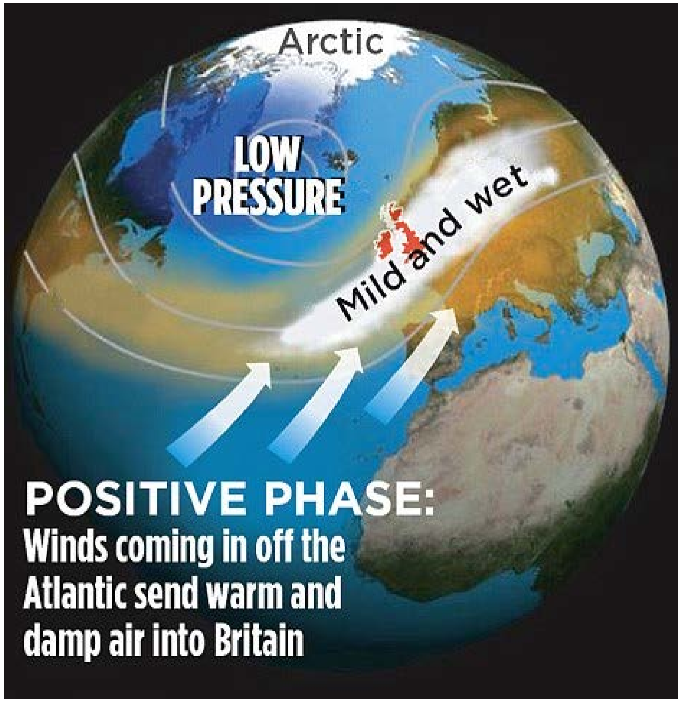


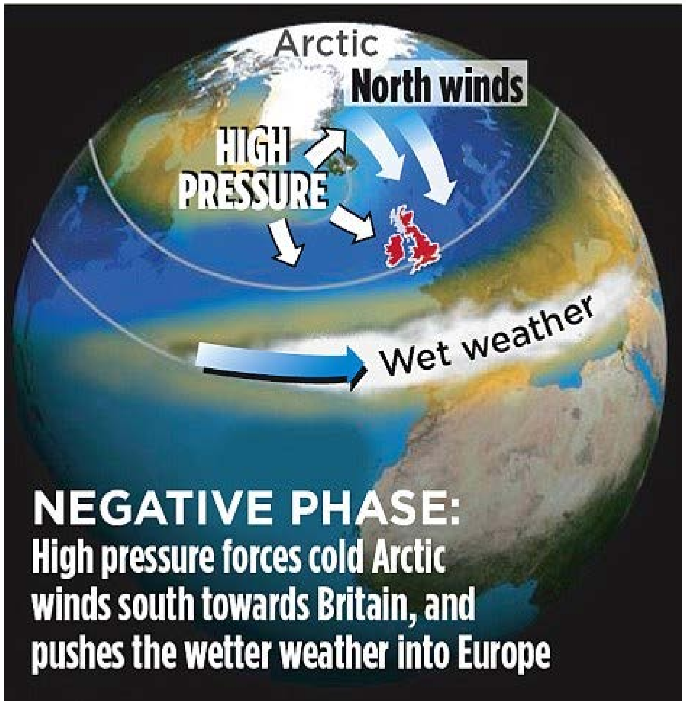
NOAA Climate Gov

- Two polar vortices: one in the troposphere and another in the stratosphere
- Vortices are strong westerly winds flowing around 45-60°N, isolating cold air inside and preventing penetration of warm air from lower latitudes
- The vortices wobble and stretch due to wave disturbances
- Extreme or persistent variability of the stratospheric vortex can (but not always) project onto the tropospheric vortex whereby it influences near surface weather

The North Atlantic Oscillation

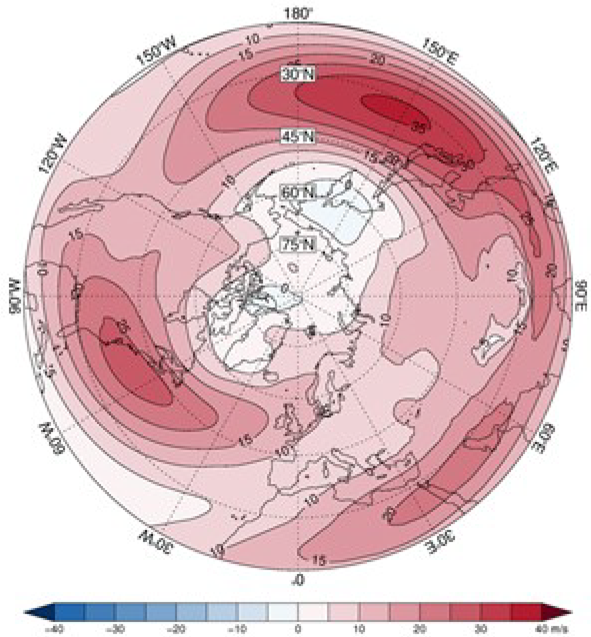




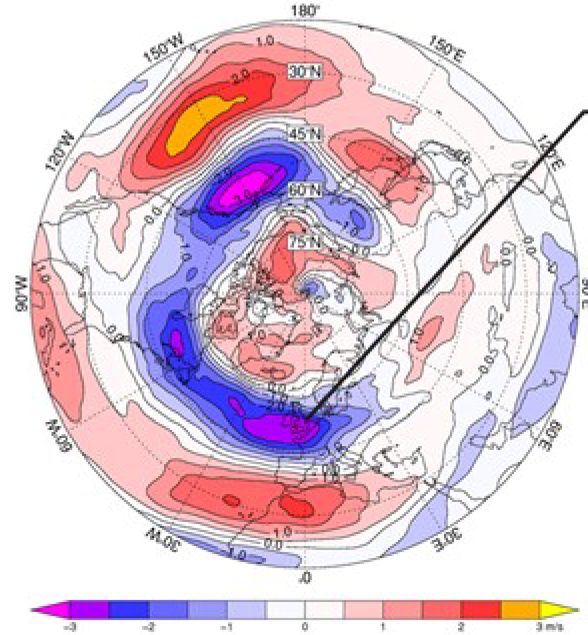


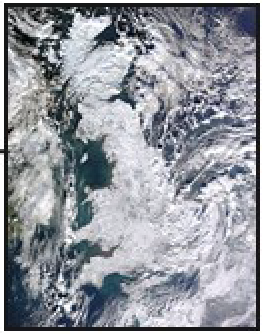
Extreme weather event & prediction

Winter Tropospheric Zonal Wind Climatology



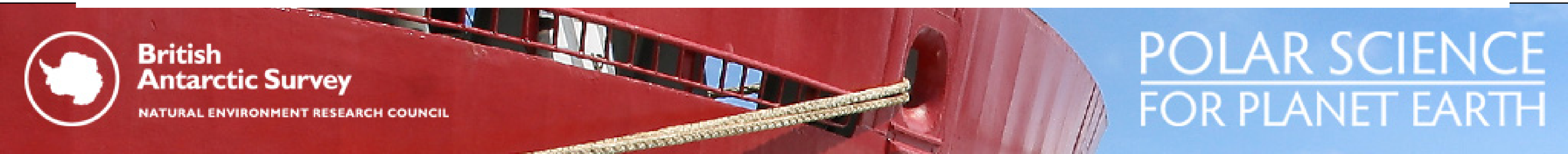
Winters without Downward Wave Reflection





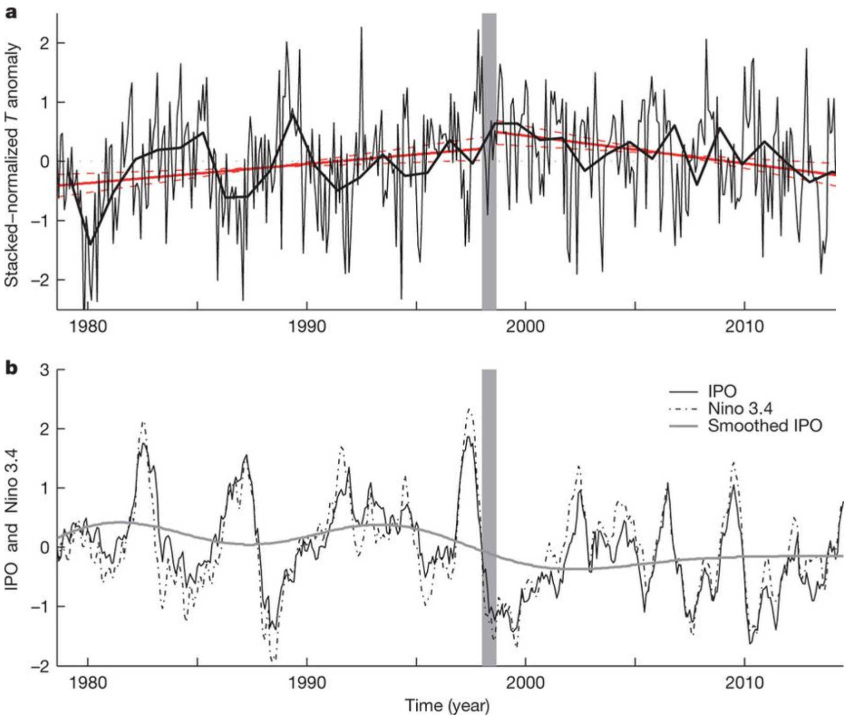
Impact on UK

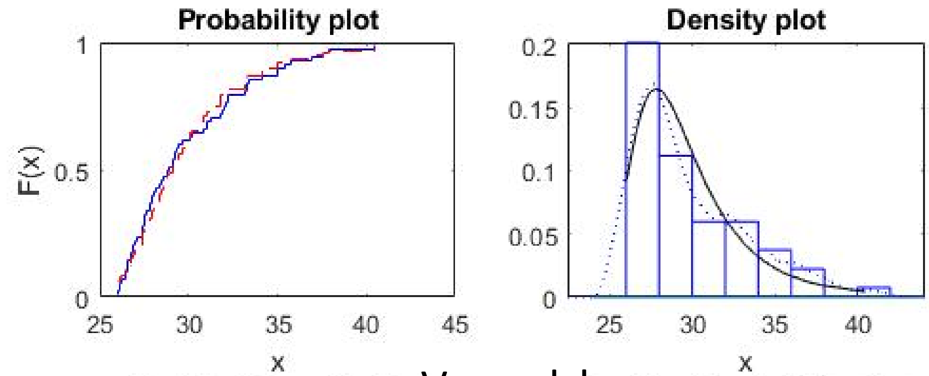
The left panel shows a climatology of tropospheric west to east (or zonal) winds. The right panel shows what happens in the absence of downward wave reflection: winds are reduced between ~45-60°N, which can typically cause colder winters over Northwest Europe. Upright: a satellite photo of the UK showing the extent of snow cover during the 2009-2010 winter, which was one of the “no-reflection” winters.



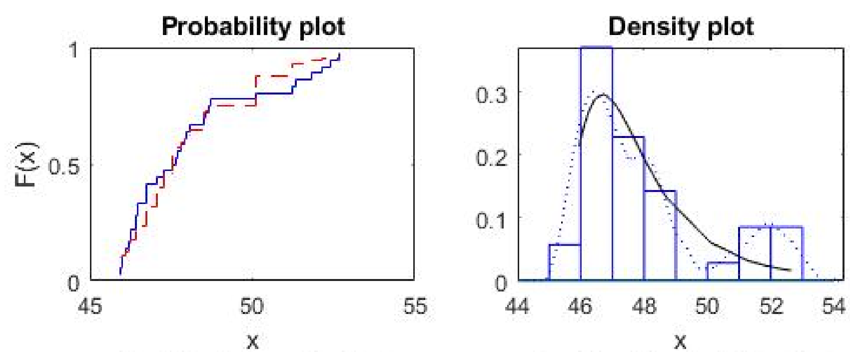
Trends and extreme temperature events in Antarctica

Mann Kendall Trend Test





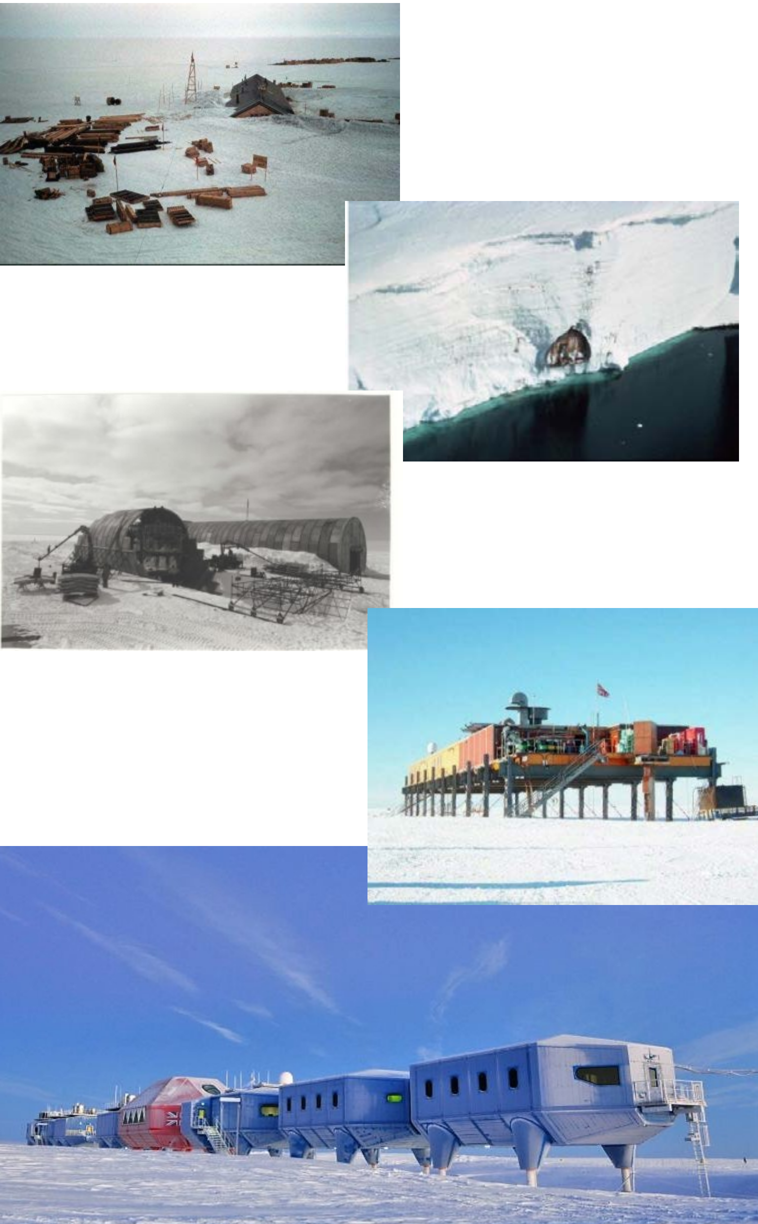
Vernadsky



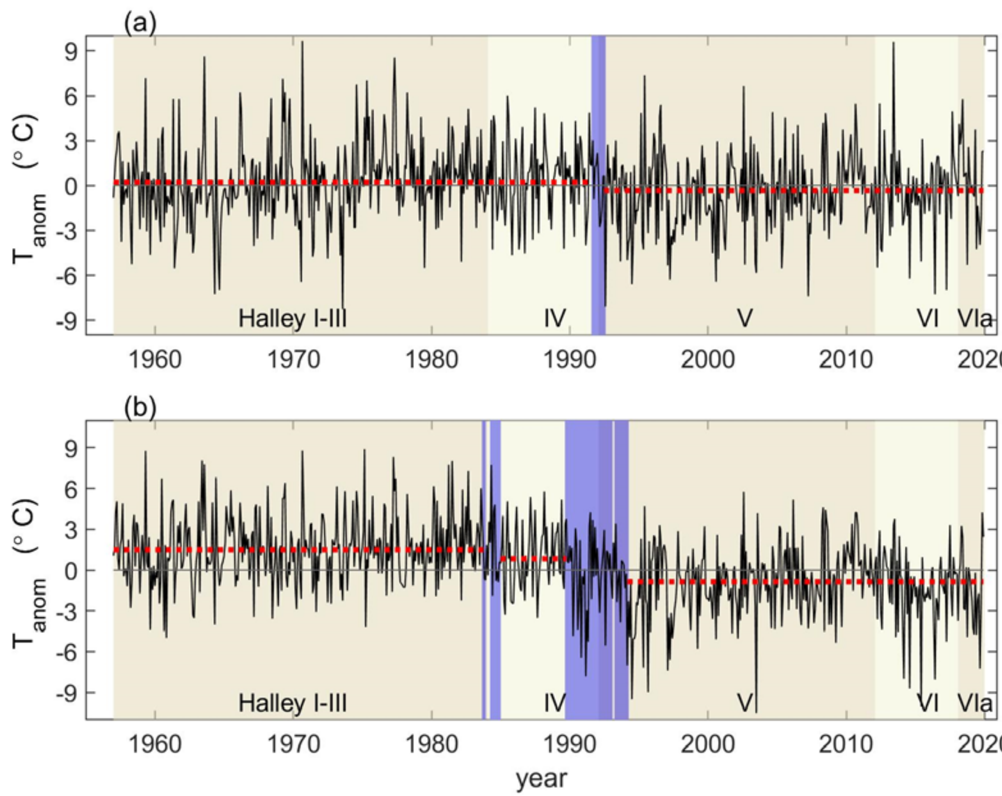
Halley

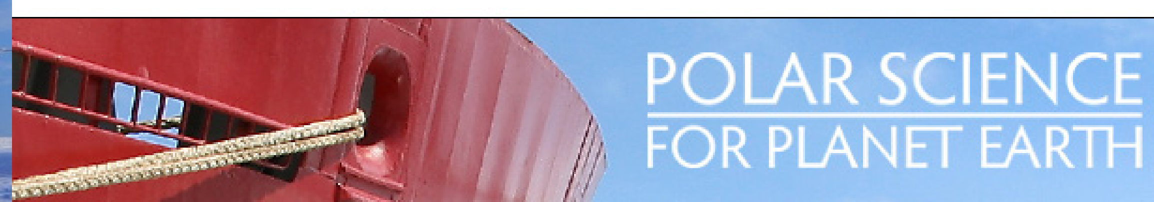
Turner et al. (2016), a ***Nature*** paper

Inhomogeneity of the surface air temperature record

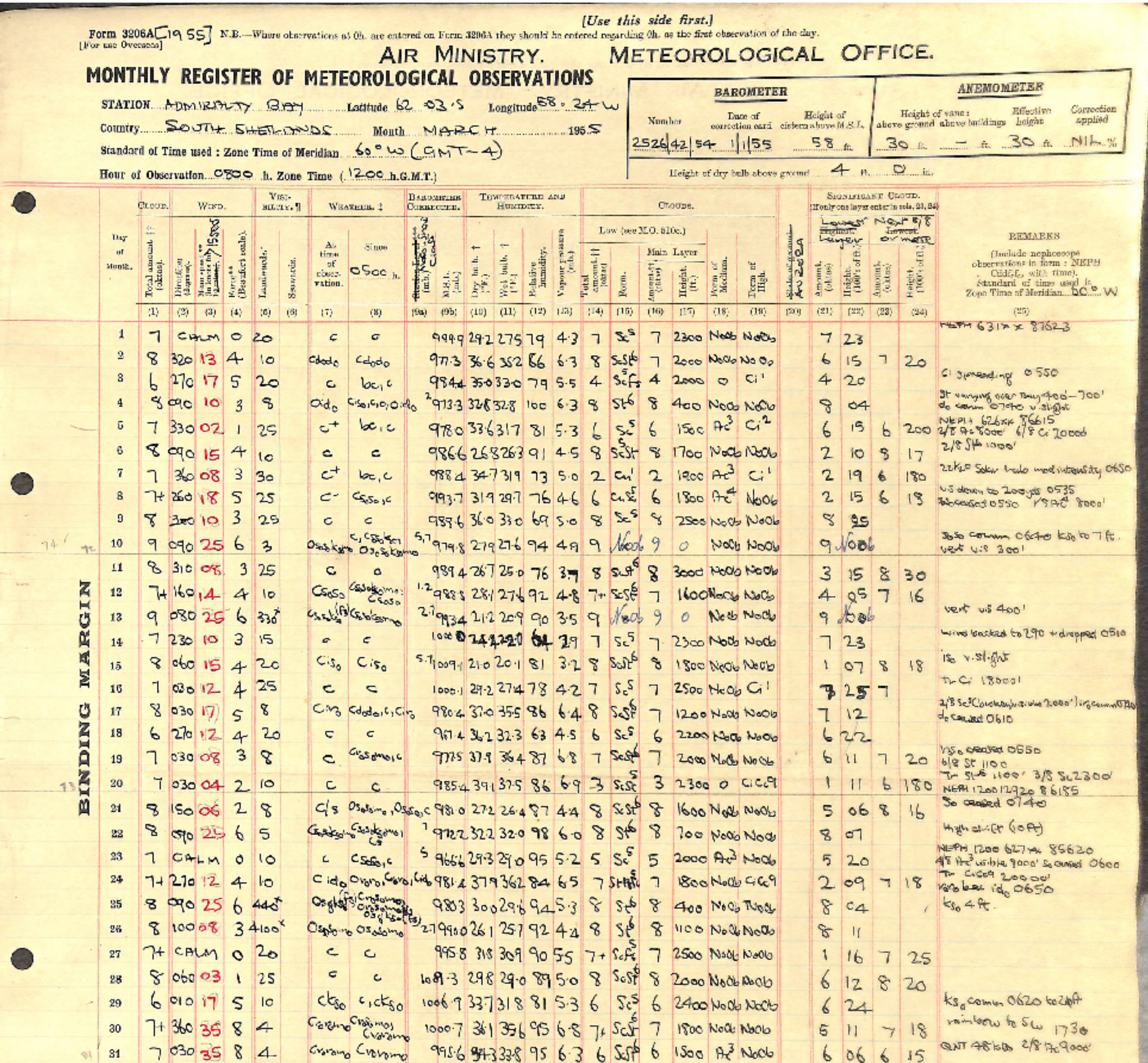


Two-sided Mann-Whitney U-test
with uncertainties





The digitization project: records


[Use this side first.]

Form 3206A [1955] N.B.—Where observations at 0h. are entered on Form 3206A they should be entered regarding 0h. as the first observation of the day.
[For use Overseas]

AIR MINISTRY. METEOROLOGICAL OFFICE.

MONTHLY REGISTER OF METEOROLOGICAL OBSERVATIONS

STATION ADMIRALTY BAY Latitude 62 03 S Longitude 58 24 W

Country SOUTH SHETLANDS Month MARCH 1955

Standard of Time used: Zone Time of Meridian 60° W (GMT−4)

Hour of Observation 0800 h. Zone Time (1200 h.G.M.T.)

BAROMETER: Number 2526/42/54; Date of correction card 1/1/55; Height of cistern above M.S.L. 58 ft.

ANEMOMETER: Height of vane above ground 30 ft.; Effective height 30 ft.; Correction applied NIL

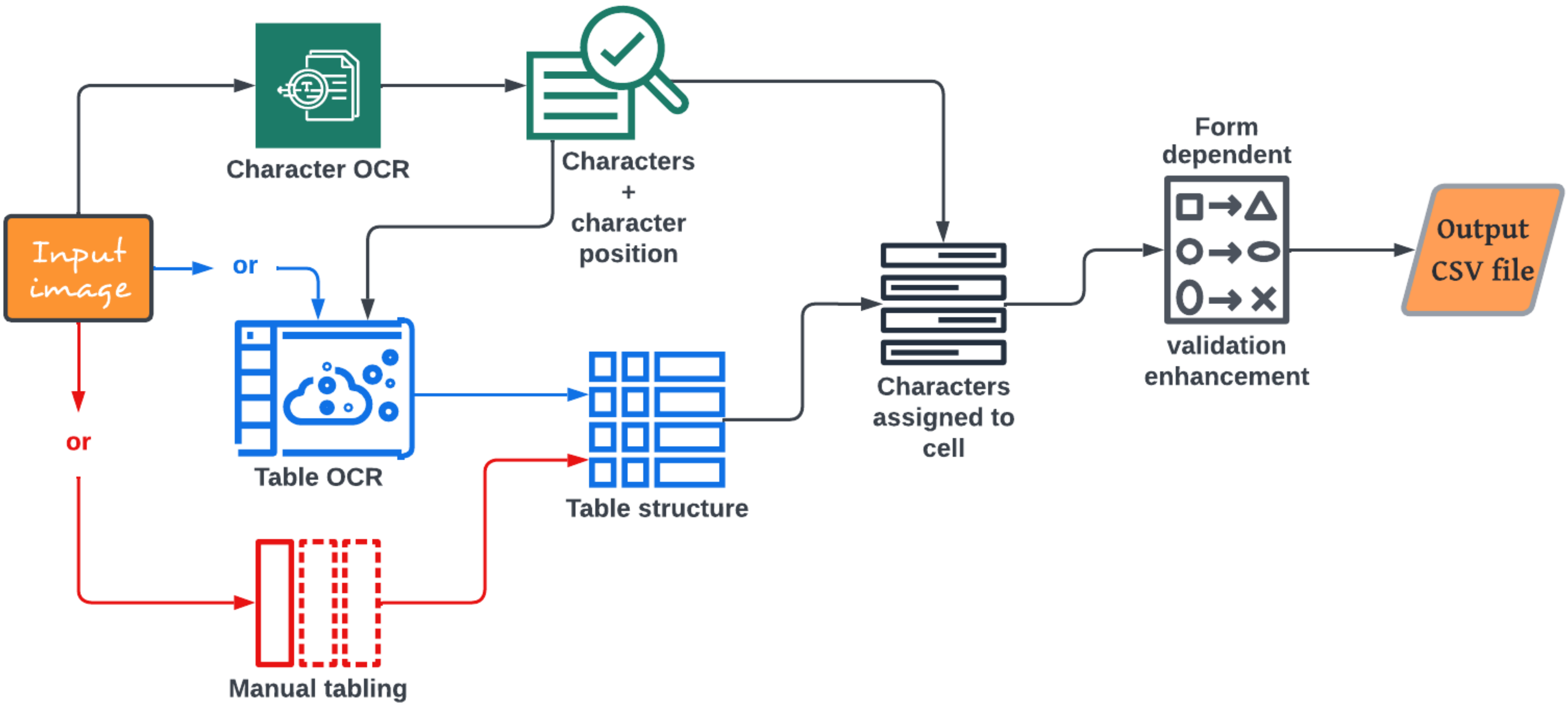
Height of dry bulb above ground 4 ft. 0 in.

BINDING MARGIN

BASOCR

Machine-learning + image process *Optical Character Recognition* **(OCR)** software that consists of multiple components

Developed mainly by two young people: Guy Phillips & Jonathan Xue



What else can mathematicians do?

- Any field involves data analysis, coding, computing, modelling processes or interpreting results according to mathematical equations and physical processes

- **Message to the early-career WiM:**

  ✓Be bold, flexible and passionate about the things that you are doing

  ✓PhD studentships can be applied via various NERC-funded DTPs

  ✓Good luck ☺