Research in Atmospheric, Oceanic and Planetary Physics at Oxford, UK

David Andrews

Before I start…

- Many thanks to Prof Hirooka for inviting me to Fukuoka and arranging my trip !
- Many thanks also to you all for welcoming me and my wife here, and looking after us so well !

Yesterday at Dazaifu

Important notice:

Please stop me if I talk too fast !!

The Oxford Physics Department

- Is one of the largest Physics departments in the UK (and Europe)
  - Nearly 100 Faculty
  - Over 600 undergraduate students
- Has 6 sub-departments:
  - Astrophysics
  - Atmospheric, Oceanic and Planetary Physics (AOPP)
  - Atomic and Laser Physics
  - Condensed Matter Physics (including Biophysics)
  - Particle Physics
  - Theoretical Physics

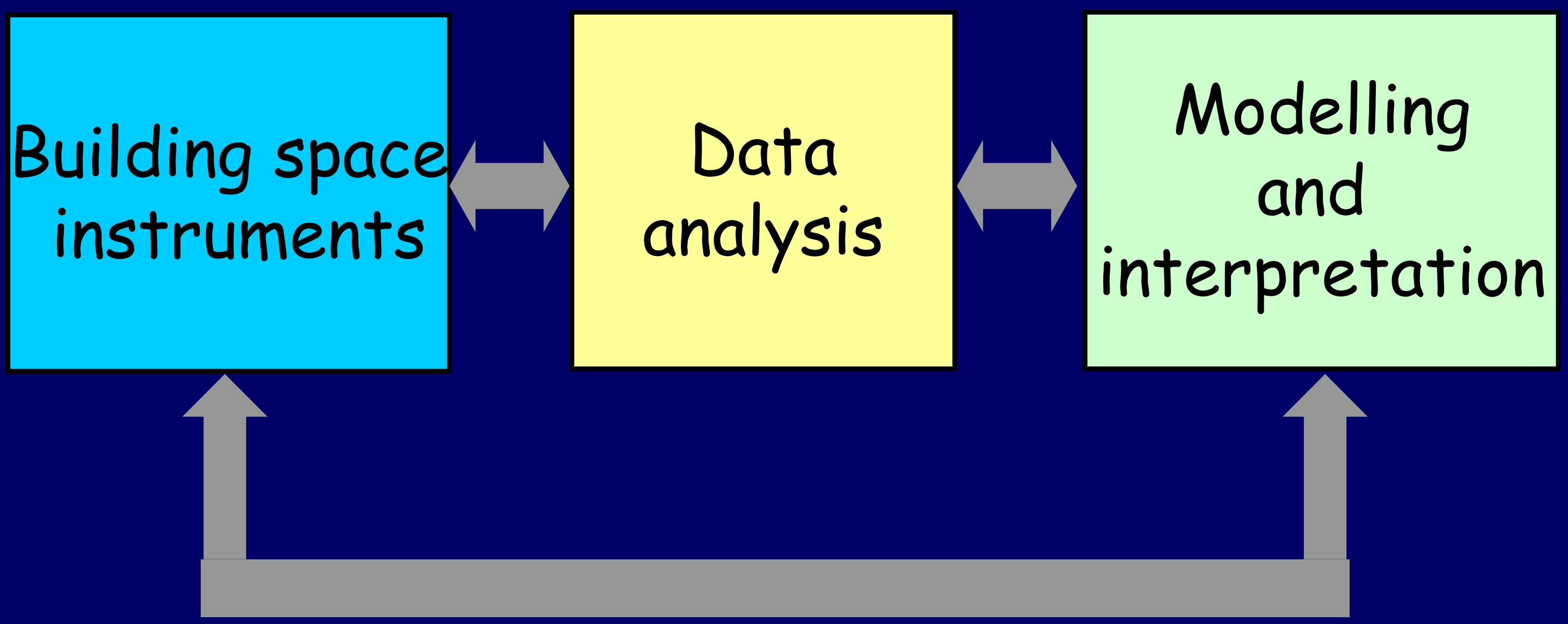
AOPP is one of the smaller Sub-Departments

We have about 75 members:

- 12 Senior Faculty members
- ~ 25 Post-Doctoral Researchers
- ~ 25 PhD Students
- + support staff

Head: Professor Peter Read

AOPP has a broad spectrum of interests:



Main research areas:

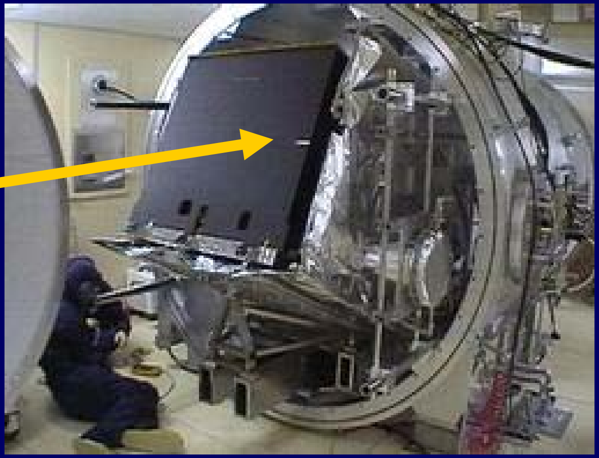
- Observations from space of
  - Earth's atmosphere
  - Other planets' atmospheres (Venus, Mars, Jupiter, Saturn, Titan…)
- Modelling of
  - Earth's atmosphere and oceans, including Climate Change
  - Other planets' atmospheres

Space Instrument Development and Testing (Earth Observation)

(John Barnett)

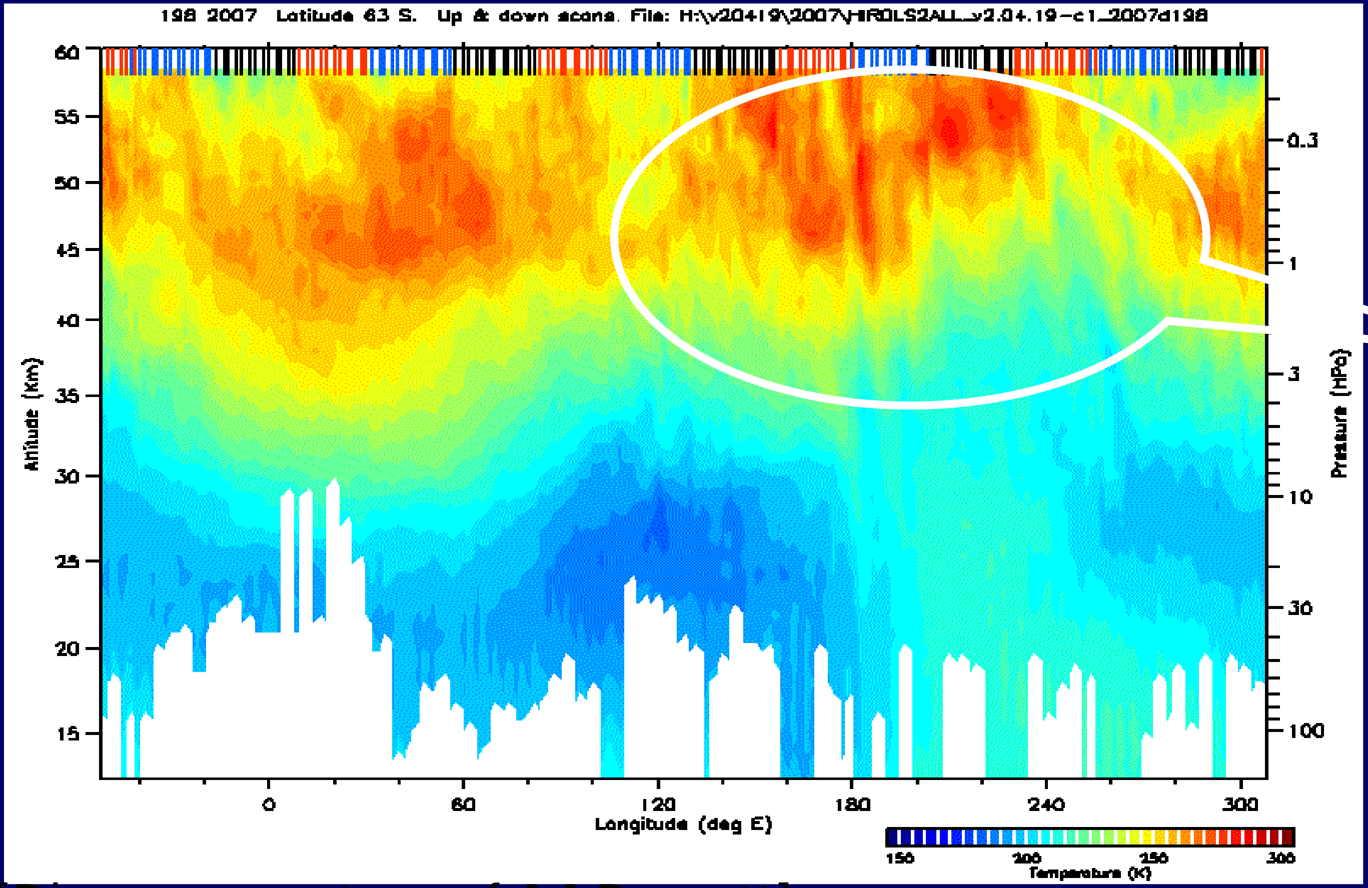
High-resolution Dynamics Limb Sounder (HIRDLS), in collaboration with U of Colorado, etc.

HIRDLS in AOPP's 2.2m test chamber…



…and integrated onto NASA's Aura spacecraft

HIRDLS data, 17 July 2007
Temperature at 63^{o}S in the stratosphere



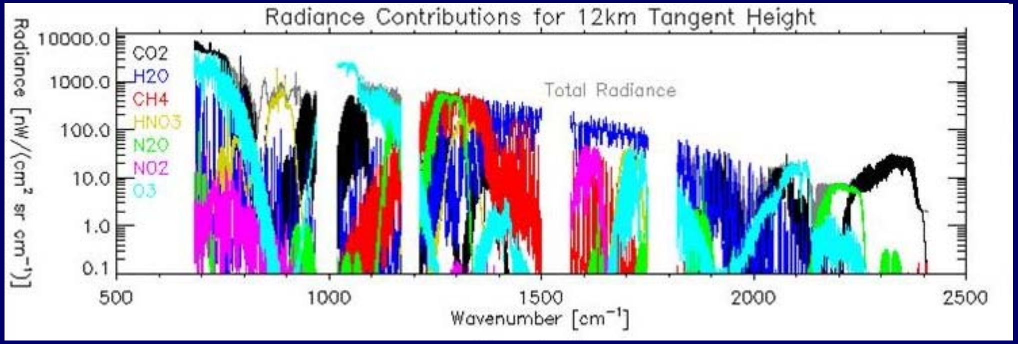
Note wavy structure in upper stratosphere: inertia-gravity waves?

[Diagram courtesy of J J Barnett]

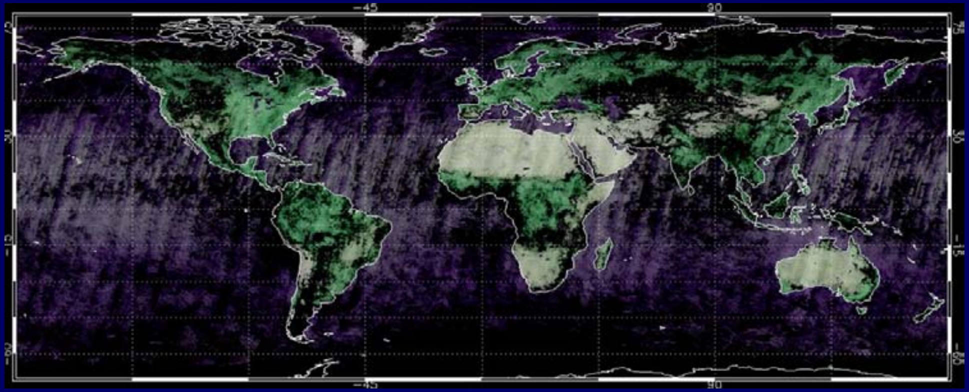
Data Analysis from Space Instruments (Earth)

(Don Grainger, Anu Dudhia)

Retrievals Using High Resolution Infrared Spectral Measurements (e.g. MIPAS)



Retrievals Using Nadir Imager Radiometers (e.g. ATSR series)



Also retrieval of aerosol and cloud; laboratory and field studies (volcanic ash, aircraft emissions)

Space Instrument Development and Testing (Other planets)

(Fred Taylor, Simon Calcutt, Neil Bowles)

Cassini at Saturn, including AOPP's CIRS instrument

AOPP's planetary instrument lab

Data Analysis from Space Instruments (Planets)

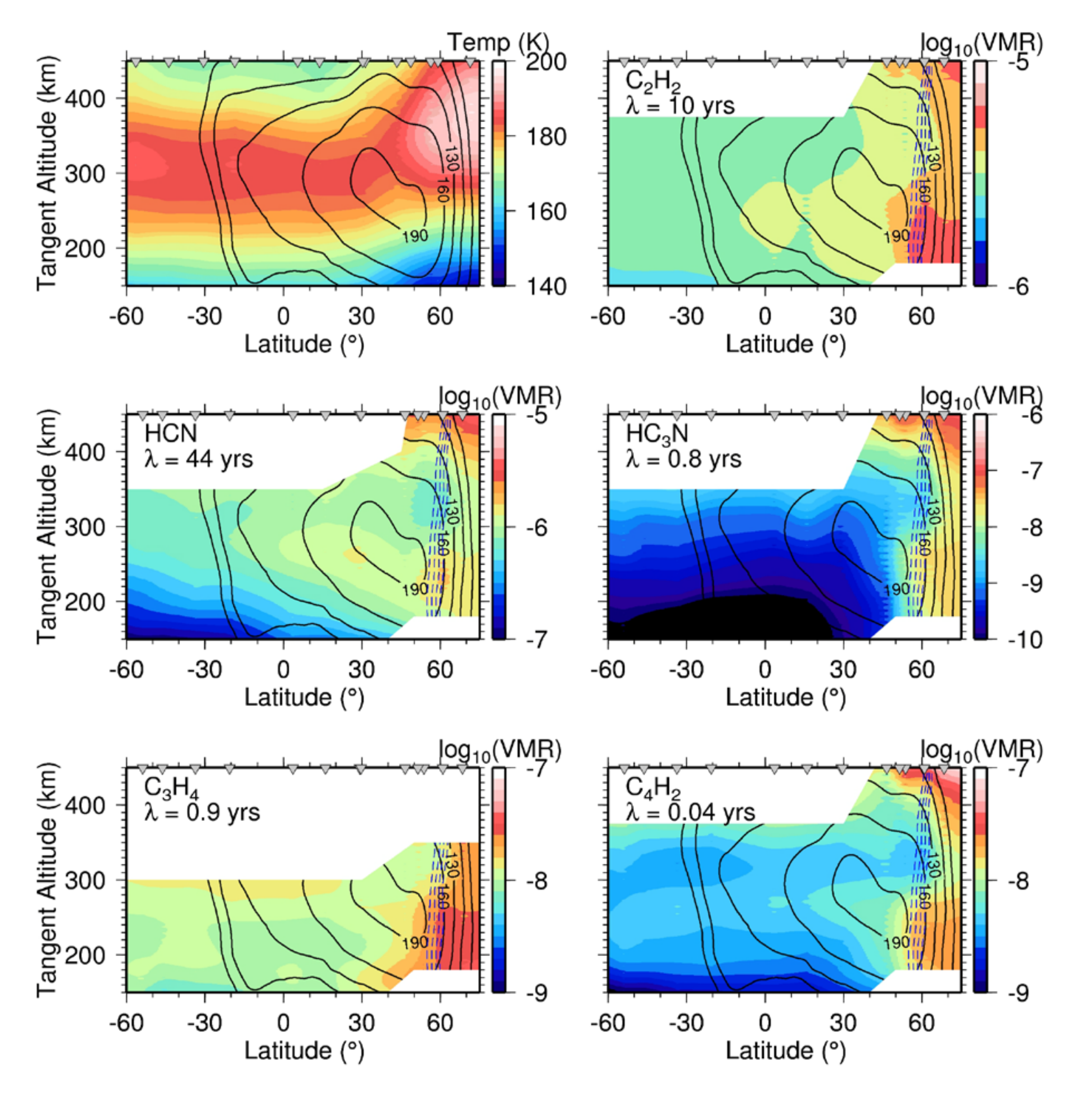
(Pat Irwin)

- Analysing data for Saturn and Titan from Cassini/CIRS
- Also data from Mars Climate Sounder on Mars Reconnaissance Orbiter
- And from VIRTIS instrument on Venus Express
- Also some *ground-based* measurements of Jupiter (UKIRT)

Probing Titan's Polar Vortex with chemical tracers (Nick Teanby)

- Confinement of tracer species within polar vortex
- Confinement is closer to pole > 300km, i.e. above stratopause
- Tongues of enriched air extend from pole to equator in stratosphere

Contours = Zonal Wind (m/s)
λ = photochemical lifetime



Climate Modelling
(Myles Allen)

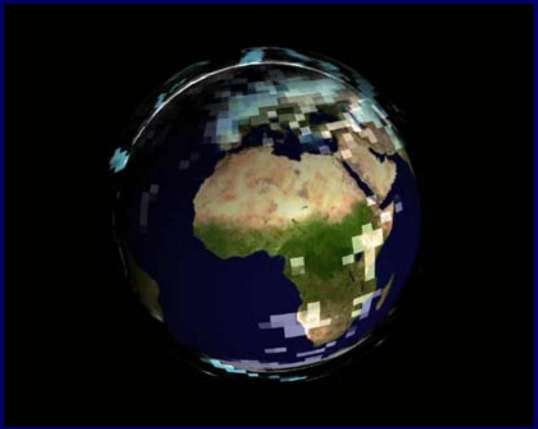
- Quantifying uncertainty in climate predictions
  - Attributing external influences on climate.
  - Quantifying the contribution of human influences to the risk of specific, harmful weather events.
  - Probabilistic climate forecasting, using **very large ensemble** simulations with comprehensive climate models, based on distributed computing: the climate*prediction*.net initiative.

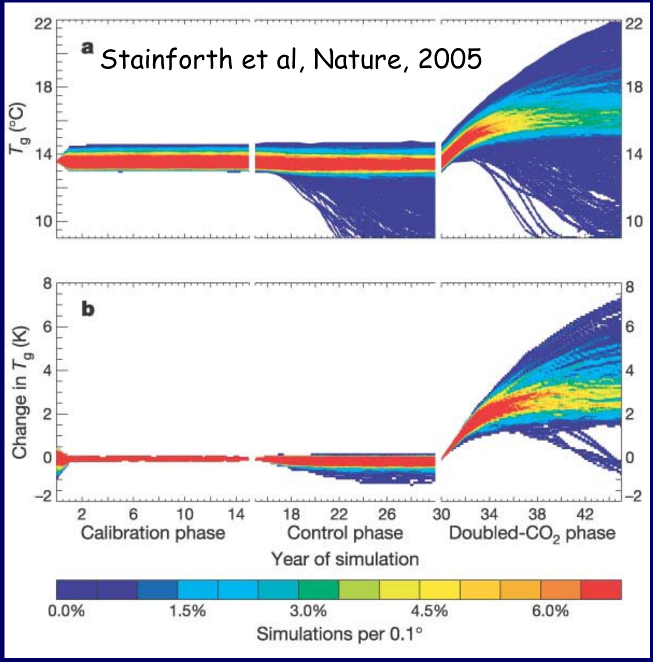
climate*prediction*.net
(Myles Allen)

A distributed computing project to produce predictions of the Earth's climate up to 2080 and to test the accuracy of climate models.

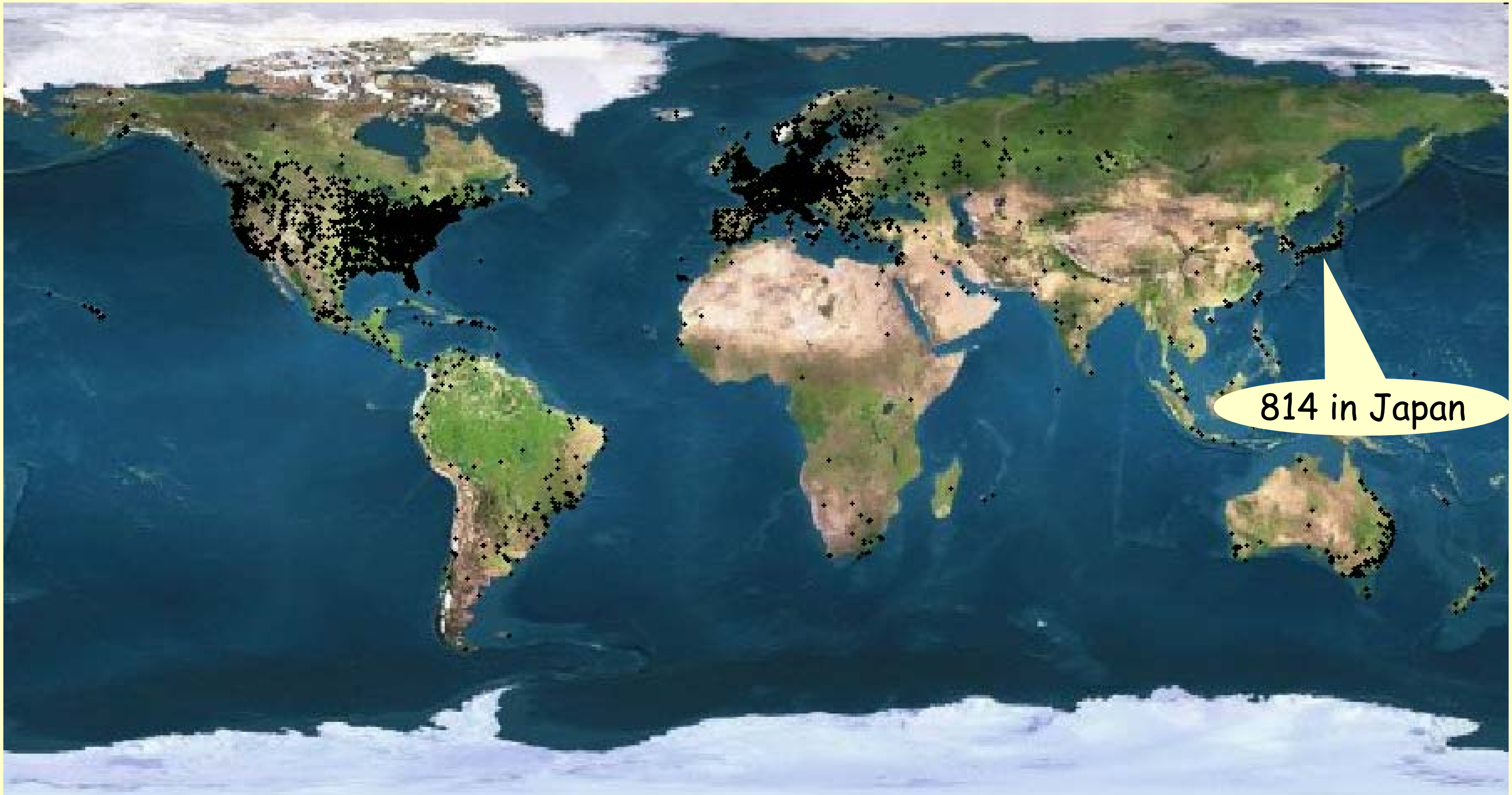
It addresses the uncertainty in predictions of climate response to rising levels of greenhouse gases, using ‘perturbed physics’ ensembles.

Currently about 50,000 regular volunteers are participating. Over 41 million years have been simulated.





climate*prediction*.net: the world's largest climate modelling facility?



>300,000 volunteers, >140 countries, >41M model-years

Hiro Yamazaki

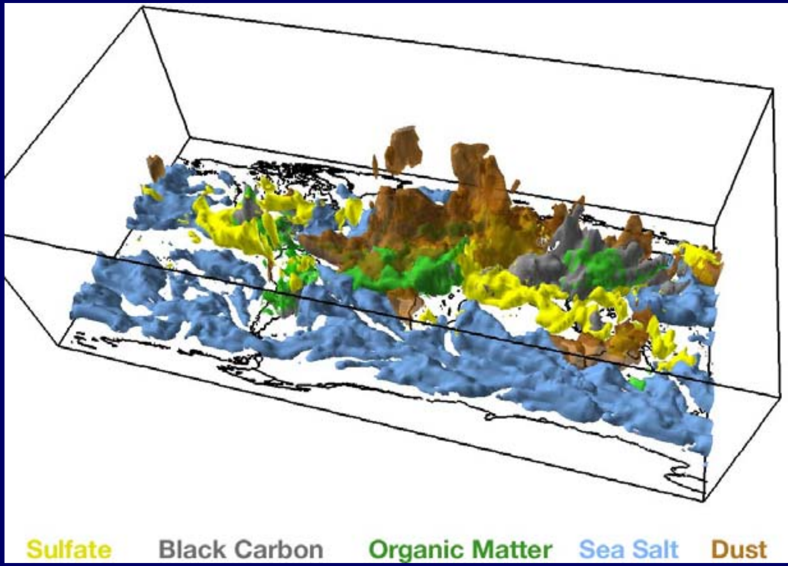
and Kuniko Yamazaki are postdocs in this group

Climate Processes
(Philip Stier)

Aerosols and clouds: their interactions, and role in the climate system

Aerosol modelling: aerosol mixing ratio isosurfaces colour-coded by component as simulated with the aerosol-climate model ECHAM5-HAM.

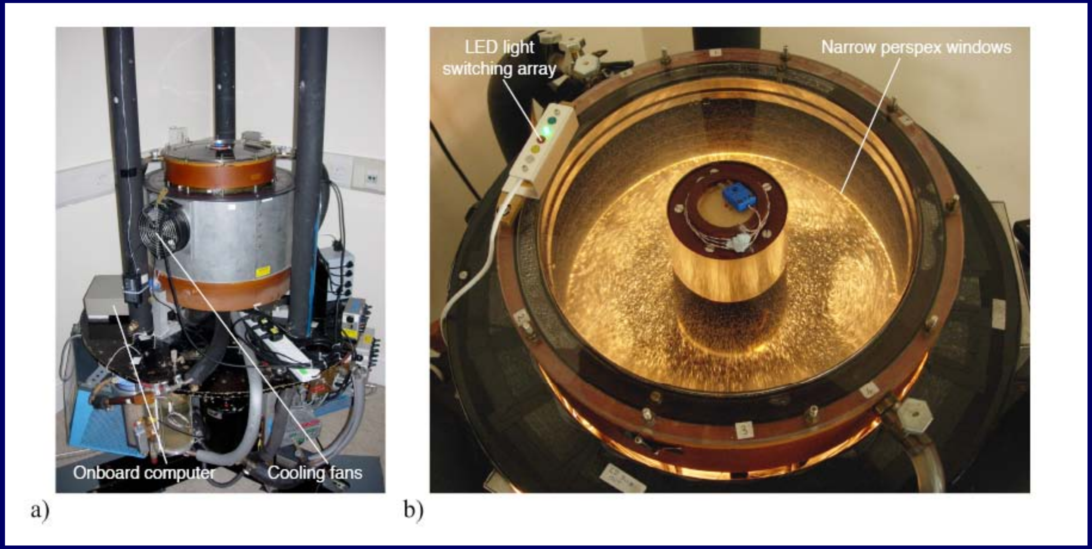
Used together with measurement data from satellites, aircraft and ground-based instruments.



Geophysical Fluid Dynamics Laboratory

(Peter Read)

Laboratory studies of rotating fluid systems, together with numerical models and data assimilation techniques

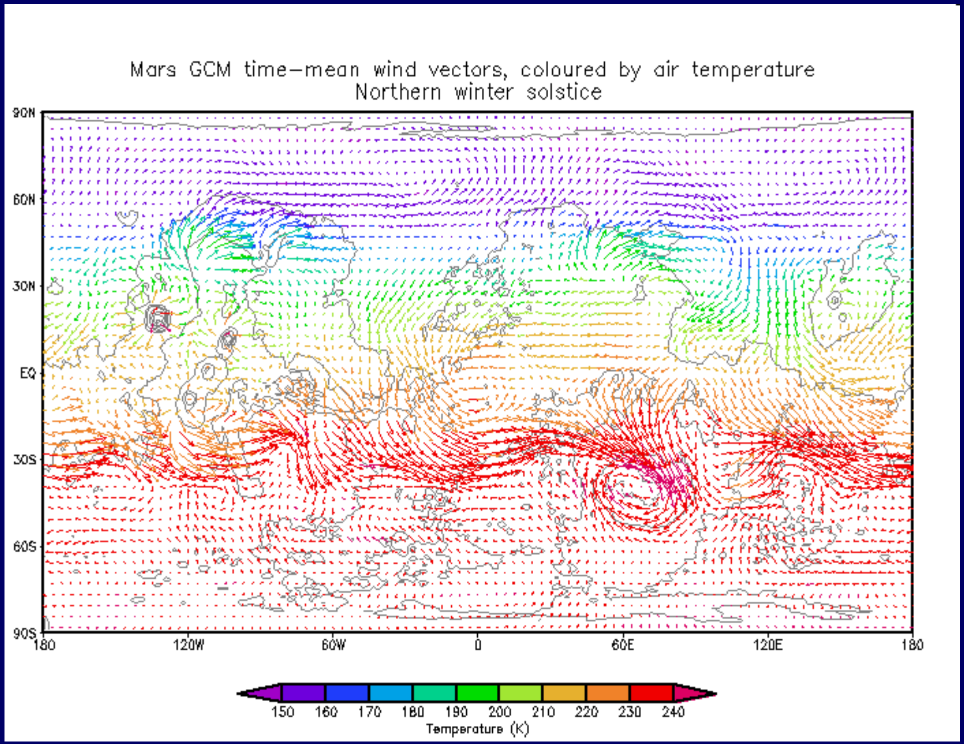


Rotating turntable (R Wordsworth)

Modelling of other planets' atmospheres

(Peter Read)

Mars GCM (with French and Spanish groups): studies of synoptic-scale and planetary waves, dust storms, etc.



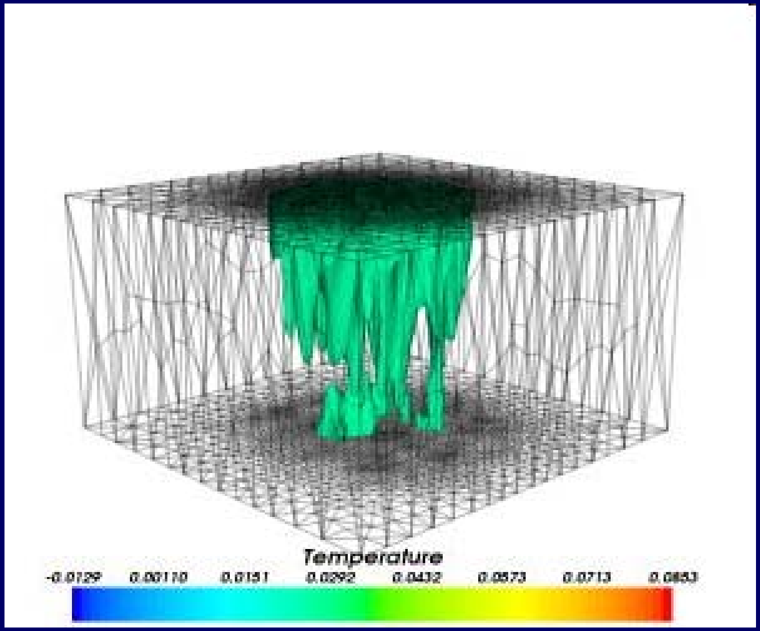
Also:
Jupiter/Saturn
Venus…

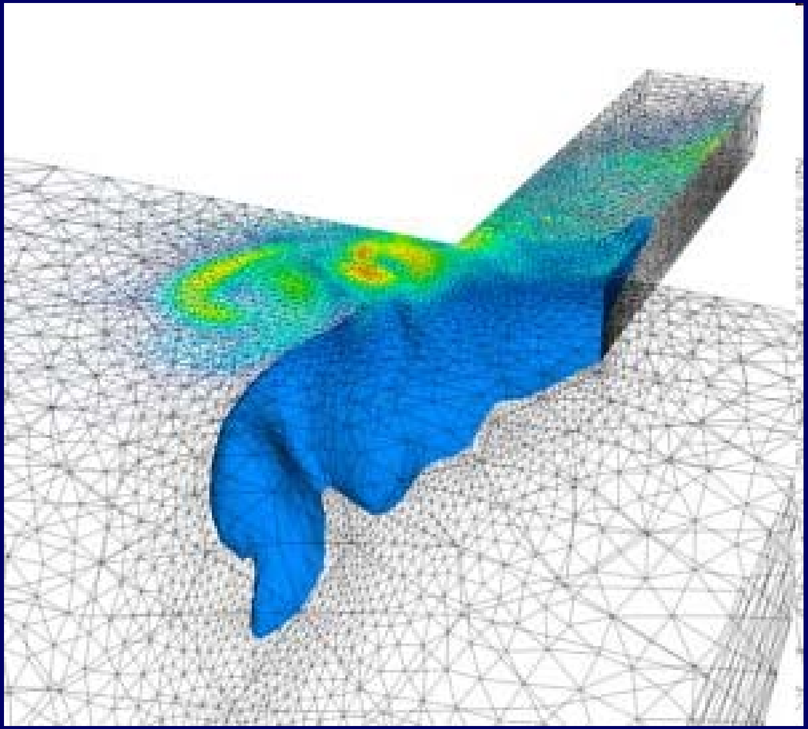
Modelling of Oceans

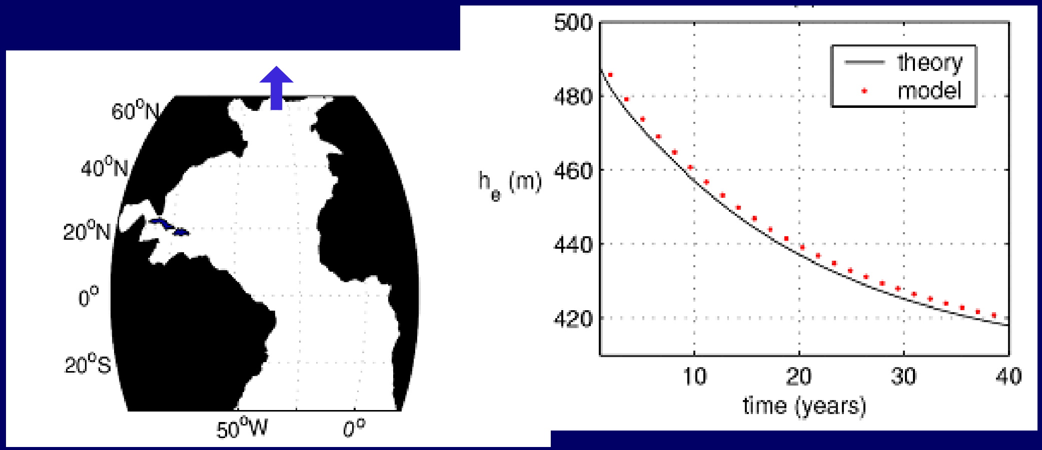
(David Marshall)

- Joint research programme with the Earth Sciences Department
- Main research interests:
  - Next Generation Ocean Model (with Imperial College London, etc), based on finite elements and unstructured, dynamically-adaptive meshes.
  - Meridional Overturning Circulation
  - Boundary Current Separation (e.g. Gulf Stream)

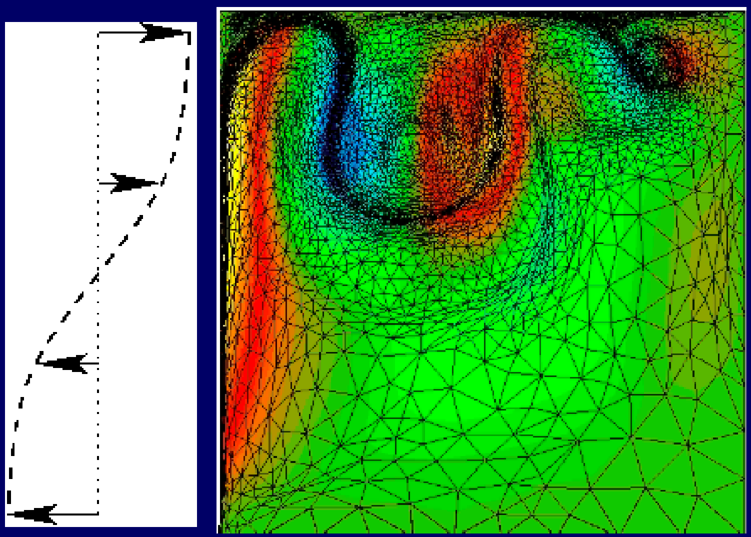
Uses of adaptive mesh for modelling complex ocean circulation processes







Adjustment of the Atlantic thermohaline circulation. The graph shows eastern boundary thermocline depth according to analytical theory (solid line) and from a full numerical calculation (dots).



Wind-driven circulation in an idealised rectangular basin. The mesh is adapted to track the evolving flow structures. Shading shows poleward velocity

About myself…

- Research
  - Have mainly worked on Middle Atmosphere Dynamics in the past.
  - But have recently been working on *simple* climate models…
- Administration and Teaching
  - Head of AOPP 2000-08. Now Ex-head!!
  - Lecture to Physics undergraduates on Mathematics, Fluid Dynamics, Geophysical Fluid Dynamics
  - I am a Physics Tutor at one of the Oxford Colleges

This year (Oct 2008 – Sept 2009) I am on sabbatical leave

- Part of the time, I'm preparing a 2nd Edition of my book

“*An Introduction to Atmospheric Physics*”

Main addition: a new chapter on the physics of Climate Change.

- Also, catching up on unfinished research…

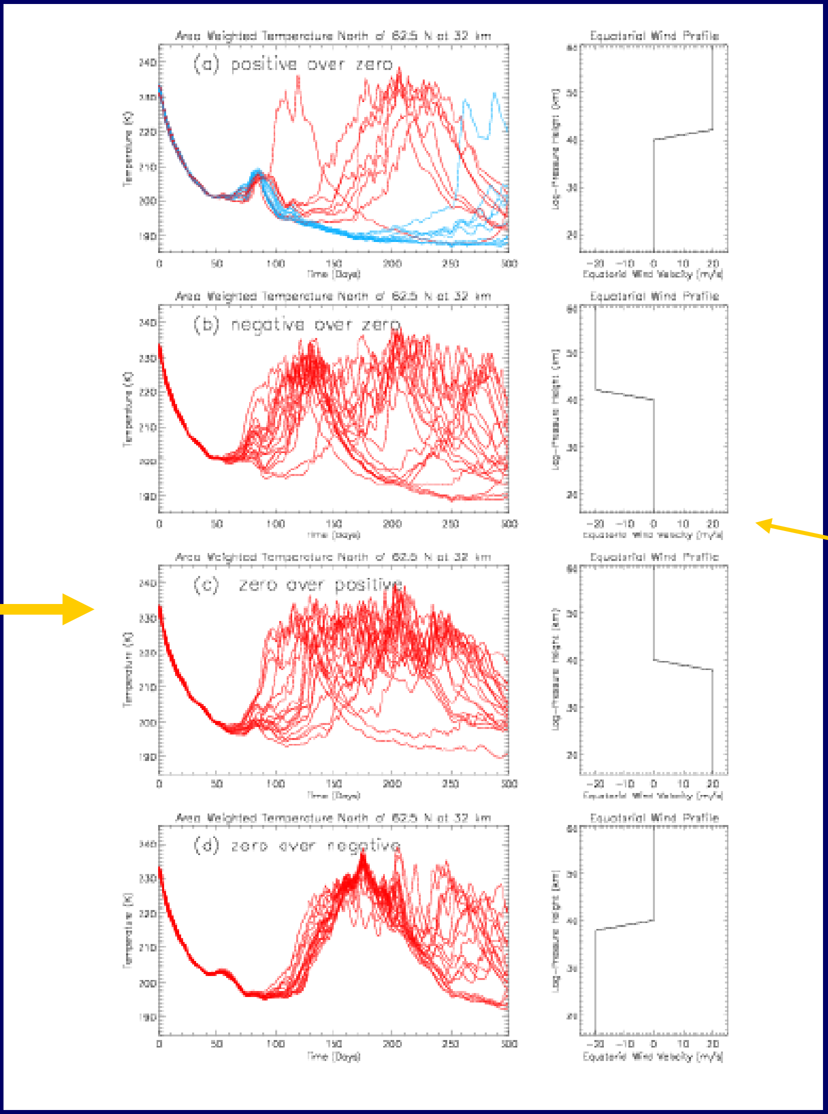
My research interests are mostly theoretical/mathematical:

- Middle Atmosphere Dynamics (but not currently spending much time on this).
  - Recent PhD student (Matthew Rigby) has worked with Prof Lesley Gray (Reading) and me on modelling Stratospheric Sudden Warmings, using intermediate GCMs.
  - I am also collaborating with researchers in the UK Met Office on applying EP diagnostics to their non-hydrostatic GCM.

An example of Rigby's PhD work: sensitivity of modelled stratospheric warmings to equatorial wind profile:

N Polar temperature at 32 km.

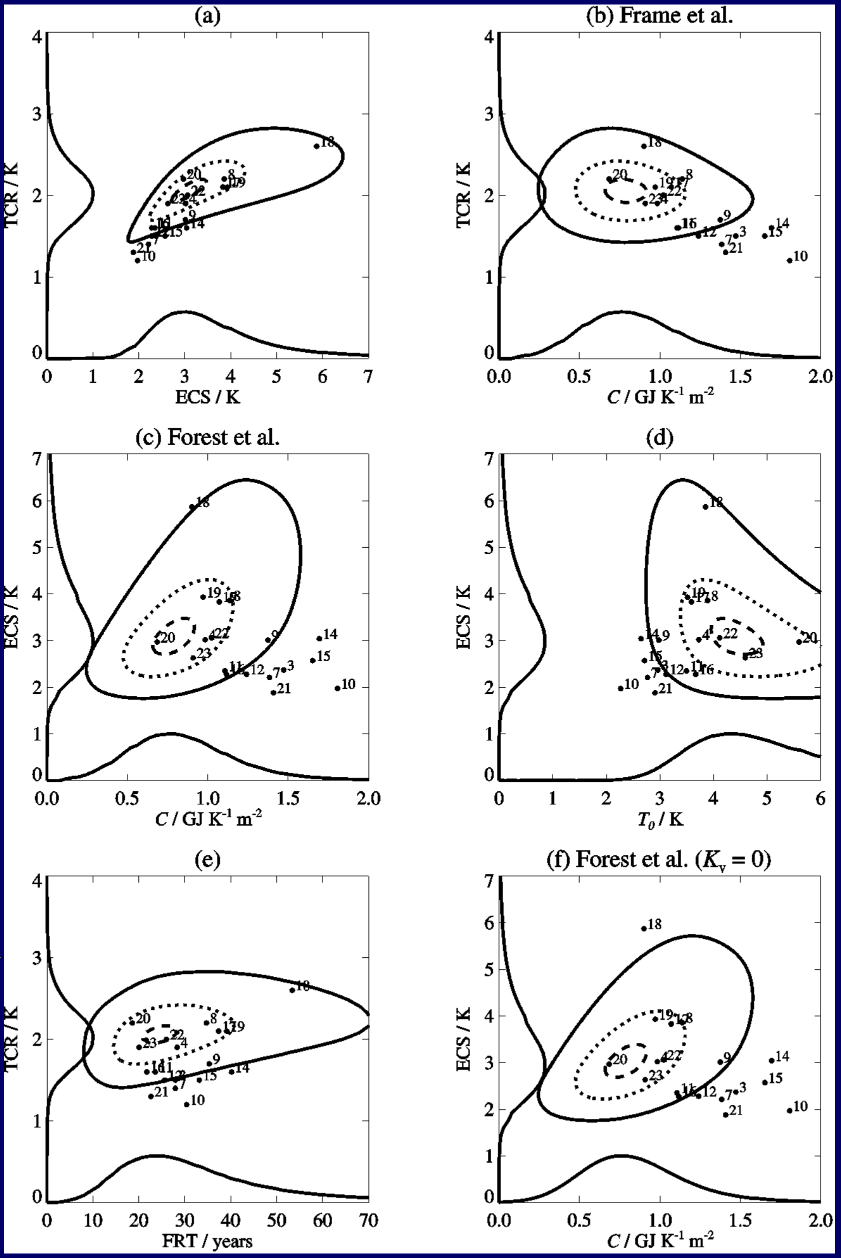
20-member ensembles, perpetual January, with equatorial zonal wind relaxed to profiles shown on right.



Target equatorial wind profiles

• Use of simple Energy Balance climate model to provide diagnostics for IPCC climate forecasting models (Andrews & Allen, *Atmos. Sci. Lett.* 9, 7-12, 2008)

Clearest interpretation is in terms of
feedback response time
and
transient climate response



Two problems I am currently working on:

- Simple energy-balance climate models, including oceanic upwelling and diffusion:
  - analytical solutions give insight into relevant parameters (e.g several different timescales).
- Why is the radiative forcing due to CO_2 roughly logarithmic in the increase in absorber density?
  - An interesting mathematical problem.