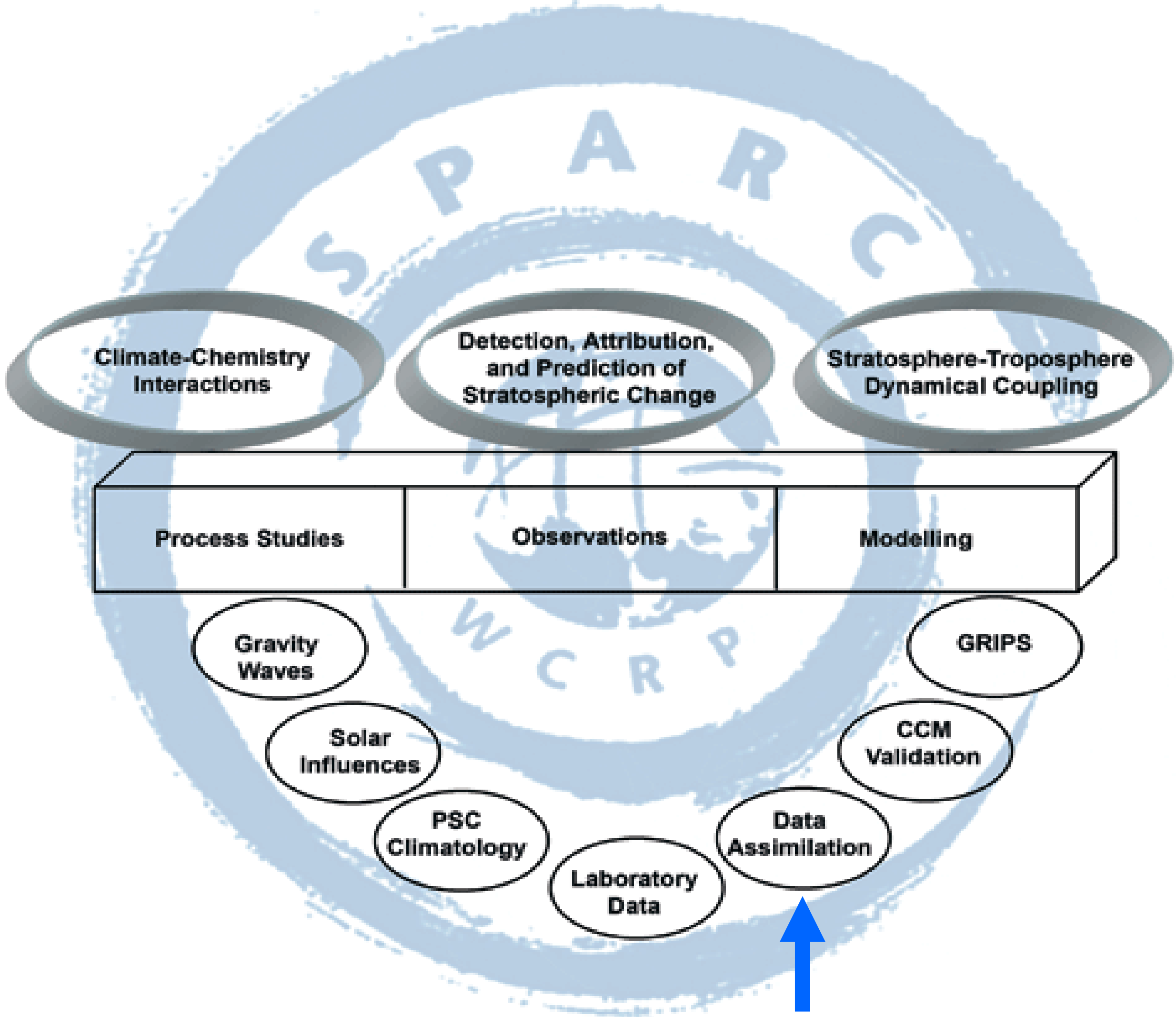
Stratospheric Processes and their Role in Climate (SPARC): value of wind measurements by ADM-Aeolus

Alan O'Neill
UK National Centre for Earth Observation

Given by Ted Shepherd
University of Toronto

Thanks Ted

Structure of the SPARC Activities



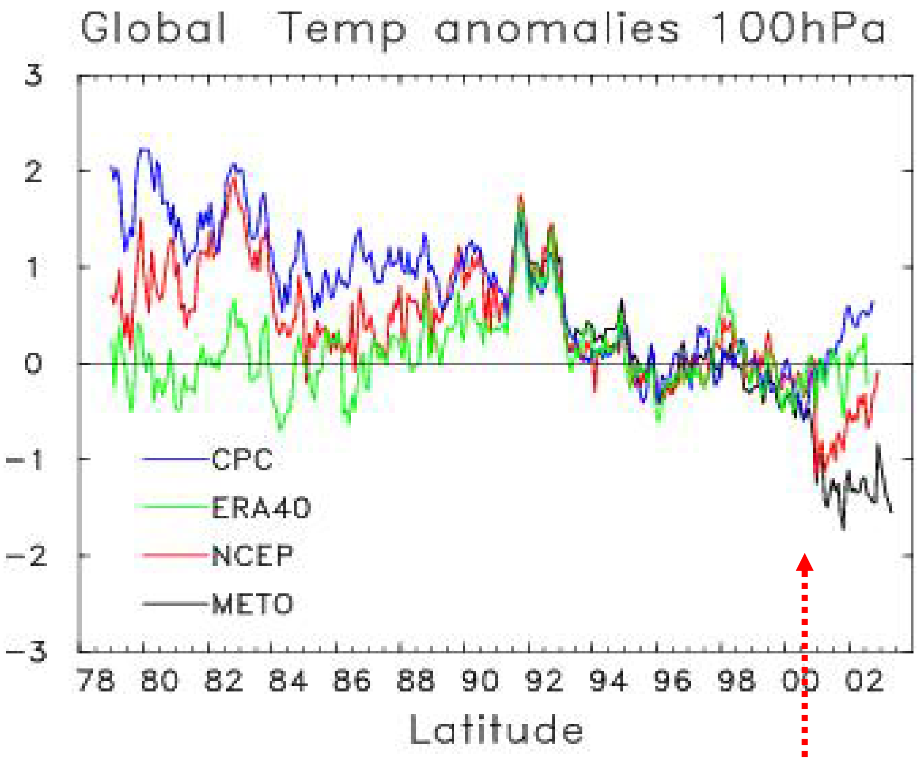
Note: SPARC Data Assimilation Working Group focuses on process-related assimilation issues for the stratosphere and mesosphere.

Global mean 100 hPa temps from analyses / reanalyses

[Slide added by TGS]

Figure courtesy of Bill Randel, NCAR

each data set normed to zero for 1992-1999



Note spurious changes due to evolution of data / analysis systems

TOVS – ATOVS change

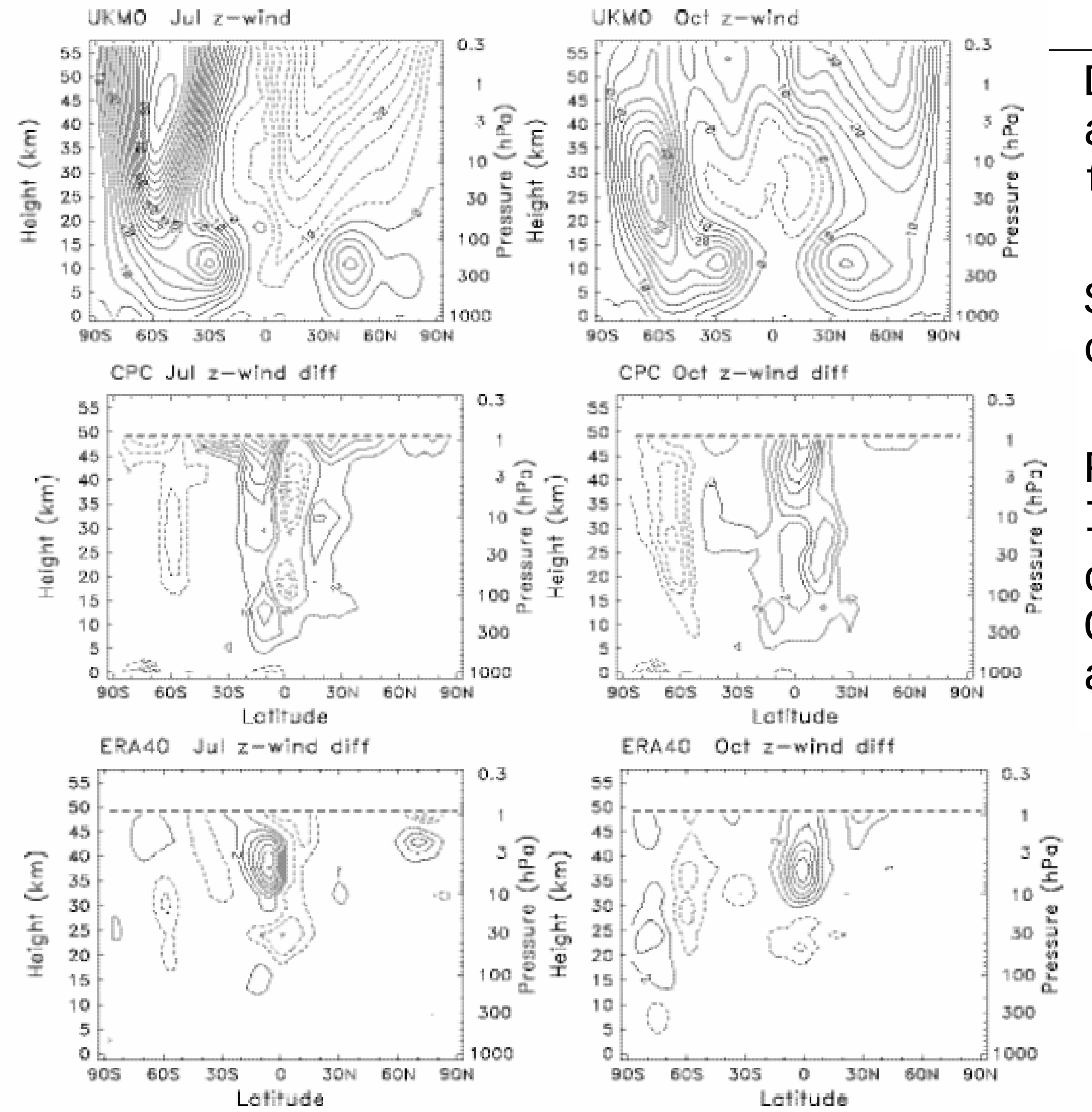
Current concerns about the Global Observing System

- Lack of global observations of stratospheric winds in the current operational meteorological system:

    - No sondes above 10 hPa (no global coverage anyway)
    - Atmospheric motion vectors in troposphere from satellite imagery
    - Wind information from temperature nadir sounders in extra-tropics (troposphere/stratosphere)
    - But, thermal wind relation breaks down in tropics

- We have no good current estimates of state of the tropical stratosphere:

    - Variability in the quasi-biennial oscillation (QBO) is underestimated
    - "Balanced" winds problematic for estimating variability of QBO (Randel et al. 2002)



Differences between analyses are largest in the tropics

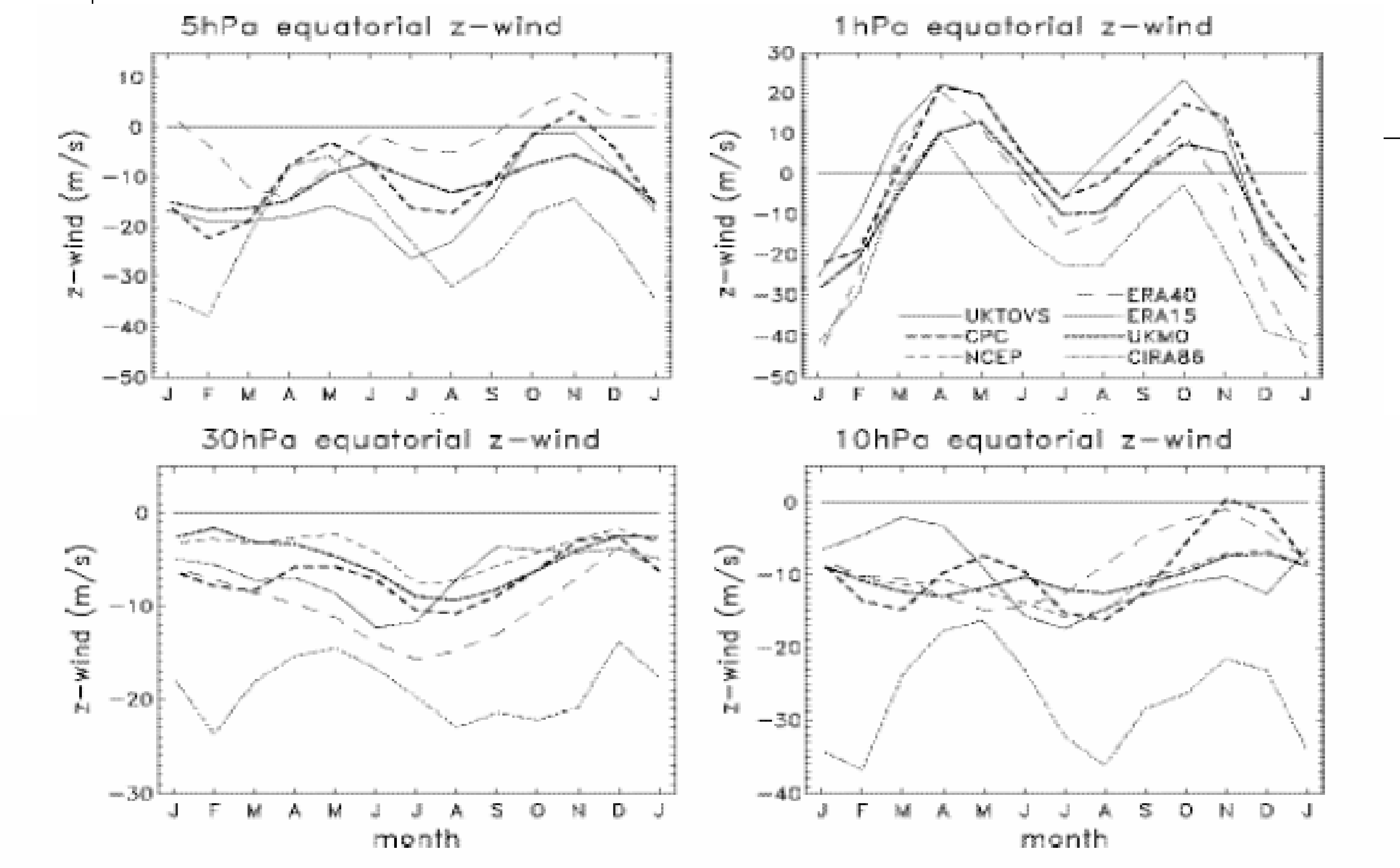
Shown here: zonal wind climatology

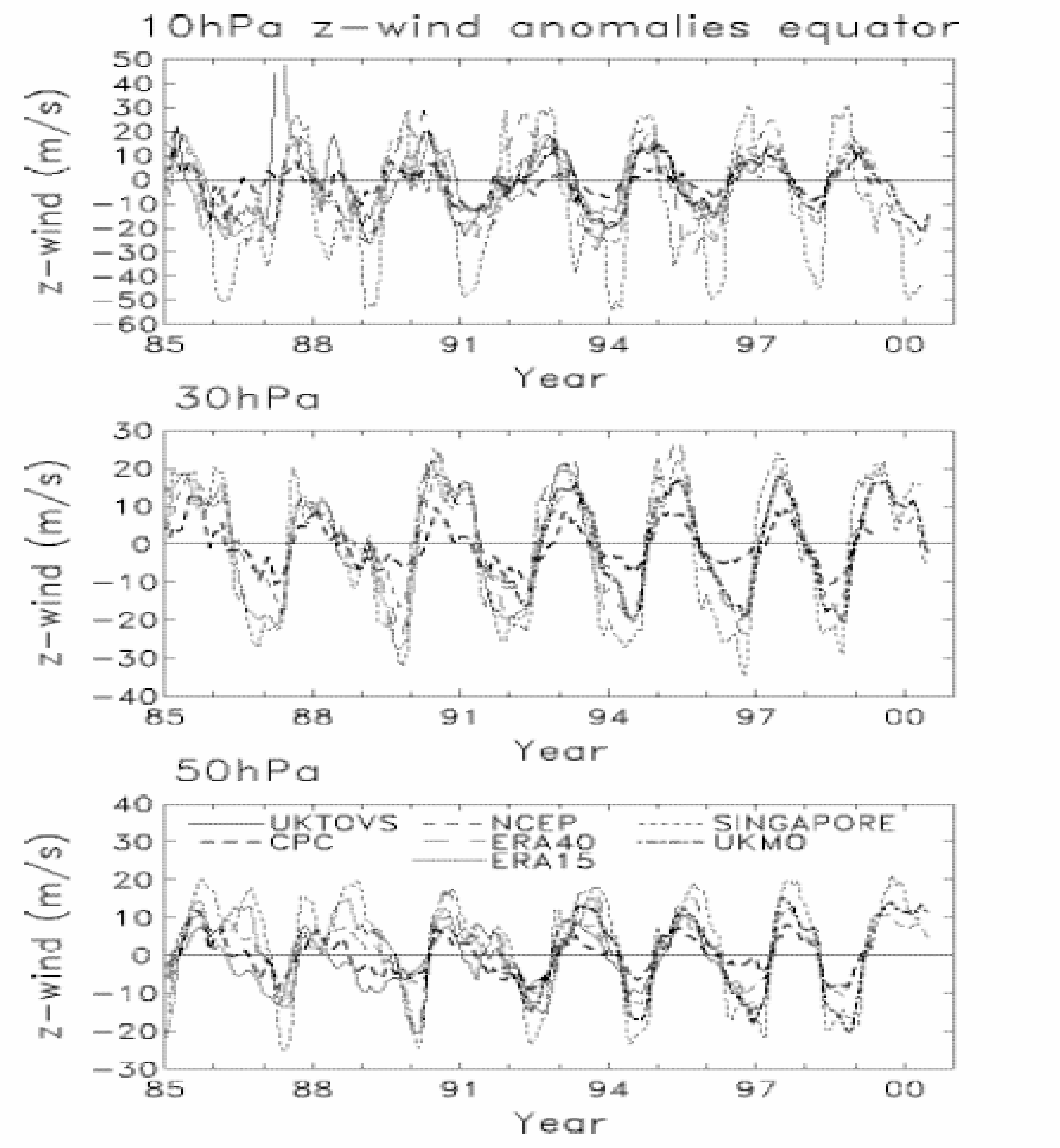
From SPARC Intercomparison of Middle Atmosphere Climatologies (Randel et al. 2002)

[Slide added by TGS]

Seasonal cycle of equatorial zonal wind

(From SPARC Report No. 3, 2002) [Slide added by TGS]

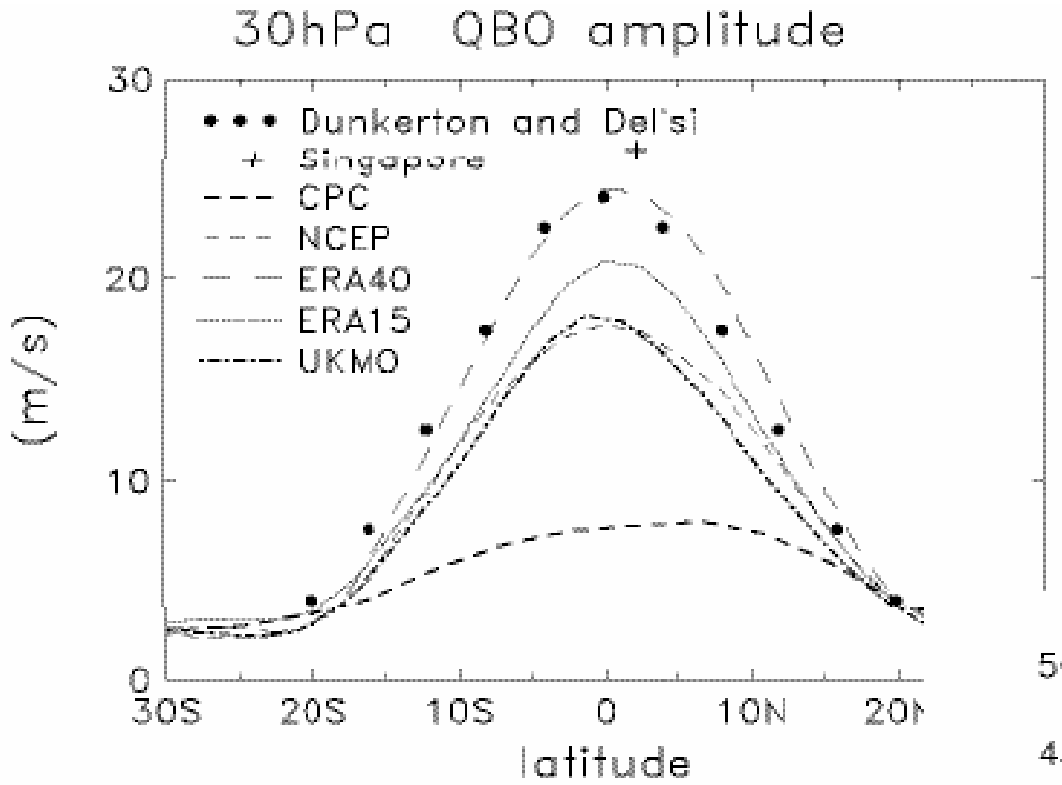




Time series of interannual anomalies in equatorial zonal wind

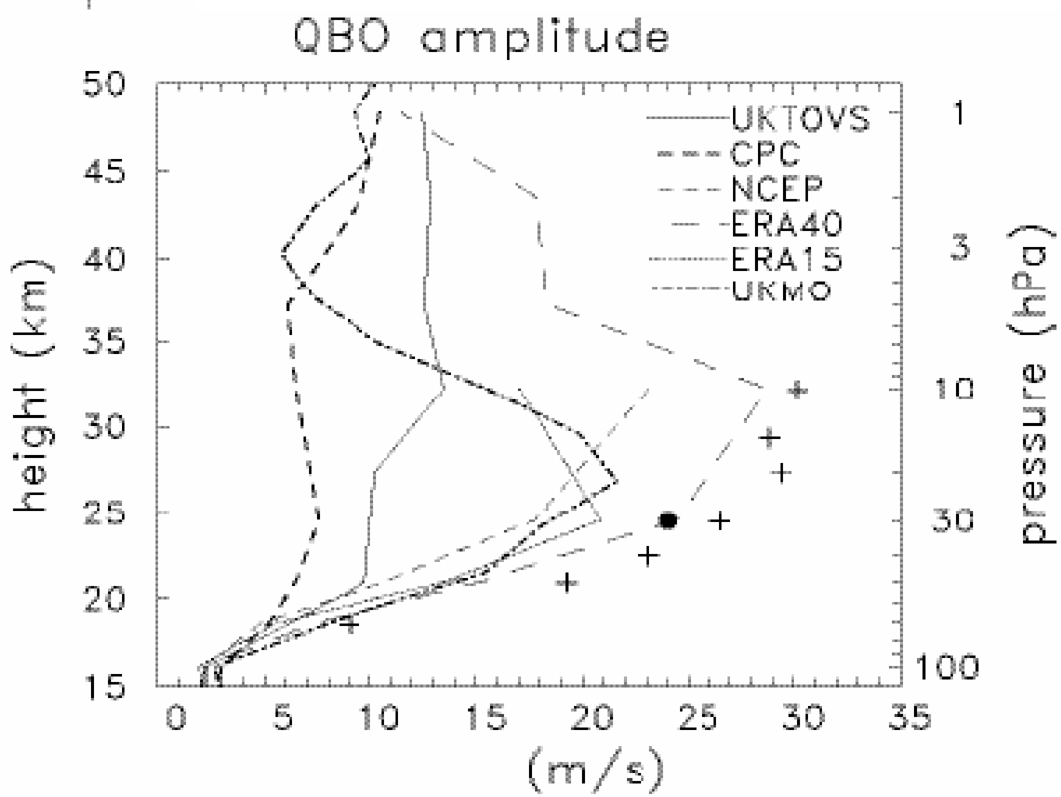
(From SPARC Report No. 3, 2002)

[Slide added by TGS]



QBO amplitude
(From SPARC Report No. 3, 2002)

[Slide added by S]



Missions measuring winds

- Recent past:
  - UARS WINDII: mesospheric winds
  - UARS HRDI: stratospheric winds, but impact marginal as observed winds not accurate enough compared to forecasts (Boorman et al. 2000)
- Future:
  - ADM-Aeolus: launch 2008?
  - SWIFT: launch 2010?

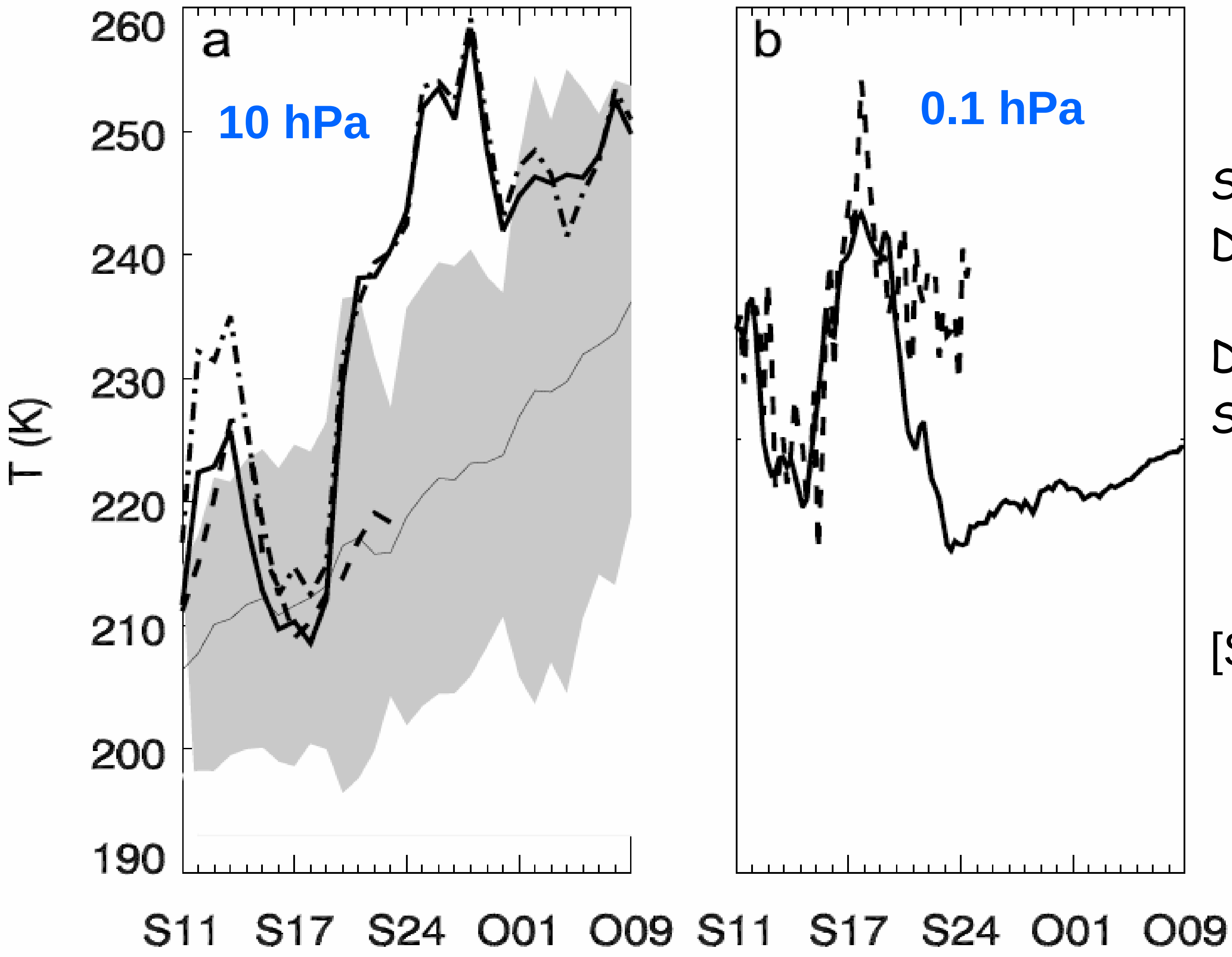
Some benefits of ADM-Aeolus for stratospheric research

- Structure and dynamics of tropical winds (QBO).
- Structure and dynamics of the stratospheric polar vortex.
- Transport, especially in the tropics and in the lower stratosphere/upper troposphere.
- Use of data assimilation as an "inverse modelling" technique to infer gravity-wave drag (by interleaving assimilation and forecast cycles).

Data assimilation will be key to the exploitation of ADM-Aeolus measurements by SPARC

Results from Ren, Polavarapu & Shepherd (GRL, subm.)

- 2002 Antarctic SSW in the CMAM-DAS; **no mesospheric data**



South Pole T

Solid: CMAM-DAS

Dashed: CMAM-DAS forecast

Dash-dot: Met O

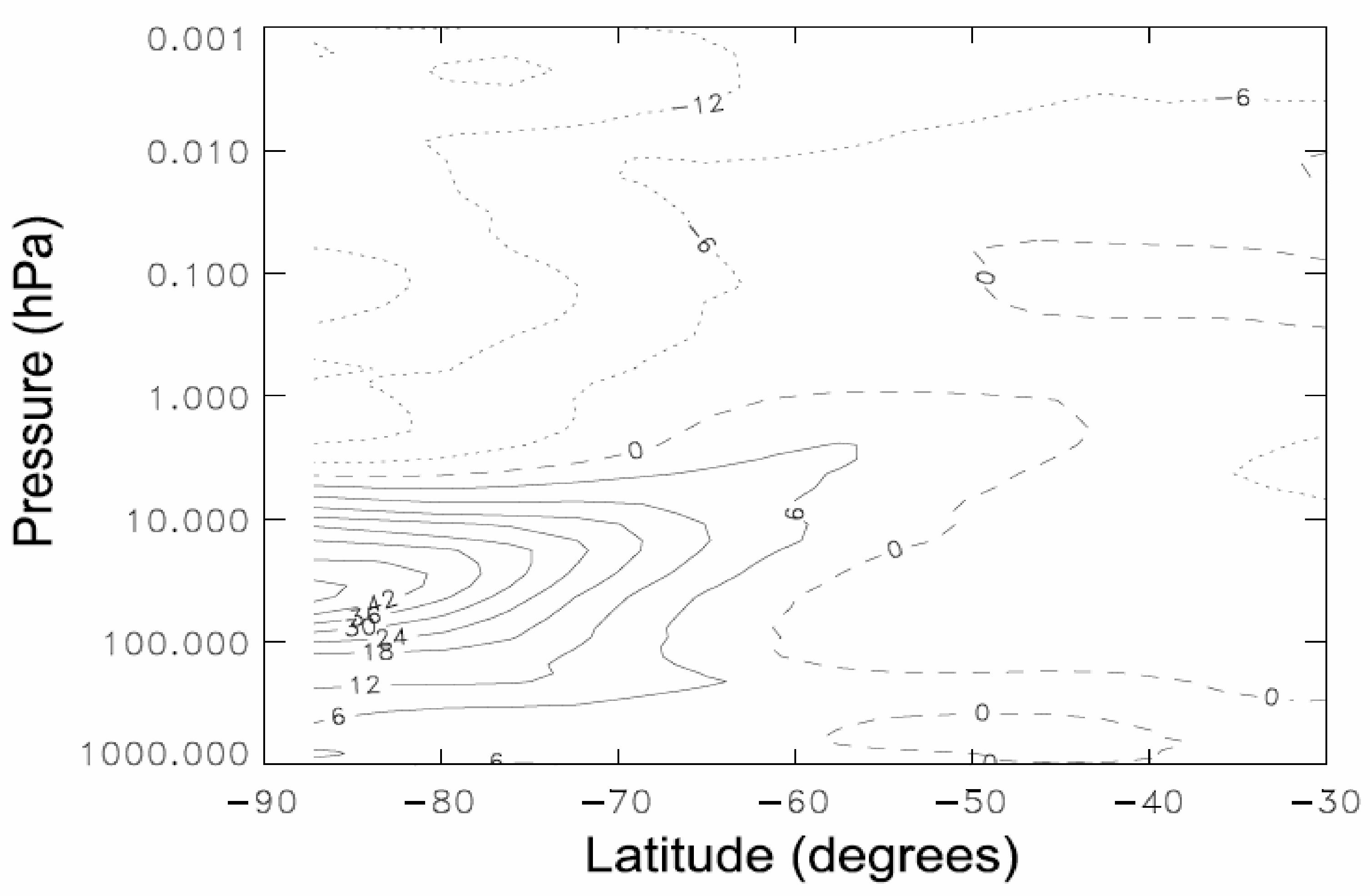
Shaded: Met O mean + 2σ climatology (excluding 2002)

[Slide added by TGS]

Difference between analysis and forecast on Sept. 25 represents the impact of the stratospheric data

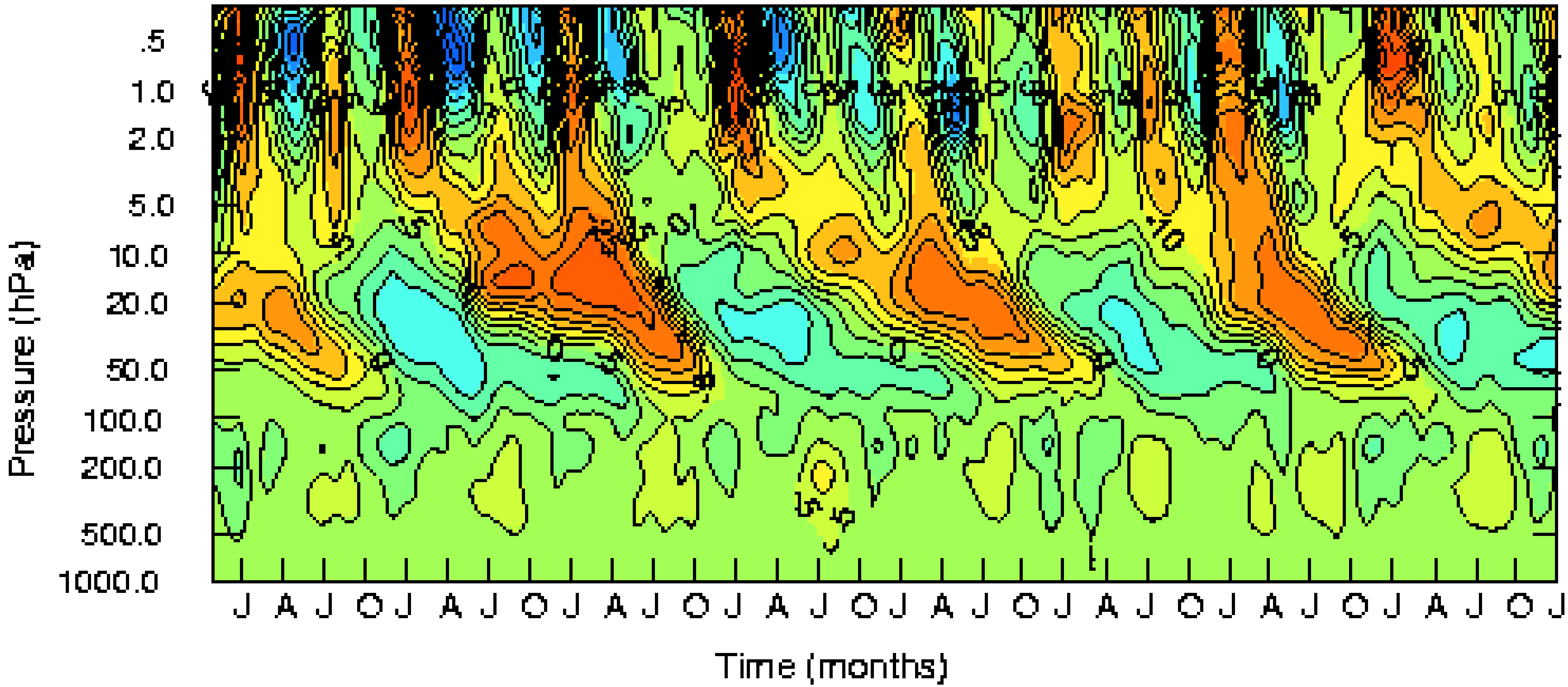
There is widespread cooling in the polar mesosphere

Results from feedback from gravity-wave drag parameterization



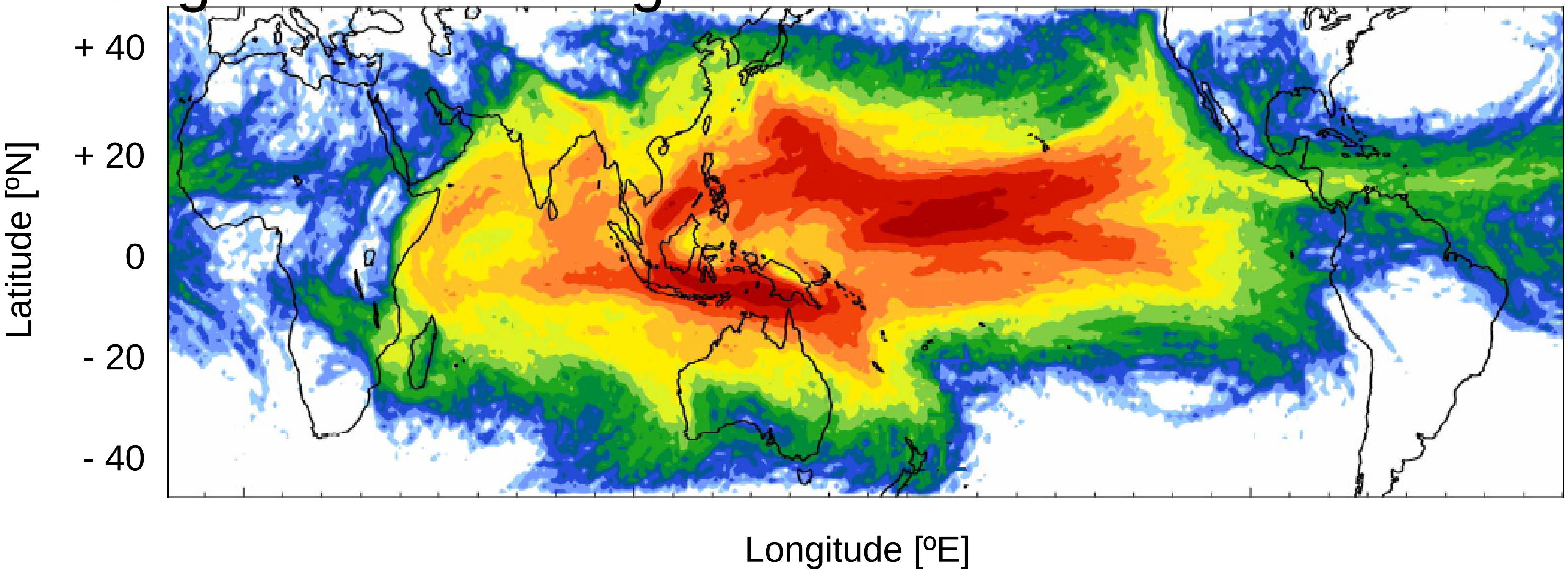
[Slide added by TGS]

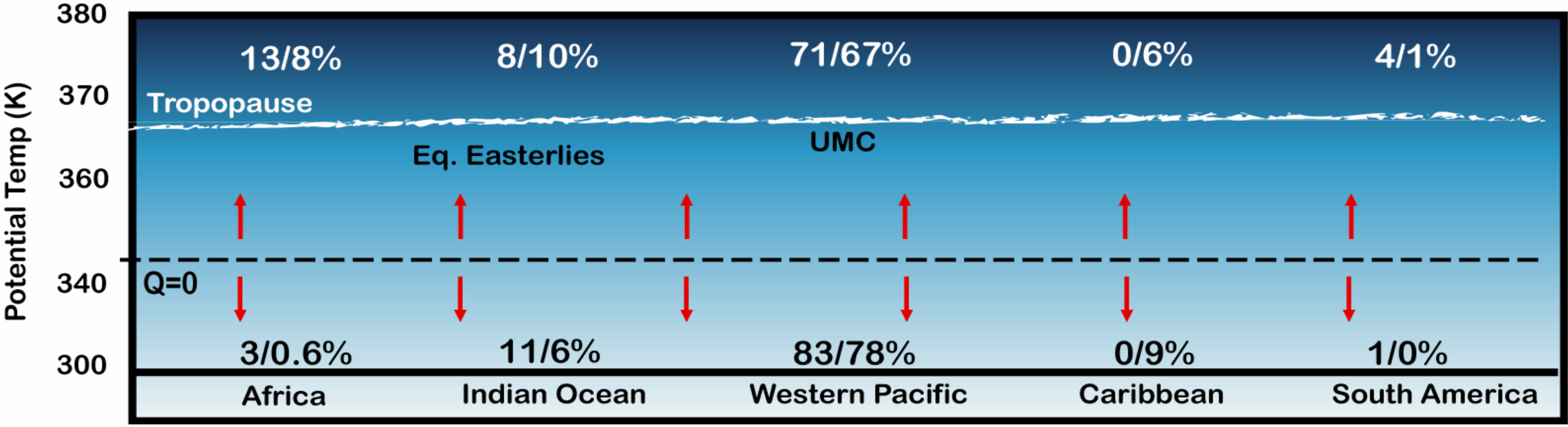
~~From Ren et al. (GRL, submitted)~~



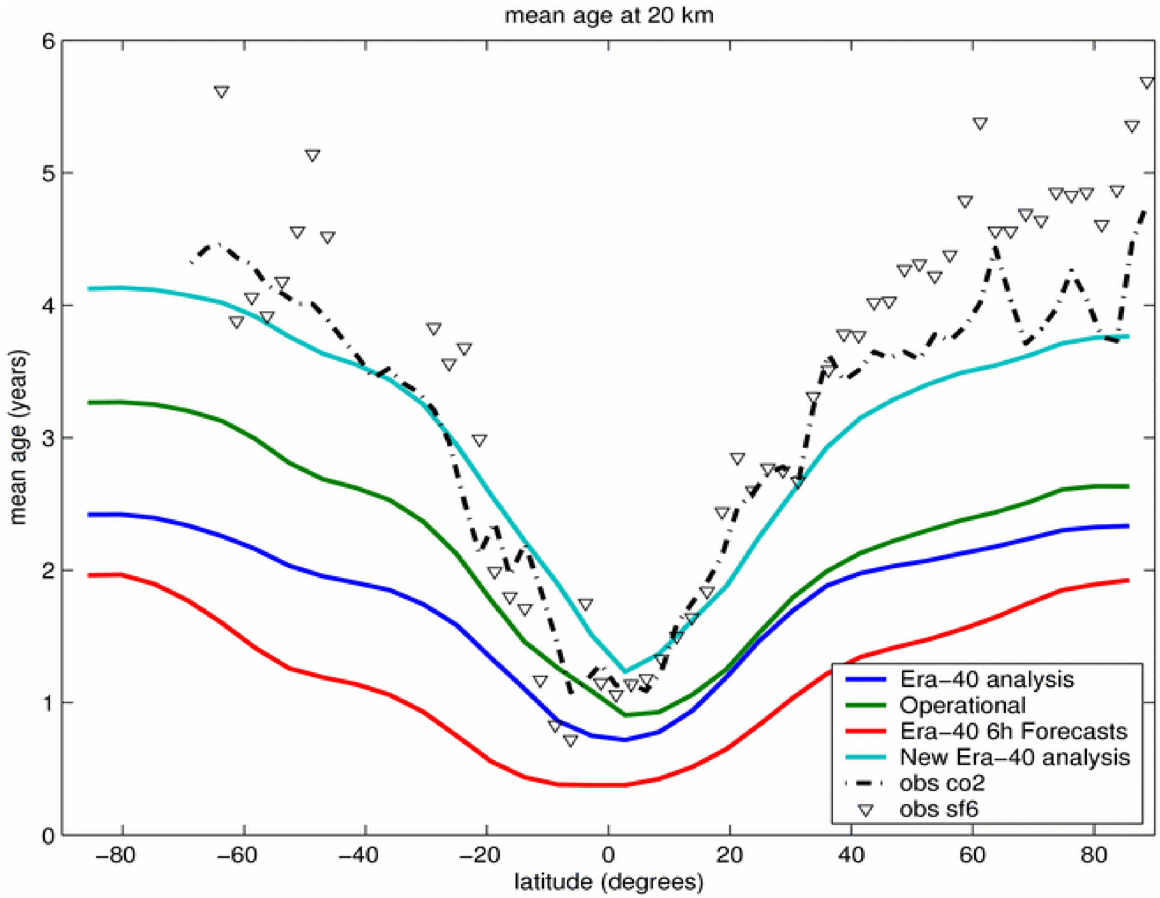
MO observational analyses of equatorial winds for Nov 1992 - Jan 2000

Comprehensive trajectory studies: Origin of air entering the TTL



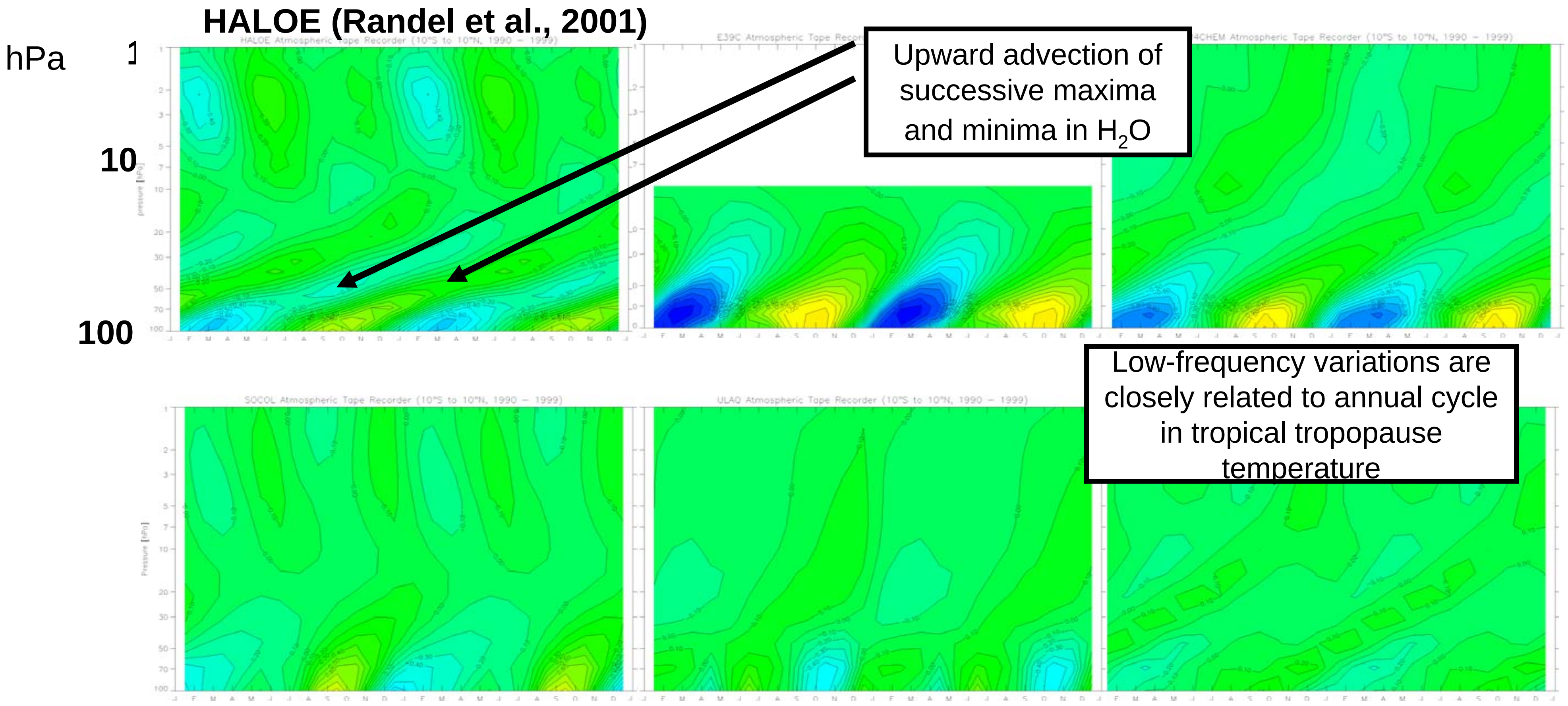


STRATOSPHERIC AGE OF AIR SIMULATIONS WITH A 3D CHEMICAL TRANSPORT MODEL



Beatriz Monge Sanz, Martyn Chipperfield and Adrian Simmons

Tropical Tape Recorder



Tropical stratospheric air appears to retain information about the tropopause conditions

N. Butchart and V. Eyring et al., SCOUT-O3

Structure of an OSSE: example for the SWIFT instrument

- Simulated atmosphere ("truth"; T): using a model
- Simulated observations of instruments appropriate to the study, including errors: using T
- Assimilation system: using a model
- Control experiment C: all observations except those under study
- Perturbation experiment P: all observations
- Experiments can involve evaluation of analyses and forecasts

OSSE goal: evaluate if the difference P-T (measured objectively) is significantly smaller than the difference C-T

Note shortcomings of an OSSE:

- Expensive (cost ~ assimilation system) -> alleviate problem: "reduced OSSE" (e.g. profiles instead of radiances)

  Note: "reduced OSSE" generally only useful when observation of interest has relatively high impact (e.g. stratospheric winds)
- Difficult interpretation (model dependence)
- Incest -> alleviate problem: different models to construct "truth" & perform assimilation

Despite shortcomings, high cost of EO missions means that OSSEs often make sense to space agencies

Design of SWIFT OSSE

- Establish basis for assimilating SWIFT observations (u, v; ozone)
- Investigate scientific merits of SWIFT observations

Models used:

- "Truth" (ECMWF directly)
- Assimilation system (Met Office)

Simulated observations:

Operational: C {MetOP, MSG, sondes, balloons, aircraft, surface}

Temperature, winds, humidity, ozone

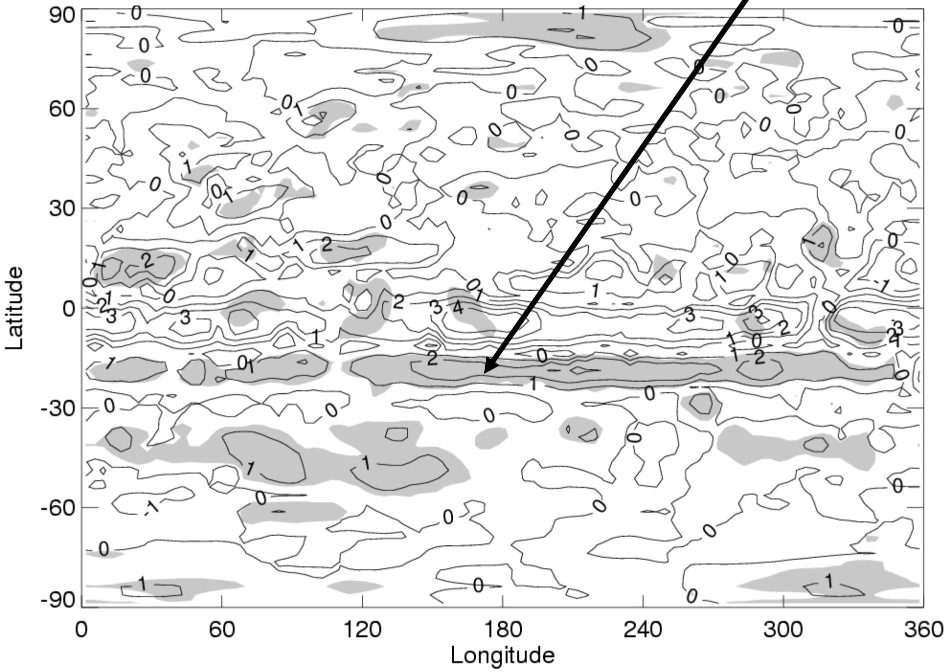
SWIFT: C+SWIFT = P

Ozone, winds (stratosphere, conservative errors)

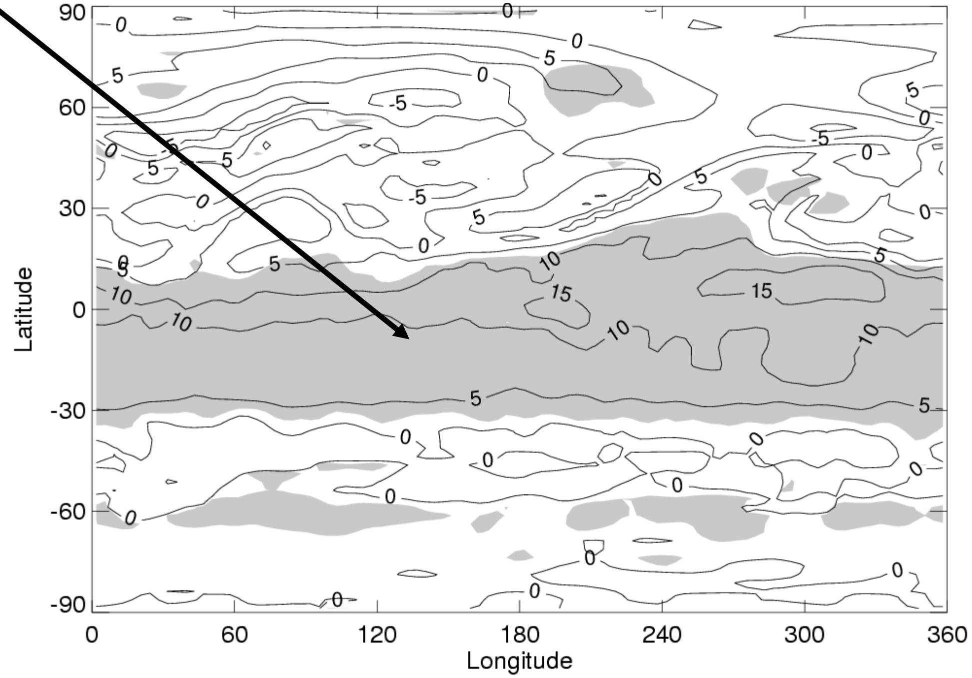
Details in Lahoz et al. QJ 2005

Impact of simulated SWIFT wind measurements

Areas > 5%



10 hPa



1 hPa

Y=Abs(C-T) -Abs(P-T); Zonal-wind (m/s); January 2000;
Shaded:95% confidence level & Y>0.

Impact greatest in the tropics. WARNING:

notice banded structure at 10hPa. Likely that model background error covariance matrix improperly specified. Need to utilise dynamical theory of tropical eddies.

Conclusions

Global stratospheric winds:

- Valuable for each of SPARC's principal science themes and for many of the underlying sub-projects

- Needed to remedy deficiencies of GOS (& GCOS).

- SPARC-related scientific benefits likely to be greatest in the tropical stratosphere and in the extra-tropical lower stratosphere

- Data assimilation will be key to exploiting ADM-Aeolus measurements.

- Assimilation will be non-trivial:
  - (1) need to use dynamical theory to understand structure of background error covariance matrices, especially in the tropics, or spurious structures will be introduced in analysed tropical winds;
  - (2) need well characterised measurement errors for ADM-Aeolus (what's the validation plan?).