The value of global wind stratospheric measurements

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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Topics

- GOS & missions measuring winds
- SWIFT/CHINOOK OSSE: quantify impact of stratospheric winds
- Lessons learnt
- Value of global stratospheric wind measurements
- Relevance to ADM-Aeolus
- Conclusions

Current concerns about GOS

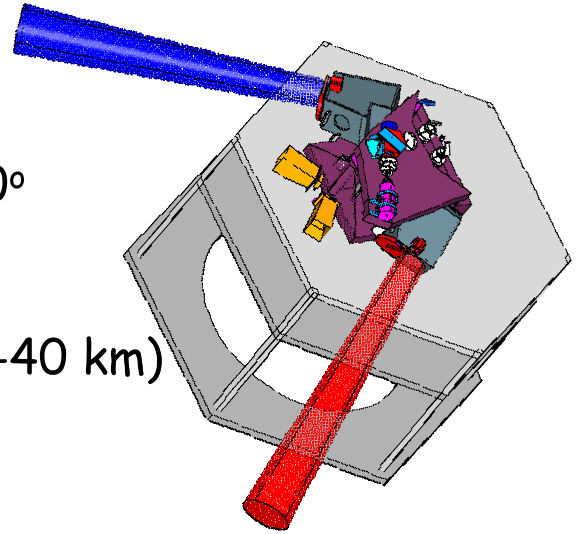
- Lack of global observations of stratospheric winds in the current operational meteorological system:
  - No sondes above 10 hPa (no global coverage anyway)
  - AMVs from satellites in troposphere
  - Wind information from temperature nadir sounders in extra-tropics (troposphere/stratosphere)
  - But, 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 varability of QBO
    Randel et al. (2002)

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:
  - ESA ADM-Aeolus: launch 2008
  - CSA SWIFT/CHINOOK: launch 2010

SWIFT:



- Based on UARS WINDII principle (Doppler effect)
- 2 wind components (u, v) using 2 measurements at ~90^o
- Thermal emission (mid-IR) of ozone (1133 cm^{-1})
- Technology difficult to implement
- Global measurements of wind and ozone profiles (~20-40 km)

WHY?

Issues about GOS

Science

- Climatologies of tropical winds
- Transport studies (e.g. ozone fluxes)
- Use assimilation to obtain 4-d quality-controlled datasets for scientific studies (e.g. climate change and its attribution)

Future EO missions

- Space agencies (ESA, NASA, JAXA, CSA) invest a lot of money on missions (e.g. ESA's Envisat has cost 2.3BEuros)
  - Important to evaluate (quantify) beforehand possible benefits of future missions, especially those involving satellites

Techniques for evaluating future missions:

- A technique often used by the space agencies is the OSSE
- Information content (e.g. Prunet et al. QJ 98, IASI)
- Ensembles (e.g. Andersson et al. WMO 2005, ADM-Aeolus)
- Note shortcomings of OSSEs (see later)

Structure of an OSSE: Value of SWIFT

- 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) -> alleviate problem: conservative errors, several methods to investigate impact

- 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

Models used:

- "Truth" (ECMWF directly, or forcing a CTM)
- Assimilation system (Met Office) (incest)

Simulated observations:

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

Temperature, winds, humidity, ozone

SWIFT; C+SWIFT = P

Ozone; u, v winds (stratosphere, conservative errors)

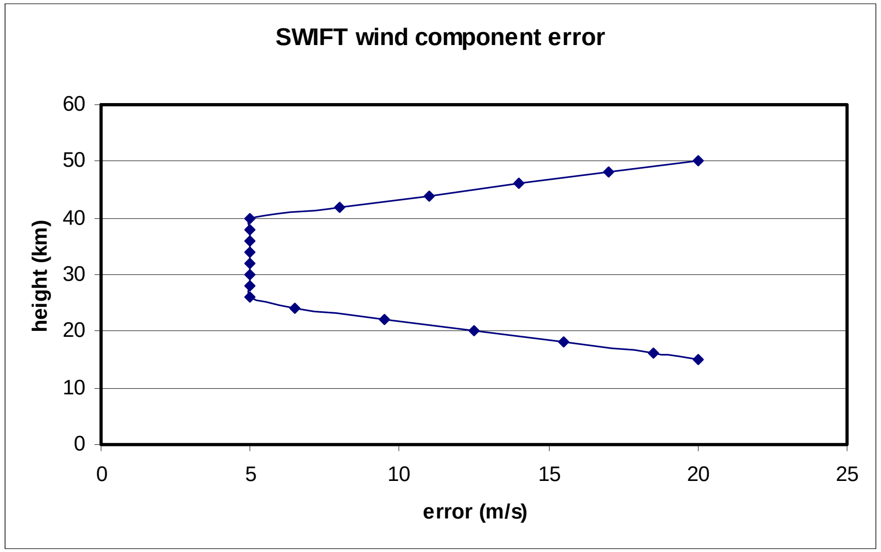
Several assimilation experiments (robustness); analyses evaluated.
Qualitative & quantitative tests (significance)

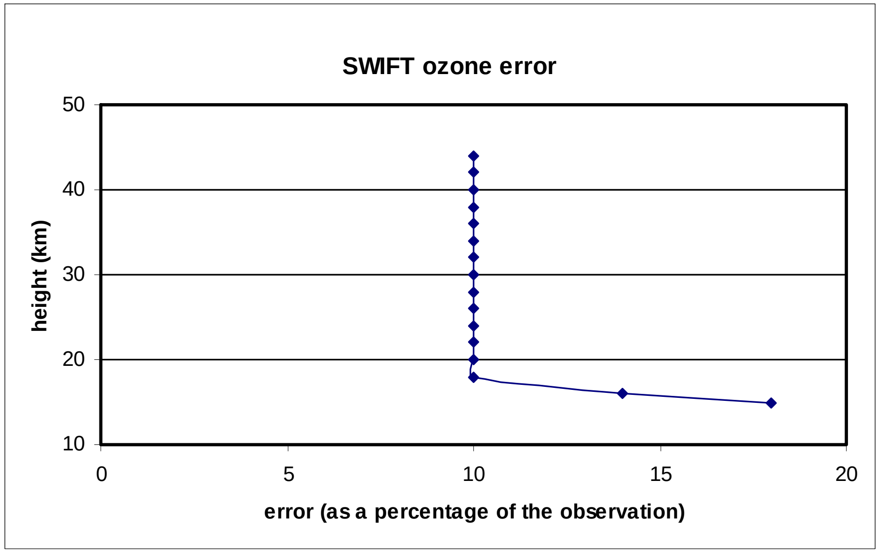
Details in Lahoz et al. QJ 2005

SWIFT characteristics

- Winds 16-50km, every 2km approximately

  Ozone 16-44km, every 2km approximately
- Errors (conservative; random; representativeness error considered to be relatively unimportant):

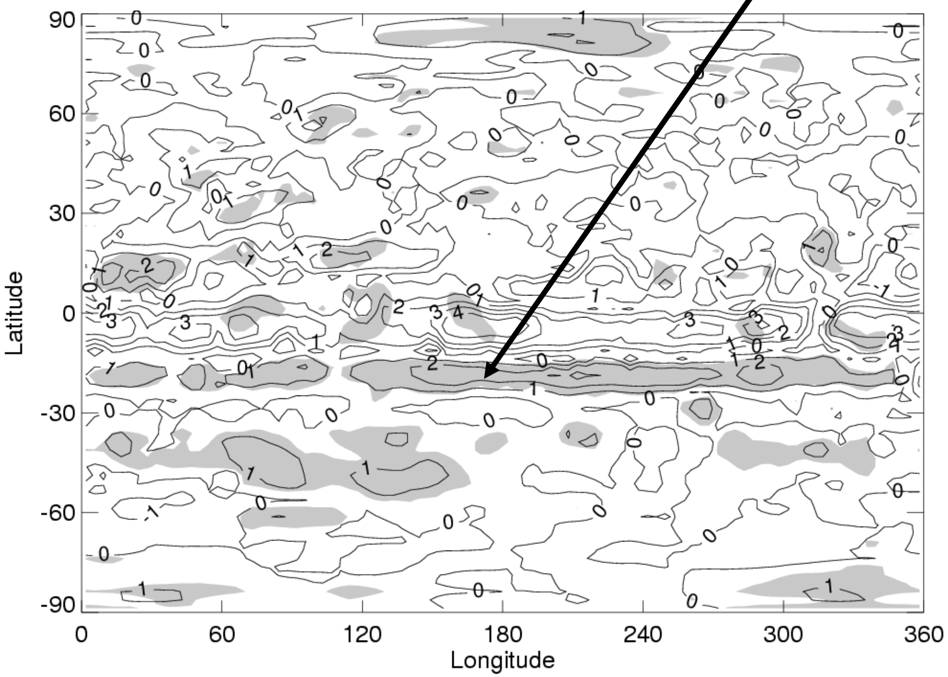




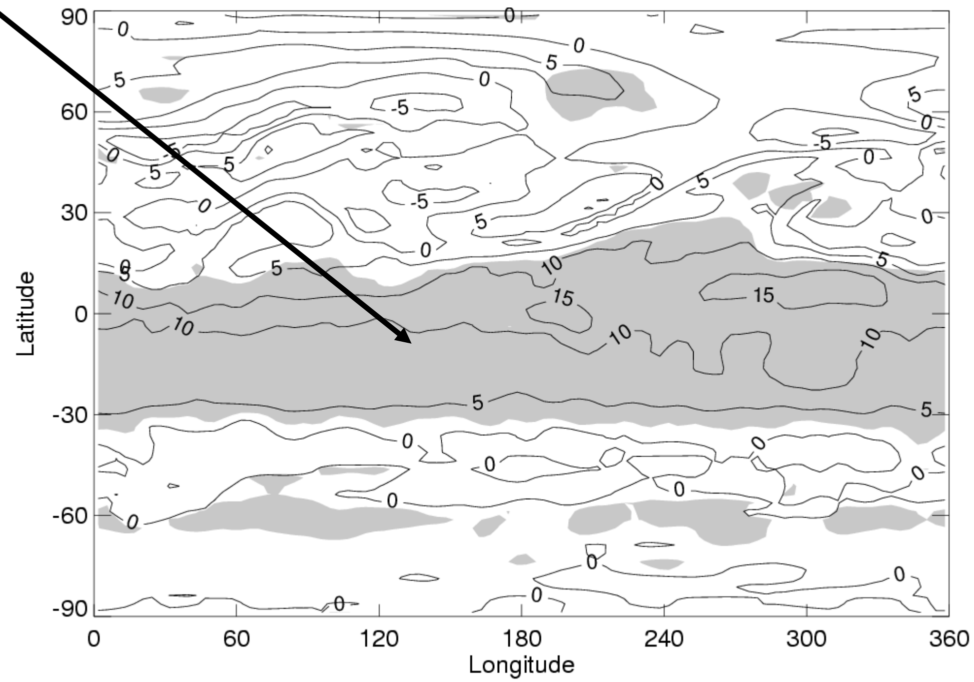
Significance tests

Areas > 5%

Shaded areas show significant impact from SWIFT winds



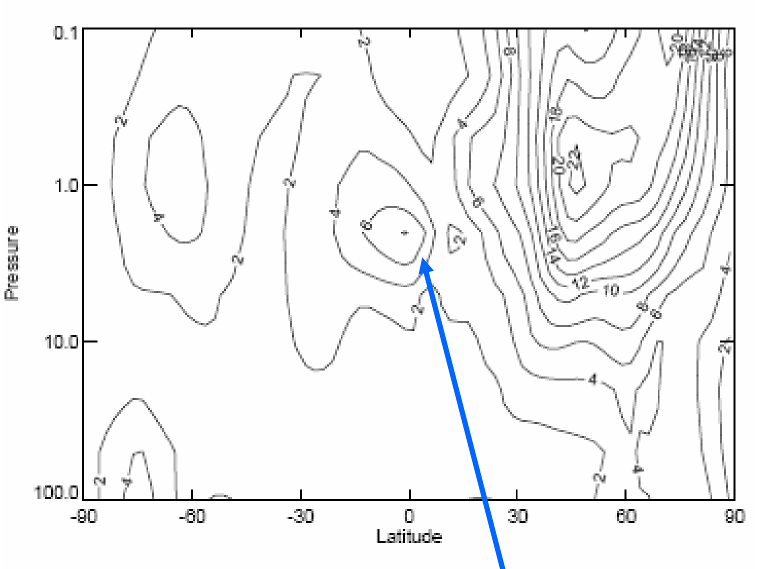
10 hPa



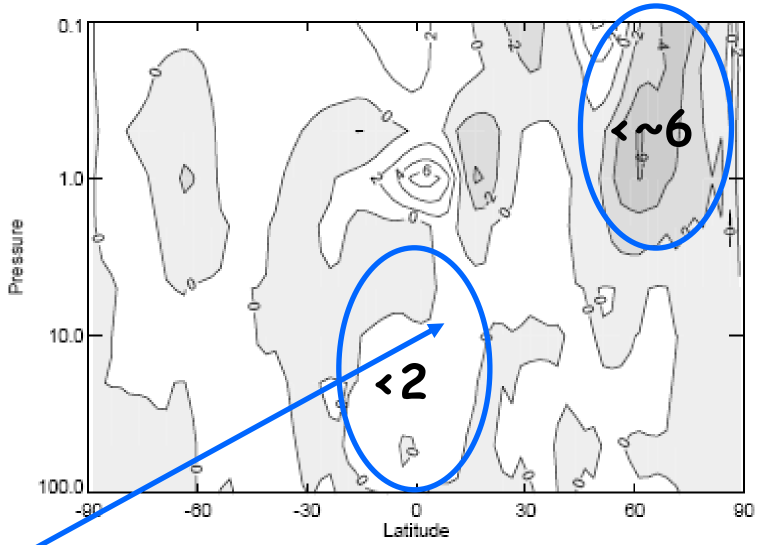
1 hPa

Zonal wind (m/s), Jan 2000: Plot of Abs (C-T) – Abs(P-T).
Shaded area: Abs(P-T) < Abs(C-T) at 95% confidence limit.

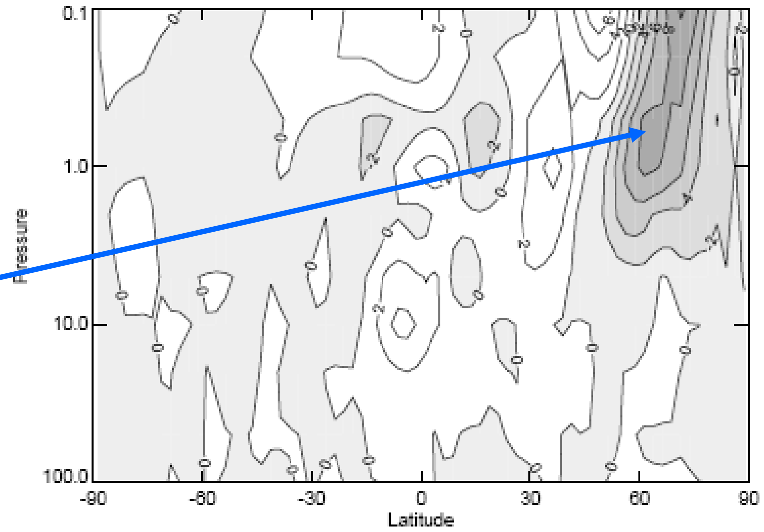
Variability



T: Zonal wind variability, ms^{-1}, Jan 2000



P-T: zonal wind variability, ms^{-1}, Jan 2000



C-T: zonal wind variability, ms^{-1}, Jan 2000

Shading indicates P, C experiments have less variability than T

Lessons learnt

- OSSEs:

1. Useful but difficult (caveats – be conservative)
2. Supposed improvements to GOS may have negative impact (DA system)

- Global stratospheric winds (also impact from SWIFT ozone):

1. Significant impact in stratosphere: tropics & extra-tropics (mainly u)
2. Scientific merit:
   - Information on tropical winds: values, variability
   - Wintertime variability

ADM-Aeolus

Doppler Wind Lidar (DWL)

1 component global wind profiles up to ~30 km
N.B. need DA to get 2 components

- Better information to predict weather
- Global wind profiles for the entire planet, including remote areas lacking any g-based weather station

Main objective:

- Correct major deficiency in winds in current GOS

- Increased skill in NWP
- Data needed to address WCRP key concerns:
  - Quantification of climate variability
  - Validation & improvement of climate models
  - Process studies relevant to climate change

OSSEs by Stoffelen, Tan

Relevance of SWIFT OSSE to ADM-Aeolus

- Value of stratospheric winds (u, v):
  extension of vertical range of ADM-Aeolus
  -> useful measurements from stratosphere (not just troposphere)

- Value of constituent/wind measurements (winds/ozone from SWIFT)
  -> winds/aerosol information from ADM-Aeolus
  -> improved transport; better use of EO using DA

- Improved representation in stratosphere & troposphere
  -> Improved forecasts & analyses

Better models, better initial conditions, model evaluation

Conclusions

- OSSEs – quantify value, but care needs to be taken (other approaches?)
- SWIFT: Global observations of stratospheric winds improve GOS
  Expected of ADM-Aeolus for troposphere
- Synergy between wind/constituent observations (SWIFT, ADM-Aeolus)

  -> make best use of EO opportunities
- Value of dynamical information: incorporate this into GOS
- End-to-end role for data assimilation

Pre-launch: GOS incremental value (OSSEs)
Post-launch: GOS incremental value (OSEs); cal-val (observations/models); added value (analysis; observations & models)