The Stratospheric Wind Interferometer for Transport studies (SWIFT) is a Canadian satellite instrument designed to measure stratospheric winds and ozone in the 20-45km region. SWIFT is a field-wide imaging system similar, in principle, to the WINDII (WIND Imaging Interferometer) instrument but will operate in the infrared rather than the visible. An overview of the current instrument is described, followed by a description of a preliminary forward model to compute limb radiances for the Michelson interferometer imaging system of SWIFT. The model is a derivative of the Fast Line-by-Line Radiative Transfer model. This model, with the addition of a gradient model, will be initially tested in retrieval mode with the aim of eventual use by the Canadian data assimilation system. This paper will briefly describe the SWIFT instrument to be flown on the Canadian Space Agency’s Chinook Mission in late 2010 following a description of the forward model.

Overall Objectives of SWIFT

To provide high resolution global measurements of horizontal wind vectors in the stratosphere under both day-time and night time conditions in order to study:

- Atmospheric dynamics in general
- Ozone transport from co-located wind and column measurements
- The potential of operational stratospheric wind measurements for medium range forecasting

Brief History and Current Status of SWIFT

- SWIFT originally proposed to ESA as an Earth Observer Opportunity Mission in 1998 by a Canadian team led by Gordon Shephard of York University. ESA short-listed SWIFT as one of the top 5 candidate missions out of 27 international proposals (SWIFT was the highest ranking atmosphere mission in this competition).
- Later, ESA and the CSA investigated an alternative mission for SWIFT.
- In 2004 the CSA made SWIFT the primary instrument for their next SciSat mission.
- In 2005 the CSA selected ARGOS (a GPS occultation experiment) to accompany SWIFT.
- Mission now named Chinook.
- Chinook is in Mission Phase A/B stage.
- Scheduled launch in 2010 for a minimum 2 year mission.

Measurement Technique

A relatively isolated O$_3$ line ($\nu_2=1133.4335$ cm$^{-1}$) in the IR region is separated from the complex limb spectrum of the stratosphere using a narrow-band filter system with a width of about 0.1cm$^{-1}$. A field-wide Michelson interferometer placed in the beam is used to sample the interferogram of the Doppler wind shifted spectrum at 4 points (Fig 1, 2 & 3). The stratospheric wind and ozone density profiles are recovered from the 4-point measurement images.

Line of Sight Wind Recovery

The relative velocity of the source and instrument is determined by a combination of earth rotation, satellite motion and line of sight (LOS) wind. Each of these causes a shift in the phase of the interferogram. The intensity, $I_{ij}$, for each pixel $i$ and each mirror step, $j$, can be written as:

$$I_{ij} = I_{ij}^{\text{mean}} + U_{ij} V_{ij} \cos(\phi_i + \psi_{ij})$$

In practice, the Michelson mirror may not step in exactly $\lambda/2$ steps, thus all $I_{ij}$ is fitted with a 3-term Fourier series. The 3 Fourier coefficients $(I_0, I_1, I_2)$ are determined by fitting the four $I_{ij}$ for each pixel. The phase is obtained from the coefficients, and hence the line of sight wind, $V_{ij}$,

$$V_{ij} = c \tan^{-1} (J_1 J_2) \times \frac{\psi_{ij} - \psi_{ij} - \psi_{ij} - \psi_{ij}}{2 \pi a \Delta \lambda}$$

Forward Model

SWIFT interferograms are simulated by the integral of limb emission, $E$, convoluted with a complex instrument function, $J$, that is:

$$J_{ij} = S_{ij} (\nu) \mathcal{G}_{ij} (\nu)$$

where

$$S_{ij} (\nu) = \mathcal{R}_{ij} (\nu) \times (1 - \mathcal{A}_{ij} (\nu))$$

Another consideration is how many sublayers are required to estimate the layer properties before an impact on winds appears. Figure 7 illustrates the differences between a 20 sublayer model ($\nu_2=1133.4335$ cm$^{-1}$) and a 4 layer model. At least 6 or 7 layers are required to minimize the impact on derived winds. All possible combinations of gases were tested in order determine if the list may be reduced. Figure 8 shows the samples where a single absorber has been dropped off the list. It appears that both HDO and NH could be ignored, as could CF$_2$Cl$_2$ if one wished to exclude winds below 20km.

Discussion

A preliminary forward model for SWIFT has been chosen. To date it has been optimized to execute as on a LINUX within Intel Architecture. One interferogram ($0.02$ cm$^{-1}$) takes about 40CPUsec. It remains to be seen if the fluxes are suitable for ASTO’s BFM cluster of 560CPU.

The preliminary wind impact studies indicate that discarding the outer 20 columns of the interferogram then a lower resolution and fewer sub layers can be used, resulting in a speed up of 3 or 4 times. One or more absorbers may be potentially omitted, however more testing is required assuming other atmosphere before any decision on omitting gases is made.

The testing and optimizing the FLBL is incomplete. In addition, the gradient portion remains to be completed, tested and integrated into a data assimilation system in order to test the feasibility of assimilating SWIFT winds into an NWP. If the FLBL is too slow on the IBM cluster, then efforts will turn to a more parameterized model.

The final instrument architecture is not finalized, as it still has to be optimized. Thus, the algorithm may have to be refined in order to reduce the wind errors to better than 5 m/s for 20 km up to 45 km and to better than 5 m/s for the extended range of 15 to 55 km through the entire life of the mission.

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References


SWIFT web page

http://swift.yorku.ca

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