National Aeronautics and Space Administration

Extending the legacy of MISR cloud motion vectors to tandem spacecraft

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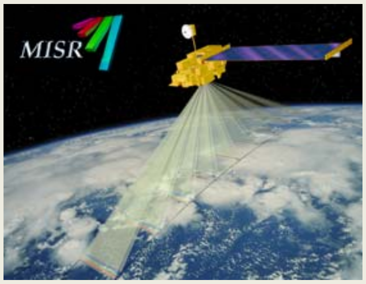
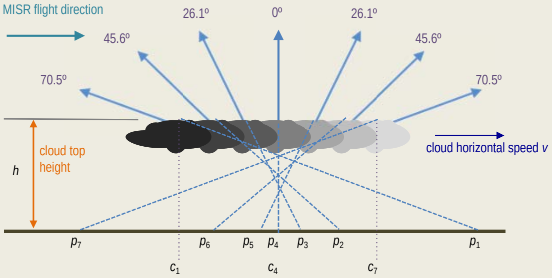
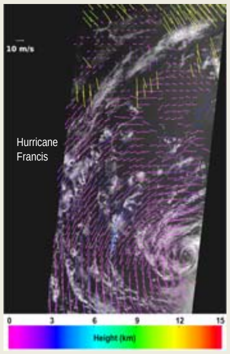
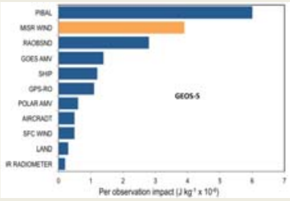






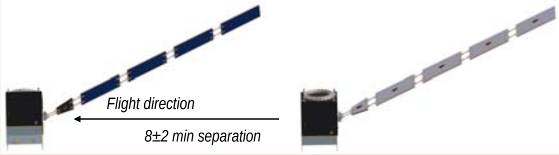


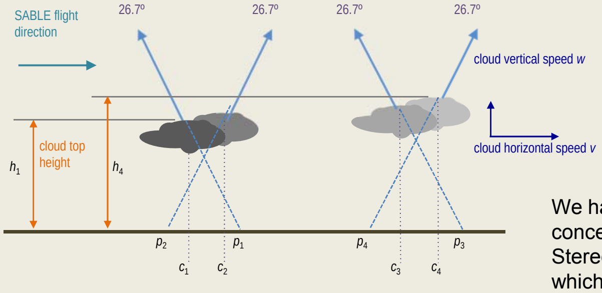
Strong positive forecast benefit of MISR winds in GEOS-5 stems from mitigation of observational gaps at high latitudes, low altitudes, and in the Southern Hemisphere (credit: Junjie Liu, JPL).

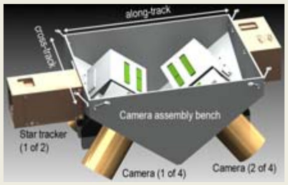
The Multi-angle Imaging SpectroRadiometer (MISR) instrument on NASA's Terra mission has been generating height-assigned cloud motion vector winds since February 2000. An example from Hurricane Francis is shown. MISR uses multiple pushbroom cameras to retrieve cloud-top heights (CTH) and cloud-top winds (CTW) across a 400-km swath. The disparities (horizontal offsets) between cloud features are obtained by pattern matching of images acquired at different look angles or times. Vector winds are generated at 17.6 km resolution, while CTH and cross-track winds are generated on a 1.1 km grid.

Diagnostics imply an uncertainty in the along-track wind component of 2-3 m s^{-1}, while the cross-track component has smaller uncertainty (1 m s^{-1}). From a single spacecraft, uncertainties in the along-track component of CTW are highly correlated with uncertainties in CTH. The MISR approach also requires the assumption of zero vertical wind.

SABLE Spaceborne Atmospheric Boundary Layer Explorer







We have developed an instrument concept known as the Multiangle Stereo and Time-lapse Imager (MSTI), which would enable acquisition of pushbroom images at 8 discrete along-track view angles. As with MISR, CTH and CTW retrievals are independent of instrument absolute radiometric calibration or atmospheric thermal structure.

Reduction in wind uncertainties in both the cross-track and along-track directions is feasible by flying identical multi-angle imagers on tandem satellites in the same orbit plane, separated by about 8 minutes. By acquiring images at the same view angle from two separate satellites, it is possible to determine CTW independent of stereoscopic parallax, allowing unambiguous and accurate correction for cloud advection of CTH from each spacecraft. With this approach, instantaneous wind uncertainties are estimated to be ±0.3 m s^{-1} for both the cross-track and along-track components. For rapidly convecting clouds, the technique also provides sensitivity to vertical wind speed. Because of the additional information provided by the tandem approach, CTH and wind vector components can all be retrieved on a 1.1-km grid.

MSTI would acquire multiangle imagery over a 1000-km swath, yielding 3-day global coverage (compared to 9 days with MISR), and have an estimated mass of only 17 kg (compared to 150 kg for MISR). An Earth Venture mission concept, known as the Spaceborne Atmospheric Boundary Layer Explorer (SABLE), has been proposed that would implement identical MSTI instruments on a pair of microsatellites. In addition to providing data of value for improving models of numerical weather prediction and storm dynamical processes, a key objective of SABLE is determination of cloud-top entrainment rate (ER). Entrainment—the mixing of relatively dry air into regions of moister air through turbulent processes—is one of the least well understood processes controlling low cloud formation. The lack of quantitative measurements of ER has impeded progress in climate model development for more than two decades.

Using a mass balance approach (see equation at right), ER in the steady state is the sum of an advection term (the rate of ABL deepening along the mean wind direction) and a subsidence term (given by the product of the CTH field and the wind divergence).

$$ER = \left(u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} \right) + h\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right)$$

x = zonal direction, y = meridional direction
u = zonal wind speed, v = meridional wind speed
h = cloud top height

Propagation of measurement errors in the mass balance equation leads to an estimated uncertainty in ER from MISR that is several times larger than the typical value (5 mm s^{-1}). The SABLE approach reduces the uncertainty by nearly two orders of magnitude.

	MISR/Terra (single spacecraft)	MSTI/SABLE (tandem spacecraft)
CTH uncertainty	200 m	100 m
Cross-track wind uncert.	1 m s^{-1}	0.3 m s^{-1}
Along-track wind uncert.	2-3 m s^{-1}	0.3 m s^{-1}
Spatial resolution	17.6 km	1.1 km
ER uncertainty	16 mm s^{-1}	0.2 mm s^{-1}

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