The Helios mission resembled the upcoming STEREO mission in several respects. Helios could reveal details about the longitudinal and latitudinal stream structure, it allowed unique associations between limb CMEs and their radial propagation towards an in-situ observer, and the large-scale propagation of solar energetic particles could also be studied.
The orbits of the Helios 1&2 solar probes in 1976

node line
The mission lasted from Dec. 1974 to March 86

Helios 1&2
a stereo-mission, but no imagers on board!

A variety of stereo and radial line-up constellations!
The solar wind stream structure, observed by the Helios 1&2 and IMP spacecraft from activity minimum in 1975/76 onward.

With increasing solar activity (in 1978), many transient events destroyed any regular solar wind structure.

Minimum

Maximum
The line-up between Helios 1 and Helios 2 in 1976, and the succeeding divergence in latitude.

It is the latitude that makes stream structures differ, rather than radial distance or time!
Latitudinal stream boundaries

Entry into a high-speed stream in 2 or even 3 steps, a mere latitude effect!

Schwenn et al., 1981

Δ Lat. [°]: 1.5 1.3 1.0 0.7 0.4

Schwenn et al., 1981
Latitudinal stream boundaries

They remain sharp, even beyond 1 AU!

The difference $\Delta V$ in proton bulk speed measured by the two HELIOS probes as a function of their separation in heliographic latitude $\Delta \varphi$. Each point represents an average over 1° in solar longitude. The crosses denote cases with corotation times of less than two days.
CIRs at high speed stream fronts can differ substantially with latitude!

No corotating shock

CIR with corotating shock

R = 0.78 AU
Lat = -0.2°
Clong = 15°
Date = 76:338:16:00 UT

0.87 AU
+3.2°
13°
76:336:21:00 UT
Burlaga et al., 1978

Note:
• the stream interface SI is observed at all S/C,
• He 2 is first to observe a corotating shock,
• the stream is gone at 1.6 AU, but
• the SI is still there, and
• the corotating shock is still there.

A CIR observed by 6 S/C in November 1977
A transient shock, seen from Helios 1&2
270° apart in longitude

Helios orbits in 1977
A transient shock, seen from Helios 1&2
27° apart in longitude

Helios 2  1977/027-033  
shock

Helios 1  1977/028-032  
Channel 8 (E = 112 eV)

No cloud, But BDEs!

Cloud, He⁺, BDEs

0.98 AU  
-5.0° lat  
351° HSE

0.952 AU  
-2.0° lat  
323° HSE
Predecessors to STEREO-A/B: Helios plus P78-1

The coronagraph on P 78-1 recorded CMEs above the limb. The plane-of-the-sky speed (which equals the radial speed for limb CMEs) of several hundred CMEs was measured.

The Helios probes happened to travel above the limb for long time periods and could observe in-situ the arrival of ICMEs.

For 49 events in 1979 to 1982 a unique association between CMEs seen at the sun and ICMEs observed in-situ (within +/- 30° of the sky plane) could be found and the travel time be determined.

Schwenn, 1983; Sheeley et al., 1985

Orbit of Helios 1 with respect to the Sun-Earth line
Stereo views resolved the flare-CME controversy

Results from correlations between CMEs and interplanetary shocks:
- an observer within the angular span of a fast (>400 km/s) CME has a 100% chance to be hit by a fast shock wave,
- every shock (except at CIRs) can be traced back to a fast CME.

Sheeley et al., 1985

These shocks and the driver gases following them have a near 100% chance of becoming geo-effective, if ejected towards Earth.

Note: no such statement applies to flares!

Indeed: there are flares without CMEs (and geo-effects) and there are CMEs (and geo-effects) without flares.
On October 28, 2003, in conjunction with a X13 flare, there occurred a gigantic halo CME.

By the way: 8 hours earlier a little comet had evaporated! Coincidence?

Note: in 10 years mission time, SOHO has seen more than 1000 little comets and some 10000 CMEs...

Even if we could measure $V_{rad}$ near the Sun, we are still in trouble. That's what we learned from Helios.

The key problem in space weather forecasting: How to measure the CME's speed component $V_{rad}$ along the LOS?
Unique radial speed measurements of limb CMEs (SOLWIND) and associated ICMEs (Helios)

The travel time of ICME driven shock fronts from the Sun to the location of Helios 1 vs the CME radial speed $V_{rad}$.

From Helios in situ

Note the substantial scatter! Reasons:
- CME speeds may not have been measured sufficiently well,
- Helios was not always hit by the fastest parts of ICMEs,
- Ejecta travel times do not equal shock travel times,
- ICMEs travel through different ambient solar wind.

Schwenn et al., 2005

From P 78-1 coronagraph
Shock fronts may extend far around the Sun

The CME center was 140° in longitude off the Helios 1 position.
Shock fronts may extend far around the Sun

X2/3B flare at N09 W40 on 81:100

$D_{st} -311$ nT on 81:103
Multipoint study of shock propagation and extent

These studies showed a lot of surprises!

Burlaga et al., 1978, 1980
Shock fronts may extend far around the Sun

Burlaga et al., 1978

The shocks A1 and A2 seen by He 2 merged, and at Earth and at the Voyagers one single shock arrived.
Stereo-constellation at the events in March 1976

- **He 1:** no shock, no ICME
- **He 2:** shock and cloud on 76:90
- **Earth:** Dst -218 nT on 76:90
- **X1/1B flare at S07 E28 on 76:88**
Multipoint study of particle propagation

Relativistic solar electrons made it to He 1, some 90° west of the flare site, but no protons!

Wibberenz, 1991
Preparing for STEREO - revisit Helios!

The Helios plasma data are available, on line,
Thanks to Peter Schroeder, SSL Berkeley!
http://sprg.ssl.berkeley.edu/htbin/impact/HeliosData.pl