ALTITUDE-CONTROLLED BALLOONS FOR LONG-DURATION FLIGHTS ON VENUS

P. B. Voss, J. Nott, J. A. Cutts, J. L. Hall, P. M. Beauchamp, S. S. Limaye, K. H. Baines, B. Bennett, L. R. Hole

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Venus is the only planet where sustained flight has been accomplished with the two VEGA balloons three decades ago?

Is the time ripe for a return to Venus with aerial platforms and if so what type of vehicle should it be?

Mars has been the target for numerous attempts to develop a mission involving sustained flight

- French Mars Aerostat of 1980s
- JPL Mars Aerobot of 1990s
- Mars airplane – Kittyhawk 2003
- Mars airplane – ARES 2000

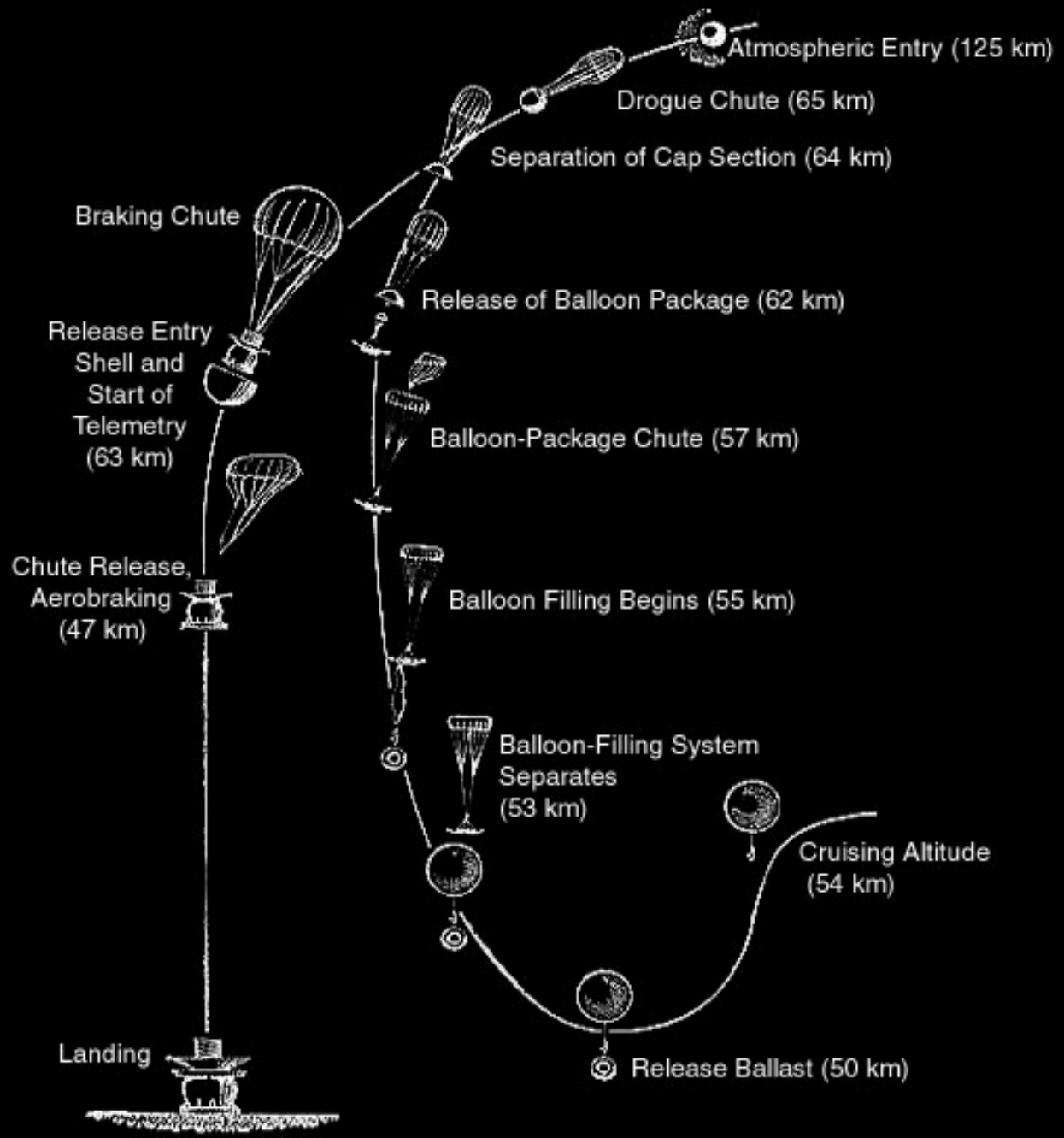
Each has failed to gain sustained support as an exploration capability.

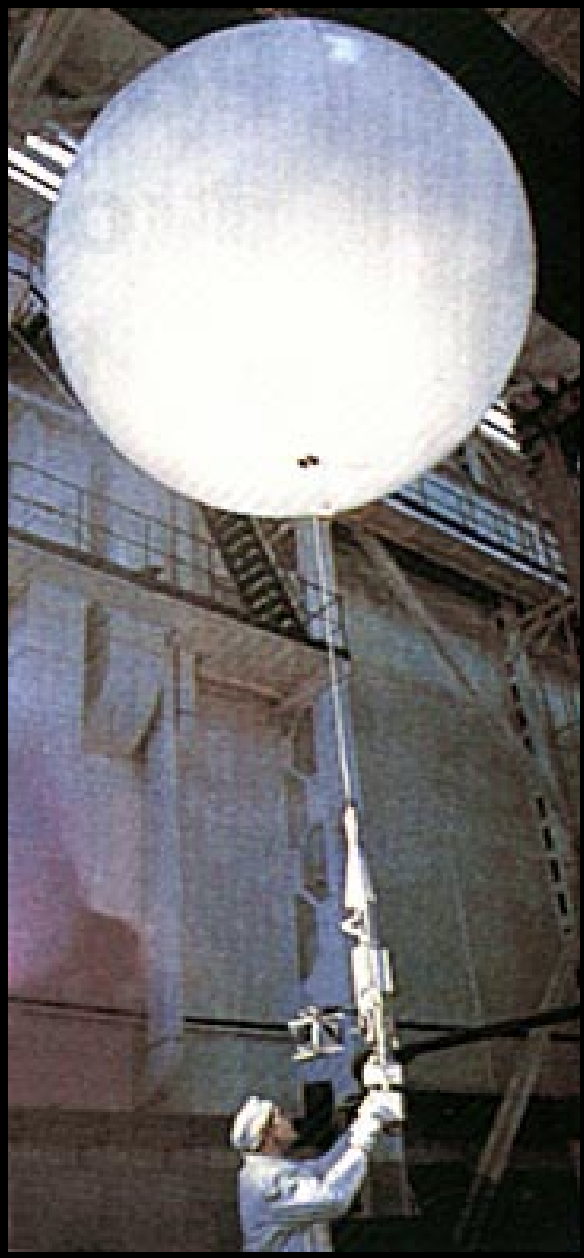
Can the mission at succeed?

Titan is viewed by many as the ideal destination for aerial exploration whether by LTA or HTA vehicles?

What technical developments are needed if aerial exploration is to play a key role in the [illegible] of Titan?

Vega I and Vega II Aerostats (U.S.S.R, 1985)





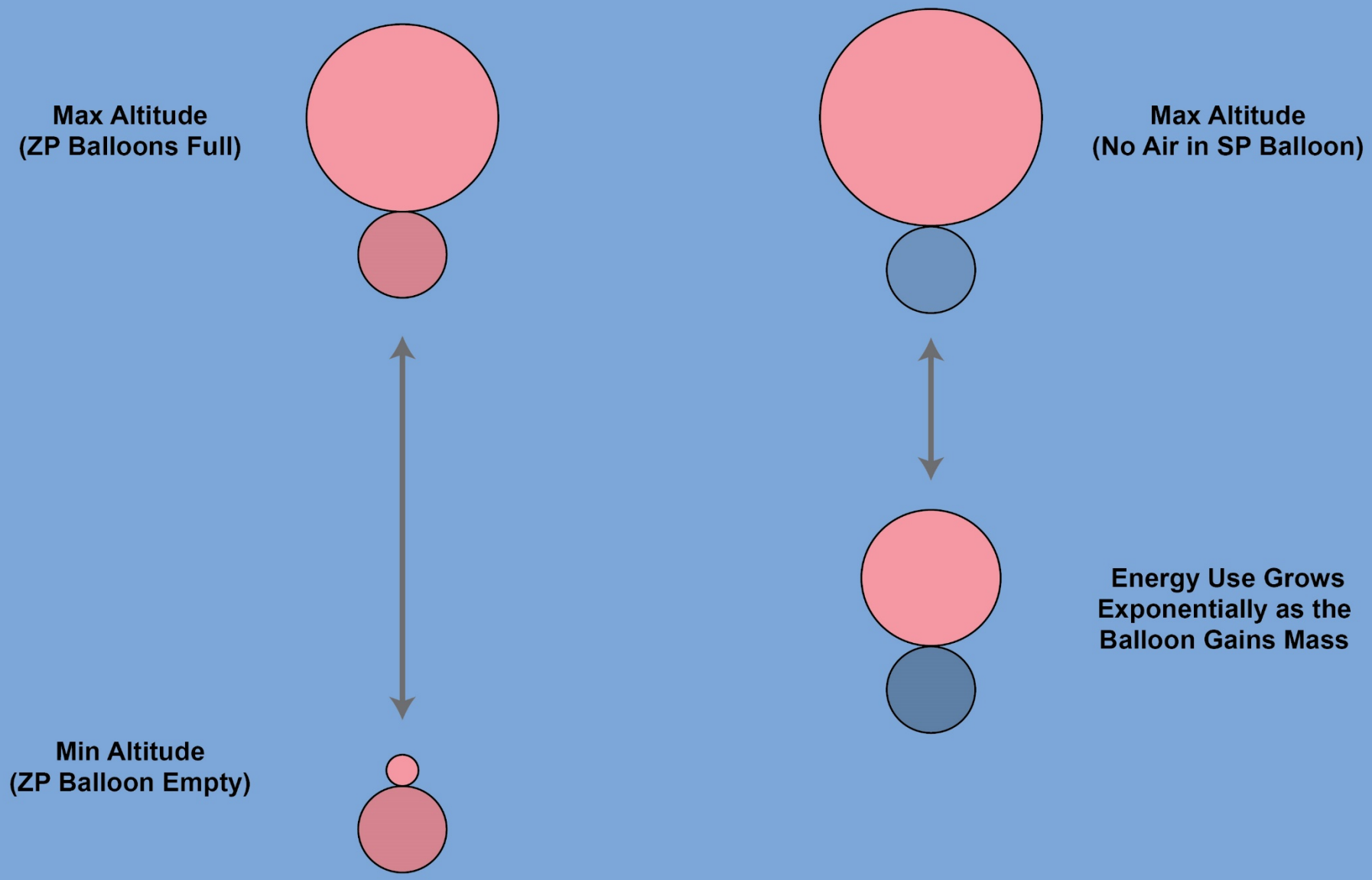
www.mentallandscape.com

Motivation for Altitude-Controlled Balloons

- Planetary atmospheres are usually highly structured in the vertical dimension. Profiles provide far more information than constant-altitude trajectories.
- Repeated soundings allow layers to be probed and verified.
- Situational awareness (above and below balloon) helps mission controllers minimize risks and maximize scientific return.
- Balloons can also be “navigated” using wind shear in order to:
  - Control poleward drift and extend flight duration
  - Hedge against unforeseen features of the circulation
  - Track atmospheric layers and observe processes
- Payload temperature can be controlled by short descents into hotter regions followed by cooling at higher altitudes.
- Power management with solar charging above the cloud layers

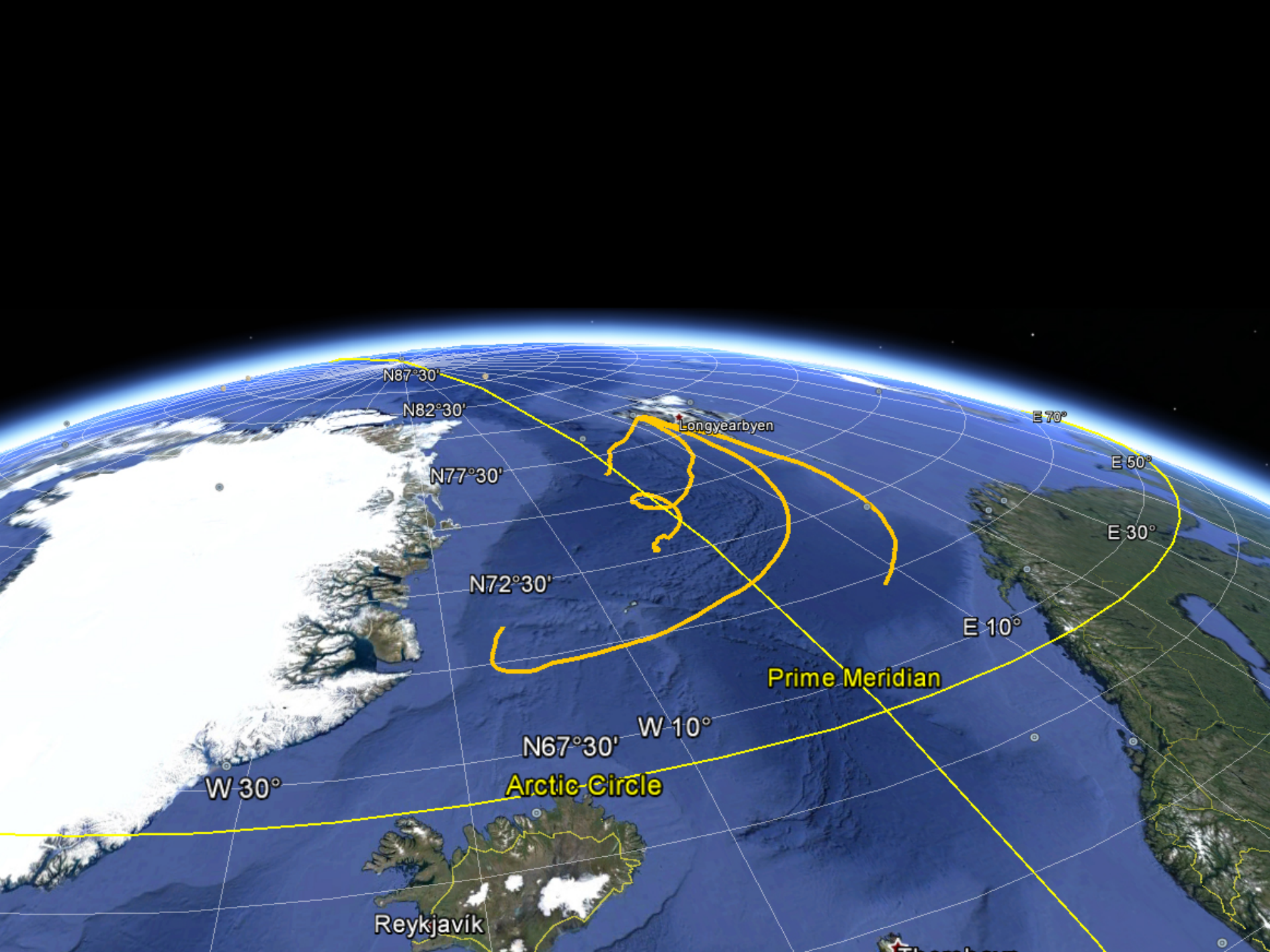
Lift Gas Compression
(CMET Balloon)

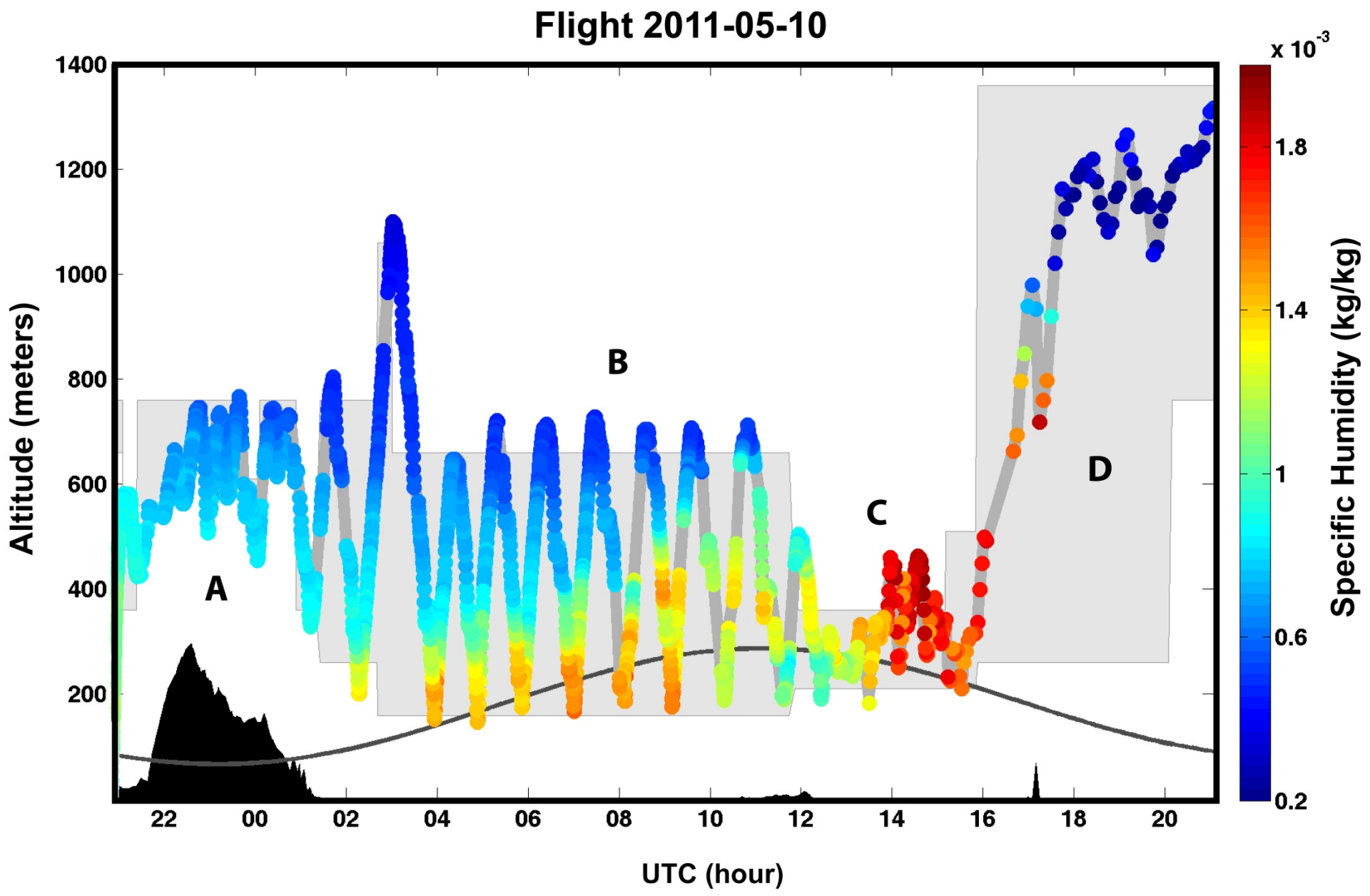
Ambient Gas Compression
(Sky Anchor)



NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

In Situ Measurements of Sulfur Dioxide Plume
Halemaumau Crater, Hawaii

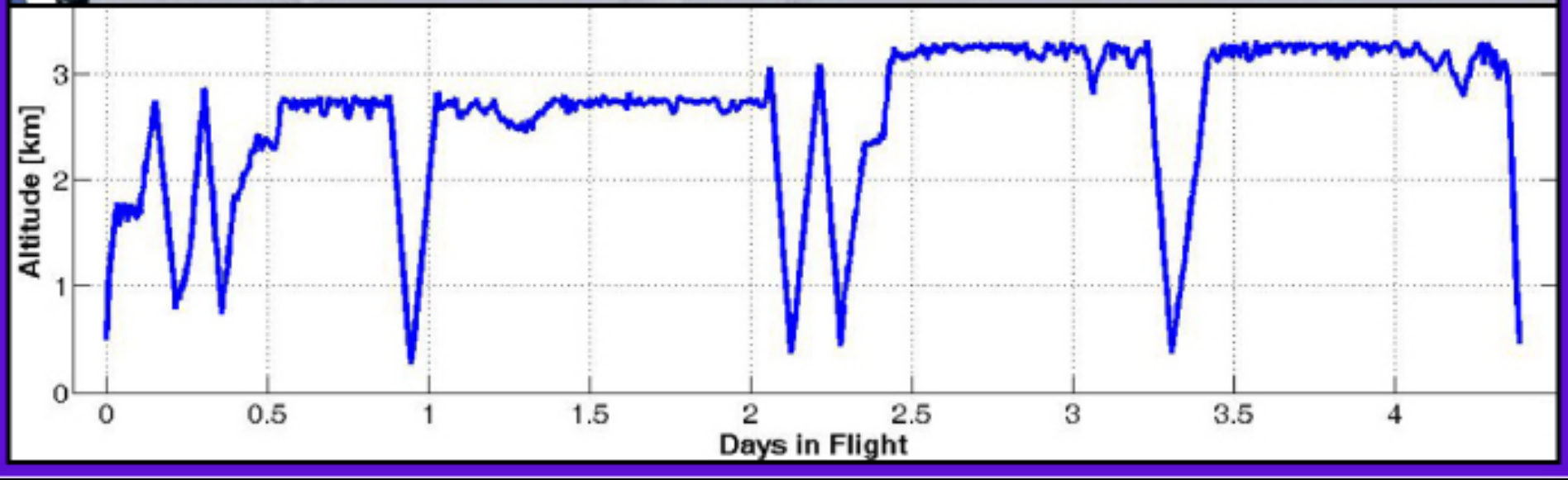

N87°30'
N82°30'
N77°30'
N72°30'
N67°30'
Longyearbyen
E 70°
E 50°
E 30°
E 10°
Prime Meridian
W 10°
W 30°
Arctic Circle
Reykjavík


Flight 2011-05-10
Altitude (meters)
1400
1200
1000
800
600
400
200
A
B
C
D
22
00
02
04
06
08
10
12
14
16
18
20
UTC (hour)
x 10^-3
1.8
1.4
1
0.6
0.2
Specific Humidity (kg/kg)

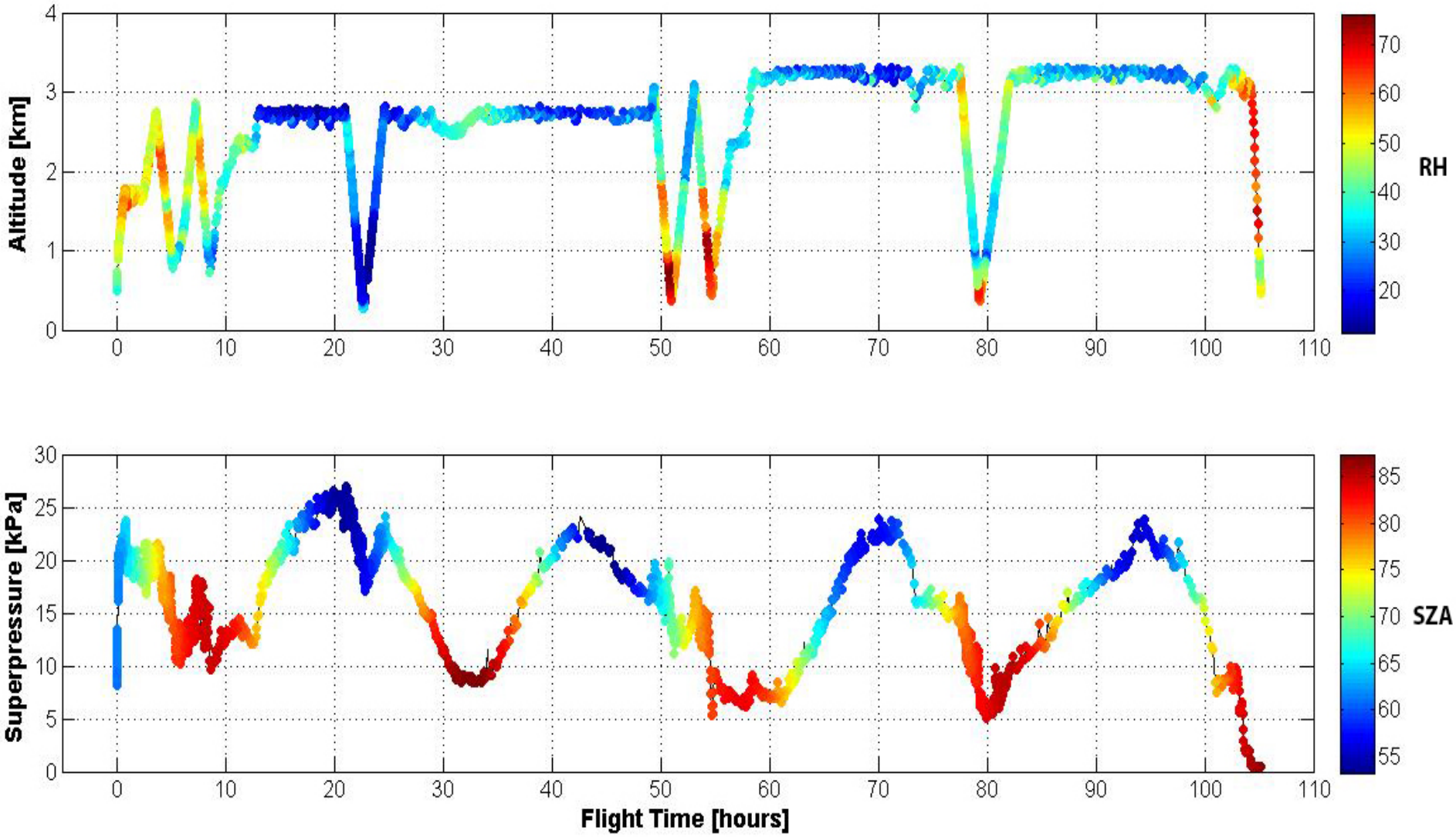
Antarctic Balloon Campaign 2013

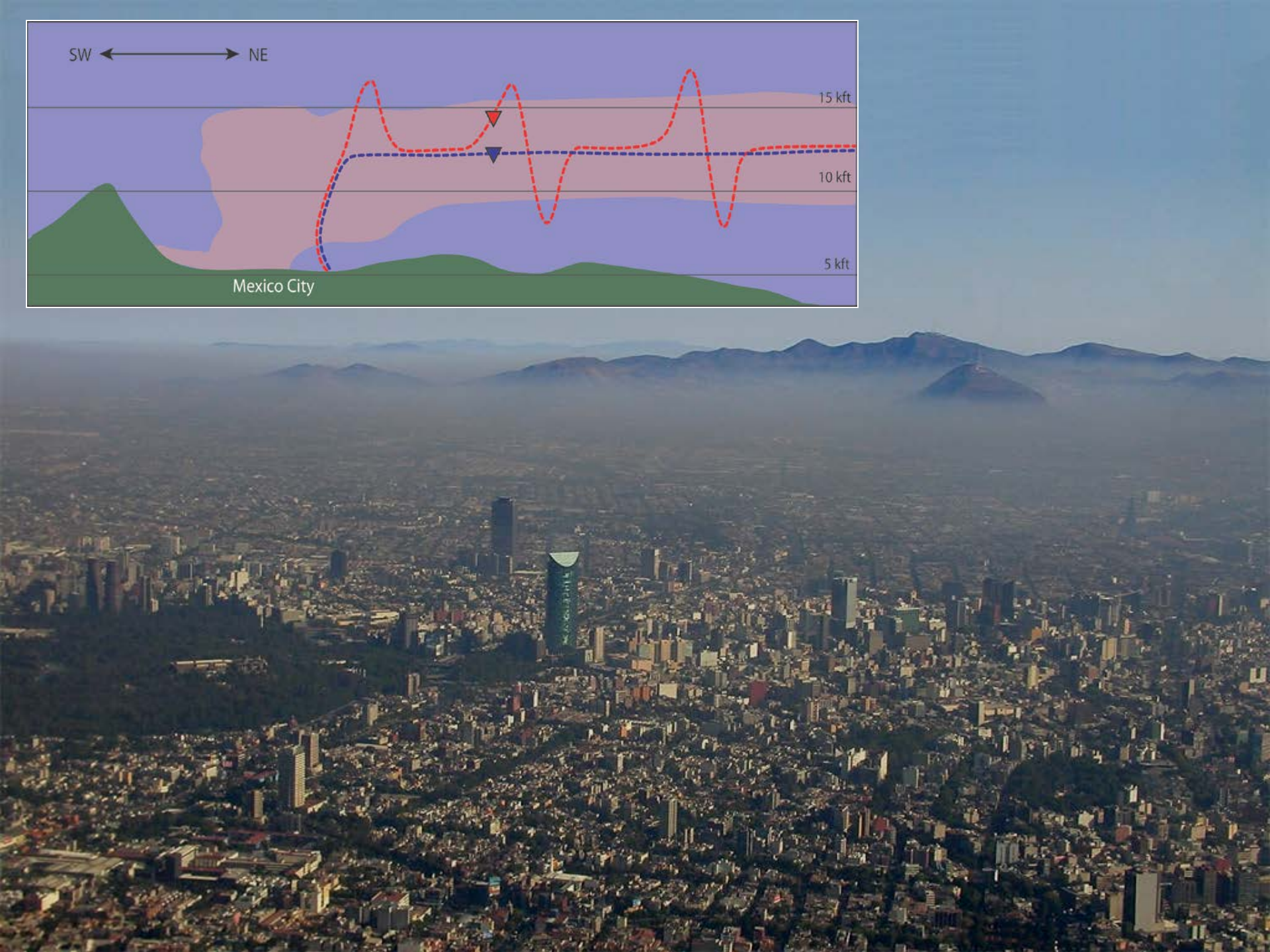
Longest Polar Flight of a Controlled Meteorological Balloon - Launched from Aboa Station (13-01-18)

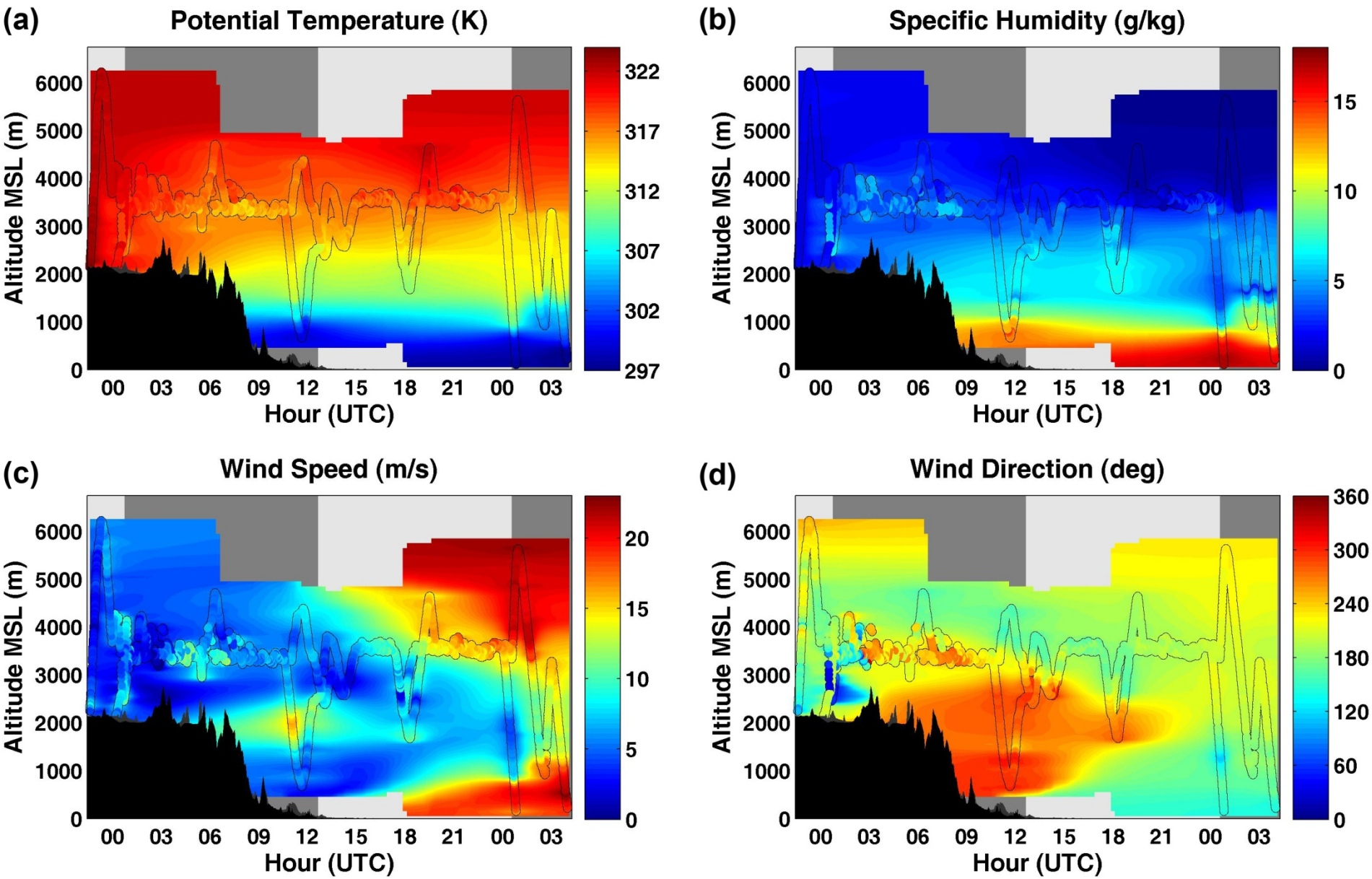
Participants: Lars Hole, Paul Voss, Tjarda Roberts, Timo Vihma, Aurora Stenmark, Lingyi Wu, Mika Kalakoski, Petri Heinonen, FINNARP Team

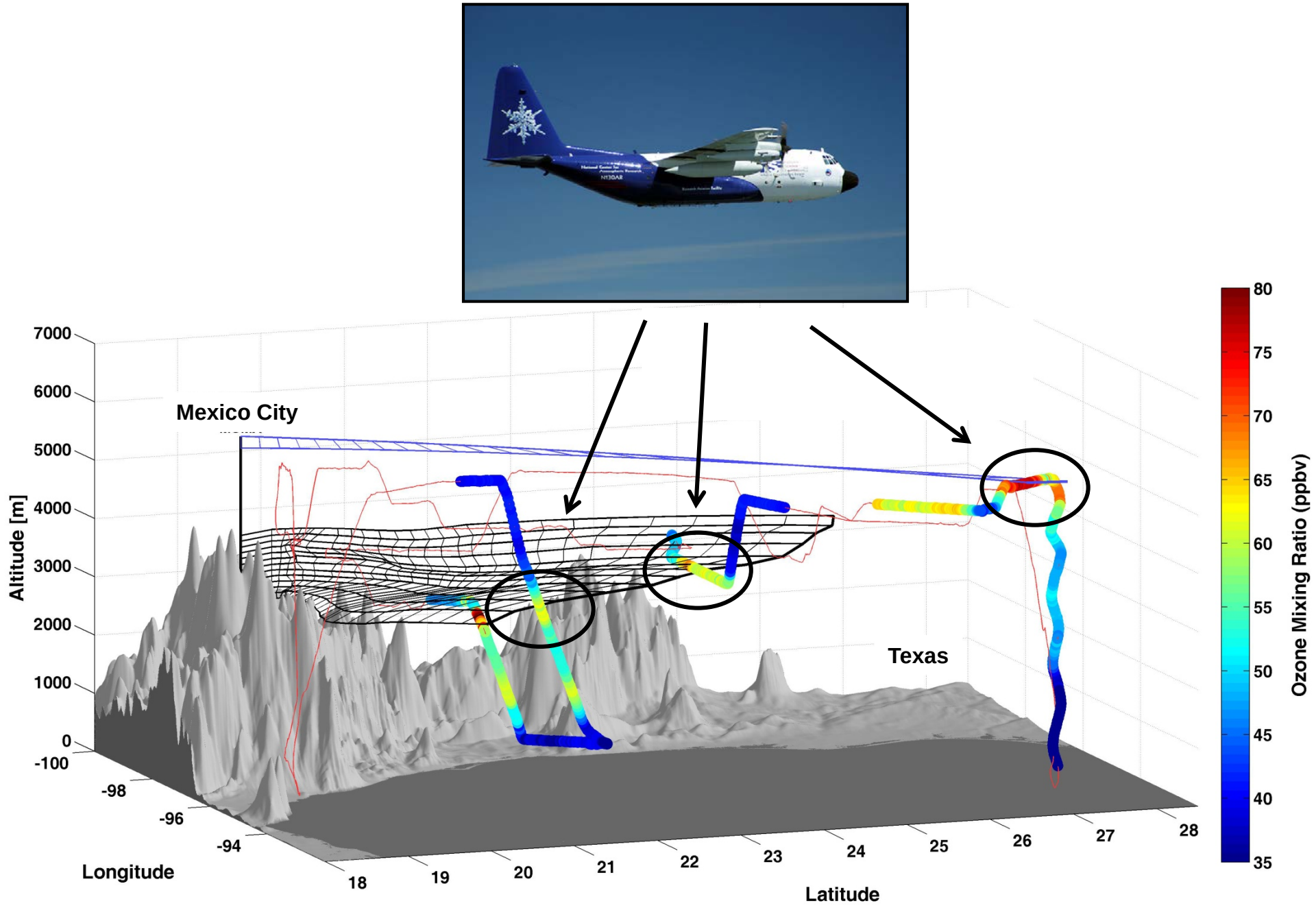


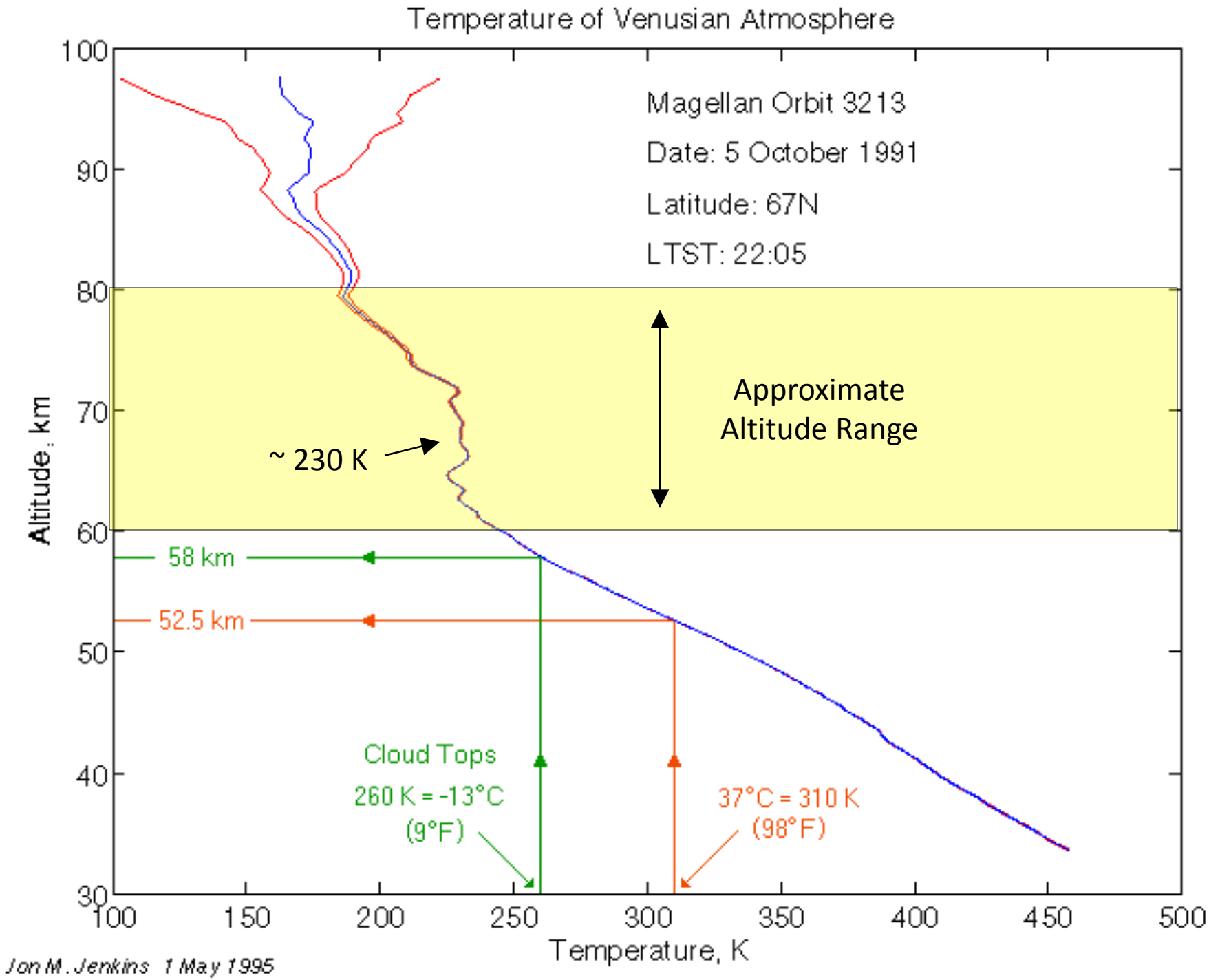
Superpressure Depends on Solar Angle with Smaller Deviations for Altitude Control




SW
NE
15 kft
10 kft
5 kft
Mexico City


(a)
Potential Temperature (K)
Altitude MSL (m)
Hour (UTC)
(b)
Specific Humidity (g/kg)
Altitude MSL (m)
Hour (UTC)
(c)
Wind Speed (m/s)
Altitude MSL (m)
Hour (UTC)
(d)
Wind Direction (deg)
Altitude MSL (m)
Hour (UTC)


Mexico City
Texas
Altitude [m]
7000
6000
5000
4000
3000
2000
1000
0
-100
-98
-96
-94
Longitude
18
19
20
21
22
23
24
25
26
27
28
Latitude
80
75
70
65
60
55
50
45
40
35
Ozone Mixing Ratio (ppbv)

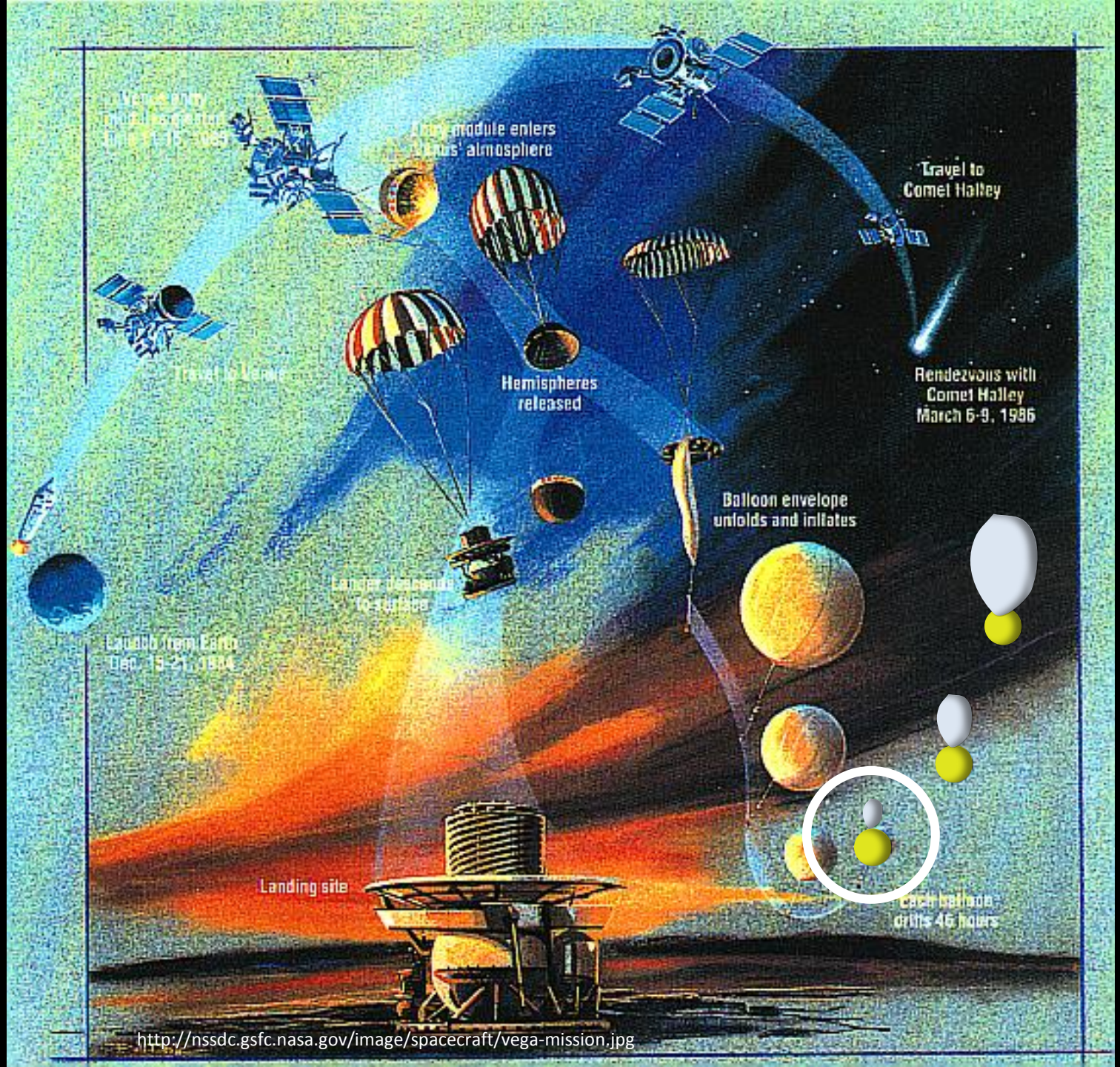

Temperature of Venusian Atmosphere
Magellan Orbit 3213
Date: 5 October 1991
Latitude: 67N
LTST: 22:05
Approximate
Altitude Range
~ 230 K
58 km
52.5 km
Cloud Tops
260 K = -13°C
(9°F)
37°C = 310 K
(98°F)
Altitude, km
Temperature, K
100
90
80
70
60
50
40
30
100
150
200
250
300
350
400
450
500
Jon M. Jenkins 1 May 1995

Lift-Gas Compression vs. Ambient-Gas Compression

Required Balloon Volumes, Superpressure, and Compressor Power

Balloon Parameters			Assumptions	Color Key
mass	60	*kg*	Venusian Atmosphere is Isothermal (60-80 km)	Balloons
alpha	0.1	-	Balloons have identical superpressure volumes	Pump
w max	0.5	*m/s*	Balloons have identical solar heating (alpha)	Energy

Atmospheric Conditions				Lift Gas Compression		Amb Gas Compression	
Z	**P**	**T**	**D**	**DP**	**Comp R**	**DP**	**Comp R**
km	*Pa*	*K*	*kg/m3*	*Pa*		*Pa*	
80	370	230	0.008	2000	6.41	2237	7.05
70	2720	230	0.061	2000	1.74	2472	1.91
60	20000	230	0.450	2000	1.10	4200	1.21
		Vsp	*m3*	133		133	
		Vzp	*m3*	7211		7932	
		dV/dz	*m3/m*		0.027		0.027
		dV/ dt	*m3/s*		0.013		0.013
		dE/dz	*J/m*		51		101
		dE/dt	*W*		25		51



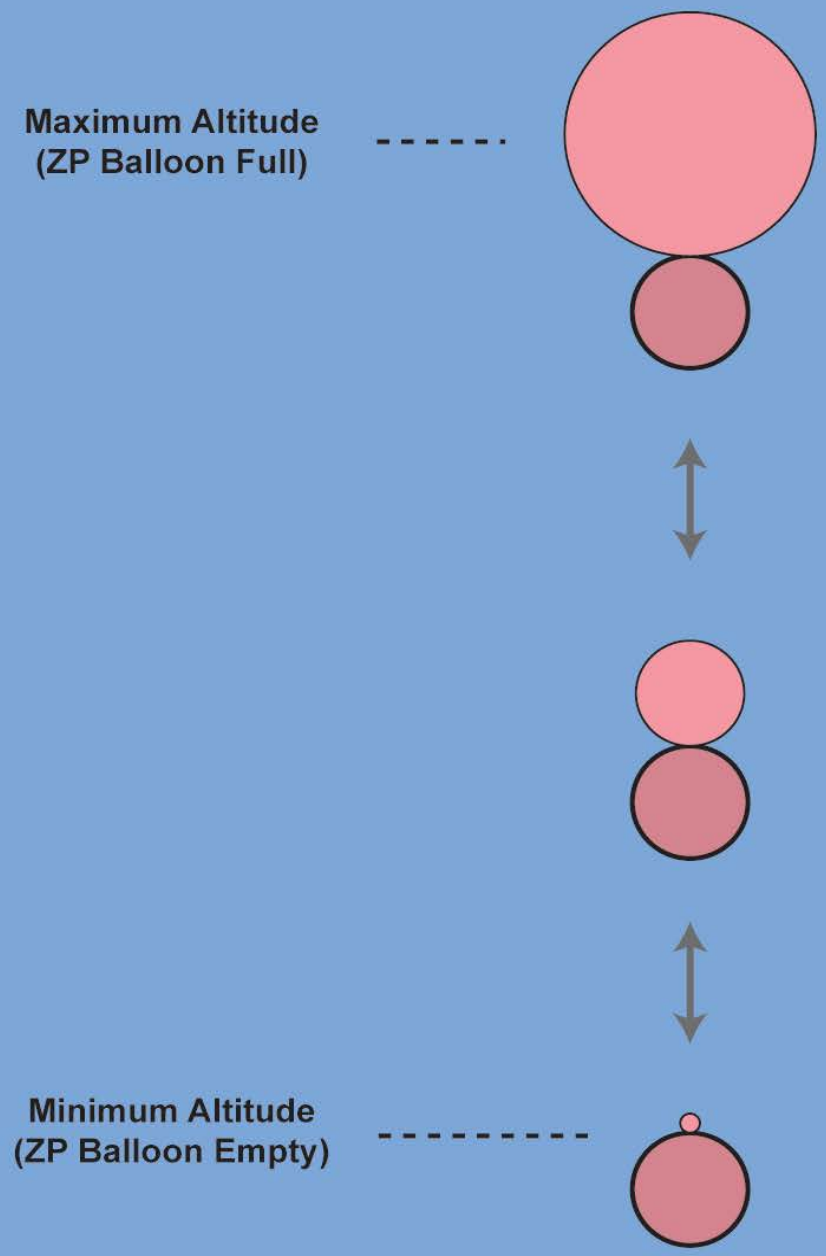
http://nssdc.gsfc.nasa.gov/image/spacecraft/vega-mission.jpg

Thank you…

EXTRA SLIDES

For use at discretion of presenter

Design Considerations for a Helium-Compression Balloon



Superpressure

The primary function of the superpressure balloon is to counteract the diurnal temperature cycle - during the day, lift gas is pumped into the superpressure balloon in order to offset the excess buoyancy due to solar heating.

The pump operates primarily in the hours after sunrise when photovoltaic energy is abundant, greatly reducing the need for heavy batteries.

The superpressure needed to offest a given solar heating ratio ($T_{balloon}/T_{ambient}$) is approximately constant over the entire altitude range. Thus the superpressure balloon has one design pressure that is fully utilized.

Stability

The balloon is highly stable at its minimum altitude and becomes progressively more metastable as it ascends. In other words, its character changes from that of a superpressure balloon to that of a zero-pressure balloon.

Often the minimum altitude is well below the lowest operating altitude, meaning that the balloon is always operating in its metastable range. In this range, the superpressure needed to initiate descent is small in comparison to that required to counteract solar heating.