Scanning Strategy for ARM Cloud Radars

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ARM
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U.S. DEPARTMENT OF ENERGY

ARM Cloud and Precipitation Radars

C-SAPR

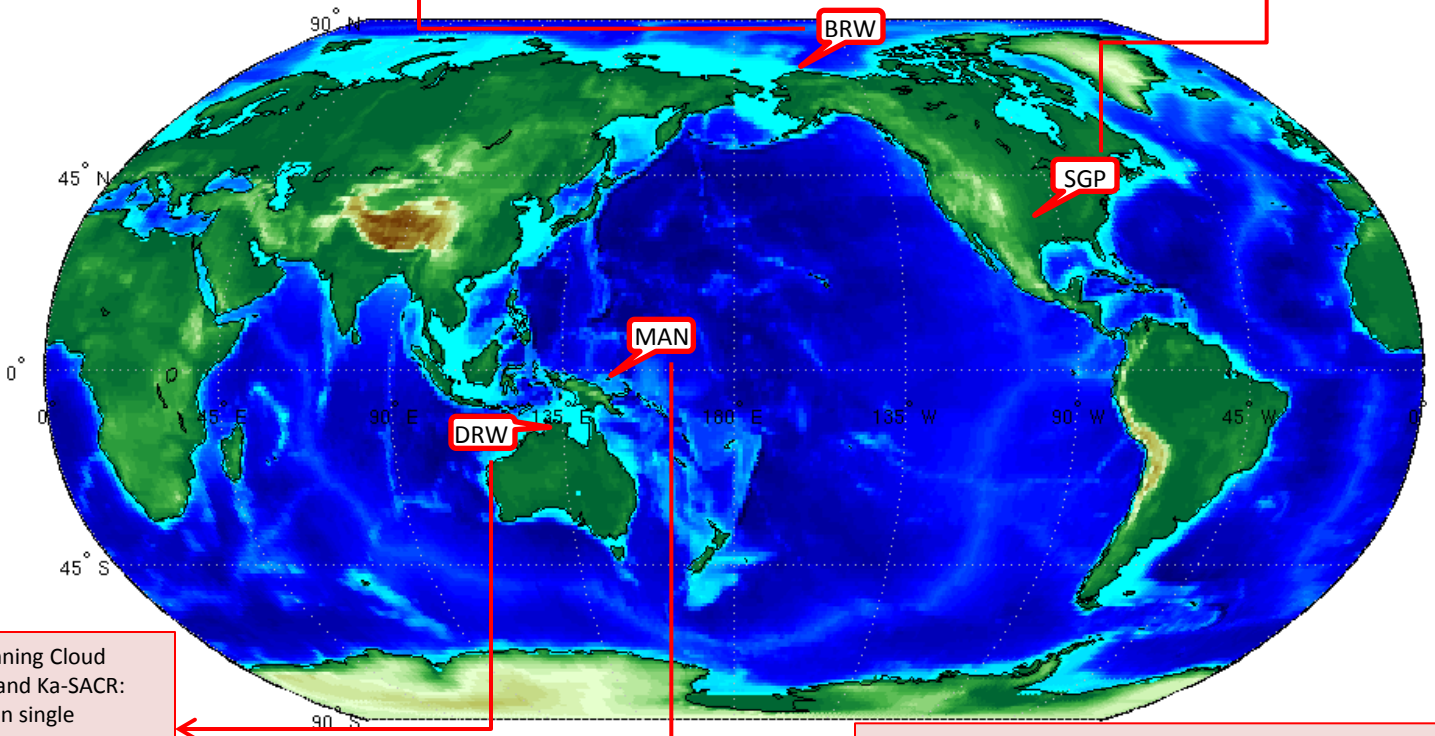
X-SAPR

X/Ka-SACR

Ka/W-SACR

1. X-band Scanning Precipitation Radar (X-SAPR)
2. Ka/W-band Scanning Cloud Radar (Ka-SACR and W-SACR: two antennas on single pedestal)
3. Ka-band Vertically Pointing Radar (MMCR)

1. Three X-band Scanning Precipitation Radar (X-SAPR) Network
2. C-band Scanning Precipitation Radar
3. Ka/W-band Scanning Cloud Radar (Ka-SACR and W-SACR: two antennas on single pedestal)
4. Ka-band Vertically Pointing Radar (MMCR)



MMCR

WACR

SWACR

1. X/Ka-band Scanning Cloud Radar (X-SACR and Ka-SACR: two antennas on single pedestal)
2. Ka-band Vertically Pointing Radar (MMCR)

1. C-band Scanning Precipitation Radar (C-SAPR)
2. X/Ka-band Scanning Cloud Radar (X-SACR and Ka-SACR: two antennas on single pedestal)
3. Ka-band Vertically Pointing Radar (MMCR)

ARM Mobile Facility I (AMF1)

1. Ka/W-band Scanning Cloud Radar (Ka-SACR and W-SACR: two antennas on single pedestal)
2. W-band vertically pointing radar (WACR)

ARM Mobile Facility 2 (AMF2)

1. X/Ka-band Scanning Cloud Radar (X-SACR and Ka-SACR: two antennas on single/separate pedestals)
2. Ka-band Vertically Pointing Radar (MMCR)
3. Scanning W-band ARM cloud radar (SWACR)

ARM Cloud Radars

Table 1 Description of cloud radar acronyms

Radar Name	Description
X-SACR	Scanning ARM cloud radar at X-band (when deployed as standalone)
Ka-SACR	Scanning ARM cloud radar at Ka-band (when deployed as standalone)
W-SACR	Scanning ARM cloud radar at W-band (never deployed as standalone)
X/Ka-SACR	Dual frequency SACR with X-band and Ka-band on single pedestal
Ka/W-SACR	Dual frequency SACR with Ka-band and W-band on single pedestal
MMCR	Millimeter wave Cloud Radar
WACR	W-band ARM Cloud radar
SWACR	Scanning W-band ARM Cloud radar (WACR with pedestal)

Band/Site	SGP	NSA	TWP-Darwin	TWP- Manus	AMF-1	AMF-2
X/Ka			√	√		√
Ka/W	√	√			√	
SWACR						√
MMCR	√	√	√	√		√
WACR					√	

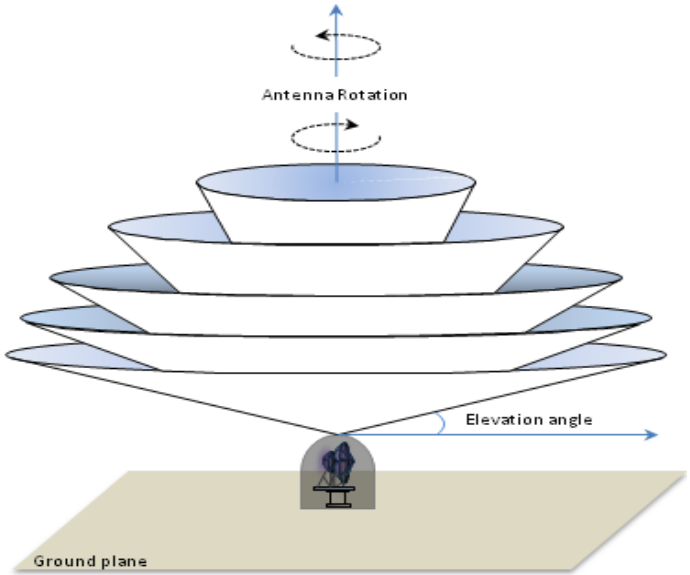
Scan Strategy System for Cloud Radars

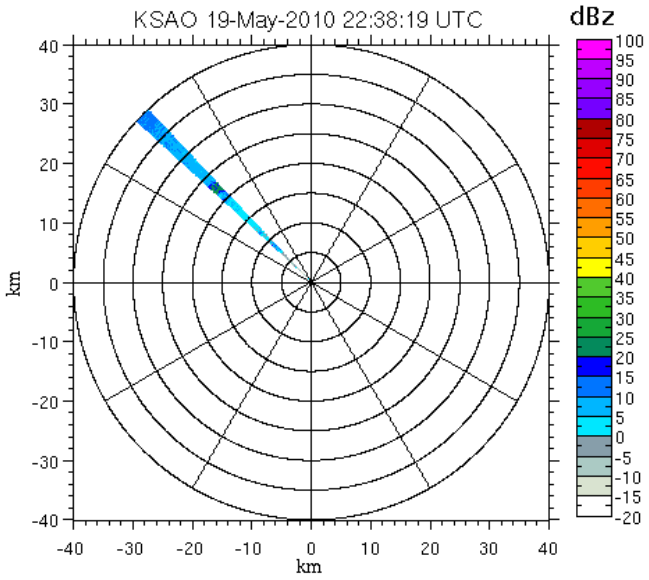
- Three dimensional mapping of targeted cloud systems
- The scanning mechanism for cloud observations are decomposed into elemental scan segment sets S_X
- The elemental scan segments are based on the nature of scan or the targeted cloud system (denoted by X in S_X)

Scan Strategy System for SACR: PPI

Plan position indicator (PPI): The PPI scan segment S_p is defined as

$$S_p \triangleq \{s(\theta_{e1}), s(\theta_{e2}), \ldots, s(\theta_{en})\}.$$

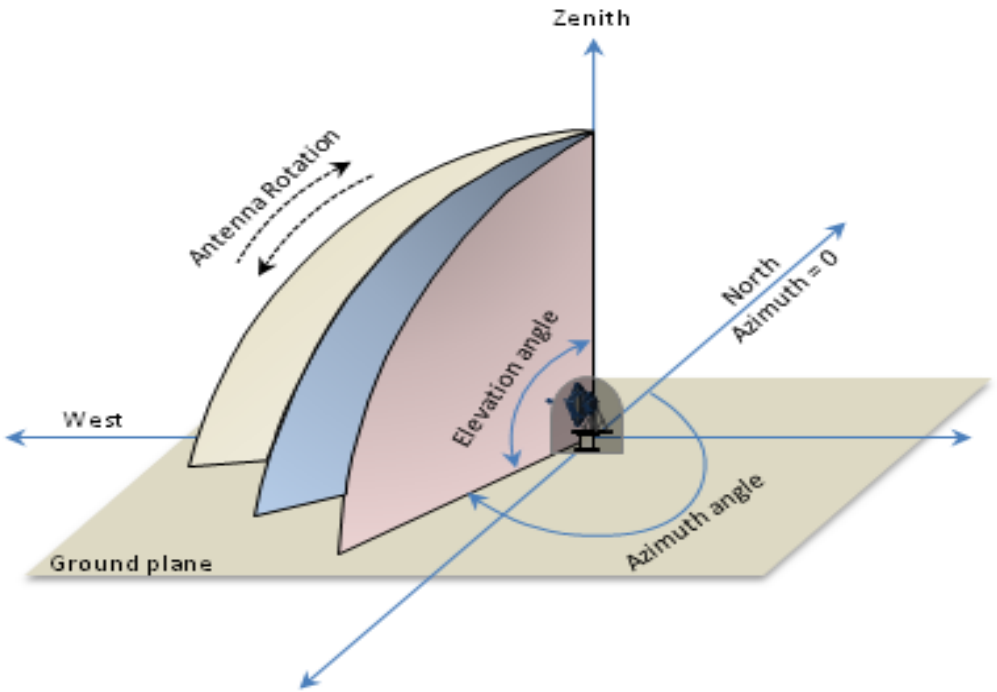




Scan Strategy System for SACR: RHI

Range height indicator (RHI): The RHI scan segment $\mathcal{S}_r$ is defined as

$$\mathcal{S}_r \triangleq \{s(\theta_a, \Delta\theta_e)\}.$$

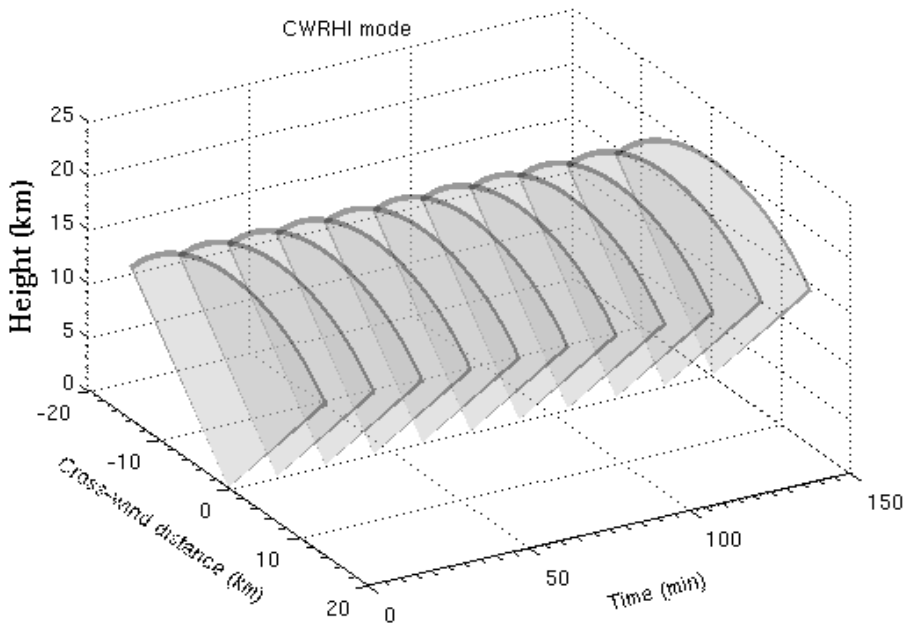


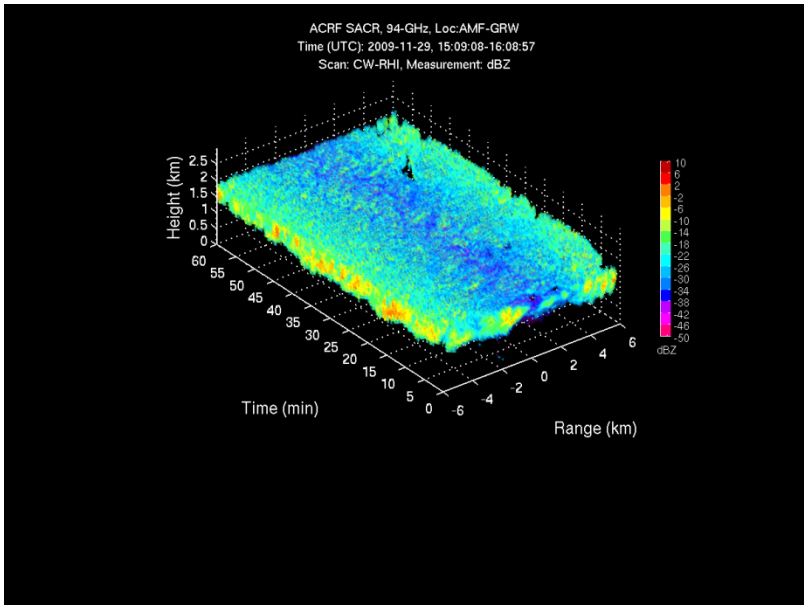
- Selection of the azimuth angle is important

Scan Strategy System for SACR: CWRHI

Cross-wind RHI (CWRHI): The cross-wind RHI scan segment $\mathcal{S}_c$ is defined as

$$\mathcal{S}_c \triangleq \{s(\theta_a, \theta_e, \Delta\theta_e)\}.$$



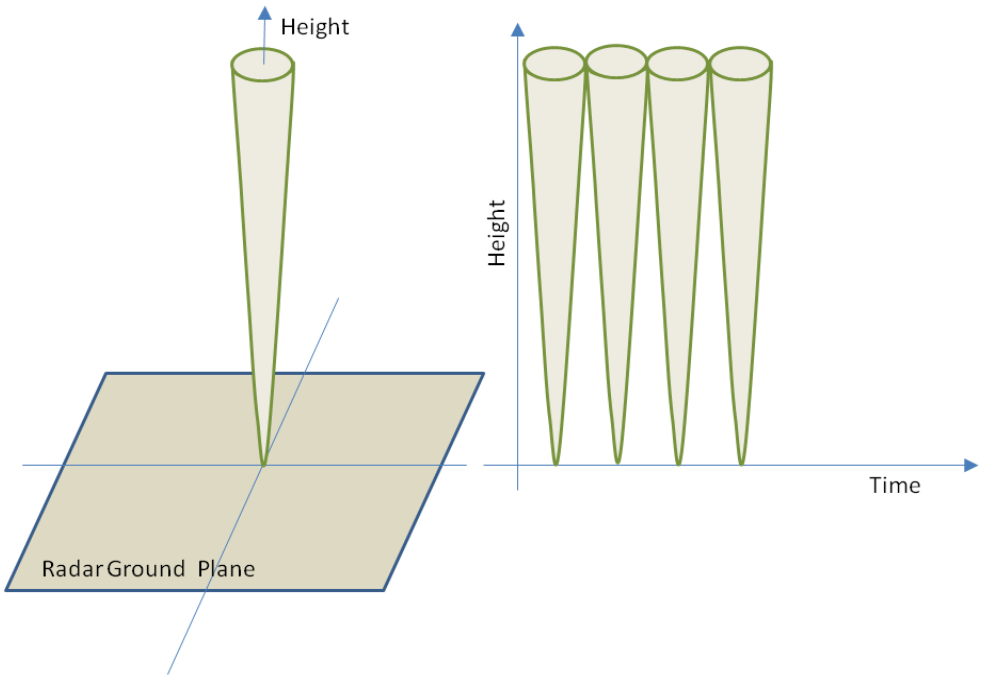


- The cross wind direction
  - Obtained from PI
  - Adaptive direction from VAD

Scan Strategy System for SACR: VPT

Vertically pointing (VPT): The vertically pointing scan segment $\mathcal{S}_v$ is defined as

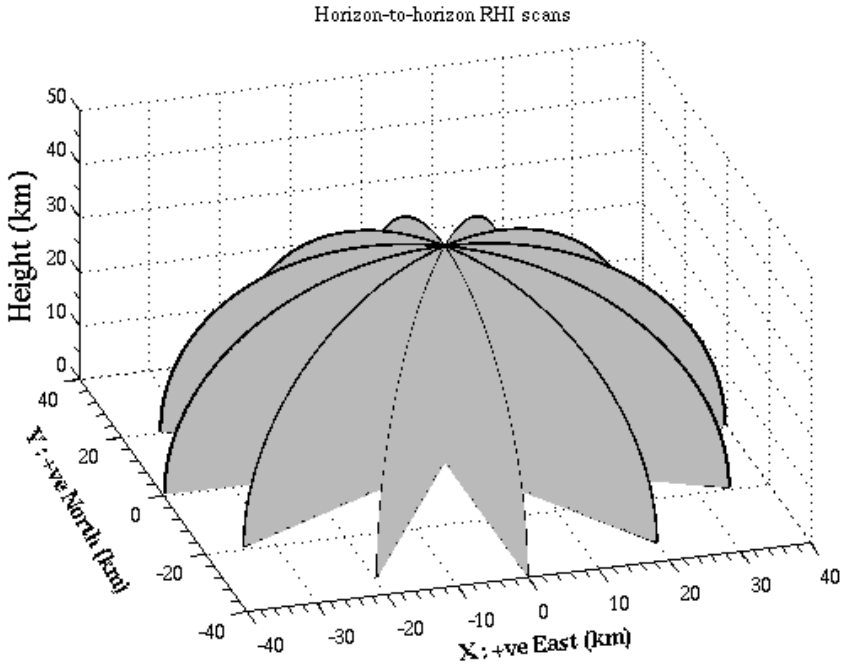
$$\mathcal{S}_v \triangleq \{s(T_v)\}.$$

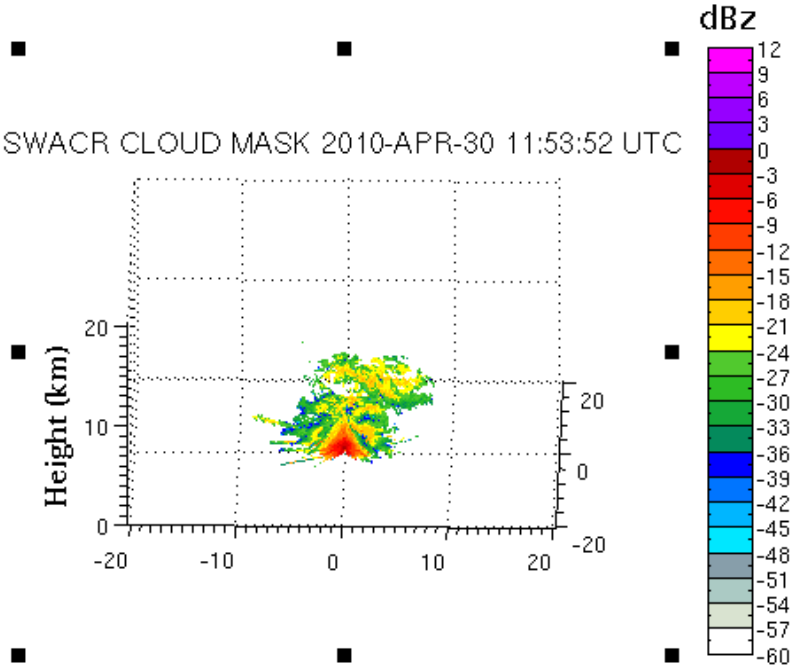


Scan Strategy System for SACR: HSRHI

Horizon-to-horizon (HSRHI): The horizon to horizon scan segment $\mathcal{S}_h$ is defined as

$$\mathcal{S}_h \triangleq \{s(\theta_{a1}), s(\theta_{a2}), \ldots, s(\theta_{an})\}.$$

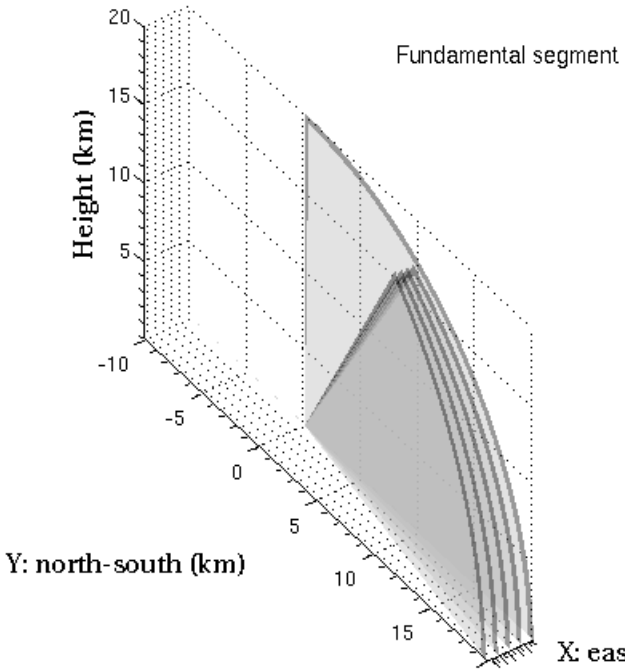


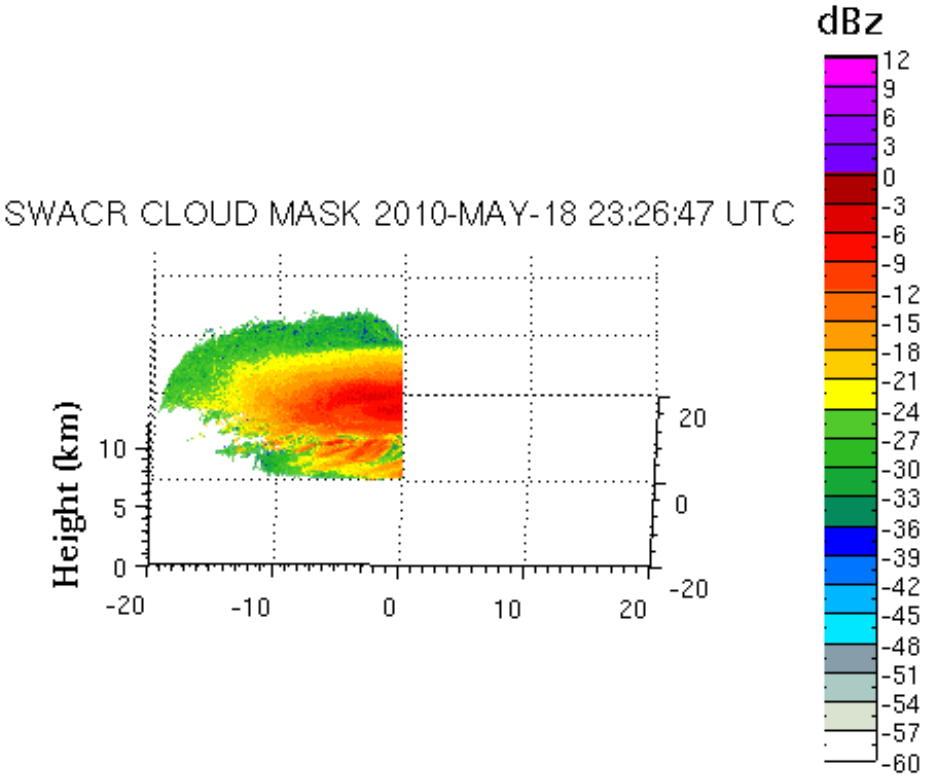


Scan Strategy System for SACR: BLRHI

Boundary layer (BLRHI): The boundary layer scan segment $\mathcal{S}_b$ is defined as

$$\mathcal{S}_b \triangleq \{s(\Delta\theta_a, n\theta_T);\ n = 1,2,..\}.$$

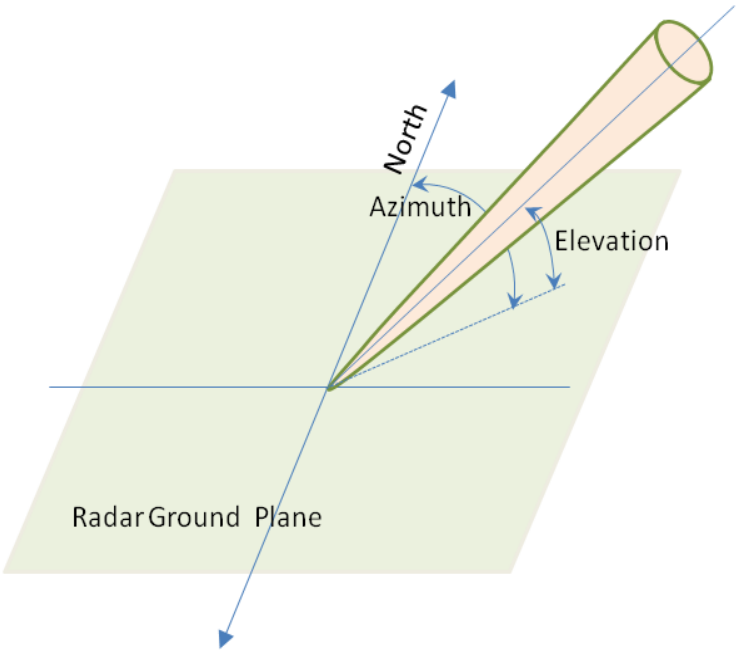




Scan Strategy System for SACR: FPT

Fixed pointing (FPT): The fixed pointing scan segment $\mathcal{S}_f$ is defined as

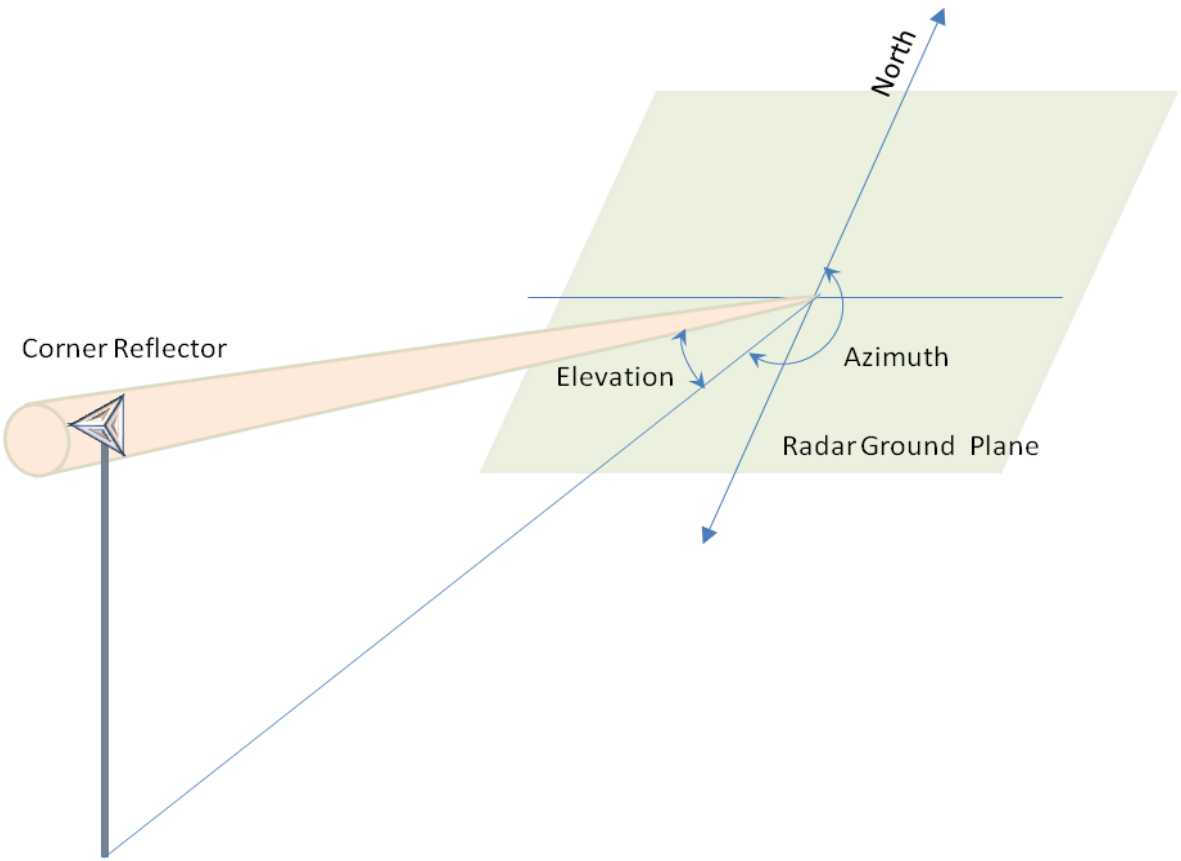
$$\mathcal{S}_f \triangleq \{s(\theta_a, \theta_e)\}.$$



Scan Strategy System for SACR: CRCAL

Corner reflector calibration (CRCAL): The corner reflector scan segment $\mathcal{S}_{\text{CAL}}$ is defined as

$$\mathcal{S}_{\text{CAL}} \triangleq \{s(\theta_a, \theta_e)\}. \quad (8)$$



Scan Strategy System for SACR

Table 3 List of elemental scan segments defined for scanning cloud radars.

Scan Segment	Description
$\mathcal{S}_p$	PPI scan segment
$\mathcal{S}_r$	RHI scan segment
$\mathcal{S}_c$	Cross-wind RHI scan segment
$\mathcal{S}_v$	Vertically pointing scan segment
$\mathcal{S}_h$	Horizon-to-horizon scan segment
$\mathcal{S}_b$	Boundary layer scan segment
$\mathcal{S}_f$	Fixed pointing scan segment
$\mathcal{S}_{\mathrm{CAL}}$	Corner reflector calibration scan segment

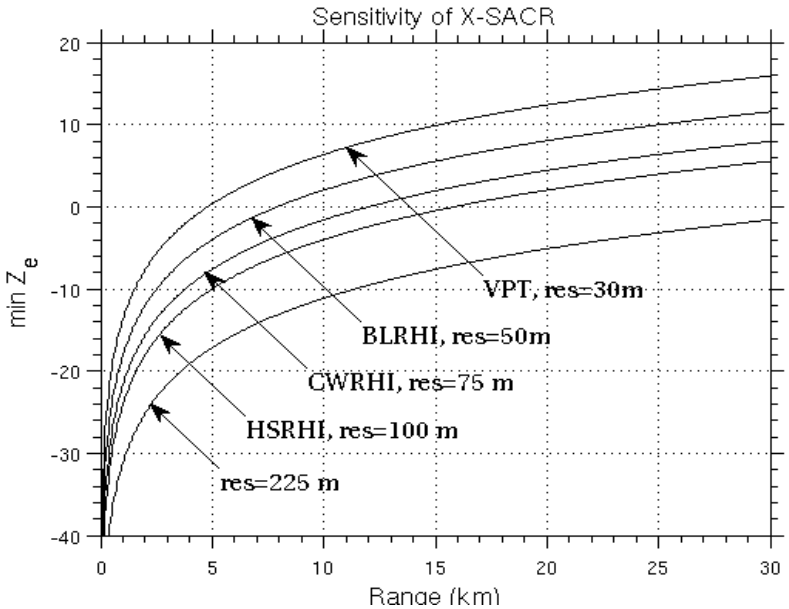
- Example:

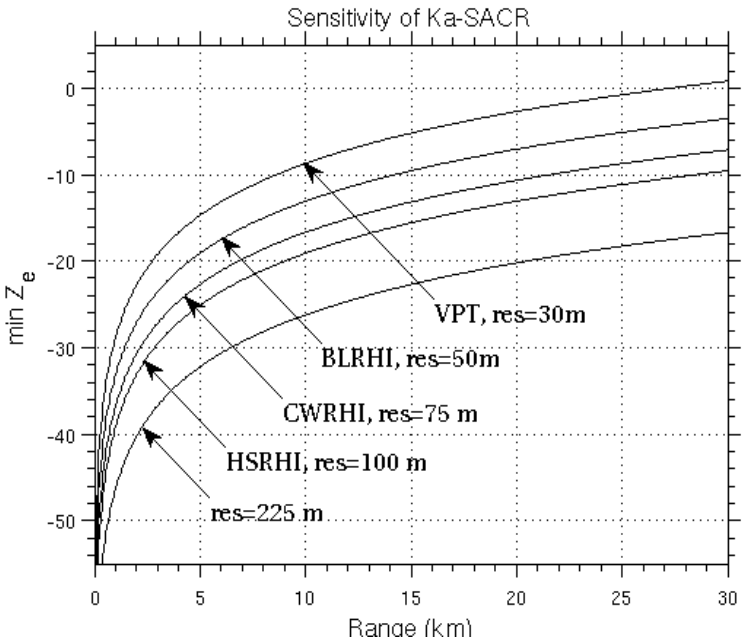
$$\mathcal{S}_{\mathrm{site}} \triangleq \{\mathcal{S}_h(t_h)\,\mathcal{S}_b(t_b)\;\mathcal{S}_h(t_h)\,\mathcal{S}_c(t_c)\}.$$

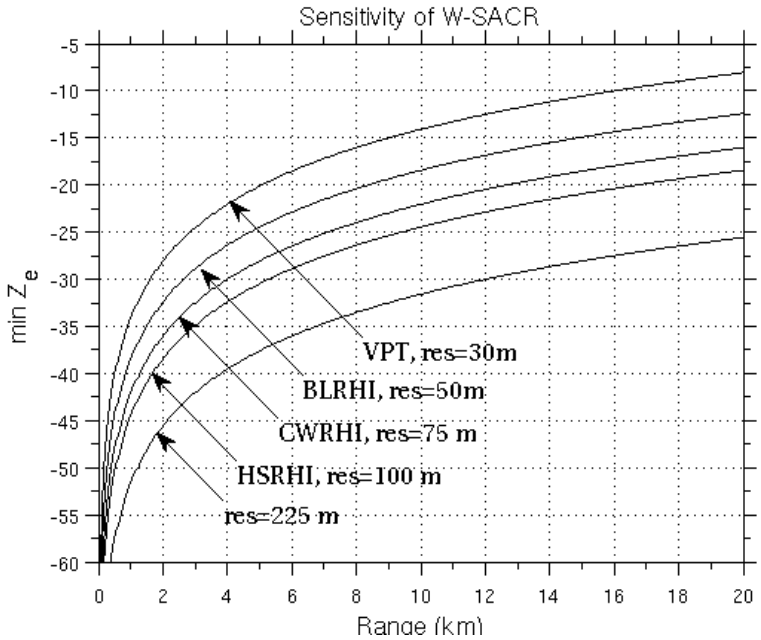
Where t_h, t_b, and t_c are the duration of the HSRHI, BLRHI and CWRHI scans respectively.

- Spectra is stored when operating in vertically pointing mode

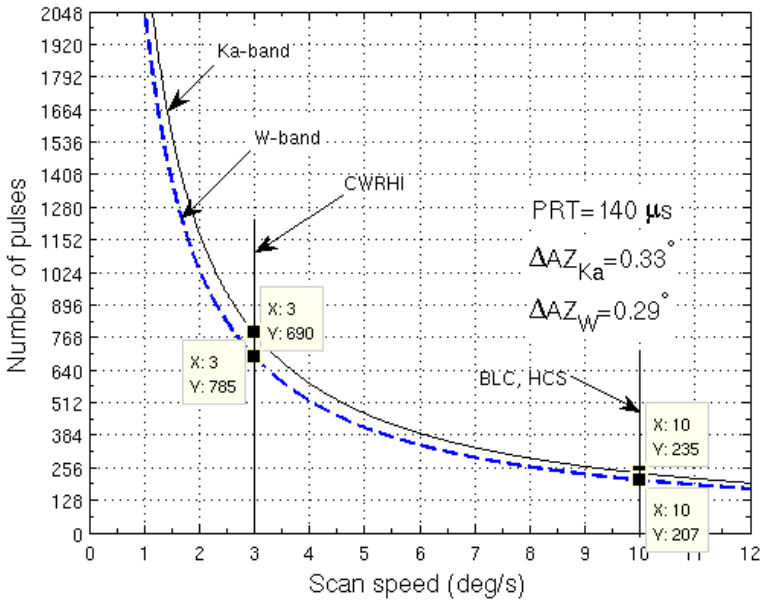
Scan Strategy System for SACR: Waveforms

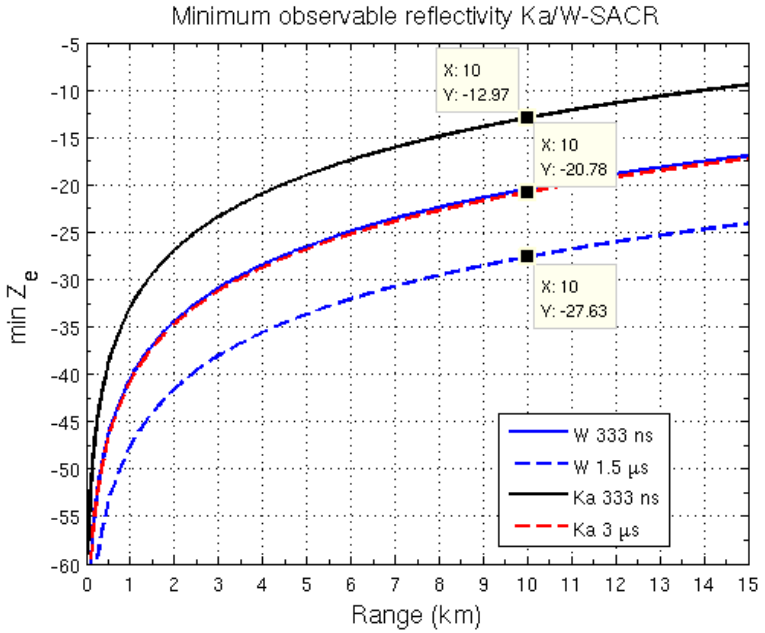


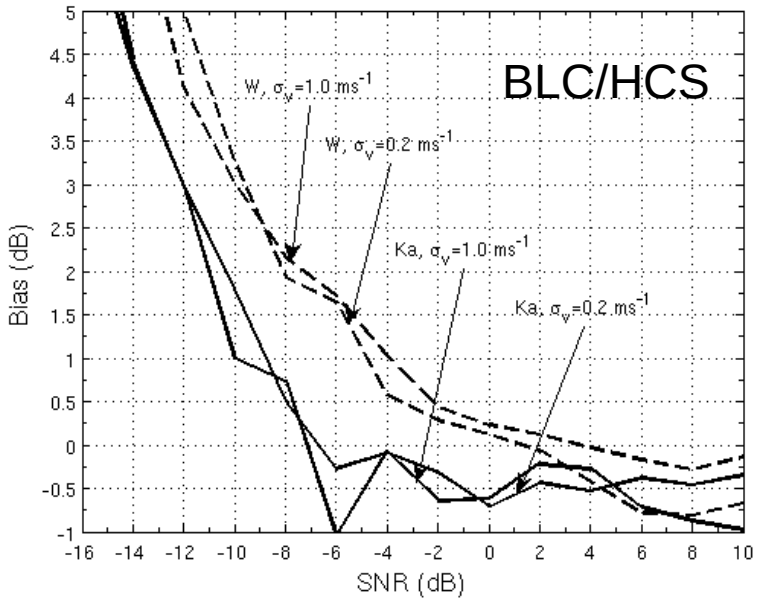


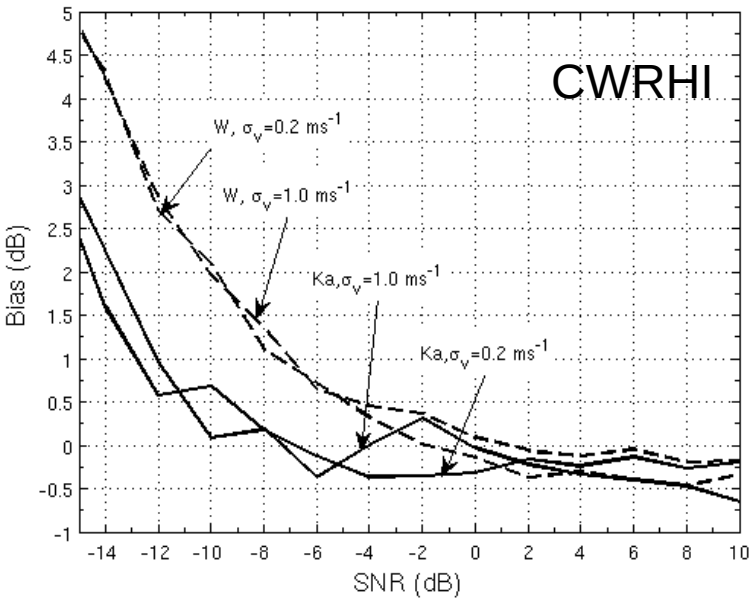


Scan Strategy System for SACR: Waveforms









Scan Strategy System for SACR: Waveforms

Table 4 Sensitivity at a range of 10 km and resolution of SACR operating modes

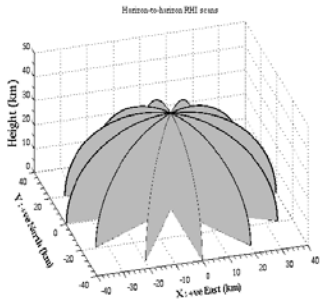
At 10 km range	VPT	BLRHI	CWRHI	HSRHI
X-SACR	6.3 dBz	2.0 dBz	-1.6 dBz	-4.0 dBz
Ka-SACR	-7.7 dBz	-12.1 dBz	-15.7 dBz	-18.11 dBz
W-SACR	-14.0 dBz	-18.4 dBz	-22.0 dBz	-24.4 dBz
Range Resolution	30 m	50 m	75 m	100 m
Scan Speed	0	10 deg/s	3 deg/s	10 deg/s

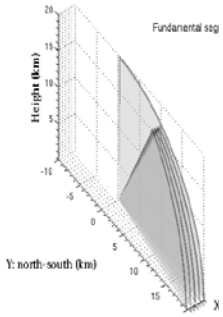
- Sensitivity improvement with spectral processing is smaller for scanning systems
- In vertically pointing modes spectral processing will improve sensitivity due to longer dwell times
- Pulse compression waveforms are being developed

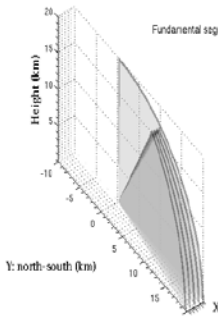
Scan Strategy for SACR: SGP

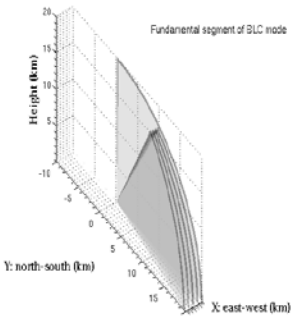
$$\mathcal{S}_{\mathrm{SGP}} \triangleq \{\mathcal{S}_h(t_h)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_h(t_h)\,\mathcal{S}_c(t_c)\}.$$

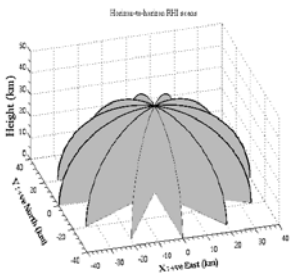
~2 min ~5 min ~5 min ~5 min ~2 min ~15 min

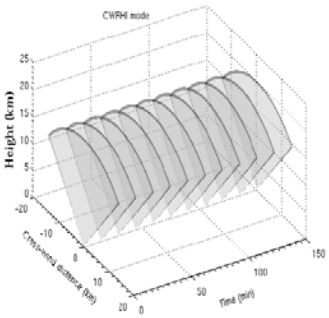


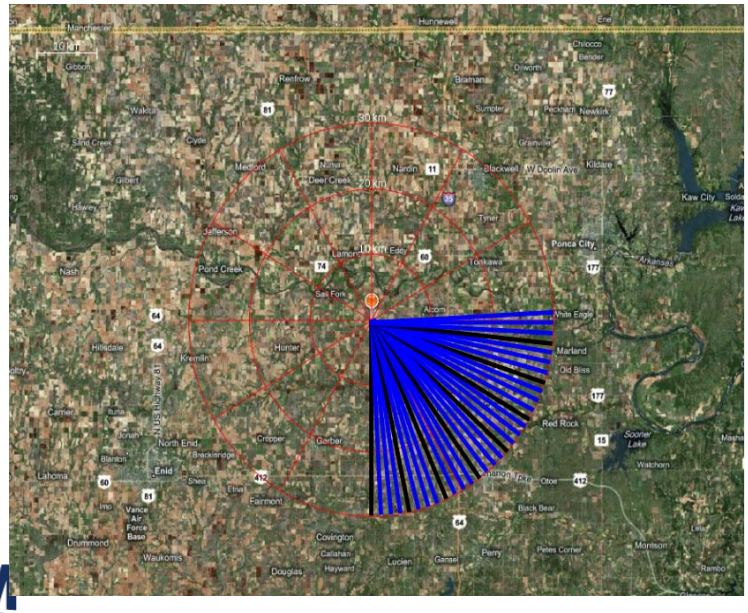








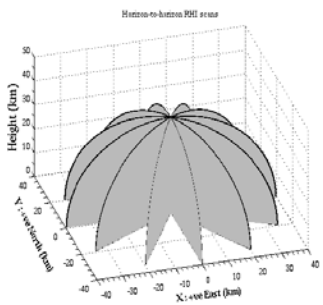


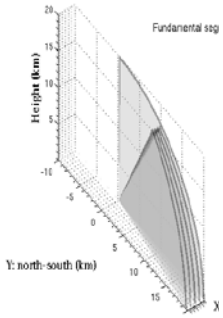


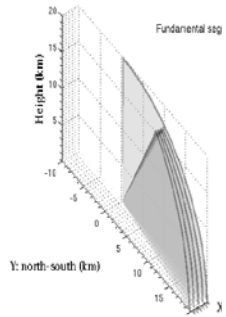
Scan Strategy for SACR: TWP Darwin

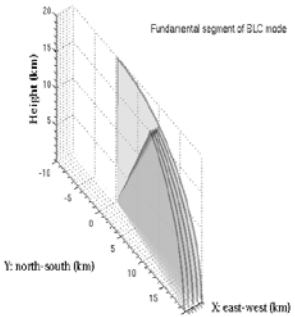
$$\mathcal{S}_{\mathrm{DWN}} \triangleq \{\mathcal{S}_h(t_h)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_h(t_h)\,\mathcal{S}_v(t_v)\}.$$

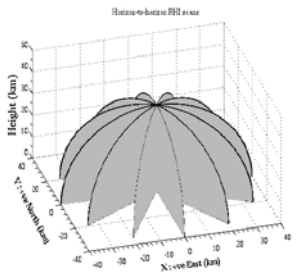
~2 min ~5 min ~5 min ~5 min ~2 min ~15 min

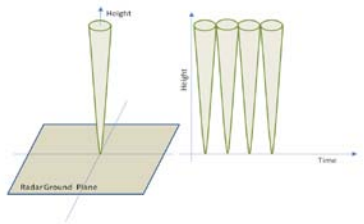


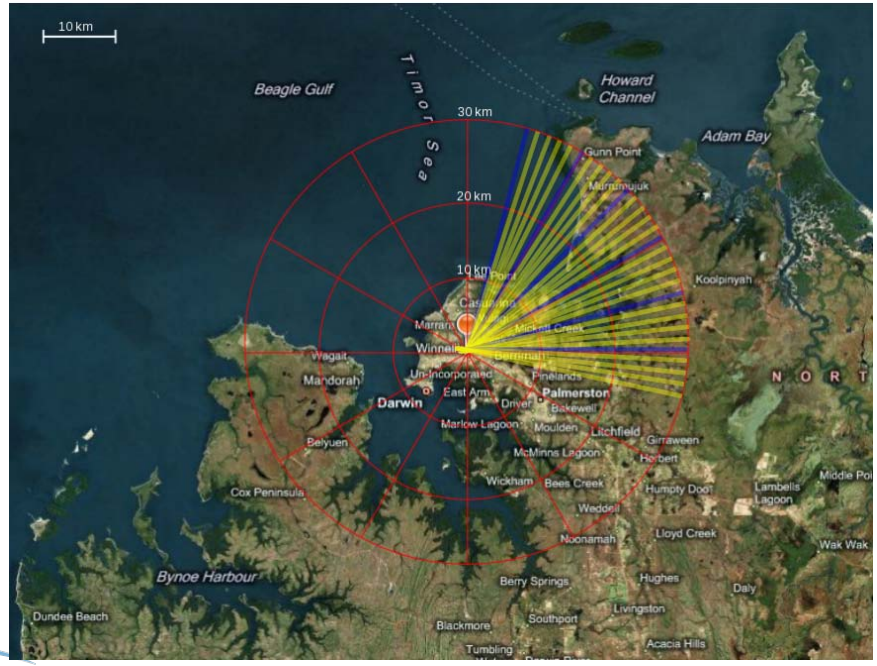








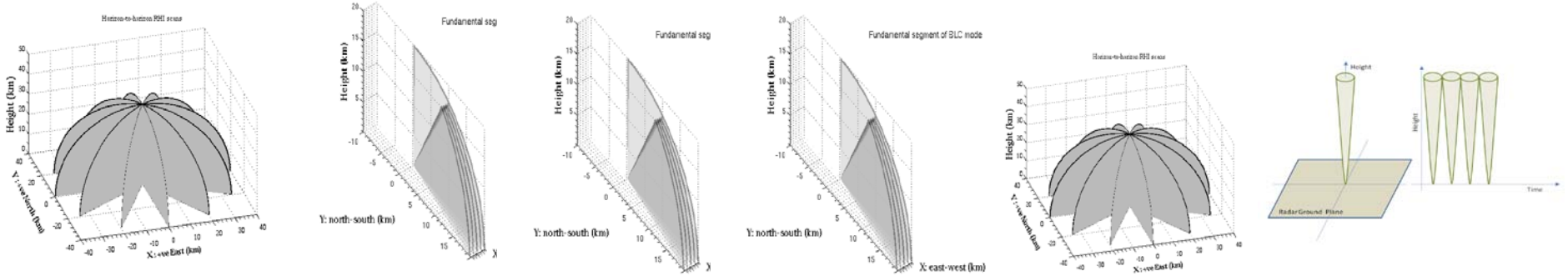


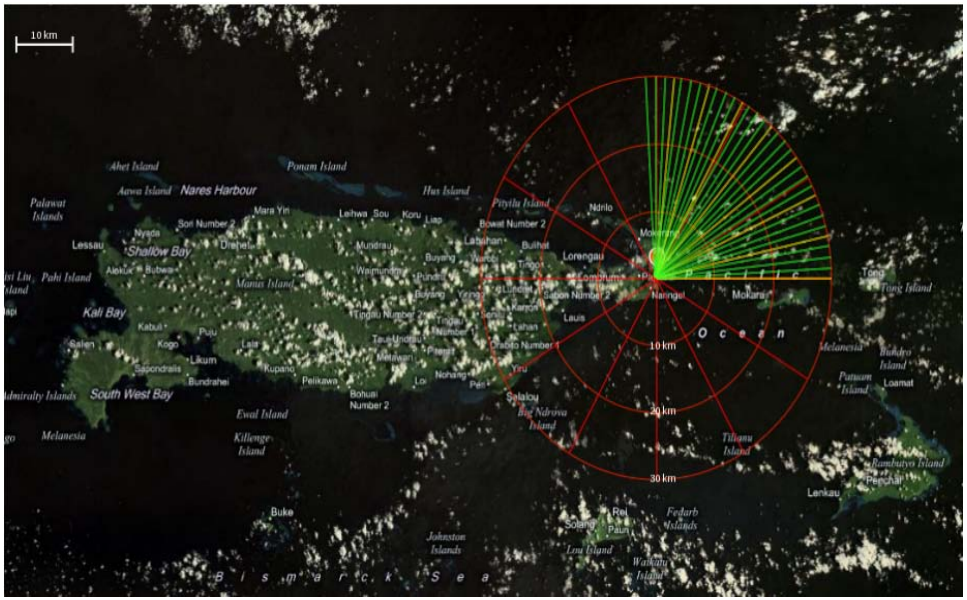


Scan Strategy for SACR: TWP Manus

$$\mathcal{S}_{\mathrm{MAN}} \triangleq \{\mathcal{S}_h(t_h)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_h(t_h)\,\mathcal{S}_v(t_v)\}.$$

~2 min ~5 min ~5 min ~5 min ~2 min ~15 min





Scan Strategy for SACR: NSA

$$\mathcal{S}_{\mathrm{NSA}} \triangleq \{\mathcal{S}_h(t_h)\,\mathcal{S}_b(t_b)\,\mathcal{S}_b(t_b)\,\mathcal{S}_h(t_h)\,\mathcal{S}_c(t_c)\,\mathcal{S}_v(t_v)\}.$$

~2 min ~5 min ~5 min ~2 min ~5 min ~15 min