

GRENE 北極気候変動研究事業 特別セミナー

北極海航路の持続的利用実現に向けて

船舶レーダを用いた氷海中の最適航路選択

# 船舶レーダを用いた氷海中の 最適航路選択

釧路工業高等専門学校

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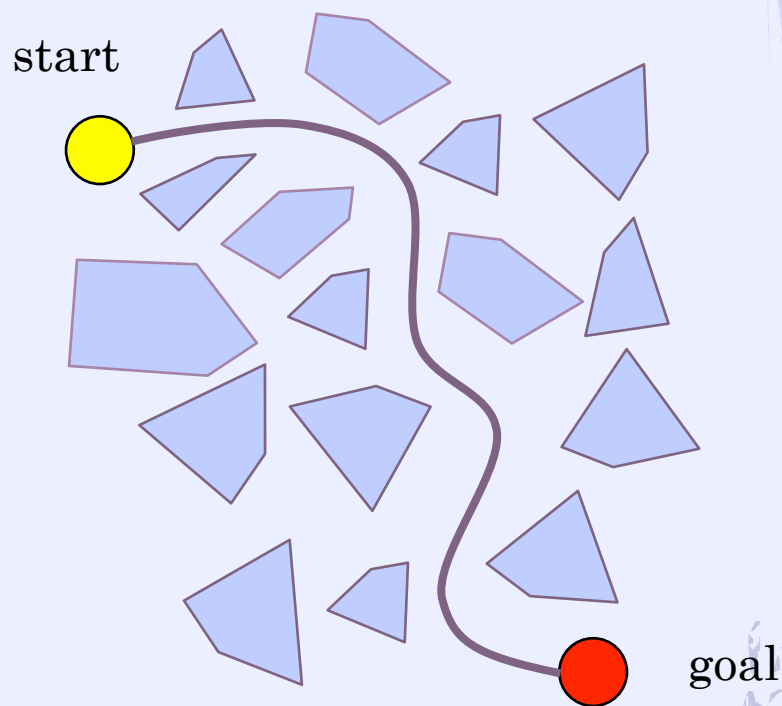
# 研究背景と障害物回避経路計画

## 海氷による船舶の損傷

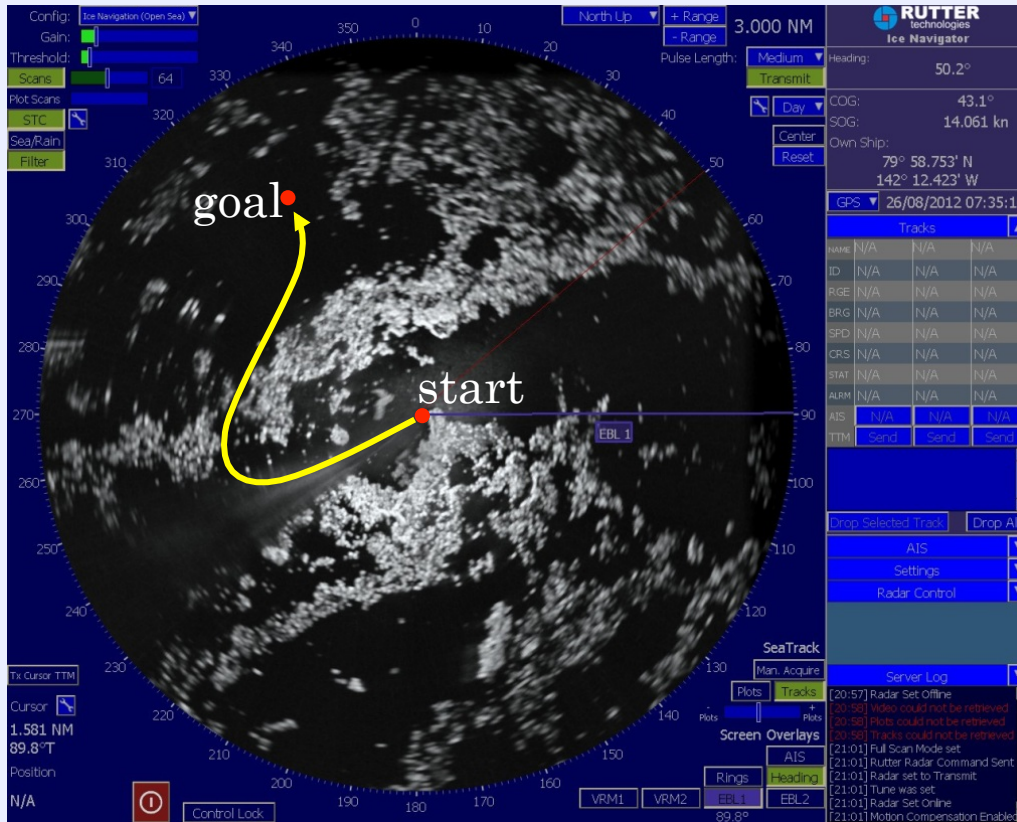


過去25年感に200件以上

## 障害物回避経路計画



# 船舶レーダ画像と航路



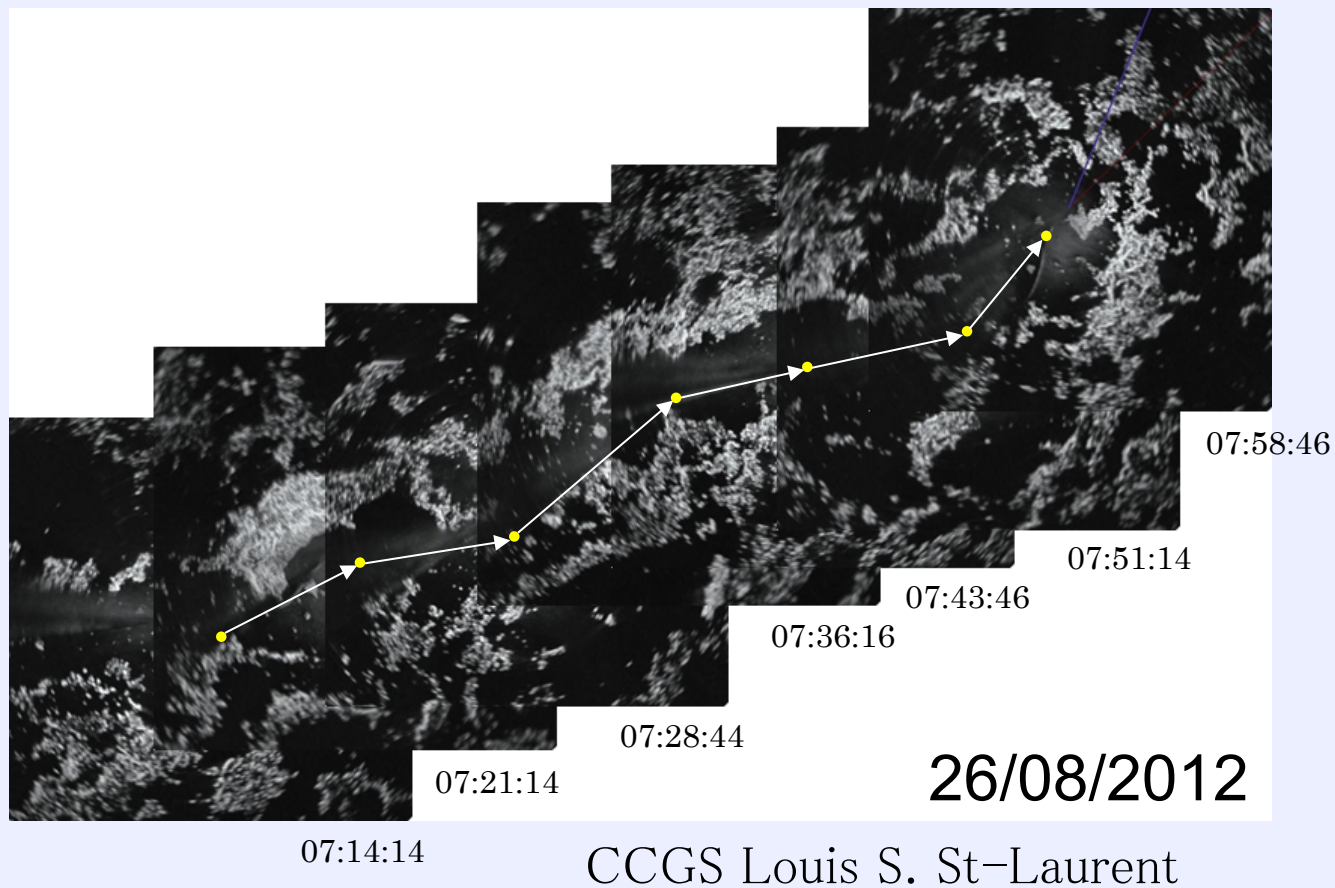
79°58.753'N  
142°12.423'W

26/08/2012

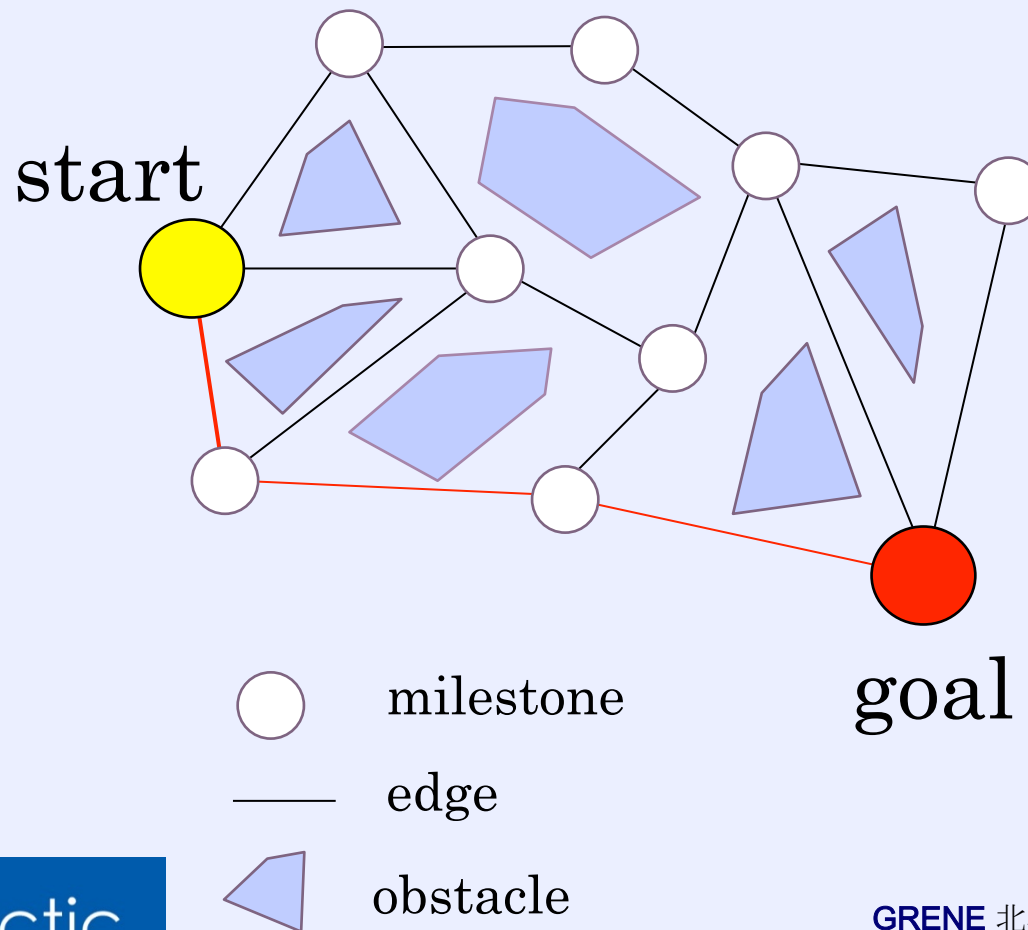
0 3.0

NM ( 5556 m)

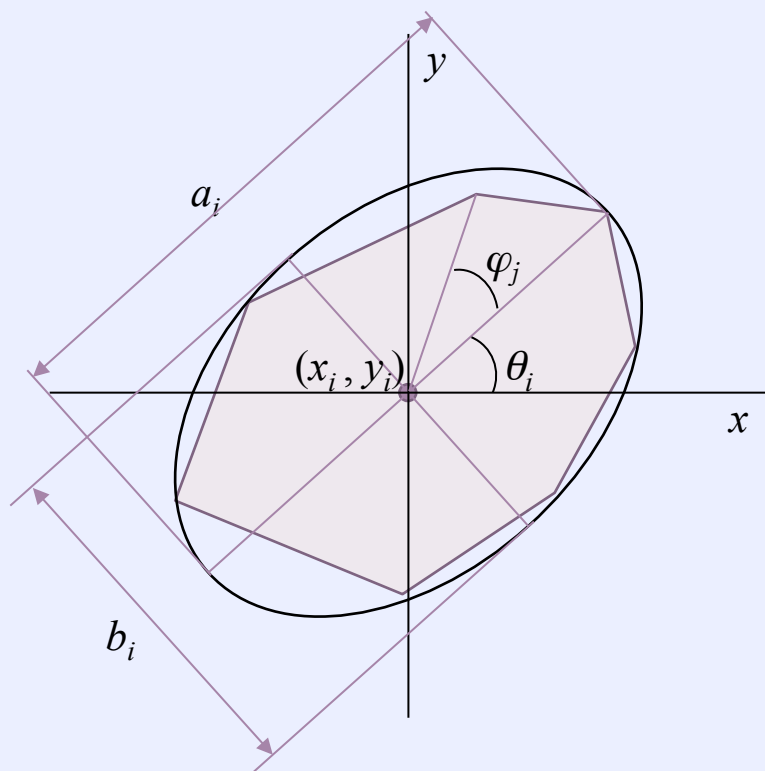
# 実際の氷海上の航路



# 障害物回避経路問題



# 海氷のパラメータ



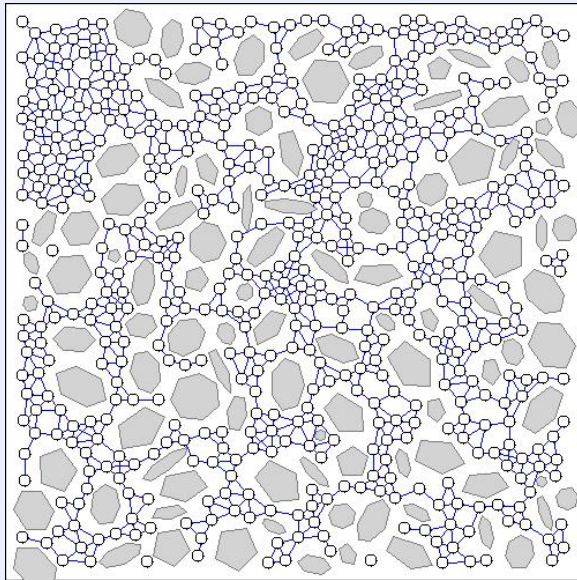
- 長軸:  $a^i$
- 短軸:  $b^i$
- 角数:  $n^i$
- 座標:  $x_i, y_i$
- 傾き:  $\theta_i$

$$\varphi_j = \varphi_{j-1} + 2\pi/n^i \quad (1+k\gamma)$$

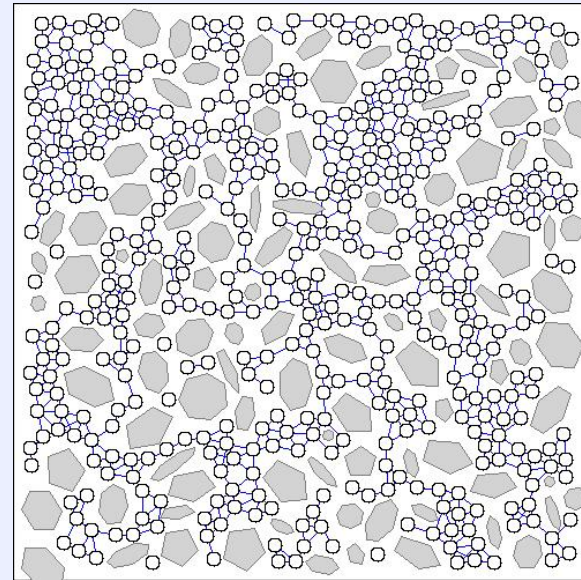
$$j=2, \dots, n^i \quad \varphi_0 = 0$$

# 衝突判定アルゴリズムによる ロードマップグラフの作成

a)  $r = 3$  [pixel]



b)  $r = 6$  [pixel]



# シミュレーション(3) —密接度6、密接度7—

## 密接度6



( $r=3$  [pixel] 1700 milestones)

including 2 tenth of big floes and 4 tenth of small floes

## 密接度7



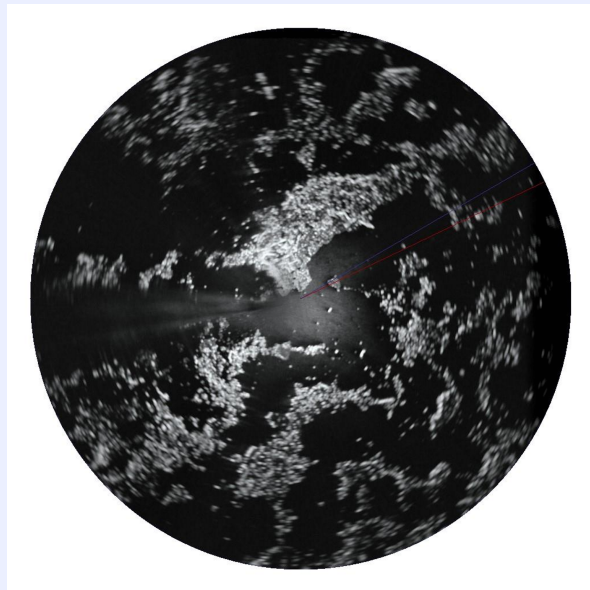
( $r=3$  [pixel] 1600 milestones)

including 2 tenth of big floes and 5 tenth of small floes

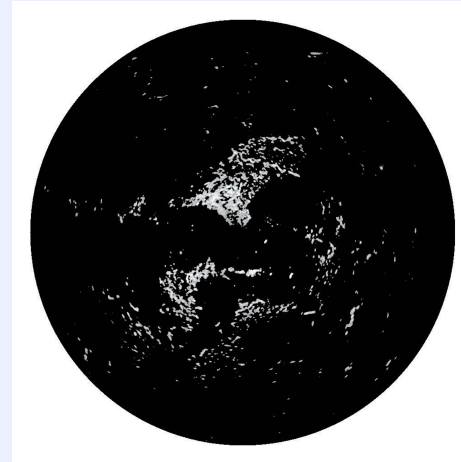


# 船舶レーダ画像の 開放水面と海氷の分離

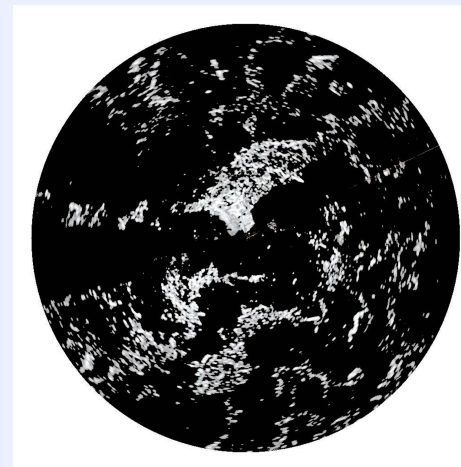
26/08/2012



0 3.0 ( 5556 m )  
NM



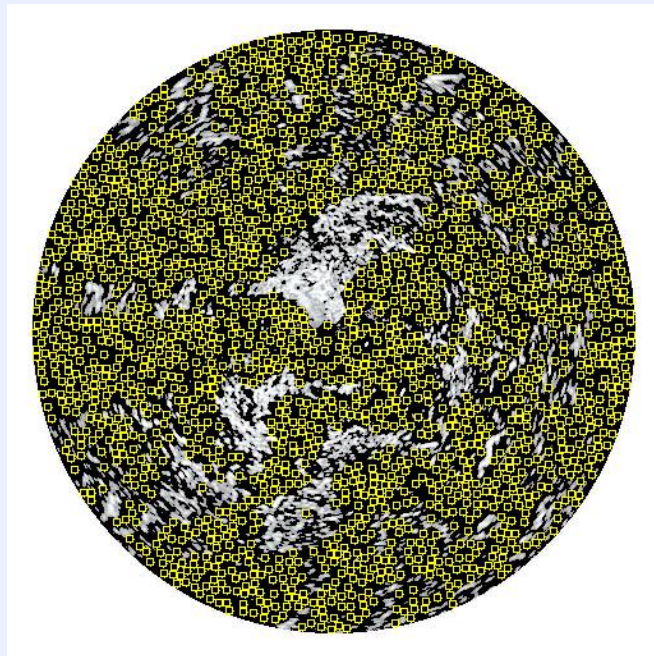
閾値処理 (150)



歪補正  
閾値処理

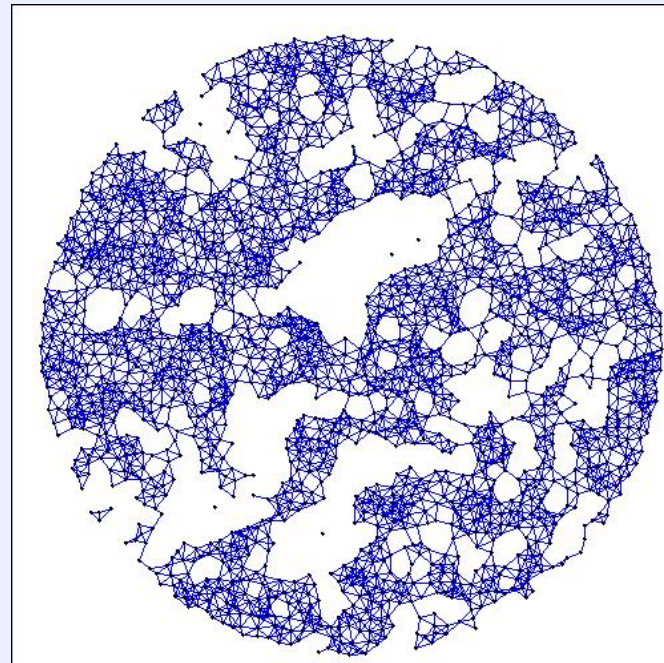
# 船舶レーダ画像上の マイルストーンとロードマップグラフ

マイルストーン



$$r = 36 \text{ [m]}, N = 1500, C = 122 \text{ [m]}$$

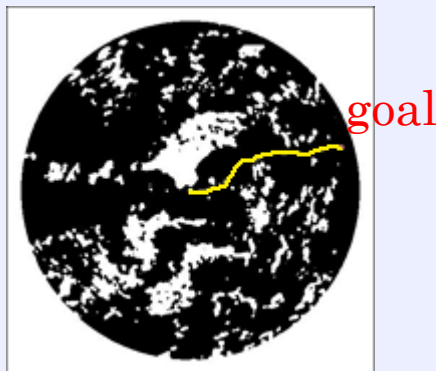
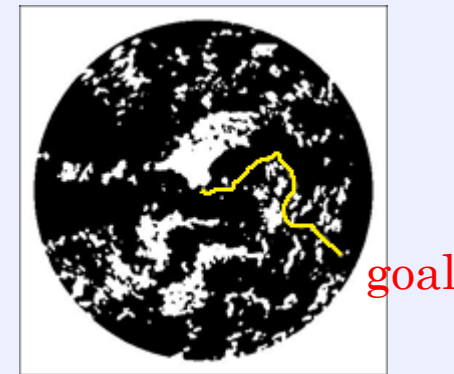
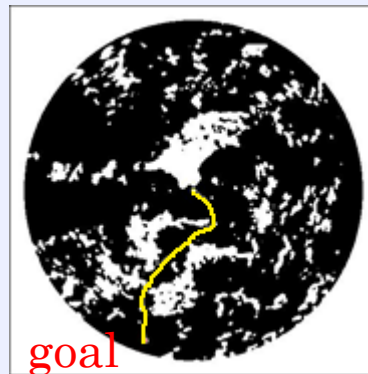
ロードマップグラフ



0 3.0

NM

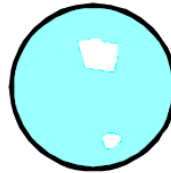
# 船舶レーダ画像を用いた航路



# 海水密接度

## Ice Concentration

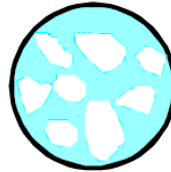
Ice coverage in an area is determined by its total concentration, expressed in “tenths”. AIRSS uses the partial concentration of each ice type in determining the Ice Numeral.



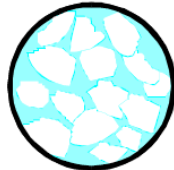
less than 1 tenth  
*open water*



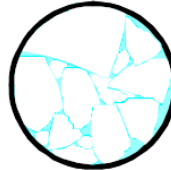
1 - 3 tenths  
*very open drift*



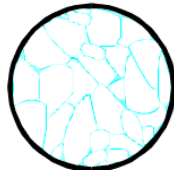
4 - 6 tenths  
*open drift*



7 - 8 tenths  
*close pack/drift*



9 tenths  
*very close pack*



9+ tenths  
*very close pack*



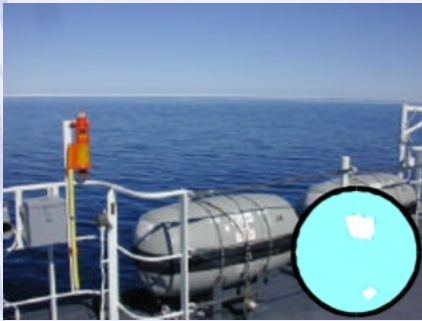
10 tenths  
*compact/consolidated ice*

Ice coverage in an area is determined by its total concentration, expressed in “tenths”. AIRSS uses the partial concentration of each ice type in determining the Ice Numeral.

# 海水密接度

Arctic Ice Regime Shipping System, CANADIAN TRANSPORT

less than 1 tenth  
*open water*



1 – 3 tenths  
*very open water*



4 – 6 tenths  
*open drift*



7 – 8 tenths  
*close pack / drift*



9 tenths  
*very close pack*



9+ tenths  
*very close pack*




10 tenths  
*compact / consolidated ice*



# Vessel Classification

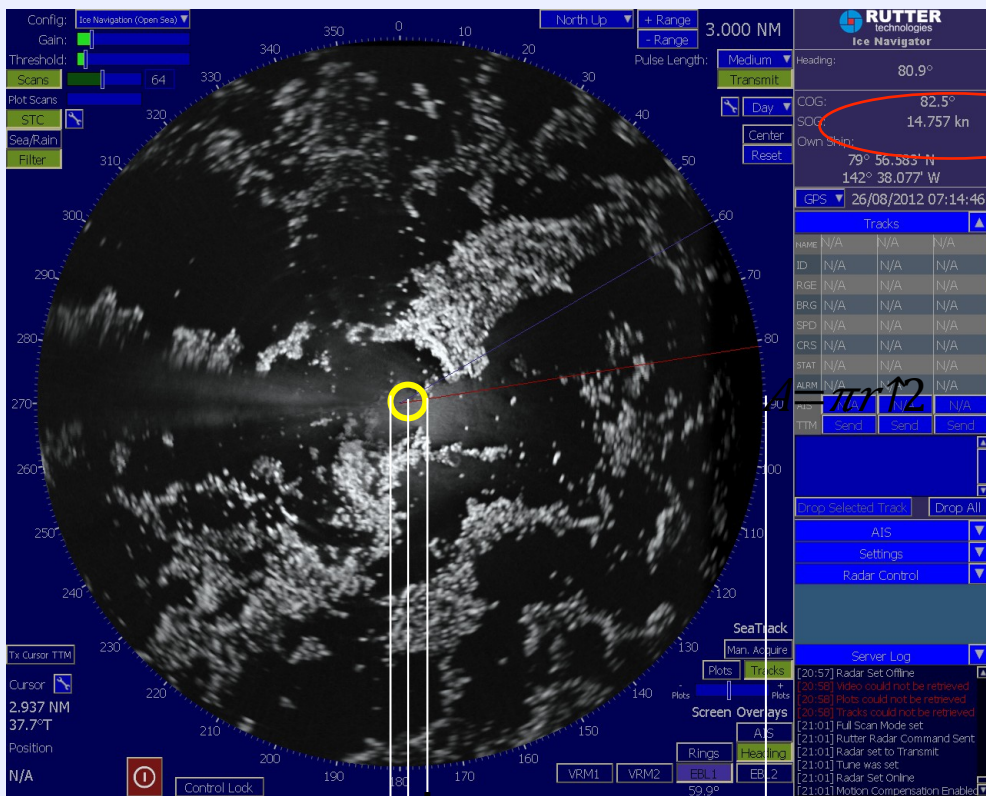
CAC-"Canadian Arctic Class" vessels

Vessel Class	Maximum Allowable Ice Type	Ice Thickness (cm)
CAC1	No Limit	no limit
CAC2	Multi-year	no limit
CAC3	Second-year	no limit
CAC4	Thick First-year	>120
Type A	Medium First-year	70-120
Type B	Thin First-year(state2)	50-70
Type C	Thin First-year(state1)	30-50
Type D	Grey-white	15-30
Type E	Open Water/Gray	10-15



Increasing Ice capability

# 海水密接度と船舶速度の関係

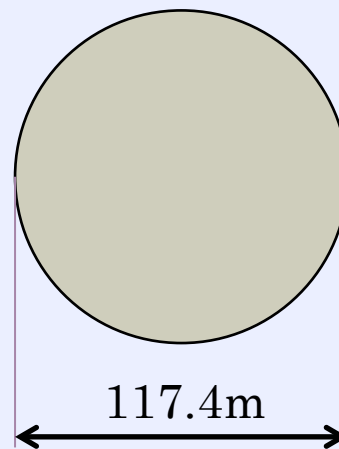


船舶速度

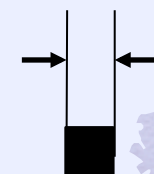
密接度

$$C(x,y) = 1/S \sum_{x,y \in S} I(x,y)$$

117.4m  
3.0 NM  
5556.0 m  
473 pixel

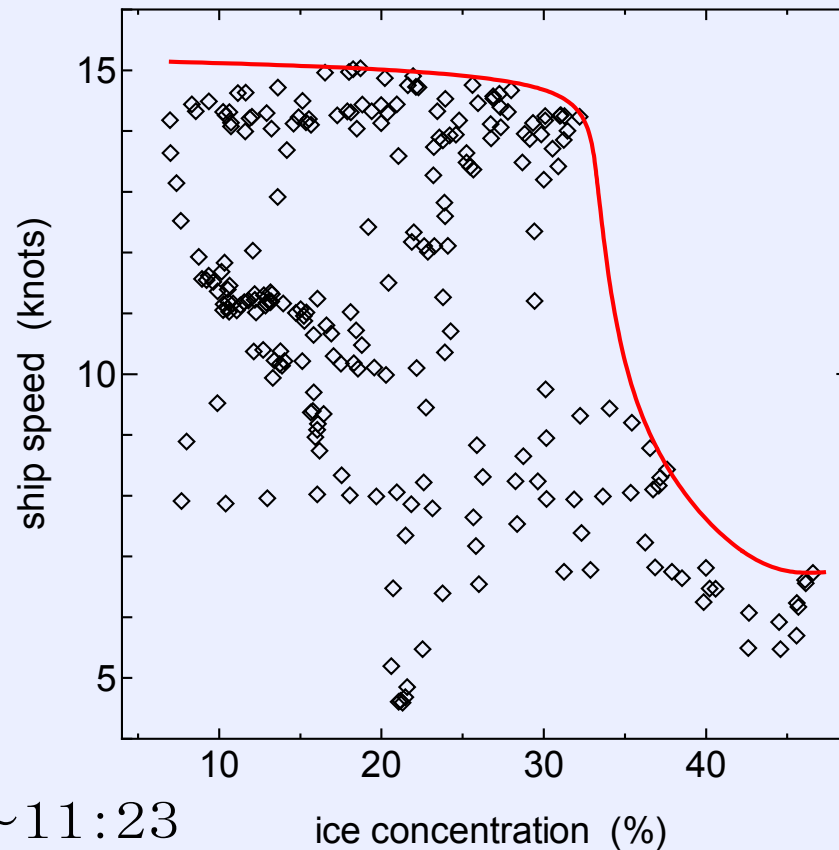


11.74m



1 pixel

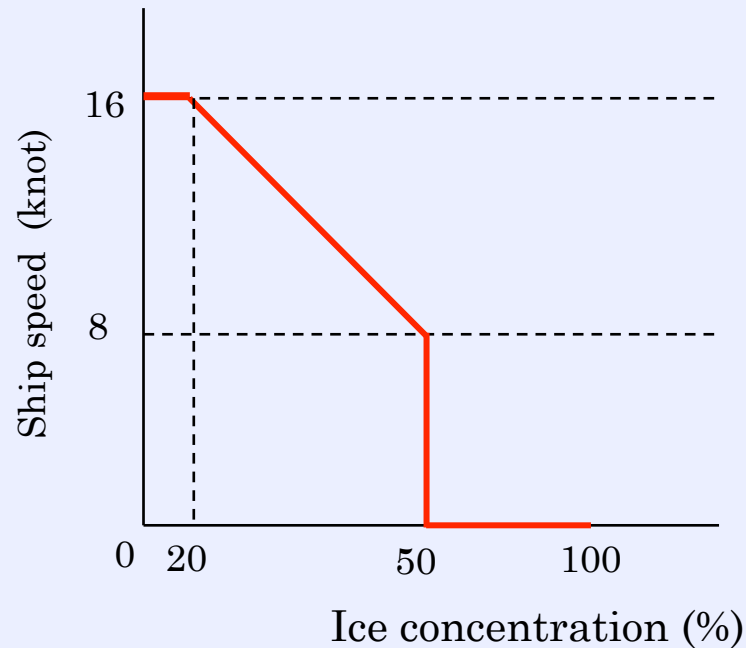
# 海水密接度と船舶速度の関係



26/08/2012 7:14~11:23



# マイルストーンの接続評価関数

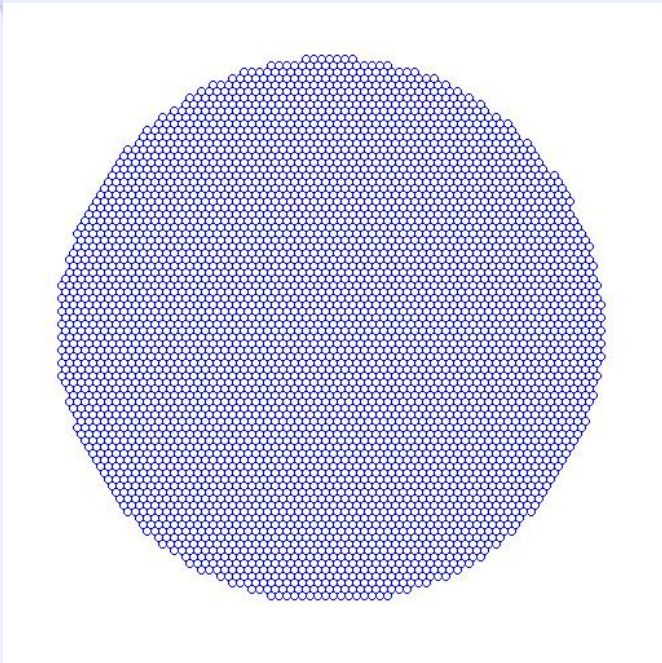


マイルストーン間の接続評価関数

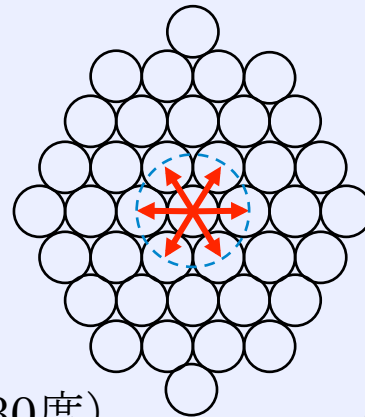
$$s(i,j)=d(i,j)/f(i,j)$$

# マイルストーンの配置と接続

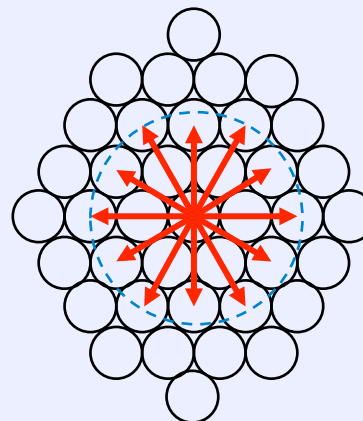
レーダ画像のマイルストーンの配置



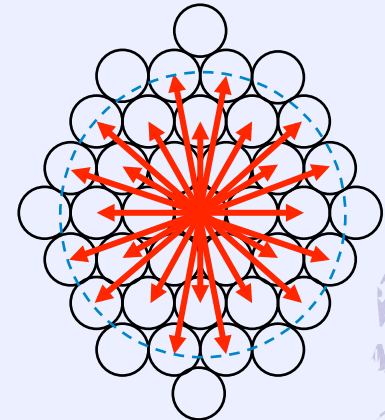
a) 6方向(60度)



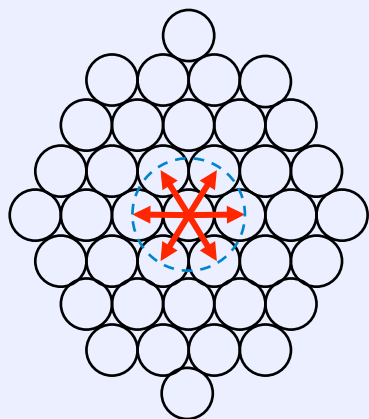
b) 12方向(30度)



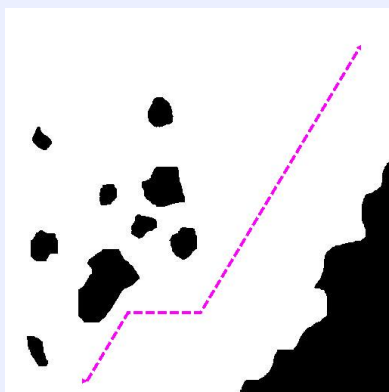
c) 24方向(15度)



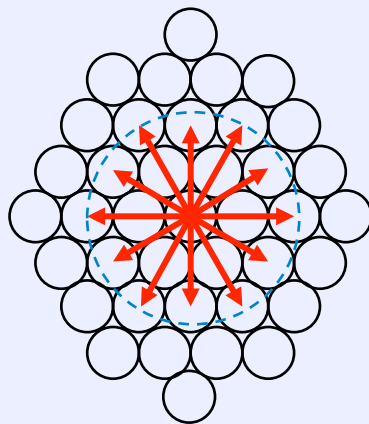
# マイルストーン間の接続距離と航路の関係



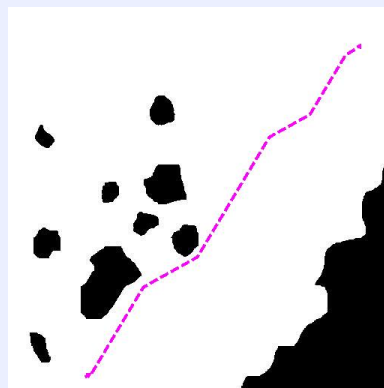
a) 6 directions



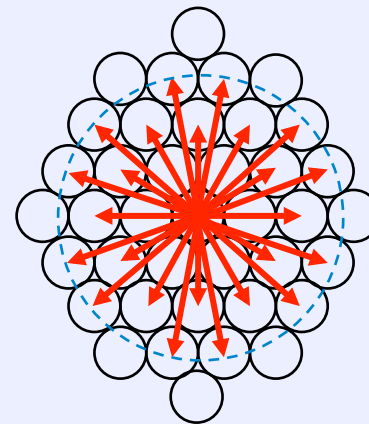
a) 7 pixels



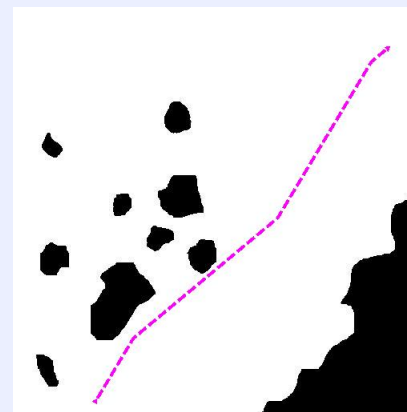
b) 12 directions



b) 15 pixels

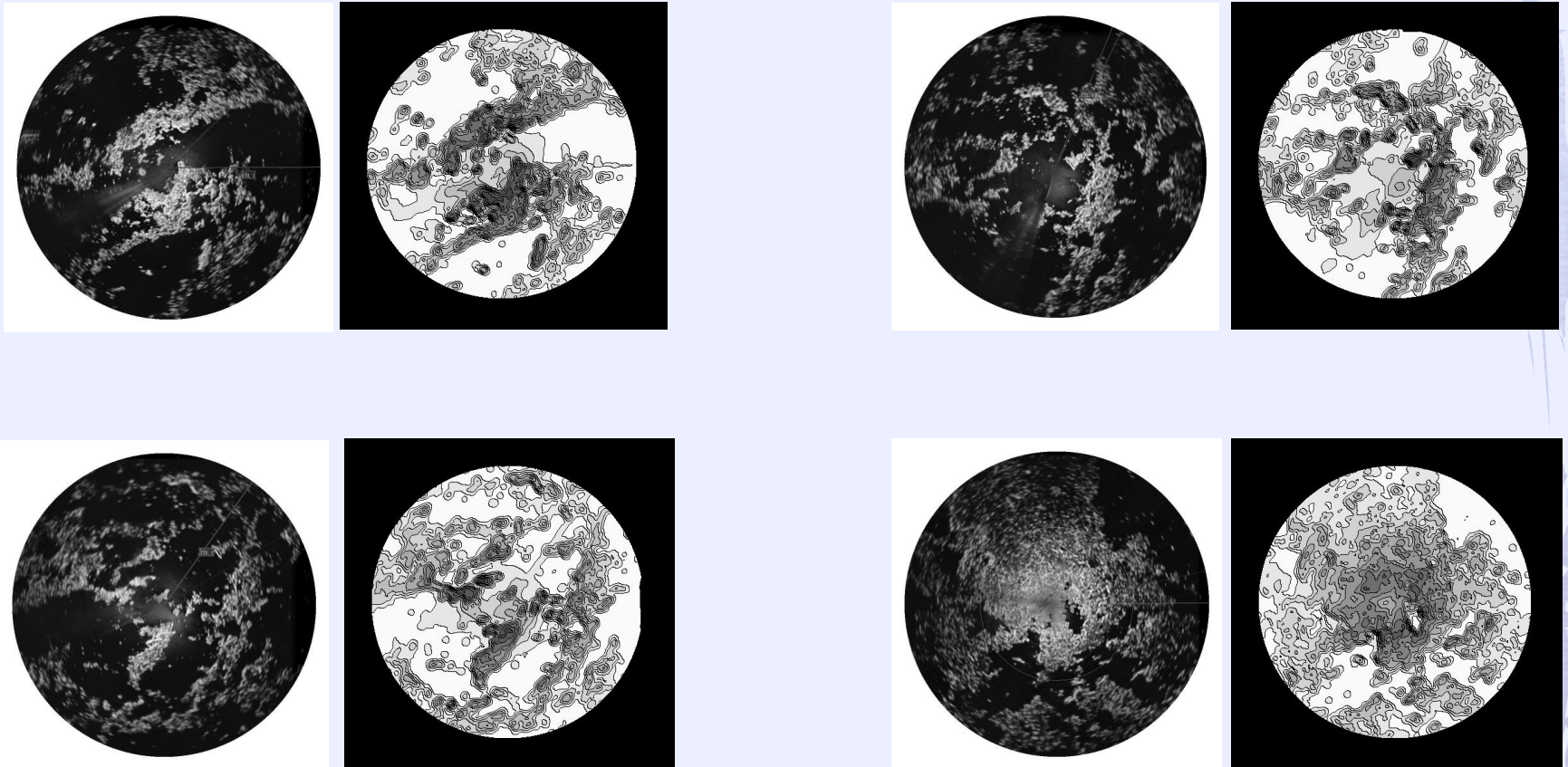


c) 24 directions



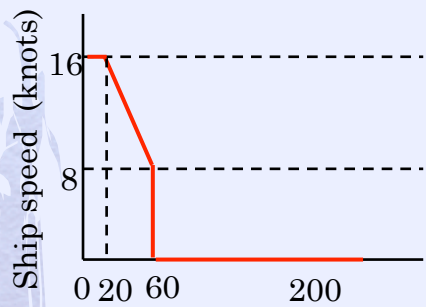
c) 20 pixels

# 海水密接度の等高線図

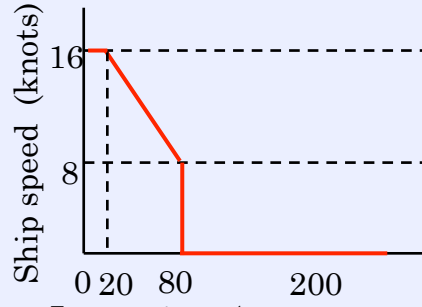


$$C(x,y)=1/S \sum_{x,y \in S} I(x,y)$$

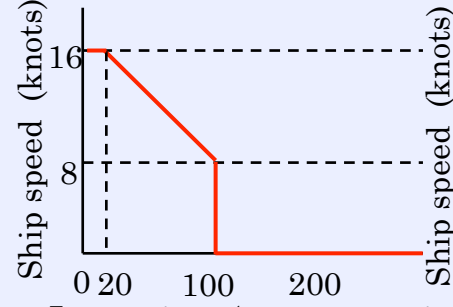
# シミュレーション結果(1)



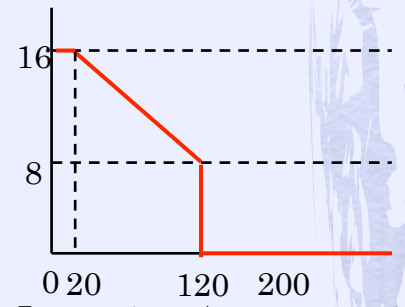
Intensity (concentration)  
(23%)



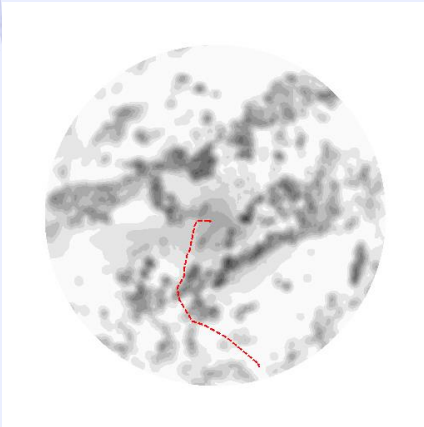
Intensity (concentration)  
(31%)



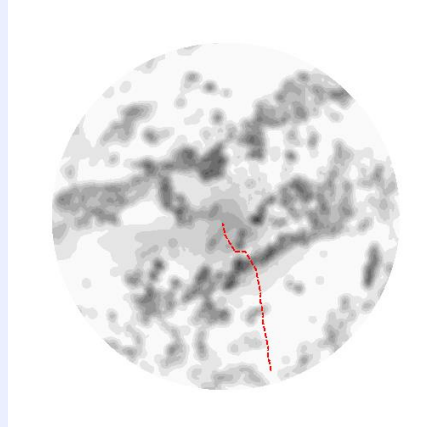
Intensity (concentration)  
(39%)



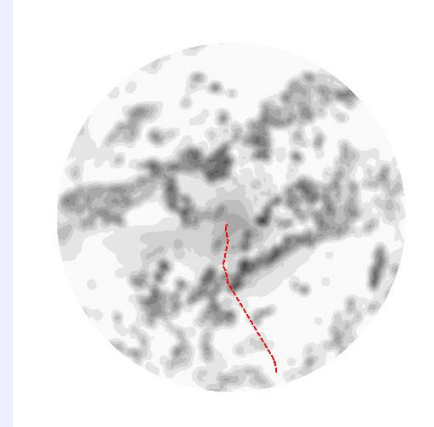
Intensity (concentration)  
(47%)



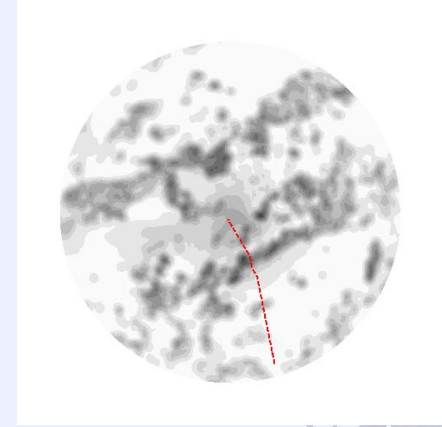
5613m



3870m

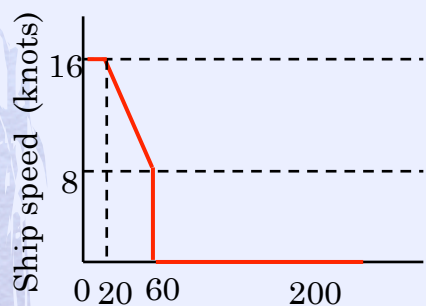


3612m



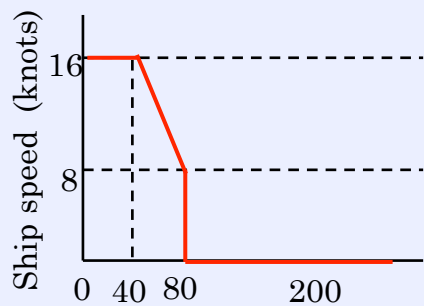
3200m

# シミュレーション結果(2)



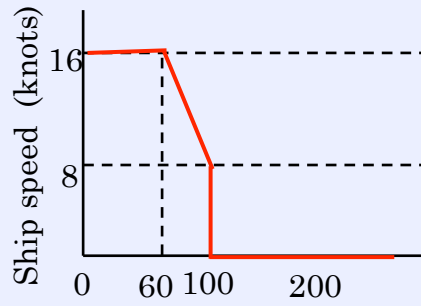
Intensity (concentration)

(8-23%)



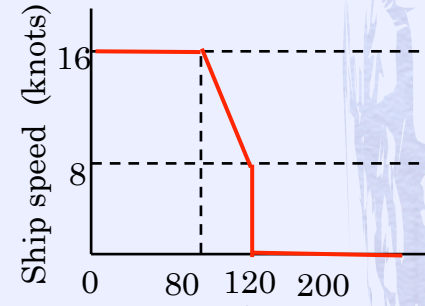
Intensity (concentration)

(15-31%)



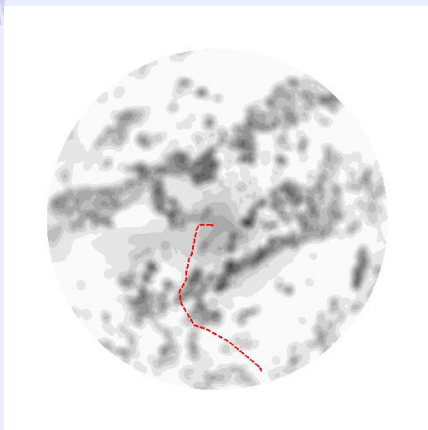
Intensity (concentration)

(23-39%)

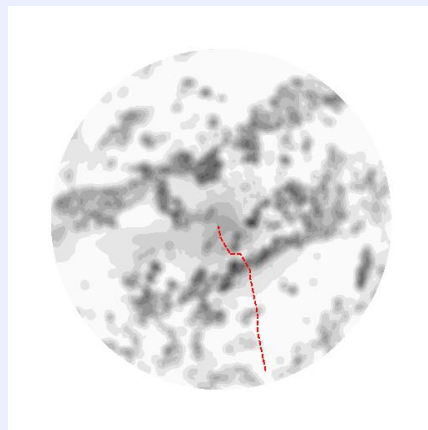


Intensity (concentration)

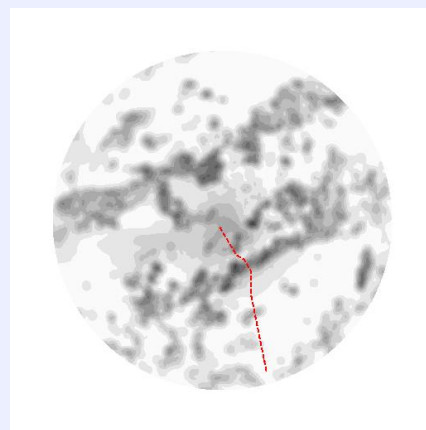
(31-47%)



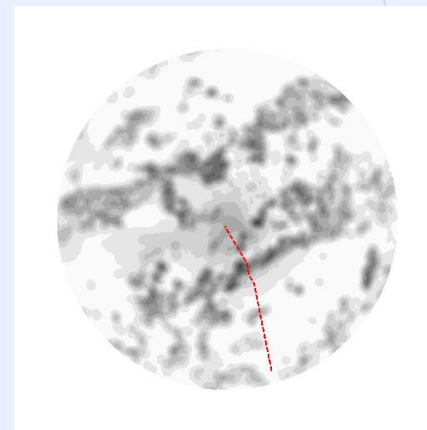
5613m



3870m

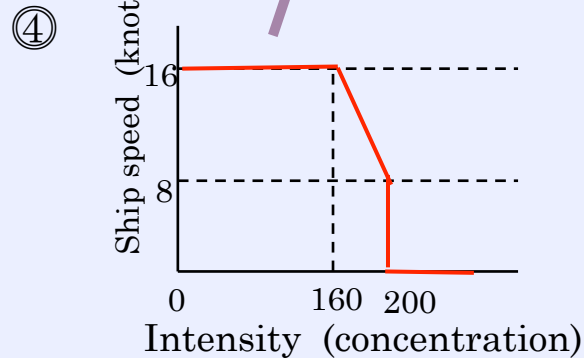
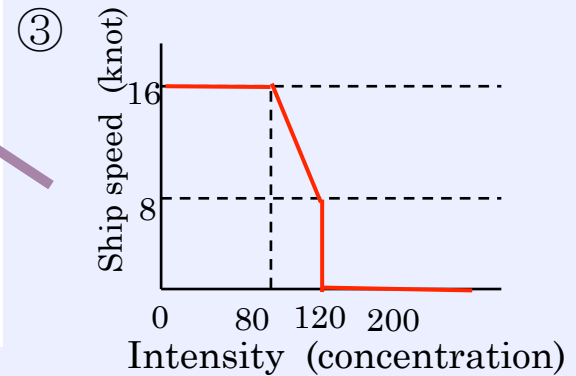
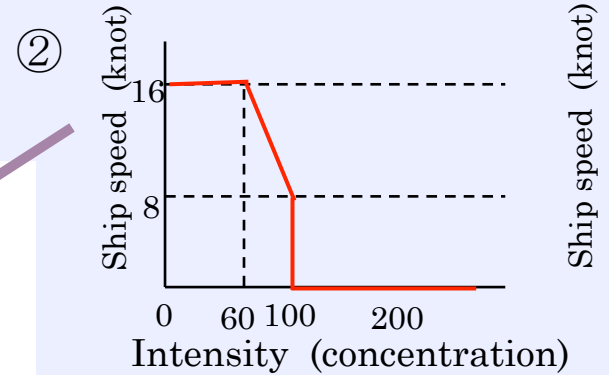
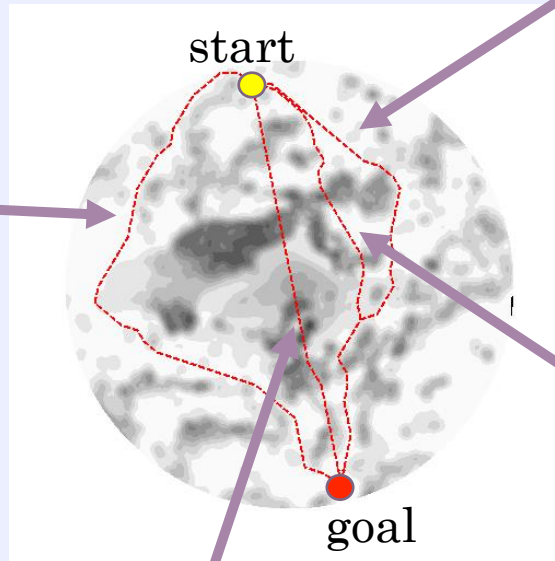
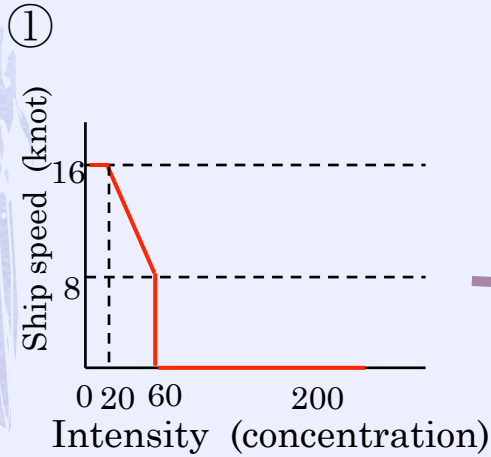


3713m

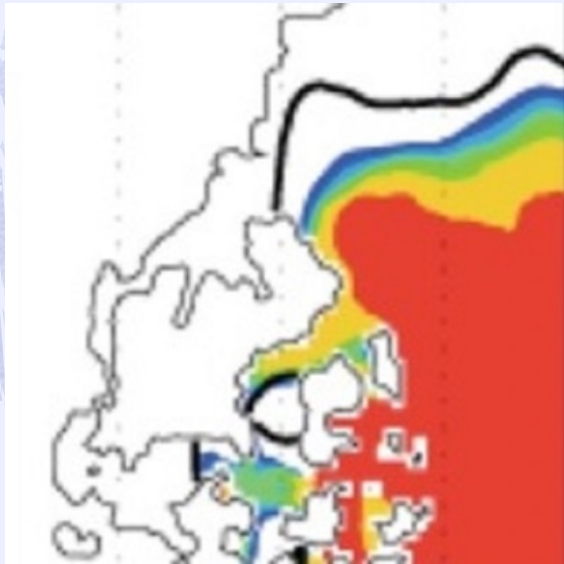


3200m

# シミュレーション結果(3)



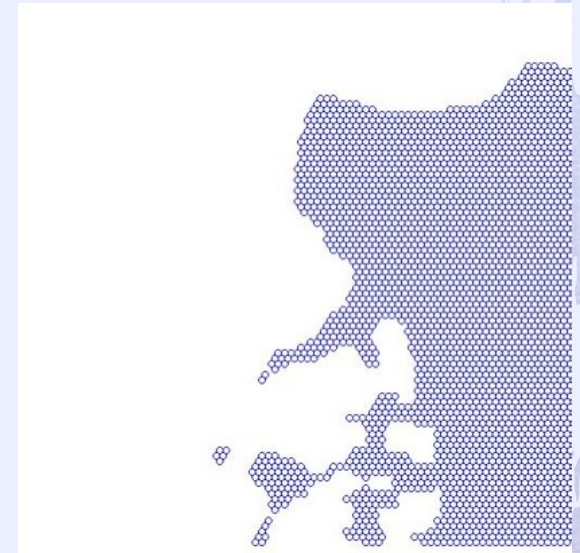
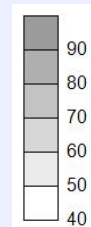
# 海氷分布予測における航路選択 (1)



① prediction image



② navigation area



③ arrangement of the milestones



# 海氷分布予測における航路選択 (2)

