ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

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Anisotropic radiative transfer in sea ice

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Why Light?

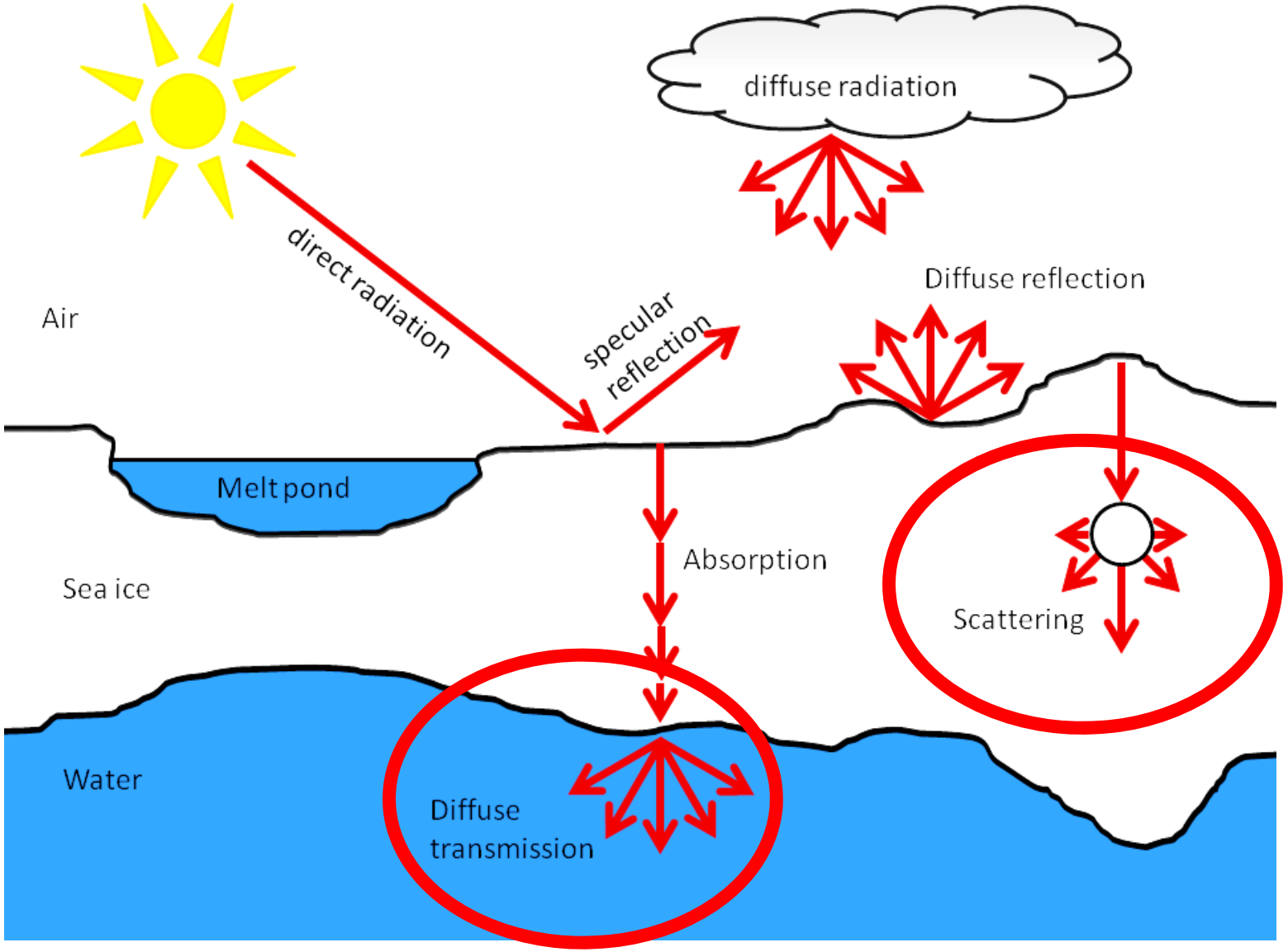
- Energy fluxes:
  - Sea ice → mass balance
  - Ocean → warming
- Light availability:
  - →biota
  - →geochemical processes

Climate Research

- Radiative transfer in sea ice

Basic Research

Radiative transfer in sea ice

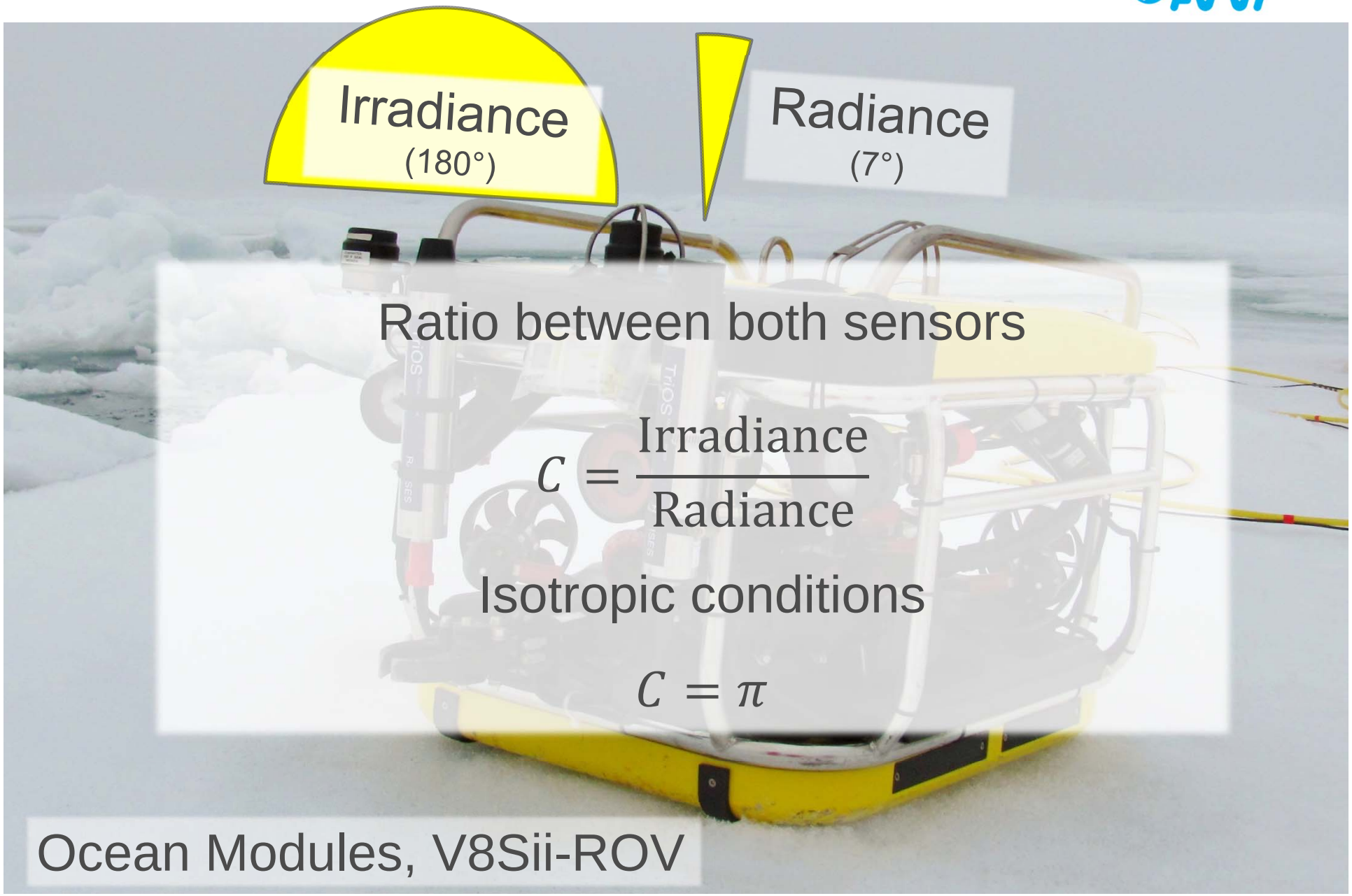


Field work

Cruises with *RV Polarstern in 2011 & 2012*

More than 10 000 data points on 17 ice stations

ROV



Ratio between both sensors

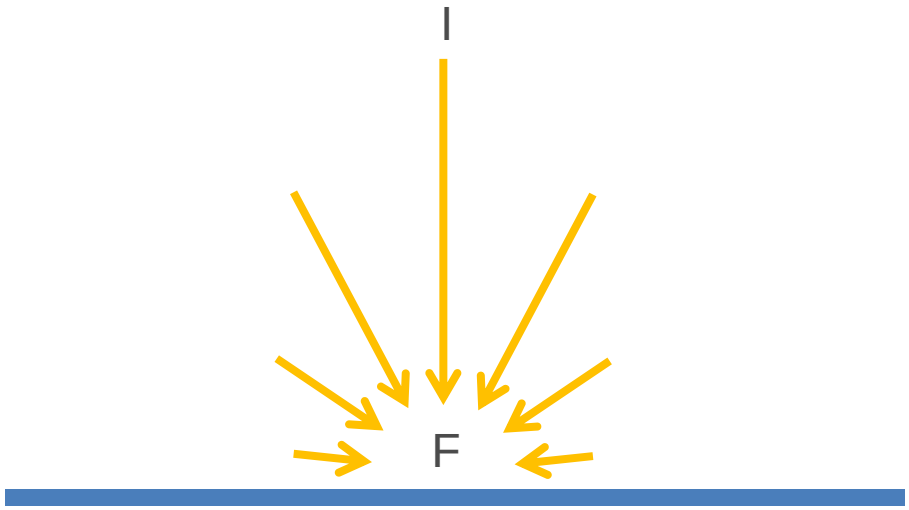
$$C = \frac{\text{Irradiance}}{\text{Radiance}}$$

Isotropic conditions

$$C = \pi$$

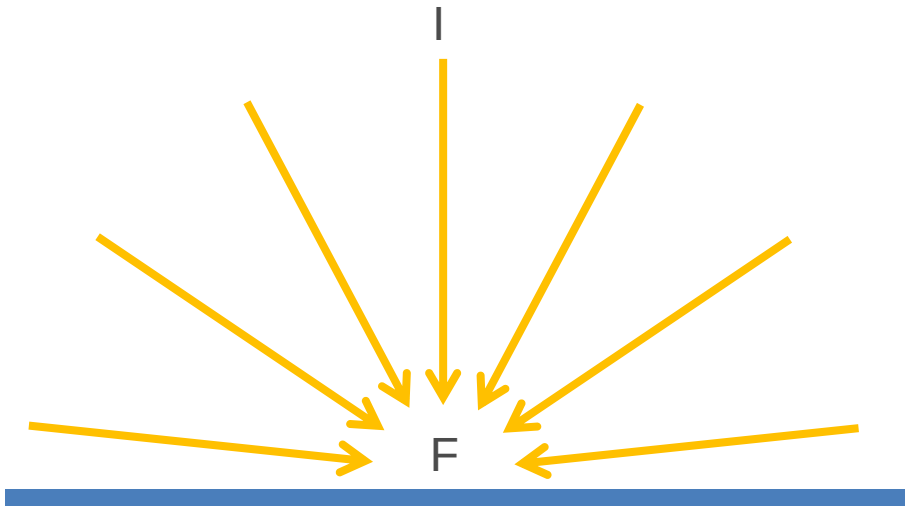
Ocean Modules, V8Sii-ROV

Definition of Irradiance



$$F = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\frac{\pi}{2}} I(\theta,\phi) \cos\theta \ \sin\theta \ \mathrm{d}\phi \ \mathrm{d}\theta$$

$$\boldsymbol{F = C \cdot I}$$



$$F = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\frac{\pi}{2}} I \cdot \cos\theta \ \sin\theta \ \mathrm{d}\phi \ \mathrm{d}\theta$$

$$\boldsymbol{F = \pi \cdot I}$$

Meaning of C-ratio

C-ratio is necessary to convert radiance into irradiance values:

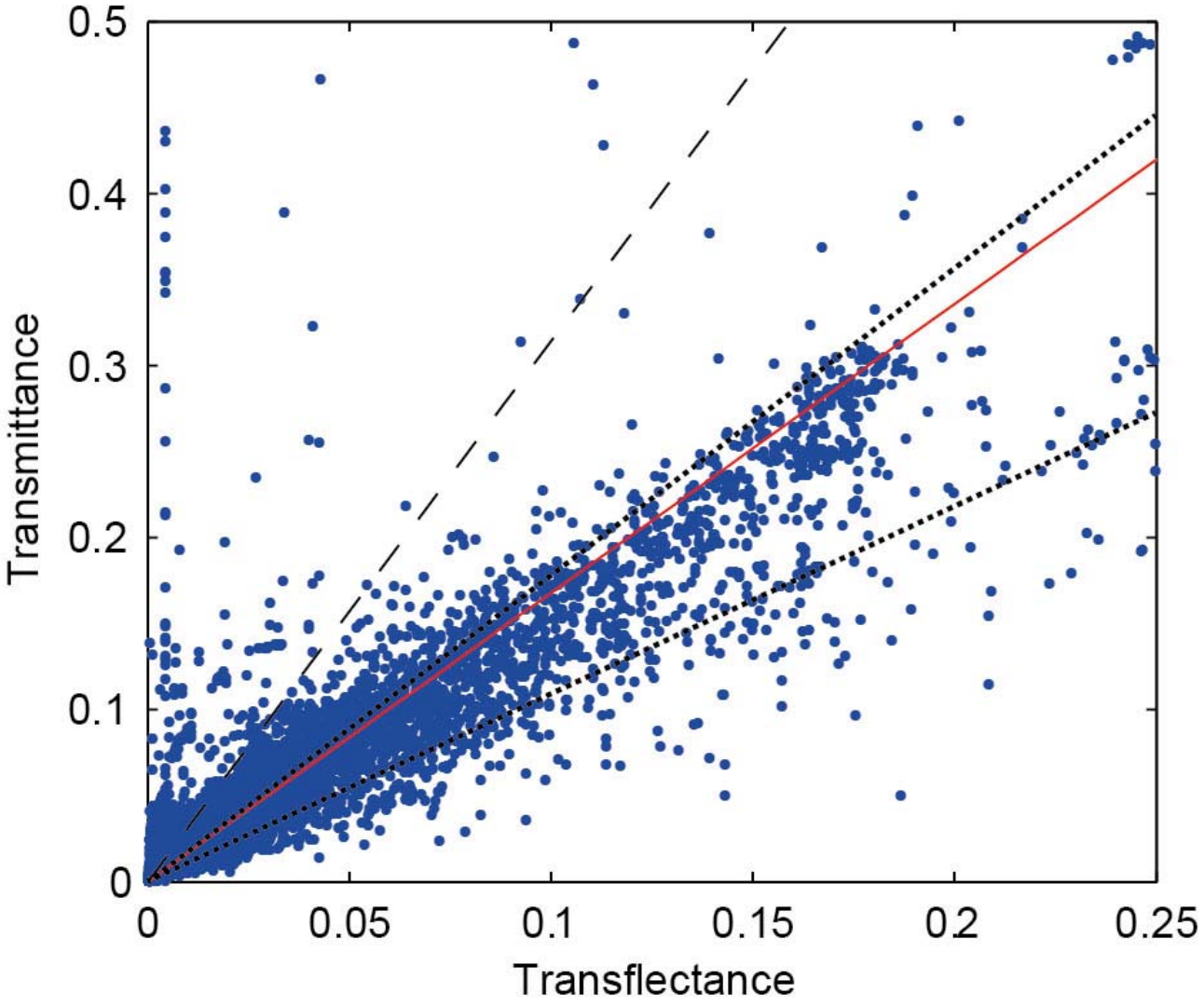
- measurement with radiance sensors (AUV, old data)
- 2D or 3D modeling of light-regime

C-ratio illustrates the error made by the isotropic assumption:

$$C = 2 \quad \rightarrow \quad C = 3.14$$

→ overestimation of irradiance by **50%!!**

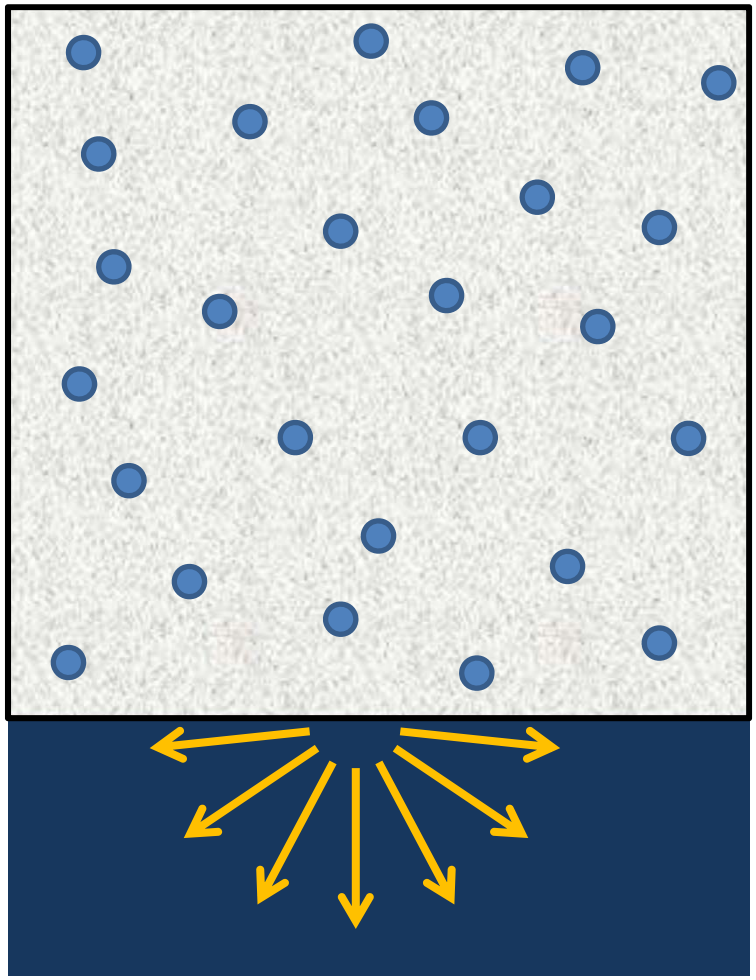
Measurements 2012



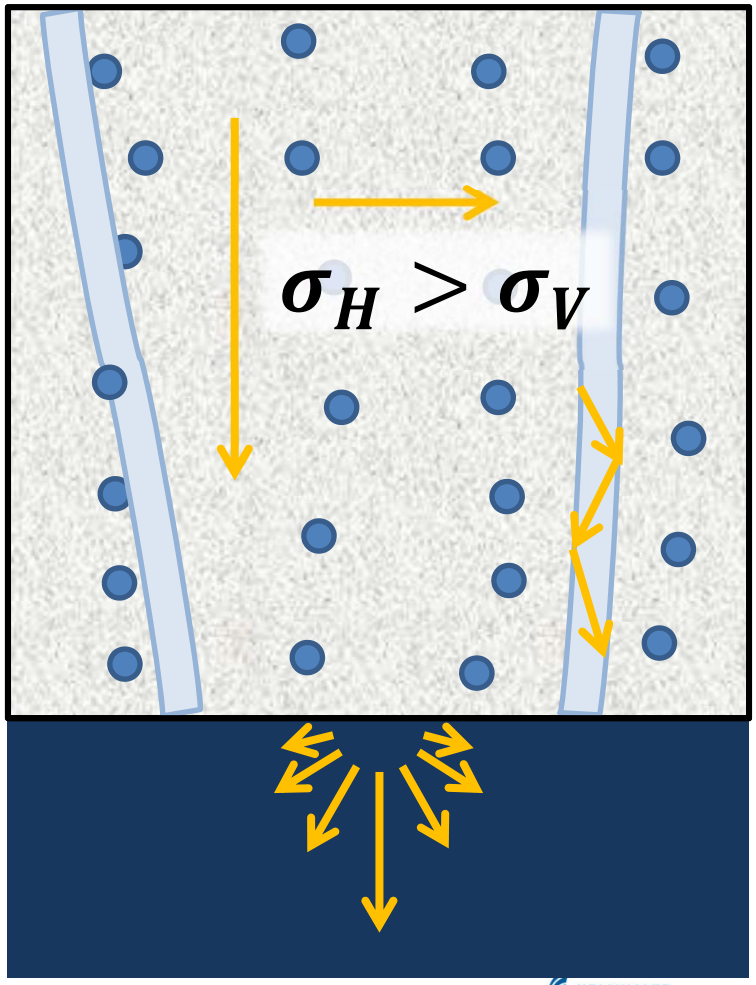
Katlein et al. (JGR, 2014)

Anisotropic scattering in the ice

Theory of radiative transfer
random and homogenous distribution of scatterers



Sea ice
lamellar crystal structure and elongated brine channels



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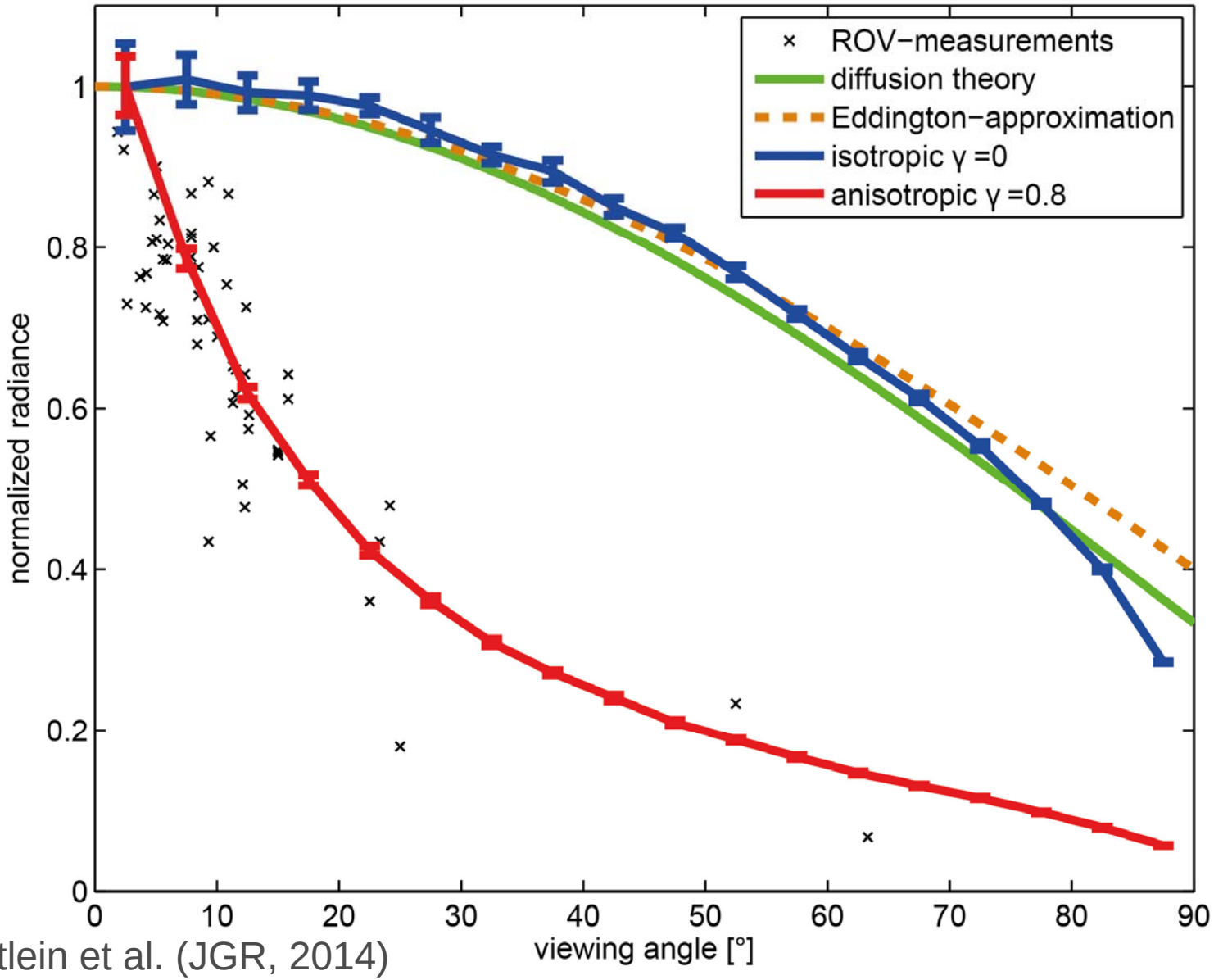
Investigating the radiance distribution

- Direct measurements by rolling the ROV
- Monte-Carlo ray-tracing model using anisotropic scattering coefficient
- Laboratory experiments

The radiance distribution



Katlein et al. (JGR, 2014)

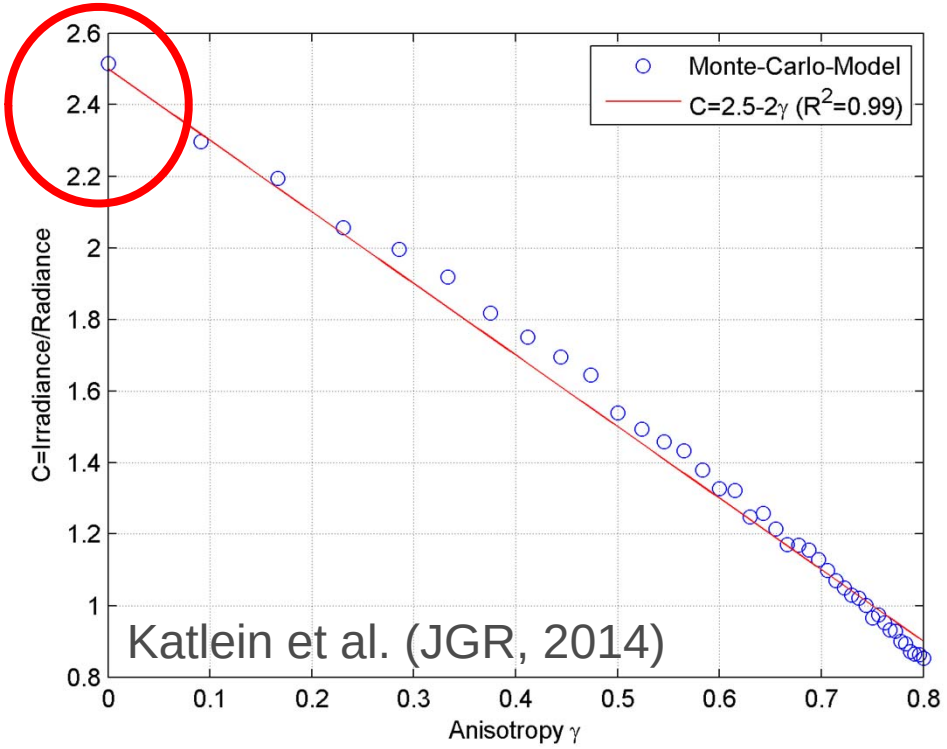
Parameterization: $C(\gamma)$

Fitted parameterization:

$$C(\gamma) = 2.5 - 2\gamma$$

Error less than 5%

$C_{\gamma=0} = 2.5 \neq \pi$
boundary effect



→correct conversion of radiance data into irradiance values possible, when anisotropy is known

Summary

- The **light field** in and under sea ice is **anisotropic**
- this anisotropy results from the sea ice **microstructure** (optical properties) and the boundary effect
- assuming isotropic conditions introduces **large errors** in analyses of measurements or modeling approaches

Thank you!

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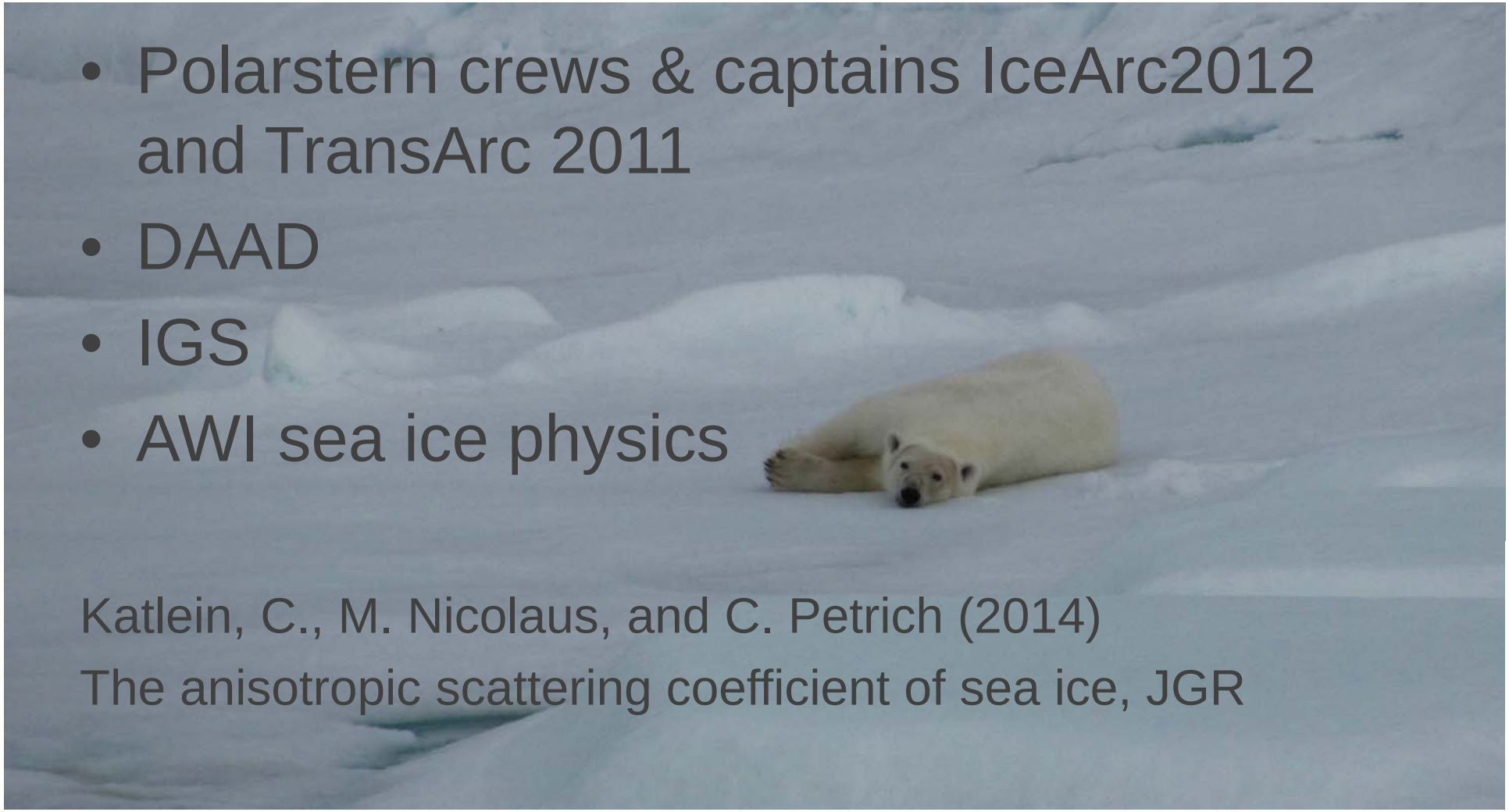

- Polarstern crews & captains IceArc2012 and TransArc 2011
- DAAD
- IGS
- AWI sea ice physics

Katlein, C., M. Nicolaus, and C. Petrich (2014)
The anisotropic scattering coefficient of sea ice, JGR

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