The Photochemical Reflectance Index (PRI) – a measure of photosynthetic light-use efficiency

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PRI Defined

PRI was originally defined as an index of the xanthophyll cycle activity on a diurnal time scale.

Because xanthophyll cycle pigments adjust the energy distribution at the photosynthetic reaction center, they provide a measure of photosynthetic light-use efficiency (LUE) and indicator of stress.

Gamon et al. 1992
The Photochemical Reflectance Index (PRI) measures xanthophyll cycle activity.

PRI Defined

\[ PRI = \frac{(R_{531} - R_{\text{ref}})}{(R_{531} + R_{\text{ref}})} \]

Where reference = 550 nm, 570 nm, etc.

Gamon et al. 1992

Gamon & Qiu 1999
PRI as a measure of LUE

Because xanthophyll cycle pigments adjust the energy distribution at the photosynthetic reaction center, they provide a measure of photosynthetic light-use efficiency (LUE).

*Midday LUE is reduced for stressed vegetation (downregulation & reduced evapotranspiration)
PRI Defined

At larger time spans and at progressively larger spatial scales PRI is strongly influenced by other factors (e.g. leaf color, determined by bulk pigment pools, stand structure)

These effects can either confound or amplify the xanthophyll signal

Fuentes et al. 2001
Justification for PRI-type product

Photosynthetic rate = \( f(APAR) \times \varepsilon \)

Where:

\( APAR \) = Absorbed photosynthetically active radiation

\( \varepsilon \) = Efficiency with which absorbed radiation is converted to fixed carbon

\textit{Determination of }\varepsilon\textit{ remains a primary challenge} 
(Field et al. 1998, Running et al. 2009)
An operational PRI product could improve ecosystem carbon flux estimates, capturing physiological change under disturbance, stress, and changing vegetation composition.
Mapping disturbance impacts on carbon and water vapor fluxes

\[
\text{CO}_2 \text{ flux} = 2.461 - 26.701s\text{PRI} / s\text{PAR}
\]

\[R^2 = 0.96\]

\[p = 0.014\]

\[
\text{Water vapor flux} = -9.097 + 10.628 W\text{B}_1 g_{70}
\]

\[R^2 = 0.94\]

\[p = 0.019\]

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Fuentes et al. 2006
PRI-LUE relationships strongest in backscatter direction (hot spot)

Drolet et al. 2005
PRI-LUE relationship strongest in backscatter direction (hotspot) where sun exposure is highest

Hall et al. 2008
Hilker et al. 2008
Middleton et al. 2009
Why HyspIRI?

• High Spectral resolution needed*
• Multiple bands provide essential spectral “context”*
  – Choice of reference bands
  – Normalize for green cover
  – Correct for sunlit canopy fraction
  – Synergy with other products
• Spatial resolution needed to resolve uniform vegetation stands
• Temporal coverage can resolve seasonal patterns

*Critical features
Producing a LUE Product from PRI

\[ PRI = \frac{R_{531} - R_{\text{ref}}}{R_{531} + R_{\text{ref}}} \]

\[ sPRI = \frac{PRI + 1}{2} \]

- Normalize to vegetation “greenness” (pigments, LAI...)
- Correct for sunlit fraction (hotspot effects)
- Stratify for look angle, sun angle (?)

Operational LUE product

Canopy temperature & water content
Airborne & field validation still needed (FLUXNET, SpecNet, BioSpec, COST, SensorVeg)

A “global” LUE metric should be able to account for slope differences between vegetation types or across seasons.
Synergy & Links to other products

• **Vegetation greenness** (e.g. NDVI, EVI, green vegetation fraction...)
• **Canopy water content** (Water indices, EWT, ...)
• **Temperature** (thermal bands)
Benefits of a HyspIRI LUE product

• Better mapping of carbon dynamics (carbon balance) via improved “stress detection” (physiology)
• Explicit links between carbon, water, and temperature dynamics (VSWIR-TIR synergy)
• Better characterization of surface-atmosphere energy feedbacks (climate modeling)
• Improved vegetation mapping (functional diversity)
• Key metric of “vegetation health” (economic and human impacts)