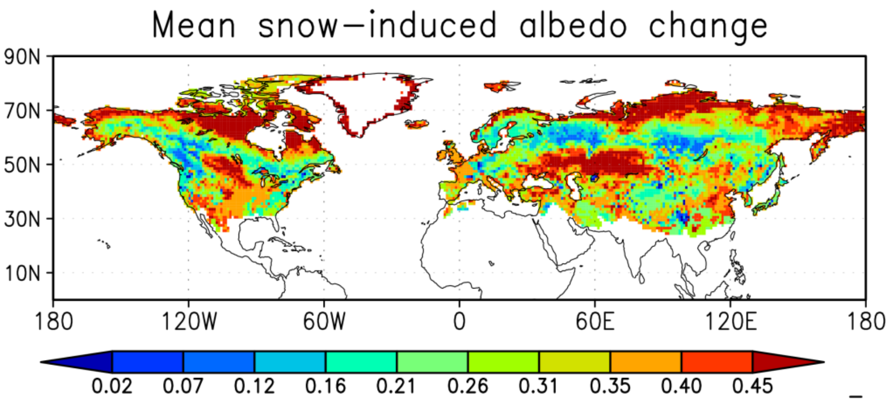
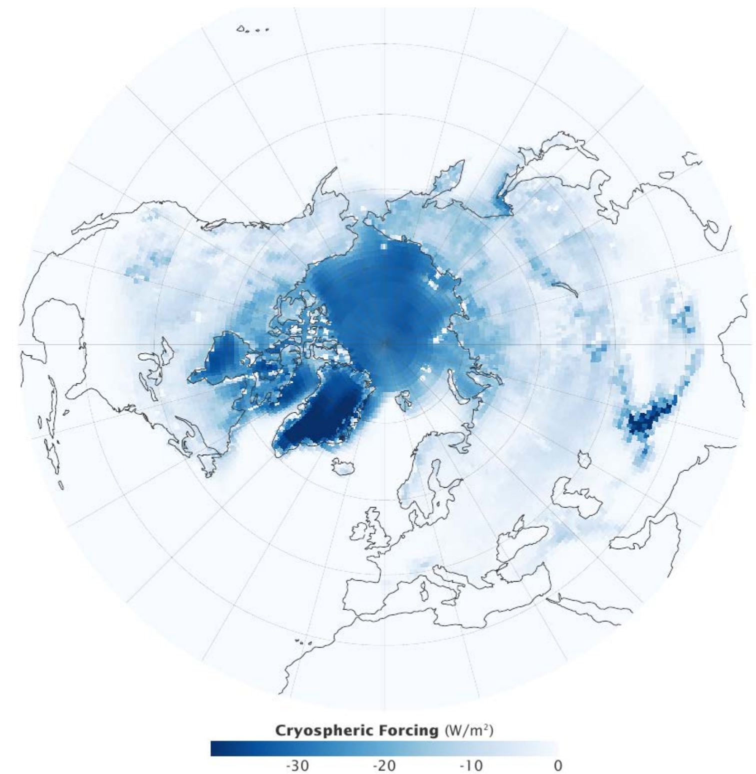
The cryosphere radiative effect

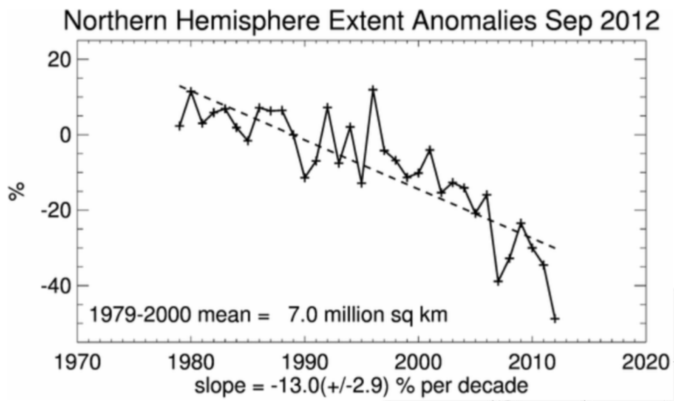
- Earth's cryosphere cools the planet by reflecting additional solar energy to space.
- *Right bottom:* Mean flux of solar energy reflected to space from the cryosphere between 1979 and 2008, determined from a variety of measurements (*Flanner et al*, 2011):
  - AVHRR, MODIS (land snow cover and surface albedo)
  - AMSR-E, SMMR (sea-ice concentration)
  - Field measurements (sea-ice albedo)
  - Observationally-derived and model-derived radiative kernels

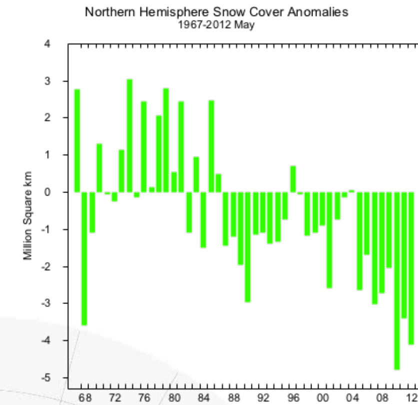


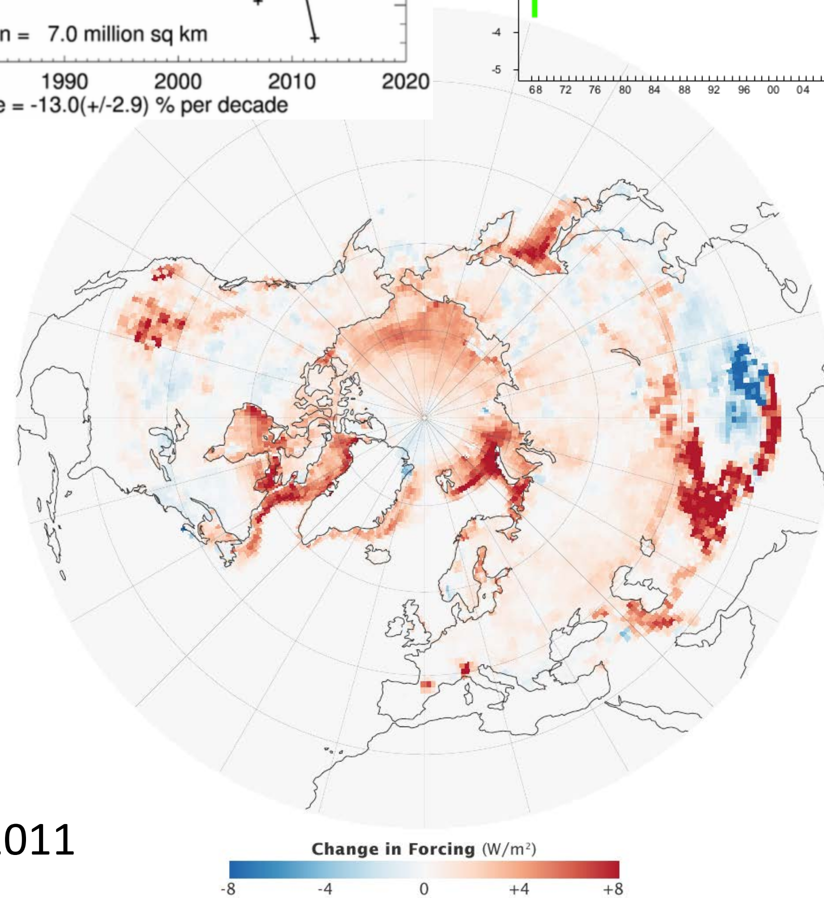


The cryosphere radiative effect

- *Right bottom:* **Change** in solar energy reflected to space between 1979 and 2008 caused by changes in cryospheric cover. Total, averaged over Northern Hemisphere, is about 0.45 W m^{-2}, equivalent to 60% of the added energy from increased CO_2 during the same time.







NASA Earth Observatory Image of the Day, 2/24/2011

Plans for future CRE development

- *Land:* Long-term derivation required AVHRR. Here, develop new continuously-updated global CRE product using high resolution data from MODIS, and (hopefully) VIIRS, e.g.,:

$$\mathrm{CRF}_{\mathrm{land}}(t,R) = \frac{1}{A(R)} \sum_{i=1}^{N} [\alpha(t,i) - \alpha_{\mathrm{snowfree}}(t,i)] \frac{\partial F}{\partial \alpha}(t,i)\, A(i)$$

- *Sea-ice:* apply concentrations derived from NASA team algorithm (*Cavalieri et al*, 1996), and also real-time data from NSIDC (*Maslanik and Stroeve*, 1999) for current state of the cryosphere. Initially, apply ground albedo measurements (*Perovich et al*, 2002). Later, explore use of remotely-sensed sea-ice reflectance (e.g., *Riihela et al*, 2013).