# RESEARCH OVERVIEW - Alan K. Betts

*A brief overview of my research.* (1 Jan, 2015)

**Since 2013,** I am working with the remarkable 55-yr hourly datasets from the Canadian Prairies to understand

1. How clouds determine the diurnal cycle in summer and winter (**Betts et al. 2013**) - **AGU Research Spotlight**
2. How the change to annual cropping in the past 25 years on 5 MHa has cooled and moistened the Prairie climate in summer (Betts et al. 2013b)
3. How the rapid transitions with snow determine the winter climate (Betts et al. 2014a)
4. How the summer climate temperature and humidity are linked to precipitation and clouds on monthly timescales (Betts et al 2014b)
5. Separating the forcing of daily climate linked to radiation/clouds, and RH, wind, and precipitation anomalies (Betts et al, 2015)

These Canadian data are remarkable because they have 55-yr homogeneous records of hourly opaque (reflective) cloud fraction (in tenths), which can be calibrated against incoming shortwave and longwave on daily timescales, to give the coupling between diurnal and seasonal climate and cloud radiative forcing. This is transforming our understanding of hydrometeorology, because one can then understand how temperature and humidity are coupled to precipitation and the surface radiation budget across timescales, based on observations, rather than models with embedded parameterizations.

**This decade**, I have revisited the BL cloud and climate change problem over land with the equilibrium BL model and a coupled carbon cycle, and completed a review of LBA research insights into land-atmosphere coupling. I have contributed to two global studies, one comparing land surface heat flux estimates and a second looking at recent trends in the tropical hydrological cycle. I contributed to a paper that evaluates the cloud fields in three reanalyses using ARM data from the Southern Great Plains site. I contributed to the development of a new probabilistic plume model for the growth of the mixed layer, shallow and deep convection.

In recent years, I have addressed the impact of global change locally in Vermont. I have worked on **Vermont climate change indicators**; and using the **Seasonal climate transitions** to explain climate feedback processes to an interested public. I have also worked with the State Agency of Natural Resources on **climate change adaptation planning**. The past seven years (2005-2012) my work was supported by the National Science Foundation under Grant AGS-0529797.

**My aim is to write papers that can be understood** by both traditional scientific audiences, other professionals and the public. This is an interesting challenge, since few of our traditional journals accept that 'plain English' has real advantages over technical jargon! So in parallel, I am writing articles to broaden our collective understanding of our **responsibility as Earth scientists** for **clear, open public communication**. I write articles for the **Sunday environment section** of two Vermont newspapers, based on the philosophy summarized in **Environmental journalism revisited**. I also lecture extensively around Vermont. Humanity will be unable to deal with climate change, both in terms of mitigation and adaptation, until a broad spectrum of society is fluent in discussing the issues

and the choices we face. I suggest that scientists consider more deeply our responsibilities to society and to the Earth.

My research in the **2000s** addressed **land-surface-atmosphere-cloud** coupling, the field programs **LBA** and **BOREAS**, and **reanalysis evaluation**. This was partly data analysis, partly evaluation of models with data, and partly developing new conceptual frameworks. I contributed to the development at ECMWF of a new land-surface parameterization for ERA-40, a revised surface hydrology scheme, and to improved modeling of the diurnal cycle of convection. I worked on an idealized framework for studying the diurnal cycle over land over Amazonia. I worked extensively on quantifying the surface SW impact of clouds, using the concept of **effective cloud albedo**. This gives symmetric roles to the surface and clouds in the surface energy budget. I developed several important idealized models which coupled land-surface processes to radiative processes: models for the **equilibrium BL over land** (with and without vegetation coupling) and for the **nocturnal BL and the diurnal cycle**. I wrote several important reviews: on **understanding global hydrometeorology**, **land-atmosphere coupling**, and the **Amazonian boundary layer**.

My research in the **1990's** was primarily on land-surface processes: stemming from my participation in **FIFE** [grassland in Kansas] and **BOREAS** [boreal forest in Saskatchewan and Manitoba]. A second thread was the **evaluation of model errors** in operational forecast models and reanalyses at ECMWF and NCEP using these field experiment data and **GEWEX** data. Major discoveries were the importance of **soil water** on BL diurnal evolution; soil water-**evaporation-precipitation feedback** in models, and the hemispheric impact in spring on short-range forecasts of **snow albedo** errors over the boreal forest (the snow-albedo feedback impact on the forecast problem). This work led to the **correction** of many forecast model errors. There were a few papers relating to earlier work on tropical climate equilibrium, and two reviews which extended the Betts-Miller scheme. I have archived a copy of the historically important US Senate hearing on "*The Role of Clouds in Climate Change*", October 7, 1991, which includes my testimony and discussion with Richard Lindzen (*otherwise unavailable on the web*).

My research in the **1980's** started with a review of convection over the tropical ocean in **GATE**. I then developed the thermodynamics of **air parcel saturation point** for conceptually organizing convective and BL processes (an extension of my work in the 1970s). This was applied to several datasets and convective regimes. It led to two important models: the **Betts-Miller** convective parameterization scheme (which is still in use today) and, when coupled to a radiation code, the **Betts-Ridgway** model for tropical BL equilibrium for the present climate, a doubled CO2 climate and the ice-age climate.

My research in the **1970's** stemmed:

1) From my PhD work on "**Cumulus Convection**", which introduced or extended many important concepts: a **mixed layer model** for dry convection and the sub-cloud layer; the **liquid water potential temperature**; and **mass, enthalpy and water transport models** for shallow convective BLs. This was largely conceptual, but it would be fair to say that it was inspired by my spending a summer in Venezuela in 1969 with Herbert Riehl and the VIMHEX-1969 experiment. I saw each day that afternoon convection was not predictable - until it appeared on the radar!

2) From my field experiment work in the tropics in Venezuela with **VIMHEX**-1969 and 1972 (the **sub-cloud layer**, **mesoscale systems** and **traveling squall-lines**); and in **GATE** in the tropical Atlantic

– where I was the ‘Convection Subprogram Scientist’ and an ‘Airborne Mission Scientist’ for this very large international program.

So my 70’s research deals with convection and BLs over both the tropical land and the tropical ocean.

My only paper on the **1960's** (and my only paper on atmospheric dynamics!) - Betts and McIlveen (1969) - came from noticing that the energy equation is not invariant in a moving reference frame on a rotating planet.